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UNEP

INTEGRATED APPROACH

to development, management and use of water resources

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PREFACE

Background

A large part of the Mediterranean basin, particularly its islands and isolated coastal areas, has for years experienced persistent water scarcity. The problem has been aggravated due to the rapid population growth, hazard development and mass Mediterranean tourism which have strained the natural resources of this region to the limit.

The negative impact of these developments on the ecosystems and their natural characteristics has been manifestly evident in the coastal strips which have been subjected to rapid urbanization, demographic pressure and unrestrained development. This has resulted in conflicts among competing uses of limited and ecologically sensitive natural resources invariably resulting in serious socio-economic and political consequences.

Among all coastal resources, the water resources are the most vulnerable and endangered because climatic, hydrological and hydrogeological conditions make their management a very complex process. The coastal strip is also the place where freshwater mixes with sea water so that ecological and economic implications aggravate the problem of managing and developing these water resources.

UNEP-MAP-PAP and Coastal Water Management

The Regional Activity Centre for the Priority Actions Programme of the UNEP's Mediterranean Action Plan has been at the forefront in acknowledging coastal water resources management as a priority issue. In the attempt to propagate and assist in the implementation of a multidisciplinary approach to water resources management UNEP-MAP-PAP, through the priority actions in the Mediterranean, has actively supported an integrated approach to water resources planning and management. The activities of PAP have extended from numerous seminars, workshops and experts meetings to the implementation of several projects, the most important of which being the project of water resources management in Malta. As a result of this activity PAP has organized, in conjunction with the Institute of Water Technology of the Water Services Corporation of Malta, five successful training courses for participants from various Mediterranean States.

PAP has been concentrating its efforts to provide assistance to Mediterranean States in implementing the general objectives as set in Chapter 18 of "Agenda 21", a policy document on water resources issues adopted by a large number of governments. The recommendations of the United Nations Conference on Environment and Development (Rio, 1992) formed the basis of the Mediterranean Water Charter (Rome, 1992) and were fully endorsed and adopted by the Tunis Conference (1994) in the Agenda "Med 21".

Guidelines & Target Audience

In full harmony with priority issues and the general principles of "Agenda 21", "The Med Water Charter" and Agenda "Med 21", one of the activities of MAP/PAP for the 1995/6 was the preparation of PAP "Guidelines for an Integrated Approach to the Development, Management and Use of Coastal Water Resources". The Guidelines are aimed at practicing engineers, natural and social scientists and middle-rank managers in the field of water resources development, management and use.

Goals

- To help countries fulfill obligations resulting from "Agenda 21", the "Mediterranean Water Charter" and Agenda "Med 21" in order to implement in a uniform and systematic way, an integrated approach to development, management and use of water resources for sustainable development of coastal areas of the Mediterranean region.
- To facilitate better understanding of the coastal water resources in the Mediterranean region.

- To improve the knowledge on, and recognize the advantages of the integrated concept in the use, development and management of coastal water resources.
- To highlight the techniques and methods used in the various disciplines involved in the field of water resources which constitute the basic concept of the integrated approach to development, management and use of water resources.
- To provide the basic framework of the above integrated approach, the master planning and follow up.

Immediate Objectives

- To present a defined approach to an improved use, development and management of the coastal water resources to ensure sustainability in meeting freshwater needs.
- To present a common and uniform methodology towards a more systematic approach to water resources development and management.
- To identify weaknesses in the current practices and ongoing activities, and implementation of their timely correction.
- To promote the need for understanding of the role, importance and necessity of each discipline involved in the study of water issues.
- To improve communication among experts in the various disciplines involved.
- To enhance cooperation among all collaborators in the field of water resources.

Structure and Contents of the Guidelines

The subject matter and purpose of the guidelines is introduced and justified in Chapter 1. Also, the basic concepts of sustainable development and of the integrated approach, as applies to water resources management, is introduced in the same chapter.

The integrated approach to development, management and use of water resources and arising issues is further elaborated in Chapter 2. In this chapter the concept of the integrated approach, as applies to the three basic systems of activities, namely those of the water resources, of the human activities and of the water resources management, are detailed, together with an introduction to the process of the integrated approach.

Chapter 3 highlights the elements and characteristics of the coastal area water resources in the Mediterranean area, treating the subject in three separate systems, those of the coastal area water resources themselves, of the coastal man-made physical system, and of the coastal water resources as an element of the overall regional system.

In Chapter 4 the most important issues and aspects within an integrated approach to development, management and use of coastal water resources are considered, such as the planning process, interdisciplinary relations, legal, economics, legislative, institutional, information support, assessment of water resources and water demand, water quality, and environmental considerations.

Finally, in Chapter 5, the basic procedures for the integrated approach are touched upon, such as master planning, techniques and methods of coastal water resources management, data management, and elements of a water resources master plan.

The guidelines are enriched with graphs, tables and, on certain aspects with detailed presentation, in box-form, of country case examples. Finally, a list of references is provided for further reading on the subject.

1. INTRODUCTION

Land and water resources in the Mediterranean region are generally scarce and are often the subject of intensive political, economic, social and environmental debate. The characteristics of these resources vary enormously from one particular area to another. Their specific features are rooted in different climatic, geological, hydrogeological and topographic conditions. The Mediterranean climate is characterized by dry and hot summers, and wet and cool winters. Moving from the north to the south of the region, the temperatures rise and precipitation diminishes. The northern and the southern parts of the Mediterranean basin differ also geologically and pedologically. The entire area, and especially the north-eastern part is characterized by Karst, while there are no rich, vast, fertile soils. The vegetation is very scarce in the southern African part.

Rapid population growth and urbanization as well as mass tourism and transport aggravate matters especially in Mediterranean coastal areas, changing their natural features and imposing nearly insurmountable challenges. Furthermore, the ever increasing demand for food severely constrains agricultural production so that more land is taken up for cultivation to the detriment of the original vegetation and forests. Intensive land use and forest fires cause serious soil erosion and loss of land with long-term economic and ecological consequences.

With the exception of some river valleys or some areas such as the northern Italy, western Balkans and Turkey where water is in abundant supply, renewable resources have been intensively exploited and withdrawal of water is extensive not only in the south (Libya 100%, Malta 100%, Egypt 92%, Tunisia 70%, Morocco 40%, Algeria 32%) and in the east (Cyprus 42%, Israel 100%, Syria 47%), but also in the north (Spain 41%, Italy 30%).

In the future, economic and social factors will make the demand for scarce resources more acute constraining existing supplies to the limit. Problems will be severely experienced among various economic sectors, and between urban and rural areas. The management of water resources will indeed become more complex and difficult. It is envisaged that considerable finance, expertise and innovative technologies would be required to tackle the daunting task.

This scenario reinforces the urgent need for Mediterranean states to take concrete action now for development to be sustainable. The solution lies in an integrated approach towards the planning and management of water resources. The question is how to develop and implement an integrated water resource management approach that can cope with the deteriorating complex conditions in the coastal areas of Mediterranean countries. In principle, integrated management has been accepted by various national governments and international organizations. However, integrated water resources management requires a more fundamental commitment in the assessment, development, and use of coastal water resources. This involves pro-active interdisciplinary participation by all concerned.

1.1 Justification

Freshwater is an essential part of the world’s hydrosphere and terrestrial systems. It is subject to many competing influences that in some parts of the world may have led to inadequate quantities and quality of this vital resource for the environment including its human component.

These influences include land use changes, pollution of the environment, over utilization and inappropriate uses of available freshwater resources and may include the impact of climate change. On the other hand, man has the ability, through appropriate technologies, planning and co-operation between the various stakeholders and the appropriate use of available resources, to meet the needs of the many interested parties - both man and nature. The facets of water management include:

- hydrological aspects of surface and groundwater;
- competing uses including water supply, sanitation, irrigation, hydropower generation, flood plain management, etc.;
- issues of supply and demand including water conservation and waste minimization; and
- socio-political issues of total catchment management including catchments that cross national and local government borders.

When speaking of water resources, the facets of water resources management have to include the coastal sea waters influenced by the fresh water resources and *vice versa*.

1.1.1 Agenda 21

One of the initiatives of Agenda 21 arising from The United Nations Conference on Environment and Development (Rio de Janeiro, 1992), is to address these issues. Seven water management programmes were proposed:

1. Integrated water resources development and management;
2. Water resources assessment;
3. Protection of water resources, water quality and aquatic ecosystems;
4. Drinking water supply and sanitation;
5. Water for sustainable urban development;
6. Water for sustainable food production and rural development; and
7. Impact of climate change on water resources.

In addressing “Integrated Water Resources Development and Management”, it is acknowledged that freshwater:

- is essential to the economic productivity and social well being of society;
- is an integral part of the ecosystem;
- is a natural, finite and vulnerable resource;
- is a social and economic good;
- quality and quantity determine the nature of its utilization; and
- demands are rapidly increasing.

Despite these compelling issues, fragmentation of water sectoral agencies is proving to be a significant impediment to integrated water management. Agenda 21 seeks to address this by enumerating a number of key objectives for integrated water management:

- Priority should be given to satisfying basic human and ecosystem requirements; beyond these requirements, water should be regarded as an economic good with full cost recovery.
- Management of water resources should be on a catchment basin basis. All aspects within a basin should be considered, including:
    - a multi-sector approach (e.g. socio-economic, environmental, health);
    - sustainable and rational approach within National economic policies;
    - programmes that are economically and socially appropriate; and
    - institutional, legal and financial mechanisms that ensure implementation of programmes.
- In areas with transboundary water resources, water resources strategies should be coordinated and harmonized between riparian states.
- Preparation of national action and sustainable water use programmes should be in place by the year 2000, and by the year 2025, all states should have achieved their freshwater programme targets.

To implement these objectives, Agenda 21 lists 19 activities which could be implemented to improve integrated water management in other areas such as:

- investigation, research and formulation of relevant plans;
- implementation of various water management initiatives;
- gaining the support and contribution from various elements of society; and
- developing and strengthening relevant institutional arrangements.

The implementation of these activities is seen as a co-operative effort though the resources of individual states and where appropriate, through bilateral and multilateral co-operation.

In discussing the means of implementing integrated water resources management, Agenda 21 makes a number of observations and suggestions. It recommends appropriate information systems to support decision making, innovative new ways of improving water management, a thorough look at economic, social and environmental aspects, and a long-term focus. Above all, for the Integrated Water Management programme, Agenda 21 strongly advocates that a total systems approach should be adopted, that this should address all aspects of water cycle management and include not only all relevant parties within a state but should extend beyond state borders since water knows no boundaries. The other programmes take a similar line and make a number of suggestions/recommendations about the application of integrated approaches to the development, management and use of freshwater resources.

Application of the Agenda 21 to coastal area water resources is particularly complex due to the specific environmental, socio-economic and other features of those areas, and the intensity of changes occurring there. It is well known that the coastal areas face intensive development and population growth, and that this trend will be continued in the future. Therefore, the conflict between development requirements and protection of natural resources is constantly present.

1.1.2 The Mediterranean Water Charter

The Mediterranean Water Charter (Rome, 1992) represents a landmark for Mediterranean states in that the ministers responsible for water in the states of the Mediterranean basin formally agreed and acknowledged that:

- Water resources are at the service of mankind and are a means of cooperation rather than conflict among states.
- Water resources are vital to balanced and sustainable development.
- Water resources development requires an integrated approach to water resources management to achieve society's existing objectives without compromising the needs of future generations.

The Ministers agreed also to adopt and implement a number of measures on:

- water planning;
- water management;
- regional cooperation; and
- international and Euro-Mediterranean cooperation.

One important outcome of the Mediterranean Water Charter was the setting up of the Mediterranean Water Network to ensure the successful implementation of the required cooperation in the field of water, in conformity and collaboration with the ongoing programmes such as the Mediterranean Action Plan. The Water Charter specifically identifies projects for special consideration:

- the strengthening of institutions and organizations for water management;
- the development of national management capacities;
- the identification and development of approaches appropriate to the Mediterranean context;
- the adaptation and implementation of standards and regulations;
- the organization and circulation of information among countries; and
- the development of partnerships.

1.1.3 Agenda “Med 21”

The conference “Med 21” on Sustainable Development in the Mediterranean held in Tunis in 1994 explicitly focuses on the urgent need for Mediterranean countries to adopt an integrated approach to water resource management.

Agenda Med 21 concisely but clearly reiterates that:

- freshwater resources are an integral part of a country’s infrastructure necessary for its development;
- development, population growth and hydrological and climatic conditions and atmospheric pollution will further constrain already scarce water resources available among competing ends; and
- the resort to expensive non-conventional resources (e.g. desalinization) and expensive water treatment, demanding ever-increasing national resource sacrifice highlights the existing threat to sustainable development in the countries of the southern Mediterranean rim.

Agenda Med 21 embodies the general view that sustainable development should be directed to achieve society’s overall objectives incorporating among others human health, economic activities and environmental quality. It reaffirms that integrated resource management is based on the perception of water being:

- an integral part of the ecosystem;
- a natural resource; and
- a social and economic good.

On a national basis, Med 21 recommends the formulation of a national policy for sustainable development on the same lines as Agenda 21 of Rio.

On a regional basis, Med 21 emphasizes the need for greater north-south co-operation and co-ordination. It advocates new mechanisms to promote:

- exchange and dissemination of information, suitable technologies and educational and training programmes;
- public awareness for the need of water conservation and protection and for accepting water as part of the common heritage; and
- support and assistance to the rehabilitation and renewal of the water supply infrastructure and to the development of new technologies to augment existing supplies and minimize water losses.

1.2 Sustainable Development

The Brundland Commission report “Our Common Future” (World Commission on Environment, 1987) defines the general concept of sustainable resource development as the process of satisfying society’s current needs without jeopardizing the ability of future generations to meet their own needs.

Sustainable development of water resources requires that we respect the hydrological cycle by using renewable water resources which will not be reduced by a prolonged exploitation.

Sustainability of freshwater resource development should not be limited solely to a physical and ecological dimension but must encompass the socio-economic elements in the process of achieving society’s overall objectives without sacrificing those of future generations (Dixon and Fallon, 1989).

Sustainable water resource management can therefore be regarded as the transformation of factor inputs, land, labour, capital and entrepreneurship, into coordination activities aimed at achieving society’s objectives without putting at risk the legitimate aspirations of future generations (Hufschmidt and Tejwani, 1993). This view of sustainable water resources management emphasizes the fact that the main goal of the services provided by water resources must be to maintain if not to increase the value that society places on these services. Such values may incorporate environmental quality, human health, economic productivity and social fairness.

It is evident that the condition of physical resources - water, the soil and the biota in the land and water and coastal ecosystems - plays a critical role in upholding the social value of the services produced by the resources. For example, the pollution of groundwater aquifers by seepage or injection of organic or inorganic substances to the aquifer from urban, industrial and agricultural sources can cause a serious and extensive degradation of the resource.

Water services are physically limited by economic constraints. Even if there was no environment deterioration and if the resource supply could be augmented by non-conventional means, reservoir storage, more efficient use, recycling and water treatment and reuse, economic constraints would limit the water available to provide sustainable services.

Furthermore, it is impossible to eliminate completely the environmental deterioration in water resource systems. Some natural deterioration is inevitable. Although sustainability in the physical sense in the long term is unachievable for all segments of a water resource system, it is imperative to avoid sacrificing permanently the social value of water to satisfy immediate needs at the expense of future generation requirements. Examples in this respect abound, such as heavily polluted aquifers which are cost prohibitive to clean up or groundwater overextraction to the extent that the aquifer is physically depleted or pumping costs increase until they are prohibitively high.

Meeting the sustainability challenge for water resources development, especially in water lacking areas, will require an advanced level of management called **integrated water resource management**. The core concept of such management, i.e. the commonly held principles, includes the management for multiple-purposes (domestic water supply, irrigation, enhancement of fishery and wildlife resources), for multiple-objectives (economic productivity, environmental quality, social equity, and before everything else human health); and through the use of multiple means such as physical structures, regulations, and economic incentives (Hufschmidt and Tejwani, 1993).

Recommended management approach for sustainable development

1. The managerial team should consist of competent and qualified managers, technicians and engineers responsible for a group of dedicated and reliable workers who operate and maintain the facility/system in efficient running order. Whenever large-scale projects are undertaken, sociologists and expert social scientists should support the technical and managerial team to advise on measures which will mitigate serious sociological impacts and reduce any social undesired interaction of the system with its surroundings.
2. A continuous and uninterrupted supply of wholesome and safe water shall be supplied fairly to all consumers in accordance with established health standards and supply regulations.
3. Maximization of efficiency is an ongoing process and should adjust to changing times.
4. Monitoring follows as an essential continuous process. Management should monitor performance and efficiency to minimize operating costs and provide the community with the most economic supply of freshwater.
5. A water development project has to operate in accordance with design specifications and it must recover all operating and running costs to be financially sustainable.
6. The sustainable development of water resources requires a strong commitment from politicians in support of managerial, technical and planning efforts to reach the desired goals.

1.3 Water Management - An Integrated Approach

1.3.1 Water Resources Management

Water resources management consists of three general systems: natural water system, human activity system and water resources management system (Figure 1.1).

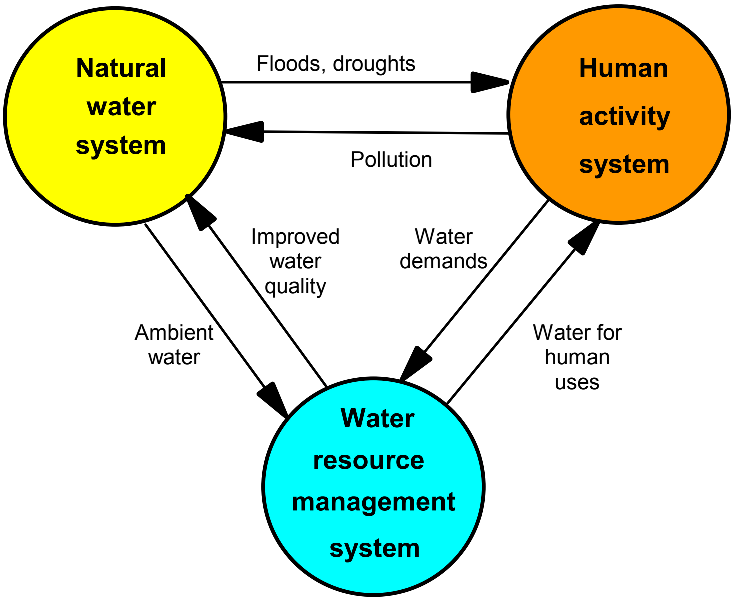


Figure 1.1: Integrated water resources management: proposed framework (UNESCO, 1993)

The natural water system consists of the hydrologic cycle with its components: precipitation, evaporation and evapotranspiration, surface water runoff, and groundwater flows including biota, soil, atmosphere and water. This system is the water and water-related natural resource endowment available for human uses and services.

The human activity system is composed of many human activities that affect or are affected by the natural water resource system. These human activities comprise the demand side for water uses such as domestic water supply, irrigation, waste disposal, hydroelectric power, navigation, fisheries, recreation and for the reduction of damages from flooding, water pollution, and drought.

The water resource management system consists of the activities and relationships in the public and private sectors concerned with harmonizing the supply and demand sides so as to achieve the objectives of the society. An essential support to the water resources management system is the institutional framework for management, consisting of organizations, rules and codes governing the use and control of water resources.

Integration is the act of forming or blending these items into a whole, or incorporating more subsystems into a larger overall system (Figure 1.1).

The case for adopting an integrated approach to water resources management has been put forward in a number of publications. In Hufschmidt and Kindler, 1991, the case is put as follows:

> *"Although more research is definitely needed in some neglected technical areas, the highest priority in research should now be given to the integration of technical results with related non-technical factors. Without this integration, the existing technical achievements cannot be applied with less than the present high risk of failure. This is particularly true for developing countries of arid, semiarid, and humid tropical zones where innovation has to be accommodated with many different long established but rapidly changing cultural, social and economic frameworks. There is a distinct need for more broadly based approaches to water resources management in these zones."*

This situation is also true for the coastal areas within the Mediterranean region. Many things have been written about integrated methodologies and approaches, many of them emphasizing different aspects, but all with a common theme of adopting a systems approach to the issues. A systems approach means resolving the situation at hand by considering all aspects of a situation not just the part that seems to be a problem at the moment. The systems view is that the whole is more than just the summation of the parts and that if the separate parts are studied independently, critical interrelationships will be ignored or misunderstood. The parts of a system remain an indissoluble whole so that no part can be altered without affecting other parts. The sub-systems should work towards the goals of their higher system and not just pursue their own objectives. This section looks at this systems approach by addressing two questions:

- What issues should be addressed in integrated water resources management?
- How should these issues be addressed?

1.3.2 A Multi-Dimensional Problem

To try and put the aspects of integrated management into some sort of perspective, we could consider it as a multi-dimensional problem. It is suggested that there are three most important layers to this: the layer (or dimension) of a particular system (e.g. a water supply system, an irrigation system, etc.); the timeline aspects of managing this group of assets; and the multi-discipline aspects of each system.

Location dimension

The geographical scale of a water project can be: locality, region, river basin, national territory, larger area spreading over two or more states, or another appropriate scale as required by the producers of water resources planning.

For a particular "water" system there is a variety of components that make it up. For example, the water supply system in Malta (see Figure 1.2 for schematic presentation) starts at a variety of production sources, passes through transfer, distribution and reticulation systems until water finally ends up coming out of the consumers tap. Similar diagrams could be constructed for the waste water system, the drainage and flood protection system, the irrigation system, and so on. In such sub-systems, the water is transferred from one site to another not only performing adequate functions, but also generating socio-economic and ecological impacts. For a particular system, an integrated approach is required to consider the system as a whole; every part interacts with the others if we wish to secure a good quality water supply. The point is that a water agency needs to be functional as a whole so that total systems are provided that meet all the needs of the customer at the optimum / affordable price.

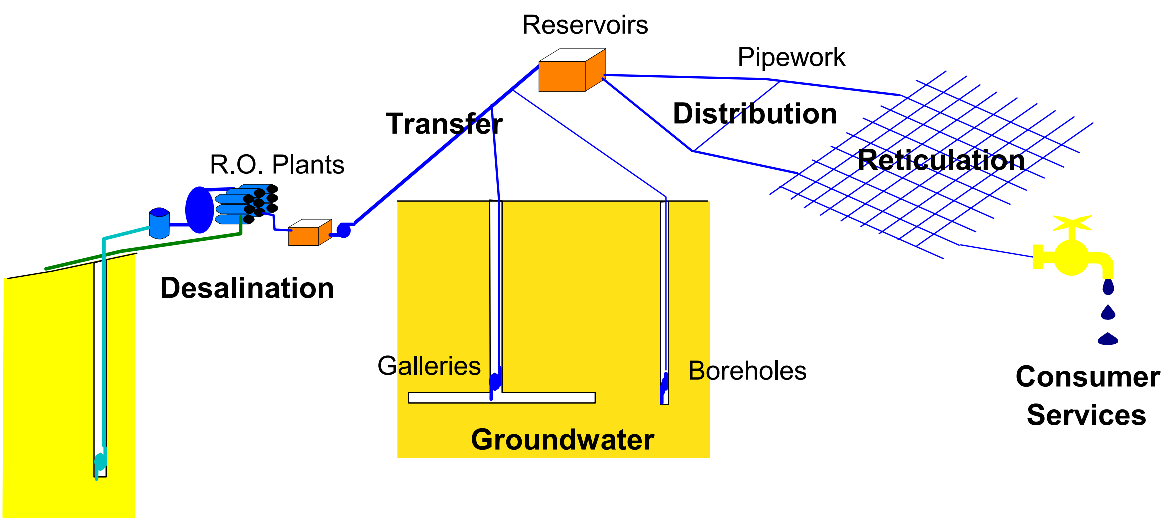


Figure 1.2: Schematic presentation of Malta water supply system

Multi-disciplinary dimension

An integrated water resources plan does not only address "engineering" issues as might be suggested by the above discussion. It must address a wide variety of other interrelated issues.

As stated above (Figure 1.1), each water management system is composed of three basic units: natural resources system, human activity system, and management system, which, in turn, are composed of a number of different smaller units/sub-systems. Therefore, the solution of this problem requires the engagement of numerous experts from various fields in order to cover all aspects of the problem.

The natural water resources systems can be thought of as a hydrological cycle. Figure 1.3 shows a conceptual model for the MIKE SHE hydrological modeling system (Danish Hydraulic Institute, 1994). This diagram is a convenient way of showing the interactions between the many subsystems in the hydrological system. It includes the quantitative and qualitative aspects and the interaction between geology, soil, biota and atmosphere. It raises issues of the hydrological continuum - to work within the natural confines of the natural water resources system (e.g. to avoid over exploitation of groundwater sources); the need to consider whole systems and whole catchments so that actions at one location do not adversely affect elsewhere. For management of coastal freshwater systems, this is particularly relevant since the coastal systems are often at the end of upland systems or the extremities of groundwater tables. This presentation shows clearly the great number of various disciplines that have to participate in the description of this system.

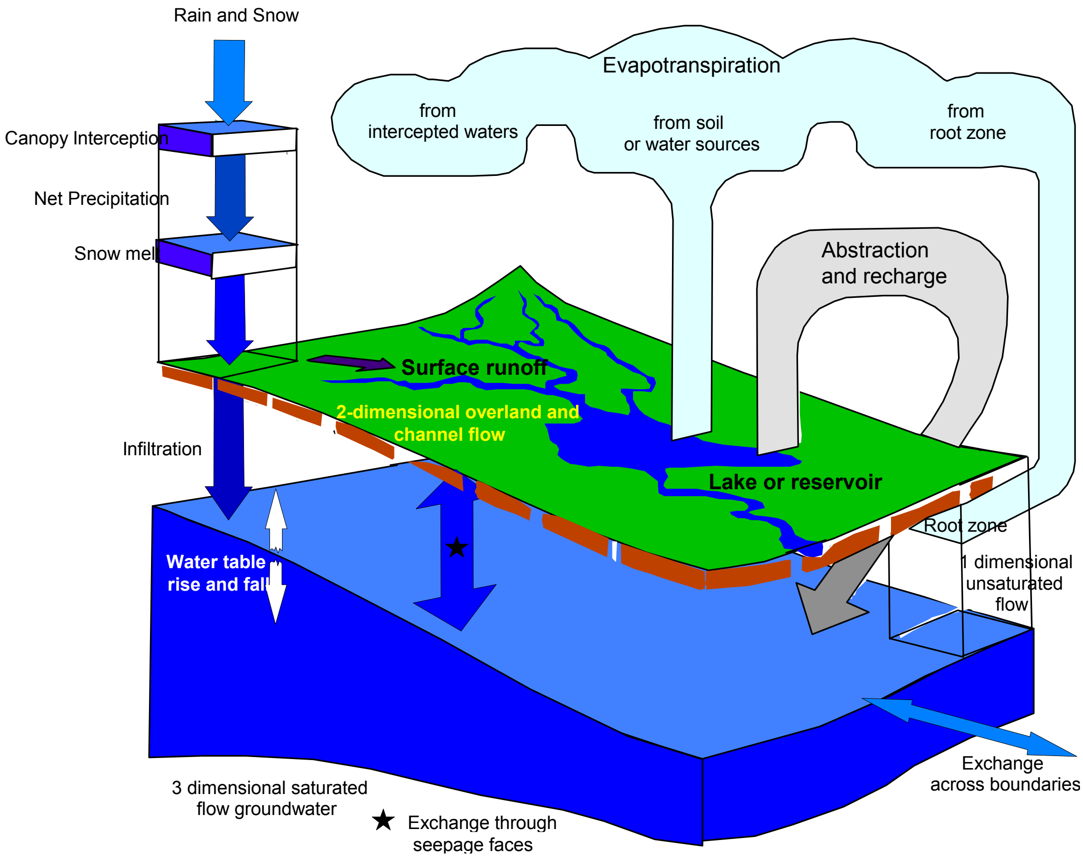


Figure 1.3: MIKE SHE conceptual hydrological model (Danish Hydraulic Institute, 1994)

The same applies to the second system - the human activity system - which includes the activities of people that affect or are affected by the natural water resources system. This includes infrastructure works such as dams, river diversions, groundwater extraction, flood prevention works, etc. Hufschmidt and Tejwani state that “a key task of integrated water resources management is to influence human activities so as to reduce adverse impacts on the natural water resources system and to minimize economic and social losses from natural hazards.” (Hufschmidt and Tejwani, 1993).

The third system is the least technical of all, and the solution of problems involves mostly various non-technical disciplines. It includes the activities and relationships of various sectors (both public and private) at harmonizing the supply and demand sides to achieve society’s objectives. An essential part of this harmonizing is the support of the institutional framework. This management system is needed to preserve the integrity of the natural system and influence the water related human activities. A number of actions are suggested as examples of making management work in an integrated way.

Timeline dimension

Water assets, customer needs, and economic conditions change with time. As shown in Figure 1.4, assets start with high capital investments and have a "capacity" which declines over time. The rate of deterioration of an asset (or group of assets) depends in part on the initial asset itself, (e.g. is it an unlined pipe in an aggressive environment?), and partially on how the asset is looked after during its life, (i.e. operating and maintenance activities). This is sometimes called "life cycle" management of assets. Customer needs also change with time; for example because of changes in culture, size of society, economic prosperity, etc. Changes in customer needs are perhaps the most difficult to forecast. Timeline aspects also cover issues of "sustainability"; will the system be able to meet demands placed upon it in the future without prejudicing future requirements, as well as the time value of finances and intergenerational equity?

Water resources management is an on-going process, performed in sequential iterative steps. The planning process is divided in a sequence of stages. In general, dynamic problems of long-term planning and management are approached by time-discrete dynamic system models. Discretization depends on the variability in time of the process to be considered. The planning horizon of about 30 or 50 years can be discretized into planning periods of small time steps of one year to long time steps of 5 or 10 years. The management models may use time steps of one month for management decisions within the year. Real-time operation uses smaller time steps according to the dynamic of the relevant process. All these "time" issues need to be addressed when developing an integrated management plan.

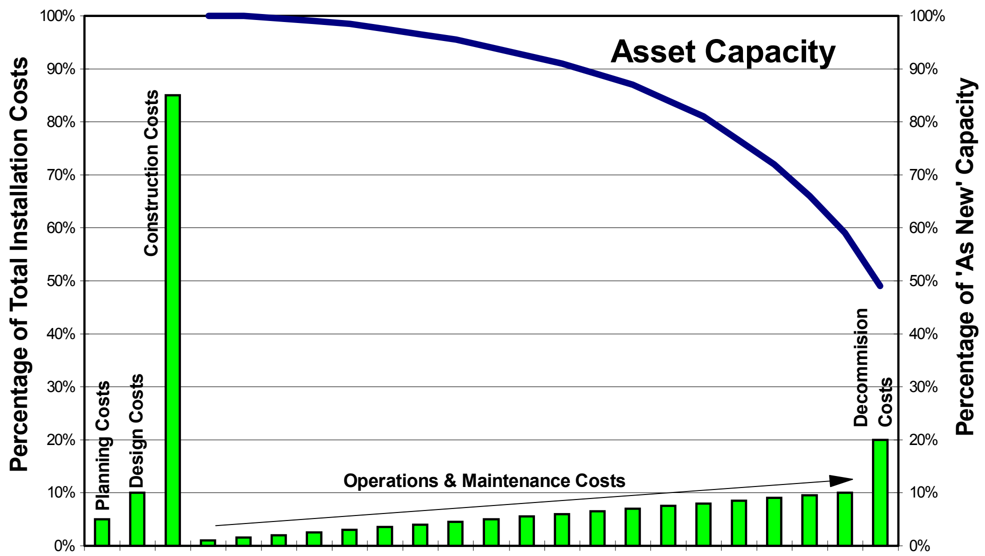


Figure 1.4: Asset life cycle capacity & costs

Aspect dimension

Needs and goals of water resources project can cover several aspects: economic (financial), political, legal, environmental control, protection of environment, social, health, recreational and others (Figure 1.5). First of all, it is the political aspect of the project which must be considered. It is necessary to be clear about needs, goals, objectives and expectations resulting from the socio-economic and cultural system and being influenced by the infrastructure. The main aspect of water resources systems is economic efficiency. All other aspects are also important in accordance with local situation and project characteristics. The point is that all these aspects should be considered in integrated management: physical aspects, social impacts and influences, organizational issues, financial aspects and effect on wider systems, such as the natural environment and other terrestrial and aquatic ecosystems.

In general situation, the project is selected on an economic basis satisfying all constrains. Financial analyses have to be made to determine the needs for financing the project construction, revenues and subsidies after project goes into operation.

Decision-making process in water resources projects is a multiobjective and multijudgemental decision-making process, which requires conflicting management strategies to reach an agreement on the objectives and to assure a reasonable trade off between the feasible alternatives.

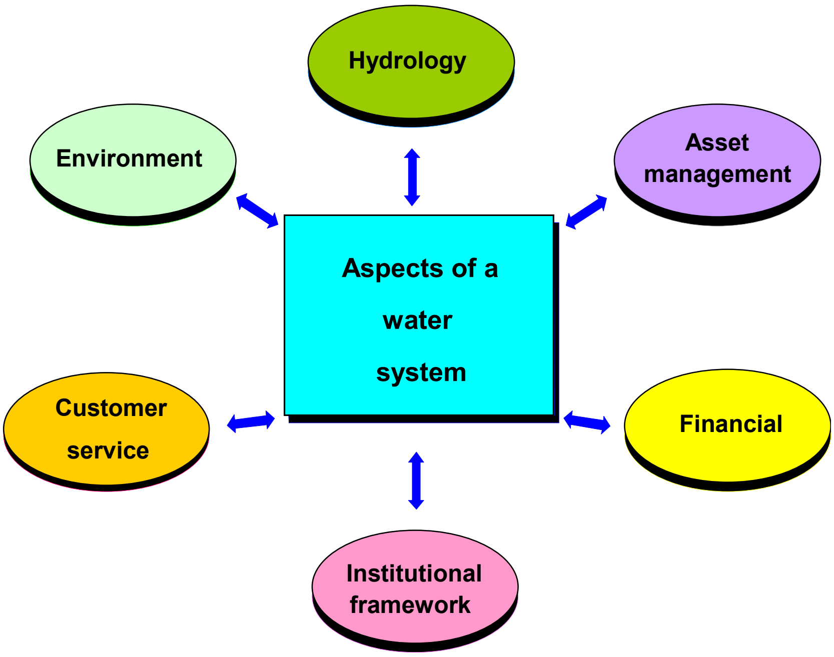


Figure 1.5: Aspects of water systems that must be considered

Action plan

Based on these, an action plan relevant to the coastal areas in the Mediterranean should seek to:

- establish unified national objectives and priorities for water resources management;
- adopt project formulation and evaluation criteria that involve cost benefit analysis, risk assessment and multi objectives;
- establish an appropriate balance between new development and more efficient utilization of existing facilities;
- adopt approaches that acknowledge the independence of water uses and the role of pricing policies;
- provide for adequate (and reliable) funding for project operations and maintenance;
- plan for effective monitoring of projects; and
- provide practical training in water resource management, particularly on achieving integration throughout the entire management process (Danish Hydraulic Institute, 1994).

1.4 Resource Management

Integrated coastal management

Resources of coastal zones and areas provide a flow of goods and services, but often include a variety of complementary and inconsistent activities. If left alone, social and economic forces at work in coastal areas competing for scarce resources would result in overexploitation of resources, negative environmental effects, equity problems and a loss of social well-being. Therefore, coastal zones and areas require management.

Coastal zone management is an activity within the broad field of resource management. Resource management may be defined as a conscious process of decision-making whereby natural and cultural resources are allocated over time and space. This allocation aims to optimize the attainment of stated objectives of a society, within the framework of its technology, political and social institutions, and legal and administrative arrangements.

The differences between the coastal zone management and other kinds of resource management are (1) in the fact that the field of activity of the coastal zone management is a specific geographic area, and (2) in the issues dealt with. Furthermore, the rich mix of human activities, natural resources and tightly linked ecological processes in coastal zone areas, and the resulting problems and conflicts cannot be addressed by traditional single-sector approach. Multisectoral and cross-sectoral, or integrated coastal zone management becomes a necessity.

There are numerous definitions of this activity. The one defining it as a process of achieving goals and objectives of environmentally sustainable development in coastal areas, within the constraints of physical, social and economic conditions, and within the constraints of legal, financial and administrative system and institutions seems the most comprehensive (UNEP-PAP, 1995).

Due to all this, water resources management is a task in which a close interaction between coastal zone management plans and all other development plans is particularly pronounced, making it component of a wider management plan for all resources.

Resource management guidelines

On the bases of the aforementioned considerations it is possible to recommend a set of guidelines for the effective water resources management in Mediterranean coastal areas.

The coastal sea and its influence on fresh water resources and *vice versa* must make part of each activity of water resources management.

- Link the water resource sector to the national economy, as proposed by (Rogers, 1993). Guide national investments in water resource development by means of capital investment budgets and programs, national/local cost-sharing, international or bilateral grants and/or loans, cost-sharing by provincial, local, and private agencies, and private investment.
- Maintain good transboundary relationships by developing sound international agreements especially between neighbouring countries.
- Establish unified national legislation and objectives prioritizing users and resolve conflicts by promoting negotiation and mediation.
- Centralize planning and implementations in cases where decentralization disrupts effective implementation.
- Maximize efficiency of existing facilities before resorting to heavy capital investment on new projects.
- Assess new projects for long-term cost-effectiveness and economic feasibility.
- Encourage public involvement and participation, and recognize the role of women in rational management strategies.
- Compensate for any social inconvenience/upheaval or for any financial loss caused to third parties as result of development.
- Adopt pricing policies which reflect the cost of waste treatment. Funding of project operation and maintenance should be derived in part from user charges, especially for projects to be turned over to local water users.
- Train the planners in the philosophy and practice of integrated water resources management.
- Establish effective monitoring networks and utilize information technology to store data generated from the new installations.

2. INTEGRATED APPROACH TO DEVELOPMENT, MANAGEMENT AND USE OF WATER RESOURCES AND ARISING ISSUES

2.1 Concept

The integrated approach to development, management and use of water resources has been gaining momentum in the last few years. Being a truly interdisciplinary concept aiming to consider quality and quantity problems of both surface and ground water simultaneously, it requires a sustained cooperation of a variety of specialists. In the new "era" we are currently entering regarding water resources management, which shows a definite shift towards operational aspects of water resources systems already accomplished, attempts have appeared to overcome sectoral thinking in resources management which characterized and hampered previous developments. This is expected to be accomplished through the integrated approach to water resources development, management and use for which a strict definition is difficult to put forward.

Water resources management in itself summarizes all the well known activities of the preparatory phase (inception and planning) as well as that of the implementation phase (design, construction and operation) of a water resources system. The question then is why the term "integrated" be added? One answer to this could be that the term "integrated" creates the aura of high aspirations, it promises quite clearly new approaches vis-à-vis the previous practice and ultimately raises the expectation of "better" decisions and a more careful use of water resources. The term "integrated" when used in association with water resources development and management, emphasizes a multisectoral and multidisciplinary character of these processes. It also sharply distinguishes them from the more traditional sectoral development and planning approach. Linguistically and mathematically, the word "integrated" suggests completeness since integrated water resources management can be thought of as an integration of water resources management considerations and efforts in space, over time, over social implications, sectoral water uses, etc. Philosophical considerations may argue against the use of this word since "integrated" in itself suggests no defined limits. This can be delimited though by accepting the imperative of practicality which can place reasonable limits to the extent of endeavor in the integration that is to be implemented. Consequently, the justification of adding the word "integrated" to water resources management is not only by the fact that the problem is studied in its multi-sectoral character but rather that decisions made under the integrated water resources management have been achieved by systematically incorporating the conflicting aspirations of different decision makers along with the presence of competing agencies, institutions and representatives of the public into the process.

The integrated approach to the development, management and use of water resources endeavors to unite the entire set of conditions and means for the assessment, planning and development of water resources to satisfy in a rational manner the water demands. It involves the comprehensive monitoring, effective protection and conservation of water resources through their efficient operation and rational use. It strives to act in the best interest of the society and its sustainable development taking into account the role of water in the formation and regulation of local and regional socio-economic and environmental processes (Figure 2.1).

In other words, this approach:

- tries to integrate the relevant knowledge in the natural, geoscience, engineering and social sciences and to create the theoretical and practical basis for its integrated problem and object oriented transformation and application on water resources; and
- seeks to effect a change in the system, in the water and land use pattern, through the use of structural and institutional measures to obtain a specific goal, or to operate existing water systems in a most efficient way.

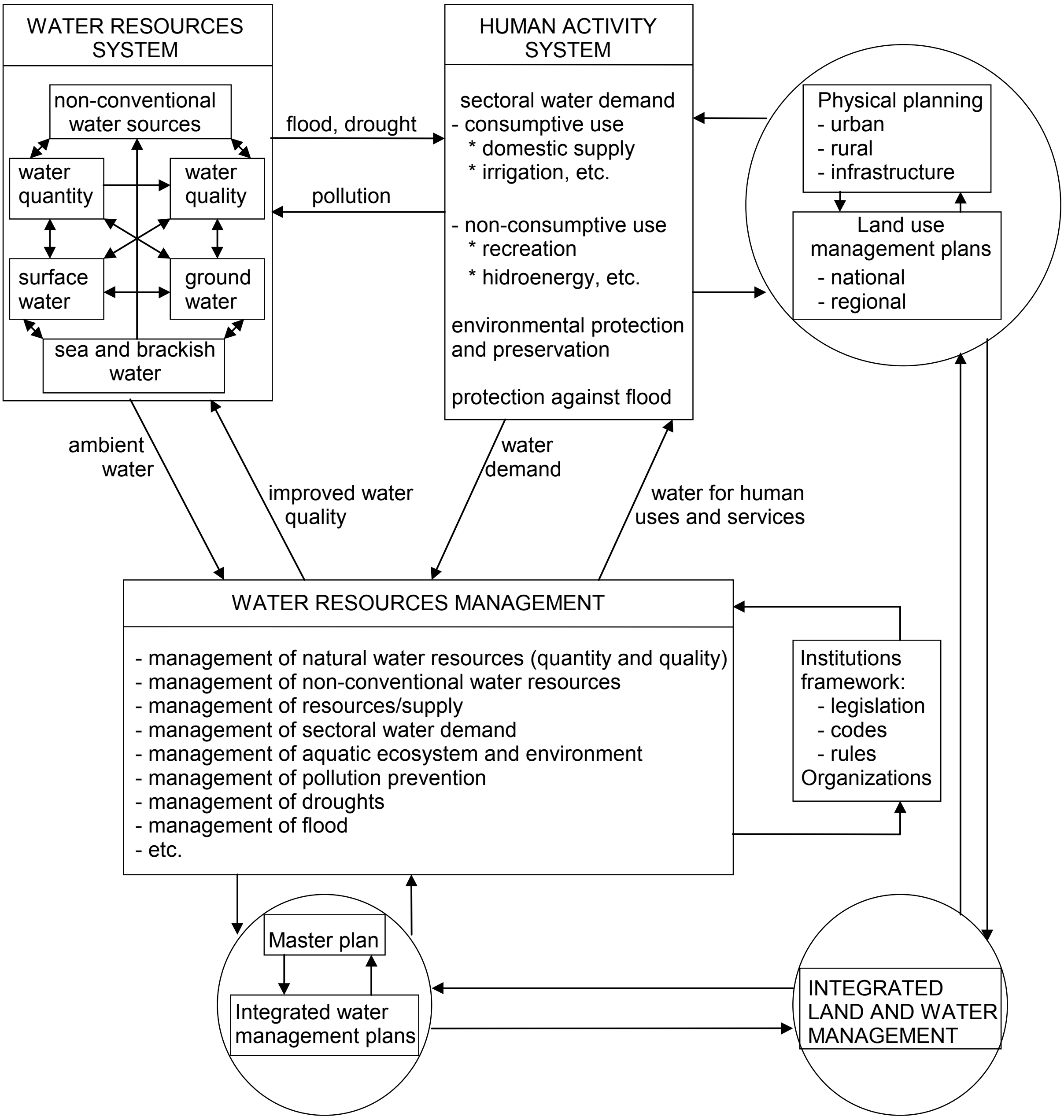


Figure 2.1: Schematic presentation of the integrated development, management and use of coastal water resources (Margeta, 1994)

Water resources management, in developing countries especially, takes place in complex planning and policy settings that are changing as development proceeds and evolves. Typically, water resources are being developed in the context of overall national plans and programs for economic and social development. Experience though indicates that most problems of reconciling water resources development and other objectives result from failure to consider them side by side. Water resources activities are usually the responsibility of a multitude of government ministries, departments, commissions and other, which creates difficulties for coordinated action. Water resources management is a complex matter and requires not only interdisciplinary effort but also proper institutional framework, supporting legislation and clear allocation of jurisdiction. To ensure a consistent approach towards integrated water resources management, a decision making framework has to be established considering the feedback and negotiating mechanisms involving the political leadership, the executive water resources management agencies and the affected public. Regional planners, engineers and decision makers need to become acquainted with systems, analytical concepts and associated methods to be used in water resources management.

Their capability to mediate and to solve conflicts inherent in water resources development and protection has to be enhanced together with quantitative techniques within the realm of multi-criterion decision making. Water is absolutely crucial to any country and as a result many people and groups are interested in the policy for its development and management. In every area there are pressure groups, political objectives, local factors and social effects that need to be taken into account in formulating a policy for water resources development. The common critical need in all countries is for more effective management of the renewable water resources using integrated approaches to regional water development, management and use. The goal of the integrated approach is the preparation of a rational plan in which all associated development sectors have been assessed for their effects on all other resources in a given geographic area (Figure 2.1). It implies significant coordination among sectors and flexibility to modify activities to avoid resource depletion and assure sustained economic productivity. It further assumes systematic incorporation of environmental issues.

An illustration of the integrated approach to development, management and use of coastal water resources and the interaction within the water resources and human activities systems id presented in Figure 2.1.

2.2 Water Resource System

2.2.1 Water Resource System and its Characteristics

The natural water resource system (hydrosphere) is a part of the global natural system which consists of the hydrological cycle linking all parts of the hydrosphere: precipitation, evaporation, surface runoff, lakes and groundwater flows, including the water in atmosphere, soil and biota (Figure 1.3). This is a system of waters and water-related natural resources available for all human uses including the enjoyment of the resource in its natural state.

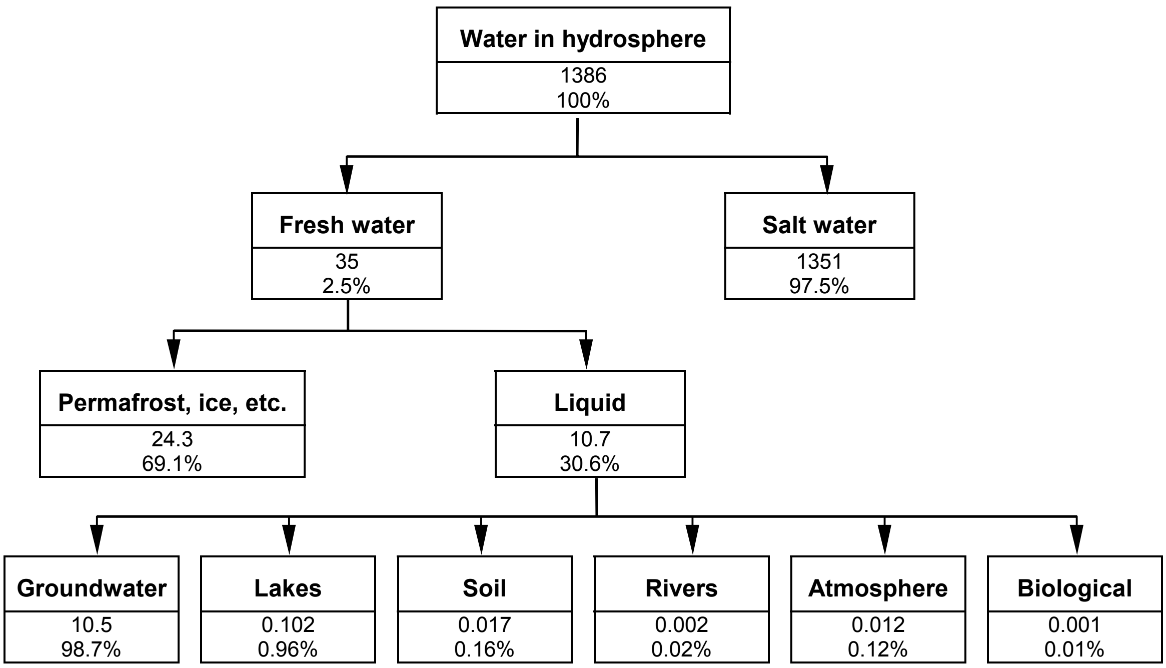


Figure 2.2: Water resources on Earth (1000 km^3) (UNESCO, 1978)

With the total volume of some 1386∗1000 km^3, water is the most abundant molecular substance of the Earth crust. Of the entire Earth surface, 70% is actually covered with oceans which contain 97.5% of the total water supply on Earth (Figure 2.2). Only 2.5% of the water supply on Earth is fresh water taking the form of rivers, lakes, permafrost of the polar caps or in glaciers high in mountains, groundwater, water in soil and atmosphere, and biological water. Some 69.4% of this amount is permafrost, ice, etc., and only 30.6% is liquid water, of which 98.7% is found as groundwater. The amount of fresh water in lakes and rivers is about 1% of the liquid water available on Earth. This amount is constantly being replenished by precipitation. Water is the most exploited of natural resources. Man uses about $100*10^9$ t/y raw materials from the nature, and almost $4000*10^9$ t/y of the fresh water. Not only human beings need water, but all life on Earth (UNESCO, 1978). Water is a renewable natural resource. The natural hydrological cycle is a permanent global process, complex and comprising a number of natural phenomena (Figure 1.3). Thermal energy and gravitation force are the principal moving forces of the hydrological cycle. Due to temperature variations, water takes various forms (ice, liquid, steam), and the gravitation force makes it to move. Globally it is an inexhaustible natural resource, but regionally and locally it is exhaustible. At a global scale today, we face the phenomenon of apparent disappearance of water (our impossibility to use it) due to great pollution.

Sustainable use of fresh water means that the amount of resources used must not exceed the amount by which these resources are replenished through precipitation. Globally, about 110,000 km^3 of precipitation fall on land every year, but half of this is lost trough evaporation (Figure 2.3). Therefore, only 45,000 km^3 a year is the absolute maximum available. In a similar way it is possible to calculate the maximum available quantities for a smaller area or region.

Water resources of an area consist of fresh surface and subsurface waters with their natural supply. They have natural potentials: energy potential, recreational potential, transport potential, self-purification potential, ecological potential, etc. The water supply of the surface and subsurface waters is the freshwater existing in a specific area for a specific time span as a component of the hydrological cycle.

Regarding the quantity of the water supply of an area we may distinguish:

- the potential water supply (difference between long-term means of precipitation and evapotranspiration);
- the stable water supply (potential water supply minus the fast runoff components, e.g. the groundwater flow or base flow); and
- the regulated water supply (water provided by storage).

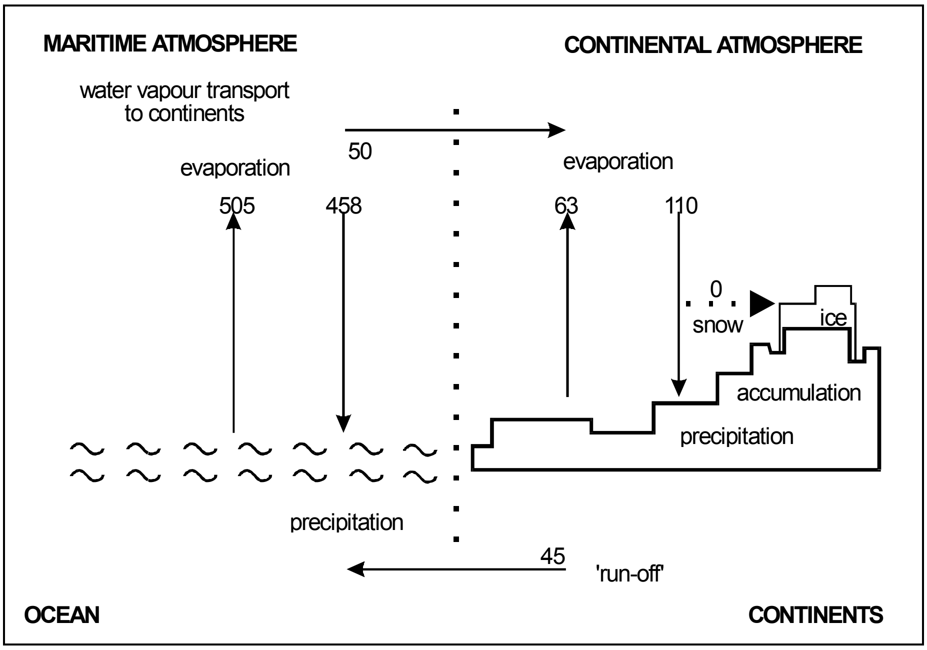


Figure 2.3: Global water balance estimates (x 1000 km^3/yr) (UNESCO, 1978)

The net water supply for use corresponds to the quantity which remains from the gross supply after the constraints due to hydrology, ecology, technology, economy and geopolitics are applied. This parameter (net water supply) is not constant and changes with time, as the hydrological, ecological, economic and technical constraints change with the overall development, so it has to be re-calculated over and over again.

The existence of a source of water does not automatically define it as a usable water resource; it must be available, or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand (UNESCO/WMO, 1988).

The distribution of fresh water differs from region to region, and from country to country in accordance with the local climate, hydrogeology, geology, and use. Among the characteristic areas, coastal zones, and accordingly the coastal water systems, are of particular importance for man. The coast is a natural area where land, fresh waters, and sea influence each other and interact, with many transitions and gradations stemming from the variety of geology, soil, humidity and salinity conditions, geomorphologic and other processes, microclimates, etc.

A peculiarity of coastal water systems is that besides the fresh water they include salt and brackish water resources. From the point of view of the global fresh water balance, this distinction has no importance, but locally, because of direct and indirect contacts and effects on the fresh water balance and usability of fresh, brackish and sea waters, all these resources require an integrated treatment. Maintaining the integrity of the hydrologic whole is essential to the sustainable use of the natural water resource system (fresh and salt). This particularly refers to the Mediterranean countries for which the coastal areas represent the most important natural resources.

In order to achieve the above, a thorough and reliable knowledge of the natural water resources system is a prerequisite. Water resources assessment means identification of sources, extent, dependability and quality of water resources which serve as the basis for the evaluation of the possibilities of their utilization and control (UNESCO, 1978; UNESCO/WMO, 1988). The basic prerequisite are the necessary data, but also an adequate approach to their analysis. It is recognized that the best way to analyze water resources is to use the complete river basin as the basic unit for data collection and interpretation, with appropriate subdivision based on local characteristics such as: geology, climate, land and water use, soil type, land cover, etc. In this case, the system is comprehensively analyzed within its natural boundaries which enables safer and easier calculation of all balances. Individual parts of the natural water resources system, such as groundwater aquifers or estuaries, can also be used as analysis units.

A quantitative assessment should use a complete water-budget approach, which accounts for water flows, withdrawals and stocks, with emphasis on interaction between surface water and groundwater, water quality and quantity. A coastal area assessment should include interaction between surface water and sea, and groundwater and sea, regarding both quantity and quality. It is a very difficult task requiring a complex analysis of hydrological and oceanographic data and processes.

<u>Non-conventional water sources</u>

Non-conventional sources of water are used ever more often in numerous countries, especially those lacking in water. Brackish water, sea water, treated waste water, secondary class water (such as storm water and flood water), imported bottled water, and supply by tankers, increasingly enter the use as new source of water.

In the Mediterranean region, two types of non-conventional water sources are used most often: reuse of waste water and desalinization.

Waste water reuse does not have a wide application throughout the region, but in some countries it is used quite extensively, such as in Israel (waste water), Egypt (drainage water) and Tunisia (waste water). The main reason why this source of water is not used to a greater extent is the lack of sewerage systems to collect waste waters and transport them to treatment plants. Reuse of waste waters is generally considered as one of the most economical auxiliary sources of water, and it is expected to represent the main complement to the natural sources of water in the future. Great quantities of water are continuously being collected in towns, and will certainly gain importance as source of water for various uses. It must not be forgotten that reuse of waste water can, at the same time, be an efficient measure of water quality control and protection, since the basic prerequisite of reuse is an efficient treatment of waste waters.

Unlike reuse of waste waters, desalinization is an expensive procedure. However, as the costs of water production decrease, the application of this method grows. In the Mediterranean, desalinization is used mostly in Malta and Libya. Desalinization of underground brackish waters is particularly favourable.

It is highly irrational if the water produced by the expensive process of desalinization, or paid at high prices, is discharged irreversibly in the sea, as when after use the water ends up in the sewerage and through submarine outfalls to the sea.

Apart from the possibility to use them directly for certain purposes, the non-conventional water sources are used for renewing the capacity of the natural resources (aquifers). This particularly refers to storm and flood waters, which in the southern Mediterranean occur seldom but with great intensity. Appropriate retention and re-directing of those large water quantities would enable their efficient use for artificial replenishment of underground waters (Tunisia). Other, cheaper non-conventional water sources (water purification) are also used to replenish underground resources.

All countries lacking in renewable natural water resources have non-conventional water resources as a component of the water resources system. Thus, the non-conventional water resources, together with the management of natural water resources, make the integrated management of water resources/supply.

2.2.2 Multipurpose Use of Water Resources

Maintaining a sustainable hydrological system is complicated due to a large number and variations of uses of the water resources which have complementary and conflicting effects on each other. This particularly refers to coastal areas where the fresh water resources management is further complicated due to the contacts and interaction with the sea. Therefore, water resources management has to be performed in an integrated way, which requires a balanced approach to various uses and services of water resources, and in coastal zones an appropriate approach to integrated management of salt and fresh water resources. The integrated approach enables strengthening of complementary effects and critical examination of conflicting uses. Apart from that, such an approach implements tradeoffs between the conflicting uses in order to arrive at the most acceptable solution which contains not only the direct economic profit, but also other benefits which can not be directly measured from the economic point of view.

At that, the greatest difficulties are faced at adequate integration and valorization of environmental purposes, such as the maintenance and enhancement of biologically diverse ecosystems, fish and wildlife in fresh waters and the adjacent coastal sea water. Already at early stages of planning and assessment, environmental consequences of water development must be carefully examined. Environmental impact assessment studies of water developments on the hydrologic whole or continuum have to be made. These studies have to take into consideration, wherever appropriate, the ecological consequences of water development on the coastal sea water resources. Typical environmental consequences of water development are:

1. Adverse impacts on fresh water and brackish water ecological systems, caused by pollution, erosion, and changes in stream-flow regimes;
2. Adverse impacts on sea water ecological system, caused by pollution, sedimentation and other impacts of fresh water;
3. Stream and reservoir sedimentation and eutrophication;
4. Coastal sea water eutrophication;
5. Soil salinization and waterlogging; and
6. Salinization of the coastal surface and underground water resources.

Environmental criteria can rarely be measured financially or numerically (non commensurable), which complicates their valorization and comparison with other, measurable criteria. A good solution for these problems can be the use of a multiple-objective approach which represents a true synthesis of environmental consequences, social fairness and economic values. Unfortunately, the role of multi-objective analysis is particularly critical in addressing non-structural elements for which the cost, benefits, and risks cannot be easily quantified in monetary terms as they can for more structured ones.

Box 1

Elements of an integrated water resources management plan

1. Domestic water supply
2. Water supply of tourist facilities
3. Industrial water supply
4. Irrigation
5. Drainage
6. Salinity control
7. Flood control
8. Pollution control
9. Aquatic ecosystem preservation
10. Recreational use of water
11. Navigation
12. Hydroelectric power
13. Sediment control
14. Watershed management, soil conservation, and erosion control
15. Insect control
16. Fish production
17. Sea water pollution control
18. Coastal sea water aquatic ecosystem preservation
19. Aquaculture
20. Recreational use of coastal sea water
21. Coastal erosion
22. Maintenance of interface between sea and fresh water
23. Desalinization
24. Treated wastewater reuse, and other sea and coastal waters related uses and services.

The solution is in the environmental impact assessment (EIA) approach in which major impacts on the hydrologic continuum, including the relevant coastal sea water, of the given project are measured and evaluated, and in which appropriate solutions have to be provided to diminish environmental consequences. EIA must clearly consider not only negative but also any positive impacts, because water development projects should have positive social and environmental impacts. This should be given attention already in the preparatory phase of planning, and kept in mind until an appropriate solution is selected.

When analyzing the use of water resources, it must be remembered that water phenomena are subject to random influences and that some hydrologic and meteorological events are essentially unpredictable, so that the planners and their solutions have to recognize the existence of elements of risk and uncertainties. Another source of risk and uncertainty are measurement errors and the underlying variability of complex natural, social, and economic situations. The total risk issue is addressed through the process of risk assessment and management.

2.3 Human Activity System

The human activity system is composed of the many activities of people that affect or are affected by the natural water resources system. Man has always tried to control the natural water resources system in order to satisfy his needs, such as domestic water supply, irrigation, waste disposal, fisheries, navigation, recreation, industrial water supply, hydroelectric power, and to protect himself from harmful effects of water such as flooding, water pollution, water erosion, drought, and diseases related do deficiencies in water supply and/or sanitation.

In coastal areas, human activities regard also the use of the coastal sea and coastal water resources, as well as protection against the harmful effects of waters and coastal sea, which makes human activities in these areas more numerous and complex. Namely, these activities regard the fresh water resources, coastal sea water, and the transition zones between these two natural resources.

Box 2

Some objectives of human interventions into the water resources systems

- provision of water for domestic, commercial, municipal, industrial and other uses;
- public health, protection of recreational values, forests and crops;
- food production;
- provision of power for economic development and improved living standard;
- transportation of goods and passengers;
- flood damage prevention and reduction;
- protection of economic development, conservation storage, river regulation, protection of life, etc.;
- improvement of habitat for fish and wildlife, reduction of fish or wildlife losses associated with development;
- enhancement of sports opportunities;
- prevention of salt intrusion in the soil and groundwater;
- conservation of the soil, sediment abatement, forest and grassland improvement, protection of water supply, and other.

In the Mediterranean basin, as in the rest of the world, it is the coastal area that bears the greatest burden. In a foreseeable future, the coastal areas will be exposed to an even greater population pressure and to the expansion and diversification of national economies. It is estimated that most of the demographic growth, especially in the developing countries, will be concentrated in urban areas, and primarily in the towns located in the coastal areas. It must not be forgotten that the Mediterranean is a popular tourist destination receiving over 100 million tourists a year, so that in the summer period the population increases considerably. For all these reasons, the Mediterranean area is a great user of resources, including the two fundamental ones: land and water.

A management system is needed to preserve the integrity of the natural water resources system and to influence water-related human activities. The principal task of integrated water resource management is to influence the human activities in the area so as to use the water resources exploitation to reduce the negative effects on the natural water resource system, and to minimize economic and social losses from natural hazards, as well as to strengthen all positive effects.

This task involves actions such as:

1. Actions affecting the demand for water use and services;
2. Actions affecting pollution from human activities;
3. Actions affecting human adjustments to flood;
4. Actions affecting human adjustments to drought; and
5. Actions affecting interventions into the natural system (town spreading, etc.)

2.3.1 Water Demand Management

Water uses include all individual and collective activities of the human society which affect water resources and change their quality and quantity. These are, among others:

1. In-stream (navigation, hydropower, etc.) and on-site (ponding, etc.) uses, without withdrawing water from the resources.
2. Water withdrawal, i.e. diversion of water from the surface or groundwater, which can be local, i.e. on-site use, or collective mass use by means of a complicated supply, distribution and drainage network.

The method of water use and distribution depends especially on the degree of development and organization of the social system. It becomes systematic as a consequence of agricultural, social and industrial development, gradually creating more extensive, expensive and complicated networks for water conveyance, distribution, use and drainage.

One of the most serious problems facing water managers is the effective allocation of an essentially fixed supply of water resources among rapidly growing and competing demand. It is particularly emphasized in the Mediterranean basin. Developing more supplies to meet the rising demand is a very difficult task in the Mediterranean region. In the Mediterranean area as a whole, the water is relatively scarce. Exceptions are some river valleys, like the Nile or the Rhone, or some areas in the north that are rich with water. With regard to the continuous growth of population and intensive urban and economic developments, managing water resources with greatest care becomes one of top priorities. This applies particularly for the towns and rural areas (especially in the southern and eastern Mediterranean) where water losses in supply networks are particularly high.

Therefore, some of the principal objectives are:

- reducing demand;
- reducing water losses;
- controlling user wastage; and
- modifying water use types and systems.

Measures to be taken into consideration are:

- Water savings must be a permanent concern within the planning and water resources management processes. It also implies costs which have to be compared with the costs of additional water mobilization.
- It is necessary to improve the knowledge of water demand, taking into account its different aspects: catchment, net consumption and quality requirement.
- Water demand is not rigid; it can change depending on the technological progress, climatic situation, or water offer conditions.
- Awareness of, and education/training on water saving are essential components of water demand management.
- In order to minimize costs and to avoid anticipating investments, it is imperative to use a better approach to the evaluation of water demand for all uses, as well as better parameters of variation and ratios which enable it (peak coefficients, loss coefficients, and rations), and to avoid uncertain approximations.

Water management should use the price as a tool of demand management, including volumetric pricing of supply or wastewater on the basis of marginal supply and disposal cost, along with increasing block rates. Where appropriate, seasonal pricing and temporary drought surcharges should be imposed. Good results can be achieved by recycling, reuse and other technical means to reduce withdrawal rates for water in industry, especially for cooling purposes.

Water management should include the following:

- municipal distribution system water savings (distribution system water audit, system leak detection and repair, water education program as part of education process, public information, etc.);
- urban consumer water-saving measures (dual-action flushing system, leak detection tablets, low-flow shower heads, shower flow regulators, faucet flow regulators, water saving toilets, etc.);
- use of technical means for reducing irrigation water use, including drip and sprinkler irrigation, land leveling, use of the pipe instead of open channels, establishment of a system for advising the farmers on their irrigation schedules, along with other institutional means, such as modification of the water rights system, and introduction of appropriate agro-technical practices to encourage efficient water use;
- use of low-grade water for certain domestic, commercial, industrial, and agricultural purposes (brackish water, treated waste water); and
- improvement and stimulation of on-site water use, such as rain harvesting and other traditional water-supply sources.

Water demand management includes not only the issue of water quantity, but also of water quality, as well as all measures that can help reduce the pressure on the use of water sources. All these activities should be implemented in a well organized manner through a comprehensive water conservation program.

2.3.2 Pollution Reduction Management

Water pollution control is one of the most important activities in the concept of integrated water resources management, and the more so in areas traditionally lacking water, such as the greatest part of the Mediterranean region. Circulating in the nature, water washes the pollution from the air, soil and underground, carries it in its liquid phase and depositing it into the storages. On the other hand, circulating within the man-made water systems water gets polluted by use and deposits the pollution in water resources and coastal sea. The small capacity of renewable water resources will be even more reduced by the pollution, particularly in the southern Mediterranean area, thus endangering supply security, especially in the future. In this way, the only reliable natural water supply sources for all incidental situations, such as natural disasters, wars, etc. will be endangered.

A prerequisite of efficient protection of water resources and coastal sea against pollution is the preparation of a comprehensive and detailed plan of protection which has to take into consideration all point and diffuse sources of pollution, pollution processes and movements, consequences and all possible structural and administrative measures of protection against pollution. The plan must take into consideration the following:

- measures to reduce the generation of pollutants at the source (changes in the industrial production processes, raw materials used, and products; recycling in the production process; pricing policy; and tax incentives);
- measures to reduce waste after generation and collection (by-product recovery, recycling of materials in waste water, reuse of effluent, treatment of effluent); and
- measures to increase the assimilative potential of water resources (dilution, mixing, re-aeration, redistribution of the pollutant, etc.).

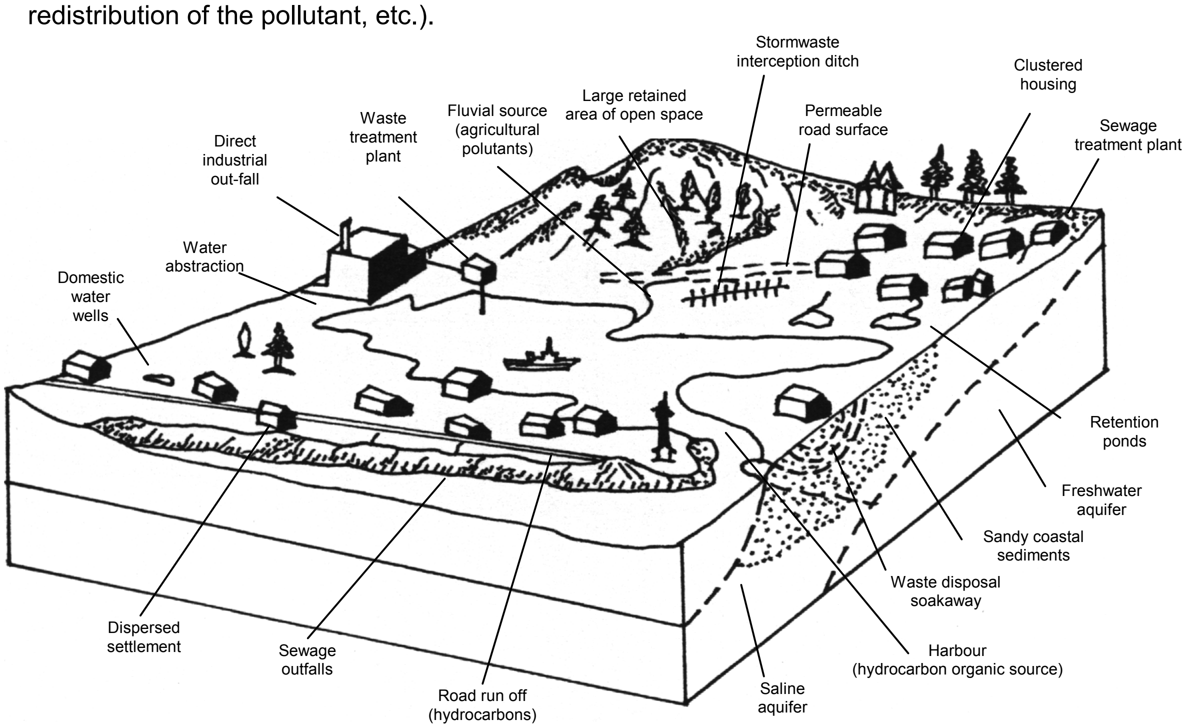


Figure 2.4: The range of coastal water management problems

Apart from that, all institutional aspects have to be considered, from legislation, organization and monitoring, to methods of force. This particularly refers to diffuse sources of pollution, such as from agriculture, where changes can be achieved only by an appropriate mix of force and assistance which should result in better agro-technical measures, and methods of applying agricultural chemicals with lower rate of environmental pollution.

When speaking of coastal water resources, the plans must include the protection of the coastal sea against pollution brought in both indirectly, through fresh water resources, and directly, through discharges of coastal point and diffuse sources. In this case, it is also necessary to analyze the pollution of coastal fresh water resources by sea intrusion, and take necessary measures to protect the coastal fresh water resources (limited exploitation of coastal aquifers, combined use of surface and groundwaters, building barriers, etc.).

2.3.3 Droughts Management

As mentioned before, the shortage of water is characteristic of a large part of the region, and especially of islands and coastal areas. Moreover, a much worse situation can be expected in the future.

The experience shows that the water shortage in the region is mainly the result of one or more of the following factors:

a) High demand as the result of:
   - increasing human population;
   - technological advancement;
   - increasing standard of living; and
   - development, especially of tourism.

b) Insufficient capacity of water resources

c) Changed environment due to:
   - pollution;
   - devastation; and
   - changed hydrological conditions.

This is a complex natural and socio-economic problem which cannot be viewed as a traditional disaster or natural hazard. Consequently, drought management is a difficult task which includes issues of comprehensive water management, ecosystem interdependencies, and risk-based management approaches.

The shortage of water (drought) is expressed through several different types. The types that can be found in the region are:

- **Meteorological drought** (period without enough rain) described by location, beginning time, precipitation levels and time variations. In the Mediterranean region, the meteorological drought is a seasonal phenomenon, but it has historically consistent conditions. Such a situation most frequently results also in other types of drought.
- **Hydrological drought** - shortage in the stream flow, reservoir storage, or aquifers.
- **Agricultural drought** depends on soil moisture level determined by precipitation and plant use.
- **Socio-economic drought** (shortages of waters), resulting in shortages, often results from poor preparation and excessive demand rather than lack of rain. Inadequate planning, lack of financial means, insufficient personnel and improper organization result in an inadequate state of water supply, particularly in the summer period.

Water managers must overcome the complexity of the problem and conflicts among the users in order to have a chance to successfully apply management methods. Preparation for water management requires planning, design and implementation of a water control system, including operation and maintenance, regulatory oversight and coordination. The management of water shortage integrates all facets of water resources management, including water supply, water quality management, irrigation and farm drainage, energy generation, fisheries enhancement, recreation and general aesthetics, as well as flood control.

In such a complex task, there is confusion about who should do what in order to be ready to handle the problem. It is especially true for islands and isolated areas, situated generally far from governmental centers. The general situation is such that water management is a direct or indirect responsibility of more than one organization, which further complicates the problem. Drought, as a specific phenomenon, involves great uncertainty and poses formidable management problems. Accordingly, effective management requires frequent preventive measures, forecasting capabilities, and contingency plans for mobilizing necessary resources for mitigation, relief and recovery operations. In the present practice, two management approaches are characteristic: crisis management, which implies a short-range, piecemental, segmented approach, and risk management which is far-reaching and systematic.

The above implies the need to develop sensitivity to a variety of conditions and responses rather than to simply promote a blanket crisis management scheme that tends to work under both time and resources conditions. The most important role has to be played by particular institutions which must be capable of handling, over a long time period, the changing circumstances in social and physical environments. Discussions, studies and mitigation programs, started when droughts appear, must be replaced by permanent improvements in response measures (conservation practice, sustainable water use in agriculture and other sectors, insurance, and others) including the establishment of long-term policies.

The variety of theoretical works and actual drought management plans have emphasized a series of interlocking actions revolving around six phases:

1. Preparation and planning;
2. Forecasting;
3. Mitigation;
4. Relief;
5. Recovery;
6. Post-drought measures.

In each of these categories, a variety of specific steps can be recommended, encouraging detailed strategies and tactics resulting usually in four different policies which are not mutually exclusive:

- disaster relief;
- control of natural events;
- reduction of damage potential; and
- combined multi-hazard management.

The implementation of drought policies requires also organizational mobilization in the form of a comprehensive planning approach. Typical drought response options are shown in the Figure 2.5.

There are three options for better management of droughts:

1. The first option invites municipalities to develop local conservation plans with a triggering mechanism and a classification system.
2. The second option requires legislation encouraging conjunctive management of ground and surface waters.
3. The third and most comprehensive option incorporates water shortage planning into the state's overall water management scheme, and requires regional management of total water resources on an integrated basis.

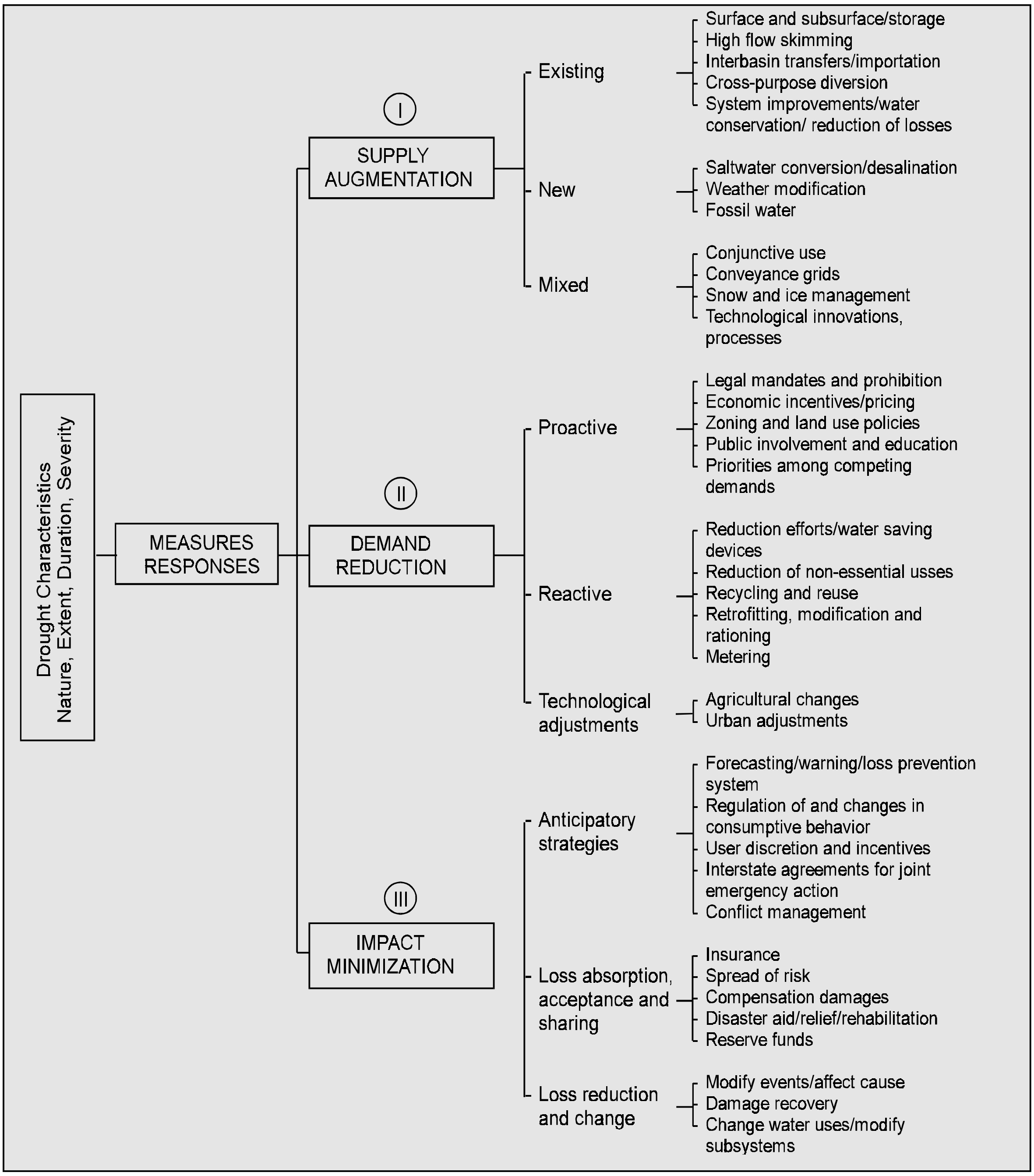


Figure 2.5: General framework for the response to drought (adapted from Grig, 1989)

2.3.4 Flood Management

Floods are natural disasters which can cause extensive and heavy damage. This phenomenon is not particularly pronounced in the Mediterranean region as a whole, but has great significance for some areas. Floods occurring in the northern part of the region present different characteristics than those occurring in the south. In the southern parts, the floods are much rarer, but occur extremely suddenly and intensively, and affect comparatively small areas, so that consequences are worse. Namely, implementation of measures to mitigate the negative effects is harder. In the northern parts, on the other hand, floods occur more often, are usually smaller in size and intensity, and cover larger areas, so that the consequences are smaller and mitigation measures more efficient. The adverse effects of floods can be significantly reduced by human adjustments, such as:

1. Building flood control structures, dams, embankments, channels, pumping stations, etc.
2. Adopting a loss-minimization strategy, including flood-proofing structures, as well as flood insurance, warning systems, and evacuation and restoration plans.
3. Adopting land-use practices which include an effective control of human occupation of flood-prone lands. Enforcement of regulations encouraging compatible land uses, such as recreational, while restricting non-compatible ones, can help achieve this goal.
4. Following flood disasters, redevelopment programs should be based on risk-minimization, land use controls and management strategies (subsidies, public investments, etc.).

Possible measures of human adjustment to flood are shown in the Figure 2.6.

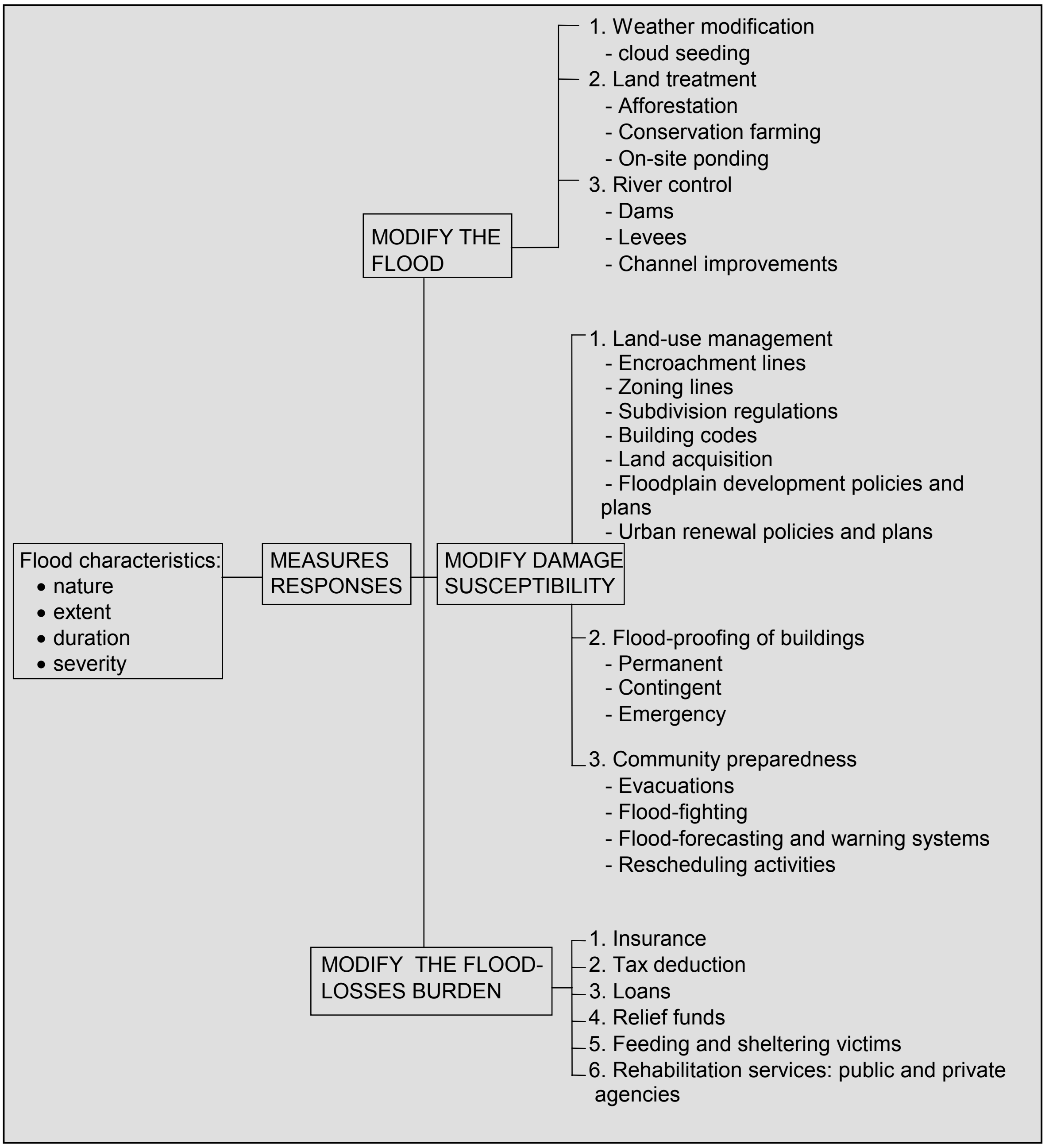


Figure 2.6: A typology of human adjustment to flood

Which measures will be applied depends on the local situation, as well as on the flood characteristics, so that protection measures against floods may differ greatly from one area to another. In the southern parts, flood waters are a significant additional source of water that has to be used to the maximum. A good example of their utilization is replenishment of underground water resources (Tunisia). A part of the flood waters is kept in retention reservoirs (time redistribution), and a part is distributed over areas free of floods and used for recharge of aquifers.

Particular problem is posed by urban flood flows which appear due to intensive changes of urban watershed characteristics, and absence of drainage systems. In areas lacking water, these waters represent a source of secondary class water that can be used for various purposes, from fight against sea intrusion into coastal aquifers to irrigation.

Besides causing usual (traditional) damages on objects and properties, and endangering of human lives, the floods have important ecological impacts, namely: soil erosion, pollution transport, changes of ecosystem characteristics, sediment supply to beaches, etc. In the southern Mediterranean area the floods form intensive soil erosion and sediment transport, causing considerable damages on water related structures. The most productive surface soil layer is being taken off by the erosion and then settled to the bottom of the accumulations, making the life time of the accumulation relatively short (10-20 years). On the other hand, the sediment input in the seashore area is of a great importance for the preservation of morphological characteristics of coastal beaches, as well as for forming of estuary ecosystems since besides the sediment, also necessary quantities of nutrients are being brought to the coastal area. Problems appear when the flooding waters wash off the pollution from the polluted terrain or disposals for hazardous substances because the pollution is then being accumulated in estuary areas and surface accumulations.

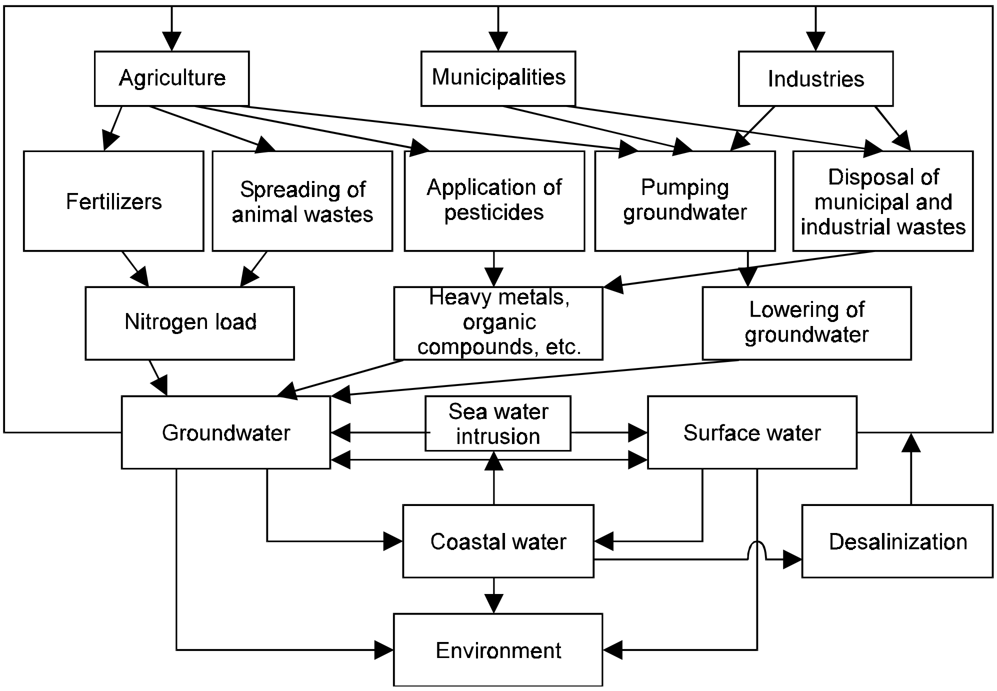


Figure 2.7: Interaction of land-use and water resources (adapted from UNESCO, 1991)

2.3.5 Actions Affecting Interventions into the Natural System (Urban Spreading and Other Forms of Land Use)

The growing numbers of inhabitants and tourists, and the increased standard of living inevitably bring about an expanding land occupation, higher rates of resource exploitation, and environmental pollution. Larger population and increased standard of living require more space for housing and traffic, more working places in industries and services, and more food and water. That means that ever more space is needed for accommodation, traffic lines, and food production; the need grows for raw materials, energy, water. As a consequence, there is ever less space, raw materials and water available, and eco-systems are destroyed. Also, air, land and water pollution increases, producing negative effects on men and eco-systems, and reducing the environmental capacities including water, land and other resources.

Interaction between land-use and water resources (Figure 2.7) is of a particular importance in this process, since water is the principal carrier of all pollution and sediment, and the sea is the end-recipient. On the other hand, land-use is the major source of pollution and, partially, recipient of the pollution carried by water and deposited to the ground.

All these changes occurring in the environment inevitably lead to the change of characteristics of the land and water resources. Water is in a permanent contact with the soil, it is its inseparable part, so that all changes occurring in the soil directly influence water, and *vice versa*.

When resolving these problems, it has to be departed from the concept that water is a naturally renewable resource with natural, theoretical, technical and economic capacities. If its quality deteriorates as to make it unsuitable for use, all its capacities are automatically reduced, especially the technical and economic ones. On the other hand, land resources are not naturally renewable, or are renewable very slowly, so that any exploitation inevitably reduces their capacities. The continuation of this trend will result in reduced productivity of the agriculture and diminished standard of living. Health and social problems grow, as social differences become more obvious, diseases spread, and the sense of general insecurity appears. The solution to the problems can be summarized as the urgent need to meet today's challenges and clean up past environmental problems, while investing in the future: the concept of sustainable development.

Land and water can not be treated separately when speaking of their utilization and management. They are linked by a number of natural processes, as well as economic issues, so that they must always be dealt with together. Since these two resources are the basis for the development of a region, various development interests get in conflict over their use. Therefore, only an integrated approach can help resolve the problems encountered, and enable the application of the concept of sustainable development.

Land and water resources, and the associated processes, know no administrative boundaries, so their successful management must be organized in natural and not administrative boundaries. Therefore, regional cooperation is the essential prerequisite of an efficient rational management of natural resources.

Box 3

Water- and land-resources management issues

- risk of water shortages;
- extreme swings in precipitation, droughts and flood during the last period;
- reliable water supplies for human, agricultural and industrial activities;
- evaluation of water demand, its sectoral distribution and water resources management;
- municipal and industrial effluent pollution affecting adversely local, regional and international waters;
- over pumping of ground water;
- ground water pollution as result of improper land disposal practice;
- sea water intrusion in groundwater;
- problem of land and water quality depletion as result of mismanagement of industrial and agricultural chemicals;
- degradation of coastal waters;
- incredible inflationary urban growth;
- deforestation impacts on land and water resources;
- desert encroachment as result of mismanagement of agricultural land;
- hazardous and solid waste disposal impacts on land and water resources; and other issues.

2.4 Water Resources Management System

There is no single answer to “how to manage the water resources”. For each unique set of circumstances, there will be a different way of addressing integrated water resources management. Despite this, there are common guidelines that need to be acknowledged to at least increase the likelihood that a more integrated approach will result.

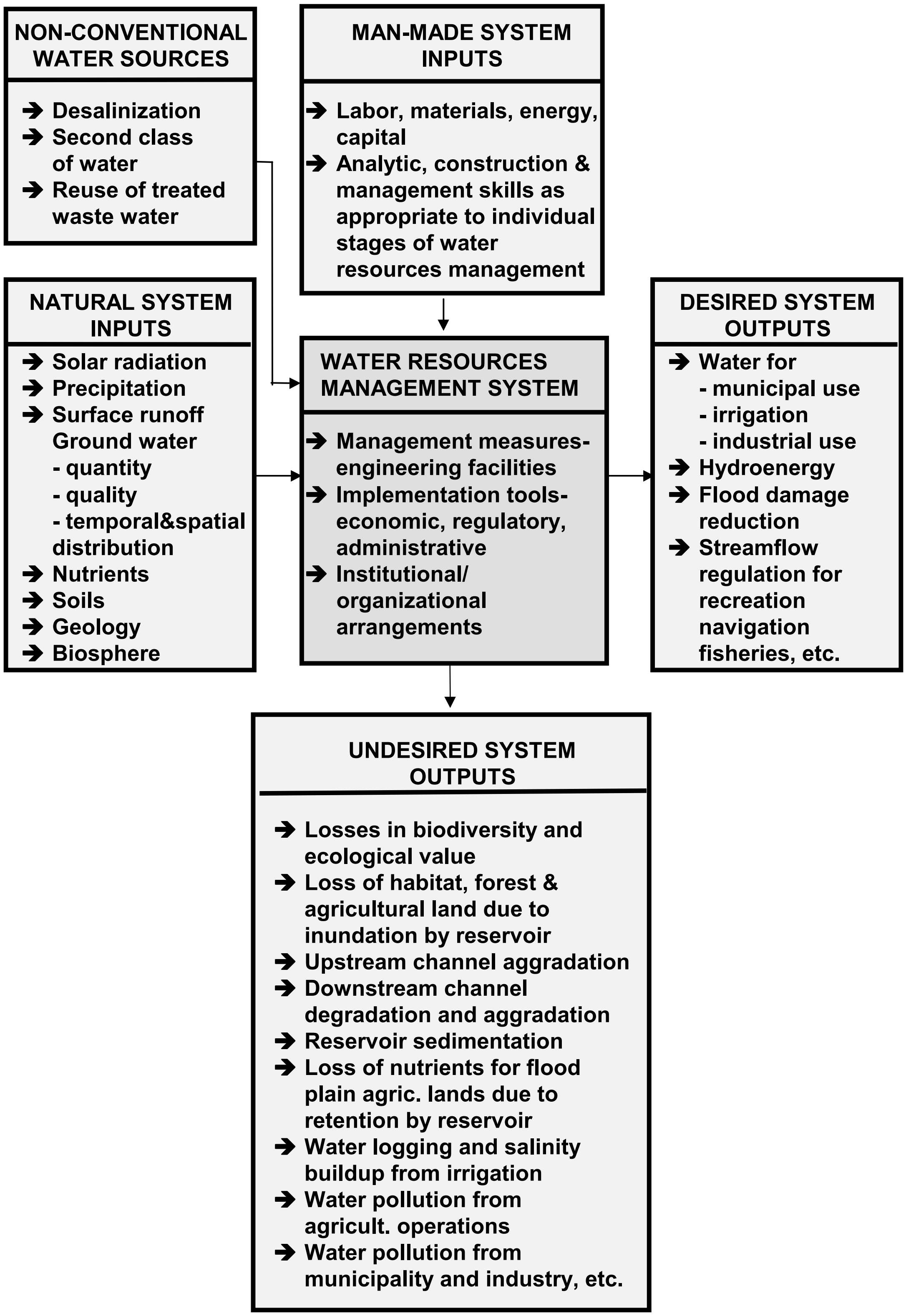


Figure 2.8: Input/output of a water resources management system

2.4.1. Water Resources Management

The development, operation and maintenance of a water resources management system requires **natural inputs** (water, energy, soils) and **human inputs** (labor, materials capital and management skills). The managed system yields desired outputs (intermediate, such as water for irrigation, industrial and municipal uses or final in nature such as flood protection, hydroelectric energy etc.). In addition, the system may generate environmental and social side effects that may be either harmful or beneficial. These side effects are shown on Figure 2.8 in terms of undesired system outputs.

Important points to be raised here in connection to the integrated approach are:

- The implementation stage, as compared to the planning stage, has received less attention although it presents more difficulties and problems. More emphasis is needed in developing sound approaches to water resources management.
- Critical to effective implementation is the development of a strategy which would link the implementation tools and the institutional and organizational arrangements (including legislative measures) with the management measures.
- Finally, the effective management of a water resources system requires that proper attention be given to all linked and associated activities and tasks.

To summarize, an integrated approach to coastal water management, requires that all relevant aspects to a water system be considered (Figure 2.9). This includes all aspect of the system itself, the impact of time on the future system and the interaction between other systems and issues that will and/or may impact on the coastal water system been considered. Some activities relevant to what needs to be considered are suggested ranging from national priorities, achieving balance between various systems and issues of appropriate financing, monitoring and training.

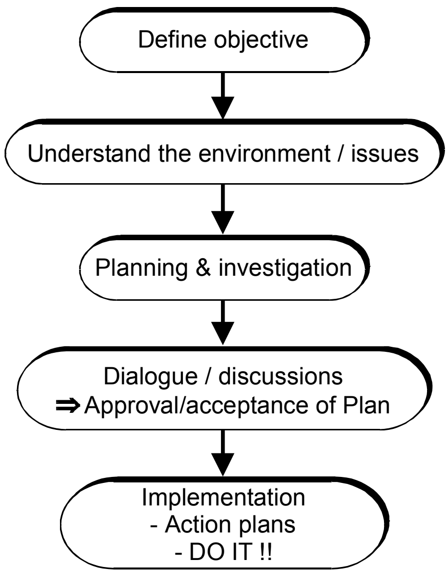


Figure 2.9: A simplified approach to strategic planning

2.4.2 Future Challenges of Water Resources Management

The water resources management in the past 30 to 40 years has been heavily preoccupied with the development and exploitation of water resources by major construction projects. The current trends indicated by the increasing concern for the environmental and natural system aspects of water management, conservation of water, effective operation of completed water development projects and project maintenance as well as the reducing number of economical reservoir sites and other water development projects, point to the need for major changes and shift in the approach to water resources management. Water resources management will have to shift towards a balanced approach that emphasizes water conservation, demand management, changes in water uses, and efficient use of available supplies, along with continued development of new supplies where these are economically feasible and environmentally compatible.

Emphasis will have to be placed on various issues for effective management, the main challenges being:

- environmental and social consequences;
- allocation of water among competing uses; and
- achievement of effective implementation of planned and existing water resources projects.

In the Mediterranean, the water-related problems are such that they require an approach that would lead to a sustainable development. Availability of sufficient quantities of good quality water is different in the northern and southern parts of the region. However, one feature is shared by the two poles: insufficient quantities, even if this problem is less pronounced in the north, while in the south satisfying the water demand would mean consuming almost all of the available fresh water. Since the situation is bound to become worse in the future, a global and integrated approach to the solution of the problem is needed.

Environmental and social consequences

Since environmental issues first became development concerns, it has been recognized that an integral approach to water resources development represents one of the best methods for properly treating these issues. If environmental and social concerns could be systematically integrated into development planning from the outset, many of the negative environmental impacts of water development projects could be avoided.

The multisectoral approach to water development planning affords a useful framework for dealing with the many existing and potential resource-use conflicts that arise during implementation. Thus, if environmental issues, as part of resource management considerations, are built into the planning process at an early stage then possibly environmental impact assessments with their high cost and adversary nature can be avoided. To the environmental issues, the social well-being of people living in the areas affected by the resource development should also be included.

Similarly, surface and groundwater quality should be covered as well as concerns for preservation and enhancement of aquatic and terrestrial ecosystems as typified by free-flowing streams, estuaries, marsh areas, etc. A closely related issue is also the land-water linkage in the river basin or watershed being developed as for example erosion and sedimentation control.

Broadly, three types of social and environmental consequences of water development may be recognized. These are:

- disruption of human settlements and human activities;
- physical and chemical changes on surface and ground water regime due to alterations of land use; and
- effects on flora and fauna and ecological impacts resulting from dam constructions.

Allocation of water to competing uses

The growing pressures of population and economic activity make the issue of rational water allocation increasingly important. As development of water becomes increasingly costly involving highly adverse environmental and social consequences the need for efficient use of existing supplies and their rational allocation for all relevant purposes is accentuated. The competition amongst the various users on the limited available water resources forces water managers to deal with rational allocation of water to achieve efficiency, equity and environmental quality.

Within this context, efforts to reduce water requirements through "**demand management**" are gaining ground. Such efforts are the pricing policy and changes in water-use technology. Similarly, increased recycling of water in industrial plants, wastewater treatment and reuse, conjunctive surface and groundwater management, appropriate pricing for water supplies and wastewater pollution loads are some of the processes and techniques being employed as a response to the increasing costs of developing new water supplies.

Achieving effective implementation

Experience has shown that so far the normal is for the occurrence of considerable shifts of actual results received from anticipated output targets of project plans. This has been especially true for irrigation projects. Also, the follow-through on plans for handling social and environmental impacts of projects has often been relaxed or ineffective. As the potential gap between available supplies and increasing demands on water resources becomes larger, the importance of effective implementation becomes greater and greater. Ineffective implementation of plans and programs is often one of the major weaknesses of water resources management.

Some major causes of this are:

- untimely institutional set-up;
- delayed or untimely promulgation of relevant legislation;
- inadequate financing of project operation and maintenance leading to deterioration of water control systems; and
- lack of involvement of local water users.

The implementation aspect of water resources management is of equal, if not of greater, importance than the planning aspect. Nevertheless, the former appears to be much neglected. There is, thus, a great need for giving the importance due to the implementation including the need for changes in policies, procedures and approaches.

2.5 Process of the Integrated Approach

2.5.1 Introduction

In view of the increasing complexity and severity of water resources problems, especially in the densely populated and overdeveloped coastal region of the Mediterranean countries, and the water resources management deficiencies experienced by most areas, the tolerance level for further inadequate management has been reduced considerably. This is further accentuated by the diminishing potential of all the coastal resources and mainly that of water resources.

For these reasons it is of the utmost importance that the key principles of a comprehensive water management approach are recognized and incorporated in any local or regional scheme along the coastal areas. These key principles are:

1. The coastal area is a unique resource system which requires special management and planning approach;
2. Water is the major integrating force in coastal resource systems;
3. The need for integrated water management, in particular the environmental and social consequences, the land-water linkage, the linkage between irrigation and municipal demand and supply, which is a water allocation problem, and the effective implementation of the water schemes;
4. The need for demand management through water conservation techniques, pricing, public awareness and water allocation and regulation;
5. The linkage between sources of surface water and groundwater, in particular the impact of surface impoundment schemes on downstream aquifers; and
6. The environmental impact assessment approach, essential to effective coastal water resources management.

Over the next years the challenge will be to apply these principles in a way that secures essential water supplies in a cost effective way.

2.5.2 Basic Components of the Approach

For increased effectiveness, the integrated approach should include among other, the following important interactions:

- The close interrelationship between surface and groundwater. This implies conjunctive planning and operation of surface water schemes and aquifers, artificial ground water recharge, quality deterioration of groundwater due to reduced replenishment withheld in surface reservoirs, redistribution and reduction of pumping to alleviate sea intrusion problems, etc.
- The complex interactions between land and water ecosystems, especially as they exist in coastal areas. This implies the integrated management of the whole watershed up to the coastal line and including both the surface and groundwater reservoirs and flows. Evaporation, surface and subsurface runoff, erosion, sedimentation and aquifer performance are items to be considered.
- The current and projected human activities affecting water management by increasing the demand for water and enlarging the problems of water pollution.
- The relationship between the water resources potential and development and the other economic activities at the local, regional and national scales. All these sectors have to be closely tied and coordinated for successful overall implementation and maximum economic return.
- The complex political, governmental and institutional context, and in all its variations among the various Countries and local peculiarities, within which the water resources management programs must be undertaken and developed. This management setting involves multiple and usually conflicting interests and objectives, multiple means, actors, pressure groups and decision makers.

For the integrated approach to be effective and successful, this must be:

- dynamic, so that it could adjust to the changes of the planning and implementation processes;
- broad, comprehensive and multi-purpose involving all the relevant objectives of water resources programs and the related land-resources management schemes;
- comprehensive, incorporating the relevant important concepts and techniques of systems analysis, risk and uncertainty evaluation through sensitivity analysis etc.; and
- sufficiently robust so that it can be readily adapted to the diverse conditions encountered between areas of different development level or of particular peculiarities.

2.5.3 Procedures and Methodology of the Approach

UNESCO have been examining the issues of water resources management for the last two decades though vehicles such as the International Hydrological Decade, the International Hydrological Programme and various international conferences to encourage a more integrated approach to water resources. Out of this work has come a number of publications. Hufschmidt and Kindler propose a “process” approach to water resources management (Hufschmidt and Kindler, 1991). The model is shown schematically in Figure 2.10.

Basic elements in the methodology and the procedures of the integrated water resources management approach are outlined separately for the “planning” and the “implementation” stage of a water resources scheme. They detail the aspects of planning as presented in Figure 2.11.

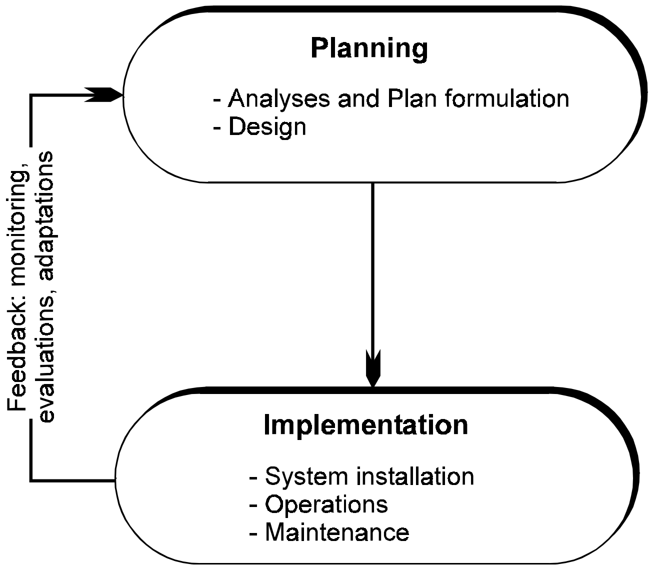


Figure 2.10: The water resources management process (Hufschmidt and Kindler, 1991)

- Definition of objectives
- Collection and analysis of data in three areas:
    1. Water resources supply
    2. Water resources demand
    3. Water resources management options
- Formulation and evaluation of alternative plans:
    1. Environmental assessment
    2. Risk assessment
    3. Economic evaluation
    4. Multicriterial evaluation
- Sensitivity analysis
- Decision on preferred plan
- Design parameters for structures and operation rules
- Detailed design

Figure 2.11: The planning phase (adapted from Hufschmidt and Kindler, 1991)

Planning

The management at the planning stage, beyond its conventional aspects, can be improved through the integrated approach by broadening the scope of planning along several dimensions.

A broad systems-analytic approach needs to be adopted that involves all the important physical, economic, environmental, social, cultural, institutional, and organizational factors. Especially the scope of the following, needs to be enlarged:

- *the areal scope*, by incorporating land use and watershed planning with river basin planning focusing on streams, lakes, aquifers, and effects on estuaries, bays, and coastal waters;
- *the management objectives,* by adopting a multiple-objective approach in planning, incorporating environmental and social aspects along with economic objectives from the start of planning;

- *the substance of planning*, by including the planning of implementation strategies involving implementation tools and the needed financing, institutional and organizational arrangements;
- *the management options*, to include demand management together with supply augmentation options at the planning stage for the development and allocation of scarce water resources;
- *the planning team*, to include social and natural scientists as well as water users and other affected persons.

Implementation

The broadened planning strategy outlined earlier, although a necessary condition for successful implementation, still needs the sustained and consistent follow-up through the implementation phase. Important elements that need to be considered for the integrated approach during this stage of water resources management are the following:

- The *breadth and integration* of the water resources management plan should be *maintained* during this stage. An integrated funding program and budget for all elements of the management plan should be secured.
- *Local people* affected by the scheme should *be involved* fully during implementation.
- *Maintain* cost-effective *monitoring,* evaluation and feedback, identifying deficiencies for developing corrective measures and provide data for the planning of the next scheme.
- *Provide for the operation and maintenance* of completed development projects by appropriate funding programs and pricing or cost-sharing policies.
- *Set up appropriate institutional and organizational* arrangements with adjustments as suggested by the monitoring and as required by the integrated complex management plans.

The Implementation phase of the "Integrated Water Resources" process, is illustrated in Figure 2.12.

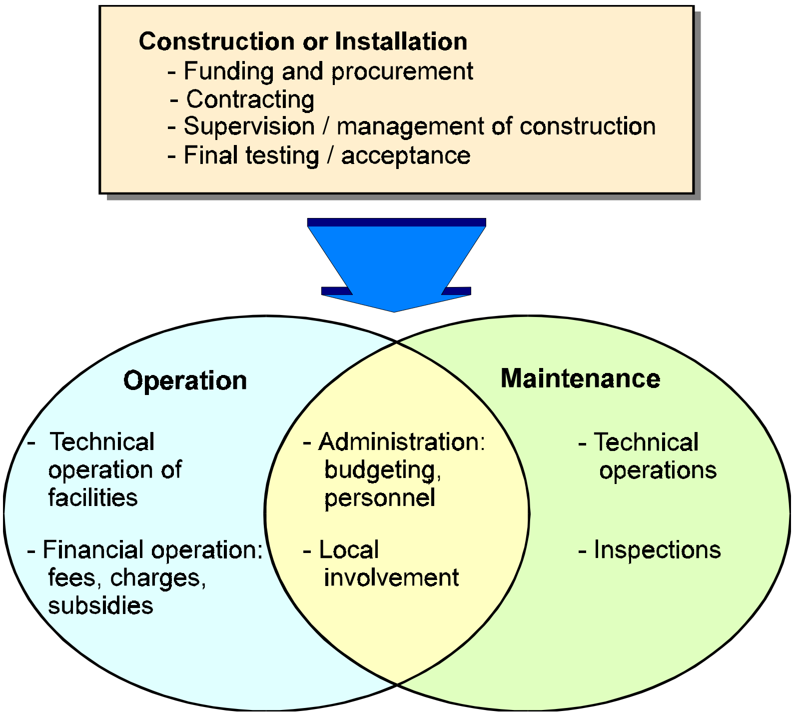


Figure 2.12: The implementation phase (Hufschmidt and Kindler, 1991)

2.5.4 Integrated Water Resource Assessment

The problem often is how to formulate cost-effective water resource development programs for the selected area that can be fully implemented to the satisfaction of local, regional and national interests and in accord to other development programs of various other sectors directly or indirectly connected with the water resource sector.

For an assessment of this type to be successful, it should have predetermined objectives and involve the interested parties from the early beginning in both the technical and financial needs of the assessment. The activities of each assessment, from start to finish, may be divided into four parts:

- organization of the assessment;
- involvement of interested organizations and groups;
- programming and scheduling; and
- reporting of the assessment results.

Organizing the assessment

To ensure success of the assessment of the water resources or setting up of a water resources scheme the following steps are essential:

- obtain and evaluate data;
- design the assessment program;
- consider environmental issues and other ongoing resource activities;
- arrange finance and budgets; and
- generate support for the assessment.

These steps may have to be repeated as the study proceeds.

Involvement of interested organizations and groups

When the study commences, a free flow of ideas and contacts should be established between the study group and other interested parties. These contacts should be maintained throughout the entire water resource assessment period to make sure that the public is aware of the progress and preliminary results. In general, development plans are more readily accepted by people if they have a clear understanding of the objectives, priorities, financial and political as well as physical constraints and the social attitudes that have been satisfied. The free exchange of ideas is essential to achieve the most efficient and effective water resource assessment.

Programming and scheduling

A detailed schedule is required for each component of the study. Critical-path analysis or similar techniques should be employed to assure that all study components are completed on time. "**Decision points**" included in the schedule help control the progress. The schedule inevitably will need to be re-evaluated as it seldom happens to achieve close adherence to it.

Terms of reference define the extent and type and breadth of assessment to be undertaken. Outside groups that would be affected by the results of the assessment need to be informed of the progress of the work. Advisory or coordinating committees is usually the best way to keep involved agencies and other parties informed and interested. The use of such coordinating committees in any major water-resource study is highly recommended. Such committees will also ensure an integration of all other activities relative to the project.

Reporting on assessment results

Reporting the assessment results is as important as the results themselves. These results must be clearly understood by the decision-makers. Effective reporting of results also promotes the general understanding of the assessment status and also promotes the general understanding of the assessment status and progress and ensures the continuous support by the interested parties.

2.5.5 Major Problems to be Included in the Integrated Water Resource Management Approach

Water resources are often developed in the context of separate projects which are not integrated, although the hydrologic cycle is itself an outstanding example of a single, integrated system. Users of water within this cycle are increasingly competing with each other for scarce resources. In these circumstances, it is difficult not only to manage water wisely, but also to measure its availability and the effects which usage is having on the resource.

Within this context, four problem areas may be emphasized:

- *Handling the environmental, social and cultural consequences of water resources projects*. These could be reduced if particular studies incorporated of such consequences and of measures for alleviating them are considered from the early planning stage rather than after major decisions have been made.
- *Integration of watershed land management with water resource development*. This will allow erosion, sedimentation, pollution, flooding and other land-water linkage problems to be addressed.
- *Allocation of water in a rational manner among competing uses in the context of efficiency, equity, sustainability and other objectives*. Within this aspect, the "demand management" practice is included through water pricing along with technical means for allocating water resources properly and attains efficient use and balance demand to the available supply.
- *Attaining effective implementation of project plans* through use of economic incentives, decentralization of project management, involvement of local people, and making the necessary institutional and legislative changes and regulations and controls.

The challenge is the achievement of such a development in order to meet social and economic goals, while maintaining high quality of water resources, and avoiding serious degradation of the physical environment.

3. MEDITERRANEAN COASTAL AREA WATER RESOURCES

3.1 Elements and Characteristics of a Coastal Area Water Resources System

3.1.1 General Considerations

The coastal areas, especially in the Mediterranean region, often include some of the most densely populated areas. This is due to the availability of fertile land of flat topography, the communications infrastructure, an easy access to sea transportation and the amenities offered by the sea shore especially as a great attraction to tourism. In view of this increasing concentration of human settlements, agricultural development and other economic activities in the coastal areas, the water resources and especially ground water, are acquiring an increasing social and economic value. More often than not, the demand for fresh water resources for irrigation, for municipal and industrial purposes, exceeds by far the available supply and water supply shortages that are common.

The intensive human activities in these areas interfere with natural processes and many physical and biological changes occur both on the water resources as well as on other resources of the area. Such interference is the depletion of coastal aquifers with the result of sea intrusion, pollution of both surface and ground water resources due to the excessive use of water from either source, the disposal of waste waters and intensive use of pesticides and fertilizers on agricultural lands of limited extent, and the destruction of the natural habitat or shore modification by civil works resulting in erosion or sedimentation. The coastal area water resources are subjected to more severe and complex repercussions of development than most other land areas in a country. The coastal areas are a transition zone between the land and the sea and between the fresh and saline water, and they often are most productive, as estuaries, lagoons marshes and wetlands. The greatest impact on the coastal area resources comes from urbanization and development.

In the performance of water resources management, the integrated approach which considers not only the water resources themselves but at the same time all other resources and the effect and impact upon them, is highly exemplified in coastal areas. The management of the coastal resources can not be separated from the management of inland water resources or the overall regional system. Similarly the reverse is also true. Although a narrow scope is frequently necessary in dealing with the water and other resources of the coastal areas, especially due to the peculiarities of the coastal areas, still this subsystem should be considered within the framework of the larger resource system. The Aswan High dam may be recalled as a classic example of the great changes and impact that can occur on coastal resources by impoundment of water inland regardless repercussions that such an action may have downstream.

In the same way, reduction of the recharge of the downstream valley and coastal aquifers by the impoundment of water upstream, leaves the downstream areas vulnerable to increases of pollutants, as fertilizers and pesticides, due to the reduction of through flow of water and its leaching effect. Pollutants generated inland are usually carried by the streams to the oceans. Direct use of this surface runoff may be difficult by the time the coastal zone is reached or replenishment of coastal aquifers with this water impairs the quality of the ground water. The long-term effects could be serious and irreversible.

Of course, not all changes in inland waters have a damaging effect on coastal resources. The important thing is that an evaluation should include the total possible effects minimizing or correcting the negative ones. Within an integrated water resources management approach, the coastal water resources management is expected to be integrated with that of the regional system and any development, either at the coast or inland, should be evaluated as to the effect it may have on the other.

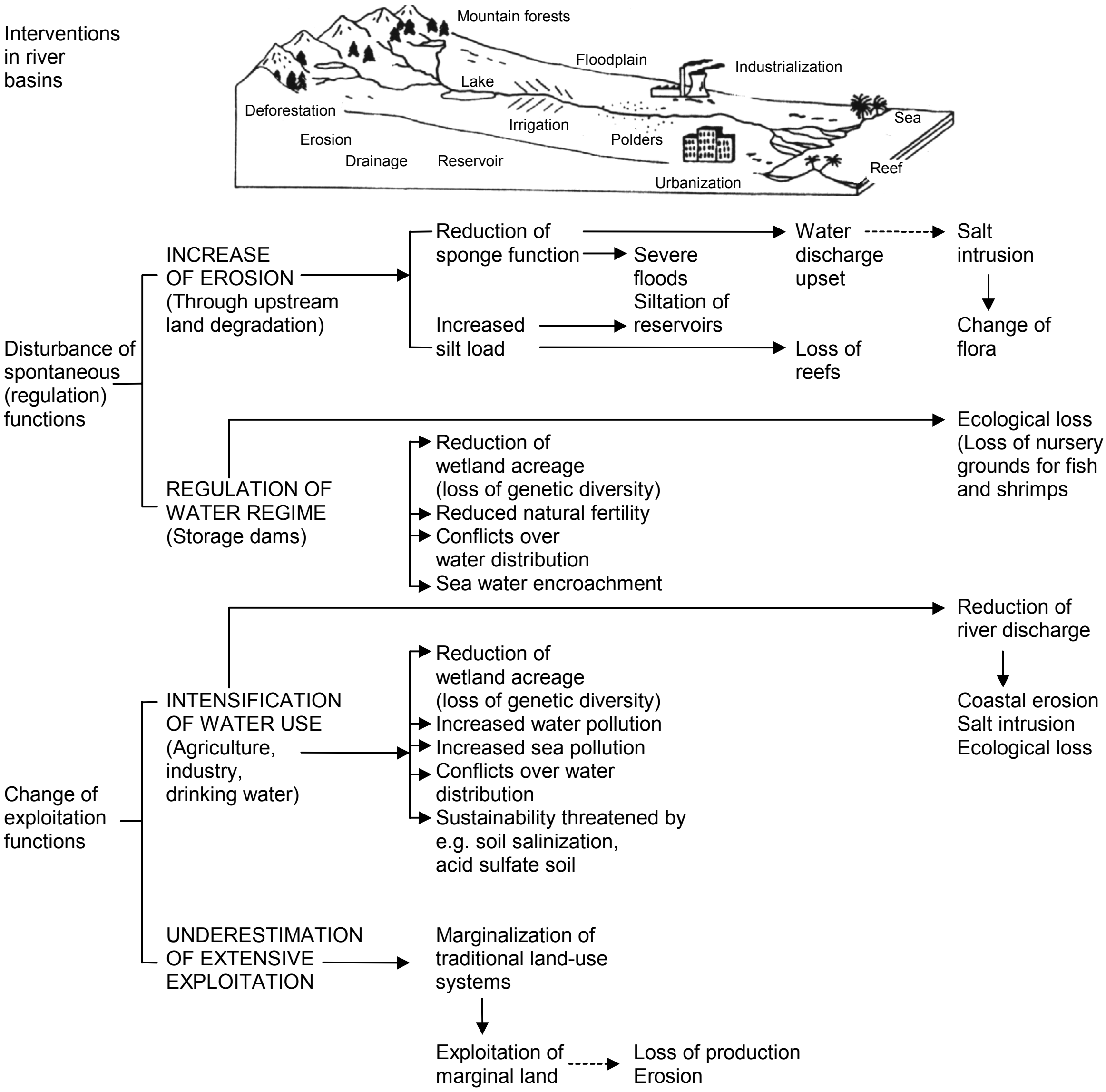


Figure 3.1: The basin “slice” of environmental assessments: sensitivity table (adapted from Marchand and Toornstra, 1986)

3.1.2 Characteristics of Coastal Water Resources

Coastal plains vary in size from small isolated valley deposits that grade inland into normal stream deposits to large, almost featureless plains that fringe large extents of the coasts.

The sediments of the coastal plains generally represent both alluvial and marine environments. The marine sediments, in turn, are represented by beach, lagoonal, estuarine as well as by deeper marine environments. In some areas alluvial and deltaic deposits are most abundant. Many stratigraphic units along coastal plains grade seaward from partly alluvial deposits into entirely marine units. This gradation is accompanied by a tendency for the sediments to become progressively finer grained. The bulk of the sediments grade from gravel to sands to clays and silts, although some areas contain abundant marls and limestones.

The water yielding properties of sediments underlying coastal plains, are in general quite similar to those sediments in large valleys. Quite often, very important ground water reserves are located in the coastal zones and high yielding aquifers have been undergoing exploitation for a long time. From the hydrogeological point of view not all types of coast have the same importance. The coasts made up of hard, low fractured rocks which are almost unproductive, are of less importance whilst terrace deposits, deltaic and alluvial fans, and large sedimentary basins are obviously of overwhelming interest. Coastal karstic aquifers are also of great importance, although these are particularly vulnerable to sea water intrusion due to their peculiar hydrogeologic characteristics which allow a very fast inland propagation of the intrusion in the case of over-exploitation. These aquifers require special methods of investigation and control.

One of the main characteristics of coastal area water resources is their association with sea water and their content of salt. The main source of salt in coastal areas is the sea water which has a rather constant chemical composition except for small changes due to the variation of evaporation rates as for example in the Mediterranean sea where all constituents are somewhat increased.

The estuarine, river flow and ground water outflow in the coastal areas have a dilution effect on the sea water salinity that affects aquatic life. River use, ground water exploitation, urbanization impact on surface runoff and ground water recharge modify this dilution pattern. Similarly, the surface - ground water interactions and relationship are of great importance in the coastal water resources management.

Sea water encroachment problems in coastal aquifers are of prominent importance in the development and exploitation of coastal water resources and full consideration of this should be made in any scheme that involves pumping or modification of the natural replenishment by the construction of surface reservoirs. This is probably the single most basic element that characterizes the coastal area water resources and as such a more detailed account of it is presented.

The other typical and important characteristic of water resources in the Mediterranean is a "***seasonality of supply***". The largest supply in water resources occurs during the winter when water demands are the lowest, while the smallest supply occurs in the summer when water demands are the highest.

3.1.3 Land and Water Resources

The land and water resources of the Mediterranean are limited and highly sensitive. They differ greatly from one area to another. The specific features of those resources are due to the climatic, geological, hydro-geological and topographic characteristics of the area. The Mediterranean climate is characterized by dry and hot summers, and wet and cool winters. Moving from the north to the south of the region, the temperatures rise and precipitation rate diminishes. The northern and the southern parts of the Mediterranean basin differ also geologically and pedologically. The entire area, and particularly its north-eastern part, is characterized by Karst, while there are no rich, vast, fertile soils.

Intensive urbanization of the area, followed by the development of industry, tourism and transports, takes up considerable space, especially in the coastal area, changing its natural characteristics. The ever increasing demand for food causes an intensive development of agriculture which occupies more land to the detriment of the original vegetation and forests. The intensive agriculture and forest fires cause serious soil erosion and loss of land, with long-term economic and ecological consequences.

In the Mediterranean region as a whole, the water is relatively scarce. Exceptions are some river valleys like the Nile in some more humid regions, or like the Rhone, or some areas in the north that are rich with water, such as the northern Italy, the western Balkans and Turkey.

Table 3.1: Mean global hydrological data for Mediterranean basin (billions of m^3/yr) (Margat, 1990)

Groups of countries	Total mean annual yield			Portion of the Mediterranean basin	Regulat. portions
	internal runoff	external flow	total		
North (Europe)	669	141	810	424	≅200
East (Asia)	211	8	219	75	≅60
South (Africa)	55	57	112	75[2]	≅65[2]
Total	935	206[1]	1141	574	≅325

(1) without duplication: inflow from countries not along Mediterranean
(2) including the Nile, regulated flow: 55.5

Water resources related problems of the Mediterranean region as a whole (Figure 3.2) have been given a detailed and comprehensive treatment within the activities of the MAP Blue Plan (Grenon and Batisse, 1989) and MAP PAP/RAC (Margeta - No. 12, 1987; Margeta - No. 13, 1987). On the basis of the results achieved through their activities, the water balance of the Mediterranean basin has been calculated (Figure 3.3). At the regional level, water is a scarce resource and poorly distributed over the Mediterranean basin.

The present state of natural water resources is given in the Table 3.1, according to the Blue Plan data for 1980s. From the presented data, it is easy to see the differences between various Mediterranean regions stemming from their specific climatological, hydrogeological, and hydrological characteristics.

However, the true picture is obtained when data are compared between individual countries, with regard to the capacity of water resources and the demand (Table 3.2). These data clearly show the critical situation in some areas where all the available natural water resources have already been practically exhausted. It is in such a situation that the importance of maintaining the integrity of water resources for sustainable use is best felt. It defines this as the maintenance of balance in the hydrologic processes of precipitation, evapotranspiration, runoff, groundwater flows, and storage.

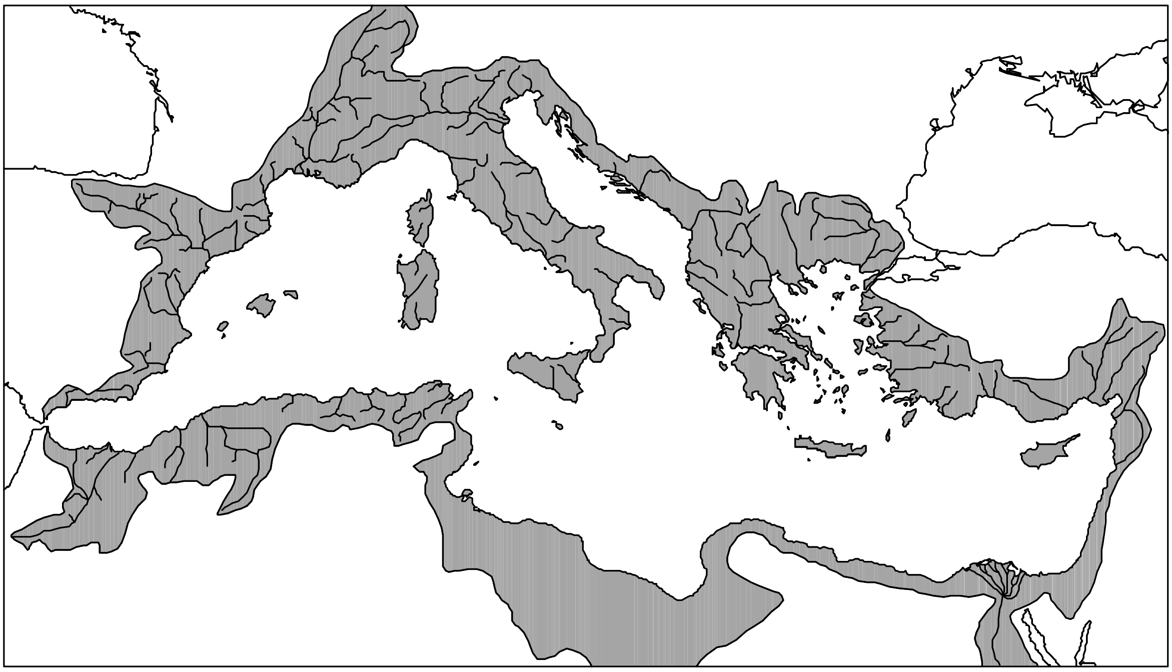
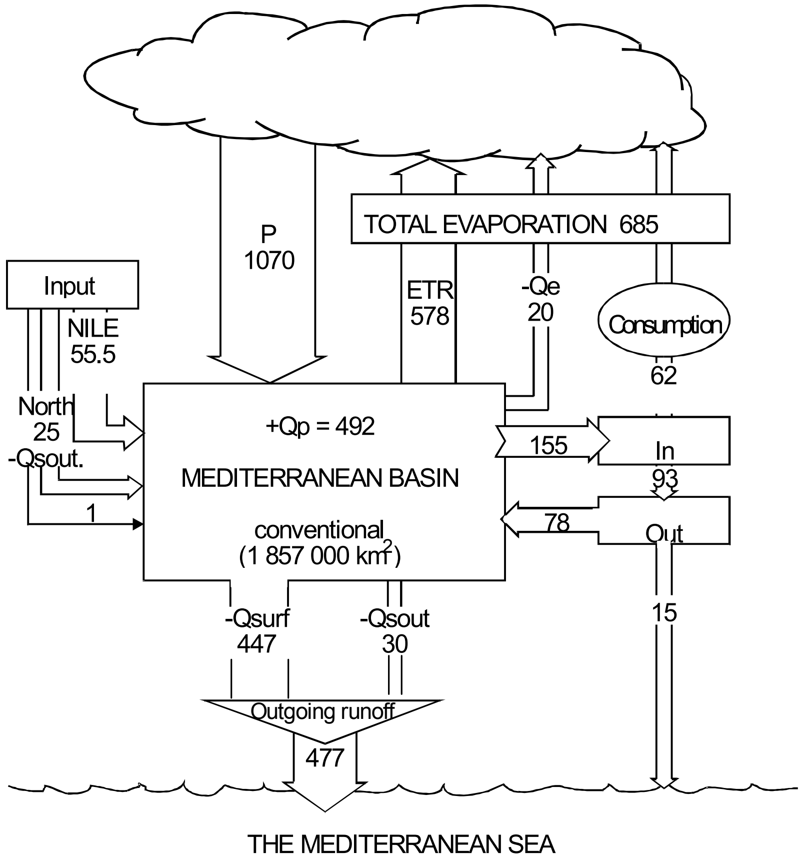


Figure 3.2: The Mediterranean watershed (Grenon and Batisse, 1989)



Unit: billion m^3/yr

P - rainfall
ETR - real evapotranspiration
$+Q_p$ - runoff (effective rainfall)
- Qe - runoff loss via evaporation
+Qsout - underground input
- Qsurf - surface runoff to sea
- Qsout - underground runoff to sea

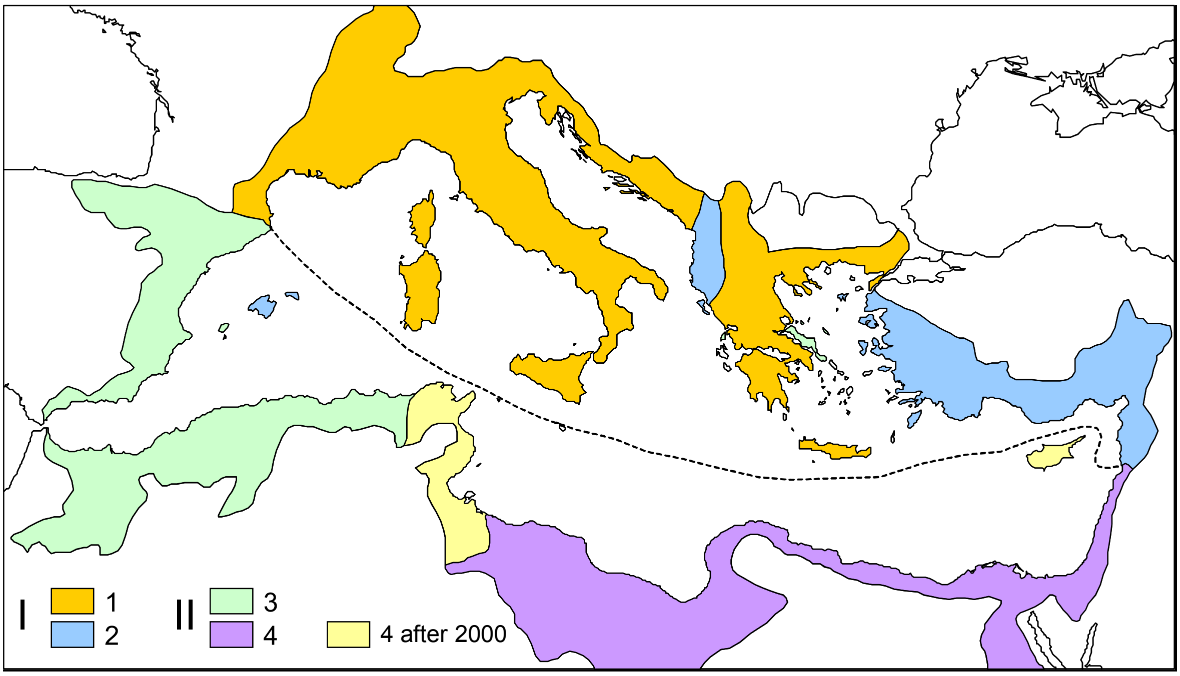
Figure 3.3: Water balance in the Mediterranean basin (Margat, 1990)
(The chart gives the current mean flows)

According to research performed within MAP (Blue Plan) the total mean annual yield of the Mediterranean countries is of approximately 935 km^3/year, of which 631.37 km^3/year relate to the Mediterranean basin. With regard to water abundance, we can distinguish three regions: North (Europe), East (Asia Minor) and South (Africa), as shown in the Table 3.2. The European part of the Mediterranean has most water (renewable water resources are 478.32 km^3/year), followed by the eastern part (76.9 km^3/year), while the southern, African part is poorest with water (75.8 km^3/year). Unfortunately, the number and growth rate of population is not proportional to the water abundance (see Table 3.2).

In the past, as well as nowadays, a considerable part of the renewable water resources has been used up, reaching an average of 65% for the whole region. Withdrawal of the water is high, not only in the south (Libya 100%, Malta 100%, Egypt 92%, Tunisia 70%, Morocco 40%, Algeria 32%) and in the east (Cyprus 42%, Israel 100%, Syria 47%), but also in the north (Spain 41%, Italy 30%). Considering the water abundance on one hand, and the present and planned water consumption on the other, then, with regard to water resources management, we can distinguish two different areas in the Mediterranean, the northern and the southern (Figure 3.4).

	Renewable resources - theoretical (km^3/yr)			Ratio (2)/(1)	Other resources			Demand			Index (%)	
Catchment area	Renewable resources (1)	Inflow from neighboring areas	Regulated resources (2)	Index of regulation	Fossil water resources	Desalinization	Waste water reuse	TOTAL (km^3/yr)	Part previously used by aquifers (%)	Total consumption (km^3/yr)	Index of exploitation	Index of consumption
Spain	31.10	1.00	7.50	24.1				20	1	12.20	64.3	39.2
France	74.00	12.00	35.20	47.6				17.2	0	2.00	23.2	2.7
Italy	187.00	7.60	30.50	16.3		54		46.35		14.85	24.8	8.0
Malta	0.07	0.00	0.03	42.9		16.1		0.034		0.03	49.0	40.0
Ex-Yugoslavia	77.50	0.00	11.50	14.8				1.5		0.28	1.9	0.4
Albania	50.00	5.50	6.50	13.0				2.97		1.10	5.9	2.0
Greece	58.65	13.50	7.70	13.1				7		3.75	11.8	6.2
Turkey	67.00	7.00	15.60	23.3				6.7		3.20	10.0	4.9
Cyprus	0.90	0.00	0.27	30.0	40	10	8	0.38	11	0.25	42.0	28.0
Syria	4.00	0.60	2.30	57.5	40			2		1.00	47.0	12.5
Lebanon	4.00	0.00	2.80	70.0				0.8		0.32	17.4	8.0
Israel	1.00	0.10	1.00	100.0	320			1.5	18	0.92	106.0	90.0
Egypt	57.30	56.50	55.80	97.4	200(*)	25(*)	3500	55.9	0.4	38.00	91.0	66.0
Libya	0.70		0.20	28.6	500	226	146	1.6	46	0.85	157.0	121.0
Tunisia	3.10	0.60	1.50	48.4	10			2	0.9	1.30	64.5	42.0
Algeria	10.90	0.03	2.50	22.9	420(*)	65(*)		1.7		0.85	15.6	8.0
Morocco	3.80	0.00	0.90	23.7		3.5(*)		1.1		0.58	29.0	15.0

Table 3.2: Water supply and demand in the Mediterranean catchment area (MAP - Blue Plan, 1995)



I - Northern hydrological part of the Mediterranean; Moderate water requirements, stable in the areas (1), increasing in the areas (2); Only local requirements more pronounced with regard to the quantity and/or quality; No particular problems in water supply expected until the year 2025, with possible local critical points; Priority will be given to the safety of the supply and water protection.

II - Southern hydrological part of the Mediterranean; Very high water requirements with increase in the future; Very high degree of exploitation of both renewable and non-renewable water resources (4); Chronical water scarcity and growing sensitivity to drought. Priorities to economical use, water importation, and non-conventional water resources (4); Priority to water protection and preservation of renewable resources (3), or occasionally (4).

Figure 3.4: Subdivision of Mediterranean water resources and management prospective (Margat, 1989)

In the northern part, richer with water, complex and expensive water resource systems were built, which distributed the water in time and space. The southern part, lacking surface water, has considerable reserves of deep underground water (Algeria, Libya), but which are not naturally renewed and will eventually dry up, so that they do not offer a long-term solution to the problem. One of the solutions used in the region for some time now is desalinization of the sea water. Malta and Libya, for example, meet more than 50% of their needs in this way.

In the future, with the growth of the population, higher standard of living and increased use for irrigation, the situation will become even harder (Figure 3.4). The scarcity of water will be felt more strongly, creating considerable problems, both among various economic sectors, and between urban and rural areas. Management of water resources will be very difficult and will require considerable funds and knowledge, and application of innovative technologies.

In this field, Israel has done more than any other Mediterranean country. At present, most of the available water resources are being used, and it is planned that very soon most of treated waste waters will be in use (Figure 3.5). Such solutions have led to the achievement of a high sanitary standard and an efficient protection of both fresh and sea water resources against pollution, as well as to the provision of considerable quantities of second class water useful primarily for irrigation. The basic prerequisite for achieving such results is qualified staff, both for planning the integrated development, management and use of water resources, and for the management of water systems.

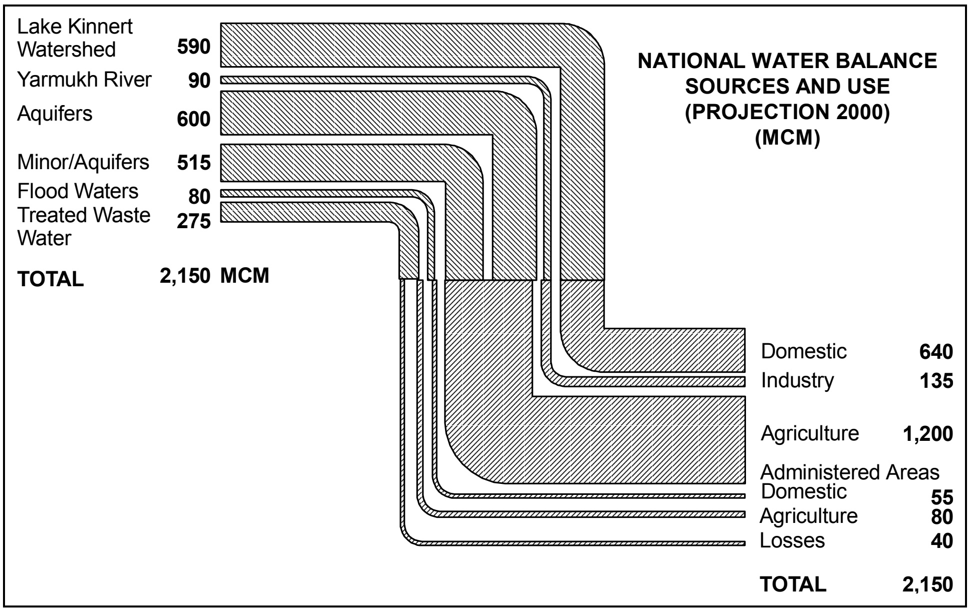


Figure 3.5: Israel water balance and use (projection for 2000) in MCM

3.1.4 Specific Problems and Particular Characteristics of Coastal Area Water Resources System

3.1.4.1 Seasonality of Supply

Several climatic characteristics play a key role in the water resources of most of the Mediterranean coastal areas and their management. Some of these are:

- Most of the precipitation falls in winter, while the greatest demand, for crop irrigation and for tourism, is in the summer;
- Both temperature and sunshine duration result in high levels of evaporation and evapotranspiration from storage reservoirs and from crops;
- Regional variation of rainfall is considerable, with abundant rainfall not coinciding always with the areas where demand is greatest. There is also a large variation of rainfall between the northern coast of the Mediterranean as opposed to the southern and eastern coastal areas which receive much less rain;
- There is also a considerable inter-annual variation of rainfall with occurrence of sequences of two and three year droughts being quite common. This necessitates large surface reservoirs to provide a steady yield inter-annually, whilst drought plays a key role in overall water management policies.

The main hydrological features of the Mediterranean region may be summarized as follows (UNESCO, 1978):

- There is a clear topographic dependence of precipitation (Figure 3.6). A minimum of 200 to 300 mm/yr occurs along the eastern Spanish coast to a maximum of more than 1,500 mm/yr on the Adriatic coast. In the southern part of the Mediterranean, in most areas, precipitation averages from 100-400 mm/yr.
- Summer drought averages three to seven months along the eastern Spanish coast; two to three months may be dry along the Italian west coast; one to two months at the Adriatic coast and four to five months along the Greek coast. In the southern part of the Mediterranean four to seven months or perhaps more are usually dry.
- Annual evapotranspiration varies between 400 and 600 mm/yr along the northern coast and 1,250 to more than 2,000 mm/yr along the southern part depending on the availability of sufficient rainfall and vegetation.

- Mean annual runoff varies considerably throughout the Mediterranean from 100 mm/yr along the Spanish east coast to 400-500 mm/yr along the coasts of the Ligurian Sea, and 300 mm annually along the Adriatic coast. The runoff along the southern part of the Mediterranean region is highly variable varying from 100 in Tunisia to 500 mm/yr in Morocco. In this area, the distribution of runoff reveals a tendency towards high monthly runoff at the beginning and end of the year coincident with the seasonal precipitation.
- Runoff coefficient ratio between runoff and precipitation, is about 0.5 to 0.6 except in southern Spain and Tunisia where it amounts to only 0.1 on an average.

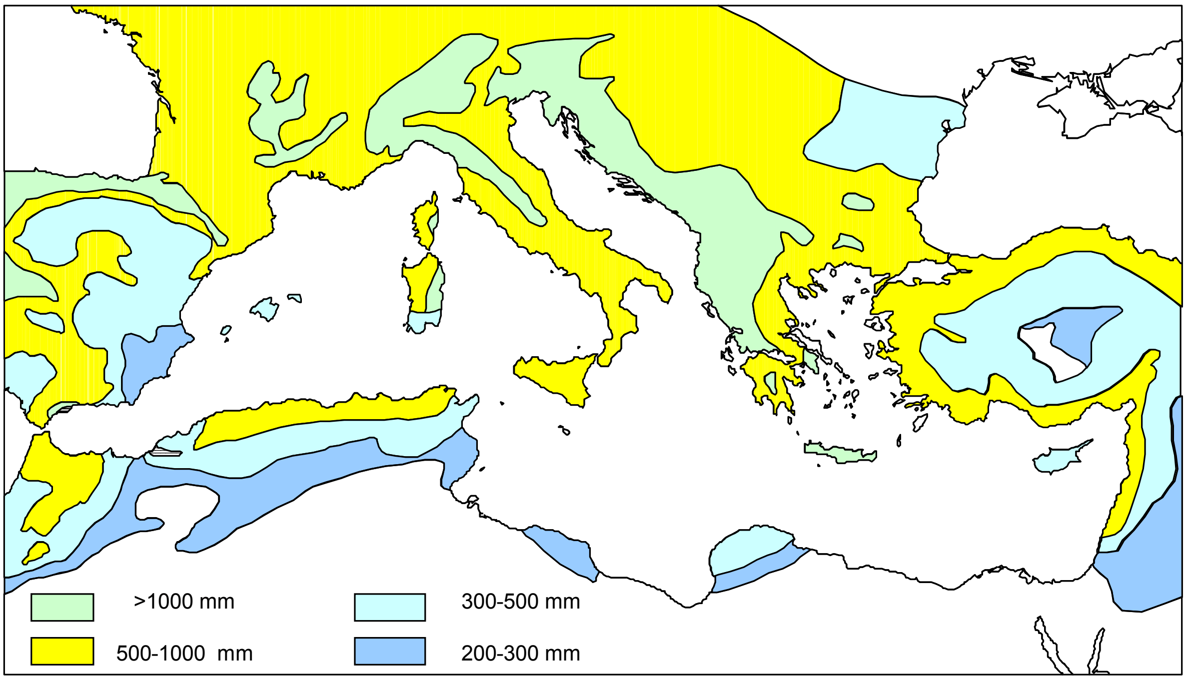


Figure 3.6: Average annual rainfall around the Mediterranean basin (adapted from Times Atlas of the World)

The scarcity of water resources throughout much of the Mediterranean makes their availability one of the key conditions for development in the region. Data on water resources and water consumption are shown on Table 3.2.

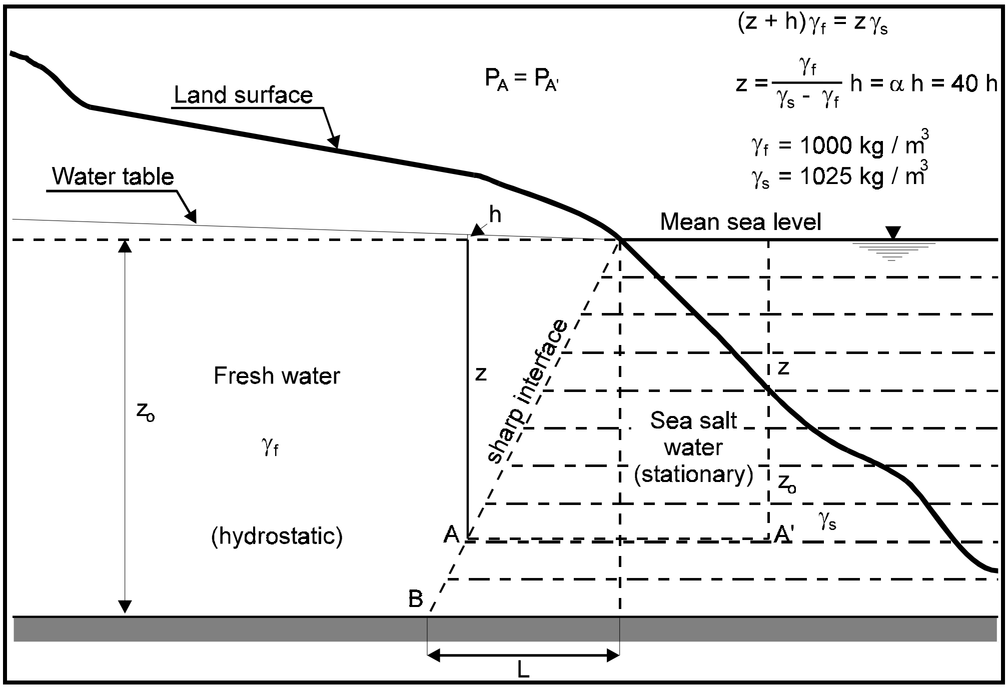
3.1.4.2 Salt - Fresh Water Relationship in Coastal Aquifers

Development activities affecting salt - fresh water relationships in coastal aquifers

Any activity that causes a reduction of fresh ground water discharge to the sea results in a change of the salt-fresh water interface and causes its landward movement. Normally, most of the effects by human direct or indirect influence on ground water flow, develop very slowly so that it is often difficult to relate cause to effect. This tends to cause an overlook of the problem until it is late for corrective measures.

The economic and environmental consequences of sea water intrusion and loss of fresh water supplies could sometimes be considerable threatening to impair the living conditions of present and future generations.

Activities affecting directly the salt-fresh water position are related to ground water abstraction which reduces the coastal fresh water discharge and alters the dynamic equilibrium (Figure 3.7). When abstraction exceeds the actual recharge, no new equilibrium position can be attained and the coastal aquifer has sea water intruded very deeply.



Legend:

P_A is the water pressure at point **A**

γ is the specific weight, **z** the depth below mean sea-level and **h** the fresh water head over the mean sea level. Applying usual γ values results in **z = 40 h**, although other values can be obtained for different γ values.

A sharp interface is assumed. In reality such system can not be hydrostatic, and thus the formula is not exact, especially near the fresh water outlet. Still it is very useful in first calculations, and reasonably accurate when applied far from the shoreline, in aquifers with a narrow mixing zone.

Figure 3.7: Salt water depth in coastal porous aquifers. The Badon Ghyben- Herzberg principle in an idealized hydrostatic fresh-salt groundwater system (UNESCO, 1987)

Activities affecting indirectly the salt-fresh water interface are related to those that affect the ground water recharge. An increase of recharge has positive effects since it increases the through-flow and fresh water outflow to the sea reversing the conditions for sea ward movement of the interface.

The potential for sea water encroachment is increased by the following activities:

- river regulation with upstream dams when the river recharges the coastal aquifer, naturally or through induced recharge;
- urbanization, industrialization and paving of former agricultural lands due to the reduction of recharge and an increase in surface runoff which normally runs to the sea;
- improvement of irrigation efficiencies which reduces the excess water when surface, or imported water is used;
- when a central sewerage system is installed, the natural recharge through cesspools is stopped;
- re-routing of channels and streams for flood protection may decrease the runoff infiltration;
- deforestation or vegetation impairment may also reduce the opportunity for infiltration and thus reduce the recharge.

Points to consider for preventing sea water intrusion

Since sea intrusion is one of the main concerns in coastal water management the following should be observed in managing the water resources of a coastal area:

- the total annual extraction from a coastal aquifer must be less than the mean annual recharge. The smaller the coastal strip in which sea intrusion occurs, the less the safe yield of the aquifer;

- control of over-pumping with a view to halting and eventually reversing sea water intrusion into coastal aquifers is mostly achieved through regulatory instruments based mainly on ground water abstraction permits;
- enforcement of the regulatory restrictions on ground water pumping is the key to the ultimate success;
- financial inducements, such as progressive charges, can also be effective as a complement to regulations and planning in curbing ground water pumping but effective implementation is however a major issue;
- sound ground water management for conserving the coastal aquifers and protecting them from sea encroachment is the best approach. This, though, requires an interdisciplinary effort, proper institutional framework, supporting legislation and clear allocation of jurisdiction;
- ground water abstraction points must be well distributed and away from the coastal shore;
- for avoiding upconing, abstraction works must limit their discharge and the drawdown must be as small as possible;
- a monitoring network of wells for water level and depth-salinity should be maintained;
- artificial ground water recharge activities should be planned and implemented;
- aquifer recharge sources must be protected;
- involvement of water users in the effective management of ground water resources through education and increased awareness and active participation in the making of government regulatory decisions.

3.1.4.3 Principal Elements of Coastal Area Water Resources Operation

The coastal aquifer is usually the major source of water supply to a coastal plain which frequently happens to be the dominant water user area of a country, especially in the Mediterranean region. The main objective of operation of the coastal water resources is to meet the annual water supply of the area based on the requirement of a firm supply.

The principal elements of coastal area water resources operation are tabulated in Box 4.

3.2 Elements and Characteristics of a Coastal Area Man-made Physical Water System - Human Activity System

Intensive human activity takes place in the coastal zone. Here a permanent and intensive interchange within and between physical, biological, social, cultural and economic processes occurs. This is the area where the maritime system, terrestrial system and fresh water resources system clash and overlap, creating a unique coastal system. This coastal system is complex and sensitive, depending on a number of natural and other processes. This area is also very attractive for living which results in intensive town spreading and changes in land use which, in turn, changes the characteristics of all three systems (fresh water resources, marine and terrestrial). The volume and complexity of the coastal activities are presented in the Figure 3.8.

The principal economic and development sectors of this area are:

- urbanization with typical socio-economic activities;
- agriculture;
- industry;
- fisheries and aquaculture;
- energy production;
- tourism;
- transport; and
- forestry.

Box 4

Principal elements of coastal area water resources operation

The following principles are suggested as guidelines for the annual coastal water resources operation:

a) Satisfaction of demand

The objective is to meet the demand at a prescribed quality and reliability level. Normally, there should be a *fixed part* of the demand and a *flexible part* which can only be met on the occasion of surplus water availability.

b) Reliability and priority of supply

The coastal area water resources are particularly sensitive to annual variations of climate, hydrology and of technical capacity in terms of developing infrastructure due to the rapid change in population, seasonal change and growth of tourism, etc. For this reason, each group of consumers and each category of consumption should be assigned a seasonally or annually guaranteed norm of supply (fixed supply). A higher reliability and priority of supply is given to the domestic demand followed by the industrial, the irrigated tree crops and finally the seasonal crops.

c) Integrated regulation of supply

The irregularity of water availability at the coast could effectively be overcome to a large extent by surface or underground water storage and transfers of water from areas in the hinterland. This principle in effect calls for operating the water system of a country as on unit.

d) Diversification of water resources

This involves the use of techniques for water reclamation, lowering of standards, development of salinity resisting crops, etc. Consequently, waste water and brackish and sea water, after desalinization, need to come into stream in the overall water supply system.

e) Satisfaction of constraints

The scope of feasible operations on water resources is restricted by constraints, physical, technical, economic, legal, etc., of which some are manageable (by change of decision) and others are relatively non-manageable.

The constraints relevant to the operation of a coastal groundwater system are:

- the groundwater balance;
- admissible maximum groundwater level;
- admissible minimum groundwater level;
- admissible maximum salt content and other constituents in the water pumped;
- effective pumping capacity, as function of groundwater level and location of front of the prescribed constituent;
- effective recharge capacity, if artificial recharge is being practiced;
- boundary of maximum admissible extension of a domain of pollution or contamination above a given level;
- hydraulic import capacity;
- hydraulic export capacity;
- spatial and temporal distribution of the demand;
- water resources operating units like available wells, boreholes, pumps, recharge units, transportation facilities etc.;
- rules and procedures of water resources administration;
- budgetary constraints;
- political constraints;
- constraints of manpower and equipment;
- ecological constraints.

f) Balanced net withdrawal

In this context, the concept of “safe yield” applies. The “potential safe yield” may be defined as the fixed maximum net amount of water of a given quality that can be annually withdrawn from the system for a large number of years at a given operational storage and under a given set of hydrologic constraints, while securing a prescribed low probability of failure. The “actual safe yield” is less than the potential safe yield due to the adherence to all presently existing constraints.

g) Equitable allocation of water

If the total demand for water exceeds its supply then, for equal levels of reliability and priority of supply and under equal constraints, the available water should be allocated to consumers proportionally to their share in the total demand.

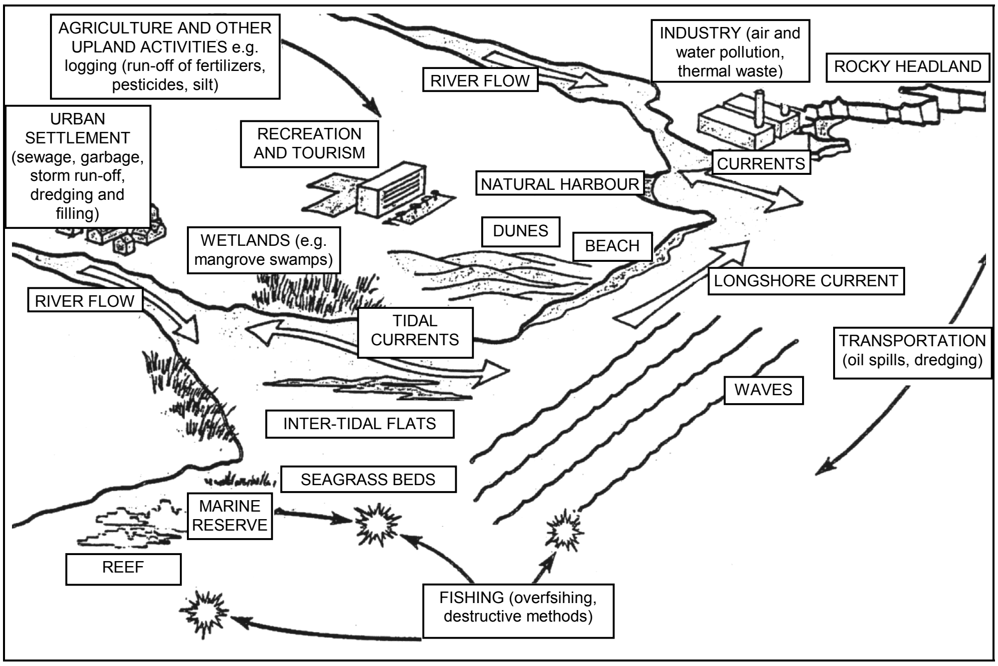


Figure 3.8: Coastal area and activities (UNESCO, 1993)

These sectors develop on the basis of the natural resources and features of the area, consisting of:

- land (vegetation, soil, minerals);
- inland water;
- coast;
- sea; and
- climate.

Distribution of these resources is the result of geological, physical, biological, ecological, meteorological and other factors such as the combination of the natural resources and socio-economic and cultural characteristics, conditions and development of various areas, including the man-made physical water systems.

3.2.1 Trends in the Development in the Mediterranean Region

After World War II, knowledge and technology developed rapidly throughout the world, as so in the Mediterranean. Since 1950, the population of the Mediterranean basin has grown by 100%, so that it is now populated by more than 400 million inhabitants (UN/Blue Plan).

In the Mediterranean basin, as in the rest of the world, it is the coastal area that bears the greatest burden. Approximately 60% of the world population lives in the coastal areas, and 60% of them lives in towns. Sixty-five percent of all cities with more than 2.5 million inhabitants are in coastal areas (Olsen, 1993). These numbers are even more drastic for the Mediterranean basin, with more than 80% of the population living in the coastal area, of which more than 70% in towns (Grenon and Batisse, 1989).

In a foreseeable future, the coastal areas will be exposed to an even greater population pressure and to the expansion and diversification of national economies. It is estimated that most of the demographic growth, especially in the developing countries, will be concentrated in urban areas, and primarily in the towns located in the coastal areas (United Nations, 1992). The Mediterranean region is one of those regions (Grenon and Batisse, 1989). It must not be forgotten that the Mediterranean is a popular tourist destination receiving over 100 million tourists a year, so that in the summer period the population increases considerably.

For all these reasons, the Mediterranean area is a great user of resources, including the two fundamental ones: land and water. It is easy to conclude that the state of the coastal resources, their exploitation, and management methods are highly important issues today, and will be even more important in the future.

Figure 3.9: Population growth in the Mediterranean area

3.2.2 Man-made Physical Water System

A man-made water related physical system is built in order to meet all the requirements of human activities relative to water resources, to protect those activities against harmful effects of water resources, and to protect the water resources against harmful effects of human activities. This system is not the same for all countries; on the contrary, it differs greatly from one country to the other according to the natural, economic, social, cultural and other characteristics.

In order to resolve these functional problems relative to the water resources, their use and protection, and the protection against their harmful effects, it is necessary to build a number of hydro-technical structures. Those structures can be divided in various systems, the most important of which are:

1. *Water supply system* - set of structures which secure permanent water supply, i.e. the adequate quantity and quality of water where and when required.
2. *Sewerage, treatment plants and pollution control system* - Set of structures for transport of waste waters, their purification to the required (necessary) level, and disposal into the recipient.
3. *Irrigation system* - set of structures to secure adequate quantity and quality of water for irrigation where and when required.
4. *Flood control system* - structures and measures to provide protection against floods according to the required level of protection.
5. *Drainage system* - structures to drain surplus surface and underground waters according to the required level of protection.
6. *Water related recreational facilities* - structures providing safe recreational activities, such as beaches, marinas, skiing and rowing areas, etc.
7. *Navigation system* - structures enabling navigation in certain parts of water resources and the sea according to the required traffic intensity and sort of vessels.
8. *Hydroenergetic and power control system* - set of structures enabling production of electricity using fresh water and sea resources.
9. *Coastline protection* - structures to protect the coastal strip against hazardous influence of sea water.
10. *Food production* - structures enabling artificial and natural growing of fish, shellfish and other organisms and water resources and the sea.

Box 5

Typical functional use of water resources

A. Water quantity

1. Meeting demand for specific uses:
   - municipal water supply;
   - rural domestic water supply;
   - tourist areas water supply;
   - crops and livestock, including agricultural irrigation;
   - processing and manufacturing;
   - assimilation and transport of bio-degradable wastes;
   - in-stream flow needs of animals and plants;
   - commercial fishing;
   - energy and synthetic fuels development;
   - mining;
   - recreation;
   - transports;
   - maintaining fresh/sea water interface; and
   - estuary-flow needs of animals and plants.
2. Controlling excess water and damages it causes:
   - developed urban areas;
   - developing suburban areas;
   - agricultural lands;
   - rural communities and other non-agricultural rural lands; and
   - coastal strip.
3. Conserving water and developing contingency plans for drought:
   - conserving water used by individual homes, farms, business, and industries;
   - conserving water used by municipalities;
   - conserving water used by hotels and other tourist facilities;
   - conserving water used by agriculture;
   - developing plans for reducing demand during droughts; and
   - developing plans for allocating scarce supplies during droughts.

B. Water quality

1. Controlling pollution from point sources:
   - discharges from municipalities;
   - discharges from tourist areas and facilities;
   - discharges from rural homes served by sewer lines;
   - discharges from processing and manufacturing;
   - discharges from synfuels development;
   - discharges from mining;
   - discharges from recreational activities;
   - discharges from cropland and animal feeding operations;
   - discharges from conventional electric power generation;
   - discharges related to waterborne transportation; and
   - discharges related to maritime transportation.
2. Controlling pollution from diffuse sources:
   - runoff and seepage from urban and suburban areas;
   - runoff and seepage from construction activities;
   - runoff and seepage from cropland, pasture land, and farmsteads;
   - runoff and seepage from silvicultural operations;
   - runoff and seepage from mining;
   - runoff, seepage and other non-point pollutants from recreational activities;
   - runoff and seepage from individual disposal systems, such as septic tanks;
   - pollution from leaking sanitary sewers; and
   - sedimentation from hydrologic modifications, such as dredging, excavation, etc.
3. Controlling pollution from atmospheric sources:
   - outfall of pollutants into water resources (dry deposit); and
   - acid rainfall into water resources
4. Controlling pollution from transports and dumping of hazardous, toxic, or solid waste:
   - entry into water resources during transport; and
   - entry into water resources after disposal at dump site.

C. Allocating water resources to competing multiple uses

1. Intra-basin transfers of water;
2. Inter-basin transfers of water.

D. Controlling the impacts of water resources development upon related land uses

1. Impacts upon critical or fragile areas:
   - coastal zones;
   - flood plains;
   - groundwater recharge areas;
   - prime or unique agricultural lands;
   - unique terrestrial and/or aquatic (fresh and sea water) ecosystems valued for their recreational, aesthetic, and/or scientific attributes;
   - shore (erosion); and
   - other areas.
2. Impacts from the disposal of dredged materials.
3. Impacts of construction and operation of structural water resource developments:
   - impacts of dams and inundation of land by reservoirs;
   - impacts of extending water or sewer lines into outlying areas; and
   - impacts of other structural measures, such as navigation facilities, port facilities, marinas, electric power plants, and synfuel developments.
4. Impacts of the disposal of residuals from wastewater treatment:
   - sludge; and
   - hazardous and toxic materials.
5. Impacts from non-structural means of managing water resources:
   - impact of watershed management, erosion control;
   - impacts of soil conservation practices designed to reduce runoff;
   - impacts of flood insurance and floodplain zoning program; and
   - impact of other non-structural practices or programs.

Three factors have greatest influence on the characteristics of these systems: climate, water consumption regime (consumption fluctuation), and position with regard to the water resources and the sea. The results are:

- *The Mediterranean area is characterized by dry and warm summer period, and humid and cool winter period.* Most of the precipitations occur in the few winter months, while in summer precipitations are extremely rare. A very important fact for the water resources management is that the hydrological phenomena occur periodically and very intensively. This means that precipitations are brief but intensive, while droughts last long but are also very intensive. Such a situation is very unfavourable for building a man-made physical system.
- *The structures for drainage or protection against excess water (floods, urban storm drainage) are used with full potential only rarely and briefly*, so that they are uneconomical from the point of view of their required capacity (size of canals, pumping installations), and technically complex. Therefore, some specific solutions are applied which are more rational while still securing adequate protection.
- *The situation with water supply is also unfavourable, since the natural input into the water resources is directly opposed to the required output.* Namely, in the periods when the water consumption is greatest (in summer, when temperatures are high and days long, and when the Mediterranean area hosts large numbers of tourists) for drinking, irrigation and other purposes, and when losses (evapotranspiration) are also greatest, the level of water resources is lowest. On the other hand, in winter, when water consumption is considerably lower and when losses are also lower, the level of water resources is highest. The complexity of the situation is further illustrated by the fact that the hydrological properties of most of the Mediterranean do not allow for longer water accumulation, underground or in the surface. Therefore, the only solution to secure sufficient quantities of water is re-distribution of water from fresh water resources over time by the construction of water storages (accumulations, reservoirs, etc.).
- *In order to balance the great differences between the volume and duration of input and output, it is necessary to develop accumulations of considerable capacity.* High temperatures cause great losses from these reservoirs and favour intensive biological activity which often leads to water deterioration. In some parts (Northern Africa) where erosion rate is high, the life span of reservoirs is comparatively short (10 odd years) due to sedimentation. For all this, the price of thus provided water is very high, influencing considerably the socio-economic characteristics of some countries.
- *Reliable water sources are mostly in the hinterlands, far from the coast, while the greatest water users are in the coastal strip where water resources capacities are smallest.* Such situation sometimes requires the construction of complex supply systems to get the water where and when required.
- *Fluctuation of water demand in the urban areas, and especially in the tourist settlements is very high, and particularly high is the daily peak demand.* Construction, management and maintenance of a water supply and distribution system under such conditions is expensive and difficult, which further contributes to the increase of expenses of water supply, and consequently, of living. The areas lacking appropriate staff and organization face great losses in urban water supply systems.
- *High temperatures and low flows in the water resources result in a small assimilative capacity of the water resources, so that even small pollution causes quick and considerable deterioration of their quality.* Under such conditions it is difficult to secure preservation of ecosystems and protection of the sources for water supply. Such a situation requires intensive purification of waste waters and strict control over the water pollution. This also refers to the coastal sea.
- *High seasonal and daily fluctuations of demand result in high fluctuations in the sewage flow which creates difficulties in defining the capacity of treatment plants and their management.* Special problems are posed by the typical tourist settlements with particularly high fluctuations (1:20 and more), since in such situations the usual cheap solution does not function. Inadequate treatment of those problems often results in the construction of treatment plants with very poor performance, and consequently, in pollution of fresh water resources and the coastal sea.

For all these reasons, implementation of adequate policies of water resources and sea protection is very difficult and complex. However, it is of utmost importance for many countries, since tourism is one of their principal economic activities. Constant and patient efforts are required, applying effective planning and management with imaginative problem-solving and implementable decision-making.

It has to be pointed out that a man-made physical system is a link between the socio-economic system and the natural system, or the hydrological cycle. This means that it has to be planned and developed in harmony with the development of the socio-economic sector and with the natural characteristics of the water resources system. The task of the water resources management system is to integrate the man-made physical system with the socio-economic system and the natural system into the integrated water resources system. How near we can get to a sustainable development of water resources depends greatly on the success of this integration.

3.2.3 Specific Problems and Particular Characteristics of Human Activity System

3.2.3.1 Introduction

The physical and biological heterogeneity of the coastline and coastal zones, combined with the driving change in these areas caused by the variety of social, cultural, and economic conditions, results in a complex interplay of processes so that conditions and the ensuing dynamic equilibrium in any area of the Mediterranean coast can be considered unique.

Some 37% of 352 million people of 20 countries bordering the Mediterranean Sea lives directly in the coastal zone, meaning that population density is generally three times greater in coastal than non-coastal areas. Population growth projections show major differences between the north and the south with the European countries having nearly stable populations, while in contrast, population growth in the southern countries ranges from 2 to 3% per year as shown on Figure 3.10. This exerts a high pressure on the limited coastal area resources, especially water resources, and which will increase with time especially in the southern countries where the availability of water resources is already very limited.

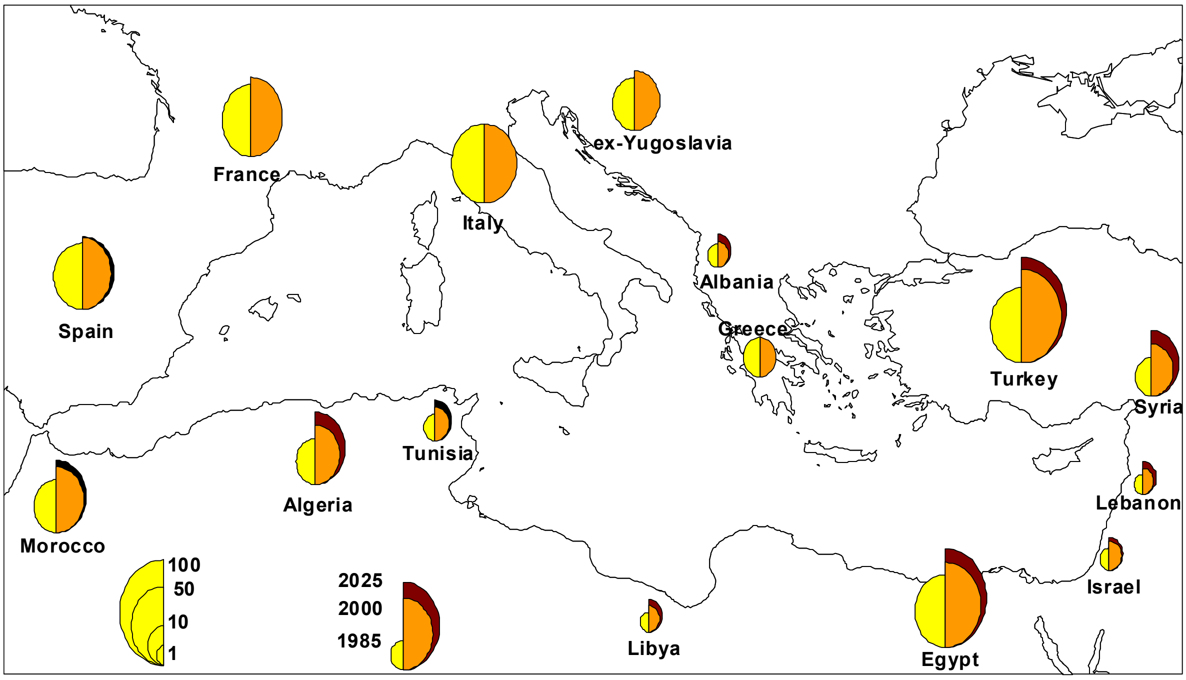


Figure 3.10: Population and population trends in the Mediterranean (UNEP, 1987)

Developing water resources management plans that allow a wider spatial or temporal view of these dynamic systems require the fullest integration of all processes and conditions. The effects in any direction will have to be determined, whether positive or negative, if future conditions are to be adequately described. The water resources along most of the Mediterranean coastal zones are scarce and expensive to exploit whilst rainfall is highly variable and droughts occur frequently. The recognition in the region of the importance of adopting a comprehensive approach to resource planning, the close relationship between surface water and ground water, and of the increasing demand for drinking and irrigation water, is a basic prerequisite for successful water management.

Within these considerations, demand management programs to limit consumption, including price of water, rationing and technical conservation measures are among the priorities for most countries in the region.

3.2.3.2 Seasonality of Demand

Role of tourism

Led by tourism, the economy of most of the Mediterranean countries develops rapidly. Most tourists visit the coastal areas for one to two weeks with nearly 80 per cent arriving over the 7-month period from April to October and 20 to 30 per cent in the summer months of July and August. Undeniably, tourism plays a key role in the growing prosperity of the Mediterranean coastal areas.

At the same time, though, tourism has already had a dramatic impact on the coastal landscape and the physical environment. The strain put on the available water resources especially during the summer period and the need for centralized sewage systems and the associated concentration of effluent to be disposed have caused the re-considering of many resource strategies. Already, authorities in many countries are now concerned to limit the continued growth in the number of visitors and focus, rather, on encouraging higher quality and off season tourism. Tighter planning controls, including lower building densities are now being enforced on new building in many areas.

Tourism affects in a direct manner the demand for water and the sewerage infrastructure. In the Mediterranean, most of the establishments catering for tourists are concentrated along the coast. The high per capita consumption rates of up to 500 l/d compared with 150 to 200 l/d for the local population exert a considerable strain on the available water resources. In most of the coastal areas in the region, population densities have traditionally been fairly low, even in the coastal towns and until recently there has been no need for central liquid waste disposal or treatment systems, in most cases, relying rather on septic tanks for each property. This has changed with the building of hotels and tourists' accommodation complexes where the concentration of wastes normally exceeds by far the absorption capacity of the soil, obliging thus, the operation of individual on-site sewage plants and eventually to central sewerage systems.

Thus, the great seasonal fluctuation of water demand, caused by the influx of tourists, is probably the single most important issue that is faced in most Mediterranean coastal zones. This specific problem necessitates the availability of such waterworks infrastructure and water management policy that could cope accordingly.

Role of agriculture

Large and rapidly growing human population in the Mediterranean region, and especially in dry and semi-arid zones, requires and will require considerable increases in food production through expanded agriculture. With water being the most important limiting factor for such growth, this area is facing enormous problems in the management of the scarce resources.

Irrigation plays a dominant role in the entire Mediterranean basin. At the regional level, irrigation accounts for about 73% of demand for water, while in the southern countries that percentage is even higher, reaching some 80%. Water demand for irrigation is different from one country to another, depending on the local conditions, climate, and irrigation technology. Water quantities used for irrigation vary between 2,000 and 20,000 m^3/ha/year, depending on the irrigation techniques used and the crops cultivated. At present, the greatest consumption for irrigation is recorded in Libya, amounting to 90% of the total water used. In the northern Mediterranean, irrigation is performed seasonally (mostly in summer), depending on the precipitation regime, while in the south, irrigation has to be performed continuously throughout the year as precipitations are rare and insufficient. However, even in the southern parts of the Mediterranean the intensity of irrigation varies over the months due to the local climatic conditions (evapotranspiration). Generally, the greatest water quantities for irrigation are used in late spring and summer when natural water input (precipitations) is smallest. Therefore, the disbalance between supply and demand is very pronounced, leading inevitably to limitations to the use of natural resources, which, in turn, causes conflicts with other users, especially tourism which has the greatest demand in the same period.

This disbalance between the supply and demand has various consequences, such as:

- higher water prices (cost of supply), and the resulting higher food prices;
- negative environmental effects (exploitation and pollution of water resources are greatest in the period when those are most sensitive; and
- conflicts with other water users which usually result in a decrease of quantities available for irrigation, since domestic supply is given priority over irrigation supply.

In order to diminish the negative effects, the following should be done:

- More emphasis should be put on the integrated water and land-use planning in river basins and coastal aquifers. Social and environmental assessment of impacts have to be stressed in those plans, as well as the need for interdisciplinary coordination.
- Involvement of local water users in planning, implementation and operation of irrigation systems is highly necessary.
- Economic incentives in water management should be given high priority. It is necessary to reconsider the subsidy policies currently in practice, as well as to promote the development of less water demanding crops, and a more extensive use of bio-fertilizer systems and organic farming.
- With the aim of reducing evaporation and water wastage, the appropriateness and efficiency of various irrigation techniques and methods need to be assessed for a variety of local conditions.
- Prevention of the use of limited groundwater resources for extensive agricultural irrigation calls for a comprehensive and long-term management planning.
- There is an urgent need for a continuous education of professionals and users of water at all levels, in order to give them the understanding of necessary integrated and dedicated professional goals and actions to be organized.

3.2.3.3 Competing Uses

Approximately 276 km³ of water are used every year in the Mediterranean region, of which 150 km³ in the northern, 45 km³ in the eastern, and 81 km³ in the southern parts (Table 3.3). The consumption varies considerably from one country to another, depending on the level of development reached and the size of population.

Table 3.3: Sectoral water demands (Blue Plan, 1996)

	Total Water demand (km^3/year)	Public supply	Agriculture	Self-supply industries	Energy (cooling)
Overall Mediterranean region (20%)	276	13	64	10	13
North (km^3/year)	150	14	49	43	24
East (km^3/year)	45	15.9	75	9	0.5
South (km^3/year)	81	9	85	6	0

In the coastal areas, water is used for various distinctive purposes. In the Mediterranean, the most important users are: agriculture (approximately 64%), domestic supply (approximately 13%), energy (approximately 13%), and self-supply industry (approximately 10%), (The Blue Plan, 1996). This consumption varies from one country to another, and the situation in the various parts of the Mediterranean is presented in Table 3.3. It is obvious that irrigation plays a dominant role in the entire Mediterranean basin, with the related consumption being greatest in the southern parts (approximately 80%). Other sectors of water consumption are much smaller, 3-8 times less than agriculture, while the sectors like recreation, environment and the like, have some significance mostly in the northern areas.

Water consumption by sectors varies through the year, so that the differences in need in various seasons are considerable, resulting in seasonal variation of conflict intensity between the sectors. With regard to the climate and activities (tourism and agriculture) implemented in this area, the needs are most prominent in summer, resulting in the highest degree of conflicts, since that is also the period when the capacity of water resources is lowest.

Such situation has already led to serious conflicts among the principal users, particularly between urban and agricultural uses. The conflict between ecological needs and the water utilization is quickly gaining on significance. The intensity of conflicts is higher where the capacity of natural water resources is lower, so that the conflicts are most pronounced in the southern Mediterranean. The conflicts are manifested with regard to: available water quantity, water quality, and economic conditions of water supply. The conflict relative to the water quantity regards the competition in sharing scarce water resources. The conflict relative to the water quality, regards the competition in sharing the available water of appropriate quality among different consumptive uses (lower costs of water purification), as well as between those using the water for water supply and those who use the water resources as recipient for waste waters. The conflict relative to economic conditions regards both the costs of water supply, i.e. exploitation of more or less favourable water resources, and the business conditions, i.e. the amount of subsides allocated with regard to various water uses.

It is expected that, in the future, the situation will get even worse, with more pronounced conflicts. With the population growth, especially in the southern Mediterranean, the water demand will grow considerably, especially for urban supply, and, to a degree, for industrial uses. At the same time, a growing need for food will result in an increased demand for irrigation water, resulting in ever more pronounced and serious conflicts among the various sectors of water users, with inevitable economic and environmental consequences. In any case, it can be expected that priority will be given to the domestic water supply, while the use of natural water resources for irrigation will decrease continuously. Therefore, it is expected that the use of second class water for irrigation will gain on importance, especially of the treated waste waters. In order to mitigate the expected tensions, each country should take a decision on priorities in the use of the available water resources by various water user sectors.

One of the crucial measures necessary for resolving the present and expected future problems and conflicts is the preparation and effective implementation of integrated plans of water resources management harmonized with the needs of sustainable development. When resolving these problems, it will be necessary to take into consideration the priority of transfers between water basins, use of non-conventional water sources, and international water exchange.

3.3 Coastal Water Resources as an Element of the Overall Regional System

3.3.1 Overall Regional or National Water Policy

A regional or national water management system provides a framework for a wide variety of water related decisions. Regional or national policy establishes principles to guide these decisions toward the attainment of national goals.

One of the basic functions of policy is the establishment of objectives that set forth the aims of water management program. These objectives then must be implemented through a set of principles that provide more specific guidance for individual water management activities. These statements of objectives and principles collectively define the role of water in socio-economic development and establish a basis for resolving the many potential conflicts that may occur within decision-making processes. In the ideal case, preparation of formal water policy should follow the articulation of policy for general socio-economic development. Water resources management is but one component of the overall development and should be integrated into broader policy to ensure consistency and coordination among the various components of development. In reality, however, a comprehensive statement of development policy is unlikely to exist since it continually evolves and rarely can be established in a complete form. Similarly, water policy will generally be incomplete and subject to continual evolution.

The coastal water resources are an element of the overall regional system and as such should fall within the regional water management policy. The extent and importance held by this element to the overall policy depend on the degree of its development and importance to the national economy. In some countries it has a controlling part of the overall policy, in the sense that inland waters are mobilized toward the coast because it is the most densely populated area or because of the dominant role it has in the production of income either from agriculture or the tourist industry.

The demand for water is concentrated in coastal areas where a large part of the urban population is to be found (135 million people, i.e. 37% of the Mediterranean population lives in the coastal areas which accounts for some 10% of the countries' surface). Coastal areas also host most of the industrial and tourist activities, and a large part of irrigated areas. This phenomenon diverts, to the benefit of the coast, a considerable share of the national resources, increasing the amount of discharge into the sea. The main effects of this situation are:

- the volume of waste water returned to the natural environment after use is reduced, thereby also reducing the degradation of the quality of continental waters;
- 80% of the water used in coastal urban areas returns to the natural environment, generally to the sea and partly to coastal aquifers (20% is consumed);
- in such situations, the water used in coastal urban areas represents a loss of fresh water resources for the coastal area, or, if it was reused, it represents a source of second class water;
- the quantity of pollutants discharged into the coastal sea has increased, affecting the quality of the coastal sea water and its ecosystems (land based pollution);
- leaking of waste waters from sewerage systems, and local disposal systems increase pollution of coastal aquifers reducing thus the possibility of their use.

3.3.2 Basic Water Policy Issues

Definition of water management objectives

The ultimate objective of water resources management is to achieve from the resource the greatest enhancement of social welfare. One way of achieving this, is through the increase of economic growth or increase in the production of goods and services by water related activities.

The inadequacy of this indicator of welfare could be overcome if environmental quality, improvement of living conditions and other objectives to this effect are included. Thus, a multi-objective approach may be more appropriate for water management plans whilst in situations where particular needs are urgent, more specific water management objectives may replace objectives such as economic growth.

Definition of water management priorities

Conflict resolution is a necessary aspect of water resources management and a basic function of water policy is to establish priorities to guide such decisions. A variety of conflicts among multiple objectives is possible such as economic growth versus environmental protection, development and preservation, conflicts among water uses and water-using sectors.

Water related conflicts between urban and rural areas and between regions like coastal areas versus inland areas or even between locations within the coastal zone, are bound to appear. Resolution of such conflict involves policies broader than water management considerations alone, illustrating the relationship of water policy to national or regional overall policy for socio-economic development.

Promotion of integrated management

The adoption of a broad perspective within all the associated areas of decision-making forms the central concept of integrated water management as used throughout this document. This approach is not only of basic importance to the regional or the overall water system but of even greater importance to specific areas with all their peculiarities and more so to the fragile environment of the coastal zones.

Public participation

The importance of public participation to water management effectiveness arises due to the extensive social dimension of water management and is gaining ground constantly. Realization of water management objectives, for development or conservation, requires integration of water management technology into daily practices governed by the socio-cultural framework. Failure of water managers to thoroughly consider this framework has been an important factor on the frequently disappointing results of management efforts. Participation of those to be affected by and responsible for implementation is the most direct approach for incorporating the public into the decision making.

3.3.3 Coastal Water Resource as an Element of the Overall Regional System

In general, the water resources along the Mediterranean coastal zone barely suffice for the existing intensive development associated with the great urbanization and agricultural production as well as the continuously expanding tourism industry. In most areas, water problems have been developed by the intensive exploitation of all the resources, and water mobilization schemes from inland water resources to cope with the growing demand is the norm. In this sense, the coastal water resources are the recipient from the overall regional system rather than a contributory source, although in themselves are still playing a major part in meeting the local demand especially where conservation and effective water management plans have been implemented.

The importance and the role of the coastal zones to the national economy of the Mediterranean countries demands an equivalent share of the effort in sustaining its continued growth. Thus, in practice the regional or national water management plans are largely geared in resolving whatever problems and inadequacies are presented by the limited coastal water resources.

The growing demand for water in the coastal zones and the enhanced technological capability has helped in expanding the concept of water resources development. In the past the scope of water resources development was relatively narrow confined to projects focusing on individual water-use activities like domestic supply and, or irrigation. A major step toward a more comprehensive approach was the adoption of the multiple-purpose development strategy addressing larger, and two or more water management needs in a coordinated fashion, as for example by the construction of large dams. These large projects modifying the natural water regime have created the concern for potential adverse effects on other resources and environmental impacts. This led to the need for the evaluation of these large water development projects, which offer the potential for substantial enhancement of benefits, in relation to other broader and somewhat contradictory considerations.

The integrated development approach led to the coordinated management of water resources within a basin-wide or whole coastal area framework. This approach allows consideration of physical interactions within hydrologic systems including individual water projects as components of the overall project. The focus on basin-wide or selected coastal area-wide water development draws attention to the whole area as a physiographic unit for water planning and management. The integrated approach to water development is related to the view that water resources development is a central component of comprehensive regional development. In this view, the benefits of water development exceed a simple summation of individual project outputs and include a synergistic combination of direct and indirect project effects of major significance in the realization of an area’s economic potential. Thus the coastal water resource system should be considered as an inseparable element of the overall regional system.

3.3.4 Key Elements of Mediterranean Coastal Area Water Policy

From the above, it is obvious that the key elements in water resources management and policy are:

- to anticipate and plan for water management during droughts;
- to provide for inter-annual storage in both surface and ground water reservoirs;
- to cope with the seasonal fluctuation of demand caused by the large influx of tourists in the summer period;
- to plan for the re-use of treated waste water for irrigation;
- to plan transfer of water between “excess” basins and “deficient” basins;

- to conserve water resources and protect coastal aquifers from sea intrusion;
- to regulate by allocating and rationing of water in times of crisis;
- to protect coastal sea water from pollution;
- to promote public awareness campaigns to enable demand management and control;
- to develop water resources on the basis of good planning regarding anticipated demand especially by tourism and adjust policies on tourism according to the availability of resources;
- to limit the misallocation of coastal resources to tourism where the depletion of all physical resources in many parts of the Mediterranean coastal zones is perceived as too rapid, including land and especially water resources. This creates environmental problems and serious strain not only to the coastal area water resources but gradually to inland water resources which are called upon to supply the coastal areas; and
- to integrate water resource management, use and development with similar plans on other resources and cater for the environment which is affected by the intensive use of the coastal areas.

4. DEVELOPMENT, MANAGEMENT AND USE ASPECTS OF COASTAL WATER RESOURCES

4.1 Planning Process and Inter-Disciplinary Relations within an Integrated Approach in the Study of Coastal Water Resources

4.1.1 Interdisciplinary Planning Approach

Scarce fresh water resources can be a serious impediment to economic development, standard of living and welfare in general. Sustainable development demands an interdisciplinary approach to water resources management. Acknowledging the multisectoral character of water resources management, an integrated planning approach is indeed an appropriate tool to satisfy society's immediate needs within a long-run framework of society's overall objectives. It provides a holistic view of water resources planning within a national, economic and social perspective.

Integrated water resources planning is a formal, systematic attempt to reconcile competing demands of different decision makers and stakeholders. It mobilizes and harnesses different disciplines in the natural, engineering and behavioral sciences to develop water resources within the context of national plans and programmes to meet the current requirements, without ignoring obligations to future generations. This implies significant cooperation and coordination among the various sectors operating in a complex interrelated social, economic, political and environmental reality.

4.1.2 Planning Process

Integrated water resources planning seeks to forecast, analyze and take decisions about vital fundamental water-related problems and issues which have far reaching implications well beyond the present century. It is a process of deciding "what is to be done today" and "how it is to be done" to meet the challenges of the future based on the best available information. Integrated planning is not an end in itself but rather it serves to establish guidelines necessary for decision-making and actions to achieve set objectives. It is a continuous process of collecting, organizing, interpreting and communicating information to upgrade the quality of current decision-making practices based on future expectations.

The critical influence of integrated planning on water resources management is not so much that it plans years ahead but rather that it embodies many types of intricate problems and the particular multiplicity of decisions made. The complexity and multi-facet aspects of the problems and developments in water resources management emphasize the absolute need for better communication and clearer policy formulation to provide the required direction and guidance.

Integrated water resources planning consists of strategic and implementational planning. Strategic planning sets an overall purpose and direction, providing a unifying guide for all operational activities by seeking consensus among stakeholders to achieve medium to long-term objectives. Operational planning is concerned with the formulation of detailed technical programmes, policies and procedures needed to accomplish the strategic plan.

Integrated resource planning can be regarded as a "top-down" planning process which involves interdependent phases of determining objectives, assumptions (strengths and weaknesses), alternatives and the final choice of a suitable course of actions (refer to Figure 4.1).

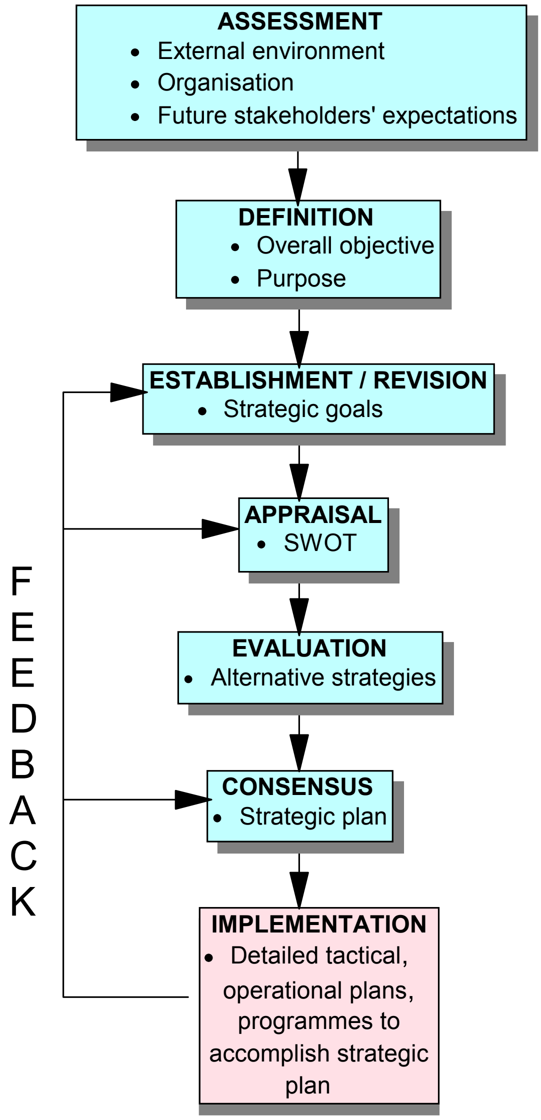


Figure 4.1: Overview of planning process

To execute this process the following should be considered:

- An assessment of the long-term objectives and priorities of the country need to be established and defined. Economic, environmental, political and social constraints have to be identified clearly at this stage, and the impact on water resources known. Setting objectives is a difficult aspect of strategic planning particularly because stakeholders invariably always find it difficult to reconcile ideals and operationally useful targets. Any attempt to undertake integrated planning must see that there is agreement about objectives between key operators and stakeholders.
- A strategic approach necessitates an overall appraisal of the strengths, weaknesses, threats and opportunities (SWOT) and the likely changes and impacts in the economic, political, technological and environmental spheres. It must incorporate the crucial and decisive elements. After taking stock of the situation, operators can then better understand the existing and probable future constraints. This will enable them to be more effective in charting the future course of action and will increase the chances of successful implementation. Such a systems approach projects the whole process as a cohesive whole and proposes unifying actions to achieve the set objectives.
- This is followed by evaluation studies with the generation of alternatives for further analysis. Planning is fundamentally about choosing - choosing alternatives. The aim is to choose viable strategic alternatives. Involvement of various disciplines and consideration for the various uses

of water resources is considered essential. Planners are duty bound to ensure that all the possible alternatives have been properly scrutinized and that the final choice is that which fits in the national socio-economic framework and also satisfies the requirements of sustainability.

- The final choice must be agreed upon. To assist with achieving consensus, simulations of the effects / impacts of alternative strategies may be necessary.
- Having achieved consensus and decided on a strategic plan, the planning process enters a more detailed level of implementational planning in order to achieve this plan. Detail programmes are formulated, cognizant of the wider issues highlighted in the integrated approach taken in formulating the strategy.
- Once tactical and operational plans have been implemented these need to be monitored and evaluated to discover whether they have achieved the stated objectives. Continuous feedback is necessary to keep the strategy plan up to date. This feedback provides information to calibrate and verify simulation models in line with field observations to allow better projections of project performance.

Implementational planning involves to some extent the difficulty of achieving balance and consistency between long- and short-term plans. Hence, there is the need for rolling and intermediate plans in the whole process. Some degree of flexibility is necessary in planning in order to adjust and adapt to an uncertain future often beyond human control. However, the advantage of flexibility must be weighed against the benefits of commitment or costs of delay.

4.1.3 Operations Management View

From an operations management point of view, implementational planning can be regarded as the setting up of programmes of action for resource conversion into desired outputs. Tactical planning would consist of identifying resource requirements, determining the design of the conversion process and anticipating problems in operating the systems and delivering the service. Once the conversion has started, planning must be integrated with the organizing and controlling functions which form the basis of the integrated water resources management process. This concept is illustrated in Figure 4.2.

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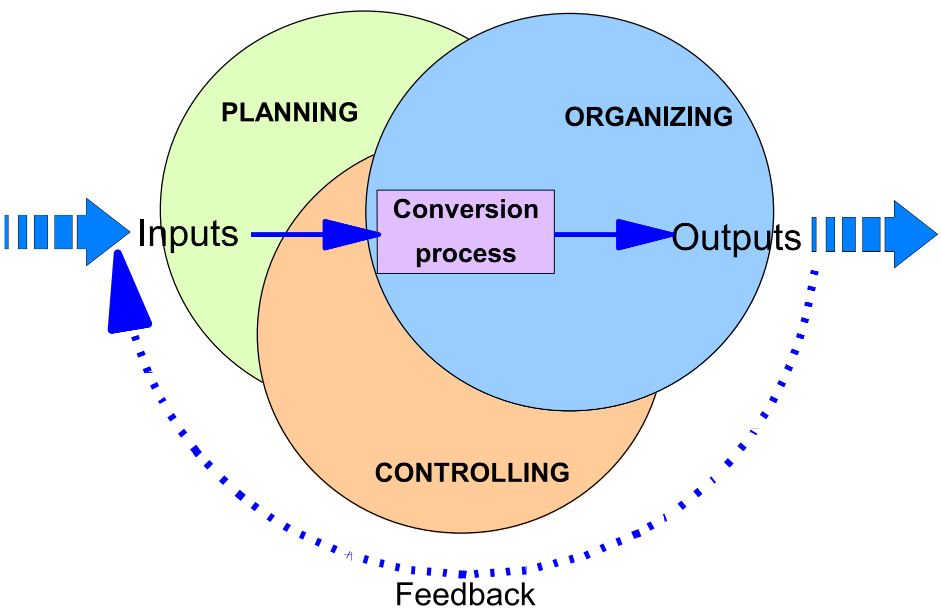

Figure 4.2: Operations management view of implementational planning

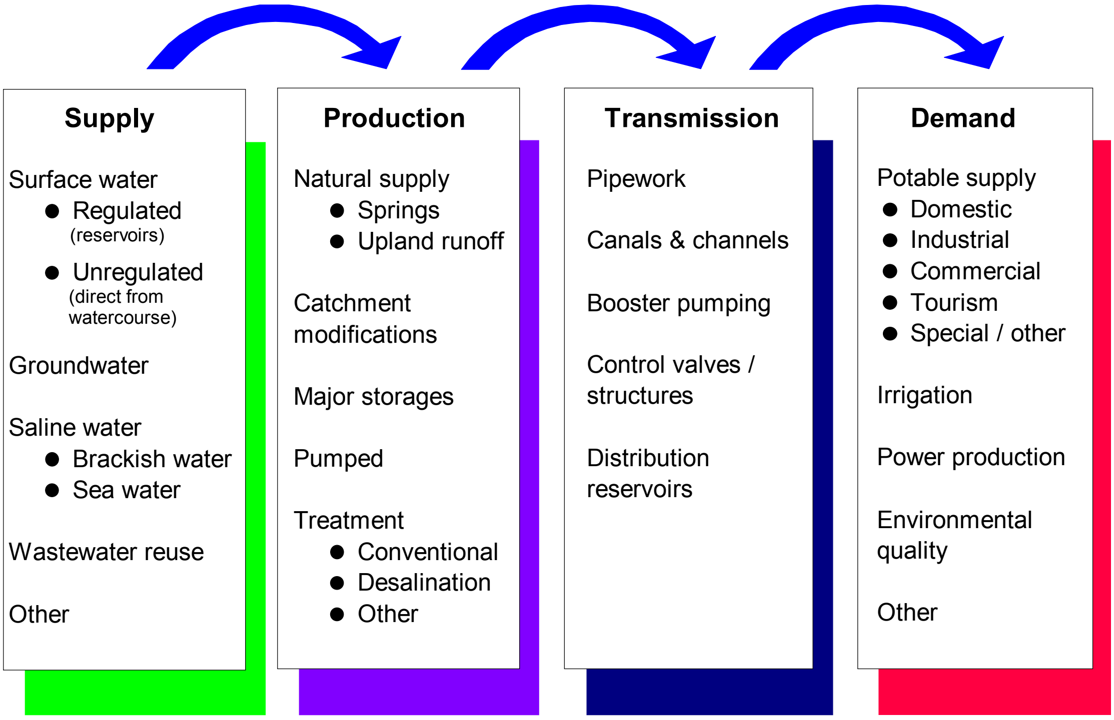

Figure 4.3: The water "delivery" chain

4.1.4 Planning Water Resources Systems

In planning water resources systems, a number of relevant issues have to be adequately addressed including among others:

- scope of water resources planning;
- data / information requirements; and
- decision-making systems.

Scope of water resources planning

Water can be seen as the product of a delivery chain like many other goods and services provided to the community as represented in Figure 4.3. Water has a number of sources, (and for wastewater a number of destinations), a variety of uses, different technologies for producing it and different types of "system components" for delivering the product to the customer. Planning of water resource systems considers all these parts of the "delivery chain". For integrated planning, the relevant planning agent must consider all sources, all users, all relevant production systems and the appropriate transmission systems. The integrated approach seeks to satisfy the competing needs of the various users within the constraints of available resources using the most cost effective and socially acceptable production and transmission systems available.

Data / information requirements

Planning depends entirely on currently available data and information. These data come in many different forms, cover a wide range of issues relevant to water resources and are always incomplete, either in quantity and/or quality.

Figure 4.4 illustrates the major categories of data requirements for managing a water enterprise. The diagram seeks to illustrate that there is a flow of data from one part of the asset life cycle to another. These parts of the asset life cycle each have their own process.

These can be conveniently split into two categories: internal data generated by the operation of the water enterprise and external data that influence how the water enterprise functions.

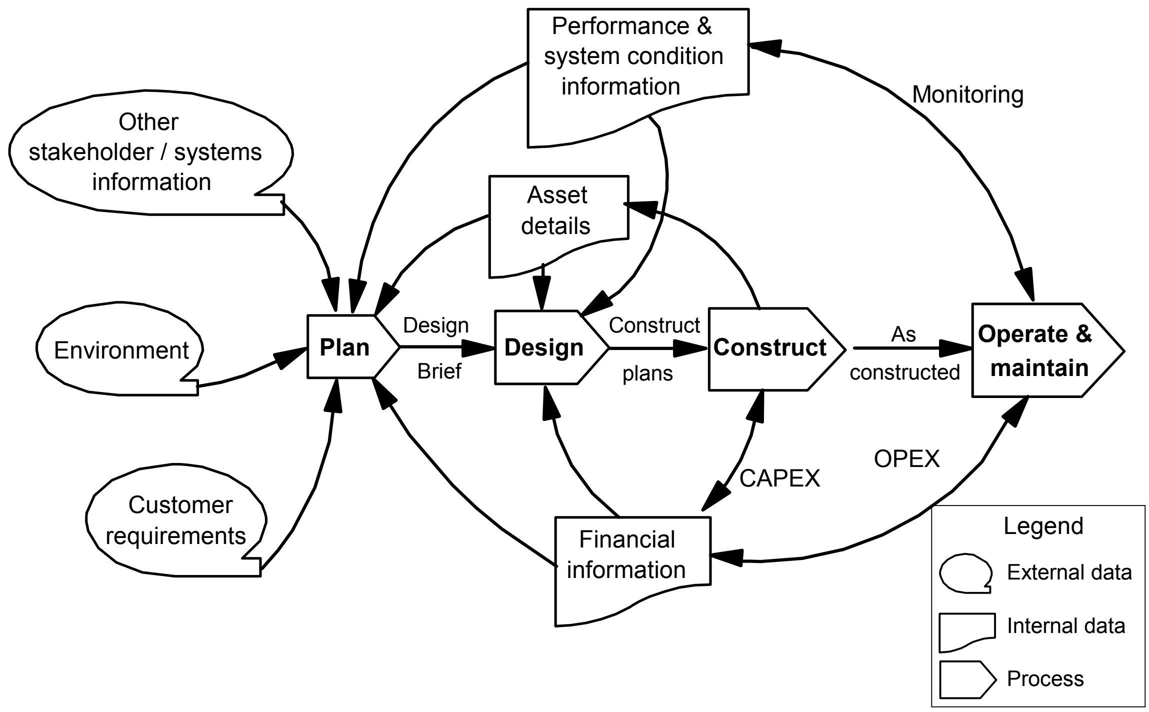

Figure 4.4: The “data exchange”

Internal Data

These data describe the water enterprise, its assets, its financial position, and its performance and condition status.

- Asset details are the enterprise’s asset registers. They are the plans and records of pipework, reservoirs, treatment plants, pumping stations, etc. They may be a paper based system or stored in digital format such as in a GIS. The information relevant to planning is their physical dimensions and characteristics and how they all connect together.
- Financial information is part of the economic reality of running a business. For planning, it both provides information about costs of existing and proposed systems and sets the parameters (budgets, financing constraints, etc.) to plan within.
- Performance and condition data tells us if the water enterprise is meeting the goals set within its charter. These goals cover a wide range of issues such as standards of service, corporate objectives and “best practice” aspirations. For planning, the performance information required includes data of hydraulic performance, water quality data, energy utilization, structural performance, etc. It will be stored in a variety of data bases such as SCADA systems, maintenance management systems and customer service data bases. Condition data provides information about the state of the assets and their performance. Example includes water quality complaints databases, sewer inspection programs and structural surveys of above ground assets.

External Data

These describe what demands and requirements its customers and stakeholders place upon the water enterprise. They are categorized as customer requirements, environment data and other stakeholder and system information / requirements:

- Customer requirements include information such as demographic information, water use data, industrial requirements, relevant agricultural data such as crop and animal husbandry requirements, water price information, market research on customer perceptions and “water” desires. These data are seeking not only to define the water demands of the water enterprise, but also to look at sensitive issues such as willingness to pay, opportunities for water conservation / demand reductions and issues of community perceptions that may be either threats or opportunities to the water enterprise.

- Environment data includes not only information about natural systems (climate, hydrology, geology, ecology) but also about the "human" environment. The natural systems include data about rainfall, streamflow, groundwater table levels, soil porosity and infiltration rates, biodiversity, natural habitats, etc. Much of this data has a time dimension to it (e.g. streamflow) such that assessments of seasonal variation, extreme conditions such as drought, sustainable levels, etc., are provided to the planning process. The "human" environment includes information such as town planning constraints, availability of other services (e.g. electricity), utilization of non water assets (e.g. road conditions and use), etc. The environment aspect of planning data is an essential part of acknowledging not only the need for integrated planning of water resources but of integrating water resources into the wider systems of natural and social / community systems.
- Other stakeholder/systems information is not so much data as in numbers and facts and figures; rather it is more an acknowledgment of opinions and preferences expressed by other parties that have an interest in water resource management. It would include issues such as the political agenda of the day, the availability of experts/specialist and practicality of certain technologies in the country, and the impact of international economics. This area of data is obviously very subjective but it nevertheless must be included within integrated planning.

Decision making systems

Planning leads to decisions guided by policies and objectives. The purpose of decision making is therefore to guide human behaviour towards future goals. Decision making is a process of diagnosing all facts, evaluating them, developing alternatives and taking action to put these decisions into effect.

Figure 4.5 describes this process emphasizing the point that decisions are a part of a continuing sequence of adjustment and action in response to unavoidable changes in the environment, different problem perceptions, new available information or some other factor which becomes relevant.

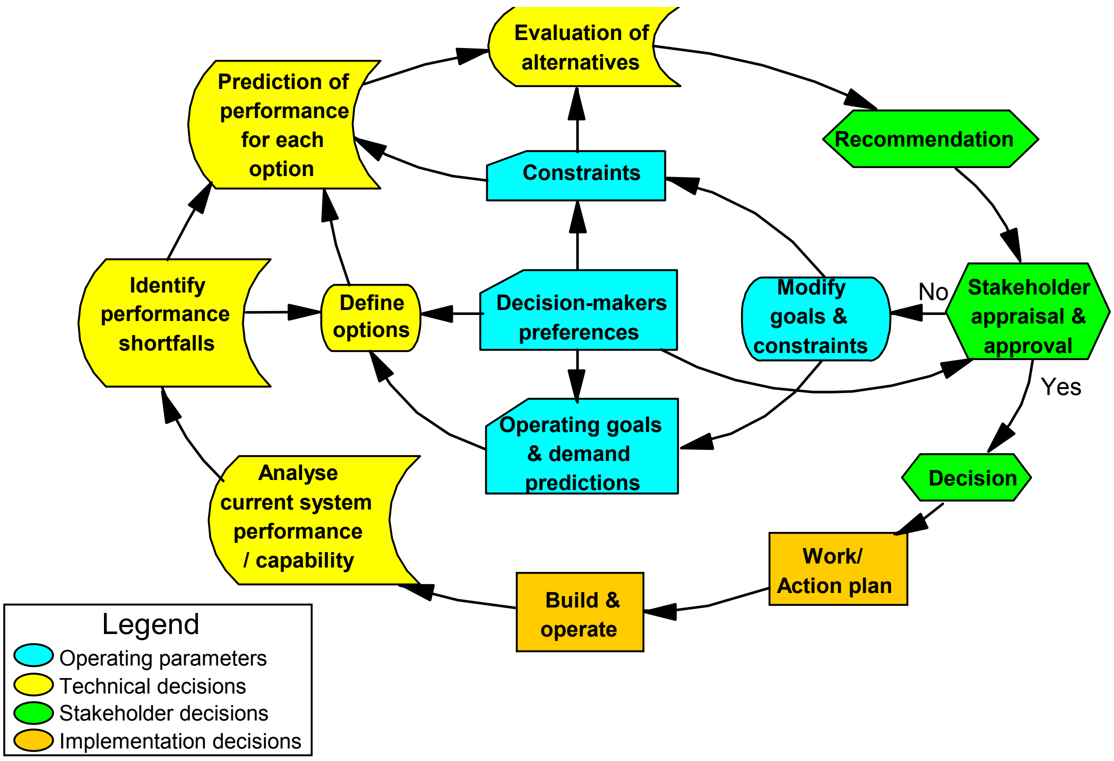

Figure 4.5: The decision cycle

Typical questions put forward in the decision making process include:

- where are the problems?

- when will these problems occur?
- what is causing these problems?
- what are the possible remedies?
- how effective will these remedies be?
- what is the best remedy / course of action?

Decisions vary from strategic to tactical and operational and a number of techniques could be used to aid quality decision making.

Examples of decision making tools incorporate:

- field trials (to clarify / determine unknown system performance);
- simple spreadsheets (e.g. to examine mass balances, costings, etc.);
- database examination and queries (e.g. exception reports);
- specialized programs (e.g project management software, statistical packages);
- simulation models (e.g. aquifer models, distribution network analysis, etc.);
- economic models (for financial evaluations);
- multi criteria decision making models (e.g. operations research techniques); and
- business models (e.g. for financial planning).

Decision making will always be constrained by risks, unquantifiable factors and problem recognition.

Skillful and imaginative planners take the available data, asks the relevant questions and use the appropriate decision support techniques to make decisions about a number of different areas. This work culminates into a recommended course of action that then goes to the "ultimate" decision makers for ratification or revision.

4.2 Legal, Economic and Legislative Framework

Integrated water resources management warrants a suitable and effective legal, institutional and organizational framework if it is to achieve its purpose. As long as economic, social, cultural and political conditions differ among countries, there can never be a specific or universal solution. Diversity between these factors makes every situation unique so that implementational tools (legal, monetary, technical, educational and entrepreneurial) which ignore these considerations are doomed to fail in achieving the desired results. This does not however mean that there is no common ground or issues that can aid planners to chart more effectively future courses of action by learning from the experiences of others.

One common concern is ownership rights and tenure. These range from private ownership of land with liberal use of resources subject to some general restriction, to public ownership with controlled use subject to government regulation, to "common property" rights to land with the right to use renewable resources as acquired by custom or tradition. In most cases institutional arrangements for land use are a mixture of all these.

Mediterranean countries are steadily moving towards stricter government control through public ownership of the resource, a condition that limits and replaces ownership rights by usership rights. Regretfully, private property status in several countries still hinders overall and direct control of water resources by the central government. This justifies an urgent recitation of the code to ensure a fair distribution of natural resources. The crux of the matter is then the suitability and adoption of specific institutional arrangement for this purpose.

4.2.1 Legislation

National legislation

Though legislation differs from one country to another common features may be identified in water laws of different countries.

Most countries regulate water supply issues by a comprehensive Water Act that provides the legal support to the central government and its dependent administrative agencies. The power of these acts covers the exploitation, protection and use of surface and groundwater. Also, most countries have a water resource legislation based upon the integrated watershed management, with ownership rights being gradually transformed into usership permits. In the past, water tended to be privately owned, surface waters were owned by the riparian owners, and groundwaters were considered as property of the land owner. Nowadays the concept of national ownership of water resources is becoming more internationally accepted.

Recent water acts do not distinguish between types of water resources and consider all waters and conduits as public property. Another feature of new water codes is the promotion of the efficient use of water. Authorities are entitled either to modify or to cancel a permit if a user has failed to fulfill the duties laid down in the respective authorization.

The issue of the rational use of water appears in various forms in the water codes of different Mediterranean countries, depending on their traditions, existing legislation, and hydrological-hydrogeological conditions. However, a feature common to recent legislation is a response to the socio-economic questions and to the problems raised by environmental protection.

The vulnerability of water resources necessitates the implementation of a protection strategy. Water protection legislation is being enacted in most countries and protection zones are being established on the basis of scientific and field observations. Protective legislation commonly limits land development on grounds of potential pollution in the event of bad operating practices. The “polluter pays” principle is being suggested as a disincentive to would-be-polluters, apart from criminal prosecution.

International legislation

International organizations have to agree to share the responsibility of a common resource between the countries concerned. The Vienna Congress in 1815 neglects the hydrological unity of waters and it does not cover those tributaries of an international river which are within the territory of only one single riparian country, and no mention is made of groundwater. Though the “international river basin” is referred to by UN as the geographic unit for water resources management purposes, there still exists disparity of opinion among several countries. As a consequent of industrial development urbanization, population growth and navigation, several riparian states had to regularize their transboundary agreements to avoid conflicts stemming from these changes.

Today most countries recognize transboundary jurisdiction of neighbouring states and also agree to adopt common pollution protection measures to prevent depletion of resources with an economic value to the countries concerned.

4.2.2 Legal Guidelines

Modern legislation tends to impose restrictions regarding use of groundwater on the owners and/or users of land, wells or other abstraction works.

Concepts of “ownership” and “right of use” are distinguished as separate in certain countries. Under normal circumstances the administrative body is vested with legal powers to exercise control over

a) the quantity and quality of groundwater abstracted; and

b) the discharge of waste waters and the aquifer protection.

Therefore, a national water legislation, commonly referred to as a water code, should include a water rights system which recognizes the hydrologic realities of surface water, groundwater, and return flow linkages, and the stochastic (probabilistic) nature of precipitation and streamflows. It should ideally include the following provisos:

a) It should clearly define ownership of surface and groundwaters. Freshwater resources should be considered as a national asset and should not be allowed to be appropriated by a mighty few. State control is therefore a must.

b) Ownership titles of natural resources should be curbed and preferably transformed in usership titles.

c) Ongoing ownership titles are to be recognized in consistence with the availability of water resources, economics, and priority of users. Nonetheless these rights should only be endorsed within a controlled usership context which does not allow a perpetual and open-ended use of those resources today considered to be part of the national heritage.

d) Resource protection regulations should be scientifically backed and incorporated in the legal structure.

e) Prioritization of uses and users should be kept flexible in view of future changes.

f) The central government should be vested with overall rights to control exploitation of natural resources and remedy by means of restrictions whenever necessary.

Legislation has to be also enforced to be effective. The common experience of Mediterranean countries is that enforcement capabilities are weak. Any non-compliance should be severely dealt with by applying strict penalties as deterrents. Surveillance is crucial to ensure effective implementation and observance of the water code by all users. Co-operation and co-ordination are urgently needed between the diverse public and private agencies. This need has not yet been understood, perhaps as integrated resources management for sustainable use of water resources is a recent development. With intense pressure building on the natural resources this co-ordination can no longer be ignored.

4.2.3 Economic and Financial Framework

Three types of financing requirements are generally essential for effective Integrated Management of Coastal Water Resources (IMCWR):

1. Financing of administrative structure, the planning, the information system and the project review mechanism;
2. Financing the water infrastructure and pollution control expenditures; and
3. Financing of conservation measures.

Depending on the objective of expenditures the financing mechanism will be different, so that:

- to finance the administrative structure and related expenditures the money will have to come from the budgets of national, regional and local authorities;
- to finance water infrastructure and pollution control, moneys can be largely generated from user charges and costs can be partially passed on the industry;
- financing conservation of water resources can be undertaken partly from users charges and partly from private voluntary financing, etc.

Coastal water resources managers' tasks in financing are different according to the type of financing involved:

- Concerning funding from the various budgets, they should try to ensure that funding requirements be incorporated into the respective legislation; otherwise, the agency most interested in the proper management of the coastal water resources might have to provide the financing;
- Concerning user charges and similar financing instruments, the manager will have to rely on them for the efficient implementation of measures as well as for financing; consequently manager will be advocating and using them as part of the implementation process in conjunction with local authorities and other agencies. Part of his task will be to secure these funds for the installation of water infrastructure and other services and minimize the amounts that are paid into general revenue and lost to coastal water resources management;
- Raising funds for water resources conservation can be based on user charges; private funds are often raised by interested environmental groups and their effects are supported in various ways by coastal water managers: for example private fund raisers usually need the assistance of the managers to establish under what conditions their efforts would be approved by the authorities; sometimes these funds are raised as matching funds (partly private and partly public).

Box 6

An illustration of legislation

In Malta, the Water Services Corporation was set up in 1991 to replace the Water Works Department in a bid to provide the necessary legal and organizational capability to adopt an integrated approach to water resources management. In essence, it establishes the constitution, functions and composition of the WSC, financial provision, human resources provisions and other miscellaneous provisions. It is a typical example of a modern institution responsible, at law, to perform integrally all the activities concerned with supply and demand in full cognizance of environmental constraints and national socio-economic requirements.

The Act clearly defines all the Corporate functions and duties leading to integrated planning. Some related excerpts are reproduced thereunder:

Functions

a) *"to acquire, produce, keep, distribute, sell, export or otherwise dispose of water (other than bottled table water) for domestic, commercial, industrial and other purposes;*

b) *to conserve, augment and operate water resources and sources of water supply;*

c) *to undertake and perform such other functions relating to water conservation supply and distribution as it may deem appropriate;*

d) *to provide for the treatment and for the disposal or re-use of sewage and waste water; and*

e) *to provide as appropriate for the use of storm water run-off from urban and rural areas."*

Duties

a) *"to develop, maintain and promote a safe and efficient production and distribution system in order to satisfy, as economically as possible, all reasonable demands for water;*

b) *to determine the short-term and the long-term objectives in relation to water supply, disposal and re-use and to develop the necessary strategy and policies to reach these objectives;*

c) *(i) to provide, improve and extend such a system of public sewers and to cleanse and maintain these sewers so as to ensure that the drainage system operates and continues to operate safely;*

   (ii) to make provisions for the operation of these sewers and such further provisions as are necessary from time to time for effectively dealing with the contents of these sewers by means of sewage treatment and disposal works or otherwise;

d) *to have regard in performing its duty under this subsection of the need to provide for the treatment and disposal or otherwise of trade effluent;*

e) *to promote the proper disposal of waste water and storm water run-off;*

f) *to consider and advise any minister on any matter relating to the formulation of an overall national policy for water and on all matters relating to any of its functions under the Act.*

g) *to manage and operate all undertakings and other installations and property transferred to and vested in the corporation by virtue of this Act or otherwise acquired by the board for the purposes of any of its functions;*

h) *to hold and administer and, if and when it thinks fit to realize any assets it may hold from time to time;*

i) *to promote the reasonable use of water and encourage the conservation and appropriate re-use of water resources;*

j) *to carry out tests and to make regulations relating to water fittings for the purpose of preventing waste, undue consumption, misuse, erroneous measurement, or contamination of water;*

k) *to provide training courses and other schemes in connection with the furthering of science and technology of water management;*

l) *to collaborate with other local organizations in placing and coordinating services including water purification, electrical power, telecommunications, road services, agriculture and industry; and*

m) *to promote and undertake alone or in collaboration with other institutions the research and development of new technology and new ideas in the production and treatment of water, in distribution and disposal networks, water desalinization and polishing, sewage treatment, disposal and re-use, plant transport and equipment, water resources management and water catchment management.*

When considering economic issues in the water resources management, the following must be taken into account:

- Water is a common good. Although in particular cases of its use water assumes characteristics of goods, it cannot be treated only following the market principles.
- Water price depends on the planned aims, and the basic factor in its forming are indirect and direct measures for realization of these aims.
- Effect of the established prices and realization of the planned aims must be followed at the State level.
- Water protection on the market basis is principally impossible.
- Some values and functions of water cannot be measured pecuniary or charged.

Economic instruments are used in conjunction with regulations to supplement them in areas where economic efficiency is important, where regulations failed and/or where funds need to be raised to implement public policy, e.g. for environmental infrastructure. The main classes of economic instruments for coastal water resources management are:

- Charges can be used to supplement water pollution control regulations; e.g.: effluent charges; fees for non-compliance with regulations; administrative charges to cover expenses; user charges imposed on all public provide services such as water supply, sewage, agriculture water supply, harbor use, etc. to make their use efficient and to cover expenses.
- Development taxes are mainly used in conjunction with land-use management, and are generally imposed on highly profitable and environmentally sensitive developments such as coastal tourism.
- Subsidies can be granted under exceptional circumstances to finance control measures on pollution from public or private activities where such measures are urgently needed.
- Resources pricing is an important instrument in the management of coastal water resources.

Concessions assignment for water resources exploitation is a standard form of water resources exploitation in the market economy. In this case, the following should be considered:

- Compensation for concessions must be a factor of development and protection of water resources and not a fiscal income.
- A prerequisite for the concessions application in this sense is an adequate water management strategy at the State level, respectively at the level of water and watershed authority areas. The local policy cannot yield here good results.
- Contracts on concessions assignment must inform precisely about who and how will exercise a professional and financial control of a concessionaire. To this aim, persons (institutions) to exercise this control must be adequately trained.

Coastal water resources managers would have to use a combination of these economic and environmental instruments to achieve their objectives.

4.3 Institutional Aspects [1]

The institutional framework is the most important aspect in each water scheme because it determines and channels the effectiveness of legal structures and financial procedures. Institutions are also important because of the increasing need to consult widely with the population before environmental policies are implemented.

One of the most frequent constraints on achieving Integrated Management of Coastal Water Resources (IMCWR) is the lack of appropriate institutional arrangements. Due to its complex nature, IMCWR requires a high level of integration within and between institutional structures. A high level of horizontal integration is particularly necessary between sectoral institutions at the planning stage and a high level of vertical integration is necessary within institutions at the

[1] Most of the text has been based on UNEP, 1995

implementation stage. Many of the institutions needed for IMCWR may exist. For application of IMCWR linkage between them may have to be created or strengthened. Where no such institutions exist, new institutional arrangements may need to be created. Existing institutional structures may be composed of government and local authority representatives. The successful achievement of IMCWR will require the active participation of stockholders in the public and the private sector in many of the institutional arrangements. This generates the need for building human resource capacity for IMCWR in the fields of water resources, coastal and marine sciences and in the fields of environmental management and conflict resolution.

Institutions for integrated management of coastal water resources have three roles:

- An executive role, for decision making;
- A judicial role, for enacting regulations and directives, standards and procedure enforcement and arbitration; and
- A market role, allocating funds, offering incentives or subsidies.

Institutional arrangements are needed at three different levels for taking specific responsibility for coastal arrangements:

- National;
- Regional (sub-national); and
- Coastal area (local).

National level administration should be concerned with development and implementation of broad coastal management policy including water resources management policy. This would include preparation of appropriate Acts and Strategies, e.g. Coastal Area Management Act and Coastal Area Water Resources Management Act, Coastal Area Management Strategy and Coastal Area Water Resources Management Strategy. At the national level environmental and conservation standards need also be laid down for coastal areas and water resources. There needs to be an interdepartmental (interministerial) committee for coastal management consisting of the major ministries operating in the coastal areas: water resources, environment, agriculture, tourism, economic development, industry, public work, forestry and transport. A degree of individual national planning is needed to inform regional and local authorities of the intentions of national development policies and especially national water resources development policies.

At the regional level, depending on the authority of regional governments, more detailed but integrated planning and management are required within the responsibilities of the regional authorities. Such a process should ensure the consistency between the activities of local governments to reduce the danger and over exploitation of coastal water resources. This should also cover areas outside local governments in accordance with integrated approach to development, management and use of water resources in the watershed basin (river basin).

Detailed planning, development and implementation take place at the local level. However, distinction should be made here between areas where one local government authority can effectively manage the coastal zone water resources and its elements and those areas where several local governments need to co-operate closely to plan and implement policy. This will depend on the nature of the coastal area and water resources characteristics both along the horizontal axis but more importantly on the perpendicular axis to encompass all the major activities having an impact on the coastal water resources.

To cover all coastal water resources and land resources all authorities involved in the operation, exploitation, conservation and maintenance in these resources should integrated their activities within an appropriate coordinating mechanism.

4.4 Information Support for Coastal Area Water Resources Use, Development and Management

4.4.1 General

Accurate information on the condition and trends of the water resources, surface and ground water, of the coastal areas is required as a basis for their development into a water resources project, their use and management. A proper perception of the local physical processes controlling the hydrological cycle in time and space will also enable the maintenance of the environmental quality and prevention of any negative effects.

Systematic water resources data collection, archiving, analysis and dissemination provide information not only to engineers but also to decision-makers on the status and trend of water resources. Such information is required for:

- assessing the coastal area's water resources, quantity, quality, distribution in time and space, the potential for water related development and the ability of the supply to meet current and future demands;
- planning, designing and operating water projects;
- assessing the environmental, economic, and social impacts of water resource management practices, existing and proposed, and planning sound management strategies;
- assessing the response of water resources to other, non-water sector activities, such as urbanization; and
- providing security to people and property against water related hazards like floods and droughts.

The information support for coastal area water resources use, development and management is similar to the information required for any part of the country except for the increased attention required to the peculiarities of the coastal region and the intensive utilization made of the scarce resources and the fragile environment of the contact zone between land and sea.

4.4.2 Information Support Required

An appreciation of the peculiarities of the coastal area water resources and the type of information required for the use, development and management of them will result in the efficient collection and correct evaluation of the data gathered. The demands for water related information are determined by the established objectives. These should guide the overall planning process of information acquisition, interpretation, presentation and actual collection. Development plans implemented in the absence of sufficient data or on the basis of a short-term data base, result in irreversible engineering works which later on are found to be inadequate, ill-designed or performing far below than expected since subsequent information collected is found to be far different than what was assumed.

A proper procedure to be followed is to conduct the planning and the initiation of a water resources assessment, project planning, implementation and management within the following framework:

- the whole particular coastal area should be used as a basic areal unit for data collection, interpretation, and planning;
- all the components of the hydrologic cycle should be evaluated: precipitation, evaporation, surface runoff, infiltration and ground water potential including current use of water;
- quantitative water resources assessments and planning using a complete water-budget approach;
- evaluations of water quantity and quality for surface and ground water, water use, and other environmental conditions and potential changes in these components, should be carried out;
- the long-term changes that could occur as a result of the water resources management schemes and use of water development plans should be considered;

- the geometry, water levels and characteristics, including permeability and specific yield of the coastal aquifers should be assessed; this should lead to an evaluation of the water balance and safe yield of the aquifer and the position of the sea-fresh water interface;
- ground water replenishment and discharge to the sea through the coastal front is an essential element in evaluating sea intrusion danger and measures to prevent it;
- water balance conditions for wetlands and marshes and other areas of environmental importance need to be assessed;
- water use information for irrigation needs and municipal, industrial both current and foreseen are essential; this means projections as to the future continued urbanization and especially for the Mediterranean coastal areas of the projected growth of tourism; and
- quality trends in the ground water in respect to sea intrusion or use of fertilizers, pesticides and of other industrial uses.

The list for the information support required as presented above is by no means exhaustive and should rather be regarded as indicative varying according to the particular needs and peculiarities of the coastal area being investigated.

Hydrologic data and other information support for coastal area water resources have a great intrinsic value in the development, use and management of water resources and of the natural environment. However, they have economic value only if they influence decisions and substantially support the management options taken for the social and economic development of the region, the safety and well being of its population and the quality of its environment both in the short and long term. Thus, the planning and setting up of information support programs and institutions should be carefully done so that it is effective, accurate and comprehensive to the requirements of the area and the development plans considered.

4.5 Assessment of Water Resources

Water resources assessment is a determination of the sources, extent, dependability and quality of water resources on which is based an evaluation of the possibilities of their utilization and control (UNESCO/WMO,1988). Water resources can be neither developed nor managed rationally without an assessment of the quantity and quality of water available.

Hydrology is the main building block and integral part of water resources management. It enters into integrated water resources management through the use of empirical and causal hydrologic models in water resources planning, management and design, operation, and protection. Prediction of existing and future states of hydrologic processes, of the existing and future distribution of water resources in space and time, and of the state of the quality of water resources, as well as water balance computations under human intervention (land surface changes and of change in climate variables) is a standard work in water resources assessment process.

If a wholesome and harmonious valorization of a water resources system and its components is to be secured, the hierarchy of the system has to be respected. Therefore, the assessment of water resources has to be implemented in three stages:

1. Basin water resources assessment - lower level of investigation (long-term plans of water resources development);
2. Regional water resources assessment - medium level of investigation (system oriented, medium and long-term regional planning); and
3. Local water resources assessment - the highest level of investigation (project specific, operation).

This approach secures that the sectoral projects consider the hydrologic continuum and environmental constraints.

Main components of each level of water resources assessment are:

- *Collecting, processing and dissemination of hydrological, hydrogeological, auxiliary data and other water related data* (collection of historical data on water cycle components at number of points distributed over the assessment area, obtaining physiographic characteristics of the territory that determine the space and time variation of water cycle components, obtaining information on the water resources characteristics at any point of the assessment area);

- *Assessment of available water resources* (areal assessment of water balance components);
- *Classification of surface and groundwater resources* (in accordance to: conditions of water management, degree of investigation, surface and ground water types, degree of protection against existing or potential anthropogenic contamination, quality of water, etc.).

The larger and more complex the system, the more difficult it is to analyze, both for the volume of work and data, and for the impossibility to view entirely and follow the analysis, and the resulting impossibility to interpret the obtained results. It has, therefore, become usual to divide large systems into smaller systems following a logical and natural procedure in order to enable a logical and natural integration of the results obtained for each part into one hydrological whole. It is thus known that large river basins are analyzed and planned so that they are first divided into smaller tributary watersheds, each of which constitutes a sizable planning unit. In any case, it is desirable that the analysis and planning of a water resources system be performed at the level of river basin or watershed, or another naturally and hydrologically wholesome and closed level, such as island or aquifer.

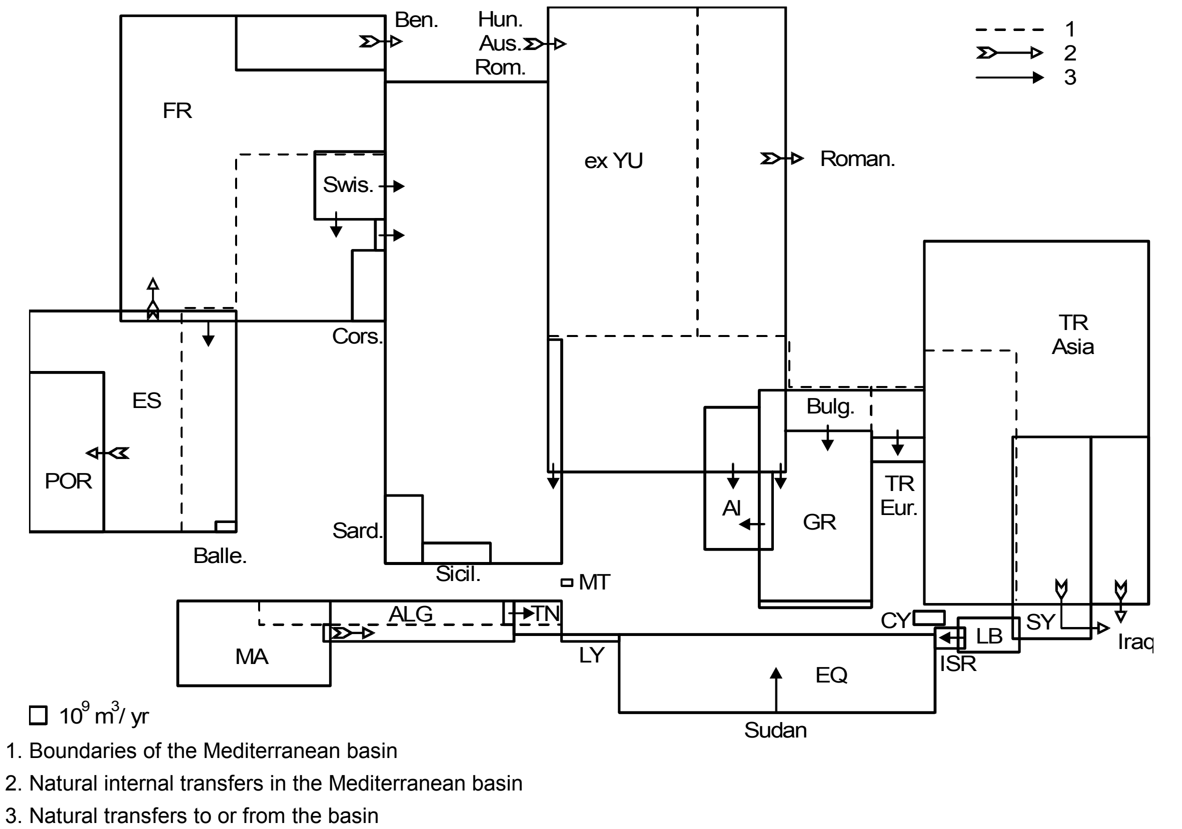

Figure 4.6: Comparative natural water resources in the Mediterranean basin (Margat, 1990)

A complicating factor limiting the use of a river basin or watershed for implementation of plans is that political and administrative boundaries rarely coincide with those of a river basin. This particularly refers to large river systems which cover several countries, regions and other administrative units. In such cases, successful planning and management of water resources requires a strict respect of the system hierarchy and its planning, so that we can distinguish:

1. International agreements on water use of an international river;
2. National water resources development plan; and
3. Regional water resources planning.

At any lower level, the plan has to fully respect the constraints and requirements resulting from the higher-level plan. The implementation of plans is usually made at the levels lower than urban and upwards. However, it is desirable that the implementation be controlled from higher levels in order to secure the verification of the compatibility of various implementations with the overall water resources management plans. This particularly refers to large users and polluters such as urban centres and their urban water resources plans which include water supply, flood control, storm drainage, and pollution control, and which almost never coincide with river basin boundaries.

Interaction between various countries of the Mediterranean countries is shown in Figure 5.6. It is easy to see which countries are called to harmonize between them the development and use of common water resources. If this situation is ignored, it is very difficult to implement the concept of integrated water resources management and secure sustainable use of water resources in the Mediterranean Basin and its individual countries.

Assessment of water resources should be completely adjusted to the characteristics of the area being analyzed, as well as to the treatment level of the implemented project, i.e. to the project aims. There are usually two major sources of water, namely surface and ground waters, although there are other minor sources such as rain harvesting, desalinization, wastewater reuse, etc. In assessing water resources availability it is important to note the linkage between surface and groundwater resources. Over-withdrawal of one could affect the availability of the other.

4.5.1 Surface water resources

Surface water is water flowing continuously or intermittently in surface channels and water contained in lakes, ponds and marshes.

The quantity of surface runoff available for meeting present and future needs may be evaluated by:

- analysis of available climatological and streamflow records; and
- reconstitution of flow by simulation using long rainfall and other records.

Reliable estimates of water available for development should be based on streamflow records of a sufficiently long period (at least 30 years). When these conditions do not exist, it is necessary to carry out extrapolation of the streamflow record using rainfall records which are usually of a longer extent. A clear statement is required as to the nature, source, reliability and adequacy of the data used in the assessment of water resources. In cases where long-term climatological and hydrological records are not available, then streamflows may be estimated by correlation with other stations. If no discharge record is available concurrently with records at other comparable stations, sufficiently reliable results can usually be obtained by applying the ratio of the drainage basins, if runoff records are available on the same stream either above or below the study points.

Some of the methods that may be used to estimate runoff are the rational formula method, hydrograph analysis method, infiltration method, regional flood analysis and flood frequency analysis. The streamflow analysis generally includes determination of:

- annual streamflow;
- yearly streamflow distribution;
- areal water resources distribution;
- high flows or maximum discharges;
- low flow or minimum discharges; and
- sediment runoff, including bedload and suspended load.

The quantitative assessment of water resources potential from streams is usually made on a monthly basis. In addition to assessing the available surface water resources, there is a need to appraise and quantify the potential water resources of the river basin. This enables to identify potential dam sites and assess their yields.

4.5.2 Ground water resources

Ground water is an important source of water for socio-economic development, especially in most of the coastal areas of the Mediterranean basin, associated with coastal deltaic deposits and where streams may flow only for part of the year replenishing coastal aquifers.

The occurrence and availability of ground water in a given area depend upon a number of factors which include the distribution of precipitation, type of soil, land topography, vegetative cover, soil-rock formation and their permeability, etc. In general, some of the basic data needed to assess the availability of ground water include:

- geology of the basin;
- precipitation on the area;
- replenishment by streamflow;
- ground water levels and extraction; and
- specific yield and permeability of the aquifer.

Quite often, considerable hydrogeological studies have to be undertaken to determine the boundaries and composition of the aquifer. These studies may include geological and hydrogeological mapping, test drilling, geophysical surveys, pumping tests, etc.

Normally the investigation programme starts with an inventory of existing wells with their fluctuating water levels recorded at periodic intervals. Where such wells do not exist, observation wells should be drilled for ground water level monitoring. This is followed by surface geological mapping of the area, based on which a test drilling programme is prepared. This will enable the determination of the physical characteristics of the strata, the depth and the type of the aquifer, confined or unconfined. These wells could be converted later into observation wells.

Through pumping tests, the permeability, transmissivity and storage coefficient of the aquifer which control the water table fluctuation can be determined. Overpumping of groundwater may cause excessive lowering of the water table, sea intrusion, decrease of available yield and deterioration of the water quality. Such conditions should be identified and remedial actions should be put forward, such as proper aquifer management measures, artificial ground water recharge, etc. As the water level and the corresponding water availability vary with seasons of the year, ground water availability should be determined on a monthly basis. The potential of ground water development also depends on the water quality criteria as influenced by water management practices, modes of ground water extraction and use. These phenomena should be studied and reported. The linkage of ground water to surface runoff availability should be considered especially since any development of one source may affect the other. A ground water balance evaluation should enable an assessment of the annual replenishment and a “safe yield” appraisal for the aquifer being considered.

4.5.3 Water Budget Approach

The planning of many projects for the development of water resources is or has been based on the basis of measurements of precipitation and the flow of water in streams. Too often these measurements alone have been used for the design and implementation of major water development projects.

The precipitation and streamflow are essential parts of the hydrologic cycle, however, they provide an incomplete picture of the water resources of a region. Unless supported by other data, these may constitute a risky base for the design of water resource projects.

An overall portrayal of all the elements of the hydrologic cycle would give a more complete understanding of the water distribution in the area. This could include estimates on the precipitation, the loss by evaporation and transpiration, the surface runoff, the infiltration to the ground water aquifers, the use for irrigation and domestic supply either by direct abstraction from streams or by pumping from aquifers and the loss of fresh water to the sea through the surface and subsurface.

Such an approach constitutes a gross water budget, which is normally based partly on measurements and partly on estimates. The usefulness of such an approach to serve as the foundation for water resource planning and management is immense.

Box 7

An illustration of water resources assessment based on the water resources master plan for the island of Rhodes

This study represents one of the main outputs of the activity related to the water resources management of the island of Rhodes which is one of the activities within the Coastal Area Management Programme of the Mediterranean Action Plan, (MAP/CAMP), implemented with the financial support of the CEC within the Mediterranean Environmental Technical Assistance Program (METAP) provided through the European Investment Bank (EIB). The approach applied by the Priority Action Plan/Regional Activity Centre of Split (PAP/RAC) in developing the study was based on the Agenda 21 as particularly related to the integrated coastal management and integrated water resources management.

The assessment of the water resources and evaluation of their availability was obtained through

- a critical examination and careful evaluation of existing climatological data which covered the aspects of precipitation, air temperature, sunshine, air humidity, wind and evaporation.

  For these parameters, all the available information on monthly and annual values were tabulated and their statistical indicators including recurrence intervals were specified. Daily values when available were elaborated particularly for the statistics on their extreme values.

- application of the mathematical watershed model HYRROM developed by the Institute of Hydrology of UK, which after having been calibrated against existing short-term instantaneous river flow data was used for producing daily runoff figures from rainfall data.

  The available data on rainfall and the computed depth area precipitation for each of the catchments, the available runoff data and the calibration achieved together with the resulting model parameters as well as the simulated runoff figures for all the catchments and at selected sites with a potential for water works were presented in technical report and supporting annexes.

- an assessment and evaluation was made of all the available information on the hydrogeology of the island involving the main lithological and geostructural characteristics, the hydrogeological characteristics of the various Formations like specific yield, transmissivity, saturated thickness, water quality and yield potential.

  A hydrogeological map in 1:100,000 and other thematic maps of smaller scale and diagrams demonstrate synoptically the various hydrogeological aspects among of which the ground water level fluctuation in boreholes, the yield in respect to drawdown, water quality and pollution sources as well as the vulnerability to aquifers pollution. Borehole yields, the springs and water abstractions were also presented.

- the evaluation of the natural water balance of the whole island which was produced by computing the balance for each catchment separately.

  The water balance equation was solved by using the available rainfall data and the evaluated runoff figures and by estimating the loss by evapotranspiration using Penmann's, Thornwaite's, Blaney-Criddle's and Turc's empirical approach. This resulted in the solution of the unknown infiltration to ground water. Selected regional water balances were evaluated by using abstractions during the dry period and evaluation of the specific yield. This was employed for the annual water balance evaluation.

- assessment of the operational possibilities for various potential surface reservoir sites and off-channel ponds which were identified either through past studies or selected under this study. Basic information on the water storage sites both surface and underground were evaluated and reported.

The characteristics of existing and planned reservoirs were presented together with the potential for artificial ground water recharge activities.

All the material presented in the various technical reports produced in the course of the study were presented into a synthesis report, its main objective being the overall collation of all the pertinent information and presentation of the water resources of the island of Rhodes in a manner suitable for the development of a Water Resources Master Plan for the island. The water budget approach should show the interrelationship between the surface and ground water in an area, since in many areas most of the fresh water moving through the hydrologic cycle is through the form of ground water. If ground water factors are not sufficiently covered, then the planner would be overlooking major elements of the manageable water resources. This is of particular importance in the coastal regions where the relationship between sea and ground water is of prime importance.

In the water budget approach, the relative amounts of water in every component of the hydrologic system are indicated, allowing a judgment to be made on the availability of water for development, utilization and management. Similarly, the relative amounts force the consideration to be made on the amounts and kinds of changes that may take place in the system as a result of water resources development and human activities that may follow. For example, if the water resource project calls for the irrigation of large extents of dry land through diversion of water from a stream, the percentage of water discharged by consumptive use and evapotranspiration will increase. These added losses will have to be reflected by reduced downstream flow and reduced infiltration and losses to the sea, maintaining the water balance throughout the hydrologic cycle. Thus, irrigation benefits would be obtained at the cost of decreased average flow downstream, and the availability of this flow for other purposes downstream, would be correspondingly reduced.

Figure 4.7 is an example of a schematic presentation of the major elements of a hydrologic system needed for a water budget of a typical coastal area. There are many ways of presentation and the degree of detail depends on the complexity of the system and the availability of estimates.

This depiction of the water budget is quite simplified. A complete in-stream water balance would include streamflow at the upstream and downstream control points, off-stream withdrawals, waste water inflow, evaporation from water surfaces, and transpiration from vegetation on the floodplain, precipitation and groundwater infiltration and discharge and finally return flow from irrigation.

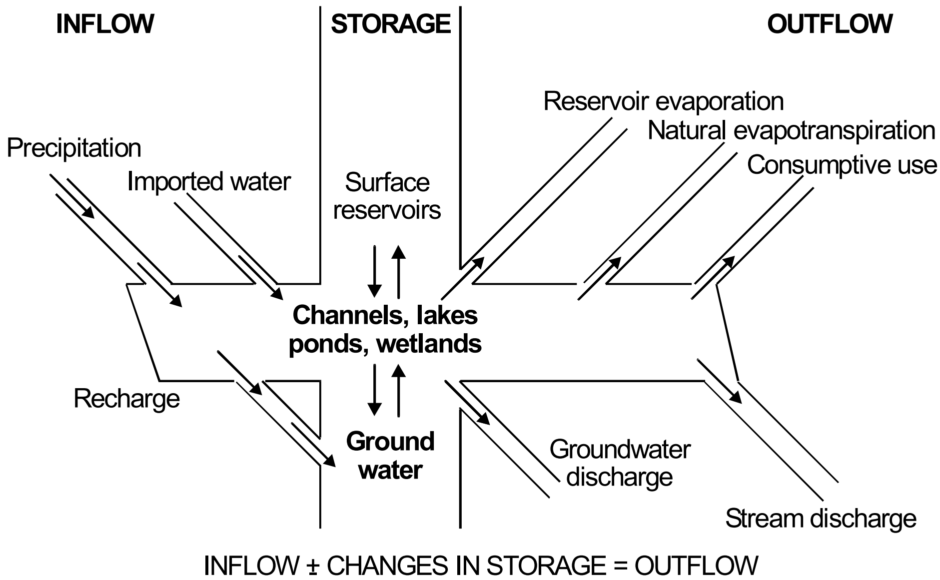

Figure 4.7: Schematic presentation of hydrologic elements

The water budget approach could proceed from subwatersheds which could then be accumulated to watersheds which in turn could be summed up into the water budget or balance of a whole region.

The estimation procedures could be as detailed as the data and information would allow, using the various hydrologic techniques available, including surface runoff models, empirical evaporation and evapotranspiration methods, ground water modeling, etc. These estimations should preferably be carried out over a common study period, a base period, which should be selected, if the available record allows, to be such as to be representative of long-time average conditions, including dry and wet years.

4.6 Assessment of Water Demand

Sound planning and management of water resources projects require information about the current water use and future demands. On the basis of this information the adequacy of the basin's water resources or of the scheme being designed will be judged and various strategies and management plans could be established. Concurrently, the effects of existing and additional water use on the hydrologic system can be evaluated.

The various important uses of water are: domestic, municipal, industrial and irrigation uses. These could also be extended to include water requirements for the support of fish, wildlife and the environment in general, hydropower generation, inland navigation, recreation, etc.

Water demand refers to the gross water requirement and includes the losses related to those uses like conveyance losses, losses due to the irrigation efficiency achieved, etc. The assessment of water demand, current and projected, should necessarily include the analysis of aggregate water withdrawals from surface and ground sources, and the bulk volumes of waste and return of drainage effluents into water bodies. The determination of downstream water releases should be based on all downstream requirements including irrigation, water supplies, fisheries, hydropower, navigation and minimum discharges needed for sanitation and environmental purposes. For the latter, it should be ensured that with the releases, sufficient dilution of pollutants is achieved. The water budget should be prepared for all planning time horizons, both short- and long-term, based on available water supply, water demands and required flow releases. Shortages of supplies and remedial measures should be identified. Of importance to the operation of the project are the peak rate demands both for irrigation as well as for domestic and industrial supply. These rates will determine the size of conveyors and the capacity of the system to meet the demand during the peak season.

Associated to the various anticipated uses, an evaluation of the quality of the water that could be made available by the project is very important as this will determine the type of demand that the project could serve. Therefore, the water quality data collection should be designed both to serve this investigation purpose and to provide baselines to measure future changes.

A relatively new approach refers to the demand management which focuses attention on ways to influence the demand rather than finding ways of allocating more water. The scarcity of water resources suggests that water demand should be controlled to the availability of it and this can be done by economic instruments aiming at enhancing the efficiency of water use and the financial sustainability of the water industry, and legal instruments which include restrictions, licenses and regulations.

4.6.1 Domestic and Municipal Demand

Estimates of water requirements for domestic use should be coordinated with economic and social studies of anticipated population growth. The estimates should show the location and type of use, the gross requirement, peak consumption rate, net consumption and amount, quality and location of return flows.

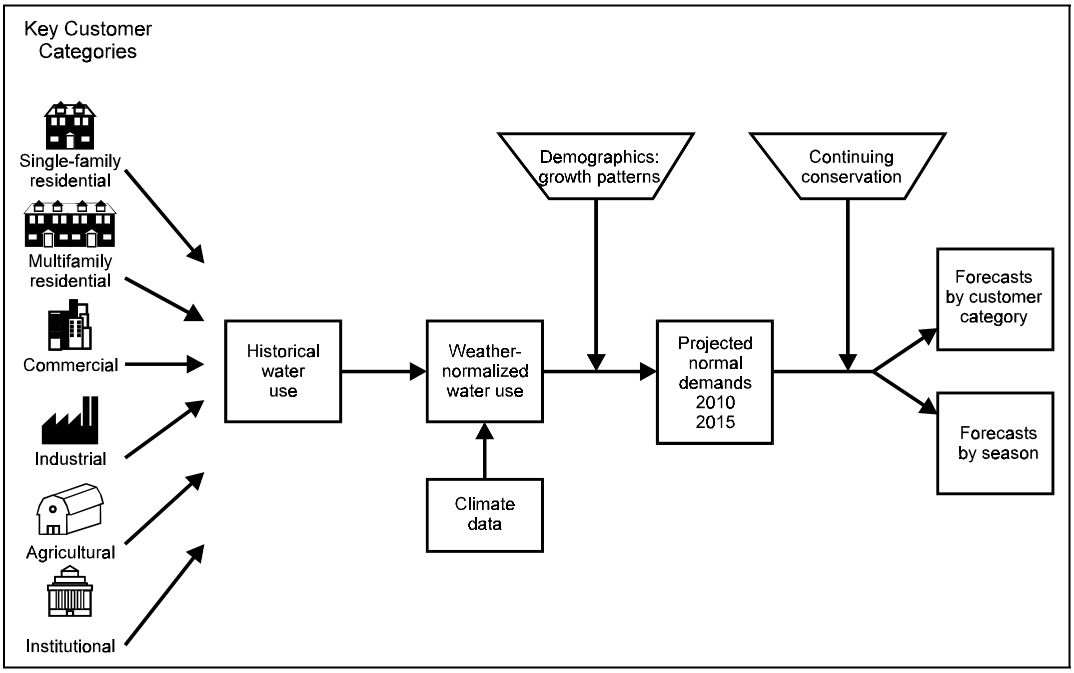

Figure 4.8: Information flow of demand forecast

Present consumption rates per capita per day together with present and changing future habits is usually the starting point for evaluating domestic water demand. Population trends together with present and predicted tourist arrivals are essential for evaluating the future demand. To this amount, allowance for water amenities and other requirements of large population centres are added such as municipal needs, etc.

In assessing the domestic water requirements the following are amongst the items that should be considered (Figure 4.8):

- The present situation should be examined. This should include the present system of supply, the historic growth of the demand, impact of shortages in supply and evaluation of present rates of demand per category of consumer.
- The variation of the consumption throughout the year and the daily variation of demand. This is of particular importance in the coastal areas of the Mediterranean basin due to the large climate variation between winter and summer and especially because of the large seasonal variation of demand due to the tourist influx in the late spring - summer- early autumn season.
- Built up of a picture regarding present population and the likely population growth for a selected future period including town planning plans and forecasts for tourist arrivals. This will provide a planning target for future water supply demand.
- Consumption criteria should be developed which will enable the estimation of future demand analyzed into domestic, commercial, industrial and other.
- Water demand projections could be made on the basis of the above, analyzed into basic and peak demand.
- Adequacy of present supply to meet demand in terms of both quantity and quality.

In the absence of data on actual per capita water consumption rates, a minimum quantity for maintaining personal and household hygiene may be taken as 40 liters per capita per day (l/c/d) as a rule of thumb. In large cities, water consumption may normally be taken as ranging between 100 to 250 l/c/d and 500 l/c/d for tourists, the latter including maintenance of hotel amenities. For smaller towns and rural areas this may vary between 80 and 150 l/c/d.

4.6.2 Industrial Water Demand

The industrial water requirements should be based upon the expected types, sizes and number of industrial plants and the specific water needs of individual industries. Water demand projection for industrial purposes should be coordinated with economic studies of anticipated industrial expansion, and should indicate the location and type of use as well as the amount of, the quality and location of return flows, waste treatment and disposal. Industrial water use can be estimated based on the amount of water fed to the plant which could include the reuse water, the water lost due to conveyance, evaporation, seepage and leakage. Water-use rates for existing industries should be based on past records of such industries. For planned industries, known international standard rates should be applied. The water requirement per industrial plant varies according to the technology used. For many industries the water withdrawals per unit of product and per employee have decreased as water reuse has increased.

The information concerning industrial waste-water quality, particularly regarding pre- and post-treated conditions, should also be provided.

Commercial water requirements are computed on the basis of the number of commercial establishments that serve the population and/or the individual estimated use per commercial outlet.

4.6.3 Agricultural Water Demand

The agricultural water demand should first be based on an overview of the agricultural sector in the country and especially at the coastal region describing the present state of agriculture and the performance of the agricultural sector in the economy as well as the policy framework in general. The assessment should include the extent of land under cultivation, crops grown, cultural practices, and the population engaged in agriculture.

The pattern of growth of the agricultural sector should be studied along with the contribution to the national income, capital formation, employment, etc. On a similar fashion demand projections for agricultural products should be determined.

Agricultural water demand should be that which is required by crops over and above the quantity of water provided by direct rainfall as effective rainfall.

Estimates of water required for irrigation development should be closely related to the land and agricultural surveys. These surveys will furnish information regarding land suitable for irrigation and the farming practices and cropping practices which might be developed with irrigation. Irrigation water requirements should be determined on the basis of the land to be cultivated, climate, type of soil, crop, cropping patterns and field application methods.

The irrigation requirements may be estimated by comparison with the rainfall and water use in similar nearby areas or be estimated from the consumptive use - temperature relationship with proper allowance of water losses. The losses, farm and conveyance losses, may add up to 50 per cent of the water diverted for irrigation and should be added to the crop water requirements.

In summarizing, evaluating the agricultural water demand besides land, copping pattern etc., the crop water requirements, farm water losses, conveyance water losses, and livestock requirements should be evaluated.

4.7 Water Quality

There are several reasons why water quality is becoming an increasingly important issue:

1. Increasing population leads to the exploitation of resources of lower quality.
2. Population growth is contributing increasing pollutant loads to the natural ecosystems.
3. With advances in health care and community awareness of health issues water quality criteria are becoming stricter.

Integrated water resource management must therefore address water quality issues throughout the whole management process.

4.7.1 System Monitoring

The various water quality criteria such as the European Union (EU) drinking water quality directive (80/788/EEC) (EU, 1980) and the WHO drinking water guidelines (WHO, 1992) specify sampling requirements. Recent revisions of various criteria have targeted sampling requirements to become customer focused. This change in emphasis is part of the world wide trend to be customer oriented. It does not mean that sampling elsewhere within the water system should not be undertaken. Rather it is encouraging the water enterprise to know about problems as the customer sees them. To understand the source and reason for unacceptable water quality, it is necessary to have water quality monitoring throughout the system. This whole system monitoring should include not only incident monitoring but also ambient monitoring programs to provide baseline information about the “normal” water quality within various parts of the system.

Not only must an appropriate sampling program be implemented, but appropriate parameters must be analyzed for. There are a number of baseline parameters specified in various water quality criteria to both ensure the health and safety of the consumer and also to act as indicators of potential unacceptable contamination. Depending on the source of water, special attention should be paid to certain types of contamination as in Table 4.1.

Table 4.1: Source and type of contamination

Source of water	Contaminants of particular interest
Agricultural areas	Nutrients, pesticides, herbicides
Industrial areas	Heavy metals, exotic chemicals
Wastewater reuse	Exotic microbiological agents

The objective of sample analysis should not only be to get a representative picture of quality throughout the system, but also to be able to characterize quality and be in a position to positively respond to a contamination incident. Insufficient or inappropriate data can lead to unacceptable risk to community health.

4.7.2 Criteria

Water quality criteria are an essential part of establishing whether water quality of a water system is acceptable or not. They have two functions:

- To provide standards where water quality either “passes” or “fails”; and
- To act as a warning signal that water quality may be becoming unacceptable.

There is an abundance of various water quality criteria. They cover quality for:

- different sorts of water (e.g. drinking water, recreational water, etc.); and
- different countries (e.g. E.U. directives, WHO guidelines, national standards).

Consider drinking water criteria. The WHO guidelines represent the opinions of international experts of what a water supply should be like to be wholesome, aesthetically acceptable and safe to consume. They are often used as the benchmark for other criteria and national drinking water standards. The 1992 revision of the 1984 guidelines are more stringent reflecting changes in world opinion of what constitutes a safe water. The new WHO guidelines are now generally close to the current E.U. directive.

The E.U. directive on the other hand is about to be revised. On the surface, apart from some changes in the heavy metals and toxic substances, it appears to be less restrictive. The current directive is prescriptive in nature. The proposed new directive is only prescriptive in a limited area and it has introduced the concept of “indicator parameters” to highlight potential contamination. The new directive requires member states to be responsible for defining national standards that include the mandatory requirements of the new directive but also set other criteria that in the light of international opinion are relevant to their own local situation. This change in the philosophy of the E.U. directive is in line with the need for water enterprises to be accountable to their consumers and not to some international body.

The WHO recommended guidelines have wide recognition in several Mediterranean countries. These emphasize the criteria on which the recommendation is made and stress that in establishing national standards it will be necessary to take into account a variety of local geographic socio-economic, dietary and industrial conditions.

4.7.3 Sources of Contamination

All substances in water - even though beneficial to human health - may be viewed as contaminants of pure water. In nature distilled water does not naturally occur. The issue with “contaminants” is whether they are of significant concentrations to render a water unacceptable for its potential use. The sources of pollution can be categorized into three groups of sources as shown in Figure 4.9.

Pollution from human activities is the direct impact of human activities on the environment from which water is abstracted. Illustrations of this would include the passage of fertilizer and other agricultural products into an aquifer, the impact of wastewater (even after treatment) on watercourses and the marine environment, the direct disposal of waste products from industry, stormwater system and overflows from sewerage systems to watercourses, and incidents such as marine pollution (e.g. an oil spill), vandalism of water enterprise assets and failure of other “human” systems such as accidents or fire. The list is endless, but real. These and many other issues associated with human activity must be accounted for in integrated water quality management. Water quality issues arising from human activities are generally independent of system flows. They are related to the magnitude of the human activity; e.g. tons of fertilizer per hectare.

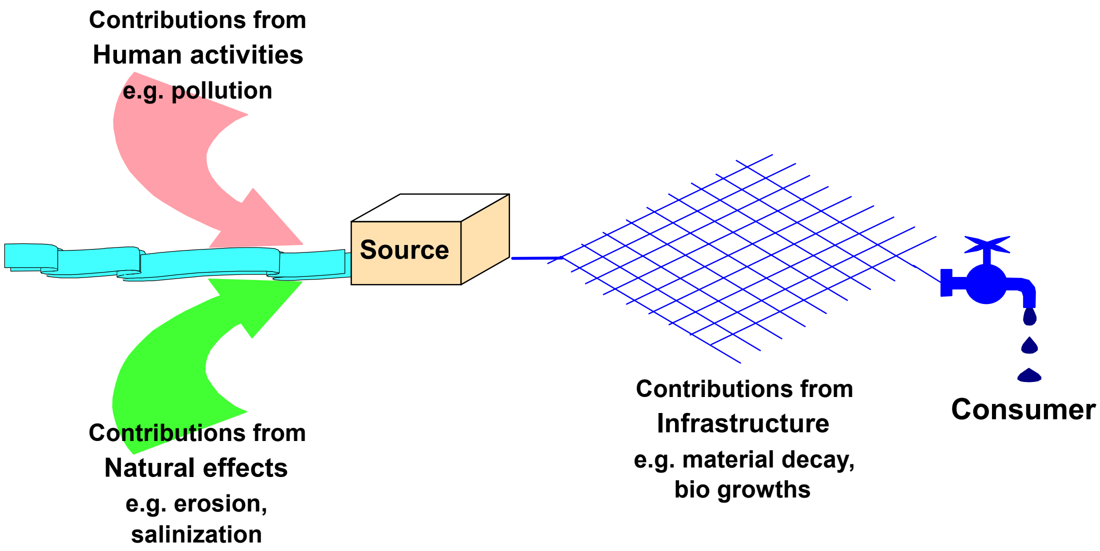

Figure 4.9: Sources of water quality contamination

Contributions from natural systems almost invariably have some human intervention factor. An example may be excessive suspended materials in streamflows resulting from erosion impacts within the catchment and/or the streambed. Erosion is invariably increased by human activities such as forest harvesting and inappropriate agricultural practices. Another example may be the increased salinization of an unconfined sea level aquifer where due to overexploitation seawater intrusion becomes an issue. One further example is the natural stratification of deep reservoirs during the summer period causing iron and manganese problems. The difference between contamination from natural systems and human activity systems is that natural systems are always striving for an equilibrium. Even an undisturbed catchment erodes, albeit much slower than when the trees are clearfelled. By changing the catchment characteristics, erosion will increase. In fact it may appear to accelerate early on until it finds a new equilibrium position. The problem is that at its new equilibrium position the quality of water is unacceptable. Similarly, for a sea level aquifer, by changing the water balance, salinity will increase but they will stabilize perhaps at a level that is unacceptable. The issue with natural systems is to find the right balance such that yield is maximized without creating unacceptable water quality problems.

A source of contamination that has often been overlooked is from within the water system infrastructure itself. Examples from pipe networks include the release of aromatic hydrocarbons from coal tar lined pipes, high lead concentrations from lead pipes, vinyl chlorides from certain PVC pipes and, of course, the common dirty water problems arising from the corrosion of unlined iron pipes. Further examples include biological growths with systems which include organisms such as crustaceans and bacteria. Another illustration of “in-system contamination” is often the causes for taste and odor problems in water supply systems: excessive chlorination to microbiological quality may in itself cause problems.

4.7.4 Coastal Sensitivity

As far as “in system” effects are concerned, coastal systems are not different from anywhere else. They use the same materials, generally construct infrastructure the same way as their upland cousins and operate them in the same way. The differences in coastal areas are due to their location, not to the system they have.

As stated before, coastal areas are generally the most sensitive to changes elsewhere. This is particularly true for water quality issues. Their aquifers are invariably related to the sea and therefore subject to salinity problems. They are at the end of river systems and are the end users of water suffering from the impacts of upland cities, industries and rural activities. A fundamental “plank” of integrated water resources management is that it must consider whole catchments. This is particularly so for water quality issues. Not only must the water enterprise plan and manage its infrastructure in the context of total catchments, it must ensure that adjacent water enterprises also do so and that they co-operate closely with coastal areas.

4.7.5 Understanding Water Quality Issues

There is the need to develop an understanding of water quality issues. Figure 4.10 puts forward some issues that need to be discussed within a water quality “agenda”.

Performance reporting is primarily aimed at addressing the first issue on the agenda. As indicated in 4.7.1, sampling should be system wide including:

- at source;
- treatment / production facilities;
- distribution; and
- taps / customers.

Supplementing this information is data collated on water quality difficulties experienced by customers (e.g. complaints database) and operational reports from activities such as pipe and reservoir cleaning, etc. Put together, this information provides the source data to address the second item on the agenda. Using statistical techniques, water quality can be characterized and trends forecast to answer the second agenda item.

• Criteria compliance:	Where is water quality unacceptable?
• Trends:	What is the variation in quality in the system? Any trends that may lead to future problems?
• Mechanisms:	What causes observed water quality? How does water quality change? Impact of alternative strategies / actions?

Figure 4.10: The water quality “agenda”

The third item on the agenda requires the development of relevant models that through the simulation process seek to encode the cause and effect relationships that explain how water quality is both generated and transformed as it passes from one part of the physical system to another. The sophistication of the model is dependent on the complexity of the system involved and the accuracy required. It may be a simple mathematical equation such as a chlorine decay function or it may be a sophisticated mathematical model that accounts for the many interactions that occur in the real world. These models include various aquifer models, streamflow and reservoir models and water quality within distribution systems.

With sufficient data and appropriate analysis and investigation, an understanding of water quality issues can be obtained which will then allow appropriate ways of managing water quality issues to be defined.

4.7.6 Managing Water Quality

Quality problems are important because they have a direct impact on the health of the community. Even for wastewater systems, given that they are discharging into a marine environment that may be used for recreational activities, the achievement of minimum quality standards may avoid health problems in the community (e.g. through consumption of contaminated shellfish). Water quality is generally less of an issue for irrigation systems but it may be a critical issue in preserving a delicate ecosystem through periodic environmental releases.

Conceptually, there are two extremes of managing water quality issues:

- the preventative approach (avoid or prevent an unacceptable situation); and
- the remedial approach (bring water to an acceptable standard by treatment).

The first approach could be called the "source" approach. It includes actions such as legislative and Government controls to avoid an unacceptable situation such as aquifer contamination or excessive nutrients and other contaminants in runoff water. It depends on adequate implementation and policing of these edicts and is therefore not always a secure way of source protection. It may include technical solutions such as public tenure over critical parts of catchments, water course improvement works to aid natural processes in providing good quality water, monitoring systems to alert operations staff when to divert water of unacceptable quality and engineering works to minimize the possibility of potential pollutants contaminating source water. These actions are necessarily proactive. It may be that this is not possible or is uneconomic which is when remedial actions are required.

The "remedial" approach seeks to ameliorate water quality problems before they reach the consumer. They generally require some form of treatment depending on the water system and the problem to be addressed. Remedial options include:

- reservoir storage;
- water treatment;
  - conventional flocculation, sedimentation & filtration;
  - membrane technology;
  - desalinization technology;
  - wastewater technologies - activated sludge, extended aeration, etc.;
  - disinfection;
  - lining systems:
    - pipeline rehabilitation;
    - reservoir coatings.

In defining remedial actions, it is imperative that whole systems are considered. For example, a disinfection strategy must not only render a water microbiologically safe, it must be safe through the whole system, it must not induce other problems such as THM's, taste and odor and it must be reliable and self sufficient.

Incident Management

Incident management is necessary to provide an effective response to the inevitable emergency situation when something goes wrong. It may be a contamination resulting from sabotage, from natural events such as excessive rainfall or it may be a significant breakdown in a treatment plant. Either way, it is vital to minimize or contain the impact of the emergency. Adequate communication with the public and consumers can prove a determining factor informing them of the situation and their need for remedial actions. Incident management is the driving force behind "Emergency Response Plans". "Contingency Plans", prepare for an unexpected event that may prejudice the quality of water delivered to the consumer or to the receiving environment.

4.8 Environmental Considerations

In the general sense, environment can mean a number of different situations. Environment refers to the circumstances, the surroundings and conditions a system operates within. In this context, for water resource management, environment can be generally broken into two major categories:

- the human activity environment; and
- the natural environment.

The human activity environment is generally the object of water resources development and management. It is the intent to provide water and/or to remove it after it has been used from the "human" system. With this intent go issues like improving standard of living, economic prosperity through value adding (e.g. the tourism and manufacturing industries), the maintenance and improvement of community health, etc. These aspects of "environment" are normally included in planning and management of water resources. This section will not discuss them further.

The other category of "environment" is the natural systems. These systems are not always properly considered. The natural environment has often been regarded in the past as a system that can be exploited and that will look after itself. In reality that is not true and we humans have an obligation to acknowledge and care for the natural environment. If we do not, we will cause not only loss of unique habitat and ecological systems but end up creating situations that, while they may achieve a new equilibrium the new environments may be unacceptable for the production of suitable water resources. This section discusses issues of the impacts of water resources development on natural environmental systems and how to manage them.

4.8.1 Environmental Issues

Environmental issues are about changes to natural balances. Some of these issues have a direct and indirect impact on the management of water resources.

Environmental issues that become topical usually do not do so because of financial considerations, rather because the changes infringe on community values and beliefs. This may extend beyond national boundaries, for example, World Heritage Listings of areas of significant environmental value. The relevant communities consider that the changes are unacceptable and the arguments usually end up being quite emotive and ultimately political.

Irrespective of whether they impact directly or indirectly on the water enterprise, they must be addressed, and addressed as part of integrated management of water resources.

There are a number of different ways of viewing environmental issues. Two of them are to look at the sustainability of the changes (is the change reversible or not) and to look at the cause of the changes.

The issue of sustainable change often provokes much discussion between various interest groups, particularly where the change is irreversible. Listed in Table 4.2 is a broad categorization of some environmental issues within the reversible - non reversible continuum. The list is not complete and the reversibility of an environmental change will vary according to the local circumstances. The list is a generalization to illustrate the concept of change reversibility.

Take for example the issue of salinization. In an aquifer, salinity levels can be manipulated by the extraction from the aquifer compared to its recharge. There is certainly a lag effect from when extraction rates are reduced but, over time, salinity levels will stabilize at a lower level. For soils, the issue is slightly different in that through inappropriate irrigation practices, salt has migrated to the soil and it is much more difficult to return the soil to its former productivity even after water tables have been adjusted.

While issues at the "reversible" end of the spectrum should not be ignored, the issues at the "irreversible" end of the spectrum will tend to generate the most dialogue with the public and scientific bodies and therefore they must be handled with particular care.

Table 4.2: Environmental change reversibility

Reversible	Non-reversible
(bacterial) Water pollution (toxic spill) (chemical) (sediment)	
(water) Salinization (soil)	
Habitat depletion	
Fauna species depletion	
(deep soils) Erosion	(thin soils)
	Loss of floral / fauna species
	Destruction of natural features

Table 4.3: Examples of change to the natural environment

Add to the environment	**Take away** from the environment
Material • additional water • organic load • additional solids • nutrients • exotic chemicals	Water • river diversion • inter catchments transfer • low land drainage • aquifer extraction
Structures • dams • channel lining • diversion works	Vegetation • forestry activities • conversion to irrigation • river bank clearing
Flora and fauna • exotic trees • weeds & pests • exotic animals & fish	Natural features • fish breeding areas • tidal variation • flooding of ecosystems

The cause of environmental change can be thought of as arithmetic; some change is because human actions add to the natural environment, other change is because human actions take away a part of the natural environment. Examples of this change are shown in Table 4.3.

Whether it is change to the environment because something that is taken away or added to the environment, the issue is that the water enterprise must ensure that in the context of overall management of terrestrial systems, the changes are sustainable and offer overall benefits without unacceptably prejudicing either the human or natural systems.

4.8.2 Impact of Water Development on the Environment

In part the question of environmental impact has been addressed in section 4.8.1. Following on from this, the impacts of water development can be seen as having both beneficial and detrimental impacts on the environment. The decision maker needs to weigh up the pros and cons of these impacts (within the context of the wider system issues and impacts) to decide if the proposed water resource development should proceed or not or if it should be modified to acknowledge unacceptable detrimental impacts on the natural environment.

It is not the intent of this section to detail all the beneficial and detrimental impacts on the environment, rather an illustration of some are given to indicate the types of impacts that need to be considered.

Beneficial Impacts

- **Decreased vulnerability**: in areas that are drought prone, a proposed storage reservoir may (except in times of significant drought) provide the security for an ecosystem to continue when it would otherwise have been significantly stressed.
- **Stability**: through regulation of manmade water systems, stable colonies of flora and fauna can be achieved.
- **Preferred ecosystems**: again through controlled regulation, man can manipulate the environment to create preferred environments - that is, value adding to the natural environment.

Detrimental Impacts

- **Loss of ecosystems**: by virtue of flooding, continual pollution from say, wastewater systems, ecosystems can be destroyed or so irreparably damaged that they fade away.
- **Uncontrolled growth**: particularly with the discharge of nutrient rich waters, algae blooms may become a new feature of the environment. For higher orders of life, the same may occur with the demise of previous natural conditions that kept populations in check.

- **Lack of robustness**: the corollary to providing a stable environment is that biodiversity tends to wane and mono-cultures are encouraged. This increases the environment's populations susceptibility to collapse when freak conditions occur.

Impacts on the environment also have a time element. Some environmental issues have very long memories, others are very short. For example, depletion or contamination of aquifers typically occur over long time frames. Conversely they take a long time to rectify. At the other end of the spectrum, a natural stream ecosystem can be wiped out almost overnight never to return. From a water resource management perspective, we certainly do have to address the fast impact issues as a priority but that should not mean we ignore the longer-term ones as they may eventually have a larger impact.

One other time-related impact of environmental change is the aspect of predictability. Some aspects of environmental change are ongoing, e.g. the gradual change of an ecosystem as it adjusts to new streamflow patterns. Other impacts are catastrophic such as the advent of a flood or a drought. Water resource management seeks to minimize hydraulic impacts but when a reservoir is full, the valley floods just the same. Likewise when it is empty the river bed dries up. At these extremes, there can be acute impacts on the environment as, in the meantime, the ecosystems have lost some of their resilience during relatively extended periods of stability. Water Enterprises should not only consider the "ordinary" impacts on the environment but should consider Emergency Response Plans for unpredictable events as well.

4.8.3 Environmental Indicators

Environmental indicators are generally of two types:

- water quality indicators; and
- ecosystem indicators.

Water quality has been discussed in the water quality section (refer 4.7.1 and 4.7.2).

Ecosystem indicators include the many different types of surveys such as biodensity, biodiversity, etc. It may be a bio assay of macro invertebrates in a stream, a survey of density in a forest or a survey of stress in shellfish in a marine environment. Depending on what the environmental issue is, appropriate surveys can be designed to both provide baseline information and to monitor the beneficial or detrimental impacts of changes to the environment.

4.8.4 Environmental Controls

There are no simple and packaged answers for appropriate measures available to address adverse environmental impacts. Every situation is unique and requires its own assessment and solution. As a guide, environmental controls or measures can be either (and/or):

- planning controls;
- engineering controls;
- operational controls.

Planning controls seek to avoid a problem or to acknowledge it and seek the best way of managing it before the environment is changed. Depending on the type and magnitude of the environmental issue, it may involve going through some form of external formal procedure decreed by the State. It will certainly be subject to internal planning as discussed in section 4.1. The internal planning will examine the environmental issues as they impact on the Water Enterprise's objectives for supply and/or disposal of water and on how they relate to the wider issues. It may be that, through prudent planning, environmental issues may not be significant or can be managed internally. Depending on the outcome of this internal planning, it may be necessary to undertake a more formalized environmental assessment.

The formal procedures imposed by state planning agencies have a variety of names including Environmental Impact Assessments (EIA's), Environment Planning Statements (EPS's), Environmental Assessments (EA's) and Environmental Impacts Statements (EIS's). Sometimes the different names refer to different levels of detail required depending on the degree of environmental impact. Irrespective, these procedures are an opportunity for the public to contribute towards debates about proposals that may affect their environment. Based on this process of assessing the impacts of proposed developments, recommendations are made including where necessary the formulation of actions to mitigate adverse effects.

Engineering controls refer to structures that are placed to mitigate adverse effects. They are capital items that generally do not add financial value to the water but do have non financial impacts of improving environmental and/or quality of life aspects. Examples of engineering controls include artificial recharge of aquifers to maintain water table levels, installation or upgrading of treatment plants to produce water of a higher standard and provision of fish ladders to allow for fish migration.

Operational controls are actions taken by a water enterprise to mitigate either actual or potential adverse impacts of its systems on the environment. They include both preventive and remedial actions. Preventive operational actions may include actions such as environmental releases of water from reservoirs, tree planting programs to minimize erosion or product substitution initiatives such as phosphorus free-detergents. Remedial actions may include river flushing after a chemical spill, additional disinfection after a contamination alert or an animal rescue program during and after a flood or wildfire. In the case of unpredictable environmental impacts, Emergency Response Plans are an operational issue that needs to be addressed.

With the right combination of these controls, the water enterprise should be able to manage environmental issues so that it is able to achieve its primary corporate objectives, the community is supportive of its actions and the natural environment can continue in a sustainable fashion.

4.8.5 Planning for the Environment

Thirteen issues have been suggested to be included in planning for environmental protection strategies:

- assessments and prediction of water quantity and quality that also address pollution issues;
- effective flood and drought warning systems;
- monitoring systems based on catchments/basins;
- surveillance centres to evaluate the health of aquatic to be encouraged;
- new assessment and application of rapid assessment procedures;
- development and application of rapid assessment procedures;
- development of programmes in priority areas of high risk;
- promotion of national legislation/agreements to manage transboundary pollution;
- strengthening the enforcement of pollution prevention and control measures;
- where possible, the use of economic instruments to encourage responsible user behaviour;
- development and application of low cost, low waste technologies, recycling and biotechnologies and indigenous technologies;
- establishment of national surveillance programmes targeted at high risk zones; and
- development of programmes for identification and control of water borne diseases.

4.8.6 Environmental Impact Assessments for Water Development Projects

An Environmental Impact Assessment (EIA) is the complete process under which a development project of a specified size of nature undergoes, such that the decision for its approval and eventual construction is based on informed knowledge of the environmental consequences (Figure 4.11). The EIA studies and assesses its impacts on the environment and these vary in size and scale depending upon the sensitivity of the area and the degree of the disruption. This process covers in a systematic way the collection of information about the area and its environmental characteristics, and the prediction of the effects of the development on the area's environment. It will provide informed judgment under which conditions the development may be permitted.

The key objectives and benefits of an environmental impact assessment are:

1. to examine and select the best from the project options available;
2. to identify and incorporate into the project plan appropriate abatement and mitigating measures;

3. to predict significant residual environmental impacts;
4. to identify the environmental costs and benefits of the project to the community;
5. to gather additional information for engineering design and decision making;
6. to streamline the consultation process; and
7. to improve coordination and understanding between environmental bodies.

In general, it is envisaged that in any development project of specified size and nature, and as may be determined by the national authority, is subject to an environmental impact assessment. The developer is required to provide detailed information regarding the description of the project, the site, design and the size of the project.

EIA is essentially a planning tool for preventing environmental problems due to an action. It seeks to avoid costly mistakes in project implementation, either because of the environmental damages that are likely to arise during project implementation, or because of modifications that may be required subsequently in order to make the action environmentally acceptable. Figure 4.11 presents a simplified flowchart of the EIA procedure.

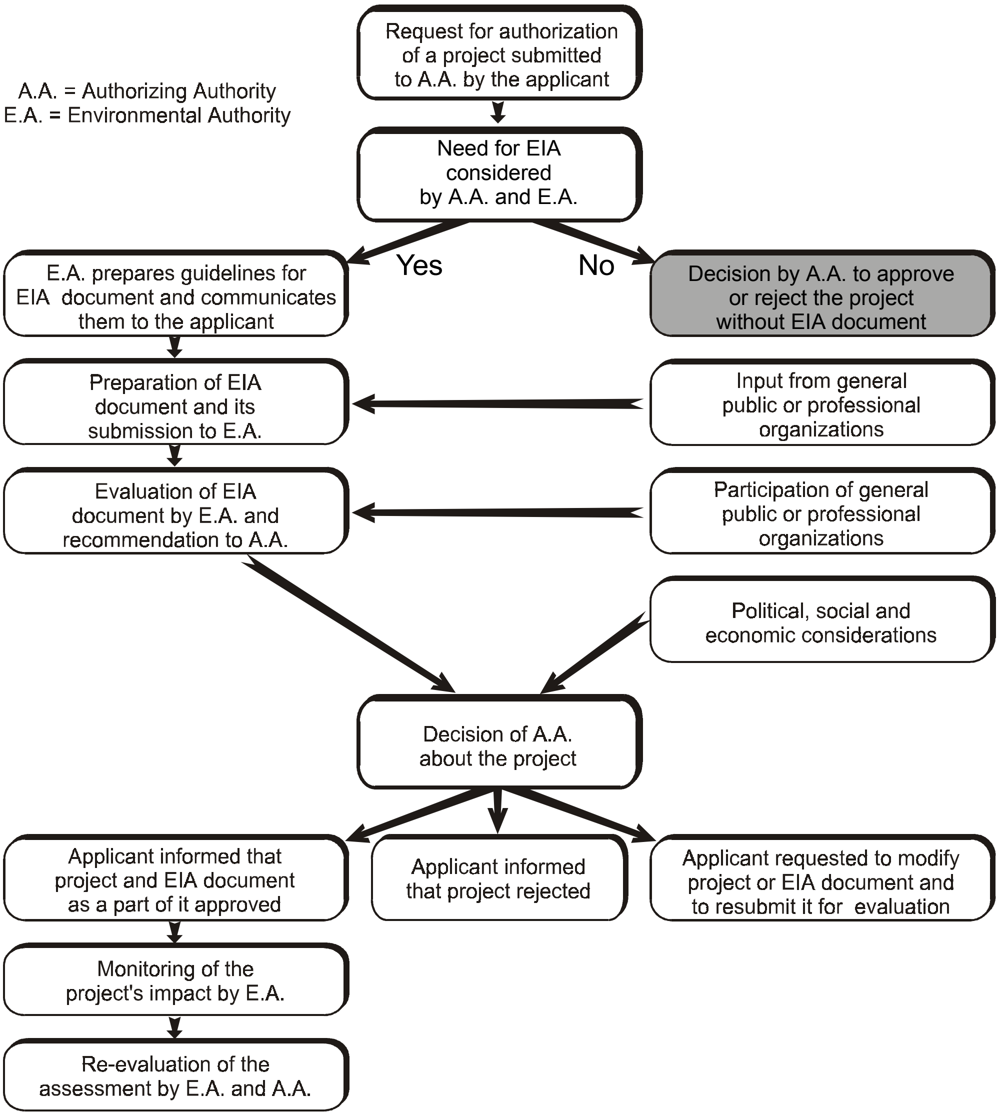

Figure 4.11: Simplified flowchart for the EIA procedure (UNEP-PAP, 1995)

The Water Sector

The identification, characterization and underlying principles of EIA studies on various types of action are applicable also in the water sector. This includes water development related projects, such as hydrographic changes, aquifer recharge, pipelines, aqueducts and main trunk sewers, waterways and drainage works, dams, ports, harbor and breakwater construction, reservoirs, wastewater treatment plants, reverse osmosis plants, reclamation and dredging works, hydroelectric plants, transport and recreation involving water bodies.

Under the integrated water resource development and management programme described in Agenda 21, sixteen activities were proposed. These activities either directly or indirectly acknowledge and highlight the need for environmental impact assessment as a tool for improved water resources management. This includes:

1. Integration of measures for the protection and conservation of potential sources of freshwater supply, including the inventorying of water resources, with land-use planning, forest resource utilization, protection of mountain slopes and riverbanks and other relevant development and conservation activities.
2. Development of interactive databases, forecasting models, economic planning models and methods for water management and planning, including environmental impact assessments.
3. Flood and drought management, including risk analysis and environmental and social impact assessment.

Assessment of Water Environment

The environmental effects on water range from marine pollution to the quality of the tap water. The indirect effects of changes to water bodies or systems are often more important than the direct effects. Changes in water level may have indirect effect on aquatic life, groundwater systems, wildlife habitats, recreation, irrigation and the interrelationship with steams or ponds.

Any given water sector may be assessed in several different ways:

- component of whole hydrological system;
- part of local wildlife habitat;
- source of industrial or domestic water; and
- recreational amenity.

Water sectors identified in an assessment could include:

- running water (lotic) - ecology of brooks, ditches, rivers and steams;
- static (lentic) - ecology of ponds, lakes;
- wetlands and marshes;
- running or static water used for recreation and sport;
- hydrological systems - aquifers, local groundwater;
- natural water supply - wells, boreholes;
- running or static water used commercially - fishing, fish-farming;
- water catchment areas;
- reservoirs;
- marine waters and estuarine systems; and
- existing discharge.

Box 8

EIA procedures in Malta

In Malta, the Environmental Protection Act 1991 requires that all major developments with a potential impact on the environment are submitted to an environmental impact assessment to predict the effects of the proposal on the physical, biological, social, and cultural environment.

A schedule of projects requiring EIA has been established by the Planning Authority. The terms of reference for an Environmental Impact Statement (EIS) are set by the Environment Protection Department (EPD) in discussion with the Planning Authority. Key issues are required within the EIS and include:

1. Description of Proposed Development Project including alternatives during construction and in operation:
   - physical characteristics, including details of access and transport arrangements;
   - land use requirements and other physical features of the project;
   - production processes and operational features including types and quantities of raw materials, water energy and other resources consumed, residues, emissions, effluents, noise, dust, vibration;
   - main alternative sites and processes.
2. Description of the existing environment in and around the site in terms of the physical features and policy framework:

   Physical features:
   - population, settlements, workplaces;
   - flora, fauna and marine biology (including habitats and species);
   - soil, agriculture quality, farm size and structure;
   - geology and geomorphology;
   - water and hydrological features;
   - air including climatic factors, air quality, etc.;
   - archaeological sites and features, architectural and historical heritage, urban conservation areas and other cultural assets;
   - landscape and topography;
   - land use;
   - other relevant environmental features.

   Policy framework: Planning policies set in the Structure Plan and Local Plans are analyzed in addition to other Ministerial policies, e.g. environmental regulations, financial and economic controls.
3. Assessment of the impacts of the Proposed Development Project.

   The effects of the project on the following are described:

   a) *Human beings*:
      - Social effects, e.g. health, welfare, safety community values and economic effects
      - Effects on landscape and cultural heritage

   b) *Buildings and man-made features*;

   c) *Flora, fauna and geology*;

   d) *Land and water* including effects on local topography, soil, agricultural land, mineral resources, surrounding land uses and waste disposal, and effects on aquifers, drainage patterns, aquifer recharge areas, coastal and estuarine hydrology and water quality;

   e) *Air and climate* including chemical emissions, particulate matter, offensive colors;

   f) *Indirect and secondary effects associated with the project*, including effects from traffic and those generated by or required to support project;

   g) *Risk assessment of accidents and hazardous developments*.
4. Design of mitigating measures: measures necessary to avoid reduce and remedy adverse effects are described.

The draft EIA is then submitted and reviewed by the Planning Authority, in consultation with the public and Government agencies to ensure that it accords with the terms of reference and is technically sound. A public meeting is also organized to allow comments to the draft EIS and to advise developers of possible improvements which could be incorporated. The proposal including the final EIS is submitted to the Planning authority for final deliberations and decision.

Environmental Impacts on Water

Development projects have various environmental effects on water including:

1. physical disturbance of the water body;
2. introduction of pollutants or chemicals; and
3. manipulation of water flow.

Physical effects: Diversion or realignment of watercourses leading to waterside ecology deterioration, and damming and other obstructions which alter water flow causing sedimentation or scouring and thus changing the watercourse bed. Alterations to water bodies by excavation or fill - changes in the water depth and aquatic ecology, and use for recreation sport or commercial purposes.

Pollutants effects: Water is vulnerable to small alterations in its constitution and damage is often irreversible. It is cumulative and surge effects of discharging effluents into water systems can produce significant effects. This includes run-off fertilizers, pesticides, alkaline, acid and other effluents which change the water chemistry.

Marine and estuarine waters are particularly vulnerable to changes in the salinity caused by altered river discharge. The way in which effluents are discharged is important particularly since concentrations can unbalance the water ecology.

Effects on water flow: This may be produced by taking water for industrial processing or cooling, diverting water courses or changing of groundwater system by excavation and other earthworks. The reduction in water supply is the most obvious effect.

5. PROCEDURES FOR THE INTEGRATED APPROACH TO DEVELOPMENT, MANAGEMENT AND USE OF COASTAL WATER RESOURCES

5.1 Introduction

Although the total amount of water on Earth is generally assumed to have remained virtually constant during recorded history, periods of flood and drought have challenged the intellect of man to have the capacity to control the water resources available to him. Currently, the rapid growth of population, together with the extension of irrigated agriculture and industrial and tourist development, are stressing the quantity and quality aspects of the natural system. Because of the increasing problems, man has begun to realize that he can no longer follow a “use and discard” philosophy - either with water resources or any other natural resource. As a result, the need for a consistent policy of rational management of water resources has become evident.

One of the important elements within this process is the Water Resources Master Plan. Master planning is the planning which for a particular time period and area gives the best possible solution in the particular time of problem solving. It is a detailed and concrete plan which attempts to solve actual problems which have occurred or will occur in the course of the planning period in a specific area. The master plan gives the best solutions for the goals and objectives which have been reached in the planning process (planning to plan) when solving the problems of water resources management and use, starting from the current state of the water resources and planning environment.

The Mar del Plata Action Plan adapted by the United Nations Water Conference in Argentina recommended the formulation of master plans for countries, regions, and river basins to provide a long-term perspective for planning, including resource conservation, using such techniques as systems analysis and mathematical modeling as planning tools, wherever appropriate. It also recommended that planning should be considered as a continuous activity and that long-term plans should be revised and completed periodically, suggesting a five-year period in this regard.

Today in the Mediterranean region, the water demand exceeds the natural capacity of the existing resources. It is therefore necessary to resolve very complex problems. This is why it is essential to consider multiple objectives and implement the analysis, bearing in mind the spatial and temporal characteristics of water resources systems and their dynamic nature. Most development decisions today have multiple objectives involving economic, social and environmental dimensions and values. However, until relatively recently, this fact was not seriously taken into consideration in planning for water resources development. Instead, economic development was considered to be a desirable end in itself, often with little regard to adverse effects on social or cultural systems and the natural environment. As the pace of economic development increases these effects can no longer be ignored. The need to formulate plans for water resources development in a rational way, the multi-disciplinary nature of water resources planning, development and use requiring co-ordination among various government bodies concerned with water, and the need to minimize adverse environmental impact owing to water development activities have all added to the complexity of water resources development and management.

Each problem and development of the plan for the management and use of the water resources represents a specific case with different characteristics so that it is always necessary to select the approach most suitable to that specific situation. The approach to be used in problem solving should be stated and selected in the plan of the study.

Planning environment and planning approach in water resources management

Generally speaking, each planning model can be described as follows (Helweg, 1985):

1. **Determine the objectives**: What does the client want to accomplish? These may be clarified and altered during the planning process.
2. **Design a plan of study (planning to plan)**: What approach fits the present environment? How should the planner allocate the available resources (financial and other) to the various steps and tasks?
3. **Obtain the data**: The correct quantity and quality of data are fundamental to any study.
4. **Formulate alternatives**: What actions are feasible and can meet the objectives? Usually two or three should be presented to the client.
5. **Choose one alternative as the plan**: The alternatives are evaluated against the objectives. The client should make the final decision.
6. **Implement the plan**: Often this is fit to a contractor and the planner's involvement is terminated with a report summarizing the first five steps; however, the planner should be involved in implementation.
7. **Conduct a post-analysis**: This is seldom a part of a planning study and some would argue that it should not be a part of the planning model. When done, it compares the predicted results of the plan to the actual results and analyzes the differences.

Accordingly, it can be seen that each planning model in its early stages of realization has two requirements: identification and definition of the project environment and the selection of the planning approach. The analysis of the project environment and the possible planning approach best suited to a specific problem (situation) are the decisive factors for the successful plan development. Consequently, these two problems should be considered with special attention particularly if the problem appears to be specific.

Subsequently, these two terms: planning environment and planning approach will be defined in detail.

Planning environment

Each planning study has a different environment and the planner tailors a planning approach to fit the environment at the beginning of the planning process. The planning environment can be described by three major elements:

1. The client's political jurisdictions;
2. The scope of the study; and
3. The stage of the planning process.

Planning jurisdiction describes the main clients or governments responsible for the plan, and this can be: international (UN), federal, state, interstate, local, private.

The planning scope describes the breadth of the study. It is divided into multisectoral, sectoral, functional, and elemental structure. For example, multisectoral planning is a development plan; sectoral planning is a water resources plan within the multisectoral plan; functional planning is a plan for wastewater treatment, water supply, etc. as a function of the water resources sector; the distribution water system, reservoirs, pump stations and others are elements of the water supply function planning.

The planning stage of the planning study describes the level of necessary details and can range from a general to a specific stage. General stages of planning are: policy planning, framework planning, general appraisal planning, implementation planning and project design.

Policy planning identifies goals. Framework planning or sketch planning broadly identifies needs, opportunities, and data that recommend additional planning studies. General appraisal planning such as river basin plan is still fairly broad but ends up with a recommended course of action and rough economic indicators to prioritize subsequent implementation planning. Implementation planning is detailed planning which evaluates the suggested implementation strategies and prepares the conceptual design. At the end we have project design which produces bidding documents, specifications, and detailed design.

More comprehensive and complex problem planning should follow the same sequence of its development in order to avoid the repetition of the planning stages and eventually to reach reliable results. In minor projects these steps can be eliminated providing the objectives and results of the previous steps in the planning process have been clearly defined.

More detailed planning environment can be described by the following descriptors: political system, sociological systems, culture, institutions, client jurisdiction, scope of the study, stage of the study, geographic area of the study, objective of the study, technical constraints, financial situation and economic situation.

The knowledge of the planning environment makes it possible to select an optimal planning approach and at the same time to define the feasible region into which the formulated alternatives should fit.

Planning approach

How to define and select the required planning approach? As previously stated, this approach depends upon the planning environment and particularly upon the planning scope. The planning approach has three significant dimensions: control, coverage and rigidity.

Planning control determines how much control the planner has over goals, objectives, and conduct of the planning study. Frequently, the jurisdiction of a plan will determine the amounts of control the planner has, ranging from client controlled to planner controlled.

Planning coverage can be rational-comprehensive or disjoined-incremented. The scope of the plan in general determines which coverage approach should be used. Multisectoral planning tends to require rational-comprehensive coverage, while functional and elemental plans require a disjoined-incremental approach.

Rigidity is the difference between general “blueprint planning” and “process planning”. The stage determines the rigidity approach so that policy planning and framework planning are more “process planning” because sufficient information is not available. As the stage of planning proceeds through general appraisal, implementation, and project design plans become more rigid, and tend towards “blueprint planning”.

However, the transition from one process to another (blueprint) is flexible according to the project environment.

These statements refer to any type of planning and generally speaking, each planning process should take into account these planning elements in order to achieve optimal results. However, the effects of the planning approach and planning environment upon master planning and, in general upon the water resources planning, will be discussed in the next chapter.

5.2 Coastal Water Resources Sustained Use, Development and Management

There are a number of definitions of the term “sustainable development”, of which the one of WCED defines it as “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (WCED, 1987).

Speaking of the natural resources, the definition is more precise: “*The essence of sustainable development is that natural resources must be used in ways that will not limit their availability to future generations. Sustainable development of water resources requires that we respect the hydrological cycle by using renewable water resources that are not diminished over the long term by that use*” (Engelman and LeRoy, 1993).

According to the Canadian Water Resources Association, **sustainability ethics** is:

Wise management of water resources must be achieved by a genuine commitment to:

- *ecological integrity and biological diversity to ensure a healthy environment;*
- *a dynamic economy; and*
- *social equity for present and future generations.*

Accepting this sustainability ethics, **the water management principles** are:

1. **Practicing integrated water resource management by:**
   - linking water quality, quantity, and the management of other resources;
   - recognizing hydrological, ecological, social, and institutional systems; and
   - recognizing the importance of watershed and aquifer boundaries.
2. **Encouraging water conservation and the protection of water quality by:**
   - recognizing the value and limits of water resources, and the cost of providing it in adequate quantity and quality;
   - acknowledging its consumptive and non-consumptive values to human and other species; and
   - balancing education, market forces, and regulatory systems to promote the choice and recognition of the responsibility of beneficiaries to pay for the use of the resource.
3. **Resolving water management issues by:**
   - employing planning, monitoring, and research;
   - providing multi-disciplinary information for decision making;
   - encouraging consultation among, and active participation of all affected parties and the public;
   - using negotiation and mediation to seek consensus; and
   - ensuring accountability through open communication, education, and public access to information.

Water engineers and scientists must accept the challenge of such approach and translate it into concepts for designing, operation, and maintaining water resources and water projects. This approach was explained in detail in the documents of the Rio Conference (Rio de Janeiro, 1992), and in other documents (Haimes, 1992; Plate, 1993).

At the engineering level of resolving the problem, the concept of “sustainability” has been traditionally respected but with different terminology, so that its application is not new. The problems occur when the concept has to be transferred to the field of development or at the political level of problem-solving. Then, the objectives could be reached by applying system analysis to economic and environmental planning, development, and management. The basic prerequisite for a rational management of these resources is their integrated planning and management.

Integrated planning and management can be defined as a continuous process of development management aimed at reconciling economic growth and social objectives along with the protection and enhancement of the environment, i.e. at ensuring “sustainable development”. An essential component of the planning procedure is integration of environmental management into the development process. The integrated planning and management is a predominantly action-oriented process, i.e. from the earliest phase the interest is focused mostly on crucial problems of the area concerned and on their resolution.

The process of water resources system planning is presented in the Figure 5.1. It consists of four stages:

1. Plan initiation;
2. Data collection and processing;
3. Formulation and screening of project alternatives; and
4. Development of final study results.

The traditional approach to planning is that, in response to a political demand, a need is projected and a planning horizon identified. The project is initiated to create the required system. The process proceeds by data collection and processing, inventory of resources, through formulation and quantification of system alternatives, to the selection of the final project through the political process. Possibly conflicting planning objectives are introduced as constraints. Plan for sustainable development does not differ from this approach. It only emphasizes some additional criteria.

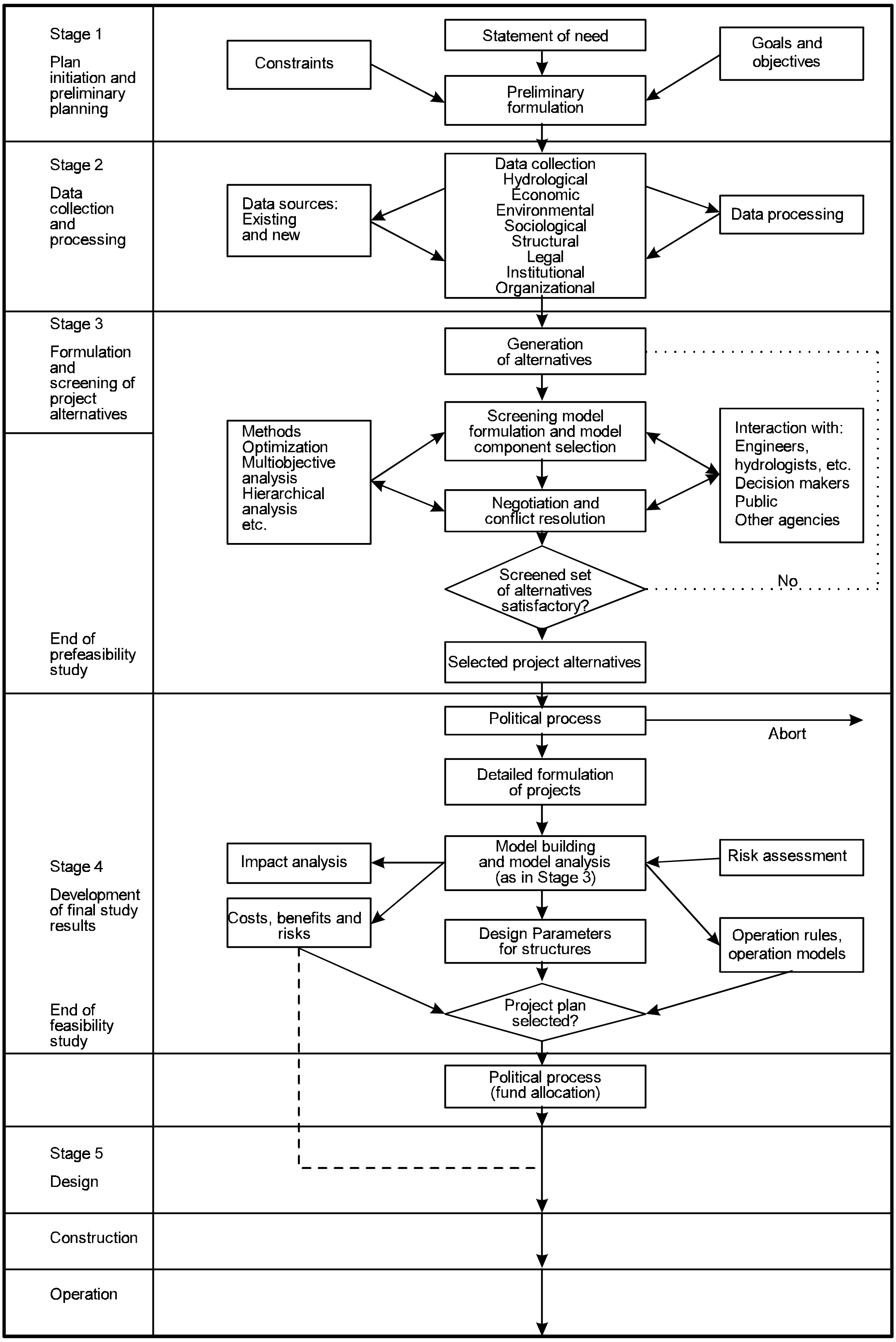

Figure 5.1: Stages in the project planning process (Plate, 1993)

Box 9

Points which should be emphasized in sustainable development of water resources
(Plate, 1993)

Planning for a dynamic society

- Sustainability requires one to consider a long-term use of the system under future conditions. Namely, already in the planning and designing stage, it requires a detailed projection of possible future changes in the use of the water resources system to meet the changing needs.
- Sustainability implies that the system serves its purposes always, or nearly always. That requires the data on which a water resources system depends to be continuously improved, and operation rules to be upgraded to reflect the changes both in the database and in the demands on the system.
- The hydrological cycle is a random process, so that the times of drought are unpredictable as much as inevitable, and it is therefore very probable that the system will not always be able to provide enough water when needed. However, sustainability means that supply shortages will be met without undue impact on the society, i.e., that a drought contingency plan exists.
- Sustainability implies that the structures provide indefinitely the services for which they have been designed. Proper maintenance is the key prerequisite of preserving the utility of the system. It also implies that the designed life of a large structure should not be too short, and that appropriate financial and technical provisions have been made to replace a structure that is no longer serviceable. That means that a reservoir has to be designed and operated in such a way that its active storage capacity is not reduced at all.

Planning for changing environment

- Water resources planners in charge of the future use of the systems often face the question of whether changes will occur in land use or climate, and whether those changes will alter the purpose and performance of the systems. The use of land may change in all, or a part of a catchment area, or a coastal area. Sustainability implies that adjustment of a system to a foreseeable change in land use can be made without expensive re-constructions, or that provisions have been made for accommodating the potential changes.
- For long-term projects the problem of climate changes must be introduced. It is especially important for the coastal areas which will, according to the forecast changes, be strongly effected by temperature and sea water level rise.

Structure design for sustainable development

- The concept of sustainability applies also to the design of structures. It implies that, with proper maintenance, the structures (dam, channels, etc.) should last indefinitely, or that their destruction will cause only a manageable disruption of living conditions of the affected people. In theory, such a design must allow accounting for the uncertainties of all variables that enter the design process.
- Stochastic design is based on the concept that a perfectly safe structure can never be built. It is difficult to convince engineers of the need to incorporate failure into their design considerations. They usually feel that any structure that is properly designed, constructed, and maintained should not fail. But sustainability requires a risk management plan: should a failure occur, one must be prepared to handle the consequences.
- A natural event that causes failure, such as an extremely fierce flood, drought, earthquake, etc., becomes a disaster only if the people that live in the area where the event struck had not been prepared to cope with it. Accordingly, technologies must be used in a sustainable water resources system to prevent natural events from becoming natural disasters.

Environmental concept in sustainable development

- A guiding principle for the planning of sustainable systems is the concept that a water resources system should interfere as little as possible with the proper functioning of natural life cycles.
- Sustainable development requires that man-made environments (including elements of the man-made physical water system) do not degrade with time, i.e., they must be compatible with land and climate conditions of the region, and adapted to the life styles and customs of the people for whom they have been created. It is, therefore, important to find out which sustainable and self-preserving natural conditions can exist under given hydrological and environmental constrains.
- A guiding principle for all future activities that may lead to contamination of soil or water is that the cost of clean-up must not be shifted to future generations.

Management requirements for sustainable water resources system

- Water management strategy for sustainable growth and development should be optimized by strategic planning, i.e., the water resources system should be integrated into the plan of the development of the region.

Traditionally, water resources were managed as a closed system: needs were made known to the system designer, and he served them as well as the system permitted, passing the cost on to the customer. Accordingly, the solutions were provided partially, meeting the partial interests of individual projects, while the relations to and effects on the system as a whole were not considered unless explicitly requested or absolutely necessary. The sustainable approach sees water resources management rather as concerned with an open system (Figure 5.2). In such an approach, a water resources manager participates actively in defining the water supply solutions, and takes care of the resources capacity, and pollution, as well as of demand identification. This means that **he participates in the creation of demand and supply strategies**. His interest is not only to meet the demand for water, but also to secure that the available capacities are not reduced by pollution, and to help the users reduce and rationalize their demand for water and diminish waste production, and consequently, environmental pollution. Thus, **his approach is comprehensive and balanced with regard to demand and supply**. As stated before, this approach is not new for many countries, but the results are not always satisfactory, and not only for technical reasons (lack of finances, weak infrastructure, etc.).

The key prerequisite of achieving a sustainable water resources development is personnel, since it is the backbone of sustainable development. Equally important is that the local population take the responsibility for the water resources system. They must be constantly informed and actively involved in the decision making process, and they must be aware of their own responsibility.

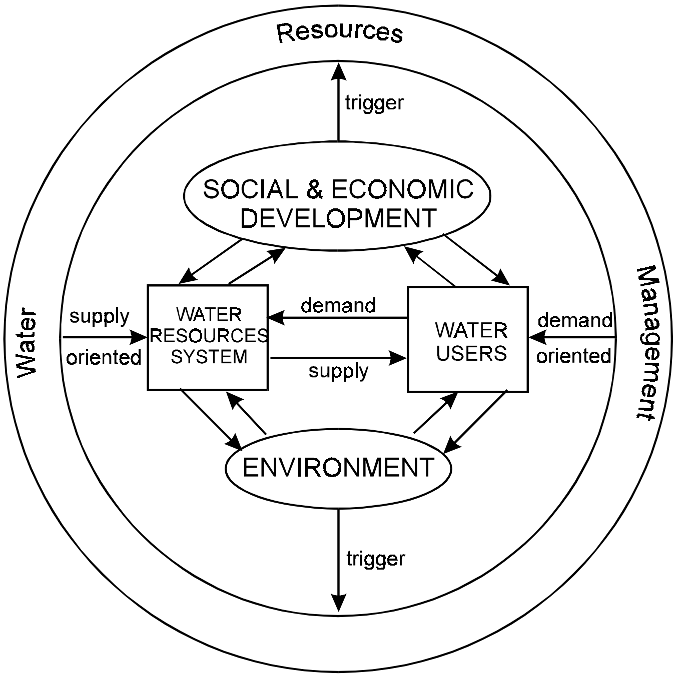

Figure 5.2: Schematic presentation of integrated water resources management (Plate, 1993)

If the sustainable development is to be successful, the process in its core (with regard to real needs) must have the "bottom up" character, starting from the potential beneficiaries. Naturally, there are situations requiring the "top-down" approach, where activities must be started at higher, national levels in order to secure success of a project. Typical governmental activities are:

- policies and guidelines;
- basic data and research;
- planning;
- review and comments;
- technical assistance;
- financial aid;
- regulation;
- management of state and locally owned resources; and
- development, construction and land acquisition.

These are highly generalized activities, especially those that deal with policies, planning and regulation, but they are precisely the activities needed to prepare for "overall water resources management".

In reality, there should rather be a mixture of procedure, where the first has a function at the national level, and the latter at village or catchment levels.

A large and complex socio-economic problem such as sustainable planning, development and management of water resources, can only be resolved by holistic-systematic approach. A system analysis interpretation of the sustainable-development paradigm necessarily leads to a vision that incorporates the following five essential operational principles (Haimes, 1992):

- multicriterial analysis;
- risk analysis, including risk of extreme events;
- impact analysis;
- consideration of multiple decision-makers and constituents; and
- assessment of relations among the components of a system, and between the system and its environment, including EIA.

When speaking of coastal zones and their water resources, we must bear in mind that, apart from land resources, an integrated natural unit is also composed of water and land, including vegetation, and sea with the coastline (Figure 5.3). Naturally, the air is also always there, as a natural resource. Accordingly, the environmental characteristics and natural processes of these areas are more complex, sensitive and vulnerable than the usual inland areas where only two resources are dominant, land and water. The basic difference between those two types of areas with regard to water resources lies in the characteristics of the system: in the coastal areas water resources consist of fresh waters and sea waters, in contact, that are dynamic as a function of various densities of the two liquid media, water balance, and geological properties of the coastline.

Logically, the natural characteristics dictate the socio-economic spheres which are based on them, and which, in turn, make the basis of the economic development of the region. The natural and socio-economic characteristics are always inter-dependent, and especially so in the Mediterranean region, since for most of the countries, tourism is a very important economic activity (Figure 5.3). Therefore, sustainable development is of a strategic interest for these countries, including inevitably the sustainable development of water resources: both sea and fresh waters.

For resolving problems relative to the sustainable development of coastal water resources, all the usual assumptions and approaches apply, provided that all the specific natural and socio-economic features of the region are strictly respected.

5.3 Master Planning

5.3.1 Main Characteristics of the Water Resources Master Planning

Water resources planning can be defined as seeking a balance between water demand and the available water resources. It is a simple search for the solution of how to meet the demands with the available resources.

The overall purpose of the water resources planning should be to improve the overall quality of life through contributions to (U.S. Water Resources Council, 1980):

a) national economic development;
b) environmental quality;
c) regional economic development; and
d) other social effects.

When plans for water resources management are developed, nowadays, special attention should be paid to the application of the sustainability concept.

Freshwater is largely a renewable resource. Accordingly, it is possible to manage water resources systems on a sustainable basis while achieving other objectives imposed by the society. Sustainable development of water resources requires that we respect the hydrologic cycle by using renewable water resources which are not diminished over the long term by that use.

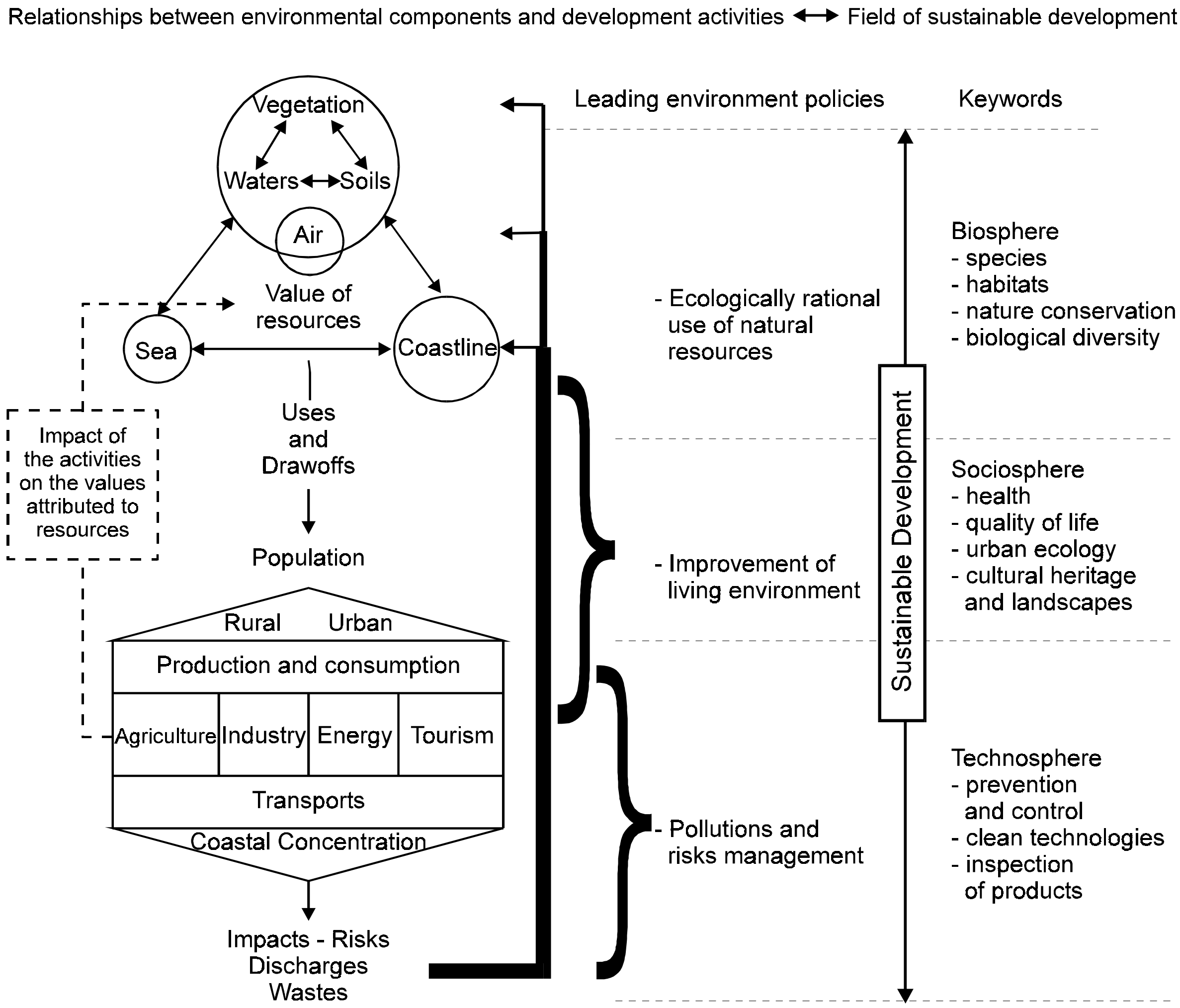

Figure 5.3: Relationships between environmental components and development activities in the coastal areas (Grenon and Batisse, 1989)

Such approach may need to sacrifice some economic productivity at short-time periods or for this generation in order to achieve sustainability for long-time period and for the next generation. A practical approach toward sustainability is to maintain and, if possible, increase the social value of water and water-related services over time, where the social value includes economic, environmental and equity values. This approach accommodates-indeed requires-changes in the quantity, quality, and the spatial and temporal characteristics of the water resources as well as changes in the specific mix of water and water- related services. In this sense, we define and apply sustainability to water resources management as a concept that combines social, economic, and ecological as well as physical elements.

What is the role of master planning in this concept of Integrated Water Resources Management? According to (Goodman, 1984), master planning is the formulation of a phased development plan to: *meet the estimated requirements for a single water resource purpose over a specific period of time; or exploit opportunities for single and multipurpose water resources projects in defined geographic area over a specific period of time or until all justified projects are completed.*

Box 10

Criteria which must be met by the planning of sustainable water resources development projects

- The project be considered as an integral part of the societal system, taking into account all interactions of the project with society and the environment. This implies that the project is designed for multiple objectives, structures and users, and that before implementation, a plan exists which takes into account all impacts of the system on other users, and which integrates the system into the general development plan of a country or a region.
- It includes optimally adapted structures designed to “work with nature” taking maximum account of existing local materials and conditions.
- Non-structural solutions as a first alternative should be considered. Such a solution requires interdisciplinary and inter-sectoral investigations that are not as final as irreversible engineering solutions.
- Due consideration should be paid to the alleviation of water-quality problems which may arise during the operation of the system. This implies that negative impacts on the water quality are avoided, or taken care of, as part of the plan.
- Full assessment of beneficial and adverse environmental impacts and of means to alleviate the adverse effects should be included. This implies that a sustainable system should interfere as little as possible with the natural environment.
- An assessment of crisis, and precautionary measures for preventing disasters should be made. This comprises possible failure states of the structures as well as possible failure states of the system, such as not being able to meet the demand during times of drought, etc.
- The structures should be resilient and such that in case of failure these can be replaced or repaired without undue disruption of services.
- Due regard to uncertainties of both supply and demand should be given. This requires comprehensive hydrological studies of water supplies, and evaluations of increased water demands resulting from population, agriculture and industrial growth with reasonable margin of errors allowed and stochastic variability.
- Considerations of social impacts caused by dislocation of people or by stress during system failures should be included. These include alleviation measures for floods and droughts.
- Provisions to cope with changes, like changes in demand, land use, etc., should be included.
- The people who will be affected by the project, should be involved in the planning process, so that projects become optimally adapted to local living conditions and to local environments. This implies informing the people to the fullest of project plans, and to prepare them for the changed situation that will be theirs once the project is completed, so that they will be prepared to comprehend and support the completed project.
- All potential for future national or international conflicts arising from the implementation of the project should be eliminated. This means that the effect of water resources projects located in the upper reaches of river basins, should be planned so that they are not detrimental to the downstream residents, particularly in large international basins.

A suitable management structure is required for the operation and maintenance of a water resource project if this is to be sustainable. Sustainable water resources project development needs the following management conditions:

- A competent staff of managers, technicians, and workers for operation and maintenance requiring the establishment of an appropriate infrastructure before the implementation and operation of the project.
- The management of a sustainable water resource project requires that a continuous supply of water is available at all times for all needs which implies that the system is operated according to carefully developed rules, including rules to be applied during shortages or excesses.
- The management should be cost conscious and consider and promote means of covering the cost of operation and maintenance in an equitable and efficient way which means that financial resources are generated and that management decisions are made for the system to function as intended.
- The management should continuously monitor the performance of the system. This implies the setting up of an appropriate data gathering and analyzing system for determining the condition of the system and the proper functioning of its elements at regular intervals.

The criteria described above for securing the sustainability of a water resource project, demonstrate that technical skills are not sufficient to make a system sustainable. It further, requires a willingness to go beyond the scope of standard technical solutions, for which better understanding of the interaction of the system with its surroundings and with other uses is necessary, and which requires optimally adapted and efficient structures.

Evidently, two facts can be stressed: a specified period of time and a defined geographic area. Consequently, the Master plan is one phase of Water Resources Planning, i.e. it is a plan for actual, previously defined conditions and a strictly defined planning environment with the initial state of water resources. It is a plan which, by jurisdiction or some other factors, becomes an obligation and has to be implemented in stages or as a whole, according to the stages of the plan realization and the realization of all its elements. Accordingly, master planning includes: planning jurisdiction, scope of planning and planning stages. Planning jurisdiction is generally regulated by laws and is most frequently under the control of water authorities within a respective Ministry.

Water related master plan is always a sectoral plan, but a plan which must be a part of multisectoral development planning. The multipurpose use of water for all types of human activities as well as the need both to provide protection against the adverse impact of water and to protect water as an environment clearly show that the planning, management and use of water resources are closely related to the planning and development of the entire economy and society in the broadest sense. That way the development of plans for the management and use of water resources must be regarded as an interactive process of development physical and economical development plan and the development water-resources master plan that support such development on the other hand (Haimes, 1977).

The Master plan, regarding the planning stages, is a more specific plan, which brings about concrete solutions so that it can be as a stage of general appraisal planning, but, also it is mostly implementation planning.

The planning hierarchy should be strictly respected within master planning, considering both geographical aspects and stages of planning. This means that general master plans should be developed firstly since they precede more detailed and specific plans. In addition, master plans should be developed first at the national level, followed by regional and lower levels. The same applies to developmental plans, which has been the common practice. Exceptions can be small settlements and individual structures as well as isolated areas (islands).

An ideal situation for the master plan development is when administrative borders are the same as hydrological, such as in case of river basins or islands. Unfortunately, these boundaries most frequently are not identical, which requires greater efforts in the plan development in order to bring into accordance the administrative and hydrological inputs. In these situations it is necessary to ensure beneficial cooperation in the boundary areas both during the plan development and its implementation.

The primary objective of coastal area water resources master plan is to establish a basic framework for the orderly and integrated planning and implementation of water resources programmes and projects, and for rational water resources management consistent with overall national/regional socio-economic development objectives. To meet these objectives, the master plan should:

- Ensure the availability of water, adequate in quantity and quality, for all necessary use during the time at required location;
- Develop a comprehensive and integrated approach to water and other socio-economic development, particularly with regard to interrelated water, land management, environment and coastal sea water;
- Encourage the preparation and implementation of comprehensive long-term plans for the sustainable development and management of water resources and related coastal sea resources;
- Formulate measures and/or water resources development projects which improve the efficiency of water supply and use;
- Identify water resources problems and set out priorities for promising water resources development projects;
- Recommend implementation of financial and economic policies which distribute the costs of water supplies equitably and provide incentives for the most economic use of water resources, with due consideration for the social and environmental aspects of development including coastal development;

- Contribute to the successful implementation of overall national/regional socio-economic development plans which also include the water and sea water sector;
- Contribute to the formulation of long-term water policy for the country as a whole or for the coastal region.

When developing a plan, it is important to determine appropriate solutions that will allow the available water resources to be transformed into required resources for use and services, taking into account both the quantitative and qualitative aspects of water resources.

The water resources master plan should determine the most rational solution from the point of view of economy, society, environmental and health protection. When doing this transformation, it is important to ensure water protection and provide protection against adverse impact of water (flood, erosion, etc.). It is very important to take into account all physical plans and the social development plans of the area.

The transformation which is carried out essentially refers to the transformation of certain available water quantities (Q_i), certain current quality (K_i), at a certain point (L_i) during certain time period (T_i) into demand vectors (q_j, k_j, l_j, t_j) (Figure 5.4).

This transformation, i.e. development of solutions which satisfy the demands with the available water resources can be achieved in such complex systems in several ways using several alternatives. However, it should be remembered that the main input into the hydrological system is precipitation, which is a typical stochastic phenomenon, i.e. the hydrological cycle is greatly subjected to changes, so that water resources are a function of both time and space. The same applies to planning horizon as water demand changes in time and sometimes in space so that the solution is not unique and it is difficult to find an optimal one. In order to facilitate the solution of the problem and the selection of the optimal solution the water system is divided into simple subsystems. This decomposition of the system should be carried out by taking into account the characteristics of the water resources, the purpose of the water use and the available space and time. Generally such problems can be successfully solved by applying the theory of system engineering.

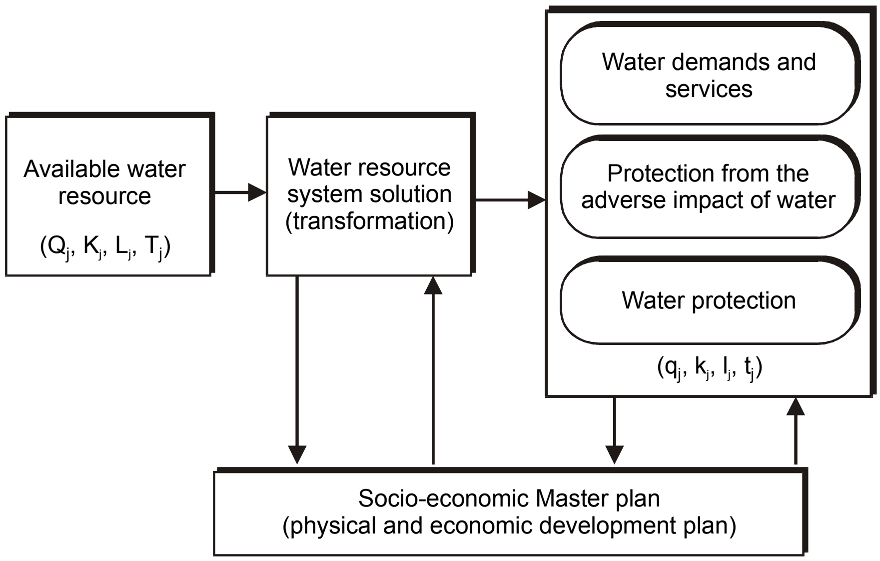

Figure 5.4: Objectives of a water resources master plan

5.3.2 Elements of a Water Resources Master Plan

Main elements of a typical water resources master plan and their purpose are:

1. *Domestic and industrial water supply:* Provision of water for domestic, industrial, commercial, municipal, and other uses.
2. *Irrigation:* Agriculture production.
3. *Flood control:* Flood damage prevention or reduction, protection of economic development, conservation storage, river regulation, recharging groundwater, water supply, development of power, and protection of life.
4. *Hydroelectric power:* Provision of power for economic development and improved living standard.
5. *Navigation:* Transportation of goods and passengers.
6. *Drainage:* Agricultural production, urban development, and protection of public health.
7. *Watershed management, soil conservation, and erosion control:* Conservation and improvement of the soil, sediment abatement, runoff retardation, forests and grassland improvement, and protection of water supply.
8. *Recreation use of water:* Increased well-being and health of the people.
9. *Aquatic ecosystem maintenance:* Improvement of habitat for fish and wildlife, reduction or prevention of fish or wildlife losses associated with development, enhancement of sports opportunities, and provision of expansion of commercial fishing.
10. *Pollution abatement:* Protection or improvement of water supplies for municipal, domestic, industrial, and agricultural use, and for aquatic life and recreation.
11. *Insect control:* Public health, protection of recreation values, and protection of forests and crops.
12. *Sediment control:* Reduction of silt load in streams, protection of reservoirs and estuaries.
13. *Salinity control:* Abatement or prevention of sea water contamination of agricultural, industrial, and municipal water supplies.
14. *Fresh and sea water aquaculture:* Production of fish in fish-breeding areas and improvement of the living standards.

Master planning must secure and maintain sustainable hydrologic systems which is complicated by the conflicts and complementary effects among the various water uses. An integrated plan requires the balanced consideration of wide range of water uses and management purposes, withdrawal uses and water problems such as flooding and pollution. This plan should present the current status of development, make an assessment of the water and other related resources, look at the needs for development and integrate these needs in accordance with available and potential resources.

National water resources master plan should generally cover a period of **at least 20 years**. These plans should be revised and completed periodically. In some countries a five-year period has been used for this purpose.

Planning is a continuous process. Therefore, master plans should be reviewed and modified as a country's ability to construct and finance projects grows, and as demands for water and land use change.

5.3.3 Four Steps of Master Planning Development

Starting from the above stated main principles (elements) of the Master Plan the planning process is essentially concentrated upon four main steps:

1. Inventory, forecast and analysis of available water resources;
2. Inventory, forecast and analysis of water demand;
3. Formulation of alternative solutions for satisfying water demands from the available water resources; and
4. The comparison and ranking of the alternative plans.

Within these steps engineering solutions make it possible to redistribute in time and space the water resources within the hydrologic cycle in order to achieve the desired effects.

Since water resources master planning is an integral part of the development planning process the goals and objectives of the latter should be identified and defined before starting the work on the Master Plan.

The planning framework is illustrated in Figure 5.5.

I. Inventory, Forecast and Analysis of Available Water Resources

This step of the planning process includes six major activities:

- inventory and analysis of hydrometeorological data;
- estimation of available groundwater and analyses of aquifer characteristics;
- surface water analysis;
- reservoirs and storages;
- unconventional sources; and
- reservoir yield optimization.

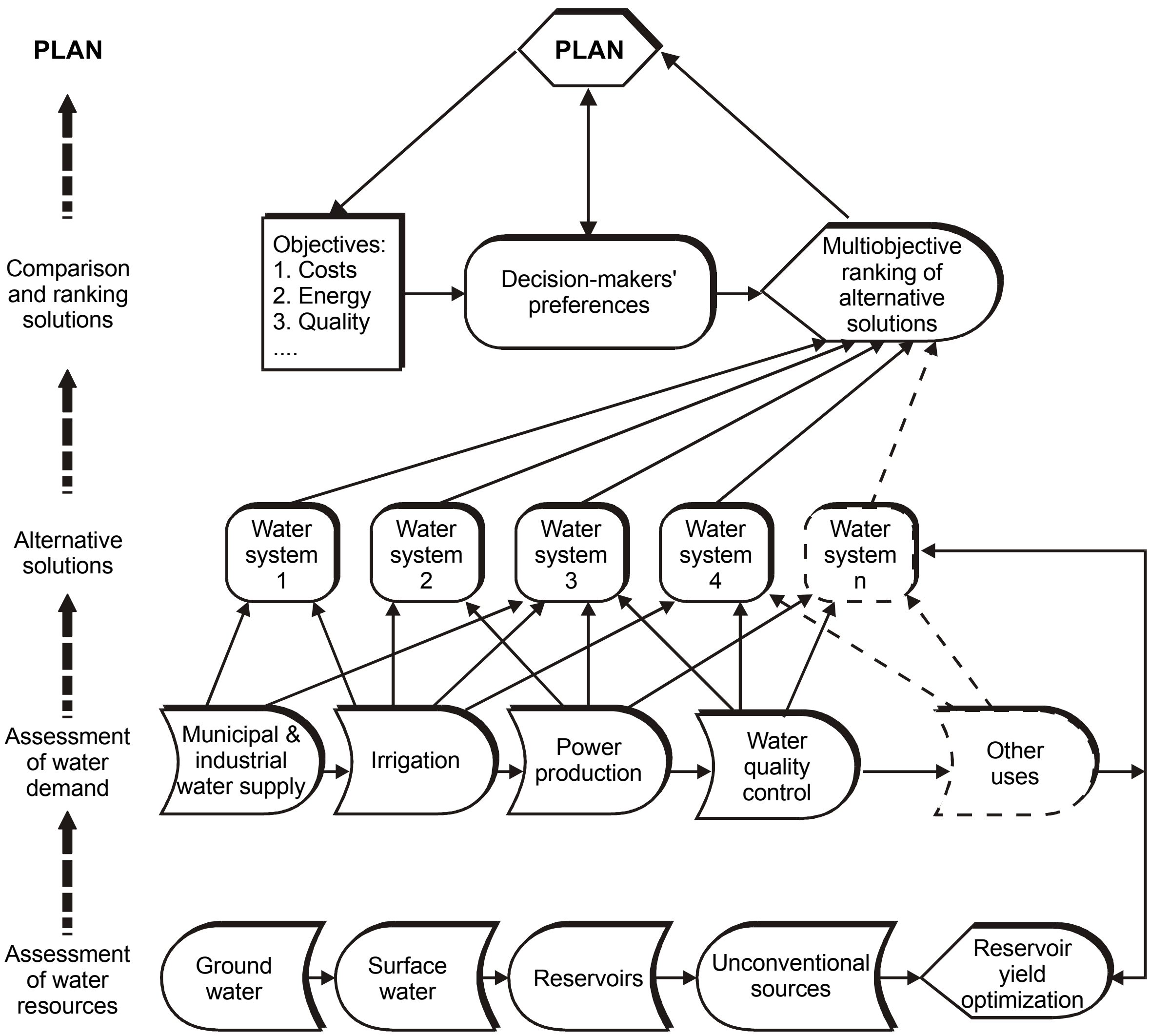

Figure 5.5: Four-step planning procedure (adapted from Simonovic, 1989)

The major purpose of this planning step is to estimate total water resources capacities and characteristics (quantity and quality of groundwater, surface water and non-conventional water sources) for every ***hydrological unit*** (physical catchment boundaries).

The assessment of water resources should ideally be carried out for river basins and their water management regions, delineation of which takes into account the natural and geographical factors, reflects administrative/territorial, economic and water management aspects and, therefore, completely encompasses the specific problems of water resource assessment for planning purposes.

The delineation of water management areas and sub-areas is implemented using topographic hydrologic maps or aerial photographs. Thus, the taxonomic units of upper level water management areas may be represented by:

- a whole basin of a major river flowing into a sea or a large lake;
- a lake basin with inflowing rivers, excluding rivers distinguished as separate areas;
- the part of a major river basin encompassed by a control point;
- a whole basin of the first order tributary;
- a large main canal diverting water from a major river, including tributaries; and
- sea coast, excluding basins of major rivers as separate areas.

Generally, water management areas are used in the framework of the national water data system which represents the basic information support for water master plan.

II. Inventory, Forecast and Analysis of Water Demand

Categories of water demand which belong to the categories of withdrawal type include public uses (domestic, commercial, industrial, public), rural (domestic, livestock), irrigation, and self supplied industrial (cooling, processing, thermoelectric and hydroelectric power). However, there are non-withdrawal uses of water (services) such as quality control by dilution, recreation, navigation, aquatic ecosystem maintenance, pollution abatement, insect control, sediment control, flood control and others.

The major purpose of this planning step is to estimate total water demand (use and services) for every ***territorial unit*** because development plans are made according the administrative division of the country.

This step should start with the analysis of water resources use by economic sectors: (a) Urban and municipal water supply; (b) Tourist areas water supply; (c) Rural water supply; (d) Agriculture; (e) Industry; (f) Electric power; (g) Recreation; (h) Fisheries; (i) Inland navigation. The summary data are to be given on surface and ground water resources use in all economy sectors by river basin and water management regions based on the national water data system. The analysis is to be conducted for the base period.

The initial data for preparation of this step of master plans are:

- concept of development and allocation of national economy sectors;
- plans for social and economic development;
- sectoral institutions (water uses) data on manufacturing major types of production, their demands on water use and disposal; and
- land and other natural resources development and water demands.

The assessment of water demand projections should necessarily include the analysis of aggregate water withdrawals from surface and ground sources, the aggregate volumes of waste water and the return of drainage effluent into water bodies. The amount of downstream water release should be determined on the basis of all downstream requirements and minimum discharges needed for sanitation and environment purposes. The water budget should be prepared for all planning time horizons, both short-term and long-term, based on available water supply, water demands and required flow release for each time horizon.

III/1. Formulating Alternative Solutions for Satisfying Water Demands from Available Water Resources

At this step, using the results of the previous two steps, it is necessary to make the water shortage-surplus map for each region under consideration.

The balance between the available resources and demand for the so-called "***water system***" has to be developed. Water systems represent the territorial units inside which all of the demands can be satisfied with available resources. These systems are determined by aggregating the initial territorial units for which the demands and the available water resources (including water transfer) are defined, up to a level when the demands can be satisfied by available water.

The major effort at this step of planning is to create the number of alternative technical solutions for satisfying water demands from the available water resources inside every "water system". The alternative technical solutions are made by engineers using such "typical structures" as water wells, pump stations, dams, water intake structures, water treatment plant, reservoirs, and so on, relating the cost of every structure type to flow capacity. The technical design will be considered on a more detailed planning level. The results are alternatives for each water system. This water system must be fully harmonized adjusted with existing water systems and solutions.

The alternative solutions should include the use of non-conventional water sources (desalinization, wastewater reuse, storm water, and other), and solutions such as: tankers, long distant transport of water, etc. Element of this step is development of water conservation measures and plans. The terms of setting up of water conservation projects should be defined and their estimation capital costs should be determined.

These water systems are neither dependent on administrative boundaries nor on the physical catchment boundaries. Now they are planning units applicable only inside the planning region and considering time horizon.

III/2. Protection from Adverse Impact of Water

Water resources in a hydrological cycle in a specific area have adverse effects such as surface floods, underground floods and land erosion. In the Mediterranean area floods can be particularly hazardous since they occur seldom, are of short duration and are very intensive. Erosion is the most significant among the adverse effects with long-term consequences, particularly in agricultural areas in the Mediterranean region. Consequently, the master plan should include solutions for the reduction of damage from floods and erosion as an integral part of other solutions. In the coastal areas, flooding influences by sea (storm surges) should be included.

III/3. Water Protection

An integral part of the Master Plan is the protection of water from pollution and the maintenance and enhancement of fish and wildlife habitat and biological diverse ecosystem, in other words environmental consequences of water development. Three types of undesirable environmental consequences of water development are particularly important:

- creation of favorable habitats for parasitic and water-borne diseases by construction of poorly conceived reservoirs and irrigation systems;
- adverse impacts on ecological systems, caused by erosion, pollution, and changes in stream regimes; and
- stream and reservoir sedimentation, soil salinization, and waterlogging.

The release for environmental purposes should ensure sufficient dilution of pollutants in the river and estuaries to ensure the preservation of wildlife. In addition to maintaining the minimum flow, the release for environmental purposes should ensure regular river channel flushing during floods.

The environmental consequences can be assessed in a multiple-objective planning approach which represents a true synthesis of the environmental and social fairness and economic values. A practical and common alternative is the environmental impact assessment approach. Such assessment should begin at the earliest stage of project planning and continue to the final selection of a project. Means for avoiding or reducing adverse environmental effects should be included in the Master Plan.

IV. Comparison and Ranking of Alternative Solutions

The general economic approach is to use available scarce water resources to improve resultant human welfare under sustainable environmental conditions. This means that alternative configurations of the use of water resources among types of use, over space, and through time must be compared in terms of the net benefits that the resources will generate, the benefits being interpreted in the broadest possible terms. The real costs of any particular configuration of resource use should include the benefits that could have been realized through other alternatives of resource use, and which have been foregone.

A comprehensive plan, such as Water Resources Master Plan, needs a multi-objective analysis since such planning involves numerous conflicting goals and objectives especially regarding sustainable approach to the management of natural resources. Planning over a 20-year horizon is a complex issue involving different interests: economic, environmental, social, political, health, etc. Since most objectives are not in general quantifiable in monetary or other units it is necessary to use a multi-objective analysis.

The set of objectives which will be used is dependent on particular problem characteristics. The following objectives can be considered:

- minimization of alternative total costs;
- minimization of negative consequences of water development;
- minimization of energy consumption;
- maximization of positive effects of alternative plans on water quality;
- maximization of the national interests;
- maximization of regional (communities) interests;
- maximization of positive environmental effects of alternatives plans;
- maximization of the system reliability;
- maximization of system sustainability, and others.

By applying proper methods of multicriterial analysis it is possible to rank alternative solutions and present them to the decision makers in accordance with the characteristics of each alternative and selected criteria.

Plan presentation

The quality of the plan is influenced, among others, by two factors: participation of all interested parties in the course of its development and the technical and visual presentation of the completed plan. The Master Plan should, within its output, contain a series of data and information, including numerous maps such as: climatological maps, geological map, hydrogeological map, hydrological map, vulnerability map, land use map, water system maps, ground water classification map, surface water classification map, maps of available water from the aquifer systems, water demand maps, water shortage-surplus map, etc. These data must be presented clear and concise as possible so that information can also be easily used by non-water specialists. The plan should not only comply with international standards but should also satisfy, to the greatest extent, the requirements imposed by international, national and local organizations and institutions, which can be achieved only by a continual cooperation between all interested parties and not exclusively by direct contacts with one client.

<u>Summary</u>

The planning of complex water resources systems is a very difficult and responsible task. It requires careful and comprehensive study and analysis of all aspects of this problem. To develop high quality master plans for the development and management of water-resources systems, it is important to:

- study carefully and define the objectives that need to be realized by planning;
- assess carefully and comprehensively available water resources, their capacities and quality;
- analyze carefully and comprehensively and define the water demand and need for water protection and protection against the adverse impact of water and water development, all based

on the physical and economic development plans made for the same water resources planning time period;

- analyze all possible alternative solutions that are important for the management and use of water resources including the protection of water and adverse effects of water and water development; and
- carefully select the most suitable realistic solution considering local, regional, national and other common interests of all users.

With a limited supply of water and rapidly increased demands for water and its services in the Mediterranean region, sustainability is becoming a difficult goal to achieve. Integrated water resources management, which means making better use of the water resources to meet current and future demands, is a good answer to this problem, while Water Resources Master Plan is a prerequisite for such management of water resources.

5.4 Techniques and Methods of Coastal Water Resources Management

The nature of the coastal water resources development, the social and environmental interactions of sectoral activities, as well as complex management and planning requirements imposed on decision makers and professionals involved in Integrated Management of Coastal Water Resources (IMCWR) require the employment of numerous specific analytical tools and techniques. The following broad classes of tools and techniques can be used in IMCWR:

1. **Forecasting and simulation tools**
   - System analysis and simulation modeling;
   - Water supply and demand forecasting and simulation;
   - Water resources quantity and quality forecasting and simulation;
   - Network modeling;
   - Financial forecasting, etc.
2. **Impact assessment tools**
   - Environmental impact assessment;
   - Social impact assessment;
   - Risk assessment;
   - Impacts of expected climate change;
   - Screening and feasibility analysis, etc.
3. **Decision-making tools**
   - Optimization modeling;
   - Multiobjective optimization modeling;
   - Decision analysis and computer-facilitated decision analysis;
   - Risk analysis and risk mitigation analysis, etc.
4. **Evaluation tools**
   - Economic evaluation;
   - Benefit-cost and cost-effectiveness analysis;
   - Qualitative evaluation systems;
   - Process evaluation methods;
   - Performance benchmark, etc.
5. **Implementation tools**
   - Regulatory and economic;
   - Social acceptability measurements;
   - Conflict resolution techniques;
   - Negotiations and voluntary agreement;
   - Survey, focus groups, and other participant methods;
   - Customer or rate-payer impact analysis, etc.

Box 11

Contents of the master water plans

1. **Executive summary**
2. **Need, scope, and objective of the plan**
3. **General and historical background**

Status of development

- Location, physical features
- Social development, demographics, urban centers, etc.
- Economic conditions, employment, food and agriculture, industry, tourism, transport, public finance, etc.
- Land use

Existing water resources development

- Historical water supply and demand
- Irrigation
- Drainage
- Water pollution control and management
- Flood control and management
- Wastewater facilities
- Navigation, hydroelectric power, fisheries, recreation, etc.
- Ecology and special protected areas
- Water legislation
- Institutional framework, etc.

4. **Assessment of water related resources**

- Geography
- Climate and meteorology (rainfall, temperature, evaporation, wind, sunshine, etc.)
- Geology and hydrogeology
- Soil characteristics (soil erosion problems, etc.)
- Land resources (present cultivated land, forest land, crop pattern, agricultural inputs, etc.)
- Mineral resources
- Energy resources (fossil fuel, imported fuel, etc.)
- Fishery resources (fish culture, aquaculture, fish production, etc.)
- Environmental characteristics and natural ecosystem
- Human resources (extent and distribution, employment opportunity, etc.)

5. **Assessment of water resources**

- Surface water resources (mean flow, low flows, flood flows, sediment load, present utilization, etc.)
- Groundwater resources (perched aquifer, aquifers in contact with sea water, location, safe yields, present use, etc.)
- Estuary, coastal brackish and sea water resources
- Water quality (present state and waste discharge, water pollution regulations, etc.)
- Reservoir site (location, characteristics, volume, etc.)
- Non-conventional water resources (treated wastewater, desalinization, etc.)

6. **Needs for development**

- National social and economic scenarios (population growth and distribution, agricultural-industrial production, tourism development, transport, financial resources for development, human resources, etc.)
- Domestic and industrial water supply (urban expansion and water demand, industrial water demand, tourism demand, rural water demand, variation of demand, etc.)
- Food and agriculture (food supply and demand, increase of irrigation area, improvement of agricultural techniques, water demand, etc.)
- Electric power (demand, alternative sources, water demand, etc.)
- Inland and estuary navigation (growth, alternatives, etc.)
- Flood management (past flood damages, flood plan area, measures, etc.)
- Pollution control (sources and quality of waste discharge, treatment of waste water, regulations, etc.)
- Fisheries (demand, river and reservoir areas for fish production, etc.)
- Tourism, sport and recreation
- Environment and special protected areas, etc.
- Administrative authorities
- Summary of existing and planned development

7. **Water demand assessment (water use by principal category)**

Infrastructure

- Drinking water
- Domestic use
- Public use in settlements
- Navigation
- Waste disposal
- Recreation
- Aesthetic enjoyment, etc.

Agriculture, forestry and aquaculture

- Rain-fed agriculture

Contents of the master water plans (continued)

- Livestock
- Fish and wildlife and ecosystem maintenance
- Forestry
- Irrigation
- Swamp and wetland habitat
- Waste disposal
- Utilization of estuaries
- Fish farming
- Soil conservation, etc.

Industry

- Hydropower
- Steam power
- Mining
- Cooling
- Processing
- Hydraulic transport
- Waste disposal, etc.

8. Statement of conditions

- Description of water delivery system (location, age, cost, physical conditions of the supply and pumping facilities, transmission facilities, treatment facilities, storage facilities, etc.)
- Description of waster water infrastructure system
- Description of other water infrastructure systems
- Description of rate structure
- Water quantity issues (supply, demand, droughts, conservation, etc.)
- Water quality issues (monitoring, data bank, contamination, etc.)
- Anticipated water infrastructure and other water related needs (replacement, improvements, additions to capacity to meet demand growth, etc.)

9. Description and prescreening of alternatives to meet development needs (structural and non-structural)

- Water exploitation (water supply in settlements, industry, agriculture, hydro-energy, navigation, tourism, etc.)
- Storages
- Protection from water
- Sewerage systems
- Protection of water resources
- Synthesis of technical, economical, environmental, and other characteristics of the proposed projects

10. Potential projects

- Water studies
- Engineering, geology and cost estimation, coordination and functions in a basin plan, etc.
- Economic evaluation
- Environmental impact assessment, etc.

11. Formulation of a master water plan

- Establishing of long-term objectives and development targets (social and economic scenario, constraints, food production, industrial growth, public health improvement, protection of environment, employment, etc.)
- Criteria for plan formulation, etc.

12. Evaluation of alternatives

- Analysis of alternatives
- Selection of alternatives for the plan
- Impact analysis of selected alternatives (economic, environmental, risk, social and cultural, regulatory)
- Organization and management of water resources
- Legislation and other administrative measures
- Water conservation program
- Proposal for monitoring
- Proposal for future study
- Proposal for the future projects
- Coordination and consistency

13. Implementation

- Planned implementation
- Administration and financing
- Public participation
- Complementary program and efforts

Integrated management of coastal water resources encourages new institution roles and increasing numbers of analytical tools and techniques, both qualitative and quantitative, to help guide water resources planners in applying Integrated Approach Principles. Most of the tools and techniques are based on standard methodologies which can be handled by national expertise available in many developing countries. Some tools and techniques have already been presented in some sections (Chapter 4, EIA), while only the more recent ones and those of a particular common interest for water resources management will be presented in more detail in the text that follows.

5.4.1 System Approach

Water resources systems are complex in their physical, biological and institutional aspects but are even more complex in their decision structure. Most of these are accomplished in a political context and in a multi-layered structure of delegated, implied and reserved decision authority. This means there will be a broad spectrum of the goals and an even more divergent set of views as to what does and does not result in goal enhancement.

The objective of management is to apply resources in a manner to achieve the best possible results. This requires many activities, including forecasting, planning, programming, budgeting, coordination, monitoring and operation.

The amount of data and information that water managers have available to them is often staggering, both in quantity and diversity. There are critical questions concerning which data are important for the management problem at hand, and how should they be processed, organized, analyzed and what kind and amount of additional information is needed.

Obviously if we want to make better decisions we will have to move in the direction of creating and using more effective plan-forging tools for managing water resources. It is possible because: a) the modern digital computers are able to organize and process enormous quantities of data rapidly, accurately, and efficiently; b) the increasingly widespread availability of computers at relatively low cost; c) the development of sophisticated mathematical rules or algorithms that enable the rapid and efficient representation and analysis of complex information on a computer.

The approach to efficient decision making is system analysis. It is *a rational approach to arriving at management decisions for a particular system, based on the systematic and efficient organization and analysis of relevant information*. This *rational approach* is carried out through a sequence of steps or procedures referred to as the *system approach*. These steps include:

1. Defining the management problem,
2. Identifying the working system and gathering relevant data,
3. Defining specific goals and objectives,
4. Defining quantitative measures to evaluate how well an alternative solution to the management problem meets the objectives,
5. Generating feasible alternatives that satisfy physical, social, political, economic, and moral constraints on the system and its management,
6. Evaluating and selecting the best alternatives possible, with the tools, manpower, time, budget, and computer power available,
7. Review, updating and feedback to insure the original objectives are being met and to incorporate new information.

Mathematical modeling is becoming an increasingly significant part of systems engineering studies. The two most general types of mathematical models used in system approach are:

a) Simulation - descriptive;

b) Optimization - descriptive and prescriptive.

Simulation techniques

The simulation model is used to predict the outputs of various designs and operational policies (Figure 5.6). The function of engineering is to *improve* the output and the feedback loop represents the process of the engineering altering of controllable variables in the system to improve the output.

The advantage of the simulation model is that the user does not have to quantify his judgment of the output to decide on changes in the controllable variables. He must only decide if he judges the output to be good or bad, which is easy if the user is familiar with the real system.

The uses of simulation models are to:

- predict impacts;
- identify data needs;
- store data;
- identify physical and Institutional relationships;
- needing research;
- identify system objective; and
- training mechanism.

There are various types of mathematical simulation models that have been used in water resources management such as: steady and unsteady flow models, quantity-quality models, hydrological models, ecological models, etc.

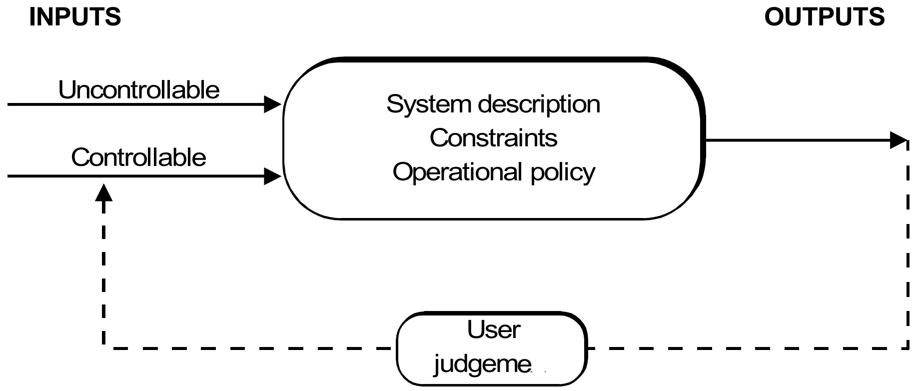

Figure 5.6: The graphical presentation of the simulation process

<u>Optimization techniques</u>

Figure 5.7. displays the optimization process. Notice that this is the same as the simulation process with the user judgment being replaced by a mathematical description of the judgment process, including an evaluation of performance and a performance structure for selecting a better solution or situation.

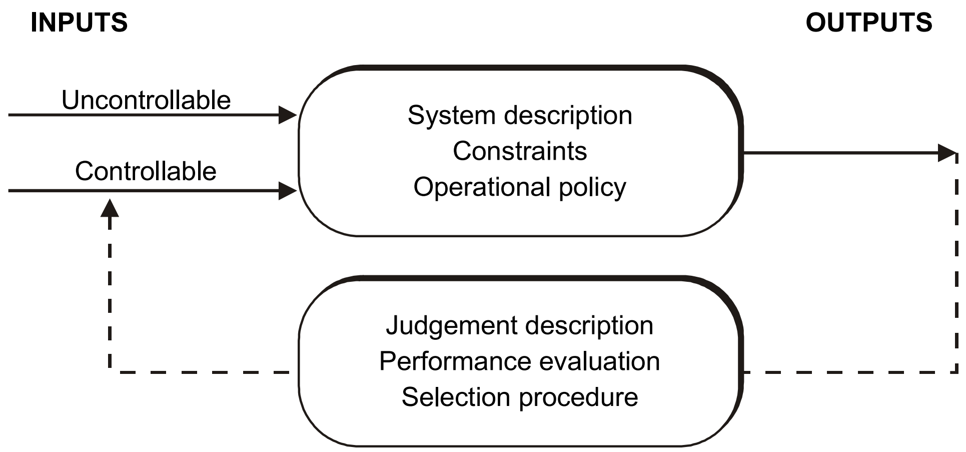

Figure 5.7: The graphical presentation of the optimization process

Every optimization contains a simulation model within it. The output of optimization models is not as easy to evaluate since it often simplifies the decision makers preferences and further, mathematical models can give their own unique characteristics to the results. The use of optimization models can help to:

- identify best actions;
- identify system objectives;
- identify preferences between objectives; and
- identify impacts of system constrains.

There are various types of mathematical optimization techniques that have been used in water resources management such as: linear programming, non-linear programming, dynamic programming, stochastic optimization, deterministic optimization, etc.

An often asked question is: which method is best? The answer is that the best method for any problem depends upon the nature of the problem. In general no one model fits all situations.

5.4.2 GIS in Water Resources Management

In the projects of water resources management, it is essential to collect, process and analyze the data for the study area on topography, hydrology, hydrogeology, water quality, ecology, land use, etc.

GIS is the most appropriate tool for these analyses, and it is widely being used in studies of water resources. It can be used in any water resources management-related activity, such as projects for development, management and use of water resources. It can be applied in the analysis of the problem, during the preparation of the project, and in the management. Once established, during its use the GIS data base is enlarged and adjusted to satisfy new demands.

Some of the activities in the water resources management in which the GIS can be successfully applied are:

- graphical presentation of the basic data layers necessary for the management;
- modeling (ground-water models, surface-water models, watershed models, etc.);
- display and analysis of stream networks, stream ecology, limnology, urban hydrology, water quality, water use, erosion and sedimentation processes, etc.

5.4.3 Computer-based Decision Support System for Water Resources Management

Computerized decision support systems are interactive computer-based systems that aid decision makers in the process of transforming data into necessary information to solve unstructured problems. The main components of the DSS are: data subsystem, model subsystem, and dialog subsystem, as illustrated on Figure 5.8.

The data subsystem is directed to the acquisition, storage, management, retrieval and processing of data and it will be subdivided into static and dynamic database. The static data base will include the physical, economic, demographic, environmental, land use, as well as other pertinent features of the system. The dynamic data base on the other hand, includes time series information such as hydrology, wastewater flow, wastewater quality, sea water quality and climate data sensing.

The model subsystem is used for analysis, predicting and decision guidance. This subsystem will include a variety of models ranging from simulation to optimization models, which may have various levels of sophistication.

The dialog subsystem, is the component of DSS which provides the essential human-machine interface. Dramatic advances in software and hardware technology have provided the means for the development of user friendly interfaces, including high resolution color graphic, animation and multimedia presentation.

Experience showed that decision support systems have been used in many areas of water resources management to the point that they have become an indispensable part of decision making process.

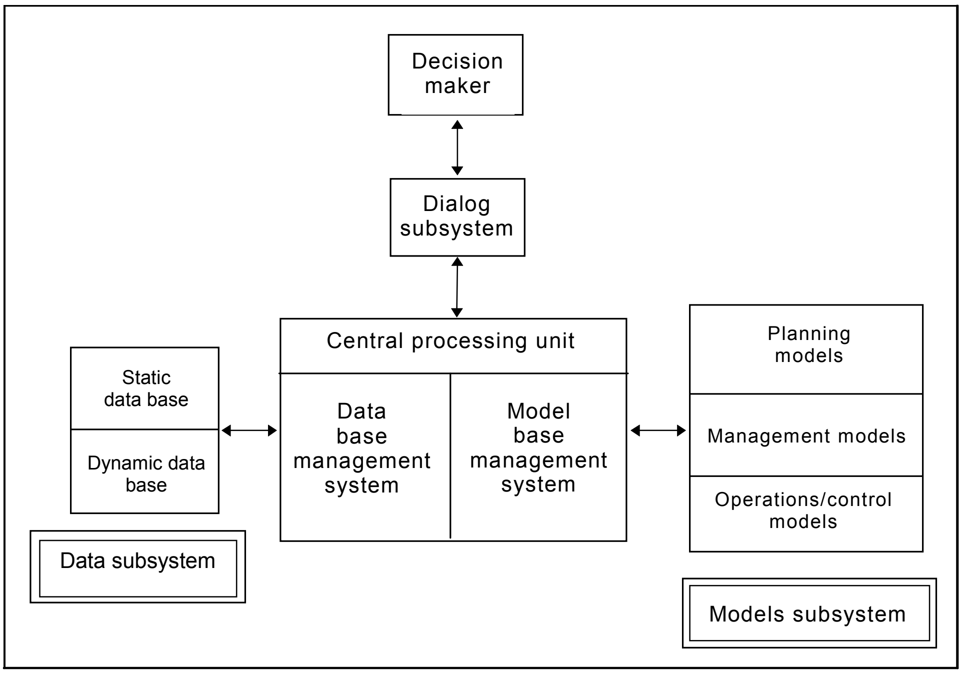

Figure 5.8: Basic components of a decision support system

5.5 Data Management

5.5.1 Data Requirements

5.5.1.1 Introduction

The nature and variety of the users of water data and information indicate the value of these data and their importance to a region's environment and economy. The type and length of record of data needed to support effective assessments of water resources are often much less than the requirements for all study topics. Normally, the institution responsible for the collection of data has a specified general plan for data collection upon which most of water resource development projects refer to and utilize the information for specific schemes.

Such data that are needed for planning, design, construction, operation and management of water resource projects in the coastal areas are the concern of the responsible institutions and are, normally, defined well in advance. These hydrological and meteorological data are obtained from networks and form the main basis for hydrological computations for water projects. The quality of computations, interpretation of data and design depend on the availability of such data, their resolution in time and space and their accuracy. Data stored in computerized Data Banks facilitate the speedy access to them and the use of various analytic techniques for their interpretation, otherwise a well kept record in a form that can be made available could be equally useful.

The hydrological data that are needed for the various stages of a water resource system or for the management and operation of such system are in most cases common to all and are shown on the Table 5.1. Nevertheless, particular information is usually required for the planning, design and construction and for the operation and management which are highlighted in the text that follows.

5.5.1.2 Data for Planning

The planning of water resource projects is based on concepts, goals and objectives of the sponsoring organization, government or local government, and many times at the request of the local population. These initial ideas need to be based on information that is complete and sufficiently reliable.

The planning stage is usually considered as developing and flexible, for this reason at its initial stage it can be based on provisional data that may have to be further examined and screened for reliability. The plans may have to be adjusted as information is reviewed and assessed. During the planning stage a broad range of data is required covering all aspects that come into stream with the plan being considered. For this reason the planning may rely partially on indirect data, synthesis of information and reasonable professional judgment. The additional data and information required for finalizing the planning of a scheme should be identified as early as possible to enable the verification of the plan before detailed investigations are carried out.

The following should be considered when a water resource project is being planned:

- equal attention should be paid to all the parts of the plan until sufficient information is available for sound decisions;
- the available data should be assessed for their reasonableness and accuracy before relying the planning on them;
- due regard for possible long-term consequences should be paid rather than on short-term benefits;
- provide sufficient resources to the assessment effort in support of the planning stage.

Inventory of water available for various uses consists of three major components:

1. Collection of hydrological data on water cycle components at a number of points over the assessment area.
2. Identification of physiographic characteristics of the territory that determine the space and time variations of the water cycle components (climate, topography, soils, surface, geology, land-use, land-cover including man-made changes, vegetation, etc.)
3. Techniques of relating the hydrological data to the physiographic data to obtain information on water resources characteristics at any point of the assessment area.

The quality of the analysis is directly dependent on the quality and quantity of data, so that a successful analysis requires:

1. Common standards for water resources assessment; and
2. Unified data collection and measurement systems to record hydrological, water use, and water-related data.

5.5.1.3 Data for Design and Construction

For the design and construction of a water resource project the data and information required become specific and narrower in scope. At the same time the degree of detail and reliability and accuracy increases considerably. The scope and detail of the data collection are controlled by the physical setting of the planned development, the type of development planned and the adequacy of the available information. The data collection needs should emphasize:

- site specific geo-hydrologic data needed for the design of the scheme;
- hydrologic, hydrogeologic and water quality data needed for the scheme construction; and
- continuation of the collection of data of broader nature needed to fill major information gaps in the general water resource assessment.

5.5.1.4 Data for Operation and Management

The operation and management of a project takes place over an extended period of time, the life of the project. Time is usually available to collect enough data to guide long-term management. Although this is true, the correct practice would be to be in a position to formulate the operation and management of the project well before this is implemented. This means that sufficient information should be available to enable such a formulation of operation rules. The operation and management of a project is an essential component of the planning and design stage and can not be left for after its implementation.

For the purpose of establishing rules of operation and management, data should be selectively collected to discern and monitor the hydrologic and water-quality effects that the development may have in modifying the environment. These impact data then can be compared and evaluated against background, or pre-development data. Such comparative studies are essential in recognizing developing problems that accompany most major development projects and could help in taking the correct action for resolving them. Adjustment to the operation and management could be made along with the monitored developing conditions in the area, the use of water and hydrologic conditions.

5.5.1.5 Hydrological Information Required for Water Resources Projects

Table 5.1 presents a general list of the type of hydrological information that is usually required for water resources projects adjusted for the coastal areas.

Hydrological data required refer to stage, discharge and sediment data although quality data are quite useful in most applications.

The meteorological data which are needed for most water projects refer to rainfall data over a long period and are well distributed in the region; these are used for extreme floods estimation, for rainfall - runoff models, for filling gaps in the runoff data series and evaporation, radiation, humidity, wind direction and speed, and snow.

For increased accuracy from hydrologic computations it is generally desirable to have continuous data records available. In many cases though, daily, weekly or monthly data are available for specific points and for particular time periods and these must be used in the best possible way. For the computation of the required storage capacity of a water supply reservoir, for example, monthly values are sufficient.

A complete list of required basic data is impossible to compile because of the variety of water resources problems and conditions in each coastal area.

Table 5.1: Hydrological data that are needed for the water resources project

	Water levels			River flow			Sediment			Water quality		
water project	time series	max	min	time series	max	min	time series	max	min	time series	max	min
water redistribution *diversions, intake, canal*	M	M	M	H	H	H	H	M	M	H	M	M
water redistribution in time (*reservoirs*)	M	M	M	H	H	H	H	M	M	H	M	M
energy production *hydropower etc.*	H	M	M	H	M	H	H	M	M	M	M	M
water confiners *dams, floodbanks*	H	H	M	M	H	M	M	M	M	M	M	M
water relievers *spillways*	M	H	M	H	H		M			M		
quality improvement *water, sewage treatm.*				H	M	H	M	M	M	H	H	H
zoning *floodplain, scenic river*	H	H	H	M	H	M	M					
sea intrusion control *artificial recharge*	H	H	H	H	M	H				H	H	H
groundwater scheme *wellfield, pumping*	H	H	H	H	M	H				H	H	H
insurance *(flood, water quality damage)*		H	H		H	H				H	H	
flow / level forecasts *flood control, reservoir*	H	H	H	H	H	H						
standards/legislation *use, water quality*	M	H	H	M	H	H				H	H	H

H = high level of priority M = medium level of priority
* water quality parameters depend on the project

5.5.2 Data Acquisition, Processing, Storage and Retrieval

5.5.2.1 General

The integrated development of the water resources of a coastal area involves a multiplicity of studies concerned with both the physical and socio-economic environment of man and the particular needs of the area as they have developed for the Mediterranean coastal zone.

This data acquisition, processing, storage and retrieval concerned mainly with the hydrologic studies required in the preparation of an area-wide plan for integrated development of water resources is presented here. Although hydrologic studies are of fundamental importance for preparation of such a plan, the overall success of the planning effort depends upon critical analysis of all alternative means of promoting social welfare and economic growth in the coastal area.

The development of water resources cannot be considered an end in itself, but rather as a contribution to the general progress as envisioned by the local authorities and the national government.

The following specification, based on the publication "Integrated river basin development" (United Nations, 1970) and adjusted for coastal areas, serves primarily as an illustrative example and also as a checklist of the major steps in hydrologic investigations for coastal area planning concerning integrated development of water resources:

- Appraise the adequacy of available hydrometeorological data (e.g. precipitation, evaporation, evapotranspiration, air temperature) and hydrologic data (e.g. flow time series, flood hydrographs, aquifer recharge characteristics, quality parameters, sediment transport parameters).
- Select key control points in the river system taking into consideration location of stream-gauging stations, major water users, present and planned flow control structures. Define location of groundwater supply sources.
- Determine what additional data are required with consideration given to the purpose of the investigations and the methods which are to be used for subsequent water management analysis (e.g., classical balances, simulation, optimization).
- Devise methods, standards, and schedules for acquiring additional data (e.g., extension of flow records, application of rainfall-runoff models, regional analysis).
- Arrange for acquisition of additional data.
- Analyze and organize the data for studying problems of
  - municipal, industrial, and agricultural water supply;
  - flood control;
  - water quality control;
  - salt/fresh water interface;
  - hydroelectric power generation;
  - inland navigation;
  - recreational use of water; and
  - nature conservation.
- Estimate annual flow variability and the characteristics of inter-annual flow distribution.
- Estimate the amount of water which can be withdrawn from groundwater resources without producing undesired results (i.e., sea intrusion or intrusion of other water of inferior quality).
- Set up and maintain monitoring of a borehole observation network for ground water levels and quality.
- Evaluate the ground water abstraction on a monthly and/or annual basis (on the basis of water meters, land use and type of crop along with irrigation methods used).
- Evaluate annual water balance of the main aquifers and check against water levels, quality estimated extraction.
- Estimate the minimum river flow requirement for maintaining replenishment of ground water.

Box 12

General list of required basic data for water resources projects

Maps

- Administrative;
- Topographic;
- Geologic (including structure, stratigraphy, lithology);
- Hydrologic (including location of wells, monitoring wells, water- table and piezometric contours, depth to water, depth to base of aquifer, quality of water recharge, discharge and contributing areas, groundwater wells iso-yield contours, iso-transmissivity and zoning of equal specific yield values);
- Vegetative cover and land use;
- Soils;
- Isohyetal;
- Hydrogeologic;
- Surface drainage.

Groundwater data

- Delineation of aquifers, their geometry and lithology with sections;
- Type of aquifers, such as unconfined, artesian, or perched;
- Thickness, depths and designation;
- Boundaries;
- Transmissivity and permeability;
- Specific retention;
- Discharge and recharge;
- Ground and surface water relationships;
- Aquifer models;
- Location, depth, diameter, types of wells, and logs;
- Static and pumping water levels, hydrographs, specific capacity, quality of water;
- Present and projected groundwater development and use;
- Corrosion, incrustation, well interference, and similar operation and maintenance problems;
- Location, type, geologic setting, and hydrographs of springs;
- Observation well networks;
- Water sampling sites;
- Groundwater extraction spatially and temporally distributed.

Surface water data

- Recording stations;
- Runoff distribution, reservoir capacities, inflow and outflow data;
- Use of water per type of consumption (e.g., municipal, irrigation, industrial, etc.) spatially and temporally distributed;
- Quality data;
- Sediment data both as suspended and bedload;
- Return flows, section gain or loss;
- Flood peaks, low flows, drought flows.

Climatic data

- Precipitation;
- Temperature;
- Evapotranspiration;
- Wind velocities, directions, and intensities.

Consumptive use data

- Area covered and types of crops;
- Consumptive use for each type of crop;
- Irrigation method used and efficiency of irrigation;
- Municipalities, sources of water supply, population, rates of consumption;
- Industries and rates of water use;
- Other uses of water (e.g., recreational, releases for environmental reasons, etc.).

- Consider the re-use of treated sewage effluent (for artificial aquifer recharge, irrigation).
- Consider groundwater conservation measures and promote regulations on the use of groundwater (licensing, monitoring of pumping permits, etc.).
- Estimate the minimum flow requirements in the control profiles (i.e., flow which must be maintained because of aesthetic, scenic, sanitary, and/or biological reasons).
- Determine available water resources and analyze potential peak storage alternatives.
- Consider conjunctive use of surface water and groundwater to increase water availability (artificial groundwater recharge during wet periods, increased pumping during droughts)
- Estimate flood characteristics for selected profiles (e.g., peak flow frequency curves for natural and regulated flow, design flood flows, channel routing criteria).
- Develop flood control alternatives (e.g., storage, flow retardation measures, levees, floodwalls, channel improvements, floodways).
- Estimate low-flow characteristics for selected profiles (e.g., minimum flow frequency curves for natural and regulated flow, design low flows).
- Develop water quality control alternatives (e.g., low flow augmentation)
- Estimate hydrologic characteristics for hydroelectric power generation studies (Develop hydroelectric power generation alternatives).
- Evaluate feasibility and costing of desalinization plants for fresh water supply.
- Estimate hydrologic characteristics for inland navigation studies (e.g., depth, width, current velocity).
- Develop navigation development alternatives.
- Estimate hydrologic characteristics for recreational studies (e.g., depth, area of water surface, water quality).
- Develop alternatives for recreational use of water.
- Estimate hydrologic characteristics for fish and wildlife studies (e.g., water temperature, water quality, required ground water discharge).
- Develop alternatives of habitat improvements for fish and wildlife.
- Analyze the present and potential institutional arrangements for water resources management.
- Evaluate all alternatives and prepare a comprehensive long-term plan for the integrated development of water resources in the coastal area, including an assessment of impacts of projects on the environment and hydrologic regime.

The data requirements and their acquisition, processing, storage and retrieval on selected information is presented in the text that follows.

5.5.2.2 Water Use and Water Demand

The water use data in the basin or coastal area are a basic requirement for monitoring the water balance of the area. In these data also, the evaluations for current and future demand will be based. This includes consumption rates, trends and variations according to the user, the consumptive use by various crops according to the soil type and irrigation method employed. The water use data are usually used together with the water resources of the area to be developed as part of the overall feasibility of a water project.

Consumptive use by the various crops in an agricultural area can be theoretically determined using empirical formulas on the basis of evapotranspiration and other meteorological data. The total water amounts used per crop per unit area for various irrigation efficiencies can be evaluated by annual land use questionnaires, electricity consumption of pumps, etc. The value of these estimates depends on the effort put on these surveys and can only be used as indicative.

Water consumption rates for domestic supply are usually obtained by institutions responsible for the domestic water distribution. These will have to be adjusted for losses in the distribution system if they are to be used for new areas.

Diversions and spate irrigation practice is usually more difficult to evaluate since this is usually done on a non-regulated basis. Other types of use like ground water extraction, reservoir water use, recreational, thermoelectric, etc., all form part of the water use in the area and as such should be monitored, estimated and be available for the water resources management in the area.

Normally the agency in charge of allocating water resources for a particular use should maintain a record of the use made. The data could be stored in computerized data banks and be readily available for use. Annual reports usually refer to uses of water under various sectors.

5.5.2.3 Surface Water

The hydrologic studies of surface water runoff characteristics are based on various types of observations usually obtained from the hydrometric network of permanent and continuously recording streamflow weirs and temporary stream gauging at selected points. Information gathered through this hydrometric network provide the basis for studies on the basin's water resource potential.

The information collected through a general hydrometric network should include:

- basic elements of streamflow stage and discharge with special emphasis on extremes;
- sediment transport (suspended and bed load); and
- water quality and its variation according to flow, reach of channel and upstream use.

A data base to provide permanent storage and easy retrieval of these records must be established so that the information can be readily accessed for further analysis and use for the evaluation of water projects. A computerized data base provides the best means for storage and retrieval of these data and the best type of data base to suit the needs of the region should be selected and implemented.

5.5.2.4 Groundwater Data

Groundwater is an integral part of the water resources of an area. This is of particular importance to the coastal areas of the Mediterranean region since the first development in these areas has quite often been based and continues to be on locally available groundwater.

Besides the standard aquifer studies regarding its geometry, properties, lithology and replenishment, continuous data gathered from permanently established borehole networks, allow the study of the performance of the aquifer, its water balance, its sea-fresh water interface position, its water quality and trends and allows the formulation of management plans in regard to the distribution of pumping both seasonally as well as spatially.

The information to be collected from the permanent observation network should include:

- water-levels (for drawing monthly or seasonal groundwater contours, changes in storage, etc.);
- groundwater samples for quality (full ionic, chloride or electrical conductivity); monitoring of pollution; monitoring of sea intrusion; and
- effect of pumping or interference of new pumping or effect of recharge activities.

Information collected from pumping wells and boreholes should include estimates of water extracted on the basis of the land irrigated, the type of crop and the irrigation methods employed.

Borehole logs obtained during drilling are essential for determining the aquifer geometry and lithology. A topographic and location survey of the observation network but also if possible of all the wells and boreholes is essential for the proper control of the aquifer performance. Pumping tests on selected wells would provide permeability, specific yield and specific capacity data which are very important for any aquifer evaluation study, groundwater modeling and sea/fresh water interface studies.

Information on groundwater is usually kept in files according to type, found in annual hydrologic reports or in past aquifer studies. Computerized data storage and retrieval is the most suitable for the vast masses of data that are usually available.

5.5.2.5 Conservation of Water Resources

Conservation of water resources applies to both the quantity as well as the quality and refers not only to surface but also to groundwater. The scarcity of water and the continuously growing demand makes conservation measures an absolute necessity if the current and future demands are to be met in a satisfactory manner.

Conservation programs require information on the current condition of water resources and the developing trends, both in quantity and quality. Water use data are also important especially on the efficiency of use and trends in the quantities used and trends on demands. Conservation plans and measures are normally required as soon as it is recognized that a certain source of water, an aquifer or system of aquifers, a stream, reservoir or lake is becoming unsuitable or its continued use is endangered. This may be the result of use in excess of its capacity, pollution or contamination.

Data on parameters that will forewarn on developing conditions of this type are essential not only for following the situation but also to enable the implementation of regulations and controls on the particular resource. Declaration of conservation areas or areas under special regulations and controls requires convincing evidence and data support not only for the civil authorities but also for the general public. Therefore it is essential that this information is collected, stored and evaluated continuously.

5.5.3 Data Storage and Retrieval - Concept of a Data Bank

Proper storage of water cycle and other auxiliary data is essential for water resources assessment, management and operation. Procedures for storage and primary processing of such data is given in (WMO, 1981) and (UNESCO/WHO, 1977).

Water cycle data can be stored in the form of original data sheets, in microfilm form, or on computer. How effective and adequate the storage system is can be evaluated by the extent of data preservation and the time required to locate or retrieve specific data. Data on the operation of water resources projects are collected and usually stored in a similar manner as for the water cycle data. However, such data being stored by the user, makes it difficult to retrieve them.

The primary processing of data consists of cataloguing and banking of data, and preparation of user oriented data as described in detail in (WMO, 1981) and (UNESCO/WHO, 1977).

Data cataloguing requires establishing of an efficient inventory of the data to enable the extent, availability and rapid data retrieval. These are normally catalogued by the dimensions of subject, object, time, space, data quality and source. Data catalogued as above and accessible through all the six categories to all data users constitutes a “conventional data bank”. Computerization of the above data catalogues enables one to search for data according to any one of the six “dimensions” given above. These are then transposed to an established, or purposely built, user friendly data bank software.

Box 13

Development of a water resources data base

Objectives

Organization of a data base.

The data base will enable the following:

- structured data storage;
- easy access to data;
- data updating;
- possibilities of data selection: cross-selection, queries and management;
- printing and plotting of output data;
- integration of the digital data recorded on measurement stations into the data base;
- data export from the data base in order to be used in various models or sub-models.

Information to be contained in the data base refer to:

1. **Hydrology;**
2. **Climate;**
3. **Surface water run-off;**
4. **Borehole data;**
5. **Existing or potential pollution sources;**
6. **Water production and use, etc.**

This information will contain the following **categories**:

1. **Identification parameters:**
   - type of measurement point;
   - name(s);
   - inventory number(s);
   - name of the owner;
   - network;
   - data of installation.
2. **Location parameters:**
   - coordinates;
   - elevation above sea level;
   - physical and/or administrative unit;
   - map: name, number, scale;
   - aerial photographs, number, year.
3. **Technical characteristics**
4. **Time dependent parameters:**
   - frequency of storing the measurement data, constant time steps, changeable time steps;
   - location of measurement points and time of installation.
5. **Origin of data:**
   - original record;
   - bibliography, reference;
   - estimates based on statistical analyses of data.

Outputs

- a centralized data base containing all the available data;
- a computerized data base, allowing storage, updating, retrieval, presentation and analysis of data, elementary statistical analysis (mean, minimum, maximum, standard deviation);
- user-oriented (sectoral) views for the data base.

There numerous systems for storing general hydrologic data on computer. The HOMS program of WMO which is a system for technology transfer in operational hydrology lists a number of them which can be investigated further if it suits the particular needs of a country and be acquired:

- Software for archiving and retrieving time - dependent data (TIDEDA);
- HYDSYS - Time series data management software;
- Automatic data quality-control and analysis system (SYSCAD);
- HYDATA - hydrological database and analysis system;
- Management system for field data (FIELDMAN);
- HYMOS: database management and processing system for hydrometeorological quality and quantity data;
- HYDROM: hydrometric data management;
- PLUVIOM: precipitation data management; and
- Hydroinform: minicomputer controlled automatic hydrologic information dissemination unit.

In addition to the above commercial database systems may well be adapted according to the existing needs and particular problems. Such are the MS-ACCESS, dBase, etc.

5.6 Elements of a Water Resources Master Plan

5.6.1 Introduction

The function of water can be categorized as natural and social, i.e. water demand in-stream, on-site uses, and withdrawals. In-stream and on-site uses do not withdraw water from the resources, so that everything happens and is built in or on the water resources. Withdrawals divert the water from surface or groundwater sources which means that the water has to be dislocated from the place of withdrawal to the place of consumption, which in turn means that the water, once used, has to return to the resources by means of appropriate structures.

If water is to perform its natural and social functions it must be available in sufficient quantities and be of satisfactory quality. If the natural water is not of required quality, it has to be conditioned so as to gain the quality needed at the place of use.

Through the use in the socio-economic system, water changes its properties. Above all, it is the quality that is subject to changes, so that a number of harmful matters are introduced into the water resources threatening the natural, but also the social functions of the downstream users. To protect the water resources, once used waters (waste waters) have to be purified and discharged into the water resources in an appropriate way. Categorization of the natural functions of water and of its utilization, including the basic characteristics, is given in Table 5.2.

Water threatens the man and his activities (floods, erosion, humidity, etc.) so that it is necessary to make appropriate interventions, both structural and non-structural, to protect ourselves. The multipurpose use of water for all types of human activities, as well as the need to both provide protection against the adverse impacts of water, and protect water as an environment inhabited by different life forms, clearly show that the planning, management and use of water resources are closely related to the planning and development of the entire economy and society in the broadest sense. Accordingly, the basic demand for water resources development comes from the socio-economic requirement.

Table 5.2: Categorization of natural functions of water, and of water utilization (Jerman, 1987)

I Natural functions	II In-stream uses	III Withdrawals	
Soil moisture conservation, soil transformation	Groundwater table & soil moisture regulation HC	Drinking & cooking HQ	Urban and rural water requirements
Transport of biogeoelements	Waste transport & disposal HV, LQ, HP	Other domestic uses HQ, HP	
Biological functions	Fish and wildlife SR	Public uses HQ, HP	
Regulatory climatic functions	General utilization LC	Heating, steam power, boiling, air conditioning HP, HC	
Aesthetic enjoyment	Water transport, public & goods	Processing HP	Industrial & infrastructural water requirements
Other environmental functions	Hydropower generation HV, LQ, LC	Cooling HV, LQ, HC	
	Recreation & water sports LC	Mining & hydraulic transport HP, LQ	
		Other industrial & agricultural uses LV	
		Irrigation HV, HC	Agricultural water requirements
		Processing HP	
		Livestock & poultry breeding HP	
		Fish & water fowl breeding	

Consumptive use	HC - high	LC - low
Quality requirements	HQ - high	LQ - low
Impact on water quality	HP - high	LP - low
Volume requirements	HV - high	LV - low
High space requirements	SR - high	

5.6.2 Major Physical Works

There are several physical works (dams, channel, etc.) which are utilized in almost all types of water-resources projects. Some of their basic characteristics will be briefly presented.

Reservoirs

Water supply, irrigation, or hydroelectric projects drawing water directly from water resources generally are unable to satisfy the demand of their users during low flows. A stream carrying little water during dry seasons, often becomes a raging torrent after heavy rains, turning into a threat to all activities along its banks, is typical of the Mediterranean situation. A storage, or conservation, reservoir can retain such excess water from periods of high flow to be used during periods of draught. In addition to conserving water for later use, the storage of floodwater may also reduce flood damage below the reservoir.

Because of the varying rate of demand for water during the day, urban water supply systems must have distribution reservoirs. Such reservoirs permit water-treatment or pumping plants to operate at a reasonably uniform rate or optimal rate, and to provide water from storage when demand exceeds the operating rate. On farms, ponds or reservoirs may conserve intermittent flow of small creeks for irrigation and other purposes.

As we can see, the main function of a reservoir is to stabilize the flow of water, either by regulating a varying supply in a natural stream, or by satisfying a varying demand by the ultimate consumers.

The most important physical characteristic of a reservoir is its storage capacity. If the reservoir is used for a hydroelectric power plant, of great importance is the height of the dam, or the depth of the dam reservoir.

By building a reservoir in a river, the natural characteristics of water, especially with regard to quality and quantity, are considerably changed, not only downstream from the reservoir, but in the reservoir as well. Slowing down or stopping the water flow in the reservoir brings about a number of physical (evaporation/heating of water, sedimentation), chemical, and biological processes and changes to the water characteristics, which is also felt downstream as the water is discharged from the reservoir. Environmental impacts of any larger reservoir are considerable, so that before building one, a detailed and comprehensive EIA has to be performed. Many planned reservoirs have never been built due to their unacceptable environmental and social impacts.

To define properly the characteristics of a reservoir, it is of utmost importance to have a good quality time sequence of the flow at the construction site, as well as all other characteristics (water quality, ecology data, geology, geomechanics, land use, seismic data, etc.).

Dams

A dam is a civil engineering construction with the function to keep water within a given space. It is the most important element of a reservoir. Dams are classified on the basis of the type and materials of construction, such as gravity, arch, buttress, and earth. The selection of the best type of dam for a given site is a problem for both engineering feasibility (topography, geology, and climate), and cost. The relative costs of the various types of dams depend mainly on the availability of construction materials near the site, and the accessibility of transportation facilities.

The most important features of a dam are its height, length and water-imperviousness. The height of a dam is defined as the difference in elevation between the roadway, or spillway crest, and the lowest part of the excavated foundation. A dam must be relatively impervious to water and capable of resisting the forces acting on it. The most important of these forces are weight of the dam, hydrostatic pressure, uplift, ice pressure, and earthquake forces.

Environmental impacts of the dam itself would be of local significance affecting only the site where it stands, but since there is always a reservoir with the dam, with all its impacts, the affected area is much larger.

Spillways, gates, and outlet works

In order to control the water flow in canals and pipelines, to control the state of water in various structures, such as reservoirs, cisterns, tanks, etc., and to manage those structures properly, it is necessary to build a number of various devices, such as: spillways, gates, outlet structures, etc. Most of these are built next to the dams in order to control the functioning of the reservoir.

Some provision must be made in the design of almost every dam to permit the discharge of water downstream. A spillway is necessary to discharge floods and prevent the dam from being damaged. Gates on the spillway crest, together with sluice-ways, permit the operator to control the release of water downstream for various purposes. In some cases, facilities to regulate the flow in channels or pipelines leading from reservoir are also necessary. For each of these functions, a variety of devices, each with specific characteristics, are available for selection. The required characteristics of these devices depend primarily on the volume of the flow and their purpose, but also on other parameters, such as water pressure, geology, topography, etc.

Open channels

The role of open channels is spatial distribution of raw water for various purposes, from the source to the user. Two types of conduits are used to convey water, the open channel and the pressure conduit. The open channel may take the form of a canal, flume, tunnel, or partly filled pipe. Open channels are characterized by free water surface. If it is drinking water that has to be transported, the conduits have to be closed, while for the transportation of raw water, open channels can be used.

The problem of channel location is similar in many respects to highway location, but solution may be more difficult, since the slope of the channel bottom must be downgrade, and frequent changes in slope should be avoided. Within the limitations of topography, the exact route of a channel is determined by the slopes that can be tolerated. Excessive slopes may result in a velocity sufficient to cause erosion of the channel bottom. If the channel slope is too steep the velocity may be so low that growth of aquatic plants will reduce the hydraulic efficiency of the channel.

Channels may be built in the earth material (unlined), or can be lined with various materials (concrete, plastic materials, etc.). Various types of linings are used to reduce seepage losses from channels, or to increase flow velocity. Water from channels is also lost by evaporation. Numerous structures are necessary for proper operation of channels: diversion structures, intakes, screens, drops, etc.

Characteristics of a canal mostly depend on the flow volume, topography, water quality, and economic characteristics. Channels have considerable environmental impacts, especially the large ones. They can also influence the local water resources by recharging ground water from seepage in dry periods, or by drainage banks in wet periods.

Pressure conduits

A pressure conduit is a conduit which is full. Such conduits are often less costly than canals or flumes because they can generally follow a shorter route from source to users. If water is scarce, pressure conduits may be used to avoid water losses by seepage and evaporation, which may occur in open channels. Pressure conduits also protect water from pollution from the pipe environment. Thus, they are preferable for public water supplies because they reduce pollution risk.

The principal pipe materials are steel, cast iron, concrete, asbestos-cement, various plastics, etc. Economical aspects play a large role in the selection of pipe material, but availability of skilled labor for construction, and site accessibility may be determining factors. A large number of different types of appliances are required for proper functioning of a pipeline: gates, valves, check valves, air-inlet valves, surge tanks, etc.

In general, environmental impacts of pressure conduits are negligible.

Hydraulic machinery

There are two types of hydraulic machinery of interest for the water-resources engineer: pumps and turbines. A pump converts mechanical energy into hydraulic energy, thus transporting water from a lower elevation to a higher one, while a turbine serves the opposite purpose, using hydraulic pressure (potential) for energy production. There are many types of pumps and turbines. Each type has its own characteristics, and for a given set of operating conditions there is a type and size of hydraulic machine best suited to the job. For ordinary pumping, the centrifugal pump is most commonly used as it provides satisfactory and economical service.

Two major variables influence pump/turbine characteristic: capacity and head elevation. The design of hydraulic machinery is a highly specialized field. Hydraulic machinery, together with associated parts, may have various types of environmental impacts, such as: vibration, noise, or pollution.

5.6.3 Principal Water Uses

5.6.3.1 Water in Agricultural Systems

Agricultural production is a result of the function of agricultural systems and has to be managed within their framework. An agricultural system can be defined as a set of interconnected soil and microbiological, plant, mechanical and human elements whose interaction produces organic matter for the nourishment of man on the basis of the supply of solar, mechanical and human energy and matter including water, fertilizers, and agrochemicals (Figure 5.9).

Agricultural water requirements are frequently satisfied by a combination of on-site and external supplies. The regulating function of water has to be achieved by an external water supply for:

- regulation of the soil moisture by means of irrigation and drainage;
- livestock and poultry breeding;
- fish and water poultry breeding;
- processing, boiling, cooling, heating, waste disposal; and
- public uses in the agricultural system.

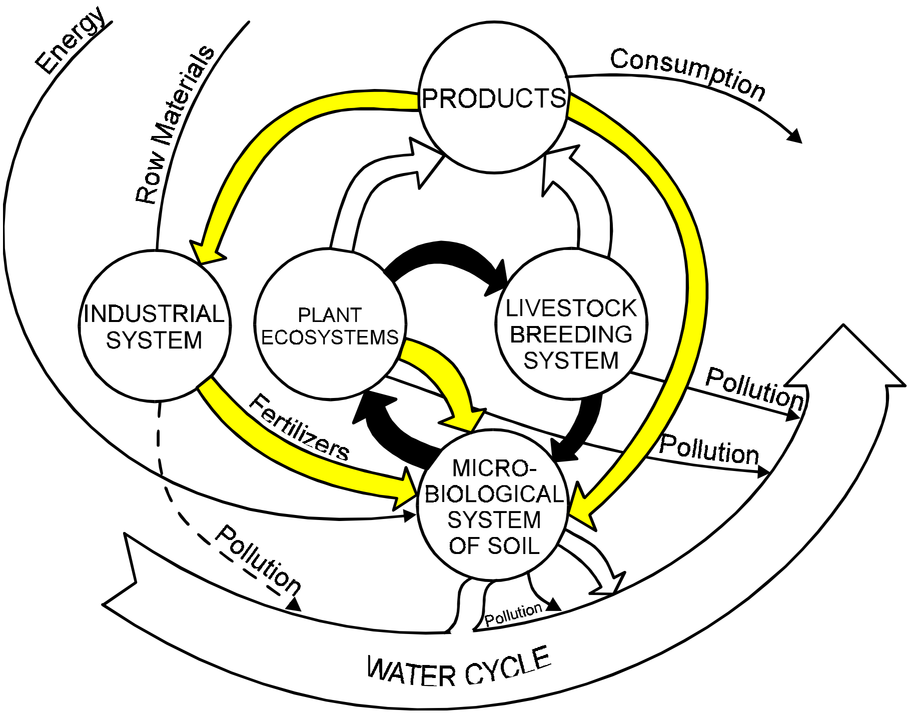

Figure 5.9: Agricultural system, its environment and basic interrelationships of its subsystems - basic inputs and outputs

Water for irrigation

The most important use, and the largest quantity of water used in agricultural sector is water for irrigation. Irrigation is the application of water to soil to supplement deficient rainfall to provide moisture for plant growth. It is the main, but not the only purpose of irrigation. By means of irrigation, bio-elements and other matter which improve plant production or soil conditions can be supplied, either naturally or artificially, favorable micro-climatic conditions to support plant growth maintained, and matter which jeopardizes the soil structure and texture or the health of plants removed.

From this point of view, irrigation can be categorized as follows:

- supplementary watering;
- fertilizing and remedial irrigation;
- protective irrigation; and
- soil leaching irrigation.

The quality of the water used for irrigation depends on the required purpose, on the soil properties and on the irrigation operation. The basic requirements affecting the quality of water used for irrigation can be summarized as follows:

- it should favorably influence plant growth and the quality of the product grow;
- it should not cause breakdowns during the irrigation operation;
- it must not cause sanitary complaint, either during its operation or during the processing and consumption of the relevant agricultural products;
- it should not endanger the quality of the surface water and the groundwater; and
- it must not deteriorate the surface, porosity and other agrochemical properties of the soil profile.

The quality of the water used for irrigation has to be categorized on the basis of its relevant physical, chemical, biological and bacteriological properties. An important property of water for irrigation is the salinity.

Soil moisture can be controlled by means of an irrigation and/or drainage system. An irrigation system consists of five subsystems: storage, transmission, distribution, soil moisture and exceptionally, also underground aquifers.

Irrigation basically supplements the water which escapes from the vegetative system, especially by evapotranspiration, thus contributing to its undistributed development. Its feasibility depends on soil and land conditions. The total water supply required for one irrigation season is the sum of uses and losses, derived from seasonal consumptive use and leaching requirements, less the amount of rainfall and groundwater input in the vegetation period which contributes to the moisture of the soil layer in question and less the utilizable moisture-holding capacity of soil at the beginning of this period.

The total rainfall with an 80% frequency of occurrence in the vegetation period may be considered as decisive, depending on local climatic conditions and yield. The efficiency of rainfall utilization depends on evapotranspiration and outflow, i.e. on climatological, geomorphological, soil, and vegetation factors. The crop irrigation depth which has to be penetrated by watering, and thus the crop water requirements too, depends on the depth of the root system. The utilizable moisture-holding capacity of soil at the beginning of the vegetation period also depends on the root depth and on the capillary rise of the soil structure. Groundwater input in the vegetative season depends mainly on the groundwater table depth and on the soil structure.

Water losses from irrigation are generally very high (up to 50%) if special measures are not applied. Typical irrigation losses are:

1. Delivery losses (losses before applying to irrigated land):
   - canal and reservoir seepage losses;
   - leakage of gates, unused spills and other escape losses;
   - evaporation; and
   - unused water in the irrigation network.
2. Farm losses:
   - supplementing of the soil moisture, not used by plants;
   - surface and groundwater outflow of the unused water;
   - deep percolation into subsoil layers;
   - inefficient evaporation from the soil;
   - evaporation during sprinkler irrigation; and
   - evaporation of weed plants.
3. Off-farm losses (irrigation of land where irrigation is not planed or where it is not feasible).

The economy of plant production and the efficiency of irrigation water application are closely interconnected. The actual irrigation rates are to be determined and irrigation operation managed on the basis of the measured actual evapotranspiration. The water rates must not overload either the plant or the soil. Useless losses through unused outflow, deep percolation and excessive unproductive evaporation should also be avoided.

The efficiency of irrigation water utilization is presently the key problem of water management, because:

- irrigation water forms the main element in water requirements on a global scale. The extent of both the irrigated land and the irrigation intensity is increasing because of the increasing demand for food;
- irrigation is an inherently consumptive use which considerably reduces the possibility of future re-use or recycling; and
- irrigation networks and their supply systems have a substantial and lasting impact on the natural environment.

The benefits of all investments in irrigation projects depend on proper water use in the field in conjunction with other agricultural inputs and cultural practices. The first step in planning an irrigation project is to establish the capability of the land to produce crops which provide adequate returns on the investment in irrigation works.

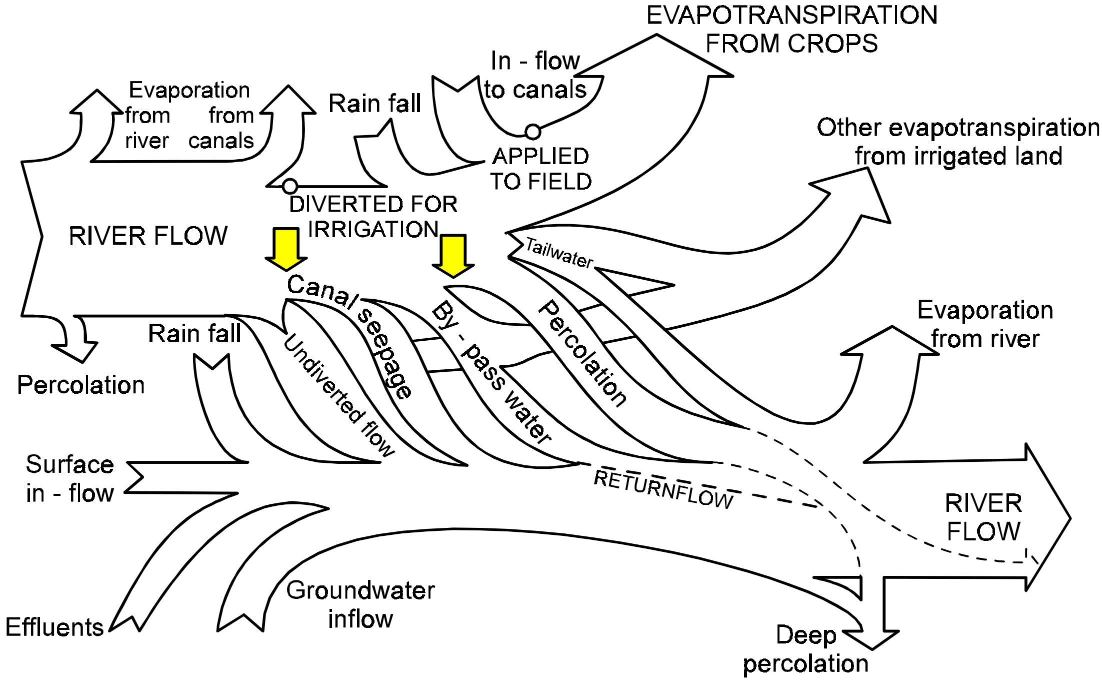

Figure 5.10: Model of an irrigation return-flow system (Jerman, 1987)

Water for livestock and processing

During livestock breeding and agricultural processing, water is used:

- to water cattle (including processes of cooking, dilution of fodder mixtures, etc.);
- as service water (for waste disposal, washing, etc.);
- as process water; and
- as drinking water for animals and for working personnel.

With regard to the quality of water for livestock, the relevant requirements are relatively lower in comparison with the drinking water quality. But the reaction of deferent species of domestic animals varies and depends on their age. The health stage and yield of livestock and poultry depend on the quality and quantity of the water delivered.

The requirements of watering livestock and of service water necessarily depend on the breeding technology. Modern technology which requires higher sanitary standards uses 50-100% more water compared with small-scale breeding. The total daily water requirements of livestock production consist of watering and processing as well as service water for waste disposal, washing and cleaning. The actual requirements for watering depend on the season, temperature, duration of the daylight, on the real weight of the relevant species, and on the particular breeding practices.

Process water in agriculture, as in industry, includes all water needed for:

- processing;
- hydraulic transport;
- cooling, boiling and heating; and
- sorting, washing, rinsing and cleaning.

Water in agriculture is used either as matter entering the product, as matter which comes into direct contact with the intermediate or final product or as a cooling or heat carrying medium. Relevant water quality requirements can be, therefore, classified in the same manner as the industrial water use.

Water pollution from agricultural production

There are three main groups of polluters in agricultural production:

- pollution from plant production: washing away of the eroded soil particles, applied and stored fertilizers, wastage of plant products, drainage waters and waste waters from irrigation polluted by extraction of salts due to over-irrigation, etc.;
- pollution from livestock and poultry breeding: wastes from small and large-scale cattle, sheep and poultry breeding, including area pollution from cattle walks, hen runs and pastures, escape of dung water and waste water from stables, escape of silage, etc.; and
- pollution from agricultural processing: waste water from processing, dairies, from washing of agricultural machines, escapes of oil and oil products, stored agrochemical, etc.

The prevailing pollution of water resources by agricultural production depends on local conditions and so any of the mentioned three groups of pollution may predominate in a given location. Under conditions of intensive plant production the aerial mineral and synthetic pollution by fertilizers and pesticides generally predominates. This pollution can be very high. Precipitation and surface irrigation washes away soil particles and agrochemical, especially under conditions of large-scale production, thus causing their leaching and extracting and the consequent contamination of surface and groundwater resources.

5.6.3.2 Water Supply Systems

The amount and quality of water used in human settlements have strong influence on the societal and economic development. These include improved health conditions resulting from increased supply of safe drinking water, better living standards owing to the availability of water for household needs, etc.

The elements that make up a modern water supply system include:

1. The source of supply;
2. Storage facilities (row water);
3. Transmission facilities (to treatment);
4. Treatment facilities;
5. Transmission (from treatment);
6. Storage facilities or distribution reservoirs (potable water); and
7. Distribution facilities.

Table 5.3: The functional elements of a public water supply system

Functional element	Principal concerns in facilities design (primary/secondary)	Description
Source of supply	Quantity/quality	Surface water sources of supply such as rivers, lakes, and reservoirs, or groundwater source
Storage	Quantity/quality	Facilities used for the storage of surface water (raw water)
Transmission	Quantity/quality	Facilities used to transport water from storage to treatment facilities
Treatment	Quality/quantity	Facilities used to improve or alter the quality of water
Transmission	Quantity/quality	Facilities used to transport treated water to distribution reservoirs
Storage	Quantity /quality	Facilities used for daily storage of treated water
Distribution	Quantity/quality	Facilities used to distribute water to the individual users connected to the system

In the development of public water supplies, the quantity and quality of the water are of great importance. The relationship of these two factors to each of the functional elements is indicated in Table 5.3. As shown in Figure 5.11, not every functional element will be incorporated in each water supply system. It depends on local conditions, which will require suitable configuration of the water supply system.

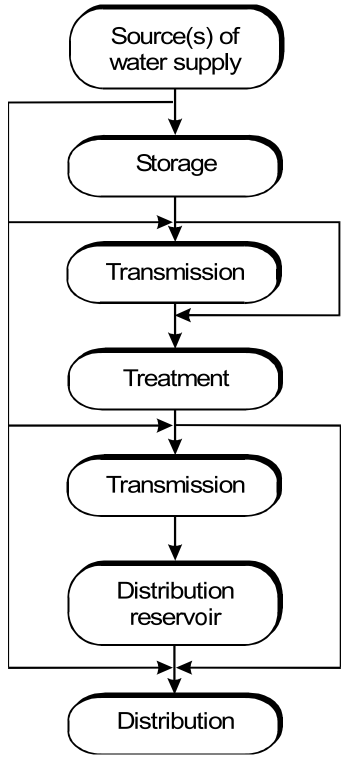

Figure 5.11: Interrelationships of the functional elements of a municipal water supply system

Each water supply system can be described with the following factors:

- population;
- water use;
- water supply;
- distribution system;
- geographic distribution of demands, sectors demand;
- leakage data;
- fire protection;
- system management;
- ordinances;
- quality analysis, etc.

Water requirements

In the settlements, water is used for different purposes: domestic, workshops, public sector and for fire protection. Water use varies from settlement to settlement, depending on the climate, standard of living, characteristics of the environmental concern, population, industrialization, and other factors. In a given area, water use also varies from season to season, day to day, and hour to hour, especially in the Mediterranean areas due to tourism. Thus, in planning of a water supply system, the probable water use and its variation must be estimated as accurately as possible.

The most important data for assessment of domestic water requirements are:

- urban population (area, density);
- rural population (area, density);
- per capita consumption rates for urban and rural areas;
- rural area domestic supply; and
- adequacy of present supply to meet demand in terms of both quality and quantity.

Water in water supply system must have the required quality. Water demand in household, workshops, and public services has different quality requirements for:

- drinking and meal preparation;
- other domestic uses in contact with the surface of human body; and
- using water in system where contact with the body can be avoided.

In the water supply network, water has uniform quality for each of these different purposes because it is the simplest method to safeguard all these requirements. In many Mediterranean country it is common to drink the bottled water instead water from a water supply network. Each country has adequate water standards which regulate water quality in the water supply system.

Planning

The design of a complete water system is the exception rather than the rule. Usually the work consists of an extension or improvement of existing facilities rather than design of a completely new project. In planning a project the engineer should obtain legal advice concerning the rights to possible sources of water before recommending any for use. A water entity is legally responsible for supplying its customers with water which is safe for drinking.

Generally, the following steps must be accomplished in planning a municipal water system:

1. Obtain data on, or estimate, the future population of the community, and study local conditions to determine the quality of water that must be provided.
2. Locate one or more sources of water of adequate quality and quantity.
3. Provide for the necessary storage of water, and design the works required to deliver the water from its source to the community.
4. Determine the physical, chemical, bacteriological, and biological characteristics of the water, and establish water quality requirements.
5. Design any water treatment facilities that may be necessary to meet water quality requirements.
6. Plan and design the distribution system, including distribution reservoirs, pumping stations, elevated storage, layout and size of mains, and location of fire hydrants.
7. Provide for the establishment of an organization that will maintain and operate the supply, distribution, and treatment facilities.

5.6.3.3 Industrial Water Supply

Industrial supply is enabled by industrial water supply and disposal systems. It is a set of structures, technological equipment such as measuring and controlling devices with associated feedback which secure the withdrawal and treatment of water, its distribution and circulation, as well as waste water treatment and recycling, sludge disposal and the harmless discharge of polluted water into appropriate recipients.

Process water in industry includes all water needed for:

- processing (water entering a product and serving functional purposes);
- mining and hydraulic transport;
- cooling and air conditioning;
- boiling and heating; and
- general use.

The use of water in industry is heterogeneous, and the relevant supply and disposal system are complicated and include:

1. Open circuit operation: water withdrawal is discharged into recipient water resources after use in the process.

2. Successive re-use operations: in this case waste water from one process is used as water in other processes. The successive re-use of waste water is characterized by the supply of water in qualities which differ from the quality requirements of the relevant production process.
3. Recycling operations: the repeated use of the same water inside a close circuit is called water recycling.

Industrial water requirements are based upon expected types, size and number of industrial plants and specific water needs of individual industries. Water demand projection for industry should be coordinated with economic studies of anticipated industrial expansion, and should indicate the location and type of use as well as the amount, quantity and location of return flow, waste treatment and disposal.

Industrial water use can be estimated based on the amount of water fed to plant which could include the reuse water, the loss due to conveyance, evaporation, seepage and leakage.

Industrial waste water is in general toxic for humans and the environment. In effect, contamination caused by industrial waste can be categorized as: chemical, bacteriological and thermal, but generally waste water is mixed.

In accordance to the self-purification, industrial waste water can be biologically degradable or undegradable. Toxicity of waste water depends also on the processes of self-purification in rivers and biological waste water treatment plants.

In order to reduce the negative impacts on future development, the utilization of water in industry should be rationalized, especially by means of water-savings measures:

- reducing water wastage;
- limiting the duration of water utilization during technological processes to the absolute minimum;
- selection processes which entail minimum water consumption and minimum water pollution;
- applying internal recycling and waste water reuse;
- decreasing the requirements on water quality to the technologically permissible limit and by using available resources of low quality; and
- using industrial waste waters in other branches of the national economy.

Boiling, steam power water, and cooling water

One of the biggest industrial uses of water is water for boiling steam, and cooling purposes. The biggest single user of this water are thermal power plants.

The boiling water is used as a heat carrying medium without any contact with the product. Boiling water and steam is used:

- during processing;
- for heating and ventilation, for power generation; and
- as warm service water.

Warm water for industrial purposes is seldom supplied by the municipal supply system. The water quality requirements follow:

- the decrease in corrosion; and
- the decrease in clogging.

The quality of water in power generation system is formed by feed water to fill the system and supplementary water to cover water losses, caused by leakage and evaporation.

Cooling water, which accepts and removes the excess heat during industrial production, forms some 60-80% of the water quantity needed for industry. This water undergoes thermal changes and often requires thermal treatment, including all the processing of water warming: cooling, destilling, etc. Cooling by water in contact with the semi-finished product as contact cooling is a part of processing.

Systems for cooling without a contact with the product are like other industrial water systems, namely:

1. open circuit system;
2. recycling system:
   - open, when the heat is removed by the direct contact of water and air; and
   - closed, when the heat is removed without any direct contact with air.

Water requirements depend primarily on the technological process and its temperature, i.e. on the quantity of heat to be removed and secondary on the type of cooling system. Closed system prevent evaporation, thus further decreasing both water consumption and water requirements. The quality requirements for water used as a cooling medium without any contact with the product are derived in a way as to ensure the safe and efficient operation of the system. They may be lower for the open circuit systems and must be high for recycling systems, preventing especially their corrosion and clogging.

5.6.3.4 In-stream and On-site Water Use

In-stream uses such as hydroelectric power generation, navigation, recreation, water sports and waste disposal are connected with the social function of the water. These uses of water resources are characterized by insignificant consumption. The only consumption are losses. Because of these uses the volume of water is important, and not the discharges.

On-site uses, such as soil moisture conservation, flood loss management, the maintenance of swamps, and wetlands are closely interconnected with the natural functions of water.

Hydropower

Electric power is developed from two types of plants: hydro and thermal. Hydroelectric generators are driven by water turbines while thermal plants derive energy from combusting fuel. Water related problems of thermal plants are treated under industrial water system and will not be covered in this section.

Hydropower generation is one of the important aspects of water use. This renewable form of energy can be generated al low cost from multipurpose projects also intended for irrigation, navigation, flood control, and water supply.

The hydroenergy production has the following advantages:

- flexibility of operation;
- possibility of multi purpose use;
- high reliability and long service life;
- small environmental impacts;
- low operational cost; and
- possibilities of using local materials and labor.

The potential energy of water can be converted into pressure energy by converting the head and discharge into kinetic energy by passing the concentrated discharge through water engines. To extract the maximum power and energy at the optimum cost the design criteria focus on the choice of the location, design discharge and head, lay-out, size and number of units, etc. This approach embodies an optimization of the power output/cost-benefit ratio on the basis of realistic operation of the plant, in the framework of the topographic and hydrological situation and power market demands. The following are indicators affecting the choice of the optimum design discharge and head:

- unit cost of energy should be competitive with other energy options;
- installed capacity should be optimum for integration into the network power market; and
- energy output in the period or season of maximum energy demand should be optimum.

A reliable assessment of hydroelectric energy potential of river basins should be made prior to the preparation of detailed schemes for multipurpose water resources development. Technical, economic and environmental feasibility of development should also be carried out at the reconnaissance level based on field investigations. The hydroelectric potential should be estimated both in terms of total annual energy output and maximum power to meet peak load.

Hydroelectric plants may be classified as run-of-river, storage, or pumped-storage, tidal power plants and power stations using the energy of waves. A storage-type plant is one with a reservoir of sufficient size to permit carry-over storage from the wet season to the dry season and thus to develop a firm flow substantially more than the minimum natural flow. A run-of-river plant has a storage of limited size and thus can use the flow as it comes or can make daily balance in order to cover peak daily demand. A pumped-storage plant generates energy for peak load, but, at the off peak, water is pumped from the tailwater pool to the headwater pool for future use.

A hydroelectric development ordinarily includes a diversion structure, a conduit to carry water to the turbines, turbines and governing mechanism, generators, control and switching apertures, housing for equipment, transformers, and transmission lines to the distribution centers. The type of plant best suited to a given site depends on many factors, including head, available flow, and general topography of the area.

The general steps in designing hydroelectric plants are:

1. Assemble hydrologic data on the streams, and determine the amount of water available and its distribution throughout the year and from year to year. Extend the data by simulation and/or stochastic methods, if necessary.
2. Make preliminary designs for all installations which seem competitive in cost, and determine the most economic design at each site by comparison of costs and estimated power revenues.
3. Determine the requirements to be satisfied.
4. Select feasible projects as close to the load center as possible.
5. Compare the best designs from the several sites, and select the site or combination of sites which proves best for production of the required power including future needs.
6. Compare the cost (tangible and non-tangible) of the hydroelectric plant with that of an equivalent thermal plant.
7. If hydroelectric power is competitive with steam, proceed with the detailed design of the hydroelectric installation.

River navigation

Waterways have always been an important avenue of commerce in world history. However, rivers in their natural state were not ideal passageways and thus they had to be properly developed. Navigable or canalized water courses including reservoirs and canals form an infrastructure for the transportation of goods and passengers. The current importance of inland water transport is primarily a result of its energy and manpower saving technology, especially with regard to its role in conveying individual types of cargo, which is mainly general, liquid, bulk, heavy, etc.

There are no absolute criteria of navigability and, in the final analysis, economic criteria control. The physical factors which affect the cost of waterborne transport are depth of channel, width and alignment of channel, locking time, current velocity, and the terminal facilities.

The network of inland waterways includes:

- river channels (natural, improved, canalized); and
- canals (artificial water courses).

The basic parameters of these waterways, i.e. those which determine the carrying capacity, include the breadth and depth of the fairway, the corresponding minimum size of the cross section, and the velocity of the flow. The other main dimensions determine the fluency, methods of operation, speed and safety of transport.

One important characteristic is operation time and period, interruptions to operation, its restriction to some 220-340 days a year. Usually it is due to:

- flood occurrence;
- periods of low discharge;
- meteorological factors (ice, wind, fog);
- maintenance; and
- technologically unsuitable and obsolete constructions.

The water requirements for inland navigation are determined by the size of the largest lock, i.e. in the case of unified horizontal dimensions by the volume of the lock with the highest head including relevant water losses. Water requirements for lockage restrict other in-stream uses, e.g. for hydropower generation, and should only be considered when the natural supply by river discharge is not sufficient.

Water losses of navigation operation are caused by:

- leakage of gates and valves;
- seepage of the bottom and the banks of the canal; and
- evaporation from the free water surface and the increased evapotranspiration from banks affected by the impounded water.

Inland water transport does not call for any important requirements on water quality. Water pollution from inland navigation is mainly caused by the liquid fuels used in vassals, washing and ballast water, and spillage from cargo during transport, loading and unloading.

Due consideration should be given to the provision of facilities for navigation as far as possible in every multi-purpose water resources development project.

Waste disposal

The hydrosphere is used for waste disposal and enables, primarily in water courses, the transportation and removal of waste. Waste water and waste materials which are conveyed into surface and ground water bodies enter the natural processes of the generation of water quality, enabled by the thermal, chemical and kinetic energy of water, by the thermal and chemical energy of the riverbed, and by the thermal and luminous energy from the environment of this system.

The erosion, fall-out and waste disposal result in an increased bed load, suspended load and dissolved matter along the water course. But a complex of other physical, chemical, biochemical and bacteriological processes in nature further changes the water quality. Self-purification processes accompany the water pollution process in the course of sediment transport and erosion processes, resulting in the destruction and melting of erosion products, waste material and fall-out.

A lack of kinetic energy causes sedimentation, the most basic of the physical self-purification processes. Sedimentation is accompanied by coagulation and melting and results in a decrease in the content of chemical matter in water and in an increase in sediment volume. Another basic process of self-purification to occur as a result of the contact of water with air is the diffusion of oxygen. Oxygen enters in water directly from air and by biological processes of plant and phyto plankton. Chemical processes of self-purification, decomposition, coagulation, neutralization as well as absorption consume the oxygen, resulting in an oxygen balance which corresponds to the relevant temperature. In the course of physical and chemical processes, the suspended matter is swallowed down by water organisms. The absorption of this matter into nutrition chains changes the living organic matter into inorganic matter and vice versa having as a consequence the decrease of oxygen concentration. If the concentration falls below the critical limit, the organisms die.

Water pollution which occurs at the same place changes in time depending on the pollution regime, the relevant discharges, the morphological factors of the river channel, the climatological factors and the coherent course of the self-purification processes. Water pollution can also be defined as a complex of processes whose result limits or makes impossible the beneficial use of water.

The natural pollution of surface water is generally low. The character of water pollution which is caused by the industrial, agricultural and other activities of human society and by urban effluents differs from that of natural pollution. This pollution considerably changes the chemical and biological properties of the water, and also the type of the relevant chemical, biological and other processes.

The water quality due to the course of sediment movement and the dilution of waste waters depends on the discharge and in direct relationship with:

- soil-erodable rate, depending on precipitation;
- soil-solubility rate, dependent on the intensity of the surface runoff;
- geological, soil and soil surface factors;
- hydrometeorological factors;
- anthropogenic activities, i.e. the pollution regime;
- accidental; and
- systematic
  a) point pollution, i.e. pollution from communities, towns, industrial and agricultural estates, and other facilities.
  b) diffuse (aerial) pollution, i.e. washed soil and fertilizers, pesticides, dump, etc.

In planning a water resources development project related pollution control must be considered on several aspects:

- Based on the assessment of existing characteristics of water resources quality, indicators of substances in waste-water effluents flowing into water bodies by urban runoff, pesticides and fertilizers, and watershed sediments, should be presented.
- Besides, water conservation measures (water recycling and reuse of treated effluent) undertaken by various sectors of the economy should be analyzed with regard to the capacities of water treatment facilities as compared with the waste water effluents.
- Comparative summary assessment of the water conservation status, including quality control by river basins should also be carried out.
- The disadvantage of water conservation activities should be analyzed and measures for water quality improvements should be suggested.
- As a result of the assessment of sectoral water demand projections, the tolerable contamination limits of effluents in water bodies should be defined by water management region.
- With the aim of establishing the tolerable contamination limits for economic sectors, the contents and scope of conservation measures for water and related natural resources should be outlined along with the capital costs and their economic efficiency.

Water for recreation

Recreation includes all activities whose social goal is to gain or recover physical and psychical forces. Water recreation includes: bathing, swimming, fishing, boating, yachting, skating on ice, and sojourns beside the water such as camping, and other forms of short-term or weekend sojourn.

Water recreation may be classified as:

- *everyday* (reservoirs and accessible water courses, swimming pools in the proximity of dwelling areas, up to 20 km);
- *weekend* (reservoirs and water courses, swimming pools in distance from dwelling areas more than 20 km, less than 200 km); and
- *seasonal* (areas of recreational character whose distance from relevant dwelling areas exceeds 200 km).

The quality of water recreation depends on: water management factors, climatological factors, local factors including topographical and aesthetic factors. The most important factors which influence recreational activities are:

- water pollution;
- water temperature;
- water depth;

- water table width;
- velocity of flow;
- water table fluctuation;
- fish occurrence; and
- variance with other water management purposes.

Water quality including temperature is the most important factor which influences the quality of recreation to the type of recreation activity.

Fish and wildlife

Water bodies as well as coastal sea and estuaries are natural habitats for aquatic life. These areas are very important environmental locations for fish and wildlife, temporary and continuously. Many fish species are migratory. To permit migratory fish to pass through man-made structures across rivers and streams, fish ladder and similar constructions should be installed in conjunction with the structures as far as possible. A multipurpose reservoir could often provide ideal facilities for fish and wildlife culture.

In planning coastal water resources development projects, due consideration should be given to the development of fish and other forms of aquatic life and appropriate surveys carried out. The survey results will be useful for guidance in future plans as well as for the correction of existing defects because man-made structures and water uses affect fish and wildlife.

Should the survey indicate that the planned water resources development projects would have adverse effects, the following preventive or remedial measures could be taken to offset the radical changes, among others, in the water quality and regime of river flow which affect the fisheries and aquaculture:

- Regulate irrigation and flood flow discharge favorable to fish culture and supply of water for hatcheries and nurseries;
- Minimizing the changes in (i) silting patter and turbidity, (ii) the nutrient content of water and coastal sea including oxygen and carbon dioxide, (iii) temperature, and damage to the river bottom through canalization and dredging, and coastline development;
- Minimizing the harmful effects of dams acting as physical barriers to fish migrations by providing fishflow, fish ladders, fish locks, fish lifts, fish screen, etc., depending on the specific requirement of the particular fishery and practical financial considerations.
- Minimizing the changes in natural characteristics of coastal water resources from man-made physical structures.

There are many other specific remedial measures depending upon the particular aspects of problem of the coastal water resources development.

The plans and project development should include the evaluation of the potential to inland and coastline water bodies for fisheries development. The hydrogeochemical regime of coastal sea, rivers, lakes and reservoirs and their fish-catch potential should be evaluated in this regard.

The factors influencing fish reserves and fish-catch potential should be presented along with the evaluation of fish catches depending on water discharge, water level, water quality and salinity. The optimum water releases for fish breeding should be identified to meet the requirements of fingerlings and growth fish in river delta areas.

5.6.4 Drainage

Drainage is the term applied to systems for dealing with excess water. The three primary drainage tasks are: urban storm drainage, land drainage, and highway drainage. The primary distinction between drainage and flood mitigation is in the techniques employed to cope with excess water and in the fact that drainage deals with water before it has reached major stream channels.

The purpose of urban storm drainage is to remove a storm water flow in an urban area to the water resources. Most cities have some form of storm drainage. It is an expensive urban infrastructure. In cities, stormwater is usually collected in the streets and conveyed through inlets to buried conduits which carry it to a point where it can be safely discharged into water resources. Urban storm runoff is an important source of pollution which complicates the solution of disposal into water resources. Because of that a single outfall may be used that requires collection of all storm water and construction of large and expensive constructions. Gravity discharge is preferable but not always feasible, and pumping plants may be an important part of a city storm-drainage system. Pump station for the storm water are very specific and unwanted because they are designed for large capacity which occur during a rainy period, but operation time is very short especially in Mediterranean region where rainy period is very short. The most important part of a successful design of a storm drainage system are good and reliable rainfall data. The stormwater management includes: rainfall record, land use, drainage system, ordinances, stormwater quality, stormwater use, and reuse efforts.

Land drainage removes excess surface water from an area or lowers the groundwater below the root zone to improve plant growth or reduce the accumulation of soil salts. Open ditches are widely used for the drainage of surface water, at considerable savings in cost over those of buried pipe. Another option is use of buried drains. Drains usually empty into ditches, although the modern tendency is to use large pipe in lieu of ditches where possible. This frees extra land for cultivation and does away with unsightly and sometimes dangerous open ditches. Sometimes pump installation is necessary for the final removal of collected water and discharges into water resources (rivers). Land drainage speeds up the runoff of water and, hence, increases peak flow downstream of drained area. The consequences of this increase should be considered in the planning of drainage systems. Land drainage is not as demanding in terms of hydrological design as other types of drainage. The purpose of land drainage is to remove a volume of water in a reasonable time. Drainage installed for removal of excess water from rainfall is typically designed to remove a specified quantity of water in 24 hours.

Highways occupy long, narrow strips of land and pose two types of drainage problems. Water collecting on the roadway or/and on the adjacent land slopes must be disposed of without flooding or damaging the highway and adjacent area. This water is polluted water and should be discharged in water resources in accordance with standards. Specially problems occur when highways pass through water supply protecting zones, and when collected water can not be discharged directly to the water resources. Highways cross many natural drainage channels, and the water carried by these channels must be conveyed across the right of way without obstruction of flow in the channel upstream of the road and causing damage to property outside of the right of way.

5.6.5 Sewerage and Wastewater Treatment

Wastewater, the water supply of a community after it has been used for various purposes, must be collected and disposed of to maintain healthful and attractive living conditions.

The elements of a modern wastewater management system include:

1. Individual source of wastewater;
2. On-site processing facilities;
3. Collection facilities;
4. Transmission facilities;
5. Treatment facilities; and
6. Disposal facilities.

These elements have their specific interrelationship (Figure 5.12) and specific characteristics in the waste water management system (Table 5.4).

Two important factors that must be addressed in the implementation of a wastewater management system are quantity and quality. Each wastewater system can be described with the following factors: collection system, flow production, treatment facilities and quality analysis, disposal, system management, ordinances, reuse, and other concerns.

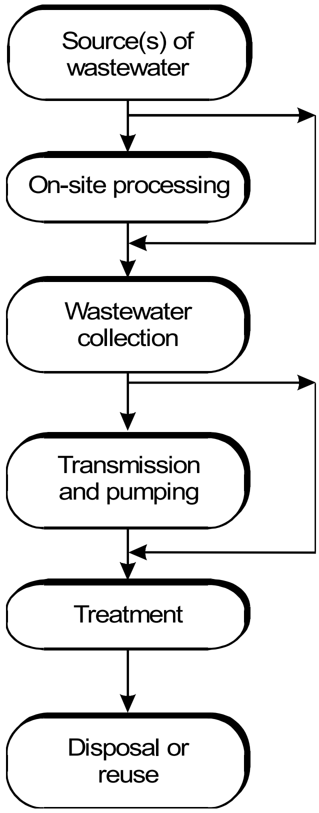

Figure 5.12: Interrelationships of the functional elements of a municipal wastewater management system

Wastewater that must be disposed of from a community includes:

- domestic wastewater discharged from residences and from commercial, institutional, and similar public facilities;
- industrial wastewater in which industrial waste predominates;
- infiltration/inflow extraneous water that enters the sewer system through various means, foundation drains, etc.; and
- stormwater.

Wastewater is removed in underground conduits called sewers. Some communities have a combined system in which sanitary wastewater, industrial wastewater, and storm runoff are all carried in same conduit. Other communities have separate system: one system for the sanitary and industrial wastewater which is connected to the treatment plant, and another for storm runoff.

Separate systems are more costly than combined systems, but the extra cost is always justified by better and efficient pollution control. With combined systems substantial quantities of waste water bypass to the water resources during storms by storm water overflow. Formerly, many combined sewers were used, but now nearly all new systems are separate systems. This system is specially suitable for semiarid areas as it is mostly in the Mediterranean area.

Wastewater must be purified before it discharged into water resources. Type of technology used and level of treatment depend of many factors but two of them are the most important: quality of waste water and required quality of effluent from treatment plant. This is highly specialized matter and will not be covered in this chapter.

The planning of urban wastewater management systems is a complex undertaking involving numerous engineering, political, and social issues. It is further complicated by the various international, national, local laws, ordinances, and requirements that have been passed in recent years to control the quality of national waters, and by the rapidity with which they are changing. Consequently there are no simple rules to be followed that will lead easily to final project implementation.

Table 5.4: The functional elements of a municipal wastewater management system

Functional element	Principal concerns in facilities design (primary/secondary)	Description
Sources	Quantity/quality	Sources of wastewater in a community, such as residential, commercial establishment, and industries
On-site processing	Quantity/quality	Facilities for pretreatment or flow equalization of wastewater before it is discharged to a collection system
Collection	Quantity/quality	Facilities for collection of wastewater from individual sources in a community
Transmission	Quantity/quality	Facilities to pump and transport collected wastewater to processing and treatment sites
Treatment	Quality/quantity	Facilities for treatment of wastewater
Disposal	Quantity/quality	Facilities for disposal of treated effluent and residual solids resulting from treatment

5.6.6 Flood Control

Floods are usually caused by excessive rainfall or snow melt, storm surges, inadequate drainage or a combination of any of these.

Many areas are periodically subjected to flood damage. In same cases, recurring floods seriously disrupt the momentum of a country's economic and social growth. The extent and frequency of flooding as well as the severity of flood damage usually determine the scale of flood management and protection work.

Flood-damage mitigation was distinguished from drainage as embracing methods for combating the effects of excess water in streams. Man can do little to prevent a major flood, but he may be able to minimize damage to crops and property within the flood plain of the river. There are many structural and non-structural measures which can be adopted to reduce or prevent floods. The commonly accepted measures for reducing flood damage are:

- confinement of the flow within a predetermined channel by levees, flood walls, or closed conduit;
- reduction of peak flow by reservoirs;
- reduction of peak stage by increased velocities resulting from cannel improvement;
- diversion of flood waters through bypasses or floodways to other channels or even another watershed;
- floodproofing of specific properties;
- reduction of flood runoff by land management;
- temporary evacuation of flood threatened areas on the basis of flood warnings; and
- flood plain management.

Flood-mitigation projects often utilize a combination of these measures.

The two most important aspects of a flood are its volume and its peak discharge. The volume of flood water discharge becomes important when a part or the whole of the flood waters are temporarily stored in reservoirs for mitigation purposes, because a greater storage capacity is required for a greater volume of flood. The peak discharge is important in the determination of the capacity of the flood discharge channel and the maximum levels to which the flood waters will reach. Thus, the peak discharge determines the height to which the flood protection dikes should be considered.

Flooding of coastal areas is usually caused by a number of factors, primarily storm surges, flood plain characteristics and tidal effects. Storm surge occurs when sea level is piled up through the effect of wind. The piling up depends upon the speed, direction and the duration of wind as well as the depth of water. The effect of the wind is most serious when it coincides with high tide. For the planning of flood mitigation measures, frequency curves of high-tide levels along with data on the heights and length of waves are required. In the absence of such data, wave characteristics can be calculated from data on wind speed, wind direction, fetch and the depth of water. The height and the orientation of the embankments are then determined based on the storm-surge water levels and height of waves.

In general, the steps in the design of a flood-mitigation project are as follows:

- Determine the project design flood and the flood characteristics of the area.
- Define the areas to be protected and on the basis of field survey, determine the flood damages which can be expected at various stages.
- Determine the possible methods of flood protection. If reservoirs or floodways are considered feasible, select possible sites and determine the physical characteristics of the sites.
- Design the necessary facilities for each method of mitigation in sufficient detail to permit cost estimates and an analysis of their effect on flood frequency or stage-damage relations.
- Select the facility or combination of facilities that offer the maximum net benefits.
- Evaluate the intangible social and environmental impacts of the project and consider alternatives that maximize benefits or minimize costs in the areas.
- Prepare a detailed report setting forth the possibilities explored, the protection recommended, and the degree of protection which will be provided.

Same steps are valid for coastal flooding taking in consideration specific characteristics of coastal flood, possible coastal mitigation measures and coastal area.

5.6.7 Water-related Environmental Issues and Health Aspects

In planning water resources development projects, environmental and health requirements as well as disaster prevention should be kept well in sight, and water quality management and environmental issues and health aspects should be included as an integral part of water resource planning.

The ultimate goal of water development projects is the sustainable socio-economic development of the nation. Precautions should thus be taken to ensure that the positive impact expected from the planned projects will outweigh the adverse impact on the water environment as well as on other development projects in the long run.

This topic should include the following:

a) Surface water quality and quantity

As the hydrologic regime of a river system will be considerably altered by planned water resources development projects, a comparison should be made of the typical hydrographs representing conditions both before and after the implementation of the project. It should include changes in water regime both upstream and downstream of project sites.

A comparison of surface water quality both before and after implementation of the projects should be carried out for average as well as seasonal conditions. A study should include analysis of expected new ecology and fish productivity in the reservoir areas, in the downstream riverine zones and in estuarine/marine zones.

b) Ground water quality and quantity

A study should be carried out on the anticipated effects of each water resources development project on ground-water quantity/quality in the vicinity of the project area. It should include possible alterations in the ground-water table, brackish water intrusion, water-logging, seepage from reservoirs and channels, etc.

c) Floods

Apart from causing visible damage to urban, agricultural, industrial areas, floods may also cause widespread and long-lasting damage to environment, sanitation of flooded areas and soil due to possible salinization and pollution.

d) Pollution control

Based on the assessment of existing characteristics of water resources quality, indicators of substances in wastewater effluents flowing into water bodies by urban runoff, sewerage systems, herbicides, and fertilizers, and watershed sediments should be presented. The advantages and disadvantages of possible water conservation activities should be analyzed and measures for water quality of the coastal water resources improvements should be suggested.

e) Siltation and erosion

An assessment should be made of the amount of sediment (silt) expected to accumulate in the reservoirs and storage from watershed erosion runoff and recommendation should be made for minimizing these effects. The study should include the problems of downstream erosion caused by scouring of water released from man-made structures.

f) Forests and watershed management

The possible impacts of projects on forests should be studied, and measures should be proposed to minimize adverse effects.

g) Fisheries

A study should be made of the expected losses in project riverine fisheries. A discussion should take place on expected new situation in the reservoirs and in the altered river and in any affected downstream estuarine and marine zones, comparing the new situation with the old, and describing plans for making up anticipated losses.

h) Flora and fauna

As the construction of hydrotechnical construction and especially reservoir projects almost always results in increased access to the watershed and thus serves to accelerate human activity and the related loss of forest, wildlife habitat, consideration should be given to the inclusion of measures for conservation of flora and fauna.

i) Health aspects

The construction of major reservoirs and irrigation projects almost always results in increased incidence of water-borne and vector-borne diseases. Thus a study should be made of the prevailing water-related diseases.

j) Water bodies and coastal areas

An analysis of the existing status of the stage, salt regime, extent of pollution of coastal sea water and lakes, and environmental requirements should be outlined. Sea water balance owing to the existing off-channel withdrawals should also be presented.

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The Priority Actions Programme (PAP), implemented by the Regional Activity Centre (RAC) in Split, Croatia, is part of the Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP). Although PAP acts as one of the MAP Centres since 1978, it is a national institution with the budget and mandate to carry out a certain number of MAP activities in coastal areas of the Mediterranean Sea.

PAP is an action-oriented organization aimed at carrying out practical activities which are expected to yield immediate results contributing to the protection and enhancement of the Mediterranean environment, and to the strengthening of national and local capacities for integrated coastal zone management. PAP cooperates with a large number of organizations in the UN system (UNEP, FAO, IMO, UNESCO, IOC, WHO, IAEA, WTO, UNDP), financial institutions (World Bank, European Investment Bank), other international organizations (European Union, Council of Europe, IUCN, etc.), as well as international institutions and consultancy companies.

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