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Environmental Security

Sustainable Use and Development of Watersheds

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Sustainable Use and Development of Watersheds

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Series C: Environmental Security

Sustainable Use and Development of Watersheds

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PREFACE

John Wesley Powell, U.S. scientist and geographer, put it best when he said that a watershed is:

> …that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community.

Watersheds come in all shapes and sizes. They cross sectorial boundaries (e.g. county, state/province, and country). No matter where you are, you are in a watershed! World-wide, watersheds supply drinking water, provide recreation and respite, and sustain life. Watersheds are rich in natural capital, producing goods (agriculture and fisheries products) and services (industry and technology) for broad geographic areas. In many countries, at the base of watersheds where tributaries empty into large water-bodies (e.g. estuaries, seas, oceans) are centers of society and are typically densely populated areas. These areas serve as concentrated centers of the socio-economic system. They also are centers of domestic and international trade, tourism, and commerce as well as the center of governments (capitals) where local, regional and national legislatures are located.

As we all live in a watershed, our individual actions can directly affect it. The cumulative effects of all the individual actions of everyone within a watershed may be, and often are devastating to the quality of water resources and affect the health of living things including humans. Therefore, watershed systems are highly subject to threat to human security and peace.

Management for sustained use of water and other ecosystem resources requires a watershed-based approach. Watershed management is a broad issue, which requires expertise from multiple disciplines including water quality and water quantity management, transport of pollutants in the aquatic medium, aquatic chemistry and ecology, as well as social sciences and decision making. In other words, multidisciplinary approaches are required and groups of natural scientists, engineers, social scientist, and managers must collaborate and develop recommendations for sustainable management of natural capital.

This book is a result of the NATO-SPS (NFA) Workshop held in Istanbul, Turkey in October 2007. The main goal of the Workshop was to provide knowledge and build skills of scientists, engineers, and decision- and policy-makers for the management of watersheds and catastrophic events. The aim of this effort was to transfer multidisciplinary approach, information and knowledge gained by the LEMSM group (NATO CCMS Pilot Study Group on Ecosystem Modeling of Coastal Lagoons for Sustainable Management) during their 12 years NATO-CCMS Pilot Study to international scientists and decision-makers.

The WORKSHOP provided participants with an excellent opportunity to develop understanding and skills in scenario-based decision-making management of watersheds. Participants from 21 countries exchanged knowledge on how to use advanced tools for assessment and decision-making that provide the ability to manage watersheds. Participants benefited from applying the sustainable use and development models to minimize and mitigate the effects on the natural capital of water resources, watersheds, and thus socio-economic systems. This lead to recommendations based on "ecosystem approach" for decision-making for protection of human security and peace. Further, group sessions resulted in the identification of Terms and Principles as well as the recommendations for application and implementation of sustainable use and development practices in developing countries. The program of the Workshop was challenging by embracing a "hands on" learning experience.

The book specifically reframes the need for decision support tools and scientific knowledge in watershed management in the context of integrated approach.

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This book is basically a product of the "Ecosystem Modeling of Coastal Lagoons for Sustainable Management (LEMSM)" Pilot Study supported by NATO – Committee on the Challenges of Modern Society (CCMS), which was initiated in 1995. I want to offer my deepest affection to the LEMSM family. This book would not exist without the support of the NATO-CCMS managers in Brussels. I particularly want to thank to Dr. Deniz Beten (CCMS Program Director) for her dedication and support.

The book is based on a NATO-sponsored SPS (NFA) 5th Workshop on "Sustainable Use and Development of Watersheds for Human Security and Peace", held in Kumburgaz, Istanbul, Turkey, 22–26 October 2007. I am indebted to my colleagues, the scientists who wrote the chapters. They are truly dedicated to improve the management of watersheds. In addition to me, the following individuals have made-up our Workshop leadership team and provided guidance and editorial review within their areas of expertise: Angheluta Vadineanu, Brenda Rashleigh, Irina Chubarenko, John Wolflin, Ramiro Neves, Rosemarie C. Russo, and Ali Ertürk, Alpaslan Ekdal, Melike Gürel, Nusret Karakaya, Selmin Burak. I want to recognize Biimyrza Toktoraliev as co-director of the Workshop and representative of the Republic of Kyrgyzstan. I acknowledge Ms. Lynn Schoolfield, USEPA, as part of the LEMSM family and one of our most ardent supporters.

This book could not have been accomplished without the dedication of many individuals and organizations. On behalf of all of the authors, I especially want to thank to Mrs. Wil Bruins for editorial guidance. The Workshop, as well as this book, would not have been accomplished without the assistance of the people from several organizations including IGEMPortal, IGEM Research & Consulting, and the staff of the Hotel Marine Princess, Kumburgaz, Istanbul, Turkey.

I also want to recognize the fourth-four participants from 21 countries. On behalf of the LEMSM family, I want to say that we look forward to working with these scientists and professional in the future and their involvement in the "Evaluation and Dissemination of Decision Support Tools and Models for Sustainable Use and Development of Watersheds- DESTMOD Network". As an editor, I devote this book to young students world-wide who will be responsible for watershed management. You are our future! My dream is that these valuable areas are conserved for future generations. This can only be achieved through the application of sustainable use and development practices that use modeling tools and ecosystem principles such as those describe herein.

We all are particularly grateful for the winter offshore breezes, which provided us coolness of spirit during our comprehensive studies and the development of this manuscript.

İ. Ethem Gönenç
Istanbul 14 February 2008

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PART 1

INTRODUCTION

INTRODUCTION

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The world's population increase in the last 50 years has affected water resources in several aspects. More water is now needed and therefore more wastewater is produced and discharged to other water bodies of the planet. These two aspects made water a limited and strategic natural resource in terms of its quality and quantity. It is then easy to conclude that water, like all the limited and vulnerable resources, has become one of the potential targets for sustainable development and use. Water use and water pollution, in consequence, are complex and emerging 21st century threats and hazards. They demand a unified and coordinated approach to domestic and international water resources management. Every country should establish a national strategy for homeland security and management of domestic water resources with clear objectives for a concerted national effort to reduce threats and manage incident response of any hazard, manmade or natural.

Traditionally, water is managed by different geographical compartments (e.g. rivers, reservoirs, lakes, estuaries, ground) using specific tools for each compartment and often by different institutions. When specific tools are used for each compartment, the interactions between compartments are specified through boundary conditions. However, the most critical situation facing the health of water resources and aquatic ecosystems is not the result of a single activity on or near a lake, river, stream or lagoon. Instead, it is the combined and cumulative result of many individual activities throughout a water body's entire natural drainage area, catchment area or watershed. A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. World-wide watersheds supply drinking water, provide recreation and respite, and sustain life. In most countries the economy is strongly dependent upon clean water and healthy watersheds. This is particularly the case for manufactured goods and tourism. Consequently, water is a natural capital that is extremely important for human security and peace.

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 3–5.

A watershed approach is the most effective framework to address today's water resource challenges. A watershed approach involves a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically – defined geographic areas, taking into consideration both natural and socio-economic system. Management tools for all the geographical compartments are coupled and used interactively. This integrated management system provides results to all the stakeholders in the watershed and consequently it stimulates collaboration directed at cooperation among competing users of the natural capital. In a framework of cooperation, it is easier to share knowledge, data, and working methods with the advantage being sustained use and development by stakeholders. Management for sustained use of water and other ecosystem resources requires a watershed based approach.

This book is a result of the NATO Science for Peace and Security Programme (SPS), Nationally Funded Activity (NFA) Workshop held in Istanbul, Turkey in October 2007. The main goal of the Workshop was to provide knowledge and build skills of scientists, engineers, and decision- and policy-makers for the management of watersheds and catastrophic events. The Workshop participants were exposed to three themes needed for watershed management: Decision Support System and Tools; Land-Based Sources, Water Quality And Management; and Decision Making, Policy & Financing. A plenary session was held for all workshop participants followed by three concurrent break-out working group sessions that addressed each theme. Each of the workgroups prepared a report including conclusions and recommendations. This book is reflective of the instruction provided at the Workshop.

The book consists of four parts and their relevant chapters.

Part 1 – Introduction

In Part 2, administration, legislation, financing systems of watersheds management in various countries are presented. This chapter contains very valuable information that will help readers with refined and synthesized knowledge gathered as a result of longstanding management experience in 10 countries from 4 continents (America, Europe, North Africa, Central and South Asia).

In Part 3, decision support tools and models, and their application in various countries for different aspects of watersheds (e.g. rivers, lagoons, bay) for integrated watershed management are presented.

The decision support (DS) tools could be best described in terms of their general type and by focusing on the stage in the decision process being supported, from information gathering, through storage, to exploring alternatives. Information, collection and management, modeling and rational decision support, visualization and the human interface, group decision making, knowledge capture and representation and decision support system integration are issues mentioned in various chapters of this part. Some chapters also describes specific modeling tools that can be used to address ecological effects on water resources. Each of these models has strengths and weaknesses for representing the aquatic ecosystem and the effects of land-based sources on such an ecosystem. The use of these models as a tool for rapid response and decision-making in today's climate of growing threat is encouraged.

A thorough assessment on how models and other tools will be employed in this process and design, improvement, implementation phases of a watershed management system are provided as various case studies chapters. Taken together, this set of tools provides scientists with options for representing the effect of natural catastrophe or human activities in a range of aquatic systems and for qualifying benefits of mitigation actions within watersheds.

Part 4, presents conclusion and recommendations on DS tools and system (Chapter 1), land-based sources and water quality and management (Chapter 2), and decision-making, policy and financing (Chapter 3). The entire information presented in the book are gathered and discussed on how to use all of the information for watershed management. Thus, even solely, this chapter is advised as a valuable reference guide. It presents the reader an excellent knowledge on advances in watershed management. The mission of this book will be accomplished only if the information and knowledge presented in this chapter are used and implemented by the reader.

Readers from various disciplines involved with different aspects of watershed management might not necessarily feel the need to recognize and absorb the information provided in every chapter in full detail. Thus, with attention paid to the structure of the book and the content of the chapters, it is advised that practitioners of modeling, ecology, land based sources to focus on relevant chapters of Part 3, whereas for those involved in management should focus on the chapters of Part 2, and finally those interested in sustainable use and development should locate relevant information in various chapters of Part 1 and 4, but as they also will find other chapters of value as well. Part 1 and 4, are recommended for all readers.

PART 2

WATERSHED MANAGEMENT IN VARIOUS COUNTRIES

Administration, Legislation, Financial System and Implementations

WATERSHED AND WATER MANAGEMENT SYSTEM IN ALGERIA

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Abstract: Water resources in Algeria are limited, vulnerable and unequally distributed. These resources have in addition undergone during the two last decades the harmful effects of drought, pollution, and unproper management. The water potentialities in Algeria are estimated overall at 19 billion cubic meters per year (correspondent with approximately 600 m^3/inhabitant/year). Thus Algeria is categorized as one of the countries low in water resources taking into consideration the threshold of scarcity established by the World Bank at 1,000 m^3/inhabitant/year).

In addition the history of water management in Algeria since independence is one of a proliferation of structures and texts in charge of hydrology matters. It was necessary to wait until the 1990s, after national bases of water in 1996, when there emerged a realization of the need for organizing the management of water resources in a comprehensive, coherent, and rational way by the adoption of a new policy of water.

A new water policy based on the principles of unifying the resource, of management integrated on a catchment area scale, of concerted management – economic and environmental – was established in 1996.

This report is organized around the following areas:

- Fundamental elements of the current assumption of responsibility for water management in Algeria (the water resources and the committed process of institutional recasting of the framework: organization, administration, financing and achievements)
- Overall appreciation of the possibilities for improvement of management by evaluating the impacts of the management structure
- Possibilities for improvement of the new water policy

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Keywords: Water resources; water in Algeria; water management system; watershed organization; water legislation; water finance

1. Introduction

Algeria with a surface area of 2,381,741 km^2 and a population of more than 32 million inhabitants is divided into 48 Wilayas (Departments). Eighty percent of the country's territory is located in the desert. Water resources in Algeria are limited, vulnerable and unequally distributed over time and space. These resources have in addition undergone during the two last decades the harmful effects of drought, pollution and inadequate management. The water potential in Algeria is estimated at 19 billion cubic meters per year overall (approximately 600 m^3/inhabitant/year). Thus Algeria is categorized as being among the countries facing water shortages, based on the threshold of scarcity set by the World Bank as 1,000 m^3/inhabitant/year.

Furthermore, in the historical evolution of water management in Algeria since independence, there have been issues of institutional plurality and overlapping of legal frameworks. Only since the 1990s, following the establishment of national bases for water in 1996, awareness was raised with regard to the need for a coherent, rational and global water management approach. That led to the adoption of a new policy in water management.

The new policy developed and adopted for water management in 1996 is based on the principles of the uniqueness of the resource and its integrated management on a catchment basin scale, taking into consideration consensus, environmental awareness, and water saving principles.

The major objectives of this policy are summarized as follows:

- Protection of existing resources
- Development of water resources at maximum level and to the extent possible
- Development of planning tools
- Efficient management through the national water plan
- Demand management
- Use of nonconventional resources (treated water use in agriculture and industry, desalination of seawater and brackish water)
- Institutional, legal and institutional reforms by restructuring of the institutional framework based on the components of the water sector by knowledge of the resource
- The mobilization, distribution of drinking water, industrial and agricultural water
- Sewerage, sewage treatment and treated water reuse
- Integrated management on a catchment scale

In order to achieve these goals, it is of the utmost importance to ensure the efficiency of the program, avoid the mismanagement and inconsistencies observed in the past in Algeria, overcome the challenges confronting the water sector, and implement the new water policy enacted in 1997 by solving the problems and bottlenecks encountered in the water sector.

We currently observe the rising national awareness related to the water shortage in Algeria, as well as a real political good will to overcome this crisis. This was concretized by:

- Establishment of the Ministry of Water Resources in 2000
- Behavior of several ministerial and governmental councils devoted to the problem of water
- Adoption of a new law on water in 2005
- A consequent financing in the sector (more than €18 billion for the period of 2006–2010)

2. Organization and administration of water management in Algeria

2.1. OUTSTANDING STAGES

The main objective of the authorities in charge of water management has been to ensure safe drinking water for all the population and increase agricultural production by extension of the irrigated surfaces.

The improvement of the conditions of hygiene in urban environments as well as in rural ones, required a significant development of the public drinking water network and sewerage, not only to catch up for delayed investments but also to take the population increase into account. In addition, in agriculture the required objective was to ensure food self-sufficiency by the development of an irrigation network in the north of the country and the Sahara.

Various stages marked the committed-to process in the plan of the organization and administration of water management since independence: shortly after independence in 1962, duties and responsibilities for water management were split between the sectors of public works and agriculture. The sector of Public Works and Construction carried out the main part of its duties through central management at the level of the Ministry and two external services: the SES (previously the service of scientific studies, the ANRH at present) and the SEGGTH (service of the general studies and large water works, ANBT and partly the ADE). The Ministry of Agriculture, among its tasks, ensured all the concessions relating to irrigation and rural hydraulics.

Between 1970 and 1989 all the missions relative to hydraulics were gathered together at the level of a single governmental department: State Secretariat of Hydraulics between 1970 and 1977, Ministry of Hydraulics of land use and environment between 1978 and 1980, Ministry of Hydraulics between 1980 and 1984, and Ministry of Environment and Forests between 1984 and 1989.

The first decade of this period (the State Secretariat of Hydraulics, in particular) was marked by the installation of Directions of Hydraulics of Wilaya, the establishment of consulting companies, and implementation. The 1980s were characterized by:

- The creation of a Structural engineering office of hydraulic control (CTH)
- The creation of a National Agency of dams, National Agency of Drinking water and sewerage, and a National Agency of irrigation and drainage
- The creation of offices of Irrigated Perimeters (five regional and eight of Wilaya)
- The creation of water institutions
- The promulgation of a decree defining the methods of tariff setting for drinking water, industrial and agricultural water and the assertion of the principle of cost recovery of the infrastructures

From 1989–2000, the missions relating to hydraulics were gathered on the level of a new government department: Ministry of equipment and territory planning, but the sector of irrigation is once again under the Ministry of Agriculture; this was initially through a State Secretariat under agricultural engineering and agricultural hydraulics under the Ministry of Agriculture (February 1992–August 1992), then directly under the Ministry of Agriculture. For this period, the following actions took place:

- Modification of the statute of the water institutions (passage of the statute of EPE to EPIC)
- The institution of a purification royalty of 10% then of 20% of the drinking water invoice
- The amendment of the code of water in 1996 to widen the concession of the public utility of drinking water to the national and international private sector
- The creation of the catchment agencies of areas
- The definition of new methods of tariffing (regional tariffing and introduction of royalties)
- The creation of national funds of drinking water and purification supplied with the royalties
- The creation of national funds of integrated management of the water resources supplied with royalties “water saving” ‘and’ “water quality”

From 2000 to date, the government has been actively involved in the complete reorganization of the water sector (conventional and non-conventional) including wastewater and irrigation under the supervision of the same ministry. The main goal is the centralization of the water sector and the privatization of certain activities. Within this framework, the Ministry of Water Resources was created by the executive decree Number 2000-325, on October 25, 2000. Moreover, in view of the importance of the environment in Algeria, the government reinforced the environmental and institutional aspects by the promotion of the General Directorate of Environment of the ministry in a separate Ministry for the Territory Planning and Environment (MATE).

This period is particularly characterized by the progressive implementation of the national policy for water management adopted in 1996 by adoption of a great number of regulations such as:

- The executive decree Number 2000-324 of 25 October 2000 fixing responsibilities of the Minister for the water resources
- The executive decree Number 2000-325 of 25 October 2000, regarding organization of the central headquarters of the ministry for water resources
- Adoption of a new law relating to water in 2005

2.2. ORGANIZATION AND ADMINISTRATION

The management of water in Algeria is centralized on the level of the Ministry for water resources; the Minister coordinates all of the activities related to water at the national level. The management structure at the central, local, and intermediate levels is described below:

2.2.1. Ministry of water resources (MRE)

At the central level:

The Ministry of Water Resources with its eight central directions given below coordinates all activities related to water at the national level.

- Management of studies and hydraulic installations (DEAH)
- Management of the mobilization of water resources (DMRE)
- Management of the drinking water supply (DAEP)
- Management of sewerage and wastewater treatment (DAPE)
- Management of water control (DHA)
- Management of planning and economic affairs (DPAE)
- Management of Human Resources, Formation and Cooperation (DRHFC)
- Management of the Budget, the Means and Regulation (DBMR)

At the local level:

In each of the 48 Wilayas of the country, the MRE is in charge of hydraulics, which, with the local responsibilities of the other government departments, constitutes “the executive” of the Wilaya.

At the intermediate level:

The following institutions are important:

- The Ministry for Water Resources (MRE) is comprised of the
- National Agency of water resources (ANRH)
- The National Agency of stoppings and transfers of water (ANBT)
- Water Distribution Agency (ADE)
- National Office of Irrigation and Drainage (ONID ex AGID), which is in charge of the development of the large irrigated perimeters and of support to the establishment of management of the irrigated perimeters
- The National Office of Sewerage and Treatment (ONA), which is in charge of the sewerage and wastewater treatment
- Offices of perimeters of irrigation (OPI) for large water works hydraulics

Five agencies of water basin (industrial and commercial institutions) under the supervision of MRE, created within the framework of the new policy of water (1996), namely: Agency of Algiers-Hodna-Soummam, Agency of Chellif-Zahrez, Agency of Constantinois-Seybousse-Mellegue, Agency of Oranie-Chott Chergui, and Agency of the Sahara. These five agencies are in charge of the integrated management of water resources (sites of the agencies of the basins) and are represented at the committees of the basins.

The Hydrographical Basin Agencies are industrial and commercial public corporations. Their statute is specified by the executive decrees of 26th August 1996, and the missions of these agencies may be summarized as below:

- To elaborate and to update the hydraulic cadastre and the hydraulic balance of the hydrographical basin and to collect for that objective all statistical data, documents and information related to water resources, samplings and water consumptions
- To participate in the elaboration of development programmes, mobilization and water resources allocation, initiated by the administrations in charge of that purpose and to follow their activities
- To submit their technical opinion on every permit required for the use of water resources in the hydraulic public field, set up in accordance with the conditions fixed by the legislation and the regulations in force

- To elaborate and to propose the distribution plans of water resources put on active service at the level of large works and hydraulic systems between different users
- To participate in the state supervision operation on pollution of water resources and to determine the technical specifications related to wastewater disposal and operation of wastewater treatment
- To inform and raise awareness among household users, manufacturers and farmers in order to promote the rational use and protection of water resources

The Five Committees of Basin are comprised of representatives of the State, the local communities and the users. They have the role of

- Discussing and formulating opinions on all the questions related to water on a watershed scale and, in particular, about the appropriateness of work and installations under consideration in the area
- Different involvements from all stakeholders related to the water being able to occur between the local communities whose basin includes the territory
- Allocations of resources of waters among various potential users
- Program of intervention of the Agency

In addition to the Ministry of Water Resources, the following ministries also have responsibilities and authorities:

- The Ministry of Interior and the local communities through municipalities
- The Ministry of Agriculture for small and medium size water works (PMH)
- The Ministry for Territory Planning and Environment (MATE) for water pollution control
- The Advisory National Council of Water Resources (CNCRE), for coordination and regulation at the national level

3. Legislative and legal context of water management in Algeria

The government establishes the overarching legal framework. In the majority of cases, their application is compulsory. The legislative texts established and taken in the Ministerial Council are adopted by the Parliament.

Evolution of the institutional framework and that of the legal framework are closely dependent. They followed the same trend. From 1962 to 1994, there has been a proliferation of laws, decrees, and regulations. These instruments were either repealed or canceled during the abolition of institutions or change of the persons in charge.

The legislative and regulatory instruments in force that govern inland waters are in the texts relating to water, health, and environment, the Wilaya, the commune – as in certain finance laws – as well as a great number of decrees of application (tariffing of water, discharge regulations, specifications concerning the regulatory and technical framework of the public water utilities).

4. The new water law

The law Number 05-12 of August 4, 2005, relating to water is constructed according to a completely renovated structure and is in total conformity with the institutional and economic system of Algeria, based on the concept of State regulations, and it contains many innovative provisions:

1. Preliminary provisions for a centralized structure for general conditions and regulations dependent on or related to the use of water and water resource development; this is in line with the objectives and constitutional principles for better water governance (right of access to water, right of use of water, protection of water resources, etc.).
2. The new aspects introduced by the legal framework for the water resources and the hydraulic infrastructures relate mainly to:
   - Clarification and adaptation of the provisions relating to consistency, delimitation and the constraints of the public domain in hydraulics (DPH); natural-like, taking into account non conventional waters, in particular sea water desalination and treated wastewater reuse
   - Prohibition of removal of alluvial material and of extraction in the beds of wadis in order to safeguard the ground water
   - Introduction of the concept of hydraulic infrastructures of general interest, whose development by the State and the dealers of water services determine, to a large extent, the improvement of the quality of the service to users, whether for the water supply, treatment or irrigation of the agricultural perimeters
3. Having legal status regarding use of water resources, the innovative aspects of the law relate to the introduction of a device of access to the resource, articulated around two modes – authorization and concession – that are differentiated according to the nature of water or the impacts and requirements related to its use (conservation of the resources, public health, safety of the installations).

4. The law establishes a particular instrument which is that of delegating the management of the water services from the public utility to the private sector. This mechanism of delegation of the water services by the public utility takes into account the most recent practices of private-public partnerships.
5. The new aspects introduced into the law carry, in particular, a clarification of the method of management by concession of the infrastructures of irrigation; and this is done according to a categorical split among large, small and medium size agricultural facilities.

5. Planning and financing of the hydraulic infrastructures

Investments are distributed between sectors receiving allocations of water resources, together with the corresponding required budget. Investment priority is decided by:

- Ministry for Finances' Central services of planning
- Ministry for Water Resources is responsible for sectoral planning
- The Wilaya
- The Commune

The investments are identified and planned within the framework of a master development plan integrated with the hydraulic infrastructures as given on Table 1.

The choice of the investment rises for:

- Projects of important dams, transmission line water supply systems, and water treatment for large cities are initiated and programmed at the central level by the Ministries for Water Resources and for Finances.
- Projects of local size of type retained collinear, feeder systems out of drinking water and cleansing, tanks, are initiated and proposed locally and the choice definitively is done after arbitration at the central level.

The financing of projects with loans by the local communities ceased at the end of 1960. Since then, approximately, all of the hydraulic infrastructures are implemented through the budgeting of equipment. The only exceptions relate to the infrastructures of drinking water supply or treatment carried out with international lending organizations (e.g., the World Bank) and for which the public distribution firms are selected to support the financial expenses.

Local programs are financed within the framework of the communal plans of development. Regional or national programs are financed by the budget of the State.

TABLE 1. Investment planning billion DA (100 DA = $1.46).

Area	Horizons Structure	2006–2010	2011–2015	2016–2020	2021–2025	Total
North	Hydro-agricultural	72.65	26.05	0.0	0.0	98.7
	Drinking water supply	168.26	57.96	13.95	0.0	240.17
	Drinking water treatment sewage treatment	69	32	23	39	163
	Mobilization of water resource	856	146	29	0.0	1,031
Northern total		1,165.91	262.01	65.95	39	1,532.87
High plateaus	Hydro-agricultural	26.3	36.4	0.0	0.0	62.7
	Drinking water supply	157.41	56.95	5.7	0	220.06
	Cleansing, purification	35	27	18	15	95
	Mobilization of water resource	177.25	39	5	0	221.25
Total High plateaus		395.96	159.35	28.7	15	599.01
CUS	Hydro-agricultural	0.1	0	0	0	0.1
	Drinking water supply	159.5	11.1	1.65	0	172.25
	Drinking water treatment sewage treatment	11	2	0.3	0,2	13.5
	Mobilization of water resource	1.5	0	0	0	1.5
Total CUS		172.1	13.1	1.95	0.2	187.35
Total		1,733.97	434.46	96.6	54.2	2,319.23

6. Conclusions

We realize that through historical evolution there was an institutional plurality and legal overlapping of the system of water resources management. No less than 12 stages characterized this evolution, and we can say that no stable structure could function correctly. There was an inadequate institutional approach. Management establishments were ineffective. There was insufficient coordination among various departments. Hope that arose with the New Water Policy was quickly dissipated. Adopted in 1996, the new water policy was to result in deep reforms of the public water service. What has been the result over more than ten years? Only in 2000, with the creation of a Government department in charge of water resources, adoption of a new water law in 2005 and of a national water plan in 2007 has water management been given high priority. The problems arising at the time of the national water conference in 1996 still exist and require effective solutions.

ADVANCES IN MANAGING AUSTRIA'S WATER RESOURCES

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Abstract: Austria has abundant natural water resources and belongs to three major river basins (namely the Danube, Elbe and Rhine). Ninety-nine percent of the Austrian population is supplied with spring and groundwater, whereas the share of treated surface water of 1% is very small compared to many other European countries. At present, 89% of the population is connected to public sewerage systems with corresponding wastewater treatment. Besides protecting lakes, rivers and streams, particular emphasis placed on the protection of groundwater which is used as important drinking water resource. Results show that most parameters related to drinking water quality are well below the specified limit values. In general, Austria applies the principle of country-wide groundwater protection. About 9% of the territory of Austria is subject to specific water supply protection regulations. The current status of the EU Water Framework Directive implementation in Austria includes the analysis and status assessment of the Austrian river basin districts which were rated and classified by the level of risk of failing to reach the required good status. The next activities will include the drawing up of the first national river basin management plans, adapting the water quality monitoring network and restoring those water bodies failing to meet the defined objectives.

Keywords: Water quality; water supply; groundwater protection; wastewater treatment; EU water framework directive

1. Introduction

1.1. THE ORGANIZATION OF AUSTRIA'S PUBLIC ADMINISTRATION

Politics of Austria takes place in a framework of a federal parliamentary representative democratic republic, whereby the Chancellor is the head of government, and of a pluriform multi-party system. Executive power is exercised by the government. Federal legislative power is vested in both the

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 21–49.

government and the two chambers of parliament, the National Council and the Federal Council. Since 1949 the party system is dominated by the conservative Austrian People's Party and the Social Democratic Party of Austria. The Judiciary is independent of the executive and the legislature. Austria's administration is based on two principles:

- The constitutional basic principle of the Federation
- The principle of local self-administration of Austrian municipalities

These two principles result in an administrative structure consisting of three levels each with corresponding administrative organisations:

- At central government level – the Federal Government
- At federal level – the federal state administrations of the nine States of Burgenland, Carinthia, Lower Austria, Upper Austria, Salzburg, Styria, Tyrol, Vorarlberg and Vienna
- At local level – self-administration of the municipal administrations of 2,359 Austrian municipalities

All over Austria there is also a network of 99 administrative districts which are not independent territorial authorities, but are rather organisationally integrated in the federal state administration (as district authorities) or within the greater city (Figure 1).

Austria has the following four-tiered administrative structure:

Federal Government – Federal States – Districts – Municipalities

The Federal Government – The Federal government is the largest administrative organisation in Austria. It is under the leadership of the Federal

Figure 1. Austria and its federal states and districts.

Ministers who preside as monocratic organs of a particular department. The Federal Chancellor is the chairman of the Federal Government and exercises the central function. As head of the Federal Chancellery, he has the same rank as all other Federal Ministers. This clearly demonstrates the prevailing distinct "department principle" of the Federal Administration.

Federal State Administration – In contrast to the Federal Administration, the administrative apparatus of the 9 Federal States is not organised according to the branch system. The state government as the leadership body of the state administration basically acts as a committee. There are no separate State Ministers, but rather a common State Government Office. Internal affairs of the Office are led by the State Governor as chairman of the State Government (at political level) and the Head of the State Government Office (at administrative level). Most of the 99 District Administrations are also part of the State Administration.

Municipalities – From the 2,359 municipalities, only 50 towns have more than 10,000 inhabitants and 85% of all municipalities have less then 3,000 inhabitants. Fifteen of the largest Austrian cities play a very specific role among the municipalities: they are cities with their own statute. This means that on top of their municipal responsibilities, they also hold the function of an administrative district.

1.2. THE ORGANIZATION OF AUSTRIA'S WATER MANAGEMENT ADMINISTRATION

The legislation pertaining to water and waterways is subject to the Federal Government (Federal Ministry of Agriculture, Forestry, Environment and Water Management, Federal Ministry of Health and Women and Federal Ministry for Transport, Innovation and Technology). The provincial governments and district authorities are mainly charged with its implementation (Figure 2).

2. The Austrian water management system

2.1. WATER BALANCE

A crucial aspect of managing water as a natural resource is the water balance, which comprises the three main components – precipitation, run-off and evaporation. An overview of the average water balance of Austria is presented in Figure 3.

The climate in Austria is continental, with minimum temperatures in January and maximal values in July. Average precipitation can be quite high in Alpine areas (up to 3,500 mm/year), whereas <500 mm/year is recorded in

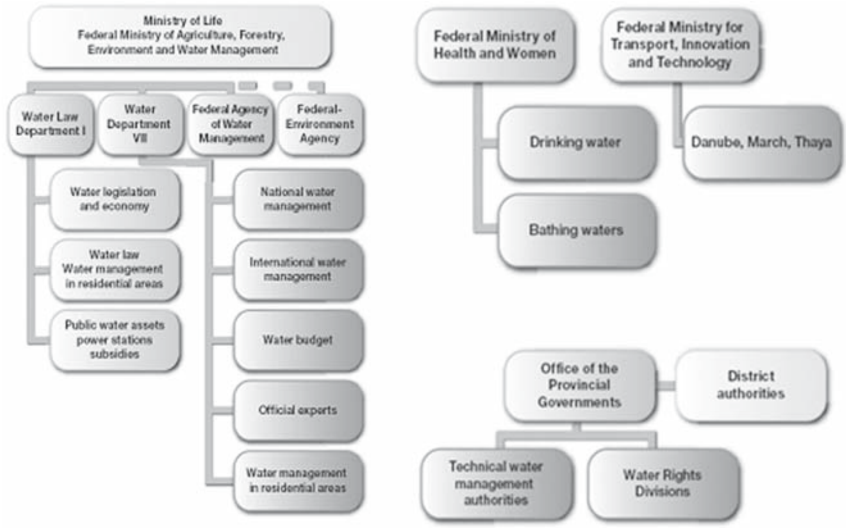

Figure 2. Organization structure of water management in Austria. (BMLFUW, 2006b.).

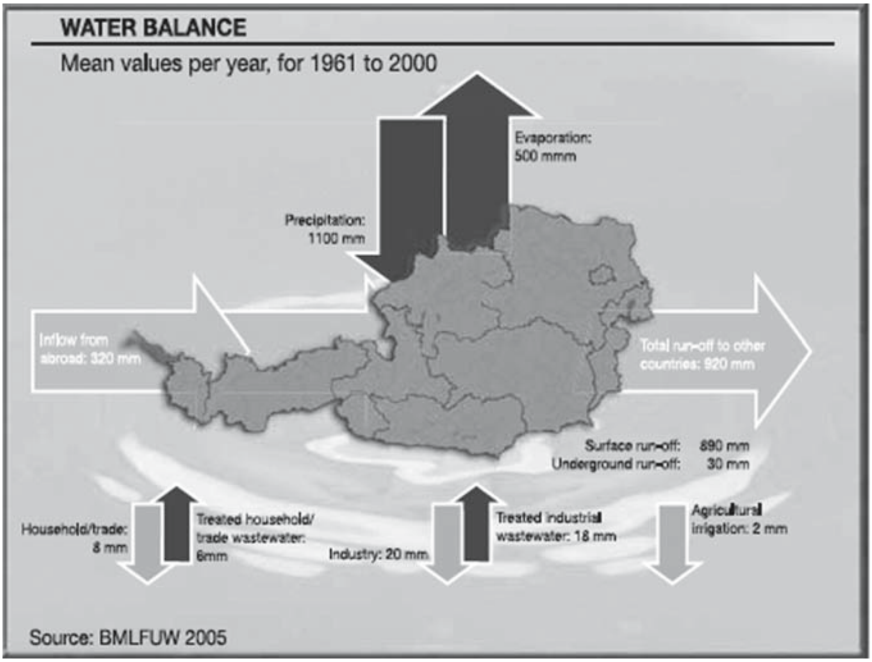

Figure 3. General water balance of Austria. (BMLFUW, 2005b.).

the dry northeast. Annual mean values are 1,100 mm of precipitation and 600 mm of run-off, leaving 500 mm for evaporation. This run-off combined with the 320 mm of water flowing in from the neighbouring countries produce a total annual run-off out of Austria of 920 mm per year. Precipitation and inflow from borderlands result in a freshwater volume of 120 billion cubic meters per year in Austria.

The annual water supply equals to about 84 billion cubic meters of which one third is groundwater. Taking the average water demand of 2.6 billion cubic meters as a basis of calculation, 3% of the total water supply and 6% of the groundwater supply are used for economic purposes. Austria obtains 99% of its drinking water from groundwater and spring water. The most abundant water resources are located in the karstic regions of the Northern and Southern Limestone Alps as well as in the valleys and basins with sediments from the Quaternary.

2.2. RIVER BASINS

The Austrian federal territory is located in three international river catchment areas (Figure 4). Over 96% (80,563 km^2) of Austria's territory is drained by the River Danube, accounting for approximately 10% of the area of the Danube Basin. In Austria 7.7 million inhabitants live within the Danube

Figure 4. Overview map of Austria and its location within the international River Basins Danube, Rhine and Elbe and national sub-catchments (planning units). (BMLFUW, 2005c.).

Basin (i.e. 9.5% of the population of the Danube Basin). About 96% of the area is located in the Danube river basin and drains into the Black Sea, about 3% drain via the Rhine and 1% via the Elbe to the North Sea.

Land use is strongly determined by topographic conditions. More than 40% of Austria's Danube Basin is used for agriculture, settlements and infrastructure. The rest is predominantly mountainous and generally not well suited for such activities. The major Danube cities are Linz, the country's industrial core in Upper Austria (ca. 270,000 inhabitants in the greater metropolitan area) and Vienna, the capital and main administrative centre situated east of the Alps (ca. 2 million inhabitants in the greater metropolitan area). Graz, on the banks of the River Mur, is the second largest city in Austria (ca. 320,000 inhabitants in the greater metropolitan area).

Hydrologically allocated planning units have been set up within Austria, whereby for the River Danube Basin six planning units and for the River Elbe and River Rhine one planning unit each were defined (see Figure 5, Table 1).

The coordination in the river basin districts is carried out bilaterally for smaller-scale tasks, whereas for multi-lateral and basin-wide issues this is pursued by basin-wide bodies (e.g. ICPDR).

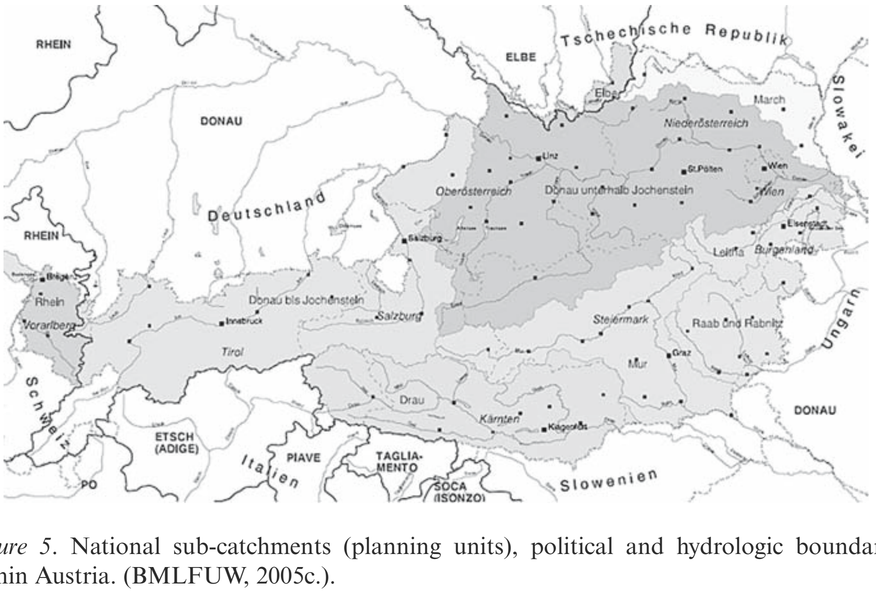

Figure 5. National sub-catchments (planning units), political and hydrologic boundaries within Austria. (BMLFUW, 2005c.).

TABLE 1. National planning units according to international river basins. (According to EU water framework directive.).

International river basin	National planning unit	Concerned Austrian provinces	Catchment area in Austria [km^2]
Rhine	Rhine	Vorarlberg, Tirol	2,365
Elbe	Elbe	Upper Austria, Lower Austria	921
Danube	Danube above Jochenstein	Vorarlberg, Tirol, Salzburg, Carinthia, Upper Austria	18,445
	Danube below Jochenstein	Upper Austria, Lower Austria, Vienna, Burgenland, Styria, Salzburg	27,527
	March	Lower Austria	3,673
	Leitha, Raab, Rabnitz	Lower Austria, Burgenland, Styria	8,793
	Mur	Styria, Carinthia, Salzburg, Lower Austria, Burgenland	10,338
	Drau	Carinthia, Salzburg, Styria, Tirol	11,789

2.3. TRANSBOUNDARY WATER MANAGEMENT

"Water per se" knows no administrative or political jurisdiction and is not constrained by national borders. The Danube, for instance, has a river basin that extends over 18 states with more than 80 million inhabitants and covers nearly 10% of the surface area of Europe (catchment area >810,000 km^2) (Figure 6).

In order to share transnational waterways and improve the condition of major rivers such as the Danube, Rhine and Elbe, which drain the Austrian territory, it is necessary to cooperate in a spirit of solidarity that transcends national borders. Austria has already had bilateral treaties with Germany, the Czech Republic, Slovakia, Hungary and Slovenia for many decades. Moreover, Austria has also been involved for many years in the multilateral Transboundary Water Commissions formed to manage the rivers Danube, Rhine and Elbe, and Lake Constance. Questions regarding the use of water-power, water protection and antipollution measures are discussed in those committees with respect to their transnational aspects. Austria uses the existing bi- and multilateral Transboundary Water Commissions to coordinate its river basin management plan with neighbouring states.

Along with issues of protective hydraulic engineering and the use of water power, water protection has increasingly gained importance. Over the last years, problems related to the catchment areas or entire river basins including the pertinent seas have been studied in an increasingly integrative manner.

Figure 6. Danube river basin overview map. (ICPDR, WFD Roof Report, 2005.).

Austria's efforts towards co-operation in favour of the protection and the environmentally compatible utilisation of the river Danube have resulted in the signing of the Danube River Protection Convention by nine states in Sofia on 29 June 1994. The International Commission for the Protection of the Danube River (ICPDR), with its headquarters in Vienna, is the organisational hub of implementation.

The objective of the Convention is not only the joint protection of the Danube River (and its network), but also the compatible utilisation of the river. One of the objectives is to set up a comprehensive uniform water protection system covering the entire Danube region. Step-by-step systematic development and implementation of water protection is intended to make a corresponding ecological improvement in the Black Sea. A special focus will be to prevent, monitor and reduce the transnational effects of point and diffuse sources of pollution. In order to combat accident-related pollution on the Danube River, a transnational warning and alarm system is developed.

On 13 December 2004, the signatory nations adopted in Vienna the Danube Declaration "The Danube Basin - Rivers at the Heart of Europe". Furthermore the "Action Plan for Sustainable Flood Protection in the Danube River Basin" was issued which aims at developing a sustainable long-term approach for dealing with flood hazards.

3. Human uses of water and water bodies

3.1. WATER SUPPLY

Austria is rich in groundwater bodies, both alluvial and karstic. Ninety-nine percent of the Austrian drinking water originates from groundwater and spring water; the share of treated surface water of 1% is very small compared to many other European countries.

About 87% of the Austrian population live in areas covered by central water supply which is organised by some 6,000 central water supply systems (see Figure 7). Most water utilities supply with natural (untreated) or just preventively disinfected water. Only 13% (1.1–1.2 million) of Austria's inhabitants receive their drinking water from individual water supply plants, domestic wells or small cooperative plants.

The average water consumption (not including trade, industry or large-scale consumers) amounts to about 135 L per day and per capita.

Besides protecting lakes, rivers and streams, specific emphasis is placed on the protection of groundwater which is used as important drinking water resource. In general, Austria applies the principle of country-wide groundwater protection which means that the quality of groundwater and spring

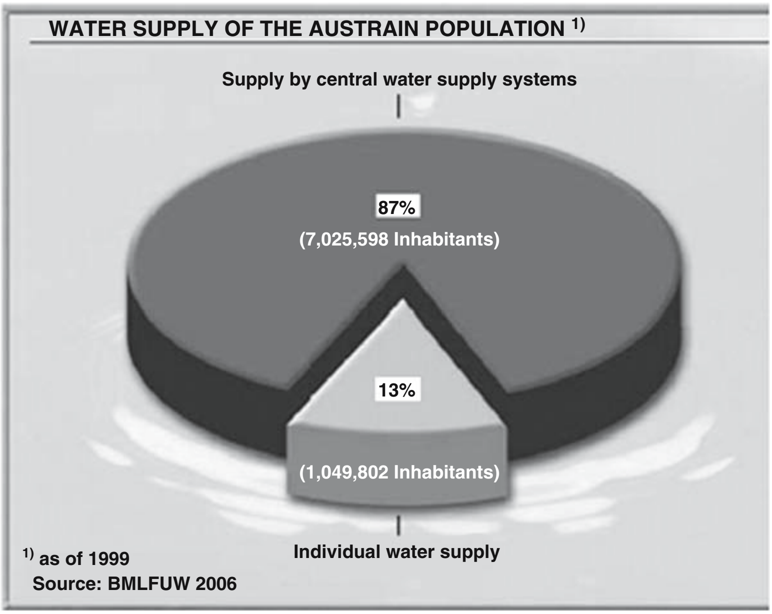

Figure 7. Water supply in Austria. (BMLFUW, 2006b.).

water must comply with drinking water standards. Key measures to protect the quality of groundwater resources include the declaration of water protection zones. This does not only apply for existing supply areas but also for the protection of expansion zones for future supplies. As a consequence, about 9% of Austria's territory is subject to specific water supply protection regulations.

In certain parts – e.g. in intensively farmed regions – groundwater is polluted by nitrates and pesticides. Atrazine is prohibited in Austria since 1995, but is, however, due to its persistence, still traceable in groundwater, even though with a significant downward trend. Due to agri-environmental programmes (e.g. ÖPUL) which promote farming restrictions in the interest of preventive water protection, an improvement of nitrate and pesticide contamination of groundwater could be achieved (see Figure 8).

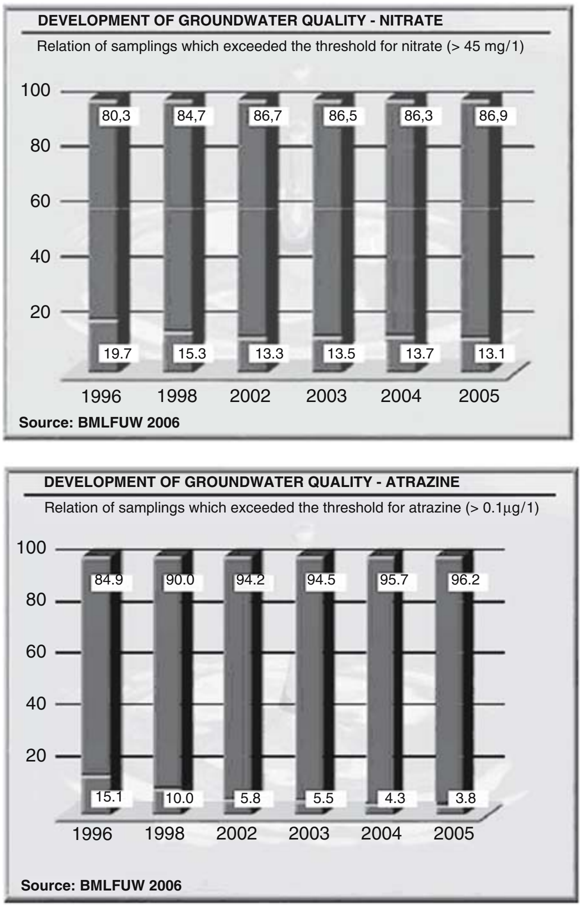

Figure 8. Development of groundwater quality (nitrate and atrazine). (BMLFUW, 2006b.).

The groundwater contained in karstic and deep percolation aquifers is in general water of particularly high quality. The karstic limestone and dolomite of the Limestone Alps act as storage for a major part of the Austrian drinking water.

3.2. RIVERS AS RECEIVING WATERS OF EFFLUENTS

The core of the Austrian water protection policy is to take a proactive approach by imposing the obligation of state-of-the-art wastewater treatment. Much has been accomplished in Austria in this respect in past decades.

Basic factors for the reduction of surface water contaminants are:

- Setting emission limit values for trade and industry, and incorporating water protection at an early planning phase for industrial plants
- Developing and maintaining sewer networks as well as wastewater treatment plants

At present, 89% of the population is connected to public sewerage systems with corresponding wastewater treatment (see Figure 9).

Ninety-three percent of the wastewater treatment plants with equal or more than 2,000 population equivalents are already equipped with tertiary treatment facilities.

Whereas the urban areas are already provided with wastewater facilities to a very high extent, effort is still needed in rural areas to meet the requirements of the European and Austrian legislation.

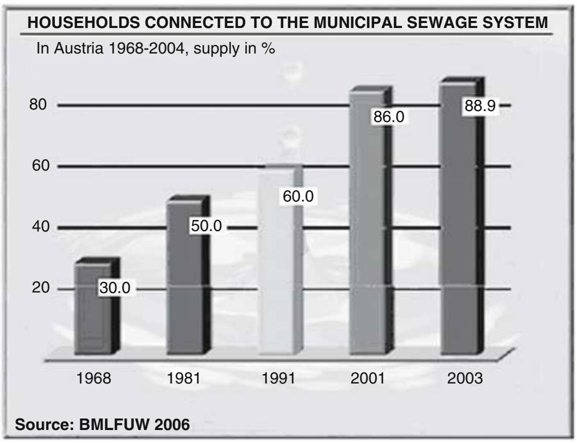

Figure 9. Development of coverage by municipal sewerage systems. (BMLFUW, 2006b.).

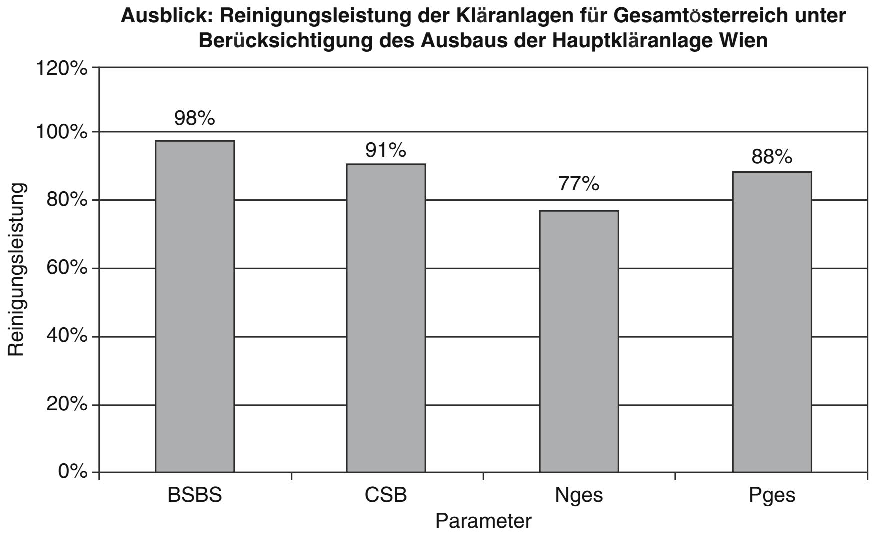

Figure 10. Total treatment efficiency of Austrian wastewater treatment plants (including the recently extended wastewater treatment plant of the City of Vienna). (BMLFUW, 2006c.).

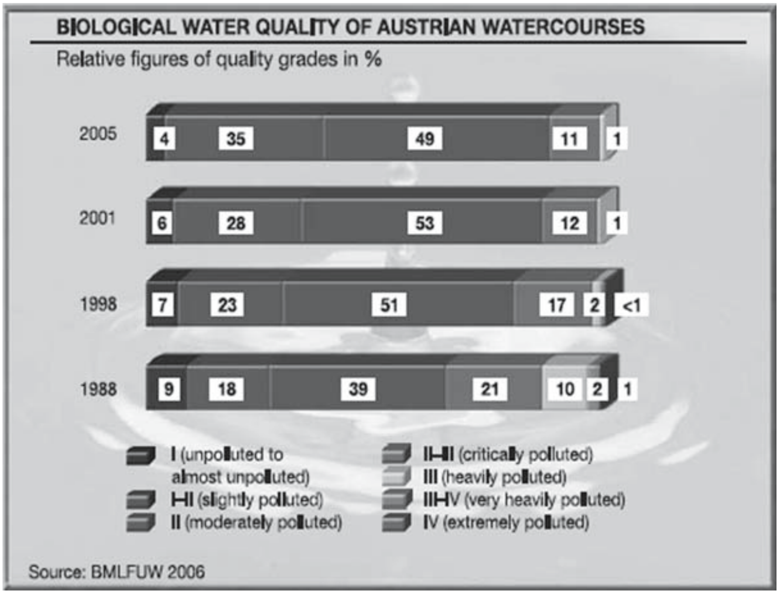

Figure 11. Development of biological water quality of Austrian water courses. (BMLFUW, 2006b.).

The total treatment efficiency of Austria's wastewater treatment plants amounts to 98% for BOD5, 91% for COD, 77% for total Nitrogen and 88% for total Phosphorus (see Figure 10).

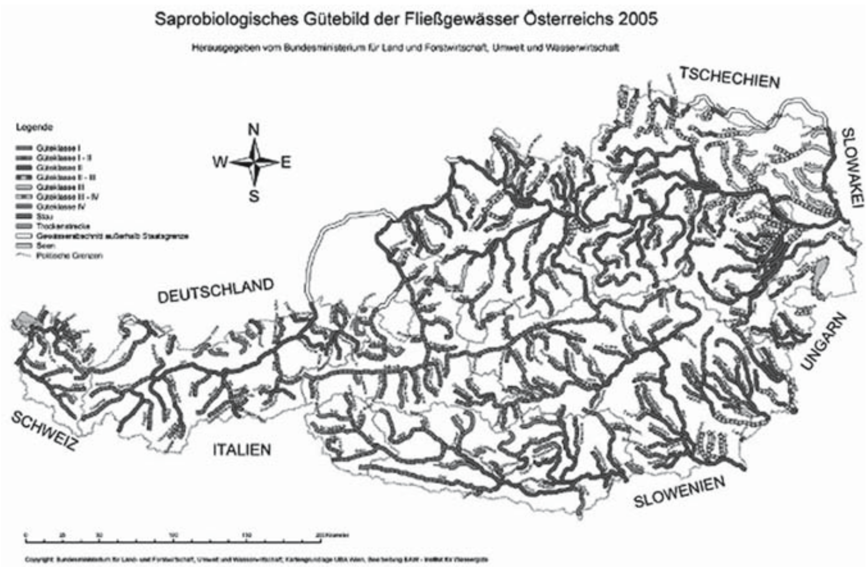

Figure 12. Map of saprobiological water quality of surface waters in Austria. (BMLFUW, 2005d.).

Due to systematic wastewater treatment, 87% of the Austrian rivers have already restored to quality class I or II (on a scale of IV of saprobiological water quality). The water quality of all Austrian lakes complies with the quality standards for bathing water. The development of biological water quality of Austrian water courses as well as a map of the current status of saprobiological water quality is presented in Figures 11, 12.

3.3. USE OF HYDROELECTRIC POWER

Utilising hydropower as a clean and emission-free way of generating electricity has become a tradition in Austria several decades ago. Hydropower covers altogether about three fourths of electricity generation in Austria (see Figure 13), its share in the total energy input amounts to about 12%.

The waterpower potential in Austria corresponds to 53,700 GWh/year, 64% of this potential is already used, while another 2% is under construction.

In addition to a great number of run-off-river power stations of which the most important are situated on the Danube, numerous storage power stations were constructed in the western alpine regions, primarily covering peak loads and the demand for electricity during the winter months (Figure 14).

Furthermore many small (<10 MW) and smallest-scale stations are operative in Austria representing a gross electricity generation of about 5,354 GWh which is equivalent to 13% of the entire gross electricity generation from hydropower.

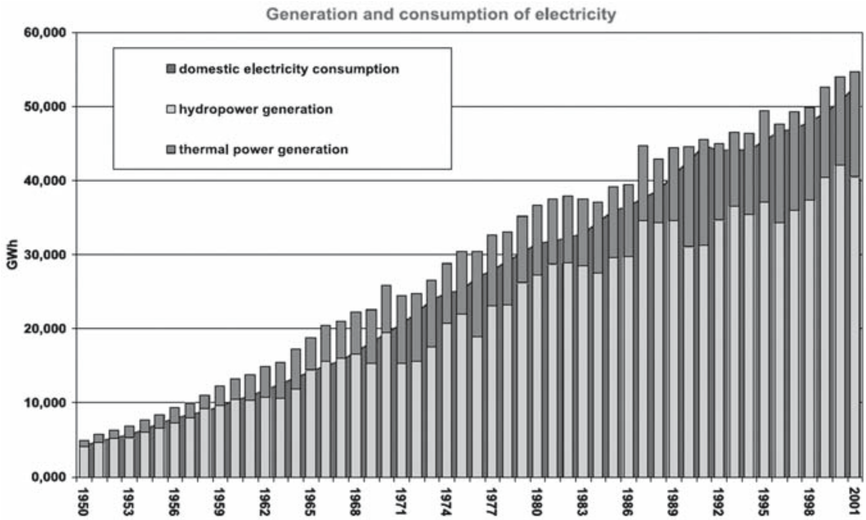

Figure 13. Generation and consumption of electricity (in GWh). (Austrian Energy Agency (1997–2007), http://www.energyagency.at/(de)/pop/bild.htm.).

A very high percentage of the surface waters in Austria are characterized by their utilization – e.g. for the generation of electricity, flood protection, navigation etc. With few exceptions, they are categorized as "heavily modified water bodies" according to the European Water Framework Directive.

3.4. WATER QUALITY MONITORING

Since 1991 approximately 2,000 ground water sampling sites (observation: 4 times per year) and approximately 250 running water sampling sites (observation: 6–12 times per year) have been monitored according to standardised criteria.

Monitoring sites for groundwater in porous media comprise investigation wells, private wells, industrial wells and partly water supply wells. Monitored springs (karst and fractured rock) comprise also captured springs.

River monitoring sites are situated along the most important river sections. The heterogeneity of the Austrian running waters is reflected in the definition of mountainous and lowland waters. Monitoring sites are classified according to this rough typology.

The parameters monitored in groundwater and running waters are split into three blocks comprising about 100 different parameters:

- Block 1: the most important inorganic parameters with relevance to the environment, e.g. nitrate, nitrite, ammonium, phosphate, boron, alkali metal and alkaline earth metal (e.g. potassium, calcium, magnesium)

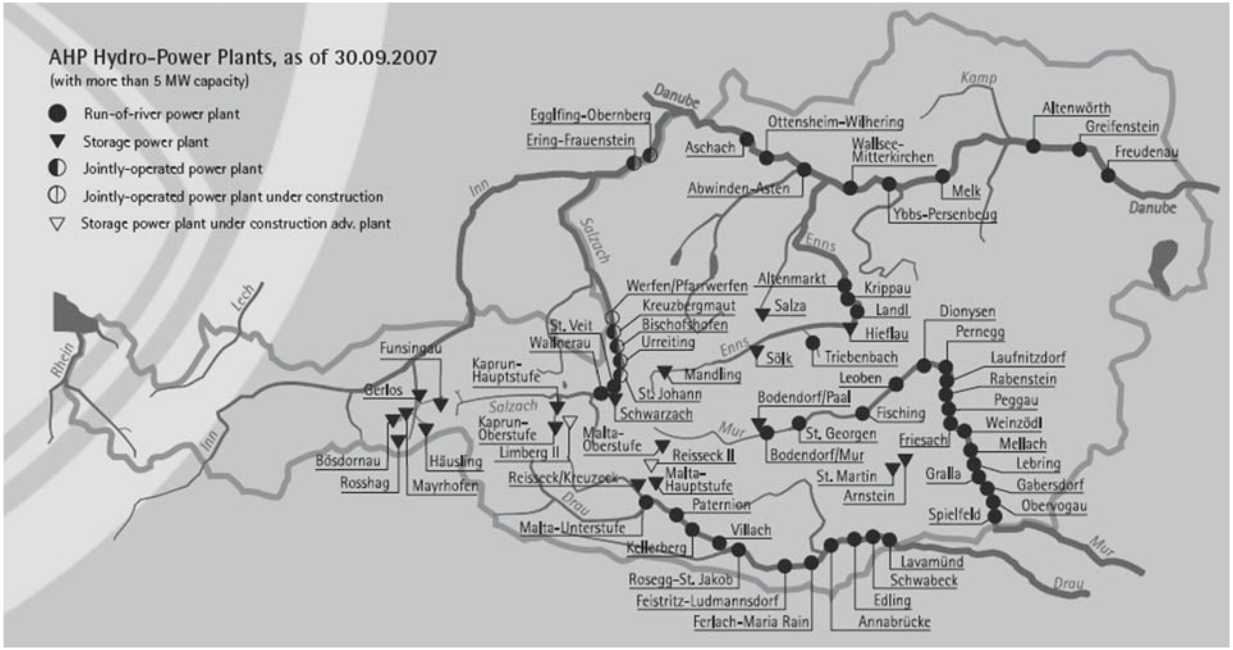

Figure 14. AHP hydro-power plants (>5 MW capacity). (Verbund, Austrian Hydro Power AG, 2007.).

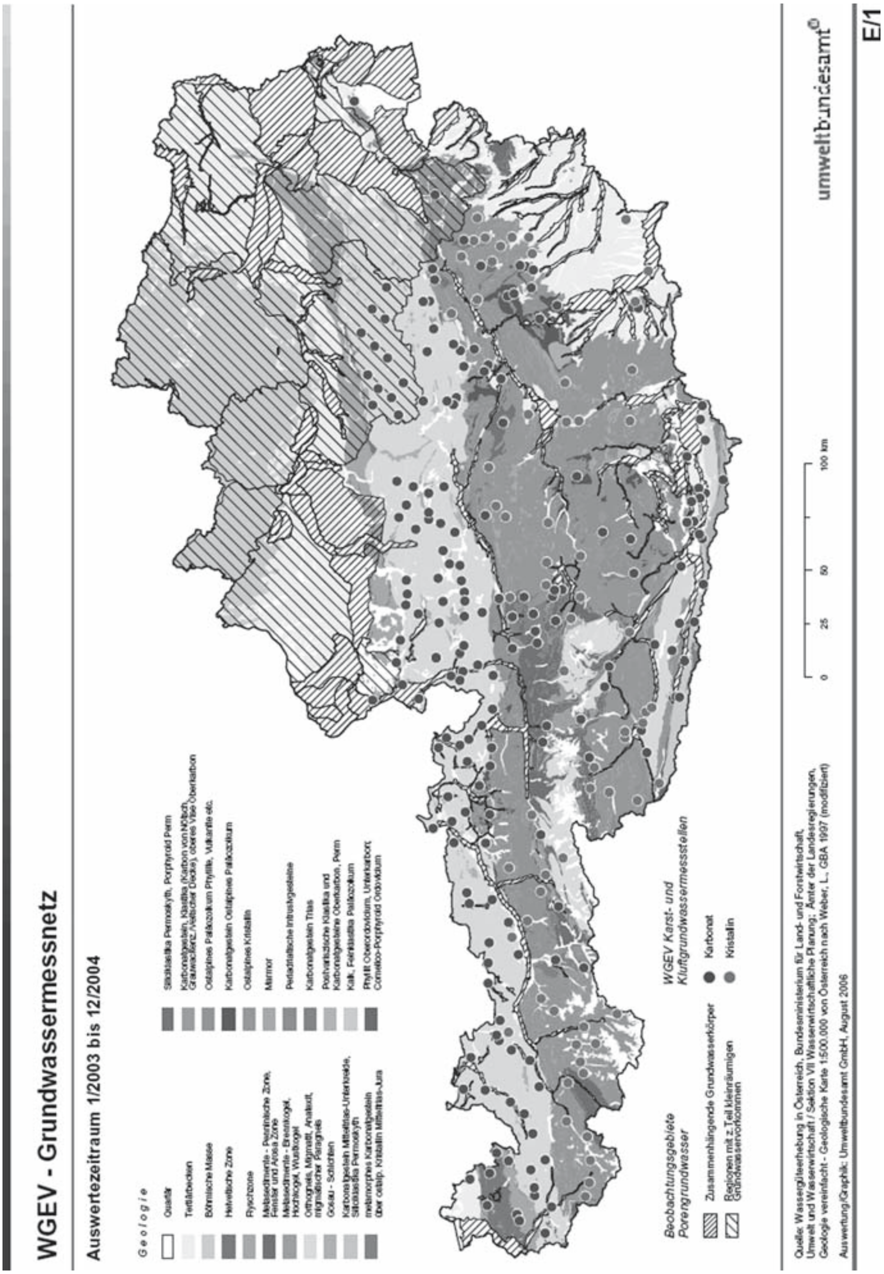

Figure 15. Map of groundwater monitoring network in Austria. (Umweltbundesamt, 2004.).

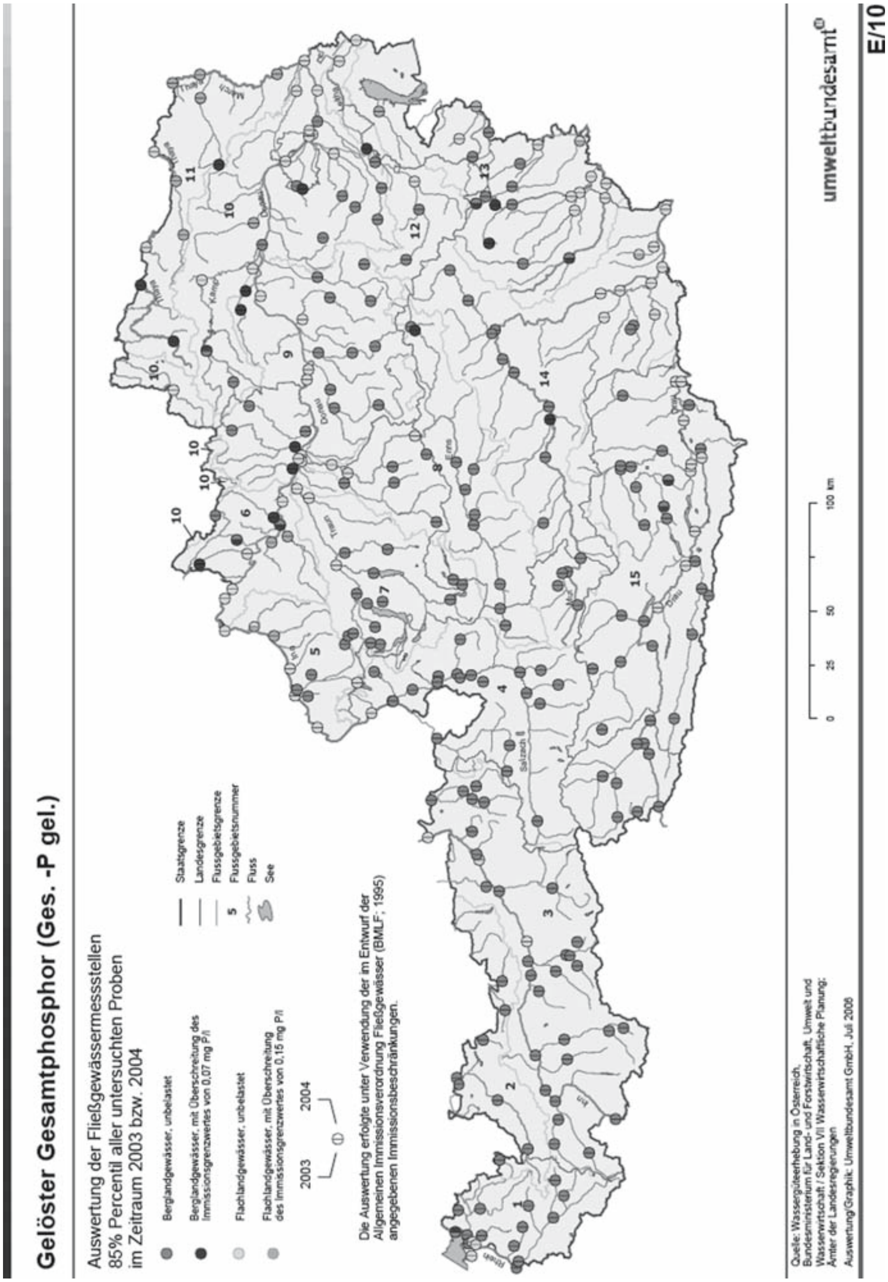

Figure 16. Map of surface water quality in Austria (dissolved total phosphorus). (Umweltbundesamt, 2004.).

- Block 2: the heavy metal group (e.g. arsenic, mercury, cadmium) and lightly volatile halogenated hydrocarbons (e.g. tetrachloroethylene)
- Block 3: the broad group of pesticide substances (e.g. triazine, phenoxy alkane carbon acids), polycyclic aromatic hydrocarbons, etc.

For rivers also heavy metal analysis of river sediments is carried out.

The results of water quality monitoring are published as annual reports and on the internet homepage of the Austrian Environmental Agency (*www.umweltbundesamt.at*) (Figure 15 and 16).

The costs of sample analyses and data transfer are met by the federal (2/3) and provincial authorities (1/3); the costs of selection and of establishing sampling sites are met totally by the federal authorities.

To meet the demands of the EU Water Framework Directive, the monitoring network is currently being redesigned from an impact-oriented network to a representative network.

4. Austrian water legislation

4.1. AUSTRIAN WATER POLICY TARGETS

The overall objective of water policy in Austria is to ensure sustainable water management with the following cornerstones (Umweltbundesamt, 2004):

- To assure a stable water balance at regional level by striking a balance between water use and the natural renewal capacity of catchment areas.
- To maintain or restore a near-natural state of water bodies while safeguarding the right to water of future generations.
- To protect the human living space against damages or threats caused by water.
- To prevent contamination of all waters including groundwater to an extent that guarantees that neither human beings nor animals are exposed to health hazards and that allows the use of ground and spring water as drinking water, and to use surface water for public or commercial purposes, to preserve the integrity of fish waters as well as to avoid impairment of nature or landscapes and occurrences of any other observable damages. In this respect water pollution prevention is the conservation of natural water conditions in terms of physical, chemical and biological parameters (water quality).
- To raise public awareness for the value of water and for a conscious use.

4.2. THE AUSTRIAN WATER ACT AND RELATED LEGISLATION

In order to achieve and safeguard these objectives the *Austrian Water Act* (Wasserrechtsgesetz – WRG), being the core of Austria's Water legislation and the respective regulatory instrument, sets out the corresponding provisions (Figure 17).

In the 1990 *Amendment to the Austrian Water Act* special emphasis is placed on water protection introducing the ecological approach and the

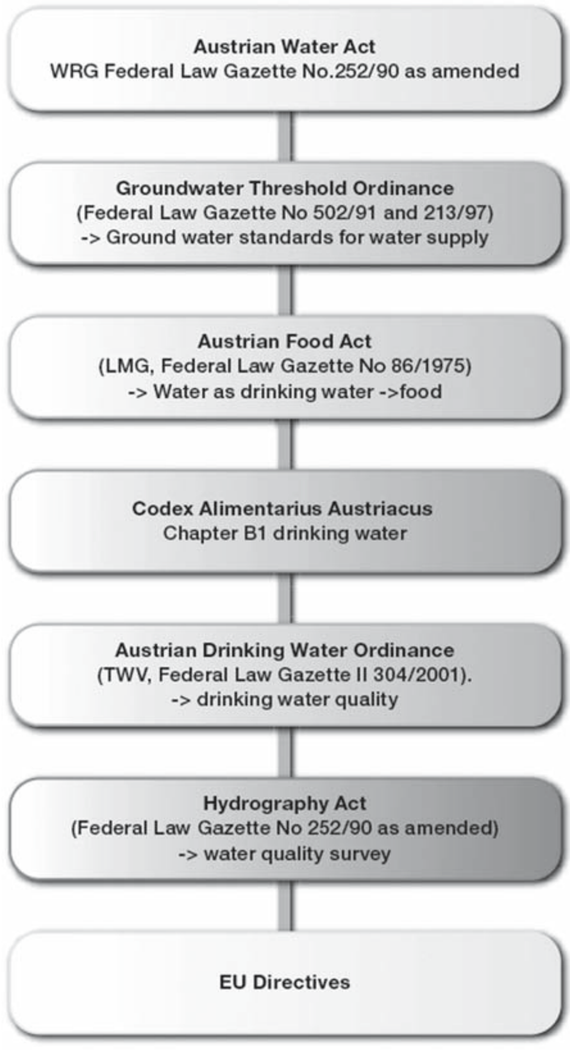

Figure 17. Water legislation in Austria. (BMLFUW, Austrian Water, Facts and Figures, 2006b.).

principle of BAT in order to reinforce sanitation. A revision in 1999 strengthened the tools for water management planning, modernised the provisions for water associations and enlarged the frame for sanctions against violations of the Water Act. Furthermore the provisions for the assessment of water quality and water quantity were adapted to the needs emerging from the EU Water Framework Directive (WFD). The Austrian Water Act was further amended in 2003 by transposing the EU Water Framework Directive into national legislation.

The Water Act falls within the competence of the Federal Ministry of Agriculture, Forestry, Environment and Water Management which is also responsible for the application of pesticides and fertilizers. As soon as groundwater is withdrawn for the purpose of drinking water, the competence rests with the Federal Ministry of Health, Family and Youth (*Austrian Drinking Water Ordinance*).

The blanket protection of groundwater is laid down in the Austrian Water Act and in regulations such as the *Groundwater Threshold Value Ordinance*.

In Austria standardised water quality monitoring based on legal provisions started in 1991. The implementation of the Austrian water quality monitoring system is laid down in the *Hydrography Act* and is the shared responsibility of the Federal Ministry for Agriculture, Forestry Environment and Water Management and the provincial authorities. The amendment of the Austrian Water Act in 1990 laid the foundation for the *Water Quality Monitoring Ordinance* which provides the legal framework for a uniform, nationwide monitoring of running waters and groundwater quality.

General regulations and limit values of emissions to water are laid down in the *Ordinance on Waste Water Emissions*. It contains detailed definitions of wastewater issues, addresses general principles of wastewater handling and wastewater components and describes basic requirements of water resource management related to wastewater treatment according to best available technologies. Based on this ordinance branch-specific wastewater emission ordinances have been and continue to be enacted.

4.3. THE EU WATER FRAMEWORK DIRECTIVE AND ITS IMPLEMENTATION IN AUSTRIA

On December 22, 2000 the Directive of the European Parliament and Council "Establishing a Framework for Community Action in the Field of Water Policy" (EU Water Framework Directive – 2000/60/EC) entered into force.

The main objectives of the Water Framework Directive are

- To set-up European-wide specific environmental objectives regarding surface water and groundwater

- To undertake comprehensive analyses of the characteristics of river basins and the impacts of human activity and their consequences
- To preserve or improve the water quality of all water bodies
- To ensure the good status of rivers, streams, lakes and groundwater
- To prevent further deterioration of the status of aquatic ecosystems (non-deterioration clause)
- To establish river basin management plans by 2009
- To apply economic instruments in order to ensure an efficient and economic use of water resources
- To encourage active involvement of all interested parties in the implementation of the Directive (public participation)

The EU Water Framework Directive was transposed into the Austrian Water Act through its year 2003 amendment. Essential innovations lie in the following principles and elements: water management based on river basin units (for Austria: the Danube, the Elbe and the Rhine), a mandate to improve conservation to at least a good ecological status of all water bodies in combination with a prohibition of their deterioration as well as the active involvement of the public.

The current status of the EU Water Framework Directive implementation in Austria includes the analysis and status assessment of the Austrian river basin districts which were rated and classified by the level of risk of failing to reach the required good status ("no risk", "risk cannot be evaluated at present" or "at risk"). The report on the analysis of the river basin districts (Danube, Elbe and Rhine) which was published in April 2005 (BMLFUW, 2005c) establishes a baseline and identifies priority actions for subsequent stages in the river basin planning cycle. It is based on:

- Nine hundred forty surface water bodies in rivers with a catchment area of more than 100 km^2 and a total length of about 11,500 km
- Sixty-two surface water bodies for lakes with an area of more than 0.5 km^2
- Sixty-four identified individual shallow groundwater bodies covering a total area of 9,682 km^2 and 62 groups of groundwater bodies with a total area of 74,026 km^2 as well as one individual deep groundwater body (thermal groundwater body) and eight groups of deep groundwater bodies

The results of the status assessment confirm the effectiveness of the measures already taken in order to reduce the impacts due to organic and nutrient pollution as well as chemical contamination from urban and industrial sources.

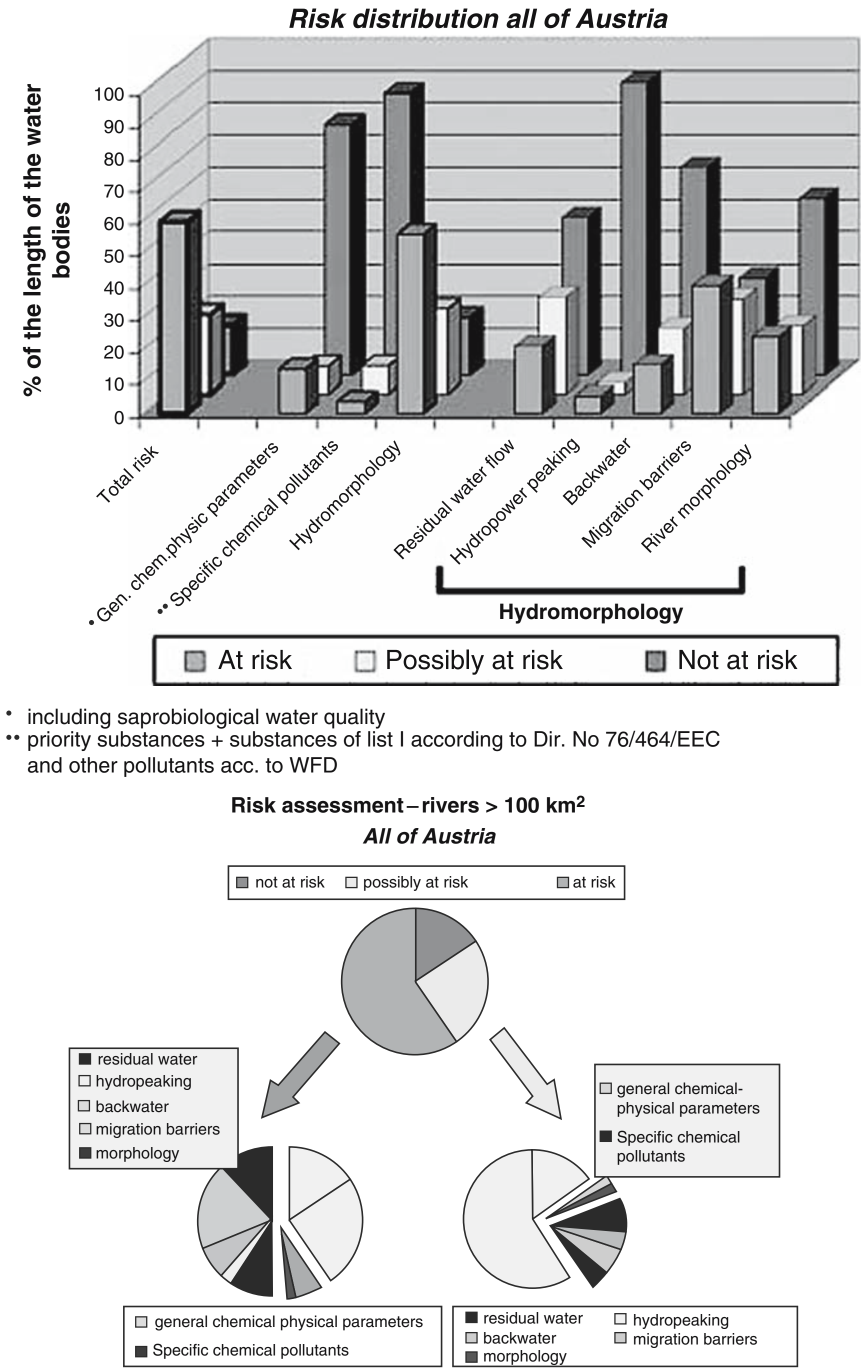

Figure 18. Results of risk assessment in Austria (likelihood of failure to meet good status for >100 km^2 network of rivers) with respect to impact categories and their sub-categories. (BMLFUW, 2005a.).

However, with regard to the chemical-physical parameters 15% or 1,770 km of the assessed rivers, but not one single lake, were classified as being at risk to meet the required good status. Deficits with regard to the requirements of the Water Framework Directive have been identified mainly in the hydrological and morphological situation of rivers which is primarily due to the generation of hydropower and flood control measures on a large number of running water bodies. Three hundred twenty-eight running waters bodies (or 4,998 km, i.e. 44% of the water network) were provisionally identified as "heavily modified water bodies". The results of the risk assessment for surface water according to risk categories are presented in Figure 18.

By combining the individual assessment of the risk of failing the "good status" according to the "one out – all out principle" (i.e. "worst case assessment") a total of 485 water bodies which corresponds to 52% of the total number of water bodies identified (or 6,839 km corresponding to 60% of the analysed Austrian river network) will be at risk of failing the "good status".

About 5.9% of the identified groundwater bodies corresponding to 3.6% (ca. 3,000 km^2) of the Austrian federal territory are at risk of not meeting the "good chemical status". This is mainly due to pollution by agricultural practices (e.g. nitrate and pesticides).

The next activities will include the drawing up of the first national river basin management plans (to be completed until 2009), adapting the water quality monitoring network and restoring those water bodies failing to meet the defined objectives for which the monitoring will confirm their non-compliance. Furthermore Austria needs to take action with respect to the structure of water bodies in the planning process. A significant number of water bodies will probably be classified as "significantly modified water bodies" in terms of structure and based on the assumption that those already meet the associated objective of "good ecological potential". Priorities will be defined in order to achieve the environmental objectives for the water bodies "at risk" for which the most cost-effective measures will be selected.

5. The financing/funding system of Austrian water management

On the basis of the *Environmental Support Act* (Umweltförderungsgesetz) and the *Hydraulic Engineering Assistance Act* (Wasserbautenförderungsge setz) measures in the fields of water management in residential areas and protective hydraulic engineering are subsidized by the Federal Ministry of Agriculture, Forestry, Environment and Water Management.

5.1. WATER MANAGEMENT IN RESIDENTIAL AREAS

Based on the (Austrian) Environmental Support Act the Federal Government grants subsidies for measures serving the municipal and operational wastewater disposal as well as the municipal water supply. These funds have allowed the implementation of a great number of projects for the protection of Austria's water resources and providing the population with a sufficient quantity of safe drinking water.

From 1959 to 1993 measures for residential-area water management were funded by the Federal Government by way of granting cheap loans from the Water Management Fund. This funding system was mainly oriented towards supporting supply and disposal in central residential areas. In 1993 the Environmental Support Act prompted a re-structuring of Federal Government funding for residential-area water management aiming at an enhanced development of wastewater disposal in rural areas. Since then, investments have mainly been boosted through annuity and investment allowances. In 2001 the system was changed over from paying out subsidies to granting allowances for financing.

From 1993 to 2003 funding was handled by Kommunalkredit Austria AG which was taken over by its subsidiary Kommunalkredit Public Consulting GmbH in 2003.

The following three areas of residential-area water management are funded by the Federal Government:

- Measures aiming at municipal water supply and wastewater disposal
- Measures aiming at disposal of wastewater at company level
- Research projects in the field of residential-area water management

The subsidies for municipal water supply and wastewater management for the period 1959–2006 are presented in Table 2, Figure 19.

The funding for the current period can be summarised as follows:

- For the years 2005–2008 the annual volume of funding approved for residential-area water management is 218 Mio EURO.
- Currently about 86.6% of funding volume is provided for wastewater disposal and 13.4% for water supply. The average funding rate is 30.3%.

TABLE 2. Investment and funding volume of water supply and wastewater projects. (BMLFUW, http://www.wassernet.at/article/articleview/19896/1/5708.).

	Funding volume, cash value (€)	Investment (€)
1959–1993		Approx. 19 billion
1993–2006 (*UFG*)	Approx. 3.94 billion	Approx. 13 billion

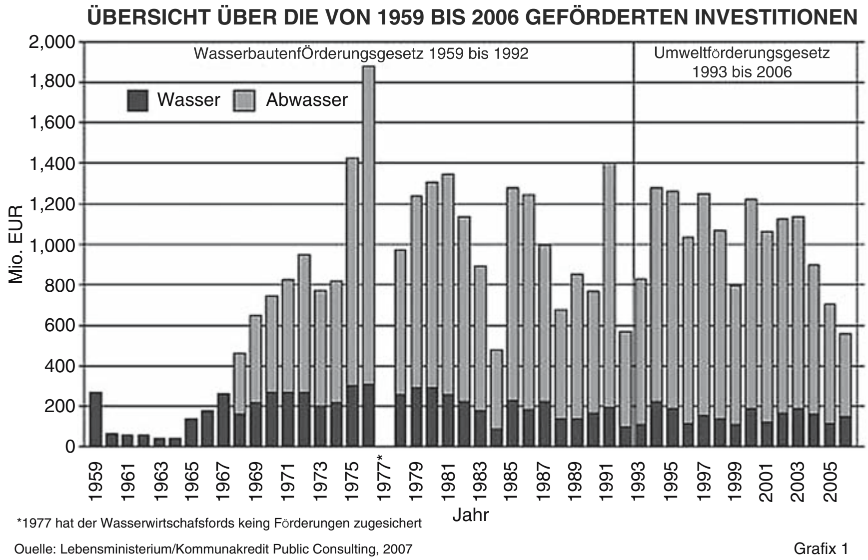

Figure 19. Overview on Federal Government subsidized investments in municipal water supply and wastewater management in Austria, 1959–2006. (Kommunalkredit Public Consulting, BMLFUW, 2007.).

- In 2006 1,961 residential-area water management projects (at municipal level) were approved accounting for a cash equivalent of funds of 178.62 Mio EURO.
- According to an investment-cost estimate from 2003, a further investment volume of approximately 4.6 billion EURO is expected for the period 2007–2015.

5.2. PROTECTIVE HYDRAULIC ENGINEERING

On the basis of the Hydraulic Engineering Assistance Act the Federal Government makes available funds for measures aiming at the improvement of the water balance and at the protection against water-related hazards as well as at measures to safeguard and to improve the ecological intactness of waters provided that the objectives mentioned before are fulfilled at the same time.

During the last years Austria has annually spent approximately 220 Mio EURO for flood protection paid by federal, provincial and municipal authorities. With these efficiently used funds a great number of projects in the field of protective hydraulic engineering, taking also into consideration socio-political requirements, could be implemented for the benefit of the Austrian population and for improving aquatic ecosystems.

5.3. WATER SUPPLY PRICES

Austria has no private profit-oriented market for water supply, but is mainly organised by municipalities and water associations. According to the Law on Water Charges from 1990, the municipalities are authorised to set their own water charges. Figure 20 shows the prices for municipal water supply in households for selected Austrian cities. The average price for Austrian drinking water is about €1.04/m^3.

6. Case studies

6.1. WATERMARK – A MULTIDISCIPLINARY RESEARCH INITIATIVE FOR THE EU WATER FRAMEWORK DIRECTIVE

WATERMARK is a multi-disciplinary research initiative at the Austrian Research Centers which aims at developing intelligent knowledge-based services and solutions in order to support the implementation of the EU Water Framework Directive. One of the basic requirements for realizing the

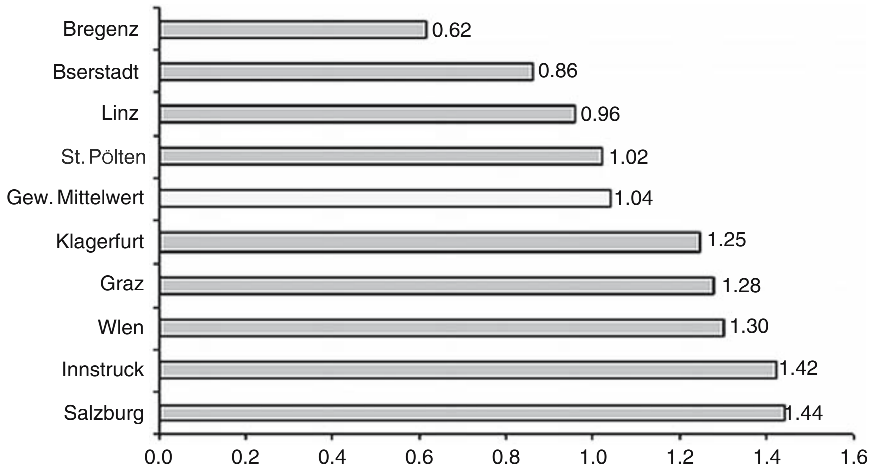

Figure 20. Prices in households in Austrian cities in Euro per cubic meter. (www.stadtwerke-bregenz.at, www.wlvnb.or.at, www.grazer-stadtwerke.at, www.ikb.at, www.stw.at, www.linz.at, www.salzburg-ag.at, www.st-poelten.gv.at, status September 2002.).

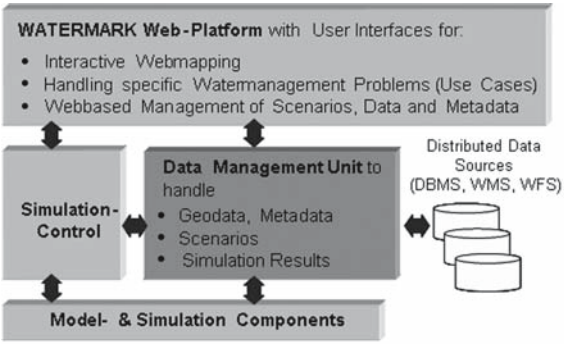

Figure 21. WATERMARK – open architecture for intelligent data management. (Klingseisen et al., 2006.).

requested integrated water management approach is to develop advanced information and data management tools and applications.

The main objective of the WATERMARK project is to produce additional value out of environmental data which will become available in the course of WFD implementation, e.g. by supporting the decision making process in companies and public authorities, providing impact and risk assessment tools and performing scenario analyses. Consequently, the WATERMARK application is a precursor of a completely new class of applications that will be able to tap into data currently available only to hydrologists (if at all), possibly merge this data with knowledge from other domains and present the end results in a way most suitable to support the decision making process. Another research component deals with the impact assessment of anthropogenic activities on the environment through selected criteria and indicators. A focus was set on raster based spatial analyses, e.g. to calculate indicators for the usability of groundwater resources for drinking water supply.

A web-based WATERMARK prototype was implemented using open source components for GIS analysis and groundwater modeling. The main components of the WATERMARK architecture are shown in Figure 21.

6.2. CONSTRUCTED WETLANDS FOR DECENTRALIZED WASTEWATER TREATMENT

In Strengberg, Lower Austria, a constructed wetland designed as vertical flow reed bed system was used as pilot plant for tertiary wastewater treatment (see Figure 22). Due to the small and sensitive receiving water a final nutrient removal stage was required.

Figure 22. Constructed wetland Strengberg, Austria.

The research activities concentrated on the efficiency of the wetland in treating residual COD, nitrification and phosphorus removal as well as operational stability. The efficiency and operational full-year reliability (summer/winter) have become of great importance when comparing constructed wetlands to competing technologies.

In order to optimise the system the hydraulic load was continuously increased within different operational stages. For a hydraulic load of $0.4\,m^3/m^2$,d the residual COD was effectively removed with rates ranging from 50% to 60%. The objective of reliable full-year ammonium removal was met sufficiently with nitrification rates in the range of 40–90% (Schönerklee et al., 1997). The results of the scientific investigation programme showed that this type of treatment system is well suited for decentralised solutions especially with regard to its easy operation and the low energy and operation costs.

7. Conclusions and recommendations

The national water resource management aims to achieve the objectives set out in the WFD by promoting an ongoing cross-sectoral dialogue primarily between water supply, wastewater treatment, hydraulic engineering, energy industry, agriculture, regional planning as well as other environmental disciplines. High investments made in recent decades, most of all in urban and industrial wastewater discharge facilities, certainly paid off as emissions rates have been reduced significantly and a high water quality of surface water and groundwater has been achieved. One of the further goals of water resource management will be to improve the ecological integrity of heavily modified river courses.

Austria as one of the countries with the most abundant water resources holds a high knowledge and technological position in terms of water protection and treatment. In future it aims to further engage at international level in order to develop concepts and solutions for sustainable water management and safe drinking water supply.

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PROBLEMS AND PROSPECTS OF WATER RESOURCES MANAGEMENT IN THE AZERBAIJAN REPUBLIC

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Abstract: This paper presents distinctive features, total usage, and the potential of water resources of Azerbaijan. The agreements on use of water resources of the transboundary rivers are described and characterized. Rational use and protection of transboundary water resources require specific actions.

Keywords: Water resources; watershed

1. Introduction

The Azerbaijan Republic is an independent state located at the western coast of the Caspian Sea between the Big and Small Caucasus systems of the mountains of Talysh (Figure 1). Azerbaijan has common borders with the Russian Federation (289 km from the north), with Georgia (340 km from the northwest), with Armenia (766 km from the west), and with Turkey (11 km) and the Islamic Republic of Iran (618 km from the South). The coastline with the Caspian Sea extends about 900 km, establishing the eastern border of the Republic.

2. Water resources

All the rivers of Azerbaijan belong to the watershed of the Caspian Sea. The river network is distributed non-uniformly over the territory of the republic. Thus, lowlands with friable non-watertight ground are dry, whereas in the mountains there are more rivers and greater rainfall. The river network is more developed at elevations of about 1,000–2,500 m (i.e., the middle-height of the mountains), above which it is rarer. On the plains, there are many fewer rivers, and a portion of them has no drainage (Figure 2).

Rivers comprise the basis of a hydrographic network in the republic. The network discharges water into the Caspian Sea, although some of the rivers

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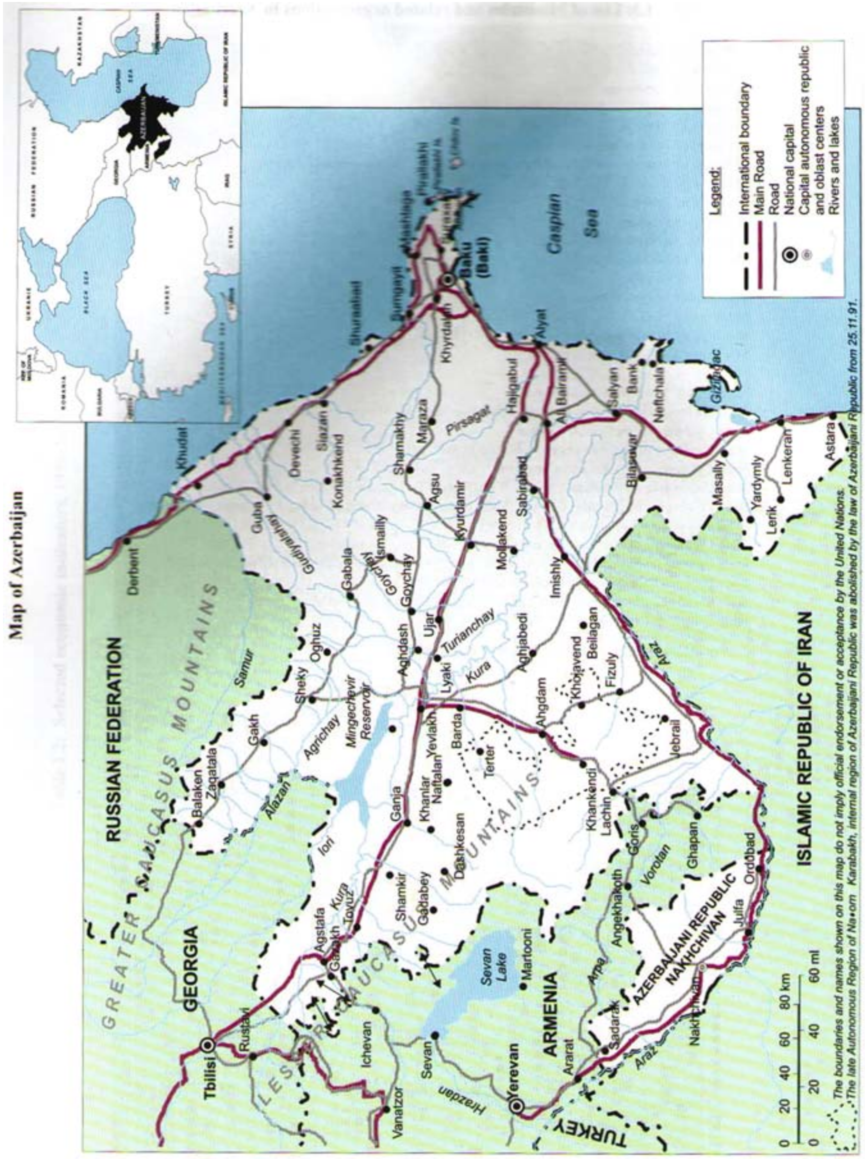

Figure 1. Map of the Azerbaijan Republic.

Figure 2. River network of the Azerbaijan Republic.

run directly to the sea whereas others flow into the Araz or Kura Rivers. The entire river network of the republic consists of 8,350 rivers. Two of them – Kura and Araz – have lengths of more than 500 km. The greatest river of the Azerbaijan is the Kura River, which has a total length of 1,364 km and a watershed area of 188,000 km^2. It begins in Turkey, and its length within the territory of Azerbaijan is about 900 km. The second largest river of Azerbaijan is the Araz River (1,072 km, 102,000 km^2) which, like the Kura River, originates in Turkey (Figure 3). There are several thousands of small rivers, of lengths less than 10 km, in the mountain areas of Azerbaijan. About 800 rivers of the republic have lengths from 10 to 100 km.

The main sources of formation of water resources of the republic are surface waters (from atmospheric precipitation – rain or snow), drainage of underground waters and river flow from the adjacent countries, and groundwaters (infiltration of atmospheric precipitation, river or irrigational waters).

2.1. WATER QUANTITY

The water stocks of the country were estimated at about 35 billion cubic meters of which 5 billion cubic meters are underground waters. River waters of the republic make up an annual average of 28.5– 30.5 km^3, which may go down to 22.5 km^3 in dry years. Local drainage contributes about 10 km^3.

Figure 3. Map of the Kura and the Araz watersheds.

Trans-boundary and boundary rivers (Kura, Araz, Ganyh, Samur, and others) make up about 20 km^3, or 67%, from the total water stocks.

In addition to the rivers network, 450 lakes are located within the territory of the Azerbaijan Republic with a total area of about 394 km^2. Bojuk-Shor, Aggel, Sary-Su, Hadzhi-Kabul, and Masazyr are the biggest lakes, and 250 lakes are small ones. In the mountains, there are lakes of tectonic and glacial origin. Along the coast of the Caspian Sea, there are littoral lakes and estuaries.

Along with the natural hydrographic network, a branched out artificial irrigating system has been constructed, which is regulated by water storage pools. In total, there are about 60 reservoirs or man-made lakes in the territory of the republic, with an overall volume of about 22 km^3. The largest of them is the Mingechaur (in the middle stretch of the Kura river, with total water volume of about 16.1 km^3), Araz (water volume of 1.35 km^3) and Shamkir (water volume of 2.67 km^3).

The basic water resources of the country are formed in the territories of neighboring countries. The annual water deficit is as large as 4 billion cubic meters. Seventy-five percent of the territory belongs to the lower catchment of the Kura River, so that up to 700 million cubic meters of polluted waters come from territory of the neighboring republics.

2.2. WATER QUALITY

Characteristic features of water resources of Azerbaijan from the point of view of their use are: limitation, non-uniform distribution, formation of about 70% of the resources of surface waters in territories of adjacent countries, and river waters being already heavily polluted when they enter the territory of the country.

The Kura river receives in a year on average about 350 million cubic meters of polluted water from the territory of Armenia, about 320 million cubic meters from Georgia, and 25 million cubic meters from Azerbaijan. Water is highly polluted with heavy metals, phenols and mineral oil. The Araz River with its tributaries is exposed to strong anthropogenic influences from the territory of Armenia. In waters of the Araz River, a tenfold excess of copper, molybdenum, and other heavy metals was found. As a result, micro flora and fauna are damaged, the process of self-purification is stopped, and the river has become a “dead zone”. Seventy-five percent of the population of the republic uses the polluted river water for drinking and agricultural purposes, and this poses a danger to people’s health and to the ecological system as a whole. However, gathering of information on pollution of the Kura River basin became extremely difficult.

Catchment areas of two main rivers of the republic – the Kura and the Araz – cover a significant part of the territories of Azerbaijan, Georgia, Armenia, Turkey and Iran. It is polluted already within the territory of Georgia because it drains large industrial cities like Tbilisi and Rustavi. When it reaches the border of Azerbaijan, Kura River water is strongly polluted: BOD 3.71 mg/L, mineral oil 0.15 mg/L, phenols 0.03 mg/L, etc. Within Azerbaijan territory, the Kura water is additionally polluted by agricultural sources, industry, and also municipal wastewaters. BOD increases sometimes up to 4.1 mg/L, mineral oil up to 0.24–0.30 mg/L, and phenols up to 0.04–0.08 mg/L.

Significant contribution to pollution of the Kura River comes from its main tributary – the Araz River, along with its tributaries, Razdan and Ohchuchaj. For the Ohchuchaj River alone, which receives industrial effluents from Kadzharan copper-molybdenum and Kafan copper-mineral factory of Armenia, the copper content exceeds the maximum concentration limit by 25–50 times and phenols by 6–15 times. The red-brown liquid, of which the effluent consists, is constantly enriched with aluminum, zinc, manganese, titanium, bismuth, etc.

2.3. MAIN PRESSURES

Azerbaijan is a country of irrigated agriculture. From a total area of the republic of 8.66 million hectares, only 4.6 million hectares are suitable for agriculture. Of these, 3.2 million hectares are suitable for irrigation. About 90% of agricultural production is on irrigated land. The area of irrigated land is 1.45 million hectares.

Within the boundaries of the republic, that has in general an arid climate, a significant part of the territory has insufficient water. In Azerbaijan, for about 1,400,000 ha of irrigated area, there are as many as 205 irrigating systems, 40 water basins, and 1,000 of the chinks extracting underground waters. Development of the irrigation network has reached 450,000 km. The Upper Karabah Canal (length of about 172 km, flow-rate 114 m^3/s), the Upper Shirvan Canal (123 km long, 78 m^3/s flow-rate), and Samur-Apsheron Canal (178 km long, 55 m^3/s flow-rate) are the biggest waterways, feeding from the Kura and Samur Rivers.

Because of weak development of sewage treatment systems in Azerbaijan, Georgia, and Armenia, the majority of settlements discharge their wastewaters directly into the rivers; thus tributaries of the Kura and Araz Rivers are constant sources of pollution for river waters.

Ground waters are not subjected to regional pollution in the territory of the republic. However, local pollution from municipal, industrial, and agricultural sources occurs. The main reason for municipal pollution is the absence or limited development of a sewage treatment system and water treatment plants in the majority of settlements. Sewage waters are discharged into the rivers, sea, into natural depressions or specially constructed wells. Pollution of surface waters occurs directly by infiltration of already polluted river waters or by migration of contaminants through a zone of aeration.

3. Legislation for water management

3.1. DOMESTIC LAWS

Water usage in the Azerbaijan Republic is regulated nowadays by corresponding laws and legislative acts. The main law is the Water Code of the Republic. The Code is supplemented by additional specific laws: the law on land improvement and irrigation, the law on water supply and sewage, the law on hydro-meteorological activity, the law on preservation of the environment, the law on water management in municipalities, the law on safety of hydraulic engineering constructions, and others.

For successful implementation of the water legislation, a number of guiding rules were developed in recent years, among which are those defining riparian protection areas, protected coastal zones, and those guiding the use of water bodies for power generation or other hydraulic schemes. In addition, all of the other laws applied to the economic sectors contain special provisions related to water resources use and protection.

The Azerbaijan Republic is constantly looking for new opportunities for collaboration, bilateral and multilateral cooperation. Our country cooperates with many other countries on problems dealing with protection of the environment and sustainable use of natural resources, including decisions on water problems.

According to the Constitution of the Azerbaijan Republic, the international conventions and agreements ratified by the Parliament of the Republic are an integral part of the legislative system of the country. It is specified in the water legislation, that if international and national rules connected with the use and protection of water resources and objects are not the same, then the international agreements (which the Azerbaijan Republic has joined) must be applied.

3.2. INTERNATIONAL AGREEMENTS

The Azerbaijan Republic ratified a series of international agreements on environmental protection as follows:

- The convention on protection and use of trans-boundary water-courses and international lakes (Helsinki, 1992)

- The convention on trans-boundary Environmental Impact Assessment (EIA)
- Convention on access to information, public participation in decision-making, and access to justice in environmental matters (Aarhus, 1998)
- United Nations convention regarding trans-boundary consequences of industrial accidents

3.3. BILATERAL AGREEMENTS

Water resources of the trans-boundary rivers Kura and Hrami are regulated on the basis of bilateral agreements of the interdepartmental organizations with Georgia. However, there are difficulties in operation of the water-intakes and other hydraulic infrastructure constructed on the trans-boundary rivers and located in the territory of Georgia.

Use of water resources of the Araz River is regulated by close mutual relations with Iran. On the river Araz, the water storage basin with a volume of 1.35 million cubic meters was constructed by both countries. There is an operating Iran-Azerbaijan Commission on sharing water and power resources of the Araz River.

Distribution of water between Azerbaijan and Dagestan (Russia) is regulated on the basis of the Protocol of Ministry for Water Industry of the former USSR (October 7, 1967). According to the International Conventions, the Agreement on sharing water resources of the Samur River is in effect.

At the present time contact with Armenia is difficult. As a result, the water industry in the zone which is under negotiations is completely destroyed. Nowadays, 8 water storage basins with a total capacity of 640 million cubic meters are on the territory of this negotiations zone, and their use by Azerbaijan became impossible. The highest dam in the republic (125 m) of Sarsang water pool (with volume of 560 million cubic meters) became a real danger for 400,000 inhabitants because of insufficient maintenance service.

4. Conclusions

Water resources of the Azerbaijan Republic are the property of the state. Different organizations are engaged in management of water resources, monitoring, maintenance service and scientific research at a national level. The joint-stock company of the open type "Land improvement and water management of the Azerbaijan" created in 2006 is a principal unit that is responsible for management, use and protection of water resources. Rational use and protection of water resources have special value for Azerbaijan which is located in the lower stream of the Kura River basin and has limited water resources.

At present the Cabinet of the Republic provides the coordination of activity of the interested parties and carries out the water policy. The Ministry of Ecology and Natural Resources of the Azerbaijan Republic, together with other interested parties, prepared a number of programs, which are approved by the President. According to the National Program "on ecologically sustainable social-economic development", the creation of the state program on sustainable use of water resources, stimulation of their rational use, improvement of quality of drinking water, improvement of the laws regulating ecosystem functioning, and protection of trans-boundary rivers from pollution are planned.

It may be concluded that the following actions should be required for sustainable use of water in Azerbaijan:

- To harmonize the National Legislations in accordance with the European Union's Water Framework Directive
- Joining the Helsinki Convention of the countries (Armenia and Georgia) located in a river basin of the Kura, for maintenance of coordinated use and protection of water resources of the trans-boundary rivers
- Preparation of the scientifically-proved scheme of complex use and protection of water resources of the Kura River basin (with help of international organizations) and bilateral agreement between Azerbaijan and Georgia on use of water resources of the Kura River
- Establishment of monitoring of quality indicators of water of the Kura and Araz Rivers on territories of each of the states according to the international legislation, in order to assess the ecosystem damage of the rivers and to prepare ways of its prevention; to develop the mechanism of compensation for the damage
- Development of a basin-wide action program for equitable, integrated and sustainable water resources management by the countries sharing the watersheds of the Kura and Araz Rivers

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WATER RESOURCES MANAGEMENT SYSTEM OF KYRGYZSTAN

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Abstract: The main requirement for sustainable use of water resources is having an integrated watershed management system. Taking into consideration global strategy guidelines and policies, special attention was given to: characterization of water resources; analysis of institutional infrastructure and responsibilities of different bodies; legislative framework; financial mechanisms for water resources management; and the current problems of implementation of watershed management.

Keywords: Water resources; watershed management

1. Introduction

The territory of the Kyrgyz Republic is about 200,000 km^2 (size ranking of 85th in the world). The population as of April 2005 is 5.134 million people, of whom 65% are Kyrgyz people, 13.7% are Uzbek people, and 12.5% are Russians. The population density is 24.6 inhabitants/km^2. The capital of the country is Bishkek city (Figure 1).

The Kyrgyz Republic is a sovereign, unitary, democratic country. The State authority of the Kyrgyz Republic is represented and implemented by its President, Parliament, Government officials, executive authorities, and courts of law.

The administrative and territorial division of the country is a three-level system: (i) Oblasts (regions), Bishkek city, and Osh town; (ii) regions and towns; (iii) villages, urban-type communities, and towns within regions (Figure 2). Local jurisdictions are town, region and village representative bodies and local state (national) administration (executive authorities).

The economy of the country underwent significant changes over the last few years, on the whole similar to changes in other countries with transitional economies. There was a period of slow increase before 1990, then a transition to a sudden fall, then after 1996 turned to a stage of some increase (Figure 3).

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 61–80.

Figure 1. Map of Kyrgyzstan.

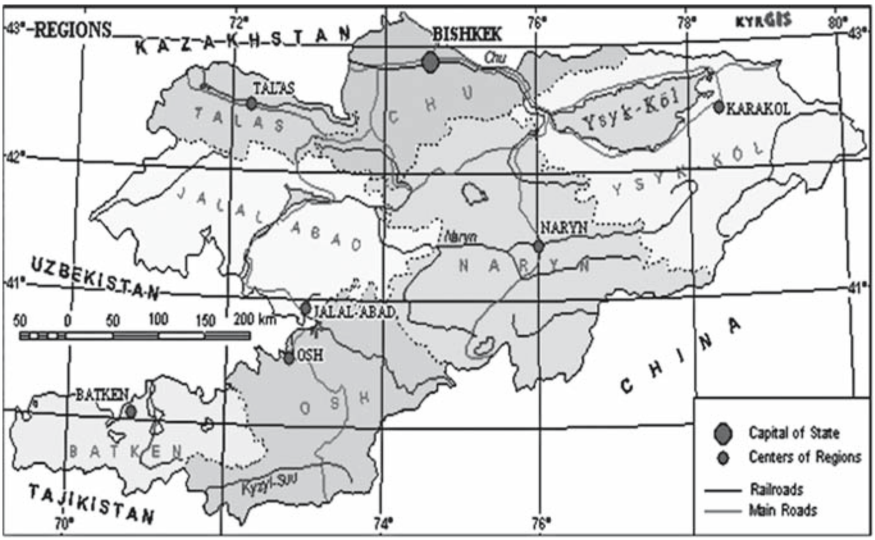

Figure 2. Administrative-territorial map of Kyrgyzstan.

However, taking into account that this increase on the whole primarily occurred through activities of one gold-mining enterprise, it is most useful to refer to the economic situation as some stabilization of economic indexes – on a rather low level – rather than about an increase.

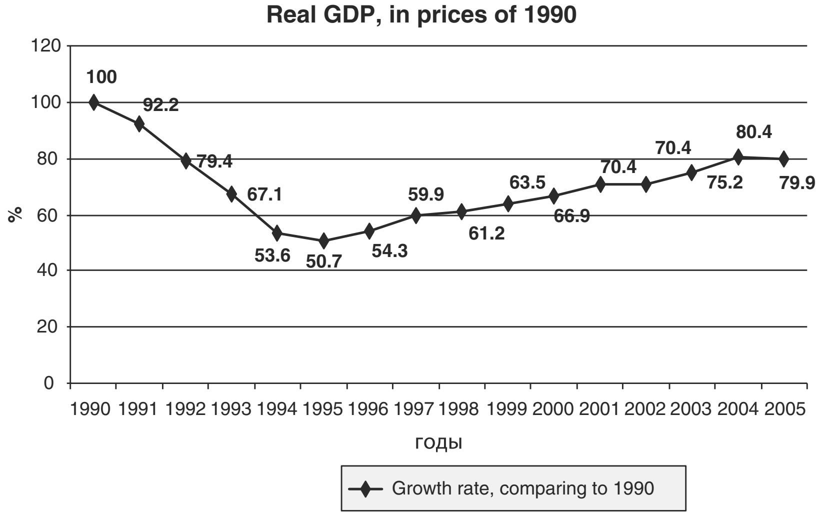

Figure 3. GDP of Kyrgyzstan during 1990–2005.

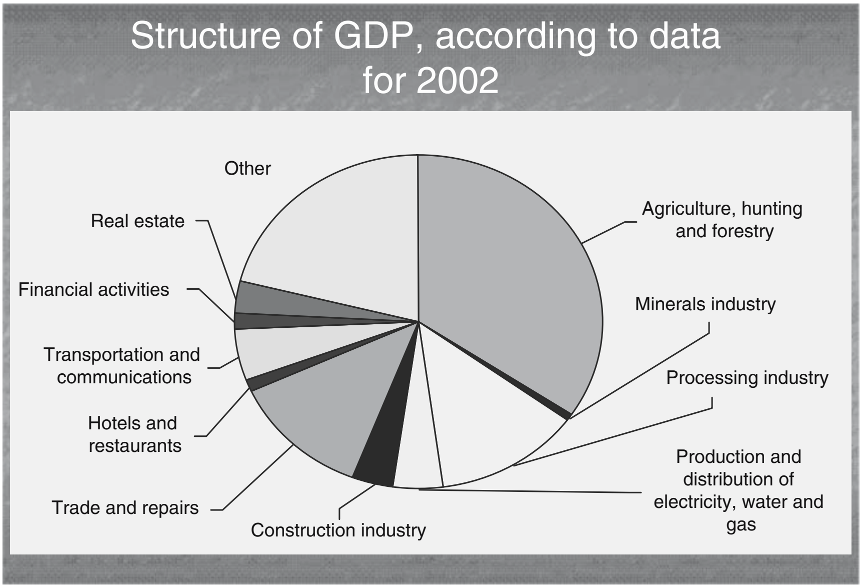

Figure 4. Structure of GDP.

The processes of economic structure changes in the country after 1990 led to an actual industry breakdown nationwide. The main economic sectors that contribute to the formation of the Gross Domestic Product (GDP) became the agriculture sector, with a specific weight of added cost of about 40% to GDP volume and the service sector (Figure 4).

2. Water resources

2.1. CHARACTERIZATION OF HYDROGRAPHIC NETWORK

The water resources of Kyrgyzstan are a complex system of rivers, lakes, glaciers, seasonal blanket of snow, and waterlogged territories (Figure 5). Of the country's total territory, 76.5% belongs to areas supplying the basin of the Aral Sea, 10.8% to the basin of Issyk-kul Lake, 12.4% to basin Tarim, and 0.3% to basin of Balkhash Lake. At present out of 47.2 km^3 of water resources, the existing apportionment of water is: Kyrgyzstan gets only 11.8 km^3; 3 km^3 goes to Issyk-Kul recharge, and 32.2 km^3 goes to territories of neighboring states. There are 28,000 rivers and river heads at the seven largest river basins, 90% of which are 10 km long. There are rivers among them with high water levels. For example, the river Naryn stretches to 500 km. There are more than 2,000 lakes and artificial storages (reservoirs) in the country.

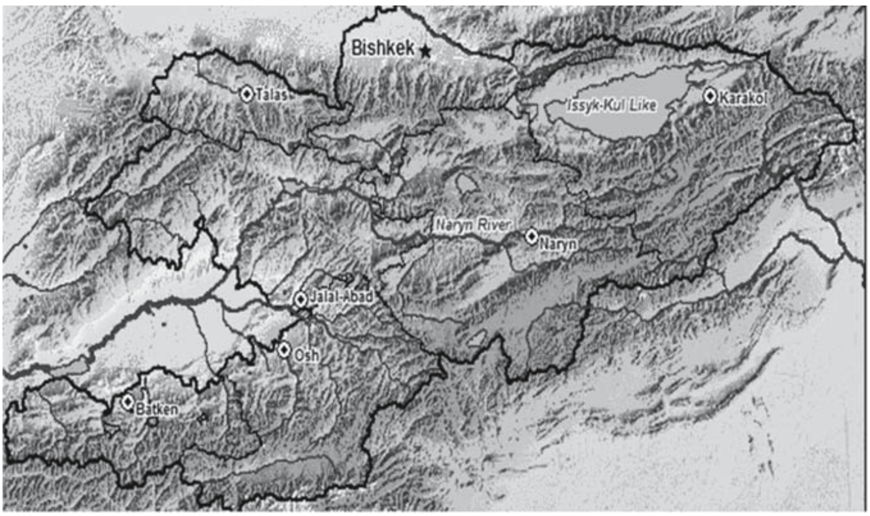

Figure 5. Surface water resources of Kyrgyz republic.

Lakes occupy 3.4% of the territory. About 90% of them are high mountain ponds and enclosed lakes. Sary-Chelek Lake is situated on the southwestern slope of the Chatkal Range at an elevation of 1,873.9 m above sea level, and it is a biosphere reserve. The high mountain lake Issyk-Kul is situated within the Tyan-Shyan Mountains at the bottom of a great tectonic basin at an elevation of 1,606.7 m above sea level.

According to the most recent investigations, the length of Lake Issyk-Kul is 178 km, width is 60.1 km, total area is 6,236 km^2, length of water line is 688 km, maximum depth is 669 m, and average depth is 278.4 m.

2.2. MAIN PRESSURES

The Kyrgyz Republic has significant surface water resources (to 50 km^3/year). Without utilizing these resources, the development of economic sectors such as land irrigation, industry, and energy would be impossible (Figure 6).

In the territory of Kyrgyzstan during Soviet times more than ten reservoirs were constructed in an effort to regulate flow of the trans-boundary rivers Chu, Naryn, Akbuura, and Karadarya, and also to provide for the interests of irrigation in neighboring countries. A water industry was established in the country that was a powerful irrigative net, with the systems of reservoirs along with the relevant infrastructure.

At present these irrigative bodies have become physically and politically old. The national irrigation fund of the country consists of: inter-economic channels having an extension of 6,200 km, hydraulic structures – 5,760 units, hydrologic points – 3,367 units, pumping plants – 87 units, collector-drainage network with extension of 5,957.4 km, reservoirs – 34 units

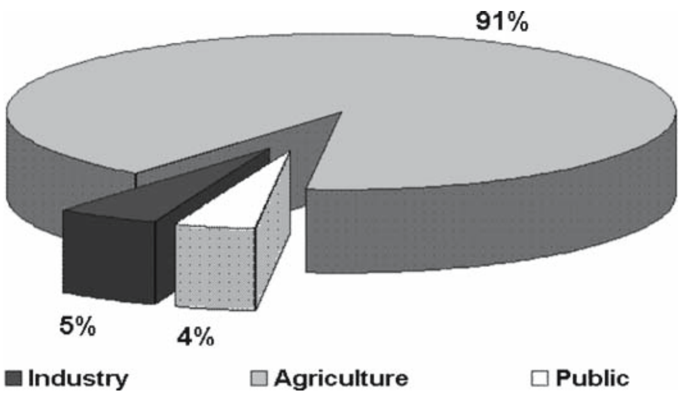

Figure 6. Consumption of water for sectors.

with general capacity of 1,323.9 million cubic meters, daily-storage basins (DSB) – 60 units with a net capacity of 21.95 million cubic meters, decade-storage basins (DSB) – 11 units with a general capacity of 50.25 million cubic meters.

2.3. CURRENT PROBLEMS OF WATER MANAGEMENT SYSTEM

The unsatisfactory state of the water resources system is evidenced first of all by the deficiency of investment directed to the hydro-economic sphere and by the incompleteness of reform processes for water relations in the country.

The main problems of the water management system are: the physical and political unfitness of the existing hydro-economic infrastructure; lack of increase in new irrigated land; production decrease of irrigated land; degradation of water resources use; low efficiency of monitoring systems to examine the condition and use of water resources; worsening of the land-reclamation status of irrigated land; increasing negative effects of water (soil erosion, raising of level of ground waters, mudflows); lack of construction of storage capacities- reservoirs; irregularity of communication, equipment and technologies for providing and analyzing data of the water industry sector; insufficient security of water resources development; irregularity of standards or the legal basis of water relations and hydro-economic activity; irregularity of the operating system of water resources management and hydro-economic infrastructure; irregularity of economic relations in this sector, mainly in tariff and investment policy; irregularity of the state control system on condition and use of water resources; insufficient development of public associations of water users and involving them as participants/stakeholders in managing and maintaining bodies of the hydro-economic infrastructure; and ineffective coordination of the functions of different involved groups.

3. Administrative infrastructure for water resources management

At the beginning of the 1990s the unified water management system was abolished, and different approaches to transforming the system were planned to implement its transformation due to the characteristics of development of the economy, based on selected models of transition to a market mechanism of economical activity, as well as the specific character of various political and social processes.

Kyrgyzstan is developing the management of water resources at a restrained pace. The transition to market principles of management is accompanied by definite state support of maintenance and rehabilitation of the hydro-economic network on the regional and oblast level. The former Ministry of Water Resources is now merged with the Ministry of Agriculture and is a part of the current Ministry of Agriculture, Water Resources and Processing Industry. This State authority implements most parts of water resources management functions through the Department of Water Resources. It directly manages irrigated agriculture – this creates certain legal contradictions with regard to water use. Other involved state authorities are the Ministry of Ecology and Emergency Situations, State Agency on Energy, Geology, and Mineral Resources, and others (Figure 7).

At lower levels of authority there was a conversion that provided a union of state and public property and of properties of legal entities. Although basin authorities were organized, nevertheless they carry only an administrative-oblast character. In future the State is planning to reserve for itself the right of property and management of all strategic objects – dams, reservoirs, hydroelectric power stations, and supply channels and so on. At the same time it is planned to privatize some state water-management systems by establishing stock companies. There are approaches to privatization of large and small hydroelectric power stations. City water supply and sewerage systems have been developing

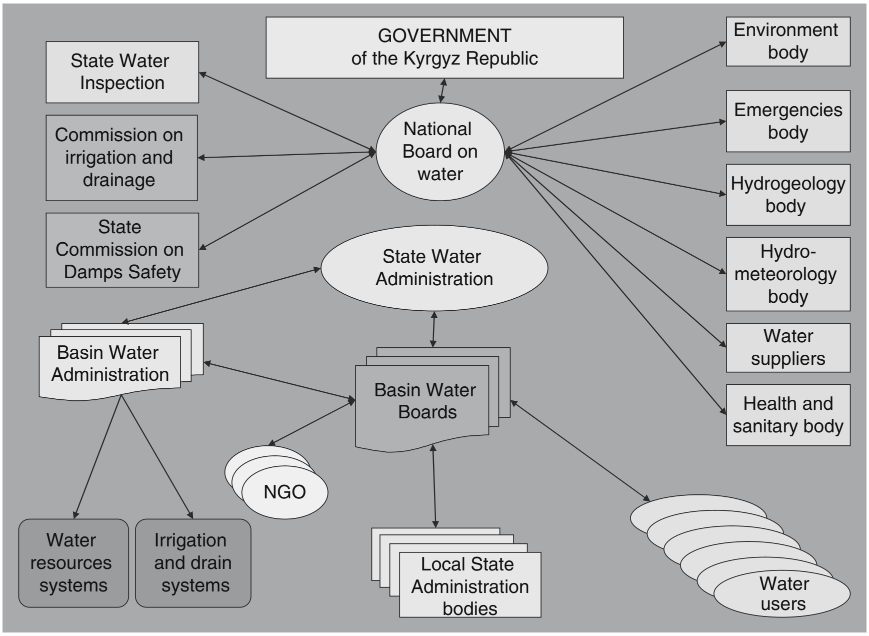

Figure 7. Water management of Kyrgyz republic.

along the privatization direction, while at the same time priorities are given to delegation of functions of operation, service and maintenance of these systems to private ownership. Although the national legislation solved a significant portion of problems regarding the legal position of water users associations, their formation is being implemented at a slow pace.

3.1. STRUCTURE AND RESPONSIBILITIES OF THE NATIONAL COUNCIL ON WATER

The Prime Minister is chairman of the National Council, and the head of the state water administration is vice-chairman of the National Council. Members of the Council are as follows: Ministers of economy and finance, justice, water resources and processing industry, emergency situations, foreign affairs, industry, commerce and tourism, and health; chairmen of committees on agro-industrial complex and ecology of the Parliament – Jogorku Kenesh – on budget and finance, on development of economy, enterprise and use of natural resources; heads of state administration – governors of the regions; mayors of Bishkek city and Osh town; heads of state agencies on geology and mineral resources, on environmental protection and forestry, registration of rights for real estate, on energy and gas; head of central administrative board on hydrometeorology; general manager of the Department of the State sanitary-epidemiological inspectorate and the chairman of the State union of enterprises of housing and communal services.

The main authorities of Jogorku Kenesh of Kyrgyz Republic in the field of water resources management are: (i) development, adoption, introduction of amendments and supplements into water legislation; (ii) ratification and denouncement of international agreements in the sphere of water relations; (iii) confirmation of annual allocations on irrigation and drainage; (iv) elaboration of policy of payment for water use as a natural resource.

The authorities of the Kyrgyz Republic's Government related to water resources management consists of: (i) confirmation of territorial borders of the main basins on the basis of hydro-geographical principles of water resources management; (ii) establishment of National Board on water; (iii) adoption of regulations on basin council; (iv) determining authorities to implement water code; (v) development and implementation of state water programs and the related financing and investing programs; and (vi) elaboration of special permits for water use.

The responsibilities of the National Board on water are related to: (i) coordination of activities of ministries, administrative departments, and other authorities on water resources management, use and preservation; (ii) preparation of proposals on establishing hydro-geological borders of main basins and their introduction to the Government of Kyrgyz Republic; (iii) preparation of the project on a National water strategy; (iv) preparation of law drafts and development of rules and instructions to implement the Water code; and (v) supervision of activities of the State water administration.

The main responsibilities of the Ad hoc authority in the field of water use are related to: (i) organization and regulation of water use and its preservation, development of programs on use and protection of water resources from pollution, abstraction and exhausting; (ii) state control on use and preservation of water resources; (iii) establishment of limits and standards of water use; (iv) issuing of water permits; (v) organization of monitoring of water resources; (vi) conducting inventory of water resources and water users for elaboration of water balance; (vii) presenting claims on reparation for damages caused as a result of water legislation violations; and (viii) conducting project, survey, research and design works related to water use and its preservation, and assessment of ecological state and reconstruction; (ix) international cooperation in the field of water relations.

The responsibilities of the Ad hoc authority on environmental protection are related to: (i) participation in the work of the National council on water and watershed management; (ii) participation in conducting state water monitoring; (iii) participation in the development and endorsement of water classification and standards; (iv) preparing and providing to the Government of Kyrgyz Republic the list of dangerous substances, dumping of which is prohibited; (v) endorsement of licenses for water use issued by the State water administration, and issuing a license for dumping pollutants into water bodies, hydraulic structures and lands of water fund; and (vi) activity on water preservation and endorsement of proposals on establishing water protection zones. Some of the responsibilities are shared with the Ad hoc authority on sanitary-epidemiological issues. Additional responsibilities of the latter are related to: (i) development of sanitary code and regulations on preservation of surface and ground water from pollution; (ii) determination of fitness for use of surface water for public water supply and in consumption for medical uses, according to regulations on preservation of surface and ground water from pollution; (iii) endorsement of conditions on wastewater disposal to water bodies; (iv) coordination of systems on water quality control of water bodies on the higher level of the sewage outfall and at the nearest points of water use.

The Ad hoc authority on groundwater hydrogeology has special authorities related to groundwater use and preservation against pollution through establishing special zones of protection. The Ad hoc authority on emergency situations and hydrometeorology coordinates proposals on building a national system of information about floods, mudflows and droughts, irrigation cadastres and periodically elaborates/renovates plans in case of flood and mudflow together with the State water administration.

The local state administration is also involved in the management of watersheds, in activities related to location, regime of zones of sanitary control, and their regulation.

At present in Kyrgyzstan reform of the authorities for the water sector is a very important issue. Objectives of reform are: (a) reduction of the number of management personnel and financial support requirements; (b) improvement of interaction of state authorities on the basis of eliminating functional redundancies, and separating rights, responsibilities, control and management functions; (c) delegation of part of management functions to water users associations, beginning first in the areas of agriculture and rural water supply.

It is essential to divide the two functions of control and management between two basic administrative agencies – water resources and environmental protection – by changing the legislation so as to separate their respective functions and responsibilities.

Participation of other ministries and departments in water resources management should be restricted to very specific functions. Functions of the service work of private water systems should be transferred to the authority of legal entities, water users associations, and municipal authorities by 2010. At the same time management of strategically important hydraulic structures should be under state agencies' control.

For the purpose of providing equal rights for the whole population and water users of all spheres of the economy it is suggested to separate agencies of water resources from the structure of the Ministry of agriculture, water resources and processing industry and to establish an independent department on the basis of executive competency.

Water resources management should provide for future preservation of basin levels of management. In a long-term plan the regional level of management in the field of irrigation may be abolished in connection with delegating service work functions to the water users associations or private water authorities, and also delegating control and management functions accordingly to the water inspectorate and basin authorities.

3.2. TASKS AND FUNCTIONS OF WATERSHED MANAGEMENT

Watershed management units are territorial authorities in the field of use and preservation of water resources, having their territorial branches at the region level (oblasts). Their main task is implementation of state management in the use and preservation of water resources at the basin level.

The main functions of watershed management units are the following:

- Integrated management of water resources at the hydrographic basin level

- Coordination of people's activities with regard to the use of water resources, with the purpose of achieving favorable economic effects and rational, right and ecologically sustainable water use
- Preparation and realization of watershed agreements on reconstruction and preservation of water bodies on the basis of perspective plans and programs of development within the framework of proper basin
- Implementation of state control on use and preservation of water resources, and compliance with water legislation of the country by legal entities
- Conducting state accounting, state water cadastre, and state monitoring of water bodies together with central executive authorities in the field of environmental protection and with authorities on the use and preservation of the Earth's interior
- Issue and suspension of licenses or permissions for activity status on special water use by orders set by legislation
- Agreements with the proper state authorities for: (i) plans of local executive authorities on rational use of water bodies on proper basin; (ii) proposals on defining places for construction of enterprises and other facilities that have an effect on water condition; (iii) projects on construction and reconstruction of enterprises and other facilities that have an effect on water condition; (iv) documents on conducting construction, bottom destruction and blasting operations on minerals mining, water plants, cabling, tubing and communication routing, throw, as well as drilling activity, agricultural and other operations on water bodies, water protection strips and zones; and (v) plans of activities of water users on preserving and improving the state of water bodies
- Restoring the participation of working state committees on putting into operation industrial, agricultural and housing bodies that have effects on water condition, as well as in works on eliminating consequences resulting from emergency situations of natural and man-made character
- Defining limits of water use from the point of view of water users and on proper basin
- Participation in confirmation of resources of ground waters
- Realization of control on operating regime of reservoirs of joint use, large interindustrial, interregional and intergovernmental reservoirs
- Developing plans on diversion capacity and water classification of interregional, intergovernmental water bodies and control over their compliance
- Agreement of multiple use scheme and water preservation of proper basin, operating rules of water bodies and hydraulic structures
- Participation in working out hydro-economic balance on proper basin

- Coordination of proposals on water bodies supplying isolated and joint water use
- Making demands and enforcing according to orders set by legislation on discontinuance of financing, designing and construction of hydro-economic and other structures having an effect on water condition and implemented by breaking established rules in the field of use and preservation of water resources
- Transmitting information on violating water legislation to the legal system and taking guilty parties to court
- Cooperation with local executive and other interested state authorities on problems of use and preservation of water resources
- Conducting activities to raise public awareness regarding the rational use and preservation of water resources

4. Legislation for water resources management

4.1. LEGISLATION

In Kyrgyzstan according to water legislation, water resources contained in natural water bodies are state properties, whereas water resources removed from water bodies can be properties of legal entities. Water use from natural water bodies and sewage disposal into water bodies was formerly implemented on the basis of licensing. On the whole this situation was up to the quality of world practice. But in January 2001 amendments to the law "On licensing" were adopted, and the licensing system for water use stopped for a while. As result, a legal vacuum arose concerning order of state property use which can lead to obvious negative judicial and other consequences.

In 2001 a decision was made to work out a new Water code for the Kyrgyz Republic. The following fundamental approaches to improve water legislation were recognized as a result of consultations and work carried out: (i) necessity of reflecting a balanced state water policy for a long-term period that is adequate to the existing social-economic situation in the country; (ii) eliminating contradictions and parallelism in current water legislation; (iii) adaptation of water relations to a market system; (iv) reflection of new principles of water use and hydraulic structures management; (v) judicial provisions for development of public associations of water users and privatization of water basic funds; (vi) broadening of legal regulations for economic activity of water users.

Legislative acts are developed by state agencies in the field of water resources management and are also initiated by Parliament – Jogorku

Kenesh. In basic laws of water relations community input and participation in adopting the legislation is not yet evident.

Water relations in the Kyrgyz Republic are regulated by the Constitution of the Kyrgyz Republic, the Water Code, and legislation on water, legislation on drinking water, government resolutions, and other statutory-legal acts. The Water code in the Kyrgyz Republic was adopted in January 2005. Under Article 99 of the Water Code, six months from the day of adoption of the Water Code the Government of the Kyrgyz Republic is entrusted with: (a) adoption of the statutory-legal acts, assuring realization of the Water Code; and (b) preparing for the Parliament of the Kyrgyz Republic drafts of changes and supplements for the legislation of Kyrgyz Republic in connection with adoption of the Water Code.

However, to the present day statutory-legal acts on code implementation are not yet worked out. Therefore, to date the following work on legislation acts that regulate water relations has been done: Constitution of Kyrgyz Republic (1993), Water Code (2002), Law "on water", Law "on drinking water", Law "on intergovernmental use of water bodies, water resources, and water facilities of Kyrgyz Republic", Law "on water users association", Law "on payment rate for environmental pollution," and a series of other decrees and regulations. Full names of the legal acts are given in the references section.

4.2. IMPLEMENTATION OF LEGISLATION

State control. An institute of specially authorized agencies was established in an effort to control the implementation of water legislation in the republic. Authorities of state agencies in the field of control on legislation observance are limited by the Water Code and by regulations of specially authorized agencies that are confirmed by Government.

Permissions for dumping and special water use. To regulate the quality of dumped wastewater and in an effort to prevent water bodies from pollution, water users should have permission for dumping contaminants. Permission is issued on the basis of page 36 of the Law "On water", and chapter 9 of Water Code of Kyrgyz Republic. There is no statutory act from January 2001 in the republic that binds the water users to get permission for special water use. This situation exists because of the excluding of licenses for water use from the Law "On licensing". The Water Code, adopted in 2005, provides obligatory permission for special water use. Today supplements are introduced into the regulations of Kyrgyz Republic's Government #103 from 25.02.2004, which confirms "List of permissions, given by state agencies".

Monitoring. A basis of hydrological and hydro-chemical monitoring of the condition of water resources in the Kyrgyz Republic is established.

The State Agency on environmental protection carries out monitoring on sewage treatment facilities, on quality of dumped effluent water, and on effects of its dumping on the condition of surface waters. Monitoring of surface water bodies' condition is accomplished by the Kyrgyz hydrometeorology organization, which belongs to the Ministry of Emergency Situations of the Kyrgyz Republic. The State Agency on geology and mineral resources carries out the monitoring of groundwater bodies and provides data about the condition and quality of groundwater. The Department of water resources carries out monitoring of use of water resources. The Ministry of Health carries out monitoring on the quality of sources used for domestic and drinking water supply.

State, cooperative, public and other organizations, enterprises, and institutions conduct primary monitoring of water abstraction, water use and its dumping. They also provide systematic observations on quantity and quality of the abstracted and dumped water.

5. Financial mechanisms for water resources management

The water management system is financed by the state budget. The state takes part in financing the work on regulating water use and its preservation in the form of budget provisions, granting credits, investments, non-repayable subsidies, long-term loans with low lending rates, and by tax reductions, investment formation of other States, and other means. The economic mechanism of water use establishes: (i) a system of financing activities on regulating water use and its preservation; (ii) establishment of standards on payment for water resources use, water bodies, and dumping of water abstractions; (iii) a system of establishing tax and credit benefits for water users; and (iv) a system of reparation for damages done to water bodies and water facilities.

Financial-technical provision is implemented by: the Ministry of Finance of Kyrgyz Republic, Ministry of Agriculture, Water Resources and Processing Industry of the Kyrgyz Republic, Department of water industry, Local state administration, Public authorities, Associations of water users, Private sector (private investment of agricultural owners), and International financial institutes.

The following bases and accounts are utilized to define financial provisions. Each year for the last seven to eight years the funds provided from the republic's budget to conduct operational activities and for service of irrigation water delivery were in the amount of US$8.6–8.8 million. Due to these funds restoration works were carried out within 1,250 hydraulic structures, 1,300 hydrologic points, 60 pumping plants, and mechanical treatment on 337 km of irrigation channels, as well as capital rehabilitation on large channels with extensions of 160 km.

According to specialist's accounts of the World Bank, ADB and local specialist's accounts, for annual operating needs of the irrigation system a fund of US$34.3 million is required, without the costs of used electric power by pumping plants, acquiring pumping equipment, and rehabilitation of irrigation networks.

By generally accepted standard costs for arid zone related to 1 ha of irrigation land, the costs are 645 soms (Kyrgyz currency) or US$18 on exchange premium. It is necessary to point out that today the republic's budget does not completely cover standard costs, and the state is obliged to attract foreign investments.

5.1. PAYMENT FOR WATER USE

Under Article 30 of the Law "On water," water use in the Kyrgyz Republic is paid for. Payment is collected from all water users irrespective of departmental affiliation, citizenship, property prospects, or form of management. Payment is collected for:

- Use of water resources within the fixed limits (except agriculture, forestry, irrigation)
- Extra limit and irrational use of water resources
- Services related to water abstraction, transportation, allocation, and water treatment and other water-related activities, dumping sewage into water bodies, and water facilities within the fixed limits

Under paragraph 48 of the Water Code adopted in 2005, payment for water was introduced as for a natural resource. Rate of payment for water as a natural resource is annually set by the Parliament of the Kyrgyz Republic for each basin on the basis of actual costs of studying, estimating and preservation of water resources, as well as costs for activities on functioning of the State water administration. Funds received under the present article are used for financing administrative costs of State water administration and other state bodies involved in water resources management, investment outlay on projects on development of water sector that provide effective management, and use of water resources in accordance with National water strategy, projects defined by State water management programs and other purposes.

At present, a system of establishing rates for service is functioning for irrigation water delivery. Kyrgyzstan was the first Central Asian country that introduced payments for irrigation water, and besides requires payment for water use, including public, industrial and irrigation water supply.

For the population payment for water is included in the general payment for public utilities, made at the municipal service. Local municipalities define water rates for population for sewerage service. Prices are intentionally abated, as it is generally known that the most of the population could not pay high prices. In addition local administration itself could not allow expenses of service for existing facilities to have an effect on payment rates. The underpayment from the private residential sector and municipal users is compensated at the expense of higher payment rates for industrial enterprises.

As a rule, cost of service is so low that the water supply companies could not work on a profitable basis. Collected payments from the population and irrigative sphere hardly cover a part of expenses and priority expenses, such as salaries and minor repair work. Today, social status and general economic crisis prevents balancing expenses with the cost of service. All listed factors together with a drop in state investing in the given sector are the main reasons for loss of service quality.

5.2. PAYMENT FOR DUMPING SEWAGE INTO WATER BODIES AND WATER FACILITIES

A payment mechanism for dumping contaminants has been worked out in the republic. Under the Decree of the Kyrgyz Republic's President #231 from 21.07.1992 "On local and republican environmental funds in Kyrgyz Republic", local funds of environmental protection are collected at the expense of taking (including foreign currency) from organizations, enterprises, institutions and other legal entities (users of natural resources), irrespective of patterns of ownership and methods of housekeeping. This is in the form of: (i) payment for admissible (limited) dumping of contaminants and allocation into the natural environment; and (ii) payment for exceeding the admissible quantities of contaminants into the environment.

6. Advantages, disadvantages, and weaknesses of the present system

The main problem in the water sector of the Kyrgyz Republic is water resources management. It is significant to point out some general disadvantages of the organizational structure of the water sector and irrigated agriculture, including: (i) water sector represents predominantly the interests of agriculture, not all sectors; (ii) the organization of managing the water industry should be modernized in order to equally represent interests of irrigation, hydroelectric engineering, staple industries and other sectors, observance of priorities of drinking water supply, water economy and so on, and following principles of equality of rights and responsibilities of all water users; (iii) at all stages, from starting any water projects until their realization, decisions are made only by state agencies, without public participation. In consequence, there is often a situation when the cost of maintenance of water systems and hydraulic structures cannot be covered by income from their operation.

The policy of full transfer of operational expenses of the irrigation networks to water users without relevant state support complicates decision making related to development, reconstruction, and modernization of irrigation systems. Depreciation periods of most of the systems in the republic have expired. Water users, who often decline all responsibility for this work, should solve the problems of their updating; also, state agencies avoid solving these problems, justifying this inaction as being due to limited budgetary funds.

The distribution of the legislative and financial responsibilities between water users and state budget is vague. There is an opinion that the government should not undertake financial burden, but at the same time the fact is ignored that the degradation of irrigation and water collection systems can cause production decrease of agriculture as well as social losses. These facts are serious risks with regard to decrease of national income and discharge of tax, and the possibility of aggravation of social tension. Establishment of water users associations and searching for optimal forms of their activity is one of the most important measures to increase the effectiveness of water use. At present there is no national strategy on water use and preservation of water resources.

Lack of such a national strategy led to a lack of collaboration and coordination on the territorial level. There are no overarching plans on water distribution management or preservation of water resources. Management is being implemented by local regional branches of the Ministry of Agriculture, Water and Processing Industry and the State Agency on Environmental Protection, separately at different regions. Local branches of these departments, with limited financial and human resources, cannot fully implement specific activities.

However, as for water distribution, each region knows how much water can be distributed by the Ministry of Agriculture, water and processing industry. In other spheres of water resources management regions do not collaborate on issues of working out general strategies and cooperation. There are also disadvantages of existing water resources management: (i) lack of attention to problems of preservation of water from pollution and exhaustion of quantity, stimulation of effective use of water resources, broadening participation of community and nature users in solving water-related problems; and (ii) inefficient monitoring of quantity of water resources, and lack of monitoring on quality of water resources (with the exception of the basin of the river Chu). As a result there is a loss of conducting water cadastre of quality and quantity of water resources.

7. Conclusions and recommendations

The watershed principle of water resources management is supported all over the world, and it has proved its effectiveness. It is based on understanding the unity of water ecosystems, the interactions and interferences of their

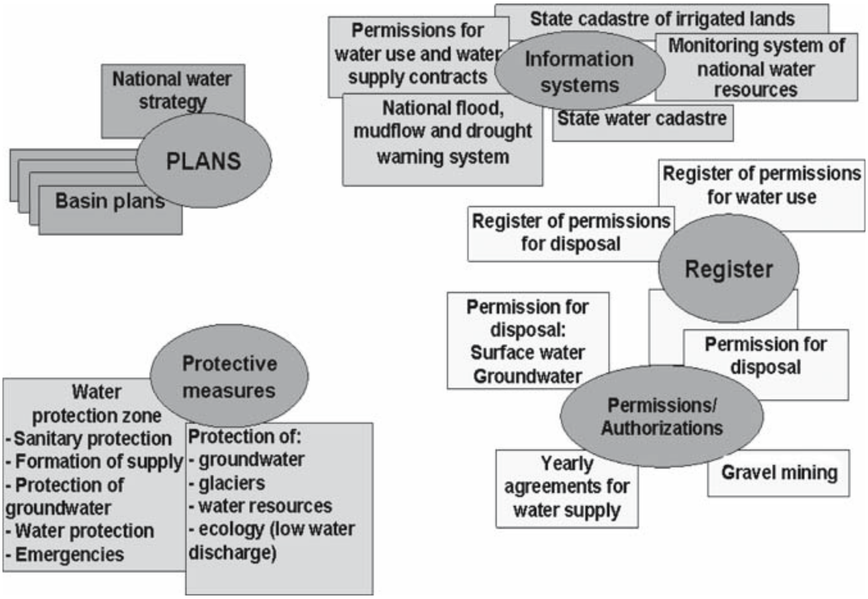

Figure 8. Key elements of water management.

components. It is known that the state of rivers and other water bodies depends not only on water use, but also on economic activities on the surrounding land. That is why it is necessary to implement regulations of nature management on watersheds, taking into account the effects on water bodies. It is recommended to carry out a reform of state management in the Kyrgyz Republic on a national level in order to improve the capacity for integrated management of water resources and water ecosystem services in the established watersheds. Integrated management of water use on a national level is usually connected with establishing basin authorities and delegating to them powers in the decision making process at the watershed scale, providing a balance of interests of all water users. The watershed authorities are also in charge of controlling the economic activity and nature management, including calling to court those who break the law (Figure 8).

Strong arguments in favor of shifting from the sectoral towards an integrated and watershed approach in water resources management were derived and underscored from recent severe floods that occurred in a number of northern and southern regions.

The proposed water management diagram (Figure 8), built on the key operational elements required for integrated water resources and ecosystem management, fits quite well with the existing water-related legislation and institutional infrastructure. However, the lack of available technologies and limited financial resources, combined with limited institutional capacity for integrated planning and implementation of water resources management at the large watershed scale, have been identified as the major constraints that do not yet permit effective actions and positive results.

In addition I consider the Water Users Association (WUA), first established in 1998 as a pilot study supported by international funds through the Asian Development Bank, World Bank, Swiss Government and other donors, as a limiting factor. The necessity of its development was caused by reforms in the agricultural sector of Kyrgyzstan. During 1994–1996 about 800 large collective farms were destroyed and their property was distributed among 250,000 small domestic/private farms. This resulted in a huge number of new problems concerning water management among which are water supply and distribution issues and poor cost recovery of water uses.

For example, the Department of Water Resources annually gets only 30% of the money collected for water supply. This is the main reason for unsatisfactory technical maintenance of the irrigation structures and the water quality monitoring systems in the large area where WUA operates.

For the short and medium term, such technological, financial, and operational limitations should be removed, but that depends on political decisions of the Kyrgyz parliament and government.

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WATERSHED MANAGEMENT PRACTICES IN THE PHILIPPINES: THE TIGUM-AGANAN WATERSHED CASE

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Abstract: Management is both a science and an art whatever is the object/subject being managed. While a watershed management policy may be placed on paper and thick documents, its translated actions may differ from watershed to watershed. The policy may lose its essence, may be reinforced, or threatened and changed to a better policy.

Watershed management in the Philippines is described in this paper from the perspective of a non-government organization participating with local governments and national government agencies in pursuing watershed protection, conservation, and development. Agreements were signed to make this collaboration happen.

The paper describes the challenges met in carrying the objectives or purposes of the agreements in the venue of a local watershed called the Tigum-Aganan Watershed. Structure, practices, financing, administration, decision making and responsibilities are described including the Board's legal basis for existence.

The administration of national agencies over watersheds in the country and over a specific watershed – the Tigum-Aganan Watershed, is also described. Issues and concerns experienced by other watershed management units led by local governments, (considered local initiatives) are reported and discussed in a national association called the Philippine Watershed Management Coalition, another non-government organization. Transfer of knowledge, deepening of understanding of issues and exchange of strategies in solving problems are shared during meetings.

In general, this paper describes a formal structure of watershed management and an informal process of policy formulation for watershed management brought about by participation from local government, private sectors, community-based organizations and non-government organizations.

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Keywords: Watershed management; watershed organizations; local government units; multi-sector councils; participation; authority; accountability; decision making; financing; environmental service payment; policy; policy formulation

1. Introduction

A description of how watersheds are managed could come from different perspectives. This paper shares the perspective of a local government unit and a non-government organization in collaborative work for the last 15 years. This paper describes not only the formal picture, the theory and the written policies prescribed by central government but it tells the story of how these were translated into action on the ground and how they fell on the lap of the local stakeholders, volunteers, community leaders and local government; and what the reactions are. In addition to a description of national policies, the paper tells a story of the stakeholders of the Tigum-Aganan Watershed and their journey towards defining the boundaries of their watershed, constructing their management structure, making decisions, funding their activities, and achieving some milestones.

2. The Tigum-Aganan watershed and organization structure

The locals don T-shirts saying "I live in the Tigum-Aganan Watershed" for their information campaign. They prefer to call their watershed the Tigum-Aganan Watershed after two long rivers, the Tigum River (57.9 km) and Aganan River (52.8 km). These two rivers converge in the town of Pavia and empty into the Jaro River (16.7 km) with water flowing through the City of Iloilo and down the Iloilo Strait. The Tigum sub-watershed has an area of 213.3 km^2, while the Aganan sub-watershed has 198.7 km^2. Jaro River sub-watershed has an area of 21.6 km^2. The whole river basin has an area of 433.6 km^2 (2007).

The coastal area of the watershed is part of Iloilo City. The Iloilo City's larger land area and another town, Oton, belong to the Iloilo River Basin. When the Aganan River, however, overflows, water feeds the intermittent creeks which are the tributaries of the Iloilo River. Iloilo River is an estuary, stretching 16 km inland. Oton, an adjacent town to Iloilo City is not only a recipient of flood waters from Aganan River but also water for irrigating 75% of its farmland. The local government units of the Iloilo River Basin decided to join the Tigum-Aganan Watershed organization.

The Tigum-Aganan Watershed is located in the Province of Iloilo, one of the four provinces of Panay Island, in the Visayas Islands, at the central part of the Philippines.

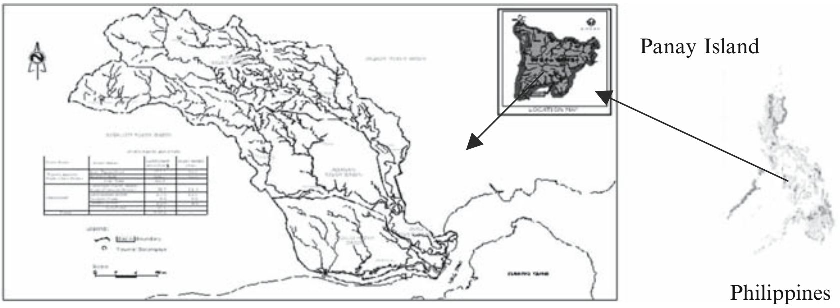

Figure 1. Location map, Tigum-Aganan watershed. Panay Island, The Philippines (2007).

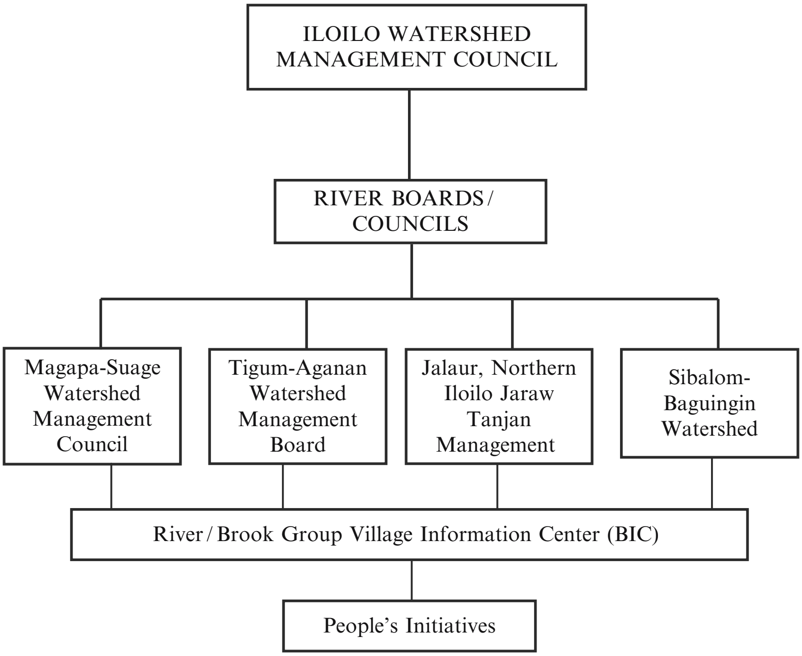

Figure 2. Organization chart, Iloilo watershed management council (Salas, 2004b).

A Memorandum of Understanding signed by representatives of eight (8) towns and one (1) city created the Tigum-Aganan Watershed Management Board (TAWMB) as portions or the whole of their political areas are located inside the watershed. The purpose of the cooperation is to pursue the objectives of the Iloilo Watershed Management Council in the Tigum-Aganan Watershed. The members contribute staff work, meeting expenses and funds to run the affairs of the Board. The Board meets almost monthly, educates

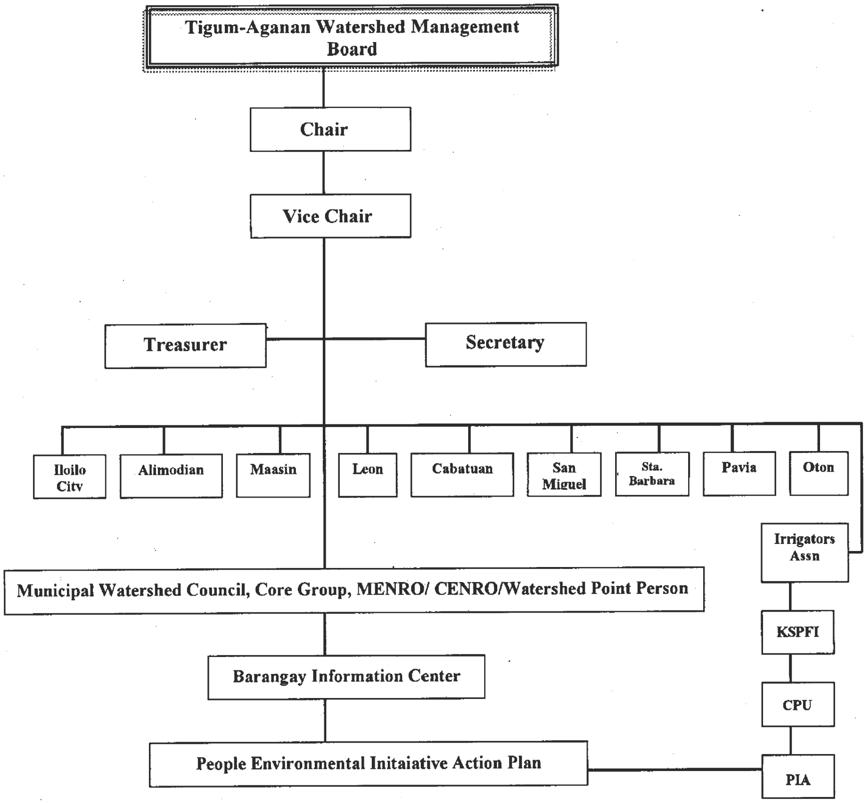

Figure 3. Organization chart, Tigum Aganan watershed management board (Salas, 2004b). Acronyms used: MENRO-Municipal Environment & Natural Resources Officer, CENRO – City Environment & Natural Resources Officer, KSPFI – Kahublagan Sang Panimalay Fnd (NGO), CPU-Central Philippine University, PIA-Philippine Information Agency.

its own members, encourages inclusion of watershed projects in the Annual Investment Plan and consolidates these projects as part of the annual action plan of the TAWMB.

The Iloilo Watershed Management Council (IWMC) is a local provincial body created by Ordinance No. 2000-41 on October 2, 2000, responsible for the conservation, development, utilization and protection of the province's watersheds. The Council is also responsible for creating instruments/mechanisms that would resolve conflicting interests and demands on the carrying capacity of the watershed resources. It is also tasked to promote awareness and to look for resources to enhance its institutional strength. Executive Order No. 260 s. 2001 signed on October 17, 2001 by Governor Niel Tupas, put the ordinance in effect.

Following this mandate, IWMC organized the Tigum-Aganan Watershed Management Board (TAWMB), Magapa-Suage Watershed Management Council, Sibalom-Baguingin Watershed Management Board and the eleven sub watersheds of Jalaur River Basin.

3. Authority and Accountability

The Local Government Code of the Philippines (Republic Act 7160) has laid the foundation for local initiatives relating to environmental management. Among others, functions and powers related to environmental management based on this law are as follows:

(a) Adopt measures to safeguard and conserve natural resources, uplands, minerals, marine resources, forests, among others

(b) Protect inhabitants from harm due to man-made or natural disasters and calamities

(c) Protect the environment and impose penalties for acts that endanger the environment

(d) Establish, maintain, protect and conserve communal forests (or forests less than 5,000 ha) and watersheds, tree parks, greenbelts, mangroves, and other similar projects.

The IWMC ordinance invoked certain provisions of the Local Government Code and the Philippine Agenda 21 which consider development sustainable when (a) communities stimulate the local economy (b) there is partnership among sectors like business, government and civil society and (c) development is anchored on natural systems. A Memorandum Order No. 399 (September 26, 1996) was issued directing local government units to realign their plans and policies with Philippine Agenda 21. Another Memorandum Order (January 20, 1999) directed LGUs to formulate and implement their respective sustainable integrated development plans.

The basis of the action of the Iloilo province in establishing its own Watershed Management Council emanates from the Philippine Constitution providing in Article 11 that the State shall protect and advance the right of the people to a balanced and healthful ecology in accordance with the rhythm and harmony of nature. Republic Act No. 7160 or the Local Government code of the Philippines (1991) provided that "a local government unit shall endeavor to be self reliant and shall continue exercising the powers and discharging the duties and functions currently vested upon them…. shall discharge such other functions and responsibilities as are necessary, appropriate, or incidental to efficient and effective provision of the basic services and facilities enumerated therein…. The local government units shall also deliver basic services and facilities with respect to watershed/forest management subject to supervision, control and review of the DENR or Department of Environment and Natural Resources."

The legislative body of the province of Iloilo approved the ordinance creating IWMC to ensure the efficient and effective implementation of this mandate. The provincial government shall "protect the environment and impose appropriate penalties for acts which endanger the environment such as illegal logging and smuggling of logs, smuggling of natural resources products and of endangered species of flora and fauna, slash and burn farming…" [Sect. 468 (a) (1) (vi)].

The Provincial Governor is responsible for the "efficient, effective and economical governance for the general welfare of the province and its inhabitants pursuant to Section 16 of the Code. The Governor shall adopt adequate measures "to safeguard and conserve … forest and other resources of the province in coordination with the mayors of component cities and municipalities." [Sect. 465 (b) (3) (v)]. He shall also "ensure the delivery of basic services and the provision of adequate facilities …" (Sect. 456).

Similar responsibilities are provided for the municipal mayors [Sect. 444 (b) (3) (vii)], the legislative body of the municipality [Sect. 447 (a) (1) (vi)], and (a) (5) (i); the city mayor [Sect. 455 (b) (4)] and the legislative body of the city [Sect. 458 (a) (1) (vi)].

The laws are clarified with guidelines issued from time to time by the Department of Environment and Natural Resources (DENR) through Administrative Orders. For example, DENR Administrative Order 92-30 is about the guidelines for the transfer and implementation of DENR functions devolved to local government units (LGUs). Rules are specified for the implementation of community-based forestry projects by LGUs. Also devolved are the management and control of communal forests with an area not exceeding 50 km^2; management, protection, rehabilitation and maintenance of small watershed areas that are sources of local water supply and others. In addition, the LGUs should set aside funds for projects which will help protect and develop the environment and natural resources. This will come from the Internal Revenue Allotment (IRA) and its 40% share in gross collection of mining taxes, royalties, forestry charges and other taxes, fees provided for in the Code.

4. National administration of watersheds

The DENR is a national government agency which has the responsibility of administration, control, regulation and management of the watersheds under Presidential Decree or PD 705. DENR is responsible for implementing policies on watersheds. According to this decree, the government "owns and has complete jurisdiction over all of the country's watersheds". This policy and several other related policies have been critiqued in several publications and papers discussed in public fora.

Aside from DENR, there are other national agencies mandated to protect watersheds and water resources. The following list was taken from Watershed Management (Philippine-Canada LGSP, 2003).

1. The National Water Resource Board implements the Water Code of the Philippines (PD 1067). This law contains policies governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources. Issues surrounding NWRB are numerous that NWRB is not able to implement fully the policies stated in this Code.
2. The National Irrigation Authority (NIA) was created in 1973 under Republic Act 3601 "to study, improve, construct, and administer the national irrigation system of the country. Recent reports showed a low cropping intensity in the areas serviced by NIA because of degradation of watersheds and silt in irrigation infrastructure.
3. National Power Corporation (NPC) is another agency which is given the management and control of specific watersheds for its use. The NPC has the responsibility that the watersheds under its jurisdiction be assured of their protection, development, management and rehabilitation.
4. The Bureau of Soils and Water Management (BSWM) of the Department of Agriculture is another national government agency mandated to help protect watersheds. Looking at its current watershed management program, BSWM generates soil and water technologies that would make farming more productive, profitable and ecologically sustainable.

There are other laws passed relevant to the protection and conservation of water resources of the country which are implemented by DENR. These are:

(a) The National Water Crisis Act and EO No. 222 of 1994 provides for water conservation through demand management, institutional reform, protection against pilferages and cooperative action of various branches of the government.

(b) The Philippine Mining Act of 1995 (RA No. 7942) provides that no mining applications should be entertained in proclaimed watershed reserves, old growth forests, wilderness and protected areas.

(c) Ancestral Domain – Republic Act 8371 recognizes, protects and promotes rights of indigenous people; establishes implementing mechanisms; and appropriates funds.

(d) The National Integrated Protected Area System Act (NIPAS Act or RA No. 7586) protects the perpetual existence of all native plants and animals. The law mandates the creation of a comprehensive system of integrated protected areas which include national parks, birds and wildlife sanctuaries, old virgin forests and other critical watersheds.

(e) Clean Water Act – RA 9275, formulates a holistic national program for water quality management, prevention, control and abatement of pollution on the country's water resources.

In addition to specific laws handed down to the Department of Environment & Natural Resources for implementation, DENR has its own programs to translate the law into comprehensive system of protection and conservation of resources. Among these are:

1. Watershed Management/Forestry Development Planning – adopts the watershed and ecosystem planning and management framework.
2. Community-based Forest Management (CBFM) – adopts a community-based program which grants organized communities (including indigenous peoples) access to the forestland resources with a tenurial agreement provided these communities use ecological, sustainable & labor-intensive means of managing the forest.
3. Industrial Forest Management Program – defines and establishes procedures, terms and conditions of the Industrial Forest Management Agreement.
4. Environmental Impact Assessment of Forestry Activities – provides guideline for forestry projects, plans and other certifications.
5. Other programs are in non-legal compliance with international covenants the Philippines has been a party to. Examples are:
   (a) Principles for a Global consensus on the Management Conservation and Sustainable Development of All Types of Forests
   (b) Convention for the Protection of the World Cultural and Natural Heritage
   (c) Convention on the International Trade in Endangered Species of Wild Fauna and Flora
   (d) Convention on the conservation of Migratory Species of Wild Animals
   (e) ASEAN agreement on the conservation of Nature and Natural Resources

A host of so many rules, incentives and restrictions could confuse an ardent scholar, an advocate or an ordinary citizen. On the other hand, an ordinary citizen may not give much attention to the policies, especially if the policeman is not looking. Many are guided by a simple wish for a better welfare. The local government and local leaders see to it that these wishes are attended to although sometimes some laws are faced with a blind eye.

BOX 1. The "Save Maasin" Movement.

For 3 decades or so, the national government has a tree planting program in the Maasin Watershed, a small watershed which serves as the headwater of Tigum River and a sub watershed of Tigum-Aganan Watershed. This watershed was declared as a Reserved Watershed for the domestic water supply of the City of Iloilo. The yearly tree planting activities have not prospered because some people residing in the watershed plowed the tree seedlings off the field and planted their own crops – rice and corn – as soon as the tree planting volunteers left the place.

In 1992, a local NGO, Kahublagan Sang Panimalay Foundation conducted a study on the Feasibility of Maasin Watershed Rehabilitation. The study showed that the watershed was 97% denuded and the existing stream flow could not supply the projected water demand in the 10th year. This report was publicized and the city residents rallied to help replant the watershed. The governor, the Hon. Arthur Defensor, in coordination with the Department of Environment and Natural Resources (DENR), the non government organizations, schools and other government offices joined effort to form "Save Maasin Movement." The governor formed a Task Force to supervise and assist the Save Maasin Movement. The Movement planted 500 ha with trees.

In 1995, the DENR borrowed some P60 million to continue the effort of the Task Force. As a result, a total of 3,000 ha were planted up to 1997. The plantation established by DENR was designed to accommodate 2,100 trees per hectare.

In the summer of 2002, local newspapers ran banner headlines saying "Tigum River Runs Dry" as no water was seen flowing down the diversion dam in Maasin town. Since then, and up to this day, there was water rationing every summer; exacerbated by longer dry season, the signs of extreme climate variability. In 2006 and 2007, the dry season was for 10 months. The local water company which distributed water to city residents reported a 47% decrease in supply. By this time, the trees were 5–15 years old.

In 2005, the Iloilo Watershed Management Council and the Tigum-Aganan Watershed Management Board held a stakeholders' assembly to report the dialogue between the DENR and the Technical Working group of the local watershed councils. The findings revealed that planting trees is not the sole solution to the problem of a denuded watershed for the purpose of improving water supply. A report was also made by a Director of DENR VII saying that a national consultation was made regarding the impact of tree planting on water supply. He reported that "plantation forestry or forest regeneration on grassland or crop will greatly reduce annual water yield (approximately 400–700 mm/year) due to the high water use of the trees."

(continued)

BOX 1. (continued).

The DENR Regional Office was hesitant to recommend even selective cutting or thinning of the trees planted since it is said that trees also help in controlling erosion and in carbon sequestration. The local office of DENR defended its plantation project saying that as trees mature, water will find its way. Others opined that since the trees planted were exotic species, planted in rows and in equal measured distances of two by two meters; biodiversity may not come to provide the fungus which could decompose the leaves and branches of the exotic trees and form the forest soil where water is kept.

The TAWMB is now faced with a grave responsibility to ascertain which law will apply and what to tell the city and rural people who had walked the path to Maasin Watershed and had planted trees because they had believed they will have water.

The story of Maasin Watershed is an example of this. Maasin watershed is the headwater of Tigum River. It is from this river that a local water company gets its raw water for processing for domestic consumption in the capital city of the province which is Iloilo City. (Read the story in Box 1.)

5. Decision making

Did the "Save Maasin Watershed" Movement save the Maasin Watershed? Some people said yes, some said no. 'Yes,' because flood waters did not come as fast as they used to be when it rained hard for weeks or so. 'No,' because every dry season, there is less and less water for the people to drink.

Where was the supervision of the national government? Can the community and the local government be left alone to do their rehabilitation work? Who made the decision? From the facts of the case, the national government led the work and has been with the rehabilitation scheme but with no success for so many years. What the community did was to participate in fund raising and actual planting of trees. In fact, the national government borrowed money to add to the meager fund which the local government and the community were able to raise. The community planted only 500 ha while the national government established a 2,500 ha plantation.

It is possible that some people in the academe (the consultants) and the government were misled by the fallacy that more trees mean more water. A research report of the UK Tropical forestry Research Program blazed through the internet in 1995 said that "Trees were overplayed as solutions to world water problems." It also said that misguided views on water management have encouraged major investments in water resource projects that were ineffective or counterproductive. The same paper called for policy makers to design water projects based on scientific evidence of benefits (Redford, 2005).

The Global Water Partnership Technical Committee (TEC), in its TEC Background Papers No. 9 pointed out that terrestrial ecosystems consumed two thirds of the rainfall over the continents, a total of 71,000 km^3/year and temperate and tropical forests/woodlands consume 40,000 km^3 of this, or 56% (Falkenmark, 2003). The other 44% comprise croplands, grasslands, swamps and marshes, tundra and desert and other systems.

The TEC Paper also mentioned Calder as saying, "The perception that forests are good for the water environment and for water resources has grown out of observation that linked land degradation with less forest and rehabilitation and conservation with more forest" (Calder, 1999; Savanije, 1995). Calder further stated that these are motherhood statements on forests and water which are against scientific evidence.

Decision making is enhanced by information. Before the advances in communication, research results, scientific studies and practices in other countries were difficult to obtain. Water in the Philippines is abundant (2,500–3,000 mm rainfall a year). Prior to the 1900s, water was not the primary concern of the communities in Tigum Aganan Watershed. The main concern was poverty,

BOX 2. The denudation and rehabilitation of Maasin watershed.

In 1921, a declaration of Maasin Watershed as a Reserved Watershed was signed by Gov. Leonard Wood, an American governor for the Philippines. Farmlands occupied by farmers and residents in the villages within the 6,150 ha watershed were purchased by the government. Fund was sent to the municipality to pay off the farmers. A perimeter fence was drawn and the locals were not allowed to get inside the "linya" as what it was called. Several village schools were closed. Two small and manually operated sugar mills were also closed. The residents transferred their houses to town or to another village outside the "linya". Guards were stationed in strategic places.

It was told, as well, that the Municipal Treasurer was imprisoned because not all of the funds sent to expropriate the lands were used to pay the farmers.

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BOX 2. (continued).

In 1992, a Feasibility Study showed that only 3% of the watershed remained as old growth area. The rest was farmed. The remaining brush land and grassland areas were burned every year to allow fresh grass to feed the animals just after summer. A population of 10,000 lived around but outside the "linya". At least 95% of the population got the resources for their livelihood inside the Reserved Watershed. Many continued to maintain their farms inside the watershed. Interviews revealed that farmers planted and harvested at night, in the moonlight, to avoid the guards.. They logged or burned small patches of trees to have their farm. Some logs burned for weeks or months and not even lumbered. All the farmers wanted was a piece of land to plant rice and corn. Bribery flourished, too, and the private guards of the Water Company were not able to protect the watershed. The military and the police did not patrol the area because when they did, they encountered the revolutionary groups, the New People's Army. The national government agency and the local government tried to bring back the trees at the Maasin Watershed for 3 decades to no success (Salas, 2004a).

The socio-economic portion of the feasibility study delved deeper into the lives of the people living around the Maasin Watershed. The Kahublagan Sang Panimalay Foundation, the same group which conducted the study, went back to the area after the study was completed and voluntarily worked with the farmers. After a year, the national government funded the same group to continue its information, education and organizing work. After 4 years, sixteen village organizations were federated into a people's organization called KAPAWA or Katilingban sang mga Pumuluyo sa Watershed – Maasin (organization of households in the Maasin Watershed). In 1997, the national government, the Department of Environment and Natural Resources – Forest Management Bureau contracted KAPAWA to establish a forest plantation, guided by consultants from the central office.

At the end of the contract, KAPAWA was awarded a security of tenure or the right to continue to stay in the area, make a living in the area, for the next 25 years, renewable for another if they can prove to be good stewards of the forest. Some suspected leaders and members of the rebel groups who returned to mainstream society are now leaders and members of KAPAWA.

KAPAWA is a member of the Tigum-Aganan Watershed Management Board and is represented in the Iloilo Watershed Management Council.

but inattention to this concern brought the denudation of the headwaters, of the Tigum Aganan Watershed. (Read the story in Box 2.)

Who decided the fate of the Maasin Watershed? How effective were the policies? To what extent were the national government agencies and the local governments able to implement the laws? What caused the turn around in the attitude of the majority of the farmers? What was the role of the national government?

The local government with their communities organized themselves in 2001 to form watershed organizations to address the pressing issues of a denuded forest. There was no government policy at that time to guide the communities. They were only guided by a concern to safeguard themselves. It was only in March, 2007 that the River Basin Control Office under the Office of the Secretary of DENR was created by Executive Order 510 with the mandate to orchestrate and provide the over-all direction and technical assistance in the implementation of policies, plans and programs for the protection, conservation, management and wise use of the country's river basins.

The new guidelines from the country's River Basin Policy reinforced and supported local governments' initiative not only from the Iloilo province but also from other watershed organizations in the country. The bi-annual meetings of the Philippine Watershed Management Coalition documented the sharing that happened during these assemblies. The Philippine Watershed Management Coalition is a venue where local governments, NGOs and the academe discuss their experiences, lessons learned, new strategies, new insights in protecting and developing their respective watersheds.

6. Financing watershed conservation and development

The regional technical director of the DENR Region VI brought about the attention to the water problems of Iloilo City in the late 80's. Supported by two Universities and a non-government organization, this small group secured funds from the Regional Development Council to conduct an investigation about the watershed. Since then, various activities were implemented with funds from various sources as shown in Table 1.

In a Philippine national workshop on Sustainable Financing for Conservation and Development, (Padilla et al., 2005) it was acknowledged that the Maasin Watershed experience demonstrated an early attempt to apply a framework now recognized as the Payment for Environmental Services, or PES. Through community organizing efforts of the Kahublagan Sang Panimalay Foundation, the local government became aware of the potential for fund sourcing from users of water from the reserved watershed. The local government demanded from the Metro Iloilo Water District (MIWD) that

TABLE 1. Sources of funds.

Watershed activities	Fund sources
A. Maasin watershed	
Feasibility study	Regional Development Council Region VI, coming from an international funding agency
Initial information campaign	Voluntary work of a non government organization
Tree planting, 500 ha	Local government units: province and municipalities
	Local community: city people, students, employees
Information, education & organizing of upland communities	DENR, regional and national offices
Tree plantation establishment 2,500 ha	Loan from an international bank by the national government, through the DENR agency
Continuing education (a) Radio broadcast (b) Inter-personal communication	NGO using international fund and its own general fund, local government, people's organization or PO
Livelihood activities	People's Organization, NGO, Local Government
B. Iloilo Watershed Management Council and Tigum Aganan Watershed Management Board	
Initial organizing	NGO using international funds
Information, education campaign	NGO using international fund and local fund, volunteers
Council and board meetings	Local government, national agencies, volunteers from the academe, NGO, PO
Projects	Local government, NGO, donors, private sector with payment for environmental services

they be paid a real estate tax and a user's fee as provided for by the law. As of 2005, a total of Php1.87 million was paid by MIWD to the local government in form of taxes and fees. Another Php2 million was paid for direct watershed projects. The report however concluded that the payments were not sustained because the benefits have not reached the communities.

The case study on Maasin Watershed (Salas, 2005) concluded with a Socio-Eco-Political Framework for Payment for Environmental Services. The framework, as shown in Figure 4, is anchored on the factors and processes surrounding the natural assets of the watershed which are the Environmental Products, Services and Intrinsic Values and the community that live within. Both upstream and downstream communities enjoy or ought to enjoy mutually these benefits. There are, however, socio-cultural, economic and political forces which impinge on the system of utilization and conservation of these

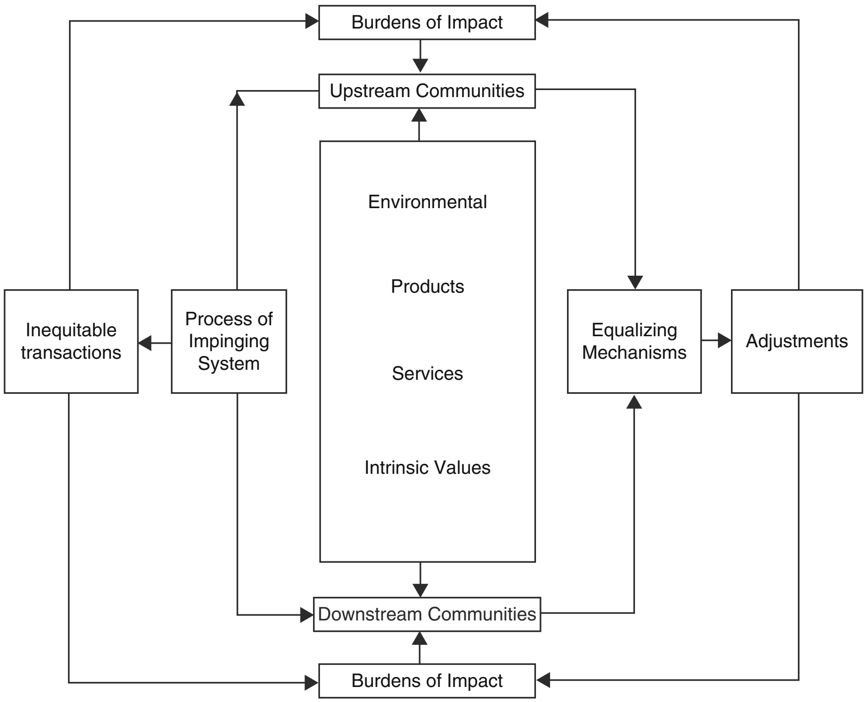

Figure 4. Socio-eco-political framework for payment for environmental services (SEP-PES Framework).

resources. These forces translate into inequitable transactions which bring changes and therefore adverse impacts on the resources. The framework shows the possibility that people living in the upstream and downstream communities could create and implement equalizing mechanisms to make adjustments in the inequitable transactions. Sharing of benefits could regain efforts to protect the natural asset of the communities and offset negative impact with real gain.

The paper also outlined some tools which may be used in the socio-eco-political transactions. The extent by which these tools were applied at the Maasin Watershed is shown in Table 2.

7. Conclusions

The paper discussed the organization, structure, authority, accountability, decision-making process and financing scheme of a medium-sized river basin against the backdrop of Philippine laws and directives of a national government agency.

TABLE 2. Tools for payment for environmental services applied at Tigum-Aganan watershed.

Dimension	Tools	Application highest, 5
Social	Education to strengthen social capital	5
	Participation for empowerment	3
	Formal venues available for communities to negotiate and claim rights	3
	Manageable units and groups (structure)	5
Economic	Organization of environmental services providers/keepers	3
	Basis to pay	5
	Instruments of agreements	5
	Presence of a broker who links the providers/keepers with buyers	4
	Local venue/platforms for information dissemination	4
	Transparency of information	3
	Service Provider for information/knowledge	5
	Informed providers/keepers	4
Political	Clear statement of objectives at all levels	1
	Clear indicators for reaching the objective	1
	Means of checking and measuring indicators	1
	Mechanism for equitable sharing of resources	1
	Mechanism for accountability	1

The example may not be a typical watershed but it is one of the several pioneering watershed organizations ran by local government councils and the community. Watershed organizations initiated by local government units and non-government organizations organized the Philippine Watershed Management Coalition. This national organization became the venue for sharing experiences and learning from each other. They meet once every 2 years since their organization in 1998.

Lessons highlighted in this paper maybe gleaned and briefly stated as follows:

1. Water and watershed resources can only be protected by the stakeholders.
2. Protection by the stakeholder is possible when there is awareness of the danger or benefits from a damaged or a protected resource.
3. River Basin management should recognize the limits of efficiencies and effectiveness of the span of management control. Micro watersheds and multi-level management schemes are helpful tools.
4. Community resiliency needed to cope with adverse impact of unprotected resource and damaging externalities is the result of continuous education, planned action, and capacity building of watershed organizations and their constituents.

5. Bottoms-Up and Top-Down strategies should recognize upstream-downstream imperatives such as the topographic trap or the interdependence of upstream and downstream communities.

The story of Tigum-Aganan Watershed and its critical sub-watershed, Maasin, shall go on and on and shall continue to unfold valuable lessons for the stakeholders themselves and their leaders.

Sustainability of watershed use rests on a communication network among the stakeholders. It is ardently hoped that such communication will not be broken; and if ever it happens, it will be repairable and will be repaired soon. The science and art of management plays a definite role in this aspect. Science lies on the study of structure and processes of organizations and a system of continuous actuation and motivation. On the other hand, the art of management rests on people whose hearts were educated towards the oneness and interdependence in a watershed community, and could see what lies beyond physical structures and studied processes. The stakeholders become peer leaders as they participate in the management of the watershed. When such concept is perceived and applied into action, the watershed community creates the elements for a zone of peace. With lessons shared, several independently managed small and medium-sized watersheds could flourish. More of these compartmentalized but interacting and interdependent watershed management units could envision a network of integrated, stable, and protected large river basin or a large watershed and promise a secure and peaceful world.

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WATERSHED MANAGEMENT SYSTEM IN POLAND AND ITS IMPLICATIONS FOR ENVIRONMENTAL CONDITIONS OF THE BALTIC SEA: AN EXAMPLE OF THE VISTULA RIVER WATERSHED

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Abstract: The Polish watershed areas have significant effects on environmental conditions of the Baltic Sea. They represent about 20% of the Baltic Sea catchment area, they cover almost 50% of agricultural land and are populated by nearly 50% of the total population of the Baltic Sea catchment area. For this reason, watershed management in Poland has a large (Baltic) scale impact and consequences.

This paper describes the most important international agreements related to the catchment area of the Baltic Sea and their consequences for the national water management. Further, it describes the Polish watersheds, Polish administration system regarding environment and water management, financial mechanisms for environmental protection and watershed management. Finally, it describes the effects of investment and management for the water quality of the Vistula River – the biggest Baltic river in terms of watershed area.

Certain positive effects as well as weaknesses of the river basin management in Poland are also presented.

Keywords: Watershed management; Vistula River; eutrophication; coastal management

1. Introduction

The Baltic Sea is dominated by freshwater inputs from its catchment area, which is more than four times bigger than the Baltic Sea itself (Figure 1). Rivers also act as a large-scale collectors of wastewater from various sources within their drainage basins. The inadequate treatment of municipal sewage and inappropriate agriculture practices, including livestock husbandry, are the major contributors to the high nutrient load to the Baltic Sea. At present,

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Figure 1. Baltic sea and its catchment area.
Marine area: 415,000 km^2; Catchment area: 1,670,000 km^2; No. of inhabitants: 85 million; River water input: 440 km^3/year; Main rivers: Neva, Vistula, Nemunas, Daugava, Oder, Göta, Kemijoki.

the approximate annual load into the Baltic Sea is some 1,000,000 t of nitrogen and 50,000 t of phosphorus. About 70% of the load comes from rivers and other direct inputs (HELCOM, 1993a, 2004). Hence, eutrophication of the Baltic Sea is a problem of special concern.

Until 1950s, the Baltic Sea was regarded as environmentally "healthy", however the situation has changed considerably since then. Large-scale industrialization, a growing number of automobiles, intensive agricultural practices and forestry (based on heavy use of mineral fertilizers and pesticides), have threatened the entire Baltic Sea catchment area and the Baltic Sea itself. Ultimately, the threat extends to the health and well-being of 85 million people living there (Figure 2).

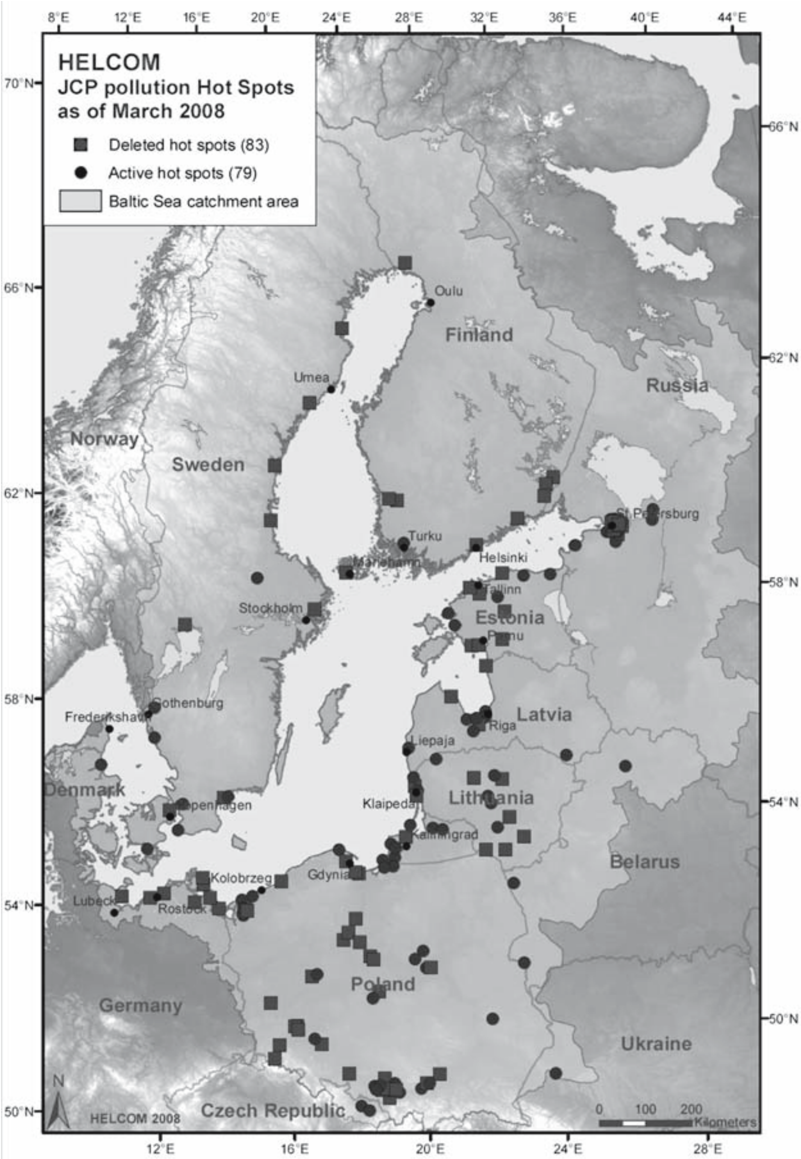

Figure 2. Distribution of pollution “hot spots” in the Baltic sea catchment area.

2. International agreements related to the catchment’s area of the Baltic Sea

Various international agreements have been signed to protect the Baltic Sea natural environment. They cover both, the Baltic Sea and the Baltic Sea catchment’s area. In 1992, the revised *Convention on the Protection of the Marine Environment of the Baltic Sea Area* (Helsinki Convention, 1992a) was signed (the background Helsinki Convention was signed in 1974). Under the regulations of HELCOM (the executive body of the Helsinki Convention), various activities are carried out:

- *Cooperative Monitoring of the Baltic Sea Marine Area* (COMBINE); a program responsible for the marine monitoring and quality assessment of the Baltic Sea
- *Pollution Load Compilation* (PLC); a program responsible for the monitoring and assessments of pollution loads to the sea from land-based sources including rivers and the atmosphere (HELCOM, 2004)
- *Joint Comprehensive Environmental Action Programme (JCP)* in which a strategy was elaborated for long-term programme of actions to be undertaken in the drainage area to restore the ecological balance of the Baltic Sea (that includes identification and removal of *Hot Spots* in the drainage area (Figure 2) (HELCOM, 1993a, 1993b).
- *Baltic Sea Action Plan* (signed in November 2007) (HELCOM BSAP, 2007), the ambitious strategy to restore the status of the Baltic marine environment touching upon all major environmental problems affecting the Baltic Sea. Baltic Sea Action Plan consists of four main targets:

• *Eutrophication – Towards a Baltic Sea unaffected by eutrophication*

• *Hazardous substances – Toward a Baltic Sea with life undisturbed by hazardous substances*

• *Nature Conservation – Towards the favorable conservation status of the Baltic Sea biodiversity*

• *Maritime Activities – Towards a Baltic Sea with maritime activities carried out in an environmentally friendly way*

The Baltic catchments area (excluding Russia) falls also under EU regulations, and therefore it is liable to comply with the *EU Urban Waste Water Treatment Directive (1991), Nitrate directive (1991), Water Framework Directive (2000)* and the forthcoming *Marine Strategy Directive*.

Transboundary rivers (e.g. Odra River between Germany and Poland), are also under regulations of the international commissions created under the *Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (Helsinki Convention, 1992b).

3. General description of the Polish watersheds

Three catchment sub-regions can be distinguished in Poland (Figure 5):

- The Vistula River Basin
- The Odra River Basin

- The coastal drainage area

These sub-regions represent about 20% of the Baltic Sea catchment area (HELCOM, 1993a), however, they cover almost 50% of the agricultural land and are inhabited by nearly 50% of the total population of the Baltic Sea catchment area. Besides this, the Polish territory is highly industrialized and intensively agriculturally used. Therefore, the Polish watershed areas have significant effects on environmental conditions of the Baltic Sea.

The Vistula River (Figure 3) is the second largest Baltic river (preceded by the Neva River in Russia), but it is the biggest Baltic River in terms of its watershed area (194,400 km^2) and pollution load carried out to the Baltic Sea. Eighty-seven percent of the Vistula River drainage basin is located within the territory of Poland, and it covers 54% of the total area of the country. Arable land forms about 60% of the basin area. About 20 million people live within the drainage basin of the Vistula River, which constitutes 27% of the entire population inhabiting the Baltic Sea drainage area. The largest Polish cities are situated either directly on the banks of the

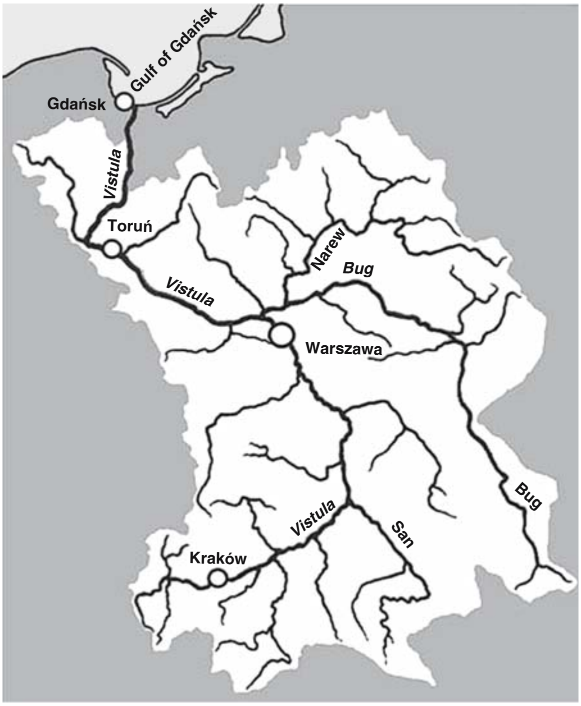

Figure 3. The Vistula River watershed basin.
River length: 1,000 km; Surface: 194,400 km^2; Population: 20 million; Water load: 32 km^3/year; Nitrogen load: about 118,000 t/year; Phosphorus load: about 7,000 t/year.

Figure 4. Vistula River middle course.

Vistula river (Warsaw, Cracow, Gdańsk) or drain their effluents into the river's tributaries (Katowice, Lublin, partly Łódź) (Figures 3, 5).

Polish rivers, in comparison to the West European rivers, represent high natural values. Most of them have preserved natural water courses. The Vistula River is regarded as the last natural – unregulated large river in the Western and Central Europe (Figures 3, 4).

4. National administration system for environment protection and water management

In the early 1990s, Poland went through decisive political and economical changes which resulted in a free market based economy and a changes in environmental practices. Due to introducing market economy prices, drastic decrease in mineral fertilizer consumption have been noticed and (at the same time environmental concerns have been raised to higher level in national priorities). These changes resulted in improvement of water quality conditions in the Polish catchment area and in decreased pollution load to the Baltic Sea.

Until 1999, in Poland, natural environment and environment related issues were under the administrative sub ordinance of different ministries. In 1999, the Ministry of Environment was established and a number of state agencies of different responsibilities (Table 1):

- *Chief Inspectorate for Environmental Protection* (and sixteen *Provincial Inspectorates for Environmental Protection*)
- *National Fund for Environmental Protection and Water Management* (and sixteen *Regional/Voivodship founds*)
- *National Board of Water Management (NBWM)* (and seven *Regional Boards of Water Management (RBWM))*
- *Institute of Meteorology and Water Management* (established in 1970s), responsible for meteorological and hydrological service and scientific background for meteorological and hydrological measurements and forecasts

Regional Boards for Water Management are responsible for water management in river basins and they are allowed to act as investors and participate in trials in courts. Watershed administration regions in Poland (divided into seven RBWMs) do not match (three) watershed sub-regions (Figures 5, 6).

TABLE 1. Administrative structure of environmental and water management agencies in Poland.

Ministry of Environment			
Chief Inspectorate for Environment Protection	National Fund for Environmental Protection and Water Management	National Board of Water Management	Institute of Meteorology and Water Management
Sixteen Regional (Voivodship) Inspectorates	Regional (Voivodship) Funds	Regional Boards of Water Management (7)	Five Regional Branches of Institute
Responsibilities: - Freshwater monitoring according to WFD - Marine monitoring -Environmental inspections	Responsibilities: - Financing environmental protection projects - Environmental investments	Responsibilities: - Urban wastewater treatment directive - Nitrate directive - Water management & inspections - WFD directive	Responsibilities: - Hydrological & meteorological service and scietific background - Scietific background for hydrological & meteorological service

Figure 5. Watershed sub-regions in Poland:
- Vistula River Basin (194,400 km^2)
- Odra River Basin (119,000 km^2)
- The coastal drainage area (26,000 km^2).

5. Financing environmental protection in Poland

The *National Fund for Environmental al Protection and Water Management* is the main source of funds for construction of wastewater treatment plants and other environmental investments. Figure 7 gives a general overview on financing environmental protection in Poland between 1999–2000. Figure 8 shows expenditures and earnings from administrative penalties from enterprises not complying with environmental standards.

The up-to-date information on financial supplies for environmental protection regarding the implementation of the Baltic Sea Action Plan in Poland is shown in Table 2.

6. Vistula river loads and effects on quality of coastal environment (Gulf of Gdańsk)

The Vistula river water is currently monitored for organic matter, nutrients, heavy metals and some selected pesticides. The Vistula River discharges into

Figure 6. Watershad administration regions in Poland – regional boards of water management (RBWMs).

the Gulf of Gdańsk, and the water plume spreads usually from 5 to 15 Nm from the river mouth.

6.1. ORGANIC MATTER

The amount of the allochthonic organic matter reaching the Gulf of Gdańsk with Vistula waters is estimated to be about 340,000 t C/year, an average concentration of organic carbon in riverine water of 10 mg C_{org} dm^{-3} (IMGW, 1987–1999; WIOŚ, 1995–1998).

6.2. NUTRIENTS

The average Vistula river loads were 118,000 t/year of total nitrogen and 7,000 t/year of total phosphorus. The contribution of Vistula loads to the total riverine discharge to the Baltic Sea in 1995 was 15% regarding nitrogen and 19% in the case of phosphorus, and was the largest of all rivers in the region (IMGW, 1987–1999; 2000–2001).

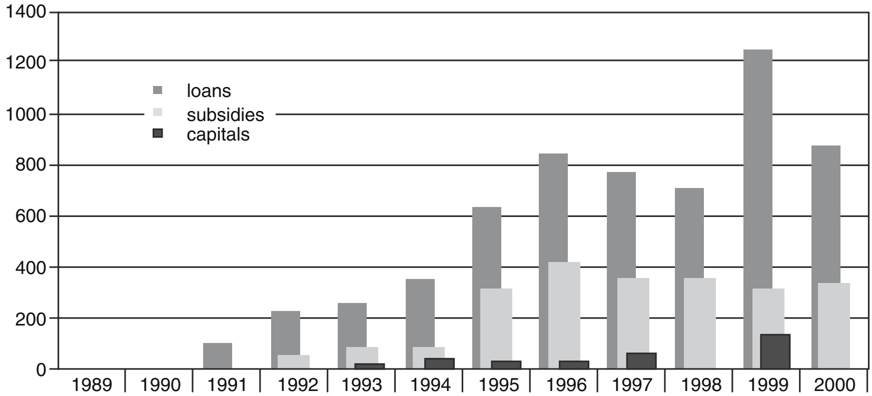

Figure 7. Financing [mill. PLN] environmental protection in Poland by the national fund for environmental protection and water management in 1999–2000 (NFOŚiGW, 2007).

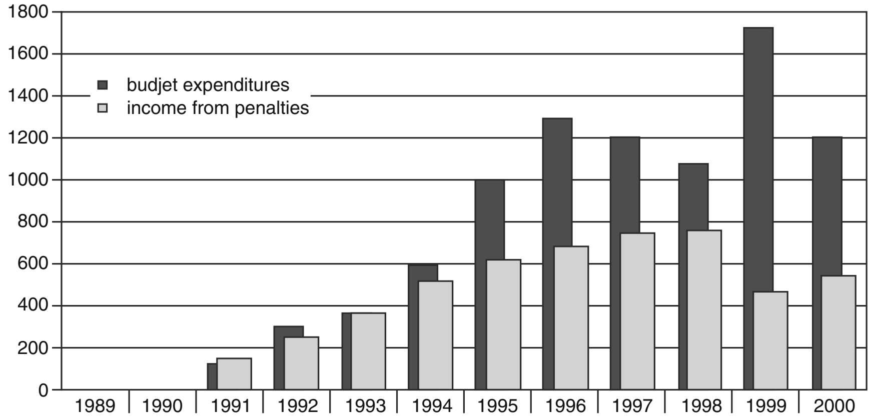

Figure 8. Expenditures and earnings [mill. PLN] of the national found for environmental protection and water management (NFOŚiGW, 2007).

Nitrogen and phosphorus discharged by the Vistula are a major contribution of the total loads of these nutrients to the Gulf of Gdańsk (Łysiak-Pastuszak et al., 2004, 2006).

This high contribution of the Vistula River is the result of its drainage area character, 60% of which is the agricultural land. As a result of anthropogenic pressure, the ecosystem of the Gulf of Gdańsk has undergone significant changes over the last 50 years (Andrulewicz and Witek, 2002).

TABLE 2. Financial resources for the implementation of the Baltic Sea Action Plan (BSAP) in Poland. (HELCOM, 2007).

Name of the financial programme	Duration	Finances (€)
Operational Programme Infrastructure Environment	2007–2013	37.57 billion
Programme for Rural Development	2007–2013	1.65 billion
Water Protection and Water Management and Supply	1995–2006	1.14 billion
EEA and the Norwegian Financial Mechanism	2004–2009	533.51 million
ECOFUND – Polish Debt for Environments Swap	1992–2009	570.00 million
Investments in the Waste Water Sector on the Polish Coast	1996–2010	669.00 million
Improvement of Competitiveness of Enterprises	2004–2006	197.29 million

6.3. TRACE METALS

The Vistula River is monitored for trace metals on a regular basis by the Woivodship Inspectorate for Environmental Protection in Gdańsk (WIOŚ, 1995–1998). From 1987 to 1999, the reported concentrations and loads of trace metals (Cu, Pb, Zn, Cd, Zn) dropped significantly. Considerably lower concentrations noted in recent years might reflect not only the reduction measures taken in the drainage basin of the Vistula River but also improved analytical techniques (Andrulewicz and Witek, 2002).

6.4. PERSISTENT ORGANIC POLLUTANTS (POPS)

The most common organic contaminants monitored in the Vistula River were DDT and its derivatives, polychlorinated biphenyls (PCBs) and lindane (IMGW, 1987–1999). These compounds have not been used in the Baltic area since the 1970s, however, they still persist in the environment and they are recorded in river water samples. Between 1984 and 1993, the estimated loads were from approximately 94–771 kg $year^{-1}$ for ΣDDT, about 200 kg $year^{-1}$ for PCBs and from 700 to 1,096 kg $year^{-1}$ for lindane (IMGW, 1987–1999). Later measurements indicated lower concentrations of POPs, however, they still seem to be very high in the Vistula River in comparison with other Baltic rivers, where POPs concentrations are usually below detection limits (usually below <0.0001 μg dm^{-3}).

7. Recapitulation/Summary

Most of the Vistula River course is unregulated and it has large parts of wetlands along its course to the Baltic Sea, therefore Vistula's discharge of organic matter and nutrients is naturally reduced and relatively low as compare to its size and use of the drainage basin and as compare to the other (regulated) Baltic rivers. Unfortunately, the quantitative effect of nutrient trapping has not been studied and/or not calculated as yet.

Many pollution point sources have been phased out or significantly reduced, this has been achieved mainly by the construction of sewage treatment plants in the Vistula River drainage basin.

Improvement in of water quality of the Vistula River as well as reduction of nutrient loads to the Baltic Sea has been observed, however, an expected reduction of eutrophication effects in coastal area of the Gulf of Gdańsk has not been observed.

Further reduction of nutrient discharges, mainly from diffuse sources, is needed.

Some weaknesses of river basin management in Poland can be assigned to the oversized administration and poor public participation.

A definite need for better integration of science and management as well as an interdisciplinary approach to marine environmental monitoring and research is clearly recognized.

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WATERSHEDS MANAGEMENT IN ROMANIA: CHALLENGES AND OPPORTUNITIES

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Abstract: Sustainable use and development of watersheds become a major target of the national, European and global strategies and policies for sustainable development.

This is based on recognition that: (i) the lotic and lentic systems are major components of the biophysical structure of natural capital which play a key role in providing a wide range of resources (e.g. water, food resources) and services (e.g. flood detention, recharging and discharging aquifers; nutrient retention and release, trace elements retention); (ii) the structure, water quality and their functions – production, regulation, information and support – were modified and degraded, in all EU countries (including Romania) in a proportion ranging between 50–90% (Castro et al., 2002; Nivet and Frazier, 2004; Revenga and Kura, 2003; Vadineanu et al., 2003); (iii) the water quality and the integrity or health of the lotic and lentic ecosystems are the results of long term integration of the cumulated stress of both human and natural pressures, acting at the watershed scales; (iv) there is a need to shift the former sectoral and reductionistic based management of water resources towards integrated/or ecosystem and adaptive management at the catchment scale (EU-WFD) and; (v) the management plans and decisions for sustainable use and development of watersheds have to rely on evaluation – in physical and monetary terms – of the impact of human pressures upon the water ecosystems structure and functions and, the quality and density of resources and services flows.

Taking into consideration the above guiding requirements and the major social, political and economic changes emerged during more than 16 years of transition and negotiation of the EU accession and integration, the presentation is focused on the current status of the new emerging institutional, governing, legislative and administrative frameworks.

A particular attention will be given to: (i) the 11 administrative units (hydrologic basins and watersheds) which cover the river network at the national scale; (ii) land use and landscape structure; (iii) water course

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management; (iv) major drivers and pressures impacting on water quality and water ecosystem health; (v) first classification of "water bodies" and assessment of their "ecological status"; (vi) former economic analysis and new requirements for "environmental and resource cost and benefit analysis"; (vii) the current institutional framework including stakeholders network and their involvement; and to many difficulties the EU–WFD implementation process is facing as well as major emerging water policy issues and risks.

Keywords: Water resources management; watershed; ecological services

1. Introduction

Like in all European countries water has been managed in Romania, in particular during last century, from a supply perspective with an emphasis on maximising short-term economic growth from the use of water and minimising the negative social and economic impacts of the extreme floods and droughts. The water quality monitoring started after 1973 and classification systems where based until very recent time, almost exclusively on a set of chemical and physical indicating variables, which provided data for purely descriptive and prescriptive assessments but not for predictive ones. In these circumstances, the quality and cost-efficiency of the implemented water management programmes have been significantly affected by the "data-rich but information poor" syndrome (Ward et al., 1986; Nienhuis and Leuven, 1998). Little attention has been paid to the need for maintaining the structural integrity and health of the freshwater bodies. In order to allow for delivering multiple functions and a wide range of goods and services on which people can benefit.

As a result of sectoral approach and technological water management based on principles of neo-classical economy, many freshwater ecosystems have been degraded and/or damaged. However, the new paradigm of Integrated Water Resources Management (IWRM) launched in 1990s helped politicians and managers to understand that they need to take care of aquatic ecosystems and the resources and services they provide for long term economic viability and social security. The IWRM has been included as a priority action within the Sixth European Action Programme for Environment (EEA, 2005) and is enforced in all EU member states through the Water Framework Directive 60/2000 (EU-WFD). According with that programme and legal instruments the IWRM should be applied in the catchments and river basins.

After 2000, in the process of negotiation of the accession and since the January 2007 as an EU member state, Romania is struggling to adapt and further develop the national operational infrastructure which should allow the IWRM according with EU-WFD provisions.

2. The Romanian political and administrative framework

2.1. GENERAL CHARACTERISTICS OF POLITICAL AND ADMINISTRATIVE FRAMEWORK

Since 1990 the Romanian social, political and economic system followed an extensive and complicated process of transition: (i) from the centralized, and state and collective ownership based economy towards free market and private based economy and; (ii) from single party based political and dictatorial governing system towards a multi-party and democratic political and governing system, which receives an increasing support from the civil society. According with the constitution adopted in 1991 and amended in 2003, Romania is a democratic republic led by an elected President and Parliament, consisting in two legislative chambers. The Prime-Minister is nominated by the President of the republic, who propose the members of the cabinet and the final approval of the cabinet comes from the Parliament. In theory the constitution assure the independence among legislative, executive and juridical powers and the President, assisted by the Constitutional Court, should guarantee the independence and collaboration between the three state's power institutions.

Unfortunately during almost 15 years of economic transition and building of the democratic institutions, the legislative activity created a rather confused and weak legislation system, which allowed, or even encouraged, a low governing efficiency associated with a high level of corruption. That was possible due to some contradictory or unclear provisions, embodied in the constitution and due to political pressures. However, in the last 4 years, corresponding to the last phase of negotiation of the EU accession and to first year of the EU membership, a quite extensive and intensive process of harmonization of the national legal, institutional and governing systems with the similar EU systems was carried out. That created a framework for improving the legislation and the capacity for its enforcement.

The principles of decentralization of the power systems and subsidiarity are also increasingly applied at the lower levels of the administrative units, consisting in: (i) 8 regions of economic and social development (Figure 1); (ii) 42 counties including the district of Bucharest – the capital and; (iii) 3,170 local administrative units, from which 319 cities and 2,851 communes.

The former legal and administrative framework for water resource management has been recently adapted, developed, in accordance with the corresponding EU framework, and incorporated as part of the overall national framework.

The elected county and municipal councils have the right and responsibility to elaborate and release ordinances and regulations which have local legal effects, but all of them have to comply with the national legislation. The fulfillment of this condition is monitored and assured by the decentralized bodies of the central Government, at the county level, which is the Prefecture.

Figure 1. Regions of economic and social development of Romania.

2.2. ROMANIAN LEGAL AND ADMINISTRATIVE FRAMEWORK FOR WATER RESOURCES MANAGEMENT

The management of water quantity has been legally regulated until 1973 based on the first Water Law established in 1924. Since 1959 there where developed and implemented the river basin plans for water quantity management, having as major objectives those emerged from different sectoral policies: (a) agriculture (e.g. land reclamation, irrigation); (b) industry (e.g. water supply for production processes); (c) households (water supply); (d) transport (e.g. Danube River); (e) energy (e.g. Hydropower generation) and; (f) flood protection. The water quality focused provisions have been inserted in the first Law for Environmental Protection (No. 9/1973). Accordingly a new Water Law (No.8/1974) has been issued which has considered equally both quantitative and qualitative (although only physical and chemical quality) attributes, and that has been amended and replaced by the Water Law no.107/1996, in order to ask and enforce for shifting from conventional towards the integrated water resources management. Soon after 2000, in the process of EU accession there was a need to adapt and strengthen the water management according with the new conceptual and operational models of ecosystem and landscape approach and adaptive management (UN-CBD/COP6/2001, EU-WFD) for allowing consideration, restoration and sustainable use of water ecosystems and the related resources and services (Vadineanu, 2001, 2005, 2007; Dyson et al., 2003; Nienhuis and Leuven, 1998; Schmutz et al., 2007). In order to reflect properly in the water legislation, that new requirements very significant amendments were brought to the Law no. 107/1996.

The transposition process of EU-WFD and other EU-Directives into the national water legislation and the adoption of the ecosystem and watershed approach, ended with the last two complementary laws (No. 310/2004 and 112/2006) which currently regulate the sustainable water resources management at the watershed scale (Serban and Galie, 2006). The legislation pertaining to water is subject of the central Government, through the Ministry of Environment and Sustainable Development (MESD)/Department of Water and its specialized operational unit represented by “The Romanian Waters Administration” (RWA), in closed cooperation with the national and regional Environmental Protection Agencies, the other ministries directly involved in natural resources management (e.g. Ministry of Agriculture, Forests and Rural Development – MAFRD, Ministry of Transport – MT), research institutes, universities and non-governmental organizations – NGOs (Figure 2).

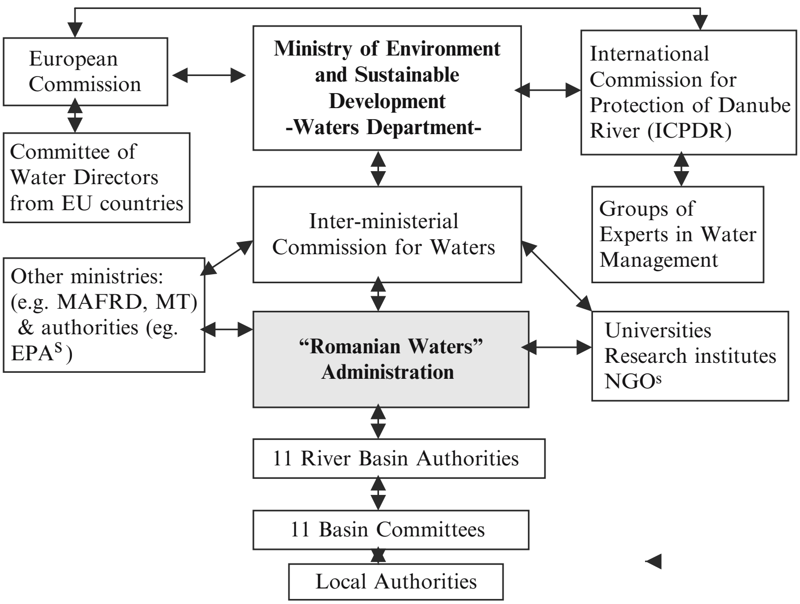


Figure 2. Institutional infrastructure for implementation of Water Framework Directive in Romania. (Adapted after RWA, 2005.).

The “Romanian Waters Administration” is the state owned company, functioning with economic and financial autonomy, according to the current legislation. That has an internal organization into five departments: (1) department of integrated water resources management; (2) department of the hydraulic structures management (human built structures); (3) department of international cooperation and integration; (4) department of development and investment and; (5) department of information technology and communication. Further, the operation of RWA is decentralized at 11 river basin and/or districts. The river basin authorities are in charged for physical, chemical and biological monitoring of water quality and “ecological status “of water bodies and for coordination the development and implementation of the river basin management plans.

The performance and quality of the river basin management plans are highly dependent on how the decision making process is structured and stakeholders participation is assured. In that regard the river basin committee has been established for each of the 11 river basins and districts. These are intended to be extensively and efficiently used as forums for discussion, analysis and deliberation on multiple options to different water management related issues.

However it has to be underlined that the new national and river basin authorities and stakeholders committees are still in the phase of institutional and capacity building, and thus the volume of work which was done until now is well below of what is needed and quality of first achievements is rather poor.

3. General characteristics of major watersheds

Romania is a medium size country with a total surface of 238,391 km^2 and a geographic position of $43^0$36’52” N and $48^0$15’56” N, $20^0$15’52” E and $29^0$40’49” E.

The climate is temperate-continental with some Mediterranean influence in the south-west region. The annual mean temperature ranges between 8–10^0C and between −2–0^0C in the upper Carpathian Mountains. Annual mean precipitation varies within the country from 200 mm (e.g. Dobrogea region in the SE) to 1,700 mm (e.g. Western Carpathians).

Hydrologicaly, 97.4% of the Romanian territory is drained by the Danube river (2,780 km long) which is the largest river in EU and second largest river in Europe. Romania is one of the 18 riparian countries and accounts for about 29% of the total area (801,490 km^2) of the Danube river catchment (ICPDR, 2005) (Figure 3). It can be noticed, also, that about two thirds of the territory belongs to the Lower Danube Basin and one third belongs to the Middle Danube Basin.

The geology and physiography around the country are very diverse. In that regard is worth to mention that the mountains (>1,000 m asl), hilly

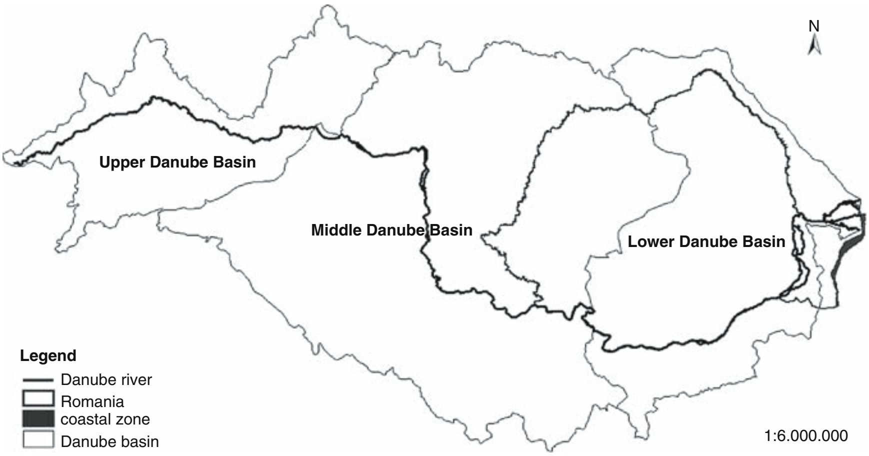


Figure 3. Location of Romania within the international Danube River Basin.

and plateau or highland (300–1,000 m asl), and lowland (<300 m asl) areas are almost equally represented. Almost 55% of the total surface of the Carpathian Mountains is spread out on the Romanian territory. That creates full altitudinal gradients from alpine to coastal zones and a wide range of mezo and micro-climatic which explain the high richness of habitats, ecosystems and plant and animal species. Such ecological and biological variability is also explained by the fact that the Romanian territory overlap with five biogeographical regions (Alpine, Continental, Pannonian, Steppic and Black Sea) and thus is located at the junction of the Mediterranean, Pontic and Eurasian subzones of palearctic floral and faunal realm. The impact of long time interactions of the human population with the environment and nature is well reflected in the current land use structure (Figure 4). It can be noticed that on this territory there are still present about 53% of natural and seminatural ecosystems, consisting in: (i) more than 149 types of forest ecosystems which cover 63,626 km^2 (26.7% of the national territory) mostly in the Carpathian Mountains; (ii) a wide range of grassland ecosystems (e.g. Alpine and highland pastures and hayfields, steppic grasslands, alluvial meadows) extended over 48,330 km^2 (20.2%) and; (iii) a high variety of aquatic (e.g. running waters, alpine lakes, large man-made lakes) and wetland ecosystems (e.g. small reservoirs, floodplain, delta and lagoons) covering 6% of the territory (14,300 km^2). As man-dominated ecosystems, established by extensive conversion of natural or seminatural wetlands, lowland forests and grasslands, there are a limited types of agro-ecosystems (mostly cereal crops), which covers about 94,200 km^2 (39% of the total land surface), vineyards and orchards planted on 6,046 km^2 (2.5%).

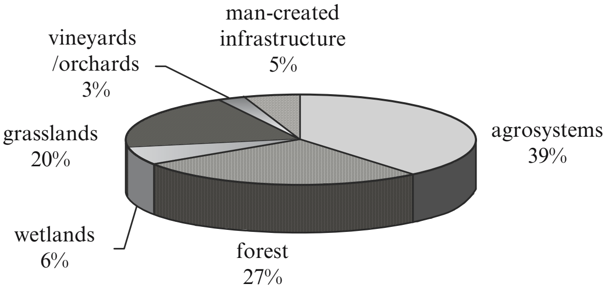


Figure 4. Land resources in Romania.

The man created infrastructure, as human settlements, manufacturing units and transport has covered at the beginning of the 1990s almost 5.4% of the total surface (12,860 km^2).

Around the country, about 6% of the land surface covered by different types of ecosystems is already managed as protected areas (e.g. National Parks-18, Biosphere Reserve- 3, Nature Reserve-195) and documentation and deliberation for designing the network of Natura 2,000 sites (~20% of the land surface) is progressing in the right direction, even slower than it is required.

According to the criteria established in the WFD for water bodies identification and classification, the RWA and its territorial sub-units have recently recorded 3,480 running water bodies and 246 standing water bodies (62% permanent), and 129 ground water bodies (RWA, 2005). They have been further considered for testing the monitoring and classification procedures of water bodies quality and ecological integrity. The recorded data during the first exercise of implementation of the WFD in Romania have been used for delineation 10 major river basins (sub-catchments of the Danube river) and Lower Danube River Wetlands (>10,000 km^2) and Black Sea Coastal zone as "Dobrogea- Litoral district" (Figure 5).

It can be noticed that some watersheds have been established by integrating the catchments of more than one important river (e.g. Buzau-Ialomita, Arges-Vedea) and their size ranges between 15,000 and 28,000 km^2. They have been proposed and accepted as the territorial planning units for holistic and sustainable management and use of water resources and water ecosystem services, according with the domestic water laws and EU-WFD.

Table 1 contains additional information concerning density of running waters network, annual precipitation and temperature within each of the established watershed.

The human population of 21.7 million peoples is not equally distributed among watersheds (Figure 6). There are less populated watersheds (e.g. Crisuri

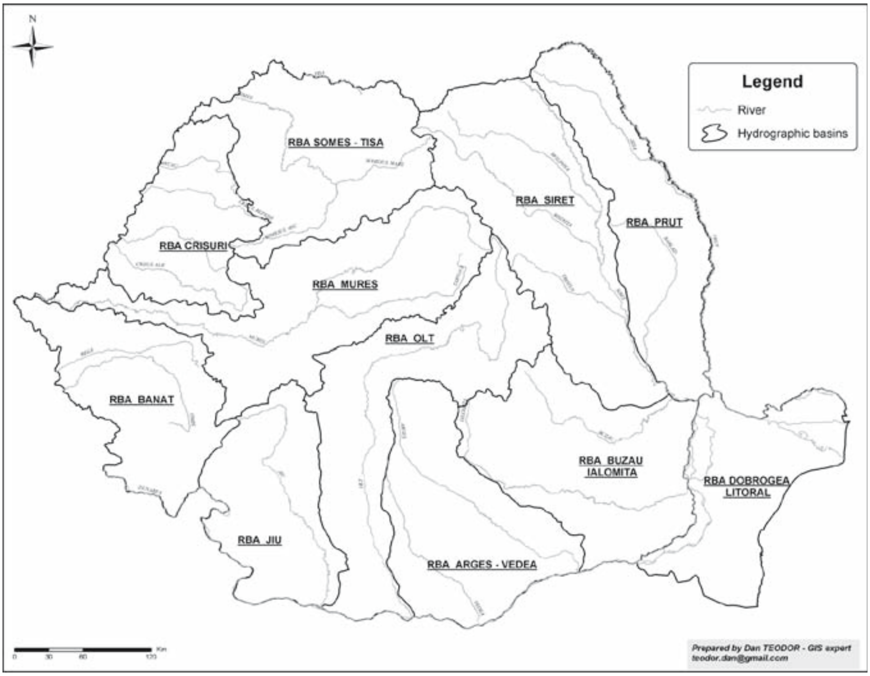


Figure 5. River Basin Districts of Romanian water management system.

TABLE 1. Major physical attributes of the watersheds. (RWA, 2005.).

Watersheds	Surface (10^3 km^2)	Water courses length (10^3 m)	Density (km/km^2)	Annual precipitation (mm/year)	Average temperature (^{0}C)
Somes-Tisa	22.4	7.8	0.35	600–1,200	0–9
Crisuri	14.9	5.8	0.39	500–1,700	10
Mures	28.3	10.8	0.39	480–980	7.9
Banat	18.4	6.2	0.34	600–1,400	−2–11
Jiu	16.7	5.0	0.29	400–1,200	10.5
Olt	24.0	9.9	0.41	500–1,570	0–10.9
Arges-Vedea	21.5	4.6	0.36	550–1,400	−2.5–11
Buzau-Ialomita	23.9	5.6	0.24	400–1,200	−4–11
Siret	28.1	15.2	0.54	450–1,000	4–10
Prut-Barlad	20.3	7.8	0.38	400–600	9
Dobrogea	16.2[a]	1.6	0.13	200–400	10

[a] Include Danube River and Romanian part of Danube Delta (82%)

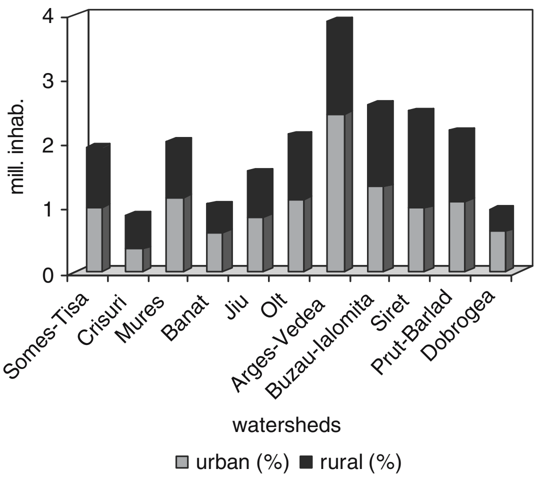


Figure 6. Distribution of human population among watersheds.

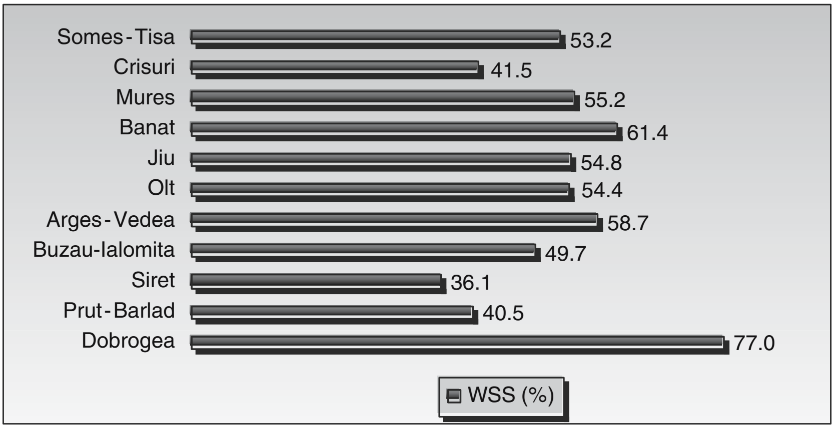


Figure 7. Human population connected to water supply system in the watersheds.

and Banat with about 1 million inhabitants or a density of 67 inhabitants/km^2; Arges Vedea with 3.9 million inhabitants or 180 inhabitants/km^2).

The main stocks of water available for human uses are delivered by the Danube river (44%), the inland running waters and built reservoirs (46%) and groundwater (10%).

It was estimated that the current stocks of freshwater available from the surface sources can provide annually about 1,770 m^3 per capita (ICPDR, 2006).

Although the amount of available water is well above critical level, estimated for 500 m^3/individuals/year (Falkenmark, 1984), only an average of 50% of the human population is connected to the water supply system

(Figure 7). However there are significant discrepancies between watersheds regarding the population connected to such systems.

4. Social and economic drivers and pressures

After the Second World War, under new and aggressive ideological and political conditions, most of them imported and imposed from outside, the Romanian socio-economic system (RSES) entered in the process of transition from the capitalist towards socialist and communist model of social and economic development, which lasted for about 43 years. In the first phase (1947/1959) of transition, the national strategy and policy has been focused on changing the former private ownership on land and built capital into state and "collective" ownership. In the second phase of the process, the aim was to change the former rural and agricultural based economy and society into an industrialized or technological based economy and modern urban society. For achieving that goals, the principles of free market economy and democratic governance were replaced with the principles of centralized, command-control and dictatorial governance.

As a major result of that, a new set of economic and social driving forces, equivalent with the specific objectives of social and economic development, and pressures, identifiable as the major managerial ways and tools for policy implementation, were very active upon the biophysical structures and their services (including freshwater bodies) at the watersheds and country levels. By the end of 1980s, the structure and metabolism of the Romanian socio-economic system and its dictatorial way of governance have collapsed, entering in a relative short phase (1990/1996) of "release" or "destructure" overlapped partially and followed by the phase of "economic transition" or "macro-economic restructuring" towards functioning market economy and effective democratic governance (1994–2004). Since 2005 it was accepted or more politically stated that the socio-economic system entered in the phase of fast economic growth (Vadineanu, 1998, 2001; Bitzenis, 2007; Scarlat and Scarlat, 2007).

The development cycle (Holling, 2001) of the RSES towards the socialist/communist model was rather short (less than 50 years), and the recent transition along the opposite direction, which is the capitalist and democratic model, had a poor scientific and methodological background and was poorly supported by the unstructured social capital. Moreover the last so-called "economic transition" overlapped with the global transition initiated after the Rio/ONU/1992 towards a model of "ecologically sustainable and socially acceptable economic development". The last transition of the RSES has generated particular driving forces and pressures but, has also preserved some of the most powerful ones from the former development cycle (1947/1989).

For the purpose of this paper we have selected and briefly described the critical policy drivers and management pressures which can help: (i) understanding the current water quality and ecological status of the aquatic ecosystems or water bodies and; (ii) formulation the appropriate policy (drivers) and management (pressures) oriented responses.

Different policies and management plans based on the utilitarian principles of the neoclassical economics have been developed and implemented, between late 1950s and late 1980s, at the catchment scale of major rivers around the country. These had a wide range of social and economic objectives from which the followings have been identified as major drivers for the changes occurred in the water quality, water consumption and ecological integrity of the aquatic ecosystems: (i) diversification and intensification of the industrial infrastructure and production activities; (ii) extensification and intensification of the production activities in the agricultural sector; (iii) enhance the capacity to feed the industrial and agricultural production systems according with the increasing requirements for material and energy inputs; (iv) identification and exploitation of new stocks of mineral resources and fossil fuels (coal, oil, natural gas); (v) river flow regulation for flood control, water supply, power generation or shipping (e.g. Danube river); (vi) decreasing the proportion of rural population and their economically dependence on primary sectors, from about 75% bellow a threshold of 40% and; (vii) urban and transport infrastructure development.

During almost 18 years of destructuring of the former socio-economic system and "economic transition" to the market based economy and democratic governance co-existed in different proportion, structural, legal and policy objectives of the former and new development cycles (e.g. state and private ownership; centralized and decentralized management; intensive agricultural production versus subsistence agriculture and very recently multi-functional agriculture). In these circumstances most of the social and economic pressures very active in the past were preserved, although some have been significantly reduced and others increased. However the following human pressures should be carefully assessed when describing the status and impact:

(i) Technological river management totally ignored the natural processes when designing large and very diverse hydrotechnical works like: dams, levees, channel stabilization and flood protection or water diversion schemes.

(ii) The arable land surface has been increased during 1970s and 1980s by extensive draining of floodplains and other wetlands and establishing agricultural polders.

(iii) Water abstraction for industrial (35%), agricultural (58%) and drinking water purposes (7%) has reached the highest level of 20.4 billion cubic meters per year in the late 1980s. Intensive agriculture practiced before 1990 in large state owned crop and animal farms, required irrigation (~3.5 million hectares) and about 1,200 kt (1 kt = 1,000 t) of fertilizers and pesticides. The demand of industry for high amount of water derived from its structure and applied production technologies. In that regard has to be mentioned that by the end of 1980s Romania has planned to produce about 25 million tons per year of products from ferrous and non-ferrous metallurgical units, to increase the oil refining capacity up to 35 million tons per year and to extend the capacity of chemical industry, pulp and paper industry, cement industry, wood industry, food processing industry and energy production in coal and nuclear power plants. Due to dramatic reduction of the industrial and agricultural production, the amount of water abstracted in 2006 for industrial use reached the level of 3.7 billion cubic meters and for agricultural use only 0.43 billion cubic meters.

(iv) Point emission sources from human settlements and households, industrial units and/or large animal husbandries together with the diffuse emissions at the watershed scale were responsible for water pollution with organic, nutrients, pesticides, heavy metals and hazardous substances. For instance the most recent inventory of the point pollution sources shown that less than 50% of the population inhabiting the watersheds is connected to the sewage and wastewater treatment systems (Figure 8).

(v) The ecological integrity of the lotic and lentic ecosystems and/or wetlands has been also affected by the intentionally and non-intentionally introduction of the alien invasive species as well as by overexploitation of biological resources (e.g. overfishing of most valuable fish species).

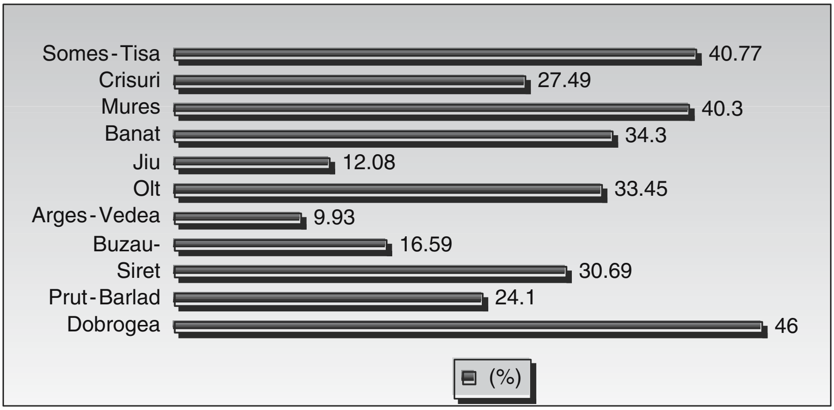


Figure 8. Human population connected to sewage and waste water treatment systems.

5. Impacts

First attempt for classification and assessment of the water quality and ecological status of the water bodies identified in Romania has been carried out between 2004/2006. In that regard have been used a large bulk of data regarding the hydrology and geo-morphology, chemistry, climate and hydrobiology of the water bodies and their catchments, collected more or less systematically in the last 100 years. Those data were complemented with that recorded in the survey carried out in 2004 and managed according with the methodology and criteria required by the implementation of EU-WFD. However it has to be mentioned that the methods, criteria and indicators were and still are in the process of development, testing and validation. Thus, the product of this first attempt, is questionable for many aspects and that should be taken mainly as partial output of an exercise for testing and validation tools and capacity building.

The need for further research and monitoring activities at the watersheds, national and EU scales, was widely recognized in order to improve the knowledge and database which are among most critical elements for reliable assessment of the ecological status of water bodies and the impacts of the socio-economic drivers and pressures, and climate changes.

However, this first exercise for the implementation of the provisions of EU-WFD allowed for getting some useful results which may guide the improvement of watersheds strategies and policies and the development of first watershed sustainable management plans.

In that regard, we have selected the results which show the effective impact and potential impact of the human pressures upon the hydro-morphological and ecological configuration of water bodies (Figure 9).

Related to these hydro-morphological changes other types of impacts occurred like: loss of lateral and longitudinal connectivity and interruption of the fish species migration routes, loss of spawning, nesting and feeding habitats and/or habitat fragmentation; reduction of nutrients, trace metals and water retention capacity (Vadineanu et al. 2003, Vadineanu 2007, Buijse et al. 2002, Bloech et al. 2006). In the case of many lotic systems, including Lower Danube River stretch and floodplain, the structural configuration has been changed beyond the critical threshold ranging between 35–40% (Vadineanu A., Vadineanu R.S., Adamescu M.C., Cazacu C., Cristofor S., 2008, unpublished) which brought the systems into different functional regime and made them less resilient and more vulnerable to extreme floods and droughts.

Another category of impacts are related to the changes in water chemistry (e.g. eutrophication), species composition of the communities, ecological processes, and the quality and quantity of resources and services. Such changes occurs due to organic and chemical pollution, introduction of alien species, overexploitation of the renewable resources and water flow limitation.

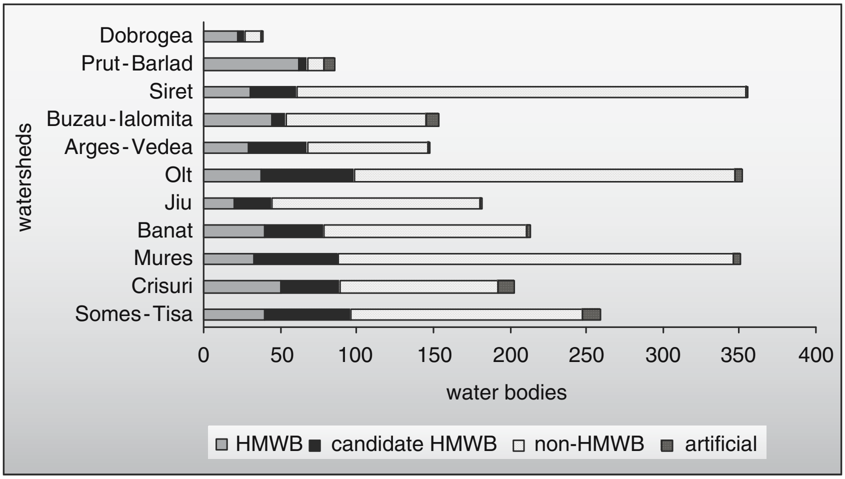


Figure 9. The degree of hydro-morphological alteration of water bodies within the watersheds.

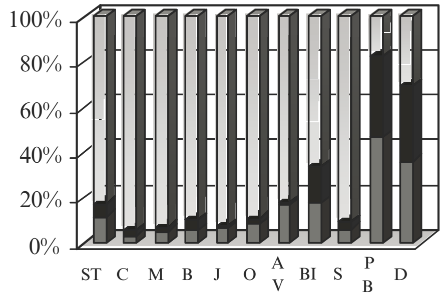
That two major categories of pressure and/or impacts identified and described for water bodies located in all watersheds were also used for water quality and ecological status assessment. Based on such evaluation the departure from the good ecological status has been estimated in terms of the risk of failure to reach that target status (Figure 10). The analysis was based on considering three forms of pollution (human pressures) – with organic substances, nutrients and hazardous substances – and one major type of impact – hydro-morphological alterations. A water body has been considered at risk when at least one of the above criteria is met.

6. Funding mechanisms of the water resources management

All major activities involved in water management, among which: water course regulation and flood protection schemes; building the water reservoirs; irrigation and water diversion schemes; water quality monitoring; development of the water supply and sewage systems and building the waste water treatment plants have received a disproportionate financial support from the central budget. Currently, the projects dealing with the development of water supply, sewage systems and waste water treatment plants are co-financed from central and local budget, national environmental funds and EU-structural funds.

The development of National Action Plan for Sustainable flood protection has been initiated in 2007 by the MESD and all activities and projects approved in the watershed management plans will be fully financed from the central budget.

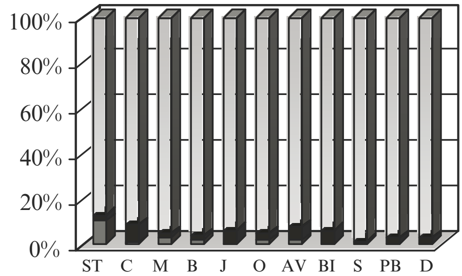
a)



	ST	C	M	B	J	O	AV	BI	S	PB	D
without risk	214	192	327	192	169	315	122	102	32	15	12
possible at risk	14	5	7	10	1	8	1	25	11	31	13
at risk	30	6	17	11	12	29	25	27	21	40	14

organic substances

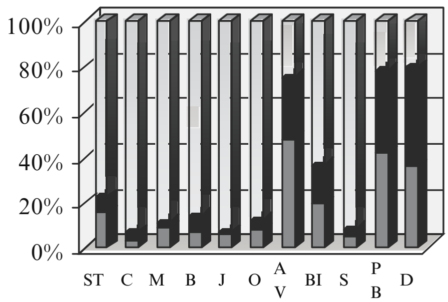
b)



	ST	C	M	B	J	O	AV	BI	S	PB	D
without risk	225	186	335	206	171	337	137	145	351	84	38
possible at risk	7	16	6	3	11	9	9	9	4	2	1
at risk	26	1	10	4	0	6	2	0	0	0	0

hazardous substances

c)



	ST	C	M	B	J	O	AV	BI	S	PB	D
without risk	20	189	312	183	169	30	37	98	325	19	8
possible at risk	18	8	7	15	1	16	40	26	13	31	17
at risk	40	6	32	15	12	27	71	30	17	36	14

nutrients

Figure 10. Risk assessment of failure to reach "good ecological status" according with EU-WFD. (RWA, 2005.).

d)

	ST	C	M	B	J	O	AV	BI	S	PB	D
without risk	151	103	258	132	136	253	62	90	297	11	15
possible at risk	55	38	55	39	25	62	38	18	28	6	5
at risk	52	62	38	42	21	37	48	46	30	69	19

hydro-morphological alteration

Figure 10. (continued)

The resource and environmental costs provide the economic mechanism for financing the qualitative and quantitative management of water resources.

The resource cost or the private cost of water use is reflected by the payment system according with the beneficiary pays principle, comprising the amount of money paid by the water users (households, public institutions or any other economic agent) to the management units for a wide range of services (e.g. water abstraction treatment and pumping, conservation for tourism and recreational opportunities, fishery, water transport by pipes or channels, etc.) or other cost categories (e.g. energy, fuels, labour, depreciation, monitoring and research).

The water users are allowed to discharge effluents, which are loaded with specific pollutants, according with the type of water use, up to certain thresholds, established by water law. However for the permission any economic agent/user has to pay a tax for each chemical compound released with the effluent. According with the polluter pays principle, for the discharges of waste water containing pollutants above the allowed thresholds the penalties are applied.

The current practice for water pricing is based on a unique price applied at national scale, regardless the fact that the water management is organized at 11 river catchments around the country.

In these circumstances significant differences among the river catchments and administrative units in terms of: (i) quantity and quality of water resources; (ii) the specific seasonal and annual variability in the hydrology at the catchment level; (iii) and marginal cost, are not taken into account.

Taking into account the water resource distribution and scarcity, the pollution problems, the expected increase demand for water and decentralization of the decision making at the regional and watershed scales it has to be recognized that the unique price is not the appropriate economic instrument for sustainable water use and watershed management.

The applied water pricing system allowed all stakeholders, regardless their economic viability, to have access to the available water resources and also, allowed the planning and management authorities from different watersheds to share the risk associated to any unexpected events (e.g. droughts, floods, pollution).

In the next phase of WFD implementation a special attention should be given: to extend the economic analysis by including the full range of the ecosystem functions and services and; to apply a much broader framework which allow options valuation and public participation.

7. Emergent actions from sectoral and watershed management

1. A set of conflicting actions derives from the national and EU sectoral strategies and policies

- Commercial energy production by increasing the use of hydropower potential from 35% to 70% (energy policy)
- Significant increase of the water way transport in Europe e.g. “the plan of Danube Navigation Commission in the frame of the Trans-European Transport Network (EU-TEN-T) to remove “bottlenecks” along the Danube; riverbank consolidation; and dredging shipping canals” (EU – transport policy)
- Consolidation and further development of flood defense infrastructure (EU and National Action Plan)

The above listed actions are expected to generate adverse effects to those envisaged from the following actions related to watershed management

- ▪ Restoration the lateral, longitudinal and vertical connectivity and resilience in the heavily modified lotic ecosystems (e.g. Lower Danube Green Corridor), in order to create good ecological potential
- ▪ Restoration the rural landscapes for adaptation to climate change and diffuse pollution control
- ▪ The need to adapt the water and watershed management according with the increasing frequency and intensity of floods and droughts
- ▪ Rehabilitation and development of the irrigation system as an effective tool for adaptation the agricultural production system to climate change

2. Actions targeted to control the land based pollution sources

Extensive development of:

- ▪ Water supply systems

- Sewage infrastructure
- Efficient and cost effective waste water treatment systems, in both rural and urban areas

3. Actions targeted to improve efficiency of the implementation of WFD
   - Updating the inventory and classification of “water bodies”
   - Establish and test the set of indicating variables and holistic indices, relevant for decision making and management of water services
   - Development the package of methods and guidelines for Water Resources and Environmental Costs and Benefits estimation and benefit transfer in order to allow proper economic valuation of the water services

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WATERSHED MANAGEMENT IN THE RUSSIAN FEDERATION AND TRANSBOUNDARY ISSUES BY EXAMPLE OF KALININGRAD OBLAST (RUSSIA)

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Abstract: Presented overview of Russian system of water management contains information on history of water accounting system, existed legislative issues and system of water basin districts and administrations, statistics on water consumption in the Russian Federation (1970–1998). Water use at the regional level and transboundary use of water resources are illustrated by example of the Kaliningrad Oblast, an enclave Russian territory in the South-East Baltic. Overlapped structure of boundaries of administrative units and watersheds is a basis for downscaling of transboundary issues till the level of local municipalities. Some basic statistics on water consumption, information on price for water use as well as on responsibilities of local water administration are given.

Keywords: Russian Federation; Kaliningrad Oblast; water use; watershed; transboundary; South-East Baltic

1. Introduction

Water industry of the Russian Federation during many years permanently supplies all branches of Russian economy by water. The main aim of Russian water industry is a regular providing the country economy with qualitative water, protection of water resources from pollution, prevention their depletion, qualitative and quantitative rehabilitation of water resources (Demin, 2000).

The increase of total and specific (water use per unit of production) water use for all purposes was observed in Russia in 60th–middle 70th. Next 15 years (middle of 70th–end of 80th) when total water use was stable, the specific water use reduced smoothly, with some variations in

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 133–149.

agriculture due to hydro-climatic conditions. In 1990–1995 decrease of total water use in industry and communal economy was accompanied by increase of specific water use, because the rate of industrial degradation was higher than reduction of water consumption due to inclusion of returned water use. (Krenkovich and Zaitseva, 1999).

Even watershed approach has used for accounting of water resources long ago (from 70th) it is not fully used for management in Russia till now.

Aim of the paper is to present main principles and organizational elements of implementation of the watershed approach in the Russian Federation, to make brief overview of legislation and administrative systems related to water use, and to illustrate the transboundary issues by an example of the Kaliningrad Oblast, enclave Russian territory in the South-East Baltic.

2. Water management issues in Russian Federation

2.1. HISTORY OF ACCOUNTING OF WATER USE

Before 70th different statistical forms were developed for reporting on water use. These forms included all types of water consumption and only 8–10% of water consumption was not reported directly, but theoretically estimated (Demin, 2000).

Comprehensive accounting was put into force in 1971 by introducing of "Provisions on State Accounting of Waters and Water Using" by decree of State Government of 01.09.71.

The process of development of statistical reporting finished in 1979 by introduction of the unified statistical form for water use and drain accounting – form of 2TP-VODHOZ. Since this time this form is the single accounting form used for water statistics in the Russian Federation.

Number of water users under accounting grew every year, and there were 80,000 (45,000 in Russia) in 1985 in the Soviet Union. Since that moment an accuracy of direct accounting of water use achieved 2–3%, i.e. only 2–3% of water consumption was estimated, not directly reported.

2.2. RUSSIAN WATER CODE (2006)

Main law for water management in the Russian Federation (RF) is the Water Code of RF adopted in 1995 and amended during 2001–2005. It is in force now, after last passing in 2006. The watershed principle as the main management principle for water management was introduced in Russia in 80th.

Nowadays the Water Code of RF, as a main legislative act in the country, provides a legal basis for implementation of watershed and other basic principles:

- A water object is a basis for human life and activity, it is a habitat and essential part of environment, it is a resource and object of ownership.
- Conservation of a natural water object has higher priority, and, therefore, some specially protected water objects with high restriction of using are assigned.
- There is a priority of using water objects for drinking and municipal water supply against other purposes.
- A process of water management decisions making should include a public participation.
- Regulation of all relations concerning water using is based upon the water basin approach with respect to existed natural water regime and hydro-technical systems.
- User-paid principle and economical stimulation of water conservation activity (fee includes costs of conservation).
- Water district is a main governing unit for using and conservation of river water resources and ground wares and seas related with them.

Despite that main principles declared are rather challenged, the Water Code of RF contains many reference notes, which are not often provided by necessary consequent law and sub-law acts determining the aims, organizational basis, economic and financial provision and terms for achievement of the target indicators (i.e. "the mechanisms of realization"). As a result, the emphasis in the Water Code of RF has obviously shifted in the direction of water use regulation to the detriment of protection and restoration of water bodies. For example, Chapter 11 "Protection of water bodies" abounds in declarative notions and almost does not contain the articles of direct action. Particularly this results in very weak realisation of the basin management principle, which is introduced in the Water Code of RF (Chubarenko and Alexeev, 2005). The weak point is the absence of legal basis for (i) development and completing of Basin Agreements, (ii) economical regulation of water use and realization of "pollutant pays" principle (Danilov-Danilian, 2006). For more information, please see the analytical overview developed within the CABRI-Volga Project (Comparative summary, 2007).

2.3. ADMINISTRATION AND ORGANIZATION

According to the Water Code of RF (2006) the water resources of the Russian Federation are subdivided into 20 watershed districts (Table 1, Figure 1). Process of legal definition of these districts (including precise boundaries) has not been finished yet, finalization is expecting in the beginning of 2008.

TABLE 1. The list of basin districts (BD) in the Russian Federation.

1. Baltic BD	8. Upper-Volga BD	15. Down-Ob' BD
2. White-Barents seas BD	9. Oka BD	16. Angara-Baykal BD
3. Dvina-Pechora BD	10. Kama BD	17. Yenisey BD
4. Dnepr BD	11. Down-Volga BD	18. Lena BD
5. Don BD	12. Ural BD	19. Anadyr'-Kalmyk BD
6. Kuban' BD	13. Upper-Ob' BD	20. Amur BD
7. West-Kaspian BD	14. Irtysh BD	

Figure 1. Subdivision of the Russian Federation into the basin districts (Water Code of RF, 2006).

A basin district is a main unit of water resource management, it consists from river basins and related groundwater basins (Russian Water Code, 2006). Areas covered by the basin districts are not equal. In the European part of the country, where economical activity and population density are higher, the districts are smaller. Basins of two really huge rivers, namely the Volga and Ob' rivers, are subdivided into four and three basin districts respectively.

Implementation of national ecological policy is ensured by the vertical governmental power. Two ministries (among other 15 in the Council of Ministries of the Russian Federation) are responsible for environmental issues. These are the Ministry of Agriculture (includes fishery) and the Ministry of Natural Resources.

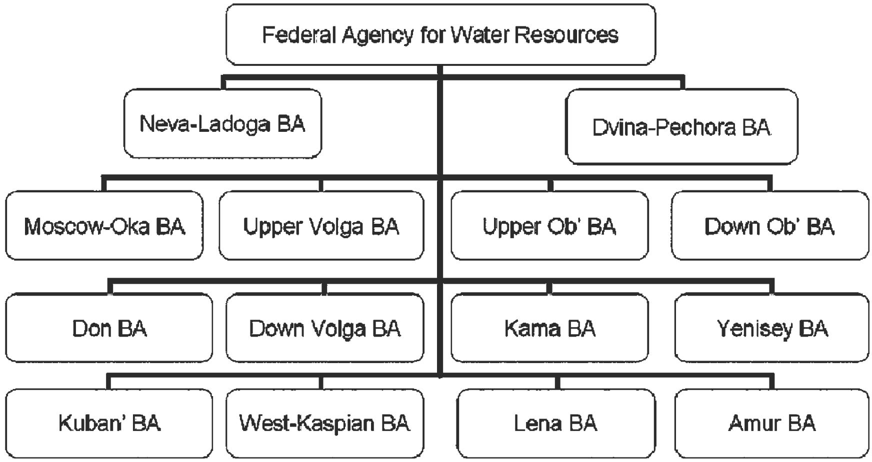

Figure 2. Basin Administrations within the structure of the Federal Agency for Water Resources of the Russian Ministry of Environment (2007).

The last reformation of the structure of the Ministry of Natural Resources happened in 2006. Nowadays, the Ministry is subdivided into four Federal Agencies:

- Federal Agency for Water Resources
- Federal Agency for the Earth's interior
- Federal Service for Environmental Control
- Federal Agency for Forestry

The federal power is implementing through the structure of regional authorities for watershed management – 14 Basin Administrations (Figure 2). These Administrations in their turn are subdivided into the local Departments for Watershed Management in each administrative unit (Oblast) of the Russian Federation.

As an example, Figure 3 shows scheme of subdivision of the Neva-Ladoga Basin Administration, which consists from five local Departments for Water Resources as five Oblasts are included into the area of Neva-Ladoga Basin Administration's responsibility. In the second part of the paper we will consider an example of Kaliningrad Oblast, an enclave of Russia in the South-East Baltic, which administratively refers to the Neva-Ladoga Basin Administration, while geographically the Oblast belongs to the catchment of the South-East Baltic.

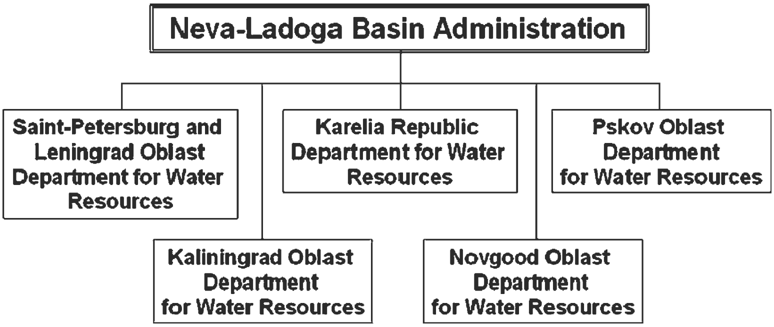

Figure 3. Subdivision of the Neva–Ladoga Basin Administration. Kaliningrad Oblast being an enclave of Russia in the South-East Baltic belongs to this basin administration.

Typical responsibilities of a local Department of Water Resources are:

- Ownership, use and administration of federal water objects
- Prevention of negative influences on federal and transboundary water objects
- Fulfilment of water protection activities
- Administration of regional section of federal information system and data bases, Federal Water Register and Russian Register of Hydro-Engineering Constructions
- Conducting of federal monitoring of water objects
- Participation in development and implementation of the plans of integrated use and protection of water objects
- Participation in development of flood prevention activities
- Development of the recommendations on redistribution of surface waters and replenishment of ground waters
- Participation in the hydro-graphic and hydro-economic regionalization

2.4. GENERAL STATISTICS OF WATER CONSUMPTION IN THE RUSSIAN FEDERATION

Surface waters are the main water source for Russian economy and household. Long term average share of the ground water supply is of 11%. This share increased trough the years. It has achieved 16% only at the end of 90th. Sea water is used mainly for cooling of nuclear power plant near St. Petersburg and partly for fish farming (Figure 4).

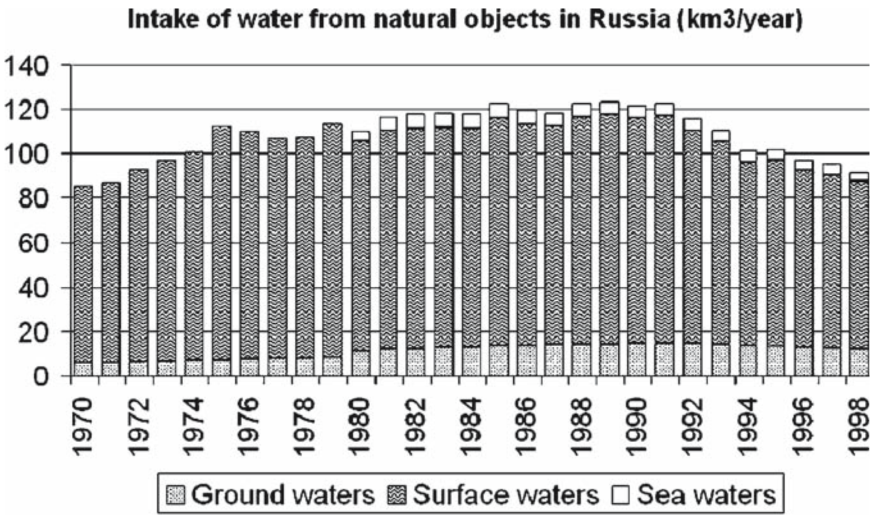

Figure 4. Dynamics of use of different types of natural waters in the Russian Federation (Demin, 2000).

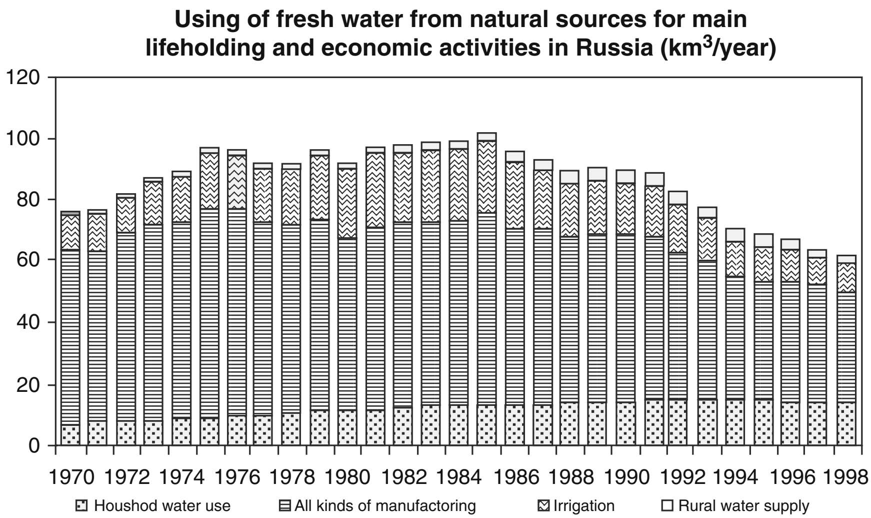

Figure 5. Dynamics of use of natural waters for different purposes in Russia (Demin, 2000).

Fresh natural waters are used for different purposes (Figure 5). Manufacturing of all kinds (in different branches of industry, including agricultural sector) together with irrigation are the most water consumable activities. Decrease of water use after 1991 is a reflection of the general decline of business activity in Russia.

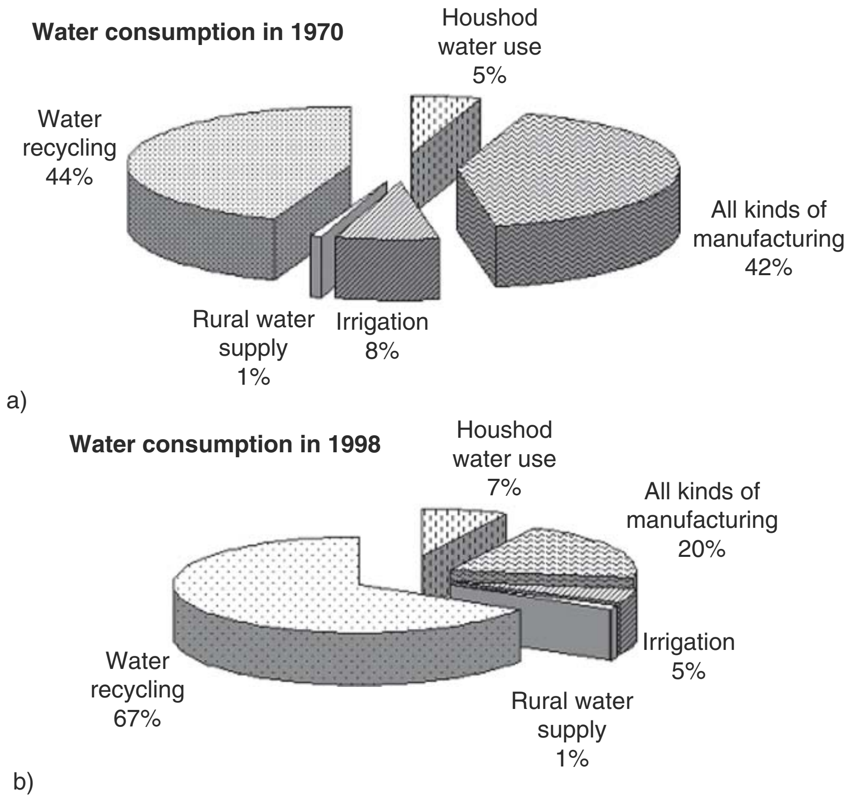

Figure 6. Change in the structure of water use in the Russian Federation (Demin, 2000) for 1970 (a) and 1998 (b).

The structure of water use was changed considerably during analyzed period (Figure 6) – the social component of water use significantly increased. Thus, the household water use was 9% (1970) and became 21% (1998) of total use of fresh waters (all waters except recycled ones). The main reason of this was an active implementation of water save technologies, reducing the areas of irrigated lands, and introduction of water recycling in industry (Demin, 2000).

Household water consumption rate varies significantly (270–610 L per capita per day) among different parts of the Russian Federation (Figure 7). The highest rate is in Moscow, but as it exceeds the rate in Saint-Petersburg nearly in two times, probably, the real population of Moscow is underestimated. Example of North-Western District (Figure 8) shows the tendency of slow reduction of water consumption after 1990 caused by increasing of the fee for water use.

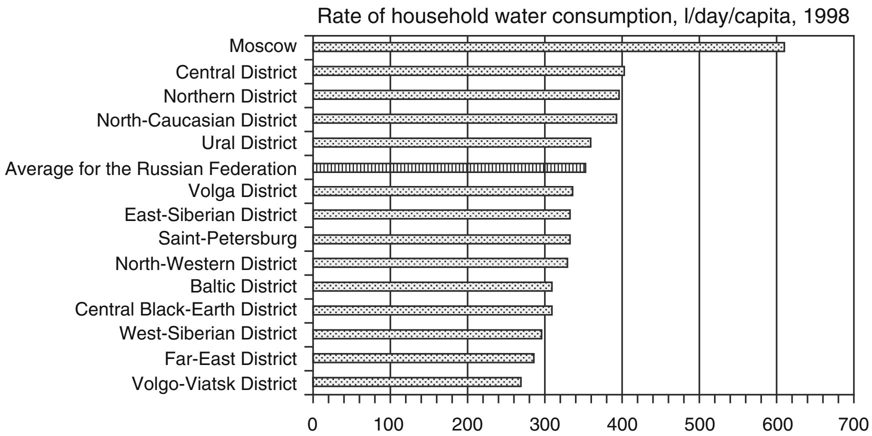

Figure 7. Variations of household water consumption (liters per day per capita) for different territories of the Russian Federation for 1998 (Demin, 2000).

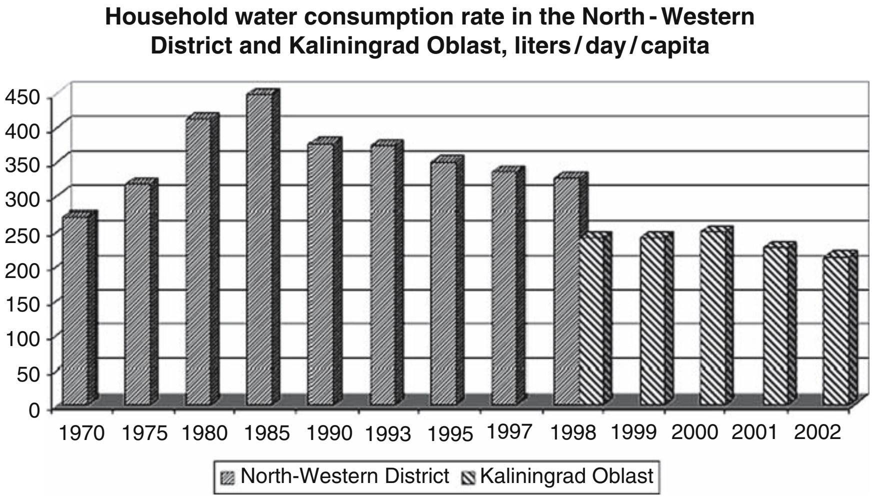

Figure 8. Household water consumption rate (liters per day per capita) in North-Western District (Demin, 2000) and Kaliningrad Oblast of Russia in some years of a period 1970–2002.

2.5. PRICE FOR WATER USE

"Pollutant pays" principle is included in the Water Code of RF (2006). Population mostly pays a constant fee per person per month for water use and disposal. Water counters are started to be introduced in the big cities,

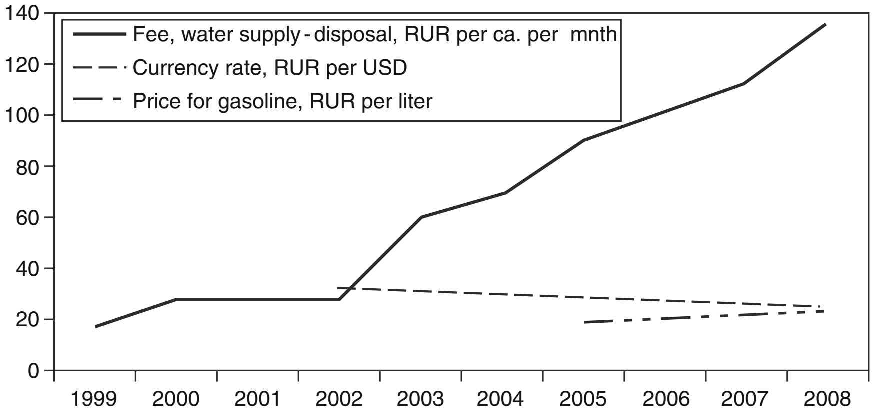

Figure 9. Permanent increase of fee for water supply and disposal in Russian cities (the example is given for Kaliningrad) have been started in 2002. Price for gasoline and rate between Russian ruble (RUR) and US dollar are given for comparison.

but its using is more an exception now than a rule. The fee for water use is rather low, but are currently increasing. The rate of increase is approximately constant and equals US$1 per year starting from 2002 (Figure 9).

3. Kaliningrad Oblast, enclave territory of the Russian Federation in the Baltic Sea region

The Baltic Sea is shared by nine countries – Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden. Kaliningrad Oblast is an enclave region of Russian Federation in the South-East Baltic. It is located inside the space of the European Union, between Poland and Lithuania (Figure 10). All main river basins in the South-East Baltic are transboundary (Chubarenko and Domnin, 2008b). Practically total watershed of the Vistula River is in Poland, 6% and 6.5% of the watershed belong to Ukraine and Belarus respectively (Forsius, 2005). The upper Neman watershed (46% of the total Neman River catchment) is in Belarus (Forsius, 2005), the rest is in Lithuania, and the low watershed includes the northern part of the Kaliningrad Oblast (Russia). The upper part of the watershed of the Pregolia River, the main river in the Vistula Lagoon catchment, is in Poland (50.7% of its watershed), the rest low part of the watershed covers nearly whole Kaliningrad Oblast (Russian Federation).

The main rivers of the Pregolia River catchment basin are Pregolia, Angrapa (it is named Vangorapa in Poland), Pissa, Lava (it is named Lyna

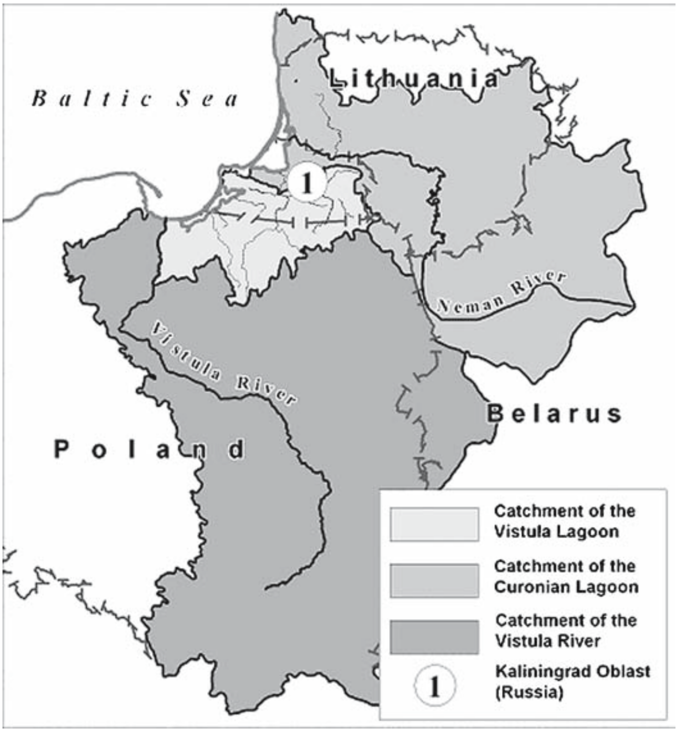

Figure 10. Kaliningrad Oblast of the Russian Federation is located in the South-Eastern part of the Baltic region. It shares watersheds of the Vistula and Curonian lagoons with Poland and Lithuania respectively.

in Poland), Golubaya and Instruch. Their basins belong to the territories of the different administrative units of Kaliningrad Oblast, Varmia-Mazurean Voivodeships of Poland and some districts of Lithuania (Chubarenko and Domnin, 2008b)

The total area of Kaliningrad region is 15,125 km^2. This value includes the southern part of the Curonian Lagoon (1,300 km^2) and the northern part of the Vistula Lagoon (472 km^2). Kaliningrad Oblast subdivided into 13 municipalities (Bagrationovskiy, Gvardejskiy, Gurievskiy, Gusevskiy, Zelenogradskiy, Krasnoznamenskiy, Nemanskiy, Nesterovskiy, Ozerskiy, Polesskiy, Pravdinskiy, Slavskiy, Chernyakhovskiy), and 9 towns (Baltiysk, Gusev, Kaliningrad, Neman, Svetlogorsk, Svetly, Sovietsk, Chernyakhovsk). These towns including adjacent suburbs have the status of urban districts (Chubarenko and Domnin, 2008a).

Catchments boundaries don't coincide with national borders as well as with internal boundaries between municipalities or other administrative units in Kaliningrad Oblast, Lithuania and Poland (Chubarenko and Domnin, 2008a). In Kaliningrad Oblast, the maximum number of the administrative units within the limits of a basin can reach nine units, and, any administrative unit of the Kaliningrad Oblast includes parts of the various river basins, minimum – three parts, and maximum – seven parts (Chubarenko and Domnin, 2008a).

The problems in the water resources management in the Kaliningrad Oblast are similar to ones existed in the neighbouring parts of the Lithuania and Poland. The issues of water supply and waste water purification can be considered as the prior directions of cooperation within the transboundary river basins and Curonian and Vistula coastal lagoons.

3.1. MANAGEMENT OF WATER RESOURCES

The Kaliningrad Department of Water Resources has the following duties with respect to mentioned above typical responsibilities for such a Department:

- To contract the water use
- To collect, storage and analyze of data on water use and water drain according to federal statistic forms of 2TP-VODHOZ
- To assign the regulation of floods and replenishment/flash of water reservoirs
- To give information from Federal Water Register upon requests
- To participate and prepare tenders on supply, research and constructing works related to federal water objects
- To participate in international projects
- To answer on public requests
- To participate in procedure of subvention
- To make approval of “Regulation of human life protection on water objects”
- To participate in hydro-graphic and hydro-economic regionalization and to organize a scientific expertise for it
- To participate in development of maximal allowed limits for pollution and setting of water quality purposes for water objects
- To develop recommendations on improvement of legislative basis related to water use and protection
- To organize conferences, seminars and exhibitions related to water problems

Among Kaliningrad Department of Water Resources the following branches of federal authorities are involved in the water management:

- Kaliningrad Department of ROSPRIRODNADZOR (general coordination and international relations)
- Kaliningrad Department of ROSTECHNADZOR (control of waste water discharge)
- Kaliningrad Departments of Control of Marine Waters (Marine Inspectorate) and of BALTECHMORDIREKCIA (lagoons and coastal waters)
- Kaliningrad Centre on Hydrometeorology and Environmental Monitoring (baseline monitoring of water quality in natural water bodies and streams)
- Kaliningrad Sanitary-Epidemiologic Departments of regional and municipal levels (monitoring of quality and control of use of drinking and bathing waters)
- Kaliningrad Centre for Geo-ecological Information (data on pollution load)

3.2. WATER USE AND DISPOSAL

Surface waters are predominantly used in the Kaliningrad Oblast. Total number of inhabitants using surface water (Table 2) is 1.5 times higher, than ones used ground water (Grunicheva et. al., 2005) Population in towns, especially in Kaliningrad, uses water from surface sources. Practically, all rural population use ground waters from shallow and deep wells. Waters in shallow wells and surface sources are very often subject of local pollution: low water quality was observed in 211 among 1,035 monitored wells, and in 4 among 10 monitored rivers and ponds in 2000 (State of the Environment …, 2001).

Proportion of water used in social sectors of economic activity is high (Table 3), and it equals to nearly 50% of total waters used in the Oblast (Report on state and conservation …, 2003). Water purification in the

TABLE 2. Percentage of inhabitants used surface or ground water in the Kaliningrad Oblast.

	Surface waters (%)	Ground waters (%)
Towns	58.8	0.2
Rural areas	5.8	35.2

TABLE 3. Water use per main economic activities in the Kaliningrad Oblast in 2000.

Economic sector	Industry	Rural water supply	Household and municipal	Others
% of water use	56	3	40.5	0.5

Kaliningrad Oblast is not well developed. Only 7% of waters are purified using biological treatment, other waters are subject of mechanical treatment (Velikanov and Proskurin, 2003).

Municipal sewages and paper mill plant are main point sources for Kaliningrad Oblast. Total annual load (in 2000) from all point sources was estimated as 20,600 t BOD5, 160 t of phosphorus and 9,750 t of residual substances. Sewage system of Kaliningrad city (approximately 450,000 of inhabitants) discharged 9,560 t BOD5, 130 t of phosphorus and 5,230 t of residual substances (Grozdev and Kondratenko, 2005)

4. Conclusive remarks

Despite the watershed principle was introduced in accounting system of water use in Russian Federation long ago, only elements of watershed management are existed nowadays. The main water law, namely, the Water Code of Russian Federation has been passed in 2006. It combined all previous water management related legal documents in one Code. So, a legislative basis at the federal level is ready, but still there is a lack of clear mechanisms for its implementation.

Twenty big river basin districts were established, precise geographic boundaries between them will be defined soon. Basins of two really huge rivers, namely the Volga and Ob' rivers, are subdivided into four and three basin districts respectively.

Water management system in Russia is under development, while a vertical structure of environmental authorities (watershed administrations) has been established, and distribution of functional responsibilities has been formulated.

Monitoring of water streams and accounting system for water use has long traditions, it is well developed and unified through whole country. The accuracy of accounting is estimated as 2–3%.

The main methods of water management are giving permissions on water use, control of discharged water quality, accounting of water use and charging related fees. All standards of water quality are based on "end-of-pipe" ideology, not on approach of "caring capacity of water pool". The scheme of active management of water quality, namely, a setting of goals for water quality in the specific water pool – planning of needed activities – implementation of plans – monitoring of results, are used in very rare cases.

'Pollutant pays' principle is implemented, but a fee for water use is low in comparison to real value of needed compensation. Therefore, governmental donation still exists for supporting population, and monthly personal fee for water use and disposal is permanently increasing (by US$1 per year) starting from 2002.

Transboundary water resources of South-East Baltic are shared by Kaliningrad Oblast, an enclave of the Russian Federation, and Lithuania and Poland, the EU members, Those feature, that all mentioned parties have different legal systems for water issues, is an obstacle for rapid development of common goals and standards for any given water basin, but, from other side, this is a great challenge and driving force for an international cooperation towards really sustainable development of water resources in the region. Till now, only few steps toward harmonization of monitoring programs and other tools supporting decision making process were made in the region of the South-East Baltic (Rasmussen, 1997; Kwiatkowski et al., 1997; ENVRUS 9803, 2000; MANTRA, 2004). More deep efforts of harmonization are to be done, and, first of all, elaboration of the joint river basin management plans for the main transboundary watersheds.

Detailed analysis of mutual location of watersheds and administrative borders (Chubarenko and Domnin, 2008a) showed that boundaries of river catchments don't coincide with national borders as well as with internal boundaries between municipalities or other administrative units in the Kaliningrad Oblast, Lithuania and Poland. This mismatching is a basis for downscaling of transboundary issues till the municipal level within the countries. In Kaliningrad Oblast, the maximum number of the administrative units within the limits of a river basin can reach nine units, and, any administrative unit of the Kaliningrad Oblast includes parts of the various river basins, minimum – three parts, and maximum – seven parts (Chubarenko and Domnin, 2008b). Municipalities sharing river watersheds are interested in mutual responsibility on water quality and quantity, and in a coordination of activities in order not to limit neighbors in water consumption.

Acknowledgement

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OVERVIEW OF WATER MANAGEMENT IN TURKEY: ISSUES, CONSTRAINTS, ACHIEVEMENTS, PROSPECT

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Abstract: The major systematic aspect of water related activities in Turkey is central planning. At the national level, the objective of the Five-Year Development Plans' (FYDP) is to ensure the optimum distribution of all kinds of resources among various sectors of the economy. The latest, 9th plan covers the period of 2007–2013 with the major goal related to environmental protection and public infrastructure development. This plan underlines the fact that rapid urbanization and industrialization process is a pressure on the sustainable use of water resources; that although progress has been made, uncertainty with regard to institutional plurality and fragmentation across sectors remains. This issue is a big challenge on the way to substantial reforms with regard to water resources management. Therefore better cooperation and coordination is needed between institutions. Water management is gradually improving towards a sustainable development policy by internalizing the concepts of water demand management in the municipal, industrial and agricultural sectors.

Keywords: Water resources; water management policy; water use; sustainability; institutional framework

1. Introduction

Turkey has encountered environmental concerns comparatively late, but from the 1970s onwards rapid and uncontrolled urbanization and industrial activities have brought environmental problems to dangerous levels in water catchment areas and coastal zones, in particular. Turkey has developed its water management policy taking into consideration the present and future water needs for its growing population, rapid urbanization, and developments at global and regional levels, as well as the on-going EU accession process. Turkey is a negotiating candidate country to the EU and has started the process of harmonizing its water-related

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legislation with that of the European Union. A project fiche that aims to assist Turkey in the implementation process of the EU Water Framework Directive has been prepared. The national objective is to pursue a sustainable development policy based on the principles of the international conventions to which the country is signatory. For the past thirty years the governmental approach has been endeavoring to raise awareness of environmental issues and encourage implementation of conservation measures in the policy documents.

This paper gives an overview of the water sector in Turkey, challenges on the way to sustainable development across an assessment of the existing situation against globally and nationally accepted management criteria.

2. Demography

The census results of 2000 give a figure of 67.4 million for the country's total population, with an average annual population growth rate of 1.26% (2005 data) (SPO, 2006). The corresponding GNP is US$5,042/capita (2005 data) (SPO, 2006). According to the national population projections, the total population was 73 million in 2006, with an annual population growth rate of 1.21%.

Due to migration from rural to urban areas during the last decade, there has been an increase of 25% in urban population, resulting in a significant increase in water demand in the corresponding areas. The census results of 2000 showed that 65% of the population lives in urban areas. Recent results show that 61.4% (2006 data) of the population lives in urban areas, whereas out of the overall urban population, one third lives in the three biggest metropolises, Istanbul, Ankara and Izmir (SPO, 2007). The largest industrial and commercial center of Turkey is the province of Istanbul and its surroundings, where 40% of industry is located. Since the water resources are unevenly and disproportionately distributed over the country; this situation has led to the implementation of large water conveyance projects for utility water supply to large metropolises. Topographical and geological conditions in some drainage basins do not permit the construction of dams for the storage of water for consumer use. Therefore approximately only half of the water potential can be made economically available for consumption. The Ministry of Environment and Forestry, General Directorate of Environment Management stipulates in the UN Report, that Turkey is situated at the critical threshold value with regard to per capita water demand. The report states that the total water quantity will decrease by 10% in 2020. As a consequence, Turkey is expected to be a water-stressed country by 2030; which means that efficient management of water resources is crucial and urgent measures must be taken to support sustainable development policies.

3. Hydrology and water resources

Annual mean precipitation in Turkey is 643 mm, which corresponds to 501 billion cubic meters of the annual water potential. Two hundred seventy-four billion cubic meters evaporate from inland water bodies and soils to the atmosphere, 227 billion cubic meters is split between groundwater infiltration and surface runoff. Sixty-nine billion cubic meters leaks into the groundwater, and out of this volume, an amount of 28 billion cubic meters is retrieved by springs contributing to surface water. A volume of 7 billion cubic meters inflow is received annually from the neighboring countries. The balance gives 234 billion cubic meters of gross renewable water potential for Turkey, out of which amount $(227 - (69 - 28) + 7) = 193$ billion cubic meters constitutes the total annual renewable surface water. However, under the current technical and economical conditions, the annual exploitable potential is computed to be 112 billion cubic meters as the net volume, composed of 95 billion cubic meters of surface water resources, 14 billion cubic meters of groundwater and 3 billion cubic meters of influx from neighboring countries (Figure 1).

Annual water resources potential (DSI, 2007)
Average precipitation: 643 mm/year Surface area: 780,000 km^2 Annual water potential: 501 billion cubic meters Evaporation: 274 billion cubic meters Internal (national) total runoff: 227 billion cubic meters Leakage into groundwater: 69 billion cubic meters Springs feeding surface water: 28 billion cubic meters Total net infiltration: 41 billion cubic meters Internal (national) surface runoff: 186 billion cubic meters Total surface inflow (gross) from neighboring countries: 7 billion cubic meters Total surface runoff (gross): 193 billion cubic meters Exploitable surface runoff (of which net inflow: 3 billion cubic meters): 98 billion cubic meters Groundwater safe yield: 14 billion cubic meters Total exploitable water resource: 112 billion cubic meters Runoff coefficient: 37%

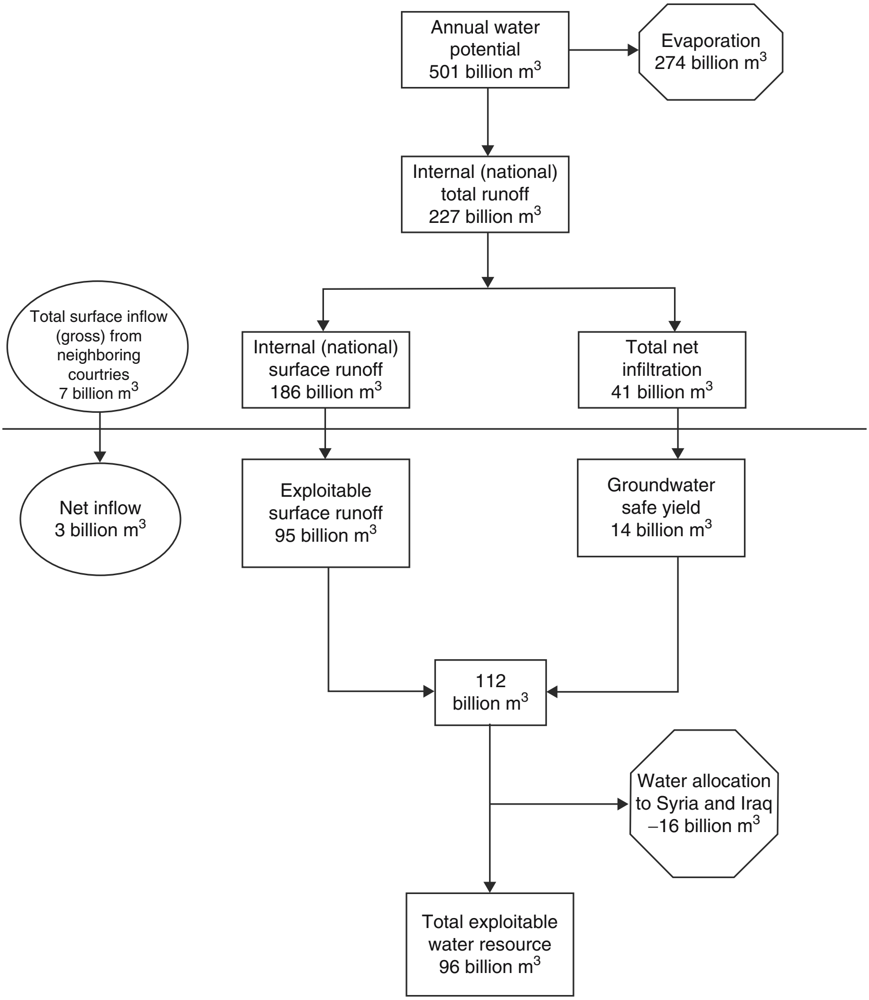


Figure 1. Annual water resources potential of Turkey.

Turkey comprises 25 hydrological basins as shown on Figure 2 and Table 1. The annual average flows of these basins amount to about 186 km^3. While basin yields vary, the Euphrates and Tigris basin accounts for 28.5% of the total potential of the country (DSI, 2007).

Unconventional water resources are not used at municipal level. However, in arid regions and on Mediterranean coastal areas wastewater reuse for irrigation and gardening is strongly recommended by the Ministry of Environment and Forestry through their regional directorates, encouraging wastewater reuse for summer homes, hotels and gulf resorts, in particular.

Figure 2. Hydrological basins of Turkey. (International River Basins Management Congress, DSI, 20–24 March 2007, Antalya, Turkey.).

TABLE 1. Hydrological features of watersheds. (DSI, 2007.).

Name of basin	Precipitation area (km^2)	Mean annual runoff (km^3)	Potential ratio	Mean annual yield (L/s/km^2)
(21) Euphrates Tigris Basin	184.918	52.94	28.5	21.4
(22) East Black Sea Basin	24.077	14.90	8.0	19.5
(17) East Mediterranean Basin	22.048	11.07	6.0	15.6
(09) Antalya Basin	19.577	11.06	5.9	24.2
(13) West Black Sea Basin	29.598	9.93	5.3	10.6
(08) West Mediterranean Basin	20.953	8.93	4.8	12.4
(02) Marmara Basin	24.100	8.33	4.5	11.0
(18) Seyhan Basin	20.450	8.01	4.3	12.3
(20) Ceyhan Basin	21.982	7.18	3.9	10.7
(15) Kizilirmak Basin	78.180	6.48	3.5	2.6
(12) Sakarya Basin	58.160	6.40	3.4	3.6
(23) Çoruh Basin	19.872	6.30	3.4	10.1
(14) Yeşilirmak Basin	36.114	5.80	3.1	5.1
(03) Susurluk Basin	22.399	5.43	2.9	7.2
(24) Aras Basin	27.548	4.63	2.5	5.3
(16) Konya Closed Basin	53.850	4.52	2.4	2.5
(07) Büyük Menderes Basin	24.976	3.03	1.6	3.9
(25) Van Lake Basin	19.405	2.39	1.3	5.0
(04) North Aegean Basin	10.003	2.90	1.1	7.4
(05) Gediz Basin	18.000	1.95	1.1	3.6
(01) Meriç-Ergene Basin	14.560	1.33	0.7	2.9
(06) Küçük Menderes Basin	6.907	1.19	0.6	5.3
(19) Asi Basin	7.796	1.17	0.6	3.4
(10) Burdur Lakes Basin	6.374	0.50	0.3	1.8
(11) Akarçay Basin	7.605	0.49	0.3	1.9
TOTAL	779.452	186.86	100	

TABLE 2. Comparative hydroelectric potential and use ratio.

Countries	Economically exploitable H.E. energy TWh	Hydro-electric production in 1998		
		Installed capacity GW	Energy TWh/year	% of H.E potential use
Turkey	125.3	10.3	42.2	33.7
Sweden	130.0	16.3	74.4	57.2
France	100.0	25.1	66.0	66.0
Italy	65.0	20.0	47.4	72.9
Greece	20.7	2.9	3.9	19.5
Portugal.	19.8	4.5	13.0	65.7
Japan	114.3	43.9	102.6	89.8

TABLE 3. Comparative per capita energy consumption. (IEA/energy statistics of OECD countries 1997–1998.).

Countries	Increase of population (%)	Area (10^3 km^2)	Total installed capacity (GW)	Total energy (TWh)	Consumption	
					Amount (TWh)	In year (kWh/ capita)
Turkey	1.5	780	23.3	111.0	87.7	1,382
Greece	0.4	132	10.0	46.4	41.0	3,909
Spain	0.2	506	50.0	195.3	169.6	4,320
Italy	0.2	301	72.5	259.8	260.8	4,537
France	0.4	552	112.6	510.9	393.2	6,734
Germany	0.3	357	113.6	556.4	487.4	5,950
Japan	0.3	378	222.4	1046.3	936.6	7,441
U.S.D	1.2	9,364	784.8	3832.6	3347.8	12,559
Norway	0.6	324	28.3	117.0	109.9	25,105

Source: IEA/energy statistics of OECD countries 1997

DSI is responsible by law for the operation and maintenance of the dams, therefore, it can modify the beneficial water use purposes and operation of dams that were set initially at the planning phase in line with emerging new water patterns, as a result of changes with regard to climatic conditions and/or demand by users after their commissioning (e.g. climate change issues, requests by riparian users for additional or different needs from those planned initially).

An average 25% of energy production relies on hydroelectric power generation, and represents only 33% of the national potential. Comparative hydroelectric power generated in OECD countries and per capita energy consumption is given in Tables 2 3 respectively (IEA, 2000).

3.1. WATER DEMAND AND PRESSURE ON RESOURCES

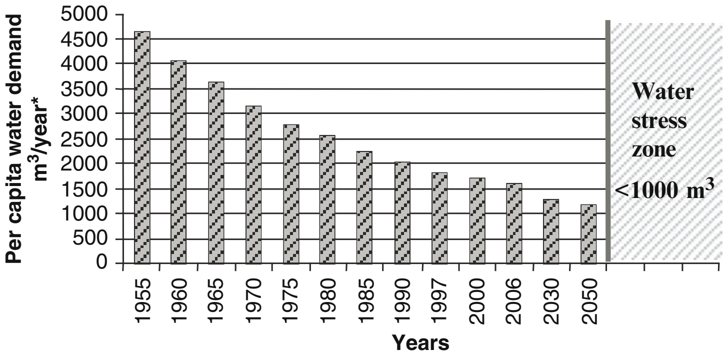
Countries can be classified according to their water wealth as rich, insufficient or poor; for which the yearly per capita threshold values are 8,000–10,000, 2,000 m^3 and less than 1,000 m^3 respectively.

Based on the renewable water resources potential of 112×10^9 m^3 and on population projections, it is predicted that Turkey will fall into the water-stressed category beyond 2030, as can be seen from Table 4 and Figure 3.

TABLE 4. Per capita water demand. (www.belgenet.com).

Years	Population census results	Per capita water demand (m^3)/year*
1955	24,064,763	4,654
1960	27,754,820	4,035
1965	31,391,421	3,568
1970	35,605,176	3,146
1975	40,347,719	2,776
1980	44,736,957	2,504
1985	50,664,458	2,211
1990	56,473,035	1,983
1997	62,865,574	1,782
2000	67,803,927	1,652
2006	73,000,000	1,534
2030	90,800,000*	1,233
2050	96,000,000*	1,116

*



*Population projection by TURKSTAT

Figure 3. Evolution of water demand since 1955.

In conclusion, since water needs increase in parallel with population growth, the crucial point is to improve the water use efficiency for all of the sectors. Table 5 gives the water use per sector; Figure 4 illustrates comparative ratios for each sector.

Water is supplied from surface and groundwater resources for all purposes. Agriculture is the highest water-consuming sector with an average rate of 75%, followed by domestic water use at 15% and finally the industrial sector at 10%, according to the DSI records. Approximately 90% of the total water use for irrigation is withdrawn from rivers.

At present, almost the totality of the urban population is connected to the water supply network, and in rural areas this ratio is close to 90%. A daily allocation of 170 L/capita is made for drinking water supply. Unaccounted-for water has a high average varying from 35–65% depending on the network and location.

3.2. WETLANDS

In the early 1950s, malaria epidemics represented a severe threat to human health, as in many other countries, and the resulting drainage of thousands of hectares of marshes resulted in loss of wetlands. One of the major tasks of DSI was to drain marshes hosting malaria vectors and causing epidemics in the hot regions of Turkey in particular. After the 1970s, the successful result of campaigns to eliminate malaria on the one hand, and rising environmental awareness on the other, halted the ill-advised policy of draining marshes. Based on the DSI's records, more than 100,000 ha of marshes were dried out between 1955 and 1970 as reflected Figure 5. Starting from the 1980s, DSI has stopped completely drying out marshes due to rising environmental awareness and policy changes towards sustainable development of water resources. Within the framework of integrated watershed management, DSI is cooperating with institutions concerned for the integrated management of wetlands. In line with this policy, DSI is implementing rehabilitation projects to recover degraded wetlands.

Turkey became a signatory to the Ramsar Convention for the protection of wetlands in 1994. Since the signing of the convention, several communiqués and circulars have been published in order to implement the convention, and the first 'Regulations about the protection of the wetlands' were issued in 2001 and their scope expanded with the revisions carried out in 2005. Within the scope of the regulations, wetlands, regardless of the criteria whether they are cited as wetlands having international importance or not, are all under protection without exception.

TABLE 5. Allocation of water use by sector (million cubic meters). (This table is computed with the DSI figures.).

Year	1990	%	1992	%	1994	%	2000	%	2004	%	2030	%
Agriculture	22,016	72	22,939	72.5	24,623	73.5	29,3	75	29.6	74	72	64
Industry	3,443	11	3,466	11	3,584	11	4,2	10	4.3	11	22	20
Household use	5,141	17	5,195	16.5	5,293	15.5	5,8	15	6.2	15	18	16
Total	**30,600**		**31,600**		**33,500**		**39,300**		**40,100**		**112,000**	
Development		**27**		**28**		**30**		**35**		**36**		**100**

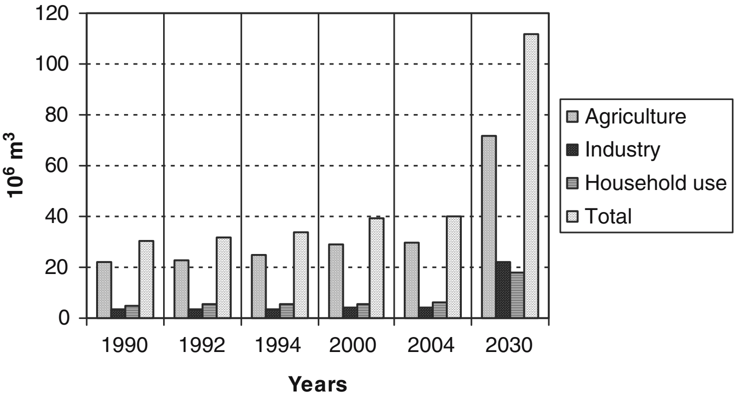


Figure 4. Comparative water use ratio by sector.

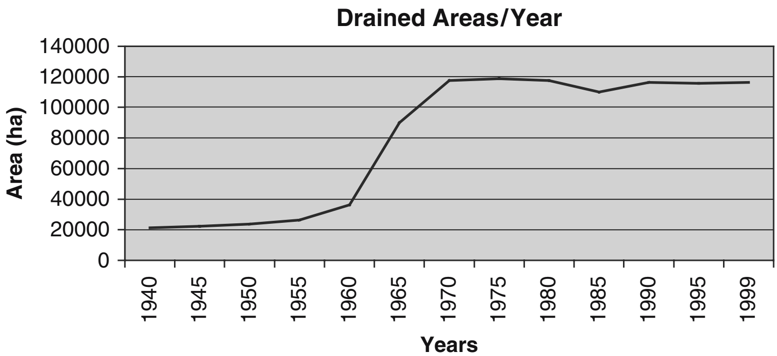


Figure 5. Drained marshes between 1955–1999.

3.3. AGRICULTURAL WATER USE

Up to the early 1980s, operations and maintenance (O&M) for irrigation systems was highly centralised, but this was imposing an increasing institutional and financial burden on the government. Contributing factors were: very low ratio of billing and collection rates or no collection at all; very high water consumption, even wastage; no cost recovery for investment; and no local interest by the farmers to protect the infrastructure.

Although some small irrigation schemes had been transferred to users over the years, the pace of change was slow. However, after 1993, on the advice of the World Bank, an accelerated process of handing irrigation O&M over to Water User Associations has been undertaken.

The recovery rate for (O&M) costs increased from less than 40% to more than 80% after the facilities had been handed over to water users' organisations (WUOs). In addition, water overuse and consequent negative environmental impacts (e.g. salinity) have gradually decreased. After PIM 'the irrigation program that was [formerly] a government program with assistance of the farmers' became 'a farmer program with assistance of the government'

However, the reform has not been accompanied by appropriate legal reform (e.g. giving title to WUAs) which has caused some problems in investment, furthermore, while WUAs must raise revenues from tariffs, the lack of legal basis has meant that incentive structures are weak.

Despite a few concerns related to WUAs, the Turkey case "the accelerated transfer of the irrigation schemes from the governmental institution to WUAs" is regarded as a success story in the Mediterranean Basin.

4. Territorial administrative structure

Turkey comprises 81 provinces covering the territory of the whole country. Each province is headed by a Governor, appointed by the Council of Ministers and approved by the President. Provinces may be divided into districts, each with their own appointed District Governor or sub-Governor. Within a province, there are four types of local authorities:

Municipalities: There are 3,225 municipalities that have been established in areas with more than 2,000 inhabitants. They cover about 75% of the country's land mass and the average municipality has a population of 15,000. Each municipality is headed by a directly elected mayor and governed by an elected municipal council.

Metropolitan Municipalities: In 16 of the main urban areas in Turkey, the municipalities are organized under umbrella organizations referred to as Metropolitan Municipalities, empowered by the Metropolitan Municipalities Act passed in 1984. Municipalities in metropolitan areas are called district municipalities and retain many functions as agreed with the superior local body in charge of the whole metropolitan area. Metropolitan areas are formed by an act of Parliament and all have separate water and sewerage utilities.

Villages: Turkey has about 35,000 villages that are governed by elected head-man (Muhtar) and a council-of-elders in line with ancient Turkish traditions. The average village has a population of about 500.

Special Provincial Administrations (SPAs): There are 81 SPAs in the country; one in each province. The SPAs cover areas that fall neither within municipal nor village boundaries. The local authority functions within an SPA are carried out by the provincial administration under the provincial Governor.

5. Institutional framework

The institutional framework of Turkey is based on a centralized approach with de-concentrated governmental institutions. More than ten governmental institutions together with their regional directorates and local/municipal agencies operate according to specific laws and regulations in water management issues. These institutions are divided in two groups, one responsible for investment and the other for inspection. Figure 6 shows the institutional structure of the water sector. The major investment agencies of the sector are as follows:

The Ministry of Public Works and Settlement has an important role in the development of municipal and territorial plans. At the regional level, the SPO is responsible for carrying out land-use plans, and establishing their management rules by providing protection/usage balance. Affiliated to this ministry is the Bank of Provinces, an investment agency in charge of the planning, construction and financing of drinking water and municipal wastewater treatment.

The Ministry of Energy and Natural Resources is responsible for supplying the energy needs of Turkey, including hydroelectric power stations and large combustion plants through the General Directorate of Electricity (EIE).

The Ministry of Culture and Tourism is responsible for the designation and conservation of all cultural, historical, archaeological and natural heritages, and is authorized to undertake preservation, rehabilitation and implementation measures related to such sites and authorized to designate tourist areas and undertake important implementation measures in these areas with respect to drinking water, municipal wastewater and solid waste disposal.

The major inspection agencies of the water sector are as follows:

The Ministry of Foreign Affairs determines the external politics with regard to environmental issues with other ministries, institutions or organizations concerned. Specifically, the General Directorate of State Hydraulic Works and Ministry of Foreign Affairs in Turkey are responsible for the management of trans-boundary waters.

The Ministry of Agriculture and Rural Affairs is responsible for land use and water resources development in rural areas. The Ministry monitors surface waters in agricultural areas for nitrate and pesticide run-off pollution. It acts as an inspection agency together with the Ministry of Environment and Forestry for receiving water suitable for fisheries and aquaculture, and for pesticide control.

The Ministry of Health plays an important role in certain aspects of environmental protection through its responsibilities for public health. Prior to the establishment of the Ministry of Environment, the Ministry of Health was responsible for environmental matters in general. In the water sector, it

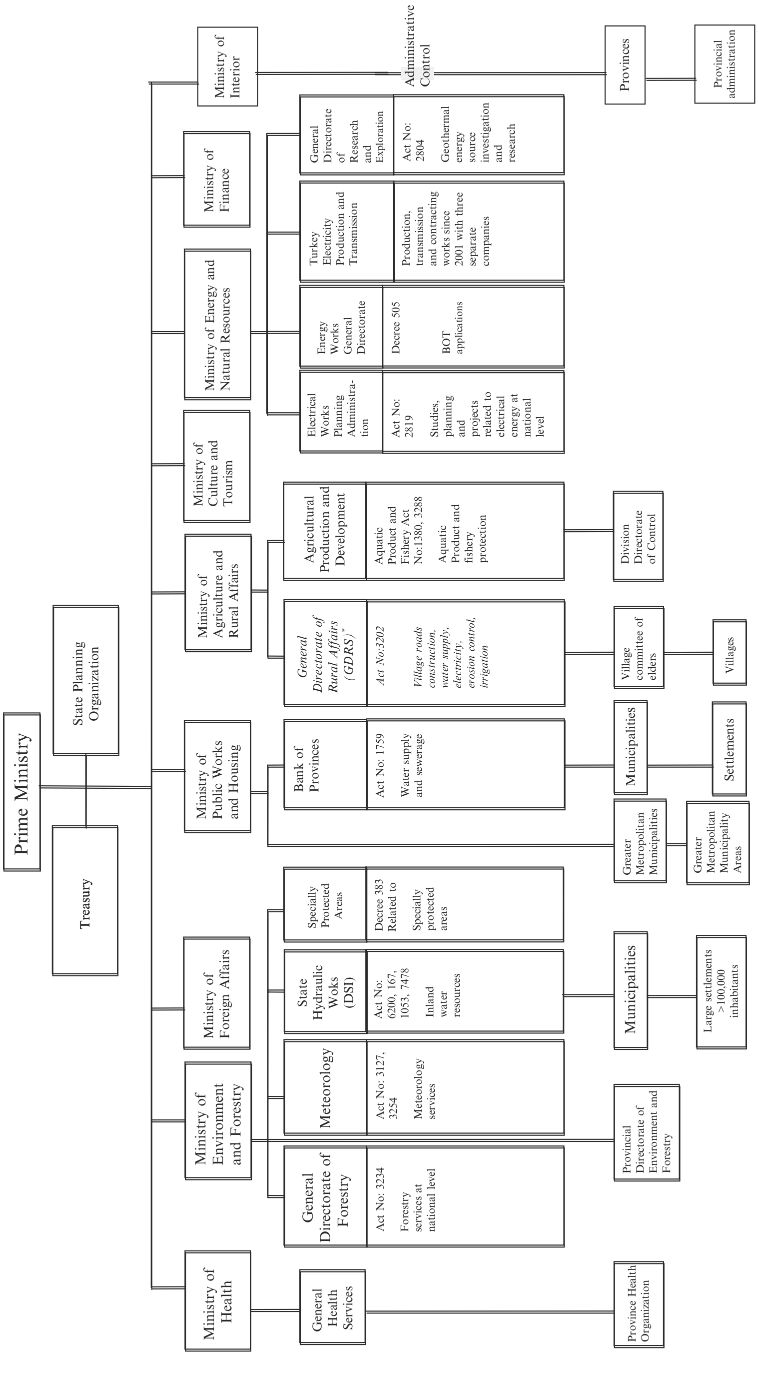


Figure 6. Institutional structure of the water sector.

has particular responsibilities for drinking water and bathing water quality. The Ministry of Health also issues permits to industrial installations with regard to their production and emission and undertakes air quality monitoring with the objective of public health protection.

The Ministry of Labor and Social Security has joint responsibility with the Ministry of Environment and Forestry for adopting and implementing legislation aimed at the prevention of industrial accidents at large installations.

The Ministry of Interior has responsibility for local government exercised through the provincial administration. The provincial governors are assigned by the Ministry and are in charge of all local government agencies.

The Ministry of Industry and Trade will have important responsibilities with the Ministry of Environment Forestry in the implementation of the EU industrial pollution control sector, especially with regard to industrial pollution prevention and control.

The General Secretary of European Union is responsible for the coordination between different governments concerning international programs of conformity activities of the European Union rules.

Additionally, the **Undersecretariat of Treasury, Undersecretariat of Customs** and **Undersecretariat of Foreign Trade** cooperate with institutions with regard to financial issues in particular.

The Ministry of Environment and Forestry plays an overall coordinating role for the development and implementation of environmental policies; it has general duties relating to the protection and management of forests with nature protection objectives. The Ministry of Environment and Forestry is directly associated with the accession process together with the General Secretariat for EU Integration, the Undersecretariat of the State Planning Office and the Undersecretariat of the Treasury, all of which carry major responsibilities for the environment. Also under the Ministry of Environment and Forestry is the Authority for Protection of Special Areas (APSA). This Authority has special responsibilities for the 13 Special Protected Areas established for the protection of certain habitats and species.

6. Legislative structure

After the 1920s, measures to prevent water pollution have been incorporated in numerous laws, regulations and directives enacted by Parliament and other authorized bodies, and in the provisions of international conventions to which Turkey is a signatory. Most of this legislation, including that in the Constitution, embodies provisions for protection of the environment and public health. The latest and most effective law among many others that have been promulgated since 1923 is the Environment Act that covers the protection of natural resources and human health.

The legal structure envisaged by the Environment Act consists of a system of technical regulations and standards that specify the principles of implementation. The Water Pollution Control Regulations promulgated in 1988 are one of the most important and comprehensive components of this system. These regulations define the technical principles for the protection of surface and groundwater.

Provisions for the protection of coastal water quality are also an integral part of the regulations, whose objectives are to protect potential water resources, efficiently manage water resources, prevent or eliminate water pollution. They deal with four main topics: (1) classification of water courses; (2) direct discharge to receiving waters from point sources; (3) municipal wastewater systems; (4) discharge permissions and monitoring.

The 'polluter pays' approach is the guiding principle of the regulations. Therefore every polluter has to inform the state authorities about the amount and content of his wastewaters and apply for a discharge permit in which the conditions for discharge and the amount of required treatment is stipulated.

Among other items, the regulations define the conditions of use of municipal sewerage and treatment systems, discharge standards and the conditions for payment. Provisions concerning hazardous wastes in aquatic environments are also defined in the Water Pollution Control Regulations. Metropolitan municipalities are also authorized by Act No. 3030 to formulate, specify and apply within their boundaries the legislation required for the most efficient management of water and wastewater facilities.

Since its establishment in 1923, the Republic of Turkey has been undergoing important and vital changes in its legal and institutional structure. The latest major legal and institutional change is being experienced with regard to the EU accession process, concerning the harmonization of the Turkish legislation with the EU Water Framework Directive. The introduction of five-year plans was the first attempt at the adoption of a long-term and centralized policy-making approach related to public investments, whose planning and programming was entrusted to the State Planning Organization (SPO) operating under the Prime Minister's Office. The SPO is charged with developing economic, social and environmental policies for the five-year development plans, and preparing annual programs and public investment programs that are implemented by the related central and local agencies and institutions that function within their establishment law. Turkey is currently implementing its 9th Development Plan (2007–2013).

6.1. FORMULATION OF STANDARDS AND ENFORCEMENT

Standards are set up in the legal framework of laws and regulations. The Turkish Drinking Water Standards as well as metropolitan municipalities and international standards determine the quality control of drinking and utility water. Quality standards of receiving waters are set up both in the Aquatic Products Act and in the Water Pollution Control Regulations promulgated by the Ministry of Agriculture and the Ministry of Environment respectively.

The Water Pollution Control Regulations and Aquatic Product Act mostly dictate discharge standards to receiving waters.

Institutions are authorized to enforce the standards laid down in the regulations applicable in the field in which they are empowered by their statutes. By law, they are entirely free to set these standards as they think fit. Once promulgated in the Official Gazette their regulations become law. Regional offices are informed about the enforcement of these standards by their central office, and if necessary, seminars are held on the subject.

The inadequacy of laboratory facilities, equipment and personnel required to put the regulations into practice obstructs the efficient operation of the inspection mechanism responsible for enforcement.

7. Environmental management

The legal infrastructure of the existing system is inadequate. The unfair penalties, overlapping powers invested in different bodies authorized to implement the law, and the lack of equipment, throws doubt on the viability of decisions reached. As a result, when disputes are taken to court, the authority concerned usually loses the case.

There is a need for revision of penal sanctions, lawyers specializing in environmental law, and environmental courts, as well as public awareness of environmental issues.

For better legislation enforcement in the water sector, the need for an integrated water resources management policy is stipulated at all institutional and legal levels. To do so, surface and groundwater resources must be managed integrally, the close relationship between the inland and coastal marine water must be considered as part of management, and consensus must be ensured among water, soil and forest management policies. These policies that were set lately in the National Environmental Action Plan (NEAP) issued in 1998 have started to raise awareness among various central institutions. But putting substantial changes into practice is a long-term process involving acceptance by relevant bodies and various stakeholders (SPO, 1998).

The NEAP has been a useful tool for the assessment and achievement of the set objectives and for the introduction of new decision making concepts in this respect. Environmental Performance Indicators that measure the trend towards or away from pre-determined objectives were decided to monitor the NEAP. Three types of indicators, (a) pressure-state-response; (b) procedural; and (c) policy-based indicators were adopted for this purpose.

8. National policy with regard to water resources development

The fact that approximately 1/3 of the national potential for hydropower generation is used; the national policy is to extend this ratio with new projects. The target is to utilize the total available exploitable potential of the country amounting to 112 billion cubic meters with the ongoing and planned projects.

The overview of the water sector proves a trend towards development in hydroelectric power, irrigation and drinking water schemes, which are inevitably supporting supply-side demand. This is mainly due to the fact that Turkey has not achieved its economic development yet. Turkey has developed only 36% of its hydroelectric potential as of today; and it is planned that 93% of the economical potential will be completed in 2020.

The per capita resource is decreasing (a decrease from 1,500 m^3/capita in 2004 to 1,200 m^3/capita is foreseen for 2030 based on a population projection of 90.8 million in 2030 and 96.5 million in 2050 according to TURKSTAT). Under these circumstances water quality protection becomes very important for the availability of the resource for every sector and to ensure that quality does not become a limiting factor for quantity.

9. Critical analysis

At the central level, the institutions operating in the water sector act in accordance with their establishment law that is investment-oriented in most of the cases (e.g. DSI, the biggest in the sector). Investment agencies hold the economic instruments, they have the power to orientate governing policies; inversely, inspection agencies are not adequately supported with technical and financial tools. Institutional strengthening, capacity building programs have been granted so far by international organizations or bilateral aid; nonetheless institutional reforms have not acquired a satisfactory level yet. Existing legislation need to be revised and extended according to real needs in existing/planned fields on the basis of a thorough evaluation of conditions in Turkey and long-term data. Feasibility of enforcement and economic deterrence should be primary concerns in this process (Burak et al., 1994).

Different sectoral studies carried out so far have stipulated the same institutional reforms, but their implementation remains a major challenge even today because of the concerns highlighted in the present report and elsewhere.

There is a need for a clear vision, a coherent articulation of strategic concerns, the establishment of clear responsibilities and incentives at each level of responsibility, setting out what should be subject to central regulation and consistent national and enforceable standards taking economic affordability, and the implementation process into account. Improved co-operation and co-ordination is needed between the existing institutions, which therefore must be equipped with better operational skills and instruments.

Constraints
• Constraints on effective management can be enumerated as: legislative, institutional, and financial • Plurality and fragmentation of the institutional structure result in lack of coordination between institutions • No single Ministry or body with overall responsibility for water • Although water and sewerage administrations are semi-autonomous and have separate budget, utilities are under direct political/financial control in broad term • Little comparative performance data available • Neither economic nor environmental role fully developed • No cost recovery from customers • Some municipalities have the skills needed but the great majority do not • No direct incentives to improve services to customer • No financial incentives as a national policy to encourage WUS's to install less water consuming techniques

Achievement
• Modern techniques increasingly introduced in DSI's schemes • Increase of efficiency in Water User Organization's operated irrigation schemes (PIM) • Unaccounted-for water detection in Greater Metropolitan Municipalities Water and Sewerage Administrations • Users pay, polluters pay principle for quantity and quality control (progressive tariff structure, classification of industries according to their pollution loads, incentives for the use of cleaner technology, internal recycling encouraged with economic deterrence) • Bathing water quality control with blue flag incentives • EU accession process (River Basin Models, integrated water resource management)

Needed improvement
• Need financial incentive and economic deterrence with regard to economic tools • Improved O&M, training • New financing models • Better co-operation and co-ordination between institutions • Better comparative service performance indicator • Applicable standards • Better enforcement

On-going reforms and studies

Turkey has carried out a number of reforms in the water sector with regard to the improvement of financial efficiency (e.g. cost recovery of O&M of public water services in urban water and irrigation facilities) Significant efforts are being undertaken to help establish how best to deliver the directives concerning water quality. This work includes:

1. MATRA/Büyük Menderes Basin Project

The objective of the MATRA Project applied in the Büyük Menderes River Basin was to support Turkey with the implementation of the WFD on a national and regional level. The aims are to:

1. Improve knowledge of the WFD and other European Legislature within water institutions
2. Develop a methodology for implementing the WFD in Turkey
3. Prepare a pilot river basin management plan to be used as an example for further implementation in Turkey
4. Inform public and policy makers regarding the implications of the WFD for Turkey

2. EU Integrated Environmental Approximation Strategy (UÇES) for the period of 2007–2023

The Ministry of Environment and Forestry has prepared a policy document entitled UÇES (EU Integrated Environmental Approximation Strategy) for the development and implementation of environmental policies with the participation of various institutions that play an important role and have responsibilities in the implementation of the

(continued)

Acquis Communautaire. This document was issued in March 2007 after approval by the government and covers the period between 2007–2023. It is prepared based on the output of the 'National Environmental Action Plan', 'Integrated Harmonization Strategy Project' and 'Environmental Heavy Cost Investment Planning Project'. The UÇES vision of Turkey is defined as "a country where the fundamental needs of today's generation as well as that of the future will be met, and where higher standards of life will prevail, biological diversity will be protected, natural resources will be managed in a rational manner with an approach of sustainable development, a country where the right to live in a healthy and balanced environment will be protected".

The fundamental purpose of UÇES is to establish a healthy and viable environment by taking into consideration the economic and social conditions prevailing in Turkey and establish the harmonization of the national environmental legislation with the EC Acquis Communautaire and ensure its implementation. The corresponding investment need is €70 billion.

Consensus within the government (and a process for reaching that consensus) on what is the appropriate balance between environmental and economic objectives must be established. Otherwise there will be no consistency in decisions taken at a more local level (Ballard, 2005).

Constraints on effective management can be enumerated as legislative, institutional, managerial and financial.

The major bottleneck of the environmental sector encountered in the institutional structure is the plurality and fragmentation that result in lack of coordination between institutions.

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WATERSHED MANAGEMENT IN THE UNITED STATES

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Abstract: A watershed approach provides an effective framework for dealing with water resources challenges. Watersheds provide drinking water, recreation, and ecological habitat, as well as a place for waste disposal, a source of industrial cooling water, and navigable inland water transport. Consequently, much depends on the health of watersheds. Watersheds are threatened by wastewater and nonpoint source runoff that load surface waters with excess organic matter, nutrients, pathogens, solids, and toxic substances. Physical alterations, such as paving and stream channelization, change both the hydrologic regime and habitat. Estuaries are of particular importance, since they have great economic, ecological, recreational, and aesthetic value. An approach to the protection, management, and restoration of these water resources in the United States, and the respective roles of federal, state, and local governments, as well as the private sector and volunteer groups, is discussed. Protecting and sustaining watersheds requires that water resource goals be prioritized within a coordinating framework.

Keywords: Watershed management framework; water quality laws; water quality databases; watershed models, watershed restoration

1. Framework for watershed approach

The most effective framework for water resources management is a watershed scale approach. A watershed is the land area that drains to a common body of water, such as a river, lake, bay, or ocean. Watersheds supply potable and irrigation water, are used for recreation and appreciated for aesthetics, and sustain human and ecological life. In the United States, more than

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$450 billion in food and fiber, manufactured goods, and tourism depend on healthy watersheds (http://www.epa.gov/owow/watershed/).

The watershed approach is a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flows (EPA, 1996). It is sensible to use a watershed basis for a number of reasons. For example, it facilitates assessments of the various activities for protection of the environment being carried out by numerous federal and state agencies, thereby enabling the understanding of the cumulative net impacts of human activities. It identifies the most important problems to be addressed, and reduces or eliminates duplication of efforts and conflicting actions. It provides opportunities for joint efforts among government agencies and/or the private sector, and this increased involvement of both sectors improves the commitment to reach watershed management goals and the probability of sustaining long-term environmental improvement efforts.

Estuaries are partially enclosed coastal bodies of water, having an open connection with the ocean, where freshwater from inland is mixed with saltwater from the sea. Estuaries provide habitat for waterfowl, fishes, and other organisms. Many large harbors or ports in the United States are estuaries, such as New York, San Francisco, Seattle, Galveston, and Baltimore. These areas are generally densely populated, and directly affect the quality of estuarine waters in many ways; e.g., the filling of tidal land, industrial, urban runoff and sewage pollution, increased sedimentation, and changes in salinity by altering the influx of freshwater. In the US, estuaries provide habitat for more than 75% of America's commercial fish catch and 80–90% of its recreational fish catch (EPA, 2007a). Much progress has been made over the past 20 years in achieving cleaner rivers, lakes, and estuaries due to laws that regulate pollution inputs from point sources, mainly sewage treatment plants and industrial sources. However, there are still many pollution issues today due to non-point sources, such as runoff from agriculture, forestry, construction sites, roofs, roads and bridges, and landscape modification; acid mine drainage; marinas and boats; and the introduction of exotic species.

In the US, there are four key elements that comprise the watershed approach and provide an operating structure (EPA, 1996): Stakeholder Involvement, Geographic Management Units, Coordinated Management Activities, and a Management Schedule.

Stakeholder involvement refers to those actions on the part of the people who live, work and play in the watershed. The watershed approach calls upon governmental entities to involve representatives of: known or suspected sources of watershed impacts; the users of watershed resources; environmental groups; and the public at large in the watershed management process. Altogether, this could include representatives from local, regional, state, tribal, and federal agencies, conservation districts, public interest groups, industries, academic institutions, private landowners, concerned citizens, and others.

Geographic management units are generally determined on the basis of hydrologic connections, taking into account other factors such as political boundaries and existing partnership program areas.

Coordinated management activities: For any watershed, there are a number of agencies charged with air and water pollution control, wetlands protection, drinking water source protection, waste management, agriculture, transportation, and navigation. The watershed approach calls for them to work jointly to prioritize, fund, and carry out management activities.

Management schedule: In order to ensure that various planned activities are well-coordinated, a management schedule for each management unit should be developed that delineates the program for maintaining, restoring, and protecting water resources and the involvement of various participants.

Five watershed management activities are set forth in the US Environmental Protection Agency (EPA) Watershed Approach Framework (EPA, 1996): the assessment and characterization of aquatic resources and problems; goal setting; problem prioritization and resource allocation; management option development and implementation plans; and monitoring and evaluation.

It is, of course, important to set goals that identify the uses to be made of the waters under consideration. There are national and state water quality standards that must be met relative to the specified uses for the water from the water body involved. There are always competing objectives and priorities. The EPA has a tool designed to help decide among objectives and priorities in developing a watershed plan (EPA, 2007b). This tool helps in setting criteria and assigning weights to each in order to rank them in importance. This planning process works within the framework of the watershed approach to identify and quantify specific causes and sources of water quality problems. It also identifies watershed goals and actions required to reach those goals.

Government agencies and stakeholders need to jointly set priorities for water resources in each management unit. Issues to consider include drinking water source protection, wetlands and riparian areas protection, point and non-point source pollution control, waste and pesticide management, air pollution effects, and water supply (EPA, 1996). Setting priorities also provides guidance for funding of agreed-upon activities.

A major component of the overall management program is monitoring the physical, chemical, biological, and habitat conditions of the watershed. This must be done to characterize the watershed, determine extent and location of problems, and assess the effects of various remedial actions. A strong monitoring program should include (EPA, 1996):

- An inventory of key existing information on resources – ground water, drinking water sources, habitat, wetlands and riparian areas.
- A carefully developed monitoring design that confirms or updates existing information, fills data gaps, and permits examination of trends.
- Reference conditions for biological monitoring programs to provide baseline data for assessments and biological and nutrient criteria development.

Data must be collected using comparable methods by the various data collectors and stored accessibly. In the US, a number of data bases are readily available. For example, the STORET (STOrage and RETrieval) data base has biological, chemical and physical data for surface and ground waters collected by numerous sources (see http://www.epa.gov/storet/). Air quality data are available from the EPA Office of Air Quality Planning and Standards (see http://www.airnow.gov/).

2. Laws and programs

A number of US federal laws were enacted for the protection of water quality, going back to 1899. In 1972, amendments to the 1956 Federal Water Pollution Control Act were passed that established a point source discharge permit system and provided for federal grants to assist local governments in financing sewage treatment systems. The Federal Water Pollution Control Act was amended in 1977, 1981, and1987; the Act and its major amendments are collectively known as the Clean Water Act. Legislative mandates to address non-point source pollution are primarily the Clean Water Act of 1972, as amended in 1987, and the Coastal Zone Management Act (reauthorization amendments) of 1990. Other US Federal laws applicable to water are the Marine Protection, Research and Sanctuaries Act of 1972, the Estuaries and Clean Waters Act of 2000, and the Beaches Environmental Assessment and Coastal Health Act of 2000.

The primary law regulating watersheds in the US is the Federal Water Pollution Control Act Amendments of 1972, also known as the Clean Water Act (CWA). The CWA was based on several earlier pieces of legislation, starting with the Rivers and Harbors Act of 1899 that prohibited dumping into navigable waters and the 1948 Federal Water Pollution Control Act that addressed waste disposal into water. A copy of the CWA is available online (US Code, 1977), and Killam (2005) provides an excellent overview of it. The overarching objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The most important sections of the CWA are:

- Water quality standards (Section 303)
- National Pollution Discharge Elimination System (Section 402)
- Identifying and Restoring Impaired Watersheds (Section 303)
- National Estuary Program (Section 320)

Additional sections of the CWA address the protection of wetlands from dredging and filling, and provide information on methods of non-point source pollution control.

Recently, there has been a focus on headwater streams, and their role in a watershed. In June 2006, the US Supreme Court ruled in two cases concerning jurisdiction under the CWA, suggesting that CWA jurisdiction is affected by the hydrological permanence of non-navigable streams and adjacent wetlands and whether they have significant nexus with navigable waters. As such, there is increased need for scientific information to support regulatory determinations and to inform future policies and legislation (Leibowitz et al., 2008). Meyer et al. (2007) recently reviewed the diversity of organisms dependent on headwaters, discussed how downstream biota depend on headwater ecosystems, and concluded that the cumulative impact of degraded headwaters contributes to the loss of ecological integrity downstream.

The Marine Protection, Research and Sanctuaries Act of 1972, also known as the "Ocean Dumping Act", provides that unless authorized by a permit, ocean dumping is generally prohibited (US Code, 1972a). This includes transportation of material from the US for the purpose of ocean dumping, transportation of material from anywhere for the purpose of ocean dumping by US agencies or US-flagged vessels, and dumping of material transported from outside the US into the US territorial sea. In addition, dumping of sewage sludge, industrial waste, radiological, chemical, and biological warfare agents, high-level radioactive waste, and medical waste is prohibited. The standard for permit issuance is whether the dumping will unreasonably degrade or endanger human health, welfare, or the marine environment. The Ocean Dumping Ban Act (US Code, 1988) was enacted in 1988 and significantly amended portions of the Marine Protection, Research and Sanctuaries Act of 1972; it banned ocean dumping of municipal sewage sludge and industrial waste (with limited exceptions).

The Estuaries and Clean Waters Act of 2000, also known as the "Estuary Restoration Act of 2000", promotes the restoration of estuary habitat and develops a national estuary habitat restoration strategy. It provides for partnerships among public agencies and between the public and private sectors. It also provides federal assistance for restoration projects and the development and enhancement of monitoring and research capabilities, including the National Estuary Program (NEP) designed to identify, restore and protect nationally significant estuaries and whose approach involves community based planning and action at the watershed level.

The NEP is based on the idea that control of point and non-point pollution sources is necessary to maintain estuarine quality for: protection of public water supplies; protection of the health of populations of shellfish, fish, and wildlife; and support of recreational activities, in and on water. The NEP program is designed to improve the quality of estuaries of national importance, often across state boundaries, through the development of long term, sustainable finance strategies and Comprehensive Conservation and Management Plans. These plans focus on the watershed, use science to inform decision-making, and emphasize collaborative problem solving among diverse stakeholders.

The Watershed Protection and Flood Prevention Act of 1954 was enacted to prevent erosion, floodwater, and sediment damages in the watershed streams and rivers of the country through cooperation of the Federal government with states, soil or water conservation districts, and other public agencies (USDA, 2006). Such cooperation should also further conservation in the development, utilization, and disposal of water and the conservation and utilization of land so as to preserve, protect, and improve the country's land and water resources and quality of its environment. This law applies to watershed or subwatershed areas not exceeding 250,000 acres. The law is administered through the US Department of Agriculture (USDA) Natural Resources Conservation Service.

The Coastal Zone Management Act (CZMA) was enacted in 1972 (US Code, 1972b) to protect the nation's coastal zones. The NOAA Office of Ocean and Coastal Resource Management administers this program at the federal level and works in partnership with 34 US coastal and Great Lakes states, territories, and commonwealths to preserve, protect, develop and, where possible, restore and enhance the nation's coastal zone resources.

The Endangered Species Act was signed into law in 1973. The purposes of the Act (US Code, 1973) are to provide a means whereby the ecosystems upon which endangered and threatened species depend can be conserved, and to provide a program for the conservation of these species. Under this law, imperiled species are listed, and they and their critical habitat receive enhanced protection to prevent their extinction. Endangered species means any species in danger of extinction throughout all or a significant portion of its range (certain *Insecta* species considered to be pests are excluded); threatened species are any species likely to become endangered within the foreseeable future. The Endangered Species Act is jointly administered by the US FWS in the Department of the Interior and the National Marine Fisheries Service (NMFS) of NOAA in the Department of Commerce (US FWS, 2007; US NMFS, 2007). As of 8 September 2007, 607 US animal species and 744 US plant species were listed as threatened or endangered. Much of the focus of the Act for watersheds in the US is on endangered mussels in the Southeast and endangered salmon stocks in the Northwest. The US is also a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES is a treaty among 171 countries that protects many species of plants and animals by ensuring that commercial demand does not threaten their survival in the wild.

The Beaches Environmental Assessment and Coastal Health Act (EPA, 2000a) was passed in 2000 and is administered by EPA. Each state having coastal recreation waters must develop water quality standards for those waters for certain pathogens and pathogen indicators. This includes the Great Lakes and marine coastal waters, including coastal estuaries that states designate for activities such as swimming and surfing. EPA is responsible (EPA, 2000a) for conducting studies to provide additional information for use in developing: an assessment of potential human health risks resulting from exposure to pathogens in coastal recreation waters, including nongastrointestinal effects; indicators for improving timely detection of the presence of pathogens harmful to human health; methods, including predictive models, for timely detection of the presence of pathogens harmful to human health; and guidance for state application of criteria for pathogens and pathogen indicators.

The Safe Drinking Water Act was established in 1974 (US Code, 1974) to protect the quality of drinking water in the US. The Act applies to the more than 160,000 public water systems. The Act authorized EPA to establish safe standards of purity for both groundwater and surface drinking water sources, and required all public water system operators to comply with primary health-related standards. State governments that have assumed this power from EPA also encourage attainment of secondary nuisance-related standards.

Four US laws address the environmental risks from toxic substances and their effect on watersheds. Industrial chemicals produced or imported in the USA are regulated via the Toxic Substances Control Act (TSCA) of 1976 (US Code, 1976a). The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly known as Superfund, 1980) created a tax on the chemical and petroleum industries, and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that might endanger public health or the environment (US Code, 1980). The Resource Conservation and Recovery Act (RCRA) gave EPA the authority to control hazardous waste from the "cradle-to-grave"; i.e., the generation, transportation, treatment, storage, and disposal of hazardous waste (US Code, 1976b). RCRA also set forth a framework for the management of non-hazardous wastes.

Pesticides sale, distribution and use are regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (US Code, 1996) that gives EPA authority to study the consequences of pesticide usage and require users (farmers, utility companies, and others) to register when purchasing pesticides (US Code, 1996).

There are a number of programs in the US that use or support the watershed approach. Those of the Federal government include the Watershed-Based National Pollutant Discharge Elimination System Program, National Estuary Program, Nonpoint Source Program, Targeted Watersheds Grants Program, and the National Monitoring Program. There are also specific large-scale projects such as the Gulf of Mexico, Chesapeake Bay, and Great Lakes Programs.

The National Pollutant Discharge Elimination System (NPDES) was first established in the US in 1972. The NPDES program regulates point sources, and all facilities that discharge pollutants from any point source into waters of the US are required to obtain an NPDES permit. This program has evolved over the years, and in 2003 the Watershed-Based NPDES became official policy (EPA, 2003). The most recent guidance for the Watershed-Based National Pollutant Discharge Elimination System was published in August 2007 (EPA, 2007c). The Watershed-Based NPDES permit includes the following information: who has permit coverage, the type of permit used to provide coverage, the geographic scope of the permit, and the pollutants it addresses. The permit also includes information on monitoring, reporting, compliance, and any special conditions, including effluent trading.

The National Estuary Program (NEP) was established in 1987 to improve the quality of estuaries of national importance. The NEP uses a watershed-based approach and operates through partnerships among government and other entities, including citizens of affected communities. The program focuses on maintaining the integrity of whole estuarine systems, including their chemical, physical, and biological properties and economic, recreational, and aesthetic values. There are 28 NEP efforts across the nation, and each develops and implements a Comprehensive Conservation and Management Plan that delineates specific actions designed to improve water quality, habitat, and living resources and address issues such as loss of wetlands, leaking septic systems, stormwater runoff, and the introduction of invasive species (EPA, 2007d). In June 2007, the NEP published its Coastal Condition Report (US EPA, 2007a). This assessment evaluated: water quality, based on dissolved inorganic nitrogen, dissolved inorganic phosphorus, chlorophyll *a*, water clarity, and dissolved oxygen; sediment quality, based on toxicity, contaminants, and total organic carbon; condition of the benthic community, based on a benthic index; and the concentrations of chemicals in target fish and shellfish species. The overall condition of the NEP estuaries was assessed to be generally fair. EPA has also developed a coastal classification strategy (EPA, 2004) for Great Lakes and marine coastal watersheds, Great Lakes coastal riverine wetlands, and marine estuaries. A conceptual model for classifying coastal systems by predicting their sensitivity to nutrients, suspended sediments, toxics, and habitat alteration was developed, based on retention time, modifying factors, and system processing capacity.

The Non-point Source (NPS) Program (EPA, 1994) provides funding to states to address polluted runoff. EPA provides grant funds to states, territories, and Native American Indian tribes to support technical assistance, training, demonstration projects, and monitoring. Grant funding ranged from $37 million in 1990 to a high of $238.5 million in 2003; $199.3 million was provided in fiscal year 2007.

The National Monitoring Program projects (EPA, 1995) are a subset of non-point source pollution control projects funded under Section 319 of the Clean Water Act. The goal of this program is to support 20 to 30 watershed projects nationwide that meet a minimum set of project planning, implementation, monitoring, and evaluation requirements. The supported projects are designed to address non-point source pollution by evaluating the effectiveness of watershed NPS control technologies and improving our general understanding of non-point source pollution.

The Targeted Watersheds Grants Program (see http://www.epa.gov/twg/) provides funding on a competitive basis to watershed projects that are community-driven and results-oriented. The program also provides grants to service provider organizations that provide training and tools for watershed organizations across the country. As of 2007, more than $37 million has been awarded to 46 watershed organizations. The Program is based on the concept of managing water resource use and quality on a holistic watershed basis. This watershed approach focuses regional and state resources on integrating ambient water and source water protection programs so as to support locally-led collaborative efforts within hydrologically defined boundaries that protect and restore our aquatic resources and ecosystems. The Program also funds these collaborative watershed partnerships to implement restoration and protection activities. In 2007, EPA awarded $13.3 million in grants to 16 organizations invited to submit formal applications. The 16 organizations are involved in projects from New York to Hawaii. For example, the Champlain Watershed Improvement Coalition of New York is working to reduce phosphorus inputs to Lake Champlain through such activities as: incentive-based assistance to farmers to implement best management practices; sediment control and stream bank stabilization; construction of wetland treatment cells; and education/outreach. In Hawaii, the county of Maui is working in the West Maui Watershed, one of Hawaii's last native rain forests; the planned program calls for the purchase of over 13,000 acres of the watershed to ensure that the forest and streams are restored, and endangered native species can flourish.

3. Roles of stakeholders

As stated earlier, in the US diverse stakeholders participate in watershed management. Federal agencies involved in watershed management include EPA, National Oceanic and Atmospheric Administration (NOAA), US Department of Agriculture (USDA), US Fish and Wildlife Service (US FWS), and the US Geological Survey (USGS). These agencies promulgate regulations, conduct monitoring, enforce laws and regulations, and provide guidance materials for watershed management, as described previously. However, much of the actual watershed management is conducted by the states and tribes. Under the Clean Water Act, states and tribes set standards that define the goals for a water body by designating the water uses, setting criteria to protect those uses, and establishing provisions to protect the water body from pollutants. Local communities are also involved in watershed management, by virtue of local land use zoning, transportation planning, wastewater and drinking water treatment, and stormwater management.

Non-Government Organizations (NGOs) and volunteer groups are also frequent stakeholders and have contributed greatly to watershed management in the US. A current trend is the growing sophistication of watershed organizations and watershed management. Since the late 1980s, organizations and agencies have moved towards planning based on a watershed approach that includes stakeholder involvement, sound science, and appropriate technology.

Two of the largest national nonprofit NGOs focused on rivers are River Network (www.rivernetwork.org), whose mission is to help people understand, protect and restore rivers and their watersheds, and American Rivers (www.americanrivers.org), whose mission is protecting and restoring America's rivers and fostering a river stewardship ethic. The largest NGO focused on lakes is the North American Lake Management Society (www.nalms.org). Nonprofit groups dedicated to the protection and conservation of estuaries in the US include Restore America's Estuaries (estuaries.org) and the Association of National Estuary Programs (www.nationalestuaries.org). Other national NGOs in the US that address water issues include the Sierra Club (www.sierraclub.org) and the Nature Conservancy (www.nature.org). The NGOs that work nationwide often serve primarily to transfer technology to local and regional groups. For example, the Center for Watershed Protection (www.cwp.org) provides local governments, activists, and watershed organizations around the country with technical tools to help protect streams, rivers, and lakes. The nationals also function to foster communication among similar, smaller scale groups, often through national conferences. Some of these national NGOs, such as American Rivers, Sierra Club and the National Resources Defense Council (www.nrdc.org), also advocate for improved watershed protection laws and regulations at the national level.

Regional and local watershed groups have increased in number and sophistication. For example, River Network lists over 6,000 local organizations involved in watershed protection efforts. The work of these groups often includes elements of education and outreach, advocacy, monitoring, and restoration. For example, the Chesapeake Bay Foundation (www.cbf.org) works to protect natural resources by: advocating strong and effective laws and regulations, and the holding of those who pollute accountable for their actions; restoring habitat through a variety of hands-on projects and citizen participation; and inspiring and engaging volunteers as effective partners and leaders. The Upper Chattahoochee Riverkeeper (www.ucriverkeeper.org) works to protect and preserve the Chattahoochee River and its Georgia watershed through monitoring, advocacy, education, research, communication, cooperation, and legal action. The Utah Rivers Council (www.utahrivers.org) has three goals: river solutions – developing solutions and researching and promoting alternatives that protect Utah's rivers for the future; river defense – protecting rivers from harm by speaking for rivers threatened by ill-conceived dams and diversions, and pollution; and community river advocacy – using education and advocacy support in order to create a network of citizens ready and able to speak for their rivers.

All of these groups' activities contribute to watershed management. Volunteer monitoring for water quality and biology is an increasing trend for streams, lakes, wetlands and estuaries (EPA, 1997). The most commonly sampled habitats are wadeable streams; the chemical parameters most often sampled are water temperature, conductivity, dissolved oxygen, and turbidity or suspended solids. The biological sampling most often involves benthic macroinvertebrates. Monitoring data are useful for assessing status of a watershed, detecting trends over time at specific sites, and identifying problems, such as illegal dumping, spills, or sewage leaks. Local and regional groups often participate in restoration activities that have direct benefits to water quality (FISWRG, 1998). These groups also contribute to watershed management through their advocacy, by ensuring enforcement of existing laws and supporting new laws, ordinances, and policies that are protective of the watershed (e.g., changes in zoning, stream buffer width, and construction site practices). NGOs at all levels will likely play an increasingly important role as watershed management becomes more proactive and comprehensive, involving all stakeholders in the decision-making process (EPA, 2005).

4. Tools used in management

4.1. DATA AND DATABASE SOURCES

There are a number of available databases containing US environmental information obtained by both governmental and nongovernmental entities. One of the best-known databases is EPA's STORET (STOrage and RETrieval) data warehouse that contains biological, chemical, and physical data on surface and ground water collected by federal, state and local agencies, Indian tribes, volunteer groups, academics and others. STORET is available to the public at http://www.epa.gov/storet/.

The US Geological Survey provides water information of several kinds – publications, data, maps, and applications software. Their NWIS (National Water Information System) Web Site contains selected water resources data for approximately 1.5 million sites across the US, including real-time and historic stream flow and status data, ground water levels, water quality data, and general site information. Water quality information/data are available at http://water.usgs.gov/data.html.

The Environmental Monitoring and Assessment Program (EMAP) is an EPA research program to develop the tools for monitoring and assessing the status and trends of national ecological resources in the US. EMAP has the goal of being able to translate environmental monitoring data from multiple spatial and temporal scales into assessments of current ecological condition and forecasts of future risks to natural resources. EMAP has a number of large, regional projects through which EMAP has developed indicators and demonstrated their use to monitor the condition of ecological resources. EMAP data are available at http://epa.gov/emap/html/data/index.html.

ECOTOX **(ECOTOXicology)** is a comprehensive database that provides information on the toxicity of single chemical stressors to aquatic and terrestrial species. ECOTOX is available on-line at http://www.epa.gov/ecotox/. The database is updated on a quarterly basis and includes more than 440,000 records abstracted from 18,800 publications, addressing the adverse effects of 8,400 chemicals to 5,900 terrestrial and aquatic species.

Sets of web-based, geo-spatial analytical tools and information are available from the EPA Office of Environmental Information (http://www.epa.gov/oei/access.htm) for use by decision makers and citizens. These tools include: "Window to My Environment", a mapping application using provided interactive maps and tools to access environmental conditions in communities; and EnviroMapper that provides access to EPA databases providing information about environmental activities regarding air, water, and land.

4.2. WATERSHED RESTORATION TOOLS

Restoration projects are being designed and implemented in increasing numbers across the country. Most of these projects are focused on streams and rivers. Bernhardt et al. (2005) found that the number of river restoration projects has increased exponentially over the last decade, with projects being conducted in all 50 states. These authors created a database of 37,099 projects called the National River Restoration Science Synthesis to track statistics on restoration projects. Their analysis showed that most projects are small, with a median cost less than US$45,000, and are from the Pacific Northwest and Chesapeake Bay watersheds.

One of the most comprehensive references guiding restoration in the US is the Stream Corridor Restoration Manual (FISRWG, 1998). A common method of restoration is Natural Channel Design, developed by Wildland Hydrology (Rosgen, 1996), where restoration is designed to recreate the natural river geometry and geomorphology determined for a particular site by a classification system. Brown (2000) examined 24 different types of stream restoration practices comprising four design elements: (1) Bank protection practices, designed to protect streams from bank erosion or failure; examples of these practices are rootwad and boulder revetments. (2) Grade control structures, designed to maintain a desired streambed elevation; examples are rock vortex weirs and rock cross vanes. (3) Flow deflection/concentration structures, designed to change the direction of flow or concentrate flow within the channel; examples are rock vanes and log vanes. (4) Bank stabilization practices employ nonstructural means to stabilize stream banks against erosion; generally the stream banks are re-graded to a stable configuration, then vegetative plantings, such as willows, and other biodegradable materials are used to stabilize the bank. Brown found that most urban stream restoration practices, when sized, located, and installed correctly, worked reasonably well. The greatest deficiency identified was the inability of the practices to enhance habitat.

4.3. MODELING TOOLS USED IN THE US

Modeling tools include software frameworks and simulation models. Over the years, numerous models were developed for specific locations, and a few general models were developed for multiple applications. These models can be broadly categorized as watershed loading models and surface water body models, although some watershed models include surface water body modules internally. One source of models used in the US is the EPA Office of Water's Office of Science and Technology that sponsors and supports BASINS and a set of associated models, currently including HSPF, PLOAD, and AQUATOX. For general information about these latter models, see http://www.epa.gov/waterscience/models/. Another source is the Ecosystems Research Division of the EPA Office of Research and Development that sponsors and supports a diverse set of water quality and exposure assessment models through its two Centers. The water quality models include WASP7 and QUAL2K that can be obtained at the Watershed and Water Quality Modeling Technical Support Center: http://www.epa.gov/athens/wwqtsc/index.html; exposure assessment models can be obtained at the EPA Center for Exposure Assessment Modeling: http://www.epa.gov/ceampubl/. Selected, commonly used models are described below.

BASINS4 – The watershed modeling framework most used in the US is BASINS. For information about BASINS, visit basins@epa.gov, the BASINS web site at http://www.epa.gov/waterscience/basins, and/or join the Listserver at http://www.epa.gov/waterscience/basins/listserv.htm.

BASINS is a multipurpose environmental analysis system designed for use by regional, state, and local agencies in performing watershed and water quality-based studies. This system makes it possible to quickly assess large amounts of point and non-point source data in a format that is easy to use and understand. BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. This framework integrates environmental data, site properties, analytical tools, and pollutant source and transport and fate simulation modeling to support development of cost-effective approaches for watershed management and environmental protection, including development of Total Maximum Daily Loads (TMDLs).

- Data: national data sets with options to import local data
- Tools: provide quick access to analysis techniques for watershed assessment
- Models: provide more detailed analysis and predictive evaluations

BASINS4 includes GIS tools in the front-end (Data Download Tool, Watershed Delineation, Watershed Characterization Reports, and weather data manager utility (WDMUtil) for time-series). The delineation of a watershed with the GIS creates sub-basin boundaries, stream networks, and input/output locations for the water quality models. BASINS 4.0 Release 1 includes HSPF and PLOAD watershed pollutant loading models, and a link to the AQUATOX aquatic ecosystem model. The USDA's watershed runoff model SWAT is being linked into BASINS4 in late 2007, and the surface water body model WASP will be incorporated in 2008.

BASINS4 is based on Mapwindow, an open source "Programmable GIS" that supports manipulation, analysis, and viewing of geo-spatial data and associated attribute data in several standard GIS data formats. Mapwindow is both a mapping tool and a GIS application programming interface in one convenient, re-distributable, open source solution. Using these open source GIS tools and non-proprietary, standard data formats to accommodate users of several different GIS software platforms, BASINS4 becomes independent of any proprietary GIS platform and available for useful "plug-ins."

HSPF – The Hydrological Simulation Program – FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates watershed-scale models into a basin-scale analysis framework that includes pollutant transport and fate in one dimensional stream channels. HSPF uses continuous rainfall and other meteorological records to compute stream flow hydrographs and pollutographs. HSPF is organized into three primary modules for simulating the main features of a watershed. PERLND simulates the water quality and quantity processes that occur on a pervious land segment. A land segment is a subdivision of the simulated watershed defined as an area with similar hydrologic characteristics. A segment of land that has the capacity to allow enough infiltration to influence the water budget is considered pervious. IMPLND simulates water quantity and quality accumulation and runoff from impervious land segments. In a connected impervious land segment, little or no infiltration occurs. Snow accumulation and melting is simulated as is water storage, evaporation and export. Various water quality constituents are loaded, accumulated and/or removed. Water, solids, and various associated pollutants flow from the segments by moving laterally to a downslope segment or to a stream or lake. The RCHRES module simulates the pollutant transport and fate processes that occur in each reach of open or closed receiving stream channel or in a completely mixed lake.

PLOAD – PLOAD is a relatively simple screening model that estimates non-point source loads of user-specified pollutants on an annual average basis. The loads are calculated using either export coefficients or Schueler's Simple Method. The effects of best management practices (BMPs) that serve to reduce non-point and point source loads, can also be included in the computations. Watershed boundaries and land-use GIS data are required for PLOAD. Prior to calculating the pollutant loads, PLOAD will spatially overlay the watershed and land use coverages in order to determine the areas of the various land use types for each sub-watershed. PLOAD is available within BASINS http://www.epa.gov/waterscience/basins/bsnsdocs.html.

SWAT – The USDA Soil and Water Assessment Tool (SWAT) is a physically based, spatially distributed, watershed scale model. The model was developed to predict impacts of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds. SWAT considers land use and soils data, and calculates the spatial overlap between soil types and land use types. Each unique land use-soil type combination is treated as a separate hydrologic response unit (HRU), with its own set of governing parameters. The areal sum of the output from each HRU within a sub-basin becomes the total output from that sub-basin, whether water, sediment, nutrients, or some other pollutant.

SWAT reads daily precipitation files, and uses either the SCS curve number method or the Green-Ampt method to calculate runoff volume and infiltration. Plant growth and evapotranspirative extraction of water from the root zone are simulated. Overland flow and subsurface flow are simulated with a kinematic wave approach. Erosion is computed using the Modified Universal Soil Loss Equation, MUSLE. Multiple soil layers are simulated, including the root zone, with downward soil water movement between layers and lateral discharge into channels. When soil water content exceeds the field capacity, downward movement between layers and discharge of excess water into streams occurs in a first-order fashion subject to a lateral flow lag with a calculated travel time coefficient. The presence of drain tiles can be accounted for through the lag time coefficient, or subsurface travel time to the stream can be computed as a function of hill-slope and hydraulic conductivity. Aquifer recharge from soil water is treated as a first-order function of time. Variable groundwater depth is simulated, and recharge to streams is treated as a function of groundwater depth, subject to a user-defined recession coefficient. Besides the water table aquifer, loss to deep groundwater is also simulated, as in HSPF. Overland flow and channel flow are both simulated with Manning's equation. Constituent/pollutant transport to streams from the surface via subsurface flow is explicitly simulated in the same first-order manner as the soil water discharge to streams.

The nitrogen cycle is simulated using 5 different N pools, NH_3, NO_3, and three different kinds of organic N (plant residues and active and labile humics). Nitrification, denitrification, and N fixation and mineralization are all simulated. Denitrification is treated as a function of soil carbon when soil moisture exceeds a specified threshold. Mineral and organic forms of P, and transformations between them, are also simulated. For pesticides and fertilizers, various management practices can be simulated; e.g., different timing of and application rates, and tillage operations.

SWMM4 – The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. SWMM accounts for various hydrologic processes that produce runoff from urban areas. SWMM also contains a flexible set of hydraulic modeling capabilities to handle the drainage system network of pipes, channels, storage/treatment units and diversion structures. SWMM estimates the production of pollutant loads associated with runoff considering the following:

- Dry-weather pollutant buildup over different land uses
- Pollutant wash-off from specific land uses during storm events
- Direct contribution of rainfall pollutant deposition
- Reduction in dry-weather pollutant buildup due to street cleaning
- Reduction in pollutant wash-off load due to BMPs
- Entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system
- Routing of water quality constituents/pollutants through the drainage system
- Reduction in pollutant concentrations by treatment in storage units or natural processes in pipes and channels

WASP7 – WASP is a dynamic, mass balance framework for modeling contaminant fate and transport in surface waters. Based on the flexible compartment modeling approach, WASP can be applied in one, two, or three dimensions with advective and dispersive transport between discrete physical compartments, or "segments." A body of water is represented in WASP as a series of discrete computational elements or segments. Environmental properties and chemical concentrations can vary spatially among the segments. Each contaminant is advected and dispersed among water segments, and exchanged with surficial benthic segments by diffusive mixing. Sorbed or particulate fractions can settle through water column segments and deposit to or erode from the surficial benthic segments. Within the bed, dissolved contaminants can migrate downward or upward through percolation and pore-water diffusion, respectively. Sorbed contaminants can migrate downward or upward through net sedimentation or erosion, respectively.

WASP is designed to permit substitution of different water quality kinetics code into the program structure to form different water quality modules. Two classes of modules are provided with WASP. The toxicant WASP modules combine a kinetic structure initially adapted from EXAMS (Burns et al., 1982) with the WASP transport structure and simple sediment balance algorithms to predict dissolved and sorbed chemical concentrations in the water and underlying sediment bed. The eutrophication WASP module simulates nutrients, phytoplankton, periphyton, organic matter, and dissolved oxygen dynamics.

WASP7 includes a Windows-based interface for constructing input datasets and managing simulations. Data can be copied and pasted from spreadsheets. A Windows-based post-processor allows the user to plot or animate model output. Output is also provided as comma-delimited files for import to spreadsheets.

AQUATOX – AQUATOX is a process-based simulation model for aquatic systems that predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fishes, invertebrates, and aquatic plants. AQUATOX simulates the transfer of biomass, energy and chemicals from one compartment of the ecosystem to another by simultaneously computing each of the most important chemical or biological processes for each day of the simulation period. AQUATOX has several potential applications to water resources management, including the specification of water quality criteria and standards and TMDLs, and the conduct of ecological risk assessments of aquatic systems, where it may help to determine the relative importance of multiple environmental stressors. AQUATOX can also be used to predict aquatic ecological responses to proposed management alternatives. Additional information on AQUATOX is available at http://www.epa.gov/waterscience/models/aquatox/.

QUAL2K – QUAL2K is a one-dimensional, steady-flow river and stream water quality model with diurnal kinetics. See

http://el.erdc.usace.army.mil/products.cfm?Topic=model&Type=watqual. Implemented within Excel, the model features:

- Unequally-spaced reaches with multiple loadings
- Carbon: slowly oxidizing CBOD, rapidly oxidizing CBOD, and non-living particulate organic matter (detritus)
- Nutrients: nitrogen and phosphorus cycles
- DO and anoxia simulation: reduced oxidation reactions at low DO
- Sediment-water interactions: DO and nutrient fluxes simulated
- Algae: phytoplankton and attached bottom algae simulated
- Light extinction: a function of algae, detritus and solids
- pH: Both alkalinity and total inorganic carbon are simulated
- Pathogens: removal a function of temperature, light, and settling

5. Case studies in watershed management

To understand the range of watershed management activities in the US better, we examine two contrasting river basins – the Mississippi and the Neuse. The former is continental in scale, draining a third of the contiguous United States; the latter is contained within a single state. These two basins share common problems, however. Both receive significant agricultural runoff and atmospheric deposition loadings, delivering reactive nitrogen to downstream coastal waters where increased primary production and periodic algal blooms contribute to bottom water hypoxia.

5.1. MISSISSIPPI RIVER BASIN

The Mississippi River originates in northern Minnesota and drains 3,208,700 km^2, encompassing 41% of the contiguous US in 31 states before reaching the Gulf of Mexico. The river's water flow increases downstream with major inflows from the Missouri, Illinois, Ohio, Arkansas and White Rivers. An extensive levee system controls flooding in the Mississippi River System. Downstream from Vicksburg, Mississippi, about 30% of the flow is diverted through the Atchafalaya River west to the broad, shallow Atchafalaya Bay and on to the Gulf of Mexico. The remaining 70% of the Mississippi River waters travel past New Orleans, entering the Gulf of Mexico through three main channels in the birdfoot delta. Most of the annual discharge occurs from December to June, although annual variability of the river flow is significant.

The major tributaries contribute differing amounts of water, sediment, and nutrients to the Mississippi. Although the Ohio River watershed comprises only about 18% of the total Mississippi River drainage area, the Ohio River System on average contributes roughly 50% of the water discharged from the Mississippi River System to the Gulf. The Missouri River System drains 43% of the Mississippi watershed and contributes only 12% of the total water in the lower Mississippi River, but most of the suspended sediments.

Thousands of lakes, small and large rivers, wetlands and estuaries feed fresh water into the Northern Gulf of Mexico, creating an environment that sustains and nourishes a huge diversity of life in a unique ecological system. The Mississippi River basin discharge, however, dominates the Northern Gulf, contributing 80% of the freshwater inflow, 91% of the nitrogen load, and 88% of the phosphorus load during the period 1972–1993 (Dunn, 1996). Nitrogen loadings have increased almost threefold since the 1960s, while phosphorus and silica loadings have declined somewhat (Goolsby et al., 2001). Nutrient loadings have contributed to the depletion of bottom oxygen concentrations over extensive regions of the northern Gulf each spring and summer (Rabalais and Turner, 2001). These regions of hypoxia (DO $<$ 2 mg/L), averaging 8,300 km^2 from 1985–1992, grew to 16,000 km^2 from 1993–2001 (Rabalais et al., 2002). Significant year-to-year variability in hypoxia extent is controlled by variability in climate and ocean dynamics (Rabalais et al., 2002).

Land use and nutrient loading relationships have been studied using statistical analysis and modeling. Goolsby et al. (1999) concluded that 90%

of nitrogen loading was from non-point sources. Multiple regression predictions of nitrogen export as a function of land use in crops and population density explained 60% of the variation in all data sets combined (Turner and Rabalais, 2004). The USGS has applied the empirical SPARROW model to watersheds in the Mississippi Basin, and identified major sources of nitrogen loading originating in the upper Mississippi Basin.

Bierman et al. (1994) calibrated the WASP model to a comprehensive set of field data in the Mississippi River Plume/Inner Gulf Shelf (MRP/IGS), and examined the relationship among nutrients, phytoplankton, and dissolved oxygen. Diagnostic analyses and numerical experiments were conducted with the calibrated model to understand the environmental processes controlling primary productivity and dissolved oxygen dynamics in the MRP/IGS region better. Results indicated the importance of light attenuation as well as nutrient limitations on phytoplankton growth, and the importance of carbonaceous oxidation, phytoplankton respiration, and sediment oxygen demand in controlling the deoxygenation of the coastal bottom waters. Scavia et al. (2003) applied a simple dissolved oxygen model, driven by river nitrogen load, and a parameterization of ocean dynamics to study a 17-year record of hypoxia location and extent. Hind-casts with this model suggested that extensive regions of hypoxia were not common before the mid-1970s. Projections indicated that a 30% reduction in nitrogen load from the 1980–1996 average might not reduce the hypoxic area below 5,000 km^2 in most years, and that return to that level of impacted area might require a 40–45% reduction in nitrogen load.

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force was formed to address nutrient management in the Basin. The Task Force was composed of eight federal and ten state agencies. An Action Plan submitted to Congress in 2001 described a national strategy to reduce the frequency, duration, size, and degree of oxygen depletion of the hypoxic zone in the northern Gulf of Mexico (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2001). One specific objective was to reduce the 5-year running average hypoxic area to below 5,000 km^2 by 2015, starting with a 30% reduction in nitrogen loads, mostly from non-point sources. Long-term goals included: encourage actions that are voluntary, practical, and cost-effective; utilize existing programs, including existing state and federal regulatory mechanisms; follow adaptive management; identify additional funding needs and sources during the annual budget process; and provide measurable outcomes.

The Task Force identified and promoted five strategic projects; the following descriptions of these projects are extracted from www.epa.gov/msbasin/strategies.htm.

Industry Led Solutions (ILS) is a coalition of leading producers of corn, soybeans, rice, cotton, dairy cattle, pork, and poultry. Their goal was to promote effective, scientifically sound water quality policies that meet the unique needs of agriculture and maintain the economic viability of the industry. The strategy was to develop, lead, and implement a voluntary, local non-point source nutrient management program in each state's critical watersheds in the Basin.

The EPA Targeted Watershed Program included three initial watershed studies. One was on the Upper Mississippi River in Iowa, focusing on reducing nitrate load by structural modifications integrating wetlands and controlled/shallow drainage systems. A second was on the Sangamon River in Illinois, with projects to optimize nitrogen and phosphorus management. The third was Fourche Creek in Arkansas, with projects to revitalize wetland function through reforestation and stream bank and wetland restoration.

The Conservation Effects Assessment Project (CEAP) of the USDA Natural Resources Conservation Service studied the benefits of most conservation practices implemented through various 2002 Farm Bill programs, including the Environmental Quality Incentives Program, the Wetlands Reserve Program, the Wildlife Habitat Incentives Program, the Conservation Reserve Program, and NRCS Conservation Technical Assistance. CEAP will also evaluate specific conservation practices and management systems for fertilizers, manure and pesticides, such as buffer systems, tillage, irrigation, and drainage practices, wildlife habitat establishment, and wetland protection and restoration.

The Iowa Soybean Association is promoting an On-Farm Nitrogen Network that works with selected growers to improve nitrogen fertilizer efficiency and quantify management performance. Area wide and individual technical and program planning assistance is supported, in addition to management evaluation, applied research, and communication efforts. The Association is evaluating management practices and environmental outcomes at the watershed level. Production data are collected and analysis is performed to evaluate response to management and correlation with variables such as soil types, tillage, and fertilizer application rates, timing, and sources. Finally, Certified Environmental Management Systems for Agriculture will implement an environmental management system that is practical and feasible for use in a farming operation.

The Coastal Wetland Strategies project includes several components. Coastal Restoration Strategies is a joint effort by the New Orleans District of the US Army Corps of Engineers and the Louisiana Department of Natural Resources to address Louisiana's massive coastal land loss problem. The Louisiana Coastal Area (LCA) Comprehensive Coast-wide Ecosystem Restoration Study will present to Congress a Comprehensive Plan that includes goals, feasibility reports, plan frameworks, resource and cost strategies, and a schedule of projects over a 10-year period. The Louisiana Coastal Wetlands Conservation and Restoration Task Force produced "Coast 2050:

Toward a Sustainable Coastal Louisiana," a plan to restore and/or mimic the natural processes that built and maintained coastal Louisiana. This plan advocates basin-scale action to restore more natural hydrology and sediment introduction processes.

5.2. NEUSE RIVER BASIN

The Neuse River rises in the piedmont of North Carolina and drains a 16,000 km^2 basin that empties into Pamlico Sound below New Bern. The Neuse River is one of the three main feeders to the Albemarle-Pamlico Sound system. The upper Neuse Basin is located in the piedmont and is experiencing rapid urbanization with loss of forest and agricultural land. The middle Neuse Basin is located in the coastal plain and experiences extensive and intensive agriculture with row crops, pasture, and animal feeding operations. The lower Neuse Basin includes the tidal river and portions of Pamlico Sound.

The lower Neuse River and Pamlico Sound is an important resource for recreational and commercial fishing. Water quality and ecosystem health in the lower Neuse River Basin are strongly influenced by high nitrogen levels from agricultural runoff in the middle Neuse Basin and urbanization in the upper Neuse Basin. By the late 1990s, increased nutrient concentrations contributed to greater primary production and periodic algal blooms, occasionally composed of toxic dinoflagellate species that kill fishes. This increased productivity, in combination with occasionally strong water column stratification, has also caused hypoxia and fish kills.

The state listed the Neuse River Basin as impaired by nitrogen. To understand the water quality problems in the lower Neuse better, North Carolina established an intensive monitoring and modeling program – the Neuse River Estuary Monitoring and Modeling Program (MODMON). This program is a collaborative effort between the University of North Carolina and the North Carolina Department of Environmental and Natural Resources, and supports the needs for space and time-intensive monitoring and assessment of water quality and environmental conditions. Work has focused on understanding the relationships among nutrient-eutrophication dynamics, algal blooms, hypoxia, and fish kills. MODMON provides data for calibration, verification and validation of water quality models being used to adaptively test and manage TMDLs for the Neuse River Estuary, and serves state and federal agencies as a ground-truthing data source for aircraft and satellite-based remote sensing of chlorophyll, turbidity and harmful algal blooms. Two modeling efforts were undertaken for the Neuse River Estuary: application of the two-dimensional, laterally averaged hydrodynamic and water quality model CE-QUAL-W2 (Bowen and Hieronymus, 2000; Bowen, 2003) and a Bayesian model (Borsuk et al., 2003). These modeling efforts supported source management plan development to achieve a nutrient reduction target of 30%.

EPA subsequently assumed both technical advisory and oversight roles for the Neuse, and developed an alternate, more complex modeling approach to account for the three-dimensional transport phenomena observed (Wool et al., 2003). To derive tributary flows and loadings to the estuary, HSPF was used with the EPA Region 4's Watershed Characterization System (EPA, 2000b). The estuary hydrodynamics were simulated with EFDC (Hamrick, 1996), and water quality was simulated with WASP6. This modeling exercise examined the effects of complex circulation on water quality, and projected water quality changes as a function of nutrient reductions. Modeling results indicated that given the proposed 30% reductions in nutrient loading, the Neuse River Estuary should meet its designated use with minimal exceedances amounting to no more than 2% of the criterion.

The North Carolina Environmental Management Commission's 1997 plan, backed by TMDL controls for point and non-point sources (urban and rural), issued a mandatory 30% reduction in N loads by 2003. Funds were derived from governmental and non-governmental sources to pay for implementation of BMPs and technical assistance. BMPs implemented by 2003 to reduce sediment and nutrient runoff included buffers, contour planting, no-till planting, and creek fencing. Partners in the program included state, federal, university, and citizen groups. By 2003 there were already some encouraging results: a 42% decrease in nitrogen loading to the estuary and a 27% instream nitrogen reduction in the Neuse River just above the estuary; flow adjusted nitrogen concentrations comparable with the 1991–1995 baseline; lower phosphorus concentrations; and less soil erosion loss.

6. Conclusion

In a Forum Summary for the 2006 World Water Week (SIWI, 2007), use of Integrated Water Resources Management was cited as an effective means of achieving access to water, to abate pollution, and to safeguard good ecological balance. Furthermore, practical tools and decision support systems are needed to underpin Integrated Water Resources Management, and such systems must be supported by data and information for both the hydrological and the socioeconomic components. It was also pointed out that decision support systems must be based on stakeholder involvement, supported by capacity-building for informed decision-making. An ecosystem has been defined by NOAA (2005) as a geographically specified system of organisms, the environment, and the processes that control their dynamics; humans are an integral part of an ecosystem. In urging more ecosystem-based approaches for fisheries science, and to effectively guide fisheries management toward long-term, productive sustainability, Francis et al. (2007) presented a list of actions ("ten commandments") for implementation. These included keeping a holistic, risk-averse, and adaptive perspective; characterizing and maintaining ecosystem resilience; and using an integrated, interdisciplinary, and inclusive management approach.

A recent development in the field of ecology is the concept of ecosystem services; that is, consideration of what ecosystems provide to humans and how these values can be maintained (Carpenter and Folke, 2006). This approach recognizes the provisioning services of fisheries given sufficient quality and quantity of clean water; the regulating services of flood protection, climate regulation, and water purification; and the cultural services provided by watersheds – recreational, aesthetic, and inspirational. The goal is to ensure that these services are recognized, valued both socially and economically in society, and conserved for future generations.

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PART 3

DECISION SUPPORT TOOLS, MODELS AND CASE STUDIES

MULTILEVEL PARTICIPATORY MODEL FOR DECISION MAKING ON REGIONAL HYDRO-SYSTEM BASIS: SERBIAN CASE STUDY

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Abstract: The Analytic hierarchy process (AHP) is used to build up and solve participatory decision making model and improve management of selected regional hydro system in northern Serbia. Recently, serious conflicts in the case study area are evidenced among governmental bodies, local authorities in municipalities, responsible water management companies, ecologists, public bodies etc. The reason for conflicts is lack of funding, improper legislation or absence of precise water policies, low efficiency in water taxation and obstruction of societal and political representatives to participate in management.

The decision-making model (hierarchy) is established with four levels and 13 decision elements. The overall goal is set at the top of hierarchy as a 'benefit for all'. Second level consists of three criteria (economic, social, and ecological) and five more decision elements are defined at the third level as primary system purposes (irrigation, drainage, used waters, industrial water supply, and other purposes). At the bottom of the hierarchy, four management strategies are posted as the decision alternatives, defined by authorized water management company. Model is established by consensus and then assessed by five key interest groups gathering in total 23 individual participants. At the final stage, the best strategy is identified by aggregating the alternatives' weights obtained in groups, assuming also that groups may have different importance in deriving the final solution.

Successful structuring and solving the participative decision-making model, based on the AHP methodology, indicated promising and scientifically sound approach in improving the decision making practices on regional scales. Results of this practically performed experiment recommend this modeling and solving concept for further use, at least in situations similar to this Serbian case study example.

Keywords: Regional water management; decision-making; participative model; AHP

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 201–213.

1. Introduction

1.1. THE WATER SECTOR IN SERBIA

Several ministries and agencies in Serbia (Figure 1) 'handle' water, and especially: planning for its utilization, distribution for various uses throughout the country, monitoring water quality and managing water reuse (Srdjevic and Petkovic, 2004). National water sector is under direct responsibility of the Ministry for Agriculture, Forestry and Water Management and its Directorate for Waters. In the Vojvodina Province, northern and most developed part of the country, this responsibility is extended toward Provincial Secretariat for Agriculture, Forestry and Water Management and Public Water Management Company Vode Vojvodine (PWMC VV) (Figure 2). Considered as a mineral resource as well, ground waters are to certain extent under responsibility of the Serbian Ministry of Energy and Provincial Secretariat for Energy and Mineral Resources.

Figure 1. Republic of Serbia and Province of Vojvodina.

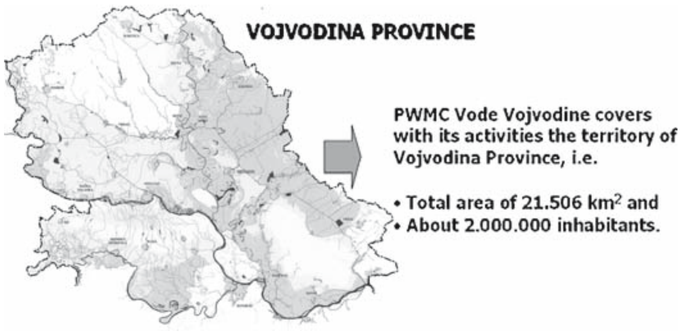

Figure 2. Waters of Vojvodina Province.

Policies and procedures related to water sector are generally proposed by ministries and secretariats, while executive decisions are made by state and provincial governments. Policies related to water use are defined by Water Law which serves as an umbrella document for most of actions and measures undertaken with regard to national waters.

Law of Agricultural Land and sets of Regulation Acts declared by Government are used to implement policies and procedures in the water sector. Laws and regulation acts are prepared by authorized expert bodies of the Republic Parliament and Government, and they are executed, after authorized by the Parliament (laws) or Government (regulation acts), by public water management companies at state and provincial level.

Generally speaking, officials in the state/province public water enterprises are aware of the lack of fruitful communication with the water users. They undertake certain actions to improve situation and to provide for better users participation in defining and implementing water related policies and procedures, which is obviously still at low level. For example, interviews with water users show that they consider the communication with public water enterprises and state and provincial government as unsatisfactory in a sense that their problems are often underestimated or superficially treated. On the other side, responsible officials are generally not reluctant to demands coming from the users; however they usually have to set unpopular priorities on use of very limited national budget and international loans and donations (Srdjevic and Petkovic, 2004).

Regarding irrigation, situation with a stakeholders' dialogue is not satisfactory causing bad situation in irrigation sector as a whole. Some users argue that periodical dialogue between academics and NGOs with users, with a support or sponsorship of responsible or interested ministries, secretariats or other associations, does not help too much to escape from the dead-trap-point. Drainage situation is much better. Regionalization and participatory decision-making at local level is much easier to provide and it is generally working. However, there is an obvious lack of rules and definitions of what are local, regional and broader interests and needs, and then of the instruments of respective financing.

1.2. FUNDING OF THE WATER SECTOR IN SERBIA

At the moment, national water sector is founded upon the principle of self-sustainable development of water sub sectors. In recent years it has been widely accepted that an integrated approach to water management requires a clear understanding of the existing policies and strategies for water resources and acquiring their coherence with the European funding models. Presently, different nation-wide actions are underway to adjust Serbian legislation and improve overall planning and management practices related to water resources towards EU standards.

A self-funding and sustainable development of water management in Serbia is now under serious consideration with principal focus on the issue that water will become an economic category rather than a social resource as perceived at the present time. Because self-funding is based on strict adherence to two basic principles, *user pays* and *polluter pays*, this way funds are expected to be secure as required for the maintenance of current and building of new water infrastructures (Srdjevic and Petkovic, 2004). However, in practice this is not so. Many polluters do not pay, or they do that with delays, there are un-registered water polluters and inspection is still unsatisfactory. Also, fees are relatively low, so polluters intentionally choose to pay the fees and pollute waters.

In view of the current economic situation in Serbia, it is unrealistic to expect applicability of the European funding model for the water sector in the short-term. The actual price of water and water services can be charged to residents only after a period of economic revitalization and increase in the standard of living. In next few years the state budget will continue to play important role in water sector funding together with international assistance (specifically: grants, loans and concessions).

2. Case study regional system Nadela

2.1. THE SYSTEM

The regional hydro system Nadela in Vojvodina Province (Figure 3) is named after the Nadela canal, 83 km long central stream flow in the system, passing from north to south where confluence into the Danube river. This system is used as a case study example to demonstrate possible scenario of motivating several key players to participate in vital (primarily financial) issues related to operation and long life development of the system (Srdjevic et al., 2005a, b).

Purposes of the system are as listed below:

- Drainage: Land users within the basin
- Collecting used waters: Milk factory and other smaller collectors
- Industrial water supply: Sugar industry
- Irrigation: Twelve irrigation systems located along the Nadela canal near villages or small cities
- Other purposes: Fishing and some outdoor recreation activities.

Along the first 30 km of the canal (its northern section), water is of desired quality ('blue and clean') and mostly used for irrigation. More downstream, and especially along the last 15 km before canal's confluence with the Danube river, it is commonly not possible during summer season to augment even ecological minimum flow of 0.5 m^3/s. This un-balanced water supply and especially heavy pollution in downstream south section of the Nadela canal in several instances provoked inhabitants along the canal, NGOs, ecologists and media to protest and require responsibility of Provincial Secretariat and PWMC VV. The later one shares its responsibility with regional water company, contracted to operate the system of lockers along the canal, inspect quality of water, contracts water supplies with water users along the canal, and take care about budgeting, operation and maintenance.

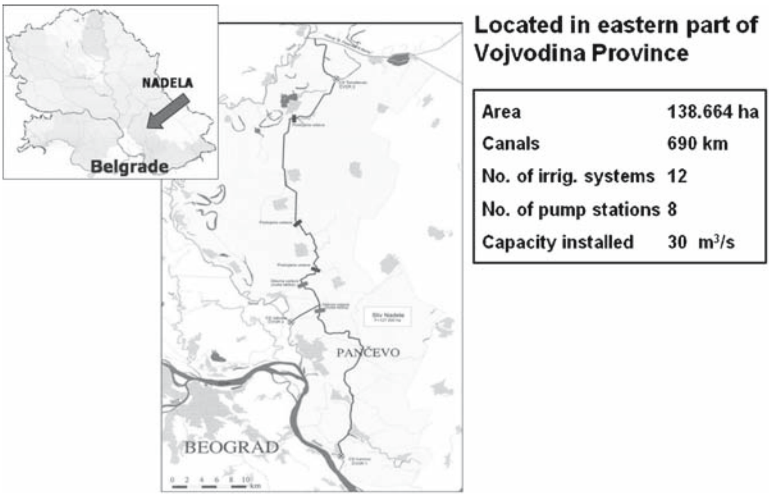

Figure 3. Regional hydro system Nadela.

2.2. THE FUNDAMENTAL PROBLEM AND AN APPROACH TO FIND THE SOLUTION

In search for how to improve overall management of the Nadela system and related system of pricing waters for various categories of users, a participative decision-making strategy is adopted which will include relevant decision elements and key players in the decision making process. The second step was to create and implement the model and apply it to present interested parties with ultimate goal to indicate how they should work in a future and join their efforts in reaching consensus on best management strategy.

Decision-making process itself is characterized by the conflict interests of different parties: government, local authorities in municipalities, responsible water management companies, ecologists, public bodies etc. The conflicts are presently sharpened because of the lack of funding, improper legislation or absence of precise water policies, low efficiency in collecting water taxes, and difficulties in motivating societal delegates to participate in management.

The main problem is stated as:

- How to build the consensus on idea that system is common good, and that it should be managed properly to become sustainable?
- How to conciliate different interests and solve conflicts?
- What to do when there are more then one participant in the decision making process with different attitudes and approaches to the same problem?

A study team composed of university scientists and professionals from the PWMC VV defined possible approach and offered the solution. To identify the best management strategy for the Nadela hydro system the AHP (Saaty, 1980), and software which implements the method known as EC2000 (EC2000, 2000), is used to support basically participative decision-making process through several major procedural steps:

1. Identifying participants (decision makers) and grouping them into ‘users groups’
2. Defining a set of decision making elements and hierarchization of elements
3. AHP assessments (individual applications)
4. Partial and group aggregations of individual AHP assessments
5. Ranking of alternatives and declaring the compromise solution as the final group decision

2.3. ANALYTIC HIERARCHY PROCESS (AHP)

The AHP is a multicriteria decision-making method which requires a well-structured problem, represented as a hierarchy. Usually, at the top of the hierarchy is the goal; the next level contains the criteria and sub-criteria, while alternatives lie at the bottom of the hierarchy. AHP determines the preferences among the set of alternatives by employing pair-wise comparisons of the hierarchy elements at all levels, following the rule that, at given hierarchy levels, elements are compared with respect to the elements in the higher level by using the *Saaty's* importance scale (Table 1). By assumption, value 1 corresponds to the case in which two elements contribute in the same way to the element in the higher level. Value 9 corresponds to the case in which one of the two elements is significantly more important than the other. Also, if the judgment is that B is more important than A, the reciprocal of the relevant index value is assigned. For example, if B is felt to be notably more important as a criterion for the decision than A, then the value 1/7 would be assigned to A relative to B.

The results of the comparison are placed in comparison matrices. After all judgments are made, the local priorities of the criteria, sub criteria and alternatives can be calculated using the principal eigenvector of a comparison matrix, as suggested by Saaty (1980). The synthesis is performed by multiplying the criteria specific priority vector of the alternatives with the corresponding criterion weight, and then appraising the results to obtain the final composite alternatives priorities with respect to the goal. The highest value of the priority vector indicates the best-ranked alternative.

In the case of group decision making, the aggregation of individual priorities is performed by the Geometric Mean Method (GMM) (Forman and Peniwati, 1998)

$$z_i^G = \prod_{k=1}^{K} \left[z_i(k) \right]^{\alpha_k} \tag{1}$$

TABLE 1. The fundamental Saaty's scale for the comparative judgments.

Num. values	Verbal terms
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2, 4, 6, 8	*Intermediate values*

where K stands for the number of decision makers, $z_i(k)$ for the priority of i-th alternative for k-th decision maker, α_k for the 'weight' of k-th decision maker, and z_i^G for the aggregated group priority value. Notice that weights α_k should be additively normalized prior to their use in (1) and that the final additive normalization of priorities z_i^G is required.

The major advantage of AHP is that it involves a variety of tangible and intangible goals. For instance, it reduces complex decisions to a series of pair-wise comparisons, implements a structured, repeatable and justifiable decision making approach and build consensus (Srdjevic et al., 2007).

2.4. PARTICIPATIVE DECISION-MAKING AIDED BY THE AHP

Participants in the decision making process are identified with a help of representatives from the PWMC VV, the company which is mostly involved in Nadela's water management. To perform a decision-making process, a meeting was organized and invited 23 participants are briefed on the main problems in system management, on possible solving methodology and on the final intent of an experiment – to gather interested parties around the same table and try to solve common problem. In fact, it was easy to identify in advance several interest groups and parties that will act as subjects of the decision making process, and also to articulate their preferences implicitly before the decision–making session started.

During the initial part of a meeting, participants are explained to how to act in the decision-making session and participate in reaching a consensus about strategy that will ensure well balanced system use and satisfaction of prescribed system purposes and users' expectations, but also that will respect defined system capacity and wider interests of a society. After short discussion, most important decision making issues were elaborated, the decision elements are identified, and the hierarchy of a problem is set-up as given in Figure 4.

A criteria set on the second level of hierarchy includes three main aspects of the water management within the region, recognized by involved participants, namely Economic, Social and Environmental (Ecological). Consensus on number and importance of criteria was easy to achieve.

Different water uses (management categories) are set on the next lower (third) level of the hierarchy: IR (irrigation), DR (drainage), UW (used waters), IS (industrial supply), and OP (other purposes). Worthy to notice is that these five uses are not decision elements in their nature, such as criteria or alternatives, but they are important constituents of the final solution.

At the lowest (fourth) level, four decision alternatives are posted representing possible management strategies for the 10-year period (2006–2015).

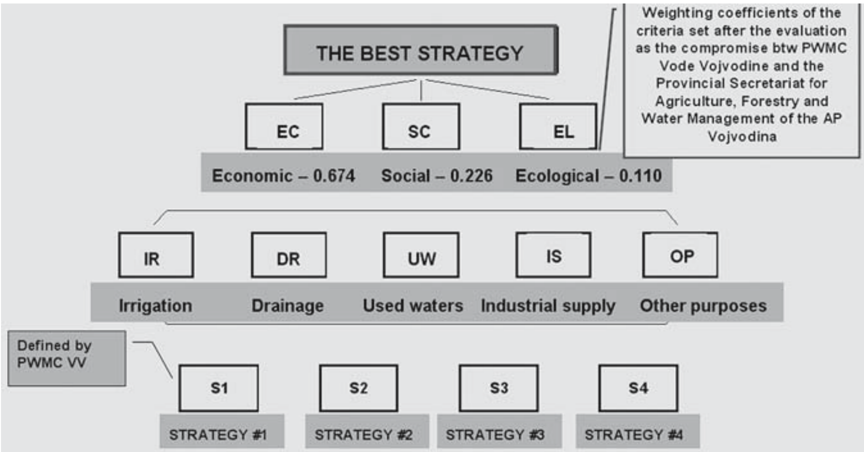

Figure 4. Hierarchy of the decision problem.

STRATEGY #1	STRATEGY #2	STRATEGY #3	STRATEGY #4
IR – top	IR – medium	IR – medium	IR – low
DR – medium	DR – top	DR – low	DR – medium
UW – low	UW – low	UW – top	UW – low
IS – medium	IS – medium	IS – medium	IS – top
OP – neglectible	OP – low	OP – low	OP – neglectible

Figure 5. Water management strategies (2006–2015) as decision alternatives.

Strategies are adopted by all participants according to justification provided by the PWMC VV and global notion of importance of 5 different categories of water use at the upper level of the hierarchy. From the Figure 5, one can easily see that in each strategy one of the purposes of the system is assumed to have dominant priority, and that some purposes have tied priority.

Priorities among water uses in stated strategies are defined considering actual status and expectation that priorities will remain the same in the first 5 years (2006–2010). For simplicity, which does not bound general approach, in this assessment it is assumed that same preferences among water uses will remain unchanged until 2015; otherwise, certain AHP assessments should be repeated with new knowledge about 'power' of specific decision elements.

2.5. GROUP DECISION-MAKING AIDED BY THE AHP

Phase #1

A session started with a 15 minutes brainstorming during which all participants exposed their individual judgments about relative mutual importance of the three selected criteria. All 23 participants (Decision Makers – DMs) used Saaty's ratio scale (Table 1) to express their semantic preferences while comparing criteria in pairs. Corresponding numerical values from the scale are then geometrically aggregated for all participants and rounded numerical values are presented in Figure 6.

Resulting weights of criteria are derived within the AHP by the eigenvector method and presented in Table 2.

Phase #2

All 23 DMs performed pair-wise comparisons of elements at the third and fourth level of a hierarchy by judging elements in one level regarding elements in higher level. That means that each DM filled-in eight comparison matrices: three 5 × 5 matrices for comparisons of water uses against three criteria, and five 4 × 4 matrices for comparisons of four offered strategies against five water uses.

An example judgment matrix presented at Figure 7 is obtained by the DM1 - PWMC VV while comparing elements at the third level of hierarchy against criterion Ecology posted at the second level (cf. Figure 4).

The resulting local weights of water uses are again automatically derived by the eigenvector method, and in turn, the AHP calculated the final weights of strategies.

Criteria v Goal

	EC	SC	EL
EC		4	5
SC			3
EL			

Figure 6. 'Rounded' group judgments after the brainstorming.

TABLE 2. Criteria weights.

Criterion	Weight
Economic (EC)	0.674
Social (SC)	0.226
Ecological (EL)	0.110

Figure 7. Example judgments made by the DM1. (Public Water Management Co. Vode Vojvodine.).

Purposes v Ecology

	IR	DR	UW	IS	OP
IR		1	3	4	1/2
DR			5	6	7
UW				5	9
IS					1/5
OP					

Phase #3

Individually derived weights of strategies are aggregated after 23 individuals are logically 'allocated' to 5 interest groups as follows:

Group 1: Irrigation (5 participants)

Group 2: Used waters (3)

Group 3: State/public interest (7)

Group 4: Industry (4)

Group 5: Local authorities (4)

'Allocation criteria' included participant's affiliation, responsibility and present professional (or political) function related to water resources and/or Nadela region. Aggregation outcome is summarized in Table 3; notice that it was assumed that participants in each particular group are of the same importance.

Phase #4

Finally, group decisions are aggregated into the so-called 'grand decision'. That is, column vectors presented in Table 3, containing weights as a result of aggregations made for each group, are aggregated as shown on Figure 8 into the 'grand vector' given in Table 4. Different importance is assigned to the groups according to their real financial input to present system operation and regular annual investments (basic maintenance of levies, embankments, bridges, spillways, pumps etc.).

TABLE 3. Aggregation of individually obtained weights of assessed alternative strategies at the group level.

	Group 1 (irrigation)	Group 2 (used waters)	Group 3 (state/ public interest)	Group 4 (industry)	Group 5 (local authorities)
Strategy 1	0.668	0.047	0.133	0.055	0.157
Strategy 2	0.187	0.050	0.056	0.087	0.032
Strategy 3	0.118	0.547	0.487	0.116	0.582
Strategy 4	0.027	0.356	0.324	0.742	0.229

Figure 8. The final aggeration of group AHP assessments.

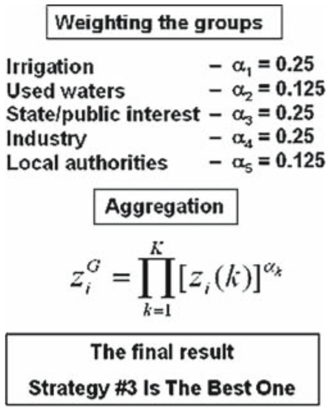

TABLE 4. The final weights strategies and ranking.

	Final weight	Rank
Strategy 1	0.211	3
Strategy 2	0.115	4
Strategy 3	0.365	1
Strategy 4	0.306	2

3. Conclusions

The final ranking of four alternative strategies seems to be fully justified by inherent priorities of water uses. Namely, under 'winning' strategy #3, top priority is at UW – users waters, second priority is a tie of IR – irrigation and IS – industrial supply, while the lowest priority is a tie of DR – drainage and OP – other purposes. The final preference of strategy #3 also comes from a weighting scheme applied to five selected interest groups (cf. Figure 8); state/public representatives, irrigators and industrial people carry 75%, and remaining two interest groups carry 25% of total power in synthesizing the grand decision. Notice also that although irrigators (Group 1) much more prefer strategy #1 vs #3, in the final aggregation this preference is suppressed by preferences of other groups.

Shadow, but very important, argumentation is that strategies with drainage (DR) as a top or medium priority water use are ranked as less desired. These are strategies #1 and #2 and it is obvious that participants considered drainage (DR) as almost solved problem (water taxation is well established and payments are collected regularly), while other water uses (OP) were probably not highlighted enough during the brainstorming phase. In general, people do not associate high priorities to something denoted as 'other(s)', so the result obtained is once more justified.

In conclusion it could be said that developed decision model based on AHP appears to be acceptable framework for multicriteria modeling of water management problems. Its practical use to support participatory decision process in part of managing waters in Vojvodina Province was successful which recommends this model for further use and more profound implementation in real-life situations.

Authors believe that proposed multilevel participative decision-making model offers new opportunities in sustainable regional water management in general, and at least in situations similar to those analyzed here. New researches devoted to coupling standard multicriteria decision-making methods with voting methods from Social Choice Theory (Srdjevic, 2007) provide also additional means and supporting tools in this field.

Acknowledgment

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SUPPORTING TOOLS FOR DECISIONAL PROCESS WITHIN WATER FRAMEWORK DIRECTIVE: FROM EU CONTEXT TO MODELKEY PERSPECTIVE

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Abstract: The European Water Framework Directive (WFD; 2000/60/CE) prescribes a series of tasks for properly assessing and managing river basins with the ultimate aim of protecting and restoring the overall quality status of European surface waters by 2015. In this context, Decision Support Systems (DSSs) and tools are needed providing water managers and decision makers with specific functionalities for integrating environmental and socio-economic factors, for comparing and selecting management alternatives, for assuring stakeholders involvement and participation, for communicating and visualising results in a transparent and simple way. Currently, different DSSs are available addressing specific assessment and management needs within WFD. In particular, a risk-based DSS is under development within the MODELKEY EU project (2005–2010) whose main objectives are (i) to evaluate risks posed by pollutants and other stressors on aquatic ecosystems by interlinking exposure/effect models and testing tools, (ii) to integrate environmental and socio-economic information for targeting management actions and (iii) to facilitate groups of experts and stakeholders involvement. The main outcome of the system is the calculation of Integrated Risk Indices (IRI) based on Weight of Evidence approaches and Multi-Criteria Decision Analysis. Although the MODELKEY DSS responds to WFD requirements, it is a flexible system adaptable also to other legislative contexts.

A review of developed or in progress systems and tools supporting WFD implementation is presented and the main functionalities and technical features of the MODELKEY DSS software are described.

Keywords: Decision Support Systems; Water Framework Directive; Integrated Risk Indices

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 215–225.

1. Introduction

The European Water Framework Directive 2000/60/CE (WFD; EC, 2000) establishes for the first time a common legislative framework for Integrated Water Resource Management (IWRM) in Europe. The Directive entered into force in 2000 requiring Member States to properly assess and manage water bodies in river basins in order to protect and improve water quality as well as to ensure sustainable use. It specifically recommends achievement of good ecological and chemical status of surface waters (rivers, lakes, coastal and transitional water bodies) as well as groundwater by the end of 2015.

The WFD contains some innovative concepts in comparison with previous European water legislation. It introduces the "river basin district" described as *the area of land and sea, made up of one or more neighbouring river basins together with their associated groundwaters and coastal waters, which is identified under Article 3(1) as the basic management unit of river basins*. In such a way it removes all administrative limits in the water management and it guarantees the unified management of all water bodies (national and international water bodies). Moreover, it defines "water body" as *a discrete and significant element of surface water* representing the assessment unit to which the environmental objectives established by WFD must apply. In fact, at the water body level the "ecological status" has to be evaluated and classified by considering structure (e.g. richness, abundance) of biological communities as key element and physico-chemical, chemical as well as hydromorphological information as supportive elements (see for an overview Heiskanen et al., 2004). From a water quality management point of view, the Directive promotes a combined approach based on environmental quality standards and emission limit values; it requires authorizations for all groundwater abstractions (unless minimal) in order to guarantee the conservation of water quantity; it incorporates the "polluter pays principle" through a set of measures for the charging of water use. Finally, the WFD requires public participation and involvement of stakeholders (i.e. all the private, public and non governative associations that are involved in the management of water bodies and whose interests can be conflicting) as key aspect of the river basin management process.

In order to bridge the gap between actual conditions and expected good status, water managers are asked for defining a set of management measures and for preparing and implementing the River Basin Management Plan (RBMP) by the end of 2009. For this purpose a series of assessment tasks with prescribed deadlines have to be accomplished according to the River Basin Management Planning Cycle (EC, 2003). This process starts with the identification of river basin districts, based on hydrological catchment, and of related competent public authorities moving on with water bodies and reference sites identification, pressures and impacts analysis, economic valuation of water uses, setting up of monitoring programs, status classification. In 2015 a first evaluation of management results have to be performed, after which the cycle can be started again. During the whole process, public participation must be guaranteed.

In order to assure the effective implementation of the WFD by Member States, a Common Implementation Strategy (CIS) was agreed in 2001 providing guidance documents and promoting harmonisation across EU Member States.

In spite of this, the WFD implementation keeps on representing a challenge for water managers because of many different tasks they have to accomplish in a strict timetable. In particular, the Directive calls for integrating water quality and socio-economic issues in taking decisions on management alternatives. In addition, the variety of stakeholders have to be managed by assuring participation of all interested groups and by communicating results in a transparent and simple way. Such complexity could be faced by decision makers and water managers by relying on decision support tools. Dietrich et al. (2004) specifically outlined reasons of demand for decision support tools in WFD implementation process, which are:

- a spatial distributed system;
- different temporal scales;
- a large variety of data and information provided by different disciplines;
- interactions between local measures and regional management strategies;
- interactions between local and regional authorities;
- use of models and expert judgement in forecasting of ecological consequences of measures;
- costs/benefits analysis of different management alternatives;
- planning of monitoring programs;
- public information, consultation or active involvement.

In this context, decision support tools are able to provide specific functionalities varying from information gathering and integration, learning, results communication and GIS-based visualization as well as management scenarios comparison. Moreover, such tools can be interlinked within a comprehensive Decision Support System (DSS), i.e. a system that helps decision makers in structuring and evaluating decisions by providing easy-to-use and integrated tools for information elaboration and displaying (Loucks, 1995; Shim et al., 2002; Watkins and McKinney, 1995). This way, DSSs are able to automate the decision-making process, making it flexible, repeatable, changeable, traceable and transparent.

The general objective of this paper is to provide an overview of the main characteristics of existing DSSs for integrated assessment and management of river basins in European countries. Although some DSSs have been recently developed in order to partially respond to WFD obligations, they represent examples of best practices in implementing decision supporting tools generally adaptable and applicable to other legislative context dealing with IWRM issues. In particular, a risk-based DSS is presented which is currently under development within the MODELKEY project (MODELs for Assessing and Forecasting the Impact of Environmental KEY Pollutants on Marine and Freshwater Ecosystems and Biodiversity). The project extends over five years (2005–2010) and is funded by the Sixth Framework Programme of the European Union (see for details Brack et al., 2005). In this paper, a brief description of the risk-based conceptual framework as well as the main technical features of the MODELKEY DSS are reported.

2. Overview of existing DSSs for water assessment and management in Europe

Many Decision Support Systems (DSSs) are currently developed or in progress for integrated assessment and management of water resources in Europe. Specifically, some of them have been recently adapted or fully built in order to support the implementation of the European Water Framework Directive 2000/60/CE (WFD; EC, 2000).

In general, the majority of the DSSs analysed in this overview adopts the DPSIR (Driving forces, Pressures, State, Impacts, Responses) framework as the conceptual scheme of reference. This framework was developed by the European Environment Agency (EEA, 2003) and has been identified by Rekolainen et al. (2003) as instrumental within the implementation of the WFD because different tasks required by WFD refer directly to the elements of the DPSIR framework. An example is the MULINO DSS (Giupponi, 2005) where the implementation of the WFD into the DPSIR framework allows to calculate pressures, impacts and state of the river of interest through specific indicators which are then integrated by means of Multi Criteria Decision Analysis (MCDA; Kiker et al., 2005).

Most of considered DSSs can be viewed as management tools. Some systems are specifically developed for dealing with water resources planning or protection against floods while other systems are aimed at guiding river quality improvement and restoration. More precisely, within such DSSs models for environmental assessment are integrated with socio-economic analysis in order to compare and evaluate different management alternatives in terms of environmental consequences on water quality and quantity as well as of socio-economic costs and benefits. Therefore, DSSs analysed in this review tend to provide end users with two main functionalities, i.e. integration capabilities and management scenario evaluation. As an instance, the Elbe-DSS (de Kok and Kofalk, 2006) is designed to assist competent authorities in defining the programme of measures for the German part of Elbe river basin in order to improve socio-economic use (e.g. navigability), to define sustainable level of flood protection, to enhance ecological status, to reduce pollution loads. It is based on a modular structure composed of various simulation models developing scenarios and assessing impacts of measures on socio-economic functions, natural functions and infrastructure. Conversely, AQUATOOL (Andreu et al., 1996) was developed for planning of hydrological resources in Spain by means of modules simulating water availability, water demand and optimization of water uses. In addition, the Water Strategy Man DSS (Peruffo and Todini, 2004) is a more complex system allowing water resources planning especially in water deficient arid and semi-arid regions. The software provides a set of models and interactive tools allowing simulation of alternative scenarios of water availability and water demand as well as comparison of alternative policy measures.

Other systems are intended to be used as information and assessment tools without providing functionalities for management scenarios comparison. An example is the River Life DSS (Karjalainen and Hekkinen, 2005) which was developed in Finland for intensify water pollution control. It contains information packages on tools and methods and it is specifically used for describing non-point sources deriving from different land uses as well as for evaluating ecological and hydrological conditions of the river environment.

In the light of integration efforts and establishment of management strategies, the majority of the DSSs are focused on river basin and catchment scales. Among others, the TRANSCAT DSS is directed to promote cooperation and to assist in the integrated management of European borderland regions in the context of the WFD. The DSS prototype is built with a modular structure allowing simulation of different climatic, socio-economic, environmental and topographic conditions of various European transboundary catchments in order to help in choosing among decision alternatives (Horak and Howsinski, 2004). The Elbe-DSS instead works on different spatial scales, from catchment scale to small river sections, which are linked through analysis results.

Another key aspect of these systems is the wide use of visualization and elaboration tools, such as GIS (Geographic Information System), which is very often included and used to support the management of a heavy amount of information, to perform spatial analysis, to verify management options.

These specific DSSs are often referred to as Spatial Decision Support Systems (SDSS; Dietrich et al., 2004). For example, the FLUMAGIS DSS (Moltgen and Rinke, 2004) developed in Germany has a powerful visualization performance by using in a GIS-environment 2D and 3D-geodata supporting management measures prognosis and planning.

It is worth noting that the most recent and innovative trend in developing decision support tools is implementing Web-based DSSs (Power, 1998). As highlighted by Power (2000), they are capable to reduce technical barriers making exchange of decision-relevant information more transparent, easier and less costly, increasing access to and use of decision tools, promoting rapid dissemination of best practices. For example, the River Life DSS is developed as Web-based infrastructure aiming at facilitating all interested parties in decision making process to find information on rivers.

Finally, as far as the availability and the development status is concerned, some of these systems are still under development (e.g. Elbe-DSS, FLUMAGIS DSS) or delivered as prototypes (e.g. TRANSCAT DSS); others systems, like AQUATOOL, River Life DSS and MULINO DSS, are instead ready and downloadable from their related websites.

3. The risk-based MODELKEY DSS

The MODELKEY (MODELs for Assessing and Forecasting the Impact of Environmental KEY Pollutants on Marine and Freshwater Ecosystems and Biodiversity) project (2005–2010) was funded by the European Sixth Framework Program gathering 26 partners from 14 Member States (see http://www.modelkey.org). The ultimate goal of the project is to develop a risk-based Decision Support System (MODELKEY DSS) integrating a set of models and testing tools in order to assist decision makers and water authorities in assessing and managing river basins according to the EU Water Framework Directive 2000/60/CE (WFD; EC, 2000) regulations. Specifically, the main objectives to be achieved by the MODELKEY DSS are (i) to evaluate risks posed by pollutants and other stressors on aquatic ecosystems (ii) to integrate environmental and socio-economic information for targeting management actions and (iii) to facilitate groups of experts and stakeholders involvement. In order to achieve these goals, the DSS provides and interlinks tools delivered by other project partners, i.e. exposure models (e.g. sediment erosion and stability, bioaccumulation through the food web), effect models (e.g. prediction of effects on higher biological levels, key toxicants identification and stressors diagnosis) and risk models (e.g. risk indices at basin and hot spot scale) as well as testing tools (e.g. effect-directed analysis based on *in vivo* and *in vitro* effects).

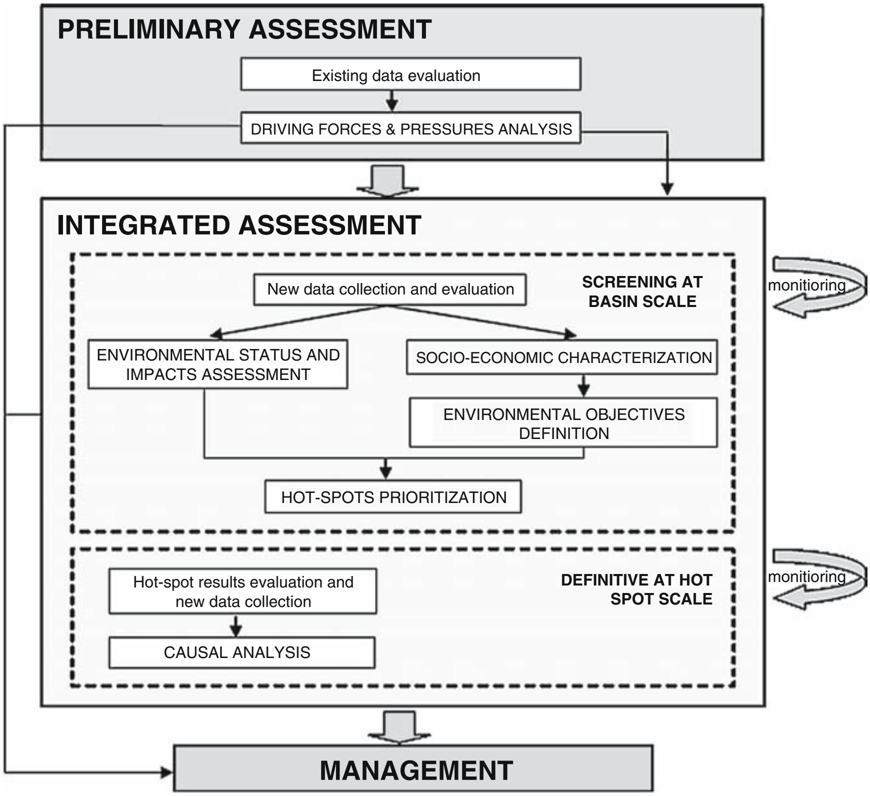

Figure 1. A simplified version of the MODELKEY DSS conceptual framework.

To date, the conceptual framework of the MODELKEY DSS describing functionalities, tools and outputs supplemented by the system has been defined. It represents a risk-based DPSIR framework fulfilling each element of the chain by means of risk assessment methodologies and tools. A simplified version of the framework is visualized in Figure 1.

It is evident that the MODELKEY DSS is mainly an assessment system whose functionalities focus on supporting water managers in carrying out assessment activities required by WFD. In fact, the overall goal of the assessment process supported by the MODELKEY DSS is to estimate the risk that water bodies will fail to achieve their own specific environmental objectives by integrating environmental and socio-economic information. In order to accomplish this task, a tiered risk-based procedure composing of two main assessment phases (i.e. Preliminary and Integrated Assessment phases) was defined allowing end users to make an effective use of available data at basin scale in order to focus further investigations on selected hot spots. Each assessment phase leads to calculate a set of Integrated Risk Indices (IRI) which will provide decision makers with relevant information for management purposes.

In particular, the Preliminary Assessment (PA) phase aims at identifying relevant driving forces and pressures acting on the river basin of interest. Initially, the system will support end users in collecting and exploring existing environmental and socio-economic data in order to identify gaps in spatial and temporal distribution of information. Then, existing socio-economic data and information are analysed in order to identify key driving forces at basin scale. Finally, a preliminary and conservative evaluation of the river basin environmental conditions is undertaken by means of Regional Risk Assessment (Landis, 2005) in order to identify significant pressures that may cause impacts over the river basin as well as to highlight which water bodies could be of major concerns and which sites could represent potential references.

In the MODELKEY DSS conceptual framework the outputs of the PA phase are input for the subsequent Integrated Assessment (IA) phase, which is the most complex one of the whole process. In fact, it is structured into two stages considering different spatial scales: the Screening Assessment (SA) stage at basin scale and the Definitive Assessment (DA) stage at hot spot scale. Consequently, the IA phase requires a combination of functionalities and related methodologies to be effectively implemented.

Specifically, the ultimate objective of the SA stage is to prioritize hot spots in need of management by integrating both environmental and socio-economic components. In case of data gaps highlighted in the previous PA phase, the system will initially support end users in collecting additional environmental and socio-economic information over the basin of interest by means of monitoring guidelines. After updating database, ecological and chemical status of water bodies is evaluated and classified according to the five quality classes proposed by WFD (i.e. high, good, moderate, poor and bad). To this end all available biological, chemical, toxicological, physico-chemical and hydromorphological data are integrated according to a Weight of Evidence approach (Burton et al., 2002). Moreover, a socio-economic characterisation of water uses (e.g. agricultural, industrial, residential, recreational uses) is carried out and integrated with results of the previous PA phase in order to define reasonable and practical environmental objectives to be achieved for each water body. To this end the MODELKEY DSS will support involved decision makers and stakeholders in eliciting and structuring their preferences and knowledge by means of Multi Criteria Decision Analysis (MCDA; Kiker et al., 2005). Finally, hot spots are prioritized by comparing environmental and socio-economic results and selected by means of GIS tools.

The DA stage specifically aims at investigating causal relationships in order to identify stressors and/or pollutants causing the detected impacts at hot spot scale. The MODELKEY DSS will initially allow to summarize and evaluate all results related to the selected hot spots in order to provide end users with guidelines for collecting appropriate monitoring data. Then, by applying diagnostic tools developed within the MODELKEY project and by integrating results according to a Weight of Evidence approach (Burton et al., 2002), causal relationships between specific stressors and organisms are quantified and evaluated.

It is to be pointed out that the whole assessment process implemented by the MODELKEY DSS can also be used for management scenarios development, e.g. by modifying input data according to efficiency of a certain restoration measure in order to forecast consequences on selected hot spots.

The software system of the MODELKEY DSS is currently under development. It will be implemented in an open source-GIS environment and will be freely accessible via Web. Moreover, the system will be characterised by an "open configuration" making end users able to connect external models providing additional functionalities.

4. Conclusions

The WFD requires to accomplish different assessment and management activities in order to achieve a good ecological status across European surface waters.

During last years many DSSs were developed or adapted with the aim of supporting decision makers and water managers in tackling such problems. The overview of existing DSSs described in this paper highlighted some generalities that can be attributed to DSSs for WFD-compliant river basin management. In particular, if the system is intended for use as a management tool, it is necessary that the functionality of scenarios' construction and comparison is provided. Conversely, if the system is simply used as an information or communication tool, other aspects must be emphasized, such as models integration capability, user interface and wide accessibility. In this context, the MODELKEY DSS is intended to be mainly an assessment system providing a set of functionalities and information (e.g. hot spots, key stressors) able to target management actions and to develop management scenarios. Moreover, it is to be pointed out that in order to address outputs and technical features of the system to the needs and expectations of end users, a close communication between scientific and policy communities is needed during the whole development process. In fact, lack of interactions between these two spheres could lead to develop useless tools which will never be applied for supporting decision making process. Finally, it is worth underlying that although the MODELKEY DSS aims at guiding water managers in meeting WFD obligations, it is a flexible system whose functionalities are generally adaptable and applicable also to other legislative contexts.

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APPLICATION OF WATER QUALITY MODELLING AS A DECISION SUPPORT SYSTEM TOOL FOR PLANNED BUYUK MELEN RESERVOIR AND ITS WATERSHED

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Abstract: Istanbul, the largest metropolis of Turkey and one of the most crowded metropolises in the world, is facing the risk of water scarcity. Analyses indicated that one of the alternative solutions coping with this problem is water transfer from a watershed that is located outside the administrative boundaries of Istanbul. Due to its water potential and relatively less degraded water quality, Buyuk Melen Watershed was considered to be the most feasible option. As the result of analyses, State Hydraulic Works (DSI) has planned construction of a reservoir in the Buyuk Melen Watershed to supply the required amount of water for Istanbul also in low flow seasons. Since the reservoir will be located at the downstream region of the watershed, its water quality will be affected by human-induced activities, thus measures need to be taken to prevent pollution prior to reservoir construction. Quantifying the response of the planned reservoir to external pollution loads is an important step in the planning and management of the watershed. Mathematical modelling is a useful tool for estimating the future water quality and understanding the possible responses of the reservoir to various pollution loads. In this study, a water quality model capable of simulating hydrodynamics, transport and water quality in reservoirs is used for preliminary estimation of possible impacts of several management options in the watershed. Model results indicated that, all of the point sources in the watershed must be controlled by advanced wastewater treatment and should be diverted from the streams and the planned reservoir. Model results also indicated that reduction of agricultural diffuse loads by 30–40% is expected to have a perceptible improvement of reservoir water quality.

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Keywords: CE-QUAL-W2; reservoir water quality modelling; scenario analyses; Melen Watershed

1. Introduction

The mega city Istanbul that served as the capital of ancient Byzantine and Ottoman Empires has been relatively large and densely populated in the past millennium, and therefore water scarcity is not a new problem in Istanbul. It is known that usually the best architects and engineers of their era were assigned to solve the water shortage problem of Istanbul.

In the 21st century several solutions such as more efficient use of water, optimization and rehabilitation of existing water resources, optimization of water distribution and decreasing the water losses along water distribution networks, reuse of water, and inter-basin water transfer exist to cope with the water scarcity problems. All these options were considered by the Istanbul Water Supply and Wastewater Disposal Master Plan (IMC, 1999) as part of the water scarcity solution of Istanbul and relevant components of the mega city's water supply system are designed and planned accordingly. The water authorities decided that an inter-basin water transfer is necessary for the mega city. Water supply from Buyuk Melen Watershed, located approximately 180 km away from the city (Figure 1) is considered as the most feasible option for inter-basin water transfer to Istanbul due to its water potential and relatively less degraded water quality.

Buyuk Melen River is regarded as the major water resource that can compensate Istanbul's water demand in the future. In the Istanbul Water Supply and Wastewater Disposal Master Plan (IMC, 1999), it is estimated that more than 52% of Istanbul's water will be supplied by the Buyuk Melen

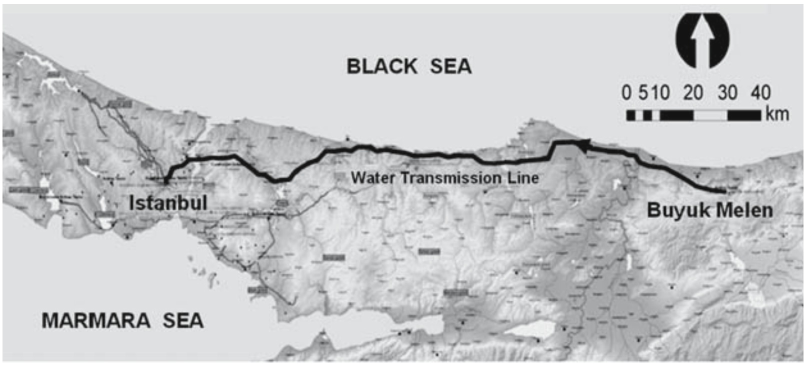


Figure 1. Location of the Buyuk Melen Watershed.

System after 2010. Great Istanbul Drinking Water 2nd Stage Project of Buyuk Melen System is being carried out by the State Hydraulic Works (DSI) to supply water to Istanbul. Comparison of Buyuk Melen River with the other available water resources of Istanbul is illustrated in Figure 2.

Besides quantity, water quality is also an important aspect in water supply issues. Therefore, Buyuk Melen Watershed Integrated Protection and Water Management Master Plan, which is an integrated management effort aiming to protect, improve and maintain the water quality of the Buyuk Melen River was initiated as a subcomponent of the Buyuk Melen System Project. Buyuk Melen Watershed Integrated Protection and Water Management Master Plan consists of three main components; water quality management, wastewater management and solid waste management. Water quality management aims to make sure that the quality of water in the watershed is improved regarding its beneficial use through regular quality monitoring and control. The master plan studies are being conducted by the Department of Environmental Engineering of Istanbul Technical University (ITU) and DSI.

According to Istanbul Water and Sewerage Administration (ISKI) Master Plan $35\,m^3.s^{-1}$ water will be transferred from Buyuk Melen Watershed to Istanbul in year 2039. Analyses jointly conducted by DSI and ITU indicated that the construction of a relatively large reservoir at the downstream region of the watershed is necessary to supply such an amount of water without interruption throughout the year to Istanbul. Therefore, the water quality of this planned reservoir is evaluated within the context of Buyuk Melen Watershed Integrated Protection and Water Management Master Plan, which covers the measures need to be taken to prevent the water quality degradation in the watershed. The quality of water in the planned reservoir is the success criteria of these measures, which requires heavy investments.

There are different methods for water quality evaluation, based on water quality monitoring, trend analyses or water quality simulation for existing water bodies. However, Buyuk Melen Reservoir is at the planning stage,

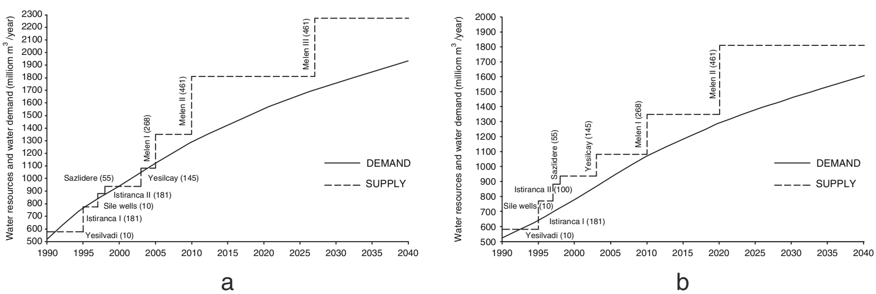


Figure 2. Istanbul water supply master plan supply/demand curves.
(a) High growth scenario, (b) low growth scenario. (IMC, 1999.)

and the investments and constructions for water quality protection have to be initiated before the construction of the Buyuk Melen Dam in order to protect the future water quality and provide the reservoir to operate under appropriate initial water quality conditions. This will also prevent the risk of the future water quality restoration costs and efforts in the reservoir.

Since the Buyuk Melen Reservoir does not exist, the most plausible method to evaluate its water quality is based on water quality simulation. In this study, a water quality model is used to estimate the effects of future measures of pollution sources on water quality. The main target of the planned Buyuk Melen Reservoir is water supply, whereas hydropower generation was also considered as an additional benefit. Therefore, the main water quality objective is the prevention of eutrophication, which increases the water treatment costs and may lead to anoxic conditions in the deeper region. On the other hand, anoxic conditions have a potential harmful impact on dam and reservoir equipment and structures.

2. Planned Buyuk Melen Reservoir and its drainage area

Buyuk Melen Watershed is located at the western part of the Black Sea Region (latitudes 41°5′00″ N to 40°40′00″ N and longitudes 30°50′00″ E to 31°40′00″ E) covers a total area of 2,437 km^2. The drainage area of the Buyuk Melen Reservoir (~2,300 km^2) covers most of the Buyuk Melen Watershed (Figure 3).

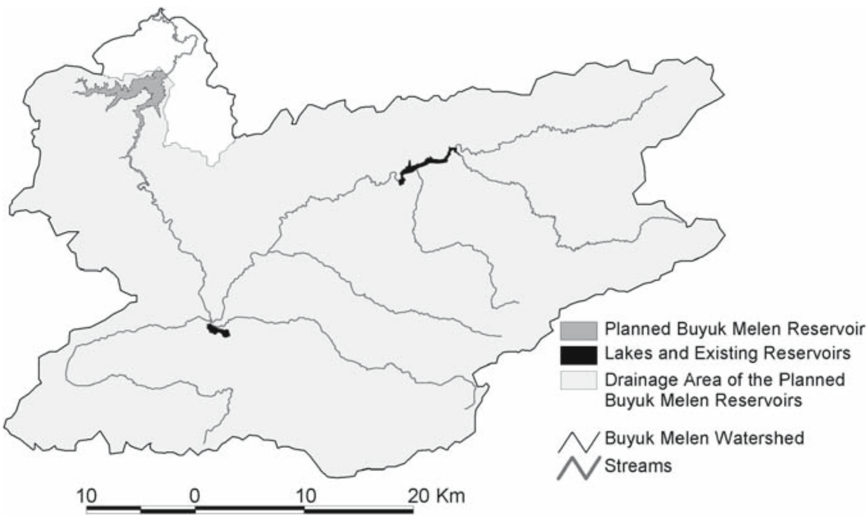


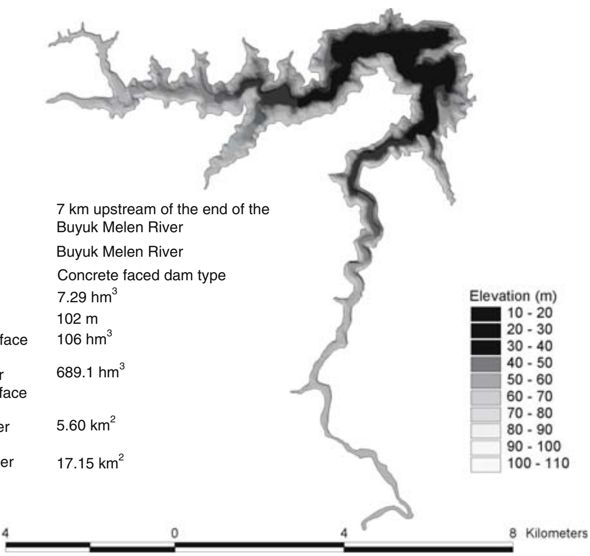
Figure 3. Buyuk Melen Watershed and the drainage area of the planned Buyuk Melen Reservoir.

Western Black Sea Region of the country has a transitional climate between Western Black Sea and Marmara Regions. Summers are hot, whereas winters can be either cold or warm. The presence of forests, lakes, rivers, as well as lack of high mountains along the sea coast cause high precipitation in the area. The Western Black Sea Region has the lowest rainfall among the entire Turkish Black Sea Coast. The highest and the lowest precipitation occur in fall and summer, respectively, and the annual average of precipitation varies between 700 and 1,000 mm. Monthly averaged long-term flow data published by DSI indicates that there are significant changes in flow throughout a hydrological year.

Bathymetry of planned Buyuk Melen Reservoir is generated by digitizing 1/25,000 scaled topographic maps. Both bathymetry and the technical specification of the reservoir obtained from DSI are illustrated in Figure 4. As seen in the figure, when it is constructed, Buyuk Melen Reservoir will be a deep and narrow reservoir with several branches.

3. Reservoir water quality model developments and application

Traditionally, water quality model development includes several steps like defining a mathematical construct for the model, modelling software selection and setup, development of the input data sets, model verification, calibration and validation. Once validated, the water quality model is used for simulating the effects of the different watershed and water quality management options on



Location	7 km upstream of the end of the Buyuk Melen River
Stream	Buyuk Melen River
Dam type	Concrete faced dam type
Dam volume	7.29 hm^3
Dam height from thalweg	102 m
Reservoir volume at minimum water surface elevation for water surface elevation	106 hm^3
Reservoir volume at the maximum water surface elevation for standard water surface elevation	689.1 hm^3
Reservoir surface area at minimum water surface elevation	5.60 km^2
Reservoir surface area at maximum water surface elevation	17.15 km^2

Figure 4. Bathymetry and technical specifications of the planned Buyuk Melen Reservoir.

the water quality by means of different scenarios. However, if the water quality data are scarce or do not exist at all and also if the water body which needs to be modelled does not exist or is subjected to heavy physical modifications, where all the transport and ecological behaviour will change, such as the case in this study, this traditional modelling approach cannot be applied directly. In these cases, model calibration and validation steps cannot be fulfilled, since there are no water quality data to compare the simulation results. Therefore, the kinetic and stoichiometric coefficients for the water quality model need to be estimated using other methods and/or simulation techniques. The overall procedure for the Buyuk Melen Reservoir water quality model development and scenario analysis followed in this study is illustrated in Figure 5.

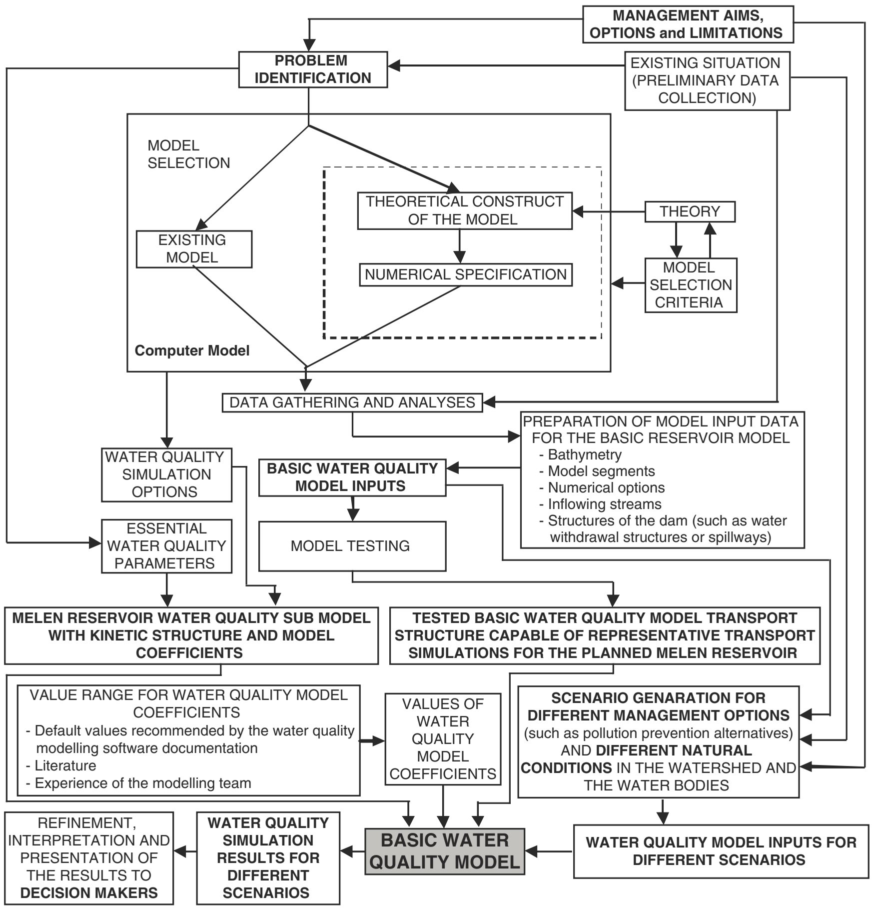


Figure 5. The overall procedure for the Buyuk Melen Reservoir water quality model development and scenario analysis.

3.1. MODEL STRUCTURE AND SELECTION

Buyuk Melen Reservoir is planned as a large, deep and narrow reservoir for water supply. Therefore, water quality models appropriate for this water body must be able to simulate reservoir hydrodynamics with all the effects of hydraulic structures and extremely dynamic water surface elevations which is subject to change several ten meters during one hydrological year.

Most of the reservoir basin will have a water depth of more than 20 m during normal operating conditions. The mean annual residence time estimated using average annual inflows, withdrawals and water surface elevation for standard operating conditions is around 180 days. A basic assumption reported by Martin and McCutcheon (1999) indicates that lakes tend to stratify if their mean depths exceed 10 m and their mean annual residence times exceed 20 days. Therefore, it is safe to assume that stable stratification conditions will be observed in the Buyuk Melen Reservoir.

The shape of the reservoir basin can be simplified to two main axes perpendicular to each other near the reservoir outlets. Their characteristic lengths are more than 10 km, and their depths are increasing continuously from upstream (several meters) to downstream (more than 90 m depending on the season), where the Buyuk Melen Dam is located. Therefore, the hydrodynamic and transport behaviour is expected to change spatially along the two main axes of the reservoir.

The reservoir basin is relatively narrow, not exceeding 1,500 m at its widest location and only several hundreds of metres for most of the system. This characteristic width is too small for the Coriolis force driven circulation to be effective. Lateral water quality gradients are also not expected at such small characteristic widths. The main stream inflows are entering to the reservoir are aligned parallel to the main axes, so that the main water mass and momentum inputs will be directed along the main axes. All these conditions indicate that only minor lateral hydrodynamic and water quality changes are expected that can be excluded from this study.

Taking into account the analyses summarized in the previous paragraphs, it is decided to use a longitudinal-vertical water quality model (the so-called x-z model) with hydrodynamic simulation capability. As stated previously, the main water quality objective is the prevention of eutrophication and anoxic conditions that may occur in deeper regions of the reservoir. Therefore, the essential water quality variables are defined as dissolved oxygen, nutrients (N, P species) and phytoplankton (chl-a).

Following criteria were considered during the selection of the water quality modelling system software:

- **Model capabilities**: The water quality model must be capable to simulate laterally averaged two dimensional hydrodynamics together with hydraulic structures. It must be adaptive to water level changes.

- **Scalability**: For the time being, the water quality sub-model must simulate dissolved oxygen, nutrient and phytoplankton. However, model application is a continuous process. The water quality model should be adaptable to future modelling needs, if new regulations are published. It should also be kept in mind that Buyuk Melen Reservoir does not exist yet, and new modelling requirements may arise because of any unexpected behaviour of the reservoir when it is constructed.
- **Applicability**: The model must be applicable with the existing modelling knowledge and monitoring infrastructure in Turkey. Data from the simulation outputs may need to be integrated with data related to other water resources serving Istanbul. On the other hand, needs for operational models for system optimization or emergency action may arise in the future. Therefore, a well documented and preferably open source water quality model is required. The simulation time is also important. For practical applications, a 1-year simulation and preparation of model outputs for further analyses should be completed in a short period of time (e.g. one working day).
- **Modelling costs**: Modelling costs are important especially in countries experiencing financial constraints such as Turkey. This study was done within a project with relatively limited budget that was used for gathering the data from different institutions. Therefore, the costs of modelling operations needed to be kept at minimum. Under these conditions it is necessary to use a water quality modelling software which is relatively cheap, preferably free.

Considering all these criteria it is decided to use CE-QUAL-W2 Version 3.5 (Cole and Wells, 2006) for this study. This water quality model is under continuous development by the United States Army Corps of Engineers and Portland State University since 1986. It is a longitudinal-vertical hydrodynamics and water quality model, which supports multi-branched systems and hydraulic structures. The model, its extensive user documentation and its source code can be obtained free of charge from the Portland State University, Department of Civil Engineering, Water Quality Research Group. The nutrient cycles, dissolved oxygen and phytoplankton (algae) kinetics used in CE-QUAL-W2 Version 3.5 is provided in Figure 6.

CE-QUAL-W2 Version 3.5 simulates dissolved oxygen, nutrients (nitrogen, phosphorus and silicon species), an unlimited number of carbonaceous BOD groups and an unlimited number of phytoplankton groups. These parameters provide simulations detailed enough to cover all the needs within this study. Apart from these parameters, inorganic carbon, alkalinity, pH, iron, unlimited number of macrophyte, epiphyton and zooplankton groups and four species of organic matter: labile dissolved organic matter (LDOM),

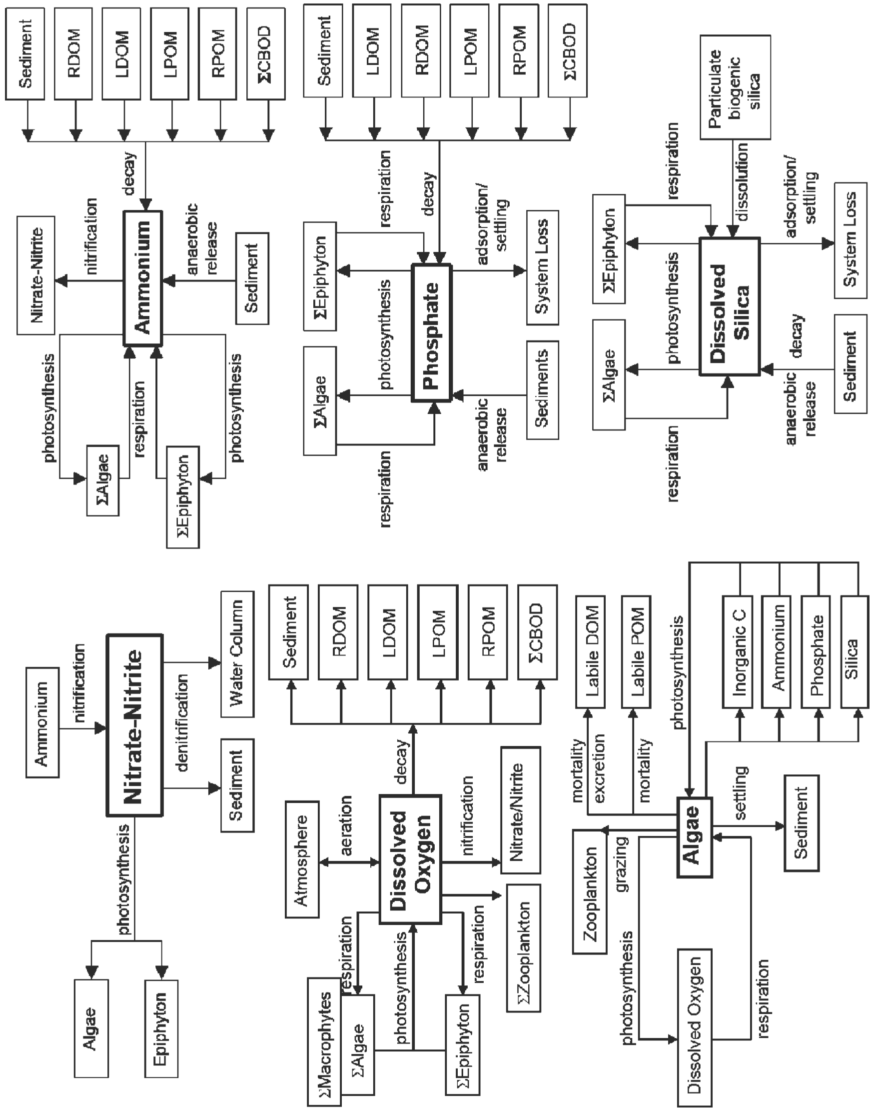


Figure 6. Nutrient cycles, dissolved oxygen and phytoplankton kinetics in CE-QUAL-W2. (Cole and Wells, 2006.)

labile particulate organic matter (LPOM), refractory dissolved organic matter (RDOM) and refractory particulate organic matter (RPOM), can be modelled. These additional parameters are switched off in this study using several options provided by the model, but they can be reactivated in the future if needed. Only one phytoplankton group is incorporated into the water quality model developed for the Buyuk Melen Reservoir. Other organisms are excluded from this study.

3.2. MODEL INPUTS

The most important model input for CE-QUAL-W2 is the model network together with bathymetry. The model network consists of water bodies, which can contain one or more branches. Branches consist of segments and segments consist of layers called cells. The model network generated for the planned Buyuk Melen Reservoir is illustrated in Figure 7. The entire reservoir basin was considered as one water body. The two main axis of the reservoir basin are defined as Branch 1 and Branch 3, respectively. The segments are divided into cells of 1 m depth.

The next part of the model input data set are the types, locations and specifications of the hydraulic structures in the reservoir. Buyuk Melen Dam, which is the most important structure, is located on Segment 64. According to the latest information obtained from State Hydraulic Works the reservoir will have two main outlet structures; the first being a gated spillway as a component of the dam and the second being a water intake structure located several hundred metres away from the dam but still in Segment 64.

Following the physical definition of the reservoir and the hydraulic structures, the next set of model inputs are the water quality modelling options and the model coefficients. As stated previously, determination of model coefficients with model calibration and validation is not possible since the reservoir itself and therefore water quality data related to it do not exist yet. In this case, three options are available. The first option is to use the default values given in the model documentation. The second option is to use the values for the model coefficient given in the literature for similar reservoirs. The third option is application of advanced simulation techniques such as Monte Carlo simulation and using the statistical distribution of values for model coefficients instead of a single value for each model coefficient. This technique combines the uncertainty analyses with existing knowledge related to model coefficients however a large number of simulations (several thousands) need to be completed. A 1 year simulation takes around 8–10 hours for the Buyuk Melen Reservoir; in this case 2,000 simulations (an average number of simulations needed for such

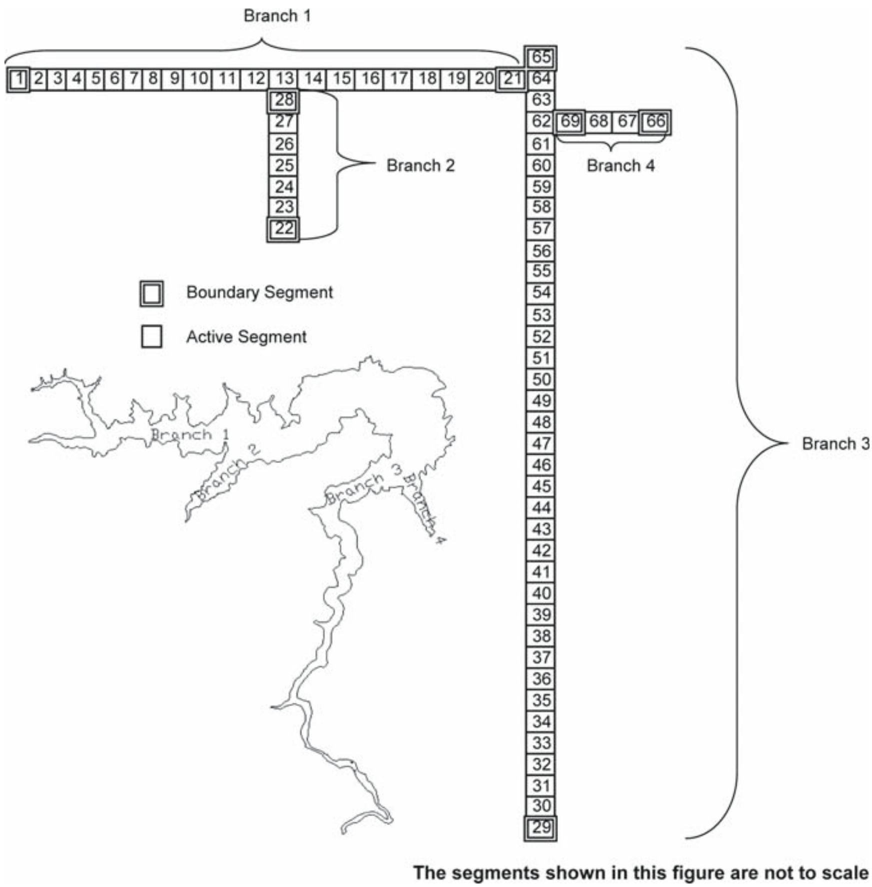


Figure 7. Model network for the planned Buyuk Melen Reservoir.

techniques) are expected to take around 750 days (more than 2 years) of computational time. Using a multi core computer processor such as Intel QUAD (four cores in one CPU), the simulations will still take around 6 months. Therefore, the third option was out of consideration for this study. A combination of the first and second options was used to generate a set of model coefficients.

Input related to the model network, types, locations and specifications of the hydraulic structures and the water quality model coefficients are independent of scenario. However, inflows into the reservoir, outflows, water withdrawals and nutrient and organic matter loads are scenario dependent. These model inputs are generated from the results of watershed and stream water quality modelling operations. The basic structures of these models are explained by Gurel et al. (2007) and Erturk et al. (2007).

3.3. SCENARIOS

Three scenarios are considered in this study. The first scenario is the so-called no action scenario in which it is assumed that no actions or pollution control measures are taken. This scenario does not represent any plans of the authorities or any real case. It is only considered as reference conditions for comparison to illustrate the benefits of pollution control actions. The second scenario concentrates on the impact of domestic and industrial wastewater on water quality. All the discharges except from two small districts are assumed to be diverted to downstream of the Buyuk Melen Dam. Wastewaters from the two small districts will be discharged to the streams in the watershed after advanced biological treatment. The diffuse loads (loads from agricultural land, forests, pasture and meadows, urban and rural runoff) however are not controlled. In the third scenario, measures for point sources are assumed to be the same as in the second scenario, and additionally diffuse nutrient loads from agricultural land and livestock breeding are assumed to be reduced according to the best applicable technologies and methods. Simulations for these three scenarios were done for the years 2024 and 2039 which represent different stages of Great Istanbul Drinking Water Supply Project.

In year 2024, a flow rate of $24.56\,m^3\,s^{-1}$ of water is aimed to be withdrawn to meet the water demand of Istanbul. However, it is determined that, at least the flow rate that will be exceeded with a probability of 99% ($4.5\,m^3\,s^{-1}$, under extreme conditions $2.25\,m^3\,s^{-1}$) has to be released in order to protect the ecological conditions at the downstream of the reservoir. In scenario 3, agriculture and livestock based nutrient loads are assumed to be reduced by 30%, which is stated in literature by Stolze et al. (2000) and FAO (2002).

A flow rate of $35.41\,m^3\,s^{-1}$ is assumed to be withdrawn from the reservoir in the year 2039 and at least $4.5\,m^3\,s^{-1}$ ($2.25\,m^3\,s^{-1}$ under extreme conditions) will be released from the reservoir to downstream. In scenario 3, agriculture and livestock based nutrient loads are assumed to be reduced by 40% which is stated in literature by Stolze et al. (2000) and FAO (2002).

3.4. SIMULATIONS

Simulations are done for three scenarios for the years 2024 and 2039. Each scenario was initiated with clean water conditions and run for 4 years with balanced inflows and outflows relevant nutrient and organic matter loads to ensure that the system became independent of initial conditions. The fifth year was run with outflows that represent the water withdrawal planned for the years 2024 and 2039. Figure 8 illustrates the vertical variation of chlorophyll-a concentration during the late spring (end of May-first week of June) peak of phytoplankton in Segment 64.The phytoplankton carbon to chlorophyll ratio was assumed as 25 mg C/mg chl-a.

As seen in Figure 8, high rates of primary production and high concentration of chlorophyll-a are expected on the water surface and in the euphotic zone of the reservoir, if no water pollution control measures are taken in the watershed. These high concentrations indicate hypertrophy in the reservoir. The water quality model also produced dissolved oxygen concentrations, which are higher than the saturation concentration. This phenomenon is a result of high rate of primary production and is observed in highly eutrophic systems.

According to the simulation results, preventing domestic and industrial wastewaters (Scenario 2) reaching to the reservoir provides significant improvements in terms of eutrophication control. Model results indicate that surface chlorophyll-a concentrations can be expected to drop by a factor of around 4 and further reduction can be achieved if the diffuse nutrient loads originating from agricultural land and livestock breeding are reduced by 30–40%.

CE-QUAL-W2 includes algorithms to estimate the composition of water withdrawn from water intake structure based on a vertical withdrawal zone. The vertical withdrawal zone is determined by the model. The model results for vertical withdrawal zone (Figures 9 and 10) present the expected quality of water, which will be supplied to Istanbul for the year 2024 and 2039.

As seen in Figures 9 and 10, the control of the point sources is expected to provide significant improvements in water quality, especially for ammonium nitrogen and phosphate phosphorus. The figures are corresponding to the results of vertically averaged water quality through the withdrawal zone. Small improvements of water quality are expected if agriculture and livestock based nutrients are controlled.

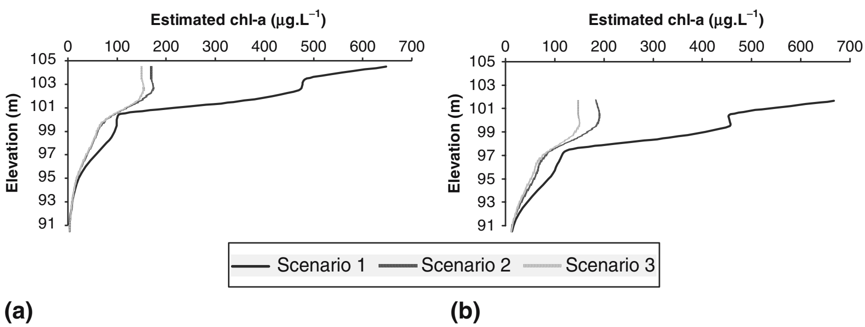


Figure 8. Vertical profile of chlorophyll-a during the late spring peak.
(a) Year 2024 (b) Year 2039.

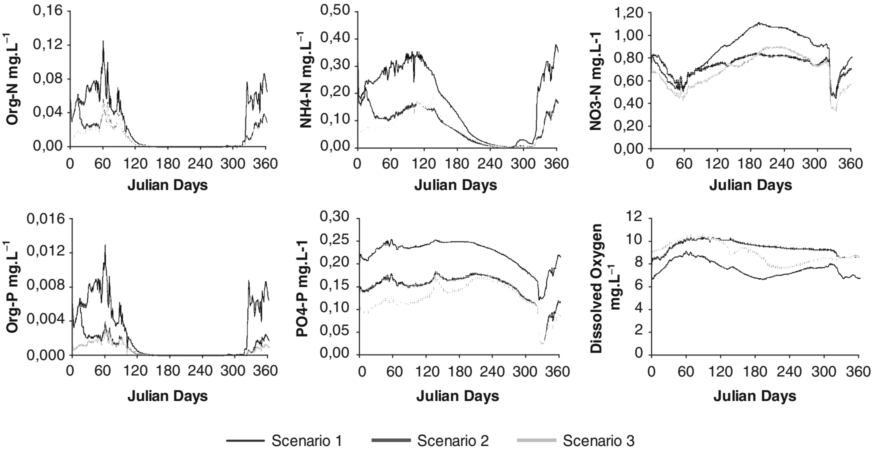


Figure 9. Expected quality of the withdrawn water in 2024 for three scenarios.

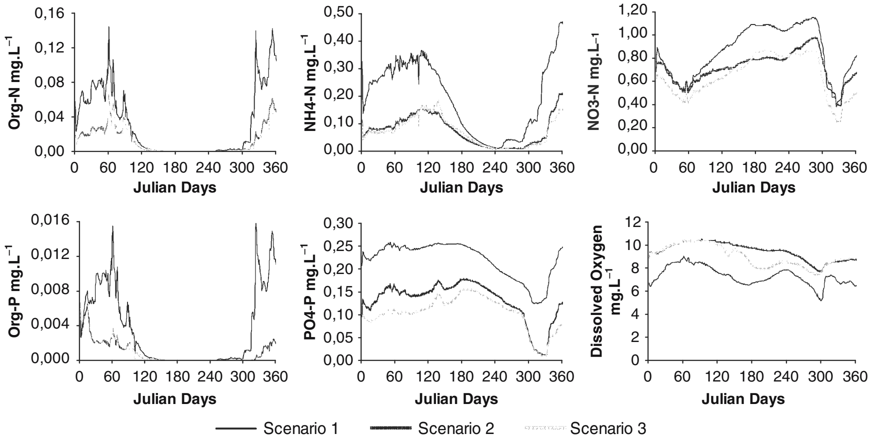


Figure 10. Expected quality of the withdrawn water in 2039 for three scenarios.

4. Results and discussion

Simulation results indicated that control of almost all domestic and industrial wastewater by preventing them entering the reservoir according to scenario 2 can provide significant improvement in the reservoir's water quality. In this scenario, two of the smaller districts in the watershed were assumed to discharge their wastewaters to the upstream of the reservoir, after advanced wastewater treatment including biological nutrient removal. It should be kept in mind that scenario 1 is for estimating the reference conditions to show what may be expected if no water pollution control measures are taken after the reservoir construction. It does not correspond to any plan of the water authorities responsible for the Buyuk Melen River or for supplying water to Istanbul. It is to illustrate the benefits of nutrient and organic matter pollution control by comparing its results with other scenario results.

Model results also indicated that control of agriculture and livestock based diffuse loads by 30–40% is expected have a positive effect in terms of combating eutrophication. However, for short periods relatively high rates of primary production and relative decrease of water quality may be expected during the phytoplankton peaks. These effects can be prevented by taking further measures such as control of the urban or rural runoffs, and application of eutrophication control techniques such as biomanipulation. However, more detailed studies are needed to quantify the benefits of these options.

It should be kept in mind that the modelling studies were conducted for a reservoir, which does not exist yet and using default or assumed model coefficients. Therefore, the results are useful for comparison purposes of different scenario alternatives and for actions on basic decisions related to water pollution control on feasibility analyses level. All the recommendations using these simulation results and also the water quality model itself is subject to further revisions as more data and results from other studies in the watershed will be available in the near future.

5. Conclusions

In this study, a water quality model was developed for the planned Buyuk Melen Reservoir and used as a decision support system tool for recommendations on the nutrient pollution load reductions within the watershed. The model produced material detailed enough for feasibility analyses illustrating both the risks if no environmental protection measures are taken on time (before the reservoir construction) and the benefits of two different levels of nutrient load reductions.

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THE USE OF NUMERICAL MODELING IN ITALIAN WATERSHED MANAGEMENT

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Abstract: The Water Framework Directive 2000/60/EC establishes the quality objective of water bodies. Modeling is presented as a necessary scientific and technical support for the water quality and quantity simulation for the evaluation of the achievement of the objectives through the adopted intervention measures. The Italian context is highlighted and an example of numerical modeling that supplements monitoring is given.

Keywords: Water-framework directive; numerical modelling; operational monitoring; priority substance

1. Introduction

The Water-Framework Directive (WFD) was established at 23 October 2000 and is in force since 22 December 2000. In all Member States these dates mark a far-reaching change in water policy and its legal foundation.

With the WFD a new political vision was introduced which affected the existing laws in many aspects. Significant changes were e.g.:

- Introduction of an integrated water management based on river basin districts.

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 243–262.

- A new system of water quality objectives: For surface waters these are ecologically oriented comprising biological, hydromorphological and chemical aspect, for groundwater they are based on chemical and qualitative aspects.
- For achieving the objectives in time Member States have to develop and implement programs of measures.
- For assuring implementation of the systems of objectives and river basin management implementation in international basins cross boarder cooperation is required.
- In developing and implementing river basin management plans the public has to be involved through consultation and participation. The public shall have open access to all data and background information.
- The WFD introduces also new economical instruments into river basin management, e.g. the introduction of cost recovery of water services and cost effectiveness in development of program of measures.

Under the roof of the WFD a number of important water quality and emission oriented European Directives are included. All activities aimed at the achievement of the objectives of these directives are now part of the program of measures in the WFD. This is a further important step towards integrated thinking in river basin management. Since that more stringently cooperation between the responsible administrative units has been required.

Therefore the WFD obviously matters for most fields of water management and will lead to many changes in the existing water administrations including legal and institutional adjustments. Moreover the WFD sets an ambitious time frame for the different steps required:

- The implementation of the WFD into the legal and sub-legal regulations had to be completed until 1st of May 2004.
- The status review including the description and evaluation of the existing situation of national waters had to be reported until March 2005.
- The monitoring systems for assessing and controlling the status of the water bodies have to be in place at the 22nd of December 2006.
- The River Basin Management Plan (RBMP) that has to provide all means required to achieve the system of objectives for surface waters and groundwater has to be finished and reported until December 2009 and implemented until December 2012.
- The objectives have to be achieved until 2015 with the possibility of a prolongation by two times six years.

This paper presents the requirements of the Water Framework Directive, specially aimed at the Italian context. In particular, it stresses the monitoring activities carried out in Italy and the importance of numerical modeling in the implementation of the WFD with a typical application. The numerical model applications mentioned here are referred to the quantitative as well to the qualitative water quality aspects.

Water quality and water quantity models are a strong and necessary support for the evaluation of the water quality status according to the interventions established with the River Basin (District) Management Plan and to understand if the quality objectives can be gathered within the WFD deadlines.

2. The water framework directive in the Italian context

2.1. WATER MONITORING: THE WATER QUALITY STATE

The directive 2000/60/EC establishes (art. 4) that for surface waters a "good" status shall be reached within 15 years from the data of entry into force, considering as a good surface water status the status achieved by a surface water body when both its ecological and its chemical status are at least "good" (art. 2); the "ecological status" is an expression of the quality of the structure and functioning of aquatic ecosystems associated with the surface waters, classified in accordance with Annex V.

The art. 8 of the WFD prescribes the duty for member States to establish a monitoring program to assess the ecological status and the chemical status of water bodies, according to the dispositions of Annex V and of art. 21 (activation of a Technical Committee for the definition of technical specifications and of standardized methods for water status monitoring).

Both the ecological and the chemical status contribute to establish the criteria for surface waters' monitoring. The WFD introduces an *integrated approach* finalized to the assessment of the ecological status of the water body; the elements on which the ecological status assessment is based according to the directive 2000/60/EC (Annex V) are: biological, hydromorphological, chemical and physical-chemical elements (Figure 1). For the chemical parameters there is a focus on the physical-chemistry, including non-synthetic and synthetic priority substances.

For the assessment of the ecological status and the chemical status, the WFD in Annex V establishes, for the first time in the European legal context, three types of water monitoring:

- Surveillance monitoring
- Operational monitoring
- Investigative monitoring

The chemical quality of a "good" status is defined according to the *environmental quality standards* (EQS); that is the concentration of a particular

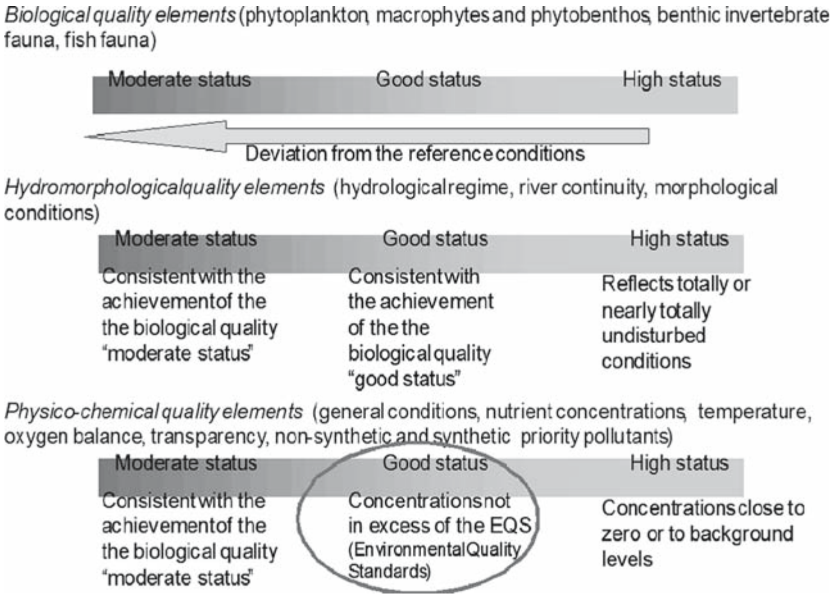

Figure 1. The WFD ecological status.

pollutant or group of pollutants in the waters, sediments, biota that must not to be exceeded, to protect human health and the environment. The approach requires, therefore, an integrated protection both for human health and for the aquatic ecosystem quality.

The procedure to define the chemical quality standards is established in the 1.2.6 point of Annex V of the WFD and prescribes tests of acute and chronic toxicity and the use of specific *safety factors* for the determination of the final standards. It must be noted that the "high" chemical quality requires:

- For specific synthetic pollutants: concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use
- For specific non-synthetic pollutants (that are pollutants already present in the environment): concentrations remain within undisturbed conditions (background levels)

2.1.1. The surveillance monitoring

The objectives of the surveillance monitoring are (directive 2000/60/EC):

- To supplement and validate the impact assessment procedure (DPSIR) detailed in Annex II of WFD

- To supplement the efficient and effective design of future monitoring programs
- The assessment of long-term changes in natural conditions
- The assessment of long-term changes resulting from widespread anthropogenic activity

The surveillance monitoring shall be carried out: (1) at points where the rate of water flow is significant or the volume of water present is significant within the river basin district (including large lakes and reservoirs) or on large rivers where the catchment area is greater than 2,500 km^2; (2) significant bodies of water cross a Member State boundary; (3) sites in which pollution is transferred from one State to the other or is transferred to the sea.

The surveillance monitoring is begun in the *River Basin Management Plan* (RBMP) for the period of one year. Samplings must be made every month for priority substances and every three months for other substances (main pollutants – Annex VIII). Greater delay times shall be supported due to technical-scientific reasons.

2.1.2. The operational monitoring

The objectives of the operational monitoring are (directive 2000/60/EC):

- To establish the status of those bodies identified as being at risk of failing to meet their environmental standards
- To assess any changes in the status of such bodies resulting from the programs of measures

Operational monitoring shall be carried out for all those bodies of water which on the basis of either the impact assessment and the surveillance monitoring are identified as being at risk of failing to meet their environmental standards and for those bodies of water into which priority list substances are discharged. For the other priority substances not covered (i.e. not included in the directive), the monitoring points shall be selected on the basis of:

- Presence of one or more point sources
- Presence of one or more non-point sources

Samples shall be conducted every month for priority substances and every three months for other substances (main pollutants – Annex VIII). The operational monitoring can be modified during the River Basin Management Plan, in particular reducing the frequency if modifications of environmental quality connected to anthropogenic activities are not evident.

2.1.3. The investigative monitoring

The objectives of the investigative monitoring are:

- To collect information on risks of exceeding the quality standards
- To ascertain the causes of a water body or water bodies failing to achieve the environmental standards, if the operational monitoring has not already been established
- To ascertain the magnitude and impacts of accidental pollution

The investigative monitoring is necessary to program the interventions to achieve a good status of environmental quality and take into act interventions of recovery following an accidental pollution.

2.2. PRIORITY AND PRIORITY HAZARDOUS SUBSTANCES' CONTROL: THE EUROPEAN APPROACH

2.2.1. The main pollutants: the European regulations

The directive 76/464/EEC of 4 May 1976 on the pollution caused by hazardous substances discharged into the aquatic environment of the Community identified, on the basis of toxicity, persistence, potential bioaccumulation, two lists of substances. The art. 2 establishes the necessity of the elimination from the environment of the substances of list I and the reduction of substances of list II. The art. 6 requires the European Council to fix quality standards for the substances indicated in list I on the basis of toxicity, persistence and potential bioaccumulation in the living organisms and in the sediments. Likewise (art. 7) some programs to reduce pollution of substances contained in list II are required; these programs include the indication of quality standards. The directive, according to art. 1, shall apply to territorial water, inland surface water, internal coastal water, groundwater (for this art. 4 of the directive 76/464/EEC had established the necessity to adopt a specific directive, which was approved as directive 80/68/EEC).

The WFD lists the principal classes, categories and the specific pollutants in Annex VIII (Table 1 – "*Indicative list of the main pollutants*", in which the lists I and II of the directive 76/464/EEC can be found, extended to other new substances). The WFD requires (art. 4) the achievement within 15 years from the date of its entry into force of a "*good chemical status*" for surface waters and groundwater, that is the status reached by a water body in which the concentrations of chemical pollutants do not exceed the *environmental quality standards* established in Annex IX of the same directive ("*Emission limit values and environmental quality standards*").

The art. 10 of the WFD establishes that all point and non-point emission sources into surface water must be controlled on the basis of a *combined approach*: controls on emissions based on the best available technologies (BTA); controls on the emission limit values; application of the best environmental practices for diffuse impacts. For the characterization of the significant pollution from anthropogenic points and diffuse pressure sources (Annex II, point 1.4) it is necessary to investigate pollution caused by substances in Annex VIII of the WFD (Table 1).

2.2.2. Priority substances

The WFD identifies two categories of substances for which specific measures are necessary: the *Priority Substances* (PS) and the *Priority Hazardous Substances* (PHS). The directive defines:

- *Hazardous substances*: substances or groups of substances that are toxic, persistent and bioaccumulative and other substances or groups of substances, which give rise to an equivalent level of concern.
- *Priority substances: substances* identified in accordance with art. 16, par. 2, and listed in Annex X (modified with decision 2455/2001/EEC). Among these substances there are “priority hazardous substances” which means substances identified in accordance with art. 16, par. 3 and 6, and for which measures have to be taken in accordance with art. 16, par. 1 and 8.

TABLE 1. List of the identified main pollutants – Directive 2000/60/EC (Annex VIII).

1.	Organohalogen compounds and substances which may form such compounds in the aquatic environment
2.	Organophosphorous compounds
3.	Organotin compounds
4.	Substances and preparations, or the breakdown products of such, which have been proved to possess carcinogenic or mutagenic properties or properties which may affect steroidogenic, thyroid, reproduction or other endocrine-related functions in or via the aquatic environment
5.	Persistent hydrocarbons and persistent and bioaccumulable organic toxic substances
6.	Cyanides
7.	Metals and their compounds
8.	Arsenic and its compounds
9.	Biocides and plant protection products
10.	Materials in suspension
11.	Substances which contribute to eutrophication (in particular, nitrates and phosphates)
12.	Substances which have an unfavourable influence on the oxygen balance (and can be measured using parameters such as BOD, COD, etc.)

The hazardous substances are the substances already indicated in the list I and II of the directive 76/464/EEC and are included as substances and classes of substances in Annex VIII of the WFD, while the priority substances are all those which present a significant risk both to or via aquatic environment, including such risks to waters used for the abstraction of drinking waters, and among them the hazardous ones are identified, in order to set up interventions to eliminate their emissions and losses in the aquatic environment. It is evident that with the WFD and the Decision n. 2455/2001/EEC the number of substances to be controlled remarkably grows up, because the criteria of toxicity, persistence, potential bioaccumulation is integrated with the criterion of risk for aquatic environment.

According to WFD substances shall be prioritized for action on the basis of risk to or via the aquatic environment (art. 16, c. 2). The risk procedures are regulated in the reference norms reported in the WFD: regulation n. 793/1993, directive 91/414/EEC, directive 98/8/EC.

In the WFD, the substances shall be prioritized for action on the basis of risk to or via the aquatic environment also with a *simplified risk-based assessment procedure*, "based on scientific principles", taking particular account of the aquatic eco-toxicology of the substance and its human toxicity via aquatic exposure routes, as well as from monitoring of widespread environmental concentrations, and other proven factors such as the production or use volume, use patterns of the substances concerned, etc. The simplified procedure shall take into account (art. 16, c. 2):

- Evidence regarding the intrinsic hazard of the substance concerned and in particular its aquatic eco-toxicity and human toxicity via aquatic exposure routes
- Evidence from monitoring of widespread environmental contamination
- Other proven factors which may indicate the possibility of widespread environmental contamination, such as production or use volume of the substance concerned, and use patterns

The list of priority substances (Annex X – "*Priority substances*") has recently been introduced with the decision of the European Parliament and of the Council n. 2455/2001/EC that modifies the directive 2000/60/EC. The decision provides for a preliminary list of 33 priority substances and classes of substances for which the Member States must define *environmental quality standards* and consequently take into action all the necessary interventions to achieve the fixed standards. The substances were selected with a procedure that defines the priority and is based on the principles of monitoring and modeling: COMMPS-Combined monitoring-based and modeling-based priority setting.

TABLE 2. List of the identified 33 priority substances contained in the decision n. 2455/2001/EC of the European Parliament and of the Council (Annex X directive 2000/60/EC).

Denomination of the priority substance	PHS	Denomination of the priority substance	PHS
Alachlor		Benzo(a)pirene	X
Anthracene	(X)	Benzo(b)fluoroanthene	X
Atrazine	(X)	Benzo(g,h,i)perilene	X
Benzene		Benzo(k)fluoroanthene	X
C10–13-chloroalkanes	X	Indeno(1,2,3-cd)pirene	X
Cadmium and compounds	X	Isoproturon	(X)
Chlorfenvinphos		Fluoroanthene	
Chlorpyrifos	(X)	Mercury and compounds	X
1,2-Dicloroethane		Naphtalene	(X)
Tributyltin compounds	X	Nickel and compounds	
Tributyltin-cation		Nonylphenols	X
Dichloromethane		4-para-nonylphenol	X
Di(2-ethylhexyl)-phthalate (DEHP)	(X)	Octylphenols	(X)
Brominated diphenylethers bromate	X	Para-terz-octylphenol	
Diuron	(X)	Pentachlorobenzene	X
Endosulfan	(X)	Pentachlorophenol	(X)
Alfa-Endosulfan		Lead and compound	(X)
Hexachlorobenzene (HCB)	X	Simazine	(X)
Hexachlorobutadiene	X	Trichlorobenzenes	(X)
Hexachlorociclohexane (HCH)	X	1,2,4-trichlorobenzene	
γ-Esachlorociclohexane, Lindan	X	Chloroform	
Fluorantene		Trifluralin	(X)
Policyclic Aromatic Hydrocarbons PAH	X		

(X) = Priority substance subject to re-examination to be classified as priority hazardous
X = Priority hazardous substance
PHS = Priority Hazardous Substance

In Table 2 the list of the priority substances indicated in the decision n. 2455/2001/EC is reported. In the same list are pointed out the priority hazardous substances and the priority substances subject to re-examination to be listed among the priority hazardous ones.

2.3. THE WATER INTEGRITY MODEL

The implementation of the *Water Framework Directive* (WFD) 2000/60/EC to achieve a good status of surface water and groundwater bodies within the year 2015 suggests to follow the approach of the *River Basin Management*

Planning implementation by using a model that works as support for decisions (DPSIR – Driving forces, Pressures, State, Impacts, Responses, is an example). According to the model, the state of waters should be monitored and pressure sources, due to human impacts, identified.

The directive 2000/60/EC (WFD) establishes that for surface waters a "good" status (ecological and chemical) shall be reached within 15 years from the data of its entry into force.

For the evaluation of the anthropogenic pressures, the WFD suggests to follow the approach to *River Basin Management Planning* (RBMP) by using a model that works as support for decisions (DPSIR – Driving forces, Pressures, State, Impacts, Responses, is an example). The suggestions established by the WFD has been interpreted by developing a mathematical model named "Integrity Model". This model, based on the concept of "*intrinsic and systemic integrity of the territory*" seems to be a tool particularly useful in the decisional path for planning and programming those interventions aimed to the mitigation of risks of pollution, resources protection and to the achievement of environmental quality objectives.

The aim of the model application (Greco et al., 2005), starting from the classification data of surface water from available monitoring data, has been to identify the external critical factors (pressure sources) that can condition the water quality. The river, in this way, has been evaluated in its integrity or vulnerability, as an ecosystem that interacts reciprocally with its territorial context and not as a separated element. It is evident that this is the correct comprehensive approach according to the WFD, which considers the aquatic ecosystems and the connected terrestrial ones.

In this way the integrity analysis cannot be conducted without the assessment of the degree of urbanization and, in general, without the assessment of the anthropogenic impact in the considered river basin. The analysis is performed using the theory of influence diagrams. An influence diagram (Howard and Matheson, 1984; Schachter, 1988; Shenoy, 1992) is a simple graphic representation of decisional problems: different decisional elements are described in a diagram of influence with different forms and then all the elements are linked with arrows according to the relationships between the decisional elements.

In particular, the river has been divided into stretches in which the evaluation of the systemic integrity has been done through an analysis of some indexes. Of course, a complete and exhaustive analysis of a complex system, like a hydrographical basin, needs the definition of a series of indexes based on a plurality of comparable parameters, which allow a global reading of the same system.

Really the objective of this work is not to identify which could be the interventions to achieve the Good Ecological Status of surface waters, but rather to point out as the proposed model, developed for different phenomena

(Greco et al., 2004, 2005; Trasforini, 2003), can be a useful analytical, planning and programming tool and can direct the public responsible authorities to the most suitable choices.

3. Monitoring: the state of the art in Italy

In Italy the first monitoring actions of surface waters have been performed by health authorities in the 1980s to assess risks coming from potabilization of the water for human use, for shellfish farming and bathing waters.

With the exception of the most advanced regional and provincial Administrations, monitoring activities for the assessment of the environmental quality status of surface waters were carried out in the early 1990s by national research institutes, without a uniform way and standardized criteria.

Since 2000, with the application of the national laws (D.Lgs. 152/1999) and the kick-off of the activities of the Regional Environmental Protection Agencies, a new monitoring program started for the sampling of physical-chemical, chemical and biological indicators, in order to define the chemical, ecological and environmental status of surface waters.

More recently the Water Framework Directive 2000/60 (WFD) defined a new methodology for the classification of surface waters, according to homogeneous comparable typologies.

In this way it will be possible to evaluate the environmental quality status of all water bodies, by dividing them into geomorphologic and hydrodynamic typologies and comparing the physical-chemical, chemical, biological and ecological properties of surface waters with the same properties of reference not polluted water bodies.

The final goal of the WFD is to achieve and/or to maintain the "good" state of quality of all the European surface and underground waters. Furthermore, water bodies are subject to a quality classification depending on the use (human use, shellfish farming, bathing use, fishing) or on the risk coming from the presence of dangerous substances.

Highest aims have to be achieved for surface waters belonging to protected areas of national and international interest. On the other hand, minimum objectives have to be reached for greatly modified water bodies, the ecological functioning of which is intrinsically compromised.

Much work has to be done to develop monitoring methods to verify the reference water body conditions for all the typologies, since nowadays especially quality-quantitative evaluation of the main biological components strongly needs standardized methodologies.

3.1. TEMPERATURE AND SALINITY

In spite of the complexity described above, it has to be pointed out that much information is periodically monitored, and in some cases decades-long data bases are available. In fact, the physical-chemical parameters (temperature and salinity) are historically measured by multiparametric probes.

3.2. OXYGEN

Oxygen concentration, expressed in mg/l, or oxygen saturation referred to measured temperature, is considered the expression of average conditions of metabolic steady state of the water body (Winkler method or probe). Until now, yearly mean oxygen saturation values less than 80% have been considered a "good" quality state condition in transitional waters.

What regards the real representativity of oxygen saturation as the most expressive parameter of quality state, especially when it is not possible to carry out continuous monitoring by high quality multiparametric probes, it is necessary to take proper precautions since sampling is influenced by day light and tidal cycle.

3.3. NUTRIENTS

Following eutrophication phenomena with microalgal blooms and anoxic crisis that determined high mortality of marine organisms, field campaigns for the monitoring of yearly variations of the main nutrients (total nitrogen, total phosphate and orthophosphate, silicate) started in the 1990s.

3.4. CHLOROPHYLL A

Chlorophyll a concentration in surface waters is directly related to phytoplankton presence, as it determines the effects due to high concentrations of nutritive substances (reference spectrofluorimetric method).

More recently, the introduction of fluorescence sensor in multiparametric probes, to evaluate chlorophyll pigments, allowed the systematic evaluation of the productivity of transitional and marine waters, at the same time with the evaluation of the physical-chemical and trophic parameters. Unfortunately, this measurement does not exactly overlap the spectrofluorimetric method.

3.5. FAECAL INDICATORS

The counting of Escherichia coli and Enterococci in surface waters and in molluscs is recently substituting the counting of the traditional total coliforms, faecal coliforms and faecal streptococci as indicators of water pollution from faecal origin.

The concentration of these indicators is correlated to the presence of enteropathogen micro-organisms. The presence of these indicators is influenced by different conditions such as salinity, lighting and stratification stability of fresh waters on salt waters.

To protect and control bathing waters, surface water sampling is performed from April to September with 15 days frequency. Sampling points are defined on the basis of the area extension (every 2,000 m).

In the areas reserved to mollusc collecting and Mytilus galloprovincialis; Crassostrea gigas and Tapes philippinarum farming, risk assessment for faecal pollution is carried out searching for the presence of high concentration of these indicators in the body of the drained mollusc.

Further, shellfish farming areas are classified depending on the level of food safety (A, B and C zones).

The overcoming of conformity limits determines restriction or prohibitions for bathing waters issued by health authorities.

3.6. TOXIC MICROALGAE AND ALGAE TOXINS

Lagoons and coastal marine areas, where shellfish farming and collection of molluscs exist, are monitored also to verify the presence of toxic microalgae and microalgal toxins in molluscs.

The overcoming of attention limits for microalgae and toxins determines restriction or prohibitions for collecting and marketing of molluscs, issued by health authorities.

In particular, the presence of toxic microalga Ostreopsis ovata is monitored in bathing waters of some coastal zones since 2005.

3.7. HAZARDOUS SUBSTANCES

Since 1980, the presence of heavy metals and PCB has been searched in the molluscs. In fact, depending on the local conditions, significant concentrations of mercury, nickel and cadmium have been found.

A recent European prescription established that 30 hazardous substances, considered as having priority (toxic, stable and bioaccumable compounds and metals), have to be systematically investigated in surface waters (monthly/quarterly frequency) and in sediments (six-monthly frequency).

In the marine-coastal environment the presence of hazardous organic substances, in particular in sediments, may be associated to the main sources of pressure (traffic, industry, agriculture).

4. Modeling: the BIOPRO pilot project in Italy

The BIOPRO project, (Pilot project of biological pollution from sewage systems in the Venice Province), promoted by the Venice Province – Environmental Policies Dept., represents an attempt to assess and characterize the microbiological pollution coming from some treatment plants and from the main rivers located along the coasts of the Venice province. The study consists both of data collection and laboratory analysis, performed by ARPAV, the Environmental Protection Agency of Veneto Region, for the microbiological parameters (e.g., Total Coliforms, Fecal Coliforms, Fecal Streptococcus, Escherichia Coli) and the presence/absence of virus. The study has been integrated with the implementation of the finite element model SHYFEM, developed at ISMAR-CNR in Venice, to identify the zones of influence of the discharges.

The investigated area consists of the part of the Northern Adriatic Sea situated in front of the coast of the Venice province. For this study nine discharge points have been taken into accounts that discharge into the Adriatic Sea: some points represent the contribution of both rivers and treatment plants and have been placed along the coast for simplicity; other points represent only rivers or only treatment plants that discharge into the Adriatic Sea, located at about 4 km from the coastline. For more details on the model application please refer to Scroccaro et al. (2005).

4.1. THE MODEL

The hydrodynamic model used is the two-dimensional version of the finite element model SHYFEM, developed at ISMAR-CNR in Venice. The finite element method gives the possibility to follow the topography of the system and to better represent the zones where hydrodynamic activity is more interesting. The model uses finite elements for spatial integration and a semi-implicit algorithm for integration in time. The terms treated implicitly are the water levels and the friction term, all other terms are treated explicitly. Details can be found in Umgiesser and Bergamasco (1995) and in Umgiesser et al. (2004).

Coupled with the hydrodynamic model a dispersion module is run that computes the transport and diffusion of a dissolved tracer in the water body. The module allows for various input sources. A natural decay of the tracer can be simulated.

The numerical grid for the simulations extends over the whole Adriatic Sea, in order to move the open boundary as far away as possible from investigated area of the Veneto coast. The grid includes the Venice Lagoon, and it contains 8,072 nodes and 15,269 elements. The horizontal resolution varies from about 100 m inside the Venice Lagoon up to 60 km in the central Adriatic Sea

The numerical simulations have been carried out with meteo-marine forcings and microbiological data of the year 2002. The time step of the simulations is 300 seconds.

Wind and pressure data have been used from the European Centre for Medium Range Weather Forecast (ECMWF) of Reading, UK. An astronomical tide has been imposed at the Strait of Otranto, taking into account the seven main astronomical components.

For the microbiological parameters, data collected during in situ campaigns by ARPAV have been used, integrated with data of the treatment plants, provided by the Venice province. For the discharges of the rivers and of the treatment plants estimates of the river authority have been used.

For the bacteriological simulations a decay parameter of two days has been used (Crane and Moore, 1986; Evison, 1988; Mancini, 1978). This parameter is not yet linked to other environmental parameters such as light climate, temperature and salinity but in the future it might be included.

4.2. RESULTS

Different scenarios have been simulated, with and without taking into account a decay rate. In the first case, merely theoretic, an infinite survival time has been imposed for the microbiological parameters, while in the second case, more closely according to what happens in nature, a decay time of two days has been prescribed.

The elaboration of the results of the simulation with the SHYFEM model produced maps for each microbiological parameter. In this work only the results for Escherichia Coli (EC) will be shown and discussed. The other modeled parameters were Total Coliforms, Fecal Coliforms and Fecal Streptococcus.

In Figure 2 the map of the average concentration for the year 2002 is presented. From this map it may be observed that the water masses transporting the bacterial load generally stays in a narrow stripe about 10 km wide along the coastline: the highest values are concentrated around the source points (treatment plants and rivers). Far from the coastline, the bacterial concentration dilutes quickly and the values decrease.

In Figure 3 the map of the influence of the discharges coming from the treatment plants and the main rivers are presented for EC. In particular, the

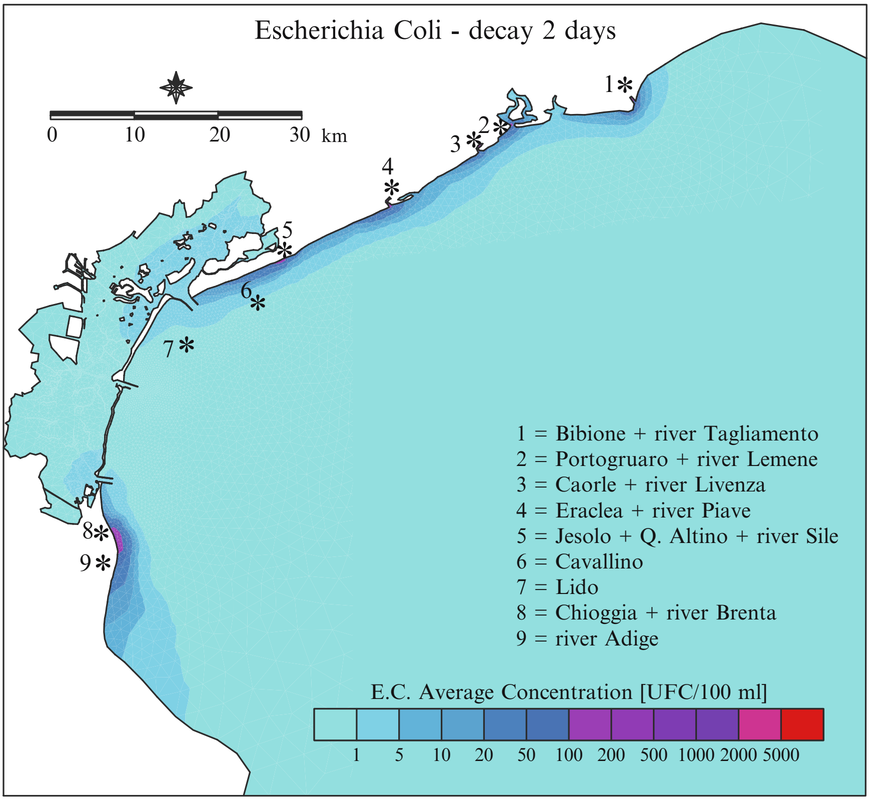

Figure 2. Example of model results for Escherichia Coli, with a decay rate of two days. Average concentration over the year 2002.

map of influence of the nine points taken into account for this study, were obtained computing the bacterial quantity due to a specific discharge, that influences the elements of the model grid.

When this quantity exceeds the threshold of 30%, the element is assigned to that discharge point. The area represented with the same color indicates the influence zone of the discharge.

From this map of influence it can be noted that the effect of the circulation that tends to transport the water masses towards south, to the area of the Po river. This means that the influence of some discharge points extends to zones located in the south of the discharge area, and it may be that the concentrations measured in some sampling stations are influenced by the bacterial charge coming from other sources, located in the northern part of the coast. This effect is mainly due to the effect of the anti-clockwise circulation and to the transport of the water masses.

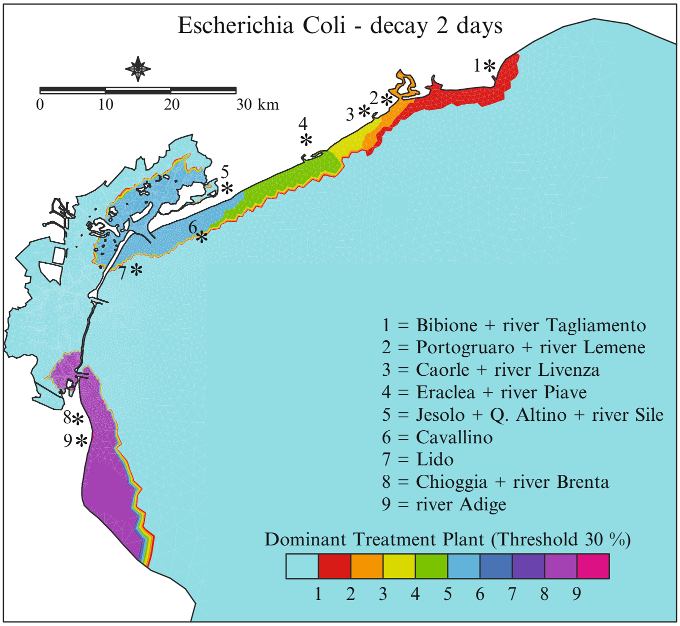

Figure 3. Example of model results for Escherichia Coli, with a decay rate of two days. Map of influence of the discharge points over the year 2002.

4.3. DISCUSSION

The results of the model application evidence the necessity to provide better treatment of the waters in the upper part of the river. This is clear when studying the total time that a microbiological parameter exceeds the threshold concentration fixed by law. In the case of EC this happens for more than 50 hours at two of the nine studied treatment stations (results not shown here).

In particular the following points can be evidenced:

- The microbiological pollution seems to be confined to the coastline, tending to move towards south (phenomenon connected to the anti-clockwise circulation of the Adriatic Sea)
- The minimum impact of the treatment plants that discharge at about 4 km from the coastline
- The 'critical' discharge concentration of point 8

Finally, these results suggest the possibility to define a new sampling methodology, basing on the zones of influence of the discharges, computed with the SHYFEM model, that are different from the geographical zones of the discharge points.

This study aims at a the description of the dispersion of the microbiological pollution due to the discharges of some treatment plants and of the main rivers located along the coast of the Venice province (nine considered discharge points).

With the SHYFEM model, the information coming from the hydrodynamic circulation and physical-chemical features have been linked to the classical methods of analysis, to assess the possible risks connected to the microbiological parameter of water, that may have economic influence on the local industry, aquaculture and touristic activities. This subject (experimental part plus numerical modeling) represents an avant-guard study in Italy, and one of the first studies of this kind in Europe.

With the results of the study it was possible to provide some qualitative information to determine the zones with higher risk of microbiological pollution and the more unfavourable situations for the quality of the bathing water, in particular depending on the wind conditions.

With further investigations, it may be possible to examine carefully the life cycle of the microbiological parameters, to obtain a better modeling. In particular in this study the decay rate has been considered constant over the whole year, whereas in nature the decay rate may vary strongly depending on the temperature-salinity conditions and on the light, parameters that vary seasonally. This information may be integrated in the model with the implementation of a specific existing part of the EUTRO module.

Other interesting information would come from the study of new scenarios with different positions of the discharge of the treatment plants, taking into account what may happen to the water quality moving the discharge of some treatment plants off coast some kilometers into the sea and/or separating the discharges of the rivers from those of the treatment plants.

5. Conclusions

The use and application of mathematical models for water quality and quantity simulations is particularly enhanced by the Water Framework Directive.

The WFD 2000/60/EC establishes that it is necessary to define the quality state of rivers, to improve the water quality to reach the status "Good" and finally introduces a new and very important concept: the integrity assessment for surface waters.

Different topics can be analysed by use of mathematical models; two of them appear fundamental: the assessment of water vulnerability and the definition of a reference conditions.

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SUSTAINABLE DEVELOPMENT OF WATERSHEDS: USING STURGEON SPECIES AS AN INDICATOR IN INTEGRATED TRANSBOUNDARY WATER MANAGEMENT IN THE URAL RIVER BASIN

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Abstract: River basins are the most appropriate geographical units for considering the management of water resources. At the same time rivers and their associated ecosystems and biodiversity provide the basis of life for a large portion of the world's population. Though there is now an international consensus on the need for an integrated approach to sustainable river basin management, there is no standard definition of the term "sustainable" nor consensus on how to reach this state.

Sustainable development of watersheds should consider three main components: economic, social and environmental, which can hardly be reached in real-life watershed management. One of the problems is the selection of sustainable watershed management indicators.

Using sturgeon species as a natural indicator and an incentive for transboundary IWRM cooperation in the Ural river basin is suggested. The only free-flowing river in the Caspian basin, the Ural River, is a unique ecosystem with a preserved natural hydrological regime and the last sturgeon spawning habitats.

Activities towards successful integrated water management will not only work towards sustainable watershed management, but also secure preservation and restoration of sturgeon, this worldwide flagship species. Community-based management of sturgeon stocks also resolves social and economic problems by restoration of the traditional life style of local communities.

High economic and social values of sturgeon allow the combination of both ecological and socio-economic aspects of sustainable development. Investment in IWRM and sturgeon conservation can be largely repaid later by "sustainable extraction" of sturgeon.

The Ural River Basin Project, which aims at sustainable watershed management and sturgeon restoration, is described in this paper. Special attention is paid to integrated assessment and modelling of the Ural river ecosystem.

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 263–288.

Keywords: Watershed management; river basin; integrated water resource management; indicator species; sturgeon; community-based environmental protection; Ural river; Cossacks; integrated modelling

1. Background

Rivers and their associated ecosystems and biodiversity provide the basis of life for a large portion of the world's population. Fresh water is expected to become the most limiting resource in many parts of the world in the near future. The world's freshwater resources are under increasing pressure. Population growth, improving standards of living, blooming economic activities and the degradation of aquatic ecosystems lead to increased competition for and conflicts over the limited freshwater resources.

The need for holistic cross-sectoral approach to water resources management is increasingly recognized and has resulted in a drastic increase in the number of watershed management programs worldwide. Depending on institutional needs and regional priorities various concepts of Integrated Water Resources Management (IWRM) have been developed recently. In brief IWRM is a process which can assist countries in their efforts to deal with water issues in a cost-effective and sustainable way.

Though the issues of sustainable watershed management and development are widely discussed, and though many articles and handbooks have been written and numerous attempts have been made to put this concept into practice, there is no uniform terminology accepted by all stakeholders nor consensus on the best way to achieve sustainability in water resource use. Nevertheless, some fundamental principles underlying best management practices are common for most approaches.

While IWRM principles, approaches and guidelines are numerous, the principles of IWRM proclaimed at Rio-92 are most commonly used. According to this approach the six basic principles of Integrated Water Management are:

1. The river basin is the most appropriate administrative unit for water management
2. Water resources and the land which forms the river basin area must be integrated, in other words, planned and managed together
3. Social, economic and environmental factors must be integrated within water resources planning and management
4. Surface water and groundwater and the ecosystems through which they flow must be integrated within water resources planning and management
5. Public participation is necessary for effective water resources decision making

6. Transparency and accountability in water management decision making are necessary features of sound water resources planning and management

This approach was incorporated in the European Union Water Framework Directive (EU WFD) adopted by EU Member Countries in 2000 and in National Water Codes in many countries.

Though there is now an international consensus on the need for an integrated approach to sustainable river basin management, practical implementation of these nice principles is problematic.

Water resources mismanagement results not only in breakdown of economic activities, but also in biodiversity loss, habitat degradation, social and political tensions.

1.1. IWRM PROBLEMS AND OBSTACLES FOR SUCCESS

The concept of IWRM is closely linked to the idea of sustainable development (SD). The generally accepted definition of sustainable development defines it as "development which meets the needs of the present, without compromising the ability of future generations to meet their own needs".

As repeatedly indicated by many authors, both concepts, SD and IWRM, have difficulties in definitions and practical implementation (Anthony et al., 2003; Jewitt, 2002; Jonker, 2002). Among them the following can be mentioned: (1) the standard definition assumes a common understanding of what development means; (2) it assumes the present generation knows what the needs of future generations will be; (3) it does not explicitly link society and resources, the two elements in development; (4) it is impossible to measure at what stage of development future generations are being compromised; (5) it does not seem to consider the different time spans between people's lifecycles and natural cycles.

With regards to these considerations a better definition of sustainable development could be "the improvement of people's livelihoods without disrupting the natural cycles". Based on this approach a more appropriate definition of IWRM would be "managing people's activities in a river basin in a manner that promotes sustainable development (improves livelihoods without disrupting the water cycle)". Unfortunately, the traditional approach still prevails in water management.

As a rule researchers and managers continue to address IWRM issues from a narrow, sectoral perspective. Many watershed management projects based on these principles not only indicate no success so far, but also often worsen the environmental situation in watersheds.

Apart from these conceptual problems there are a number of obstacles in practical IWRM implementation.

The first commonly accepted principle recognizes a river basin as the most appropriate unit for considering the management of water resources.

Nowadays this principle is mentioned in almost every water management-related directive or policy recommendation, though rarely duly realized even in national environmental management practices. For example, the new Russian Water Code adopted in 2006 proclaims the need for river basin-wide water management strategies, but stipulates national water management depending on the existing administrative territorial division (RF, 2007).

Another undisputable point in the theory of IWRM is that sustainable development of watersheds should consider three main components: economic, social and environmental. However, the history of human communities' development in river basins shows that this is hard to achieve. Some components are often neglected in favour of others.

Freshwater is a limited resource, which is very much affected by uncontrolled weather conditions and often even the best management strategies cannot provide enough water for all users. This consideration leads to the necessity to prioritize water users in conditions of both scarce and available water resources. Traditionally the first priority in water use is given to economic development at the cost of environmental needs. However, it is clear that such an approach cannot be sustainable even in case of abundant water resources taking into account the constantly growing economic needs and related anthropogenic impacts.

The very definition of "sustainable" applied for water use is a vague concept, as has been repeatedly indicated by some authors (Lagutov, 1997; Lagutov, 1995; Hedelin, 2007; RAMSAR, 2002). Despite numerous regulations and projects the attempts to synchronize understanding of the IWRM concept by different stakeholders and to introduce integrated water management into management practices are often not very successful. Not only different stakeholders and water users, but also different scientists define this concept in various, often contradictory, ways. This creates problems for a participatory approach, one of the pillars of sustainable watershed management, which implies transparency and participation in decision-making for all involved stakeholders and water users. Apart from that, particular essential ecological water services such as biodiversity needs are often not represented by any stakeholders, organizations or communities who participate in the decision-making process of IWRM. Hence, these needs are often neglected even in case of participatory decision-making.

Another basic yet controversial IWRM principle is the introduction of the economic analysis of water use (EU, 2000). Though seeming to be a good idea, it often cannot be implemented. Assessment of a certain species' extinction in monetary terms or, even more, economic comparison of such a loss to, for example, electricity generation, is hardly possible. In addition the integrated watershed management is often complicated by the transboundary nature of the river basins. IWRM implies the need to manage transboundary water resources jointly, which can rarely be achieved. The interests of a particular country and its willingness to participate in the process directly depend on its upstream or downstream position along the river stream. For instance, EU Member States adopted the Water Framework Directive (WFD) in 2000 and are rapidly moving towards unifying management systems and standards (EU, 2000). According to WFD, Member States are obliged to protect, enhance and restore all surface waters with the aim of achieving good ecological status by 2015. However, by 2007 the pressing issue of transboundary water management for EU members not only lacks enforcement, but even the principles have not been agreed on yet (UNECE, 2007). The natural hydrological cycle is perceived by managers and decision-makers as a uniflow river stream. If any damage to the river ecosystem (pollution, hydrological cycle disruption, etc.) is made by an upstream country and downstream countries are bearing ecological or economic losses it seems that no harm is caused back upstream. The case of the cyanide spill at Baia Mare (Romania) in March 2000 revealed the problems of integrated transboundary water management and political implications very well (UNEP, 2004).

New approaches should be sought and applied to integrated water resources management to make it an effective tool in practical environmental management. These approaches should be based on an ecosystem's sustainability, e.g. water cycles, and non-disruptive character of human activities with regards to ecosystem functions. An ecosystems approach to IWRM focusing on the role of the hydrological cycle is under discussion in the scientific literature (Jewitt, 2002; RAMSAR, 2002).

1.2. IWRM INDICATORS

Careful selection of appropriate indicators in altered watersheds is an essential part of sound policy and decision-making in IWRM. On the one hand, these indicators should integrate the long-term temporal and spatial basin-wide environmental characteristics of a watershed. On the other, it should ideally be possible to assess the socio-economic activities in a watershed using this indicator. However, indicators in general and integrated indicators in particular are still not a well elaborated aspect of IWRM (Chaves and Alipaz, 2007; He et al., 2000).

There are many indicators and indices suggested to evaluate the progress in a particular aspect of the IWRM process. For example, the number of published articles or sent messages to stakeholders are suggested as indicators of public participation or awareness raising in IWRM (Hedelin, 2007).

Another case study for indicators' usage in IWRM can be drawn from WFD, which aims at "achieving good status of surface water" (EU, 2000). Surface water is defined as of good ecological quality if there is only slight variation from the ecosystem with minimum anthropogenic impact. A long list of different indicators to be selected from is suggested for appropriate authorities, who can choose several indicators to work with and set up their own standards. The indicators are isolated and treated separately, which by itself cannot result in sound policy (Chaves and Alipaz, 2007). Most of these indicators and, correspondingly, activities within WFD concentrate on water quality. At the same time other river-floodplain system characteristics (i.e. habitats fragmentation), economic or social aspects are either not taken into consideration or inadequately considered.

In comparison to isolated indicators of the physical environment, economic or social aspects of the IWRM process the ecological and biodiversity indicators are usually either not taken into account or little attention is paid to them in water management practices. At the same time the concepts of "key-", "indicator-" or "keystone-" species for sustainable development and IWRM have been widely discussed in last 15 years (Lagutov, 1997; Lagutov, 1995; WWF, 2002a).

According to the species classification system introduced by WWF and used for conservation purposes the species can be used as one of the following (WWF, 2002a): (a)Flagship species; (b)Species of special concern; (c) Indicator species.

According to this classification,

Flagship Species act as a symbol for their habitat. Since most of the species chosen appeal to the public, major ecosystem programmes can be built around them, in order to influence human behaviour and thereby realise specific conservation objectives.

Species of Special Concern are usually threatened species and their protection promotes conservation by safeguarding biological diversity and ecological processes. These species play a crucial role in ecosystem functioning ("keystone species").

Indicator Species are "markers" which help to measure changes or trends within a particular environment. An indicator can be thought of as a variable that can help to measure or "indicate" whether progress (towards any given objective or target) is being achieved. Indicators are not targets, but markers of progress towards reaching objectives, whether immediate or long-term."

Taking into account that ecological aspects, in particular conservation, are an essential part of the SD process this classification should be applied to IWRM to consider watershed development as sustainable.

Moreover, given the holistic, "integrated" nature of IWRM it is essential to introduce some river basin-wide single natural indicator of sustainable watershed development which can bring together different sectors and stakeholders concerned with IWRM, allowing the interests of various water users (including ecosystem services) to be taken into account. This indicator should also encourage involvement of different disciplines related to water management as well as incorporate concerns of ecological, socio-economic and policy aspects of sustainable development.

Such integrated natural indicators of sustainable watershed management are sorely lacking in practical environmental activities and the need for this indicator has been mentioned by many authors (Chaves and Alipaz, 2007; Jewitt, 2002; van Delden et al., 2007).

1.3. TRANSBOUNDARY INTEGRATED WATERSHED MANAGEMENT IN FORMER SOVIET UNION COUNTRIES

The system of integrated river basin management that once existed in the Soviet Union collapsed in the early 90s and drastic deterioration of environmental conditions of all transboundary watercourses can be observed since then.

Many countries of the former Soviet Union do not have even agreements on transboundary water management. Though some agreements do exist, they are of a superficial character and not fully implemented. These documents may not be effective tools to tackle the issues addressed. The current state of IWRM in the region can be characterized by a lack of cooperation among countries and a shortage of incentives for such cooperation (UNECE, 2003). Paradoxically, the general attitude towards transboundary water cooperation is positive and there is a strong need to stimulate it and present the best management practices.

It should also be noticed that many countries in the region are parties to international conventions and agreements on various aspects of water protection and sustainable development, though this is not explicitly reflected in water management practices.

2. Ural river basin

The Ural River, the third longest river in Europe, forms the traditional boundary between Europe and Asia. It rises in the South-eastern slopes of the Ural Mountains and goes into the Caspian Sea. The total length of the river is 2,428 km, of which 1,082 km are in Kazakhstan.

The Ural river is the only free-flowing river in the Caspian basin. A small reservoir, situated far upstream (1,810 km from the river mouth), does not have a major influence on the hydroecological regime of the river (Cowx et al., 2004). Hence, the natural hydrological regime and essential floodplain ecosystems (i.e. meadows) are still preserved. Generally speaking, this feature is unique not only for the Caspian basin, but also for most of the major water streams through the Northern hemisphere, most of which have undergone severe anthropogenic alterations (i.e. damming, channelization, etc.). As indicated above, according to EU WFD, a lot of effort should be invested just in order to try to return European rivers to the state of "slight variations from the ecosystem with minimum anthropogenic impact". Though located in a densely populated industrialized area, the Ural river is still at this stage, which should be simply maintained.

Thanks to its natural hydrological regime the Ural riverine biodiversity has not deteriorated as much as that of other big rivers. The Ural river contains the only available spawning and wintering habitats of worldwide famous sturgeon species which are protected under numerous international conventions.

Unlike many other transboundary basins (e.g. the Danube) the Ural river basin is shared by only two countries, Russia and Kazakhstan. The basin is divided into two approximately equal parts, of which the Russian share is located upstream the Ural river. Seventy-two percent of its total runoff is formed in the Russian part of the basin.

Such a basin division between countries suits the criteria for a pilot project on sustainable watershed management. Basin cooperation is often complicated by the high number of parties in the water management scheme and the complex nature of administrative and national borders. By contrast, the Ural river basin provides an opportunity to develop and adapt best international and national practices of water management to the local conditions and put them into practice. In this situation the upstream-downstream roles of the countries-members of a transboundary IWRM are well defined and indisputable.

Figure 1. The geographic position of the internationally shared Ural river basin.
Source: Ural Basin Project

Although Russia and Kazakhstan are both remnants of the Soviet Union and at that time had a single indivisible water management system, at present official transboundary cooperation on water management and regional environmental issues is almost negligible. However, the cultural and personal links are still very strong and the need for cooperation is well understood by stakeholders in both countries.

From the IWRM point of view the basin of the Ural River is a unique ecosystem. It provides a perfect case study to develop, test and put into practice a sustainable watershed management strategy taking into account all the principles of IWRM. All components of traditional sustainable management – social, economic and environmental – can be linked here and considered jointly.

While there is plenty of experience and knowledge in transboundary river management accumulated in European countries as well as the former Soviet Union, this knowledge cannot be simply copied to the Ural river basin given its different institutional and regional specifications. Careful evaluation of best practices and consideration of regional specifics is needed to develop a sound sustainable basin development strategy.

2.1. STURGEON POPULATION AS AN INCENTIVE FOR TRANSBOUNDARY INTEGRATED WATER MANAGEMENT

One of the biggest obstacles to transboundary IWRM in Central Asia in general and in the Ural river basin in particular is the lack of incentives for cooperation. This statement is especially true in cases of upstream-downstream watershed division as in the case of the Ural river basin. The selection of these incentives is always region-specific and depends on the current state of international affairs and environmental conditions.

Being a unique ecosystem the Ural river basin provides an encouraging incentive for transboundary IWRM through preservation of the sturgeon species.

There is no need to describe the importance of sturgeon conservation and worldwide concern over its fate. The importance of this flagship species' preservation is acknowledged by many international Conventions and Agreements (CITES, 2004; FAO, 2007; TRAFFIC, 2003; WWF, 2002b). The reason for such an interest in this species' preservation is its high commercial value. Sturgeon caviar is synonymous with luxury and wealth worldwide.

Sturgeon is an *anadromous* species, whose reproduction takes place in freshwater with the growing phase in the sea. Spawning habitats are located in the upper branches of rivers. After maturation in salted water sturgeons migrate back to freshwater for the purpose of breeding (Larinier, 2000). Their size varies from 0.5 to 6m and from 0.5kg to 1.5t. Sturgeon is a long-lived fish standing at the top of food webs. The Caspian Sea is considered to be the world's biggest sturgeon habitat, holding according to some estimates up to 85% of the world's sturgeon stock (Caviaremptor, 2004).

It is estimated that the number of sturgeons in major basins has declined by 70% over the last century (WWF, 2002b). Out of 15 sturgeon species known, most are considered critically endangered or vulnerable to extinction worldwide (WWF, 2002b). Out of six different sturgeon species inhabiting the Ural river basin, five are indicated in the IUCN Red Book as endangered or critically endangered (IUCN, 2007). Many authors consider even these conclusions as too optimistic and believe that the "point of no return" towards extinction for most sturgeon populations has been reached (Dulvy et al., 2003; Jonsson et al., 1999; Smith et al., 1993; Stephan and Wissel, 1999).

Extinction of sturgeon, probably, is one of the most tragic and representative examples of the destructive influence of humankind on Nature. Sturgeon, sometimes called the "living fossil" or living "dinosaur" of the fish world, is known to have lived since the time of the dinosaurs, for at least 250 million years, and is currently on the verge of extinction solely due to anthropogenic impacts.

The drastic decrease in the sturgeon population of the Caspian Basin is believed to be caused by various reasons (i.e. overfishing, pollution, etc.), but the main ones are habitat degradation and blockage of the spawning places and migration routes by dams on the main basin rivers (Uralbas, 2007). From this perspective the Ural river is unique since it contains the only self-sustaining, viable sturgeon population capable of natural reproduction. The future of the whole Caspian sturgeon stock and worldwide restoration programs depends on the Ural river's spawning and nursing habitats.

The only available Caspian sturgeon spawning grounds are located in the Ural's upper branches on the territory of Russia, while the migration routes, nursing and feeding habitats are in Kazakhstan. Thus, the sturgeon can be preserved only by joint efforts and transboundary cooperation in river basin management. Taking into account the high economic value and worldwide demand for sturgeon, maintaining its natural reproduction and sustainable extraction is a genuine interest of the basin countries. In order to secure this possibility integrated sustainable management of water resources in the basin should be assured.

Though the importance of the Ural river basin sturgeon habitats for the conservation of the whole Caspian Sturgeon population is well understood, practical measures which have been undertaken so far in this area are not satisfactory. For instance, the Russian National Action Plan developed within the framework of the Caspian Environmental Programme does not mention the river Ural even once, even though the restoration of the spawning habitats is one of the Caspian Strategic Action Programme's objectives.

Sturgeons are high on the international political agenda nowadays and this region increasingly attracts attention from international and national institutions. For example, from August 1st, 2007 Russia has introduced a total ban on sturgeon caviar production to facilitate sturgeon restoration programs. In August 2007 a Russian State Council presidium took place in the Caspian region and focused mainly on fishery and sturgeon restoration. Special attention in these efforts has been paid to cooperation with neighbouring countries, in particular Kazakhstan. In the last few years a number of bilateral summits devoted to Russian-Kazakhstan cooperation in the Ural river basin have been conducted.

2.2. STURGEON POPULATION AS AN INDICATOR OF THE SUSTAINABILITY OF WATERSHED MANAGEMENT

Apart from its high economic value, sturgeon is a perfect indicator (an umbrella) species for the river basin it inhabits (Lagutov, 1996, 1997; Lagutov, 1995; Uralbas, 2007). The presence and well being of the sturgeon population in a river network indicates the "good quality" of a river ecosystem's health.

Sturgeon meets the requirements for integrated IRWM indicator discussed above. Some considerations supporting this statement are listed below.

Sturgeons utilize a variety of habitat types throughout their life cycles: rivers for spawning; rivers, lakes, estuaries, or the sea for feeding and wintering. Depending on life stages sturgeon habitats are spread through the whole river network, estuaries and adjacent marine areas. Living in the Caspian sea and regularly migrating for spawning to the upper river branches in Russia through the territory of Kazakhstan, the Ural sturgeon population links together the marine and riverine ecosystems.

Figure 2 depicts the sturgeon life cycle with sea and river based stages distinguished. Some factors influencing sturgeon well-being are also indicated. The most influential factors for the Ural population are over-fishing, river water regime, and habitat degradation, and each of these factors depends on both environmental and anthropogenic factors.

Second, there is no natural predation for mature sturgeons, so apart from fishing efforts the sturgeon population is a function of river environmental conditions, which can to a great extent be controlled by IWRM.

Next, the sturgeon life cycle lasts up to 100 years which is comparable to the expected life duration of a human being. Taking into account its top position in the food chain (like human beings) and the fact that sturgeon is a subject for bioaccumulation, sturgeon is a good *integral* indicator of water quality over a long period of time. In case of river contamination the river stream can be self-purified quickly (e.g. Baia Mare case) and water quality tests will not indicate

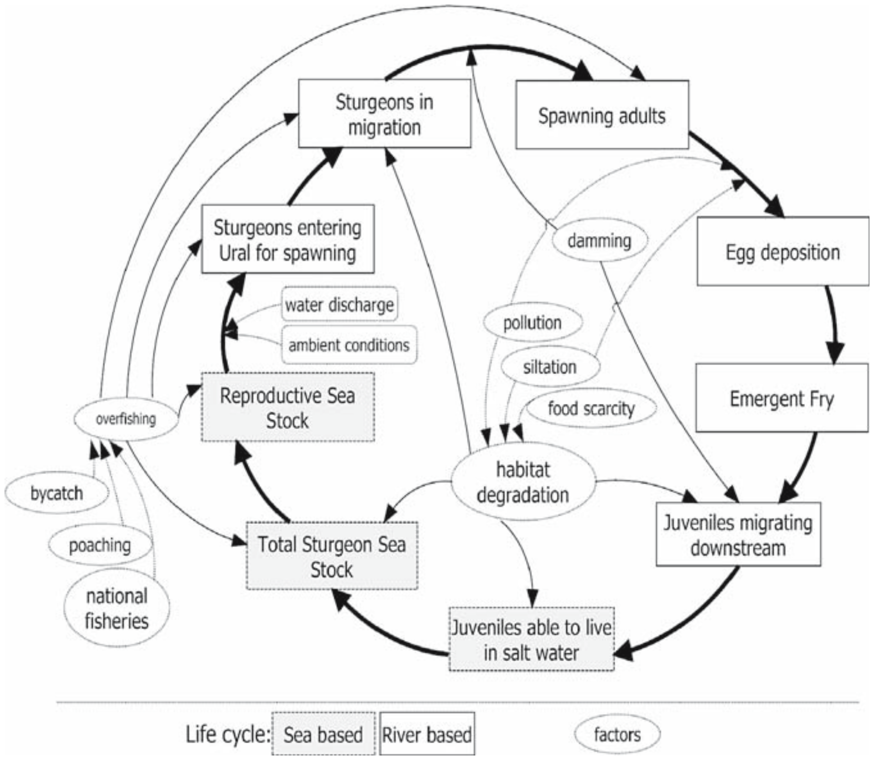

Figure 2. Sturgeon life cycle.

any problems, while living organisms (e.g. sturgeon and human beings) might be subjects for the accumulation of harmful substances.

Sturgeon is a late maturing species, reaching its reproductive age at 10–15 years old.

There is a positive relationship between sturgeon presence and a river's hydrological regime, which can be altered by damming, channelization or excessive water intakes. This species is very sensitive for water discharge in spawning periods. Figure 3 shows the relationship between water discharge and sturgeon catch in the Ural river in 19 years when matured sturgeons are returning for spawning (Uralbas, 2007).

Sturgeon presence in the river indicates the natural character of the hydrological regime, including regular floods and river self-purification (Figure 4).

Apart from that, sturgeon is an indicator of river physical characteristics: blockage of migratory routes, habitat degradation and fragmentation, siltation, pollution, water quality, etc. Some of these factors directly depend on the land use patterns in the river basin due to water runoff from the catchment area.

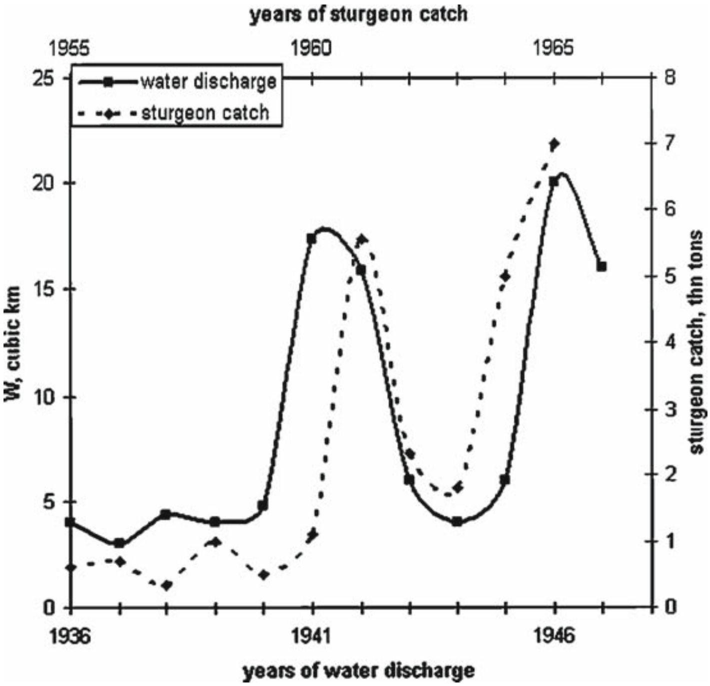

Figure 3. The relationship between river discharge and sturgeon catch in the Ural river 20 years later. (Uralbas, 2007.)

Sturgeons also represents regional economic development and social structure, as poaching and illegal fishing which reduce sturgeon populations develop in areas with a poor unemployed population. For example, the WWF's European Freshwater Programme considers Sturgeons as all the above mentioned species, namely Flagship species, Species of special concern and Indicator species (WWF, 2002a, b).

It is obvious that securing of natural sturgeon reproduction, protection and sustainable management of sturgeon stock is directly linked to integrated water resources management in the river basin and sustainable watershed development. These activities influence each other and should be considered only in an integrated manner.

Preserving sturgeon in the region would not only be of pure environmental benefit, but would also greatly contribute to economic and social stability in the region as well as food and water security. Thus, the measures aimed at preservation and sustainable management of the Ural sturgeon population can bring together environmental and socio-economic aspects of sustainable development and underpin the strategies for sustainable watershed development.

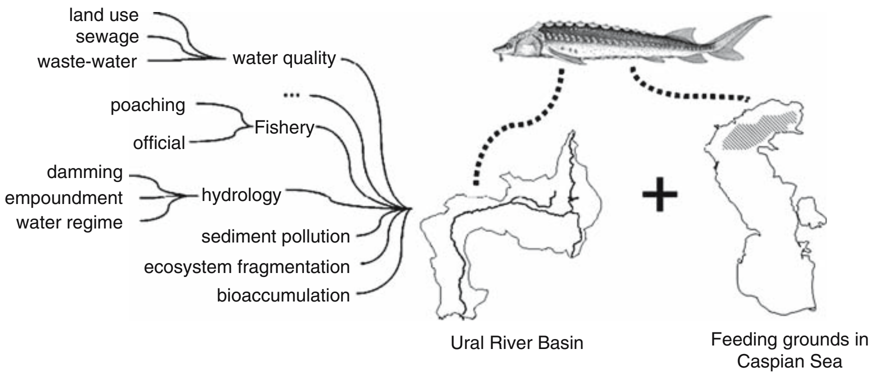

Figure 4. Sturgeon as an indicator of river ecosystem health.

2.3. PUBLIC PARTICIPATION (COMMUNITY-BASED BIODIVERSITY CONSERVATION AND WATERSHED MANAGEMENT)

As stated above, public participation is one of the essential principles of IWRM and sustainable watershed development. Any nature protection activities are ineffective if they are not supported by local communities. Moreover, some authors mention the rights of local communities over water and water ecosystem related resources as an important factor contributing to sustainable basin development (Kgarebe, 2002)

In many cases practical implementation of these requirements are hardly possible or has a limited, formal character, since often local communities have no incentives to participate in these activities. This is well illustrated by conservation of sturgeons with high market value, which makes this species a subject for poaching. So, poaching and illegal fishing are widespread regional threats in the Ural region nowadays.

However, a high level of public participation can be easily achieved in the Ural watershed. Active cooperation of local communities with regional authorities might be possible thanks to the peculiarities of regional identity. This area is historically populated by Ural Cossack communities, a self-governing paramilitary ethnic group. Cossack troops were traditionally involved in various State services in Russian Empire. They were either protecting Russia's borders in their areas or serving as combatants during military campaigns. In exchange for military service they enjoyed exclusive rights to control natural resources on their territory (e.g. fish and water) and paid no taxes (Semple, 1907; Von Harthausen, 1972).

The Self-governing Lands of Cossack Communities in the Russian Empire were historically located in the river basins (Don, Volga, Cuban, Terek, Ural, Amur, etc.) in the frontier areas. Cossacks were living in small villages (*stanitcas*) throughout the river floodplains, relying on fishing, hunting and small scale farming as food sources. Any industrial or agricultural activity on their Lands had to be confirmed at Cossack gatherings ("Cossack Circles").

The Ural Cossacks are one of the oldest Cossack communities in Russia. Their historical settlements are stretched in a line along the banks of the Ural river for more then 450 km. As can be seen from

Figure 5, a reprint of an old Russian map from the beginning of the 20th century, the Ural Cossacks' Land closely matches the shape of the Ural basin, covering all sturgeon habitats.

The traditional life style of the Ural Cossacks directly relates to the problems of sustainable water management in a river basin. Living in harsh environmental conditions characterized by low soil fertility they had to fully rely only on the river ecosystem to support their communities. Consequently, all the aspects of water usage and fishery were very carefully described, regulated and enforced. There were fishery and water laws. Out of two elected commanders (*atamans*) one was a military commander, while the other one was solely responsible for river-related issues (e.g. fishery). Special troops used to guard the river streams during spawning migrations.

Baron August Von Harthausen in his book "Studies On The Interior Of Russia", first published in German in 1847, described the Ural Cossacks as follows:

Figure 5. The territory of Ural Cossacks Land before 1917 fully covered the sturgeon habitats from the river mouth to sturgeon spawning grounds upstream.

> …they do not farm the land at all… and live principally from fishing… Fishing is precisely regulated. It is limited to specific times in the winter, spring, and autumn. Whoever dares to catch a fish out of season loses his share for that year. Even if the Cossack happens to find a sturgeon which has been tossed onto the land, he will carefully throw it back into the water rather than take it home…. (Von Harthausen, 1972)

Sturgeon and river worshipping by Ural Cossacks was reflected on their coat of arms: sturgeon and water were the only items depicted on it in addition to their weapons.

Unfortunately, this interesting experience of sustainable river-related managements not adequately reported in Soviet, and correspondingly, foreign literature, due to the persecution of Cossacks by the Soviet regime during the 20th century.

Cossacks were, probably, the most severely persecuted ethnic group after the Bolshevik Revolution in 1917. Revival of the Cossack movement is a widespread phenomenon through the whole territory of Russia nowadays. Recovering from repressions they are actively looking for their place in modern Society and possibilities of State Service, demanding changes in legislation and society structure (BBC, 2007). For example, often regional Cossack organizations serve as voluntary mounted police in cities in their region.

While it might be impossible to fully restore Cossacks' former rights and privileges, this potential and these grass-roots initiatives should be utilized. The idea of using reviving Cossack groups for environmental protection has been actively promoted in the last decade by some Cossack and NGO leaders (Lagutov, 1995; Uralbas, 2007). The involvement of local communities in nature protection activities (e.g. establishment of ethno-natural protected territories) in the Ural river basin may not only protect this species and ecosystem of worldwide concern, but also stabilize the social and economic situation in the region by providing employment. In this case, Cossack groups can be effectively used for guarding the protected areas to prevent poaching and serving as rangers.

2.4. LEGAL AND INSTITUTIONAL FRAMEWORK

The existing legislative base including, but not limited to, National Constitutions, International Conventions, ratified by both countries, national laws and a number of bilateral agreements creates an adequate legal framework to initiate transboundary watershed management cooperation. However, further improvements and amendments are needed for its successful realization.

The new RF Water Code, a framework national law regulating the protection and use of water resources, was adopted in Russia in June 2006, and came into force on 1 January 2007. The Code is mostly based on existing national water legislation. It also incorporates a number of contemporary approaches to water management presented in IWRM and, as an example of a well elaborated water Directive, the European Union Water Framework Directive. In particular, one of its innovations is the introduction of a basin management approach to water management practice, institutional coordination based on a basin approach and the creation of basin councils. It also envisages comprehensive basin management schemes that are to be developed for the purposes of integrated water management.

However, the EU WFD urges "management of a river basin as a single system of water management" and suggests that the usual administrative boundaries should no longer be applied to water basin management. At the same time, the territorial unit for water management (basin "okriug") in the Russian Water Code is based on the existing administrative structure in Russia. The Water Code simply coordinates water policies between the federation, the 89 federal subjects and the municipalities by defining the scope of their competences within the traditional administrative borders. It also aims at coordination between multiple stakeholders and water-users.

It should also be noticed that a basin management approach was also foreseen by the 1996 Water Code of the Russian Federation, though without any practical implementation. The legal framework for integrated river basin management was also developed and adopted in the Soviet Union in the 1960s.

By contrast, Kazakhstan is a few steps ahead in implementing the basin water management principles. The new edition of its Water Code, incorporating the principles of river basin management, was adopted in 2003. The Basin Councils for most of the river basins within the territory of Kazakhstan are already established and functioning. A number of internationally-funded projects on IRWM are undergoing. However, according to UNDP reviews the situation with water resources management in Kazakhstan "is best described as being fragmented, underfunded and poorly governed" and there is still a long way to go to implement IWRM principles.

Transboundary aspects of watershed management have received very little attention in either country so far. Though both countries have ratified a number of international and bilateral conventions and agreements on transboundary water issues and pollution, they have not been enforced yet.

The preservation of the ecosystem and sustainable watershed management of the Ural River depends not only upon efficient cooperation by both basin countries, Russia and Kazakhstan, but also on active involvement of international institutions. The latest trends show that international organizations and donors are increasingly interested and willing to fund and participate in transboundary water management projects and threatened biodiversity conservation (in particular sturgeon and other flagship species) (CITES, 2003; Raymakers and Hoover, 2002; Turnock, 2001; UNECE, 2006, 2007; WWF, 2003).

Taking into account the above considerations and the development stage for regulations and methodologies in both basin countries, the case of the Ural River Basin is ideal for a pilot study on development and implementation of transboundary basin management directives aimed at sustainable watershed development.

3. Ural basin project

The Ural River Basin Project was launched to facilitate the sturgeon restoration and sustainable watershed management in the Ural River Basin in 2007. The Project is a joint initiative by Central European University, the Russian Environmental NGO "Green Don" and a number of Russian and Kazakhstan NGOs and environmental state agencies.

The underlying idea of the Project is the concept of sustainable basin development by securing natural reproduction of migratory sturgeon species. In order to assure the implementation of this idea an international Ural Sturgeon Park should be established, spreading through the full extent of sturgeon migration routes and habitats, from the spawning grounds in the river upper branches to the river mouth. Such a Park should also have features of a Biosphere Reserve and Ethno-Natural Protected Area. Integrated water management and community-based management of sturgeon stocks can be the basis for sustainable basin development. In this way the Project aims not only to preserve this flagship species, but also to solve social and economic problems by restoration of the traditional life style of local communities.

In order to achieve this, close cooperation and agreement should be established not only on communities' level, but mainly on the level of local and regional authorities of Russia and Republic of Kazakhstan. The proposal for the creation of such an International Park should be developed in collaboration with all the interested parties and a cross-sectoral feasibility study should be carried out in cooperation with national and international agencies. The final proposal should take into account the interests of all stakeholders with priority given to sturgeon conservation to secure regional sustainable development.

The areas under the scope of the Project include different environmental disciplines and anthropogenic activities related to the well-being of the sturgeon population, taking into account its triple function in the river ecosystem (as indicator species, flagship species and species of special concern). By adopting this holistic, integrated approach the Project will be a focal point for specialists on water quality, fishery, international and national environmental law, as well as sturgeon experts.

The consultations with the main regional Cossack organizations in the region have shown their interest and full support for this initiative. Moreover, the first joint fishery inspections by State Agencies and voluntary Cossack troops have been conducted.

While the establishment of a Ural Park seems to be long-term distant goal, other activities have been carried out in the framework of the Project. Public awareness raising has been approached through a number of regular publications in regional and local mass-media. The website of the Ural Basin Project was launched at the beginning of 2007. A number of research projects on river management and biodiversity has being also undertaken in cooperation with regional organizations (i.e. GIS databases creation, river ecosystem and sturgeon population modelling).

One of the Project's goals is to develop a network of specialists involved in different aspects of integrated water management and sturgeon conservation. Such a network should unite not only different scientists (biologists, hydrologists, economists, chemists, lawyers, etc.), but also water users (industry, agriculture, local communities, etc.) to provide integrated interdisciplinary analysis of watershed-related problems and develop sound recommendations for decision-makers. Managerial insight and opinion should also be taken into account through their involvement and feedback to the developed recommendations supplied to them. Figure 6 displays the idea of this network and the role of the Ural Basin Project in it.

The cooperation with educational institutes aimed at the review of current environmental-related courses is carried out as a part of the project. In particular, it is planned to include in syllabi discussions of transboundary environmental management and nature protection and to introduce to institutions and schools of the Ural Basin experimental training courses for officers of environmental agencies and state services.

The First Ural River Basin International Workshop "Rescue of Sturgeon Species by means of Transboundary Integrated Water Management in the Ural River Basin" was held in Orenburg (Russia) on June 13–16, 2007 within the framework of the Ural Basin Project. Organized by the Research and Consulting Center DonEco and Central European University, the Workshop was also conducted with active involvement and assistance by the Russian Federal Agency for Environmental Inspections. The workshop was attended by more then 60 experts, researchers and practitioners from Governmental Environmental Agencies, NGO and business representatives from both basin countries (Russia and Kazakhstan), and representatives from relevant international organizations such as the Food and Agriculture Organization of the United Nations, the Secretariat of Wetland Convention (RAMSAR), the International Association on Danube Research, and many others covering the whole spectrum of Ural

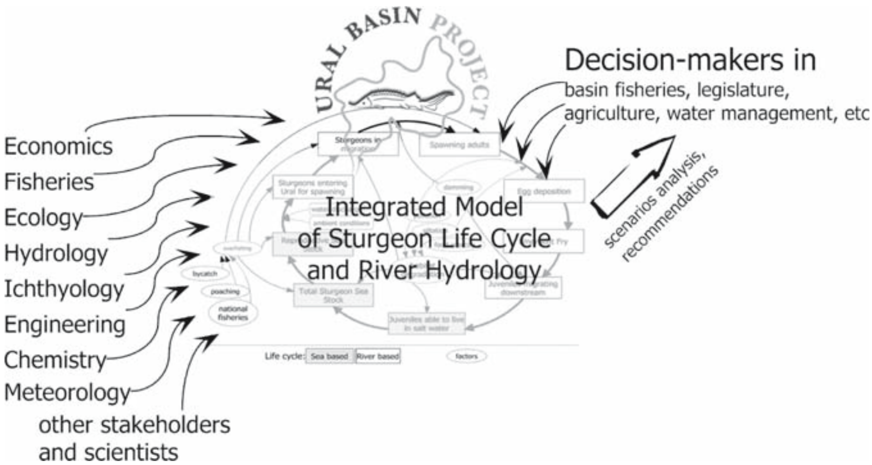

Figure 6. The network of specialists in integrated watershed management of the Ural river and role of Ural Basin Project.

Basin management stakeholders. More information on this and other Project activities can be found on the Project's website at http://uralbas.ru.

4. Integrated modelling

As has been indicated by many authors, one of the most convenient and useful ways to approach the highly interdisciplinary nature of environmental assessment and management in river basins is to use techniques and tools of Integrated Assessment and Modelling (Harris, 2002; Jakeman and Letcher, 2003; Jansky et al., 2004; Janssen and Goldsworthy, 1996; Krysanova et al., 2007; Lagutov, 1997; Letcher et al., 2007; Parker et al., 2002; Shen et al., 2005).

Thus, special attention within the project activities is paid to the modelling of sturgeon population and water management issues. Such a model has proven to be a very useful tool in integrated water-resources management in a river basin and analysis of sturgeon protection activities (Lagutov, 2003; Lagutov, 1996, 1997). Moreover, some authors state that sustainable river basin management is only possible by means of applying catchment models to evaluate management alternatives (Fohrer, 2005; Refsgaard et al., 2005).

Given the wide acceptance of the need for integrated modelling it may be somewhat surprising that there is no understanding of the ways in which integrated modelling can be useful in environmental assessment and management.

Traditionally the role of modelling is perceived by environmental managers and practitioners as a way to produce end-user tools for predictions and analysis of the consequences of management strategies for decision-makers (Giupponi, 2007; Mysiak et al., 2005; Scoccimarro et al., 1999). These tools, called "Decision Support Systems" (DSS), are computer-based programs with easy-to-use interfaces allowing managers and practitioners to take into account expert opinion in some areas. Despite their popularity, the success of DSS development is uncertain and many computerized decision-support tools have failed when dealing with complex and unstructured problems (Larocque et al., 2006). The level of uncertainty in environmental models and associated socio-economic subsystems is very high, and often it is impossible to forecast the behaviour of a certain ecosystem and/or related management strategies. Limitations and disadvantages as well as advantages and benefits of using DSS should be well understood by end users.

Undoubtedly, DSS is still a very important function of environmental modelling, but sometimes it is not the main goal of modelling efforts.

Another important function of integrated modelling is serving as a framework for the organization of existing multi-disciplinary knowledge, to identify gaps in knowledge and to bring scientists, stakeholders and decision-makers together (Keyl and Wolff, 2007; Parker et al., 2002; Suter and Glenn, 1999).

Development of a conceptual watershed model can be used as a tool to facilitate debates and consultations among stakeholders and scientists, thus to enhance the participatory process (Lanini et al., 2004; Sendzimir et al., 2007). The integrated modelling should be perceived not as a finished product but as a tool for problem exploration and communication of results.

In accordance with Projects' underlying principles and priorities, the river hydrological modelling is combined with sturgeon population models. This should introduce a long term perspective to water management strategies.

Process-based spatial model simulating river hydrology and upstream-downstream migration of sturgeon populations has being developed. Corresponding human activities (i.e. water intakes, pollution, fishery, etc.) as well as environmental conditions are also simulated. Based on the input control parameters and calculated river characteristics, Habitat Suitability Indices are generated along the river stream. Using these indices the possible locations of spawning, wintering and feeding grounds are to be identified.

Figure 7 shows the basic structure of a coupled river-hydrology and sturgeon population simulation model to support the development of watershed management strategies.

Modelling efforts of hydrological and population processes should be supported by reliable data on various parameters (Thorsten et al., 2004; Vidal et al., 2007) A single river ecosystem-related monitoring system which was established in the Soviet Union has collapsed in both countries in the 1990s. Though each basin country is now trying to develop a monitoring system independently, a lot of information is still not available or biased (e.g. data on sturgeon catches). Using an integrated modelling approach, missing data can be substituted by expert opinion (Liu et al., 2007).

To support modelling efforts and to collect data available on the Ural river basin GIS databases of the Ural River ecosystem are being developed. There are a number of techniques which can be used for linking GIS and environmental modelling (Aspinall and Pearson, 2000; Pullar and Springer, 2000).

5. Conclusions

Sturgeon species can be considered a perfect natural bioindicator of a river basin's health – in this case the Ural river basin. Their conservation will also serve the Region's sustainable economic and social development.

It should be noted that fish have been used as indicators for solely ecological status assessment for about 20 years as one of many indicators along with phytoplankton and amphibians (Hughes and Oberdorff, 1999; Scardi *et al*. 2006). For example, fish populations are one of many ecosystem health indicators in the EU's WFD. To date, however, even EU Member States have not yet included fish in their routine monitoring programs. Sturgeon is one of the suggested indicators for biodiversity abundance. However, use of this indicator for European rivers is a matter for the very distant future, if at all, since it is totally extinct from every European river without hopes for restoration due to habitat loss and damming. The only exception is some landlocked

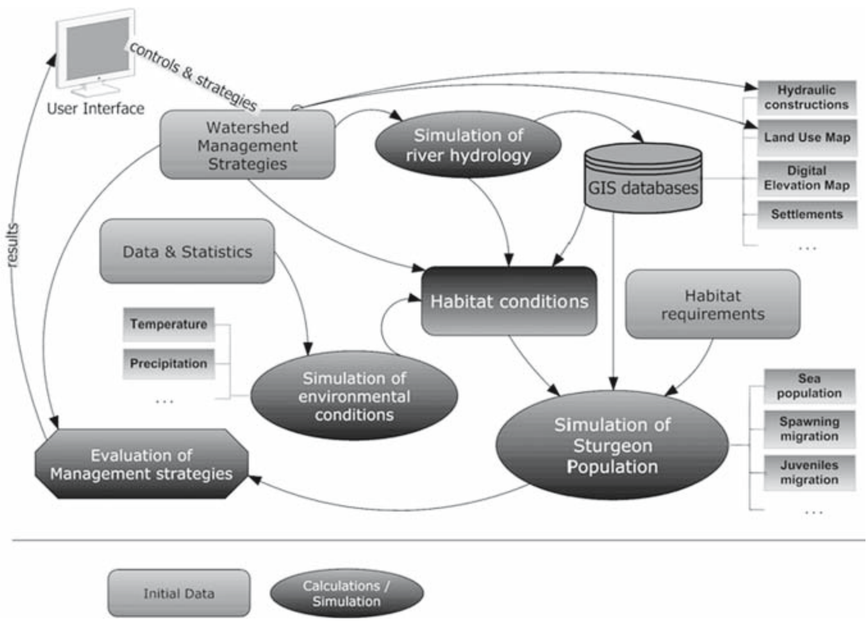

Figure 7. Basic structure of Simulation Model to support sustainable watershed management based on community-based sturgeon conservation.

freshwater sturgeon subspecies of little ecological and economic value, which cannot be used as an indicator in the same way as other sturgeon species (e.g. sterlet in the Danube).

Appropriate experiences and practices from the UralBas project can be applied to worldwide sturgeon restoration and watershed development programs.

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LAGOON ECOSYSTEM STUDY TROUGH TWO CASES: OUALIDIA (ATLANTIC) AND NADOR (MEDITERRANEAN) – MOROCCO

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Abstract: The present study is interested in two watersheds that have a great socio-economic interest. One is located on the Atlantic coast (Oualidia lagoon) and other on the mediterranean coast (Nador lagoon). This work is mainly focussed on hydrodynamical study, in order to understand the functioning of their ecosystem and to provide informations for different decision makers.

Keywords: Morocco; Oualidia; Nador; lagoon; 2D/3D numerical modeling; current; groundwater inflow estimates; water renewal times

1. Introduction

Constituting buffer zones between the continent and the marine environment, the paralic water bodies (lagoons, bays and estuaries) often constitute an important hereditary biological material, regarding their important environmental assests and biological diversities. These zones are also reproduction areas of a great number of biological species and are a traditional passage of many migratory birds species.

Lagoons attract many human activities (tourism, urbanization, agriculture, fishing and breeding…), involving use conflicts between these different activities which are sometimes inconsistent. As an example, we can mention:

- The use of the space which can be coveted by several types of activities: fishing, shellfish farming, tourism, salt-marshes, balneal activities…
- Residual waste of different products (waste water, manure, pesticides…) into the water, likely to disturb both the lagoon ecosystem and the activities developed around it (tourism, shellfish farming, fishing, salt-water marshes,..)

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Although they are highly appreciated and coveted, these lagoons environment remain, however, fragile ecosystems, under the combined effect of the natural modifications and the anthropic pressures.

The present study is interested in two watersheds that have a great socio-economic interest. One is located on the Mediterranean coast (Nador) and the other (Oualidia) on the Atlantic. This work is mainly focussed on their hydrodynamic study, in order to understand the functioning of their ecosystem. The aim of this study is to provide some information for different decision makers, particularly for local authorities to facilitate their management practices and decision making.

2. Presentation of the lagoons

2.1. OUALIDIA LAGOON

Oualidia lagoon, located on the Atlantic coast of Morocco (Figure 1), is 7km long and on the average 0.5km wide, and it exchanges waters with the ocean through a major inlet of about 150m width and 2m depth and, during spring tides, with a secondary, shallower inlet of about 50m in width. An internal delta with a surface area of about 0.2km^2 is normally found close to the inlet (Carruesco, 1989).

The lagoon morphology is characterized by side channels connected to a main meandering channel where the mean depth is 2m and the maximum depth does not exceed 5m during flood tides. Intertidal areas on both sides of the channels occupy about 53% (1.6km^2) of the 3km^2 surface area of the lagoon at low tide. Flood tides covers more than 75% (2.25km^2) of the lagoon surface, bringing salt water up to the upstream reaches of the lagoon and into a saline marsh beyond the second dam. The artificial dam (causeway) was built more recently to facilitate the crossing of the lagoon. It has a breach of about 10m wide and 2m deep, which allows some water exchange between both sides of the dam at higher water levels. The dry season occurs from July to September and is followed by a wet season from October to June (Carruesco, 1989).

There are no rivers discharging into the lagoon, but several authors have mentioned the existence of underground freshwater seepage somewhere within the lagoon (Carruesco, 1989; Hilmi, 2005; Hilmi et al., 2005a; Rharbi et al., 2001). Some indications are that it is located in the first part of the lagoon and upstream of the lagoon (near the artificial dam) and, more recently, it has been estimated more recently by numerical model to be 0.25 $m^3\ s^{-1}$ (Hilmi, 2005). Rainfall over the lagoon region accounts for only 1% of the fresh water entering the lagoon. The annual average rainfall, estimated from 1977 to 1998, is about 390mm, with a maximum in December and no rain during the dry period. The annual estimate of evaporation

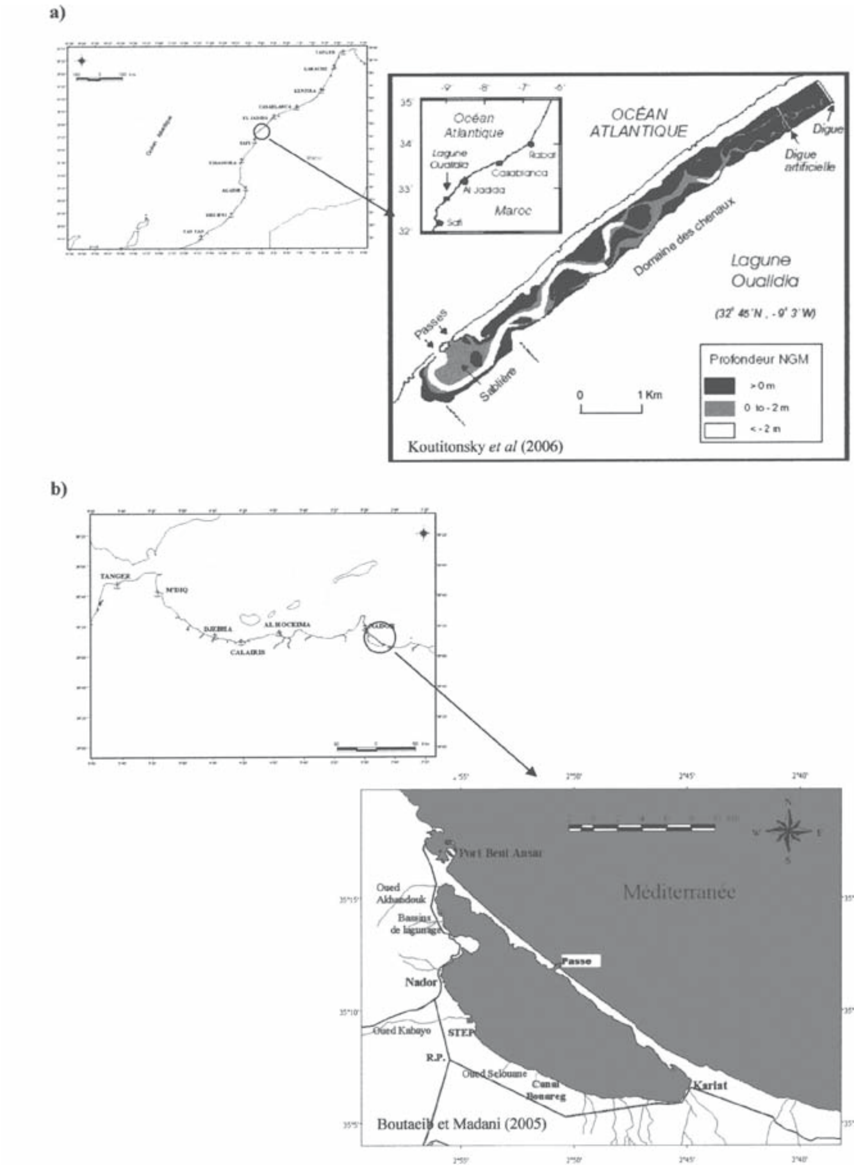

Figure 1. Localisation of (a) Oualidia lagoon (Atlantic sea) and (b) Nador lagoon (Mediterranean sea).

minus precipitation is 650 mm. The predominant wind directions are WSW to NW during the wet season and NNE to NE during the dry season (Carruesco, 1989). Violent and sporadic winds (*Chergui*) occasionally blow from ENE during the dry period and may contribute to high evaporation rates over the lagoon as well as to extreme air temperatures reaching sometimes 40 °C. More generally, winds blowing from the northern sector will produce southerly geostrophic currents along the coast, offshore transport and coastal upwelling of nutrient-rich deep waters close to the coast (Orbi et al., 1998). Upwelled waters with high nutrient contents should be advected by flood tides into the lagoon. They support biological production and enhance aquaculture yields inside the lagoon. In addition, Oualidia lagoon is a site of intense tourism activities during summer. The major aquaculture activity in the lagoon is oyster aquaculture. To date, more than eight oyster farms (locally called *Parcs*) occupy more a sixth of its surface. The sustainable development of additional farms requires a better knowledge of the circulation, mixing and turnover time of water in the lagoon.

2.2. NADOR LAGOON

Nador lagoon is of great socio-economic interest for the surrounding area where various types of activities related on artisanal fishing and aquaculture have been exerted during several decades. Within a surface of 115 km^2, it is the largest lagoon of Morocco and its depth increases rapidly, from banks to stabilize around 6–7 m in its central part (Figure 1). It communicates with the Mediterranean sea through a main inlet (around 250 m length, 150 m broad and 3 m of average depth), located on barrier which has been varied during time (Erimesco, 1961; Tesson, 1977; Lefebvre et al., 1997).The climate of the lagoon is Mediterranean and the rain, weak and irregular, varies depending the years (between 150 to 450 mm.$year^{-1}$), reaching its maximum values during December and April (Lefebvre et al., 1997). Under the period 1991–2001, this latter has varied between 225 mm $year^{-1}$ (1998) and 390 mm $year^{-1}$ (1992) (Arid et al., 2005). The monthly air average temperatures vary between 13 °C in January and 28 °C in august, with a minimum of 1 °C, however, observed during January and a maximum of 35 °C during august (Lefebvre et al., 1997). The monthly temperatures/salinities averages of lagoon water generally follow the same tendency and are minimal during winter season ($T < 27$ °C and $S < 40$ psu) and maximal during summer season ($T > 27$ °C and $S > 40$ psu) (Hilmi, 2005). Fresh water and sediments lagoon's input come mainly from the continent (Oued Selouane and Oued Bouareg (Figure 1) during winter but their flows are not known with accuracy. In fact, the volume of fresh waters arriving to the lagoon are weak and estimated between 40 with 200×10^6 m^3 $year^{-1}$ from stream and to 18×10^6 m^3 $year^{-1}$ from ground water (cited by Lefebvre et al., 1997).

3. Material and methods

The models used in this study are the hydrodynamic (HD) module of the integrated MIKE 21/MIKE3 modeling system from DHI (Danemark).The HD module simulates unsteady three dimensional flows into account density variations, bathymetry and external forcing such as meteorology, tidal elevations, currents and other hydrographic conditions (DHI, 2002). The mathematical foundation is the mass conservation equation, the Reynolds-averaged Navier-Stokes equations in three dimensions, including the effects of turbulence and variable density, together with the conservation equations for salinity and temperature.

The cartesian grid, developed for Nador lagoon, includes 200 cells in X (Eastern) and 200 cells in Y (Northern). Their horizontal dimensions are respectively 90 × 90 m. In the vertical dimension, the grid is divided into six layers of 1 m thickness, except close to surface where the thickness is of 1.5 m. The 3D model is forced at seaward side of the lagoon entrance by around days long water level measurement (Hilmi et al., 2005b) at Beni Ansar harbour (Figure 1). The hydrodynamic model used for Oualidia lagoon was the MIKE21-HD model (DHI, 2002), a horizontally two-dimensional (2D) model that solves the vertically integrated equations of conservation of mass and momentum using finite-difference numerical integrations in time and space. The computational grid for Oualidia lagoon was constructed from local bathymetry and consisted of 303 cells in the X direction and 40 cells in the Y direction, each measuring 25 × 25 m. The grid origin was at 32°43.86' N–9° W, the X-axis being oriented at 50° TN and the grid upper limit being the artificial dam (Figure 1).

Measurements from current meters inside both lagoons are used to validate the models. Hourly wind data (speed and direction) are also used either at Nador airport (for Nador lagoon) or Safi for Oualidia lagoon) to force the model's surface. More details about these models are mentioned in Hilmi et al. (Hilmi et al., 2005a, b).

4. Results

4.1. OUALIDIA LAGOON

The tidally averaged renewal time for whole the lagoon is found to be 7 days, while the local renewal time at the upstream end of the lagoon is 25 days (Hilmi et al., 2005a). During summer-spring 2005, for example, current speeds exceeded 1 m s^{-1} during spring tides and decreased to 0.1 to 0.2 m s^{-1} during neap tides (Figure 2). Current directions follow the major channel axes, reversing by 180° between the flood and the ebb tides. Harmonic

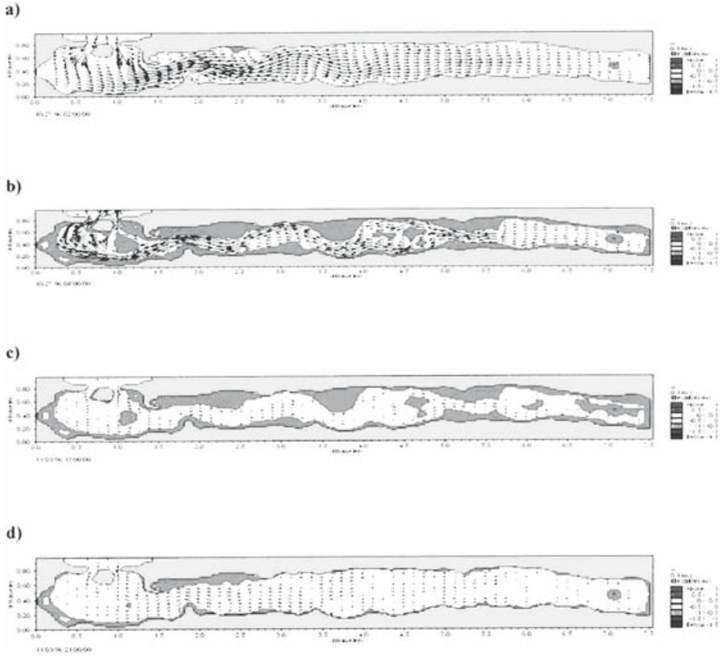

Figure 2. Example of Oualidia circulation lagoon during (a) flood and (b) ebb of a neap tide; (c) flood and (d) ebb of spring tide (Hilmi, 2005).

analysis of tide and current indicate that they are mainly semi-diurnal, with a predominance of M2 harmonic (period of 12.42 h). During its propagation outside of the lagoon's inlets to its upper limit (artificial dam), the time delay is about 2 h 35 min. Maximum speeds of current (>1 m s^{-1}) are observed near the inlet of the lagoon and surrounding areas and are reduced upstream of the lagoon (<0.5 m s^{-1}) (Hilmi, 2005). The lagoon is classified as "leaky" lagoon (Kjerfve, 1994) where its water time turnover is estimated to be around 7 days (Hilmi et al., 2005a). Spectral analysis of tide and currents (figure not shown) indicate, in the low frequencies, the influence of meteorological forcing between 1.5 and 3 days; inertial period at about 23 h and the influence of M3, M4, …sub-harmonics of M2 in the high frequencies. These sub-harmonics are resulting from the non-linear interaction of the flow with the shallow bottom and with the channel meandering curvature and play a significant role in asymmetric tidal cycles (Hilmi, 2005). In fact, non-linear tidal distortion is a composite of two principal effects: (1) frictional interaction between the tide and channel bottom causes relatively shorter floods and (2) intertidal storage causes relatively shorter ebbs (Friedrichs and Aubrey, 1988). As a consequence, this asymmetric tidal cycles might play a significant role in the transport and accumulation of sediment in this lagoon. Inside the lagoon, this sediment is sandy near the inlets and surrounding areas, a mixture of sand/mud at the intermediate part and mud/sand upstream of the lagoon (Sarf, 1999). Temperature-salinity analysis indicated that water temperatures and salinities close to the mouth are clearly of marine origin. Ocean waters are advected upstream past the middle of the lagoon during flood tides and they return mixed with fresh water during ebb tides. Salinity decreases further upstream, attributed to underground freshwater seepage into the lagoon (Hilmi, 2005; Hilmi et al., 2005a).

4.2. NADOR LAGOON

In this lagoon, the tide are mainly semi-diurnal (M2) but their amplitude are low (Pugh, 1987) and reduced from 0.13 m at Beni Ansar harbour (Figure 1) to 0.03 m at the internal part of the lagoon's inlet, with around of 3 h delay (Hilmi, 2005; Hilmi et al., 2005b). The tidal currents in the lagoon are very intense at the inlet of the lagoon (approximately 1 m s^{-1}) and decrease gradually towards north/south of the lagoon's banks. Inside the lagoon, surface currents are weak and decrease to be less than 0.05 m s^{-1} on the bottom (Hilmi, 2005) (Figure 3). The lagoon is classified as "choked" lagoon (Kjerfve, 1994) where its water time turnover is estimated to be around 80 days (Hilmi, 2005; Hilmi et al., 2005b). The most important factor that controls the residence time is the wind action on the lagoon surface; the residence time is ranging from 590 days under a situation without wind down to less than 30 days under the action of moderate to strong winds (Umgiesser et al., 2005). In the absence of tides, the winds are thus the main factor of the water circulation and exchange of the lagoon (Hilmi, 2005; Hilmi et al., 2005b; Umgeisser et al., 2005). Under the period 1991–2001, the seasonal water circulation of the lagoon is governed by winds which are generally S, WSW with W from November to February and N to E from march to October, forcing between 2 days to 3 months. The average intensities of westerly winds vary between 3.8 and 4.4 m s^{-1}, NE winds vary between 4.6 and 5.3 m s^{-1} and more intense (between 4.6 to 6.2 m s^{-1}) are ENE winds. In terms of surface circulation of the lagoon, those winds generate instantaneous surface currents which are involved in the same direction and pile up the water at the north/south ends of the lagoon (Figure 1b), where they plunge into depth in the middle part of the lagoon. A return current against the direction of the wind is observed, caused by a longitudinal hydrostatic gradient pressure (Hilmi et al., 2005b). Equivalent 3D circulation structures are generally observed for lagoons where depth are often higher than 5 m and more (Kjerfve, 1994; Koutitonsky et al., 2002, 2004).

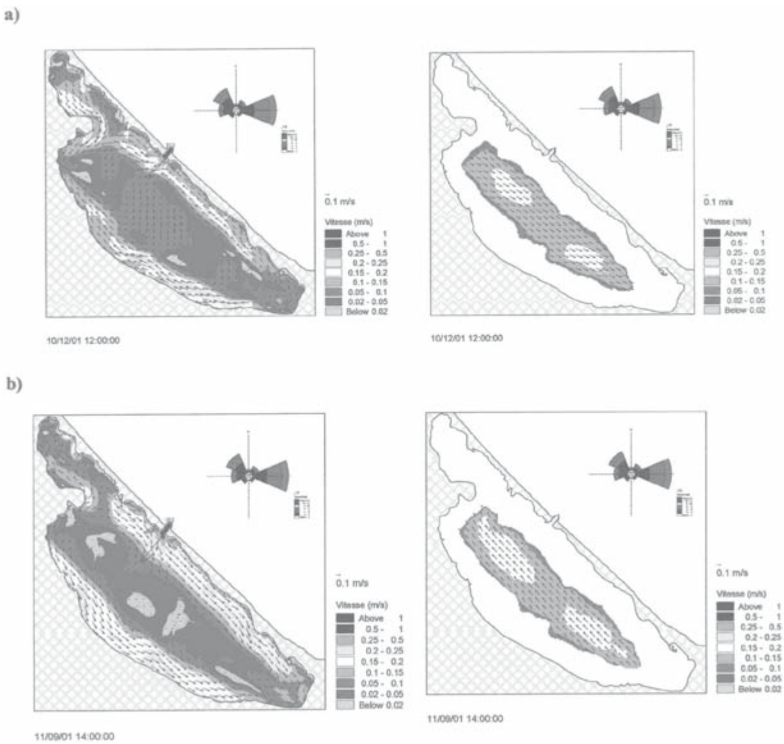

Figure 3. Example of surface circulation (left) and bottom circulation (right) in Nador lagoon during (a) eastern and (b) during spring 2001. Windy roses are represented in each box (Hilmi et al., 2005b).

5. Conclusions

This present study is mainly focussed on their hydrodynamical study, in order to understand the functioning of their ecosystem.

For Oualidia lagoon, the tidally averaged renewal time for whole the Oualidia lagoon is found to be 7 days, while the local renewal time at the upstream end of the lagoon is 25 days Current speeds exceeded 1 m s^{-1} during spring tides and decreased to 0.1–0.2 m s^{-1} during neap tides. Current directions follow the major channel axes, reversing by 180° degrees between the flood and the ebb tides and are asymmetric in the lagoon. Water temperatures and salinities close to the mouth are clearly of marine origin. Ocean waters are advected upstream past the middle of the lagoon during flood tides and they return mixed with fresh water during ebb tides. Salinity decreases further upstream, attributed to underground freshwater seepage into the lagoon.

In Nador lagoon, tides are mainly semi-diurnal (M2) and their amplitude decreases from $0.13\,m^{-1}$ outside the entrance channel to $0.03\,m^{-1}$ inside the lagoon. Its relative phase is also retarded by about 3 h as it enters the lagoon. Predominant winds blow from the north-west and from the east and produce down-wind coastal currents close to both the north and south shores of the lagoon. Close to the bottom, currents are directed against the wind or up-wind. Water time turnover is estimated to be around 80 days and the most important factor that controls the lagoon's circulation is the wind action on the lagoon's surface.

It is also recommended to develop an integrated project whose overall objective is to develop modelling tools for environmental authorities to facilitate their every day management practices and decision making. Models or system of models will help decision makers to clarify the reasons of existing trends in water quality conditions, to make an environmental impact assessment and to develop short-term and long-term predictions according scenarios of economical and civilian development in the lagoon watersheds (Gonënç et al., 2006).

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COASTAL LAGOONS IN THE CONTEXT OF WATER MANAGEMENT IN SPAIN AND EUROPE

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Abstract: Water management is one of the main problems facing humanity and follows a hierarchical perspective from the whole planet to water body. Spatio-temporal scales change at each level, as do driving forces, impacts, and the processes and responses involved. Recently, the European Union adopted the Water Framework Directive (WFD) to establish the basic principles of sustainable water policy in member states and one of the main concerns of the Directive is the need to consider the vulnerability of coastal aquatic ecosystems and to establish their ecological status. Water deficits and geographical water disequilibria in Spain have traditionally been faced with the development of hydraulic infrastructures, including long distance water transfers from water-rich basins to regions with scarcity, but the strong degree of decentralization existing actually in Spain and the number of administrations, authorities and institutions involved, hinders a common policy and administration of water resources. At water body level, coastal lagoons face conceptual and ecological difficulties in applying the WFD from their inclusion in a typology to the assignment of an ecological status as a consequence of inter and intra-lagoon variability in hydrology and biological assemblages and ecosystem homeostatic mechanisms.

Keywords: Coastal lagoons; water management; water framework directive; Mar Menor

1. Introduction

All over the world, water and its management is one of the main problems facing humanity. Problems vary from scarcity and worsening water quality for human uses, to floods in areas with torrential rainfall and rising sea levels in coastal zones. Many of these problems are becoming more pressing due to climate change. In Europe, the European Commission recognizes that waters

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in the Community are under increasing pressure from the continuous growth in demand for sufficient quantities of good quality water for all purposes.

Accordingly, the European Union adopted the Water Framework Directive (WFD) (Directive 2000/60/EC) (European Union, 2000) to establish the basic principles of sustainable water policy in the European Union and to improve the sustainability of water management in member states.

Overall, the WFD's aim is to integrate the protection and ensure the sustainable management of water within other Community policy areas, such as energy, transport, agriculture, fisheries, regional policy and tourism. This Directive tries to provide a basis for continued dialogue and for the development of strategies to foster further integration of policy areas.

One of the main concerns of the Directive is the need to consider the vulnerability of aquatic ecosystems located near the coast and estuaries or in gulfs or relatively closed seas, bearing in mind that their equilibrium is strongly influenced by the quality of inland waters flowing into them, in the conviction that protection of the water status within river basins will provide economic benefits by contributing towards the protection of fish populations, including coastal fish populations (European Union, 2000).

From a scientific point of view, the WFD provides a challenge to develop new ecological knowledge and new and accurate methodologies for impact assessment and ecosystem restoration. At the same time, from a management point of view, it addresses the assessment of Ecological Quality Status within European rivers, lakes, groundwaters, estuaries and coasts, and, for first time in many countries, these water bodies must be managed as a whole, so that coordination at river basin and coastal levels becomes necessary.

Although this directive is simple and flexible in its concept, it is necessary to develop an approach based on scientific principles; however, at the same time, it should remain as straightforward as possible, in order to fulfil the requirements and achieve comparability of results for all European waters. This involves selecting typologies and reference conditions, determining biological quality and ecological status, and identifying possible problems involved in implementing the WFD.

Therefore, the first step consists of identifying water bodies following a hierarchical approach from the hydrographical basin, including estuaries and coastal waters, classifying the different water bodies therein (i.e. rivers, lakes, transitional waters, artificial water bodies and heavily modified water bodies, etc.).

Each one of these categories must be subdivided into different types and for each type different levels of water quality and the respective reference conditions must be defined. With this information, the ecological status, which is an expression of the quality of the structure and functioning of a given aquatic ecosystem, must be established.

2. Hierarchical approach to water management

Water management must follow a hierarchical perspective: spatio-temporal scales change at each level, as do driving forces, impacts, and the processes and responses involved.

At the highest level management decisions are supranational and involve the entire planet. They must be based on and take into account the earth water cycle, climate and water balance heterogeneity and the heterogeneous distribution of water resources, human population and water demands. From the point of view of water quality deterioration, the driving forces will be related with the massive industrial use of water in developed and developing countries and human population growth in the third world. Global climate change, which is a consequence of industrial growth and its exponential dependence of non-somatic energies, is an added stressor and a source of uncertainty for the future distribution of the resource and the water cycle. The response of society to reducing water deterioration and to preventing future scarcity of the resource has little to do with local ecological processes but much with the global economy, and consists of a few international agreements and declarations of intent. This does not mean that measures applied at a lower scale do not have consequences at the higher level. At the lowest level, for a particular water body or aquatic ecosystem, individual behaviour, small scale ecological processes and local management actions are relevant. Between these extreme levels comes a hierarchical sequence of political agreements, laws and action plans, socio-economic constraints and hydrological, hydrogeological, climatic and ecological processes.

3. The Spanish system

Water is a public domain in Spain, and the main concerns in its management include ensuring its good status and an adequate level of protection, fulfilling the overall demand and looking for an equilibrium in sectorial and regional development. This is easy to say, but not an easy task to carry out in Spain where the distribution of water resources are unequal and where a wet Spain, with regular rainfall periods and a mean precipitation of over 1,000 mm per year, has traditionally been differentiated from the southern dry Spain, with less than 300 mm per year and rainfall concentrated into a few periods with torrential episodes. The water deficit in southeast Spain (more than 800 mm) is the highest in the European Mediterranean area (Thornes, 2001). Water demand in the south is increasing due to changes in agricultural practices from extensive dry farming to intensive irrigated farming, tourist development and increasing industrialization. At the same time, during the 20th century the population has risen in the south and east of Spain while the north has lost inhabitants (Puyol, 2000). According to data from the Spanish National Statistics Institute (INE http://www.ine.es), the Mediterranean area shows the higher population density in Spain (100–300 inhabitants per km^2) and the highest population growth rate in the last decade (14% increase in the province of Murcia for 2001 compared with 1991).

This makes one of the main concerns for the Spanish government (of any hue) to increase the availability of water, protect its quality and economize its use, balancing when possible the effects of floods and dry periods.

Hydrologic planning in Spain depends on two main tools: the National Hydrologic Plan and the Basin Hydrologic Plans. The former is the responsibility of the National Government, and the latter corresponds to the National Government for intercommunity basins and the Autonomous Regional Governments in the case of intracommunity basins. All actions must be approved by the National Government according to the Water Law.

Water deficits and water disequilibria in Spain have been tackled from different perspectives in recent history. From the 1940s to the 1970s the strategy consisted of the building water reservoirs in the main water basins and rivers. This was one of the pillars of the agricultural policy after the Spanish Civil War (1936–1939) aimed at supporting the development of irrigated agriculture (Lamo de Espinosa, 2000). The transformation of dry agriculture to irrigated lands (including structural policies, irrigation laws, etc.) was one of the driving forces of the social and economic transformations of the mid 20th century in Spain (Lamo de Espinosa, 2000; Velarde, 2000). Part of this policy has traditionally considered the development of hydraulic infrastructures, including long distance water transfers from water-rich basins to regions with scarcity. This idea was paramount in Spain during all the 20th century under the so called “hydraulic paradigm”, a mode of state-based resource regulation of surface water with the ultimate objective of ensuring cheap water availability for economic growth (Saurí and Del Moral, 2001). However, it was not until the Law 21/71, on the 19th of June (1971) that the first large infrastructure for water transfer between basins was approved (Flores Montoya et al., 2006). Since 1979, the Tagus-Segura Transfer System, over 300 km long, transferred water from the head of the Tagus River in central Spain to the Segura River basin in the south-east.

The National Water Plan (NWP) of 1993, attempted to generalize the transfer of water between basins implementing the solidarity principle by which those having the resource share it with those in need (Saurí and Del Moral, 2001). It included high water demand estimates (up to 9 billion cubic meters in 20 years) and, according to the Water Act of 1985, considered the development of water plans in the country at two scales: basin scale and nationwide. As mentioned above, the responsibility for approving basin plans lies with the Spanish Ministry for Public Works with the collaboration of other state ministries, the regions concerned and the water users. The NWP, on the contrary, has to be approved by the Spanish Parliament which discusses and may modify proposals presented by the General Directorate for Hydraulic Works and submitted to Parliament by the Council of Ministers (Saurí and Del Moral, 2001). The NWP included measures for flood control, water quality, riverine and wetland protection, the construction of about 100 new reservoirs totalling 10,000 hm^3/year, as well as the development and transfer of new water supplies, increasing from the 600 hm^3/year at the end of the 1980s to more than 3,800 hm^3/year. According to these previsions, the National Plan envisaged an increase in irrigated land of about 600,000 ha in 20 years. The plan, however, generated strong territorial and social opposition and suffered several modifications (see Saurí and Del Moral, 2001 for details) and approximations to determine quantity and price by simulating the recipient demand curve and the donor supply curve for transferable water were developed (Ballestero, 2004). After long years of complex and hard work, the approval of the National Hydrological Plan on 5 July 2001 (Law 10/2001) seemed to fulfil the process of hydrological planning conceived and designed by the Water Act of 1985. The Plan considered new transfers of water from the Ebro River to the southern basins but assumed, as one of its basic principles already contained in the White Book of Water (Ministerio de Medio Ambiente, 2000), that no volume of water at all will be transferred to the receiving basins in order to increase the irrigated area. It was accepted, however, that water could be transferred for drinking supplies and for the allocation of water for environmental purposes. As regard irrigation and with respect to the environment, the water transfers would only be assigned to recover the present situation of overexploited underground aquifers and to alleviate low supply and guarantee water for irrigated areas with an uncertain supply (Martín Mendiluce, 2003). However, finally the Law concerning the transfer of waters was defected in 2004, and a new National Hydrological Plan was approved in 2005, one of its main objectives being to promote desalinization.

Since then, desalination, even though may involve environmental problems not yet studied, has been developed as an alternative solution and the construction of new desalination plants has risen quickly along the eastern and southern coast of Spain.

3.1. THE WATER FRAMEWORK DIRECTIVE IN SPAIN

The incorporation of the WFD to Spanish legislation has involved the introduction of important conceptual and juridical changes. These include important changes related to water management, a new definition of hydrographical basin, the introduction of the concept of hydrographical demarcation, changes in the Public Administration of Water, introducing the figure of Water Demarcation Council and the Competent Authorities Committee. Furthermore, new environmental objectives have been introduced regarding the conservation of the quality status of the water bodies, an inventory of protected areas and the introduction of the recovery costs concept.

In addition, incorporation of coastal and transitional waters within the same management framework involves coordination with other laws both at national and regional level, among them the Law 27/1992, of November 24th (1992), of Puertos del Estado and of the Marina Mercante (State Harbours and Merchant Navy). Here the Competent Authorities Committees must play a relevant role.

The strong degree of decentralization existing in Spain increases the difficulties involved in water policy. The hydrographical basins in to which Spain is divided are shared by more than two autonomous administrations, and up to nine in the case of the Ebro basin. So, the number of administrations, authorities and institutions involved has increased in recent years, with a heterogeneous geographical distribution and distinct influence depending on the different Autonomous Regions. This hinders the coordination and administration of water resources since the economic and political interests of the Hydrographical Confederations (responsible for water management in the respective basins and depending on the Central Government) and those of the different regions are usually divergent. This has led to great variety of proposed management tools in the different Basin Plans. In the case of coastal lagoons, for example, a water body can be administered by the Hydrographical Confederation or by the respective Regional Government, depending on its classification as transitional water or coastal water, respectively. All this means that Spain does not yet have a clear scheme or even homogeneous criteria for implementing the directive on transitional or coastal waters, for example.

4. Conceptual and ecological difficulties in applying the WFD to coastal lagoons

Traditionally, coastal lagoons have been considered as transitional systems between continental and marine domains (Bianchi, 1988), a consideration that has gained in importance in the context of the Water Framework Directive (WFD) of the European Union. As mentioned above, application of the WFD requires scientific and biological criteria to establish the basis for typifying coastal ecosystems and transitional waters (lagoons and estuaries). In the case of the former, such criteria have long been established, while for transitional waters they do not exist yet. The proposed criteria are not the same for both categories, and while there is no doubt about the nature of estuaries, there is some controversy concerning whether lagoons should be treated as coastal or transitional waters.

The WFD establishes a well differentiated typology of water bodies for its application: On the first level it differentiate surface from groundwaters. For their part, surface waters are classified as Rivers, Lakes, Transitional waters (defined as bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows) and coastal waters. Other types defined by the Directive are "artificial water bodies" meaning a body of surface water created by human activity, and "heavily modified water body" for a body of surface water which as a result of physical alterations by human activity is substantially changed in character.

Despite the apparent simplicity and clarity of the definitions, one of the first difficulties when applying the WFD to coastal lagoons is to include them in only one of these categories.

Lagoons under the influence of river mouths are clearly included in the transitional waters category, while lagoons, such as the Mar Menor in Spain, with no significant influence of fresh water, or the Venice lagoon, which no longer receive the rivers which flowed into it in ancient times, should be included in coastal waters, especially if we take into account that typologies for coastal waters usually include several degrees of fresh water influence.

To what extent reference conditions can be similar for one type or another, or whether common features in all coastal lagoons (such as the isolation from the sea but with marine biota) are more important to differentiate them from other water bodies than the existence or not of fresh water influence, is unclear and needs to be elucidated.

Furthermore, in accordance with the WFD, the ecological status of a water body must be evaluated using biological indicators, including macroalgae, seagrasses, invertebrates, fishes, etc. in the context of hydromorphological and physico-chemical conditions (Ballesteros et al., 2007). In the coastal marine environment, a high number of taxonomic groups are considered good indicators of water quality, and different indices and methodologies based on them have been proposed for assessing the ecological status of coastal waters in the context of the WFD (Austoni et al., 2007; Ballesteros et al., 2007; Borja et al., 2000; Pasqualini et al., 2006; Pinedo et al., 2007; Rosenberg et al., 2004; Simboura and Riezopoulou, 2007; Simboura and Zenetos, 2002; Wells et al., 2007; see Salas et al., 2006 for a review). However, some of these indicators are difficult to apply to transitional waters in general, and to coastal lagoons in particular as a consequence of the "estuarine paradox" *sensu* Elliott and Quintino (2007). That is, since estuaries are naturally stressed, highly variable ecosystems and at the same time they are exposed to high degrees of anthropogenic stress, it is difficult to differentiate any changes in species composition along the natural gradients of environmental conditions and adaptations in the structure and composition of estuarine biota to the natural stress from the consequences of human impacts. If it is true for estuaries, it becomes more evident in lagoons, where the heterogeneity in environmental conditions can respond to a more complex pattern of gradients. For example, in the case of macrophyte indicators, some recent proposals look at the problem in estuarine transitional waters but explicitly exclude lagoons (Wilkinson et al., 2007).

4.1. VARIABILITY AND HETEROGENEITY IN COASTAL LAGOONS

4.1.1. Inter-lagoon variability

In general, coastal lagoon ecosystems are dynamic and open systems dominated and subsidized by physical energies that made them environments with frequent physical and chemical disturbances and fluctuations (UNESCO, 1981). They are characterized by particular features, such as shallowness, relative isolation from the open sea, usually as a result of coastal barriers that maintain some communication channels or inlets, and the presence of boundaries with strong physical and ecological gradients (Gamito et al., 2005; UNESCO, 1981). Due to their shallowness, bottoms are usually well irradiated, while currents and hydrodynamics are closely conditioned by bottom topography and wind affects the entire water column, facilitating the input of materials and nutrients from the sediment surface layer into the water column. Because of these characteristics, coastal lagoons are usually among the marine habitats that show greatest biological productivity (Alongi, 1998).

However, despite these common features, the term lagoon includes a wide range of environments. Inter-lagoon variability has been attributed to many biotic and abiotic factors (Ross and Epperly, 1985; Yáñez-Arancibia et al., 1985). Most of the physical and environmental variability in Atlanto-Mediterranean coastal lagoons is related to lagoon size, differences in salinity with respect to the open sea and the trophic status of the water column (Pérez-Ruzafa et al., 2007a). Size can vary from a few hundred square metres to extensive areas of shallow coastal sea. Salinity ranges from nearly fresh to hypersaline waters (Barnes, 1980). The salt balance relies on several factors such as the exchange of water with the open sea, the input of continental waters from rivers, watercourses, groundwater, and the rainfall-evaporation balance.

Joyce et al. (2005) found a high degree of heterogeneity in the hydrographical characteristics, vegetation and invertebrate assemblage composition in 28 English coastal water bodies, which were mainly determined by differences in salinity, sea influence, bank slope and parameters describing habitat heterogeneity.

This means that when comparing human impact in different lagoons or for stabilising reference conditions in the context of the WFD, this large scale variability must be removed or taken into account, by carefully selecting lagoons with similar characteristics.

But perhaps, the main factor structuring lagoon assemblages is related with the degree of isolation from the sea. Kjerfve (1994) subdivided coastal lagoons into three geomorphic types, choked, restricted and leaky, as three points along a spectrum reflecting the exchange of water with the coastal sea. The rate and magnitude of oceanic exchange reflect both the dominant forcing functions and the time-scale of hydrological variability. Physical gradients within the lagoon environment derived from such exchange rates have also been related to biological gradients in species richness, abundance and productivity. In the early 1980s, Guelorget and Perthuisot (1983) rejected salinity as an essential parameter for explaining the observed gradients in density, biomass, species richness or diversity and proposed that horizontal zonation patterns and species distribution inside the lagoons be determined by confinement, a parameter which represents the turnover time for marine waters and impoverishment in some oligo-elements of a marine origin. Later, for faunal assemblages, Pérez-Ruzafa and Marcos (1992, 1993) suggested that, rather than the recycling of vitamins and oligo-elements, the main factor explaining lagoon assemblage structure in a confinement gradient would be that of colonization rates by marine species, while macrophyte assemblages structure is probably more related with environmental stress and fluctuations in environmental conditions (Pérez-Ruzafa et al., 2008).

In either case, according to Pérez-Ruzafa et al. (2007a), most fish assemblage characteristics, including species composition and productivity, would be related to the geomorphological characteristics of the lagoons. While geomorphological features explained by itself 22% of the variance in the canonical analyses with an additional 75% shared with hydrographical and trophic characteristics of the lagoon, the latter explained only 3% of the fish assemblage composition. That means also that hydrographical and trophic factors show a strong dependence on geomorphological features. So, in terms of species richness, the main factors promoting them were the openness parameter, which characterizes the potential influence of the sea on general lagoon hydrology, and the size of the lagoon (volume or surface) while the trophic status of the water column (phosphate concentration) had a negative influence on the number of species (Pérez-Ruzafa et al., 2007a). This coincides with the findings of Basset et al. (2006) for the macroinvertebrate fauna of Italian lagoons. As regards the fishing yield, this increases with the Pshore (PSH) parameter, an index for measuring shore development. Otherwise, fishing catches decrease with increasing mean depth of the lagoon. This seems logical, as in shallow lagoons, light reaches the bottoms and the above mentioned interchange of materials from the sediment layers and the water column is facilitated, increasing productivity (Conde et al., 1999; Gamito et al., 2005; Miller et al., 1990; Nixon, 1982; Suzuki et al., 2002).

The relationship between species richness and sea influence agrees with the above mentioned confinement theory of Guelorget and Perthuisot (1983), reformulated by Pérez-Ruzafa and Marcos (1992, 1993), and reinforces the idea that fish species richness in coastal lagoons is determined by colonization rates from the open coastal sea (Mariani, 2001; Pérez-Ruzafa et al., 2004, 2006) and, depending on the estuarine influence, by colonization rates from rivers. Therefore, coastal works that increase the number or size of the inlets, and therefore increase renewal rates and decrease water residence times, would facilitate the penetration of species by means of active migratory movements or random passive transport in pelagic and planktonic stages.

On the other hand, the positive relationship between species richness and lagoon volume, a synthetic expression of surface and depth, is coherent with the expectation that larger lagoons could provide a greater diversity of environments and types of bottoms with specific assemblages (Pérez-Ruzafa, 1989; Pérez-Ruzafa et al., 2006).

Finally, the positive influence of the maximum chlorophyll *a* concentration on fishing yield and the negative influence on species richness suggest that the increase in primary productivity favours the abundance of some species at the expense of species richness. This would agree with ecological theory and the expected response of ecosystems and community structures, in terms of diminishing ecological diversity when faced with high external nutrient and energy inputs (Tilman, 1982, 1999).

The strong influence of geomorphological features on the fish assemblage composition alerts us to the fact that coastal works affecting the shoreline, the inlets or the size of a lagoon can affect the biological assemblages and goods and services provided by them, perhaps more than direct wastes or pollutants. On the other hand, geomorphological parameters (especially volume, sea influence and shoreline development) are easy to measure and can be used as the basis for typification, as required in the context of the WFD. Furthermore, all of these parameters are strongly affected by changes in sea levels related with climate change. A rise in the sea level involves an increase in lagoon size and depth and in some areas can affect the isolation status with respect to the open sea. Human works modify shoreline development, sedimentation rates and depth as a result of land reclamation or the building of dykes or marinas, and also affect the influence of the open sea, when the structure of natural inlets is altered or new ones are built. Such activity could intentionally be directed at improving some biological features. However, the effects on species richness may well be the direct opposite of any effect on fishing yield or species composition and therefore, when designing management strategies and evaluating the impact of human activities, it is necessary to bear in mind the importance of maintaining the naturalness of these exclusive ecosystems and not only the improvement of one particular characteristic.

It is also important to take into account that marine or fresh water influence largely determines not only the species richness but also species composition. Both elements are determinant in the nature of food webs and the complexity of the system, and both are linked to the homeostatic response capability to face environmental stress (Pérez-Ruzafa et al., 2005a).

4.1.2. Intra-lagoon variability

If the continuum in differences between lagoons hinders their organisation into clear typologies, intra-lagoon variability is no less of a problem. In practice, although coastal lagoons are relatively well studied systems and their environmental variability is considered an intrinsic characteristic of these ecosystems, very little is known about their natural spatial or temporal scales of variation. Different authors, such as Pérès and Picard (1964), Augier (1982) or Guelorget and Perthuisot (1983), consider Mediterranean lagoon systems as a well differentiated and unique homogeneous community, the so-called euryhaline and eurythermal biocenoses. This consideration has been maintained in the habitats lists of conservation agreements, including OSPAR, Barcelona or Eunis. Therefore, the patterns of variability of biological assemblages in coastal lagoons has scarcely been studied. A few studies have explicitly characterized different communities according to the water characteristics of one or several lagoons (Chassany de Casabianca, 1980; Lovric, 1979; Zouali, 1979) or describe vertical zonation patterns (Cecere et al., 1988; Occhipinti Ambrogi et al., 1988; Sfriso, 1988) but most of the works that analyze the differences in species distribution or biomass related to environmental variables such as salinity or trophic conditions (Curiel et al., 2004; Lin and Hung, 2004; Sfriso et al., 2003), do not consider the possibility of different communities similar to those existing in coastal marine habitats or refer the observed heterogeneity to a single community for the whole lagoon (Bachelet et al., 2000; Cecere et al., 1991, 1992; Chassany de Casabianca, 1979; Mouillot et al., 2005; Nagy, 1979; Skolka and Tiganus, 1985).

However, patchiness in the distribution of marine organisms is widespread in all environments and is present at all spatial scales, from the distribution of individuals of a population in their habitat to the mosaics of faunal benthic communities and to the faunal provinces at a biogeographical level.

From a macrofaunal perspective, marine coastal 'landscapes' can be viewed as a set of patches hierarchically arranged in space over different spatial scales, ranging from 10^{-3}–10^{4} m (Benedetti-Cecchi et al., 2003; García-Charton and Pérez-Ruzafa, 1998; García-Charton et al., 2000).

Knowledge of the scales at which changes in the abundance of organisms can be detected may help identify the ecological processes that determine the observed patterns of distribution (Underwood and Chapman, 1996). This knowledge is therefore essential for developing and testing hypotheses about processes and when designing sampling strategies for environmental impact assessment, in which the changes produced by human activities need to be differentiated from the sources of natural variability (Anderson et al., 2005). Furthermore, to detect changes in ecosystems due to human impact, sampling experimental designs must include replicates, avoiding "pseudoreplication" *sensu* Hulbert (1984). Without such replication, it cannot be demonstrated that statistically significant differences between different areas are due to the investigated factor (pollution, coastal works, protection) and not simply due to chance variations among the units measured and to the intrinsic variability of the system (Underwood, 1997).

However, this fact is rarely taken into account when studying lagoon assemblages and these ecosystems are managed as units, with decisions adopted at lagoon scale, even though different areas of each lagoon might require different management options (De Biasi et al., 2003). These considerations take on special relevance in the EU since the European Water Framework Directive establishes that the development in water status should be monitored by Member States on a systematic and comparable basis throughout the Community using standardized methods of monitoring, sampling and analysis (European Union, 2000).

Intra-lagoon variability is, in fact, very high, and has been related with depth (Pasqualini et al., 2006), type of substratum (Pérez-Ruzafa, 1989; Pérez-Ruzafa et al., 2006) and, mainly, with confinement gradient *sensu* Guelorget and Perthuisot (1983), which, as mentioned above, is an indicator of the degree of marine influence on lagoon ecosystems (Mariani, 2001). The physical gradients related with confinement within the lagoon environment are linked to biological gradients in species richness, abundance and productivity.

According to this, lagoon assemblages would be the result of complex environmental and biological interactions, and not only a response to extreme physico-chemical conditions or to a single horizontal gradient. The structure and composition of lagoon communities would be described by the same structural parameters as used in open coastal areas. Hence, multifactorial approaches are needed and structural indices of lagoon assemblages could be used to describe the ecological status of a particular lagoon site and community, but taking into account the main stressors at each individual site.

Therefore, it is especially important to know the factors responsible for the possible sources of heterogeneity on different spatio-temporal scales in coastal lagoons since, in several respects, such environmental and biological variability may mask any impact produced by human activity.

At the Mar Menor, for example, water column characteristics (including nutrient concentration) show small scale spatio-temporal variability, from 10^0 –10^1 km and from fortnightly to seasonally (Pérez-Ruzafa et al., 2007b). Temperature showed a uniform distribution at the smallest spatial scales considered but showed differences at zone scale (10^1 km). For salinity, ammonia and phosphate, the spatial patterns change temporally. The fact that all the parameters showed relevant patterns at all temporal scales, from fortnight to season, indicates that comparisons to detect human-influenced differences must consider natural variability, sampling over the same period at lower temporal scales or including a sufficient number of random independent replications when monthly or seasonal comparisons are made.

At the same time, biological features (such as chlorophyll *a* concentration and ichthyoplankton assemblage descriptors, such as species richness, diversity and abundance) showed changes at all temporal scales. Chlorophyll *a* concentration and ichthyoplankton abundance showed spatial patterns at 10^0–10^1 km, changing fortnightly, monthly and seasonally. The nearly identical scales of response of chlorophyll *a* and ichthyoplankton abundance confirms previous observations about the regular cycles in phyto and zooplankton assemblages, despite the high degree of variability in the planktonic habitat (Pérez-Ruzafa et al., 2005a; Smayda, 1998).

On the other hand, the infauna also shows high spatial variability in coastal lagoons (Norén and Lindegarth, 2005). In the Mar Menor, sessile benthic assemblages showed significant differences between types of substrate in the same locality, and between localities according to horizontal gradients related with the degree of confinement in the lagoon, at the scale of 10^0–10^1 km. This was also true for fishes, despite their mobility. Fish assemblages are highly sensitive to changes in substrate characteristics (Pérez-Ruzafa et al., 2006, 2007b) and show significant variation at a scale of 10^1 km, which is related to the degree of lagoon confinement (Ecoutin et al., 2005; Mariani, 2001; Pérez-Ruzafa et al., 2007b).

In a recent study on macrophyte assemblages, Pérez-Ruzafa et al. (2008) found that the seasons of maximum and minimum biomass were not the same in different localities, depending on local environmental conditions and not on assemblages. This coincides with the findings in the seasonal patterns in productivity in the water column that also show time lags among lagoon basins at spatial scales involving only tens of kilometres (Pérez-Ruzafa et al., 2005a).

It is also important to take into account that macrophyte and faunal assemblages can show different patterns. According to the confinement theory, a decreasing gradient in species richness and diversity should be expected from the less confined to more confined zones in a lagoon (Guelorget and Perthuisot, 1983; Pérez-Ruzafa and Marcos, 1992). Indeed, this has been confirmed in macrozoobenthic (Pérez-Ruzafa and Marcos, 1993) and ichthyoplankton assemblages (Pérez-Ruzafa et al., 2004), and in benthic fishes (Mariani, 2001; Pérez-Ruzafa et al., 2007b), although macrophyte assemblages did not show this pattern. Pérez-Ruzafa et al. (2008) found that species richness and diversity were highest in more confined localities and, in each locality, in the infralittoral rocky assemblage, suggesting that environmental stability is probably more important in the case of algal assemblages than colonization processes linked to confinement. Furthermore, vertical zonation (at scales of 10^1–10^2 cm), which was related, as usual in marine benthic communities, with vertical gradients in light and hydrodynamism, overlapped changes in substrata and confinement-related horizontal gradients.

According to the temporal patterns of variability observed, in general, seasonal sampling or comparing samples in the same season could be sufficient for monitoring human induced changes in benthic assemblages. However, control and impact sites should be located at basin scale (closer than 10^1 km) and in accordance with the scale of influence of the open sea. Such scales may differ depending on the number and size of inlets and the water renewal rate in each particular lagoon. Long term colonization processes (Pérez-Ruzafa et al., 1991, 2006) must also be taken into account when there are modifications in the interchange of waters through inlets to avoid confusing the effect of trends in water quality change with trends in colonization.

Our results imply that, in general, for the pelagic system, low scale spatial ($<10^0$ km) and temporal (fortnightly) variability should be considered for monitoring purposes and impact assessment, while monthly sampling is probably sufficient for monitoring the mean annual dynamic and to detect changes in pelagic biological assemblages if factor and control samples and all the replicates are taken in the same week. In the case of benthic assemblages, seasonality must be understood and low scale spatial variability (between substrate type, vertical zonation in macrophytes and between zones (10^1 km)) may mask the detection of human impact. This means that sources of variability should be controlled by sampling replicates at the lowest significant scale, and maintaining impacted and control sites within a suitable spatio-temporal scale.

4.2. HOMEOSTATIC MECHANISMS IN COASTAL LAGOONS

Homeostasis is the property of complex systems which permits them to maintain a relatively constant internal state and functions despite any changes that may take place in the external environment. The processes that help maintain homeostasis are referred to as homeostatic mechanisms and are usually controlled by feedback interactions.

As mentioned above, coastal lagoons are considered naturally stressed systems with frequent environmental disturbances and fluctuations (Barnes, 1980; Kjerfve, 1994; UNESCO, 1980, 1981), and are usually considered as physically controlled ecosystems *sensu* Sanders (1968). At the same time, their close relation with terrestrial ecosystem boundaries makes these environments especially vulnerable to human impact and terrestrial and freshwater inputs.

Species strategies respond to these situations according to a continuum of life-history strategies, *r versus K*. The *r*-strategy involves increased reproductive effort through early reproduction, small and numerous offspring with large dispersive capability, short life span and small adult body size, providing a selective advantage in such unpredictable or short-lived environments.

According to this, it is assumed that in coastal lagoons a transient physiological capability to cope with lagoon conditions will give immigrants (mostly *K*-strategists) a competitive advantage over the *r*-strategists, at least on a temporary time scale (UNESCO, 1981).

Therefore, coastal lagoons are considered immature and ecosystems of low complexity, maintained by physical constraints in an early stage of ecological succession, and showing scarcely developed homeostatic mechanisms.

However, some of our recent knowledge gained in the study of the Mar Menor lagoon and the response of the system to different sources of stress, open new perspectives into the understanding of the structure, complexity and homeostatic mechanisms of coastal lagoons.

Until recently, the waters of the Mar Menor were oligotrophic and primary productivity was mainly benthic, based on macrophytes (Pérez-Ruzafa et al., 2005b). In recent years, however, nutrient input dynamics in the Mar Menor has changed as a consequence of changes in agricultural practices. The agriculture in the watershed has undergone profound transformation since the 1980s, changing from extensive dry crop farming to intensively irrigated crops receiving surface waters diverted from the Tagus river, 400 km to the north, to the Segura river. The total water volume available for irrigation in the watershed rose from 75 hm^3 in 1979 to 108 hm^3 in 1984 and to 223 hm^3 in 2001 (Carreño et al., in press). The arrival of surface water for irrigation took the pressure off the overexploited aquifers, raising phreatic levels (Pérez-Ruzafa and Aragón, 2002) and enabling the main watercourse on the watershed to maintain a continuous flow (24 L/s) fed by ground and waste water with high nitrate levels to the lagoon (García-Pintado et al., 2007).

During the years when dry agriculture predominated, nitrogen was the limiting nutrient for both benthic (Terrados and Ros, 1991) and planktonic primary production in the lagoon, with nitrogen entering mainly via run-off whilst phosphorus came from urban sewage.

Due to overfertilization with nitrogen and the pesticides used in agriculture, this flow is at present the main entrance for nitrate into the lagoon and pesticides into the trophic food web (Pérez-Ruzafa et al., 2000, 2005a). From 1988 to 1997, nitrate concentrations increased from less than 1 μmol NO_3^- L^{-1} throughout the year, to concentrations of up to 8 μmol NO^-_3 L^{-1}. In contrast, phosphate values, commonly higher than 2 μM in 1988, now seem to be the limiting factor during most of the year.

It was expected that eutrophication process would lead, due to competition of primary producers for nutrients, to the progressive replacement of seagrasses (*Cymodocea nodosa* in the case of the Mar Menor), which mainly take up nutrients through the roots, and slow-growing macroalgae by fast-growing macroalgae and phytoplankton, which take nutrients faster from the water column. At high nutrient loads, a final dominance of phytoplankton was expected (Cloern, 2001; Duarte, 1995; Gamito et al., 2005; Nienhuis, 1992; Scheffer, 1998).

However, instead of the expected eutrophication process and phytoplankton proliferation, the waters maintained their quality at reasonable levels and chlorophyll *a* concentration in the water column was similar or lower than before.

This is due to an un-expected top-bottom control of the food web. The comparison of planktonic size distribution, or biomass spectra, before and after the mentioned changes in the nutrient inputs into the Mar Menor, showed an almost invariable slope (Pérez-Ruzafa et al., 2002). Such slope has been related with the energy flow through the planktonic food web (Gaedke, 1993; Rodríguez et al., 1987; Silvert and Platt, 1980) and with the trophic state of ecosystems (Sprules and Munawar, 1986). Apart from the nutrient concentration, the difference in the Mar Menor between both situations was the proliferation of jellyfish in recent times (Pérez-Ruzafa et al., 2002). Comparison of the size spectra suggests that jellyfish can be an efficient top-down agent controlling the consequences of eutrophication processes, apparently maintaining the trophic state of the lagoon.

Furthermore, the correlations found between chlorophyll *a* and nutrient concentration disagree with traditional models of eutrophication based on freshwater ecosystems, which supposed a direct response of phytoplankton-related variables to nutrient loadings (Cloern, 2001). In the Mar Menor, relationships with nutrients are negative at small temporal scales, suggesting that the phytoplankton controls nutrient concentrations. At the same time, the fact that such relationships become positive if a time lag of two weeks is considered in the relationship between chlorophyll and nutrients or when data are factored in at higher time scales (monthly or seasonal) suggests a very rapid response by the primary producers to nutrient enrichment (Pérez-Ruzafa et al., 2005a).

This is confirmed by the strength of the positive correlation between chlorophyll *a* concentrations and fish larvae density, again suggesting a top-down control of the trophic web. The seasonal dynamics of the relationship between fish larvae density and chlorophyll *a* concentrations shows a limit cycle (Pérez-Ruzafa et al., 2005a), as in the zooplankton and algae interactions simulated by Scheffer (1998). Oscillations in this limit cycle can be biologically explained as the result of overshoots resulting from the delayed response in the population density of herbivores to the amount of available food, or differences in the assemblage structure and life cycles, which would introduce homeostatic controls and time lags into the responses of successive trophic levels.

All this suggests that coastal lagoons are more complex ecosystems than previously expected, especially lagoons with a strong marine influence and containing marine fauna. This complexity involves or leads to higher resilience and the development of homeostatic mechanisms that permit readjustment of the system after human perturbations and a top-down control of the trophic webs in the face of eutrophication processes that permits them to maintain their water quality.

In agreement with Cloern (2001), the results suggest that when considering the problem of coastal eutrophication several process and factors need to be considered, probably including different time scales for responses through the trophic web. The resulting complex system would be an important component of the filter, *sensu* Cloern (2001), which modulates the response of the change signal in nutrient loading in estuarine and coastal marine ecosystems (Pérez-Ruzafa et al., 2005a).

The response of planktonic food webs to nutrient enrichment in coastal marine ecosystems varies greatly worldwide due to the broad range of both direct and indirect effects of the eutrophication process (DeAngelis, 1992; Kerfoot and Sih, 1987; Scheffer, 1998). When bottom-up control exists, the general patterns described include the substitution of macrophytes by macroalgae at benthic level as a first step, followed by a change to a phytoplankton-based system with anoxic events arising when light penetration is severely affected by phytoplankton density (Nienhuis, 1992). However, the response of ecosystems to increases in nutrient load differs widely because biological control mechanisms of the eutrophication process are not always the same. Predation can be a very efficient control mechanism, providing alternative energy flow pathways in the food web by removing excess biomass generated by excess nutrients (Pérez-Ruzafa et al., 2002).

Because of the observed shifts in the response and the top-down control exerted by the different trophic levels on their resources, a detailed analysis of the responses in the different fractions of the biomass spectrum would probably provide valuable information concerning the homeostatic and regulatory controls that exists in these environments and would probably explain the differences in response between simple and complex, or freshwater and marine, ecosystems.

Therefore, the response of the system may fit a model Phase I (direct positive relationship between nutrient inputs and chlorophyll concentration), or Phase II or III *sensu* Cloern (2001) in which the homeostatic mechanisms produced by the filter of complex ecosystem relationships can produce negative relationships between chlorophyll and nutrients. This will depend on the temporal scale considered, and one of the most effective filters seems to be the trophic network. In the last case, the system response is so rapid that positive correlations are probably only detected two or three steps down the food-chain, after a time lag of several days, or at long temporal scales (Pérez-Ruzafa et al., 2005a).

The main consequence of these observations, in the context of this chapter, is that our capability to detect pressures using parameters or indices based on the assumptions of the model Phase I and the increase of chlorophyll as a direct response to nutrient inputs, can be precluded by the homeostatic response of the lagoon ecosystem. This would explain why some indices, such as TRIX (trophic status index) do not always produce the expected results (Giovanardi and Vollenweider, 2004).

5. Conclusions

Water management follows a hierarchical perspective from the whole planet to water bodies. Spatio-temporal scales change at each level, as do driving forces, impacts, and the processes and responses involved. Ecological considerations can play a role at all levels. At national or at European level, the environmental impact caused by the development of hydraulic infrastructures, including long distance water transfers, or desalinization should be taken into account in the decision taken process or when designing policies. However, socio-economic pressures and political constrains play a decisive role at this level. At water body level, ecological processes are more closely linked to the management actions and a deep knowledge of the ecosystem functioning is needed to guarantee its ecological status. In the case of coastal lagoons knowledge gaps leads to some difficulties when applying European directives. Coastal lagoon assemblages show high spatio-temporal variability, similar to or higher than that expected in open coastal assemblages. This means that the patterns in species and community distribution, and the sources of such variability, must be taken into account when designing sampling strategies to evaluate human impact. Only if this is done, can the changes in communities caused by human pressure be differentiated from natural variability. At the same time, our capability to detect pressures in these ecosystems depends on our knowledge of the homeostatic mechanisms operating through their complex trophic network.

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WATER FRAMEWORK DIRECTIVE: DEFINING THE ECOLOGICAL QUALITY STATUS IN TRANSITIONAL AND COASTAL WATERS

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Abstract: The European Water Framework Directive (WFD) has established the concept of Ecological Quality Status (EQS) as a way to assess the biological quality of surface waters. The EQS will be mainly based upon the composition of different biological quality elements and their metrics. These are phytoplankton composition, abundance and biomass, composition and abundance of other aquatic flora and benthic invertebrate fauna. For transitional waters, the composition and abundance of fish fauna are also included.

The scientific community, together with the competent authorities of the Member States, is developing the methodologies for defining the reference conditions and the ecological status of the major water bodies in Europe. Several biotic indices are being tested and discussed for different coastal or transitional waters, based on one or more of the EQS elements of the ecosystem. The results are sometimes contradictory. The major challenge is the frontier between a “good” ecological status and a “moderate” status. If a water body is classified as “moderate” remediation measures are necessary.

Some of the biological indices are based on the relative abundance of species that are either sensitive or tolerant to increasing concentrations of organic matter. But the tolerant species may also be tolerant to natural stressors such as low water renewal in estuaries or coastal lagoons, making it difficult to distinguish a naturally stressed habitat from an anthropogenically stressed habitat.

In this chapter some aspects of the implementation of the WFD will be discussed, with special focus on the methodologies applied in the benthic invertebrate fauna compartment in Transitional and Coastal Waters relative to the North East Atlantic Region.

Keywords: Ecological quality status; water framework directive; macroinvertebrates; transitional waters; coastal waters

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1. Introduction

The European Union Water Framework (WFD) was published in 23 October 2000 establishing a framework for Community action in the field of water policy (Directive 2000/60/EC. Official Journal of the European Communities, 43, 75 pp.)

Their main objectives are:

- Prevention of deterioration of the ecological and chemical status of all bodies of surface water
- Achievement of "good surface water status" within the next 15 years

In setting ecological targets for surface waters, the Commission has recognized the need for an integrated approach to managing three of the key components of aquatic habitats: water quality, water quantity and physical structure (Logan, 2001). In order to assist the WFD implementation, a "common implementation strategy" (CIS) was agreed in May 2001. The CIS includes four key activities, including: (i) the development of guidance on technical issues; and (ii) the application, testing and validation of the guidance provided. Several working groups were created to deal with these issues (Borja et al. 2004). In transitional and coastal waters, the implementation of the WFD has provoked a large debate on the use of benthic bio-indicators and indices to determine the water quality in Europe and along its coast, in terms of the WFD's Ecological Quality Status (Dauvin, 2007 and references there in). In the next sections some of the difficulties in the implementation of the WFD in transitional and coastal waters will be discussed.

2. Ecological status definition

The WFD has established the concept of **Ecological Status (EQS)** as a way to assess the biological quality of surface waters, which will be mainly based upon the composition of different biological compartments in the ecosystem. The biological compartments differ with the surface water type (Table 1).

The Biological elements are supported by **hydro-morphological** and by **chemical and physico-chemical** elements.

In Transitional and Coastal Waters, the **hydro-morphological** elements are:

- Morphological conditions (such as depth and structure of intertidal zone)
- Tidal regime (freshwater flow (TW) or direction of dominant currents (CW); wave exposure)

and the **chemical and physico-chemical elements** are:

TABLE 1. Biological compartments considered in each water surface type.

Surface waters	Phytoplankton	Aquatic flora	Benthic invertebrate fauna	Fish
Rivers		Composition and abundance	Composition and abwundance	Composition, abundance and age structure
Lakes	Composition, abundance and biomass	Composition and abundance	Composition and abundance	Composition, abundance and age structure
Transitional waters	Composition, abundance and biomass	Composition and abundance	Composition and abundance	Composition and abundance
Coastal waters	Composition, abundance and biomass	Composition and abundance	Composition and abundance	

- Transparency
- Thermal conditions
- Oxygenation conditions
- Salinity
- Nutrient conditions

Specific pollutants such as all priority substances identified as being discharged into the body of water and other substances identified as being discharged in significant quantities also need to be monitored.

The WFD requires Member States to classify their surface waters (lakes, rivers, transitional and coastal waters) into five ecological statuses: high, good, moderate, poor and bad. **'High Ecological Status'**, in any type of water body, is defined as the biological, chemical and morphological conditions associated with **no** or **very low** human pressure. This is also called the **'reference condition'** as it is the best status achievable. These reference conditions are type-specific, being different for different types of rivers, lakes or coastal waters considering the wide diversity of ecological regions in Europe (in: http://ec.europa.eu/environment/water/water-framework/objectives/index_en.htm, accessed December 20, 2007)

The type specific reference conditions for High Ecological Status are defined as:

> There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. (Directive 2000/60/EC)

In Transitional and Coastal waters the **High Ecological Status**, considering the biological element **Benthic invertebrate fauna,** is defined by (Directive 2000/60/EC):

> The level of diversity and abundance of invertebrate taxa is within the range normally associated with undisturbed conditions and all the disturbance-sensitive taxa associated with undisturbed conditions are present.

The other four statuses contemplate increasing anthropogenic interference and a correspondent increasing negative impact in the water bodies reflected in their quality and biological elements characteristics.

3. Comparability of biological monitoring results

Each Member State needs to define the ecological status of their water bodies. The results shall be expressed as **Ecological Quality ratios** for the purpose of classification of ecological status, and must be comparable among the different states. The **Ecological Quality ratio** shall be expressed as a numerical value between zero and one, with **high ecological status** represented by values close to **one** and **bad ecological status** with values close to **zero**. For each status a color was assigned: blue for high ecological status, green for good, yellow for moderate, orange for poor and red for bad ecological status (Directive 2000/60/EC).

4. Difficulties in defining the ecological status

Several questions rose during the last 7 years, from the attempts to apply the WFD, such as: What are Transitional waters? Do we have pristine water bodies? How to sample the biological compartments? How to define good ecological quality? How to reach comparable ecological classification? Which biotic index/integrator use? How to distinguish physical stress and other stressors from organic stress?

4.1. WHAT ARE TRANSITIONAL WATERS?

According to the WFD, transitional Waters are “Bodies of surface water in the vicinity of river mouths which are partially saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows” (Directive 2000/60/EC).

It is a good definition for a classical estuary "tidally dominated at the seaward part; salinity notably reduced by freshwater river inputs; riverine dominance inward" (McLusky and Elliott, 2007). But how can fjords, deltas, rias and lagoons be incorporated into Transitional waters? There are also problems with the definition with respect to the river mouths discharging either into predominantly brackish areas such as the Baltic Sea or into freshwater-poor areas bordering the Mediterranean. The authors gave a good description on what is going one in the Baltic: Finland and Estonia with wholly Baltic coasts do not appear to have TW nor does Sweden. The North Sea and Baltic coasts of Denmark have no TW, whereas Germany has designated TW for its North Sea estuaries (the Weser, Elbe, etc.) but not for its Baltic Sea estuaries and lagoons. In contrast, Lithuania and Latvia will consider the Curonian and other lagoons as TW, as well as the outlet of these to the Baltic and also the Daugava River. Poland has designated as its transitional waters the entire areas of the Szczecin Lagoon, Vistula Lagoon and a part of the Gulf of Gdansk. Finally, Lithuania and Poland have also included coastal areas receiving riverine/lagoonal plumes into the open Baltic as TW.

The situation with estuaries and coastal lagoons bordering the Mediterranean Sea and the south coast of Atlantic countries such as Portugal is also not clear. For example, Ria Formosa, a mesotidal coastal lagoon in the south coast of Portugal, was classified as a coastal water body (Bettencourt et al., 2004). Care must be taken when considering monitoring programs for coastal waters, as the mean depth of this lagoon is only 2 m.

According to McLusky and Elliott (2007) the term "Transitional waters" is being used, in practice, as: "Aquatic areas which are neither fully coastal nor enclosed or flowing freshwater areas". Their boundaries may still be defined by physiographic features or discontinuities or by salinity or any other hydrographic feature.

4.2. DO WE HAVE PRISTINE WATER BODIES?

Assessment of Ecological quality is based on the extent of deviation from the reference conditions, following the definitions in the Directive. 'Good status' means 'slight' deviation, 'moderate status' means 'moderate' deviation, and so on. The ecological state of the water bodies need then to be compared to a reference condition, which can be determined by one of four ways (Elliott and de Jonge 2002):

- Using historical records

- By a direct comparison with a pristine area
- By predictive modeling
- By use of expert opinion

Several Member States do not have reliable historical records for must most of their water bodies, and few pristine areas, if any, can be found in Europe. The last two options are somewhat subjective.

4.3. HOW TO SAMPLE THE BIOLOGICAL QUALITY ELEMENTS? HOW TO DEFINE GOOD ECOLOGICAL QUALITY? HOW TO REACH COMPARABLE ECOLOGICAL CLASSIFICATION?

Member States were required to start their Directive compliant monitoring in 2006. The sampling strategies needed to be defined, for each water type. Guidance on how many sampling stations, the sampling effort in each station, the periodicity, and more specific questions such as the sieve mesh size for benthic invertebrate fauna can be found in WFD (2003). However, these questions are still being discussed among the several Member States. Non EU countries such as Norway are also involved in the WFD implementation.

The WFD makes explicit reference to the need for comparability of ecological assessment across Europe through an 'intercalibration exercise', currently comprising 1,500 sites, 232 coastal, 883 river and 385 lake sites (in: http://ies.jrc.cec.eu.int/529.html, accessed December 20, 2007). The main objective of the exercise is the setting of "good" status boundaries, consistent with WFD definitions and comparable among the 27 Member States.

Setting "good" ecological status is important as reaching this status by 2015 is the main objective of the WFD and below this status restoration actions are needed. Different countries may underestimate the EQS and spend large amounts to restore sites that do not need to be restored. The opposite can also happen. Member States may overestimate the EQS and classify ecological state water bodies as having good quality when they should have been classified as "moderate".

Intercalibration is a complex task that takes into account current scientific knowledge about the structure and functioning of aquatic ecosystems, and how human activities influence them in: http://ec.europa.eu/environment/water/water-framework/objectives/index_en.htm, accessed December 20, 2007. It implies the monitoring and assessment of the biological and chemical quality of the water bodies and the development of indicators and methodologies to the integration of the information gathered.

4.4. WHICH BIOTIC INDEX TO USE?

Several biotic indices are being tested in different systems all over Europe.

Most of them are based on different degrees of macroinvertebrate tolerance/sensitivity to stress factors, such as organic pollution. Some of the more frequently used can be found in the next section.

Univariate indicators:

S – Number of species

N – Total number of individuals (usually per unit area, as individual's m^{-2})

$N \sum_{i=1}^{S} n_i$ – where n_i is number of individuals belonging to the i^{th} species

$p_i = {}^{n_i}/N$ – Relative abundance of the i^{th} species

Diversity indices:

Shannon-Wiener: $H' = -\sum_{i=1}^{s}\left(p_i \log_2 p_i\right)$ (Shannon and Weaver, 1963)

Margalef: $D = {}^{(S-1)}/(\log_e N)$ (Margalef, 1986)

$ES_{(50)}$ = Expected number of species for 50 individuals (Hurlbert, 1971)

$$ES_{(50)} = \sum_{i=1}^{s} \frac{(N-n_i)!(N-50)!}{(N-n_i-50)!N!}$$

Only samples with more than 50 individuals must be considered.

Biotic indices:

AMBI (Borja et al., 2000, 2003)

$AMBI = (0 \times EG_I + 1.5 \times EG_{II} + 3 \times EG_{III} + 4.5 \times EG_{IV} + 6 \times EG_V /100)$

EG – Ecological groups, in percentage, according to their sensitivity to increasing pollution gradients:

EG_I – comprises very sensitive species
EG_{II} – indifferent species
EG_{III} – tolerant species
EG_{IV} – second-order opportunistic species
EG_V – first-order opportunistic species

Information about the sensitivity of more than 4,100 taxa from European and Mediterranean soft-bottom sediments is available in: http://www.azti.es/. Borja et al. (2000) proposed a site pollution classification as a function of AMBI. Unpolluted sites would be dominated by ecological group I, corresponding to a normal benthic community health, with AMBI varying between 0 and 0.2. Heavy polluted sites would be dominated by the ecological group V and the community health would correspond to heavy polluted, with AMBI values varying between 5.5 and 6.0. Extremely polluted sites would have azoic environments. Subsequently, in 2003, Borja et al. adapted this scale to WFD, stipulating a correspondence among the AMBI values and the Ecological Status. AMBI values between 0.0 and 1.2 correspond to a High Ecological Status, between 1.2 and 3.3 correspond to Good Status, between 3.3 and 4.3 to Moderate Status, between 4.3 and 5.5 to Poor Status, and values between 5.5 and 7.0 to a Bad Status.

BENTIX (Simboura and Zenetos, 2002)

$BENTIX = (6 \times G_I + 2 \times (G_{ii} + G_{iii})/100$

G – Ecological groups, in percentage, according to their sensitivity to increasing pollution gradients:

G_I – comprises sensitive species

G_{II} – tolerant species and second-order opportunistic species

G_{III} – first order opportunistic species

This index is a simplification of AMBI, trying to avoid the uncertainty of assigning species to one of five ecological groups. A compilation of the three groups can be find in Simboura and Zenetos (2002) Annexes I and II. The authors also establish a correspondence between BENTIX and the Ecological Quality Status. Values between 4.5 and 6.0 would correspond to a High quality status, between 3.5 and 4.5 to Good Status, between 2.5 and 3.5 to Moderate, between 2.0 and 2.5 to Poor Status and equal to 0 to a bad state.

Benthic Quality Index (BQI) (Rosenberg et al., 2004)

$$BQI = \left[\sum_{i=1}^{S}\left({}^{n_i}\!/_{N} \times ES50_{0.05i}\right)\right] \times \log_{10}\left(S+1\right)$$

This index is based on a combination of the species tolerance values, abundance and diversity. $ES50_{0.05i}$ corresponds to the species *i* tolerance value. Values for 308 species or taxa are available at: www.marine-monitoring.se. The BQI varies with water depth. For depth below 20 m: $BQI \geq 14.4$ – High Ecological Status; $10.8 \leq BQI < 14.4$ – Good Ecological Status; $7.2 \leq BQI < 10.8$ – Moderate Ecological Status; $3.6 \leq BQI < 7.2$ – Poor Ecological Status; $BQI < 3.6$ – Bad Ecological Status.

Infaunal Trophic Index (ITI) (Word, 1978)

$ITI = 100 - 33.3 \times (TG_2 + 2TG_3 + 3TG_4)/TG_{1,2,3,4}$

TGi – number of individuals in Trophic Group *i*

TG_1 – Suspension feeders
TG_2 – carrion feeders (carnivorous, omnivorous and necrophagous)
TG_3 – surface deposit feeders and those species that are both suspension feeders and surface deposit feeders
TG_4 – subsurface deposit feeders that feed on sedimentary detritus and bacteria

ITI values near 100 means that suspension feeders are dominant and that the environment is not disturbed. At values near 0, subsurface feeders dominate, meaning that the environment is strongly disturbed, probably due to human activities (Salas et al., 2006).

Dauvin et al. (2007) tested these and other indices with data from the Bay of Seine and the Seine Estuary, in France. Though the specific ecological quality values calculated with the various indices were different, the overall trend of the results was similar. These authors (and references therein) recommend the combination of several indices when assessing the Ecological Quality Status of an area in order to take the complexity of the ecosystem into consideration and to minimize errors.

Biotic integration

Several different approaches were tested in order to calculate the Ecological Quality Ratio (EQR). Borja et al. (2003) proposed the combination of three metrics: Shannon Diversity, Species Richness and AMBI. For each of the metric values there is an Equivalent Assigned Value (EAV). The EQR is calculated as the mean of the EAVs for each station. Then, each EQR has an associated ecological status.

Bettencourt et al. (2004) also proposed a combination of several metrics (Margalef diversity, Shannon diversity, AMBI and W-statistic (Warwick, 1986; Clarke, 1990), assigning intervals of each index to the five Ecological Quality Status. They propose a combination of two or three of the selected indices, depending on the type of data available, to determine the Ecological Status.

Teixeira et al. (2007) tested these two methodologies with data from the Mondego estuary, in Portugal. Application of Borja et al. (2003) methodology resulted in the classification of 13 stations (out of 25 stations) in Poor Ecological State, 11 in Moderate state, and 1 in Good state. Application of Bettencourt et al. (2004) methodology resulted in only 2 stations being classified in Poor state, 17 in Moderate state and 6 in Good state. Another team (Chainho et al., 2007) using a different data set from the same estuary, also obtained different classifications with different indices and among seasons and they concluded there was low agreement between indices and index – season interactions. Diversity indices were better correlated to eutrophication related variables than AMBI and ABC method (W-statistic).

The Environment Agency, Peterborough, UK, 2005, unpublished in Quintino et al. (2006) derived an index in order to incorporate the main community parameters required for inclusion under the EU WFD:

$$EQR = \frac{\left(\left(2\times\left(1-\left(\frac{AMBI}{7}\right)\right)\right)\times\left(D'\right)\right)}{3}\times\frac{\left(\left(1-\left(\frac{1}{N}\right)\right)+\left(1-\left(\frac{1}{S}\right)\right)\right)}{2}$$

The suggested tentative EQR thresholds for the purpose of the Ecological Quality Status classification of a site are: "high status": 0.80–1.00; "good status": 0.65–0.79; "moderate status": 0.43–0.64; "poor status": 0.20–0.42; "bad status": 0.00–0.19.

Quintino et al. (2006) tested the application of this index and compared the results with the application of the Benthic Quality Index (BQI) (Rosenberg et al., 2004) with data from different coastal and transitional waters in Portugal. They concluded that EQR appears to over-estimate the ecological status for "poor" areas and underestimate it for "good" areas in comparison with BQI.

Recently, Muxika et al. (2007) proposed a different approach when analyzing benthic ecological status. They again propose the use of three metrics: Shannon Diversity, Species Richness and AMBI combined together with discriminant analysis in assessing ecological quality. This assessment requires previous classification of water bodies and typologies, together with the definition of reference conditions, using historical data, expert judgment and multivariate analysis.

4.5. HOW TO DISTINGUISH PHYSICAL STRESS AND OTHER STRESSORS FROM ORGANIC STRESS?

Elliott and Quintino (2007) recently addressed the question of the Estuarine Quality Paradox: "The dominant estuarine faunal and floral community is adapted to and reflects high spatial and temporal variability in naturally highly stressed areas and has features very similar to those found in anthropogenically stressed areas thus making it difficult to detect anthropogenically-induced stress in estuaries." In other words, environmentally variable areas are more able to withstand the effects of anthropogenic perturbations (Environmental Homeostasis).This makes it more difficult to detect anthropogenic signals against a background of environmental noise.

Suspension-feeding animals dominate sandy sediments, whereas deposit feeders dominate muds, although carnivores and other feeding types occur in both types of sediments. Small sedimentary particles are indicative of a quiet water environment and it is here that fine-grained organic matter tends to settle from the water column. Suspension feeders function poorly in muds owing to the clogging effect of resuspended particles and to the destabilizing effect of deposit feeders on the sediment (Levinton, 2001)

To some degree, suspension feeders must depend upon currents to deliver planktonic food. Sandy bottoms are characteristic of faster currents and therefore probably have greater supply of phytoplankton. In estuaries and coastal lagoons, muddy sediments are characteristic of places with low water currents or with low water renewal, colonized by detritivores of opportunistic *r* type. These areas may be subjected to high physical stress, such as daily high temperature and salinity variation, but also wide fortnightly and seasonal variation (Gamito, 2006). The sediment may therefore be dominated by *r* opportunistic detritivores and their abundant presence may be due to physical stress and not to organic stress. The harsh conditions prevent the development of other species, usually strong competitors of the K type.

Most of the biotic indexes are based in the Pearson and Rosenberg model (1978). According to this model, with increasing organic input there is an increase of abundance, biomass and species richness in a first step, and a progressive declining of species richness and biomass when eutrophication increases, while abundance (mainly of type *r* opportunistic species) continues rising. But the problem is that the tolerant species, which tolerate high organic concentrations, may also be tolerant to natural stressors (Dauvin, 2007) such as physical stress due to low water hydrodynamics found in some areas of estuaries and coastal lagoons (Gamito, 2006, 2008). However, Quintino et al. (2006) concluded that opportunist species responding to organic enrichment, such as the polychaetes *Capitella* and *Malacoceros*, will not be the same as species responding to physical disturbance, such as the polychaetes *Chaetozone* and *Polydora*. Hence, factors derived for one stressor should be rederived for other stressors. Gamito (2008) also observed different taxa responding to different stressors. The physically stressed areas of Ria Formosa, a coastal lagoon in southern Portugal, were dominated by chironomid larvae and hydrobiid gastropods and the most polluted areas were dominated by oligochaetes, mainly tubificids. However, both structural (species richness and diversity indices) and functional indicators (trophic composition) indicate the same trend – low species richness, low diversity indices, and a community dominated by detritivores species at the locations characterized by high anthropogenic impact or by physical stress.

5. Conclusions

As shown above, a consensus does not exist on the adequate methodology for classifying the ecological quality status of the water bodies, based on macroinvertebrate fauna, for transitional and coastal waters. Several metrics have been proposed and tested, but the results are not consistent, although the majority gave the same tendencies. However, problems may arrive near the frontier between a "good" ecological status and a "moderate" status, since if a water body is classified as "moderate" remediation measures are necessary.

Furthermore, estuaries and coastal lagoons are naturally stressed areas, making difficult to differentiate anthropogenic caused stressors from natural stressors.

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THE ROLE OF ECOLOGICAL ENDPOINTS IN WATERSHED MANAGEMENT

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Abstract: Landscape change and pollution in watersheds affect ecological endpoints in receiving water bodies. Therefore, these endpoints are useful in watershed management. Fish and benthic macroinvertebrates are often used as endpoints, since they are easily measured in the field and integrate over time and stressors. A range of approaches are used to incorporate ecological endpoints into watershed management. A common approach is the use of metrics, such as species diversity and the presence of rare or unique species; metrics are also combined into multimetric indices. Multivariate analyses are used to relate endpoints to landscape characteristics. Detailed ecological models can be used to represent effects of multiple stressors and predict the response to ecological endpoints to future conditions and alternative management scenarios. Ecological endpoints are currently used to assess or classify sites or water bodies, to identify impaired sites and waters, support water quality permits or enforcement, identify areas for conservation, or to set restoration goals or monitor progress. In the future, it is likely that ecological endpoints will be incorporated with aspects of water quality and economic valuation to create sophisticated decision support tools for watersheds.

Keywords: Mulitmetric; multivariate; ecological endpoints; assessment

1. Introduction

Aquatic ecological populations and communities are affected by the nature and quality of the water system in which they live. Specific factors that affect instream biota include chemical variables, biotic interactions, energy source, flow regime, and habitat structure (Karr and Chu, 1999). Human activities on the landscape, such as development, agriculture, industry, and forestry, can alter these factors and affect aquatic life in the receiving water body. As such, nearly all organized environmental management programs focused on watersheds incorporate the ecological endpoints in the receiving waters to

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some degree. Aquatic ecological endpoints are useful watershed management because they are often easily measured in the field, and unlike chemical and physical measures, integrate over time and stressors. The presence, condition, numbers, and types of aquatic biota can provide direct information about the health of specific water bodies.

Data on ecological endpoints are collected through field sampling in diverse water bodies, including streams, rivers, lakes, reservoirs, and estuaries. Most often, data are collected for fish and invertebrates, but algae, vascular plants, mollusks, and amphibians may also be sampled. Field sampling programs often integrate several monitoring designs (e.g., fixed monitoring stations, targeted intensive monitoring, a rotating basin approach), and should also include probability-based networks that support statistically valid inferences about the condition of water bodies over time (U.S. EPA, 2003). Monitoring designs and sample sites should be selected by how well they serve the objectives and decision needs of the management agency.

Once data on ecological endpoints are collected, they can be processed or analyzed to provide useful information for decision-makers and managers. A common approach for using ecological endpoints for these purposes is the use of metrics and multimetric indices. Metrics are biological attributes or indicators calculated for each assemblage sample that are assumed to be sensitive to degradation. Metrics may be combined into a multimetric index, in which metrics are calibrated to a unitless scale (typically 1–10) and then summed to give a multimetric index score. A second approach, multivariate analysis, can be used to directly relate ecological endpoints to habitat, water quality, and landscape variables. Multivariate statistical analysis takes advantage of joint structure between variables and can simultaneously examine the behavior of more than one dependent variable. A third approach for incorporating ecological endpoints into watershed management involves more detailed ecological modeling, where models are developed and applied to specific systems of interest.

The results of analyses of ecological endpoints data are used to support watershed management (Bain et al., 2000; Brooks et al., 2006; Heinz Center, 2002). These results can be used for:

- Assessment – to assess or classify sites or water bodies
- Protection – to identify impaired sites and waters, support water quality permits or enforcement, identify areas for conservation
- Restoration – to set restoration goals or monitor progress
- Examples of all of these applications are discussed below. These examples illustrate the important role of ecological endpoints in sustainable watershed management.

2. Metrics and multi-metric indices

2.1. METRICS INDICES

Perhaps the most common metric used in aquatic ecology is species richness or diversity, simply the number of species at a given site or area. Species richness has been shown to decrease with impairment in the watershed for both fish and benthic invertebrates (e.g., Das and Chakrabarty, 2007; Park et al., 2007), however, species richness also varies with natural factors, including stream size, primary productivity, and flow regime (Abell et al., 2000; Matthews, 1998). A common metric for benthic invertebrates is the EPT richness, which is the number of taxa in three insect orders known to be sensitive to watershed impairment: Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies). EPT richness is also expected to decrease with increasing impairment in the watershed and declining habitat and water quality.

Another common metric is the presence, absence, or abundance of a particular indicator species. Historically, aquatic resource management often focused on the abundance or biomass of a commercial, recreational, or subsistence fishery. Now, there is often more interest in the presence of a sensitive, rare, or imperiled species that may decline as watersheds become impaired. Often, imperiled aquatic species are a focus of management activities, where they and their critical habitat receive enhanced protection to prevent their extinction. The Heinz Center report (2002) included at-risk native freshwater species and at-risk freshwater plant species as indicators for freshwater in the United States, which they stated could be used to report on the condition of ecosystems, and should be tracked over time in order to detect trends. This report also included non-native aquatic species as an indicator for watersheds. The presence of tolerant or invasive species can result in a decline in native species.

Most work with ecological endpoints focuses on the level of populations and communities; however, there are several other biological endpoints of interest in watersheds, including behavior, genetic and endocrine indicators, and bioaccumulation of toxic chemicals in fish and shellfish (e.g., Depledge and Hopkin, 1995; Karr and Chu, 1999). Because of the human health and economic implications of bioaccumulation, control of the source and treatment of the contamination often becomes a focus of management in watersheds with significant toxic issues.

2.2. MULTIMETRIC INDICES

Multimetric indices are often used to assess biological integrity, which is the ability to support and maintain a community of organisms having a species diversity, composition, and functional organization comparable to those of natural habitats within a region (reference condition) (Karr and Dudley, 1981). Barbour et al. (2000) described several elements that should be included in a bioassessment program: the development of study objectives; selection of indicators and indices; classification of sites, in order to identify naturally homogeneous areas; the development of reference condition for all of the site classes; standard protocols for sampling and quality assurance; and data analysis to assess integrity. Biological integrity is typically determined through the comparison of measured index values with data from a site in reference condition. This information can also be used in watershed protection, where threshold values of index scores can be identified to judge attainment of designates watershed uses (Barbour et al., 2000).

The most common use of the multimetric approach for watersheds is the application of an Index of Biotic Integrity (IBI), first developed for fish assemblages by Karr (1981). This index combines metrics for species richness and indicator species with metrics for trophic function (e.g., % omnivores, % piscivores), reproductive function (% hybrids), and abundance and condition (e.g., % individuals that are diseased, deformed, or have tumors). The IBI was originally developed for wadeable rivers and streams, but has been extended to lakes, wetlands, and estuaries (U.S. EPA, 1998; Coates et al., 2007). The IBI approach is also used for invertebrates (e.g., Kerans and Karr, 1994; Astin, 2007; Haase and Nolte, 2007). Diaz et al. (2004) provide a comprehensive description and review of 64 benthic indices used for streams, rivers, and estuaries. Multimetric approaches are easily understood and useful communication tools for policy-makers and the general public (Coates et al., 2007).

Another form of multimetric index involves the use of tolerance values for individual taxa collected in a sample that are combined into an index. Hilsenhoff (1988) developed a biotic index where species/families were assigned tolerance values based on the response to organic pollution from 1(sensitive) to 10 (tolerant). An early example of this was the North Carolina Biological Index (NCBI), developed by Lenat (1993), where tolerance values were calculated for >500 benthic invertebrate taxa based on their abundance in relation to water-quality ratings. Wu (1999) developed a Genus Index for algae, as the ratio of abundance of more sensitive genera, such as *Achnanthes, Cocconeis*, and *Cymbella*, to less sensitive genera of *Cyclotella, Melosira*, and *Nitzschia*, where a lower score for the ratio (<1.5) represents moderate or severe pollution.

Multiple indices can also be combined to provide a more comprehensive assessment. Assemblages of algae, invertebrates, and fishes show differing responses to stressors, so an assessment approach where metrics for these are combined may increase the utility of the multimetric approach to diagnose environmental stressors (Griffith et al., 2005). For example, the Index of Stream Condition (ISC) was developed in 1995 for use in Australia (Ladson et al., 1999) with applications to other regions. This is an integrated measure of the state of a stream based on an assessment of five components of streams: hydrology, physical form, streamside zone, water quality, and aquatic life.

Several methods exist to relate measures of physical habitat to the quality, or suitability, of physical habitat for fishes based on instream habitat characteristics. One of the earliest quantitative approaches to assess the suitability was through the use of habitat suitability index (HSI) models. The HSI models are composite scores of the suitability of multiple habitat characteristics. For each of the habitat characteristics, suitability ranges from 0 (unsuitable) to 1 (fully supporting of the species) and is represented as a hypothetical nonlinear curve. These models are based on the assumption that there is a positive relationship between the suitability index and habitat carrying capacity (U.S. Fish and Wildlife Service, 1981). More detailed information on fish population structure, distribution, and growth can indicate the integrity of habitat condition, which can used to set management and engineering criteria for restoration (Schiemer, 2000). In the Whitefish Mountains in Montana, USA, a multi-scale watershed analysis technique was used to identify the most important habitat forming processes for native fishes and use that information to prioritize and implement the most appropriate watershed restoration activities for these species (Bohn and Kershner, 2002).

A recent development is the use of models that relate aspects of flow regimes to the suitability of aquatic habitat, mostly for fishes. The Indicators of Hydrological Alteration (IHA, Postel and Richter, 2005) provides a set of ecologically-relevant indicators for managing watershed in terms of flow. The Range of Variability Approach (RVA) quantifies the effects of flow variability on the conservation of aquatic biodiversity and allows managers to set targets that are protective of biodiversity (Richter et al., 1997). The MesoHABSIM approach (Parasiewicz, 2001) allows users to estimate amount of available physical habitat for fishes as a function of flow, and this can be used to support restoration planning. An understanding of how alteration of flow regimes affects the ecological endpoints is critical to supporting management and decision-making in modified streams (Tharme, 2003; Lytle and Poff, 2004; Acreman, 2005).

3. Multivariate approaches

Classification, the act of putting sites or species in groups, is a common approach used to process data on aquatic biota so that it is useful for watershed management. Whittier et al. (1988) and Angermeier and Winston (1999) demonstrated that ecoregions were a useful framework for classifying streams in the states of Oregon and Virginia, respectively. The River InVertebrate Prediction And Classification System (RIVPACS) model, which was developed for stream management in the UK, uses classification to predict the freshwater macroinvertebrate fauna expected to occur at a site in the absence of pollution and to provide a framework for assessing the degradation of test sites (Wright, 1995, Clarke et al., 2003). The BENTIX biotic index used on the European Framework Directive is also of this form (Simboura and Zenetos, 2002).

Ordination is the ordering of a set of data points with respect to one or more axes. In Canada, the BEnthic Assessment of SedimenT (the BEAST) program uses ordination to compare benthic macroinvertebrate assemblage data from sampled freshwater sites to the reference (expected) condition (Reynoldson et al., 1995). Sampled sites are plotted in the same ordination space as matched reference sites, and the distance of the test site from the reference space is used as an indicator of impairment. For the United States, Meador and Carlisle (2007) used principal components analysis, an ordination technique, to distinguish between tolerant and intolerant fishes and identify the dominant water quality factors related to these patterns. In California, Marchetti et al. (2006) used ordination to identify shifts in the diversity of fish over time at multiple sites. Muxika et al. (2007) used factor analysis, a type of ordination, along with discriminant analysis to assess ecological condition of river sites in the Basque Country. Sasaki et al. (2005) used ordination to understand patterns of recovery in the stream benthic fauna below a mine drainage treatment plant on Japan's Akagawa River.

Multiple regression models, neural networks, and bayesian methods are popular tools for predicting fish distribution as a function of habitat quality (Guisan and Zimmermann, 2000). All of these techniques have successfully been applied to develop predictive habitat models for stream fish (Porter et al., 2000; Oberdorff et al., 2001; Rieman et al., 2001). Predictive habitat models have several applications in watershed management, such as in conservation, where the models can be used in identifying high-priority areas for aquatic species protection and reintroduction (Wall et al., 2004), and in restoration, where models can be used to evaluate the response of biological endpoints to restoration scenarios in order to optimize management efforts (Guay et al., 2000; Porter et al., 2000). The identification of fish-habitat associations is a critical first step in the restoration of degraded streams (Bond and Lake, 2003).

4. Ecological modeling

Ecological modeling involves the development of a simplified mathematical representation of an ecological system. Although modeling is widely used for physical and chemical processes in watersheds, ecological modeling tends to be used less often in watershed management. Modeling is particularly useful for ecological systems that show complex dynamics. For example, shallow lakes have shown nonlinear responses to environmental change, and modeling of these responses has been used to predict threshold values of environmental factors that control these systems (Scheffer, 1989).

Ecological models are often used for assessing effects of toxic chemicals on aquatic ecosystems and for simulating bioaccumulation in a food web. These approaches range in complexity from steady-state mass balance food chain bioaccumulation models (e.g., Gobas, 1993) to more complex simulation models. Koelmans et al. (2001) reviewed common simulation models for bioaccumulation in aquatic systems, including AQUATOX, GBMB, CATS-5, and IFEM. Bartell (2002) provides a useful overview of models that can be used for chemical risk assessment in aquatic systems.

Ecological models are powerful tools for supporting watershed management because they can forecast future conditions under alternative scenarios. Some packaged models exist to support modeling of aquatic ecology, such as ECOPATH, a popular trophic mass-balance model that can be used to evaluate ecosystem effects of environmental change and explore management policy options (Christensen and Walters, 2004), and AQUATOX, an aquatic system simulation model that has been used to set water quality criteria for nutrients in the Cahaba River in Alabama, USA (U.S. EPA, 2004). Models can also be developed in programming packages. For example, Gamito (2007) provides an example using to STELLA modeling package to assess impacts of a terrorist attack on a coastal lagoon foodweb and Akçakaya et al. (2004) show several examples using the RAMAS modeling system to evaluate persistence and viability of fish species under alternative management scenarios.

Ecological models can be linked with watershed flow and chemistry models for complex analysis of water systems. For example in the Everglades of Florida, fish models were linked with spatial predictions of hydrology for assessment of management alternatives (Gaff et al., 2000). Young et al. (2000) incorporated a model of silver perch with models representing the flow regime and instream and floodplain conditions into the decision support system for the Murray-Darling Basin in Australia. It is likely that linked modeling systems will be used for watershed management and decision-making in the future.

5. Conclusions

Ecological communities are the endpoints in a watershed system, so they are responding to all of the activity that occurs throughout the watershed. Novotny et al. (2005) described a concept of a layered hierarchical model for watersheds, with ecological endpoints in the top layer, water chemistry and sediment risks and a habitat quality index in the layer below, in-stream concentrations in water and sediments and habitat impairment parameters in the third layer, and aspects of landscape pollution, land use change, and hydrology in the lowest layer of stressors. Within this framework, tools and models of varying complexity have been developed to support watershed management. Bain et al. (2000) have noted that the assessment of aquatic ecosystems is not limited by methods, since several methods and tools are available, and they are generally flexible enough for many different types of applications.

Ecological endpoints are used to assess, protect, and restore biological integrity in watersheds. One emerging use of aquatic ecological endpoints is their use in the diagnosis of the causes of impairments in watersheds. The U.S. EPA Stressor Identification Guidance Document describes a formal process to identify stressors causing biological impairments in aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions (U.S. EPA, 2000). Simon (2002, and papers therein) has reviewed the status of the science for using "biological response signatures" as indicators for watersheds and provided several examples where these methods are being used.

In the future, ecological endpoints will likely be considered in the light of how they contribute to human health and wellbeing: the diversity of species and the presence of sensitive, rare species for aesthetic and cultural value; and the abundance/quality of a commercially or recreationally important fish stock for food provisioning (Carpenter and Folke, 2006). It is likely that these considerations will be incorporated into future watershed management risk assessment and decision support systems that also include economic valuation and stakeholder concerns (e.g., Wilson and Carpenter, 1999; Serviess, 2002; Ohlson and Serveiss, 2007). Specifically, it may be necessary to relate cost estimates of restoration activities and their associated ecological benefits, in order to assess trade-offs in management and restoration (Holmes et al., 2004). One example is in the CALFED Bay-Delta Program in California, where the costs and benefits of actions affecting the restoration of fish species were considered in the context of an adaptive, integrated resource management system for the region (Luoma, 2007). This sophisticated type of analysis can lead to more comprehensive planning and sustainable decision-making for watersheds.

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BIOIDENTIFICATION OF XENOBIOTICS AS A BASIS OF WATER MANAGEMENT

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Abstract: We have been developing non-traditional methods of the identification of pollutants, using various hydrobionts as biological objects and the study of the mechanism of toxic action of xenobiotics. The experiments were carried out with using of *Daphnia magna. Daphnia magna* is a Crustacean in the order of Cladocera. This aquatic animal extensively used as a test organism in aquatic toxicology due to their small size, short life cycle and amenability to lab culture. *Daphnia magna* is the most sensitive test-object in relation of different pollutants among all known biological objects including experimental animals. Experiments were performed with a 2-days old culture of *Daphnia magna*. The toxicity of xenobiotics was determined by the value of LC_{50}, a concentration of the compounds causing death to 50% of hydrobionts during incubation with toxicants for 24 hours. In the first stage of the work, toxicity of organophosphates (Dipterex, DFP, DDVP, Paraoxon, Malathion, Malaoxon), carbamates (Aminostigmine, Physostigmine, Sevine), heavy metals (Hg, Pb, Cu, Co, Cd, Cr, As, Al), organochlorines (Aldrin, Dieldrin, Endrin, Aroclor, DDT, Lindane, PCBs etc.) and pyrethroids (Cypermethrin, Fenvalerate, Deltamethrin, Permethrin, Allethrin, Resmethrin, Phenothrin, Kadethrin, Cyphenothrin) was determined. The effects of a number of antagonists on the toxicity of xenobiotics were studied. At the first time we discovered that in experiments to *Daphnia magna* some muscarinic cholinoreceptor blockers (atropine, glipine, pediphen etc.) reduced the toxic effect oforganophosphates and carbamates. In the case of heavy metals the chelating agents (EDTA, Dithioethylcarbamate, Unithiolum, Sodium thiosulphuricum, L-Aspartic acid) were effective, for certain organochlorine poisonings – anticonvulsive drugs (diazepam, phenobarbital). In the case of pyrethroid's poisonings the antagonist of glutamate receptor (ketamine), DOPA receptors (haloperidole) and blocker of calcium channel (nimodipine) reduced the toxicity of xenobiotics. As far as these antidotes have a specific treatment action only against definite classes of pollutants, we have elaborated the sensitive express-methods of bioidentification of pollutants.

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Keywords: Bioidentification; xenobiotics; *Daphnia magna*; water management

1. Introduction

With a constant growth of the anthropogenic pressure on water bodies the development and usage of bioindication methods supplementing physical and chemical methods of xenobiotic identification acquires especial significance. In view of the fact that chemical analysis require special equipments, they are expensive to perform and do not allow to evaluate the environmental toxicity, during the recent decade large scale investigations have been performed to study various test-objects that are suitable for bioassay. At present biotesting plays an important role in the system of water quality control. On the currently used methods of bioassay provide only the integral evaluation of the pollutants effect but not the determination of the xenobiotics a origin (Flerov, 1989).

We have been developing non traditional method for determination of different classes of pollutants using various hydrobionts as biological test-objects and our knowledges of the mechanism of toxic action of xenobiotics. Knowing the mechanisms of the specific toxic action of poisons, it is possible to use various pharmacological compounds to decrease or increase the effects of toxicants. This approach allows us to use biological objects to identify certain xenobiotics, poisoning from which can be prevented by means of poisoning's antagonists. All above mentioned methods are widely used when employing experimental animals (mice, rats) as test-objects, but it has not been developed at all for alternative biological objects, particularly for hydrobionts. The elaboration of a new methods of bioidentification was founded on the study of Cholin-, GABA-, Dopamin- and Glutamate- ergic system of *Daphnia magna* and usage of pharmacological antagonists of xenobiotics. Such new pharmacological approach with usage of *Daphnia magna* as bioobject have made possible to perform the general identification of different classes of the most toxic for aquatic ecosystem health xenobiotics (organophosphates, carbamates, heavy metals, organochlorines, pyrethroids) without usage of chemical analysis.

2. Materials and methods

As a background of discussed method, we have chosen a big amount of anticholinesterase (antiChe) compounds, different heavy metals, organochlorine pesticides and pyrethroids. Many compounds of these classes are used as pesticides, drugs and chemical warfare agents. Currently, dozens of pesticides capable of polluting the aqueous media through the runoff from agricultural lands or as a result of chemical industry accidents are produced. The experiments were carried out with using of *Daphnia magna. Daphnia* *magna* is a Crustacean in the order of Cladocera. This aquatic animal extensively used as a test organism in aquatic toxicology due to their small size, short life cycle and amenability to lab culture. *Daphnia magna* is the most sensitive test-object in relation of different pollutants (organophosphates, heavy metals, organochlorines, pyrethroids etc.) among all known biological objects including experimental animals (Peters and De Bernardi, 1987).

Experiments were performed with a 2-days old culture of *Daphnia magna*. During the experiments, hydrobionts were placed in beakers with 25 mL of dechlorinated settled tap water at 18–20 °C. The toxicity of xenobiotics was determined by the value of LC_{50}, a concentration of the compounds causing death to 50% of hydrobionts during incubation with toxicants for 24 hours. In the first stage of the work, toxicity of organophosphates and carbamates (Dipterex, DFP, DDVP, Paraoxon, Malathion, Malaoxon, Aminostigmine, Physostigmine, Sevine), heavy metals (Hg, Pb, Cu, Co, Cd, Cr, As, Al), organochlorines (Aldrin, Dieldrin, Endrin, Aroclor, DDT, Lindane, PCBs etc.) and pyrethroids (Cypermethrin, Fenvalerate, Deltamethrin, Permethrin, Allethrin, Resmethrin, Phenothrin, Kadethrin, Cyphenothrin) was determined. The effects of a number of poisons antagonists on the toxicity of xenobiotics were studied. Xenobiotics and their antagonists were added to the incubation mixture simultaneously.The results of the protection experiments are expressed as the protective coefficient (PC) – the ratio of LC_{50} value in treated and in untreated *daphnids*.

3. Results

On the base of study of mechanism of xenobiotics action to *Daphnia magna* and the usage of pharmacological antagonists of poisonings the new methods of bioidentification of different pollutants were elaborated. At the first time we discovered that in experiments to *Daphnia magna* some muscarinic cholinoreceptor blockers (atropine, glipine, pediphen etc.) reduced a toxic the effect of organophosphates and carbamates (Table 1). In the case of heavy metals the chelating agents (EDTA, Dithioethylcarbamate, Unithiolum, Sodium thiosulphuricum, L-Aspartic acid) were effective (Table 2), for certain organochlorine poisonings – anticonvulsive drugs phenazepam, phenobarbital (Table 3). In the case of pyrethroid's poisonings the antagonists of glutamate (ketamine), DOPA (haloperidole) receptors and blockers of calcium channel (nimodipine) reduced the toxicity of xenobiotics (Tables 4, 5). As far as these antidotes have a specific treatment action only against definite classes of pollutants, we have elaborated the sensitive express-methods of bioidentification of pollutants. Such new pharmacological approach with use of hydrobionts as test-objects have made possible to perform the general identification of different classes of xenobiotics in fresh water.

TABLE 1. The influence of cholinolytics on toxicity of DDVP and aminostimine in experiments to *Daphnia magna*.

Drugs (mg/L)	LC_{50} DDVP (mg/L)	PC	LC_{50}, aminostigmine (mg/L)	PC
Control	0.00021 ±0.00005	–	0.012 ±0.002	–
Atropine				
1.0	0.00052 ±0.00004	2.5	0.018 ±0.002	1.5
2.0	0.00063 ±0.00007	3.0	0.042 ±0.009	3.5
6.0	0.00073 ±0.00006	3.5	0.042 ±0.009	3.5
Glipine				
1.0	0.00042 ±0.00008	2.0	0.021 ±0.005	1.75
2.0	0.00074 ±0.0001	3.5	0.069 ±0.019	5.75
Pediphen				
1.0	0.00032 ±0.00008	1.5	0.024 ±0.002	2.0
2.0	0.00063 ±0.00008	3.0	0.036 ±0.004	3.0

TABLE 2. The influence of GABA-mymetics on toxicity of DDT and lindane in experiments to *Daphnia magna*.

Compounds (mg/L)	LC_{50} mg/L DDT	PC	LC_{50}mg/L Lindane	PC
Control	0.08 + 0.02	–	0.12 + 0.02	–
Ethyl alcohol (g/L)				
0.1	0.15 + 0.03	1.9	0.23 + 0.07	1.9
0.025	0.24 + 0.03	3.0	0.26 + 0.07	2.2
Phenobarbital				
2.0	0.21 + 0.03	2.6	0.24 + 0.06	2.0
1.0	0.23 + 0.07	2.9	0.32 + 0.09	2.7
Phenazepam				
0.1	0.32 + 0.09	4.0	0.28 + 0.09	2.3
0.05	0.25 + 0.07	3.1	0.23 + 0.08	1.9

TABLE 3. The influence of EDTA and Unithiolum on toxicity of $Pb(NO_3)_2$ and $HgCl_2$ in experiments to *Daphnia magna*.

Chelates (mg/L)	$HgCl_2$ LC_{50}(mg/L)	PC	$Pb(NO_3)_2$ LC_{50} (mg/L)	PC
Control	0.16 ±0.06	–	1.70 ±0.52	–
EDTA				
2.5	1.59 ±0.47	9.97	3.38 ±0.56	1.98
5.0	2.1 ±0.05	13.1	5.1 ±0.56	3.0
10.0	3.2 ±0.06	20.0	6.6 ±1.48	3.88
25.0	–	–	13.3 ±2.9	7.8

(continued)

TABLE 3. (continued)

Unithiolum				
25.0	0.46 ±0.11	2.87	3.38 ±0.56	1.98
50.0	1.38 ±0.38	8.60	7.67 ±1.79	4.5
100.0	1.69 ±0.28	10.6	13.45 ±2.24	7.9

TABLE 4. The influence of ketamine and nimodipine on the toxicity of pyrethroids in experiments to *Daphnia magna*.

Pyrethroids (mg/L)	Cypermethrin LC_{50} (mg/L)	PC	Phenothrin LC_{50} (mg/L)	PC
Control	0.057 ±0.003	–	0.05 ±0.12	–
Ketamine				
7.5	0.62 ±0.17	10.9	0.52 ±0.12	10.4
4.0	0.51 ±0.13	8.9	0.46 ±0.10	9.2
Nimodipine				
25.0	0.29 ±0.03	5.1	0.42 ±0.03	8.4
12.5	0.16 ±0.02	2.8	0.21 ±0.09	4.2

TABLE 5. The influence of haloperidole on the toxicity of pyrethroids to *Daphnia magna*.

Pyrethroids LC_{50} (mg/L)	Cypermethrin LC50 (mg/L)	PC	Phenothrin LC_{50} (mg/L)	PC	Permethrin LC_{50} (mg/L)	PC
Control	0.057	–	0.05	–	0.05	–
Haloperidole						
3.0	0.46	8.1	0.6	12.0	0.36	7.2
1.5	0.48	8.4	0.55	11.6	0.50	10.0

4. Conclusions

We have been developing non-traditional express- method of the identification of pollutants/ organophosphates, carbamates, organochlorines, heavy metals and pyrethroids/using Daphnia magna as biological object and the study of the mechanism of toxic action of xenobiotics. The new method was proposed for water pollution control.

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GIS ANALYSIS OF SUSTAINABLE DEVELOPMENT INDICATORS FOR COASTAL WATERSHEDS IN THE SOUTH-EAST BALTIC

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Abstract: Sustainable development indicators for coastal zone recommended by EU WG-ID were estimated for low part of watersheds in the South-East Baltic, namely, for territories of Klaipeda County (Lithuania), Kaliningrad Oblast (Russian Federation) and Pomeranian Voivodship (Poland). Comparative analysis made clear differences in level and rates of development, revealed some disproportion in concentration of population and economic activities in the big cities, and evident prerequisites for balanced sustainable development of studied region.

Keywords: Indicators; sustainable development; Kaliningrad Oblast; South-East Baltic

1. Introduction

Sustainable management of the coastal zone is an essential in the conditions of rapid economic development. An indicator analysis, considering environmental, social and economic parameters, is one of the basic integrative approaches used as a supportive tool for management in different countries: Nordic indicators (Focus on Sustainable Development, 2006), Australian indicators (Are we sustaining Australia?, 2002), Canada indicators (Environment and sustainable development indicators for Canada, 2003), World Bank indicators (Segnestam, 2002).

In the presented paper we shall discuss the results of using the indicator system (Lescrauwaet et al., 2006), recommended by EU Working Group on Indicators and Data (WG-ID). This system was finally developed in the DEDUCE project (2004–2007). Here it will be used for comparative analysis of the situation in the low stream part of the coastal watersheds in the South-East Baltic, namely in the coastal coterminous administrative units of three countries – Lithuania, Poland and Russian Federation (Kaliningrad Oblast) (Figure 1).

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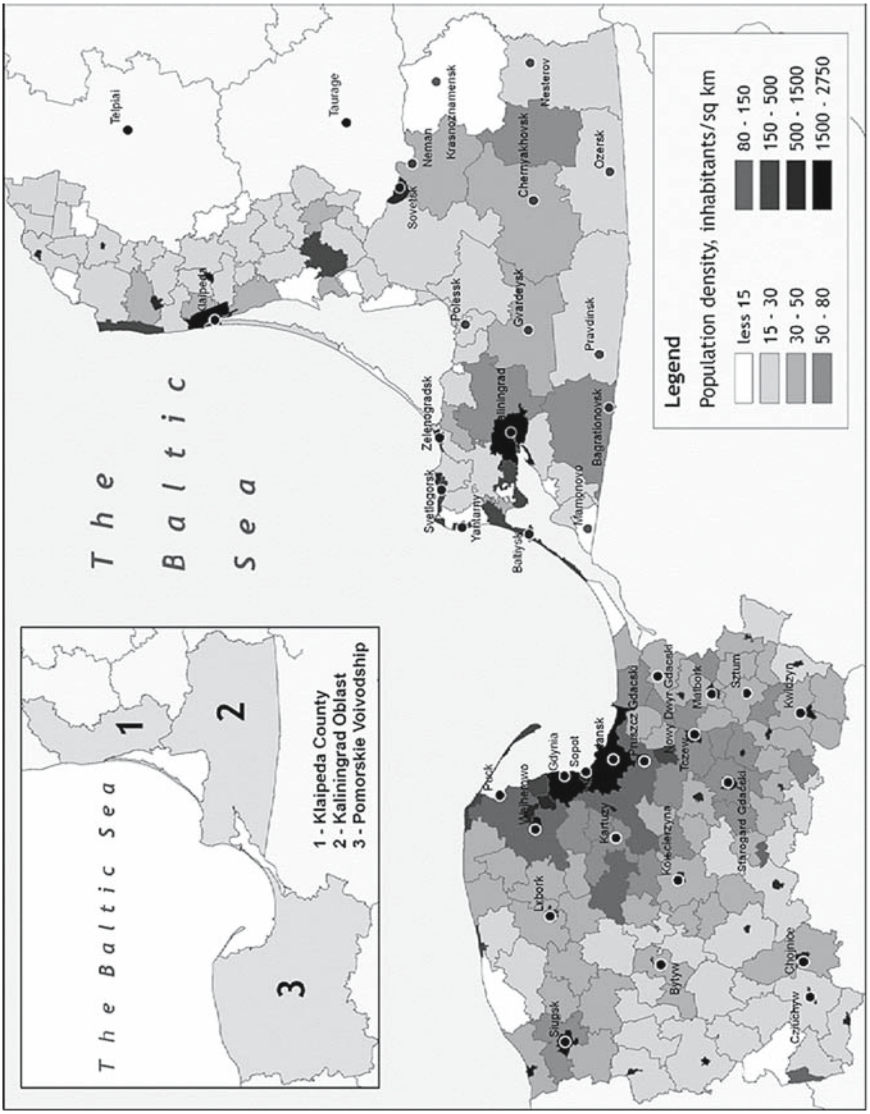

Figure 1. Density of population in the Klaipeda County (Lithuania), Kaliningrad Oblast (Russia) and Pomeranian (Pomorskie) Voivodship (Poland) for 2000. Coastal NUTS4 is subdivided into NUTS5.

2. Methods

Indicators of Sustainable Development (ISD), a core set of 27 indicators, composed of 46 measurements, were recommended by WG-ID to monitor sustainable development of the coastal zone (Indicators Guidelines, 2007). They are structured as per the seven main objectives of the Recommendation (2002):

- To control further development of the undeveloped coast as appropriate
- To protect, enhance, and celebrate natural and cultural diversity
- To promote and support a dynamic and sustainable coastal economy
- To ensure that beaches are clean and that coastal waters are unpolluted
- To reduce social exclusion and promote social cohesion in coastal communities
- To use natural resources wisely
- To recognize the threat to coastal zone posed by climate change and to ensure appropriate and ecologically responsible coastal protection

This paper will present an analysis of indicators related to objectives 1, 2 and 6, as a first order approach considering land use, nature protection and exploitation of marine life resources (Table 1).

Watersheds of the Vistula, Neman and Pregolia rivers opening into the South-East Baltic cover nearly whole Poland, Lithuania and Kaliningrad Oblast (Russian Federation) (see paper by Chubarenko of this book). Considering the coastal part of these watersheds, as a zone of maximal run-off of 0.25–1 day and minimal run-off of 1–5 days (in dependence of season), we took into consideration coastal NUTS3, i.e. the Kaliningrad Oblast, Klaipead County and Pomeranian Voivodship. The correspondence between European spatial division (National Units of Territorial Structure or NUTS) and existing in the Russian Federation structure of administrative units is given in Table 2. Kaliningrad Oblast (Russia), Klaipeda County (Lithuaia) and Pomeranian Voivodship (Poland) correspond to a level of NUTS3. They consist of administrative units of two further levels of spatial division (NUTS4 and NUTS5 levels).

Analysis presented in the paper included a comparison of indicator's parameters (measurements) calculated for coastal and non-coastal NUTS4 or NUTS5 within the Kaliningrad Oblast, and comparison of them with similar NUTS of Klaipeda County and Pomeranian Voivodship. The NUTS is considered as coastal if its territory has direct access to the Baltic Sea or the Vistula or Curonian lagoons.

TABLE 1. Indicators used for first order estimation were selected from the whole list of ISD developed in Recommendation (2002). First number in the code corresponds to objective number, second – to indicator number, third – to measurement number. Availability of data for target areas Klaipeda County (LT), Kaliningrad Oblast (RU), Pomeranian Voivodship (PL) is marked by plus "+". If data are available, but are not in full accordance to methodology, the mark "+?" is used.

NN	Indicator	Code	Measurement	LT	RU	PL
1.1	Demand for property on the coast	1.1.1	Sise, density and proportion of the population living on the coast	+	+	+
1.2	Area of the built-up land	1.2.1	Percentage of built-up land by distance from the coastline	+	+?	+
1.3	Rate of development of previously undeveloped land	1.3.1	Percent of new development on previously developed land	+	+?	+
		1.3.2	Area converted from non-developed to developed land uses	+	+?	+
1.4	Demand for road travel on the coast	1.4.1	Volume of traffic on coastal motorways and major roads	+	+	+
1.5	Pressure for coastal and marine recreation	1.5.1	Number of berths and moorings for recreational boating	+	+	+
1.6	Land taken up by intensive agriculture	1.6.1	Proportion of agricultural land farmed intensively	+	+?	-
2.7	Amount of semi-natural habitat	2.7.1	Area of semi-natural habitat	+	+?	+
2.8	Area of land and sea protected by statutory designation	2.8.1	Area protected for nature conservation, landscape and heritage	+	+	+
6.23	Fish stocks and fish landings	6.23.1	State of main fish stocks by species and sea area	+	+	+
		6.23.2	Recruitment and spawning stock biomass by species	+	+	+
		6.23.3	Landing and fish mortality by species	+	+	+
6.24	Water consumption	6.24.1	Number of day of reduced supply	+	+	+

TABLE 2. Correspondence of administrative spatial division in the Russian Federation to different levels of NUTS.

NATS0	NUTS1	NUTS2	NUTS3	NUTS4	NUTS5
Community of Independent States	Russian Federation	North-Western Federal District	Kaliningrad Oblast	Municipality or city	Rural district or town

Basic data for calculation of measurements were collected from open statistical overviews for studied areas and INTERNET resources. Calculation of indicators 1.2, 1.3, 2.6 and 2.7 are based on spatial analysis. In case of Lithuanian and Polish territory basic digital data were obtained from the European database CORINE Land Cover. Data for Kaliningrad Oblast were obtained from satellite image Landsat 7 ETM of 1999 year according to the standards of the CORINE Land Cover (CLC, 2000) using GIS system.

Due to some differences in initial data for different national territories, the comparison between them were made with some limited level of accuracy, which may be estimated in a range of 5–10% of analyzed value. This inaccuracy doesn't influence on revealed tendencies. To have fully comparable set of spatial data for the South-East Baltic, it is needed to implement modern methods of land inventory in Kaliningrad Oblast and incorporate the Oblast into European CORINE Land Cover (CLC) Project.

3. Results and discussion

Average population density (Figure 1) for coastal parts of three studied areas (Klaipeda County, Kaliningrad Oblast and Pomeranian Voivodship) is of 330 inhabitants per km^2. Minimum density is in the Kaliningrad Oblast (255 inhabitants km^{-2}, 77% of average), maximum is in the Pomeranian Voivodship (426 inhabitants km^{-2}), Klaipeda County – 307 inhabitants km^{-2}. Population density (2002) in the coastal NUTS4 of the Kaliningrad Oblast is 7.5 times higher than one in non-coastal areas (34 inhabitants km^{-2}). Similar relations were observed in the Klaipeda County (5:1 for 2001) and in the Pomeranian Voivodship (8:1 for 2003).

Urbanization and its development in the coastal zone were analyzed in Indicators 1.2 (Figure 2) and 1.3. On the whole for South-East Baltic, the urbanization in coastal NUTS is 1.3–2.2 times higher than in non-coastal. In the case of the Kaliningrad Oblast percent of built-up land in 1999 was higher in coastal NUTS4 (57%) than in hinterland (43%). The fast increase of urbanization in coastal regions was recognized in Pomeranian Voivodship, where the share of built-up areas in the coastal units increased from 37% to 41% during 10 years (1990–2000). In the case of Klaipeda County, the urbanization rate has increased only by 0.4% in the coastal NUTS4 during the period of 1995–2000.

On the whole for South-East Baltic, the high share of urbanized area was observed in 0–1 km buffer zone, and the highest growth in 0–10 km buffer zone. According to data of 2000 for Pomeranian Voivodship, Kaliningrad Oblast and Klaipeda County the built-up areas occupied respectively 13%, 21% and 10% of the 0–1 km coastal buffer zone, and 8%, 15% and 7% of the 0–10 km buffer zone.

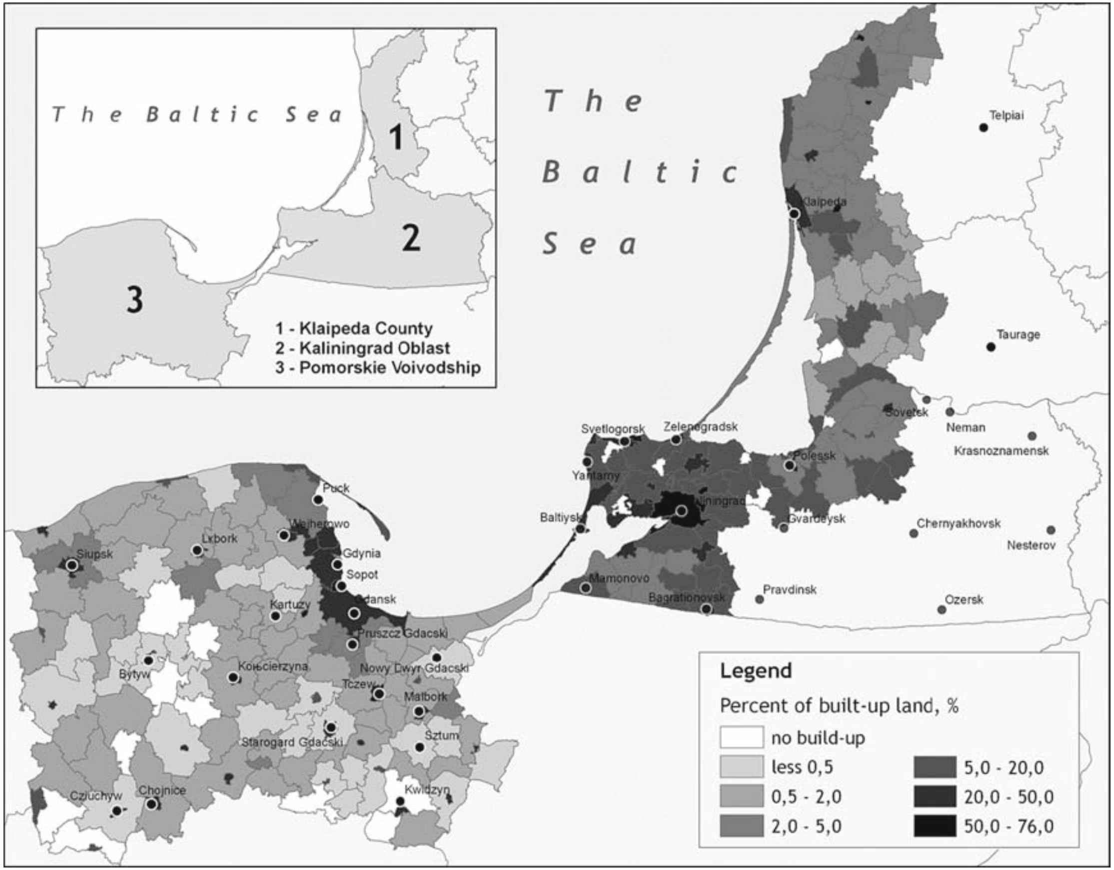

Figure 2. Percent of built-up land in the in the Klaipeda County (Lithuania), Kaliningrad Oblast (Russia) and Pomeranian (Pomorskie) Voivodship (Poland) for 2000. Coastal NUTS4 is subdivided into NUTS5.

Except the development of an infrastructure along main car transit roads, water tourism may be significant component of local economic activity. Even, marinas' infrastructure is not well developed in the South-East Baltic, potentially dense network of inland marinas is a good basis for future development of recreational boating on the inland water ways (Indicator 1.5, Figure 3). Most equipped marinas are at the Pomeranian coast. Marine ports (Leba, Wladyslawowo, Gdynia, Gdansk, Baltiysk, Pionersk, Klaipeda), located at the Baltic shore, provide some limited facilities for recreational boating, and marinas in these ports need to be developed. Low number of marinas on the open South-East Baltic shore is an obstacle for development of safe recreational boating in the foreshore area.

Indictor 1.6 shoes that, in average, 16% of territory of Kaliningrad Oblast and 48% of Klaipeda County is occupied by agricultural land, but there is almost no agricultural land farmed intensively in the South-East Baltic region within the 10 km coastal zone, except of allotment gardens. Proportion between intensively farmed areas in coastal and non-coastal NUTS are qualitatively different in Lithuania and Kaliningrad Oblast: share of intensively farmed land in non-coastal NUTS of Klaipeda County is higher than in coastal NUTS, while in Kaliningrad Oblast amount of intensively farmed land in coastal NUTS is slightly higher than in non-coastal ones (Figure 4).

Due to a graded character of the coastline and large pressure from the urbanization, the South-East Baltic is characterized by the lesser percentage of natural and semi-natural habitats in the 1–10 km coastal zone (Indicator 2.7) compared to the rest of the Baltic Sea Region. On the other hand, the pressure from the urbanization implies the need for a stricter regulation of land use in the coastal zone which results in a rather strict and sustainable coastal zone planning and management efforts in Klaipeda County, Kaliningrad Oblast and Pomeranian Voivodship. Monitoring of the area of natural and semi-natural habitats within the coastal zone should be implemented combining standardized remote sensing and land-truthing methods throughout the entire target region.

Area of the terrestrial coastal natural and semi-natural habitats within the Klaipeda County comprises 54%, whereas the acreage of these habitats, which are eligible for inclusion into the NATURA 2000 List of Lithuania is 21–22% of the total area of the county. Area of the terrestrial natural and semi-natural habitats within the Pomeranian Voivodship, which are eligible for inclusion into the NATURA 2000 List of Poland is 24% of the total area of the voivodship. Area of the terrestrial natural and semi-natural habitats within the Kaliningrad Oblast, which correspond to the criteria of the NATURA 2000 List, is above 20% of the total area of the oblast.

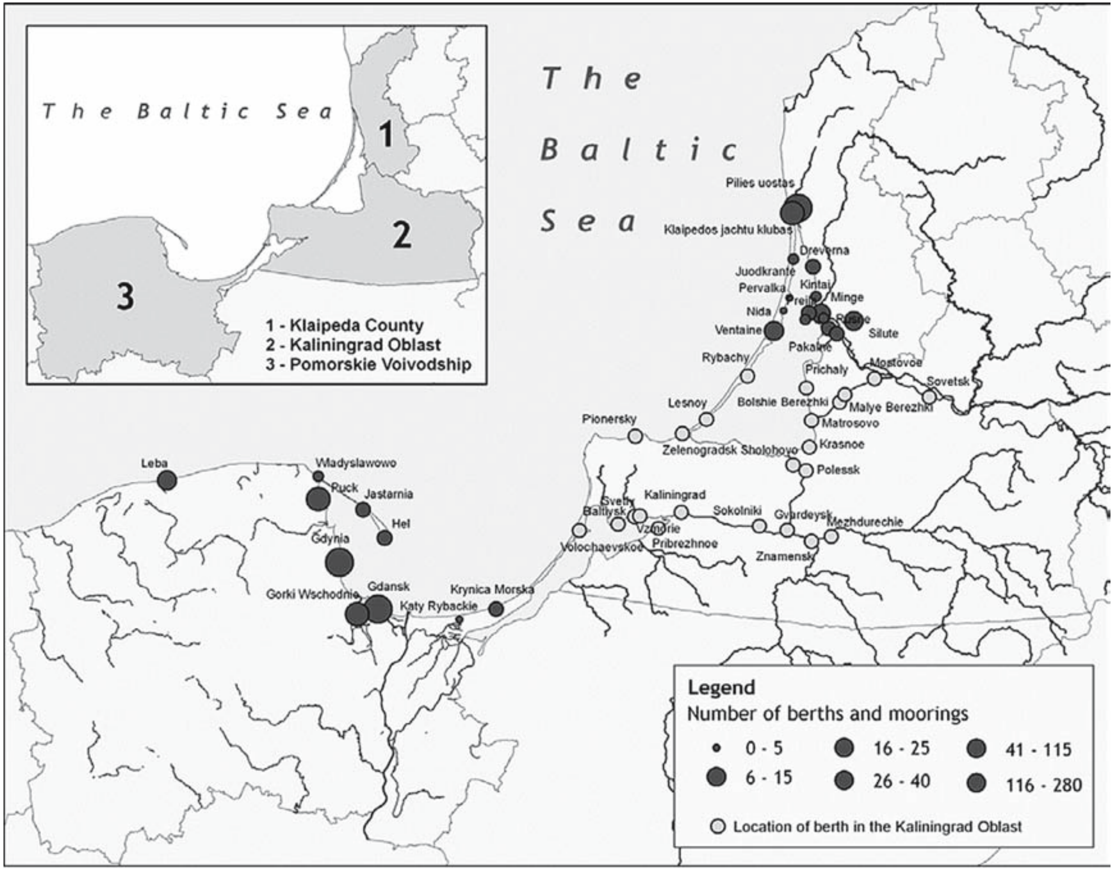

Figure 3. Locations of berth and moorings in the Klaipeda County (Lithuania), Kaliningrad Oblast (Russia) and Pomeranian (Pomorskie) Voivodship (Poland). For Kaliningrad Oblast only locations of berth are shown as marina's infrastructure is not developed yet.

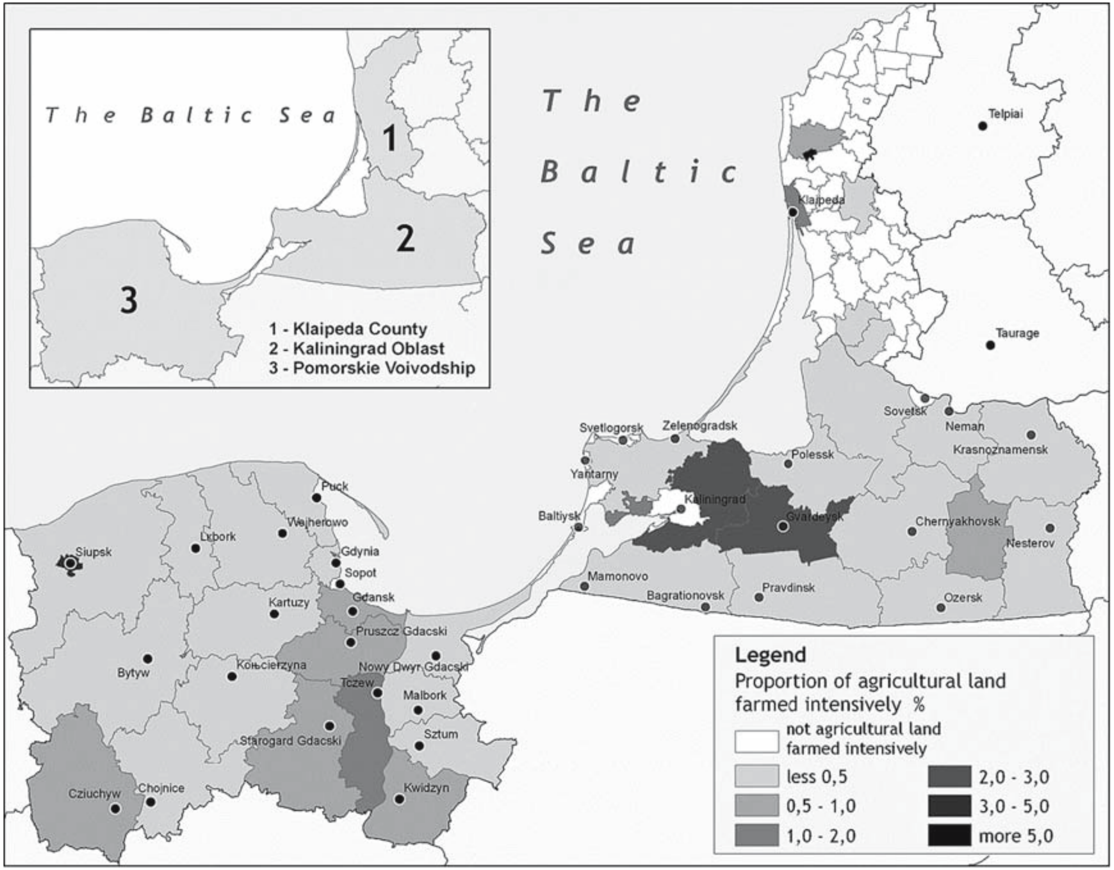

Figure 4. Percent of intensively farmed agricultural land in NUTS4 of the Klaipeda County (Lithuania), Kaliningrad Oblast (Russia) and Pomeranian (Pomorskie) Voivodship (Poland) for 2000.

Indicator 2.8 shows activity on nature protection and conservation in the region (Figure 5). There are two protected water areas in the South-East Baltic which are transboundary and divided by national borders – Curonian and Vistula spits. There was a tendency of extending of protected areas in all three national areas in the South-East Baltic during a period of 1990–2005, and at this time the increase of protected areas in Lithuania and Poland are the result of application of EU regulations in these countries (the establishment of Natura 2000 protected areas). In Klaipeda County and Pomeranian Voivodship the area of protected territories within the area of coastal NUTS has grown intensively (up to 1.9 and 2.9 times) during 1995–2005. Now it occupy of 45% and 55% of coastal zone (within 10 km) respectively, while percentages of protected area for reference regions of NUTS3 level, Klaipeda County and Pomeranian Voivodship, are of 26% and 39%. There is no one protected area in Kaliningrad Oblast which includes waters (marine or inland), while in Klaipeda County and Pomeranian Voivodship there are several marine areas protected under Natura 2000.

Indicator 6.23 shows an exploitation of environmental resources. Catch of fish in the Russian Exclusive Economic Zone (EEZ) in the Baltic Sea varied from 30,000 to75,000 t during 1996–2006. Maximum allowed catch (75,000 t) was in 2001, the catch was reduced down to 50,000 t during the last 4 years. Main target species are salmon and sprat. The catch of salmon dropped down to 12,000 t in 2006, while catch of sprat remains at the same level (20,000–30,000 t). The catches for herring, cod and flounder didn't exceed 10,000, 5,000 and 1,000 t during 1996–2006.

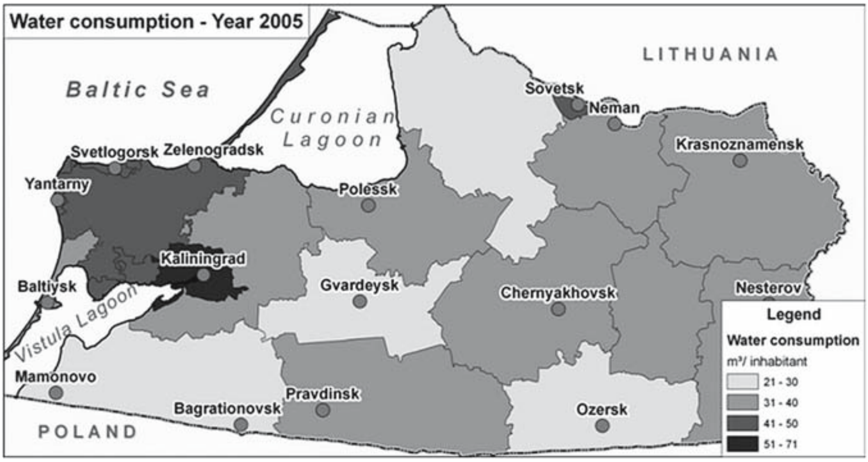

Figure 5. Rate of water consumption in different municipalities (NUTS4) of the Kaliningrad Oblast (data for 2005).

The Curonian and Vistula lagoons are other important fishing areas for the Kaliningrad Oblast. Maximum catches in these areas were about 2,500 and 3,000 t respectively. Main target species in the lagoons are different: these are Baltic herring, pike pearch, bream, roach, eel, sabrefish for the Vistula Lagoon, and pike pearch, pearch, bream, roach, sabrefish, smelt and ruff for the Curonian Lagoon. The catch of bream (800–1,000 t) is maximal in the Curonian Lagoon among other species. In the Vistula Lagoon, the Baltic herring is the main target species (1,000–2,500 t). Catch in the Curonian Lagoon remains constant, while catch in the Vistula Lagoon permanently increased during the period of 1996–2006 (2,300–3,100 t).

Fish landed in the Kaliningrad Fishery Port comes not only from the Baltic Sea. Russian fleet fishes in the Norwegian and North Seas, in Central-Eastern part of the Atlantic Ocean. Dramatic decline of landing (from 600,000 t down to 150,000 t) was observed in 1990–1993. Total landing remains within the range of 100,000–200,000 t per year during the period of 1994–2006, with exception in 1999 and 2000 (up to 300,000 t).

Shortage in water supply is not a problem in the South-East Baltic (Indicator 6.24). Cold water supply has never been cut down since the beginning of the year 1990 in the City of Klaipeda. Restriction of water supply in Kaliningrad occurs sometimes during wind surges in the autumn period.

Regarding the volume of groundwater consumption by the households (Indicator 6.24), it should be noted, that coastal municipalities consume more water than non-coastal ones. The rate of water consumption in Neringa seaside resort (Klaipeda County) and Sopot seaside resort (Pomeranian Voivodship) are highest in the region, 97 and 88 m^3 per capita per year respectively. Zelenogradsk and Svetlogorsk municipalities are the leaders in water consumption per capita in the Kaliningrad Oblast (Figure 5).

There is a slow reduction in household water consumption in the Kaliningrad Oblast (Figure 6) in a whole, while consumption in coastal municipalities increases the one in non-coastal NUTS by 5–10%. Meanwhile, the water consumption by the industry in the coastal areas of the South East Baltic Region is steadily increasing (by approx. 3–5% annually).

4. Conclusions

World-wide tendency of increasing a population and concentration of economic activities in the coastal zone is evident also in the Kaliningrad Oblast (Russian Federation) and in the South-East Baltic on the whole. In numbers, this tendency is expressed in following:

- An average population density in the coastal NUTS4 of the South-East Baltic is ca. 330 inhabitants km^{-2}. It differs up to 1.7 times between three national territories: minimum density is in the Kaliningrad Oblast (255

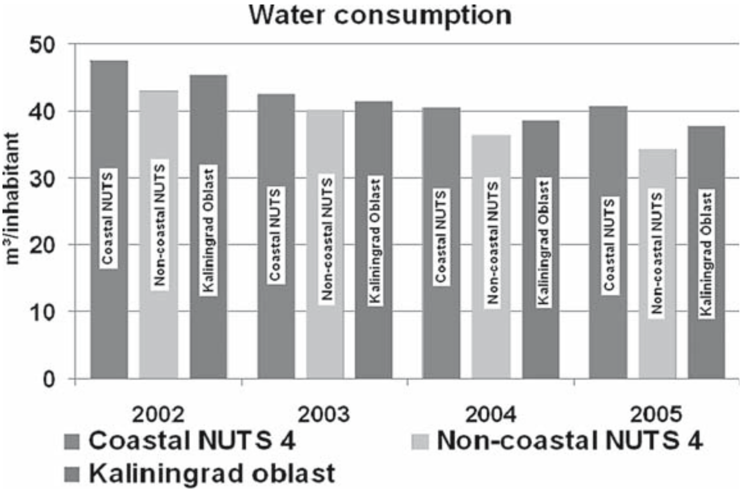

Figure 6. Dynamics of water consumption in coastal and non-coastal NUTS of the Kaliningrad Oblast (2002–2005), cubic meter per capita per year.

inhabitants km^{-2}), maximum is in the Pomeranian Voivodship (426 inhabitants km^{-2}), and density of 307 inhabitants km^{-2} is in the Klaipeda County.

- Population density in the coastal NUTS5 of the Pomeranian Voivodship (2003), Kaliningrad Oblast (2005) and Lithuania (2003) is respectively ca. 5, 7.5 and 8 times higher than the population density in the NUTS5 in the hinterland. One reason is that all big cities in the region (Gdynia-Sopot-Gdansk, Kaliningrad and Klaipeda) are located in the coastal zone, but despite of it a population density in rural coastal NUTS5 is higher than in non-coastal. Therefore, the pressure on coastal zone is much higher than on non-coastal areas. To diminish this disproportion specific management efforts are needed to increase life standards in the inland territory.
- The rate of urbanization in the coastal zone (coastal NUTS5) is 1.3–2.2 times higher than in the hinterland. Development of urbanized areas is concentrated in 1-km coastal strip, where percentage of built-up land is 1.3–1.5 higher than in the 10-km coastal strip; but, this development is still limited, total percentage of built-up land in these strips is in the range of 7–21%.
- Coastal zone of the Kaliningrad Oblast is relatively more urbanized than in neighboring counties. Built-up areas in Kaliningrad Oblast occupy 21% of 1-km coastal buffer (and 15% of 10-km buffer), while in the Pomeranian Voivodship and the Klaipeda County these percentages are only (13% and 8%) and (10% and 7%) respectively.

- Demand for property on the coast, and, respectively, price for property dramatically increased in recent years in the South-East Baltic, particularly in the valuable recreational areas.
- The intensity of traffic at the coast area of the Kaliningrad Oblast is six times higher than the intensity in the hinterland.
- Sixteen percent of territory of Kaliningrad Oblast and 48% of Klaipeda County is occupied by agricultural land, but there is almost no agricultural land farmed intensively in the South-East Baltic region within the 10-km coastal strip, except of allotment gardens.

Reasonable part of coastal area in the South-East Baltic is under active nature protection. Protected territories occupy of 45% and 55% of 10-km coastal strip in the Klaipeda County and Pomeranian Voivodship, There is no one protected area in the Kaliningrad Oblast which includes waters (marine or inland), while in the Klaipeda County and Pomeranian Voivodship marine areas protected under Natura 2000 occupy 29% and 63% of the 10-km coastal strip respectively.

The region of the South-East Baltic has evident prospects for development of water tourism. Even, marinas' infrastructure is not well developed yet, dense network of mooring places on the open coast and on the banks of inland waters is a good basis for future development of recreational boating.

Exploitation of fish resources in South-East Baltic is mostly within the allowed limits. The main natural resource, drinking water, is consumed at the level of 40–100 m^3 per capita per year. Consumption of water in the coastal areas is higher than in non-coastal areas, but difference is not more than 10%. There is slow trend of reduction of water consumption.

There is a difference in development of territories within the South-East Baltic. Analyzed data shown, that coastal zone of Kaliningrad Oblast is less developed, than one in neighboring Poland and Lithuania. To have fully comparable set of spatial data for the South-East Baltic, it is needed to implement modern methods of land inventory in the Kaliningrad Oblast and incorporate the Oblast into European CORINE Land Cover (CLC) Project.

As a whole, we may conclude, that despite some differences in the level of social-economic life, territories in the South-East Baltic have evident prerequisites for balanced sustainable development. The main disproportion is still in concentration of population and economic activities in the big cities. Organizational efforts for development of small-scale local economy, trade and service infrastructure along the main car roads, and marinas' infrastructure for water tourism and recreation boating are needed.

Acknowledgement

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COMBINED USE OF WATERSHED MODELS TO ASSESS THE APPORTIONMENT OF POINT AND NON POINT LOAD SOURCES TO SURFACE WATERS

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Abstract: The sustainable management of watersheds is critical since it deals with many aspects of the anthropogenic use of natural resources. The quality of water resources is a central issue for the management of watersheds. Over the last few years it has grown worldwide the need to implement tools for a knowledge-based management of the environmental resources and processes. Particularly there is the need to evaluate the response of the system to different pressures and different management alternatives. This is normally done through a Scenario Analysis which in many cases implies the use of modeling tools and the creation of a G.I.S. archive of the available knowledge. Understanding the source apportionment of pollutant loads driven through the watershed to a coastal lagoon or evaluating the socio-economical consequences of a new environmental policy or the effect of a natural or not natural catastrophe are all issues that can be studied through a sound scenario analysis. On this perspective, diffuse pollution's effect on surface and groundwaters is often difficult to quantify. Diffuse pollutants enter the environment through a multitude of pathways at different temporal scales. During rainfall events most of the diffuse pollutant load follows the surface runoff pathways and, at the net of the plant uptake, reaches the aquifers. A fraction of this load follows the sub-surface runoff pathways and may possibly reach the surface waters after a certain time lag. Very rarely the sub-surface pollution events can be directly correlated to a specific rainfall event. In this study some case studies are presented where river and watershed modelling tools are combined with factor analysis techniques to identify the effect of the sub-surface runoff on the water quality of specific stream reaches. Through this approach the sub-surface runoff was proven to be a significant source of diffuse pollution even in dry weather conditions.

Keywords: Watershed modeling; source apportionment; nutrients

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1. Introduction

The quality of water resources is a central issue in the watershed management. Over the last few years it has grown worldwide the need to implement tools for a knowledge-based management of the environmental resources and processes. Particularly there is the need to evaluate the response of the system to different pressures and management alternatives. This is normally done through a Scenario Analysis which in many cases implies the use of modeling tools and the creation of a G.I.S. archive of the available knowledge. Understanding the source apportionment of pollutant loads driven through the watershed to a coastal lagoon or evaluating the socio-economical consequences of a new environmental policy or the effect of a natural or not natural catastrophe are all issues that can be studied through a sound scenario analysis. On this perspective, diffuse pollution's effect on surface and groundwaters is often difficult to quantify. Diffuse pollutants enter the environment through a multitude of pathways at different temporal scales. During rainfall events most of the diffuse pollutant load follows the surface runoff pathways and, at the net of the plant uptake, reaches the aquifers. A fraction of this load follows the sub-surface runoff pathways and may possibly reach the surface waters after a certain time lag. Very rarely the sub-surface pollution events can be directly correlated to a specific rainfall event. In this study some case studies are presented where river and watershed modelling tools are combined with factor analysis techniques to identify the effect of the sub-surface runoff on the water quality of specific stream reaches. Through this approach the sub-surface runoff was proven to be a significant source of diffuse pollution even in dry weather conditions. The nitrate pollution case is described because of the complexity of its fate and transport processes.

2. Source apportionment: methods

The source apportionment of pollutant loads is a key-knowledge for the management of water quality in watersheds. Point loads can be easily quantified from measurements or by using indirect emission estimates. Although point sources are certainly affected by variability, notwithstanding they can be considered fairly constant when compared with rainfall-driven non point sources. On the other hand, diffuse loads having transport dynamics strictly related to the hydrologic cycle and particularly to rainfall events, are extremely variable and therefore more difficult to estimate. Moreover, the water-soil interface, which depends on the watershed characteristics, is a relevant issue in determining the fate and transport of diffuse pollutants. Another relevant issue is the groundwater recharge to surface waters, which only rarely is considered in the apportionment because of the intrinsic difficulties of its quantification and the lack of information about sub-surface phenomena. The lack of quantitative information about sub-surface transport dynamics is mainly due to the temporal scale of these phenomena that is much longer and quite different from the scale of the surface and erosion runoff. Surface runoff is generally faster and strictly related to rainstorm events. Such complexity is the reason of the broad variety of methods that have been proposed to evaluate the contribution of diffuse loads. These methods comprehend solutions that go from the computation of indirect estimates (i.e. by using emission factors) up to modelling (i.e. physical or empirical models). Instantaneous instream measurements are the most common type of information available for watersheds. These measurements can be directly used to estimate the global budget of the loads transported to a receiving water body, but they are not directly usable to assess the source apportionment.

Moreover, it is well known that for the better understanding of diffuse pollution dynamics, specific monitoring activities are needed to quantify the contribution of point and non point loads, in dry and wet weather scenarios. However, monitoring programs in wet weather conditions are rarely available and, even when they are available, they generally refer to a temporal scale too short to be significant when dealing with diffuse transport phenomena. So the integration of modelling and measurements seems to be the most informative approach. Many models have been developed to simulate water quality and quantity either at field scale or at watershed scale. Such models can be used for the evaluation of nutrient loads and may be relatively simple, requiring only estimates of variables as number of people in a watershed and certain loss coefficients (Gaines, 1986; Cole et al., 1993), or have a complex structure with many components (Frimpter et al., 1990; Kellogg et al., 1996; Valiela et al., 1997; Birkinshaw and Ewen, 2000; Arnold et al., 1998; Behrendt et al., 2000).

Valiela et al., 2002 provided an accurate review of the models that can be found in literature and analysed their performances. Generally watershed scale models are capable to adequately describe water and nutrient transport in the unsaturated zone and not the processes occurring in the saturated zone. Some authors (Galbiati et al., 2006; Conan et al., 2003) linked watershed scale models with models simulating the nutrient transport and transformation in the saturated zone. However very rarely such models rely on experimental data for what concerns the processes occurring in the soil layers (e.g. denitrification rates, nitrate leaching rates etc.), especially when large scale basins are involved.

3. Model applications

3.1. SWAT, SOIL AND WATER ASSESSMENT TOOL

The SWAT model (US Department of Agriculture, Arnold et al., 1998 Di Luzio et al. 2002) is a physical based, basin scale model developed to predict the long-term impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions. In the case studies here described we used the SWAT model to quantify the contribution of the surface rainfall-driven runoff to the nutrient load carried to a coastal lagoon environment.

3.2. QUAL2E

QUAL2E model (US-Environmental Protection Agency, Brown and Barnwell, 1987) is also physical-based and for a long time it was considered the standard for modeling water quality (Shanahan et al., 1998). The QUAL2E model was used here to quantify on a mean annual basis the contribution of point sources during dry weather conditions to the global pollutant load carried by surface waters.

QUAL2E, in fact, being a steady-state model (i.e. constant streamflow and constant emissions), is particularly appropriate for simulating on a mean annual basis the point sources' effect on river water quality.

3.2.1. Data needed as input for models

- Data available for the modeling were the following:
- A 50 × 50 m Digital Elevation Model grid
- Daily series of meteorological data (i.e. precipitation, wind speed, solar radiation and dew point temperature)
- Soil geomorphological and textural characteristics that were aggregated into 20 soil classes
- Information about the main agricultural uses within the watershed, annual crop rotations and land use classes
- Streamflow daily data at gauging stations
- Water quality data, on monthly basis
- Anthropogenic load measurements of all the significant point sources (i.e. wastewater treatment plants, WWTPs, and industrial facilities)

3.3. SOURCE APPORTIONMENT OF THE NUTRIENT LOADS: THE VENICE LAGOON WATERSHED CASE STUDY

The Venice Lagoon Watershed (VLW) is located in the North-Eastern part of Italy. It is well known that the nutrient loads coming from VLW have a critical role for the eutrophication of the Venice Lagoon (Bendoricchio et al., 1999). Since the VLW is characterised by a very intensive agricultural land use, a multicriteria approach was used to evaluate the risks of agricultural pollution for water resources (Giupponi et al., 1999) and to validate the agri-environmental policy measures that have been proposed to protect the lagoon. The source apportionment of three watersheds within the Venice Lagoon Watershed (VLW) is here presented: the Naviglio Brenta-Bondante (NBB), the Dese-Zero (DZ) and the Vela (VL) watersheds (Figure 1).

The three basins cover about 35% of the VLW surface area and are characterised by a very complex network of irrigation channels that intercept

Figure 1. Study area: Dese-Zero watershed within the Venice Lagoon Watershed (VLW).

also direct sewage discharges. Moreover, the three watersheds are influenced by a groundwater recharge area (Figure 2), which significantly contributes to the hydraulic and nutrient load transported by the main channels.

As shown in Table 1, agricultural activities constitute the dominant land use within the area.

SWAT model was applied in order to describe the agricultural characteristics of the watersheds and to assess the source apportionment in terms of point and diffuse sources. SWAT model allowed the simulation of a better-business agricultural scenario, in which alternative management strategies were implemented.

The analysis of the available data allowed to identify two main classes of nitrogen sources:

The *point loads*, which consisted of all localized emissions, in terms of WWTPs, industrial facilities' discharges and direct sewer discharges into surface waters.

The *diffuse loads* subdivided in:

- *Dry weather loads*, deriving from the irrigation channel network (mostly coming from bordering basins) and from groundwater recharge zone
- *Rain-driven diffuse loads*, i.e. nitrogen loads carried by surface runoff

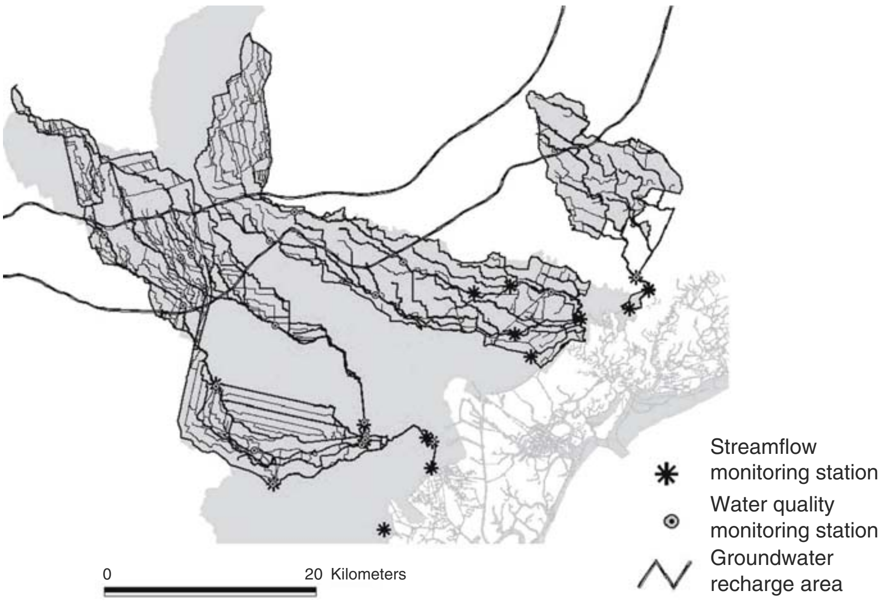

Figure 2. NBB, DZ and VL watershed characteristics: hydrography, water quality monitoring stations, streamflow monitoring stations, spring and groundwater recharge area.

TABLE 1. Characteristics of the three watersheds.

	NBB	DZ	VL
Drainage area (km^2)	293	310	102
Urban area	24%	26%	13%
Agricultural area	69%	72%	86%
Dominant crops	Corn, soy, wheat, sugar beet	Corn, soy, wheat, sugar beet	Corn, soy, wheat, sugar beet

Concentration and flowrate measurements enabled to quantify the load coming from the irrigation channel system. Finally, groundwater recharge loads were estimated by the differences as the following:

$$\text{N-tot}_{\text{measured}} = \text{N-tot}_{\text{WWT+Industries}} + \text{N-tot}_{\text{Irr.channels}} + \text{N=tot}_{\text{sewage}} + \text{N=tot}_{\text{groundwater}}$$

where:

N-tot $_{\text{measured}}$ and N-tot $_{\text{Irr.channels}}$ were calculated from water quality instream measurements, N-tot $_{\text{WWT+Industries}}$ was calculated from the discharge data measurements, N-tot $_{\text{sewage}}$ was estimated on the basis of the PE_{BOD} =60 g/D BOD people equivalent and 2 g N/D PE and N-tot $_{\text{groundwater}}$ was the unknown parameter estimated by difference from the others.

The dry weather source estimates were validated by means of QUAL2E model (Brown and Barnwell, 1987) according to the methodology used in Azzellino et al. (2006) and were used as input data for SWAT model. QUAL2E model predictions, in fact, were compared with the mean annual statistics (i.e. the median value of the concentration data series) available from the water quality measurement stations located in the area (see Figure 2). The statistics for central tendency of the water quality data were considered representative of the stream dry-weather water quality conditions since most of the measurements available from the local monitoring network referred to low – or mean – flow conditions and less than 25% of the measurements corresponded to higher flows. The median was preferred to the mean because of the distribution skewness of the water quality measurements. QUAL2E predictions, when compared with measurements revealed a mean error of about 15–20%.

SWAT model performance in terms of hydrologic calibration were evaluated by means of the Nash-Sutcliffe coefficient of efficiency (Nash and Sutcliffe, 1970). SWAT simulation showed a good fit on a monthly basis (median E of 0.65) whereas on a daily basis, only the simulations at the basin closures showed a good agreement with measured data. The Nash-Sutcliffe efficiency (E) was of about 0.4, ranging from 0.11 to 0.67 from year to year. Figure 3 shows the daily streamflow time series, measured and simulated by SWAT model, at the Dese-Zero river basin closure.

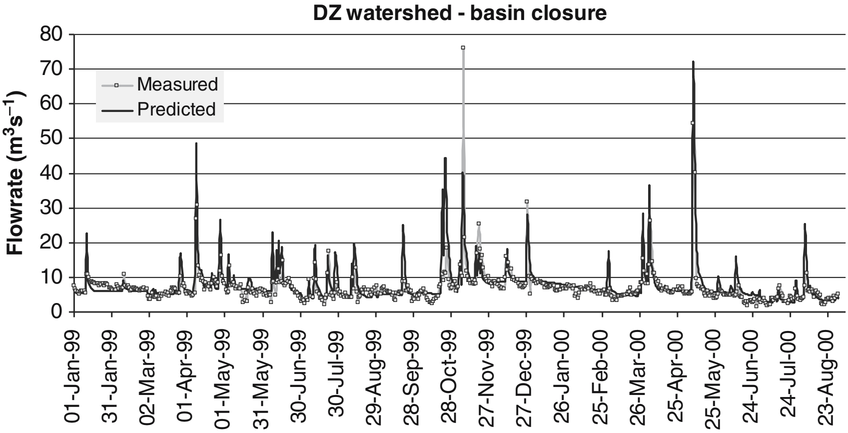

Figure 3. Daily streamflow measured and simulated by SWAT model at the Dese-Zero river basin closure.

TABLE 2. Total annual load and runoff load at the present state and in the agricultural scenario.

		Total annual load		Annual runoffload	
		N tot t N year^{-1}	P tot t P year^{-1}	N tot t N year^{-1}	P tot t P year^{-1}
NBB	Business-as-usual	1,155	64	181	23
	Better-business	1,101	60	134	19.5
DZ	Business-as-usual	696	51	199	19
	Better-business	636	49	133	17
VL	Business-as-usual	335	25	89	7
	Better-business	310	24	63	6
Sum	Business-as-usual	2,186	140	469	49
	Better-business	2,047	133	330	42.5

For the three watersheds SWAT outputs indicated a total annual load of about 2,200 t N year^{-1} and of about 140 t P year^{-1} (Table 2). The most important contribution to the total nutrient load is given by NBB (about 50%), because of its higher streamflow. In Figures 4 and 5 the source apportionment is reported for both the nutrients. As it can be seen, the dry weather diffuse load is the most important contribution.

As far as nitrogen is concerned, nitrogen from groundwater recharge resulted to be about 35% of the total annual load. A similar contribution

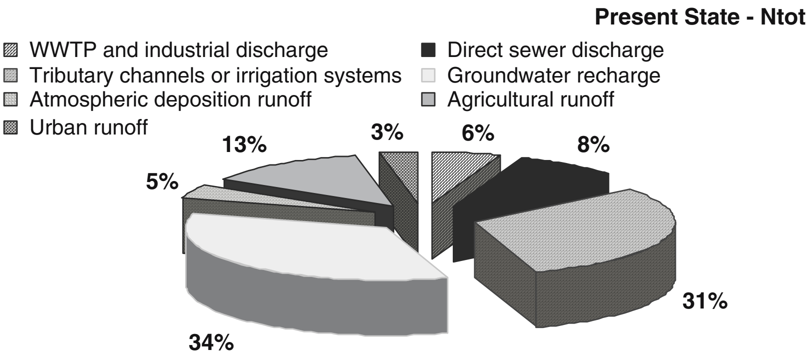

Figure 4. Source apportionment of the total nitrogen annual load.

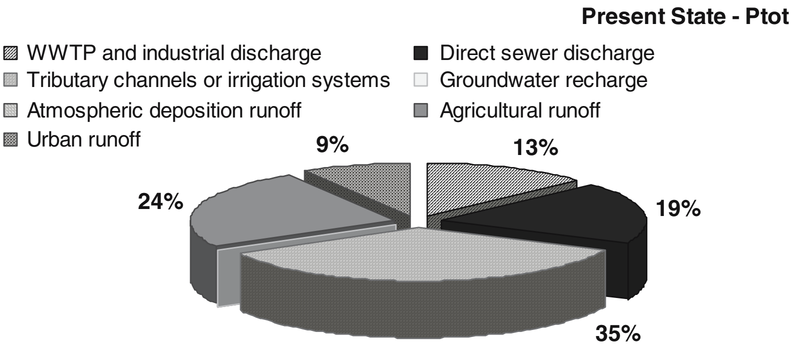

Figure 5. Source apportionment of the total phosphorous annual load.

derived from channel load coming from external basins, while point loads (WWTP, industrial discharge and direct sewer discharge) constituted about 15% of the total annual load. SWAT outputs indicated for the runoff loads the remaining 20%, in which the most important source derived from agricultural runoff (63% of the runoff load), followed by atmospheric deposition (22%) and urban runoff (15%).

The results in terms of runoff apportionment (i.e. 26% of the total annual load) are coherent with what was found for other Italian watersheds (Salvetti et al., 2006). Runoff loads, in fact, if during rainstorm events constitute the most of the instream total load (up to 80–90%, Azzellino et al., 2006), on an annual basis contribute much less. As far as phosphorus apportionment is concerned, external channel load constituted about 35% of the total annual load and a similar contribution derived from point loads (because of the absence of groundwater recharge load). Runoff loads amount to about 33%, in which about 2/3 comes from agricultural runoff and 1/3 from urban runoff. In order to test the potential of the SWAT implementation in the VLW for supporting future environmental policies, a scenario analysis was carried out by comparing business-as-usual management with the implementation of better-business agricultural management strategies. Hence, the indications of environmental legislations (both European and national) for reducing nitrate discharges were used as reference for the scenario of the full enforcement of such agricultural policy measures. The scenario analysis showed the effectiveness of the proposed measures imposing changes of agricultural management, especially for nitrogen (Table 2). In fact, agricultural nitrogen runoff load was almost halved (being reduced from about 300 t N year^{-1} to about 150 t N year^{-1}) and become about 7% of the total annual nitrogen load. Phosphorus runoff load decreased of about 16% and become about 21% of the total annual phosphorus load. Therefore, the better-business scenario assessment allowed to obtain a total annual nutrient load decrease of about 5–7%, corresponding to a total annual load of about 2047 t N year^{-1} and 133 t P year^{-1}.

4. Combined use of models and multivariate statistical analysis

Comparing model predictions with the available instream direct measurements, we have seen how it could be "validated", although with approximations, any assumption of source apportionment between point and non point sources. However, model simulations, when used in combination with other statistical techniques such as Factor Analysis, may give even further insights about the influence of non point sources to the river water quality. Here two case studies are presented where Factor and Principal Component Analysis (FA/PCA) were performed (according to Afifi and Clark, 1996) on the correlation matrix of the measurements data to better understand the apportionment of the pollutant load in two different watersheds. PCA techniques extract the eigenvalues and eigenvectors from the covariance matrix of the original variances. The principal components extracted are uncorrelated (orthogonal) variables, obtained as weighted linear combinations of the original variables:

$$F_1 = w_{11}X_1 + w_{12}X_2 + ... + w_{1k}X_k$$

$$F_2 = w_{21}X_1 + w_{22}X_2 + ... + w_{2k}X_k$$

where:

F_i are the principal components or factors

X_i are the original correlated variables

w_{ij} are factor scores chosen to satisfy the requirements of maximising the variance (eigenvalue) explained by every relationship, and of having orthogonal factors resulting from the extraction (i.e. uncorrelated).

Looking at the factor loadings matrix (i.e. the list of the correlation coefficients of the original variables with the extracted components) it is possible to identify the most meaningful parameters within each component. That leads to few components that are able to describe the whole data set with minimum loss of the original information. Parameters that lie on the same component reasonably derive from the same source. Factor analysis enables to further reduce the contribution of the less significant parameters within each component, by extracting a new set of varifactors through rotating the axis defined by the Principal Components Analysis. By using a Varimax rotation criterion it is possible to rotate the PCA axes so that they go through clusters or subgroups of the points representing the response variables although maintaining their orthogonality (i.e. being uncorrelated) to each other. The number of factors to be retained can be chosen on the basis of the "*eigenvalue higher than 1*" criterion (i.e. all the factors that explained less than the variance of one of the original variables were discarded). Factor Analysis applied with a Varimax rotation to the water quality measurements of the two studied watersheds, shed further light on the source apportionment of water pollutants and outlined finer differences between the lowland (Cherio river) and the upland watershed (Adda river). Since it was performed on measurements that were for the most available during dry weather conditions, Factor Analysis obviously reflected the dry weather scenario where the point sources should be the most important if not the only direct contribution to the stream total load. Notwithstanding interesting findings came out.

4.1. ADDA RIVER BASIN (UPLAND)

Six factors were extracted on the basis of the "*eigenvalue higher than 1*" criterion for a total explained variance of 73.3% (see Table 3). As showed by the factor loadings matrix, nitrates and nitrites surprisingly were loaded on different factors, being nitrates associated to chlorides on factor 2 (explained variance: 16.6%) and nitrites loaded with dissolved oxygen and *E. coli* on factor 4 (explained variance: 8.8%). This evidence is also reflected by the significant correlation (r: 0.724; $P < 0.001$ n: 180) found between nitrates and chlorides and the lack of such correlation between nitrates and nitrites (r: −0.153; $P > 0.25$ n: 55). Such a pattern suggests for nitrates a different apportionment than nitrites. Nitrites, in fact, being loaded on factor 4, together with dissolved oxygen and *Escherichia coli*, can be associated with urban point source emissions, whereas the relationship found between nitrates and chlorides, suggests an exchange of water from the groundwater to the surface water system (in that area N-NO3 and Cl- concentrations in groundwater are much higher than in surface waters). This hypothesis is also supported by QUAL2E simulations, which came up with a systematic

TABLE 3. Adda River Basin: factor loadings matrix.

Factor loadings (VARIMAX rotation)	Factors					
	1	2	3	4	5	6
pH	**0.526**	0.017	−0.023	0.415	0.099	−0.426
Conductivity	**0.920**	0.160	0.013	−0.017	−0.014	−0.047
Hardness	**0.961**	0.151	−0.013	0.015	−0.013	−0.079
Suspended material	0.017	−0.167	−0.065	0.080	**0.717**	−0.199
Dissolved oxygen	0.061	0.016	0.151	**0.567**	−0.363	−0.112
Total nitrogen	0.161	**0.916**	0.141	−0.001	0.008	0.005
N-NO3	−0.062	**0.944**	0.026	0.005	0.021	−0.008
P-PO4	0.042	0.022	**0.879**	0.123	0.092	0.050
Total phosphorous	−0.025	0.087	**0.863**	0.070	−0.093	−0.134
Chlorides	0.199	**0.798**	−0.025	0.123	−0.063	−0.104
Sulfates	**0.954**	−0.013	0.027	−0.101	−0.046	0.061
E. coli	−0.114	0.160	0.184	**0.623**	0.298	−0.135
Extended Biotic Index (IBE)	−0.040	−0.067	−0.067	−0.074	−0.038	**0.818**
Zn	−0.023	0.101	0.065	−0.012	**0.696**	0.114
N-NO2	−0.045	−0.035	−0.038	**0.622**	0.076	**0.525**
% Explained variance	**20.3**	**16.6**	**10.7**	**8.8**	**8.4**	**8.3**
% Cumulative explained variance	**20.3**	**37.0**	**47.7**	**56.5**	**64.9**	**73.3**

underestimation of nitrates along the Adda river course reaching a maximum of –11%.

4.2. CHERIO RIVER BASIN (LOWLAND)

Five factors were extracted on the basis of the "*eigenvalue higher than 1*" criterion for a total explained variance of 84.1% (see Table 4). In this case no relationship was found between nitrates and chlorides and nitrates were loaded on factor 4 together with pH, hardness and conductivity. Moreover the first two factors that loaded respectively *E. coli*, dissolved phosphorous, ammonia and total nitrogen, the first, and the organic matter and total phosphorous, the second, explained almost 50% of the variance revealing a completely different scenario from the upland, with pollutants far more linked to the suspended rather than to the dissolved fraction.

TABLE 4. Cherio River Basin: factor loadings matrix.

Factor loadings (varimax rotation)

	Factors				
	1	2	3	4	5
Dissolved oxygen	−0.097	−0.361	**0.669**	−0.009	−0.276
BOD5	**0.595**	**0.779**	−0.004	0.027	0.046
COD	0.347	**0.888**	−0.034	0.074	−0.002
E. coli	**0.873**	0.363	0.085	0.090	−0.102
N-NH4	**0.957**	0.107	0.039	0.067	−0.076
N-NO3	0.000	0.082	0.146	**0.852**	0.196
Total phosphorous	**0.663**	**0.641**	0.126	0.200	0.190
P-PO4	**0.827**	0.211	0.355	0.110	0.156
Total nitrogen	**0.860**	0.036	0.137	0.419	0.127
PH	−0.301	−0.019	0.356	**−0.677**	0.013
Conductivity	0.293	−0.296	0.341	**0.675**	−0.286
Hardness	0.140	**−0.618**	−0.005	**0.544**	−0.290
Suspended solids	0.082	**0.884**	0.090	−0.149	−0.236
Chlorides	0.438	0.125	**0.746**	0.119	0.273
Sulfates	0.262	0.186	**0.791**	0.018	0.012
Extended Biotic Index (IBE)	0.123	−0.134	−0.041	0.004	0.858
Temperature	−0.461	0.375	0.433	0.072	0.511
% Explained variance	**27.8**	**21.1**	**13.3**	**13.1**	**8.8**
% Cumulative explained variance	**27.8**	**48.9**	**62.2**	**75.3**	**84.1**

5. Conclusions

- The lessons learnt from these case studies are the following:
- The dry weather diffuse sources (i.e. groundwater/spring recharge and tributary/irrigation channels coming from bordering watersheds) may constitute significant nutrient sources: up to 65% in case of nitrogen (mostly nitrate from groundwater) and 35% in case of phosphorus (mostly deriving from irrigation channels).
- Annually runoff loads may account for about 20% of the total nitrogen load and 30% of the total phosphorus load. Around 2/3 of the runoff load derives from agriculture.
- Models can be used to improve the source apportionment understanding allowing the simulation of the point sources contribution excluding the effect of non point sources.
- Models may help in evaluating the effectiveness of management alternatives (e.g. simulating the benefit of a better-business agricultural scenario which assumes that best agricultural practices are extensively enforced).

- Model simulations, when used in combination with statistical methods such as Factor Analysis, may outline the hidden effect of not rainfall-driven diffuse sources such as the nitrate loads that derive from groundwater exchanges to surface waters.

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DEVELOPMENT OF NATIONAL ACTION PLAN TO ADDRESS POLLUTION FROM LAND BASED ACTIVITIES IN TURKEY

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Abstract: Countries surrounding the Mediterranean Sea and Black Sea signed the Barcelona Convention (1976) and Bucharest Convention (1992) respectively and Turkey is the one of the contracting parties for both of them. In this content, they formed the "Mediterranean Action Plan (MAP)" and "Black Sea Environment Programme" to control water pollution in the Mediterranean and Black Sea, respectively. To achieve this goal, each region formed their Land Based Sources Strategic Action Programme (LBS SAP) in the second part of the 1990s within the framework of the Land Based Sources Protocols (LBS Protocol) which are sub protocols of the Barcelona Convention and Bucharest Convention. These programmes define the major land based environmental problems and proposed solutions to the problems and set the deadlines to perform the necessary tasks. In the line with LBS SAP's, Mediterranean countries have been already developed their "National Action Plan's for Land Based Sources (LBS NAP) in 2005.

Within the framework of the LBS NAP development study in Turkey, detailed investigations were carried out on region and basin basis relating to the land based pollutants. In the context of the project the land based activities in the 19 river basins, which are chosen according to the SHW (State Hydraulic Works) drainage areas were evaluated. LBS Pollution sourced from industry, residential areas, agricultural activities, ports, and transportation and tourism activities has been determined. The coastal river basins have been assessed in terms of environmental risks and environmental priorities and an action plan involved supporting tools for the action plan, measures to control investment portfolio and economical instruments has been developed by TUBITAK MRC under the coordination of Ministry of Environment and Forestry.

Keywords: National Action Plan; land based sources pollution; hot spot; sensitive area; Mediterranean Sea; Black Sea

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1. Introduction

Intensive human activities, especially in enclosed or semi-enclosed seas, have considerable contribution to the formation of coastal and marine deterioration. Mediterranean is a semi-enclosed sea being under similar risks due to long-term residences, intensive population on its coasts and regularly growing tourist activities. Rapid urbanization, domestic and industrial wastes, agricultural activities, tourist activities and motor vehicles are the most crucial environmental factors having decisive nature on the coasts of Turkey.

In line with these facts, especially over the last 20 years, Mediterranean countries have been initiating and implementing several environmental programs via various regional and international organizations devoted to safeguarding Mediterranean. Likewise, UNEP has been coordination the "Mediterranean Action Plan (MAP)" and implementing scientific, socio-economic and legal programs devoted to protecting Mediterranean since 1975. In 1976, Mediterranean countries have established the first legal document on regional basis destined to protecting the Mediterranean (Barcelona convention). This document, to which Turkey is also a party, was put into force in 1978. Later, while striving to develop and finalize the legal framework on one hand, the Mediterranean countries have commenced to establish programs for monitoring the marine pollution on the other hand.

The Protocol on Protecting Mediterranean from Land Based Pollutants (the LBS-protocol) was put into effect in 1983 as an annex to the Barcelona Convention and revised in 1996 in Syracuse. Turkey, one of the parties to the Barcelona Convention has adopted these modifications.

The Strategic Action Programme (SAP) was adopted by the Tenth Ordinary Meeting of the Contracting Parties to the Barcelona Convention, held in Tunis in 1997. The main objective of SAP is to promote and provide support to the Mediterranean countries for the formulation, adoption and implementation of relevant national plans, as well as a scientifically-based long-term programme of targets to be achieved and actions to be implemented at national and regional levels. The formulation of comprehensive and realistic National Action Plans (NAPs) to address pollution from land-based activities, based on the agreed principles and targets is the major national instrument for the implementation of SAP.

The fundamental objectives of the National Action Plan are the formulation of principles, approaches, measures, high-priority actions and last realization dates for the implementation of SAP on national level, formulation of the result investment portfolio, identification of high-priority actions for boundaries and for boundary-exceeding issues/actions, identification of NGOs (Non-governmental organizations) taking part in the process together with their bodies concerned, and identification of different monitoring and reporting systems.

In addition to such national efforts devoted to protecting Mediterranean, countries bordering Black Sea have gathered to ensure centralized management and protection of live resources in the common sea. In this regard, representatives of the countries located along with the Black Sea coast have formulated the "Convention on Preventing Black Sea from Pollution". This draft convention has been executed in Bucharest on April 1992 and approved in the beginning of 1994 by the legal legislators of six countries. "Bucharest Convention" encompasses three special protocols in addition to the basic framework of the convention. These protocols embody the conduct of common action for the control of land based pollutants, waste dumping and any accident.

Protection of the Black Sea Against the Pollution Convention of Protection of Black Sea and Surroundings Against the Land Based Pollution Protocol supported by the Ministers Declaration for Protection of the Black Sea (1993, Odessa), and Strategic Activity Plan for Protection and Rehabilitation of the Black Sea (1996, Istanbul), explains the main aspects of reducing the pollution and declares the responsibilities of the parties, who accepted the Convention, on the mentioned subject. Yet, the Protocol is not completely in use (Protection of the Black Sea against the Pollution Commission, 2002).

In Turkey, studies in this regard have been being implemented under the coordination of the Ministry of Environment and Forest and with the participation of related organizations and agencies.

In the scope of Barcelona and Bucharest Convention's LBS protocols, Turkey was responsible for preparing its own "National Action Plan for LBS" including priorities, measures, table schedules and implementations together with other related countries. Then the development of "National Action Plan for the Land Based Pollutants for Turkey" has been entrusted to the TÜBITAK-Marmara Research Center – Institute for Chemistry and Environment by Ministry of Environment and Forestry.

The objective of the NAP developed was to address the sources and loads of land based pollutants arising along Turkish coastal areas, determination of priorities in the region and necessary investments for controlling and preventing such pollution especially in hot spots and sensitive areas. The National Action Plan will yield valuable benefits in the most effective utilization of the resources, directing the investments in the most rational way and preventing pollution.

2. NAP methodology and studies for development Of NAP to address LBS pollution In Turkey

The Strategic Action Programme (SAP) addresses the land based pollution problems in Mediterranean and specifies the targets required to be attained to solve such problems. For this purpose SAP addresses the measures to be taken on national and regional level for controlling and eliminating pollution and establishes a general program and time frame for implementing such measures. National Action Plan (NAP) is a plan in relation to the SAP targets on emission reduction and its success depends on the successful fulfillment of these targets. SAP targets have been provided under three categories namely Urban-based, industrial-based pollution and physical alterations and destruction of habitats in Table 1 below (UNEP/MAP, 2004a).

TABLE 1. SAP targets (UNEP MAP, 2004a).

	Targets	
Issue	2015	2025
1. URBAN ENVIRONMENT		
1.1 Municipal sewage	To dispose sewage from cities and urban agglomerations exceeding 100,000 inhabitants and areas of concern in conformity with the LBS Protocol	To dispose all municipal wastewater (sewage) in conformity with LBS Protocol
1.2 Urban solid waste	At least to base solid waste management on reduction at source separate collection, recycling, composting and environmentally sound disposal in all and urban agglomerations exceeding in 100,000 inhabitants and areas of concern	At least to base urban solid waste management on reduction at source separate collection, recycling, composting and environmentally sound disposal
1.3 Air pollution	The levels of air pollutants in cities exceeding 100,000 inhabitants and in areas of concern shall be in conformity with the provisions of the Protocol and the other internationally agreed provisions	The levels of air pollutants in cities shall be in conformity with the provisions of the Protocol and the other internationally agreed provisions
2. INDUSTRIAL DEVELOPMENT		
2.1. Industrial pollution	To reduce by % 50 discharges, emissions and losses of substances that are toxic, persistent and liable to bioaccumulate from industrial installations as well as in hot spots and areas of concern	Point source discharges and air emissions into the protocol area from industrial installations to be in conformity with provisions of the LBS Protocol and other agreed international and national provisions

(continued)

TABLE 1. (continued)

3. PHYSICAL ALTERATIONS AND DESTRUCTION OF THE HABITATS		
3.1. Physical alterations and destruction of the habitats		To safeguard the ecosystem function, maintain the integrity and biological diversity of species and where practicable to restore marine habitats

To develop NAP for Turkey, targets given in Table 1 and related documents preparing by UNEP MAP were taken into consideration. These documents are a training document for development of NAP's (UNEP(DEC)/MED WG.212/3, 2002; UNEP(DEC)/MED/GEF WG. 245/3-7, 2004b) and the "Implementation of SAP for Pollution due to Land Based Pollutants" (UNEP/MAP, 2004a).

The milestones for the preparation of the National Action Plan are given in Figure 1. Parallel with these milestones, the following projects have been prepared by the TÜBITAK Marmara Research Center under the coordination of the Ministry of Environment and Forestry since 2001.

- Development of the National Action Plan for Land Based Pollutants, Serial Projects: Phase I: Mediterranean Region, 2001; Phase II: Aegean Region, 2002; Phase III: Black Sea Region, 2003; Phase IV: Marmara Region, 2004
- National Diagnostic Analysis, 2002
- Baseline Budget, 2003
- Revision of Baseline Budget, 2005 within the scope of formulating the National Action Plan, the data have been taken from the revised Baseline Budget

With a view to addressing the financial resources and economical instruments to be employed to implement the National Action Plan in line with the SAP targets, a project titled "Economic Instruments to Address Marine Pollution from Land Based Activities for National Action Plans, 2004" has been implemented by Istanbul Technical University with the support of PAP/RAC (ITU, 2004). Furthermore "Sectoral Plan" project was carried out by Istanbul Technical University in 2005, and the report has also been used for the development of the NAP.

State Hydraulic Institute (SHI) divided Turkey into 26 river basins as drainage regions (SHI, 1997). When performing "Development of the

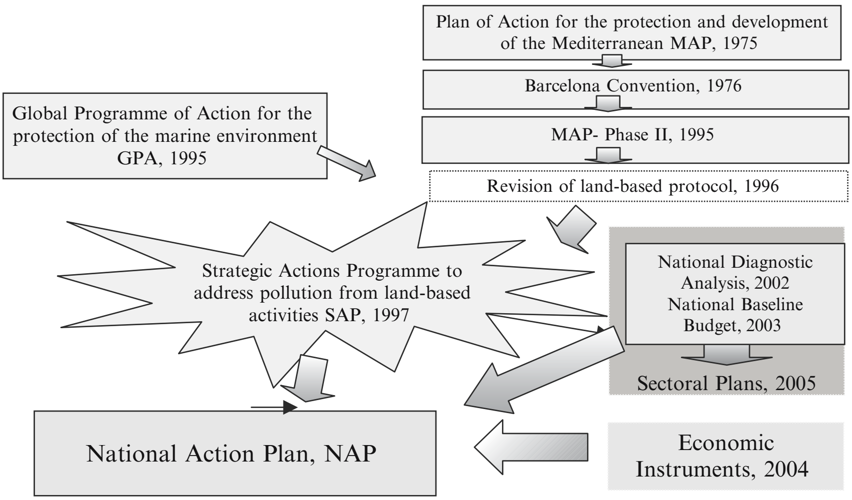

Figure 1. Development of NAP (UNEP MAP, 2004a).

National Action Plan for Land Based Pollutants" serial projects between 2001and 2004 for the river basins in different regions of Turkey, the sources of land based pollutants were specified according to the sectors in Annex 1 of the Barcelona Convention – LBS Protocol (1996) (Table 2). An example for distribution of the LBS pollutants for Kuzey Ege River Basin is given in Figure 2.

NAP has been developed for the river basins through all coastal areas of Turkey. These river basins, namely Bati Akdeniz, Antalya, Doğu Akdeniz, Seyhan, Ceyhan, Asi, Kuzey Ege, Gediz, Küçük Menderes, Büyük Menderes, Meriç-Ergene, Marmara and Susurluk are given in Figure 3.

National Diagnostic Analysis for Turkey (NDA) that was prepared in 2002 has been defined by SAP as a major input from the countries that is a pre-requisite for the preparation of the NAPs. In NDA for Turkey, national conditions and major environmental and health issues including problems, impacts, specific contaminants, physical alterations and destruction of habitats, sources of degradation, significance of impacts, and concern areas have been addressed and assessed.

The most basic reason lying behind the formulation of NAP is the formulation of the process of reducing the SAP target pollutant loads. Then, another major input for NAP is the National Baseline Budget (BB). The BB is the sum of the releases of each SAP targeted industrial pollutant reaching the Mediterranean Sea in the year 2003, a year which has been selected as the "base" year from which pollution reductions are to be achieved according to the provisions of the SAP, and tracked in subsequent years (UNEP MAP, 2002).

TABLE 2. The priority sectors in "Protection of Mediterranean Sea from Land Based Pollution Sources Protocol (LBS Protocol, 1996)".

Sectors	
Production of energy	Manufacture of other organic chemicals
Manufacture of fertilizers	Manufacture of other inorganic chemicals
Manufacture of formulation of biocides	Tourism
Manufacture of pharmaceuticals	Agriculture
Manufacture of refined petroleum products	Farming of animals
Manufacture of paper	Food packing
Manufacture of cement	Aquaculture
Training and dressing of leather	Treatment and storage of hazardous waste
Manufacture of metals	Treatment of urban wastewater
Mining and quarrying	Management of urban solid waste
Building and repairing of ships and boats	Treatment of sewage sludge
Port services	Waste management activities
Textile	Waste incineration and management of its residues
Manufacture of electronics products	Industries causing physical damage on the environment
Recycling activities	Transport

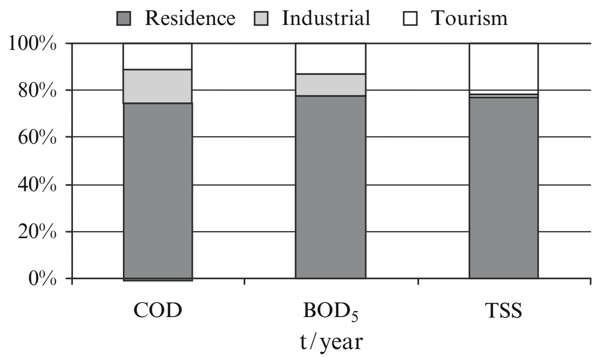

Figure 2. Distribution of COD, BOD and TSS loads in the Kuzey Ege basin by the pollutant source (TUBITAK-MRC, 2005a).

BB for Turkey has been completed by TÜBITAK MRC in 2003 under the coordination of the Ministry of Environment and Forestry. In BB for Turkey LBS target pollutants have been determined for coastal river basins of Turkey to be based integrated coastal and river basins management in Turkey (TUBITAK MRC, 2003b).

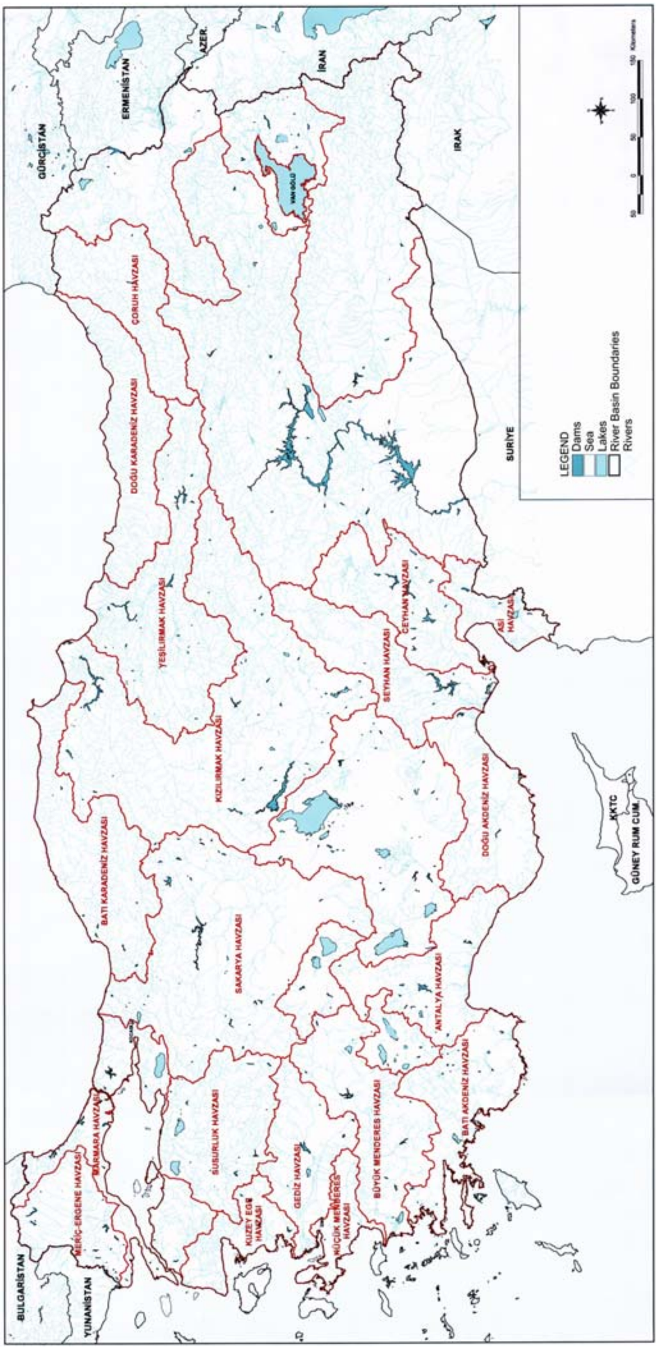

Figure 3. River Basins of NAP for Turkey.

With the preparation of NDA, Turkey completed the stage of filling in the event/impact matrix. The high-priority environmental problems of the basins and the sequence of priority of environmental problems have been established in consideration of the results of the prioritization matrix scaling over river basin-based pollutants and the distribution of pollution loads by basins and sources. The high-priority actions in NAP for each basin for the year 2015 were determined according to this matrix results (TUBITAK MRC, 2003c).

The next stage was taking into account the priorities of the river basins to formulate sectoral plans covering the issues such as regional plans, general measures, environmental quality criteria, emission limits and capacity development. In Turkey, it was given a start to formulate sectoral programs in 2004. In this regard, sectoral programs have been developed by ITU Environmental Engineering Department for the sectors as follows: sewer management, urban solid waste, air pollution due to mobile sources, pollution due to Hg, Cd and Pb, organohalogens: halogen aliphatic hydrocarbons, chlorinated phenol compounds, organohalogen pesticides, organic compound wastewater and solid wastes stemming from industrial plants (ITU, 2005).

In the final stage, NAP was formulated on the basis of the NDA, BB and Sectoral Programs and further submitted to the official approval. NAP for Turkey involved priority actions to achieve pollutant reductions, investment portfolio and economic instruments to be approved by the responsible national authority so that the implementation phase can begin.

The investment portfolio has two major components allowing the identification of investment priorities and discussing of investment priorities with decision makers, politicians and public. In forming basin-based investment portfolios, a scoring was made in consideration of items such as high-priority environmental problem of the basin, benefits of the project, being a hot spot, sensitive area and being a tourism area, its contribution to the development, financial sustainability, feasibility and estimated cost (TUBITAK-MRC, 2005a). As an example, investment portfolios matrix for Kuzey Ege River Basin is given Table 3.

After the formation of the investment portfolios matrix prepared on basin basis, ultimately projects have been listed as sorted by priority. Such sorting of projects by priority have been effected according to the results of the investment portfolio matrix, and the sorting of projects pertaining to basins having equal total scores have been effected in consideration of the priority of pollutants for the basin in terms of their pollution capacities. As an example, investment portfolio list for Kuzey Ege River Basin is given Table 4.

TABLE 3. Elaboration of the investment portfolio for the Kuzey Ege basin (TUBITAK-MRC, 2005a).

		Scoring					
Basin	Project	Benefit	Contribution to development	Financial sustainability	Feasibility	Estimated cost	Total
Kuzey Ege	Advanced WWTP for **Balikesir-Ayvalik (Hot Spot)** and **Balikesir-Gömeç (Hot Spot)** counties	5 × 5	4 × 5	3 × 5	2 × 5	1 × 5	75
Kuzey Ege Hot spot Rehabilitation of existing WWTP	Rehabilitation of the existing Domestic Wastewater Treatment Plant (e.g.: increasing capacity, transforming physical treatment into advanced treatment etc.) for **Balikesir-Edremit** and **Balikesir-Burhaniye** counties	5 × 5	4 × 5	3 × 5	2 × 5	1 × 5	75

(continued)

TABLE 3. (continued)

Kuzey Ege	Wastewater Treatment Plant for summer housing complexes and accommodation facilities	5 × 5	4 × 5	3 × 3	2 × 3	1 × 5	65
Kuzey Ege	Domestic WWTP for **İzmir Bergama**	5 × 5	4 × 5	3 × 3	2 × 3	1 × 5	65
Kuzey Ege Hot spot Population <100,000	Transportation of solid wastes to the nearest landfill for **Balikesir-Ayvalik, Balikesir-Gömeç, Balikesir Edremit** and **Balikesir-Burhaniye** counties	5 × 5	4 × 5	3 × 5	2 × 3	1 × 5	71
Kuzey Ege Sensitive area Population >100,000	Landfill Construction (solid wastes stemming from tourism have also been included) for **İzmir-Bergama** county	5 × 5	4 × 5	3 × 5	2 × 5	1 × 5	75

(continued)

TABLE 3. (continued)

Kuzey Ege	Treatment of industrial ww stemming from **food industry** effected in lack of ww treatment plants, improving the existing WWTP's.	5 × 5	4 × 5	3 × 3	2 × 3	1 × 5	65
Kuzey Ege	Treatment of industrial ww stemming from **tannery industry** effected in lack of ww treatment plants, improving the existing WWTP	5 × 5	4 × 5	3 × 3	2 × 3	1 × 5	65

TABLE 4. Investment portfolio for Kuzey Ege River Basin (TUITAK MRC, 2005a).

Basin	List of projects	Estimated cost ($)	Financial resource (ITU, 2004)	Term
List of high priority projects (projects with score higher than 70 according to the investment portfolio matrix)				
	Landfill construction for the İzmir-Bergama county	$6,000,000–10,000,000	Public	2010
	Sending solid waste to the nearest solid waste disposal area for **Balikesir-Ayvalik (hot spot), Balikesir-Gömeç (hot spot), Balikesir-Edremit (hot spot), Balikesir-Burhaniye(hot spot)**	3,000,000–6,000,000	Public	2010
Kuzey Ege Basin	Sewage and advanced domestic wastewater treatment plant for the **Balikesir-Ayvalik (hot spot), Balikesir-Gömeç (hot spot)** counties	1,500,000–20,000,000	User charge + Ecocharge	2010
	Rehabilitation of existing domestic wastewater plant up to advanced treatment for **Balikesir-Edremit (hot spot), Balikesir-Burhaniye (hot spot)**	6,000,000–8,000,000	User charge + Ecocharge	2010

(continued)

TABLE 4. (continued)

Basin	List of projects	Estimated cost ($)	Financial resource (Kinaci et. al., 2004)	Term
List of high priority projects (projects with score higher than 70 according to the investment portfolio matrix)				
	Treatment of industrial wastewaters produced during the production activities of Tannery industry, – furnishing Wastewater Treatment Plants in areas in lack of the latter, – Rehabilitation of current Wastewater Treatment Plants	5,000,000–10,000,000	User charge + Ecocharge	2010
Kuzey Ege Basin	Wastewater Treatment Plant for summer housing complexes and accommodation facilities	8,000,000–12,000,000	User charge + Ecocharge	2010
	Sewage and domestic wastewater treatment plant for the İzmir-Bergama county	8,000,000–12,000,000	User charge + Ecocharge	2010
	Treatment of industrial wastewaters produced during the production activities of Food Sector, – furnishing Wastewater Treatment Plants in areas in lack of the latter, – Rehabilitation of current Wastewater Treatment Plants	10,000,000–20,000,000	User charge + Ecocharge	2010

While formulating the NAPs, the integrated environmental management approaches have been adopted, the Integrated Coastal Areas and River Basins Management (ICARM) methodology has been employed, and Best Available Technologies (BAT) and Best Environmental Practices (BEP) have been taken as basis within the framework of pollution prevention plans.

With the consciousness of the importance of public and stakeholder participation in the success of NAP implementation; public participation and stakeholder meetings have been organized in different places of Turkey. Two public participation meetings were organized in June 2005 for those purposes and a web site and a brochure were constructed. Related municipalities, universities, environmental directors of the big cities, the regional branches of NGO's and other public and private organisations were invited to both meetings. First meeting was organized in Antalya, located on the Mediterranean coast of Turkey. Fifty-eight participants were participated to the Antalya Meeting from seven cities. The second meeting was organized in Izmir located on the Aegean coast of Turkey. Ninety participants were participated to the Izmir Meeting from 10 cities (TUBITAK MRC, 2005b). Additionally a stakeholder meeting was performed in June 2005 in Ankara with 46 participants from related governmental and private entities, NGO's and media (TUBITAK MRC, 2005c).

3. Conclusions

By developing of NAP addressing land based pollutants for Turkey, Turkey has defined the way of the prevention of Turkish coastal areas from LBS pollutants parallel with Barcelona and Bucharest Convention's related protocols.

Since harmonizing of the EU "Integrated Pollution Prevention and Control Directive" with Turkish Laws and Regulations studies are carried out by related Ministries, Environmental Practices (BEP) and "Cleaner Production" practices can be started after these studies. An IPPC Center should be established under the coordination of the Ministry of Environment and Forestry in order to promote and encourage the private sector to promote, effective modalities for giving access to cleaner production technologies and for the application the BAT and BEP with a view to preventing, reducing or phasing out inputs of pollutants from selected LBS and activities as well as to improve their up-to-date information, experience and technical expertise. Furthermore this center should work for favourable access to and transfer of environmentally sound technologies through supportive measures that promotes technology cooperation and the transfer of the necessary technological know-how, as well as building up economic, technical and managerial capabilities for the efficient use and further development of transferred technology by continuing systematic training and capacity building at all levels. As a result BAT's and BEP's should be primarily implemented starting from the each primary industry taken place in hot spots, sensitive areas and cities with population over 100.000 by means of the cleaner production action plans which will be prepared by this IPPC Center.

The next and most important phase of the NAP is implementation of the NAP. This phase has been coordinated by Ministry of Environment and Forestry since 2005. However, Turkey has some restrictions due to the long coast line, heavy industrialization and high population growth rate comparing with many other Mediterranean countries. In this direction, the budget for required investments to reach SAP targets especially in sensitive areas and hot spots are very high in NAP for Turkey. Thus, Ministry of Environment and Forestry decides to start a new separate project to reassess hot spots and sensitive areas and investments for those areas in Turkey. TUBITAK MRC with two partners namely Middle East Technical University Marine Sciences Institute (METU MSI) and Dokuz Eylul University Marine Sciences and Technology Institute (DEU MSTI) have submitted a proposal on reassessment of hot spots and sensitive areas to TUBITAK. This proposal accepted by TUBITAK and to be started in near future. By revised investment portfolio, implementation of the NAP will be more realistic and applicable for Turkey. The most important targets and outputs of this project are: to provide the use of newest concept, idea and technologies in order to protect ecosystem in our coastal regions and to reduce the wastewater input from land based sources; to improve the management strategy of HS and SAs; to help to achieve responsibilities of Turkey defined both in LBS SAP and LBS NAP compliance with LBS Protocols of Barcelona and Bucharest Conventions; to enhancing of integrated environmental studies in Turkey which is necessary in environmental sciences.

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REDUCTION OF THE LAND-BASED DISCHARGES TO THE CURONIAN LAGOON IN A VIEW OF A CLIMATE CHANGE PERSPECTIVE

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Abstract: Following the EU Water Framework Directive along with the earlier Nitrate and Wastewater treatment directives there was a national programme to reduce the nutrient and organic load into the Nemunas river and the Curonian lagoon that was adopted in 2006. However, the implementation of the programme could shift N:P ratio even more towards the nitrogen limitation, facilitating the development of the cyanobacteria blooms. The role of the foreseen climatic trends in the region discussed along with the possible ecological consequences.

Keywords: Nutrient load reduction; climate change; eutrophication; estuarine lagoon

1. Introduction

The resent adoption of the EU Water Framework Directive along with the earlier Nitrate and Wastewater treatment directives facilitated the development of national programmes focusing on the reduction of nutrient and organic loads into the lakes, rivers and coastal waters. In Lithuania, nearly 80% of the territory belongs to the Curonian lagoon watershed. The Curonian Lagoon, being the largest lagoon in Europe, lies along the Baltic coast of Lithuania and the Kaliningrad oblast (province) of Russia. It is separated from the Baltic by a narrow (~1–3 km) sandy spit, the Curonian Spit. Total area of the Lagoon is approximately 1,584 km^2. The border between the two countries divides the Lagoon into a smaller, northern portion in Lithuania (413 km^2) and a southern portion in Russia. Total volume of water of the Lagoon is approximately 6.2 km^3, and the average depth, about 3.8 m. The Lagoon has been heavily polluted from a combination of

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shipping, military and industrial sources. Pathogenic organisms characteristic of untreated sewage loads are also abundant. Concentrations of petrochemicals and heavy metals in Lagoon waters have been very high. Not surprisingly, fishing and bathing in the Lagoon have declined significantly in modern times.

Curonian lagoon and Baltic sea costal zone is very important for both natural heritage and economy of Lithuania. Sea related industries account for 10–12% of the GNP. Even more important is the share in the recreation and tourism sector (over 70%) and fishery (over 99%).

Coastal systems consisting of the Baltic sea coastal areas and the Curonian lagoon are the transitional ecosystems, where the physical and biogeochemical processes are the result of terrestrial, oceanic and atmospheric systems interaction. Curonian lagoon is an estuarine coastal lagoon, dominated by the Nemunas river discharges, which make up to 90% of the total runoff.

2. Nemunas river and the watershed

The area of land draining into the Curonian Lagoon covers 100,458 km^2, of which 48% lies in Byelorussia, 46% in Lithuania, and 6% in the Kaliningrad oblast (Figure 1), with a total population of about 5 million inhabitants. Curonian lagoon is an estuarine coastal lagoon, dominated by the Nemunas river discharges, which make up to 90% of the total runoff.

The total length of the Nemunas is 937 km. That makes it the 14th largest river in Europe and the 4th largest in the Baltic Sea basin. Four hundred and fifty-nine kilometers flow in Belarus, while 359 km are in Lithuania. One hundred and sixteen kilometers of the Nemunas serves as the border between Lithuania and Russia's Kaliningrad oblast and Belarus. Its greatest depth is 5 m in the lower part, and at its widest it extends about 500 m. During floods, water discharge can increase up to 11 times, to more than 6,800 m^3s^{-1}. Severe floods occur on the lower reaches of the river about every 12–15 years, which sometimes wash out bridges.

The Nemunas basin in Lithuania drains more than 20,000 rivers and rivulets and covers 72% of the Lithuania's territory. The total area of the Nemunas drainage area is 97,863 km^2; the Lithuanian portion of this basin is 46,695 km^2.

Nemunas in Lithuania is moderately polluted or polluted. High concentrations of organic pollutants, nitrates and phosphates occur in different parts of the river. Environmental issues include water quality (eutrophication and pollutants), changes in the hydrological regime, and flooding control. The environmental problems in each of the countries that make up the basin are slightly different. In Belarus the main problems are oil products as well as

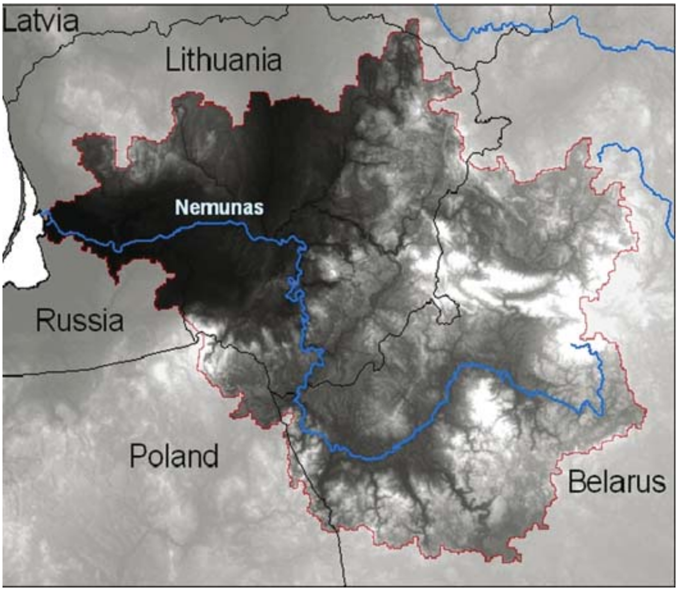

Figure 1. Nemunas river watershed elevation map.

nitrogen and BOD (biological oxygen demand). The environmental issues in the Kaliningrad section include high concentrations of BOD, lignosulphates, and nitrogen. In Lithuania, the operations of the Kaunas hydropower station cause changes of the water level that affect the riparian ecosystem. Old wastewater treatment facilities along the entire river also contribute to pollution.

According to Šileika (Sileika et al., 2006) study where nitrogen and phosphorus concentrations were evaluated from 1986 to 2002, including the period 1992–1996, characterized by the drastic cut in the use of fertilizers. Surprisingly area-specific load of NO_3-N increased over the entire period, being particularly large (43–78%) in the Lithuanian part of the river. The corresponding load increase in the Belarussian part of the river was only 1–15%. On contrary to nitrate-N, the area-specific load of PO_4-P decreased significantly at all sites along the Nemunas River (31–86%). The decrease of PO_4-P levels was attributed to the reduction of municipal and industrial point source emissions and to the decreased livestock numbers.

The NH_4-N load showed the same pattern as PO_4-P. At the river mouth the load decreased from 90 kg km^{-2} year^{-1} to only 20–30 kg km^{-2} year^{-1}. The declines were explained by decreased emissions from cities and large animal breeding farms.

The co-operation necessary to ensure the health of the river is complicated by the political divisions in the basin – its territory is shared among Russia, Belarus and the European Union country of Lithuania. Several co-operation initiatives are underway to address the environmental issues of the river.

3. Management perspective

As the water quality in Curonian lagoon is of general concern for both fishery and recreation (both are dominant industries in the area) in 2006 Lithuanian government approved a programme aimed to improve it. (The programme to improve the water quality in the Curonian lagoon, 2006). In that document most emphasis was put to combat the point and disperse pollution to reduce the nitrogen, phosphorus and organic material. The objective of that programme is to decrease the pollution from the point sources in the total nitrogen loads by 810 t, phosphorus loads by 85 t and organic matter expressed as BOD_7 by 1,050 t. To combat the non-point pollution sources objective is to reduce the nitrogen loads by 15% and phosphorus by 8%. As a result of that approach proportionally higher reduction in nitrogen than phosphorus compounds is expected (Figure 2).

However, nutrient loads being mostly controlled by the human activity also could be heavily modified by the climatic variation in the hydrological cycle. As a primary factor the discharge volume itself could be a good measure of the nutrient loads into the lagoon. As the variation in total nitrogen and total

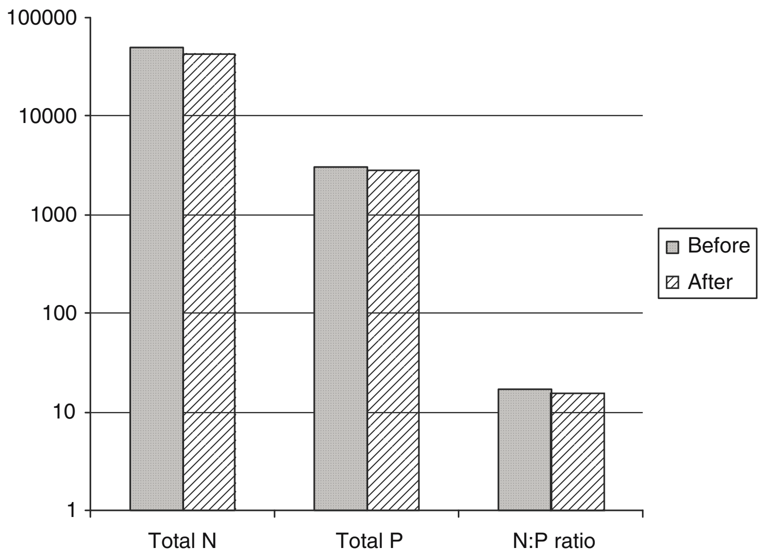

Figure 2. Expected targets of total nitrogen and total phosphorus (t/year) decrease by 2010 as compared to 2004 baseline (logarithmic scale).

phosphorus concentrations in Nemunas river are much lower that the variation in the discharge volume both the short term (interannual) and long term discharge variations could be critical for the nutrient loads to the Curonian lagoon. Moreover, seasonal runoff variation patterns could also modify significantly the absolute amounts and the proportional share of nitrogen and phosphorus entering the lagoon. According to Tilickis (Tilickis, 2005) differences in groundwater versus surface runoff in the drainage basin of the Nemunas river are strongly influenced by the soil infiltration properties and, consequently by the climatic factors (wet vs dry years).

4. Climatic trends

As the climate changes are expected to be quite significant in the Northeast Europe (increase of 0.15–0.6°C) in the winter months that also already caused quite significant response in both water level, temperature and hydrological cycle.

Temperature changes during the last 45 years were characterized by clear temperature increase during the spring (February–May) and the second part of the summer (Figure 3).

Water level trends are also quite clear pointing towards the general increase of water levels both inside and outside the Curonian lagoon (Figure 4).

The discharges of the Nemunas River were significantly altered after the construction of the Kaunas HE power station in the middle course of the Nemunas river in 1960 by reducing the magnitude of maximum runoff

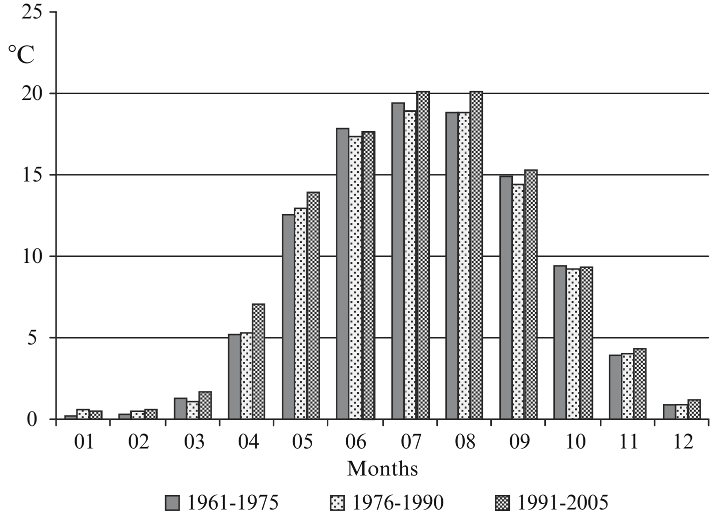

Figure 3. Temperature changes in the Curonian lagoon temperature during 45 years.

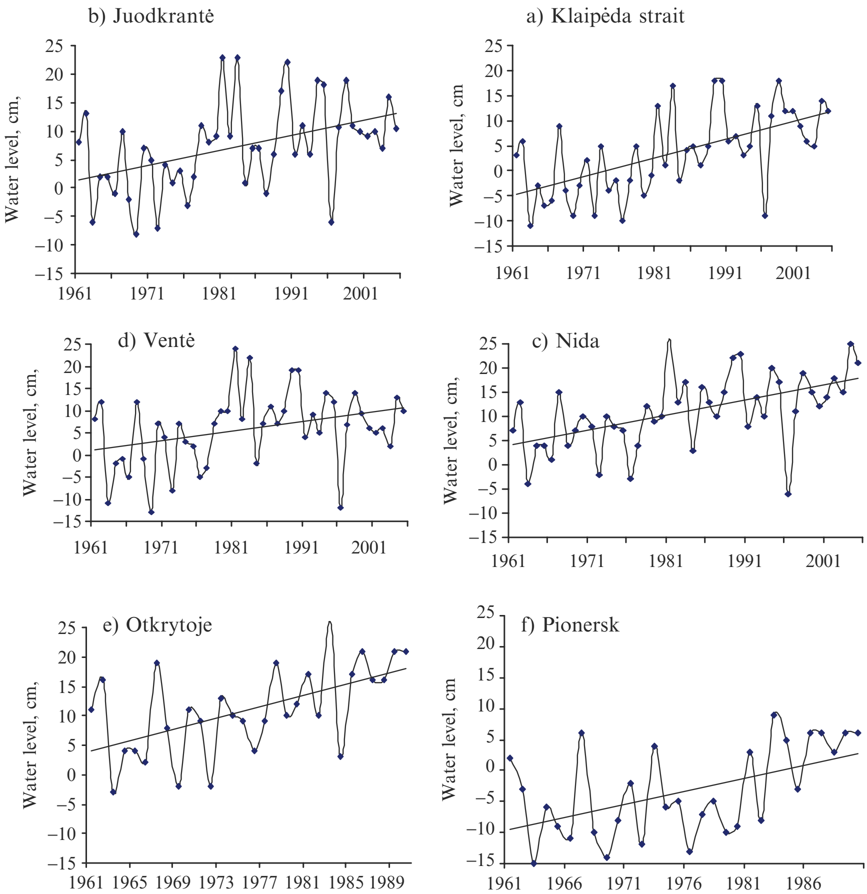

Figure 4. Water level changes in the Curonian lagoon (a–d) and the South-Eastern Coast of the Baltic sea (e–f).

during the spring flood period. However, later, it is climatic change that influenced the structural and magnitude changes. It could be seen quite clear that from 1960 there was a shift of a spring flood maximum from April to February–March period (Figure 5).

5. Biogeochemical processes in the lagoon

Curonian lagoon and the coastal Baltic sea according to the WFD Both fall into the definition of the transitional coastal waters. The conditions in the Curonian lagoon as highly eutrophic and productive water body also effectively decide the water quality in the neighboring Baltic sea north of Klaipeda because of the significant freshwater runoff and dominating water currents. Phytoplankton remains the most important autochthonous organic matter producer both in Baltic

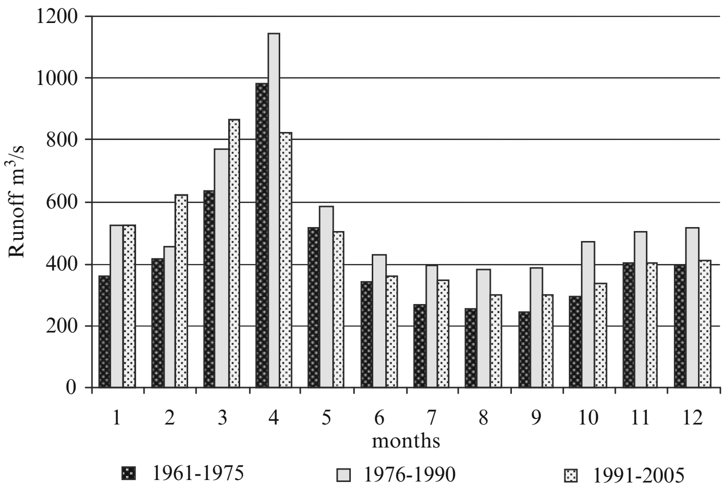

Figure 5. Changes in the Nemunas river runoff in 1961–2005.

sea and in the Curonian lagoon. Not surprisingly the phytoplankton seasonal dynamics is highly related to the seasonal changes in the water quality. The spring bloom, mostly formed of diatoms is not so critical to the water quality because of lower temperatures. However, the summer cyanobacteria bloom is often of higher intensity (up to 20 mg ChlA/L) and often cases a number of water quality problems inside the lagoon (hypoxia, fish kills, cyanotoxins) as well as transported to coastal zone creates sanitary problems at the popular resorts along the Lithuanian coast. It is that problem was considered when the National programme to improve the water quality in the Curonian lagoon was adopted. The main mechanisms governing phytoplankton seasonal development and succession in the Curonian lagoon were studies during the recent years (Razinkovas and Pilkaityte, 2002; Razinkovas et al., 2005; Pilkaityte and Razinkovas, 2006, 2007; Pilkaityte, 2007). The generalized scheme of these mechanisms is presented at the Figure 6.

Quite recently it was also found that period of the nitrogen limitation coincides with the atmospheric nitrogen fixation maximum, performed by the cyanobacteria. In the summer 2005 the massive development of cyanobacteria caused significant atmospheric nitrogen fixation rates accounting for over 10% of the total nitrogen inputs to the lagoon.

6. The effect of climatic factors on the production processes in the Curonian lagoon

Cyanobacteria usually dominate in the eutrophied oligohaline waters during the summer (Carrick et al., 1993; Nixdorf and Hoeg, 1993; Kavaliauskiene, 1996; Schiewer, 1997; Plinski and Jozwiak, 1999). The cyanobacteria appear when the water temperature reaches 16−20°C, usually in June, and remain abundant till late October (Olenina, 1998; Kanoshina et al., 2003) (Pilkaityte and Razinkovas, 2007). The most dominant cyanobacterium is *Aphanizomenon flos-aquae*, contributing to near 80% of the total density (Pilkaityte and Razinkovas, 2007). The high temperature (Kanoshina et al., 2003; Pilkaityte and Razinkovas, 2007) and high irradiance (Havens et al., 2003) both favour nitrogen fixing cyanobacteria development during the summer. Their abundance (especially *Aphanizomenon flos-aquae*) depends on the water temperature (Figure 6).

There is suggestion, however, that cyanobacteria dominate during the summer not because of high temperature, but due to low wind conditions (Oliver and Ganf, 2000). Wind speed about 3 m s^{-1} induces the fastest surface current (4.5 cm s^{-1}), while the vertical turbulence is weak (Oliver and Ganf, 2000). Starting from May to August, the days when wind velocity is 3 m s^{-1} or less take about 49% (Gailiušis, 2000). As a result the cyanobacteria could spread over large part of water body in a short time. The gaseous vesicles of the cyanobacteria allow regulate their buoyancy. Therefore, during calm whether and high water temperature cyanobacteria accumulates at the surface and diminishing light penetration to the deeper layers. This influence negatively submersed vegetation.

Some of the cyanobacteria species, particularly *Aphanizomenon flos-aquae*, are known to perform diurnal vertical migrations (Kononen, 1992; Heiskanen and Olli, 1996; Hägerhäll-Aniansson, 2001). Intensive water turbidity due to wind action could disturb such migrations. The negative effect found between wind velocity and cyanobacteria abundance during summer over the long-term data series confirms that (Figure 7).

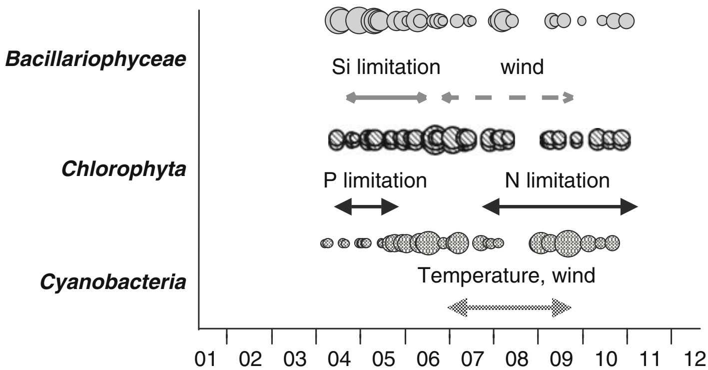

Figure 6. Phytoplankton dynamic after Pilkaityte and Razinkovas (2007).

7. Conclusions

According to the foreseen climatic changes the average water temperature is expected to increase in the spring and the second part of the summer along with decrease in average wind speed. Along with changes in Nemunas river runoff (mostly structural changes) the overall scheme of non-manageable changes could be represented as in the Figure 8. Because of the complex character of the biogeochemical processes and their interaction with hydrodynamics in the Curonian lagoon it is still not possible to make clear forecast regarding the trends in wind speed and Nemunas river discharges effect on the Curonian lagoon ecosystem. However, in general the climatic trends favor for the eutrophication process, especially potential activity of the atmospheric nitrogen fixing cyanobacteria. According to the programme to improve the water quality in the Curonian lagoon the nitrogen loads are expected to be reduced even more than the loads of the phosphorus compounds. In a turn that could further improve the competitiveness of nitrogen fixing cyanobacteria and could end up in prolonged algal blooms, even further degrading the water quality both in the Curonian lagoon and the neighboring coastal Baltic sea.

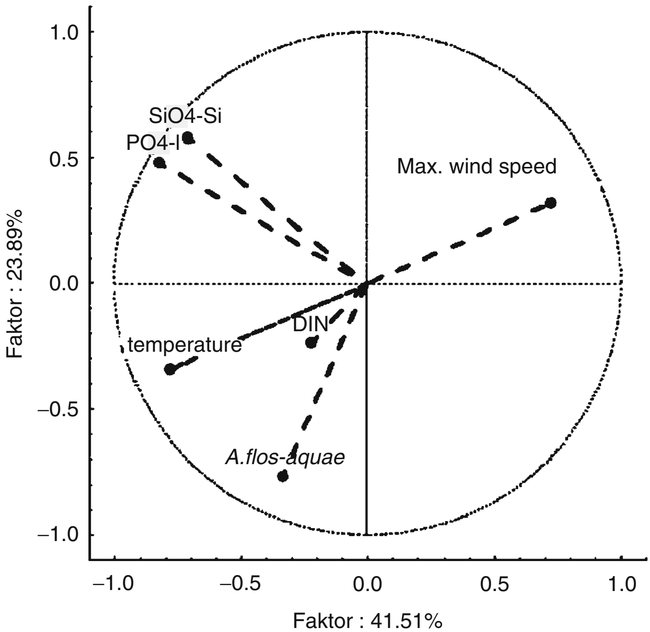

Figure 7. Results of PCA of the long-term data set (1984–2001). Projection of the first two principal component variables on the factor-plane (Pilkaityte and Razinkovas, 2006).

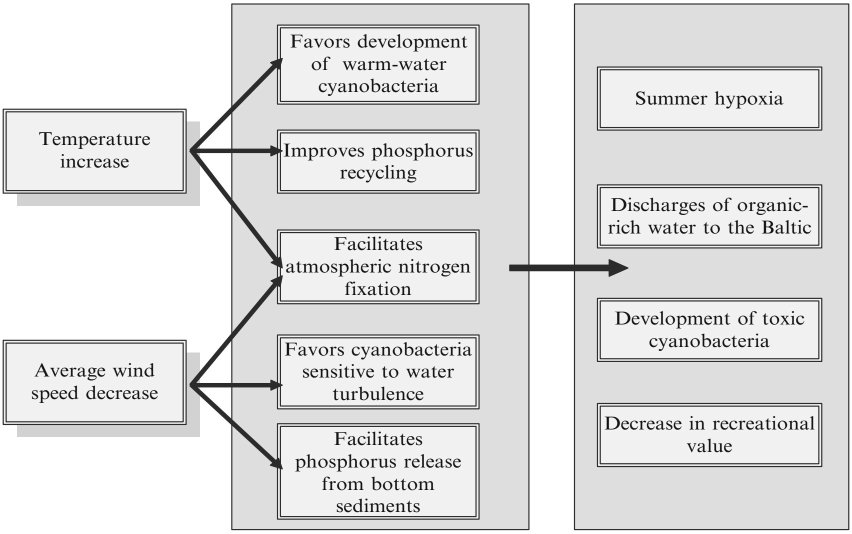

Figure 8. Generalized scheme of climate impacts on the Curonian lagoon ecosystem.

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THE STUDY OF HYDRO-MINERALOGICAL AND ECOLOGICAL REGIME OF KARA-BOGAZ-GOL LAGOON, TURKMENISTAN

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Abstract: The hydro mineral behavior of the Kara-Bogaz-Gol is related to changes in Caspian Sea level. Several times in past the lagoon was dried and filled by water again. There was considerable decrease of the Caspian Sea level during the period from the end of 19th century until the 1980s. This has resulted in sharp change in hydro mineral regime of the lagoon, and accompanying human interference has caused the ecological catastrophe. In the years from 1980 to 1984 the strait connecting the sea and the lagoon was blocked with a dam. The result was a complete drying up of the Kara-Bogaz-Gol and its transformation in a dry salt lake. The formation of a new ecological system has begun after destruction of the dam and the entering of seawater into the lagoon, at first in a limited quantity (1984–1992 years) and then in a quantity without impediment, as a natural drain basin.

Keywords: Kara-Bogaz Gol Lagoon; salt lake ecology

1. Introduction

Kara-Bogaz-Gol (KBG) in Turkmenistan is a vast shallow lagoon located on East coast of the Caspian Sea and surrounded with desert. It is connected by a strait with the Caspian Sea and is an unique salt-formation pool, one of the largest in the world. Kara-Bogaz-Gol is situated between N 40°31′ and N 42°29′, E 52°43′ and E 54°46′. Due to a combination of favorable conditions the lagoon represents a natural pool for a precipitation of mirabilite ($Na_2S0_4.10H_20$). Mineral resources of the lagoon are rich for a chemical production of sodium, magnesium and potassium salts (mainly sulfates and chlorides) together with boron, bromine, and other rare elements. The mineral resources are present in surface brines of the Lagoon, buried brines of the second salt level, solid salt precipitates, and overflow brines of the industrial plant. The Kara-Bogaz-Gol salt deposits are of marine origin.

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Before 1956, surface brines were used for mirabilite production. At present, only the buried brines are used in industrial manufacture for mirabilite, epsomite ($MgS0_4.7H_20$) and cooking salt production. In the long term, the surface brines will be the most valuable, large scale, and a self-renewing source of raw materials.

2. Characteristics of the lagoon and watershed

2.1. CLIMATE

The climate of region is sharp continental. The average temperature is +13.1 °C, average winter and summer temperature are −0.5 °C and +27.1 °C, consequently. Maximum temperature is equal to +39 °C; the minimum is equal to −18 °C.

The wind's direction is different in accordance with the season. October through March the direction is mainly north-east and in summer it is mainly north-west and west ones. The average wind speed of many years is equal to 8 m s^{-1}, during the storm speed month's winds to 30 m s^{-1} occur.

The area is calm 6% per year. A temperature regime of the lagoons water differs based zone of mixing of water of Caspian Sea and brine as well as for all the other zones. In the mixing zone the temperatures difference of surface and deep waters reaches 7–10 °C in summer and 3–4 °C in winter, and in autumn surface and deep waters are the same. In the other parts of the lagoon the temperatures difference of surface and deep waters is about 0.5–2 °C. A quantity of water precipitation is 70–90 mm per year. Absolute humidity is equal to 8 mm, relative humidity in the west coast fluctuates from 50% in summer on 70% in winter (Akovetskiy and Bogdanov, 1988).

2.2. HYDROMINERAL REGIME.

A level change of the Kara-Bogaz-Gol is mainly determined by an annual drainage value from the Caspian sea and evaporation from the surface water. In 1897–1929 the drainage was equal to 18–32 km^3, in 1941–1974 drainage did not exceed 7–15 km^3 (Akovetskiy and Bogdanov, 1988), and in 1980–1984 drainage was completely stopped. The water evaporation from the lagoon's surface depends on brine mineralization, which was equal to 900–1,300 mm per year. Evaporation from the surface was close to water inflow and the volume of brine was stable, as the drainage of Caspian Sea water was equal to 8–10 km^3 per year (Lepeshkov et al., 1981)

It is a characteristic feature that the density and mineralization of Kara-Bogaz-Gol brines in various parts of the lagoon and at various depths are different. The mixing zone, where water of Caspian Sea inflows to the lagoon, has unstable composition and losses concentrations of salts. A depth of mixing of brines does not exceed 1.5 m.

In the conditions of the stable behavior, up to 1980, water mineralization was the largest in the central part of lagoon and in a coastal zone, and a value of salts concentration reached 30% or higher. In the period from January to April the main precipitation of mirabilite occurred, and from the beginning of April the salt began to dissolve, and in July the process ended completely. Since 1939, in the summer a precipitation of the NaCI together with epsomite ($MgS0_4.7H_20$) and astrahanitebloedite ($Na_2S0_4.MgS0_4.4H_20$) occurred (Buynevich et al., 1959).

The KBG Lagoon is connected with the Caspian Sea by an 11 km strait. The composition of surface brines is determined by the changes of the Caspian Sea level. The maximum area of the Lagoon reaches about 20 km^2. After complete damming the strait in 1980 the surface brines dried for 2.5 years. Later, in the middle of 1980s, in order to reanimate the Lagoon, 11 pipes were put in the dam and provided seawater from the Caspian Sea in the amount of ca. 2 km^3 per year. This allowed recovering part of the surface brines level. In 1992 the dam between the KBG Lagoon and the Caspian Sea was completely demolished. After destruction of the dam, the amount of seawater entering from the sea to the Lagoon was determined by the difference between the levels of the sea and the lagoon. This difference decreased from 6.50 m in 1991 to approximately 0.49 m in 1996 and remained constant for the next six years (Figure 1). The formation of new surface brines started being conditioned by both the evaporation of entering seawater and the interaction of seawater and brines, with salt deposits formed during the Lagoon evaporation. In the beginning the volume of seawater entering into the KBG Lagoon was about 50 km^3 per year, however, during recent years this volume dropped to about 20 km^3 per year. At present, the amount seawater entering the Lagoon from the Caspian Sea determines the relative stability of surface water composition. The Lagoon reached its natural shorelines: the volume of the surface brines is 25–30 km^3, the Lagoon water area is ca. 20,000 km^2, and maximum depth is about 8–10 m. The natural variation of sea level for the Caspian Sea until the mid 1980s is discussed by Akovetskii and Bogdanov (1988).

Water level changes of the Kara-Bogaz-Gol are mainly determined by annual water input from the Caspian Sea and by water evaporation from the Lagoon surface. At present, the stabilization of seawater input (18–19 km^3/year) is observed. However, the input of seawater is slightly less than the water evaporation from the lagoon surface (Table 1). As a result of the negative water balance, increased mineralization of Lagoon brines is noted (Khodjamamedow et al., 1998).

The data related to the drainage of the Caspian Sea water to Kara-Bogaz-Gol (Table 2) shows that after the stabilization of the drainage on the level 18–19 km^3/year during 1997–2001 the drainage began to decrease (between

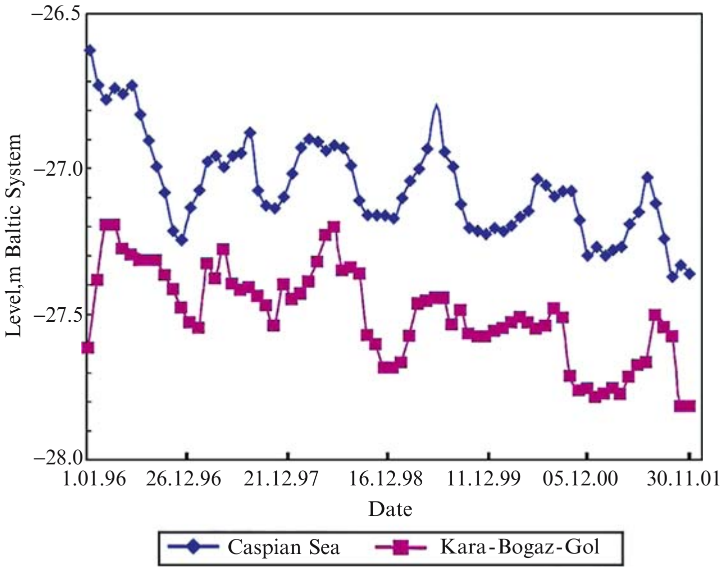

Figure 1. Water levels of Caspian Sea and Kara-Bogaz-Gol from 1996 till 2001.

TABLE 1. Water balance of Kara-Bogaz-Gol for 1996–2001.

Year	Lagoon Surface (km^2)	Year average Level (BSL) (m)	Seawater Input (km/year)	Rain Input[a] (km^3/year)	Water Evaporation (km^3/year)[b]	Water (Balance) (km^3/year)	Lagoon Volume (km^3)
1995	18,400	−27.96	52.2	2.1	22.5	+32.8	90.9
1996	18,600	−27.36	25.3	2.1	22.5	+4.9	95.8
1997	18,600	−27.50	17.7	2.1	22.5	−2.7	93.1
1998	18,600	−27.40	18.0	2.1	22.5	−2.4	90.7
1999	18,600	−27.54	18.5	2.1	22.5	−1.9	88.8
2000	18,600	−27.58	18.9	2.1	22.5	−1.5	87.3
2001	18,600	−27.69	17.8	2.1	22.5	−2.6	84.7

[a]The yearly volume of rains was accepted as the value of equal to average for many years.
[b]Water evaporation from the lagoon bittern surface depends on brine mineralization and was regarded as about 1.1 mm/year (Lepeshkov et al., 1981).

2002 and 2006). This phenomenon is very important for the formation of the surface brines of Kara-Bogaz-Gol.

The surface brines reached the saturation of sodium sulfate and during the last several years, the mirabilite crystallization was observed in the Lagoon. The chemical analysis of surface brines shows a content of major ions (Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3) and minor ions (B_2O_3, Br^-, Li^+, heavy metals) for the last several years. This demonstrated that the chemical

TABLE 2. Drainage of Caspian Sea water to Kara-Bogaz-Gol for 1992–2007.

Year	Water volume (km^3)	Difference in the lagoon and Sea levels (m)
1992	11.3	8.0
1993	36.6	–
1994	40.8	–
1995	52.2	1.31
1996	25.1	0.49
1997	17.7	0.43
1998	18.0	0.35
1999	18.5	0.47
2000	19.4	0.46
2001	18.0	0.46
2002	13.7	0.59
2003	15.8	0.55
2004	15,2	0.62
2005	16.1	0.62
2006	12.2	0.74

composition of brines began to be stable with mineralization equal to 29–31%. The concentrations of the industrial important components (sulfate, potassium, bromide and boron ions, and microelements) increase in average from 5% per year and have reached the following values: 2.72–2.88% SO_4^{-2}, 0.11–0.12% K^+, 150 mg/L Br^-, 130 mg/L H_3BO_3, 5–6 mg/L Li^+. The current brines compared with brines before dam creation are depleted in sulfate and potassium ions but enriched in boron, bromine, and rare metals. The composition of the surface brine in winter-time is identified on the solubility diagram of the system for Na^+, Mg^{2+}, Cl^-, SO_4^{2-} H_2O at 0 °C in the field of Na_2SO_4 crystallization. The KBG Lagoon became again the unique basin for industrial mineral precipitation.

The surface brines were used in sodium sulfate production at an industrial scale in 1934–1956. At present time, the underground and buried industrial brines of the second level of KBG Lagoon are used in industry for the production of glauberite ($Na_2SO_4.10H_2O$), bischofite ($MgCl_2.6H_2O$), epsomite ($MgSO_4.7H_2O$), and other minerals. These brines with density 1.23–1.24 g cm^3 contain more than 7.7% of sodium sulfate and less than 8.5% of magnesium chloride. The most promising raw materials are the surface brines, since they are renewable, inexhaustible ((1–2) 10^{12} kg of mineral salts reaches the KBG Lagoon with seawater each year) and are situated on the Lagoon surface. These factors condition the minimum expenses for transport and production.

3. Seasonal changes for chemical composition of surface brines

A comprehensive monitoring studies were carried out to evaluate change of chemical compositions of surface brines of Kara Bogaz Gol during 2002–2003 (Krumgalz et al., 2004; Gurbanow et al., 2001, 2002, 2004, 2006).

3.1. SAMPLING LOCATIONS

The most available place for surface brine sampling was at the northwest shore zone closed to the existing mineral production plant. The sampling was conducted in a shore area approximately 500 m from a dam between Karasukut Bay, the central zone and in a canal which connected Karasukut Bay and the central zone (Figure 2). It was found that mineralization of Kara-Bogaz-Gol brines in various parts of the lagoon appeared to be different. The mixing zone, where the water of the Caspian Sea flows into the lagoon, has a variable composition and the lowest salt concentrations. The highest mineralization was observed in central zone and the northwest coastal zone. Statistical analysis of the chemical composition of Kara-Bogaz-Gol water from 1995 until the present shows that the composition of brines in the central zone, in Sartas Bay and approximately 500 m from a dam between Karasukut Bay and the central zone, are almost identical. For these stations, at the same sampling period, the difference between both concentrations of particular ions and total salts content is less then 5%. This allowed for consideration that composition of brine sampled in 500 m from a dam between Karasukut Bay and the central zone is average for northwest shore zone.

3.2. THE COMPOSITION OF KARA-BOGAZ-GOL SURFACE BRINES

Brine samples after sampling were kept in glass bottles equipped with ground glass stoppers. Contents of major ions in the brines were determined in accordance with standard techniques as follows:

No.	Place of sampling	Coordinates
1	Karasukut Canal (a zone of the lagoon closet to the Dlant)	N 41°38′, E 52°43′
2	Karasukut dam (a zone of the lagoon closet to the plant)	N 41°37′, E 52°44′
3	Sartas (Northwest zone of the lagoon - approximately 600 m ITom the coastal line)	N 41°48′, E 52°57′
4	Central zone of Kara-Bogaz-Gol	N 41°28′, E 53°23′
5	Central zone of Kara-Bogaz-Gol	N 41°10′, E 54°01′

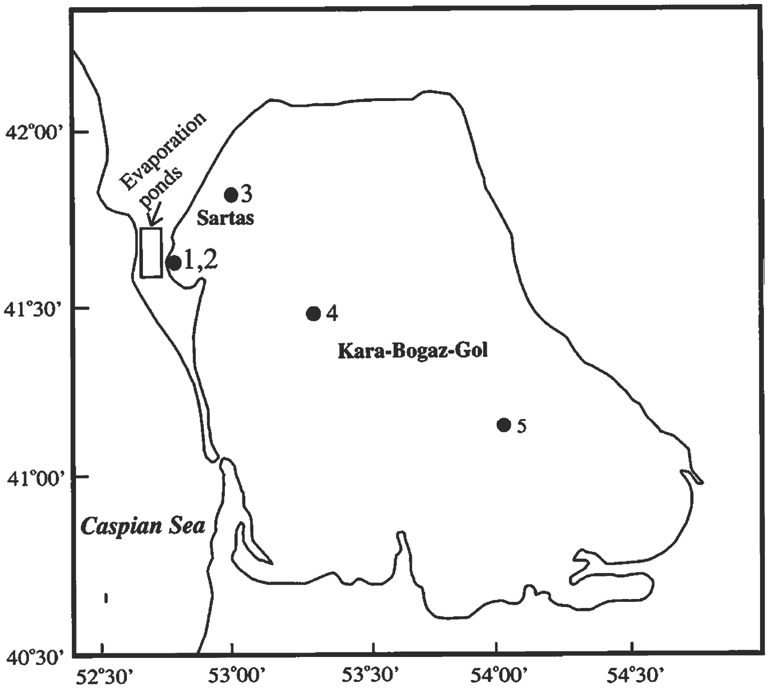

Figure 2. Map of sampling locations.

HCl, phenolphtalein and methilorange as indicators.

Ca^{2+} and Mg^{2+} concentrations were determined by complexometric analysis (0.001N solution of trilon was used for titration by using an automatic METTLER TOLEDO DL50 Titrator).

K^+ and Na^+ concentration was determined by the flame photometry method using Flame Photometer 410.

Boron concentration was determined by volumetric titration using 0.01 M NaOH with mannit for complexation and with methyl-rot and phenol-rot as indicators.

Br^- concentration was determined with using an ion selective electrode DX280-Br^- and METTLER TOLEDO DL50 Titrator.

The standard solutions have been prepared by using solutions resembling the surface brines. The natural solutions and solid phases, formed in the evaporation process, were either diluted or dissolved in distilled water. The relative precisions of the Cl^-, SO_4^{2-}, HCO_3^-, Ca^{2+}, Mg^{2+}, K^+ and Na^+ determination were as follows: 0.10%, 0.05%, 0.20%, 0.20%, 0.05%, 1.19%, 0.45%, respectively.

According to the data obtained, the concentration of salts increased during the summer. The largest mineralization (26.12%) was observed in August. In November when temperature of the brine reached less then 10 °C, precipitation of mirabilite occurred. At present, the shore zone is covered by layer of mirabilite containing a small quantity of halite and epsomite. Due to a combination of favorable conditions, the lagoon represents a natural pool for precipitation of mirabilite ($Na_2SO_4.10H_2O$). The brine for investigating the mirabilite precipitation and solar evaporation was sampled at Station #2. Existing observations for seasonal changes of chemical brine composition demonstrated that maximum mineralization was reached in September–October before the rainy season. The brines were found to be formed only due to seawater input and water evaporation from the lagoon surface. It is possible that the dissolution of bottom minerals settled during the phenomenon of lagoon dry-up, when the lagoon was separated from the Caspian Sea by a dam, is completely accomplished. The analysis of the data obtained allowed for the conclusion that the depth of surface brines mixing does not exceed 3 m. At present, there are no conditions for massive mineral precipitation from Kara-Bogaz-Gol waters. Only the precipitation of mirabilite during winter months (January–February) was observed.

The composition of Kara-Bogaz-Gol buried brines from two production wells used at the present for the production of mirabilite, epsomite, and bischofite were also investigated. The composition of the surface brines and the buried ones are almost identical. The only difference found is that buried brines are relatively richer in magnesium and sulfate ions and by content of H_2S (150–280 mg/L).

4. Conclusions and recommendations

On the base of the information presented we can make the following conclusion:

- Free inflow of sea water into the Kara-Bogaz-Gol dramatically changes the hydrological and hydro-chemical conditions of the lagoon.
- Currently, surface brine composition and Caspian water inflow are relatively stable.
- The lagoon became again a unique natural settling basin. A formation of a technologically suitable brain is re-established, which can be used for complex processing and obtaining of substances important for different branches of industry.

For forecast of hydro-chemical and hydrological regime of the Kara-Bogaz-Gol, a development of a numerical model is required, which takes into account the volume of water inflowing from the Caspian sea, evaporation of surface brines, weather conditions, climatic change, etc.

Acknowledgements

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COMPARATIVE ANALYSIS OF WATER MANAGEMENT PRACTICES IN MEDITERRANEAN COUNTRIES

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Abstract: Water resources potential exhibits an important discrepancy in Northern and Southern Mediterranean countries. The water availability and dependency of countries on external resources have shaped their water policies to a great extent. Although centralized and traditional in many instances, the Mediterranean countries are subject to mutation with regard to their legal framework and institutional structure since the adoption of regional binding documents by the contracting parties (e.g. the Barcelona Convention and its protocols) and regional actions like the Mediterranean Action Plan initiated by the UNEP. Sustainable development objectives enunciated at the Rio Conference have been a driving force for the Mediterranean countries to re-evaluate their environmental policies, of which water management is considered to be the most important component. The legal and institutional framework related to the management of continental freshwater has been analyzed in Mediterranean countries with regard to water rights, the role of the state, institutions, planning, allocation, investment and cost recovery issues. After this analysis, a synthesis highlighting the major shortfalls and the corresponding solutions that the countries envisage in practice is given. This study was initiated and supported by the UNEP/MAP Blue Plan in 2000 and updated in 2005.

Keywords: Mediterranean countries; water management

1. Introduction

The Mediterranean region has been facing water related issues for decades. Although part of the same region, Mediterranean countries exhibit very different levels of water resources availability, demographic characteristics and development. Differences have become increasingly important between the 23 northern, southern and eastern riparian countries, namely Spain, France, Italy, Greece, Monaco, Slovenia, Croatia, Bosnia-Herzegovina,

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Serbia, Montenegro, Albania, Cyprus and Malta belonging to the group of Northern Mediterranean countries (NMC); Egypt, Libya, Tunisia, Algeria and Morocco situated on the Southern Mediterranean coast (SMC); and Turkey, Syria, Lebanon, Israel and the Palestinian Territories constituting the Eastern Mediterranean countries (EMC). The present study is based on 13 riparian countries of the Mediterranean basin that reflect the most pertinent and representative aspects of the three groups (Figure 1).

2. Mediterranean features and concerns

The Mediterranean basin known as the cradle of the civilization is a rich but fragile eco-region. Deserts and mountains that cover 5.7% of the emerged surfaces constitute the natural landscape of this region and give rise to the variety of eco-systems. A significant share of the World's biodiversity as regards endemic species (e.g. 10% of higher plants in 1.6% of land surface, 7% of marine species in 0.8% of the total ocean surface) makes this region a particularly rich.

The population of the basin is 427 million, accounting for 7% of the World's total. One hundred and ten million people live in cities and around 150 million people are concentrated on the 46,000 km of the Mediterranean coastline. Each year 220 million visitors, equivalent to approximately 32% of international tourism, come to the Mediterranean countries. The fact that 60% of the 'water-poor' population lives in the Mediterranean shows to what extent the natural hydric stress is a concern in the region. In addition, an increasing CO_2 emission that is currently 8.3%, occurrences of natural hazards, degradation of natural resources due to depletion and pollution are among the major global problems in the basin (Benoit and Comeau, 2005).

The receiving medium of the Mediterranean Sea is also under pollution pressure. Thirty percent of the world's international maritime freight, 20–25% of oil maritime transport transit, untreated municipal wastewater and urban solid waste disposal, storage, transportation and disposal of radioactive and hazardous waste, as well as activities contributing to the destruction of the coastline and coastal habitats are the contributing factors to the pollution of the Mediterranean Sea and its surrounding natural resources on which the wealth of the Mediterranean population is based (Benoit and Comeau, 2005).

As a result, the concept of sustainable development is particularly relevant in the Mediterranean since development is dependent on the environment (UNEP/MAP, 2006).

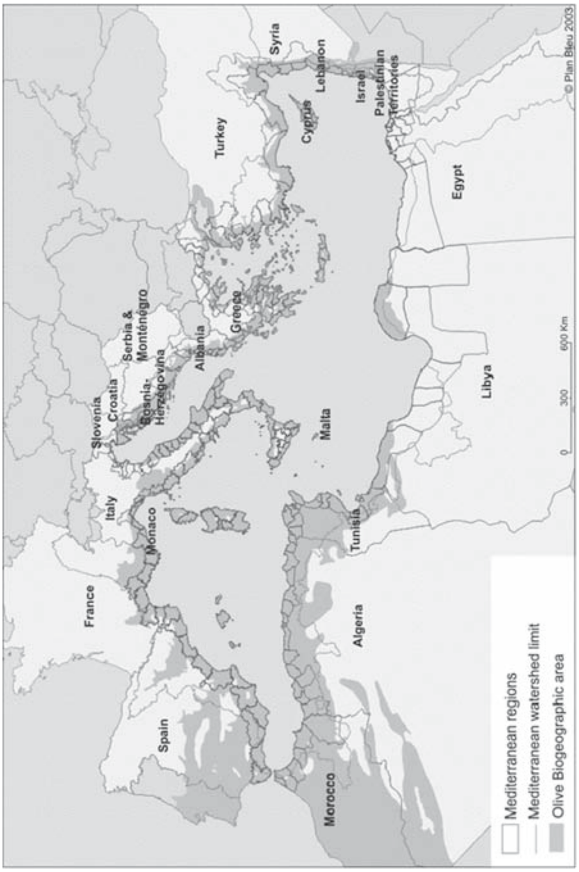

Figure 1. Mediterranean basin (Benoit and Comeau, 2005).

3. Water management issues in the Mediterranean countries

Despite socio-economic and cultural discrepancies, Mediterranean countries started joint actions for a common future understanding that their destiny lies in solidarity and, in particular, that joint action is imperative to prevent the deterioration of the environment in which they live (Margat and Vallée, 2000).

The solution adopted by the Mediterranean countries has favored supply-sided policies by extracting water and storing more water than in the rest of the world. Hydrological systems are deteriorating as the results of over-exploitation of watersheds. Moreover, climate change impacts on water resources lead to irregularities in flow regime, which constitutes an additional severe burden on management issues (Burak, 2007).

Every country has its own understanding of these problems in translating global targets into local actions. Some countries have begun to undertake more efficient water management as called for by the Johannesburg Summit. Recommendations adopted in 1997 by the contracting parties to the Barcelona Convention on the proposal of the Mediterranean Commission on Sustainable Development (MCSD) stipulated the demand management as a short-term priority for a common understanding among the riparian countries.

The Fiuggi forum held in 2002 has been a regional platform for the assessment of the progress made on this issue. Turkey has also actively taken part in this process as a member of the UNEP/MAP/MCSD since the beginning as part of its regional and international commitments and willingness to improve water resource management at national and regional levels.

4. Comparative analysis of water management practices

Water abundance and water scarcity coexist in the Mediterranean basin. The major discrepancy with regard to water resources in the Mediterranean is the uneven distribution of the resources between countries with 72% in the North, 23% in the East, and 5% in the South. As a consequence water management practices are orientated on the Southern and Eastern rims principally by quantity concerns such as drought management, whose consequences are particularly severe both for water resources because they lead to a deficit in storm water and snowmelt input in winter and spring and for soils and agriculture when normal summer drought is exacerbated. The concept of demand management as opposed to supply-sided management is gaining growing importance.

Generally demand has doubled since the beginning of the 20th century and increased by 60% over the last 25 years; demand is growing very slowly and tending to stabilize or even fall in Northern countries (in line with demographic changes) and in some Southern countries (where demand is regulated due to water shortages like in Cyprus, Israel and Malta). Demand is growing in the other countries but falling on a per capita basis. Some other countries have a relatively growing demand on a national scale due to either the natural increase of previous low demand ratio (e.g. Algeria) or developing water and irrigation schemes (e.g. Lebanon, Libya and Turkey) (Margat and Vallée, 2000). So far, the trend has remained constant according to the results of the Zaragoza Forum (Blue Plan, 2007).

Figure 2 gives the exploitation index of natural and renewable water resources. This index gives proven evidence on the ratio of resources availability and the demand of a given country. Furthermore, degradation of water quality due to over-exploitation and pollution is another severe burden on the scarce water resources. Water scarcity leads also in some countries (i.e. Libya) to the unsustainable use of water resources (e.g. exploitation of fossil water in deep aquifers) (Burak, 2000).

Table 1 exhibits the general water management tools and related concerns of the Mediterranean countries.

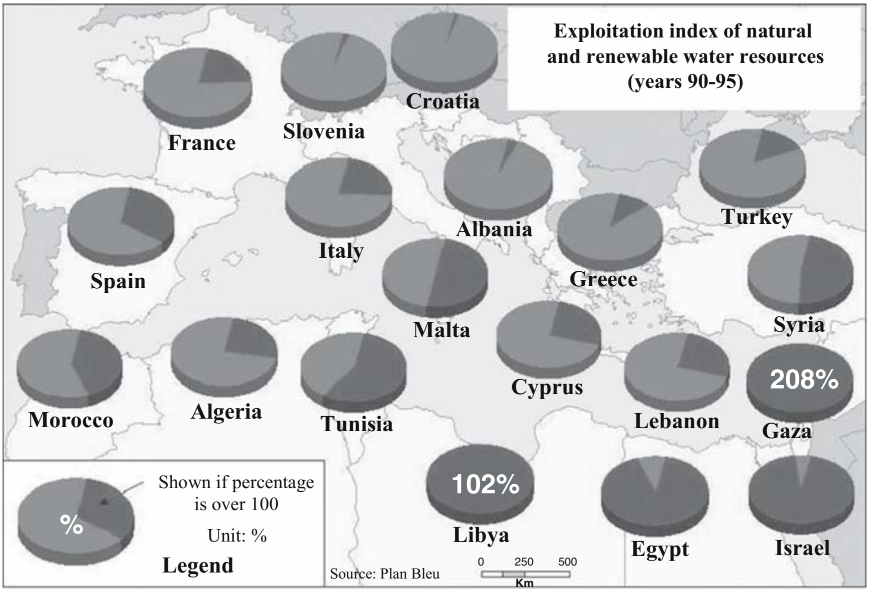

Figure 2. Exploitation index of natural and renewable water resources. (Burak, 2000.)

TABLE 1. Comparison of water management tools and related concerns.

1. Resource & use
* Insufficiency, discrepancy between data (except: IL, MA, CY)
→ Solution: establishment of hydrological network, reference laboratories (PA, TR)
* Lack of planning in AL
→ Solution: master plan in line with national water policy

2. Quantity
* Overexploitation of the aquifers with high risks of sea water intrusion
→ Solution: (a) optimization modeling of the aquifers, MA
(b) Development of unconventional water use (MA, EG, IL, LY, PA, CY)
(c) Aquifer recharge (CY, IL, LY, PA)
(d) Further development of surface water (AL, EG, TR)
* Lack of balance between demand/supply
→ Solution: transfer between basins (IL, LY, PA, CY, TR)
Development of unconventional water resources (MA, EG, IL, LY, PA, CY)

3. Quality
* Quality degradation of aquifers
→ Solution (pollution control through integrated watershed management IL)
* Domestic pollution (except IL, CY, MA)
→ Solution: (wastewater treatment plant)
* Agricultural pollution (except CY, MA)
→ Solution (restriction of pesticide use in IL, EG)
* Industrial pollution (except MA, CY satisfactory pollution control
→ Solution: reduction of pollutant at source
inadequate O&M
→ Solution: Technical and institutional measures (PA, TR)

4. Institutions
* Plurality (except IL, MA)
→Solution: CY gathering power in one water agency
* No separation of duty between investment, inspection, management
→Solution: decentralization, delegated management

5. Legislation
* Lack of the clear definition of water rights, need for a Water Act to define allocation between sectors
→Solution: revision of the legislation

6. Financial
* Not full cost recovery not even for O&M (except CY, MA, IL)
→ Solution: delegated management

7. Irrigation
* Significant subsidy by the states (except CY, MA)
→ Solution: promote participation of the users progressively

AL: Albania, CY: Cyprus, EG: Egypt, IL: Israel, LY: Libya, MA: Malta, PA: Palestinian Territories, TR: Turkey

5. Discussion

According to the World Bank, the Middle East-North Africa Region (MENA) suffers from the least water availability per capita compared with any other region in the world. It has less than 1% of the world's freshwater resources and 5% of the world population (Baroudy et al., 2005). Based on lessons learned through natural hazards, threats demonstrated with prospective scenarios and in line with emerging policies, Mediterranean countries have started to adopt modern and more sustainable management tools. Regional binding documents and fora help to raise awareness among stakeholders and water professionals.

Table 2 summarizes the present situation with regard to the use of resources, ruling policies, trends and emerging policies.

Bearing in mind that Mediterranean countries are closely interdependent, sharing the same resources, the way to "reconcile development with the environment" can be facilitated through "dialogue; solidarity and exchange of information".

TABLE 2. Existing and emerging policies in Mediterranean countries.

Existing situation
• Rise in water supply
• Growth of conflicts between uses
→ Control of water demands
Similarities between Mediterranean countries
• Irrigated agriculture is the highest water consuming sector (70% on the average)
• Many countries rely on irregular water resources → construction of dams, water transfer between basins
• Heavy sediment loads in the Southern countries where resources are the most scarce (0.5–3%)
• Overexploitation → salinization of coastal aquifers
• Utilization of non-renewable resources in the SMC&EMC
Trends: use of non-conventional water use
Use water several times
• Urban wastewater reuse in agriculture (SMC, EMC)
• Drainage water recycling (SMC, e.g. Egypt)
• Use brackish water for certain crops
• Desalination of saline/brackish water
• Growing consideration to environmental flow
Ruling policy
• Principle of unity
• Preservation of water ecosystems
• Consensus among stakeholders
• Water is an economic good

(continued)

TABLE 2. (continued)

• Management of international water resources based on the principles of international law

Legislation
• Many laws & decrees
But
• Inadequate enforcement
• Responsibilities spread over several institutions
But
• Contradicting duties under the same body

Emerging institutional policies
• Administrative deconcentration/decentralization
• Cost recovery
• Polluter pays principle
• Progressive tariff structure
• Separate budget/re-allocation of water services income
• Cross-subsidy
• WUA's in agriculture
• Delegated management in municipal water

Acknowledgments

This paper is based on the study 'Water Politics in Mediterranean Countries' prepared in 2000 and updated in 2005 and also on the national report entitled 'Water demand management in the Mediterranean, progress and policies' presented at the Zaragoza Forum in March 2007. Both of the studies were supported by the UNEP/MAP/Blue Plan. Data was provided by 13 riparian Mediterranean countries.

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CHESAPEAKE BAY PROGRAM – A WATERSHED APPROACH TO MANAGEMENT

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Abstract: The Chesapeake Bay Program is a unique regional partnership that directs and conducts conservation actions in the Chesapeake Bay watershed directed at sustainable use and development. It brings together local, state, and federal governments; non-profit organizations; watershed residents; and the region's leading academic institutions in a partnership effort for protection, restoration, and application of sustainable management of the Bay. Those involved in the Chesapeake Bay Program have committed to a partnership directed at reducing pollution, restoring habitat, and sustainably management principles. This paper presents the history of this partnership and a description of its organization, identification of sustainable management principles and the Bay Program goals, an assessment of the health of the Bay, and status report on the progress toward sustainable management.

Keywords: Chesapeake Bay; Chesapeake Bay Program; watershed management; sustainable management

1. Introduction

The Chesapeake Bay is North America's largest and most biologically diverse estuary, home to more than 3,600 species of plants, fish, and animals (Figure 1). For more than 300 years, the Bay and its tributaries have sustained the region's economy and defined its traditions and culture. It is a resource of extraordinary productivity, worthy of the highest levels of protection and restoration directed at sustaining the Bay's beauty and bounty. The Bay's watershed covers an enormous 64,000-mile^2 area that includes parts of six states – Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia – and all of the District of Columbia. Billions of gallons of water flow each day through thousands of streams and rivers that eventually empty into the Bay. While the size of its watershed contributes to its productivity, it also helps contribute to its problems. With a watershed land to Bay water volume ratio seven times that of any other major estuary in the world, the

İ.E. Gönenç et al. (eds.), Sustainable Use and Development of Watersheds, 435–451.

Figure 1. Chesapeake Bay watershed.

Bay must process runoff from a large amount of land with a relatively small body of water.

The cumulative impact of centuries of population growth (currently over 16 million) and landscape changes has taken its toll. The human population in the Chesapeake watershed is now growing by more than 170,000 residents annually. A healthy Bay requires balancing the needs of the region's people and economy with the needs of the Bay for clean waters and ample habitat for aquatic life. The goal of Bay restoration is to restore this balance by reducing pollution, protecting and restoring critical habitat, and ensuring sustainable populations of fish and shellfish.

In 1983 the states of Virginia, Maryland, and Pennsylvania; the District of Columbia; the Chesapeake Bay Commission; and the U.S. Environmental Protection Agency, representing the federal government, signed an agreement that established the Chesapeake Bay Program partnership for protection, restoration, and sustainable management of the Chesapeake Bay watershed. The partners to this agreement have worked together to ensure clean water and a healthy and productive resources throughout the watershed. They sought to protect the health of the public that uses the Bay and consumes its bounty.

The restoration efforts have attempted to reverse the decline of the Chesapeake Bay's health. The initiatives have produced significant results in the health and productivity of the Bay's main stem, the tributaries, and the natural land and water ecosystems that compose the Chesapeake Bay watershed. Although there are a number of success stories and incremental progress has been made, the over-all ecosystem health remains degraded. Progress is not calculated on a day-to-day basis in the Bay watershed as is the case in any environmental restoration initiative. However, by using detailed scientific data that have been collected, analyzed and interpreted, changes in the health can be seen over time. Change is occurs, but slowly!

While the individual and collective accomplishments of the efforts have been significant, even greater effort will be required to address the enormous challenges that lie ahead. Increased population and development within the watershed have created ever-greater challenges for the Bay's restoration. These challenges are further complicated by the dynamic nature of the Bay and the ever-changing global ecosystem with which it interacts. In order to achieve the existing goals and meet the challenges that lie ahead, the basic partnership goal is sustainable management – manage for the future. The partners have a vision – a system with abundant, diverse populations of living resources, fed by healthy streams and rivers, sustaining strong local and regional economies, and preserving the unique quality of life. The partners recognize the importance of viewing this vision in its entirety, integrated with no single part taken in isolation of the others. The vision reflects the Bay's complexity in that each action taken, like the elements of the Bay itself, is connected to all the others. The common vision agreed upon responds to the problems facing the ecosystem in a comprehensive, multifaceted way. And, have committed to put programs into place that will secure it. To realize the vision, the partners have commitment to engage everyone – individuals, businesses, schools and universities, communities and governments – in the effort. All citizens of the Chesapeake Bay watershed must be encourage to work toward a shared vision that brings all stakeholders together.

2. The Chesapeake Bay watershed partnership – implemented through the Chesapeake Bay program

Formation of Chesapeake Bay Program – In the late 1970s, the U.S. Congress funded $27 million for a five-year study to analyze the rapid loss of living resources that was devastating the Bay. The study identified an oversupply of nutrients as the main source of the Bay's degradation. The publication of these initial research findings in the early 1980s led to the creation of the Bay Program as the means to restore this exceptionally valuable resource.

History of Chesapeake Bay Program – The Chesapeake Bay was the first estuary targeted by the U.S. Congress for restoration, protection, and application of sustainable management principles. Since the formation of the Bay Program in the 1980s, the partners have signed several agreements to reduce pollutants into the Bay and restore its living resources. In addition to these agreements, each year the Chesapeake Executive Council meets to reaffirm its commitment to Bay. New policy documents are signed annually to address needs for adaptive management given emerging issues or new opportunities.

Chesapeake Bay Agreement of 1983 – The original Agreement Chesapeake Bay Agreement, a simple, one-page pledge by the partners to work together to restore the Bay, was signed in 1983 by the governors of Maryland, Virginia, and Pennsylvania; mayor of the District of Columbia; the administrator of the Environmental Protection Agency; and the chairman of the Chesapeake Bay Commission, a tri-state legislative body. The group that later became known as the Chesapeake Executive Council.

Chesapeake Bay Agreement of 1987 – In this Agreement, the Executive Council set a goal to reduce nitrogen and phosphorous entering the Bay by 40 percent by the year 2000. Agreeing to numeric goals with specific deadlines was unprecedented in 1987, but the practice has become a hallmark of the Bay Program.

Chesapeake Bay Agreement of 1992 – This Agreement focused at attacking nutrients at their source – upstream, in the Bay's tributaries. Also, a watershed-wide evaluation of toxics and a reduction strategy was initiated.

Chesapeake Bay Agreement of 1994 – Federal officials from 25 agencies committed to ecosystem management. This document outlined specific goals for management of federal lands as well as new cooperative efforts by federal agencies.

Chesapeake 2000 Agreement (EPA, 2000) – This Agreement set the course for Bay restoration and protection through year 2010. Also, headwater states of New York and Delaware committed to water quality goals (West Virginia was added in 2002).

How the Chesapeake Bay Program Works – The Chesapeake Bay Program is America's premier watershed partnership. Each of the Bay Program partners agrees to use its own resources to implement projects and activities that advance Bay restoration. The partnership defines its collective actions through formal, voluntary agreements and provides general policy direction through consensus documents, called directives. When partners sign Executive Council documents, they commit to use all their available resources to achieve the document's goals.

- Governors commit all state agencies to work to implement directive terms and meet the goals.
- The EPA administrator signs directives next to the Seal of the United States, representing the entire federal government, not just EPA.
- Chair of the Chesapeake Bay Commission signs directives next to the Commission's seal, signifying support of all partner state legislatures.
- Directive agreements are entered into voluntarily; however, they may result in mandatory actions. The agreement to reduce phosphorus, for example, was supported through state-mandated bans on phosphates in laundry detergent. Other actions, such as a forest buffer goal, are entirely voluntary, relying on partner advocacy, funding, and ability to work with willing landowners.

Chesapeake Bay Program Office – Day-to-day operation of the partnership is carried out by the Bay Program Office, located in Annapolis, Maryland. The Office houses the Bay Program's permanent staff, which includes federal, state, and non-government organizations employees representing:

- Alliance for the Chesapeake Bay
- Chesapeake Research Consortium
- Conservation Fund
- Environmental Protection Agency
- Interstate Commission on the Potomac River Basin
- Maryland Department of the Environment
- National Oceanic and Atmospheric Administration
- National Park Service
- U.S. Fish and Wildlife Service
- USDA Forest Service
- U.S. Geological Survey
- University of Maryland
- Virginia Technical University

This office supports the Executive Council "by implementing and coordinating science, research, modeling, support services, monitoring, data collections, and other activities that support the Chesapeake Bay Program."

Chesapeake Bay Program Structure – The Bay Program works through a series of committees: Principals' Staff Committee is composed of cabinet-level representatives from the states and District of Columbia, EPA's regional administrator, representative from the Bay Commission, and the Bay Program director. It serves to advise the Executive Council and provide policy and program direction to the Implementation Committee. This group is composed of senior managers from each of the partners, chairs of the Program's subcommittees, federal agency representatives, and other restoration leaders. It directs and coordinates all of the subcommittees and workgroups under it. Subcommittees draw upon experts from throughout the watershed. Thus, academic experts, advocacy organizations, and others become active members of the broad restoration partnership. Subcommittees have Work Groups that meet regularly to develop and implement management actions needed address the commitments of the Executive Council. The Bay Program Office director chairs the Implementation Committee, and the Bay Program Office supplies the staff to support the work of the committees and subcommittees.

3. Sustainable management principles and Chesapeake Bay program goals (EPA, 2000)

Water Quality Protection and Restoration Principles – Improving water quality is the most critical element in the overall protection and restoration of the Bay and its tributaries since achieving and maintaining water quality conditions is necessary to support living resources, including human-kind. Where actions fail to achieve established water quality goals, remedial measures needed to reach and maintain those goals are necessary. Pollution prevention must be a central theme in the protection of water quality. Protection freshwater flow regimes for riverine and estuarine habitats are, likewise, a basic tenet. Actions are needed to ensure improvements in water clarity in order to meet light requirements necessary to support submerged aquatic vegetation by reducing sediments and airborne pollution through source control. Remediation and clean-up of toxic pollution is needed to occur to protect living resources and human health. Finally, is necessary to monitor water quality conditions and adjusts management strategies accordingly, including evaluation of emerging issues such as airborne and non-point sources of chemical contamination. CHESAPEAKE BAY PROGRAM GOAL: Achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health.

Living Resource Protection and Restoration Principles – The health and vitality of the living resources provide the ultimate indicator of the success of the restoration and protection in any program of sustainable management. The Bay's fisheries and the other living resources that sustain them and provide habitat for them are central to the initiatives that must be undertaken.

The interconnectedness of the living resources and the importance of protecting the entire natural system must be recognized. The essential elements of habitat and environmental quality necessary to support the living resources must be identified. A key in protecting commercially valuable fisheries is harvest management with precaution to maintain fish health and stability and protect the ecosystem as a whole. Restoration of passage for migratory fish and work to ensure that suitable water quality conditions exist in the upstream spawning habitats upon which they depend is critical.

The actions to address sustainable management must be conducted in an integrated and coordinated manner. Actions must be continually monitored, evaluated, and revised to adjust to the dynamic nature and complexities of the targeted watershed and changes in global ecosystems. To advance this ecosystem approach the management needs to graduate from single-system to ecosystem functions and commit to expanding protection efforts by shifting from single-species to multi-species management. It is important to undertake efforts to determine how future conditions and changes in the chemical, physical, and biological attributes of the watershed will affect living resources over time. CHESAPEAKE BAY PROGRAM GOAL: Restore, enhance, and protect the finfish, shellfish and other living resources, their habitats, and ecological relationships to sustain all fisheries and provide for a balanced ecosystem.

Vital Habitat Protection and Restoration Principles – A watershed's natural infrastructure is an intricate system of terrestrial and aquatic habitats, linked to the landscapes and the environmental quality of the watershed. It is composed of miles of river and stream habitat that interconnect the land, water, living resources, and human communities of the watershed. These vital habitats – including open water, underwater grasses, marshes, wetlands, streams, and forests – support living resource abundance by providing key food and habitat for a variety of species. Submerged aquatic vegetation reduces shoreline erosion while forests and wetlands protect water quality by naturally processing the pollutants before they enter the water. Long-term protection of this natural infrastructure is regarded as essential.

In managing an ecosystem as a whole, there is a need to focus on the individuality of the tributaries – each river, stream, and creek. Their protection must be secured in concert with the communities and individuals that reside within these small watersheds. Management must continue to refine and share information regarding the importance of these vital habitats to fish, shellfish, and waterfowl. Efforts to preserve the integrity of this natural infrastructure will protect the waters and living resources and will ensure the viability of human economies and communities that are dependent upon those resources for sustenance, reverence, and posterity. CHESAPEAKE BAY PROGRAM GOAL: Preserve, protect, and restore those habitats and natural areas that are vital to the survival and diversity of the living resources of the Bay and its rivers.

Sound Land Use Principles – There is a clear correlation between population growth and associated development and environmental degradation in aquatic systems. Future growth can result in cancelling nutrient reduction and habitat protection gains made in a restoration program. Therefore, it is critical that approaches be developed and implemented for land use in order to ensure progress in protecting watersheds. This will frequently involve difficult choices and require political will to enhancing, or even maintaining, the quality of the aquatic environment while accommodating growth. It will require a commitment to appropriate development standards. It also will be necessary to limit and mitigate the potential adverse effects of continued growth. In most cases, local jurisdictions have the authority over decisions regarding growth and development which have both direct and indirect effects on a watershed system and its living resources.

The role of local governments in watershed restoration and protection efforts needs recognition and support through state and federal resources/ incentives. A basic premise must be that future development will be sustainable only if there is protection of natural and rural resource lands, limits be placed on impervious surfaces, and new growth in existing population centers be concentrate or suitable development areas served by appropriate infrastructure. Environmental, community, and economic goals must be integrated. This can be accomplished by promoting more environmentally sensitive forms of development that coordinate land-use, transportation, water and sewer, and other infrastructure planning. Funding and policies at all levels of government can not contribute to poorly planned growth and development or degrade local water quality and habitat. To advance these policies partnerships between national, state, regional, and local governments need to be established to protect the public's interests in the broader geographic area – the watershed. CHESAPEAKE BAY PROGRAM GOAL: Develop, promote, and achieve sound land use practices which protect and restore watershed resources and water quality and maintain reduced pollutant loadings in the Bay.

Stewardship and Community Engagement Principles – Watershed management is dependent upon the actions of every citizen in the watershed, both today and in the future. The cumulative benefit derived from community-based watershed programs is essential for progress toward a healthier environment. Promoting citizen engagement will result in a broad conservation ethic throughout the fabric of community life, and foster within all citizens a deeper understanding of their roles as trustees of their own local environments. Through their actions, each individual can contribute to the health and well-being of their neighborhood streams, rivers, and the land that surrounds them, not only as ecological stewards of the environment but also as members of watershed-wide communities. By focusing individuals on local resources, watershed-wide restoration will be advanced and sustained use and development is possible.

The future of the environment also depends on the actions of generations to follow. Opportunities for cooperative learning and action must be made available so that communities can promote local environmental quality for the benefit and enjoyment of residents and visitors is paramount. Assistance needs to be provided to assist communities throughout the watersheds to improving quality of life, thereby strengthening local economies and connecting individuals to the environment through their shared sense of responsibility. Financial and human resources need to be made available to localities to meet the challenges of restoring the environment. CHESAPEAKE BAY PROGRAM GOAL: Promote individual stewardship and assist individuals, community-based organizations, businesses, local governments, and schools to undertake initiatives to achieve the goals and commitments of this agreement.

4. Health assessment (EPA, 2007) – water quality

River Flow and Pollutant Loads Reaching the Bay – The 1987 Agreement included a commitment to achieving a 40 percent reduction in controllable nutrient loads to the Bay. The 1992 Agreement furthered the commitment to tributary-specific reduction strategies to achieve this reduction and agreed to stay at or below these nutrient loads once attained. Measurable reductions in pollution loading have been, and continue to be challenging given continuing growth and development.

Annual Chesapeake Bay water quality conditions are largely determined by a combination of the amount of pollution deposited on the land and the amount of water flowing into the Bay. As the volume of water flowing into the Bay – or river flow – increases, its potential to carry increased pollutants increases as well. Total river flow to the Bay varies from year to year. In recent years flows have been very close to the long-term average. Pollutant loads were close to average as well. However, their combined impact on the Bay may have been greater in 2006 and 2007, as flows and loads were greatest during the critical spring time period. Precipitation does not just increase river flows by washing directly off the land. Some water seeps into the land, carrying nutrients into groundwater. It can take years for these waters and their associated pollutants to slowly travel through underground systems until they reach the streams that drain into the Bay. Some of each year's pollutant load actually comes from pollution sources that are decades old as a result of the ground water feed to rivers.

Scientists calculate annual pollutant loads to the Bay through a combination of monitored water samples and modeled information. Whenever possible, scientists measure pollution levels in water samples from the point-source and rivers that flow into the Bay. Model generated estimates are used where monitoring is not practical. By capturing water samples at the point where large rivers meet the Bay, scientists can calculate pollution loads from 78 percent of the watershed. For the remaining area, model generated estimates are used. This combination of monitoring and modeling data allows scientists to provide the most complete accounting of the amount of pollution reaching the Bay.

Provisional estimates indicate that approximately 370 million pounds of nitrogen and 26.1 million pounds of phosphorus reached the Bay during the 2007 water year (October 2006 to September 2007). These amounts are well above the restoration target of 175 million pounds of nitrogen and 12.8 million pounds of phosphorus. Additional pollution-fighting measures are being put in place throughout the watershed to reduce annual pollution loads in the future. One of the most important is the low oxygen levels observed in the Bay and some of its rivers during the summer. To support a vibrant Chesapeake Bay ecosystem, waters must become clearer, oxygen levels higher, and the amount of algae and chemical contaminants in its waters must be reduced.

Recent actions taken under the federal Clean Water Act resulted in listing portions of the Bay and its tidal rivers as "impaired waters." These actions have emphasized the regulatory framework of the Act along with the ongoing cooperative efforts of the Bay Program as the means to address the nutrient enrichment problems within the Bay and its rivers. In response, the partners have developed, and are implementing, a process for integrating the cooperative and statutory programs. They have agreed to the goal of improving water quality in the Bay and its tributaries so that these waters may be removed from the impaired waters list prior to the time when regulatory mechanisms called for by the Clean Water Act would be applied.

Dissolved Oxygen – In the summer in recent years near-record low dissolved oxygen conditions existed in many parts of the Bay. In many areas, oxygen levels were insufficient to support resident aquatic life. Oxygen levels were lowest along the mid-channel areas of the Bay and its rivers, especially in the mid-Bay area. The low dissolved oxygen area is progressively lasting longer and covering an increasing larger area. Low oxygen conditions are the result of excess pollution combining with weather conditions and the bottom contour of the Bay. This saturation is exacerbated with heavier spring rains which wash large amounts of pollution into the Bay. Once there, the summer's light winds are unable to mix the Bay's waters, and large-scale low oxygen areas persisted in bottom waters. In recent years, higher than average water temperatures, which have resulted with summer drought conditions, have further reduced the water's ability to retain sufficient oxygen for aquatic life. Like terrestrial animals, the Bay's fish and shellfish need oxygen to survive. During summer months, a large volume of the Bay's waters does not hold enough oxygen to support them. Throughout the summers of 2006 and 2007, scientists estimate about 25 percent of the Bay met dissolved oxygen restoration goals designed to protect resident aquatic life. Over time, large-scale reductions in the amount of nutrients flowing into the Bay will help improve low oxygen conditions.

Mid-Channel Water Clarity – Clear waters are indicative of a healthier Bay, with acceptable levels of nitrogen, phosphorus, sediments, and algae in the water column. Water clarity is most important in shallow areas close to shore. Unfortunately, systematic monitoring of shallow water clarity has been underway for only the past few years and there are not yet sufficient data to provide a bay-wide assessment. However, water clarity in deeper, mid-channel, areas can be used to indicate general conditions and trends. Based on the mid-channel monitoring network, water clarity in 2006 and 2007 was better than in the previous two years, but the long-term trend is downward. About 45 percent of approximately 150 monitoring stations reported acceptable levels of water clarity. Assessed by measuring how far light can penetrate into the water column, improved water clarity will come from reduced amounts of nutrients and sediment flowing into the Bay and its rivers. Water clarity will always fluctuate annually, as it is greatly impacted by weather events, however, reduced nutrient loadings, abundant bay grasses, and healthy Bay life will help improve annual conditions.

Chlorophyll a – Scientists measure the amount of *chlorophyll a* (the green pigment in plants) in the Bay's waters to assess the amount of algae present. The Bay needs the right amount of microscopic algae to maintain a balanced food web. Too much algae can cause large-scale algal blooms that block sunlight from reaching bay grasses, reducing available habitat to aquatic organisms. Lower algal levels promote better water quality, more available habitat, and fewer harmful algal bloom effects. Scientists estimate that about 30 to 40 percent of the Bay's waters had acceptable *chlorophyll a* concentrations in 2006 and 2007. Bay scientists attribute the poor conditions to the pulse of nutrients washed into the Bay during spring heavy rains.

Chemical Contaminants – Chemical contaminants are not only found throughout the Bay's waters but also in the sediment and tissues of fish. When they reach certain levels, they can impact aquatic life and human health. One way scientists assess levels of contamination is to examine a group of harmful chemical pollutants called PCBs in tissues of white perch – a resident species of fish found in the Bay's rivers. Since perch tend to stay in the same river for their entire life, they serve as an excellent measure of chemical contaminants for that river. White perch examined in about 38 percent of the Bay's rivers have PCB levels safe for unrestricted human consumption. Generally fish from rivers on the more populated and urbanized western shore have higher concentrations than those on the rural, less populated eastern shore, and rivers further north have higher concentrations than those in the south, again, reflecting the level of urbanization and relative population. Scientists are also concerned about mercury levels in the Bay's waters, however, evaluation of this issue is just beginning.

5. Health Assessment (EPA, 2007) – habitats and lower food web

Bay Grasses – Submerged Aquatic Vegetation – Aside from the water itself, underwater bay grasses are one of the most important habitats in the Chesapeake Bay. As their health is closely related to the quality of local waters, grasses serve as an excellent barometer for the overall health of the estuary. Bay grass abundance has a profound effect on the Bay and its aquatic life, as it provides critical habitat to key species such as striped bass and blue crabs while improving the clarity of local waters. The most recent bay-wide data from 2007 show bay grasses covering 59,090 acres – or about 32 percent of the 185,000-acre restoration goal. This represents a decrease from 2006 when bay grasses covered 72,935 acres, about 39 percent. Variability from year to year is expected as weather and other conditions vary. The importance of this indicator is associated with the multiple year trends which is generally in a positive direction. In general however, as water clarity improves from nutrient and sediment pollution reductions, bay grass acreage should continue to expand.

Bottom Habitat – The health of the Bay's bottom dwelling, or benthic, communities is greatly reduced when pollution levels increase and oxygen levels drop. Benthic habitats serve as a good indicator of long-term environmental conditions, as their inhabitants are long-lived, have limited mobility and their responses to stress are well documented. In 2006 and 2007, about 41 percent of the Bay's benthic habitat was considered healthy as measured by the composite Benthic Index of Biotic Integrity. Scientists attribute the decline from 2004 to 2007 to low dissolved oxygen levels during the summer. Reduced amounts of nutrients, sediment, and chemical contaminants flowing into the Bay will help these bottom dwelling communities improve.

Phytoplankton – Microscopic plants commonly called algae, – are an excellent indicator of the health of the Bay's surface waters, as they are especially sensitive to changes in nutrient pollution, water clarity, temperature, salinity, and grazer communities. Phytoplankton are primary producers and form the base of the food web. While increased populations provide more food to organisms further up the food web, too much or the wrong type of algae can harm the overall health of the Bay. In some cases, harmful algal blooms can impact human health. Scientists assess microscopic algal community health with a Phytoplankton Index of Biotic Integrity. Data from spring

2006 show that about 9 percent of the Bay's phytoplankton communities were considered healthy. In 2007 spring monitoring results indicated that about 36 percent of the phytoplankton communities were healthy. This demonstrates the variability in this indicator, which can occur nearly daily with changes in surrounding environmental conditions (e.g. weather conditions). Again, this underscores the need to regard this and certain other indicators as demonstrating trends (verse short-term assessment) and as part of broader evaluation of multiple indicators of the Bay's health. Again, nutrient reduction will assist in the overabundance of phytoplankton in the Bay.

Tidal Wetlands – Wetlands that are tidally flooded by salt or brackish water and are found chiefly along the shores of the Bay and its tidal rivers. Wetlands link land to the water. In both tidal and non-tidal parts of the Bay, they serve as critical habitat to terrestrial and aquatic life, and act as natural filters and sponges by absorbing runoff and removing pollutants from water before they can reach local streams and the Bay. Many researchers believe Bay tidal wetlands are threatened by sea level rise, storms, shoreline development, and invasive species. However, regulatory programs have significantly reduced the impacts of development in recent years. There also are programs that are addressing invasive species problems and providing incentives for restoring wetland on private lands. As of 1993, there were approximately 282,000 acres of tidal wetlands in the Bay. Assessments of acreage in 2001 and 2005 are pending data analysis. Measuring the health and acreage of wetlands throughout the watershed is a difficult and expensive task. Regional scientists are currently developing methods to assess wetland function and track changes in acreage on a watershed level.

6. Health assessment (EPA, 2007) – fish and shellfish

Blue Crab: An edible, bluish swimming crab (*Callinectes sapidus*) that has a wide distribution in the Bay and along the Atlantic and Gulf coasts of North America. It is estimated that more than one-third of the nation's blue crab catch comes from the Bay. Commercial harvest from the Bay between 1968 and 2005 averaged around 73 million pounds. The most recent harvests have been approximately 60 million pounds, a significant reduction. The low harvest corresponds to low exploitable stock abundance but also reflects restrictive management measures adopted in 2001. In 2007, the abundance of adult crabs in the Bay remained well below the restoration goal. Scientists estimate that the population of blue crabs in the Bay in 2006 is about 57 percent of the 232 million crab interim goal. Blue crab abundance has been below the target for the past ten years. These numbers are estimated through winter dredge and summer trawl surveys. The blue crab fishery is vulnerable to exploitation; therefore, harvest restrictions will continue to remain in place. Proper management of the crab harvest, improved water quality, and habitat restoration efforts will help restore the Bay's blue crab populations.

Striped Bass: *Morone saxatilis* is chiefly a coastal waters fish, having dark longitudinal stripes along its sides. Striped bass swim up the Bay to spawn. The population has dramatically increased over the past decade in the Bay. Scientists attribute this increase to a 1980s fishing moratorium and responsible fisheries management since the lifting of the fishing ban. In 1995, populations had increased to the point where the species was considered restored. While biomass remains high, data gathered over the past three years show a slight decline. Scientists are concerned over the species' health, as a large percentage of striped bass suffer from poor nutrition and 60 to 70 percent of the population is infected with the disease mycobacteriosis. Research is underway to better understand the disease's impact on stocks. The current status of Bay striped bass – high abundance but uncertain health – illustrates the need for an ecosystem-based fisheries management approach in Bay.

Oysters: An edible bivalve mollusk (*Crassostrea virginica*) which lives in a wide range of depths and salinities of the Bay. For more than a century, oysters constituted one of the Bay's most valuable commercial fisheries. Over-harvesting, pollution, and diseases have caused a severe decline in their numbers. Scientists estimate that the population of native oysters in the Bay in 2007 is about 7 percent of the restoration goal.

American Shad: *Alosa sapidissima*, a fish that occurs along the Atlantic coast from southern Labrador to northern Florida. American shad undergo extensive seasonal migrations, moving into rivers to. After spawning, shad migrate north along the coast to Canada where they feed during the summer. A southward migration occurs later along the continental shelf where the fish overwinter prior to spring spawning migrations to their natal rivers. The introduction of hatchery raised fish, a moratorium on shad fishing, the removal of dams, and installation of fish passages on key Bay tributaries have helped to increase the number of shad returning to the Bay. One of the ways scientists currently estimate spawning shad populations is by counting the number of fish annually lifted over Conowingo Dam near the mouth of the Susquehanna River, the major tributary to the Bay. Annual estimates have increased from several hundred per year in the early 1980s to an average 101,140 per year in 2003–2007. In spite of their increased abundance, the Susquehanna River population is far below the long-term restoration goal of two million fish. Assessing the annual bay-wide spawning populations is difficult as each river stock is unique. To provide better bay-wide estimates, scientists are developing new monitoring methods to estimate populations in other key Bay tributaries.

Atlantic Menhaden: *Brevoortia tyrannus* are small schooling fish related to herring, shad, and sardines. Menhaden consume large quantities of phytoplankton and zooplankton, and are themselves a favorite food of striped bass, bluefish, sea trout, tunas, sharks, and sea birds. Menhaden spawn in the ocean, in waters off Chesapeake Bay. Scientists currently do not produce Bay-specific population estimates of menhaden. Estimates are made on an Atlantic Coast-wide basis. Populations along the Atlantic Coast appear to be healthy, however, reductions in Bay harvest of the species over the last several years has concerned scientists. Further, the number of juvenile menhaden in Chesapeake Bay has been declining in recent years, with current recruitment levels being about 50 percent lower than the mid-1980s. In 2006, Virginia placed a cap on the amount of menhaden that can be harvested annually from the Chesapeake Bay by the commercial fishing industry. Maryland currently prohibits the commercial industry from harvesting menhaden from Maryland waters. Since menhaden are an important forage species in the Bay food web, a number of studies are underway to assess their status in the Bay.

7. Conclusions

The Chesapeake Bay is at a crossroads, with its future health still at stake. For over two and a half decades restoration efforts have been underway to reverse the decline of the Bay health, but the cumulative impact of centuries of population growth (currently 16 million) and landscape changes has taken its toll.

Water Quality – Most of the Bay's waters are degraded. Each summer, a large expanse of its waters does not hold enough oxygen to support striped bass crabs, and oysters. Algal blooms fed by nutrient pollution block sunlight from reaching the underwater bay grasses needed to support aquatic life. Sediment from urban development and agricultural lands is carried into the Bay, clouding its waters and covering critical oyster reef habitat. Currently, about one-third of Bay water quality goals are being met. High quality waters are the foundation of a healthy Chesapeake Bay. To support a vibrant Bay ecosystem, waters must become clearer, oxygen levels higher, and the amount of algae and chemical contaminants in its waters must be reduced.

Habitats and Lower Food Web – The Bay's critical habitats and food webs are at risk. Nutrient and sediment runoff have harmed bay grasses and bottom habitat. Excessive algae growth has pushed the Bay food web out of balance. Historically, a large portion of the Bay's wetlands were lost to development. Losses have been stemmed by regulatory programs that require avoidance or compensation for impacts. In addition, there are federal and state programs that provide incentives for wetland and forest land restoration. Currently, the Bay's habitats and lower food web are at about a third of desired levels. Life in the Bay needs high-quality food and habitat to thrive. From the clams and worms that live within the Bay's bottom, to the rockfish that prowl its open waters, to the juvenile fish and crabs darting among underwater grasses and wetlands, habitat supports the Bay's aquatic life. When healthy habitat is supported by a balanced food web, healthy aquatic communities can flourish. As both of these areas improve, the ecosystem's potential to support larger and more diverse populations of aquatic life expands as well.

Fish and Shellfish – Many of the Bay's fish and shellfish populations are below historic levels. The number of adult blue crabs is below the long-term average for the seventh straight year and oyster populations are at or near historic lows. American shad are recovering slowly, while other species like striped bass show mixed signals. Current striped bass populations exceed restoration goals, but approximately 60 to 70 percent are infected by a disease called mycobacteriosis. Researchers are currently working to understand the extent and severity of the disease and the extent to which environmental conditions in the Bay influence it. Ecosystem-based goals are not yet developed for fish and shellfish species. The long-term health and sustainability of the Bay's fish and shellfish is critical to restoring ecosystem health. Ample aquatic habitat, clean water, and well-managed fisheries are key components to restoring abundant fish and shellfish populations to the Bay. Scientists and natural resource managers are working to develop ecosystem based fisheries management strategies which take into account numerous factors when setting harvest targets, including the species' role in the food web and other water quality, habitat, and climatic considerations. These strategies need to be further developed and ecosystem goals defined to compare annual data to population targets for a balanced Bay system.

Health of the Bay over Multiple Years – With about three-quarters of the nutrient pollution entering the Bay through surface runoff and groundwater, the annual health of the Bay is largely driven by the amount of pollution deposited on the landscape coupled with weather conditions across its vast watershed. Rains, especially heavy downpours, wash pollution off the land and into local streams and eventually the Bay. In years where there is less rainfall and lower river flow, the Bay's tidal waters will likely be clearer, hold more oxygen and generally be much healthier. Conversely, high rainfall years will generally lead to poorer water quality conditions. The challenge to Bay restoration partners is to reduce the amount of pollution flowing into the Bay in all years. Restoring the land's ability to naturally filter water and putting in place pollution-fighting practices across the entire watershed is needed to improve Bay health and reduce annual variability.

Improving the Health of the Bay – Although there are a number of smaller-scale success stories, the overall ecosystem health of the Bay remain degraded. For more than 20 years, restoration efforts have managed to offset the impact of the region's growing population while making modest ecological gains in some areas. Major pollution reduction, habitat restoration, fisheries management, and watershed protection actions taken to date have not yet been sufficient to restore the health of the Bay. Water quality dips dangerously low during some critical periods annually, and essential habitats face constant pressure. The restoration's goal of "abundant, diverse populations of living resources" will require improvements in water quality and other habitat as well as improved fisheries management.

Chesapeake Bay Program: A Watershed Partnership – For more than 25 years, watershed residents have worked with government leaders to put in place programs to restore and protect the Bay and its watershed. The Chesapeake Bay Program brings together state and federal governments, non-profit organizations, watershed residents, and the region's leading academic institutions in a partnership effort to protect and restore the Bay. Partners have developed science-based plans to improve the waters, habitats, and fisheries of the Chesapeake. On-the-ground efforts are taking place throughout the 64,000-mile^2 watershed and new initiatives are being implemented to accelerate progress. While those efforts have been numerous and widespread, they have not been enough to yield large-scale improvements in water quality and habitat. The health condition of the Bay without the Chesapeake Bay Program is hard to estimate, however, it is reasonable to conclude that the conditions would be a significantly more degraded.

References

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PART 4

CONCLUSIONS AND RECOMMONDATIONS

Workshop Groups Reports

DECISION SUPPORT SYSTEMS AND TOOLS

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1. Concept of Integrated Watershed Management

Traditionally water is managed by different geographical compartments (e.g. rivers, reservoirs, lakes, estuaries, ground) using specific tools for each compartment and often by different institutions. When specific tools are used for each compartment, the interactions between compartments are specified through boundary conditions (e.g. aquifer recharge in case of aquifer management), which must be set by means of field data describing spatial and temporal variability.

The specification of the boundary conditions between compartments into a watershed causes errors in hindcasting and makes forecasts difficult

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because data related to boundaries must be forecasted or generated. IWRM solves this difficulty because management tools for all the geographical compartments are coupled and used interactively. The implementation of an integrated approach is more complex, but its exploitation is much more economical, minimizing the amount of data required for running the models.

Another advantage of the integrated approach is that the modelling system provides results to all the stakeholders in the catchment and consequently it stimulates the cooperation among them. In the framework of this cooperation it will be easier to share knowledge, data and working methods, with advantages in terms of investment and terms of solutions acceptance by stakeholders.

2. Decision Support Systems and Tools for Integrated Watershed Management

Decision making process is extremely complex even at small scales, and needs to be supported by different tools providing assessment (e.g. models) and visualization (e.g. GIS) functionalities with the aim of building consensus on a transparent and common decision. In this context, Decision Support Systems (DSSs) can be seen as systems that help decision makers in structuring and evaluating decisions by providing easy-to-use and integrated tools for information elaboration and displaying (Watkins and McKinney, 1995; Loucks, 1995; Shim et al., 2002). This way, DSSs are able to automate the decision-making process, making it flexible, repeatable, changeable, traceable and transparent. A DSS provides integration capabilities of data and tools that allow managing a large variety of information, to take into account environmental and socio-economic viewpoints, to include expert judgment and to facilitate participation and preferences elicitation of all interested parties (i.e. decision makers and stakeholders). This process is often supported by using Multi Criteria Decision Analysis methods (Kiker et al., 2005).

The decision tools and DSSs could be best described in terms of their general type and by focusing on the stage of application in the decision process being supported, from information gathering, through storage, to exploring alternatives. Information collection and management, modelling and rational decision support, visualization and the human interface, group decision making, knowledge capture and representation and DSS integration are the issues worthily to be mentioned.

A key capability of DSS is the interoperation of tools obtained from different sources. Decision maker would be able to choose the appropriate tool for a particular job and provide for input and output of transfer information as he explores the alternative decisions. This transfer of information is still difficult at present, in spite of rapid development in the field. There is a clear move towards more open systems that will provide for data interchange in producing and monitoring natural resources such as plant coverage, water, or forests. Standards developed for GIS in United States, United Kingdom, France, Canada and Australia are good example in this regard. As a toolbox, a GIS allows performing spatial analysis using its geoprocessing or cartographic modelling functions such as data retrieval, topological map overlay and network analysis. Of all the geoprocessing functions, map overlay is probably the most useful tool for planning and decision-making. For example, there is a long tradition of using map overlays in land suitability analysis. Decision makers can also extract data from the database of GIS and input it into different modelling and analysis programs together with data from other database or specially conducted surveys. GIS has been widely used in information retrieval, development control, mapping, site selection, land use planning, land suitability analysis, and programming and monitoring. GIS can be seen as one form of spatial DSS.

It is difficult to suggest application of some specific systems since it depends on management goals and needs of each end user. However, some main characteristics should be considered in identifying which is the most appropriate Decision Support System (DSS) to be applied. First of all, the conceptual framework of the system should fit in management goals of end users; it should be adaptable to the case-study of concern and to the associated legislative context. There are also some functionality that could be more useful for end users as integration capabilities of tools for environmental assessment and socio-economic analysis, comparison and evaluation of alternative management scenarios, prioritization of issues (stressors, areas, etc.), GIS-based visualization tools, methodologies for facilitating involvement of groups of decision makers and stakeholders. A recent trend in developing Decision Support Systems (DDS) is to implement web-based systems where some functionality runs as online resources (e.g. databases, models).

Different tools are used for integrated watershed management as listed below:

- Monitoring system as a tool for collecting data about environmental conditions
- Approved system of indicators and indexes, threshold analysis as the tools for making assessment of today situation
- Watershed models for water quantity, quality, biological aspects (better to have it in operational using) as the tools for scenario impact assessment, forecasting, hindcast cause analysis
- GIS based data base as a tool for collecting information, data and facts:

  - Cadastre of river basins and water bodies:

    List of river basins and water bodies with hydrographic descriptions

    Water balances, nutrient balances, sediment balances for them

  - Cadastre of water users

- Time series of data about water conditions and land uses evolution (remote sensing or field survey)
- Facts on extreme events (floods, droughts, blooms…) in descriptive form (usually there are no measurements during extreme events) that suppose a specific monitoring protocol/system (more data are essential to describe extreme hydrological functions and consequences on the ecosystem) only working when extreme event occurs

- Decision making systems to support decision making directly (multi criteria analysis tools, etc.). DSS must include knowledge based tools (such as expert systems or other types of tools using Artificial Intelligence technology or local knowledge i.e. participation)
- Expert Councils, Associations of Water Users etc. as the tools of public and expert involvement to achieve the highest quality of decisions and build a global acceptation of decisions
- Open databases (for public and water users) as a tool for public involvement

More detailed information related to these tools is given in the following sections.

2.1. ENVIRONMENTAL MONITORING

Environmental monitoring supplies the data required to describe the existing status of the water dynamics and quality by utilizing selected parameters measured over time. Temporal and spatial variations of parameters also provide the basic data for other decision support system tools such as GIS and models, which are used in the further stages of the decision-making process.

Monitoring programmes should take into account different aspects of aquatic systems related to physico-chemical conditions (e.g. Temperature, pH, oxygenation, nutrients, etc.), pollution levels in sediment, water column and biota tissues (i.e. chemical concentrations of organic substances, heavy metals, emergent pollutants, etc.), abundance and composition of different biological communities (e.g. macroinvetebrates, fish, macrophytes, etc.) and finally hydromorphological conditions (e.g. riparian zone, substrate, river flow, etc.). Monitoring systems should avoid bypass situations due to extreme events. Monitoring of groundwater and its quality is an important issue in integrated water resources management and should not be bypassed.

2.2. MODELS

Models are useful tools for decision-making, as they provide a better understanding of mechanisms, processes and carrying capabilities of the system as well as the response of the systems under the stress of different pollutant inputs. A model provides the scientists, engineers and managers with predictions based upon the best scientific information available. In this manner, the basic advantages and drawbacks for various management options, which may be applied for the future, can be put forth. The basics of modelling are explained in standard texts such as Thomann and Mueller (1987), Chapra (1997) and Lung, 2001. More advanced or specific aspects of modelling are given by Gonenc and Wolflin (2005), Loucks and van Beek (2006), and Gonenc et al. (2007). The basic steps common for many modelling studies, where models are used as decision support system tools are illustrated in Figure 1. This figure indicates that models are living tools, which need to be verified and updated continuously.

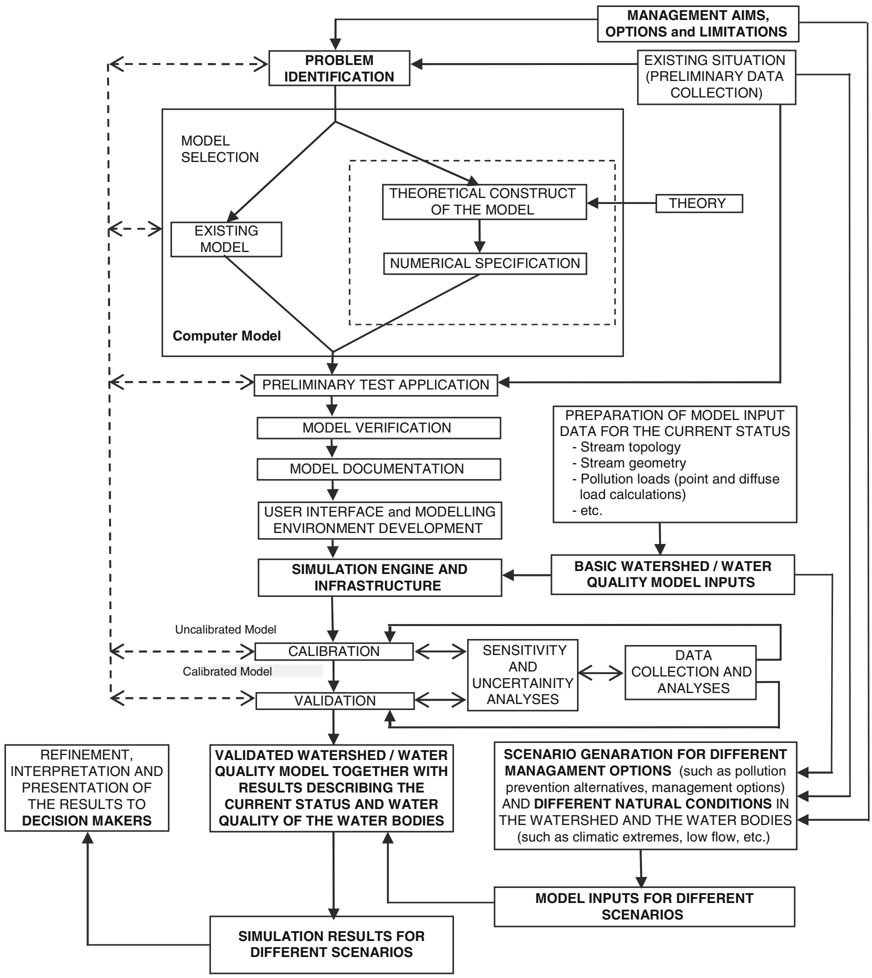

Figure 1. The modelling process.

Models may be employed to acquire the knowledge about the watersheds object of the study. On the basis of these knowledge sound scenarios analysis may be performed to evaluate the efficacy of management or restoration alternatives. Sometimes these models may serve itself as elements supporting the decision making process or provide the input to Decision Support System utilities.

In many situations models are only used to forecast future status of watershed systems. However models have also another important descriptive function. They can help a lot in the understanding of the functioning of watersheds. The combination of different techniques may contribute to extract precious information from the available set of water quality measurements offering unique insights about key-features of watersheds such as the source apportionment of pollutant loads carried by water bodies. That was the case of the research described by Azzellino et al., 2006, where Qual2E simulations, used in combination with Factor Analysis, showed hidden features such as the groundwater exchanges to the surface water system, and gave insights about the effect of non point sources on the instream water quality also during dry weather conditions. Using the same perspective, the research described by Salvetti et al., 2006 allowed the assessment of apportionment between point and non point sources of the total nutrient load carried by Po River to the Adriatic Sea. On the other hand, the same authors (Salvetti et al. in press) used SWAT model as forecasting tool to evaluate the benefit of a “better-business scenario” (i.e. the full implementation of agricultural policy measures for reducing nitrate discharges) versus the “business-as-usual” agricultural management scenario.

The MODELKEY Decision Support System (DSS) is currently under development within the European MODELKEY project (2005–2010; www.modelkey.org) and the prototype will be applied and tested on three case studies: Elbe, Scheldt and Llobregat river basins. The system aims at integrating and interlinking a set of exposure models, effect models and analytical methods developed within the project in order to provide decision makers with useful functionalities for assessment and management of river basins according to EU Water Framework Directive (EU WFD). Specifically, the DSS leads to calculate Integrated Risk Indices (IRI) based on Multi Criteria Decision Analysis (MCDA; Kiker et al., 2005) for identification of significant pressures, for evaluation and classification of quality status, for prioritization of hot spots by considering both environmental and socio-economic perspectives, for identification of causes and most impaired endpoints. Moreover the risk-based methodology will be developed in a close collaboration with potential end users, decision makers and stakeholders related to the three case studies in order to address their specific needs and expectations. The web-based software system will be implemented in an open source GIS environment.

The SHYFEM model is an integrated model solver for basic physical parameters of hydrodynamics (currents, water levels, temperature and salinity) but has integrated also a sediment transport module for cohesive and non-cohesive sediments in suspended and bed load and a water quality model EUTRO of the WASP package of US-EPA. A wave module is also present. The model is especially well suited for very shallow lagoons and coastal areas due to its stable resolution of the underlying equations. The model is of finite element type which means that the triangular mesh can adapt easily to complicated geometries and morphologies and is not limited to a fixed quadratic regular grid. Zooming at interesting features and hot spots is easily possible. The model has been applied extensively to the Venice lagoon, which is very shallow with deep narrow channels cutting through large shallow flats. Moreover, it has been applied to other Italian (Orbetello, Taranto, Cabras), Mediterranean (Melieha Bay in Malta, Nador in Morocco), European (Curonian lagoon in Lithuania, Danube Delta in Romania) and other lagoons (Tam Giang – Cau Hai in Vietnam). The model can be downloaded from http://www.ve.ismar.cnr.it/shyfem/ free of charge.

The MOHID Land Model is a watershed distributed model focused on solving the fundamental physical equations for water flow, including Richards equation for infiltration, St. Vennant for river flow and a diffuse wave for overland flow. It includes the sediment water quality processes described in RZWQM, and several water quality modules can be used to model water quality in river flow, including routines similar to WASP and CEQUAL-W2. As a simplified calculation model, we can mention the OSPAR guidelines that can estimate diffuse nutrient loads based on a source oriented approach, where all the sources in a basin are accounted and multiplied by a retention coefficient and the load oriented approach, that requires data on both flow and water quality parameters. The MOHID Land Model and SWAT both coupled or standalone have been applied in several watersheds in Portugal to obtain nutrient loads to reservoirs. The model can be downloaded from www.mohid.com free of charge.

COHERENS (http://www.mumm.ac.be/EN/Models/Coherens/) is a modelling framework developed during some EU projects that solves the hydrodynamic equations together with an ecosystem model. The model can be applied to coastal ocean, shelf seas and the open ocean. Of the same type (finite differences) are the POM (Princeton Ocean Model) (http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/) and its successor ROMS that includes modules for waves, sediment transport and ecology. All of these models are freely downloadable from the Internet and enjoy a large user community that can also help for all kind of questions that might arise during the application of the models.

AQUATOX is a simulation model for aquatic systems. AQUATOX predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants. AQUATOX is a valuable tool for ecologists, biologists, water quality modellers, and anyone involved in performing ecological risk assessments for aquatic ecosystems. The model can be downloaded free of charge from USEPA, http://www.epa.gov/athens/wwqtsc/html/aquatox.html and relevant training materials are published on web page http://www.epa.gov/waterscience/models/aquatox/training/.

QUAL2K (or Q2K) is a steady state stream water quality model that is intended to represent a modernized version of the QUAL2E (or Q2E) model (Brown and Barnwell, 1987). Q2K is similar to Q2E in the following respects: It is one dimensional along the stream channel. The channel is well-mixed vertically and laterally. Steady state hydraulics with non-uniform, flow is simulated. The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale. All water quality variables are simulated on a diurnal time scale. Point and non-point loads and abstractions are simulated. It is quite easy to learn and to implement in the new Microsoft Excel user interface. Documentation about how to use it is provided together with model when downloading. It's complete because it considers the kinetics of all the processes (e.g. Algae, nutrient cycling etc.) that were implemented in QUAL2E. With respect to QUAL2E, it gives the possibility to use a better speciation of the organic matter component (i.e. slowly oxidizing carbonaceous biochemical oxygen demand, fast oxidizing carbonaceous biochemical oxygen demand, not biodegradable detritus) and it allows simulating additional water quality variables such as alkalinity, and pH. Sediment-water interactions are also described. The kinetics of the model can be considered quite detailed enough for most of the general water quality studies, however the hydraulics of the model is extremely simplified. QUAL2K can be downloaded from http://www.epa.gov/athens/wwqtsc/html/qual2k.html.

BASINS is a multi-purpose environmental analysis system that integrates a geographical information system (GIS), national (United States) watershed data, and state-of-the-art environmental assessment and modelling tools into one convenient package. It contains and integrates watershed, hydrology, diffuse load and water quality modelling tools. The latest version is 4.0, which is based on a free and open source GIS software called Map Window. It can be downloaded from http://www.epa.gov/waterscience/basins/ and relevant training material is published on web page http://www.epa.gov/waterscience/basins/training.htm.

The SWAT model (US Department of Agriculture, Arnold et al., 1998) is a physical based, basin scale model developed to predict the long-term impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions. It is integrated into USEPA's BASINS tool and also separately available. The model and its documentation are freely available from Internet. Besides the simulation of the effect of non point sources for the water quality of watersheds, it allows also the simulation of point sources on the river water quality by considering biochemical oxygen demand, nutrients and pathogens, using roughly the same processes and equations that are included in the USEPA QUAL2K model. SWAT is not considered to be very user-friendly and it is quite complex to implement especially in watersheds where the natural hydrology is overlaid by the anthropogenic network of drainage and irrigation channels. Moreover the simulation of the exchanges between groundwater and surface waters is extremely simplified and not reliable in many situations. Grounding on the fact that the USDA SWAT model does not allow a reliable simulation of the exchanges of water and pollutants between ground and surface waters, there is research going addressing this issue. Some work has been done (Conan et al., 2003; Galbiati et al., 2006) in the attempt of linking watershed scale models with models simulating the nutrient transport and transformation in the saturated zone. However very rarely such models rely on experimental data for what concerns the processes occurring in the soil layers (e.g. denitrification rates, nitrate leaching rates etc.), especially when large scale basins are involved. SWAT can be downloaded form http://www.brc.tamus.edu/swat/.

EPD-RIV1 is a system of programs to perform one-dimensional dynamic hydraulic and water quality simulations. The computational model is based upon the CE-QUAL-RIV1 model developed by the U.S. Army Engineers Waterways Experiment Station (WES). This modelling system was developed for the Georgia Environmental Protection Division of the Georgia Department of Natural Resources, Dr. Roy Burke III, Program Manager and the U.S. Environmental Protection Agency, Region IV, Dr. Jim Greenfield. EPD-RIV1 is a one-dimensional (cross-sectionally averaged) hydrodynamic and water quality model. It consists of two parts, a hydrodynamic code which is typically applied first, and a quality code. The hydraulic information, produced from application of the hydrodynamic model, is saved to a file which is read by, and provides transport information to, the quality code when performing quality simulations. The model can be downloaded from http://www.epa.gov/waterscience/basins/.

MONERIS (Behrendt et al., 2000) is specifically designed for the source apportionment of nutrients into watershed. MONERIS is not deterministic but empirical and enables to consider the retention and losses processes involved in the catchment transport of nutrients. MONERIS was developed within the EUROCAT project – acronym for EUROpean CATchments: catchment changes and their impacts on the coast, funded by the European Union. The aim of the EUROCAT project was to estimate the effective nutrient loads (either point or diffuse) transported to the sea of the most important watersheds in Europe.

The models discussed so far are free software that can be downloaded directly or after registration procedures from the Internet. Several institutes or companies provide their models for a fee. These software may be expensive (from several thousand up to hundred thousand euros), however there are significant discounts for academic use.

Danish Hydraulic Institute (DHI) sells a series of software (MIKE). MIKE 11 is a versatile one-dimensional hydrodynamic software package including a full solution of the St. Venant equations, plus many process modules for advection-dispersion, water quality and ecology, sediment transport, rainfall-runoff, flood forecasting, real-time operations, and dam break modelling. MIKE FLOOD is an integrated tool for detailed floodplain studies. MIKE FLOOD is ideal for many types of analyses such as flooding, storm surge, dam break, embankment failure, and more. MIKE FLOOD WATCH is a decision support system for real-time forecasting, fully integrated into ArcGIS. This product is applied operationally at Flood Forecasting Centres World-Wide. It integrates data management, forecast models and dissemination methodologies in a single system within an ArcGIS platform. MIKE 21C is an integrated river morphology modelling tool based on a curvilinear version of the water model MIKE 21 and adjusted to river applications. The model can be used to simulate changes in the river bed and planform, including bank erosion, scouring, shoaling associated with for instance construction works and changes in the hydraulic regime. MIKE BASIN is a versatile GIS-based water resource and environmental modelling package. MIKE BASIN represents all elements of water resource modelling: users, reservoirs, hydropower, surface water, groundwater, rainfall-runoff, and water quality. MIKE SHE is an integrated hydrological modelling system which covers the entire land phase of the hydrological cycle. MIKE 21 (2D) is a general numerical modelling system for the simulation of water levels and flows in estuaries, bays and coastal areas; MIKE 3 (3D) is a general numerical modelling systems for simulations of flows in estuaries, bays and costal areas as well in oceans.

Many people use deterministic (mass balance-based) models to perform scenario analysis, however a stochastic approach is also used in few systems. The SIMCAT model is widely used by Environment Agencies in UK to assess the impact of point discharges into the river. SIMCAT is a statistical water quality model that has been developed and used in the UK and elsewhere for over 20 years since the introduction of percentile based standards. SIMCAT uses the Monte Carlo Simulation approach to mix discharges and diffuse inputs with river waters and then routes flows in the river down through the watershed, applying water quality transformation processes en route. Hence, SIMCAT allows predicting flow and quality distributions at any selected point in the watershed and producing results as statistics for comparison with specific river quality standards. SIMCAT is a one dimensional, steady state model and is able to simulate the following types of pollutants: conservative, non-conservative, dissolved oxygen with a reaeration and BOD decay interaction. According to the developers, the power of SIMCAT lies in the ability to derive quality relationships between points in a river based on the statistics of observed data. This enables SIMCAT to consider errors associated with sampling of data rather than errors associated with calibration of more detailed deterministic water quality process representations. Hence, the advantages of speed ease of use and maximized value from existing data. SIMCAT is included in the SMURF desktop System to allow the assessment of impacts due to changes in the river watershed on water quality. The full desktop SMURF System is an advanced Geographical Information System (GIS). SMURF System uses a set of models, working on a whole host of data. This includes geographical data (e.g. land use), time series data (e.g. GQA Chemistry Grade over time) and derived data (e.g. SuDS suitability).

In this section, brief information is given about several watershed/water quality modelling tools. There are other modeling tools not mentioned in this report. Brief information and reviews about some of them are given by Shoemaker et al. (1997) and Deliman et al. (1999).

2.3. GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

GIS is an evolving, catchall phrase that initially referred to management of information with a geographic component primarily stored in vector form with associated attributes. This definition quickly became too restrictive with advances in software and ideas about information management. An advanced GIS system should be able to handle any spatial data, not just data tied to the ground by geographic reference points. The capacity to handle non-geographic spatial data was formerly the domain of systems referred to as AM/FM (Automated Mapping and Facilities Management). Other non-geographic applications, such as interactive medical encyclopedias that retrieve information based on the human form, should also be manageable by a robust system. Integration of imagery with vector data is now a necessity for a full-featured GIS system. Imagery was once thought to be the exclusive domain of image processing systems, but is now often required as a backdrop for vector, or other data, types. No up-to-date GIS system is complete without surface modelling and 3D (technically 2 1/2 D) visualization with “fly-by” capability. In addition to drawing a path for the simulation, you should be able to orbit with the view directed at a specified point or have the view pan around a stationary viewer. Vector overlay on this 3D surface should also be an integral part of the package. A GIS system should be production oriented, which may or may not mean product oriented. Production work in

GIS involves making maps (a product), but it also involves interactive analysis (a result which may have no tangible product).

GIS is an important tool used extensively to manage spatially distributed data such as land use, administrative boundaries along with other geo-referenced data such as above-ground and under-ground constructions (treatment plants, sewer lines, roads etc.), and monitoring stations. Since GIS has two basic subsystems (maps and data), it can be used as a data storage system as well as for generating self-explanatory dynamic and thematic maps which are powerful visual aids for engineers and managers. On the other hand, GIS outputs are widely used in modelling studies especially for generating model inputs, visualizing and displaying model outputs.

Data are distributed among various organizations and can be found in diverse forms or there may not be available required data. At this point, the significance of storing environmental data in a reliable systematic manner and of serving the updated data to users becomes important. It is for sure that application of Geographic Information Systems (GIS) to fulfil the requirements of the planning strategies is of utmost importance and is a useful management tool. It has well been recognized in most of the studies that GIS is a tool that can enhance spatial assessment of watershed quality since spatial data from a variety of sources can be integrated, manipulated and transformed to produce new derived maps that aid to understanding spatial inter-relations. Such successful application of GIS however, must evolve from an inventory tool to an analysis tool, and in turn, to a management tool. In general, GIS provides facilities for data capturing, data management, data manipulation and analysis, the presentation of results in both graphical and report form with a particular emphasis on preserving and utilizing inherent characteristics of spatial data. The ability to incorporate spatial data, manage it, analyze it, and answer spatial questions is the distinctive characteristic of GIS.

GIS technology provides input data, which will then give a chance to modellers to apply watershed models to control diffuse sources and estimation of their long-term impacts. Obtained results can be visualized by means of different thematic maps, charts and reports. Visualization by means of GIS maps is also a powerful tool for dissemination and communication of results to non experts such as citizens, decision makers, economists, etc. GIS is considered as a useful tool to renew the information that can change very quickly (e.g. land uses) especially in developing countries (quick urbanization without planning and water infrastructures, etc.) by using remote sensing or field survey.

There are two different levels of implementation of GIS one being the GIS design and development the other being the GIS operation. The personnel, who will be assigned to GIS design and development task usually requires intensive training that may take several months, whereas GIS operation team needs much less training. Several commercial GIS software, and also commercial GIS software such as ArcGIS and IDRISI, which also contain analyses specific modules are on the market. The average cost of these software is around several thousands US$, and additional costs must be accounted for additional modules. These software are supported by their developers and vendors. The total cost for GIS is the sum of the software costs, training costs and personnel costs. An option, which decreases the total cost for GIS is to use free and/or open source GIS software such as GRASS, MapWindow, QGIS, Diva GIS, etc., however they are usually more difficult to use than the commercial GIS software.

2.4. OPEN DATABASES

Water Resources Management requires historical and recent data, knowledge and computing capacity. Historical data is fundamental for understanding the evolution of the watershed and for defining background values and reference situations. It is owned by the institutions working in the watershed or managing it in various formats – often in reports – and it is not always easily known or available. Knowledge is owned by people and sometimes is included into computational models, which are essential tools for integrated management. Databases bring order to decentralized data.

Open databases are important tools, which can save time and costs related to data gathering and editing. In many watershed studies, time required to gather the necessary data is comparable with the time needed to implement sophisticated tools such as models, GIS, and knowledge based tools so that even projects of relatively small scale and budget that are expected to give quick results may become too inertial. However, if data are available easily and freely through Internet, both sides, the institutions prepare data for each demand separately and environmental experts which need the data for environmental projects.

Several institutions provide free data on the Internet on global or even local scale. Topographical data (that is the most essential coverage in any watershed modeling study) covering most of the earth is generated by NASA during the SRTM (Shuttle Radar Topographic Mission) operation at a lateral spatial resolution of 90 × 90 m is freely available on the Internet. Climate data from the years 1950–2000 including monthly total precipitation; monthly mean, minimum and maximum temperature, and 19 derived bioclimatic variables can be downloaded from WORDCLIM (www.wordclim.org) for free. NASA provides satellite images based on the LANDSAT 4/5 data (for the year 1990) and LANDSAT 7 (for the year 2000) data. They can be downloaded from the url https://zulu.ssc.nasa.gov/mrsid/. Several institutions in USA such as USEPA and USGS provide local flow and water quality monitoring data; however these data are limited to United States territory.

2.5. INTELLIGENT SUPPORT TO THE DECISION-MAKING PROCESS

Artificial Intelligence (AI) was a big buzzword in the last 20 years. Especially through the form of Expert Systems (ESs) they were expected to guide inexperienced users through all kind of problems and advise them for the best steps to take. However, they have fallen short of expectation, and they have never been able to substitute real skilled people as the major form of advice. ESs may be useful for enhancing other decision support system tools such as models.

Amongst instruments, mechanisms, and methodologies that can be categorized as 'intelligent' support to the decision-making, three groups can be identified: (1) Expert Systems (ES), (2) Stochastic Search Engines (SSE), and more recently (3) Ant Colony Optimization (ACO). All they found place in engineering at various levels of implementation. While ES are self-contained and discipline oriented, SSE are typically imbedded into more complex programming systems to serve as quick and efficient search mechanisms over infinite solution spaces, that is in solving multimodal and NP-hard optimization problems or in searching for no dominated solutions within complex decision space. ACO appeared in the 1990s and is now finding place in the subject area.

Expert Systems (ESs) are considered as a special field of AI. Their success lies in their ability to analyze large amounts of information according to pre-established rules resembling the reasoning of a human expert or group of experts. ESs differ substantially from conventional computer programs in that their goals may have no mathematical solution, and they must make inferences based on incomplete or uncertain information. Typical structure of advanced ES generally is: (1) a data base and interactive editor tools to maintain/compare multiple alternatives; (2) a multiple-layer (hierarchical) GIS covering the entire area as well as the areas immediately affected by individual projects; and (3) a set of special data bases. ES architecture includes: (1) a knowledge base with checklists, rules, background information and guidelines and instructions for the analyst; (2) the inference engine, that guides the analyst through a projects assessment in a simple menu-driven dialogue; and (3) a report generator that summarizes and evaluates the assessment or decisions.

Stochastic Search Engines (SSE) are composed of three dominant classes: Simulated Annealing (SA), Tabu Search (TS), Genetic Algorithms (GAs) and

Ant Colony Optimization (ACO). To understand the power of SSEs, recall that there are three main types of traditional (conventional) search methods: (1) calculus-based; (2) enumerative; and (3) random. Stochastic search methods are strictly random walks through the search space while saving the best. For example GAs, as representative SSEs, differ from conventional optimization/search procedures in that: (a) they work with a coding of the parameter set, not the parameters themselves; (b) they search from a population of points in the problem domain, not a singular point; (c) they use payoff information as the objective function rather than derivatives of the problem or auxiliary knowledge; and (d) they utilize probabilistic transition rules based on fitness rather than deterministic one. On the other side, ACO emulates distant sharing of information that is usually considered as distributed intelligence.

2.6. EXPERT AND PUBLIC PARTICIPATION IN DECISION MAKING

Expertise is used in decision making in order to enable understanding and evaluation of results provided by other tools as monitoring programs, indices and models. Experts are asked for expressing judgments on specific issues based on their previous knowledge.

In decision making process it is fundamental to take into account perspectives of all interested parties in the problem of concern: citizens, economic sectors, environmental agencies, NGOs, communities, etc. To this end transparency in dissemination and communication of results should be enhanced.

Every extreme event should be used as a powerful starting point to build/enhance/renew the watershed community between stakeholders, decision makers and experts

2.7. INDICATORS AND INDEXES

Indicators and indexes are generally used for assessing quality status of environments. They can also be used for evaluating efficiency of management measures overtime. Indicators and indexes belong to two different levels of abstraction.

Indicators are characterized by one or several measurable parameters. They may be a parameter with a broader meaning (e.g. abundance, species richness), or qualitative integral characteristic (water quality). Indexes are aggregations of indicators based on statistical/mathematical methods or by means of Multi Criteria Decision Analysis (need of a common scale → normalization) (see EEA, 2003 and OECD, 2005).

Water quality evaluation requires the use of an appropriate system of indicators and indices (indexes) integrating all heterogeneous data provided by monitoring programs. This will provide synthesized information for decision making process that can be easily disseminated and communicated to public and to all interested parties.

2.8. STATISTICAL TECHNIQUES USEFUL FOR THE REDUCTION OF THE LEVEL OF REDUNDANCY IN THE INDICATORS

Multivariate Statistical techniques such as Principal Component Analysis (PCA) and Factor Analysis (FA), may help in reducing the level of redundancy that sometimes is present in the information contained in indicators. PCA techniques extract the eigenvalues and eigenvectors from the covariance of the original variances (e.g. Afifi and Clark, 1996). The principal components extracted are uncorrelated (orthogonal) variables, obtained as weighted linear combinations of the original variables:

$$F_1 = w_{11}X_1 + w_{12}X_2 + \ldots + w_{1k}X_k.$$

$$F_2 = w_{21}X_1 + w_{22}X_2 + \ldots + w_{2k}X_k.$$

where F_1 and F_2 are the principal components or factors, X_i are the original correlated variables, w_{ij} are factor scores chosen to satisfy the requirements of maximizing the variance (eigenvalue) explained by every relationship, and of having orthogonal factors resulting from the extraction (i.e. uncorrelated).

By looking at the factor loadings matrix (i.e. the list of the correlation coefficients of the original variables with the extracted components) it is possible to identify the most meaningful parameters within each component. That leads to few components that are able to describe the whole data set with minimum loss of original information. Parameters that lie on the same component share the same information. Factor analysis sometimes improves the results of PCA since it enables to further reduce the contribution of the less significant parameters within each component, by extracting a new set of varifactors through rotating the axis defined by an initial PCA extraction. The VARIMAX rotation criterion is the most commonly used and it enables to rotate the PCA axes so that they go through clusters or subgroups of the points representing the response variables even though maintaining their orthogonality (i.e. being uncorrelated) to each other. The number of factors to be retained can be chosen on the basis of the “eigenvalue higher than 1” criterion (i.e. all the factors that explained less than the variance of one of the original variables were discarded).

2.9. MULTI CRITERIA DECISION MAKING (MCDM) TECHNIQUES

There are different multi criteria decision-making methods and models that can be classified under generally adopted differentiation amongst approaches and mathematical mechanisms used to support evaluation of decision elements in search for optimal, compromise or best solution. It should be noted that except AHP, all other methods use performance (or rating) matrix where alternatives are assessed across given set of criteria.

General classification of models is as follows:

- **MOLP** (Multiple Objective Linear Programming). A number of different MOLP procedures have been reported, of which GP (Goal Programming) is best known. The weighted-sum technique and vector-maximum algorithms are regarded as members of the more frequently applied MOLP approaches.
- **MOMP** (Multiple Objective Mathematical Programming) encapsulates several problem types, such as MOLP, MOILP (Multiple Objective Integer Linear Programming), and NMOO (Nonlinear Multiple Objective Optimization). A typical one is GP.
- **MAUT** (Multi-Attribute Utility Theory) gathers broad spectrum of methods to select the best solution among the no dominated ones. Frequently used methods are: (1) Analytic Hierarchy Process (AHP) – characterized by pair wise comparisons among decision elements and linear additive utility function, SMART – which stands for Simple Multiattribute Rating Technique; SMARTS – which is SMART with Swing weights; and SMARTER – to make things even simpler), and (2) Outranking methods (PROMETHEE and ELECTRE) characterized by producing a (weak) ordering of alternatives.

Simpler methods that directly use performance (rating, decision) matrix are:

- **SAW** (Simple Additive Weighting). This is one of the most simple, but nevertheless good decision making methods. Its results are usually very close to more sophisticated methods. SAW consists of three basic steps: 1 – scale the scores to make them comparable, 2 – apply criteria weights, and 3 – sum the values along rows and select best (top ranked) alternative.
- **SPW** (Simple Product Weighting). This method is similar to SAW, except the products of ratings in the matrix are used instead of summations. In SPW applications scaling is not necessary, as well as normalization, however both are permitted.
- **TOPSIS** (Technique for Order Preference by Similarity to Ideal Solution). It is rational and relatively simple method with the underlying concept as that most preferred Top-ranked alternative is with the shortest distance

from ideal solution and TOPSIS guarantees that it also has the longest distance from negative-ideal solution.

- **CP** (Compromise Programming). This technique ranks alternatives according to their closeness to so called 'utopia' point. The distance measure used in CP is the family of L_p–metrics defined with a parameter p to implicitly express the DM's attitude to balance criteria, to accept decreasing marginal utility), or to search for absolutely dominant solution.

All above mentioned methods can be fuzzified. While standard (crisp) versions are frequently used, still there are not relevant reported applications of their fuzzy versions.

More complicated but advanced MCDM methods are:

- **AHP** (Analytic Hierarchy Process). AHP decomposes a complex multi-factor problem into a hierarchy. It uses hierarchic structures, matrices and linear algebra to formalize the decision processes. The AHP determines the priorities of each alternative with the assigned weight for each alternative by analyzing the judgmental matrices and by applying mathematical theory of eigenvalues and eigenvectors. AHP combines both subjective and objective judgments in an integrated framework based on ratio scales from simple pair wise comparisons. In last 25 years it has been used in thousands of studies worldwide, many of them available at Internet. More information on AHP is given in Appendix 1.
- **PROMETHEE and ELECTRE.** These are two best known outranking methods characterized by an aggregation of criteria, where multicriteria value is replaced by single criterion and complete dominance relation is established. Typically, in interactive versions of these methods the decision maker's preferences are not modeled globally, but incrementally. Enrichment of dominance relation is achieved by adding arcs to dominance relation and/or by building "fuzzy" dominance relations.
- **DEA** (Data Envelopment Analysis). This is a special method that do not use decision matrix directly. While standard MCDM tools are used to select a best alternative, DEA evaluates the efficiency of a group of alternatives, but does not indicate a clear winner. DEA has a multicriteria flavor: minimize all inputs, and maximize all outputs. Standard version of DEA does not use DM's preferences over inputs and outputs; however, this can be done. There is several weight restrictions related to criteria that lead to various versions of the method.

Supporting real-life decision-making processes by advanced MCDM techniques commonly means that certain commercial, academic; demo or project-specific software tools are employed. Such a support becomes necessity in developing countries in their run toward broad integration with developed western countries. To preserve for rational decision-making in situations where and when human and technical resources are limited, several hints are worthy to mention, such as:

1. Carefully analyze the decision problem in hand and structure it
2. Learn from the others
3. Use existing software tools (develop additional or new only if necessary)
4. Follow-up the consequences of the decision made, and be ready to repeat some calculations

3. Expected Evolution in Decision Making and Related Supporting Tools

A recent trend in developing Decision Support Systems (DDS) is to implement web-based systems where some functionality runs as online resources (e.g. databases, models). Contribution of **remote sensing** products for coastal areas like MODIS is considered to be important and could be also an alternative tool for validation the models. Additional statements can be put regarding perspective in the DSSs developments as follows:

- More and more DM processes will be required to relay on clear and justified methodologies and scientifically sound models.
- Audit trail will become standard in controlling the whole DM process: How decision was made? which methodology is used? Which method is applied? What was the DM background (expertise, willingness, informed about all implications decision will have once implemented)?
- MCDM methods itself will not be improved significantly. Methods for controlling consistency of the DM process and DM are necessary o develop. There are just very few and their performance is not really satisfactory.
- Competitions of developers will lead to better coverage of market interests and reduction of cost of software. It is expected that Internet will enable on-line, web-based DM, both individual and group. It already exists but is not sufficiently developed.
- AI based MCDM tools will not be widely accepted in near future. Maybe to certain extent only focused Expert Systems and similar knowledge-based systems.
- We need new generations of managers who will understand necessity of using scientifically proven DSS and related techniques.

- Improvements in HC interface and rapid development of ICT (Information and Communication Technologies) will empower the whole issue of modern DM.

4. Conclusions and Recommendations

4.1. WHAT ARE THE TOOLS IN GENERAL?

In general, everything that helps the managers to obtain an answer management can be considered as a tool. In the context of IWRM and DM, following tools are considered:

- *Monitoring systems*, which include *indicator system* and *threshold analysis* that are the tools for status assessment
- *Models* (the best – in operational use), as the tool for scenario assessment, forecasting, hindcast analysis
- *GIS based data base*, as the tool for collecting information, data, facts like the Cadastre of water bodies, Cadastre of water users, streams and basins, hydrographic descriptions, water balances, nutrient balances, sediment balances, time series of data, facts on extreme events in descriptive form (usually there are no measurements during extreme events)
- *Indicators, indices, protocols, classifications*
- *Open databases*
- *Associations of Water Users*, as the tool for public involvement

However, in many cases a number of different tools (models, sets of indices, etc.) should be used simultaneously. In USA and Europe there is a wide experience on use of indicators and indices for water quality evaluation, on use of models for fate and transport of contaminants and also on decision support systems for water management.

4.2. WHICH WELL-DEVELOPED AND PROVEN TOOLS ARE AVAILABLE?

Many well-developed models and other tools are available, some are "freeware", other are commercial. Freeware are often obtained directly from developers. Brief information about these tools and how to obtain them are given in previous sections. Most of theses tools can be considered well-developed and reliable. In general, they should have a conceptual framework as reference (e.g. DPSIR); partially fulfill legislative requirements; link different spatial scales; communicate results in a transparent and simple way and be preferably open source and freely accessible via Internet. Moreover on the one hand they should be scientifically sound (e.g. by means of validation) and on the other hand they should address needs and expectations of end users. Models should be transparent to the decision makers (clear presentation, simple words in explanations, direct communication with potential users, training is sometimes required prior to initiation effective DM process. Good computer interface is essential.

4.3. HOW TO USE THESE TOOLS FOR EFFECTIVE DM?

Understanding of the tools, their aims, capabilities and limitations by water/watershed authorities is essential for using these tools effectively in decision making. The first problem is the selection of the most appropriate tools for the problem of concern. The selection should be based on a deep understanding of the problem and on the definition of specific management goals to be achieved. It is better to analyze all aspects of the problem by using a pool of tools providing different information. Input data, tools characteristics, assumptions and final results should be communicated to all interested parties, including public (i.e. citizen), in a transparent way. The tools should be applied in advance and obtain the simplest relationships between causes and effects and transfer the knowledge.

As stated previously, training of staff that will operate the tools is important, since tools are useless without the experts who can use them. Organizing of an advisory board from experts facilitated by different tools (available for quick decision support) will further increase the efficiency to utilize the tools.

If several tools are used together, an institutional infrastructure, which integrates the tools, is generally useful. For this purpose a "system" for (i) data collection, (ii) analysis, (iii) generalization of data to information level, (iv) development of recommendation can be set up.

Current work of experts (or groups) on supporting and improvement of tools, on analyzing data and preparing of regular overview of situation should be financed.

4.4. ARE THE ARTIFICIAL INTELLIGENCE DM TOOLS OUR FUTURE?

Artificial intelligence decision making tools are considered to be more effective in the future on long term basis. This approach is really interesting and very useful mainly because it permits to overcome data gaps and to find hidden relationships among data. However, these tools and methods are currently complex and strong background on computer science is needed to understand how they are working. They must be designed transparent enough to be "perceived" in their functioning by the watershed and water quality management experts and decision makers.

4.5. RECOMMENDATIONS ON PRACTICAL APPLICATIONS OF DM TOOLS PARTICULARLY FOR DEVELOPING COUNTRIES

Training is the most important issue. Trainers from developed countries should meet the users in developing countries, and people from developing countries should attend training programs offered by institutes to receive training. It is very important for those countries to insist in training of their experts. Tools are complicated to be used effectively if there is not enough experience. The best choice for developing countries is achieve their own experience on case studies while guided by international experts. NATO/LEMSM/CCMS could organize training course (seminar like NATO ASI course, for example) for developing countries in Tunisia or Morocco (or other countries) in order to regroup all decision makers (not only students) of the Mediterranean countries (Morocco, Algeria, Tunisia, Egypt) and to do some applications on this integrative water resources tools. It could be must benefit for these countries.

Monitoring of the water bodies of watersheds like rivers/lagoons/estuaries/bays where the importance is vital for their living resources and the local population is extremely important. This monitoring could integrate the water column parameters (pollution, physical/chemical/biological parameters) and also sediments, particularly in developing countries where this monitoring is very deficient and need special attention and equipments.

Publications (books, etc.) produced by local experts that aim to teach application of these tools (with both, theory and practice) in local languages adapted to local conditions can also be useful for developing countries.

Another important issue is that all the tools especially models used in integrated water resources management in developing countries should be scalable from simple to more complex. Developing countries usually have a common problem, the lack of experience and funds and therefore are forced to use more simple methods and approaches than the developed countries. Such methods usually provide relatively rough analyses that can still be considered useful as initial steps. However, more detailed analyses may be required in future studies that can be conducted when more experienced experts operating the tools and more funds become available. Several models and other tools are designed in a modular fashion so that they can still be used for relatively simple analyses using the basic modules and further modules can be "switched on" when more detailed analyses are needed and/or can be conducted with available funding, data and experience.

Appendix 1

The Analytic Hierarchy Process: a General Methodology and Tool for Supporting Individual and Group Decision-making

1. Basics

The AHP is a multicriteria decision-making method developed in mid 1970s of the 20th century in US by Thomas Saaty. Today it is considered as the most popular tool in supporting decision-making processes in almost all fields of human activity. Thousands of applications are reported in scientific and technical documents, many of them posted on the Internet. Some recent reviews say that more than 10,000 articles in peer reviewed journals use or refer to this method. Software that supports AHP is commercially available through Expert Choice Inc. (Pittsburgh, USA), for both individual and group applications. The method is relatively simple to program for a computer.

AHP requires a well-structured problem, represented as a hierarchy. Usually, at the top of the hierarchy is the goal; the next level contains the criteria and sub-criteria, while alternatives lie at the bottom of the hierarchy. AHP determines the preferences among the set of alternatives by employing pair-wise comparisons of the hierarchy elements at all levels, following the rule that, at given hierarchy levels, elements are compared with respect to the elements in the higher level by using the *Saaty's* importance scale (Table 1). By assumption, value 1 corresponds to the case in which two elements contribute in the same way to the element in the higher level. Value 9 corresponds to the case in which one of the two elements is significantly more important than the other. Also, if the judgment is that B is more important than A, the reciprocal of the relevant index value is assigned. For example, if B is felt to be notably more important as a criterion for the decision than A, then the value 1/7 would be assigned to A relative to B.

TABLE 1. The fundamental Saaty's scale for the comparative judgments.

Num. values	Verbal terms
1	Equally important
3	**Moderately more important**
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2, 4, 6, 8	*Intermediate values*

The results of the comparison are placed in comparison matrices. After all judgments are made, the local priorities of the criteria, sub criteria and alternatives can be calculated using the principal eigenvector of a comparison matrix. Several alternative methods often called prioritization methods, are developed for doing these calculations, such as additive normalization, weighted least square method, logarithmic least square method, fuzzy linear programming method, evolution based genetic algorithms, or most recently data envelopment analysis. The synthesis is performed by multiplying the criteria specific priority vector of the alternatives with the corresponding criterion weight, and then appraising the results to obtain the final composite alternatives priorities with respect to the goal. The highest value of the priority vector indicates the best-ranked alternative.

In recent years various versions of fuzzy AHP are introduced as well as different ratio scales are tested in search for better modelling of the decision-making process pillars, in particular humans' judging about decision elements in presence of their backgrounds (education, attitude, expertise, interests etc.).

The major advantage of AHP is that it involves a variety of tangible and intangible goals. For instance, it reduces complex decisions to a series of pair-wise comparisons, implements a structured, repeatable and justifiable decision making approach and build consensus.

2. Strengths of the AHP

Strengths of AHP are listed below:

- Helps decision maker to cope with a problem complexity by decomposing problem into a hierarchical structure.
- Only two elements are compared at the time. Both qualitative and quantitative elements are compared with ease.
- Verbal terms, numeric scale or graphic bars may be used to express the intensity of preference of one element over the other (interactive séance at computer).
- Calculates inconsistency index as a ratio of the decision maker's inconsistency and randomly generated index.
- Its simplicity and intuitive logic facilitate the participation of various decision makers and even stimulate their involvement in brainstorming sessions which ultimately may improve collective thinking, reasoning, and the efficiency of group decision.

3. Weaknesses of the AHP

Weaknesses of AHP are listed below:

- If verbal judgments are used, then a quantitative scale is imposed on the decision maker; e.g. one may think that A is weakly more important than B. The AHP assumes that this implies that A is three times more important than B.
- Any method for obtaining weights is not transparent to most decision makers.
- The failure to distinguish options and attributes reduces clarity.
- The addition of a new option to a decision problem can lead to a reversal of the rankings of the original options.
- The number of comparisons can make the method extremely time consuming; e.g. 5 options compared with respect to 5 attributes would need 60 pair wise comparisons.

4. AHP in Group Decision-Making

In the case of group decision making, the aggregation can be performed in two ways. The first is to aggregate individual judgments in each matrix, compute weights and synthesize in a standard manner. The second, more advisable, is to aggregate the final priorities derived by individuals. In later case aggregation of individual priorities is best to perform by the Geometric Mean Method (GMM) allowing that DMs may have different'power' ('weight').

Appendix 2 – Decision Support Systems In Europe

Currently, many Decision Support Systems (DSSs) for water management are available or under development in Europe. Some examples of DSSs are listed below:

- **MULINO (Mul**ti-sectoral **In**tegrated and **O**perational) **DSS** (http://siti.feem.it/mulino/) is a decision support system where the implementation of the WFD into the DPSIR framework allows to calculate pressures, impacts and state of the river of interest through specific indicators which are then integrated by means of Multi-Criteria Decision Analysis (Giupponi, 2005; Kiker et al., 2005).
- **AQUATOOL** was developed for planning of hydrological resources in Spain by means of modules simulating water availability, water demand

and optimization of water uses (Andreu et al., 1996). The demo version can be downloaded from (http://www.upv.es/aquatool/).

- **River Life DSS** was developed in Finland for intensify water pollution control by describing non-point sources deriving from different land uses as well as by evaluating ecological and hydrological conditions of the river environment (Karjalainen and Hekkinen, 2005).

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LAND-BASED SOURCES, WATER QUALITY AND MANAGEMENT

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1. Introduction

Water is a limited resource in increasingly short supply. The ability of watersheds to provide sufficient water quantity and quality is threatened in the face increasing population growth and human activities in the watershed. In the context of these threats, many governments and organization are increasing efforts in planning and decision making for water resources. Such efforts promote sustainability and efficiency in water use and provide many benefits for society, however, a lack of shared knowledge and useful tools may impair success of such efforts. In order to successfully manage water resources, it is essential to view the landscape and hydrologic system together as an integrated unit (Winter, 2001). Several key elements are important for a successful approach to relating land based sources and water quality management.

One of these key elements for watershed management and decision making is the cooperation of stakeholders hand the role of public participation,

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including partnerships among decision makers, stakeholders, scientists, and NGO's, with decision-making and conflict resolution procedures in place among these partners. A key element to facilitate cooperation and communication is the appointment of a coordinating body as a focal point. For example, in EC Mediterranean countries, most watersheds are under the mandate of Basin Authorities (BAs), as well as the relevant national technical agencies. It is also necessary for the group of stakeholders to have sufficient capacity and funding mechanisms, as well as a policy and legal framework to support integrated water resource management. For the policy and legal framework, it is necessary to consider country-specific governance structures in order to develope workable solutions. The holistic, flexible approach of sustainable watershed management may contrast with conventional systems in which different sectors and skills are separated and handled by different ministries and agencies, with differing agendas, priorities, financial systems and political power (Fé d'Ostiani, 2004). Cooperation will be critical for success.

Another key element is the consideration of boundaries and scale. It may be necessary to address transboundary issues, since watershed boundaries usually do not coincide with the political and administrative borders. The absence of watershed-scale jurisdictions or decision-making institutions, and the lack of coordination among water resource programs across borders, may lead to fragmented and inefficient management of watersheds (Schlager and Blomquist, 2000). In this case, responsibility for administration and evaluation has been parceled out among multiple agencies and multiple levels of government, and they carry out some program or policy that affects only one portion of the overall watershed. Decisions about water resources are best made within the context of watershed boundaries. It is best to consider watersheds at different scales, from local to regional watersheds, since they are connected by hydrology and decisions at one scale may have effects at other scales.

Perhaps the most critical element for sustainable and integrated water resources management is a conceptual model that characterizes the land and waterscapes of the natural environment, the existing and future socio-economic conditions of human populations living there, and the connections that exist among these elements. As such, we may consider the watershed to be a socio-ecological system (Vadineanu, 2001, 2007). The conceptual model should include aspects of scale in time and space; relation of humans and the natural environment; recognition of connected land and waterscapes; and analyses of policies and strategies with the requirement for environmental equity. Taken together, the aspects of a conceptual model provide the starting point for all watershed management, planning, and policy. The conceptual model should support a long-term vision and strategies that can be captured in a watershed plan.

The valuation of resources and the benefits that humans derive from ecosystems should also be considered within the conceptual model. Ecosystems provide value in terms of provisioning, regulating, supporting and cultural services, and new techniques were developed to assess these services so that they can be fully considered in policy decisions (Costanza et al., 1997). In particular, the spatial patterns of these services are significant in the watershed (Naidoo and Ricketts, 2006). Odum and Odum (2000) have argued that classical economic valuation of ecosystem services may be incomplete since it fails to capture even utilitarian benefits that are external to economic markets. Alternative valuation methods can include stated preference methods, replacement cost and opportunity cost, environmental and sociocultural indices (Adamowicz et al., 2007). The science of valuing ecosystem services is constrained by the state of knowledge about ecosystem services themselves; additional knowledge about the classification of socio-cultural services is needed (Wallace, 2007).

A conceptual model should be the basis for development of a management framework. Such a framework can be structured as a box-and arrow diagram, representing the indirect relationships and causal pathways among the elements (Stevenson et al., 2004). A useful example is the DPSIR framework, developed by the European Union (EU, 2000):

- Driving forces of environmental change
- Pressures on the environment
- State of the environment
- Impacts on population, economy, ecosystems
- Response of the society

This framework includes driving forces of social and economic activity in watersheds, and considers the pressures, or sources of stress, that result from these driving forces. From this, status and impacts resulting from these pressures are considered in the context of water resources management. Finally, the approach considers possible management responses to promote sustainable watersheds, mitigate negative impacts on the environment, and to protect and conserve water resources for future generations. Andrulewicz (2007) describes the application of the DPSIR approach to the Baltic Sea, and Borja et al. (2006) used this approach in a case study of the Basque (northern Spain) estuarine and coastal waters, and found it useful, particularly if there were enough data available to reduce uncertainty. The management framework provides a clear way forward to managing the link between land and water, in the context of the socio-economic system. However, appropriate approaches and methods for implementing sustainable watershed management are not always available, particularly for developing countries. Below, we discuss approaches and methods for each of the elements in the DPSIR framework and how they may be used to support sustainable watershed management.

2. Driving forces

Changes in freshwater, flows and stocks as well as water quality or changes in physical structure and functional regime/ecological integrity of the inland water ecosystems have been historically driven by the natural and anthropogenic driving forces, active across hierarchical watersheds.

The geographical context reflected in a holistic manner by the recommended conceptual framework of socio-ecological systems (Vadineanu, 2007), includes the dynamic environmental and natural components (e.g. climate, water cycle, geological substrate, species/populations and communities) and the dynamic components of the socio-economic systems as well as the cumulative effects of the interactions between them. Thus, the managers, experts and other stakeholders involved in the sustainable use and management of water resources have to consider all positive and negative feedbacks within and among human – nature or socio-ecological systems established at watershed or across watersheds in order to design and implement plans for sustainable watersheds management and development. This requires successful identification and assessment of the major acting or potential acting natural and socio-economic driving forces. Further it will be possible to develop the package of measures for adaptation to (e.g. climate changes) or minimizing the effects against (e.g. extreme droughts and floods, earthquakes, volcanic eruptions) changes of natural driving forces. It will be also possible to establish complementary measures in order to control and continuously adapt the social and economic driving forces, acting at watershed scale, according to the need for preservation or restoration the integrity or good ecological status of the freshwater ecosystems. For example, France has 43 years of experience (Water Act of 1964) in managing water issues at watershed scale. In the 15 years since the Water Act of 1992, the concept of integrated water management (IWM) (including the stakeholders participation process) has been integrated in the watershed management plan implementation.

Having in mind the unanimous recognition that the social and economic driving forces have been, at least in the last century, and will remain for long term, the most powerful, direct and indirect drivers for worldwide changes in water cycle, water resources quality and quantity and ecological status of fresh water ecosystems, we considered it useful to briefly: (1) discriminate among most active social and economic drivers; and (2) describe some of most effective methods and tools used to describe drivers.

2.1. SOCIAL AND ECONOMIC DRIVERS

- Social drivers – watershed and regional social policies regarding the improvement of life quality, human health, social cohesion, demography, family structure, occupation. A special attention should be given to other important social drivers, like dynamics of the stakeholders' structure and institutions as well as to the changes of people's perceptions, values, attitudes and behaviors related to the environment, and water resources and ecosystems, in particular.
- Economic drivers for changes in water resources and ecosystems, are more or less directly linked to socio-economic use of resources such as materials, energy, land and other services, at the watershed scale.

Thus, among economic drivers, the analysis has to consider: the economic growth or decline; changes in dominant economic sectors; changes in production infrastructure and metabolism, and the related patterns in the use of resources or manufactured goods; land use changes; changes in working time regulations or resource price.

2.2. METHODS AND TOOLS FOR ANALYSIS OF DRIVERS

- Prospective analysis

  There is a real need for prospective analysis in watershed management. Many environmental trends at various scales (e.g. global warming, groundwater pollution, erosion) or natural hazards are directly connected to the water system, its functionalities, and therefore its management. They should also be considered as drivers with a short to long term impact on the water system. Another important point is that integrating the sustainable development concept in water management means that one has also to care about natural hazards (floods, runoff) and climate change. Building water management scenarios both based on water system knowledge gathered through driver analysis and both environmental crisis and trends analysis should be one of the first objectives in river basin management plan implementation. In other terms, there's a crucial need of building a long term vision if one wants to cope with water uses conflicts and environmental impact of the socio-economical development into the water management decision making process.

- GIS and DSS

  GIS is a powerful tool to manage, to compute and to map spatially distributed data. As land use activities and society evolutions should be implemented in a sustainable way, it means that water management has to integrate GIS. GIS can also be a part of a Decision Support System

TABLE 1. Evolution of Corine Land Cover projects.

	CLC1990 specifications	CLC2000 specifications	CLC2006 specifications
Satellite data	Landsat-4/5 TM single date (in a few cases Landsat MSS, as well)	Landsat-7 ETM single date	SPOT-4 and/or IRS LISS III two dates
Time consistency	1986–1998	2000 +/−1 year	2006+/− 1 year
Geometric accuracy satellite images	≤50 m	≤25 m	≤25 m
CLC minimum mapping unit	25 ha	25 ha	25 ha
Geometric accuracy of CLC data	100 m	Better than 100 m	Better than 100 m
Thematic accuracy	≥85% (not validated)	≥85% (validated, see Büttner, G., Maucha, G., 2006)	≥85%
Change mapping	N.A.	Boundary displacement min. 100 m; change area for existing polygons ≥5 ha; isolated changes ≥25 ha	Boundary displacement min. 100 m; all changes >5 ha have to be mapped
Production time	10 years	4 years	1.5 years
Documentation	Incomplete metadata	Standard metadata	Standard metadata
Access to the data	Unclear dissemination policy	Free access	Free access
Number of European countries involved	26	32	38

(DSS) which is also a very efficient tool for decision makers to find the best solution within a complex system such as watersystem. Both GIS and DSS have to use database with a sufficient spatial, temporal resolution (i.e. Table 1 CLC parameters) to monitor efficiently land use evolutions and help stakeholders in the decision making process.

- Geodatabases

  Watershed managers should access data inventories or build in data clearinghouses. General information is easily accessible through internet like satellite imagery or global vegetation monitoring (i.e. GLCF web site, EEA web site for Corine Land Cover). A good example of driver analysis has been implemented to create the Corine Land Cover (CLC) database which is a geographical dataset created by the European Environmental Agency. Based on satellite imagery analysis (mainly

Landsat data) this dataset offers a broad overview of the spatial distribution for different types of drivers. CLC gives a hierarchical typology at three different scales. The first one is a basic land cover classification (e.g., artificial surfaces, agricultural areas, forest and semi natural areas, wetlands, water bodies). The second one is an intermediate classification (16 classes). The third level provides a detailed landcover classification (47 classes). CLC is used by every European water agency that has to cope with water management at basin scale. As a shared database for many EU countries, the CLC is very useful in transboundary watershed land use analysis (e.g., for the Scheldt basin in France, Belgium, and the Netherlands SCALDIT, 2004).

3. Pressures

Pressures are factors affecting the aquatic environment that result from the driving forces. Main pressures or sources of stress include pollutant wastes as heavy metals from industry or mining activities, pesticides and organochlorine compounds from intensive agriculture and oil wastes. But not all the stress in aquatic ecosystems came from toxic compound inputs. Sediment pumping or dredging produces turbidity which affects light penetration and photosynthesis capability of vegetation. An excess of sedimentation rates can affect benthic assemblages and filter feeder organisms. Nutrients and organic matter produce eutrophication, which is one of the most common causes of instability in aquatic ecosystems, by increasing the energy fluxes in the trophic web and leading to a change in the species composition, biological strategies, and trophic food web structure (Gamito et al., 2005).

Not all the sources of stress came from wastes or the deposition of substances. Dams in regulated rivers, modification of streams, coastal works and land reclamation, widening of inlets, etc., affect the hydrology of the aquatic ecosystems by changing the renewal rates of water masses, the natural fluxes of substances, sediments, food and oxygen, the microbial loops, the migratory movements or the colonization processes of species. These pressures cannot be monitored except through their effects on the ecosystem, and could only be anticipated if well developed (at least conceptual) models of cause-effect relationships were available.

The most common methodology to estimate pollutant loads from land-based sources start with monitoring and measurement. Point sources effluents can be measured at their source while diffuse sources (including waterborne loads – overland flow, infiltration – and airborne loads – wet and dry deposition) require a more extensive net of sampling stations. In both cases, there is temporal variability in the intensity of emissions, as a consequence of irregular production cycles or intentionally to avoid vigilance, forces to maintain expensive and intensive surveying plans. A second approach for estimating loads from the landscape, specially recommended for diffuse pollution, involves modeling. Models range from simple calculations to complex/spatially distributed models. Data requirements for different models may include land use, hydrology, meteorology etc.

Although directives and general policies are developed in response to general problems at the highest levels of National or Supranational entities and Administrations, the approach to face water management respond to a hierarchical structure through those the main key elements, driving forces and pressures change from the highest level which include all the planet to the particular water body that is exploited by local communities. From an ecological and hydrographical point of view, the water resources are also organized in a hierarchical or fractal way. Global driving forces include climate change, and population growth and the main pressures are related with sea level rise, increasing water demand, and increasing unpredictability in the quantity and distribution of water and a decrease of the water quality due to the overexploitation and waste inputs, coming from industrial, urban and agriculture activities that are moved by global socioeconomic interests. The response will be in the form of international agreements, directives and general policies. However, maintaining the ecological status of a given water body involve an approach at medium and local scales. At this level relevant processes are at basin and ecosystem spatio-temporal scales. The connectivity of aquatic ecosystems through the water cycle makes that main pressures must be identified at the basin scale. In some cases inputs of pollutants or other sources of stress can be spatially identified (urban or industrial wastes), but most of the times the aquatic ecosystems are affected by diffuse pollution, via runoff, underground waters, rain or dusty deposition.

4. Status and impacts

The purpose of identifying status and impacts in a watershed is to characterize wat (ecological) quality. The problem of managing water resources is linked to the necessity and concern of maintaining the ecological status of the water bodies, including good water quality for human uses and the preservation of ecological compenents and processes. This concern has started to be addressed in the legislation of many countries (see previous chapters) and is one of the main targets in the Eurpoean Water Framework Directive. Status and impacts may be identified through the following steps:

- Characterize the natural setting
- Identify reference conditions

- Select set of indicators and/or indices for the problem based both on water quality and ecology
  - Indicators should be selected to be consistent with monitoring
  - Indicators should be selected to be relevant for decision making
- Design monitoring program (with spatial and temporal scale, methods, frequency appropriate for water body)
- Conduct assessment

4.1. CHARACTERIZE THE NATURAL SETTING

The first step in characterizing the ecological status and impacts of a water body is to understand the natural setting in the region, in order to understand the environmental context of a particular watershed. Steps for characterizing natural setting include the identification of subregions and major drainage networks and the definition of water body types. Typically, waters are identified as rivers, lakes, transitional waters, coastal waters, and heavily modified water bodies. Perhaps the most difficult to define is transitional waters. They may be characterized by several methods, the best may be to define these waters providing criteria based on ecological processes. But inside these categories a high heterogeneity of conditions can be found and different subcategories can exist. If possible, it is also useful to characterize the nature and scale of variability in the system. Furthermore, some contradictions can arise during the definition of the water bodies, mainly among transitional and coastal waters (see, for example, McLusky and Elliott, 2007).

4.2. IDENTIFY REFERENCE CONDITIONS

The above mentioned sources of stress can lead to disorganizations in the ecosystems by changing their components or the ecological relationships between them. Assessing the ecological status of a water body requires the knowledge of the reference conditions for well-functioning, differentiating among changes corresponding to homeostatic mechanisms or responses which try to minimize or adsorb the impact, from changes which really cause a disorganization of the system, with high energetic costs and that in extreme cases could be irreversible, leading to the death of most of the species and the loss of the previous community.

Ecological principles are general, but the way in which they express depends on multiple factors including the complexity of the ecosystem, the velocity of the fluxes or the spatial scales involved. According to this, to evaluate the ecological status of a water body requires comparing it to reference conditions for well functioning. Such reference conditions will depend on the morphological and environmental conditions determining the climax of the community. Therefore, it is necessary to typify the water bodies according to such relevant characteristics.

As commented above, any change in the ecological status of a water body must be analyzed in function of a reference condition or baseline, considered as the ecological status of the system in pristine conditions. Such reference conditions cannot be universal, neither for a given typology, but for each water body. Unfortunately, deterioration of ecosystems due to human impacts have developed much quickly than the knowledge of the composition and structure of most of the aquatic ecosystems in the world making nearly an utopia the finding of such reference conditions. So, a compromise using the best conditions known for a given ecosystem and the conditions of the best conserved ecosystem of its type is needed.

4.3. SELECTION OF INDICATORS

An indicator is any parameter able to show a change in the ecosystem structure or functioning. They measure the degree of response of the ecosystem to a given driving force, and different definitions can be found in literature (Iserente and De Sloover, 1976; Lebrún, 1981). A bioindicator would be a biological parameter able to do this function. An index is an algorithm designed from more than one indicator or variable in the aim to improve the sensitivity to the changes or to integrate distinct sources of variability. Bioindicators can be designed for all levels of biological organization, from the subcellular scale to the ecosystem (Figure 1).

Despite the organization level at which an indicator can be designed, a good indicator should be sensitive to small changes in the physiological, population or ecosystem status, be sensitive to low levels of stress, should be more or less specific for a type of pollution or stress, must show a known function of response to the stress, and finally, must be easy to apply and easy to understand and interpreting for the general public, stakeholders and managers. The extremely high number of indicators proposed in literature is evidence that few, if any, meet all of these requirements, making necessary the use of a set of such indicators and a strong ecological knowledge of the studied system to assess its quality status. Some indicators recently proposed as potential candidates to be used for the EU WFD are shown in Table 2.

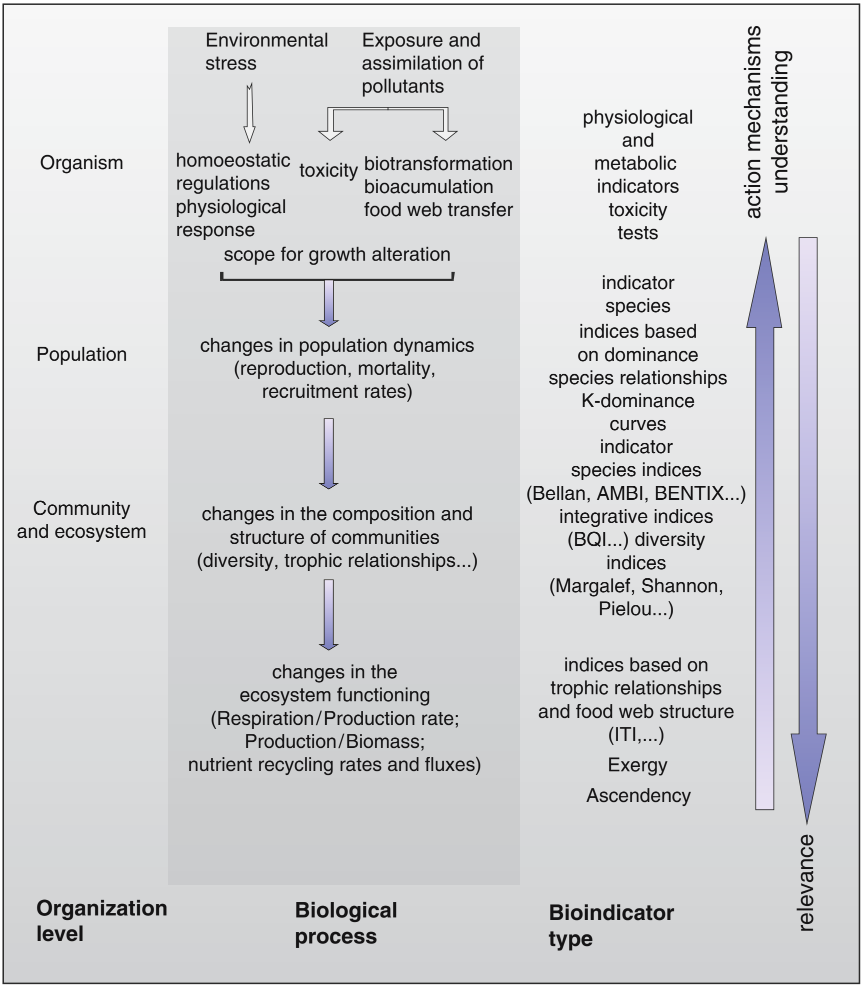

Figure 1. Response of the different biological organization levels to environmental stress and pollutants and main types of bioindicators used to detect impacts. At low organization levels, biological indicators are closer to action mechanisms and therefore to the understanding of the involved processes. At highest organization levels, biological indicators are closer to the consequences for human uses and therefore, more relevant for managers. (Modified from Pérez-Ruzafa and Marcos, 2003).

4.4. DESIGN MONITORING PROGRAM

The knowledge of the scales at which can be detected changes in the abundance of the organisms can help to find the ecological processes that determine the observed patterns in distribution (Underwood and Chapman, 1996). This knowledge is therefore essential when designing sampling strategies in

TABLE 2. Assigning a quality status to water bodies.

Descriptors	Observations
Species richness	Total number of different species. Applied to any group of organisms
Abundance	Total number of individuals. Applied to any group of organisms
Relative abundance	Applied to any group of organisms
Density	Usually per unit area, as individuals m^{-2}, or per unit volume, as number of cells L^{-1}
Diversity indices	
Simpson diversity	Simpson (1949). Applied to data expressed in density, or abundance, or biomass, or production of a group of several species
Shannon-Wienner diversity	Shannon and Weaver (1963). Applied to data expressed in density, or abundance, or biomass, or production of a group of several species
Evenness index	Pielou (1969). Applied to data expressed in density, or abundance, or biomass, or production of a group of several species
Margalef diversity	Margalef (1968). Applied to data expressed in abundance (total number of individuals sampled) of a group of several species
Hurlbert rarefaction	Hurlbert (1971). Applied to data expressed in abundance (total number of individuals sampled) of a group of several species
Indicator/index observations	
Phytoplankton and chlorophyll a:	
TRIX and Trophic Index (Vollenweider et al., 1998)	The TRIX combines factors that are direct expressions of productivity, such as Chlorophyll a and oxygen deviation from saturation, together with nutritional factors, such as total nitrogen and total phosphorus. As supplementary data transparency is also considered.
Freshwater and Brackish water?	The Trophic Index is a simplification of TRIX. The index is scaled from 0 to 10, covering a wide range of trophic conditions from oligotrophy to eutrophy.
Trophic State Index (TSI) (Carlsson, 1977)	TSI uses algal biomass as the basis for trophic state classification and three variables are used to independently estimate algal biomass, chlorophyll pigments (μg L^{-1}), Secchi depth (m) and total phosphorus (μg L^{-1} P). The range of the index is from 0 to 100, although theoretically it has no lower or upper bounds.
Freshwater only?	

Macroalgae and macrophytes:	
Conservation Index (CI) (Moreno et al., 2001)	This index is only applicable in the distribution area of the seagrass *Posidonia oceanica* and measures the degree of alteration that the *Posidonia* meadow has undergone.
For TW and CW	
Ecological Evaluation Index (Orfanidis et al., 2001)	Considers the absolute abundance (%) of each of two ecological groups: ESG I include late successional stages species such as seaweed species with thick or calcareous thallus, low growth rates and long life cycles. ESG II includes opportunistic species, sheet like and filamentous seaweeds species with high growth rates and short life cycles (Orfanidis et al., 2001).
For TW and CW	High proportion of group ESG I species indicates a high or good ecological quality.
Macrobenthic invertebrates:	
AMBI (Borja et al., 2000, 2003)	AMBI is a biotic index derived from the proportions of individual abundance in five ecological groups, which are related to the degree of sensitivity/tolerance to an environmental stress gradient
For TW and CW	Information about the sensitivity of more than 4100 taxa from European and Mediterranean soft-bottom sediments is available in: http://www.azti.es/. Borja et al. (2000) proposed a site pollution classification as a function of AMBI and later the equivalence to the ecological quality status (Borja et al., 2003).
BENTIX (Simboura and Zenetos, 2002)	BENTIX is also based on the differences of species tolerance to increasing anthropogenic stress. It is based on the relative proportions of three ecological groups: the first group comprises sensitive species, the second group tolerant species and second-order opportunistic species and the third first order opportunistic species.
For TW and CW	
Benthic Quality Index (BQI) (Rosenberg et al., 2004)	This index is based on a combination of the species tolerance values, abundance and diversity: Values for 308 species or taxa are available at: www.marine-monitoring.se. The BQI varies with water depth.
For TW and CW	
Infaunal Trophic Index (ITI) (Word, 1978)	ITI is based on the relative composition of four trophic groups: suspension feeders, carrion feeders (carnivorous, omnivorous and necrophagous), surface deposit feeders and those species that are both suspension feeders and surface deposit feeders, and subsurface deposit feeders that feed on sedimentary detritus and bacteria. ITI values near 100 means that suspension feeders are dominant and that the environment is not disturbed. At values near 0, subsurface feeders dominate, meaning that the environment is strongly disturbed, probably due to human activities (Salas et al., 2006).

(continued)

TABLE 2. (continued)

Descriptors	Observations
RIVPACS freshwater	The RIVPACS is a model that can be used to predict the macroinvertebrate fauna to be expected at any site in the absence of pollution or other environmental stress (Wright et al., 2000; Clarke et al., 2003).
Fish:	
Index of Biotic Integrity (Karr, 1981)	This index, developed for American waters by Karr (1981), have been adopted by European researchers (see for example Angermeier and Davideanu, 2004; Belpaire et al., 2000; Breine et al., 2004). The index combines different metrics, such as total number of fish, indicator species (tolerant or sensitive species); trophic function groups percentage, etc.
Transitional Fish Classification Index (TFCI) (Coates et al., 2007)	This index it is also a combination of 10 metrics: Species composition; Presence of 'Indicator Species; Species abundance; Species relative 'abundance'; Number of taxa that make up 90% of the 'abundance'; Nursery function; Number of estuarine resident taxa; Number of estuarine-dependent marine taxa; Trophic integrity; Functional guild composition; Number of benthic invertebrate feeding taxa; Number of piscivorous taxa; Feeding Guild Composition.

environmental impact assessment in which we must differentiate the changes produced by human activities from the sources of natural variability (Pérez-Ruzafa et al., 2007). Sampling design must then be performed according to the objectives of the survey. For monitoring purposes spatial and temporal scales of natural variability must be controlled to determine where and when the samples must be taken and how many replicates we need. In addition, for evaluation impact assessments, the election of adequate control stations became essential.

As commented above, in several ways, the natural environmental and biological variability in a given water body can preclude the detection of impact produced by human activity (Pérez-Ruzafa et al., 2007) and the patterns in species and communities distribution and the sources of such variability should be taken into account when designing sampling strategies to evaluate human impacts. Only if it is done, the derived changes in communities caused by human pressure could be differentiated from natural variability. Sources of variability should be controlled sampling replicates at the lower significant scale and maintaining impacted and control sites within the adequate spatio-temporal scale (Pérez-Ruzafa et al., 2007). When patterns of variability are not known, pilot studies, previous to the regular monitoring, must be performed. To analyze the significant scales of variation in environmental or biological processes, one useful approach consists in applying structured hierarchical sampling designs, where smaller-scaled phenomena or sampling structures are nested within larger-scaled ones (Anderson et al., 2005; Dethier and Schoch, 2005; Moranta et al., 2006; Moore and Fairweather, 2006). This approach can be combined with multifactorial analyses (Pérez-Ruzafa et al., 2007).

4.5. CONDUCT ASSESSMENT

Figure 1 provides guidance how an assessment can be conducted once ecological data are collected using the sampling design. The assessment involves the development of quantitative relationships between pressures and indicators, to identify nature of impairment and limiting factors. This step may include modelling and scientific analysis. The end result of the assessment should include an executive summary for decision makers and public.

5. Responses

Responses refer to the actions taken by government, institutions, groups, non-governmental organizations and individuals to mitigate, adapt to, or protect from human induced negative impacts on the environment as well as to avoid or reverse environmental degradation; and to preserve and conserve the environment. These responses include legislation, economic instruments, new technologies, changing community values, international obligations and others to reduce the pressures on the environment. Some societal responses may be regarded as negative driving forces, since they aim at redirecting prevailing trends in consumption and production patterns. Other responses aim at raising the efficiency of products and processes, through stimulating the development and introduction of clean technologies (EEA, 1999). The responses are directed to achieve good ecological potential instead of good ecological status in the case of heavily modified and artificial water bodies (Rekolainen et al., 2003). The choice of particular responses is complex and dependent upon specific social, environmental, economical and institutional needs (OECD, 2004).

5.1. SOCIAL RESPONSES

Social responses are important components of integrated watershed management, which includes public participation and environmental capacity building aiming to change public's behavior and activities through information, communication and education and to increase the awareness of the public. In the past, involvement of public in the planning activities was not widespread. Easter and Dixon (1991) noted that 'planning for watershed management was approached from the engineering perspective, largely by planners who were generally not a resident of the watershed of concern. In this case, the residents in the watershed were often seen as obstacles or part of the problem, and in some cases, they were ignored. Thus, many watershed management plans developed under these assumptions have failed. In fact, public involvement in the legislative and regulatory process and close cooperation amongt parties involved can help to insure efficient use and development of watershed resources (Kneese and Bower, 1984; White, 1992; Lee and Dinar, 1995; World Bank, 1997). Public participation processes should be considered as opportunities for mutual education of everyone involved (Dawei and Jingsheng, 2001).

By means of effective public participation, relationships get strengthened as communication barriers are ruptured, and people learn how to functionally work together. Public participation encourages innovative solutions with input from the various stakeholders, especially at the local level. On the other hand, decision-makers, often can learn preferences regarding those individuals or groups who will be most impacted by their decisions. The public participation about environmental issues is reflected in the number of participants in the environmental protection publicity and educational activities/programmes organized by the relevant government departments, and the number and category of environmental complaints raised by the public (Environment Council of China, 2005). Establishment of community-based environmental resource centers also increase the participatory potential of the public.

In the case of the Axios River, which drains from the Former Yugoslav Republic of Macedonia (FYROM), parts of Bulgaria, the Federal Republic of Yugoslavia and Greece (Hellas), a research was performed under the auspices of the project EUROCAT. Within the context of this research, it is reported by Karageorgis et al. (2004) that information to the stakeholders appeared to be the main problem for the implementation of environmental regulations. The design of policies, as a societal response to the deterioration of the environment does not indicate the stakeholders' opinion, and is not accompanied by a proper downscaling of information, which leaves a big gap of knowledge to the stakeholders. All stakeholder groups declare that the enforcement of control measures by the state is minimal. Especially the group of industry representatives is unaware of the new environmental regulations and their impacts on industrial performance, expressing fears about sector viability in the case of a potential enforcement of regulations (Karageorgis et al., 2004). This case shows the importance of the public participation in terms of integrated watershed management. In some developed countries like the U.S., public involvement is mandatory in assessing the environmental consequences of major governmental actions.

5.2. ENVIRONMENTAL RESPONSES

Environmental responses are the management and control actions aiming to conserve, maintain, or improve the quality of natural resources for sustainability by preventing and/or reducing pollution. Preventive measures focus on prevention of pollution production and reusability of materials, whereas curative measures consider reducing of pollution after it has been generated. Preventive measures can be taken through various methods as given below (Crichlow, 2001):

- Demand management should be taken into consideration during production processes. Demand management helps agencies to improve asset management and planning, reduce capital and operating costs and make more informed decisions based on the economic, social and environmental benefits.
- The development and application of environment friendly technologies which results in less environmental impact such as manufacturing refrigerators not based on PCBs as coolant.

- Pollution control at the source is an effective option for pollution reduction. During the production processes, the materials which generate less pollution can be used (e.g. oil based lubricants vs. water based lubricants/paints). Source controls are considered to be the easiest approach to regulate and implement.
- Changes in the behavior of public through increasing environmental awareness and promoting activities with less impact on environment can be realized (e.g. using public transport instead of a private car or plane).
- Application of reuse, recycle and recovery for reutilization of materials is important in terms of pollution prevention. Reusing glass bottles, recycling plastics or recovering nutrients from sludge can be given as examples.
- Create/use energy from renewable sources can be induced. Best available techniques and best environmental practices given below can be applied for pollution reduction after its generation in the watersheds (Colorado State University, 1994; Karageorgis et al., 2004; Giupponi et al., 2006).
- Structural controls usually require some capital outlay and maintenance, but are very effective in controlling pollution (e.g. Creation of buffer zones, wetlands, grassed waterways, vegetative filter strips, construction of diversions, terracing, for nutrients and sediment removal).
- Cultural controls in agricultural practices are cropping and tillage practices that either minimize pest problems and reduce the need for chemical controls or maximize nutrient use efficiency (e.g. conservation tillage, crop rotations, strip cropping systems, cover crops).
- Managerial controls are strategies and tools that minimize pollutant losses in groundwater or surface waters (e.g., promotion of integrated pest management and organic farming, change in land management practices to reduce nitrate leaching, irrigation management).
- Increasing the quality of effluents through wastewater treatment and promoting widespread construction of treatment plants.

The efficiency of environmental responses can be assessed through (1) environmental monitoring to determine the state of environmental conditions, (2) simulation and modeling, to analyze the causes and effects of environmental problems and predict the result to alternative responses, and (3) cost-effectiveness and scenario analysis. Most environmental responses act at the level of pressures, and they will be most effective when they are combined with changes in drivers as well.

5.3. ECONOMIC RESPONSES

Economic responses can act as incentives for the management of the watersheds and sustainable use of natural resources (Shah and Muramira, 2001). They have gained particular attention in recent years as effective measures which serve to integrate environmental concerns into economic development strategies (Klarer et al., 1999a). One basic objective of economic instruments is to ensure an appropriate pricing of environmental resources in order to promote an efficient use and allocation of these resources (UNEP, 2006). Klarer et al. (1999b) state that OECD countries' experience shows that economic instruments, if designed and implemented properly, often in combination with environmental policy instruments, can contribute to achieving economic benefits.

Klarer et al. (1999b) declares that economic instruments (1) can reflect the real costs of pollution and attempt to incorporate them into the prices of products and services – they encourage pollution reduction where abatement activities can be implemented in the most cost efficient way; (2) raise revenues which governments can use for catalyzing environmental investments of national priority, or for decreasing income taxes, profit taxes or social security contributions; and (3) encourage the development and trade of more efficient technologies by raising the price of pollution and natural resources.

Economic instruments support the "Polluter and User Pays" Principles. Economic instruments ask for direct payments from those who introduce pollution into the environment and those who use natural resources taken from the environment. WFD recommends using this approach and pricing as a management tool (Giupponi et al., 2004). Economic instruments include:

Fees: generate revenue that can be used by the enforcement program. Unlike monetary penalties, fees create an immediate cost to the facility for polluting. Fees should be high enough to deter pollution, so as to prevent them being perceived as a "license to pollute."

Tax Incentives: These are reduced taxes for costs associated with improving environmental quality e.g. installing pollution control equipment, or changing a process to prevent pollution.

Taxes and Subsidies: Taxes are based on the volume and/or toxicity of emission, effluents, or wastes generated (e.g. increase of taxes on fertilizers). Subsidies can lower the cost to the consumer and thus promote their purchase and use in cases where environment friendly alternatives are more expensive. Taxes and subsidies raise the cost of technologies and products that degrade the environment in line with the costs of damage they cause and discourage people from using them (Emerton and Muramira, 1999; UNEP, 2006).

Ecotourism: Ecotourism refers generally to tourism in natural areas that promises to protect the environment by generating money for protection while ensuring that visitors act in an environmentally sensitive manner. Pirrone et al., (2005) reported that promotion of eco- tourism in Po Basin Area-Italy is encouraged.

Emissions Trading Programmes: While this tool tends to be more common in developed countries, a growing number of countries are exploring and developing emissions trading programmes. Most of these programmes place an overall limit on the emission of a particular pollutant or group of pollutants. If a company would like to emit more of that pollutant, it must buy the right to emit that amount from another company.

Creative Financing Arrangements: Cost can be a barrier to compliance. Experience in industrial environmental management has shown that oftentimes facility managers may want to comply but may not be able to afford the cost of fulfilling the requirements. Business people can use it for mobilizing and channeling funds for equipment, technologies and production processes, which are greener and cleaner (Emerton and Muramira, 1999).

Elimination or Reduction of Environmentally Harmful Subsidies: Certain subsidy schemes may lead to environmentally unsustainable economic development patterns and affect or offset arduously achieved improvements by environmental policy. Therefore, elimination or reduction of environmentally harmful subsidies is necessary (Klarer et al., 1999b).

Penalties act as deterrence to violating the law, and an incentive for staying in compliance with the environmental statutes and regulations. Penalties are designed to recover the economic benefit of noncompliance as well as account for the seriousness of the violation. Note that not all enforcement actions require a penalty; other remedies may be specified (U.S. EPA, 2006).

5.4. INSTITUTIONAL/POLITICAL RESPONSES

The implementation of integrated and sustainable watershed management falls within the responsibility of government institutions at both the national and local level. They share the responsibilities for the implementation of national policy with the other institutions, non-governmental organizations and the public (UN, 2002). Appropriate institutional and organizational mechanisms are required for the coordination/implementation of watershed management activities (Achouri and Tennyson, 2005). Watershed-scale institutions are also recommended to craft and implement watershed policies and programmes (Schlager and Blomquist, 2000).

Government institutions enforce following existing regulations, directives (e.g. EU Water Framework Directive), multilateral environmental agreements (e.g. Basel Convention, RAMSAR), regional binding or non-binding agreements (UNEP, 1997). It may be possible to develop new policies, strategies, action plans and legislative framework, with clear objectives and priorities with regard to watershed management, and they may be useful if they incorporate valuation of ecosystem goods and services (Achouri and Tennyson, 2005). Other useful tools for the management strategies required by law are environmental impact assessment (EIA) and strategic environmental impact assessment (SEA), which can provide information on how sources can best be controlled.

6. Recommendations and Conclusions

Sustainable water resources management should be focused on maintaining and/or restoring the physical, chemical, and biological integrity and health of lotic, lentic, and transitional/coastal water ecosystems. For the EUWFD, this would be good ecological status or restoration of good ecological potential for heavily modified water bodies. For the US, this would mean for a water body to support all of its designated uses. The goal of this type of management is to ensure that the water quality and quantity and many other goods and services provided by the aquatic ecosystem to human systems are sustained.

Watershed management efforts should be directed at the level of landscape sources and activities (drivers), rather than at the pressures that result from these drivers. We suggest this focus because changes and deterioration of water systems has proved to be mostly driven by socio-economic policies and strategies and management activities applied at different watershed scales. This is particularly important in the face of climate change, an increasing global pressure that integrates long-term and long-distance cumulative effects on many of the drivers and pressures.

Watershed management and planning must integrate across ecosystems and the land-waterscape through multiple scales. In terms of physical configuration (composition and structure) and functional regime, watershed management has to encompass complexity and uncertainty and be designed and implemented at large temporal and spatial scales (Holling, 2001). Yet it is also necessary to link grassroots and community based initiatives with the wider national or transnational perspectives or natural resources management. A set of programmes and networks of representative ecosystems and land or land water scapes, such as Corine Land Cover (CLC), the agri-environmental indicator program IRENA (EEA, 2004) the area sampling process LUCA (Eurostat), the European Landscape Mapping Initiative LANDMAP, the Long Term Ecosystem Research (LTER) and Long-Term Socio Ecological Research (LTSER Europe) platforms, and the National Earth Observation Network (NEON) must be considered cornerstones for the systematic development of an ecosystemic and landscape monitoring and reporting system.

Four tools are necessary for successful management:

1. Extensive use of traditional ecological knowledge (TEK). Is defined as "a cumulative body of knowledge, practices, and beliefs concerning relationships of living beings (including humans) with one another and with their environment (Failing et al., 2007).
2. Good current and historical scientific information and physical, chemical, biological social, and economic data, preferably delivered from an integrated long term ecosystem and land watershed or socioecological system research, monitoring, and reporting program.
3. A restricted number of policy and management relevant holistic indices (see Section 4.4). Relevant information should be abstracted to indices that are accessible and understandable by stakeholders and provide guidance for restoration.
4. Mathematical models describing water and material flows at the watershed scale (see PART 3). These models can be used to assess alternative future scenarios and management options.

Participatory deliberative approaches should be used for proper assessment and management. These approaches are needed for watershed management, which involves conflicting interest between stakeholders, a plurality or legitimate standpoints and diffuse responsibilities and impacts (Fiorino, 1990; Van den Hove, 2000; Kenyon, 2007). Such approaches and their related methods have been developed and extensively used after 1990, for natural resource management and more recently for the development of alternative scenarios and structured decision making at large space scales (e.g. watersheds of different size, regional and subregional socio-ecological systems extended in one or more watersheds) according with the requirements of recent EU legislation (e.g. EU-WFD) or UN-conventions (e.g., Aarhus convention). Kenyon (2007) re-iterated the advantages of those approaches and methods, in that: (i) more people and expertise are brought in to analyze the problem; (ii) in getting agreement and acceptance of the problem and positive solutions; (iii) in terms of building capacity within communities to get involved in complex decision making processes.

For the purpose of the book we chose to recommend to those involved in watershed management a deliberative multi-criteria method which was developed and applied by Kenyon (2007) for evaluating flood risk management options in Scotland. The reason for our choice derived from that the method was built on the other existing participatory approaches and it is flexible, which can be easily adapted for being used for specific or very complex problems. In that regard the author has adapted and adopted a number of key ideas and elements from the Citizen Juries (CJ) approach, which is a group of randomly selected people, who represent a microcosm of their community and promote the public interest in the decision making concerning a wide range of environmental problems (e.g., wetland creation, waste management) (Kuper, 1996; Alfred and Jacobs, 2000; Kenyon and Nevin, 2001).

The most influential elements from Citizen Juries approach which were selected and incorporated in her method concerns: (i) the time and information given to people involved in deliberation; (ii) the structured agenda that breaks down the decision making process into manageable tasks and well focused agenda which reduces the cognitive burden and enables participants to perform and engage better into the process; (iii) the increased transparency of the final outcomes; (iv) the possibility the jurors have to scrutinize and question information and to seek out their own information by calling and asking particular witnesses. She also tried to balance the power relations between experts and participants, and to reduce one of the major limitations of the Citizen Juries approach.

Other essential elements were borrowed and adapted by Kenyon, from the deliberative monetary evaluation (DME) method which usually help to value in monetary terms, the non-market benefits from the environment, for the policy process (Macmillan et al., 2003; Alvarez-Farizio and Hanley, 2006). Those elements concern: (a) the combination of qualitative and quantitative outputs; and (b) the opportunity to make trade offs and comparisons explicit in the decision making. In order to avoid the ethical, psychological and hypothetical problems that usually arise when money is used as the metric for comparison, the element concerning the monetary valuation has not been incorporated in the process.

Finally, the method was built on very important elements derived from other participatory, multi-criteria (MC) approaches, which in essence follow a process of identifying options in response to a problem, determining criteria against which the options can be assessed and then ranking and scoring each option against the agreed criteria (Prato, 2003; Stagl, 2006; Failing et al., 2007). In particular have been incorporated from MC approaches those elements which deal with mixed quantitative and qualitative data inputs, with the ability to accommodate data gaps and, more important, with those characteristics which makes such approaches – simple, intuitive and transparent (Mendoza and Prabhu, 2003). Two additional elements have been adapted from the "deliberative mapping method" (Davies et al., 2003). Those relate to the use of visual methods during deliberative events in order to engage participants, to record information and to summarize results to participants, and to the initiative to split the process into parts, for allowing participants to gather more information from their own sources, to consult family and friends and to assimilate the information.

Governing institutions involved in water systems management should move from a competitive, sector-oriented style of governance towards a landscape *and water oriented form*. Governance based on the landscape (Görg, 2007) or socio-ecological system (Vadineanu, 2007) creates the framework for integration across scales.

Economic analysis, using economic principles, methods (polluter pays principle, cost-benefit analysis, cost-effectiveness analysis), and instruments (e.g., water pricing), must be a key element of integrated and sustainable watershed management. The requirement for economic analysis is clearly stated in the long-term sustainable development strategies and specifically enforced by national and international water legislation (e.g., EU WFD, U.N. Ramsar Convention). For instance, the WFD specifically calls in Articles 5 and 9 and Annex III for economic analysis, the results of which have to be integrated in the policy and management cycle in order to complement the outputs of the deliberative, multi-criteria methods and to strengthen decision making when preparing river basin management plans. Strong economic arguments are also required by Article 4, when derogation for not achieving the major objective of Good Ecological Status (GES) or Good Ecological Potential (GEP) it is formulated in the watershed management plan by EU member countries.

Thus, a key element of the economic analysis, required in the watershed management plan, concerns the assessment of costs and benefits of current and future water use. In particular, the assessment of environmental and resource costs and benefits has a central role in the economic analysis. In order to meet this basic requirement the experts and practitioners should be able to identify and assess, based on the existing scientific and traditional knowledge, and monitoring data, the dynamics of the structural configuration and functioning of water ecosystems and land-waterscapes, in particular the production, regulation and support functions and their related flows of goods and services which feed the metabolism of the socio-economic system and are valued by people. The value of changes in the functions, under the pressures of social and economic drivers or climate change, can be derived from the change in the value of the stream of benefits (Vadineanu et al., 2003; Vadineanu, 2007; De Groot, 1992; De Groot et al., 2002; Maltby et al., 1996; Turner et al., 2004; Brower and Georgiou, 2007). In the process of economic analysis, the focus is on economic values of goods and services provided by the aquatic ecosystems, which depend on human preferences.

The aggregation of all function-based values (use and non-use) provided by a given water ecosystem or land-waterscape yields the total economic value (TEV) of that ecological unit. The TEV concept combined with the ecosystem functional approach and related goods and services outputs created a comprehensive economic assessment framework which is very suitable for the environmental and resource costs and benefits estimation in watersheds of different size. Within this framework, might be identified and applied a wide range of valuation methods and techniques which include the estimation of demand curves, analysis of market like transactions, use of production approaches that consider the contribution of water resources to the production process, estimation of the costs of providing alternative sources of water or more complex integrated techniques based on water modelling approaches coupled with economic production and consumption functions, from which derive shadow prices and opportunity costs of different existing or future water use patterns (Brower and Georgiou, 2007; Lowell et al., 2007). For more detailed information about the theory, classification, and the selection and application of the existing valuation methods and techniques as well as about their limits and some particular and/or general difficulties the practitioners are facing in applying them, we are recommending a set of guidelines and textbooks (Brower and Georgiou, 2007; Bateman and Willis, 1999; Bateman et al., 2002; Freeman, 2003; Barbier et al., 1997; Bergstrom et al., 2001; Champ et al., 2003; U.S. EPA, 1995, 2000; Turner et al., 2004; Young, 2005; Ward and Beal, 2000).

For the quality and performance of the decision making process, all of the above recommendations must be taken into account equally.

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DECISION MAKING, POLICY AND FINANCING

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1. Introduction

The most critical situation facing the health of water resources and aquatic ecosystems is not the result of a single activity on or near a lake, river, or stream. Instead, it is the combined and cumulative result of many individual activities throughout a waterbody's entire natural drainage area, catchment area or watershed. A watershed is the area of land where all of

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the water that is under it or drains off of it goes into the same place. John Wesley Powell, U.S. scientist and geographer, put it best when he said that a watershed is:

> …that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community.

World-wide watersheds supply drinking water, provide recreation and respite, and sustain life. Throughout the world, countries depend on clean water and healthy watersheds for food, fiber, manufactured goods, and tourism. This natural capital is the basis for social economic systems in developed and developing countries and the building block for the future in undeveloped countries. In the United States more than $450 billion in food and fiber, manufactured goods, and tourism depends on clean water and healthy watersheds. Watersheds come in all shapes and sizes. They cross county, state, and national boundaries. No matter where you are, you are in a watershed! As we all live in a watershed, our individual actions can directly affect it. The cumulative effects of all the individual actions of everyone within a watershed may be, and often are devastating to the quality of water resources and affect the health of living things including humans. Management for sustained use of water and other ecosystem resources requires a watershed based approach.

Watershed Approach: A watershed approach is the most effective framework to address today's water resource challenges. A watershed approach is a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow.

This chapter presents the basic elements of a watershed approach to planning including:

- Building partnerships
- Characterizing watersheds
- Setting goals and identifying solutions
- Designing an implementation program
- Watershed plan development
- Implement watershed plan
- Measuring progress and making adjustments

Further, this chapter sets forth Terms and Principles as well as recommendations to be applied in implementing sustainable use and development practices.

2. Terms and principles

Terms and Principles to be applied in implementing sustainable use and development practices (EPA, 1995):

1. A Watershed Approach is defined as:
   (a) Is hydrologically defined:
   - Geographically focused
   - Includes all stressors (air, water, and land use)

   (b) Involves all stakeholders:
   - Includes public (federal, regional, state, local) and private sector
   - Is local community based
   - Is multi sectorial/jusrisdictional
   - Includes a coordinating framework

   (c) Strategically addresses priority water resource goals (e.g., water quality and quantity, living resources, habitat):
   - Integrates multiple programs (regulatory and voluntary)
   - Based on sound science and appropriate technology
   - Uses adaptive management

2. Sustainable management is managing to meet present needs as well as providing for the needs of future generations. Conceptually it requires the awareness and consideration of the ecological system. It also requires measurement of, and accountability of the values of an ecological unit, such as a watershed area.

3. Sustainable management is a conscious social decision that provides for the long term health of both the ecological and economic systems of the ecological unit. The finite capacity of the ecological unit's natural capital cannot meet the growing demands of society without a plan for sustainable management.

4. In arid and semi-arid countries where water resources are rare and disproportionately distributed, degradation of watersheds give rise to economic short-falls impairing the development of rural populations whose economic conditions oblige them to move from rural to urban areas.

5. The use of the best available information, knowledge, and tools needs to be applied throughout the decision making process. A monitoring program is a key factor in establishing a baseline of conditions, to evaluate results of actions, and to direct the future management for sustainability.

6. The use of models as tools in the decision making process will enhance awareness of the interrelationships within the ecological unit, especially its input and output variables. This will further enhance accuracy of predictions for, and awareness of the consequences of decisions on management actions.

7. Decision making should consider all state interested parties including governments (federal/national, regional, and local), non-government organizations (NGOs), scientific institutions, business users groups and industry, agriculture, fisheries, forestry, tourism as well as the general public in a participatory approach on an equal level.

8. Management of decision making requires a formal Cooperative Institutional Structure that is empowered through appropriate policy and legal authority.

9. The Cooperative Institutional Structure should have a written Charter or Agreement that commits the parties to work cooperatively to address the goals, and meet schedules for sustainable use and development of the natural capital.

10. A conflict resolution process should be identified that provides ample and open/transparent consideration of differing views and interests as well as consultation with technical experts and stakeholders.

11. Incorporate into the national legislation and multi sectorial treaties/agreements of the basin countries the strictest international environmental standards, principles and processes, and the strictest rules for monitoring of those standards.

12. Environmental education is essential in order to insure long-term sustainability of a participatory process. Education should be at two levels: (1) public awareness of sustainable management of the environment, especially the linkages between watershed activities and consequences on the downstream water body and the need for an integrated water resources management including the coastal zones, and; (2) formal education of young people in order for them to understand the central role of the natural environment in their future welfare.

13. Capacity building to preserve and protect watershed resources is an important consideration as it is a need in developing countries and undeveloped countries. Training of those implementing the management plan for sustained use will in these cases be necessary in order to ensure that those making monitoring measurements are using the appropriate equipment, methodologies, and procedures and are conducting the tests correctly and reproducibly. Similarly, training will be required for those doing such activities as operation of wastewater treatment plants. Technology transfer of assessment tools and models is needed, and there

should be active exchange of information and experiences, as part of an annual human resource management and development program.

14. Outreach from participants in the planning and implementation phases must be a continuous process in order to ensure that all concerned parties (stakeholders) – from politicians to scientists to citizens, from those working in research to those gathering data, to those implementing, using the natural capital or ameliorative actions – are aware of actions taken and progress made.

15. Financial tools – generation of funds based on the principles of economic deterrence and incentives (e.g., taxes and tariff structure taking into account affordability-to-pay of all stakeholders, generate funds for compensation measures as appropriate). Many aspects may be accomplished through volunteer efforts, incurring no costs.

16. Operational costs – the cost of doing business needs to be taken into account when developing the watershed plan. This cost is a critical factor in the implementation of any plan, particularly a plan for sustained use.

17. The budget structure and funding sources for the activities associated with watershed management and sustainable development can have different forms depending on the economic situation and geographic and political features (national/transboundary) of a watershed. The watershed management plan and implementation needs to be realistic and affordable with regards to the available funds and resources. Reframing water usage issues can be useful to obtain the funds required for use of the public's transit in the water and living resources. Consideration of the costs of training and providing the necessary tools for watershed management, particularly for those in developing countries, must be taken into consideration. Watershed management planning should contain provisions of financial security of future activities.

18. Possible approaches to secure the funds for watershed management activities include the following:
    - Voluntary-based activities (education, public awareness, local communities' rights over the water-related renewable resources).
    - National subsidies.
    - Private donations.
    - Polluter pays/compensation (changes in legislation are required).
    - Water living resources user fees (taxes, tariffs, levees). In addition, cost subsidies may need to be considered given that users who produce socially valuable commodities may not be initially able to pay for the resource use. This societal development decision may be made particu-

larly in countries where economic factors are major limiting factors to sustainable use and development practices.

- Financial schemes provided by international organizations (e.g., grants, loans, inter-country bilateral agreements).

3. Watershed approach to planning (EPA 2005)

A watershed approach to planning is a strategy and a work plan for achieving water resource goals that provides assessment and management information for a geographically defined watershed. It includes the analyses, actions, participants, and resources related to development and implementation of the plan. The watershed planning process uses a series of cooperative, iterative steps to characterize existing conditions, identify and prioritize problems, define management objectives, and develop and implement protection or remediation strategies as necessary (see Appendix 1).

3.1. BUILD PARTNERSHIPS

The very nature of working at a watershed level means that work with partners to improve watershed conditions because it is often too complex and too expensive for a single entity. New ideas and input provided by partners not only provides a more solid commitment to solutions, but also helps to eliminate redundancy in financial distributions. Stakeholders' involvement further increases the probability of long-term success through trust, commitment, and personal investment. Critical elements of this step are listed below:

- Identify key stakeholders
- Identify issues of concern
- Set preliminary goals
- Develop indicators
- Conduct public outreach

3.2. CHARACTERIZE THE WATERSHED

Characterizing the watershed, its problems, and pollutant sources provides the basis for developing effective management strategies to meet watershed goals. The characterization and analysis process helps focus the planning efforts on the most pressing needs and targets data collection and analyses to the specific area of the watershed within the scope of the plan. The scope is defined as not only the geographic area to be addressed but also the number of issues of concern and the types (and breadth) of the goals that need to be attained. If the scope is defined and preliminary goals established early in the planning process, it is easier to work through the later steps in the process. The process of watershed characterization includes the following steps:

- Gather existing data and create a watershed inventory
- Identify data gaps and collect additional data
- Identify research needs
- Analyze data
- Identify causes and sources that need to be controlled
- Estimate pollutant loads

3.3. SET GOALS AND IDENTIFY SOLUTIONS

Now that the problems in the watershed have been characterized and quantified, the preliminary goals set at the beginning need to be refined and developed into detailed objectives, measurable targets, and indicators. Also, select management strategies that, when implemented, will help to achieve the goals, need to be identified.

- Set overall goals and management objectives
- Develop indicators/targets
- Determine corrective actions needed (e.g., load reductions, species introduction, tree planting, etc.)
- Identify critical areas
- Develop management practices to achieve goals

3.4. DESIGN IMPLEMENTATION PROGRAM

The implementation plan is a road map for not only turning the management strategies from paper into reality but also for determining how to measure progress toward meeting the goals. Putting the implementation pieces together involves laying out the detailed tasks that need to be done, identifying who will do them, identifying the funding and technical assistance needed, and setting up a process to measure the effectiveness of the program. The implementation plan identifies watershed management measures and should take into consideration economic, social, and environmental factors. The design of an effective watershed implementation plan should provide the following several key elements:

- Develop an implementation schedule
- Milestones
- Criteria to measure progress
- Monitoring component
- Research component
- Information/education component
- Evaluation process
- Identify technical and financial assistance
- Assign responsibility

3.5. WATERSHED OUTLINE

The watershed plan provides a context and a road map for how to manage the watershed. This should include land-use planning and social economic analysis and planning as a major management tool. Enough information needs to be provided in the plan so that it clearly shows how the goals were developed and how to achieve those goals. Caution needs to be exercised to avoid pitfalls: Many watershed plans are broad, exhaustive documents with lots of historical information, but no clear, concrete plan of action that links back to the major problems and sources of pollution in the watershed. In addition, many plans do not quantify the stressors/pollutants so that it is almost impossible to determine the amount of reductions that are needed to achieve goals.

A Plan Builder (refer to: http://iaspub.epa.gov/watershedplanBuilder) can help the development of an outline of a watershed plan with the recommended sections that can be fill in with the stakeholders in the targeted watershed.

3.6. IMPLEMENT THE WATERSHED PLAN

While much of the watershed planning process is focused on the development of the plan, results will not happen until the plan is actually implemented. Implementation can begin with an information/education component or with on-the-ground management measures. Implementation activities should follow the road map developed in the plan.

- Prepare work plans (including land use and socio-economics)
- Implement management strategies
- Conduct monitoring
- Conduct information/education activities

3.7. MEASURE PROGRESS AND MAKE ADJUSTMENTS

Periodically the implementation activities outlined in the work plan need to be reviewed; the results need to be compared with the interim milestones, feedback provided to stakeholders, and determine whether corrective actions are needed. Also, decision points need to be identified at which information is reviewed and decisions made on whether to make changes in the program or stay the course.

- Track progress
- Make adjustments

4. Recommendations

The following recommendations are suggested as guidelines. They are based on successful work directed at sustained use and development of natural capital resources in interjurisdictional/trans-boundary situations. It should be recognized that in different countries with different cultures the recommendations may need to be modified to address existing institutional structures, agreements, and unique interests of those involved. At the same time, it should be recognized that, cultural practices and traditions also may need to be adapted to meet the needs of sustainable management. Such pending changes may take a period of time with incremental steps to achieve the desired results. Again, involvement of all stakeholders and education are key aspects to success.

1. Establish a Cooperative Institutional Structure, empowered through appropriate policy, legal, and financial instruments. An example is provided in Appendix 2.

2. Establish a Charter, a formal Letter of Agreement or treaty that commits cooperation between sectors (e.g., countries, national, regional, and local governments). The signatories should be at the highest levels of the respective governments, and this group should serve as an Executive Committee, The Executive Committee establishes commitments, goals, and monitors the results of management actions.

3. Existing Agreements need to be inventoried, evaluated, and modified (as appropriate) for direction consistent with sustainable management principles. Along with the commitments goal (identified above), which are the tools for guiding management direction.

4. Establish an Implementation Committee that serves as the principal advisor to the Executive Committee. This committee should be made up of staff to service and manage the Cooperative Institutional Structure. The

Implementation Committee should identify policies and legislative needs as well as seek consistency in management of interjurisdictional/trans-boundary issues. The staff needs to include experts in social, economic, and environmental management as well as conflict resolution based on consensus. The Implementation Committee also should serve a functional role in directing the technical working group's (noted below) to address priority work issues.

5. Establish Technical Working Groups. The following working groups are recommended: Water Demand and Quality Management, Nutrients, Toxics, Hydrologic and Ecological Modeling, Hydro-biological, Coastal Monitoring, Fish Resources and Fisheries, Exotic/Invasive Species, Land and Water Developments (e.g., commercial navigation and dredging), and Migratory Birds. Working Groups should be established to address local needs and national and interests. These groups will establish plans to address agreed upon, by Executive and Implementation Committees, trans-sectovial goals and objectives taking into account water rights including ecosystems, and emerging global environmental concerns (e.g., climate change).

   These groups also will recommend goals and objectives to Executive and Implementation Action Committee for adoption.

6. Establish Advisory Committees for the general public (citizens), scientific and technical interests, local governments, and non-government organizations (NGOs). Other Advisory committees also may be appropriate to meet local interests as well as national and international issues.

7. Invite stakeholder involvement from all businesses and industrial sectors that have an interest in the water unit and its watershed area. This should include representatives from industry, agriculture, fishermen, foresters, tourist industry (developers and managers), citizen residents, and others (all stakeholders).

8. Hold Round Table meetings at each level of the Cooperative Institutional Structure on a regular basis. For example:
   - Executive Committee – Annual
   - Implementation Committee – Quarterly or Bi-monthly
   - Working Groups – Every two month's or bi-monthly

9. Facilitate the decision making process by modern and joint use tools for trans-boundary management, (e.g. unified data bases, geographic information system (GIS), modeling tools for impact assessment based on national, regional, and international commitments). Establish procedures for data

base replenishment and access to data base resources as well as exchange of information for environmental impact assessment and operational needs.

10. Establish an environmental education program directed at: (1) public awareness of sustainable management principles and a environmental issue, especially the linkages between watershed area activities and consequences on the downstream water body(including the coastal zone) and the need for integrated water resources management and 2) formal education of young people (education curriculum for primary and secondary levels) in order for them to understand the central role of the natural environment in their life and life of future generations.

11. Design and establish a training program to train those persons, especially from developing countries, who will be conducting monitoring analyses. This will ensure that measurements are being made using appropriate techniques, and performing the analyses correctly. There should be an active technology transfer program to provide the models and decision support systems used in watershed management to those who need training in the use and proper application of these tools.

12. Establish an outreach program that informs all interested parties of work underway and progress made. This can be done through several media: newspapers, television, websites, written and distributed reports. Outreach materials should be tailored to the audience they are intended to address, (e.g., a report to politicians will differ from a report to the citizenry, which will differ from a technical document intended for the scientific community).

13. Establish a formal dispute resolution process. Differences of opinion need to be elevated to higher authority within Cooperative Institutional Structure to ensure that sectorial competing interests for natural capital are fully considered. Furthermore, compensation measures need to be identified to mitigate the negative impacts of decision that are necessary to support sustainable management.

14. Establish a planning process. The planning process can be simple. The following seven step process can serve as the basic components
    - Set the goals for sustainable use and development of the watershed
    - Define problem(s) – describe the problems/conditions that affect the ecological and social-economic structures
    - Define the system – the ecological and socio-economic structural components
    - Develop and use an effective decision support system, a Cooperative Institutional Structure

- Develop and integrate this plan into the infrastructure by functional committees and workgroups of the Cooperative Institutional Structure
- Formulate action plans to address identified needs for information, policy, and legal framework
- Evaluate progress on a regular basis (at least annually by the Executive Committee and Implementation Committee)

15. Formulate funding strategy for watershed plan formulation and implementation.
16. Monitor new industrial and agricultural projects in the basin and enforce the implementation of independent environmental impact assessment with mandatory consideration of impact on the watershed spacially and temporally (over time) for sustainable management.

References

EPA 1996, Watershed Approach Framework, EPA Office of Water.
EPA 2005, Handbook for Developing Watershed Plans to restore and Protect Our Waters, EPA 841-B-05-005.

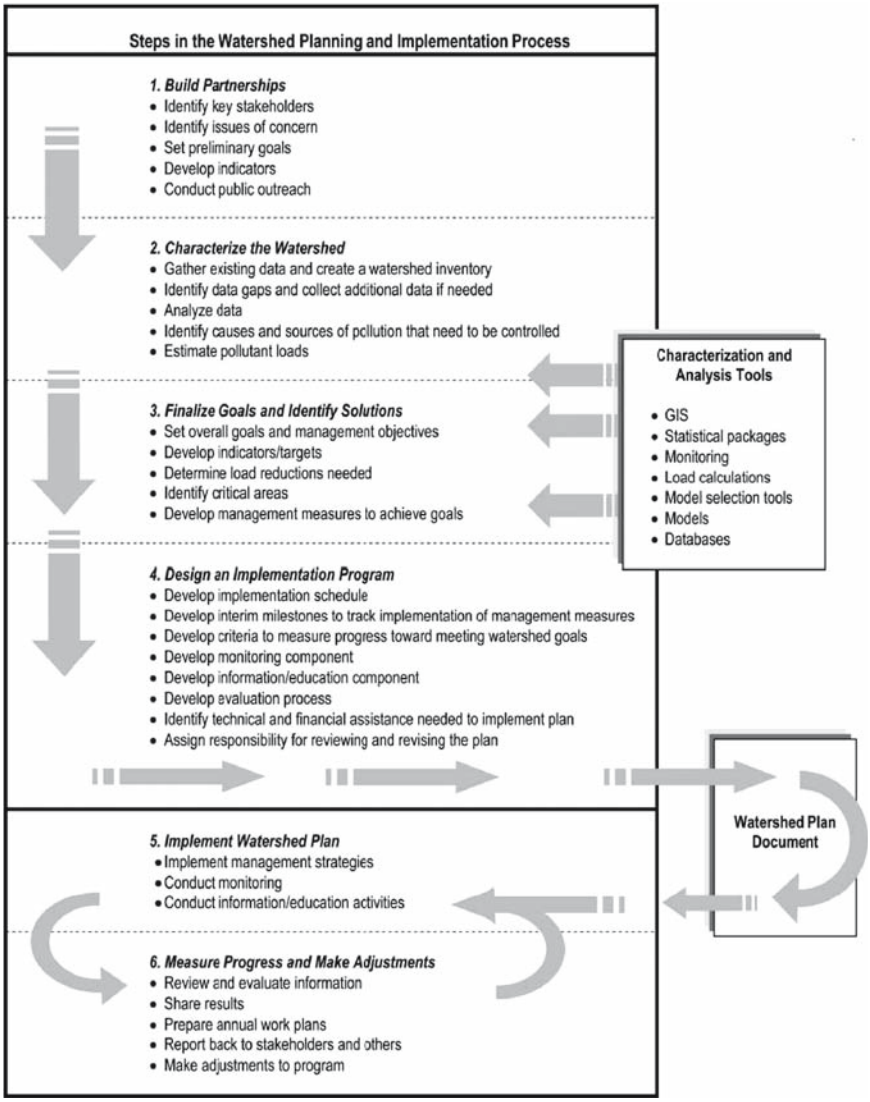
Further Reading

The following references are provided for further reading on the subject of watershed management

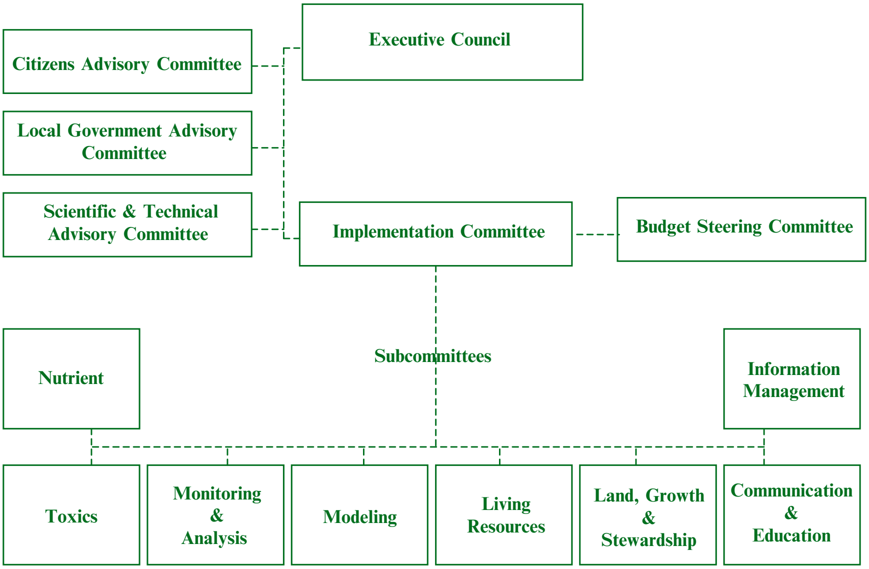
- National Estuary Program is a coastal watershed-based program.
- Total Maximum Daily Loads are a planning tool that can be used to establish pollution budgets for polluted watersheds.
- Nonpoint Source Program provides funding to states to address polluted runoff.
- Section 319 Success Stories illustrate measurable results in nonpoint source pollution reduction.
- Targeted Watersheds Grants Program provides implementation and capacity building grants.
- Watershed Funding tools and resources are available.
- Try out the Watershed Plan Builder online to create your watershed plan.
- Technical Tools for Watershed Management includes databases, mapping, and water quality models.

- EPA's Strategic Plan (Chapter Two: Clean and Safe Water) includes a goal to protect the quality of rivers, lakes, and streams on a watershed basis and protect coastal and ocean waters.
- The Watershed Approach is one of the four pillars of the Sustainable Infrastructure Initiative.
- Why Watersheds? (1996) describes various benefits of using watershed approaches.
- Other Watershed Links includes a list of other websites related to watershed management.
- The Watershed and Wetland Protection Information Kit is a collection of resources by the Center for Watershed Protection and the National Association of Counties (with support from EPA) to assist county and local officials with efforts to protect and restore the multiple benefits of their community's water resources.

APPENDIX 1


Steps in the Watershed Planning and Implementation Process
1. Build Partnerships
• Identify key stakeholders
• Identify issues of concern
• Set preliminary goals
• Develop indicators
• Conduct public outreach
2. Characterize the Watershed
• Gather existing data and create a watershed inventory
• Identify data gaps and collect additional data if needed
• Analyze data
• Identify causes and sources of pollution that need to be controlled
• Estimate pollutant loads
3. Finalize Goals and Identify Solutions
• Set overall goals and management objectives
• Develop indicators/targets
• Determine load reductions needed
• Identify critical areas
• Develop management measures to achieve goals
4. Design an Implementation Program
• Develop implementation schedule
• Develop interim milestones to track implementation of management measures
• Develop criteria to measure progress toward meeting watershed goals
• Develop monitoring component
• Develop information/education component
• Develop evaluation process
• Identify technical and financial assistance needed to implement plan
• Assign responsibility for reviewing and revising the plan
5. Implement Watershed Plan
• Implement management strategies
• Conduct monitoring
• Conduct information/education activities
6. Measure Progress and Make Adjustments
• Review and evaluate information
• Share results
• Prepare annual work plans
• Report back to stakeholders and others
• Make adjustments to program
Characterization and Analysis Tools
• GIS
• Statistical packages
• Monitoring
• Load calculations
• Model selection tools
• Models
• Databases
Watershed Plan Document

APPENDIX 2


Executive Council
Citizens Advisory Committee
Local Government Advisory Committee
Scientific & Technical Advisory Committee
Implementation Committee
Budget Steering Committee
Subcommittees
Nutrient
Information Management
Toxics
Monitoring & Analysis
Modeling
Living Resources
Land, Growth & Stewardship
Communication & Education

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ANNEX 1   GENERAL REPORT - ARW

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