Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions

WaterStrategyMan

Project Final Report

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PREFACE

This section constitutes the **Detailed Report** for the WaterStrategyMan (WSM) Project, "Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions", Contract No: EVK1-CT-2001-00098. The WaterStrategyMan Project was supported by the European Commission, under the Fifth Framework Programme, and contributed to the implementation of the Key Action *Sustainable Management and Quality of Water* within the *Energy, Environment and Sustainable Development (EESD)* Specific Programme.

The WaterStrategyMan Project was part of the ARID Cluster of Projects, supported by the European Commission through the Accompanying Measure *"ARID Cluster: Strengthening complementarity and exploitation of results of related RTD projects dealing with water resources use and management in arid and semi-arid regions"*, Contract No: EVK1-CT-2002-80018.

This section has been structured according to the "Guidelines for Reporting" issued by the EESD Programme, as follows:

- Chapter 1, *Background*, gives an overview of the water management problems frequently encountered in arid and semi-arid Southern European regions.
- Chapter 2, *Scientific/Technological and Socio-economic objectives*, details the objectives that the WaterStrategyMan project aimed to address.
- Chapter 3, *Applied Methodology, Scientific Achievements and Main Deliverables*, describes the methodology, research outcomes and deliverables realised during the implementation of the project.
- Chapter 4, *Conclusions* presents the overall conclusions drawn from the research effort, and summarises the overall socio-economic relevance of project outcomes and the respective policy implications.
- Chapter 5, *Dissemination and Exploitation Plan*, details the dissemination efforts undertaken by the Project team, and discusses the further exploitation of results at the Consortium level.
- Chapter 6, *Main literature produced*, summarises the main publications issued by the WaterStrategyMan project during its implementation.

CONTENTS

1. BACKGROUND

Water stress problems in the arid and semi-arid regions of Southern Europe are different to those faced by Northern European countries. The main characteristics of these regions are the high spatial and temporal imbalances of water demand and supply, seasonal water uses that strive for inadequate water resources, and poor institutional water management. Water scarcity is further intensified by periodic droughts, and, most importantly, by the impacts of human activities that disrupt water regimes and lead to a deterioration in water quality in both surface and groundwater bodies. In particular, in many cases the overexploitation of vulnerable groundwater resources, especially in coastal areas, has led to aquifer salinisation and depletion.

On the other hand, new infrastructure needs to be built to provide adequate supply and sanitation services. However, it has become more difficult and quite expensive to develop new sources or expand supply from existing ones. The difficulties are both technical and financial. From a technical perspective, the most accessible sources have already been tapped or exploited. In addition, the exploitation of surface water requires the construction of regulatory storage systems (dams – reservoirs) of doubtful feasibility and sustainability. From a financial perspective, such technical factors entail sharply rising costs for the expansion of service facilities and significant capital investments for the development of new infrastructure.

Scarcity and disparity of water resources are further exacerbated by the different levels of usability. The coastal regions, where the unevenly distributed population tends to concentrate, are an attractive tourist destination, and as a result the employment base is shifting towards tourism-related activities. The seasonal peak induced by the increasing population and the massive tourist arrivals should be taken into account in infrastructure planning; this in turn raises the question of adequate institutions and administration that can enable the development of such infrastructure, as well as the allocation of the imposed economic burden. Limited rainfall makes irrigation a necessity for sustaining local agriculture, and traditional economic activities. Increased use of water for agriculture further compounds the problem, even though the rate of growth is not as high as the one for urban domestic purposes.

It therefore becomes evident that solutions to water scarcity problems depend not only on water availability, but also on many other factors, such as lifestyle, economic activity and development trends, sufficiency of funds, etc. However, the most important factors remain the processes through which water is managed and the processes that determine the social and environmental conditions in the regions concerned.

In most arid and semi arid regions of the Mediterranean Basin, and even in the Southern EU Member States, the institutional water management framework is inefficient, characterized by overlaps of responsibility, and represents the main drawback for the application of efficient water resources management strategies. The main challenge is to develop functioning structures, methodologies, and tools to regulate and manage resources and increasing demand. Integrated water resources management requires good performance at all levels of the water management institutional structure. Potential interventions include policy formulation and legislation at the institutional/legislative level, allocation of water resources, coordination of water use and establishment of water use rules at the organizational level, and provision and control of water services for specific purposes at the operational (water service) level.

Until now, water planners and managers have mainly focused in the identification and coverage of growing demands for water primarily through long-term projections and construction of large facilities for storing, moving, and treating water. However, the aforementioned pressures indicate the need for a more integrated approach in water planning; one that would be able to respond realistically to the increasing requirements for infrastructure and water treatment, but at the same time promote demand management efforts, needed for encouraging greater efficiency in water use and postponing excessive infrastructure investments.

In the above setting, efficient and equitable water policies that take into account the costs and benefits of water usage as well as environmental and resource costs could have a significant impact on water demand for different uses and users. The diversity of economic and environmental practices, in combination with the variety of hydrologic patterns and cultural background, implies that water management strategies differ substantially among different water deficient regions. Consequently, the analysis of typical regions facing diverse water deficiency problems could lead to the formulation of appropriate, generalized recommendations on dealing with water scarcity and deficiency, in line with the principles of the newly adopted Water Framework Directive.

2. SCIENTIFIC/TECHNOLOGICAL AND SOCIO-ECONOMIC OBJECTIVES

2.1. Scientific and Technological Objectives

The goal of the WaterStrategyMan project was to develop and evaluate alternative strategies for regulating and managing water resource and demand management in Southern European regions, characterized by water deficiency problems. The central objective was to arrive at:

a) Regional strategies, which could guarantee a sustainable water use,

b) A set of water management guidelines, and

c) Protocols of implementation.

To that end, project methodology, tools and outputs can enable decision makers to delineate and assess a wider range of integrated water management options, and eventually select and implement relevant water schemes for mitigating water stress and achieving adequate water cost recovery. These developments were formulated and evaluated for selected typical regions and watersheds and therefore may easily be applied to any similar region.

The specific objectives of the Project included:

1. The definition of a typology of water deficient arid and semi-arid regions in terms of a) socio-economic, cultural and environmental characteristics related to present and prospective development policies, b) water resources, water supply, use patterns, water management practices and policy-making functions.
2. The formulation of principles of integrated water resources management frameworks appropriate for arid and semi-arid regions, in the context of implementing the Water Framework Directive, and also addressing the aspect of intersectoral competitive uses.
3. The development of a methodology for outlining/analysing alternative supply/demand scenarios and evaluating each intervention through the use of a multi-criteria approach that takes into account cost, benefits, efficiency, social and environmental implications.

4. The development of a Decision Support System as an integral part of the above methodology that would be utilized in analyzing quantitative and qualitative impacts, in describing the entire gamut of potential responses; and in suggesting appropriate solutions.
5. The selection of a set of representative cases, according to an elaborated typology, conceptualised as paradigms, with the purpose of providing concrete examples of implementation/evaluation steps.
6. The detailed analysis of the identified paradigms through the development and assessment of alternative scenarios on current and future allocation of water resources.
7. The development of alternative integrated water resources management options for each paradigm that take into account the full economic and environmental costs.
8. The development of improved resource demand/management strategies on the basis of the lessons learned from the six paradigms.
9. The formulation of widely applicable guidelines and protocols for the efficient implementation of the Water Framework Directive under different socio-economic conditions or assumptions.

2.2. Socio-economic Objectives

Water shortages and deterioration of freshwater quality in water deficient regions have been the major constraints for regional development. In this regard, one essential element of an integrated sustainable management approach is the regulation of water supply through tools and strategies specifically tailored to the characteristics of the regions. Improved water resource and demand management in arid and semi-arid regions should be based on efficient water management framework on one hand, and on improved water resources allocation on the other hand.

At present, there is a pronounced need for coping with rapid social changes, efforts for economic development and escalating water demands in a continuously changing environment. Appropriate water management tools and decision-making practices, as well as well-planned interventions for increasing the availability of supply and/or managing the growing demand are urgently needed. Investment for new water supply schemes and improved management of existing infrastructure should be planned and scheduled on the basis of valid and reliable data and taking into account all interactions between society and environment. Poorly conceived projects, inappropriate management practices, and inability to adapt to the changing demand patterns, have all contributed to non-sustainable development efforts, especially in terms of systematically disregarding a vision of the future. The development of an integrated water management methodology can help decision makers in planning sustainable regional development efforts in an increasingly complex socio-economic context and at the same time to conserve resources.

The project aimed to respond directly to such challenges through a holistic policy analysis that provides tools for the formulation and application of an integrated management framework. The development and use of a Decision Support System for the formulation and assessment of alternative resource allocation scenarios and responses allows the application of the information technology for implementing concrete intervention policies and helps in the assessment, evaluation and monitoring of developmental strategies and tactics. In addition, the application of a methodology that takes into account technical, environmental, social, institutional and economic parameters for the formulation of improved water management strategies can ensure that the resulting guidelines may be applicable to the entire range of conditions found in water deficient regions.

3. APPLIED METHODOLOGY, SCIENTIFIC ACHIEVEMENTS AND MAIN DELIVERABLES

The overall methodology of the WaterStrategyMan project was based on the study of the differences between quantity and quality dimensions in water management, and the development of alternative options and long-term scenarios, under the perspective of water stress problems experienced in arid and semi-arid regions. The objectives of the Project (see Chapter 2) were accomplished through the establishment of a broad framework on the existing knowledge on Integrated Water Resources Management practices, while highlighting the importance of regionalization and the relevant cultural context in the participating countries and regions analysed.

The adopted research approach was based on successive generalization, resulting from systematic analysis of specific conditions. On the basis of a generalised concept for aridity, the analysis of specific regions provided "lessons" that were used to develop Regional Models, to be further analysed through Case Studies. The analysis of Case Studies yielded results that can be used for a broad spectrum of similar regions, in the form of methodologies for the formulation and evaluation of Strategies for Integrated Water Resources Management, and Guidelines and Protocols that could provide the basis for their efficient and effective implementation.

The Project was carried out in four phases, each referring to a major step in the overall project methodology:

1. The **Diagnostic/Descriptive Phase**, which aimed at analysing the range of existing circumstances in arid and semi-arid regions of Southern Europe, and at identifying representative regional paradigms, to be further elaborated as Case Studies;
2. The **Analysis Phase**, which aimed at developing methodologies and tools for (a) the analysis of these Case Studies and (b) the formulation of alternative long-term scenarios and management strategies;
3. The **Strategy Formulation Phase**, in which current management practices were analysed, management options were evaluated and forecasts, long-term scenarios and improved strategies were developed;
4. The **Synthesis/Dissemination Phase**, which aimed at the synthesis of all analyses conducted into recommendations for improved water management, and guidelines and protocols for the promotion and application of an integrated water resources management approach.

Each Phase was organised into a number of Work Packages, which were further broken down into specific tasks. The applied methodology, research outcomes and main deliverables of each Phase are further elaborated below.

3.1. Diagnostic/Descriptive Phase

The main objective of the research carried out in the Diagnostic/Descriptive Phase was the development of a typology of water deficient regions, describing common and representative water scarcity and management problems in Southern Europe. The elaboration of this typology resulted in the selection of a set of representative water deficient geographical entities (regions or watersheds) to be further elaborated as Case Studies. In addition, special emphasis was given to the identification of specific water management inadequacies in each case, in order to form representative Paradigms of water deficient regions. The identification of commonalities and gaps within and between the Paradigms was the main tool for the development of a general roadmap towards the formulation of strategies for integrated water resources management and adequate water cost recovery. Moreover, the analysis carried out within this Phase highlighted the specific needs and water management issues in arid and semi-arid regions, in comparison to basins characterised by relative water abundance.

The Phase included three work packages:

- **WP1, "Range of existing circumstances"**, which aimed at the identification of the existing circumstances in water deficient regions of Southern Europe.
- **WP2, "Workshop on the range of existing circumstances"**, in which a Workshop was organised for the consolidation and evaluation of the results of WP1. As this WP is also related to the Dissemination of Project Results, outputs are further discussed in the relevant Chapter 5.
- **WP3, "Developing a Systematic Typology of Comprehensive Problematique"** which aimed at developing a systematic typology in terms of water resources, water supply and use patterns, water management practices and policy-making functions for the analysed water deficient regions.

The following paragraphs describe the methodology and outcomes with regard to the initial objectives set, and the deliverables produced as a result of the research undertaken.

3.1.1. Methodology

The main focus of the Phase was the definition and modelling of a coherent typology of water deficient regions by outlining the basic differences and similarities on key issues related to water resources management. In this context, an entire range of circumstances, in terms of water resources availability, water supply and policy options as well as institutional and socio-economic conditions was analysed both on a country and on a regional level.

Country level analysis

The main aim was to select a set of arid and semi-arid regions facing water deficiency problems for further characterisation. The analysis was conducted in six countries (Greece, Cyprus, Spain, Italy, Portugal and Israel) and involved an overview of the country in terms of:

- The current situation regarding water demand and supply;
- Environmental issues, focusing on water pollution and relevant mitigation measures;
- Water laws and regulations;
- Institutional and administrative framework, and the constraints and problems that it imposes to the water sector.

In addition, a preliminary non-exhaustive dataset was collected on a more disaggregated spatial scale, to form a basis for the next steps of the analysis.

Regional level analysis - Definition of Typologies

The methodology followed for the formulation of Typologies was structured in three major steps:

- **Step 1: Selection of the Sample of Regions**, based on the following criteria: (a) the existence of natural aridity in the areas, (b) the existence of water shortages on a permanent or seasonal basis due to natural or man-made reasons, or the recurrence of drought and/or flood cycles; (c) the insufficiency of efforts for water resources management; (d) the lack of proper administrative or institutional frameworks for the effective water resources management and (e) the occurrence of socioeconomic conditions adversely affecting the management of water resources.

  Regions selected were: Attica, Thessaly and Cyclades in Greece, Emilia-Romagna and Belice Basin in Italy, Tel Aviv and Arava regions in Israel, Germasogeia, Akrotiri and

Kokkinokhoria areas in Cyprus, Canary Islands and Dõnana in Spain, and Guadiana, Sado and Ribeiras do Algarve in Portugal.

- **Step 2: Data selection and collection.** The data selection and collection involved four distinct stages:
  - the selection of a set of indicators,
  - the data collection stage,
  - the data verification stage, and
  - the conflict resolution stage, where discrepancies and conflicts were resolved.

  More specifically, the 15 regions were described in terms of climatic and meteorological conditions, water availability and quality, and demand and consumption patterns. In addition, for each region a Matrix (the Matrix of Existing Circumstances) was compiled to assist in the definition of typologies. This Matrix involved quantitative and qualitative information on natural conditions and infrastructure (climate, aridity, water availability, quality and major supply sources, network coverage), on the economic and social system (water consumption per use sector, pressure indicators related to water demand, pricing policies, levels of public participation and awareness) and information describing the prevailing decision-making processes with regard to water resource management and overall developmental priorities.
- **Step 3: Data Analysis.** The analysis of data was also performed in 4 stages:

  The first stage involved the determination of the range of circumstances. The data for all regions was examined and the gaps and commonalities among regions as well as the data ranges, were determined. Secondly, a classification scheme was developed, which could be used to assess the data obtained. The classification was effected in three separate approaches, based on (a) natural conditions (Drivers), (b) human pressures (Pressures) that result into the conditions of water deficiency, as well as (c) the Responses to these conditions.

  Thirdly, for the analysis of the quantitative data for the Pressures classification approach, an appropriate statistical analysis methodology was selected based on the multivariate methods of cluster and factor analysis. Finally, the distinguishing parameters in each classification approach were identified, and then used to form a synthesis of regional types.

Regional Level Analysis – Set of Representative Paradigms

The overall objective of the identification of Paradigms in the selected regions was to provide the framework of developing, analyzing and evaluating alternative water resources scenarios and management options.

In Water Resources Management, the word “paradigm” describes a school of thought on prioritizing policy options for the management of water resources. Each paradigm refers to the:

- Geographical entities and their grouping regarding physical and human criteria,
- Driving forces like population or economic activity trends,
- Physical parameters of the available water resources (state, uses, effects),
- Planning and measures regarding the available resources.

The understanding of the existing policy options and actions that have been followed in order to manage water resources, and their theoretical background, can lead to the identification of some basic and distinct Paradigms of Water Resources Management for each region (Kuhn, 1962; Gleick, 2000). Therefore, a Dominant Paradigm for each region is the existing, traditional way of “how things have always been done”, combined with the conditions that have led to that approach.

The formulation of a Paradigm is a difficult and complicated procedure, as it reflects the conflicts between the established scientific and technological approach and the political and social opinions and demands. In order to define the range of and collect concepts that describe structural (dams, pipes) and human (administration, financial management) parameters of a water system, one must understand the technical, social, financial, cultural and environmental issues of the Paradigm.

The DPSIR approach (Walmsley, 2002; Smeets et al., 1999), which is often used for the assessment of water management systems using indicators describing the existing Drivers, Pressures, State, Impacts and Responses, can lend itself to a new interpretation in the description of Paradigm formulation. The Drivers and Pressures and their Impact of water stress on the system were qualitatively defined in terms of a Typology, whereas the Paradigm corresponds to the dominant responses used to mitigate water stress.

3.1.2. Research Outcomes

Definition of Typologies

The main observation made was that aridity should be understood in a wider context encompassing both natural and man-made processes. Various concepts have been used to exemplify a prevailing confusion among such terms which signify dry environments or water deficiencies. The terms vary all the way from the extremes of desert to aridity, to drought and to temporary water shortages (Vlachos, 1982; Bailey, 1998). There are four different terms that are important to the initial separation between physical and social conditions with regard to what one can summarily label water deficiencies:

- **Aridity (Type A)**, signifying a permanent natural condition and a stable climatic feature of a given region,
- **Drought (Type B)**, referring to a temporary feature of the climate or to regular or unpredictable climatic changes,
- **Water shortage (Type C)**, a term that can be understood mostly as a man-made phenomenon reflecting the concern with temporary and small area water deficiencies, and
- **Desertification (Type D)**, as a process of alteration of the ecological regime often associated with aridity and/or drought but principally brought about by man-made activities which change the surrounding ecosystem to a significant degree.

On the basis of the spectrum of water management circumstances in the 15 regions, and the above scheme, a typology for water stress conditions was proposed. The typology categorises the 15 regions into the above four broad Types with respect to the processes leading to water stress, and to the water stress context, i.e. man-made or natural processes, causing temporary or permanent water deficiency:

- Type A: Attica, Akrotiri.
- Type B: Thessaly, Germasogeia, Emilia-Romagna, and Donana.
- Type C: Cyclades, Kokkinokhoria, Belice Basin, Guadiana, Algarve, Sado.
- Type D: Tel Aviv and Arava regions.

This initial categorisation was further elaborated, to distinguish between the prevailing regional socio-economic characteristics and sectors mostly affected by water stress and permanent or seasonal deficiencies. With regard to the set of regions analysed, three main types of regions were determined (I, II, III):

- **Type I**, which characterizes regions that include **metropolitan/large urban centres** (Tel Aviv, Emilia-Romagna and Attica) with the following main characteristics:

- Main economic activities largely belong in the tertiary sector, although secondary sector activities are also present.
- Water deficiency is either permanent, due to insufficiency of resources for the existing population, or seasonal due to meteorological/hydrological fluctuations (e.g. droughts).
- There exists a varying degree of price elasticity in water supply.

- **Type II**, which denotes regions dependent on **tourism**, with small to medium sized urban centers and large seasonal population fluctuation (Cyclades, Canary Islands, Algarve, Akrotiri and Donana). The main characteristics are the following:
  - There is dependence on agriculture as well but the main source of income is tourist activities.
  - Seasonal water deficiency is a result of population fluctuations due to the tourist industry's peak in the summer months.
  - Price elasticity is variable, depending on the local conditions.
- **Type III**, which includes regions dependent on **agriculture**, with small to medium sized urban centers and limited population fluctuation (Germasogeia, Kokkinokhoria, Arava, Belice Basin, Guadiana, Sado and Thessaly). The main characteristics are the following:
  - The dependence on secondary and tertiary sector activities is often limited compared to agriculture, which is the main source of income.
  - Usually seasonal water deficiency as a result of increased crop requirements of water in the summer time.
  - Price elasticity is variable, depending on the local conditions.

Selection of Representative Paradigms – Case Study definition

According to the premises regarding Typology Definition and Paradigm Identification, and the overall Project objectives, six regions were selected out of the total of 15 analysed, and developed as Case Studies for the formulation and analysis of improved water management strategies. These were: Paros island in the Cyclades complex, Greece, Belice Basin in Sicily, Italy, Limassol Region in Cyprus, the region of Tel Aviv in Israel, the island of Tenerife in Canary Islands, Spain and the Ribeiras do Algarve river basin in Portugal. A brief summary, focusing on typology of water use, current and emerging water management issues, and dominant responses to water deficiency is presented below.

1) Paros Island in the Cyclades complex, Greece. The main water stress issue is the peak in demand during the summer months, due to the high tourist influx onto the island. The existing infrastructure capacity is stretched during that period and is often insufficient to cover demand at peak times, leading to temporary shortages that in return are damaging to tourism.

- *Typology:* Predominantly tourist (Type II), insular.
- *Dominant Paradigm:* Since the water demand started to grow significantly in the 1980s, the residents of Paros have attempted to cover the water deficit through the construction of private and public drills, small dams and interception walls and desalination. However these have not been the result of a systematic effort, and as such the policies followed have led to a number of problems in terms of both hindering economic development and exerting pressure to the environment. The Dominant Paradigm on the island shows a strong tendency towards small-scale structural supply enhancement solutions.

2) Belice Basin, Italy. The major source of water stress is the peak in demand during the summer, due to irrigation demands in the region, and new interventions are needed in order to satisfy the local irrigation demands.

- *Typology:* Predominantly agricultural (Type III).
- *Dominant Paradigm:* The formation of the Arancio Lake on the Carboj River in 1952 served irrigation purposes for the nearby territories, and the increased water availability contributed to a change in agricultural practices from crops requiring little irrigation to more irrigation dependent ones. The subsequent creation of the Garcia dam on the Belice Sinistro River provided further supply for irrigation and domestic demand. The Dominant Paradigm in the region is focused on the construction of large-scale supply enhancement infrastructure.

3) Tel-Aviv region, Israel. There are conflicts arising between the provision of water for urban water supply and for agriculture irrigation in a country where water is a very scarce and valuable resource. The Tel Aviv region is the largest in Israel with two million people, 30% of the total population, and 5% of the total cultivated land in the country. The water economy in Tel-Aviv is characterized by relatively high domestic and industrial consumption, and relatively low agricultural consumption.

- *Typology:* Predominantly urban (Type I).
- *Dominant Paradigm:* The water consumed in the region comes from desalinated sea water, groundwater abstractions and water reuse. About two thirds of it is supplied to Tel-Aviv via the national water system operator, and the remainder is provided by private producers from the coastal aquifer. The Dominant Paradigm relies heavily on large-scale water production technologies and pricing incentives.

4) The Limassol area, Cyprus. The region is one of the main tourist destinations in Cyprus, while at the same time its agricultural production accounts for more than 50 % of the fruit trees, 50% of the vegetable and 60% of the table grapes production of the country. Thus, the impacts of the competition for water resources between tourism and agriculture, the two major sources of income of the island, are being analysed, in order to identify a compromising water management solution, beneficial to both sectors.

- *Typology:* Predominantly tourist (Type II), regional.
- *Dominant Paradigm:* The current strategy used for ensuring adequate water supply for all uses, responding to the current conditions of water deficit, is based on a combination of a number of policy options, which fall short however in achieving the goal of meeting demand. The Dominant Paradigm in the region is the combination of large-scale infrastructure, smaller structural interventions and reuse for supply enhancement.

5) The island of Tenerife in the Canary Islands, Spain. The year-round high water demand in the island is caused by a tourist influx much larger than the local population, demanding large infrastructure that nevertheless needs to be paid for by the locals. In addition, the combined effect of increased tourist activity and maintenance of high water-demanding crops in the last decades is highly alarming, while impacts from the overexploitation of the groundwater resources are obvious.

- *Typology:* Predominantly tourist (Type II), insular.
- *Dominant Paradigm:* The water shortages in Tenerife have traditionally been addressed through the increasing drilling of underground water galleries for abstraction. The dominant paradigm for the island relies mostly on supply enhancement through medium to large-scale infrastructure development, and desalination capacity augmentation.

6) Ribeiras do Algarve, Portugal. Despite the relative abundance of water resources, salinisation of the aquifers is a rapidly intensifying problem due to the over-abstraction of water for use in golf courses and other tourism-related uses. In the last decades the basin has suffered deep changes in its demography mostly due to the development of tourist activities. The pressure on water resources created by seasonal population is very strong, leading to water shortage problems during the summer months, and is compacted by the significant agricultural demand. The increasing abstraction has led to salinisation of the underground aquifers in the area, making finding an alternative means of supply both necessary and urgent.

- *Typology:* Predominantly tourist (Type II), regional.
- *Dominant Paradigm:* The water demand of the region has traditionally been covered with abstracted groundwater; this however has changed in recent years, and water demand is now mostly covered through surface water from reservoirs. The current dominant paradigm in Ribeiras do Algarve involves mainly the use of large-scale supply enhancement infrastructure.

3.1.3. Main Deliverables

The Deliverables elaborated during the Diagnostic/Descriptive Phase of the Project were:

Deliverable 1, Range of existing circumstances

The Deliverable summarises key issues relating to the availability, demand and management of water in the six selected countries (Spain, Portugal, Italy, Israel, Cyprus and Greece). The deliverable is organised in the following way: The first section briefly describes water availability, water quality and institutional frameworks with regard to water management in the countries in Southern Europe. The key issues with regard to management approaches and the responses to the driving forces imposed by a water deficit are described in the next section. Section 3 gives a brief summary of the key issues identified. Individual country reports are provided in the Appendix.

Deliverable 3, Workshop proceedings

The Deliverable is the compilation of the proceedings of the "Workshop on the Range of Existing Circumstances", held at Hermoupolis, Syros Island, Greece, on July 8th 2002.

Deliverable 4, Systematic Typology of a Comprehensive Problematique

The Deliverable summarises the research carried out for the formulation of a typology of water deficient regions. The report includes: a) an overview of the regions selected; b) a review of existing classification schemes; c) alternative classifications developed for the definition of the typology, and the indicators used to that end. In addition, the Appendices to the report include the regional analysis conducted in the 15 regions, in terms of overall description, collected data and compiled matrices.

Deliverable 5, Selection of representative Paradigms

The Deliverable aimed to provide a better understanding of the forces that drive decision-making processes in the regions selected and the current management practices in response to water shortages. On a first level the report presented the paradigms that were identified as representative of the specific character of the regions analyzed in the project. These Paradigms included a plethora of water supply options, water uses, economic and environmental frameworks and water cost recovery policies. On a second level, the analysis formulated clusters of regions sharing similar approaches to water management, with the aim to arrive at a final selection of regions and cases, to be further elaborated as Case Studies.

3.2. Analysis Phase

The aim of the Analysis Phase was to provide the analytical tools and methodologies to be used during the Strategy Formulation Phase for the development and evaluation of long-term scenarios and strategies for improved water management. The first stages involved a critical review of commonly used methods for the analysis of water resource systems, the estimation of costs (financial, environmental and resource costs), and appropriate indicators, indices and multi-criteria approaches. Additionally, a thorough review was made of existing Decision Support Systems (DSS) used in water management applications, and their adaptability to the Paradigms of the Diagnostic/Descriptive Phase. The second stage focused on the development of a prototype Integrated Decision Support System Tool, the WSM DSS, which implemented the methods previously selected, and of a GIS Database for each Case Study. The prototype was used extensively in the Strategy Formulation Phase in order to accomplish the objectives of scenario and strategy formulation and evaluation. Throughout this process, the overall methodology and the WSM DSS were further refined, according to feedback received from the Case Studies of the project.

The Analysis Phase comprised four work packages:

- **WP 4, "Development of a methodology"**, which aimed at the development of a consistent methodology for assessing water availability and demand, at estimating economic and environmental costs for water management interventions, and at selecting appropriate multi-criteria approaches and indicators. The Work package was divided in four Tasks:
    - Task 4.1, *Review and evaluation of available methods for the quantitative analysis*,
    - Task 4.2, *Review and evaluation of available methods for estimating costs,*
    - Task 4.3, *Review and evaluation of multi-criteria approaches,*
    - Task 4.4, *Determining the best approach.*
- **WP 5, "Review, testing and adaptation of tools for water resources management"**, which aimed at reviewing and evaluating the applicability of available models, tools and decision support systems in the identified Paradigms, and at integrating the tools selected in WP 4 in multi-criteria decision-making system, able to support the Strategy Formulation Phase. The WP comprised two tasks:
    - Task 5.1, *Review of available models and Decision Support Systems for water resources management,* and
    - Task 5.2, *Adaptation of tools to the emerging responses*.
- **WP 6, "Data and GIS database"**, with the objective of collecting available information for the identified paradigms, and developing a GIS Database to accommodate all collected data in an efficient and updateable mode in order to provide the necessary inputs to the DSS for the Case Studies.
- **WP 7, "Workshop for Presenting Findings and Training on DSS"**, which focused at the organisation of a workshop for the presentation/discussion and evaluation of all findings and results of WPs 4 and 5 to the participating decision-makers. This WP is also considered part of the effort to disseminate project results; therefore it is discussed in the relevant Chapter 5.

The following section presents the methodology followed and the scientific achievements with regard to the elaborated methodology and the development of the WSM Decision Support System and GIS Database.

3.2.1. Methodology and Scientific Achievements

Review of methodologies and selection of appropriate methodological approaches

The development of the methodology provided the framework for a quantitative assessment of water management strategies, taking into account the spatial and temporal character of water supply and demand as well as the socio-economic and environmental implications of water use. The eventual aim was to select models that could be used in an Integrated Decision Support System, under WP 5. The following paragraphs elaborate on the research undertaken to select appropriate methodologies for the consecutive analysis of Paradigms. Methodologies selected and incorporated in the WSM DSS are discussed in the pertinent section.

Quantitative Analysis of Water Resource Systems

The initial stage included a review and evaluation of a number of methods and models for the quantitative analysis of water resource systems with regard to the selected Paradigms. Methods and models reviewed were selected based on their data requirements and complexity.

In general, methods for the quantitative analysis include: (1) methods for the analysis of water supply including water availability and water management options, (2) methods for analysing water demand in different sectors, (3) models and tools for forecasting both water demand and availability and (4) methods for optimising and/or simulating water resource systems at the river basin level.

Emphasis was placed on forecasting water resources components, taking into account the spatial and temporal scale. Appropriate models for managing water resources were reviewed and evaluated according to advantages, limitations and data/complexity constraints. On the demand side, models and methods for analyzing and forecasting water demand for industry, domestic demand, irrigation water demand as well as environmental demand were examined.

Furthermore, models that represent the above mentioned components as well as their interrelations and interactions on a river basin level were analysed. These included models for the simulation of river basins, models for the optimization of water allocation, and combined models that take into account economic and environmental implications and impacts.

Indicators and multi-criteria approaches for assessment and evaluation

This review focused on evaluating existing indicator approaches for assessing water resources systems, and on selecting a multi-criteria methodology for an overall assessment of water management interventions and strategies.

The first step was therefore the presentation of a comprehensive overview of existing indicator approaches addressing both quantitative and qualitative aspects, as well as economical and social/ institutional aspects. The review included both methods for structuring indicators, such as the P-S-R approach, the D-P-S-I-R approach, and indicators for assessing water quantity such as the Falkenmark water stress index, the World Development Indicators, Index of Watershed Indicators, etc.

In addition, a number of multi-criteria-decision making (MCDM) methods that are commonly used in water resources management have been discussed and evaluated in terms of mathematical sophistication (i.e. selecting a Pareto-optimal set of alternatives) and methodological transparency.

Review and selection of available methods for the estimation of costs

The review focused on a critical evaluation of the different methods and methodologies for the estimation of financial, environmental and resource costs and their allocation, according to the Water Framework Directive and the respective CIS Guidance Document (WATECO). In addition to analysing the theoretical background of the different approaches, and at presenting advantages and disadvantages for each, the review critically assessed:

- Method complexity, with regard to data and time application requirements;
- Method generality, in order to select methods applicable to a variety of water management systems and water management issues;
- Possibilities for integration with a Decision Support System, and compatibility with the selected quantitative methodology.

For external environmental costs, the idea was to select a cost-based valuation approach, where total environmental costs are estimated on the basis of costs for mitigation measures. It was proposed that computation would be based on unit costs, impact coefficients (denoting the vulnerability of each water body) and generated pollution loads or abstractions from each economic activity. For resource costs, and additionally to the computation of indicators such as the total social welfare surplus and the private welfare surplus for each use sector, the selected approach involved an approximation through the scarcity rent for each scarce supply source.

Selection of appropriate methodological approaches

The main criteria used for selecting and modifying a method were (a) data availability, (b) compatibility among methods for water systems analysis and cost evaluation, (c) compatibility among methods for cost estimation and MCDM practices (e) robustness of the methodology, and (f) adaptability of the method to the identified Paradigms.

For a quantitative analysis of water resources systems, an integrated model based on a network representation on the river basin scale was proposed, taking into account water quantity, water quality and economic aspects. The overall recommendation was that the evaluation of long-term water management interventions (strategies) should be based on a simulation of water allocation over a given period, and the performance of the strategies under different scenarios (developments that cannot be directly influenced). In terms of economic assessment, the performance of the strategy is evaluated by a set of five spatially and temporally aggregated economic indicators.

For an assessment of water quantity and quality, the method proposed encompasses indicators estimated on a regional scale as well as indicators that are valid only for a given component of the system. Spatially aggregated indicators for assessing water quantity include water deficits per sector, whereas water deficits at the user level are "measured" using performance indicators (reliability, resilience and vulnerability) and the frequency distribution of allocated water. The performance of given strategies in terms of water quality was assessed by the frequency distribution of commonly used water quality parameters. In particular, thresholds implied by the relevant European legislation (Urban Waste Water Directive, Drinking Water Directive and others) are used as target values.

Given the wide range of characteristics in the case study regions in terms of water availability, possible water management interventions, and development priorities, it is impossible to develop and apply a unique set of indicators to all regions. It was therefore agreed to conclude to a predefined core set that would be supplemented – if necessary – by user-defined criteria according to the specific conditions in a region.

Review of available models and DSSs for water management

An additional task to the review of methodologies focused on the review of commercially available software packages for water resource management. Most of the reviewed packages are currently being applied to river basins. However, the embedded features, models and approaches are general and can fit specific user-defined areas and zones.

Software packages and models reviewed and evaluated included *Mike Basin*, by the Danish Hydraulic Institute (DHI), *Basins*, by the U.S.- Environmental Protection Agency, *A DSS for Water Resources Planning Based on Environmental Balance*, developed within a project funded by the Italian Cooperation with Egypt, *A Spatial Decision Support System for The Evaluation of Water Demand And Supply Management Schemes*, by the National Technical University of Athens, *Iqqm*, by the New South Wales Department of Land & Water Conservation, with collaborative assistance from the Queensland Department of Natural Resources (QDNR), *Ensis*, by the Norwegian Institute for Water Research (NIWA) and the Norwegian Institute for Air Research (NILU), *Realm*, by the Victoria University Of Technology and the Department of Natural Resources and Environment, in The State of Victoria, Australia, *Mulino*, the main objective of the related European Mulino Project, *Ribasim*, by Delft Hydraulics, *WEAP*, by the Stockholm Environment Institute's Boston Center at the Tellus Institute, *Waterware*, main objective of the European research program Eureka-EU487, *Aquatool*, by the Universidad Politecnica de Valencia, Spain, and *Iras*, by the Civil and Environmental Engineering Department of Cornell University and the Resources Planning Associates Inc of Ithaca, New York State.

The aim of the review was to select potential packages and/or models that could support the analysis foreseen for the following stages of the WSM project. Focus was given to the user-friendliness of the reviewed DSSs, the capability of supporting GIS analysis and geo-referenced data, the capability of schematising in a water network form the studied water resource systems, and the compatibility of the incorporated models to the selected methodological approach.

Although not exhaustive, the comprehensive review pointed out the emerging requirement for a prototype DSS that could combine the multidisciplinary information needed for the analysis of strategies and evaluation of long-term management strategies, taking into account economic, hydrologic and environmental interrelationships, also in the context of applying the economic principles of the Water Framework Directive. It was therefore decided to combine accumulated knowledge and existing know-how for integrating models already developed by the Consortium in a comprehensive integrated package, which would be linked to the GIS database developed by the project.

The following paragraph gives an overview of the design of the GIS database, and the interlinked Object Model, which formed the business layer of the developed WSM DSS. The overall framework of the WSM DSS and its various modules are discussed in the next sections.

GIS Database and Object Model

The GIS Database is the heart of the spatial DSS, providing the central system that allows communication and intermediate storage between models. The Database is strictly interrelated with the methodology applied in analyzing and simulating water resource systems and consequently with the WSM Decision Support System. The Data Model has been developed under Arc GIS 8.x, by ESRI. The main output of the Data Model is an Arc Info geodatabase, which stores information on all spatial and non-spatial attributes and classes included within the model.

In addition to the accommodation of available data and the selection of the appropriate platform for facilitating data collection and entering, the GIS Data Model has been developed keeping in mind the final goal of the WSM DSS (i.e. is the analysis of water management strategies in the case study areas of the Project). To this end, the Data Model is able to:

- Accommodate all data related to the simulation of different water availability scenarios and demand forecasts, including forecasts of pressures;
- Store information on the different water management instruments proposed for the different case studies of the project.

Since the spatial extent of the selected regions was variable, ranging from a river basin district in Portugal (Ribeiras do Algarve) to a small Greek island (Paros) in the Aegean Sea, one primary aim achieved during the development and the implementation of the data model was to allow for the modelling of those very different systems under a single flexible framework.

In this regard, the design of the Database was performed in such a way as to adequately describe any system in terms of water resources availability, demand, infrastructure and management options and developmental policies to be formulated within the scope of the analysis. Within the model, logically related features are grouped together. Thus, the model extends the basic distinctions between water resource systems, demands, infrastructure and administrative structures. The core components of the Data Model are:

- *Basic Regional Data*, which organises general information on the case study area, and also contains basic map information on the regional characteristics.
- *Water Bodies*, which groups spatial and attribute data on the most important water bodies, as those are classified in the Water Framework Directive, and the monitoring network.
- *Water Network Data,* which is a geometric network that models the water resource system under study.
- *Administrative Structures*, which incorporates regional and water resources administrative structures and authorities.
- *Time Series*, which describes time varying properties of spatial objects, related to the formulation of water resources management scenarios, and other data that can be considered critical for the analysis, such as population and precipitation variations, water requirements, inflows and outflows, quality measurements, etc.

As previously mentioned, water resource systems were modelled on the basis of geometric networks. A geometric network is described as a set of junctions (points) and edges (polylines) that are topologically connected to each other. In the Object Model junction elements are conceptualized as water nodes while the connections between them are the water links. Water nodes are classified into three categories, (a) supply nodes standing for alternative water supply sources and characterized by the monthly available supply, (b) demand nodes modelling water uses and flow requirements and, (c) transhipment nodes standing for treatment plants and generic network junctions. Water link objects are classified in four categories according to the connectivity rules of the system and the particular modelling requirements of the DSS, (a) supply links (pipelines and canals) conveying water from supply sources to demands, (b) groundwater interaction links (recharge and discharge), representing the natural interaction between surface and groundwater bodies, (c) return flow links, conveying return flows from consumptive demand uses to receptor bodies (surface or groundwater) or wastewater treatment plants, and (d) river links, representing the natural course of a river water body.

The WSM Decision Support System

The overall aim of the effort undertaken was to provide an integrated Decision Support System for the systematic evaluation of water management interventions for a long time horizon, simulating long-term accumulative effects and anticipating potential future changes and uncertainties. The developed prototype GIS Decision Support System aims to assess the state of a water resources system in terms of sources, usage, water cycles (pathways) and environmental quality in a simulation environment that responds realistically to external and internal modifications. It has the potential to evaluate the effects of actions and measures proposed or adopted, on the basis of the different scenarios, alternatives and policies. Within the simulation, water resources are allocated according to a set of demand and supply priorities reflecting the pricing system, social preferences, environmental constraints and developmental priorities. Among the many ways of classifying implementation approaches or policy options, responses are of particular importance for the WSM DSS, summed up in four types of management options:

- **Supply enhancement options**, intended to increase available water quantities during drought; they concern structural interventions which attempt to enhance water supply;
- **Demand management options**, aiming at decreasing water demands through various conservation techniques and use limitation;
- **Socio-economic measures** needed to mitigate impacts, also by means of socio-economic instruments, such as pricing and changes in the regional development priorities;
- Methods able to produce management strategies through **combinations** of control measures seeking optimum and efficient solutions.

Key words in the overall modelling approach are: *Description*, *Assessment*, *Strategy*, *Forecasting* and *Evaluation*. These reflect the main functions of the DSS, which, through the assistance of the GIS Database, aim at:

- **Describing** the existing situation in a case study area, in terms of hydraulic and environmental characteristics of man-made and natural water systems;
- **Assessing** the state of a water system, by addressing different aspects such as available water sources, actual usage practices, water cycles (paths), environmental quality and economic issues;
- **Defining and applying** alternative strategies for an integrated water resource management, built on technical and demand management options/actions;
- **Forecasting** the behaviour of the water system state, on the basis of assumed or envisaged scenarios of water availability, and water demands for different use sectors;
- **Evaluating** the impacts of the actions, by observing and analysing the results of forecasted scenarios, alternative options and policies, through a multi-criteria evaluation approach, taking into account local or national constraints.

The developed DSS can model water conditions in a given area and be used to estimate how much water is needed to meet the existing and projected demand, to determine what interventions are necessary, as well as when and where, and their cost. It can provide indicators of performance for selected actions under potential availability and demand scenarios, and use them to rank the scenarios.

Under this context the WSM DSS played a fundamental role in the formulation and analysis of improved and integrated water management strategies in the undertaken Case Studies, providing a coherent framework for their articulation, modelling and systematic evaluation. The following paragraphs give a brief overview of the key features and incorporated models.

Operational Aspects

The developed (prototype) DSS evolves around the DPSIR context (Walmsley, 2002) and uses the concept of a water management scheme (WMS). A WMS has been defined as a set of scenarios for Driver variables (e.g. rainfall patterns and population growth) and the application of one or more water management interventions or instruments (Responses) in a suitable time frame.

The design concept is based on the estimation of Pressures from the consecutive computation of future demand and availability time series, and the forecast of the State of the water system through the simulation of water management strategies or single interventions. Then those can be compared, and the decision maker or the analyst can formulate responses to mitigate water stress impacts with respect to the undertaken objectives, economic or environmental. For this purpose, different models have been incorporated for estimating water availability, demand, allocation of available resources to different uses, and most importantly estimation of financial, environmental and resource costs. Water resource systems were modelled on the basis of geometric networks, composed of the objects already described in the section on the *GIS Database and Object Model*.

Water Demand

The analysis of water demand in the WSM DSS is strictly functional to the allocation of water resources. The Water Demand module generates alternative demand scenarios, which along with availability scenarios, constitute the basic and discriminating factor in the distribution of water from the sources to the users.

A specific formulation for scenario building has been adopted for each one of the different types of activity and water use, considered to be part of a water resource system. Those are:

- Permanent and tourist population, representing domestic use of water,
- Agricultural demand, differentiating between irrigation and animal breeding demands, and
- Industries of various types.

In addition to activities related to consumptive water uses, as those above, the WSM DSS also addresses non-consumptive demands, such as hydropower generation, navigation and protection of aquatic life in rivers/ecosystems (environmental demand). In order to consider water transfers to neighbouring zones/regions, an additional water demand is modelled to describe the amount of water to be allocated outside the region under study.

Estimation of water requirements for each use is based on commonly applied models, carefully customised to account for data availability limitations. Irrigation demand is modeled according to the FAO crop coefficient method, incorporating also conveyance, distribution and application efficiency. Domestic and industrial demands can either be modelled on the basis of different activities, where each is assigned a different activity level and consumption rate, or through a more simplified approach, i.e. on the basis of population variations and consumption rates.

Scenarios are generated by specifying appropriate growth rates to the key variables (**Drivers**) that determine water demand, such as population for domestic use, cultivable area and livestock for agricultural practices, and production growth and energy requirements for industries and hydropower plants respectively. This specification can be made in two ways, either globally for all uses and requirements, or by assigning specific projections for each use. An additional feature includes a feedback loop where drivers (e.g. cultivated areas or population) can be affected by the volume of water allocated over a certain period of time.

Water Availability

The Water Availability Module constitutes the second pre-processor of the WSM Decision Support System aimed at estimating the amount of water that is available in a water resource system. The water sources considered in the WSM package comprise surface water, such as artificial or natural lakes and the river network system, and of groundwater, renewable and not.

Water availability modelling generates monthly time series of forecasted available supply for each water source of the system. The output of the module concerns natural recharge for renewable groundwater and surface run-off for reservoirs and river reaches. Scenarios can be implemented in two ways, depending upon the type of input data by:

- Defining a set of customized years to be repeated in time, based upon real observations at monitoring stations, and
- Estimating runoff and natural recharge from a surface water balance performed on a monthly time step.

In the first case, calculations are based on monthly average year data of run-off for lakes and river reaches and infiltration for renewable groundwater. User-input can be obtained from statistical analysis of existing, recorded data. Scenarios are formulated through customising a series of base years, where available resources are defined as having monthly positive or negative rates with respect to the normal (average) one.

The alternative way is based on water balance computations performed at the watershed level. Time series of available run-off and infiltration are computed for selected river reach nodes, lakes and aquifers. User-input is defined as a set of required maps, which, among others, include hydro-geological catchments for aquifers and lakes and the Digital Elevation Model of the area. As far as meteorological data are concerned, twelve maps of precipitation, reference evapotranspiration (ETP) and temperature, containing monthly data for the average year are used as input. Scenarios can be built in three ways, by:

- Repeating the base year as is for the entire duration of the scenario,
- Defining a total increment over the entire period, either annual or monthly, thus defining a yearly or monthly trend, or
- Building up a sequence of previously created base years.

Evapotranspiration computations can either be performed using the input data, or through the application of the Thornthwaite formula, taking into account the altitude distribution of the region. A stochastic option is also available; the idea involves generating a certain number of forecast discharge time series based on a statistical analysis of historical discharge data series. The trend of historical data is kept in the forecast and fluctuations produced try to maintain the statistics of the historical fluctuations, such as mean value, standard deviation and skewness to the greatest extent.

Water Allocation

The water allocation is the heart of the WSM DSS, and constitutes the basis for the forecasting of its state of the system, under different scenario assumptions and management measures. Several methodologies have been used increasingly over the last decades for the optimal design, planning, and operation of water resource systems. The two basic categories of water resource models are simulation and optimisation models (Wardlaw, 1999). Mays (1996) carried out a wide review of these models. Some authors (Mannochi and Mecarelli, 1994; Reca et al., 2001) introduced economic objective functions in irrigation water allocation models. However, the introduction and development of economic objective functions still remains closely related to the specific characteristics of the area for the application of the model, making most of the developed models not readily adaptable to any case study.

In the WSM DSS, water allocation is achieved through a simulation model, aiming to minimise water shortage under limited water supplies. In situations of water scarcity, conflicts arise in distributing to the uses the available water from the various supply sources. The model solves this problem using two user-defined priority rules (Manoli et al., 2001). First, competing demands are treated according to their assigned priorities, which can express social preference or constraints (e.g. urban water needs would be met first), economic preference (highest priority is given to activities with the highest economic output), developmental priorities for a particular economic sector, or a system of water rights. In case that a particular use can be supplied by more than one resource, supply priorities are used to rank the choices for obtaining water. Supply priorities can express: (a) cost preference for supply "paths" with low costs (b) quality preference of uses (e.g. domestic or industrial use) for supply sources with high water quality; (c) need for the protection of resources and the creation of strategic reserves.

The mathematical concept of the model is to find stationary solutions for each monthly time step. For each month, the problem is to find on the network the flow that minimizes the water shortage on all uses and requirements, subject to constraints related to the capacity of supply connections, estimated demand and available supplies. The formulated model is reduced to an equivalent Maxflow problem, which is solved using the Ford-Fulkerson method, known as the Augmenting-Path Maxflow (Dolam and Aldous, 1993; Sedgewick, 2002).

Modelling of water management options

An additional characteristic of the WSM DSS is that it predefines a number of "abstract" water management measures and instruments (actions) and incorporates them as methods into the system (Table 1). These actions modify accordingly the properties of the water system objects or introduce new ones, to respond to water infrastructure development. An "abstract" action becomes "application specific" by the user-definition of its magnitude, time horizon and geographic domain. Incorporated actions are mainly focused on options to deal with the frequent water shortages occurring in arid regions. Their main aim is to either enhance supply, mostly through structural interventions, or to regulate demand through the promotion of conservation measures, technological adjustments, or to consider pricing policies for achieving adequate recovery of costs and provide incentives for conservation.

Table 1 Summary table of management options modeled in the prototype WSM Decision Support System

Management option	Description
Construction of surface storage reservoirs	Construction of water storage facilities that will be able to collect and hold water to be used later.
Desalination unit construction	Construction of desalination units that will process sea or brackish water to produce drinking-quality water.
Groundwater exploitation	Sustainable exploitation of underground aquifers through the drilling of new boreholes, pumping from existing boreholes and wells.
Importing	Importing of water from nearby or remote areas by transporting it through any means or container possible such as pipelines, water barges etc.
Water reuse	Transport of varying quality effluents for use to sectors where that quality is acceptable (e.g. treated wastewater used for irrigation of certain crops).
Conservation measures in household use	Application of water-saving devices and measures in the home, such as fitting flow-restrictors to faucets, insulating water pipes, outfitting garden hoses with shut-off nozzles etc.
Introduction of new crop types	Substitution of existing crops with other crop species or varieties that have either lower irrigation requirements, or require irrigation during the less water-stressed season.
Irrigation method improvement	This Action involves changes in irrigation practices in order to improve irrigation efficiency and reduce water losses (e.g. changing from flood to drip irrigation).
Process change in industry	Implementation of changes in industry processes, in order to reduce the amounts of water required during processing and production (e.g. new processes, recycling

Management option	Description
	etc).
Quotas	Restriction of the amounts of water available per user, either directly through the allocation of a set volume to each user, or by limiting the duration of time that the water flow is available to users.
Reduction of network losses	Repair and/or replacement of old networks in order to reduce the water losses that are a direct result of the network aging.
Change in regional developmental policy	Implementation of changes in the regional developmental policy, such as shifting the local economy towards another sector that is less water-intensive. This is effected either through different priorities for the water sectors or through different growth rates.
Pricing	Control of the elastic water demand through the application of varying pricing levels.

Evaluation

The evaluation of different Water Management Schemes takes into account the entire simulation horizon. Indicators are evaluated on three levels and are aggregated to an overall index, using a bottom-up approach. On a first level, indicators are derived from the simulation results and computed for each component of the water resource system. On a second level these are spatially aggregated for the entire region (Table 2), to describe the overall behaviour in terms of achieving effectiveness, and environmental and economic objectives.

Table 2 Summary of second-level indicators in the WSM DSS evaluation procedure

Category	Indicator
Environment Resources	Dependence on Inter-basin water transfer
	Desalination and reuse percentage
	Groundwater exploitation index
	Non-sustainable water production index
	Share of treated urban water
Effectiveness	Coverage of Domestic, Environmental, Hydropower, Industrial and Agricultural Demands/Requirements
Economics	Direct Costs
	Benefits
	Environmental Cost
	Cost recovery rate

Then, second-level indicators are temporally aggregated on the basis of statistical criteria for reliability, resilience and vulnerability (Bogardi and Verhoef, 1995; ASCE, 1998). The statistical criteria express the behaviour of the monthly or yearly time series of each indicator with respect to a predefined range of satisfactory values that the indicator can assume. *Reliability* is defined as the probability that any particular indicator value will be within the range of values considered satisfactory. *Resilience* describes the speed of recovery from an unsatisfactory condition. *Vulnerability* statistical criteria measure the extent and the duration of unsatisfactory values. Performance for each indicator is computed as the product of the above criteria, and the relative sustainability index of each WMS is estimated according to multi-criteria analysis, as the weighted sum of the performance of the selected indicators. This relative index can then be used to rank alternative strategies or modelled actions according to the overall objectives.

Economic Analysis

The evaluation can also be performed through economic analysis, based on the computation of financial, environmental and resource costs. Estimation of financial costs is rather straightforward, depending on data entered for the amortization of capital investments, specific energy consumption and cost, and other operation and maintenance costs associated with each part of the infrastructure (WATECO, 2002). Environmental costs are assessed using a practical model based on the concept of cost valuation (approximation of environmental costs through the measures required to prevent/mitigate environmental damage or achieve good status). Resource costs are approximated through the scarcity rent. The scarcity rent of water, (i.e. the rent per unit of a scarce resource - water in this case) is a surplus, the difference between the opportunity cost of water (equal to the market equilibrium price P) and the per unit (marginal) direct costs (such as abstraction, treatment and conveyance) of turning that natural resource into relevant products. The model that is integrated in the WSM DSS in addition to estimating the above costs allocates them to the water use(r)s in accordance with the "polluter-pays" principle, i.e. proportionally to the cost induced by the different uses in terms of pollution, overexploitation of natural resources etc.

3.2.2. Main Deliverables

The Deliverables elaborated during the Analysis Phase were:

Deliverable 7, Methodology Report

The Deliverable presents the work undertaken in WP 4 with regard to the assessment of available methods for the analysis of water resource systems in terms of (a) Quantitative analysis of water resources, uses and infrastructure, (b) Estimation of financial, resource and environmental costs (c) Multi-criteria approaches and potential indicators, which could be used for the evaluation of alternative water management strategies.

Deliverable 8, Methodology for evaluating water resources management scenarios

Deliverable 8 integrates the different reviewed methods to a consistent methodology, and outlines a preliminary set of indicators and aggregation methods that have been considered most appropriate for the selected paradigms.

Deliverable 10, Report on Models, Tools and DSS for Water Management

The Deliverable constitutes the review of available Decision Support Systems and Tools undertaken in WP 5.1. Although not exhaustive, the review emphasises on a critical analysis of the potential of the developed DSS and their limitations, and disseminates concepts relevant to the application of Decision Support Systems in Water Resources Management.

Deliverable 11, Integrated Decision Support System Applicable to the Paradigms

The Deliverable 11 elaborates on the concepts, the philosophy and the usage of the prototype WSM Decision Support System. The report analyses the modelling approach, the methodology followed and the various models incorporated. The Deliverable also presents the usage of the DSS, giving particular emphasis to the illustration of the Graphical User Interface of the different modules, and the incorporated functionalities.

Deliverable 12, GIS Database

The Deliverable presents the concepts, the design and the development of the WaterStrategyMan GIS Database, which aimed at providing a unique framework for collecting water resources and demand in the identified paradigms and the development of a GIS Database, to accommodate them in an efficient and updateable mode.

Deliverable 13, Workshop Proceedings

The Deliverable constitutes the proceedings of the workshop *"Towards Comprehensive Water Management Strategies for Water Stressed Regions"*, held in Paris, France, at the Ecole Nationale des Ponts et Chaussées, on the 8th and 9th October 2003.

3.3. Strategy Formulation Phase

The Strategy Formulation Phase formed the core of the Project, aiming at the comparison of alternative water management scenarios based on selected user-defined criteria. This in turn allowed the identification of appropriate plans, actions and pricing policies that apply to each paradigm.

The principal target of the analysis undertaken for the Case Study Regions was to determine appropriate Strategies that will contribute to the mitigation of water stress conditions; the secondary, but of no lesser importance, analysis target is the achievement to the maximum possible degree of the set goals of the EU Water Framework Directive 2000/60/EC (WFD) and of Integrated Water Resources Management. The latter involve (Global Water Partnership, 2000):

- The goal of **Equity**; in addition to an equitable allocation of the water resource in itself, this goal also involves the equitable distribution of costs among the water users, including households, the tourist industry, the farmers and Industry.
- The goal of **Environmental Sustainability,** mainly through the mitigation of the impacts incurred in the production and supply of water, which, in arid and semi arid areas dependent on groundwater, involves the reduction of drillings to sustainable levels.
- The goal of **Economic Efficiency,** involving the minimisation of costs associated with the provision of water, achieved through the selection and application of management options that are most efficient and making use of best practices, new technologies and improvements.

In addition to the above, alternative cost recovery structures were explored for the Case Study Regions under the premises of the developed Strategies, in order to achieve a desired level of cost recovery and determine the effect that this will have on the Strategy implementation. The recovery of the costs incurred in the production and supply of water includes not only direct costs but also opportunity and environmental costs; in keeping with the set equitability goal, these costs need to be recovered on a local level, reducing State subsidies to a minimum.

The Phase included two Work Packages:

- **WP8, "Generation of Coherent Water Management Scenarios"**, which referred to the development, analysis and comparison of alternative water scenarios for each Paradigm. The Work Package involved three tasks:
    - *Task 8.1, "Review of existing water management plans"*, which aimed at reviewing proposed and existing water management plans in the Case Study regions and developing the reference scenarios to be used for the evaluation of management options and strategies.
    - *Task 8.2, "Update of GIS Database"*, which aimed at updating the Case Study regions' database with data on the reviewed water management plans and reference scenarios.

- *Task 8.3, "Generation of Coherent WM Scenarios"*, in which different management options were evaluated with regard to their effectives, economic efficiency and environmental impacts under different assumptions regarding water availability and demand.

- **WP9, "Development of Water Management Strategies"**, which referred to the development of alternative integrated water resources management strategies for each paradigm that take into account economic and environmental costs.

3.3.1. Methodology

In order to achieve the desired integrated approach to water resources management, it is necessary to take into account not only the allocation of water and incurred costs, but also to incorporate the issue of the recovery of costs, one of the key points of the WFD.

For that purpose, the adopted methodology was elaborated into two stages, and involved the work undertaken in all foreseen tasks. In the first stage, the Water Resources Management Strategies were developed, analysed and evaluated; these primarily aimed at the coverage of demand and the resolution of conflicts arising from water shortage and/or overexploitation, while minimizing the associated costs and environmental impacts. In the second stage, an additional element was introduced in the form of a Cost Recovery Strategy attempting to achieve a set level of recovery of the costs associated with the provision of water, as well as the environmental costs associated with the process and the applicable resource costs (where these exist), therefore encouraging a more efficient and rational use of water. Throughout these two stages, the governing principles remain those of IWRM.

A key factor was the involvement of Stakeholders and end-users, which at the first stages provided unique insight and hands-on experience in the issues of the regions studied, and a range of responses potentially unidentified under different circumstances. Therefore, the first step of the methodology, realised in Task 8.1, was to approach stakeholders and decision makers, and to collect their opinions on Water Management in their regions, discussing the regional development goals, which should guide the entire process of formulating the strategy, as well as their own perception of the problem and its solutions. They were able to provide a wide overview of the specific issues that they have had to deal with, and to identify solutions that they have successfully (and unsuccessfully) employed. They also proposed their own specific development goals in their respective sectors, which were valuable in projecting the future demand.

After collecting all the opinions from the various stakeholders, the next step was to integrate those solutions proposed into a list of options provided by experts that incorporates the IWRM principles. This was followed by a thorough examination of the strategy goals and of forecasts for the future; quantitative and qualitative projections were developed for the supply and for the demand in the various sectors. Using the WSM DSS, each option was simulated under different scenarios, in order to evaluate the extent of its applicability and the potential impact of application. In the framework of strategy development, timing was an important issue to determine, as issues may need to be addressed in different timeframes. Having a clear goal in sight, the options provided could then be ranked to produce a sequence of acceptable/available measures, which formed the proposed strategies.

The overall methodological approach, briefly described above, was elaborated in all tasks undertaken. The following paragraphs present an overview of each task while the paragraph on *Strategy Formulation* integrates these tasks in the approach.

Review of Existing Management Plans - Stakeholder Consultation

Until recently, central and regional administration developed "master plans" for managing water resources, usually a set of structural interventions in the water sector that did not take into account or even consider the importance of the view of affected parties (Le Moigne and Subramanian, 1994). In many cases strategies formed this way, even if deemed essential, failed to win stakeholder acceptance. Their implementation raised significant opposition, or they were never implemented at all. Under this context, and as summarised above, stakeholder involvement was one the key aspects in identifying both water management issues and responses. The procedure followed was split in two tasks:

The first task involved the selection of the stakeholders and the analysis of their interests and positions as well as their perceptions of the issues regarding water resources management in their region. In more detail this task involved:

- The identification of potential stakeholders;
- The selection of representatives to be approached, including both end-users and decision makers;
- The organisation of meetings, interviews and discussions;
- The identification of opinions, wishes and expectations.

Field research and analysis were considered necessary prior to approaching the stakeholders. In addition to data collection from existing studies and management plans, each research group was able to form a global view of the situation and define the circumstances that led to the current responses used to meet water deficit on the region.

The next step was the identification of potential stakeholder groups and actors to be approached. The different levels of involvement were a decisive factor of the final selection, and during this step two categories of stakeholder groups were distinguished and consulted: (a) Stakeholder groups that promote the water resource system and (b) Stakeholder groups that benefit from the system.

Consultation and meetings with the selected stakeholders followed. During these meetings, opinions, wishes and expectations were discussed. In addition, these meetings served as the basis for data review, validation and interpretation, since most interested parties can be excellent sources of information on their field of interest/specialisation.

Information collected from the various groups that were contacted in the case studies was used to:

- Identify management issues to be addressed on a regional level. This identification led to the selection of appropriate indicators and to the definition of the targets to be met through strategic planning in the next phases of Strategy Formulation;
- Formulate a synthesis of proposals and potential responses that are both feasible and accepted by the local society.

Development of coherent water management scenarios

The next step consisted of the development of scenarios from the proposed measures that, after an evaluation process, can lead to the new Strategy to be applied on the region, involving the following steps:

- Formulation of the different proposals into comprehensive water management scenarios;
- Modelling of the scenarios through the WSM Decision Support System;
- Evaluation of management options through indicators and targets identified in the stakeholder consultation process;
- Formulation of a proposal on new strategies and potential responses.

In addition, this Step entailed the *Update of the GIS Database (Task 8.2)*, generated under WP 6 with information regarding availability and demand scenarios, as well as indicators and weights to be used for the further evaluation of water management options.

A scenario, for the purposes of the project, was defined as "*Developments which can not be directly influenced by the Decision Maker*". Such developments significant to the outcome of a given Strategy include the weather and its influence on the water balance. The coverage of demand is dependent on the supply of water, and directly influenced by dry years; it therefore follows that the effectiveness and performance of a selected strategy will be directly affected by the frequency of dry years forecasted in the scenario. This is therefore a factor to be considered when evaluating the strategy; its efficiency under actual conditions may differ unless the scenarios tested reflect the actual forecast of the region based on time series data.

The main objectives of scenario analysis were to determine the options that could be effective in meeting the targets of each Case Study analysis, and estimate their potential extent, cost and environmental impact. These water management instruments were combined in order to meet the targets for each Case Study analysis as Strategies. Under this context, the analysis process was based on the concept of a **"comprehensive scenarios"**, which has been defined as a combination of:

1. A **hydrological** (availability) scenario and a **demand** scenario, which represent alternative future developments that are not affected by the decision-making process. These are not however sufficient to develop Water Management Scenarios that will satisfy the requirements of the Project, as they do not cover the issue of supply and demand-side interventions. For that purpose the third component that will allow the formulation of Comprehensive WM Scenarios, is
2. A selected **water management option** to be evaluated, one of a set of alternative supply or demand side management measures available.

The reference scenario compared to which the alternative options were evaluated has been defined as the current state of the water system, including scheduled interventions as these are planned, under the assumption that water availability and water demand will continue following the currently forecasted trends. For the purposes of the WSM Case Studies, the scenarios were evaluated for a long time horizon, from 20 to 30 years, using the WSM Decision Support System.

For each individual management measure, the behaviour of the water system was assessed and evaluated, in comparison to the reference scenario. The parametric analysis focused on the range of cost, effectiveness in demand coverage, and environmental sustainability of the system, expressed in terms of environmental costs. The performance of each of the management options applied was evaluated under different availability and demand conditions, and more specifically:

- a **"worst case scenario"**, combining low water availability and high demand,
- a **"best case scenario"**, combining high water availability and reduced demand, and
- a **"business as usual scenario"**.

In that way, it was possible after analysing the evaluation outcomes of all scenarios to select the options that were efficient in meeting the specific requirements of the Case Study, since the performance of each option under a range of conditions is critical in defining the extent of applicability and impacts.

Availability Scenarios

The formulation of water availability scenarios was based on the *Water Availability Module* of the WSM Decision Support System. Scenarios were formulated in two distinct ways, depending on data availability:

1. by defining a set of customized years to be repeated in time, based upon the real observations at existing monitoring stations, and
2. by estimating runoff and natural recharge from a surface water balance performed on a monthly time step.

Methodology selection and assumptions on availability varied within the Case Studies, due to data constraints. In the Belice Basin, availability scenarios were based on an analysis of past historical trends regarding average monthly temperature and rainfall; the Case Study of Limassol, Cyprus was based on rainfall time series provided by the Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment. The case studies of Paros island, Greece and Ribeiras do Algarve, Portugal were based on a continuous series of "Normal" (average) availability pattern and the definition of a "wet" and "dry" scenario, denoting "high" and "low" availability time series.

Demand Scenarios

The analysis of water demand and the formulation of projections are strictly functional to the allocation of water resources. Hypothetical demand scenarios along with availability assumptions constitute the basic and discriminating factor in the distribution of water from the sources to uses and users.

Main driving forces considered, in relation to regional development patterns and desired economic growth, consisted of:

- Permanent population growth, and consumption rate projections defining the need for improved living standards;
- Tourism development;
- Agricultural development, either due to the expansion of cultivable/irrigated areas or attributed to enhancement of animal breeding activities;
- Industrial development, which however did not represent a major factor driving water demand in all regions.

On the basis of observed trends, or existing/own forecasts, scenarios were generated by specifying appropriate growth rates to the examined key variables. In all Case Studies, the formulation of demand scenarios entailed a thorough data collection on the current demand patterns, consumption, losses, and pricing incentives that determine demand elasticity.

Management Options

The options that were modelled, simulated and evaluated in the Case Studies using the WSM DSS are grouped under four categories:

- Measures related to Supply Enhancement, introducing new structural interventions to increase water availability;
- Demand Management Measures, aiming to regulate and limit water demands;
- Regional Development measures, affecting the socio-economic preferences given to certain types of water use with respect to others and finally,
- Institutional policies, such as changing water pricing.

Their identification was based, as mentioned above, to the outcomes of the stakeholder consultation process, so as to ensure that options selected would be accepted by stakeholders and end-users. The definition of the potential extent of application that was simulated for each option depended mostly on data collection from existing water management plans, information provided by local authorities and stakeholders on technical constraints and acceptance, and own judgement.

Evaluation of options

No single option, as those examined in comprehensive scenario analysis, can address all of the goals of IWRM. However, each option should be evaluated against a set of indicators that at best can address such issues in order to formulate a set of candidate options that can achieve those targets.

In order to achieve a meaningful overall evaluation for the options examined in the range of Case Studies, it is necessary to ensure comparability. For that purpose, a set of indicators was selected for cross-Case Study comparison for each measure evaluated. The overall aim is to collectively score measures in order to rank those as to their general applicability and efficiency in arid and semi-arid regions.

For this purpose, a series of indicators was selected to be used for all Case Studies; those are:

- **Effectiveness vs. time** for irrigation and domestic water use, expressed as:
    - Coverage of water demand
    - % improvement of deficit with respect to each reference scenario
- **Total direct (financial) cost** for the provision of water services and the application of the different options, expressed in present value terms,
- **Total environmental cost**, incurred from pollution and (over)abstraction of surface and groundwater, expressed also in present value terms.

Those indicators are not comprehensive for all Case Studies and the list was enhanced in order to include other indicators that are meaningful in the respective regional context. An example is the Cost Recovery Rate and the Non Sustainable Water Production Index used for the Case Study of Ribeiras do Algarve, or the Groundwater Exploitation Index, chosen for the case study of Limassol region in Cyprus. In all Case Studies, indicators were used to derive a **Performance Matrix** that permitted the ranking of the options identified through stakeholder consultation, modelled and simulated in the WSM Decision Support System. Following the outcomes of the Comprehensive Scenario evaluation and ranking, the next stage was the formulation of strategies. This involved the planning of combinations of management measures in the timeframe set, and the re-evaluation of the strategies in their entirety using the WSM DSS, as previously done for each measure individually. The final goal was the ranking of the selected strategies for each Case Study and the selection of the best suited approaches.

Strategy Formulation

As mentioned above, both *Stakeholder Consultation* and *Comprehensive Scenario Analysis* were two building blocks of an overall process, aiming to lead to the formulation of improved water management strategies, taking into account economic efficiency, environmental sustainability and social equity. The overall approach included 7 steps, grouped in two major stages, further elaborated below.

Stage A – Formulation of a strategy for water resources management

Step 1: Definition of primary target and assumptions

In the outset of any process of strategy formulation, it is necessary to define what the primary target is. The definition of this target emerges from the analysis of current water management issues, water management strategies, and most importantly stakeholder consultation. In the water deficient regions, analysed as Case Studies, the target was defined as the coverage of a set percentage of water demand. This target can be applied either on the entire water system, or vary either temporally or across water use sectors, according to the specific characteristics of the area of application. Secondary goals, which need to be addressed, are the minimisation of costs, and the mitigation/ alleviation of environmental impacts from water allocation, consumptive use and pollution loads.

In addition, primary assumptions that are made for each Case Study need to be defined:

- The timescale of strategy application, ranging from medium to long-term, such as a time horizon of 30 years.
- The availability conditions for which the strategy is designed, applied as a set scenario of anticipated hydrological years, e.g. a series of normal/average years.
- The projected demand in the duration of the strategy application, reflecting the current demand and its trends, defined in a Business-As-Usual (BAU) demand scenario.

Step 2: Identification of available and feasible options

The identification of the available and feasible options entails the selection, among the wide range of water management instruments available worldwide, of those options suited for, and applicable in, the region analysed. For that purpose, in each Case Study local Stakeholders were consulted on their preferences and opinions with respect to applied and potential management instruments, and existing management plans were reviewed (see above). Following the Stakeholder consultation results and the options proposed in the existing management plans, an initial selection of options can then be made based on their suitability and applicability in the Case Study Region.

Step 3: Option performance evaluation

The third step in the development of water management strategies was the evaluation of each selected option in terms of performance. Each single option is evaluated under different demand and availability scenarios simulated in the developed WSM Decision Support System (DSS), determining the extent to which it has the potential to meet the analysis targets (see section Tasks 8.2 and 8.3, above). To compare the performance of different water management strategies over a sufficiently long period of time, the evaluation approach was based on a two step procedure. The first step is aimed at providing time series of indicators as additional information to the decision maker. The second step involves a temporal aggregation of time series into single values, and the computation of an overall index as a result of multi-criteria analysis and user-defined weights. Indicators that were selected throughout this approach reflected the effectiveness of the proposed measure/instrument, the total direct cost or the total social welfare surplus (depending on data availability), in order to describe the economic efficiency, and the total environmental cost, which was related in each Case Study to the main environmental issues arising from current water management practices.

Step 4: Strategy formulation using available options

The evaluation of the newly formulated Strategies for integrated water management should be complemented with a comparison of their performance against the current or foreseen responses to water stress. For that purpose, in each Case Study two separate Strategies are formulated; one reflecting the current trends of water management in the region and one targeting a more integrated approach trying to combine carefully planned, centralised infrastructure with small-scale decentralised solutions and measures aiming to improve the productivity of water use (Gleick, 2003).

In more detail, the first Strategy reflects the traditional **“hard-path”** approach, involving:

- The use of options reflecting the Business-As-Usual approach, using instruments either already in use or currently emerging in the area, that are acceptable to the local population;
- A basis of the traditionally used structural interventions otherwise known as “hard” measures - dams, desalination, network improvements and enhancements, groundwater exploitation etc.

The second Strategy, referred to as a **“soft-path”** approach involves:

- The combination of “soft” and “hard” measures into a more integrated approach;
- An emphasis on the “soft” measures that promote efficiency and reduce water waste (conservation, changes in irrigation methods – crops, industrial recycling and reuse, regulation through pricing and quotas);
- The use of “hard” approaches as complementary in order to achieve targets wherever soft measures are insufficient.

The actual formulation of the Strategies involves the selection of the options to be applied, based on the recommendations of *Step 2* and the results of *Step 3*. Using the developed WSM Decision Support System, these options can then be simulated for the Case Study Regions in a specific timeframe. The Strategy can be built option-by-option through successive simulations in the WSM DSS, the temporal planning of applications being based on the technical aspects of the selected options (e.g. lifetime, construction time etc), their performance, additional feasibility constraints, etc.

Step 5: Evaluation of strategy performance

In Step 5 the developed Strategies are evaluated against each other, as well as against the reference state of the water system. The indicators used for evaluation include:

- The relative sustainability index for demand, including criteria for reliability, resilience, and vulnerability (Task Committee on Sustainability Criteria, 1998), as this is estimated through the Evaluation Module of the WSM DSS,
- The direct costs incurred by the strategy application,
- The environmental costs incurred by the application of the options selected (including groundwater and surface water abstraction costs, pollution costs), and
- The resource cost incurred by the allocation of water to specific uses, especially in the case of proliferating shortage problems.

These indicators can then be used, subject to user-defined criteria, to provide an overall score for each of the Strategies.

Stage B - Formulation of a strategy for adequate cost recovery

Step 6: Development of a cost recovery strategy

The proper formulation of a cost-recovery strategy requires the actions taken in Steps 6 and 7. Step 6 that refers to the development of an initial cost-recovery strategy requires the setting of a cost recovery target for each of the three major cost categories, Direct, Environmental and Resource costs. The current pricing scheme can then be analysed with respect to the recovery of these costs, thus providing an estimate of the required increases in price in order to reach the set targets. These estimated increases will be then incorporated in the current pricing system, and yield a set of initial prices in order to meet cost-recovery targets.

Cost recovery issues are addressed to major water uses, depending on the current institutional and governance framework, and taking into account the allocation of costs in accordance with the "polluter-pays" principle performed by the WSM DSS.

As the elevated water prices will in most cases influence water demand, and therefore the overall strategic planning, the Water Management Strategy will then need to be re-evaluated in Step 7, incorporating the new pricing system.

Step 7: Strategy re-evaluation

As the pricing system changes and water charges are increased, the price elasticity of demand will determine the degree to which the demand will be affected. Any significant drop in demand will need to be taken into account in the planning of interventions, as it will also affect the required supply and the strategy performance as a whole. Therefore, before a final Cost Recovery Strategy is decided on, it will need to be simulated in a number of iterations, depending on the relevant elasticities, re-adjusting the prices, re-evaluating the size of interventions, and also re-evaluating the selected strategy's performance. When a balance between the demand and the pricing system is achieved, then the final Cost Recovery Strategy can be evaluated in overall and compared to its alternative(s), eventually yielding the final evaluation for each examined region.

3.3.2. Research Outcomes

The main research outcomes of the Strategy Formulation Phase can be classified as follows:

- Outcomes related to the performance and applicability of the different water management options, as assessed through the Scenario Development and Evaluation Process.
- Outcomes related to Strategy Development, and the potential impact of alternative cost recovery schemes.

These are further elaborated below.

Performance and applicability of Water Management Options

Throughout the process of formulating water management scenarios a variety of options, both structural and non-structural, were examined. The comprehensive list of options includes technical measures for the enhancement of supply, demand management options, and water saving technologies. Institutional/legislative measures or reform, and capacity-building, as well as instruments and measures aiming to increase public awareness on water scarcity have not been examined at this stage, as they aim to support the formulation of an enabling environment for the application of the above measures and instruments.

The paragraphs that follow summarise the outcomes of scenario analysis for each Case Study. Results are also summarised in Table 3.

Table 3 presents the overall evaluation for each option and each Case Study, ranking the examined options as to their applicability in the development of integrated WM strategies.

Table 3 Applicability of different management options for the identified Paradigms, under the concept of Strategy Development[1]

Paradigm Type	**I**	**II**				**III**
		Insular		**Regional**		
Management Option / Region	**Tel-Aviv**	**Paros**	**Tenerife**	**Limassol**	**Algarve**	**Belice Basin**
Network unifications and system expansion	-	***	***	**	*****	-
Storage Reservoirs	-	**	***	-	**	-
Loss Reduction	-	***	****	**		**
Irrigation Improvement	-	***	***	-	***	*
Irrigation Pricing	-	****	**	****	-	-
Domestic Pricing	-	***	**	***	-	***
Desalination	***	*****	*****	-	***	-
Conservation	*****	****	****	**		-
Cisterns	-	*	-	-	-	-
GW Exploitation	**	*	*	-	-	
Surface water exploitation[2]	-	-	**	-	-	***
Wastewater recycling and reuse	***	-	***	*	**	****
Increase of forested area	-	-	***	-	-	-

In general, for each region, the following can be summarized:

Typology Type I – Predominantly urban

Options were examined for **Tel Aviv region in Israel** (**Typology Type I**) under two different availability scenarios, normal (average) water availability, and cyclic (defined as a sequence of years where three consecutive years with average supply are followed by three consecutive dry years with a supply that is 30% lower than the average). Criteria used for evaluation included social and private welfare surplus, environmental costs and direct costs. Four options were evaluated: (a) increase of recycling of treated wastewater, (b) desalination (c) increase of groundwater abstractions (overpumping), and (d) conservation measures, aiming to reduce gross domestic demand. From a social and environmental point of view and under both availability scenarios, increased supply of recycled water is one of the best options examined, as it results to both increased social welfare surplus, and negligible environmental costs (best option under the normal scenario and second best

[1] Legend: (*): least applicable
(*****): highly applicable
(-): not examined/not applicable

[2] Includes exploitation plans for the Belice river for the Belice Case Study (diversions and enhancement of current system) and rainfall harvesting systems for Tenerife

under the cyclic scenario). On the other hand, this is the only management option under which agricultural supply is not fully met during all the years of the time horizon; this results in a lower value for private welfare surplus, that may result in opposition by the agricultural lobby. The effect is stronger in the case of the cyclic weather scenario, where private welfare surpluses and improvements with respect to the reference scenario are the lowest among all options examined. Measures aiming to reduce gross domestic demand also yield high social surplus and zero values for environmental costs. Domestic conservation has the additional advantage of augmenting private welfare surplus, as the demand reduction results in higher supply available for all uses. With respect to the increase of groundwater overabstractions, the measure results in increased supply for all uses, thus incurring a high private welfare surplus and increased efficiency. However, the high values for environmental costs as well as the low values for social welfare surplus should discourage the application of the option from a social and environmental point of view under all cases.

Typology Type II – Predominantly tourist and Insular

Options examined for **Paros Island, Greece**, included network unifications and enhancements, desalination, groundwater exploitation, storage reservoir construction, reduction of network losses, cistern construction, improvement in irrigation methods, conservation measures in domestic use and pricing for irrigation and domestic users. The evaluation of each was conducted under three different scenario combinations, a business-as-usual state, a high shortage state (high demand-low availability), and a low shortage state (low demand-high availability). Indicators used expressed effectiveness improvements with respect to each reference scenario for irrigation and domestic demand coverage, direct costs and environmental costs. The main outcome was that potential strategies cannot rely on the application of a few options only. Although desalination seems to occupy an advantageous position in terms of technical and environmental sustainability and adaptability to emergency requirements, very high costs indicate that the measure should be combined with other interventions. Potential measures mostly comprise smaller structural solutions (interception dam, network unifications, network loss reduction through replacements), and "softer" interventions, aimed to management of demand (domestic conservation, irrigation method improvements). Irrigation pricing also appears to be one of the most effective options. However, given the current institutional framework it is highly unlikely that such an option can actually be realised, at least in the short term.

Two different demand scenarios were used for the analysis of different water management methods was examined in the case study of **Tenerife, Canary Islands, Spain**. The analysis included structural, both small and large-scale interventions (network enhancements and unifications, storage reservoirs, groundwater exploitation, wastewater recycling, reduction of network losses), and non-structural measures (recovery and increase of forested area, rainfall harvesting systems, and conservation measures for domestic users). Under both scenarios examined, solutions can be found through the combination of different instruments, with different weights. Other than the fact that desalination stands out among the other options, it is confirmed that interventions such as network loss reduction and saving measures can have an important weight. From the analysis undertaken the risks of betting on a massive structural solution, such as desalination, are also evident. Under a possible scenario of contention and of more appropriate and sustainable development, desalination stops being seen as a panacea and becomes a more targeted solution. This could cause a technical and structural inertia within the system difficult to reverse. Finally, the analysis emphasises the risks derived from maintaining the prevailing assumptions on growth rates, especially in a possible situation of long-lasting water deficit.

Typology Type II – Predominantly tourist and Regional

Options examined for the **Limassol Region in Cyprus** included water recycling, expansion of the existing water treatment plant of Limassol, wastewater treatment expansion, measures aiming to reduce network losses, conservation measures to domestic use and application of domestic and irrigation pricing schemes. The options were evaluated under three different combinations of demand and availability scenarios according to their relative performance with respect to demand coverage, the benefit/cost ratio and the incurred environmental costs. Results indicate that pricing reforms can have a significant effect in the overall water balance. The effect is more pronounced when pricing is oriented to irrigation water. However, the expansion of the water treatment plant is also necessary, presumably at a lesser extent if combined with other more "soft" interventions. This was presented as one of the issues that remain to be examined in the Strategy Formulation phase.

The analysis for the **Ribeiras do Algarve region, Portugal** focused on the examination of six options under three different scenario combinations of demand and availability scenarios. The options, which include dam construction, expansion of the primary water supply system, desalination, water recycling, reduction of network losses, and improvement of irrigation methods, were ranked according to their effectiveness in meeting domestic and irrigation water needs, direct cost and rate of cost recovery, and environmental impact, expressed in terms of groundwater exploitation index and non-sustainable groundwater production. One important conclusion that was drawn from the analysis is that structural solutions, as dam construction, although occupying an advantageous position in terms of effectiveness, can be characterised neither as economically efficient, nor as environmentally sustainable. Economic and environmental performance can be improved through combinations of options, as system expansion, or demand management in the form of increased irrigation efficiency (improvement in irrigation methods). Due to the complexity of the water system, a variety of water management problems (small localised deficits or overexploitation problems) can be solved through the application of small scale, structural solutions (local application in a municipality, river basin or sub-basin), without necessarily requiring large scale structural interventions.

Typology Type III – Predominantly agricultural

Scenario analysis for **Belice Basin, Sicily, Italy (Typology Type III)**, involved the examination of two supply enhancement methods (i.e. exploitation of Belice river, and wastewater treatment and recycling), two conservation methods (irrigation method improvements, reduction of distribution losses), and domestic pricing. Options were evaluated under three different combinations of demand and availability scenarios, depicting a normal state, a high shortage state and a low shortage state. Indicators used concerned effectiveness, with particular emphasis to irrigation, which is the main target of the assessment, and improvement with respect to each reference scenario, direct costs and environmental costs. The main outcome of the analysis was that water recycling takes an advantageous position in terms of effectiveness and economic efficiency; however softer instruments, such as water pricing and network loss reduction should be integrated with structural options in order to ensure adequate coverage of water needs for both urban and irrigation demand at the **whole** of Belice Basin area.

Improved water management strategies and cost recovery issues

Typology Type I – Predominantly urban

Tel Aviv Region - Israel

The impacts of the recent water policy change in Israel were examined under an assumption of relatively unfavourable future weather conditions, we assume hereafter a time horizon of 15 years with a fluctuating replenishment series, in which three consecutive years of average natural supply of water (estimated from long-term values) are followed by three consecutive dry years with a supply that is 30% lower than the average. The main targets of strategies aimed at improving this reference scenario (BauC) were:

- Meeting 100% of domestic and industrial demands during each of the 15-year time horizons.
- Meeting at least 70% of the agricultural demand during each of the 15-year time horizons (the fulfilment of this goal guarantees that none of the mature orchard groves in the region will “dry out”).
- Increasing the Social Welfare Surplus **(SWS)** in the region. The total present value of SWS in the region is defined as the difference between the discounted stream of annual values or benefits accrued by water consumers, and the total direct and environmental costs. Following consultation with stakeholders and decision-makers in the water economy of Israel, we came to the conclusion that for the Israeli case study, the SWS is a good criterion to rank the various scenarios. Obviously, a management option implying a high SWS value is preferred to one implying a lower value.
- Minimizing the long-term overexploitation (overpumping) of the coastal aquifer that leads to its salinisation.
- Reducing dependencies and cross-subsidies between the region of Tel Aviv and the national water system (in an extreme case the Tel Aviv region can be completely disconnected from the national system and managed as a single economic entity).

To achieve the above targets, two strategies were examined, which both involved a grand combination of three management options—sea water desalination, wastewater recycling and fresh water conservation in the domestic sector. This combination was found to be preferable to any partial combination of these options. The first strategy also included a preservation of the current centralised institutional setting, under which prices of water delivered by the national company Mekorot are set by the Government and depend on the type of the water source. On the contrary, the second approach assumes a partial institutional and economic separation of Tel-Aviv's water resources from the national water system and operation as a balanced economic entity with respect to the industrial and domestic sectors.

The present values of SWS associated with both strategies are higher by 11.5% and 12.3% respectively, with respect to the reference case BauC. However, it is important to note that the welfare criterion does not capture all the differences between the two institutions under consideration. With respect to the current centralized institutional setting, the Shifting (separation) Paradigm has several advantages:

(a) It decreases the competition for limited water resources between regions (especially during dry years) as well as institutional inefficiencies due to bad management at the national level. Each region strives to manage its water economy more efficiently, taking into account long-run processes (such as the accumulation of salts in water resources and/or increasing water deficits) in order to decrease risks and increase sustainability.

(b) Under the current institutional setting, the amount of fresh water exported from the Sea of Galilee and conveyed to the southern consumers via the National Water Carrier (NWC) water through the NWC is affected by the amount utilized in the region of Tel Aviv: the higher the amount of NWC water consumed in Tel Aviv, the lower the (remaining) amount exported from Tel Aviv to the south. Under a partial institutional separation, Tel Aviv does not compete with the southern regions for water from the Sea of Galilee. Therefore in this case, the stability of the supply of fresh water to the south of the country and the welfare of the southern water consumers are expected to be higher.

(c) The positive environmental contribution of cultivated land in the highly populated region of Tel Aviv ("green lungs") is steadily increasing. The level of unmet agricultural demand is higher in the first case, implying a larger cultivated area under the latter strategy.

(d) The very high increase in the Private Welfare Surplus (PWS) suggests that the (significant) change in the institutional setting associated with the Shifting Paradigm Strategy will not be opposed by the consumers in the region. On the contrary, they are expected to exert political pressure on the relevant decision-makers to adopt this strategy.

The present value of environmental costs associated with each of these two strategies is much lower than those obtained under the reference scenario, pinpointing that neither is likely to be opposed by the environmentalists (or green lobbies).

Based on the above findings, the Shifting Paradigm Strategy appears to hold the advantage. Although its associated SWS is slightly lower, it involves a negligible level of unmet demand and a negligible level of environmental costs. However, the feasibility of its political application is questionable, as it is unlikely that only one of the regions that are currently part of the national water system would be separated from it. A significant institutional reform under which the national water system would be subdivided into separate regions is likely to be opposed by consumers residing in regions currently subsidized by the national water company, Mekorot, even though the latter's monopolistic position may be weakening.

Typology Type II – Predominantly tourist and Insular

Paros Island – Greece

Targets set for the development of strategies for the case of Paros Island, Greece expressed the ultimate goal of resolving social conflicts that arise between users, and at supporting the income produced by tourism-related activities, while maintaining the traditional agricultural activities of the island. Two strategies were formulated in this regard:

- The first strategy is focused on small to medium scale structural interventions shown to be effective and efficient in the case of Paros, such as boreholes, network improvements, interception dams and desalination.
- The elaborated soft-path approach is framework is highly dependent on efficiency improvements and dealing with water waste; however, as these are not sufficient in themselves to guarantee reaching the demand coverage targets set, it also incorporates some small-scale structural interventions, aimed at complementing the efficiency improvements.

Following the final evaluation of the two Strategies against each other and the reference case, it can be inferred that pricing will not influence the size of the infrastructure needed for the coverage of demand. Due to the current institutional frameworks in Greece, pricing of irrigation water is an instrument that cannot for the time being be implemented in Paros, as it would require a major governance reform; a subsidy is therefore always present between the domestic and agricultural use of water. For this reason, it was considered preferable to develop two cost recovery strategies, separating each use and user, in order to respond realistically to the limitations imposed by the current institutional framework and decision-making practices.

The evaluation results for the soft-path approach compared to the other two cases, emphasise that the high temporal water imbalance in the island of Paros can best be solved through a combination of small-scale structural interventions and soft interventions aiming to increase the efficiency and productivity of water use. The further use of institutional measures, aiming to centralize the decision-making process for the allocation of resources and costs could make a significant contribution to the solutions of the Problems that are faced on the Island.

Based on the outcomes of the Paros Case Study analysis, it can be concluded that in similar regions that face high temporal water imbalance problems, appropriate strategic planning should incorporate:

- Measures to increase the efficiency of water use, reducing water waste and the overabstraction of finite resources, particularly vulnerable groundwater resources;
- Medium-scale inter-seasonal storage that will enable the balancing of demand and supply, and increase supply stability; and
- Fast response supply enhancement solutions, such as desalination, that are able to satisfy peak demands and can increase the reliability of the water system.

Tenerife, Canary Islands, Spain

The comprehensive analysis of current water production patterns and management practices adopted in Tenerife portrays that in addition to sectoral and territorial issues, a critical factor has to be considered: the development model, which has or will soon exceed the carrying capacity of the island. Within this context, the formulation of strategies was based on moderate scenario assumptions for population growth and aimed at: (a) meeting 100% of domestic and tourist demand, permanently, all the year round, (b) assuring water supply for the irrigation of at least 80% of the irrigable area, taking into account the foreseeable evolution of local and export markets, and (c) preserving traditional small irrigation systems in mid-altitude areas.

Two different strategies were developed. The first, “hard-path” approach is practically based on structural solutions, following the original directives on infrastructure development of the PHI (Island Hydrological Plan). According to the current water policy, increasing deficits would be covered through seawater desalination, re-use of treated wastewater, and use of regulatory reservoirs. This strategy partially reflects the present-day situation, which is characterized by pronounced delays in carrying out network rehabilitation and improvements. The second strategy is much nearer to the principles of the Canary Islands Land and Tourism Planning Directives, which are supported by the Canary Islands Government as a framework for sustainable development. This approach evolves a combination of structural (always through the prism of integrated systems) and non-structural measures, where the tendency to prioritise soft interventions dominates. It is necessary to underline that in this “soft-path” approach structural interventions are understood as components of regionally integrated complete water cycle systems (water catchment, treatment, desalination, re-use). Thus, they ensure higher efficiency and help in avoiding extensive water conveyance. Non-structural measures, such as water conservation, gradual reduction of losses within distribution networks, as well as application of fair and equitable prices, are understood not only within the framework of the need for adequate cost recovery for the provision of water services, but also for the development of a so-called “water culture”.

The analysis of the two strategies showed that in both cases the set targets can be achieved at very acceptable levels. The evaluation portrayed that a "soft-path" approach is clearly favoured, both from the adequate supply provision point of view and from the coherence with the principles formulated within the Water Framework Directive. It should be noted that both strategies are can be considered as "socially-acceptable" as they synthetically express the different positive views of most stakeholders. Additionally, the second approach also depicts that development policies cannot be imposed or superposed to water policies since, as it was shown by this analysis, a "BAU" development model would not be viable under any hypothesis. Therefore the interest of this approach has been to achieve the consolidation of a water "positive" strategy, which can be used as reference for a more rational development model. Such a model should be integrated within the Canary Islands' General and Tourism Planning Directives.

Typology Type II – Predominantly tourist and Regional

Limassol region – Cyprus

Traditionally, water management policies in the region aimed to reconcile competing demands between the urban (and tourism) and agricultural sectors, and the environment. The aim of strategy formulation was to meet at least 80% of domestic and irrigation needs during the sensitive peak summer period. The first strategy involved a continuation of current practices, while the second evolved around soft responses, incorporating interventions not currently applied or accepted. Both strategies achieve to meet local water needs for domestic and irrigation use since they both reach 100% demand coverage for both uses. Strategy 1 (that also included pricing measures), achieved better results than the hard-path approach (which was based only on structural measures); this is an indication that the adoption of soft measures, like pricing, can contribute to the recovery of the full cost of the water for domestic use, in line with the suggestions of the WFD.

Ribeiras do Algarve – Portugal

The formulation of management strategies for **Ribeiras do Algarve Basin, Portugal** aimed at: (a) meet at least 95% of domestic demand, addressing deficits observed or forecasted for the western part of the river basin, and at solving localised deficits in the agricultural sector. Additional targets involved the promotion of measures to prevent overexploitation of groundwater resources, especially in coastal regions and to achieve a more economically efficient water usage, while also addressing the WFD cost recovery principle. The formulation of the two strategies reflected the concerns of the stakeholders that are trying to respond to the pre-defined goals, by adopting two distinct approaches:

- The first one focused on the traditional, "hard-path approach", and reflected the current trend of applying structural solutions for the further exploitation of surface water resources.
- The second represented a mild shift towards the application of "soft instruments", introducing localised small-scale structural options, other, non-conventional supply options and efficiency improvements.

The undertaken analysis portrayed that both strategies can be effective in meeting the predefined targets; however with the soft-path approach the same levels of effectiveness are reached through lower direct, environmental and resource costs. Therefore, one of the overall conclusions drawn from the analysis is that the combination of localised, non-conventional measures allows for alleviating water stress issues in a more cost-effective way, which incurs lower prices to consumers.

Typology Type III – Predominantly agricultural

Belice Basin – Italy

Belice Basin is a predominantly agricultural area, relying on extensive irrigation of high-income crops. Therefore, the primary aim in developing strategies for the region is to meet irrigation demand, especially during the period from May to October, and to lower deficits in domestic usage. Two distinct approaches were developed. The first (hard-path approach) was predominantly structural, relying on the further exploitation of water resources and involving construction and rehabilitation of large-scale projects. The second also included use of non-conventional water sources, such as water reuse for enhancement of irrigation supplies.

The results of the two strategies portray that a combination of “soft” and “hard” measures adopted in a medium-long term planning horizon is the best solution in order to meet the local water demand. However, incurred costs are high and not always easy to recover. In addition, alternative solutions aimed at meeting water demand (use of water from waste water treatment plants and/or expansion of Basso Belice station) could be adopted. Other interventions, such as building a new drinking water treatment plant or expanding the capacity of facilities used to store and convey water could increase water availability.

On the basis of the results analysed within the Belice case study, interventions that can be suggested in order to meet local water demand and integrated in a suitable and more sustainable strategic plan are:

- Improvement of the efficiency of water distribution networks, by reducing water losses in the secondary network and along the main pipelines;
- Waste water reclamation and reuse, and improvement of irrigation efficiency;
- Increase of the availability of domestic water by expanding the existing drinking water treatment plant or building new ones, increasing the flow capacity of pipelines abstracting water from the Garcia Lake, and operating already existing reservoirs not yet connected to the main network;
- Development of a firm pricing policy, in order to partially recover the direct costs for domestic and irrigation water provision, and waste water treatment.

3.3.3. Main Deliverables

During the Strategy Formulation Phase the following Deliverables were produced:

Deliverable 14, Review of existing water management plans

The Deliverable summarizes the work undertaken in Task 8.1 of the Project, describing the existing and proposed water management plans in the Case Study Regions. The analysis included both field work and the collection of data by the Case Study Partners. Undertaken field work mainly involved detailed consultation with the local stakeholders and end-users, with respect to their perceptions on issues spanning the appropriate allocation of available resources, the potential for water resources development and the effectiveness of current practices and policies.

Deliverable 16, Coherent water management scenarios

The Deliverable presents the work undertaken in the Case Study regions in Task 8.3 of the Project. The scenarios were based on specific supply interventions or demand side actions, and assess their effect on the current and future matching of water demand, in comparison to the reference case. The evaluation was performed using a predefined set of indicators, complemented with user-defined criteria set by water users, regulators and decision makers. The main objectives of scenario analysis were to determine the options that could be effective in meeting the targets of each Case Study analysis, and estimate their potential extent, cost and environmental impact.

Deliverable 18, Strategies for improved water management

The Deliverable presents the work undertaken in the Case Study regions in WP 9. The purpose was to build appropriate Water Management Strategies for the examined Case Studies, emphasizing on integrated approaches and on the development of cost recovery schemes. The Deliverable includes the overall methodological approach applied in the WSM Case Studies, and the analysis conducted for each, in terms of developing alternative management plans for alleviating water stress and addressing cost recovery objectives.

3.4. Synthesis and Dissemination Phase

The main objective of the Synthesis and Dissemination Phase was to synthesize of the results from the previous project stages in order to develop and formulate, on the basis of the lessons learned from the six paradigms, widely applicable guidelines and protocols for the implementation of Integrated Water Resources Management, and of the Water Framework Directive principles.

In addition, and in recognition of the significant potential to exploit the project results, and the importance of maximising dissemination information on project outcomes on the widest possible European level, specific work packages (i.e. WPs 2, 7, 12, 13, and 14) were devoted to the definition, execution, monitoring and administration of the Dissemination and Exploitation activities. The activities undertaken in these WPs are elaborated in Section 5. Related deliverables are however presented in this section.

The Synthesis Phase comprised two Work Packages:

- **WP 10, "Development of Guidelines"**. The work package aimed to enable the dissemination of the Project results, by providing a step-by-step analysis of the specific options to be used within the framework of a strategy and their specifications (relative costs, duration, and project lifetime). Guidelines also included the regional experiences from the Case Study Regions in the application of these options.
- **WP 11, "Development of protocols for implementing integrated approaches"**, which aimed to delineate a set of prerequisite measures that are required for the implementation of each strategy developed in Work Package 9.

Dissemination activities, which spanned most of the project duration were part of the following Work Packages:

- **WP 2, "Workshop on the range of existing circumstances"**, which aimed at disseminating and consolidating the outcomes of the analysis undertaken in WP 1 (see Section 3.1).
- **WP 7, "Workshop to Present Findings and for Training on the DSS"**, which organised a training workshop for the discussion and presentation to the public of the results of the Analysis phase of the WaterStrategyMan Project (see Section 3.2).
- **WP 12, "Elaboration of project results into publishable form"**, with the purpose of to elaborating the main project results into publishable form, in order to facilitate their dissemination. The WP included 7 separate Tasks, each referring to the preparation of a major Project result into a form that was publishable, and the printing of a number of copies per deliverable. These deliverables are listed in Section 3.4.3 (D21.1 to 21.7).

- **WP 13, “Seminar”**, with the aim to organise a seminal event for the dissemination of the project methodology and results, and to present and discuss water management guidelines with authorities and decision makers.
- **WP 14, “Information campaign, Training and Exploitation Plan”**, with the overall objective to inform decision makers, stakeholders and end-users on the Project results, and to train personnel of water authorities on the developed tools and Project outcomes.

In addition, the Consortium undertook several initiatives in order to ensure the maximum potential outreach towards the scientific community and decision-makers, regulatory authorities and stakeholders. These are further discussed in Chapter 5.

3.4.1. Methodology

Development of Guidelines for Integrated Water Management

The main aim of the work undertaken was to develop Strategy Guidelines, a set of instructions that analyze a given strategy into actions required within the selected water management options, set within a suitable but flexible time framework. The developed guidelines provide a literature presentation and an empirical review on the major management options or methods currently available in water resources management, with respect to their applicability and efficiency in water stressed regions. Management options examined were:

- **Desalination**, an option widely used in regions facing severe scarcity,
- **Recycling and reuse**, concerning the use of treated and untreated wastewaters,
- **Groundwater Exploitation**, including the drilling of boreholes as well as the use of groundwater enhancement methods that enable the sustainable exploitation of both surface and groundwater.
- **Storage Reservoirs and Dams**, constructed for water storage and aquifer enhancement,
- **Conservation measures in domestic use**, including the use of cisterns, low-flow devices, as well as behavioural modifications for the reduction of water waste,
- **Irrigation Method Improvements and Crop changes**, including shifts of irrigation practices and methods, as well as crop substitution and rotation,
- **Network improvements and enhancements**, including new connections for improving efficiency as well as replacements of old components to reduce losses, and
- **Pricing**, used as a tool and/or incentive for demand management in the domestic and agricultural sectors.

Development of Protocols for the Implementation of Improved Approaches

A protocol is defined as a set of comprehensive set of measures for the regulation of human activities and the preservation of the environment. For dealing with water deficiency, required protocols should be directed towards integration, coordination, and facilitation of water deficiency strategies. On yet a larger scale, the problem is of the appropriate development and management of water resources for multi-purpose use. Such an approach implies that protocols, although seemingly simple in their structural characteristics, are extremely complex in their social and economic aspects. This may explain why there are few -if any- readily identifiable water deficiency protocols at higher levels of proposed hierarchies, such as the national and international levels.

The analysis towards the development of Protocols was conducted for each Case Study undertaken in the WaterStrategyMan Project. The analysis involved a thorough examination of the following:

- Current economic development, trends, and background of water management practices;
- Present and emerging policies, as these are formulated in the current decision-making context;
- Major stakeholders and actors involved in decision-making on a local/regional/national level;
- Regional recommendations, as outcomes of the development of improved water management strategies;
- Additional considerations for the implementation of these strategies, aiming to provide a framework for the definition of protocols for their implementation. These considerations were primarily classified in terms of institutional reforms, education and awareness campaigns, cost recovery issues and impact mitigation requirements for each measure incorporated in the developed strategies.

3.4.2. Research Outcomes

Guidelines for Integrated Water Resources Management: The regional experience

The findings from the research undertaken in the Case Study Regions have demonstrated the current trends in water management in the selected regions. Possibilities for the implementation of new management options and for adoption of integrated management have been also examined. Issues such as cost, efficiency, option applicability and social acceptability, have been taken into consideration in an attempt to identify the advantages, the ease in application, and the constraints involved with the selected option or the integrated approach.

For each option, the following were reviewed and analysed:

- Overall description of the different methods applied,
- Rules of thumb for implementation,
- Relative costs and lifetime,
- Bibliographical information on scope and applicability,
- Critical evaluation of advantages and disadvantages, with regard to applicability, efficiency, cost and impacts.

In addition, and where applicable, the description of each option was complemented with regional experiences from the Case Study Regions regarding cost, efficiency and impacts. This information concerned both experiences from actual implementation and from the scenario analysis undertaken in WP 8 (see Section 3.3).

The overall effort allowed for drawing extended recommendations and identifying barriers in the application of each suggested water management option within an integrated water resources management framework. The formulated guidelines can be used as a baseline for integrated management in areas facing similar water management issues, and as a paradigm for the identification of good and bad practice examples on water management. The work undertaken can be also utilised as a basis for similar research in other areas and countries and can also be seen as an incentive for stakeholders to undertake the challenge of promoting and adopting integrated approaches to environmental management.

Protocols of Implementation

The interaction with a complex and fast changing environmental, economic and social reality incorporates growing limitations. Such limitations are usually confronted by multiple alternative responses to the complex reality. However, these responses are not able to converge to a complete whole, unless certain assumptions for their interrelations are made.

In this perspective, the variety of water deficiency strategies and coping mechanisms must be understood through measures implemented at various hierarchical levels of systems, compatible both physically and institutionally. At the system component level, decisions are usually made according to the cost-effectiveness of each measure, with little attention given to the larger, organisational framework or to far-reaching secondary effects. On the other hand, the protocols required are directed towards integration, coordination and facilitation of integrated strategic planning for coping with water deficiency.

In the emerging paradigm of water resources management focus is placed not only on the water-using but on water resources management and the connections between resource use and service management. Under this context it is important to address, in addition to the need for the development and management of infrastructure, management instruments and eventually the institutional framework. The latter defines, among others, the responsibilities of the different actors, rules for water allocation, construction and management of infrastructure and standards for water quality and provision of water services.

In the above context, and taking into account that the regions selected for Case Study Analysis are considered representative of water deficient areas, the definition of barriers, constraints and additional measures required in terms of regulating human activities and preserving the environment can be of value in formulating improved approaches in order to deal with water scarcity problems in regions facing similar issues.

3.4.3. Main Deliverables

The main Deliverables produced in Phase 4 were:

Deliverable 19, Guidelines for integrated water management

Deliverable 19 presents guidelines for the Water Management methods and options that have been used in the development of suitable water management strategies for the WaterStrategyMan Project Case Study Regions.

Deliverable 20, Protocols for implementing integrated water resources management

The Deliverable presents the work undertaken in Work Package 11 towards the definition of appropriate Protocols for the implementation of improved water management strategies for coping with water deficiency. Emphasis is put on defining additional requirements for the implementation of the strategies developed in Work Package 9. This could prove valuable in defining an appropriate framework for their implementation.

Deliverables 21.1 and 21.2, Publishable reports on Typologies and Paradigms *(Typology and Representative Paradigms of Water Deficient Regions in Southern Europe)*

The report is the elaboration of the deliverables "*Typology of Comprehensive Problematique*" and "*Set of Representative Paradigms*" into a form suitable for publication.

This volume presents a thorough investigation of fifteen regions in the Mediterranean basin, analysing prevailing conditions in terms of natural conditions, human pressures, adopted responses, water policies and constraints to solving water deficit problems. Regions presented and analysed are Attica, Thessaly and Cyclades in Greece, Emilia-Romagna, and Belice Basin in Italy, Tel Aviv and Arava regions in Israel, Germasogeia, Akrotiri and Kokkinokhoria in Cyprus, Canary Islands and Dõnana in Spain, and Guadiana, Sado and Ribeiras do Algarve in Portugal.

Deliverable 21.3, Publishable report on Methodologies (*Water Management Methodologies for Water Deficient Regions in Southern Europe*)

This volume reviews some of the concepts and methods that are useful for river basin management. It is organised in the following manner: Chapter 1 summarises models for the assessment and forecasting of water availability and demand, taking into account temporal and spatial variability and water shortage conditions. The aim of Chapter 2 is to present a methodological approach for the estimation of financial, resource and environmental costs associated with water management interventions and uses. The different sections of this chapter analyse the theoretical background for the estimation of the different components of the cost and propose a simplified, easy-to-implement approach for their computation. Chapter 3 outlines different methods for MCDM in water resources management and describes basic requirements for indicators to "measure" the achievement of a given objective in the planning process. Finally, data requirements, structuring approaches and the most commonly used indicators in water resources management are presented in Chapter 4.

Deliverable 21.4, Publishable report on DSS *(The WaterStrategyMan DSS: A Comprehensive Decision Support System for the Development of Sustainable Water Management Strategies)*

This Publishable Report presents the Decision Support System developed in the framework of the WaterStrategyMan project. The WSM DSS was functional to the analysis of the dominant and shifting paradigm options and of their quantitative, qualitative and economic impacts in the selected regional water resource systems. The system is a tool able to simulate the behaviour of water resource systems under different scenarios of water availability and demand, and including a module for simulating and evaluating alternative water management strategies. The volume is structured in two parts: Part I presents the principles, concepts and methodology of the WaterStrategyMan DSS, while Part II is a comprehensive review of existing tools for water management and planning.

Deliverable 21.5, Publishable report on Strategies *(Developing strategies for Integrated Water Resources Management in water deficient regions: Methodological approach and case studies)*

This volume is structured in two parts. Part I presents the step-by-step methodological approach elaborated in the course of the WaterStrategyMan project for developing water management strategies in the six selected Case Studies, complemented with an overview of the overall project methodology and results. Part II is dedicated to presenting the outcomes of a building block of the adopted approach: the analysis of different water management options in the context of selecting, out of a range of proposed methods, those that can be most efficient and effective in alleviating water scarcity problems.

Deliverable 21.6, Publishable report on Guidelines *(Guidelines for Integrated Water Management: Regional experiences and management methods applicable to water stressed regions)*

This Deliverable is the elaboration of Deliverable 19 into publishable form. The document provides a step-by-step analysis of the specific options to be used within the framework of a strategy. Case Study regional experiences in the application of these options have been included in order to provide input based on hands-on experience regarding the implementation of different management methods.

Deliverable 21.7, Publishable report on Protocols of implementation *(Protocols for the implementation of improved water management strategies in water deficient regions)*

This Deliverable is the elaboration of Deliverable 20 into publishable form. On the basis of the Water Management Strategies formulated in WP 9, the report presents an initial analysis of regional requirements for their actual implementation.

Deliverable 22, Seminar Proceedings (Proceedings of the ARID Cluster Conference)

The Deliverable includes the papers presented in the ARID Cluster Conference *"Coping with Drought and Water Deficiency: From Research to Policy Making"*, held in Limassol, Cyprus on the 12th and 13th May 2005.

Deliverable 23, Training material and multimedia package

The deliverable consists of an interactive Multimedia CD which incorporates the major outputs of the project and a training programme. The latter involves an analytical presentation of the adopted methodological approach for the formulation and evaluation of Integrated Water Management Strategies, and provides hands-on experience with the WSM DSS.

Deliverable 24, Exploitation Plan

The Deliverable elaborates on the strategy agreed by the Consortium for further exploiting the main outcomes of the WaterStrategyMan project, through the identification of potential market sectors and the analysis of scientific and business opportunities. An Intellectual Property Rights (IPR) Agreement that sets the framework for the exploitation and use of the WSM DSS is also included.

4. CONCLUSIONS

This section discusses socio-economic relevance and policy implications and conclusions, and is organised in the following way:

- The first paragraph focuses on the aspects of socio-economic relevance and policy implications, in relation to the research outcomes of the project.
- The second presents the overall conclusions of the project, summarising project outputs and achievements.

4.1. Socio-economic Relevance and Policy Implications

Access to adequate water supply is a basic social need, which cannot be constrained. Human welfare and regional development strongly depend on the availability of fresh water. Investments for new water supply schemes and improved management of existing ones should be planned and scheduled on sound data and in a holistic fashion taking into account all interactions and interrelations between society and environment. An Integrated Water Resource/Demand Management approach, taking into consideration all parameters and impacts, should satisfy water needs in a sustainable way, without the adverse environmental effects that traditional policies often entail.

This is the concept addressed by the WaterStrategyMan Project, which focused at the development and evaluation of alternative policies for an integrated water resource/demand management with the aim to achieve a more sustainable development in Southern European water deficient regions. The overall developed methodological approach, which takes into account economic, technical, social, institutional and environmental implications, can assist and provide valuable insight supporting the formulation of policies that meet directly or indirectly the EU policy requirements concerning:

a) *Preservation and enhancement of the quality of the environment and the availability of natural resources.*

The Project used a holistic approach for formulating water management strategies, recognising water as an inherent part of the environment. In addition, the project elaborated on the development of suitable and relevant pricing schemes for achieving adequate water cost recovery and pinpointed the difficulties that pricing aiming at full cost recovery can impose in water stressed areas, where the recovery of costs, especially under scarcity or drought can result in prohibitive prices.

b) Improvement of the quality of life

The WSM Project introduced a framework and methodological approach that can assist policy makers and decision makers in the formulation and assessment of effective water resources management efforts in water stressed environments. Towards this end, it can be concluded that elements of the overall project approach can assist in the definition of mitigation options, which in turn can be able to alleviate social and political tension related to water scarcity and improve health and prosperity in water stressed areas.

c) Improvement of employment

Water scarcity in Southern European regions has frequently been described as one of the limiting factors for economic development. The identification of water management issues and the suggestion of suitable responses able to alleviate water shortage and prevent deterioration of freshwater quality can assist in enhancing regional development and prosperity.

In terms of **added value on a European Level**, WaterStrategyMan managed, throughout its duration, to highlight some of the benefits decision-makers can obtain by addressing water problems through an Integrated Management approach. At the same time scientific information and experiences on water management techniques and technologies were widely integrated, disseminated and promoted. Finally, elements of the overall project approach directly respond to aspects of the foreseen implementation of the Water Framework Directive in Southern Europe, and other key policies (in force or potential), such as the reform of the European Common Agricultural Policy, national pricing policies for enhancing the sustainability of water resources, Agenda 21, and national policies for resource allocation and use.

4.2. Concluding Remarks

The traditional approach to water management has been based on the concept that natural systems should be managed in a way that provides supply to meet externally determined water needs. In this way, the fact that water can be supplied with very different properties (e.g. in terms of quality, availability or in low flow or peak demand periods) is a fact that is usually ignored. When it comes to analyzing human activities or service systems, virtually all aspects of integration involve an understanding of the natural system, its capacity, vulnerability and limits. Such integration is inevitably a complex task and perfect integration is unrealistic.

During the implementation of the WSM Project, the determination of the Range of Existing Circumstances led to the identification of water stress Drivers and Pressures often observed in water deficient areas of Southern Europe. Descriptive regional analysis and the proposed typology formed a first level of the overall process of understanding of the functions and operations of water management systems under scarcity conditions. The synthesis of the approach, where the interactions between the Natural and Human Environment were analysed, helped in the formulation of cluster types according to crucial parameters of the water deficit characteristics that have emerged. In this context, the proposed typology can be used to determine the status of the management of water in deficient regions, on a broad range of regions in Southern Europe, other than the ones assessed in the WSM Project. On a second level, the Paradigms applicable to the Southern European regions, which were assessed in the Project, have been shown to vary little between regions, suggesting similar issues that can potentially be addressed within the framework of one single policy approach.

On the other hand, the developed methodology for quantitative assessment is a valuable contribution for the assessment of water resources systems, particularly in regions characterised by acute water shortage. The elaborated approach is particularly relevant for the efficient implementation of an integrated water resources management approach in arid and semi-arid regions in Southern Europe, as it considers cost, benefits, efficiency, social and environmental implications, and thereby enables the comparison of current policies and adopted responses both in terms of current conditions as well as implications of an intervention in water management. The integration of this methodology in the prototype WSM Decision Support System, along with the development of an analysis framework that integrates environmental and socio-economic aspects, have led to the development of a potentially valuable tool for decision making and policy formulation in Southern Europe, able to address a variety of water resources management problems in a holistic, integrated approach.

Under the above premises, the development of regional water management strategies undertaken in the WaterStrategyMan project aimed to provide recommendations on reconciling supply and demand in arid and semi-arid regions characterised by different origins of water stress. Each region presented a unique and distinct water resources management framework highlighted through the development and implementation of water-related policies as function of the prevailing socio-economic environment, the institutional framework and the regional and national cultural context. Thus, specific objectives and targets for the reconciliation of supply and demand and the alleviation of water scarcity were differentiated per region, varying according to the expectations and awareness of the contacted stakeholder groups, environmental problems and the sources of social conflict.

It is widely accepted that region-specific issues require the development or acceptance of indicators addressing both scientific and policy requirements. According to scientific requirements, indicators should be both specific for a certain stress or effect, and general enough to be used in different regions and describe different water management issues. According to policy requirements, indicators should be tailored to the needs of the primary users and most importantly, they should be simple, easily interpretable and appealing to society in order to ease communication between policy makers and citizens.

Throughout the process of determining improved and eventually Integrated Water Resources Management Strategies, which was presented in this volume, the principal goals and ambitions remained the same. They were articulated through appropriate indicators, aimed at translating the broader goals of economic efficiency, environmental sustainability and equity in the framework of water resource planning and allocation in arid and semi-arid regions. Selected indicators involved (a) efficiency and effectiveness in demand coverage, (b) the total direct cost or the social welfare surplus incurred from potential application of water management options and the current operation of the water system, (c) the total environmental cost and (d) the total resource cost. Environmental costs were linked to environmental impacts from water use, while resource costs were estimated according to foregone user-benefits from the current water allocation practices. The estimation of costs and their allocation to water uses and users was in line with the economic principles of the recently adopted, and under implementation, Water Framework Directive.

These indicators also portrayed, through the formulation of preliminary cost recovery strategies, that in some cases full cost recovery is difficult, if not impossible. Such constraints are imposed by the aridity and low availability characterising the regions; they are further strengthened by the need to preserve agriculture for social, environmental and economic development reasons. In other cases, cost recovery is linked to constraints imposed by the legal and institutional framework which defines water rights, by allocation rules, or by stakeholders who due to political power can influence decision-making in the allocation of both water and cost. Although in most countries (and therefore regions) examined, the transposition of the WFD in the national legislation has already taken place, the overall administrative structure has not yet started to, or it is just starting to, operate. Therefore, it is difficult to draw conclusions on how cost recovery mechanisms will be implemented in the near future.

These indicators were linked to the entire strategy formulation process, from the evaluation of water management options to the formulation of water management strategies and the development of cost recovery strategies. The step-by-step methodological approach that was followed and validated through its application in the Case Studies, demonstrated that even under relatively low data availability, and assumptions with regard to parameters, conclusions can be drawn with regard to current water management practices and foreseen responses to water stress. This approach that can be easily followed in other regions facing similar problems or other environmental issues was linked to models and forecasts, through its implementation in the WaterStrategyMan Decision Support System.

The overall approach aimed to draw on existing data and knowledge; the process of formulating strategies highlighted water management issues and the importance of soft approaches in dealing with water stress, as opposed to the traditional approach of large-scale structural interventions. Eventually the actual solutions to be adopted depend on public acceptance. Such an effort should be promoted through the actual participation of stakeholders, end-users and citizens in the decision-making process. However a step has been made towards this end through the analysis and evaluation of water management options in line with stakeholder expectations and regional development targets.

5. DISSEMINATION AND EXPLOITATION OF RESULTS

As mentioned in Section 3.4 of this document, specific Work Packages were defined in the WSM Project, in order to identify the exploitation strategy for the project results and maximise the dissemination of information on research outcomes at the widest possible local, national, European and international levels.

In general terms, benefits derived from the Project consortium’s complementarity were fully utilised in order to provide a sound basis for the comprehensive exploitation of the project results and ensure their widest possible applicability. The framework of the partners’ contribution involved the utilisation of their networks and contacts in their respective countries/regions, in order to consolidate and promote the project results through close co-operation with local decision-makers, water agencies and stakeholders. An example can be demonstrated through the application of the project approach on the economic analysis of water uses and services for meeting the 2005 EU reporting requirements of the Republic of Cyprus for the Implementation of the Water Framework Directive.

Activities undertaken with regard to the Dissemination and Exploitation of Results, as well as the future plans of the WSM Consortium with regard to these, are described in the two paragraphs that follow.

5.1. Information Exchange & Dissemination

Dissemination and information exchange activities undertaken in the course of the Project can be classified into three interrelated categories:

- The organisation of Workshops and Conferences, undertaken in the framework of the WaterStrategyMan and the ARID Cluster Accompanying Measure Projects;

- The development of publications and the synthesis of material related to the Project outcomes. Material was elaborated in a variety of formats, such as:
  - Electronic, including the WSM Project web site, and the issuing of electronic Newsletters;
  - Publications, in the form of publishable reports and scientific publications;
  - Multimedia package in CD-Rom format, which also included training material regarding different aspects of the WSM Methodology.
- Activities undertaken in the framework of *WP 14 "Information Campaign, Training and Exploitation Plan"*, in relation to the identification and collaboration with:
  - Other relevant projects;
  - End users, including water resource managers;
  - Legislative authorities and regulatory bodies.

In addition, Project Participants participated in a considerable number of Conferences, Workshops and Symposia in order to present the project achievements and exchange information with other members of the scientific community.

5.1.1. Identification and information exchange with stakeholders, end-users and decision makers

Project participants identified end users and stakeholders in the participating Southern European countries (Cyprus, Greece, Italy, Israel, Spain and Portugal) to be involved in the WSM Project. Stakeholder consultation was a key stage of the Strategy Formulation Phase, including information exchange with regard to the water management issues encountered in the Case Study Regions, the successful or unsuccessful application of mitigation options, and the overall evaluation of the proposed integrated approaches. Stakeholders and end-users have also been involved in the workshops and meetings organised by the project, sharing their views and practical know-how regarding the application of appropriate responses. A non-exhaustive, per country list, of institutions that have been identified/participated or collaborated with the WSM project throughout its lifetime is presented below.

- In Cyprus:
  - The Water Development Department of MANRE;
  - The Planning Bureau;
  - The Water Boards of Nicosia, Limassol, Larnaka, and Pafos;
  - The Sewerage Boards of Nicosia, Limassol, Larnaka, and Pafos;
  - The Municipalities of Nicosia, Limassol, Larnaka, Pafos.
- In Greece:
  - The Aegean Islands Water Basin Authority and the Eastern Peloponnese Water Basin Authority;
  - The Water Utility Company of Athens, the water-sewerage service providers and councils of the Cyclades Islands and of the Argolis Prefecture;
  - The Cyclades Prefecture Authorities, the Argolis Prefecture Authorities and the Local Municipalities;
  - Agricultural co-operatives in the Cyclades and in the Argolis Prefecture;
  - The Hellenic Ministry of Development;
  - The Hellenic Minstry for the Environment, Physical Planning & Public Works;
  - Anatoliki S.A., the Development Agency of Eastern Thessaloniki region;

- The Municipality of Paros Island, Greece;
  - The Municipal Water Utility for the provision of water supply and Sewerage services of Paros Island, Greece;
  - The Union of Agricultural Associations in Paros Island, Greece;
  - The Union of Hotel and Lodging Owners in Paros Island, Greece;
  - The Municipal Water Utility for the provision of water supply and sewerage services of Hermoupolis, Syros, Greece.
- In Israel:
  - The Israeli Water Commission;
  - The Mekorot company;
  - Representatives of Private Water Suppliers;
  - Representatives of the agricultural sector;
  - Representatives of the urban sector.
- In Italy:
  - The Autorità di Bacino del Liri-Garigliano, Volturno, located in Naples;
  - The River Arno Authority, located in Florence;
  - The Reno River Authority, located in Bologna;
  - Consorzio 3 Agrigento – Agency of Menfi in Belice Basin, Sicily;
  - Ente Acquedotti Siciliani (EAS), in Sicily.
- In Portugal:
  - The Ministry of Cities, Land-use Planning and Environment (MCOTA);
  - The INAG – Instituto da Água (Portuguese Water Institute);
  - The CCDR Algarve – Comissão de Coordenação e Desenvolvimento Regional do Algarve which includes the DRAOT Algarve – Direcção Regional do Ambiente e Ordenamento do Território;
  - The IRAR – Instituto Regulador de Águas e Resíduos;
  - IDRHa – Instituto de Desenvolvimento Rural e Hidráulica;
  - Águas do Algarve S.A., the primary urban water supply utility;
  - The Association of Municipalities of Algarve (AMAL);
  - The Farmers Associations: (i) of the Mira Public Irrigation Site; (ii) of the Alvor Public irrigation Site; (iii) of the Silves, Lagoa and Portimão Public Irrigation Site);
  - The Algarve Tourism Office and Hotel Industry Association.
- In Spain:
  - The El Hierro Island Council;
  - The Consorcio de Aguas del Sud in the island of Tenerife;
  - The Asociacion Hotelera y de Servicios de Tenerife.

In addition, the project, in the framework of the ARID Cluster, developed a close collaboration with the **WFD-Common Implementation Strategy Water Directors** (Water Scarcity Drafting Group), both in terms of scientific co-operation and organisation/support of common dissemination events.

5.1.2. Organisation of workshops and conferences

From the very beginning and throughout the Project implementation, meetings, workshops and seminal events involved experts, decision-makers, stakeholders and end users, in order to take on board recommendations and perspectives with regard to specific water stress issues and consolidate research outcomes. This section summarises the most important seminal events realised or supported by the WSM Project during its execution.

Workshop on the "Range of Existing Circumstances", Hermoupolis, Greece, 8th July 2003

This first Workshop, organized under WP 2, was part of the Diagnostic/Descriptive Phase (see Section 3.1) and aimed at disseminating research carried out in the first six months of the project focusing on water management issues identified in the studied regions. The Workshop was organized in four sessions, in which the following aspects were presented and discussed:

- The range on existing circumstances;
- The typology for water deficient regions;
- The range of policy alternatives in water management;
- Water management practices for the selected regions.

The workshop was attended by invited experts, policy makers, decision makers, and stakeholders involved in management of water resources in Greece. Thus, the workshop served as a first opportunity to discuss and interact with potential end-users of the project results regarding not only the overall water management framework, the project methodology and the anticipated outcomes, but also their specific needs and problems they face.

Workshop "Towards Comprehensive Water Management Strategies for Water Stressed Regions", Paris, France, 8th October 2003.

This workshop, organised under WP 7, formed part of the Analysis Phase (see Paragraph 3.2), and aimed at:

- Presenting and discussing the results of the Phase with experts and decision makers;
- Validating the developed methodology and selected tools, and preparing the development of water management scenarios in the identified Paradigms;
- Training participants on the developed DSS and on methodology application issues.

The workshop was attended by invited experts in the field of natural resource and environmental management and economics. The extensive discussion on methodologies for the estimation of financial, environmental and resource costs, and their implementation in a Decision Support System, allowed the dissemination of the project approach with regard to evaluation methodologies and approaches for assessing different options in the context of water scarcity.

Conference on "Water Resources Management in Water Stressed Environments and Islands – the Challenge of Ecoadaptation", Santa Cruz de la Palma, Canary Islands, Spain, February 2nd-4th 2004.

This Conference was the first major dissemination event organised in the framework of the ARID Cluster, with the aim of presenting research outcomes of the ARID Cluster Projects, and showcasing the instruments available for the management of water resources in arid regions. Structural and non-structural instruments were discussed by Stakeholders who provided their own hands-on experience and personal and professional outlook with regard to their applicability and potential. The WaterStrategyMan project participated by:

- Organising the event, in collaboration with the La Palma Biosphere Reserve, and the other ARID Projects;
- Demonstrating the overall project methodology, approach and expected outcomes;
- Disseminating the progress to-date, in terms of analysing water deficiency issues, developing analytical tools and evaluating different water management options.

Further information can be found at the relevant section of the ARID Cluster web site (http://arid.chemeng.ntua.gr/Project/Default.aspx?t=62).

Sicily Joint Workshop on "Drought and Water Deficiency: From Research to Policy Making", Palermo, Italy, 8th-9th October 2004.

The Sicily Joint Workshop "Drought and water deficiency: from research to policy making" was jointly organised by the European Commission (DG Research and DG Environment) and France, and supported by the ARID Cluster. The contribution of the WSM Project comprised the following:

- Participation in the organisation of the event;
- Demonstration of the project methodological approach, focusing on the application of analytical tools for the for the formulation and evaluation of integrated water management strategies;
- Dissemination of the first results of the adopted approach for the case study of Paros Island, Greece.

Further information can be found at: http://arid.chemeng.ntua.gr/Project/Default.aspx?t=66.

ARID Cluster Conference "Coping with drought and water deficiency: from research to policy making", Limassol, Cyprus, 12th-13th May 2005.

The ARID Cluster Conference event was jointly organised with the Water Scarcity Drafting Group (Common Implementation Strategy/WFD), the European Commission and DG Environment, and the Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment of the Republic of Cyprus, and also incorporated the WaterStrategyMan Seminar initially planned under WP 13.

The WaterStrategyMan project participated through the organisation of the event, the publication of Proceedings (WSM Deliverable 22), and through the broad dissemination of the results of the research undertaken within the Strategy Formulation and the Synthesis Phases.

Further information on the event is available at: http://arid.chemeng.ntua.gr/Project/Default.aspx?t=74.

5.1.3. Development of dissemination material

The web site of the WaterStrategyMan Project

The web site of the WaterStrategyMan Project, http://environ.chemeng.ntua.gr/wsm/, has been in operation from the very beginning of the Project, and constitutes the primary means of disseminating project-relevant information, achieved progress and research outcomes, as well as information on forthcoming events and undertaken initiatives.

The public domain of the web site is organised in four main themes:

- The **"Introductory"** Section, which introduces the project and its participants. This section discloses the overall scientific objectives, and contains information on the research approach and progress made.
- The **"Meetings and Workshops"** Section, which hosts material from the workshops and meetings realised during the execution of the Project.
- The **"Deliverables"** Section, which includes all public (non-confidential) reports produced by the Project.
- The **"Publications"** section which includes:
    - The elaborated publishable reports;

- The Newsletters published during the Project's execution;
- Scientific publications produced by Project participants.

The web site includes summaries of all public project deliverables, which are also available for download.

Newsletters

Major project outcomes were published in six quarterly electronic Newsletters, which, through established e-mailing lists, were sent to participants of other Projects touching similar issues, Experts, Stakeholders and Decision Makers. The Newsletter Issues, which are also disseminated through the Project Web Site, are considered part of the literature produced by the project, are presented in Chapter 6.

Publishable Reports

The compilation of publishable reports in WP 12 formed an integral part of the Dissemination Phase of the project, aiming at the disclosure of project methodology and results, through the circulation of pertinent information. In total 6 volumes were produced, each elaborating on a major building block of the overall methodological approach and outcomes (see Section 3.4.3, Deliverables 21.1 & 2 to 21.7). Printed copies were distributed to a significant number of decision makers, water management authorities and experts on a European Level, and to stakeholders and end-users that have been approached and collaborated with the Project throughout its duration.

Training Material and Multimedia CD Package

An additional effort for achieving the maximum possible disclosure of the Project Methodology and results was effected through the development of a Multimedia CD Package. The CD incorporated the major outputs of the project and a training programme, which involved an analytical presentation of the adopted methodological approach for the formulation and evaluation of Integrated Water Management Strategies, and provided hands-on experience with the WaterStrategyMan Decision Support System.

The Multimedia CD was disseminated to the participants of the Cyprus ARID Cluster Conference, and will also be incorporated in the overall training material developed in the framework of the ARID Cluster Accompanying Measure.

5.2. Exploitation of Results

As the implementation of the Water Framework Directive proceeds, a huge increase in demand for the methodologies and services developed during the implementation of the project is expected. Because of the mandatory character of the WFD, it is reasonable to expect that within the next few years most European regulatory authorities, Water Boards, Governmental Departments, Water Companies, etc. working in the field of water management, could make use of the approach developed within WSM.

With regard to individual exploitation, exploitation plans were defined in the course of the project with input from all project partners. The basis of this work, which was updated on a yearly basis, is included in a reference document, the project Exploitation Plan (Section 3.4.3, Deliverable 24). The deliverable, which is confidential and commercially sensitive, analyses the project results which can be considered commercially exploitable, and details:

- For each result, an overall description with regard to its competitive advantage and the potential marketing scenarios and exploitation opportunities.

- For participating countries, the segmentation of the targeted market, and the role that user categories may have towards the results identified as above.
- For project partners, the exploitation strategy regarding the identified results, and the anticipated impact in their core business.

The Exploitation plan also includes an IPR Agreement concerning the application and use of the WaterStrategyMan Decision Support System, as agreed and signed by all Project Participants. The aim of the Agreement is to protect future use and development of the WSM DSS, which is encouraged with non-partners beyond the project, but at the same time safeguards integrity and efficacy.

6. MAIN LITERATURE PRODUCED

The following paragraphs outline the main literature produced throughout the duration of the project. Items are classified into:

- Articles published in scientific journals or included in conference proceedings,
- Contributions in books.

In order to provide a comprehensive overview, this section also includes reference to the publishable reports and newsletters issued by WSM. The latter are considered part of the main literature produced by the project, as they consolidate and synthesise its main outputs and scientific achievements. Reference is also made to the main public (non-confidential) deliverables of the project.

6.1. Articles and Book Chapters

A number of papers, presenting various aspects of the work undertaken in the 42 months of the project, have been produced and published in scientific journals and conference proceedings. A non-exhaustive list of 18 scientific publications follows.

Publications in Journals

Manoli, E., Assimacopoulos, D., and Karavitis, C.A., (2004), Water supply management approaches using RES in the island of Rhodes, Greece, *Desalination*, **161**, 179-189.

Voivontas, D., Arampatzis, G., Manoli, E., Karavitis, C., and Assimacopoulos, D. (2003), Water supply modelling towards sustainable environmental management in small islands: the case of Paros, Greece, *Desalination*, **156**, 127-135.

Manoli, E., Arampatzis, G., Pissias, E., Xenos, D., and Assimacopoulos, D. (2001), Water demand and supply analysis using a spatial decision support system, *Global NEST: The International Journal*, **3 (3)**, 199-209.

Publications in Conference Proceedings

Glekas, I. P., (2005), Water Management Strategies for Cyprus, Proceedings of the *ARID Cluster Conference: Drought and water deficiency: from research to policy making*, Limassol, Cyprus, 87-102.

Katsiardi, P., Manoli, E. Karavitis, C., and Assimacopoulos, D. (2005), Scenario-based strategy development for Integrated Water Resources Management, Proceedings of the *9th International Conference on Environmental Science and Technology*, Rhodes, Greece, 738-745.

Manoli, E., Katsiardi, P., Arampatzis, G. and Assimacopoulos, D. (2005), Comprehensive water management scenarios for strategic planning, Proceedings of the *9th International Conference on Environmental Science and Technology*, Rhodes, Greece, 913-920.

Manoli, E., Katsiardi, P., and Assimacopoulos, D. (2005), Putting the WFD into practice: Strategy formulation for IWRM under scarcity conditions, Proceedings of the *ARID Cluster Conference: Drought and water deficiency: from research to policy making*, Limassol, Cyprus, 47-56.

Maia, R. (2005), Water Management Strategies for Ribeiras do Algarve, Portugal, Proceedings of the *ARID Cluster Conference: Drought and water deficiency: from research to policy making*, Limassol, Cyprus, 113-124.

Assimacopoulos, D., Barraqué, B., Berland, J. M., Feinerman, E., Katsiardi, P. and Manoli, E. (2005), Estimation of the level of cost recovery of different scenarios of water allocation in arid areas / a proposition for an easy-to-implement approach, Proceedings of t*he Second International Workshop: Implementing economic analysis in the Water Framework Directive*, Paris, France.

Teiga, P., Silva, C., Faria, R., and Maia, R., (2005), Application of a Water Management Tool to the Development of Irrigation Sites in the Algarve Region, (in Portuguese), Proceedings of the *7th Symposium on Hydraulics, Water Resources and Environment of Official Portuguese Language countries*, Évora, Portugal.

Wisser, D. (2005), Common Trends of Water Use in the Mediterranean- The EU WaterStrategyMan Project, Proceedings of the *SUSTAINIS Advanced Study Course: Sustainable use of water on Mediterranean Islands: Conditions, Obstacles and Perspectives*, Cyprus, 2003, Centre for Environmental Research Publications, Münster, 2005.

Assimacopoulos, D. (2004), Cost-Effectiveness Analysis for Water Management. The case of Paros island, Greece, Proceedings of the *International Conference: Renewable energies for islands: Sustainable Energy Solutions*, Larnaca, Cyprus.

Assimacopoulos, D. (2004), An Integrated Decision Support System for the evaluation of water management strategies, Proceedings of the *IDS-Water Europe web conference*.

Couto, V., Chia-Yau, C., and Maia R. (2004), Evaluation Tool of the Possible Impact in Surface Water Quality in Arade Sub-basin, Algarve, (in Portuguese), Proceedings of the *IV Iberian Congress on Management and Planning of water resources*, Tortosa, Spain.

Silva, C., Faria R. Lucas, H., and Maia, R.(2004), Application of a Decision Support System Tool to the Ribeiras do Algarve River Basin: Importance of the Primary Water Supply System in the Sustainable Management of Water Resources (in Portuguese), Proceedings of the *11th Encontro Nacional de Saneamento Básico, Universidade do Algarve*, Faro, Portugal.

Silva, C., Neves, M. H., Faria, R., Cruz, P., and Maia R. (2004), Water Management Decision Support System Tool in water deficient regions: Application to the Ribeiras do Algarve River Basin (in Portuguese), Proceedings of the *IV Iberian Congress on Management and Planning of water resources*, Tortosa, Spain.

Gerasidi, A., Katsiardi, P., Papaefstathiou, N., Manoli, E., and Assimacopoulos, D. (2003), Cost-effectiveness for water management in the island of Paros, Greece, Proceedings of the *VIII International Conference on Environmental Science and Technology*, Lemnos, Greece, 261-269.

Voivontas, D., Manoli, E., Arampatzis, G., and Assimacopoulos D. (2003), Water management in small islands: an optimization model for Paros, Proceedings of the *Hydrotop 2003* Conference, Marseille, France.

Book Chapters

In addition, the WSM project has contributed with two chapters in the first book to be published in the framework of the ARID Cluster Accompanying Measure. The book under the title "*Water management in Arid and Semi-arid Regions: Interdisciplinary Perspectives*" is to be published by the end of 2005 by Edward-Elgar Publishing Limited. The WSM contributions present part of the research carried out in the Analysis and Strategy Formulation Phases (see Paragraphs 3.2 and 3.3 respectively), and are the following:

- **The WaterStrategyMan Decision Support System**, by E. Todini, A. Schumann and D. Assimacopoulos. The chapter presented the overall principles, methodology and architecture of the Decision Support System developed in the framework of the project.
- **Evaluation of alternative water management scenarios: the Case Study of Ribeiras do Algarve, Portugal**, by R. Maia. The chapter presented the application of the WSM DSS in the case study undertaken in Portugal, with the aim to highlight methodological aspects in the evaluation of different water management options.

An additional contribution regarding **The Range of Existing Circumstances in the WaterStrategyMan Case Studies**, by B. Barraque, C. Karavitis and P. Katsiardi, will form part of the second book prepared in the framework of the ARID Cluster. The book is expected to be published in 2006.

6.2. Other Literature

Other literature produced by the project concerns the elaborated project deliverables, and newsletters, which are disseminated via the project web site. Due to their particular importance, separate reference is made to the projects' publishable reports and training material.

Newsletters

The Newsletter issues published in the course of the WSM project are:

- **Issue 1, March - June 2003**, which introduced the project, its participants and the progress made thus far, including deliverables and project meetings of the first year.
- **Issue 2, July - September 2003**, which presented the range of existing circumstances for Greece, and the regional analysis elaborated for Attica, Thessaly and the Cycladic Islands.
- **Issue 3, October - December 2003**, which included an overview of the progress achieved during the second year, and the analysis of the range of existing circumstances in Italy, Israel, Cyprus, Spain and Portugal.
- **Issue 4, January - March 2004**, which presented the set of Indicators and Indices frequently used in Water Resources Management, and material from the La Palma ARID Cluster Conference (see above).
- **Issue 5, April – June 2004**, which elaborated on the major outcomes of the Analysis Phase of the project, i.e. the WSM Decision Support System and the GIS Database.
- **Issue 6, October - December 2004**, which concentrated on the developed methodological approach for the evaluation of alternative water management options and demonstrated its application to the Case Study of Paros Island, Greece.

All issues are available at: http://environ.chemeng.ntua.gr/wsm/Default.aspx?t=73.

Training Material

Deliverable 23, *Training Material and Multimedia Package,* is also considered part of the literature produced by the project. The contents of the Multimedia CD were organised in three main categories:

- The Project History (objectives, partners, contact information),
- WSM Project Outputs (Project Deliverables, Presentations & Publications), and
- WSM Training Material referring to the application of the methodological approach and the developed Decision Support System.

The incorporated training material was designed for assisting potential users in obtaining a comprehensive understanding of the project approach for formulating and evaluating Integrated Water Management Strategies. This target is achieved through a demo application of the WSM DSS in the Case Study undertaken in Cyprus, in order to provide a complete step-by-step analytical demonstration on the way that the DSS can be utilised for formulating scenarios, assessing different water management options and eventually evaluating integrated strategic plans.

Publishable reports

The publishable reports, which constitute the first step towards a book publication of the outputs of the project have been presented in Section 3.4.3, and are repeated here in order to provide a comprehensive overview of the literature produced by the project. They are:

- Deliverables 21.1 and 21.2, Publishable report on *Typology and Representative Paradigms of Water Deficient Regions in Southern Europe*;
- Deliverable 21.3, Publishable report on *Water Management Methodologies for Water Deficient Regions in Southern Europe*;
- Deliverable 21.4, Publishable report on *The WaterStrategyMan DSS: A comprehensive Decision Support System for the Development of Sustainable Water Management Strategies*;
- Deliverable 21.5, Publishable report on *Developing Strategies for Integrated Water Management in Water Deficient Regions: Methodological Approach and Case Studies*;
- Deliverable 21.6, Publishable report on *Guidelines for Integrated Water Management: Regional Experiences and Management Methods Applicable to Water Stressed Regions,*
- Deliverable 21.7, Publishable report on *Protocols for the implementation of Improved Water Management Strategies in Water Deficient Regions*;

Other Public Project Deliverables

Deliverables produced by the Project have been extensively discussed in the respective paragraphs of Chapters 3.1, 3.2, 3.3 and 3.4. They are:

- Deliverable 1, *Range of Existing Circumstances*;
- Deliverable 3, *Proceedings of the Workshop on the Range of Existing Circumstances*;
- Deliverable 4, *Development of a Systematic Typology of Comprehensive Problematique*;
- Deliverable 5, *Set of Representative Paradigms*;
- Deliverable 7, *Methodology Report on the Quantitative Analysis of Water Systems*;
- Deliverable 8, *Methodology for Evaluating Water Resources Scenarios*;
- Deliverable 10, *Report on Models, Tools and DSS for Water Management*;
- Deliverable 11, *Integrated Decision Support System Applicable to the Paradigms*;
- Deliverable 12, *GIS Database;*

- Deliverable 13, *Workshop Proceedings*;
- Deliverable 14, *Review of existing water management plans*;
- Deliverable 16, *Coherent water management scenarios*;
- Deliverable 18, *Strategies for improved water management*;
- Deliverable 19, *Guidelines for integrated water management*;
- Deliverable 20, *Protocols for implementing integrated water resources management*;
- Deliverable 22, *Seminar Proceedings* (Proceedings of the ARID Cluster Conference: Drought and Water Deficiency: From Research to Policy Making, organised in Limassol, Cyprus, on the 12th-13th May 2005.

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