Protocols for the implementation of improved Water Management Strategies in Water Deficient Regions

Preface

The present document provides insight to Protocols for the implemention of improved water management strategies in water deficient regions. The analysis has been carried out within the framework of the WaterStrategyMan Project (*"Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions"*, Contract no. EVK1-CT-2001-00098), a project supported by the European Commission under the Fifth Framework Programme, and contributing to the implementation of the Key Action *Sustainable Management and Quality of Water within the Energy, Environment and Sustainable Development*.

Throughout the last century, water resources management has overcome most technical problems regarding water purification, storage and distribution. However, it is often hard to understand why some technologies are preferable to others or why they face either significant acceptance or rejection. Until recently, central and regional administration developed "master plans" for the management of water resources, which were usually a set of structural interventions in the water sector that did not take into account or even consider the importance of the different parties/citizens affected. This is mainly the case in arid and semi-arid environments, where shortfalls in water supply and consecutively water stress issues raise strong conflicts between management authorities, stakeholders and end-users.

A protocol is defined as a comprehensive set of measures for the regulation of human activities and the preservation of the environment. On the basis of Integrated Strategies, formulated in the course of the WaterStrategyMan project, this report aims to present an initial analysis of regional requirements for their implementation. These requirements are primarily classified in terms of institutional reforms, education and awareness campaigns, cost recovery issues and impact mitigation requirements.

The document is structured in 3 chapters: The first chapter provides an overview on the evolvement of protocols and protocol types. Chapter 2 presents protocols aimed at dealing with water deficiency and water stress issues. It briefly describes supply-oriented, demand-oriented and impact minimisation, and additionally analyses the aspect of protocol impact assessment. Finally, Chapter 3 presents, for each WSM Case Study, (a) the background in the formulation of water management policies, (b) a brief presentation of stakeholders and actors directly involved or influenced by the decision making process, (c) the final outcomes of the strategy formulation process, and (d) additional considerations regarding the implementation of these, aiming to define a framework for the determination of the enabling environment for their implementation. This analysis was undertaken for five regions, namely Paros island (Cyclades, Greece), Belice Basin (Sicily, Italy), the region of Tel Aviv (Israel), the region of Limassol (Cyprus), and Ribeiras do Algarve (Portugal).

The WaterStrategyMan Project partners have all been actively and directly involved in the development of this report: the National Technical University of Athens, the Ruhr-University Bochum, ProGEA S.r.l., the Office International de l'Eau, the Hebrew University of Jerusalem, the Water Development Department (Governmental Department – Cyprus), INSULA (International Scientific Council for Island Development), Aeoliki Ltd, and the Faculdade de Engenharia da Universidade do Porto. They are all gratefully acknowledged.

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Chapter 1 Evolvement of Protocols and Types

The interaction with a complex and fast changing environmental, economic and social reality incorporates nascent limitations. Such limitations are usually confronted by multiple alternative responses to the complex reality. However, these responses are not able to converge in a complete and coherent whole, unless certain assumptions for their interrelations are made. The basic premise upon which such interrelations are built consists of a complex system transformed by the development process. Thus, development is a process derived from and contributing to the ecological and socio-economic system. The long series of international conferences on water and development including Mar Del Plata, Rio de Janeiro, Dublin, The Hague, Kyoto, or Johannesburg are but only recent manifestations of the centrality of water, environment and development.

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 with each corresponding level of such a hierarchy. At the system components level, decisions are usually made primarily on the basis of assessment of component cost effectiveness with little attention given to the larger picture or to far-reaching secondary effects. The **protocols** required are, on the other hand, 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.

Yet on a national or international level general “protocols” for Integrated Water Resources Management or even more of environmental protection, have started to appear (e.g. Water Framework Directive, EU and the National Environmental Policy Act, U.S.). Overall more detailed “protocols”, such as conventions, treaties, bilateral agreements that delineate implementable action and monitoring performance techniques, are also part of the pertinent arsenal.

Protocol Types

Since the majority of systems neither are hierarchical nor linear, protocols have to include a variety of dimensions of responses to water deficiency, with emphasis on confronting such characteristics. Primarily and briefly, responses may be distinguished to “structural”, which include technical measures (i.e. dams, infrastructure, maintenance etc), and “non-structural” which represent administrative and/or regulatory measures (i.e. legal mandates, pricing etc.). Ideally, protocols should be a mixture of both categories, reflecting the area and time horizon of their implementation. Lately a progressive shift has been started towards cooperation, instead of conflict (conflict prevention, conflict management).

Another distinction is based on the differentiation between protocols including responses aiming at human use modification versus natural event modification. Additionally, any protocol of strategies in order to respond to a stress event in a natural system may be directed towards (Vlachos, E.C., 1991):

- modifying the cause,
- modifying the losses, and

- distributing the losses.

In this context human systems must incorporate some degree of reserves, flexibility and mobility as key traits to survival under conditions of water deficiency. The types of protocols with responses to water deficiency may be delineated among (Vlachos and Grigg, 1993; Karavitis, 1999):

- tactical,
- strategic.

Protocols incorporating tactical responses are made to a particular water deficiency situation at a particular time. Protocols including strategic responses suggest that there is recognition that water deficiencies are part of the climate regime and the societal evolution and will occur from time to time, and therefore, ways to mitigate the adverse impacts should be constantly part of the planning process (thus an integrated water resources management strategy must exist). Finally, ad hoc responses to water deficiency are essentially "spontaneous" crisis reactions based not on any long range policy and, thus, are considered members of a protocol.

Another interesting classification of water deficiency responses protocols is by differentiating along some dimensions or scales. Such are time, space, society, activity, perception, and technological level. The temporal dimension refers to the scale of the water deficiency event in terms of its duration. The spatial dimension is suggestive of the geographical scale of water deficiency effects and their relative location. The dimension of society reflects the continuum from individual to region, and manifests itself through different survival mechanisms. The activity scale includes the differences in economic system. The perceptual dimension differentiates cognition and behaviour in the face of the risk of water deficiency. Finally, technological development simply constitutes the capacity and organizational requirement levels as well as the specific techniques for responding to water deficiencies.

All in all, such differentiations may be expanded by reflecting on the broad mechanisms of human adjustment to the natural environment. These include:

(a) **Engineering mechanisms**, such as technological innovations and their applications,

(b) **Symbolic mechanisms**, which reflect the concern with culture and it constitutes norms and roles,

(c) **Regulatory mechanisms**, which define public policy and governance, and

(d) **Distributional mechanisms**, which specify the movement of people, activities and resources.

Various ways of protocols coping with water deficiency modes may be grouped under absorption, acceptance, reduction and change, and separated by three recognizable threshold levels -awareness, action and intolerance.

The first mode of coping with a hazard is **"loss absorption"**, where society absorbs the impact of environmental calamities and remains largely unaware it is doing so. In the second mode of coping, **"loss acceptance"** is reached through the threshold of awareness. In this mode a society arranges to bear the loss, often by sharing it with a wider group than those directly affected in the case of water deficiency, by spreading the loss among a variety of groups both rural and urban. Loss acceptance yields to **"loss reduction"** when a second threshold is crossed, namely the one resulting from determination to take more positive actions to reduce loss (intolerance). This threshold divides also loss reduction from the mode of 'radical change' in either location or resource use. This final mode of coping occurs when the loss is seen as no longer tolerable.

Such an important differentiation of modes of coping makes it possible to differentiate also between absorption, acceptance, reduction, or evasion of hazard loss as part of a total effort required to confront environmental vagaries. Yet, each category does not stand by itself but most often it appears as part of protocols that are a mix of responses to hazards as affected by the following factors:

(1) The presence of water deficiencies, depending on the frequency, duration, area extent, speed of onset, and spatial dispersion;

(2) The localized experience with hazard and the success of adjustment;

(3) The intensity of resource use, including higher capital labor investment per unit area, etc.; and

(4) The level of material wealth attained, implying that the presence of great material wealth increases the awareness threshold as contrasted, e.g. to conditions of poverty.

Considering the types of water deficiency protocols, a coherent approach may distinguished among four different policies which are not mutually exclusive, namely:

1. Disaster relief;
2. Control of natural events;
3. Comprehensive reduction of damage potential; and
4. Combined multi-hazard management.

However, risks from water deficiency are a consequence of the character of both the physical and social systems. Effects can be lessened by adoption and implementation of policies to mitigate the risk and negative consequences of water deficiency. Such a system is dynamic since changes in human use patterns and activities, as well as in the physical environment, alter levels of risks.

Such protocol process has been described in various ways, either as a defensive step, or as a "hierarchy of flexibility restoring mechanisms", and involves a set of graduated and temporarily ordered responses with escalation and de-escalation from level to level. It is important then, to distinguish between centralization and decentralization as alternative organization schemes. The last affords a high degree of individual and societal flexibility, while the first emphasizes concentration and loss of flexibility through a diminished ability to cope with local problems.

In the context of such concerns evolves the larger perspective of socio-cultural aspects of present and future water management strategies. Socio-cultural aspects in water resources should relate to the basic socio-economic activities of any region through the following water uses: (a) food production; (b) urban water demands; (c) industrial water demands; (d) municipal waste disposal; (e) power generation; (f) recreation and wildlife demands; (g) environmental enhancement, and (e) navigation needs. Hence, both technological and social responses protocols to such concerns, as well as legal mechanisms for carrying out the pertinent management strategies, would tend to fall under four major categories:

1. Strong incentives for efficient or new uses, including economic benefits, redefinition of the doctrine of beneficial use, etc;
2. Structural changes, such as new organizational arrangements, creation of new water agencies, or general capacity building etc;
3. Regulatory counter-incentives, enforcement and pricing policies; and
4. Changes in "water intensive" lifestyles and cultural practices.

In this regard, the responses/protocols conceived comprise of four types of water deficiency control measures:

1. **Supply measures**, intended to increase available water quantities during water deficiency;
2. Measures aimed at **decreasing water demands** through various conservation techniques and use limitations;
3. Measures needed to **mitigate impacts** by reducing losses; and overall
4. Methods **able to produce strategies** for management through mixes of water deficiency control measures seeking appropriate solutions in combating water deficiencies.

The general ability of decision makers and societies to engage in proactive resource management strategies has been primarily due to prior long-range public policy decisions, especially with regard to technological breakthroughs, reservoir construction, soil conservation and erosion prevention problems, water deficiency resistant plant research, and generally the creation of programs and policies with adequate resource development focus.

Thus, the need for “improved institutional arrangements” and capacity building, the development of which should be done along with the technological advances, is emerging. Then a necessity arises on how to close the gap between the rhetoric of some cogent intervention scheme and the reality of making social and political adjustments based on an applied protocol in the face of water deficiency. It is not only the inherent difficulty in developing alternative institutional mechanisms, but also the prevailing attitude of simply responding to water deficiencies through a crisis management approach (which implies a short range, piecemeal, segmented responses) versus a far-reaching and systematic risk management that requires a more complicated social options emphasis and alternative schemes of organization and administration.

The above imply that there is a need to develop sensitivity to a variety of conditions and responses rather than to simply promote an ad-hoc scheme that tends to work under both time and resource constraints. Indeed, the fundamental question that is raised is not what remedial action can be taken, but whether particular institutions are capable of handling on a longer horizon the changing circumstances of both the social and physical environments.

Chapter 2 Water Deficiency Coping Protocols

Introduction

Protocols applied to mitigation of water deficiency impacts may incorporate two types of measures: proactive and reactive. The **proactive measures** are defined as all measures, conceived or prepared by the conscious and systematic actions, which may help in the alleviation of water deficiency consequences. The **reactive measures** are defined as those measures that are basically improvised once a water deficiency is set on and the visible impacts are already underway. These reactive measures include also the alternative of doing nothing, usually applied under the conditions that individuals or organisations have enough resiliencies to sustain impacts and a post water deficiency recovery.

Five terms: coping with water deficiency, water deficiency control, water deficiency alleviation, water deficiency mitigation, and water deficiency combating measures and strategies, are considered as synonyms in this text.

The difference between the proactive and reactive measures is mainly in the approach: contingency planning versus improvisation of various ad hoc measures. It may be further important to stress that the decrease of various water deficiency impacts in proactive measures should sufficiently exceed their cost in comparison with the effects of implementing reactive measures.

The first phase of the proactive strategy, the pre-water deficiency preparation of various measures, is basically intended to make water users more resistant to water shortage and deficit in comparison with the ongoing practices and conceptions. It should have these characteristics: (a) all experiences of previous water deficiency impacts, taking into account the technological, economic and social contexts of each past water deficiency, are well investigated and the appropriate knowledge on future water deficiency impacts identified and applied, (b) extrapolation of technological, economic and social conditions into the immediate future that has a reasonable probability of experiencing a water deficiency, has been properly made, and (c) impacts of available water deficiency-coping technologies, in the form of the water deficiency losses and the cost of implementing various measures under these technologies are well assessed and optimized. To properly implement this first phase of proactive strategy, the case studies of water deficiency (types, impacts, active measures undertaken, reactive measures, etc.) become very important as the information sources. Each past water deficiency case becomes then a point in the sample of historical water deficiency occurrences.

The second phase of the proactive strategy, namely the measures undertaken during the ongoing water deficiencies, must, by necessity, relate to changes in water supply and water demand that would, in one way or another, decrease the water deficiency impacts in an optimal way (benefit/cost ratio greater than one). Furthermore, these proactive measures may be applied to decrease impacts and losses beyond the effects of the measures to increase water supply and decrease water demand during water deficiencies.

The third phase of the proactive strategy measures, namely the measures undertaken in the post-water deficiency period, basically contains the well-planned activities intended to minimize the spread of water deficiency impacts beyond the unavoidable geographic areas and their economic and social sectors involved.

The reactive measures are related only to time phases of ongoing water deficiency and post water deficiency periods. Water deficiency protocols are composed in each particular case of a mix of water deficiency mitigation measures, which are in turn selected out of a relatively large exhaustive set of various types of measures. Measures are of physical/technological/structural and non-structural/technological nature. The non-structural measures consist of economic, social, institutional, political and other measures, either intended to decrease impacts or to distribute losses equitably, whatever the concept of equity in incurred losses may prevail in an impacted region or society.

Water deficiency protocols of responses are classified in three groups: (1) Supply-oriented, (2) Demand-oriented, and (3) Minimization of impacts and losses. Any decrease of supply requires a decrease in water use, meaning the consumption is forced to match the supply. When this physically imposed adjustment presents large stress on water users, measures for water supply augmentation, use of flexibility for demand reduction, and optimal minimization of impact and losses remain to be applied.

On the supply side, measures are divided in:

1. Better use of existing supplies,
2. Development of new supplies, and
3. Use of complex or unconventional approaches for increasing supplies.

The following text provides a brief description of each measure, with the state-of-the-art of its applicability. On the demand side, the measures are divided in

1. Active, consisting mainly of legal constraints, public pressures, economic incentives for reduction of water use,
2. Reactive, with the eventual water recycling, the production adjustment, etc., and
3. Impact analysis of demand-oriented measures that increase the total demand reduction.

On the impact-minimization side, water deficiency mitigation measures are divided in:

1. Anticipation of water deficiencies, with forecast and warning, and
2. Spread of risks and losses (such as insurance, self-protection, disaster aid and various adjustment); they represent the major measures that permit an organized approach to required matching of supply and demand through acceptable impacts.

The low-flow impact mitigation measures are based on risks involved due to flow duration, level, deficit, minimal volume for given duration, etc. Basic low-flow mitigation measures include (1) anticipated adjustments of users to impacts by proper planning, design, construction, operation and maintenance; and (2) low-flow augmentation in case of an excessive pressure to use water or maintain the existing flows and their water quality.

Water deficiency-coping protocols contain all those actions that lead to mitigation of water deficiency impacts on water users and through them on local or regional economy. As actions defer widely, and as water users are of a variety of types, the best water deficiency-coping structural and non-structural measures vary significantly from case to case. This activity represents a use of a mix of measures out of an exhaustive set of all types of water deficiency mitigation measures.

Water deficiency mitigation measures are defined as single, specific actions of variety of types, that in their mixes or aggregates may represent the suitable water deficiency-coping **STRATEGY** of appropriate economic and social water deficiency control options.

The following descriptive scheme classifies all water deficiency mitigation protocols in three basic areas:

1. **Supply-oriented measures**, that are intended to augment supply during water deficiencies in the supply-minus-demand economic water deficiency equation;

2. **Demand-oriented measures**, that are intended to decrease demand during water deficiencies in the suply-minus-demand economic water deficiency equation; and
3. **Impact-minimization measures**, that are basically related to water users, water user environments, and various economic, social and administrative factors, which can minimize impacts of any new or adjusted supply-minus-demand equation in one way or another during severe water deficiencies.

Its basic usefulness is in the potential of providing an exhaustive set of water deficiency-coping measures which should be considered both in proactive and reactive strategies.

Supply-oriented Protocols

Better use of existing supplies

The use of existing water supplies during water deficiencies has two basic aspects. First, the trade-off of present and future benefits at the expense of future benefits with the high risks of future deficits. The inherent reluctance by users to accept a proper balance between the present and future benefits may significantly increase the future losses due to water deficiencies. The users' rationale often advanced is that present benefits are certain while the future losses are subject to uncertainties. However, on the long run these uncertainties will become certainties. Second, the relationships between losses and intensities of water deficit most often are non-linear so that the excess of present benefits do not compensate for the future losses (an example is an intense deficit that may destroy crops completely).

Therefore, the operation of storage capacities during water deficiencies must take into account: (1) **constraints**, involving the penalties associated with water release rules, and (2) **economic trade-off**, involving the present and future benefits as well as related penalties. These problems have been already shown in recent water deficiencies to be crucial in decisions on water deficiency mitigation. The basic mitigation measures that may be incorporated into protocols with a better use of existing water supplies are as follows. Overall they have been extensively demarcated in Guidelines for Integrated Water Resources Management (WaterStrategyMan project, 2005), however not in relation with their impacts as implementable protocols of actions.

Use of surface water storage

This measure in water deficiency mitigation is as old as the first reservoirs built to supply water in dry seasons and in dry years, regardless of purposes for which water storage was created. The basic problem with such reservoirs is that chances of mitigating water deficiencies effectively decrease as the ratio between the average beneficial water use and the average river flow increases. For the same risk of losses due to deficits during water deficiencies, the needed storage capacity increases rapidly and non-linearly as this ratio increases toward one. In some cases, a firm storage capacity of reservoirs is retained as ultimate reserve for large water deficiencies. In other cases, penalty functions are applied whenever the reservoir falls below certain level, with marginal penalties increasing as the level falls more and more below that prescribed level. All of these methods, including various reservoir operational rules, are intended to search for an optimal trade-off between the present and future benefits. The fact that the risks of water deficiency losses increase with the increase of the percent of total water budget utilised, must play an important role as the allocations of waters in a river basin reach to their maximal values.

Use of subsurface water storage

Use of subsurface water storage has significantly increased in water deficiency alleviation with time. This overdrawing is a consequence of policy of getting maximum present benefits, with a rapid depreciation of investment. The economic limitations in pumping water for higher head differences has become in some ways a controlling factor in this overdrawing. The second aspect in using the groundwater storage as water deficiency mitigation measure is the improved technology of induced natural or artificial recharge of groundwater aquifers by surplus surface waters and irrigational waters. The third aspect is the development of conjunctive water use technology, representing a proper planning of water storage, transfer, recharge, withdrawal and joint use of surface, subsurface and effluent waters. The principles and approaches applied to management in water deficiencies of surface storage can be applied to management of subsurface storage as the water deficiency mitigation measure.

Interbasin and within-basin water transfer and exchange

This is likely the second most important water deficiency mitigation measure that is used in protocols on the water supply side, ranking immediately after the use of water storage capacities. Often, the transfer of surplus water in time via storage to meet water deficiency conditions has preference over the water transfer in space through water conveyance lines. Apart from investments that are specific to both time and space water transfers, the transfer in space always faces the problems of how much water is available and under what conditions. The water deficiency mitigation potentials of uni-directional water transfer and its bi-directional exchange are constrained by two basic factors: (a) whether water is available for transfer or exchange at the times of water deficiencies, and (b) whether sufficient conveyance capacities are available for transfer or exchange, especially in case of large water deficiencies and transfers on long distances. Several trade-offs with optimizations are involved in water transfer, by trading off the present and future benefits, under given risks of future water deficiency losses.

Improving supplies by water conservation

This is a feasible but often uncertain water deficiency mitigation measure. The search for trade-offs between benefits of conservation and the cost of doing it is important. Such conservation includes decrease of losses along the conveyance structures (lined instead of unlined canals or channels, unlined channels made impervious by using sealing materials), management of vegetation for lesser water consumption, soil conservation for increased infiltration and water yield, decrease of evaporation by the general runoff management, irrigational water conservation practices, and similar measures. Most of these approaches to water conservation may be classified as extensive measures, because their implementations require relatively small work per units of length, area or space. However, the total length, area or space in these activities is large, with the cost nearly proportional to them. Rarely the economics of scale works effectively in order to decrease the unit costs. These widely spread activities make measures extensive, often only at the margins of acceptable benefit-cost ratios. However, a combination of water conservation with the other potential purposes or benefits of these measures may still result in acceptable economic solutions.

Development of new supplies in water deficiencies

Any construction of new surface reservoirs, further or new development of groundwater, new conveyance structures, and any new conservation measure, as they are defined and outlined above on better use of existing water supplies, belong to existing supplies as soon as these measures are completed. Here, in turn, new supplies are conceived as measures that are not used in non-water deficiency periods but may be used or can play a role in water deficiency mitigation.

Emergency use of fixed-level lakes and reservoirs

This use represents an attractive mitigation measure in water deficiency emergencies. Fixed levels are imposed by various water users of these bodies of water, particularly for recreation, fish and wildlife habitats, navigation and uses that require relatively well-maintained levels of natural lakes, reservoirs and ponds. During the hard-pressed water deficiency deficits, a general trade-off of benefits may show significant benefits in using these bodies of water as storage reservoirs exceptionally at these rare occasions regardless of the negative effects on their basic purposes of use. These water deficiency mitigation measures can greatly surpass benefits that are coming from the fixed-level water uses.

Desalination

Desalination may serve as a new water supply in water deficiencies, basically in two ways: (1) by using continuously the full capacity of existing saline or brackish water desalination in severe water deficiencies, with the full capacity in non-water deficiency periods only partially or occasionally used; and (2) by having contingency, mobile equipment for saline or brackish water conversion in critical water deficiencies or other emergency cases. For this equipment to serve for contingencies in some other emergency purposes, besides the water deficiency mitigation, will likely be a prerequisite for its justification as the contingency for water deficiencies also.

Weather modification

Weather modification is considered as an alternative in water deficiency mitigation, because it may be conceived and organized as an ad hoc action. The basic dilemma in the application of this measure is whether the meteorological conditions that are responsible for water deficiencies are or are not conducive for a successful weather modification.

Use of fossil water

This measure can represent a water deficiency mitigation under the following conditions: (i) fossil water is economically accessible, (ii) it is not highly loaded by minerals, and (iii) there is the possibility to use the water withdrawal arrangement to eventually replace fossil water in times of exceptional regional water surplus.

Alternatives of complex water supply enhancement in water deficiencies

Water resources systems are becoming larger and more complex with time in many countries of the world. Their objectives change, needs expand, criteria for quality of water continuously evolve, and social and environmental constraints become more versatile and complex. With these water deficiency mitigation by necessity has become complex in this supply-oriented group of water deficiency-coping measures. The complexity of problems expected to be experienced in future water deficiencies will thus also increase. Some of the new complex water supply potentials are presented as water deficiency-coping measures.

Connection and extension of large water supply grids

Integration of existing water conveyance grids (networks) represents a potential and effective water deficiency mitigation measure, regardless of various complexities of connection between large grids, and extension of large grids to incorporate the small adjacent grids. The larger an area covered by a water supply network, or the area of interconnected networks, the smaller is the probability of a water deficiency to cover the entire area. This enables the shift of water from a surplus sub-area to a deficit sub-area, similar to the shift of surplus electric power in energy deficits. This measure has become attractive in water supply of large, adjacent, metropolitan urban and suburban areas, as well as in very large and geographically widespread industrial regions. Trade of surpluses in normal water years makes the water transfers by shifts in complex network also feasible as a water deficiency-coping measure.

Conjunctive use of all sources of water

This measure is a way of mitigating water deficiency impacts regardless of its relatively complex aspects. The solutions of water supply problems in water deficiencies by spreading shortages in time (by water storage) and in space (by water conveyance and transfer) can be supplemented by dividing water deficiency deficits in an optimal manner among various sources of water (surface, subsurface, effluent, saline, brackish and other sources of water).

Snow and ice

The management of accumulated snow and ice is often a potential for coping with water deficiency deficits. The snow and ice management for water deficiency purposes is already made by nature. When accumulated snow and ice are carried from year to year, the ratio between the river runoff of wet and dry years are smaller than the case as in areas without such an accumulation. Dry seasons and dry years have more heat for melting of the accumulated snow and ice than wet seasons and wet years. To further stimulate this natural process, two actions may be feasible: implementing the technology of channelling wind blown snow into depressions of the terrain, and spraying snow and ice by materials that retard or induce their melting. Though these measures have been attempted with various degrees of success, circumstances should be specific to use economically either of the two or both of these actions.

Demand-oriented protocols

The water deficiency mitigation measures -incorporated in protocols- on the demand side of supply-minus-demand economic water deficiency equation have as the basic objective to trim the water use of the least unit impact, provided the legal, economic and consent conditions permit it. This assumes flexibility in water demand which can be decreased during water deficiencies without significant impacts regardless of resulting inconveniences. There is a plethora of experiences supporting the premise that many water users can withstand a stress of reduced water consumption or use during severe water deficiencies.

The demand-oriented water deficiency mitigation measures may be divided in three basic groups): (1) active measures; (2) reactive measures and (3) impact analysis of demand-oriented measures. Demand-oriented water deficiency mitigation measures are imposed, in the final count, by any inadequate water supply. The intentionally imposed water-use restrictive measures are basically intended to serve water users most effectively regardless of reduced supplies. In one way or another, lack of physical supplies always limits demand, so that supply always matches the reduced demand. Water pricing is often the most effective market mechanism of achieving this supply-demand balance.

The joint application of active and reactive demand reductions requires a relaxation of environmental protection rules and a reduction in energy use. These relaxations and reductions represent indirect water deficiency mitigation measures. They reinforce the acceptance of coercion and inducement in cutting water demand, by relaxing temporarily the environmental standards and decreasing the energy uses in water deficiencies.

Active measures of demand reduction

The active measures may be divided in those which are implemented by pressure (coercion) and in those which are produced by inducements of various kinds (incentives) in order to directly reduce the demand pressure on decreased water supply of the system. When important historic water deficiencies are analyzed, these active measures are shown to be present in the aggregate response of water users to water deficiency stresses.

Legal restriction and public pressure

This type of water deficiency mitigation measures is basically achieved by coercion, either direct or indirect. It includes rationing, legal limitation with sanctions, and economic, social and political pressure including that of public opinion. Basic condition for implementation of any coercion type of demand decrease and control is the availability of an appropriate institutional system. The proper authority and responsibility, used under prescribed or discretionary conditions, are necessary. This system may either exist and is activated during water deficiency conditions, or it may be created ad hoc. The use of this institutional system must be based on adequate information of relative potential impact of any restrictive measure in order to operate it efficiently. Authority must be available to eventually impose legal limitations to existing water rights, with a legally-based access to information for evaluating the relative consequences and related priorities in water restrictions, the potential of land use control as means in minimizing water use during water deficiencies, etc. This measure is a powerful tool as a part of a protocol whenever the will exists to implement it.

Economic incentives for reduced water use

This water deficiency mitigation measure is exclusively based on economic incentives not to use water beyond a necessary minimum, or on penalties in the case of exceedence of an agreed upon allocated water supply during the reduction periods. Pricing is a proper economic inducement whenever feasible, either by an increase of water price in function of accumulated deficit in water supply or by a decrease of price in case of an abundant water supply. This measure is a function of factors that influence the short-term price-demand relationship. The larger variation of demand in function of the price, the more flexible is a water user for water deficiency mitigation through demand decrease. This flexibility is affected by the degree of obsolescence of water use technology, investment bonding strength, general economic reserve, etc. The best way of testing this flexibility is by studying how recent water deficiencies affected the price-demand relationship of water users.

Reactive measures of demand reduction

Reactive measures in demand reduction in water deficiencies may be best qualified as consequences of intentional or unintentional active water deficiency mitigation measures, or simply they are imposed by physically forcing demand to match reduced supply.

User recycling systems

Portable water recycling equipment of low investment can be a temporary water deficiency mitigation measure, especially in dealing with the peak water demand. It can be combined with separation of water uses according to their tolerance for water quality. As an example, off-the-shelf, membrane-type, desalting units may be used for treating return flows from irrigation, already well-treated effluent, brackish or other waters. The other types of recycling water maybe temporarily implemented just to fit the water quality tolerance of the same or next water user, in a sequence of water users along the river. Well-established technologies with contingency equipment can be used for all these types of recycling.

User production adjustments

These water deficiency mitigation reactive measures result from capacities of many water users to adjust either production or water use quantities in order to decrease water demand in water deficiencies. In agriculture, this reduction is made by changes in crops and cropping patterns and practices. Large water users in industry, energy and agriculture may apply the trade-off relationships between products and water (a decrease in water means a decrease in pro. The production functions depend on resource (water, energy, fertilizer, etc.), price of resource input and product output, technology, constraints in discharge of wastes, resource recovery and its re-use, transfer of water rights, trade-off between resource inputs, etc. The adjustments are often very flexible, especially in water use in households (reducing it up to 40-50% of the normal water deliveries). These measures are likely the most important reserve left for mitigation of impacts of most severe water deficiencies, when the lack of sufficient water supplies force users to adjust their production and water consumption use to the upper limits of economic and social tolerances.

Impacts of demand-oriented measures

A synthesis of impacts of active and reactive water deficiency mitigation measures of reducing demands helps produce the information leading to the objective of making the water users less susceptible to water shortage. Examples are restriction of vegetation on lawns, the stimulation of cultivation of recognized water deficiency hardy species (trees, shrubs, grass), the restriction of industries and agriculture practices that have small flexibility in water use, etc.

Total demand reduction potential

An assessment of the total potential of water savings with various restrictions and their cost-effectiveness makes demand-oriented water deficiency mitigation measures more effective, especially in relationships of non-consumptive to consumptive water uses. In some cases, water use reductions may result in the intensification of adverse water deficiency effects downstream. Efficient water conservation in non-water deficiency periods represents a diminished flexibility of water users in water deficiencies. Trade-offs are important aspects of the joint use of active and reactive water deficiency mitigation measures.

Permanent water deficiency-imposed reductions and future conditions

The flexibility of water users to adjust for short periods of times must not be conceived as a permanent potential for demand cuts. The active and reactive demand reduction measures may lose their effectiveness if prolonged beyond a tolerance period of time. This joint use of demand reduction by active and reactive measures is especially sensitive in agriculture.

Impact Minimisation Protocols

It is logical to start cutting losses once supply cannot be economically increased and demand reductions become least manageable. To reduce impacts, three types of measures seem feasible: (a) anticipation of water deficiencies when feasible with timely preparations to meet them; (b) introduction of measures that spread risks and losses over a large number of individuals and groups; and (c) reduction of direct or indirect losses.

Anticipation of water deficiencies

Water deficiency can be anticipated by one of the two methods: (1) forecast of water deficiencies by the classical approaches of looking into the future; and (2) analysis of data by finding how often and how long water deficiencies occurred and lasted in the past. It is difficult to forecast weather conditions beyond an outlook for a couple of days or weeks to come. However, the question of worsening of an ongoing water deficiency can be assessed in some cases with warning. If reservoirs serve as water deficiency mitigation measures, the state of remaining water reserve may be estimated. Semi-arid regions are more prone to dry years than humid regions. The efforts for anticipation of water deficiencies are common in arid region planning and operation of water resources.

Water deficiency forecast and warning

Two basic questions arise in evaluating benefits of impact minimization by water deficiency forecast and warning: (a) whether water deficiencies are feasible to forecast, and in cases claimed that they are, whether forecast is significant in the sense that a larger portion of forthcoming water supply is covered by forecast; and (b) if both forecast and warning are issued, whether credibility in forecast and reactions by interested groups are such that a decrease in impacts would result. Both questions do not have the reliable answers at present.

Measures of implementing forecast and warning

Attitudes toward water deficiencies differ from reactions to natural disasters of the sudden type (such as earthquakes, volcano eruptions, floods, landslides, avalanches, fires, tornados, etc.). Usually, no urgency is conceived in water deficiency. Sometimes, even when one becomes aware of it, it may be too late for any preventive or pre-water deficiency remedial action. Capacity building may be considered as the water deficiency-mitigation measure of a special kind. To store water and to start conservation by water demand reductions needs time. The lead time in water deficiency warning is usually so short that the pre-water deficiency supply-demand aspects of mitigation are often of small effects in the overall operation of the water system.

Spread of risks and losses

The spread of risks and losses in disasters are as old as any organized society. The larger the spread, the more acceptable are risks and losses.

Water deficiency insurance

Feasibility of water deficiency insurance depends upon the quantification of risk in a system characterized by instability and not subject to accurate prediction. Economic water deficiency insurance was not feasible in the past for two reasons: exceptional water deficiencies may be so damaging that it would require a build-up of huge monetary reserves, and without these reserves even the large insurance organizations could become insolvent. Often it is difficult to precisely define risks and damages. It was a logical outcome for public institutions, especially the governments or regional authorities, to become involved with specific types of insurance, such as crop failures. Water deficiency insurance schemes are in force in some countries, but they differ in form and are functions of political, socio-economic and cultural systems.

Individual protection

Savings in forms of money, grain, other crop storage, game and cattle reserves, by individual farmers or smaller and larger groups, represent the forms of self-protection against devastating water deficiency losses. Diversification of activities is another way for individuals and groups to spread risks and losses.

Disaster aid

Any disaster of specific impacts, particularly those of non-insurability type, attracts relieves and rehabilitation program by social and political necessities. This is also a water deficiency mitigation measure of a proper spreading of risks and losses on local, regional, national, multinational or even international levels. These programs take various forms, such as credits, grants, mortgage aid, seed and livestock aid, tax adjustments, human subsistence aid, technical assistance, and similar disaster aids. Among all these alternatives, the problem resides with the proper selection of such a mix of disaster aids that fit the general and specific conditions of each individual water deficiency and each area covered by it.

Resistant species

Plants differently react to water deficiencies. Many species are considered water deficiency resistant. A mixture of common and resistant crop species may also represent a spread of losses in water deficiencies. The overall knowledge on all water deficiency resistant species provides useful information in implementing this measure. Resistance of species is function of physiologic mechanisms, genetic variability, breeding and other factors. Arid regions are sources of some of water deficiency resistance plants.

Agricultural adjustments

Optimal scheduling of irrigation could improve or maintain crop yields in water deficiencies. It is a complex function of expected water supplies and impact of soil moisture deficit during critical crop growth. Minimum tillage practice, regardless of pest and disease hazards, may save water in water deficiencies and serve as water deficiency mitigation. Water conservation practices in dry farming areas, as well as in irrigational agriculture, belong also to water deficiency mitigation measures both as the agricultural adjustment and as the spread of losses.

Institutional considerations and indirect economic losses

At the same time, the previous discussion on estimating the economic loss directly caused by water deficiency is founded on application of production theory to a water user operating in a perfectly functioning market system. Water resources economists have long recognized that water projects also have indirect and secondary effects. Indirect effects occur through technological external impacts as illustrated by dust conditions, aesthetic deterioration, long term groundwater level declines or salinization, etc. Secondary effects occur through pecuniary external impacts or shock waves sent through the economy as the direct losses (say to agriculture) hurt other industrial sectors (say those selling to farmers or buying farm product). The indirect impacts are best estimated by inventory, individual estimation, and summing.

Secondary impacts are best estimated by an input-output model, provided that one is available with a fine enough geographical grid to be responsive to the direct loss estimates.

Assessment of Protocol Impacts

The principal reason for estimating water deficiency impacts is for assessing protocols to mitigate water deficiency losses. These also include short term or emergency measures taken during the water deficiency, facilities designed to enhance water supplies in the future, and financial relief for the afflicted.

The needed information on water deficiency impact depends on the proposal being considered. The policy maker might for example be interested in comparing: (1) water resources development projects, (2) policies for operating a large water project or regulating groundwater withdrawals, (3) management strategies for water delivery systems, irrigation or culinary, during water deficiency periods, or (4) policies on declaring a water deficiency disaster and providing financial relief. He may want only a rough estimate or feel need for precise numbers. He may want to know the immediate impact of a water deficiency event or be looking at the long run effects of a water deficiency-vulnerable situation on the economy.

The short-term impacts of water deficiency are generally well known, although not adequately understood. However, few disagree that there is an overall environmental stress. Dryland agriculture is often the first to experience significant effects in the form of reduced yield and dust blowing. Irrigated agriculture usually follows, with low flow streams also affecting other water uses such as industrial uses (e.g. curtailment of the use of cooling water), recreation, domestic use, etc. Other less well recognized short and long term direct and indirect effects become also apparent, such as losses in the recreational industry (e.g. because of diminished snowpack), increased water quality degradation as dilution is diminished, far-reaching economic dislocation and upheaval stressing surrounding environments, losses of shallow-rooted grasses and their replacement with deep-rooted shrubs, reductions in herd sizes, increased fire threats, etc.

Given the practical difficulties of instituting marginal cost pricing, water consumption in periods of acute scarcity can be placed within the larger context of a “commons dilemma”: short-run individual interests conflict with long-run public welfare so that, ultimately, no one's self-interest is really served. To take a recent example, the prospect of continued overdrafting of an aquifer has apparently prompted individual farmers to extract the maximum amount of water their crops can effectively utilize. From the perspective of each individual farmer, this is the best way to ensure the greatest short-run profits. With water supplies diminishing in the near future, farmers will eventually be forced to accept smaller yields from water-intensive crops and/or smaller profits from crops requiring less irrigation. Therefore, conservation programs seek to alter individual perceptions so that consumers understand their place in the larger picture. In microeconomic terms, preferences (“tastes”) are modified, and the demand curve is shifted.

Conservation protocols are organized under three broad headings, speaking to the organizational and implementation process involved: voluntary conservation by individual consumers; institutional conservation by public agencies; and proscriptive conservation imposed by statute, ordinance, or regulation.

The following general conclusions that implicitly guided many local conservation efforts and may be used to design more effective conservation programs in the future:

1. Conservation programs will be more effective when consumers can be convinced that a genuine shortage exists and that it constitutes a problem for a group(s) with which consumers identify.
2. Conservation programs will be more effective when appeals are made to moral principles, stressing the need to make a “fair” contribution to group welfare.
3. Conservation programs will be more effective when consumers are convinced that their individual efforts can make a difference for collective welfare.
4. Conservation programs will be more effective when consumers can be convinced that the individual costs and inconveniences stemming from their conservation efforts will not be great (assuming this is true).
5. Conservation programs will be more effective when consumers are convinced that all members of the relevant group(s) are also making sincere efforts to conserve.

All of these findings can be integrated into local conservation protocols. For example, one could imagine enclosing in consumer bills literature asking consumers to do their fair share and stressing the ease with which conservation activities can be implemented, and also enclosing a community "scorecard" reporting aggregate water savings for the previous month.

One of the critical conclusions of the relevant micro –economic theory is that water is significantly under-priced. This derives in part from the fact that, in the long run, water production is subject to increasing costs, and therefore the marginal cost curve is typically above the average cost curve. Since water districts generally base their prices on average costs, water becomes too cheap. In addition, water supply systems are often heavily subsidized by European and National funds that are not reflected in consumer bills. Finally, a host of externalities are routinely neglected, regardless of whether average or marginal costs are considered.

Chapter 3 Regional Recommendations and Protocols

Introduction

Integrated Water Resources Management means decision-making on development and management of water resources for various uses, taking into account the needs and desires of different users and stakeholders (Van Hofwegen and Jaspers, 1999). IWRM focuses at interests in use, control or preservation of water systems, and their sustainability. To pursue IWRM two situations need to be assessed. The first is the context in which policy is pursued, formulated and the constraints that such a policy imposes. This is directly controlled by actors, at either national or regional level, whose actions are shaped by the environment, whether natural or manufactured and by rules, imposed either by the legal and regulatory framework or by the historical trends and perceptions in decision-making. The second is the level at which actions and decision making occurs and, by extension, where integration occurs.

Therefore, 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 (World Bank, 2002). 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.

Towards this end, the Global Water Partnership (GWP) Technical Committee has proposed a simple framework as the starting point for IWRM, illustrated in Figure 1. This framework pinpoints the need for concurrent development of practical management instruments, enabling environment and appropriate institutional roles. The enabling environment comprises national, provincial, and local policies, and legislation. These constitute the "rules of the game" which allow all stakeholders to play their respective roles. These "rules" should promote both "top-down" and "bottom-up" participation of all stakeholders from the national level down to the village or municipality, or from the level of a catchment or watershed up to the river basin or river basin district level.

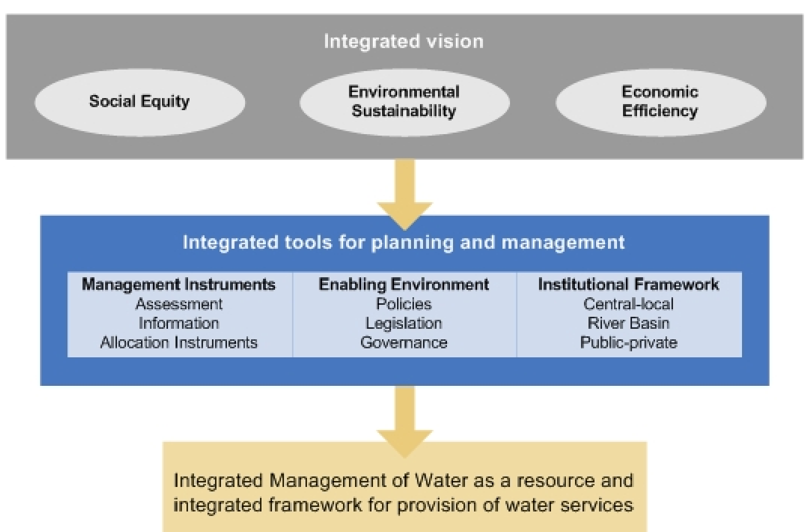

Figure 1 Framework for moving towards IWRM

Consequently, a key to the actual implementation of improved water management strategies is the identification of the framework in which current policies are formulated. In this context, and for each region examined, this chapter presents:

- An overview of each region, in terms of economic development, trends, and background of water management practices;
- The analysis of present and emerging policies, as these are formulated in the current context of decision-making;
- The major stakeholders and actors involved in decision-making on a local 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 potential framework for the definition of protocols for their implementation.

Regional analyses are presented for 6 regions facing water deficiency, namely, Paros Island, Greece, Belice Basin, Italy, Tel Aviv Region, Israel, Limassol Region, Cyprus, and Ribeiras do Algarve, Portugal. These regions constitute the case studies of the WaterStrategyMan project, selected out of a total of 15 regions on the basis of the following criteria:

- The existence of natural aridity,
- The existence of water shortages on a permanent or seasonal basis due to natural or anthropogenic reasons, or the recurrence of drought and/or flood cycles,
- The insufficiency of water resources management efforts in the areas,
- The lack of proper administrative or institutional framework for the effective water resources management,
- The existence of socioeconomic conditions affecting the management of water resources.

For each Case Study two alternative strategies were formulated, evaluated, and analysed in terms of additional considerations:

- The first Strategy, **Strategy 1**, involves the use of options reflecting the Business-as-usual approach, using instruments either already in use or currently emerging in the area, that are already acceptable to the local population. The core of the strategy is the application of the traditionally used structural interventions otherwise known as “hard” measures – dams, desalination, network improvements – enhancements, groundwater exploitation, etc.
- The second Strategy, **Strategy 2**, involves a combination of “soft” and “hard” measures (Gleick, 2003) into a more integrated approach, aimed at promoting efficiency (conservation, changes in irrigation methods – crops, industrial recycling and reuse, regulation through pricing and quotas). In this context, the traditional application of “hard” approaches is complementary, in order to achieve targets where soft measures are insufficient.

Each of the regions presented in this document forms a specific paradigm in terms of consolidating water management responses and policies aimed at coping with water deficiency. In that way, 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.

Paros Island, Greece

Background of water management practices and emerging policies

Overview of the region

The island of Paros is one of the most popular tourist destinations in the Cycladic Complex. During the summer months, the seasonal population is almost three times greater than the permanent population (from 10,000 to 30,000 or 35,000). An interesting fact is also that during the winter months only 50% of the permanent registered population lives on the island.

The development of tourism and the consequent prosperity of the island began slowly in the early 1960s, after many years of decadence. Since 1950 the local inhabitants were mainly farmers and fishermen. Between 1950 and 1965 there was a large emigration trend and a great population decrease. In 1970s a reverse to this emigration trend took place due to tourism that grew rapidly during the 1980s, bringing about changes in the traditional way of living. Unfortunately this development took place without planning and control, leading to the problems that the island is facing today, both economic - offer of accommodation being greater than demand of accommodation - and environmental - great seasonal pressures applied on water resources. Simultaneously, the agricultural activity that had been abandoned to a large extent was enhanced by the tourist development, and the demand for local traditional products (for example local wines).

The water demand growth of the last decades has been addressed mostly with the construction of extensive water drillings, both public and private, to supply the domestic and agricultural sectors. Paros is a typical case where the water shortage occurs on a seasonal basis. Tourism and irrigation demand reach their peak during the same time during the summer months, creating conflicts between uses and problems with water supply adequacy during peak consumption. The island has the potential to combine multiple activities; both tourism and agriculture can offer a prosperous future for the inhabitants under suitable planning and control. So far however, the existing infrastructure is inadequate for dealing with these issues, and therefore new water management responses are necessary to cover the shortage.

Current and emerging policies

The people of Paros, in order to satisfy the domestic and agriculture demand, primarily used water from springs and wells – an easy and relatively inexpensive solution – or, less frequently, stored water in rain reservoirs. This practice was abandoned because of the tourist development that created the possibility of high profits by room rentals. Inhabitants chose to pay high prices for water rather than build reservoirs, as they could build rooms instead.

When the demand grew significantly, they pursued the construction of private and public drills, as the central administration delayed the construction of new and large scale infrastructures (supply networks, dams, etc.). At the time, such interventions were realised without any planning or control, and salinisation or aquifer depletion was a common result. At present and for domestic supply only 58 drills are in use, which cover 95% of the island needs in drinking water. Daily withdrawals range from 4,000 m^3 in the winter to 12,000 m^3 in the summer, and reach 14,500 m^3 during the high peak period in mid August. The uncontrolled abstractions of the previous decades for both irrigation and domestic consumption have had a severe environmental impact on the water quality of the most productive aquifers of Paros. Additionally, during the last 20 years and due to the intense exploitation of groundwater resources, especially during the summer months, a lot of wells and springs have dried out. As expected, the areas facing water deficiency and overexploitation are those that concentrate the main tourist and irrigation activities of Paros. Construction of groundwater drillings in the

Aegean Islands cannot be financed by the State. However, the costs associated with groundwater exploitation remain low as compared to other supply enhancement options, and the solution is preferred by the majority of local authorities. Licensing by the Regional Authorities is required. Although Paros does not have significant run-off, inter-seasonal water storage is a viable option. There are some private initiatives for the purchase of small tanks (from 2 m^3 to 50 m^3), mainly by the owners of lodgings in order to ensure supply during the peak season. The island economy is viable enough so that projects such as the construction of small dams can be easily financed. At present one small dam has been constructed and a second is in the planning stage of feasibility study, under the supervision of the Ministry of Agriculture. Figure 3 analyses the DPSIR functioning and current water resources management in Paros.

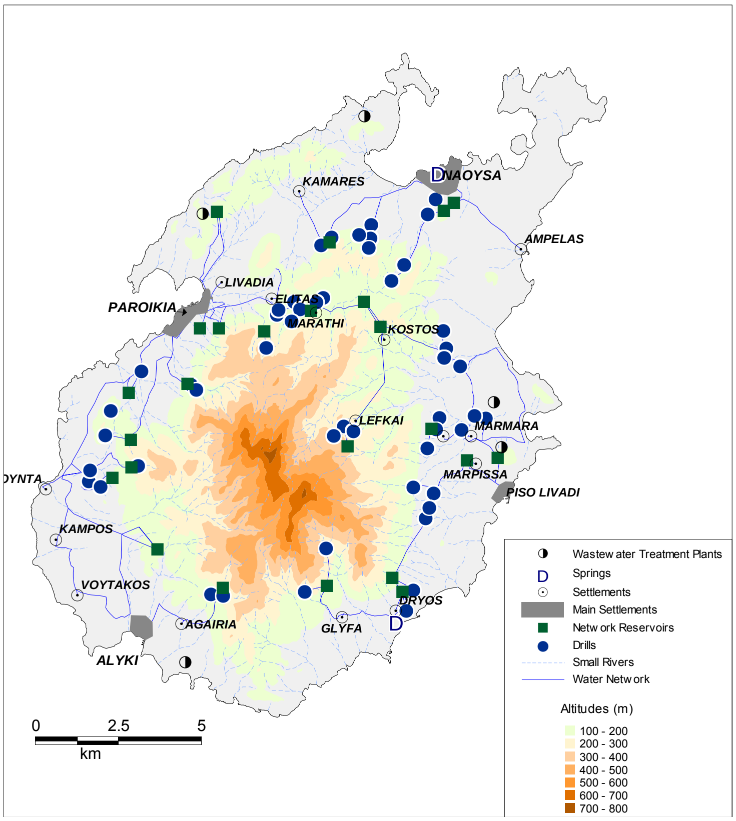

Figure 2 Domestic water Network of Paros

Currently one desalination plant with 1,450 m^3/day capacity operates in Naousa, where there is a brackish spring with a relatively stable and substantial supply of 2,000 m^3/day throughout the year. Since the full operation of the unit started in 2002, domestic water deficits in the traditional settlement of Naoussa have been considerably alleviated, and the quality of water supplied to the tourist sector has substantially improved. In view of these results, the Municipal Office for Water Supply is considering the construction of other units in the tourist areas of the island. The fact that during the off-peak season a small amount of water is supplied to irrigation had a significant effect in the resolution of social conflicts between the farmers of the area and the hotel owners. The majority of local stakeholders are favourable towards the construction of additional plants to supply tourist areas. The operation of the unit has had a considerable effect on the water balance of the Naoussa-Ksiropotamos aquifer, which faces a serious overabstraction problem and in fact has been, due to the previous exploitation patterns, sea-intruded. The construction of the desalination plant was financed by the Ministry of Development and its operation falls under the authority of the Municipality of Paros. In 2002 the construction cost of the unit was equal to 440,000 €. Data for the operating, maintenance and energy costs of the plant are not available by the local authorities, but are expected to be typical of brackish water desalination plants.

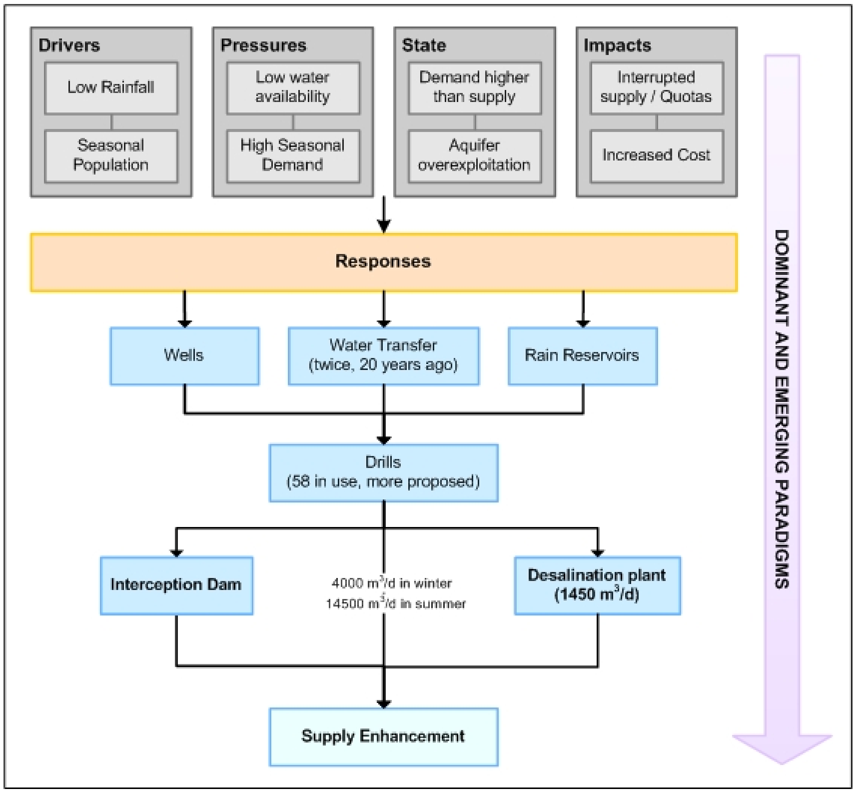

Figure 3 A DPSIR analysis and the dominant water management practices in the island of Paros

Water transfer in containers has only been used twice so far, about twenty years before the present. Aquifer enhancement is being considered, as the main water resource of the island is groundwater. For this purpose, seven interception walls have been built in the area of Naousa and one interception and storage dam has been constructed in the Tourlos area, which however is not yet operational.

Stakeholders and actors

Since 1999 the domestic water supplies of the island are under the administration and management of a municipal office (DEYAP), and maintenance and control follow a centralized and better organized decision-making path than before. In the region of Naousa irrigation water supply is managed by the Local Board for Land Improvement (TOEV). Agricultural activities in the rest of the island are self-supplied. The overall political responsibility is taken up by the Ministry of Agriculture and under the new governance framework (as a result of the transposition of the Water Framework Directive in the Greek Law) by the Regional Government and the Ministry of Environment, Town Planning and Public Works. The overall governance framework is presented in Figure 4.

The groups of stakeholders and actors that are involved with or are directly influenced by the decision-making process are:

- The **Municipality of Paros**, which constitutes the local authorities that take part in the decision making processes regarding water management.

- The **Municipal Office of Water Supply and Sewerage of Paros (DEYAP)**, which is the administrator for domestic water supplies in the island. DEYAP has an overall responsibility for the type of activities or measures considered and proposed, at least on what concerns domestic water supplies.
- The **Union of Agricultural Associations**. It represents the traditional agricultural character of the island, it is directly involved in water use through irrigation and it is also directly affected by water allocation.
- The **Union of Rent-Room Owners**, which represents the interests of a significant share of the population. Many of the locals are involved in tourism, both as main activity and as a part-time occupation. Tourism, the main source of income for the island; is one of the reasons for the seasonal peak of water demand.

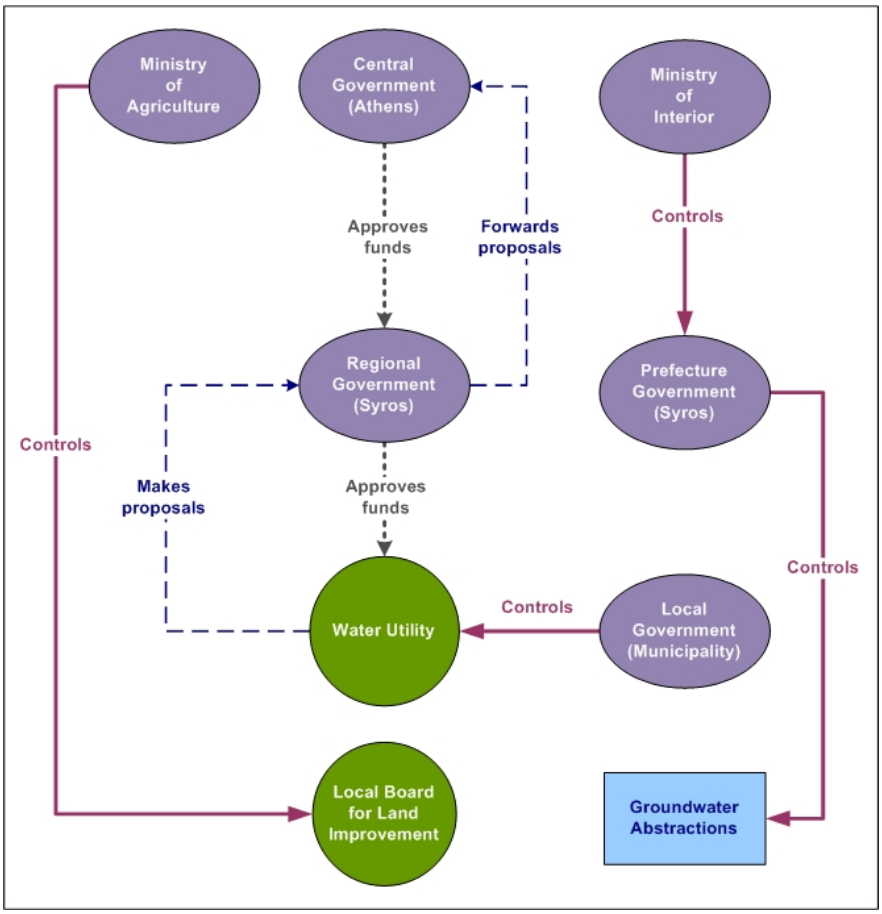

Figure 4 Overall governance framework for water resources management (before Law 3199/2003)

Formulated and evaluated Strategies – Summary of analysis outcomes

Given the strong seasonality of demand in Paros, the priorities set for the development of suitable strategies reflect a general goal of managing the peak demand without incurring excessive direct costs, avoiding large-scale expensive interventions, and minimising environmental costs. For achieving the latter, groundwater abstractions should be reduced to the levels considered sustainable given the available data.

Following the evaluation of alternative water management options as proposed by the aforementioned stakeholders and end-user groups, two alternative strategies were formulated based on the current and emerging approaches. **Strategy 1** reflects the current approach in dealing with water management issues, incorporating the newest techniques and methods applied and proposed. Measures focus on small to medium scale structural interventions shown to be effective and efficient in the case of Paros, including:

- Further groundwater exploitation using boreholes abstracting sustainable quantities of water ($M1_1$);
- An interception dam to prevent the loss of runoff, and enhance aquifer replenishment ($M2_1$);
- Network improvements throughout the island aiming at the reduction of network losses in settlements ($M3_1$);
- Small desalination plants, with a total capacity of 4,150 m^3/d in 2030 ($M4_1$).

Strategy 2 implements a "soft" path approach, attempting to reconcile the supply and demand in Paros without resorting to hard interventions where possible. The Strategy formulated within this 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. Interventions were determined to be:

- Conservation measures in the domestic and tourist sector, and particularly use of low flow taps in hotels ($M1_2$);
- Irrigation method improvements through the application of drip irrigation for all crops except cereals, applied in all municipal departments ($M2_2$);
- Network improvements throughout the island aiming at the reduction of network losses in settlements ($M3_2$);
- Network unifications between neighbouring municipal departments and settlements to enable the allocation of available resources throughout the island ($M4_2$);
- Exploitation of groundwater at a sustainable rate through additional borehole drilling ($M5_2$);
- Exploitation of surface water through the construction of an interception dam for aquifer replenishment ($M6_2$);
- Small desalination plants, with a total additional capacity of 600 m^3/d in 2030 ($M7_2$).

The evaluation of the two strategies and their comparison emphasise that the high temporal water imbalance in the island of Paros can best be solved through a combination of small-scale structural options, and soft interventions aiming to increase the efficiency and productivity of water use. The further use of institutional measures, aiming to decentralize 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.

From evaluation to implementation – Additional considerations

Table 1 and Table 2 present some additional considerations regarding the measures foreseen for the implementation of the two strategies.

Additional borehole drilling ($M1_1$ and $M5_2$) requires the issuing of special permit by the prefecture while the only measures that are the sole responsibility of the Municipal Office for Water Supply and Sewerage are network replacements and network unifications. Other measures related to supply enhancement and environmental protection (e.g. interception dams, desalination) should either be approved or financed by the relevant authorities (region, or central government).

Table 1 Additional considerations for implementing Strategy 1 in Paros Island, Greece

Strategy measures	$M1_1$	$M2_1$	$M3_1$	$M4_1$
Responsible authority for implementation	Prefecture, DEYAP	Central Government, Regional Government, DEYAP	DEYAP	Central Government, Regional Government, DEYAP
Education/awareness efforts required	None	None	None	None
Administrative/legislative reforms required	None	None	None	None
Timeframe of application	Immediate	≈ 5 years	≈ 4 years	Immediate
Cost considerations	Low	Moderate	Low to Moderate	High
Impact mitigation required	Medium to Serious	None	None	Low

At present, measures aiming to improve efficiency in water use and reduce water waste should not require extensive awareness/education efforts. Both rent-room and hotel owners and farmers seem to be aware of the benefits derived from water conservation, and the fragility of groundwater resources of the island. However, options such as introduction of drip irrigation entail high costs, which users are more than reluctant to pay. Taking also into account the rather low income incurred from agricultural activities, the implementation of such options should be promoted through economic incentives, taken up either by the Government (Ministry of Agriculture or Ministry of the Environment) or by the competent regional authorities.

Table 2 Additional considerations for implementing Strategy 2 in Paros Island, Greece

Strategy measures	$M1_2$	$M2_2$	$M3_2$	$M4_2$	$M5_2$	$M6_2$	$M7_2$
Responsible authority for implementation	DEYAP End users (Hotels)	Central Government, Regional Government, Local Board for Land Improvement, Farmers	DEYAP	DEYAP	Prefecture, DEYAP	Central Government, Regional Authorities, DEYAP	Central Government, Regional Authorities, DEYAP
Education/awareness efforts required	Moderate	Moderate	None	High	None	None	None
Administrative/legislative reforms required	None	None	None	None	None	None	None
Timeframe of application	Immediate	≈ 5 yrs	≈ 4 yrs	Immediate	Immediate	≈ 5 yrs	Immediate
Cost considerations	Low	High	Low to Medium	Low	Low	Medium	Low to Medium
Impact mitigation required	None	None	None	None	Moderate to Serious	None	Low

Another option that is expected to require extensive efforts for implementation is network unifications, especially in the case of neighbouring municipal departments. In the past these municipal departments used to be independent in terms of local administration, which was also responsible for the management of water resources and the provision of water services. As a result of this past structure, most networks throughout the island are fragmented, inhibiting the alleviation of water deficits through a more even distribution of resources. The option of network unifications is an issue that creates strong conflicts between the inhabitants of the different municipal departments. Water-rich areas strongly protest against sharing their water resources, while the aggravated deficiency of other areas creates problems in their economic development. Under this environment, it is therefore believed that the implementation of this option will require extensive education and awareness efforts, but most importantly, the development of a common vision and understanding regarding the equitable, and economically, socially and environmentally sustainable allocation of groundwater resources.

Belice Basin, Italy

Background of water management practices and emerging policies

Overview of the region

The irrigated district of Garcia Arancio is located on the southern coast of Sicily, in the province of Agrigento. This district was named after two artificial reservoirs that provide almost the whole water supply needed for irrigation. Such reservoirs are the Garcia Lake, located on the left branch of the Belice River, and the Arancio Lake, resulting from the artificial catchment built on the Carboj River. The irrigated area of Garcia-Arancio, together with the nearby Gorgo-Verdura-Magazzolo and Valle dei Platani e Tumarrano districts, are part of the territory managed by the Consorzio di Bonifica (Land improvement co-operative) no. 3 – Agrigento. The Consorzio di Bonifica is a co-operative founded in 1995, pursuant to 45/95 Act, Sicily Region, which establishes the merging of existing associations into a single body to manage water resources used for irrigation in the three districts mentioned above.

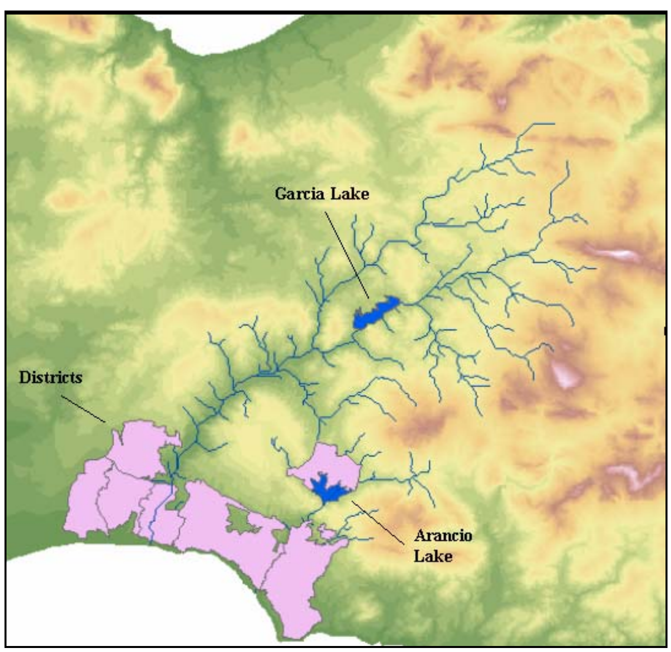

Figure 5 The case study location

The Arancio Lake was formed in 1952 as a consequence of the building of a dam on the Carboj River. This lake served as a basin for irrigation purposes for the nearby territories. It was managed by the Consorzio di Bonifica Basso Belice (Land Improvement Co-operative Basso Belice), a local authority set up the same year and located in Menfi. Originally, the territory falling within the competence of the co-operative was 8,904 hectares wide, including the towns of Castelvetrano (3,988 ha), Menfi (3,687 ha) and Sciacca (1,228 ha). In 1990 it was extended to Montevago, S. Margherita Belice, Sambuca di Sicilia e Partanna, totalling 35,000 ha.

The effectively irrigated area has increased from 700 ha in 1957 to 12,165 in 1991 and to 17,099 in 1997. The Arancio Lake has increased the local water availability: with time, this has also affected the type of cultivations grown in the area. In fact, the most frequent cultivations typically were sowing cultures and almond grove, which do not demand large amounts of water. Little by little these were replaced by viticulture and artichoke plantations that provided a better and plentiful production due to the increased water provision. Originally, an irrigation network of hydraulic grade line canals was used. The first pipelines were built in the 1960s, enabling fields located at a higher altitude to be irrigated through water abstractions from the Arancio Lake. The areas that first benefited from this system were Sambuca di Sicilia and Menfi. During the same period a weir was built on the Belice River in the Margio Rotondo area. The pipelines and the weir together could then serve an additional area of 1,000 ha in the surrounding territory. In the 1980s the Consorzio Basso Belice started to replace 850 km of hydraulic grade line canals with a pressure line. This work made the water transport system more efficient, while at the same time it minimised water consumption. In the past, the pipeline network was regulated at users' requests. It currently works under a fixed rotating shift scheme, put into place in order to meet specific water needs. Thus, both the diameter of the outlet pipes and network building cost could be reduced. At the end of the 1980s the irrigation network in operation was 1,280 km long, and included 430 km of pipelines while the remaining 850 km were hydraulic grade line canals. By 1993 the whole network was made up of pressure line: it was possible to start the automation of the irrigation system, to introduce new methods of irrigation – such as sprinkler and drip irrigation; and to cultivate the unused parts of the fields that were previously occupied by the canals.

Figure 6 The Basso Belice zone was the first irrigated area managed by the Consorzio

The automation of the irrigation network has improved the water supply system and has even reduced its cost. The water supply is directly controlled by the operators, who can immediately identify any breaks in the network, and consequently water leakages. On the other hand, the user can check at any time the effective volumes of water supplied. Water is supplied according to a shift plan determined in agreement with all the users. The amount of water delivered depends on the kind of cultivation and the size of the area to be irrigated. The main and secondary water supply systems of the Consorzio are provided with flow meters, electronic valves and sluice valves operated by a computer network. On-site computers, located near the junctions of the network, control up to 189 valves each.

Between 1977 and 1985 the artificial dam of Garcia was built on the Belice Sinistro River. Water from the Garcia Lake was used for irrigation and domestic purposes in the provinces of Palermo, Trapani and Agrigento. At the beginning of the 1990s the Consorzio Basso Belice Carboj had a water supply pipeline built between the Garcia and the Arancio lakes, so that the Arancio Lake could be supplied with more water to irrigate other portions of land. In 1993 the water pumping plant of the weir on the Belice River was enhanced in order to improve the existing water resources used for irrigation, to meet the increasing demand, and to face possible drought periods. The Belice pumping plant was connected to the network of the Arancio Lake in order to supply the lake with water during the winter season.

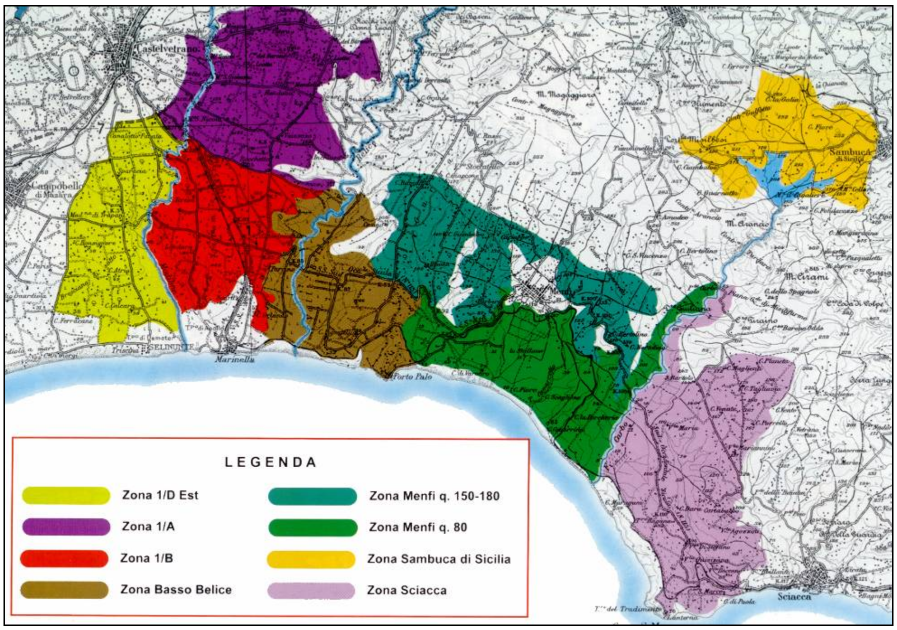

Figure 7 The irrigation districts in 1997

Current and emerging policies

At present, the surface water of the Garcia and Arancio reservoirs represents the most important source of water supply, both for irrigation and for domestic use. As far as water management by Consorzio 3 Agrigento is concerned, water is supplied to the relevant irrigation districts from the two lakes and from the Belice River. The Arancio Lake was exclusively built for irrigation purposes: with 32.8 hm³ available yearly, it represents the primary water source in the area all year-round. The Arancio Lake is refilled with water from the Garcia reservoir on the Belice River. This operation is generally performed during the summer, when water demand reaches its peak. Since the altitude of the Garcia Lake is 194 m, while the Arancio Lake's is 179 m, the connection between the two reservoirs through the supply network (Principal, East and West supply pipelines) is done gravitationally without further energy cost. According to demand needs, water from the Garcia Lake can be conveyed to the districts of the Garcia-Arancio territory through the storage tanks and the pumping stations on the East and West branches.

During the winter months water requirements are also met with water from the Belice River. Water is pumped into the East water supply pipeline to the Arancio Lake, as a refill, or directly to the final users. The water management of the Garcia-Arancio-Belice territory is supported by the remote control centre at the Menfi branch.

The Garcia-Arancio irrigated district is divided into four sub-districts, Castelvetrano, Menfi, Sciacca and Sambuca di Sicilia. Hereunder some details about the water management of each sub-district are given.

The **Castelvetrano** area includes since 1997 four different zones: 1/A, 1/B, 1/D Est and Basso Belice, all located in the administrative territory of the towns of Castelvetrano and Partanna. Zone 1/A is 2,745 hectares wide. Water service for irrigation has been operating since 1992 and makes use of a distribution network of 214 Km, made up of steel conducts. This network is supplied with water from the main pipeline connected to the Garcia Lake: water is pumped from the pipeline towards two storage reservoirs located at an altitude of 240 and 190 m. The Zangara pumping station comprises six pumps of 100 m head, and input power of 684 kW, allowing the transfer of 748 l/s. The internal distribution network has been designed for a computer-based delivery of a 15 l/s discharge, and according to a fixed rotating shift scheme. Zone 1/B is 2,189 ha wide. Irrigation water comes from the tank 1/B that has a capacity of 40,000 m^3 and is situated at the south end of the main Garcia adductor, where it splits into the West and East branches. The tank feeds an internal network of 155 km, which is computer-based and under the remote control of the agency headquarters. The network operates since 1993 and carries a discharge of 15 l/s by gravity. Zone 1/D Est is 1,946 ha wide and is served since 1999. It is supplied with water from the West branch, whose ending is the 1/D tank of 90,700 m^3. The distribution network has the same characteristics with those of zone 1/B. Zone Basso Belice was the first irrigated area in 1952 under the competence of the newly founded Basso Belice-Carboj Agency for Land Reclamation. In the 1950s the distribution network was made up of grade line canals, replaced in 1964 by the actual pressure line. The irrigated area of about 1,130 ha is served by a network of 125 km, which conveys a discharge of 5 l/s, through conduit diameters of 150 and 1,000 mm. Water is supplied to the BB storage reservoir either by gravity, by the East branch, or by pumps from the weir on the Belice river. In the Basso Belice zone the water service is on demand (no shift schemes) and supply is not computer-based. The Castelvetrano irrigated district has a total irrigation network of 494 km with an average efficiency of 0.8. The maximum cultivable area is 8,010 ha.

The irrigated district of **Menfi** comprises two separate areas, at an altitude range of 0-80 m a.s.l and 150-180 m a.s.l. respectively, each one having its own storage tanks and irrigation network. The 0-80 m zone, of about 3,360 ha, is one of the first irrigated areas of the Consorzio, being served by grade line canals in the 1950s and by a pressure line. The internal water network works by gravity, has a length of 255 km and is provided from the East branch of the Garcia adductor through the tanks 1/F1 and 1/F2 of 12,200 m^3 and 28,000 m^3. The water supply works actually under a fixed rotating shift scheme, while in the past the Consorzio allocated water to each user according to the estimation of the actual water required by the types of crops and irrigated areas. The 150-180 m zone, of about 2,000 ha, has a distribution network of 230 km including pipelines of various diameters (range 150 mm – 900 mm), and involves the four storage reservoirs, V1, V2, V3 and V4 of the total capacity of 23,900 m^3. The water delivery is not controlled automatically and works by gravity for the 150 m areas, while water is pumped to the users of the 180 m. A discharge of 20-24 m^3/s is available to the users of the district. The maximum cultivable area of the Menfi district is about 5,360 ha and is covered by a total network of 485 Km.

The **Sciacca** district lies on four altitudes, 80-150-180-220 m a.s.l., covering 3,925 ha of irrigated land over 17,040 ha of surface area. The distribution network has a length of 311 km, with pipelines made of different materials such as steel and PVC, and measured with diameters from 355 to 1,000 mm to supply a discharge of 15 l/s. 50% of the irrigated area is at an altitude lower than 100 m and receives water by gravity from the Caricagiachi storage tank, in turn fed directly by the Arancio Lake. Water is carried to the upper sites of the zone by pumping stations.

The fourth district belonging to the Garcia-Arancio area is the **Sambuca di Sicilia**. These lands are located in the surroundings of the Arancio and are irrigated directly from the lake by pumping water up to the Vs storage tank of a 5,000 m^3 capacity, and then from the tank to the internal irrigation network. The pipelines lie for a total length of 200 Km and are designed for a 16-18 l/s discharge. The maximum cultivable area of the Sambuca di Sicilia district is about 1,750 ha.

According to the tariff plan approved by the Consorzio in the 1998, the local crops are divided into seven classes based on their own water requirement, and a maximum supplying water volume per season has been defined, which corresponds to a specific price of water. The management rule usually applied by the agency is that the tariff does not change as long as the customer asks for up to 10% more water with respect to the defined maximum agreed volume. Any volume exceeding this 10% is sold at 0.12 €/ m^3.

The water price for industries, hotels and animal breeding activities is about 0.31, 0.51 and 0.72 €/ m^3, respectively.

Since the Consorzio started operating in the area, the applied irrigation methods have changed from surface to sprinkler and drip irrigation, reducing, thus, manpower needs and increasing both efficiency indexes and water savings. The sprinkler method is actually used for crops such as fodder plants, grass for hay and orchards, whereas drip is for vines, olive trees, artichokes, peppers and tomatoes. Water supply to the agricultural users is performed upon previous submission of applications on dedicated entry forms. One month before the irrigation season starts, usually in March, each water user presents a detailed request for water to the Department for Irrigation of the Consorzio. This submission regards only annual crops, as the areas and the types of perennial cultivations are already known. The weekly or fortnightly turns of irrigation are fixed on the basis of all the requests that have reached the department in time. The total amount of water supplied to the single user is estimated according to the type of crops and the respective cultivated areas. At the end of the irrigation period for annual crops, the computers of the remote control automatic centre provide the data about water volumes actually delivered.

Stakeholders and actors

The local water authority, directly involved in the water management of the Garcia-Arancio irrigated district is Consorzio 3 Agrigento – Agency of Menfi. This agency was founded in 1997, when the water management for irrigation of Sicily region was organized in eleven macro-zones of competence, overlapping the administrative territories of the provinces.

Figure 8 The eleven Consortia of Land Reclamation of Sicily

In the territory of Consorzio 3 Agrigento (C3A), there are 42 Commons of Agrigento, 2 of Trapani, 6 of Caltanissetta and 6 of Palermo. The total area is about 280,139 ha, of which 43,778 ha are equipped for irrigation, 33,033 ha is the cultivable area and 10,745 ha is the actually irrigated area. An area of 1,123 ha is equipped with a network of pipelines extending for 29 Km, while the rest of the area is covered by networks of open surface canals.

The C3A controls and administers eight different districts for irrigation. The first is Garcia-Arancio, the one under examination. Three of them are indicated as the Gorgo-Verdura-Magazzolo District: the Sosio-Verdura, whose name is derived from the two rivers of Sosio and Verdura, the Gorgo and the Castello are related to the homonymous present reservoirs. The Turvoli, Valle Platani and S. Stefano Quisquina are indicated as the Valle Platani-Tumarrano District which refer to the Valley of Platani and Tumarrano rivers. The last district managed by C3A is the S. Giovanni–Furore, whose name origins from the two reservoirs supplying the area.

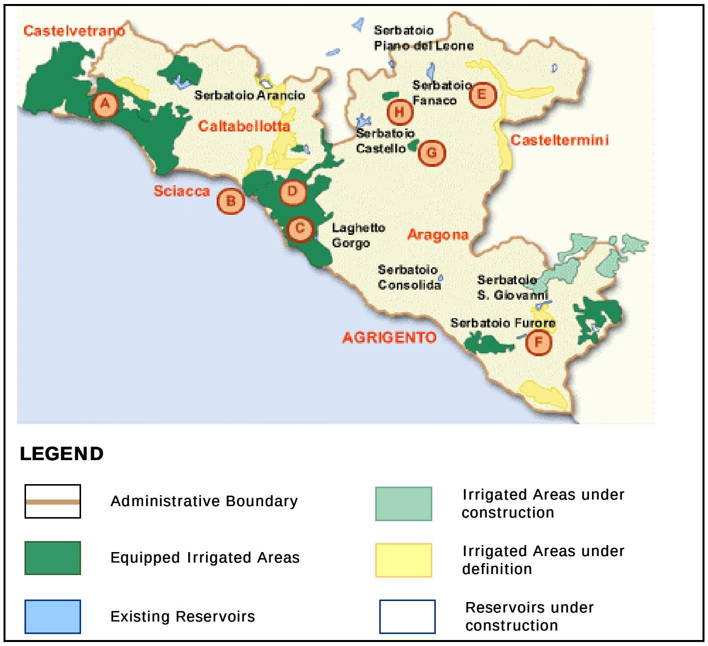

Figure 9 The eight different districts for irrigation under the C3A administration: (A) Garcia-Arancio; (B) Sosio-Verdura; (C) Gorgo; (D) Castello; (E) Valle Platani; (F) S.Giovanni-Furore; (G) Turvoli, (H) S.Stefano Quisquina

The Consorzio 3 Agrigento is responsible for land reclamation and for some institutional activities. Among the reclamation schemes and works, C3A carries out:

- Conservation and protection of soil and of its hydro-geological structure, with particular attention to soil consolidation, stability of slopes , prevention of hillside erosion and landslides;
- Preparation and adaptation of free-hold lands and related drainage networks;
- Monitoring and protection of surface and groundwater used for irrigation and animal breeding;
- Building of infrastructures for pumping, delivery, transfer and distribution of irrigation water;
- Maintenance of infrastructures;
- Landscape protection and preservation of the agrarian ecosystem.

The involvement of the C3A authority in institutional tasks regards:

- Preparation and adoption of land reclamation plans;
- Surveillance and inspection of compulsory private works as provided in the reclamation plans;
- Processing of indexes of water quality, and analysis an definition of acceptable standards for agricultural uses;
- Design of related public works.

The activities of the Consorzio are distributed among five different offices, three of which are technical: Department for Irrigation, Department for Land Register, and Department for Works Programming.

The **Department for Irrigation** operates the water distribution network in terms of ordinary maintenance, administrative issues, analysis of water demands, and definition of the water volumes to be supplied to each user.

The **Department for Land Register** handles the census of all the landowners in the administrative territories of the Consorzio. It also works with the Regional Office for Agriculture and Forests finalizing decisions about the land dispossession oriented to new public works for reclamation.

The **Department for Works Programming** is responsible for the preparation of the three-year plan of public works to be implemented, and for the design phase of the work. It collects and processes the data defining the state of the territory and the available water resources. It also handles the monitoring of the infrastructure and indicates the needs of maintenance.

At present, the two reservoirs are co-managed by different authorities:

- The Garcia reservoir is managed by the Consorzio di Bonifica (Land improvement Co-operative) no.2 Palermo, in collaboration with EAS, Ente Acquedotti Siciliani (local authority in charge of aqueducts in Sicily);
- The Arancio lake is managed by the Consorzio di Bonifica (Land improvement Co-operative) no. 3 Agrigento in collaboration with ESA, Ente di Sviluppo Agricolo Siciliano (local authority for agricultural development in Sicily).

Formulated and evaluated Strategies – Summary of analysis outcomes

The two strategies developed for the Belice Basin aimed to assist in solving the problems caused by a widespread water deficiency in the region. The main source of this phenomenon is the escalating demand, and limited available freshwater resources due to low rainfall, especially during the summer, when demand for agriculture is higher. Targets to be achieved by the two strategies were the coverage of specific water needs for irrigation and domestic purposes.

Strategy 1 reflects the current approach, incorporating management options and instruments either already in use or emerging in the area as newest techniques and methods applied or proposed. These responses are dominantly structural and involve construction and rehabilitation of large scale infrastructure. **Strategy 2** also includes small scale decentralised solutions, and measures aiming to increase the productivity of water use.

More specifically, Strategy 1 interventions include:

- An expansion of the existing pumping station on the Belice river, in the district of Castelvetrano, and a new connection of Garcia lake with the right branch of Belice ($M1_1$);
- The expansion of the drinking water treatment plant of Sambuca di Sicilia ($M2_1$);

- Replacement of secondary distribution networks in the settlements of the region, with the aim to reduce network losses ($M3_1$).

Strategy 2 is highly dependent on efficiency improvements and measures aiming to reduce water waste, including:

- Expansion of the drinking water treatment plant (DWTP) of Sambuca from 25,920 m^3/d to 51,840 m^3/d ($M1_2$);
- Replacement of the existing pipeline connecting Garcia lake to DWTP, increasing its flow capacity from 25,920 m^3/d to 51,840 m^3/d ($M2_2$);
- Irrigation method improvements through the application of drip irrigation for the areas of Menfi, Sambuca di Sicilia and Sciacca ($M2_2$);
- Use of the effluents of waste water treatment plants to directly supply irrigation sites (Menfi, Castelvetrano, Sambuca); the maximum additional volume available for irrigation is about 12,497 m^3/d ($M3_2$);
- Exploitation of surface water from Belice river. This is performed through pumping from the right river branch (yielding 6 hm^3/yr) and through the expansion of the existing station of “Belice Basso”, which yields 7 hm^3/yr ($M4_2$);
- Reduction of network losses, currently estimated at an average 40%, to 21% in municipal departments with the exception of Menfi and Sciacca and to 21% in the pipelines connecting the drinking water treatment plant of Sambuca with settlements ($M5_2$).

The analysis of the evaluation results for the two strategies shows that the suggested interventions can possibly meet local water need for irrigation use, while domestic demand can be met only with Strategy 2. Domestic demand coverage is highly dependent on the size of the local drinking water treatment plant, as well as on the characteristics of the pipelines that convey water from the basins and from the Montescuro Ovest aqueduct. If interventions on plants and pipelines are carried, the analysis suggested that nearly 90% of domestic demand could be met.

Overall, results pinpoint that a combination of “soft” and “hard” approaches adopted for medium and long term planning has proven to be the best solution to meet local water demand. However, the analysis of alternative cost recovery schemes demonstrated that allocated costs and consequently the economic impact of cost recovery policies can be remarkable. Under this context, 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 financial costs for domestic and irrigation water provision, and waste water treatment.

From evaluation to implementation – Additional Considerations

Table 3 and Table 4 list the additional considerations with regard to different strategy measures for Belice Basin. One of the notable issues is that most measures entail high costs that eventually will have to be recovered by the end-users. In line with the development of cost recovery strategies, performed as part of the strategy formulation process this will result to high prices. Therefore, one of the prerequisites for the actual implementation of all proposed interventions is the development of a firm pricing policy, in order to partially recover at least the financial costs of water service provision. This is more than necessary for network rehabilitation, a measure incurring high costs, especially for replacement of secondary distribution networks, and pipelines, managed by the EAS (Ente Acquedotti Siciliani), the local authority in charge of aqueducts in Italy.

Table 3 Additional considerations for implementing Strategy 1 in Belice Basin, Italy

Strategy measures	$M1_1$	$M2_1$	$M3_1$
Responsible authority for implementation	EAS	EAS, Consortium 2, Consortium 3	EAS
Education/awareness efforts required	None	None	None
Administrative/legislative reforms required	None	None	None
Timeframe of application	≈ 2 yrs	≈ 2 yrs	≈ 3 yrs
Cost considerations	Low	High	High

Measures targeted to increase irrigation efficiency through the installation of drip systems or to promote treated waste water as an alternative water resource are likely to require increased education and awareness efforts. Such campaigns have probably been realised on a local level; however no information has been made available on their impact and extent.

Table 4 Additional considerations for implementing Strategy 2 in Belice Basin, Italy

Strategy measures	$M1_2$	$M2_2$	$M3_2$	$M4_2$	$M5_2$
Responsible authority for implementation	EAS	EAS	Consortium 3	EAS; Consortium 2; Consortium 3	EAS; Consortium 3
Education/awareness efforts required	None	None	Moderate	None	High
Administrative/legislative reforms required	None	None	None	None	None
Timeframe of application	≈ 2 yrs	≈ 2 yrs	Immediate	≈ 2 yrs	Immediate
Cost considerations	Low	Low	High	High	Very High

Tel Aviv Region, Israel

Background of water management practices and emerging policies

Overview of the region

The region is located in the coastal plain on the eastern shore of the Mediterranean Sea (and it lies above the coastal aquifer. In terms of population, the Tel Aviv region is the largest in Israel with two million people, 30% of the total population. The region has 160,000 dunam (1 dunam = 0.10 hectares) of cultivated agricultural land, 5% of the total cultivated land in the country. The region's water economy is therefore characterized by relatively high domestic and industrial consumption, and relatively low agricultural consumption. About two thirds of the fresh water is supplied to the region via the national water system operator by the national water company, Mekorot. The remaining third of the fresh water is provided by private producers from the coastal aquifer. In the future, this region is slated to receive a significant amount of desalinated sea water.

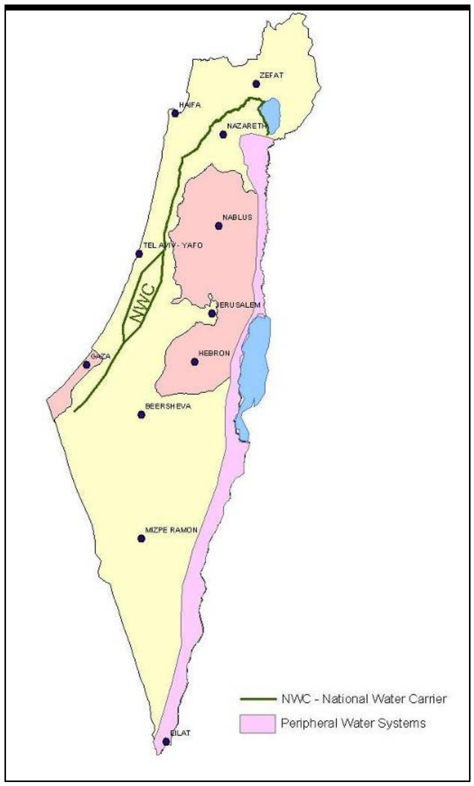

Figure 10 Water Network of Israel

Domestic consumption is similar to the national average (100 m^3 per capita per annum). This consumption is expected to increase by 20% with the development of metropolitan parks and the improvement in quality of life. The quality of the freshwater is good, with a salinity level of 150-250 mg chlorine per litre. In the future, the use of desalinated water will lead to an improvement in the water quality. The region's large population creates the potential for a large supply of recycled water for agriculture. In addition, high quality treated waste water can be used for irrigation of metropolitan parks and for rehabilitation of streams like the Yarkon River. The climate in the region is Mediterranean, semi-arid, with annual precipitation of 450 mm.

There is no private ownership of water in Israel. By the Israeli Water Law of 1959 all water sources are publicly owned and their utilization is controlled by the Water Commissioner. The allocation of water is administrative: the commissioner issues permits for production (extractions) to suppliers as well as allocations (quotas) for agricultural consumers.

Prices of water delivered by the national company Mekorot are set by the government, and are determined in a procedure which is open to political pressure (skilfully applied by the agricultural lobby). Viewing water prices not as an allocation instrument, but as a means to improve income distribution, water charges depend on the type of use: farmers pay the lowest prices, industry pays higher prices and households pay the highest. Within each sector prices do not depend on location: users in all parts of the country face the same prices, regardless of the supply price of water. Private water suppliers are subject to quotas but can set prices independently.

Current and emerging policies

The actual planning of water allocation made by the Water Commission follows several stages:

- Predicting annual water demand by sector and region (including, of course, that of Tel Aviv), given the actual water prices.
- Determination of "red lines" for each of the major water sources and the implied total production permits of fresh water;
- The gap between aggregate demand and total supply of fresh water is bridged via investments in the water economy aimed at:
    - increasing the volume and flexibility of the within-region and between-regions conveyance systems of fresh water,
    - development of additional (environmentally safe) water treatment plans, reservoirs and conveyance systems;
    - improving the quality of fresh water as well as of the recycled effluents; and, in the longer run,
    - desalination of sea water.

The current management practices result in:

- Continuous pressure on the governmental budget to increase the share allocated to investments in the water economy, and continuous pressure of the budget department of the Ministry of Finance to increase water prices, including the prices for agricultural use.
- The above pressure to raise prices is balanced by the agricultural lobby which is very influential in Israel. The main interest of the farmers is to receive the largest possible an allocation of fresh water at the lowest attainable price. The consequences of the success of the agricultural lobby have been over-utilization of water for many years, hydrological deficits, the intrusion of seawater into the coastal aquifer, contamination of reservoirs, and the reduction of the carry-over capacity of the system. A major part of the hydrological crisis is also an environmental crisis, with continuous pollution of the rivers, aquifers and other natural resources. Serious ecological damage affecting unique natural resources and landscapes often results.

These detrimental effects are among the major reasons for the current severe water crisis. Although still very influential, the agricultural lobby lost some of its political power in the last two decades.

Additional conflict in the water economy exists between the agricultural and the urban sectors regarding the purification standards for disposal set for the cities by the government. Another conflict is over the allocation of the costs and the benefits associated with recycling between the generators of sewage (the municipalities) and the agricultural users. An additional conflict is the issue of assurance for the municipalities that the farmers will not reduce usage suddenly (due to an economic crisis for example) and leave the cities with treated water that cannot be disposed of.

New and forthcoming partial privatization of water supply is a potential source of conflict between the government-owned company, Mekorot, and private entrepreneurs on two issues: the control of the supply of newly developed water resources (mostly desalinated sea water and recycled wastewater) and the responsibility for the operation of the intra-cities water systems (currently operated by the cities themselves).

The current paradigm is the result of inefficient institutional and administrative mechanisms for water allocation and of a poor decision making culture (hydro-politics). The above-mentioned unsolved ongoing conflicts partially paralyze the water economy. This is especially true in a run of dry years (as in 1998-2001) in which many of the problems become more severe. The main quantitative expression of the current crisis is the severe reduction in the ability to produce freshwater from the aquifers (approximately 500 hm^3) without operating additional wastewater reclamation systems and desalination plants. The agricultural sector bears the brunt of the cuts (since the demand of the other sectors is rigid), and its allocation was recently reduced by about 40%.

To conclude, Israel (with the Tel Aviv region being a representative example of the situation associated with the national water system) is an example of a developed water economy experiencing a man-made water crisis. There has been neglect and attention must be paid to changing circumstances. A sustainable growth of the water sector requires a new paradigm. Fortunately, the fundamental structure of the sector is sound and the basis for reform exists.

Stakeholders and actors

In Israel decision making and management relating to the water economy take place in many forums. The process is greatly affected by special interest groups, each pulling in its own direction. The main stakeholders in the water arena relevant for the analysis carried out are:

1. **The Water Commission**, which is the authority in charge of managing the water system. The authority is headed by the Water Commissioner, who is appointed by the government. The commissioner issues permits for production (extraction) to suppliers as well as allocations (quotas) to agricultural consumers. The latter is coordinated with the Ministry of Agriculture and requires his agreement.
2. **The Water Council** is a national entity appointed by the government to advise the Minister of Agriculture on a wide range of water issues, including water pricing. It includes representatives of interest groups and its decisions are subject to political pressure (hydro-politics), skilfully applied by the agricultural lobby.
3. **Mekorot**. Israel’s national water company, responsible for most of the supply and maintenance activities, including the operation of the National Water Carrier. In effect, Mekorot is the only entity with significant financial and operational abilities in the field of water resources.
4. **The Ministry of Agriculture**. The Minister of Agriculture is in charge of implementing many water laws, can promulgate secondary legislation such as determining norms for agricultural water use. The Minister’s influence on governmental decisions on water pricing and on the Water Commissioner's decisions (regarding the allocation and distribution of water quotas) is crucial.
5. **The Ministry of Finance** is responsible for the overall budget and for the allocation of financial resources (including subsidies) to the various entities involved in the water resources. This ministry continuously supports a policy of raising water prices for farmers as a means of saving fresh water, reducing water subsidies, and increasing the efficiency of water use.
6. **The Ministry of Health** is responsible for determining standards for purification for all water types and their uses. This includes authorizing recycled wastewater irrigation of lands overlying groundwater aquifers. The Ministry of the

Environmental Quality is responsible for preventing water pollution and protecting water resources from contamination.

7. **Farmers (agricultural water users)**. As mentioned above, decisions on water prices are made in the political arena and are affected by pressure from interest groups. Each attempts to affect public decisions in its favour. The farmers' representatives are the strongest and most influential interest group. The main interest of the farmers is to receive large allocations of water, to be supplied at the lowest attainable price. Water is a significant input in agricultural production in arid and semi-arid regions like Israel, and many farmers strongly support their representatives in the political arena. The agricultural lobby is very well organized, and so far, its influence on water policies and pricing decisions has been significant. The share of water costs in the budget of households or in the cost of manufacturing is relatively small. Therefore urban and industrial water users have only little incentive to organize political lobbies and, in effect, they do not comprise a strong opposition to the agricultural lobby.
8. **The Ministry of the Interior** is in charge of the local authorities. By controlling their budget, the Ministry supervises the local authorities' water and sewerage activities. Urban water consumption has the highest priority in the allocation of fresh water resources. The industrial sector also has high priority.

Formulated and evaluated Strategies – Summary of analysis outcomes

In the analysis carried out in the framework of the WaterStrategyMan project, four water management options were evaluated under two different water availability scenarios. Those are:

- **Recycled Water (R):** Increasing the annual supply of recycled waste water by 12 hm^3/yr.
- **Desalination Plants (D):** Increasing the annual supply of fresh water by establishing one desalination plant, capable of desalinating 100 hm^3 of sea water annually, in the second year of the planning period, and then establishing another desalination plant in the seventh year of the planning period capable of desalinating 50 hm^3 of sea water annually. The plants are operated only in periods of freshwater shortage.
- **Water Conservation (WC):** Reducing gross annual domestic demand for water by 7% via investments in water conservation.
- **Over Pumping (OP):** Increasing the annual supply of fresh water via over-pumping of ground water from the coastal aquifer.

Both formulated strategies were based on a combination of the first three water management options, i.e. recycling, desalination and water conservation.

Strategy 1 focuses on the enhancement of water supply via desalination of sea water and an increase in the amount of recycled waste water for irrigation, combined with a reduction in domestic demand via water conservation, while preserving the current (centralized) institutional setting of the water economy.

Strategy 2 assumes the same grand combination of management options as the first strategy. However, it differs from Strategy 1 by the assumed institutional setting, presuming 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. This implies termination of the option to import and export water via the National Water Carrier (NWC).

With respect to the current centralized institutional setting (Strategy 1), the separation setting Strategy 2) has several advantages, briefly presented below:

(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 Strategy 2, Tel Aviv does not compete with the southern regions for water from the Sea of Galilee. Therefore, 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 under Strategy 2 than under Strategy 1.

(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 under Strategy 1 is higher than that under Strategy 2, implying a larger cultivated area under the latter strategy. In other words, relative to the current situation, Strategy 2 is expected to improve the positive environmental contribution of the agricultural sector.

(d) According to the results of the economic analysis, private welfare surplus for consumers under Strategy 2 is higher, since lower water prices are imposed on domestic industrial water consumers. This 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.

From evaluation to implementation – Additional considerations

Table 5 presents some additional considerations for implementing the management options considered for developing strategies in the region of Tel Aviv. The list of options also includes the option of increasing water supply via overpumping, an option that due to environmental impact considerations, was not included as part of the formulated strategies.

With respect to environmental impacts, impact mitigation is considered a prerequisite in the case of overpumping, where increased abstractions from the coastal aquifer can result in serious quality deterioration due to sea water intrusion. Desalination is the supply enhancement option that presents the lowest additional environmental impacts, associated with brine discharge and chemicals disposal, but mostly with air emissions linked with additional energy production requirements. With respect to the decentralisation in water supply development, increase of recycled water supplies depends on both municipalities, that produce and treat the effluents, and on the "willingness" of farmers to accept the new supply source. On the other hand, and although desalination can be developed by municipalities individually, all other options fall under the responsibility of the Central Government, either in the form of permits for abstraction, construction or through the prerequisite of adopting a particular strategy for increasing education and awareness in order to promoting conservation measures.

Table 5 Additional considerations for implementing selected management options in Tel Aviv region, Israel

Management Options	Recycled Water	Desalination Plants	Water Conservation	(Over Pumping)
Responsible authority for implementation	Municipality, Farmers	Central Government, Municipality	Central Government	Central Government
Education/awareness efforts required	No	No	Yes	No
Administrative/legislative reforms required	No	No	No	No
Timeframe of application	Immediate	1-2 years	Immediate	Immediate
Cost considerations	High	Very high	Low	Low
Impact mitigation required	Medium[1]	Low	None	Serious

With regard to the administrative reform examined in the framework of Strategy 2, involving a partial institutional and economic separation of Tel Aviv's water resources, 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.

Limassol Region, Cyprus

Background of water management practices and emerging policies

Overview of the region

Cyprus is an arid to semi-arid island situated in the north-eastern Mediterranean. The renewable freshwater resources of the island are highly constrained, and characterized by a strong spatial and temporal scarcity caused by the seasonal distribution of precipitation, and the topography.

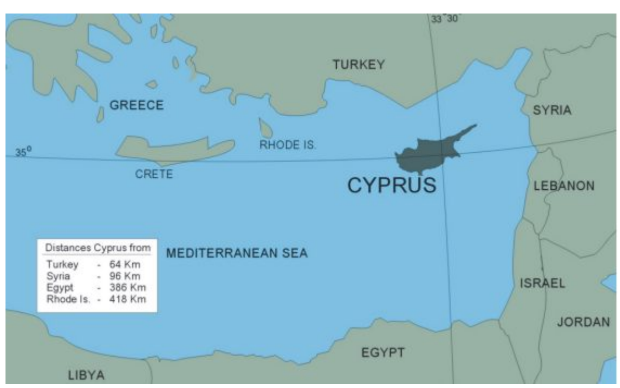

Figure 11 Cyprus in the Mediterranean

[1] Wastewater irrigation may be hazardous to the environment, health, the soil, aquifers and crops. It contains pollutant like macro-organic matter (biochemical oxygen demand, (BOD), chemical oxygen demand (COD) and total suspended solids (TSS); micro-organic pollutants, trace elements, pathogenic microorganisms, macro-nutrients (nitrogen, phosphorus) and salts.

Although a large number of various water supply investments and interventions have been realised in the past, such as surface water exploitation through extensive dam construction, groundwater exploitation, interbasin water transfers, desalination and reuse of tertiary treated effluent, Cyprus is still a long way from reconciling the demand to the availability of water. Competing demands and the dynamic competitive tension between agriculture, urban growth and tourism, and the environment are posing a definite challenge on the existing water management practices in the island.

The selected representative region, Limassol region, is depicted in Figure 12 and is characterised by water scarcity problems, as well as by particular social and economic characteristics that result in conflicting and competing water uses (water for the tourist industry – domestic demand – agriculture), and a complexity of the water system.

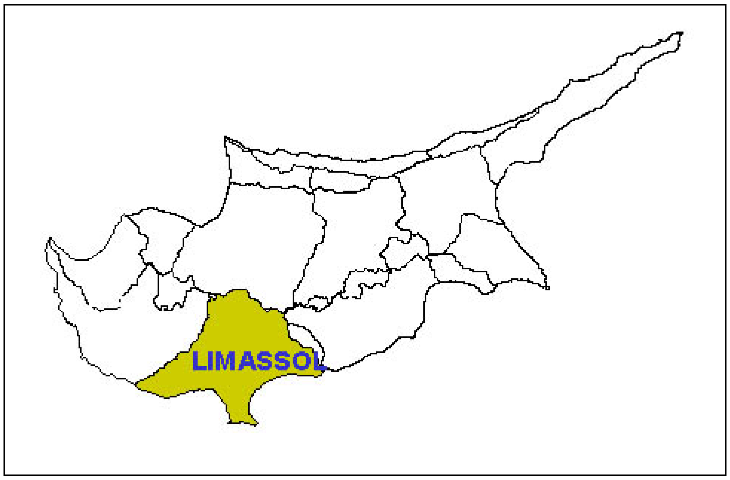

Figure 12 The selected Limassol region

The conflicting and competing uses as a result of the area's development pattern, pose great pressures on water resources, since the Limassol area is one of the main tourist destinations in Cyprus. On the other hand, agricultural production in the area accounts for more than 50% of the fruit trees, 50% of the vegetable and 60% of the table grapes production of the country.

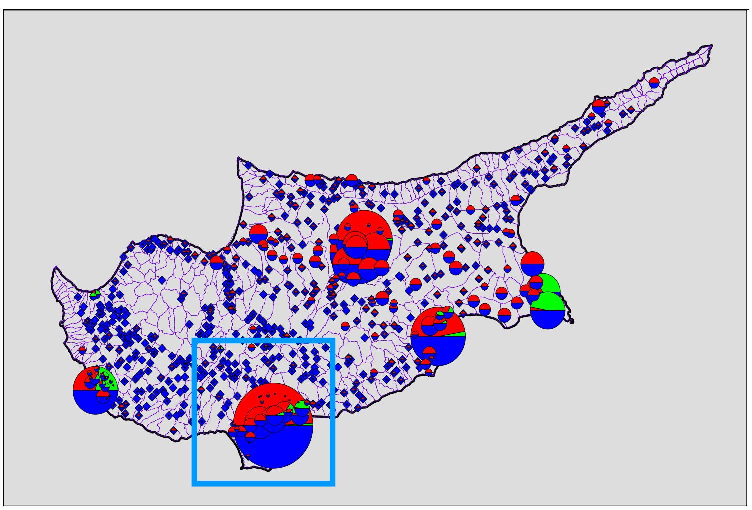

Figure 13 Permanent Population Evolution

The domestic consumption of the region accounts for almost 12.8 hm^3, while consumption for tourism (seasonal population) accounted for 3.6 hm^3 in 2000, representing almost 26% of the island's total seasonal consumption. Water for domestic use is supplied from surface waters after treatment in the Limassol Water Treatment Plant (almost 7.8 hm^3), and from groundwater boreholes and springs (almost 8.2 hm^3).

Water demand for irrigation in the region accounts for almost 31 hm^3 from which 24 hm^3 are supplied from the major Government Irrigation Schemes. Animal husbandry water requirements are estimated at 820,000 m^3. Industrial demand is also limited totalling 1.5 hm^3. However, this figure represents 43% of the total industrial demand of the island. Environmental demand is estimated at 4 hm^3 (3 hm^3 groundwater, 1.5 hm^3 landscape irrigation in municipalities, and 0.5 hm^3 treated effluent).

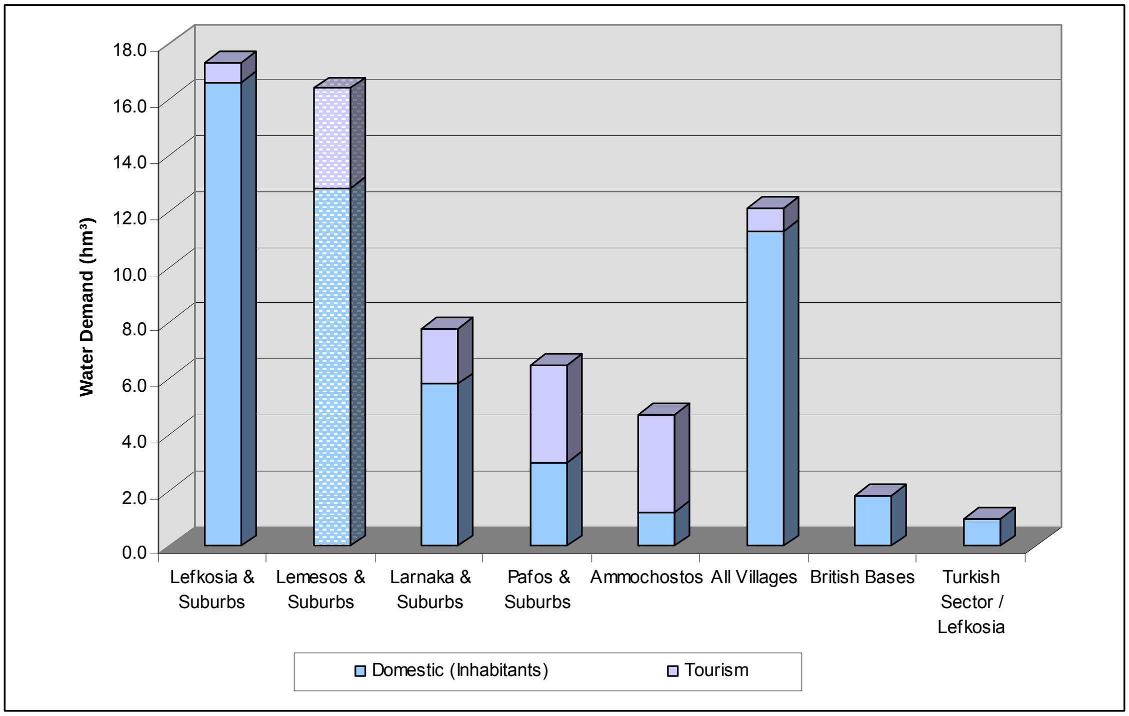

Figure 14 Domestic and Tourism demand (2000)

The main sources of water supply are:

- Surface water stored in the three dams of the region, i.e. the Kouris Dam (capacity of 115 hm^3), the Polemidhia Dam (capacity of 3.4 hm^3) and the Germasogeia Dam (capacity of 13.5 hm^3), which is used for domestic and irrigation purposes.
- Certain quantity of the stored surface water resources is treated and used for domestic purposes in the Limassol Water Treatment Plant which has a current capacity of 40,000 m^3/d with a potential capacity of 80,000 m^3/d. The plant receives raw water from the Kouris Dam and supplies water to the Limassol city, some villages west of Limassol and to the British Bases of Akrotiri.
- Ground water abstraction from a number of boreholes. Groundwater is used for domestic and irrigation purposes.
- Treated effluent from the Waste Water Treatment Plant of the Limassol-Amathus Sewerage Board, which used for irrigation of crops and landscape.

Irrigated areas in the region can be classified in two categories: (i) Areas within the Major Government Irrigation Schemes (Akrotiri West and Germasogeia-Polemidhia), where water is mostly supplied through Government Water Works, and (ii) Areas outside the Government Irrigation Schemes.

Current and emerging policies

At present, the adopted strategy for ensuring adequate water supply for all uses and responding to the current conditions of water deficit is based on a combination of policy options that include supply enhancement, demand management, social-developmental policies and institutional policies. Figure 15 analyses the DPSIR causal interrelationships and the current responses adopted in Limassol region, while the following paragraphs present the management options and instruments already implemented in the area.

In terms of **Supply Enhancement**, measures currently undertaken are:

- *Efficient pumping control:* Groundwater levels are monitored on a monthly and bi-monthly basis from a network of approximately 200 boreholes since 1960, 85 to 100 of which are regularly sampled. Groundwater pumping is quite well monitored through water meters that are observed every month. About 90% of the annual abstraction is metered and recorded at monthly intervals.
- *Water transfer from surface reservoirs:* Until 1998 part of the irrigation requirements were covered by water from the Germasogeia dam. From this year and onwards, the Germasogeia-Akrotiri pipeline is being used to transfer recycled water to the Polemidhia dam. As a consequence, there is no possibility for water transfer from the Gerrmasogeia dam. For solving the water deficit problem, water is transferred from the Kouris dam instead (~ 6 hm^3 in 2002).
- *Artificial recharge with water from surface reservoirs:* Water from Kouris dam is transferred to the region in order to recharge the aquifer at selected locations. This management option depends on the available quantities of water in the dam (in 2002 2.6 hm^3 were transferred, compared to only 0.042 hm^3 during the drought period of 1998).
- *Direct use of recycled water:* Currently a major project for using tertiary treated effluent (up to 6 hm^3) for irrigation purposes from the Limassol Central Waste Water Treatment Plant is being implemented. The recycled water is stored in Polemidhia dam during the winter period, and diverted for irrigation during the summer months.
- *Coordinated program of releases from Germasogeia and Kouris dams for artificial aquifer recharge:* The complete cut-off of natural replenishment by the construction of the Germasogeia dam and the proximity to the sea, coupled with the increasing abstraction from the riverbed aquifer made necessary the development of a coordinated programme of releases from the dam for artificial recharge, for meeting abstraction levels and minimising groundwater losses to the sea. At present, the recharge of the aquifer depends on controlled releases from the pertinent dam and its spills, and complemented with releases from the Kouris dam (6.5 hm^3 in 2002 compared to 2.3 hm^3 in 1998). With such action sea intrusion is controlled and at the same time an efficient use of the scarce water resources is made. In addition, the small Germasogeia riverbed aquifer has been turned into a natural treatment plant for domestic water supply without the need for complicated and expensive surface water treatment requiring chemicals, qualified technical personnel and necessary civil engineering structures. This conjunctive use of surface and groundwater reservoirs enabled a dramatic increase in the extraction from this aquifer (more than three times its active storage capacity is being pumped annually) deferring the need for an expensive treatment plant for many years. Groundwater is pumped mostly for the domestic water supply of the Limassol town, the surrounding villages, and the tourist zone, being the only source of water supply for the last two categories.

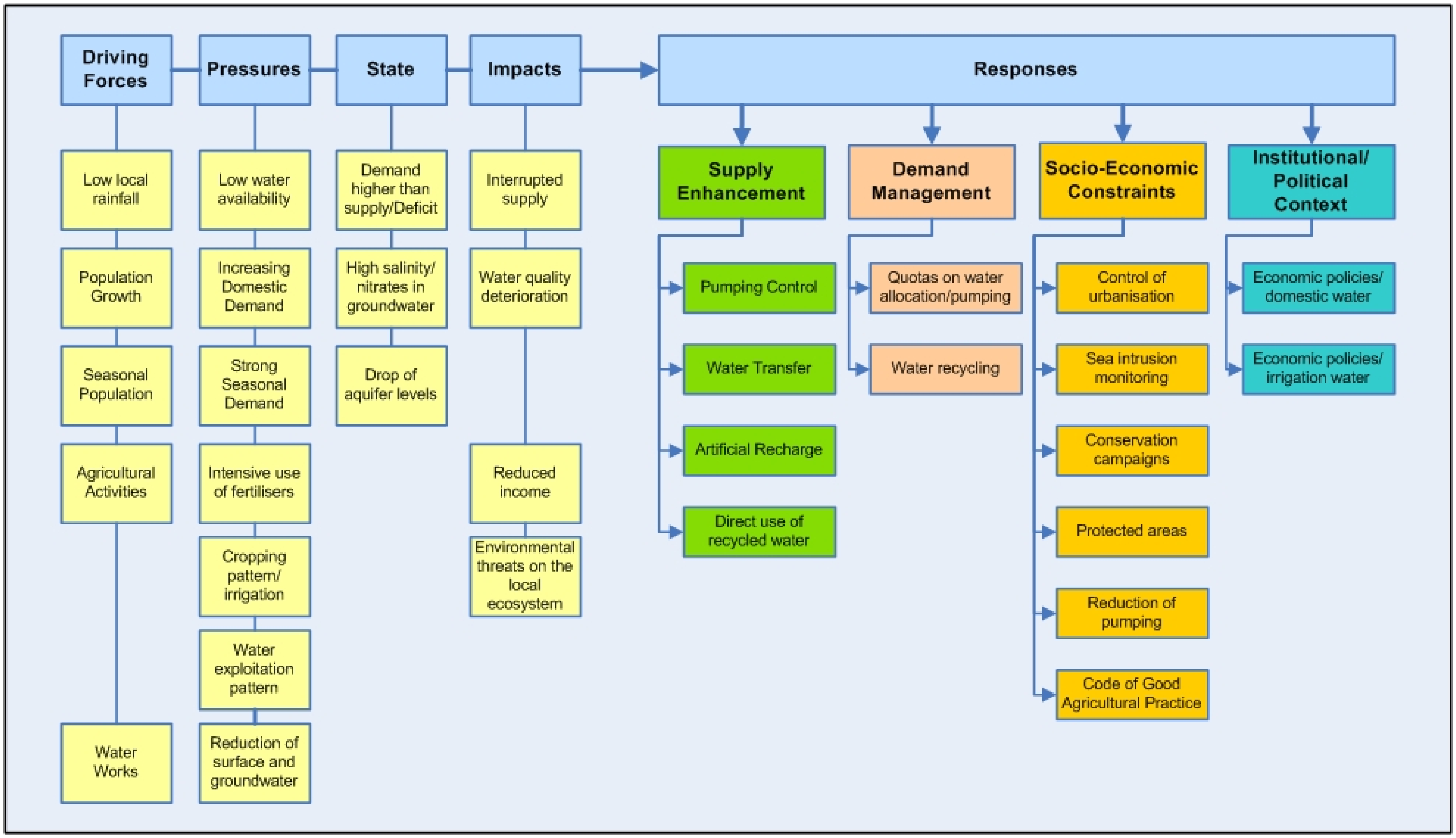

Figure 15 A DPSIR analysis and the dominant water management practices in the Limassol region

In terms of **Demand Management**, three measures are in force at present:

- *Application of special measures for water allocation (quotas):* A quota system is applied on an annual basis in the Akrotiri area for the allocation of irrigation water from the Government Water Works. Allocated quotas are based on current groundwater conditions and water levels in the surface reservoirs. The quota system in conjunction with penalty charges for overwithdrawals contributes to the efficient use of the water. Under conditions of water scarcity, especially during droughts, priority and preference is given to covering a higher proportion of the domestic supply followed by greenhouse agriculture and permanent crops. Seasonal crops under these conditions are reduced dramatically.
- *Application of special measures (water conservation law) to control drilling and pumping on an annual basis requiring water metering (quotas):* Special permits are issued on an annual basis, which determine the quantity of the water to be pumped. Preference is given to areas with problems of getting water from existing irrigation schemes.
- *Water recycling (Limassol Central Sewerage Treatment Plant):* Quantities of tertiary treated effluent (from the Limassol Central Sewerage Treatment Plant - LCSTP) are transferred at the Kouris river “Delta” area to recharge artificially the Akrotiri aquifer. It is expected that 5.25 hm^3 of recycled water per year will be produced during the first stages of the operation of the LCSTP, and 10.6 hm^3 per year at later stages.

Measures and instruments directly linked to or influencing the **Social and Developmental Policy** adopted for the region are:

- *Implementation of Good Agricultural Practice Code* regarding the use of fertilisers and pesticides: The provisions of the Code of Good Agricultural Practice are applied in the entire Akrotiri area, and include control of fertilizer use, use of improved irrigation systems and preparation of irrigation schedules, relocation (wherever possible) of animal husbandry units, slurry collection, mechanical separation and land application of piggery waste, on-going farmer training programmes, etc.
- *Strict control of urbanization within the Germasogeia aquifer area through Town Planning zoning and domestic sewage management:* A fast growing urbanisation within the Gernasogeia aquifer area (the aquifer is crossed by the Limassol-Nicosia highway, by local important roads, the main Southern Conveyor pipeline, the main pipeline and the irrigation network of the Germasogeia dam, the main pipelines of the Limassol-Amathus raw and treated sewage, the local sewage system, etc.) and tourist development are causing concern about the environmental conditions (mainly the possible deterioration of the quality of groundwater) of this highly susceptible aquifer. As a result this is considered a high risk aquifer. A number of protection measures have been applied, including strict control on the planning zones of the area. Germasogeia Municipality was one of the first Municipalities to be connected to the Limassol Central Sewerage System.
- *Reduction of pumping for domestic water supply and replacement with water from other sources:* The Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment, the responsible authority for the management of water resources in Cyprus, is examining alternative potable water supply sources for the areas depending on the Germasogeia aquifer, in order to reduce the pumping from it and use it as a strategic reserve.
- *Increased monitoring of sea intrusion propagation and adjustment of artificial recharge regime accordingly:* The hydrogeological regime and the water balance of the Germasogeia aquifer are “regulated” by controlled releases from the dam into the

river valley and continuous monitoring of sea/fresh water interface (conductivity records are kept for 10 boreholes).

- *Development of protection areas around wells and well-fields:* Due to the vulnerability of the Germasogeia aquifer, all the wells and boreholes in the aquifer are surrounded by a protection zone within which urban development is prohibited.

Institutional policies are mostly oriented towards the development of appropriate pricing policies, in order to achieve full cost recovery, minimise over-consumption and promote efficient water use, i.e.:

- *Implementation of block tariffs, seasonal prices and over-consumption penalties in domestic consumption:* The Water Board of Limassol and the local authorities of the area set progressive block tariffs, seasonal prices and over-consumption penalties to promote domestic water consumption efficiency and water conservation.
- *Adjustment of water pricing to reflect true cost of irrigation water:* Contrary to the costs of domestic water that is almost fullly charged to customers, the price of irrigation water did not cover either the full financial or the economic costs. The present tariff for the Akrotiri area is 0.06 C£/m^3. The Water Development Department is currently implementing a progressive increase of irrigation water tariffs. This will promote efficiency in water use and the promotion of conservation measures. Such an approach complies also with the provisions of the new Water Framework Directive of the EU.

Stakeholders and actors

The groups that were identified and selected for consultation in Limassol region were:

- The **Water Development Department** of the Ministry of Agriculture, Natural Resources and the Environment.
- **The Water Board of Limassol**.
- **The Sewerage Board of Limassol**: The Sewerage Board of Limassol-Amathous (SALA) was established in 1980, and its main functions are the construction, operation and maintenance of the Limassol sewerage network, the collection and treatment of sewage of the wider Limassol area, as well as the construction of drainage systems. SALA operates a waste water treatment facility (tertiary level of treatment), located in Moni (Limassol), providing on an annual basis, more than 6 hm^3 of water that can be used for irrigation purposes.
- **Municipalities and villages of the region**, which account for a significant share of the population. Many of the locals are involved in tourism, which is the main source of income for the region, and responsible for the seasonal peak on water demand.
- End-users:
    - **The Cyprus Farmer’s Association**. The Cyprus Farmers’ Union, established in 1948 represents a large majority of the Cypriot farmers. Its main objectives are to promote the successful and socially aware agriculture, while ensuring the long-term viability of the rural community.
    - The three major agricultural estates of the region, namely **Tskistou Agricultural Estate**, **Lanitis Agricultural Estate** and **Fasouri Agricultural Estate**.

Formulated and evaluated Strategies – Summary of analysis outcomes

Current water management practices in the region are determined by the competition for scarce resources between agriculture, urban growth including tourism, and the environment. Strategy formulation was therefore targeted to achieving the provision of adequate water supplies during the peak summer period for satisfying at least 80% of domestic and irrigation water requirements. This objective is in line with the perceptions of stakeholders who believe that priority should be given to the coverage of domestic demands and to the sustainable distribution of the water at a national level, while on the other hand agricultural activities should be maintained for socioeconomic reasons.

After an evaluation of the different options which, in line with stakeholder perceptions, focused on a more efficient use of available resources, two alternative strategies were formulated. These were based either on structural interventions for fresh and waste water treatment and reuse (Strategy 1), or on promoting efficiency in water use through reduction of losses, conservation and most importantly pricing (Strategy 2).

More specifically, **Strategy 1**, focuses on structural interventions, and includes already applied and planned measures which, according to the experience of various stakeholders, are expected to be effective and efficient for eliminating the problems of the Limassol water system. Measures incorporated are:

- The construction of a waste water treatment plant to serve the western, rural villages of the region ($M1_1$);
- Enhancement of water reuse for crop irrigation ($M2_1$);
- Expansion of the existing Limassol Water Treatment Plant ($M3_1$).

Strategy 2 attempts to reconcile the supply and demand by integrating “soft” interventions which can reflect a shift in the traditional water resource planning and management. The strategy formulated is highly dependent on measures dealing with internal recycling and reuse in households, and conservation measures in general, reduction of network losses, domestic and irrigation pricing. These options are introduced as complementary to the already planned structural measures, reducing their size and extending the timeframe for their implementation. Measures included are:

- The construction of a waste water treatment plant to serve the western, rural villages of the region ($M1_2$);
- Enhancement of water reuse for crop irrigation ($M2_2$);
- Expansion of the existing Limassol Water Treatment Plant ($M3_2$);
- Reduction of losses in domestic water supply systems ($M4_2$);
- Conservation measures aimed towards domestic users ($M5_2$);
- Domestic pricing ($M6_2$);
- Irrigation pricing ($M7_2$).

The analysis of both strategies portrayed that they can both adequately meet water needs for domestic and irrigation use. However, the evaluation of pricing policies, aimed at achieving an adequate contribution of both uses to the total water cost, demarcated Strategy 2 as an effective strategy in meeting the targets set for an adequate cost recovery for domestic water provision.

From evaluation to implementation – Additional considerations

Table 6 and Table 7 present some additional considerations regarding the implementation of the measures incorporated in the proposed strategies for the Limassol Case Study.

Table 6 Additional considerations for implementing Strategy 1 in Limassol region, Cyprus

Strategy Measures	$M1_1$	$M2_1$	$M3_1$
Responsible authority for implementation	CG[2] (WDD of MANRE[3])	CG (WDD of MANRE)	CG (WDD of MANRE)
Education/awareness efforts required	Yes	Yes	No
Administrative/legislative reforms required	No	No	No
Timeframe of application	> 5 yrs	Immediate	< 5 yrs
Cost considerations	High	Low	High

Some of these measures, (e.g. the expansion of the drinking water treatment plant) have already been adopted or are currently being planned by the competent authorities. Others, although already planned are facing significant opposition from the public. This is the case for the construction of the rural wastewater treatment plant. All village communities recognise the necessity of waste water treatment, and are aware of the measures imposed by the implementation of the Urban Waste Water Directive. However, inhabitants are not willing enough to accept the construction of the plant in the vicinity of their village.

In addition, the promotion of water reuse is expected to require extensive education and awareness efforts. Although the quality of the treated effluent is good, farmers are reluctant to accept it as a primary or alternative water resource. A campaign to convince farmers to accept treated sewage effluent is an ongoing process, and was supported by initially supplying treated effluents free of charge; at present interest in using this water is gathering momentum.

Table 7 Additional considerations for implementing Strategy 2 in Limassol region, Cyprus

Strategy Measures	$M1_2$	$M2_2$	$M3_2$	$M4_2$	$M5_2$	$M6_2$	$M7_2$
Responsible authority for implementation	CG (WDD of MANRE)	CG (WDD of MANRE)	CG (WDD of MANRE)	Limassol Water Board	Limassol Water Board	CG (WDD of MANRE), Limassol Water Board	CG (WDD of MANRE)
Awareness / education efforts required	Yes	Yes	No	No	Yes	Yes	Yes
Administrative reforms required	No	No	No	No	No	Yes	Yes
Timeframe of application	> 5 yrs	Immediate	< 5 yrs	> 5 yrs	> 5 yrs	Immediate	Immediate
Cost considerations	High	Low	High	Moderate	Low	Low	Low

[2] Central Government of the Republic of Cyprus
[3] Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment

The same stands for water conservation; the penetration of measures targeted at reducing domestic consumption is rather low and not popular, especially for the installation of systems for the recycling of "grey" water. Additional campaigns are required to convince end-users to reduce wasteful water use. Such efforts were successful in the past, and especially during the drought period of 1997-2001, when the Water Board of Limassol, in addition to quotas, imposed a series of measures which resulted in an overall reduction in the use of domestic water by approximately 15%:

At present, the Government of the Republic of Cyprus is in the process of implementing a major pricing reform in order to achieve adequate cost recovery on what concerns bulk domestic water supplies and irrigation water. Bulk domestic tariffs have already been set, while irrigation water prices are gradually being increased to reach a uniform charge of 0.11 C£/m^3 in 2005. With regard to domestic pricing two authorities are involved: the Water Development Department, the ministerial department in charge of Government Water Works and the Limassol Water Board which determines the final tariffs charged to consumers. Irrigation pricing is implemented by the WDD and to a lesser extent by Irrigation Divisions, since the majority of irrigation water supply is sold on a retail basis, directly to the farmer.

Ribeiras do Algarve, Portugal

Background of water management practices and emerging policies

Overview of the region

The Ribeiras do Algarve River Basin suffered, in the last decades, deep changes in its demography mostly due to the important development of the tourist activity that created a new reality. In the 1980s, one could identify a productive structure based in three "basic" activities: agriculture, fishing and tourism. In the recent years, a polarization of the regional economy is happening. Economic development is concentrated in tourist services and related tertiary activities, turning tourism and services into the backbone activities of Algarve's economy.

In 2001, the population in the Ribeiras do Algarve River Basin was about 350,000 inhabitants, about 3.5% of the total population of the country. The demographic analysis is very important in this region since the seasonality of the territorial occupation leads to an increase of the population by 150% in some periods of the year. In fact, Algarve is the main tourist region of Portugal, hosting annually approximately 5 million visitors. In 2000, this region alone supported 39% of the national ranked hotel accommodation offer, 43.1% of overnight stays (14.6 million overnights), representing also the most significant contribution (33.5%) to Portugal's hotel income.

One of the most specific demographic characteristics of the River Basin is the very unequal population distribution: most of the inhabitants are living in the littoral zone while the hinterland is suffering from a deep process of depopulation, associated with significant ageing of the population still living there. The analysis of the resident distribution evolution confirms the trend of the last decades: the disparity between an attractive littoral zone and a recessive inland region. This way, the pressure on water resources created by seasonal population is very strong, leading to water shortage problems during the summer months.

Agriculture is still important in this region, especially when compared to the national figures. In the 1950s, agriculture in Algarve evolved, mostly because of the adoption of irrigation practices, encouraged by the State, through the construction of two dams and related infrastructure for irrigation purposes. This way, it increased the influence of the most developed and enterprising farmers, creating large public irrigated areas. After that, the State stopped investing in the improvement of the water resources in Algarve for agricultural use, compelling the small farmers to create cooperatives/associations, necessary to allow for the realisation of investments in drills, pipelines and reservoirs. This way, they created larger agricultural areas, with better irrigation infrastructures and equipment. At present, both surface water and groundwater are used for agriculture. The agricultural area represents about 22,900 ha, 85% of which are irrigated with groundwater.

Concerning urban water supply, there was an important change during the last few years. The creation of a Multi-municipal supply system inverted the previous trend of aquifers overexploitation. In fact, supply is now mostly assured by surface water abstracted from the storage reservoirs in the region or imported from the Guadiana River Basin.

Traditionally, domestic and agricultural demands were satisfied through groundwater resources. In fact, the aquifers assumed an essential role in the Ribeiras do Algarve River Basin, allowing the strong development of tourism and irrigated agriculture. The available groundwater resources were sufficient to satisfy the different uses in the River Basin, and presented good quality. However, the combination of natural processes and overexploitation lead to salinization of aquifers and deterioration of groundwater quality and forced to abandon the aquifers for urban supply. In fact, in the last few years, this assisted to the substitution of groundwater by surface water. The urban water supply was based on a large number of Municipal network systems, managed by Municipalities and supplied with groundwater. In 1999, the exploitation of primary water supply systems began, based on two inter-municipal companies: one for the west part of the basin, "Águas do Barlavento Algarvio" and another one for the east part, "Águas do Sotavento Algarvio". The important change is that the system is supplied entirely with surface water from the storage reservoirs existing in the river basin: Bravura, Arade and Funcho for the Barlavento and an importing from the more recent Odeleite-Beliche dams existing in the Guadiana Basin. With the operation of these two systems a significant improvement of the water quality was observed, allowing the aquifers to recover their initial capacity and quality and also regularity in the supply to be fairly achieved. In 2000, the two companies were joined into one, "Águas do Algarve SA." aiming to serve most of the river basin territory in terms of water supply. Supply enhancement now depends on the construction of the Odelouca dam, an initiative of the National Water Institute (INAG) that will allow a significant improvement in water supply in the west part of the basin. Since 2001 Águas do Algarve S.A. also has the concession for the primary network for wastewater drainage and treatment aimed to be operational by 2006.

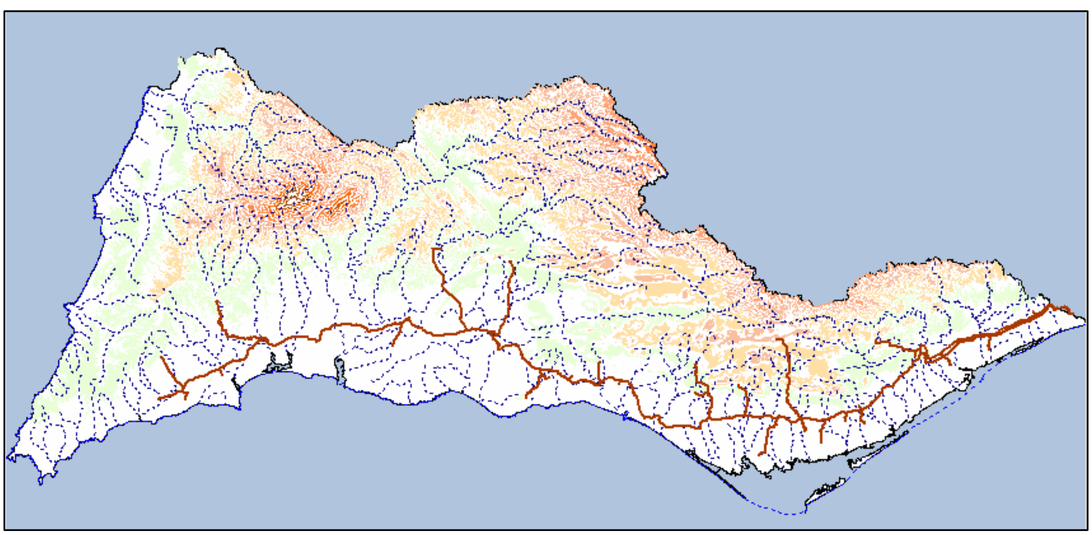

Figure 16 The Primary Water Supply System of the Águas do Algarve Company

The percentage of population served with water supply is currently 82%, but improvement is planned, aiming to achieve 95% in 2006. For wastewater drainage, the percentage is just of 73%, with 72% benefiting from treatment facilities. Urban water supply overall losses are currently high (average of 37%). It must be noted that the major losses occur in the municipal networks. The average losses in the primary system are only 2 - 5%.

In agriculture, groundwater is still the main supply resource. Only public irrigation sites are supplied with surface water. There is a low overall efficiency in agriculture water use (about 60%). This use may be added to the one correspondent to the golf courses existing in the river basin as they may also be considered as a specific kind of irrigated culture. These courses represent an important economic activity and are mainly located by the sea. They are currently mostly supplied with groundwater, but given the salinization of the aquifers, alternatives are necessary in order to eventually supply them with the outflow of wastewater treatment plants or with desalinated water. This however implies an important increase of associated costs

According to the Water National Plan, the total annual water consumption is 340 hm^3 (about 95 hm^3 returning back to the hydric environment), distributed as follows: 305 hm^3 of water are used in agriculture, 21.8 hm^3 in domestic uses, 10 hm^3 in tourism, and in industry about 2.4 hm^3. The percentage distribution of water uses per sector can be seen in Figure 17.

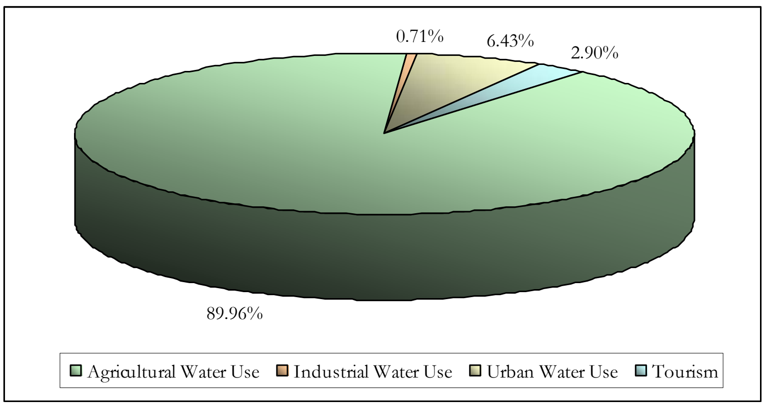

Figure 17 Water uses per sector in Ribeiras do Algarve

Current and emerging policies

Figure 18 presents the DPSIR analysis for the region. The current situation and foreseen measures are framed on national and regional planned water resources policy.

Portugal has, since 2001, a national wide planning policy and characterization in compliance with the WFD. This way, data are recent and complete, although eventually not homogeneous and accurate.

In fact, the Portuguese National Water Plan (NWP), approved at the end of 2001, is aimed to co-relate and co-ordinate the River Basin Plans measures and actions, decide inter-basin water transfers and coordinate planning actions with Spain. At the River Basin level, the River Basin Water Management Plan (RBP) (approved in 2001) and present data on, and addresses issues related to: (i) biophysics and socio-economic characteristics of the territory; (ii) legal framework and institutional organization; (iii) Portuguese-Spanish relationships; (iv) uses, demands and water needs; (v) water resources; (vi) quality and water uses; (vii) nature conservation, ecosystems and biological quality; (viii) aquatic domain and territory management; (ix) risk situations and civil protection; (x) qualitative and quantitative monitoring of water resources; (xi) water’s economy; and information, participation and co-responsibility. The fundamental articulation between those Plans is made through general and specific measures, in order to achieve short, mean and long-term (from 2006 to 2020) quantitative and qualitative goals on water resources issues.

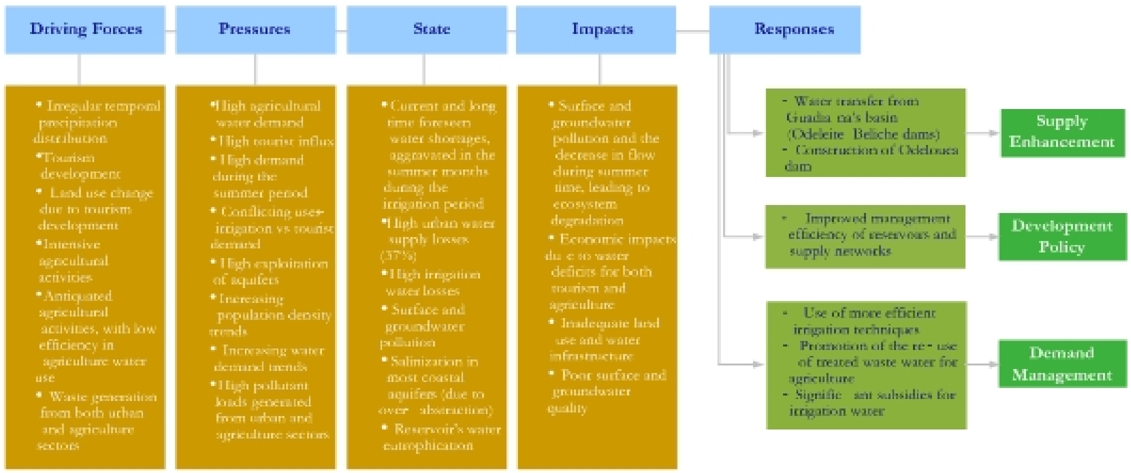

Figure 18 A DPSIR analysis and the dominant water management practices in the Ribeiras do Algarve River Basin

However, in those plans, data is sometimes insufficient, eventually not homogeneous and accurate. In order to solve that problem, some recent plans and actions were developed at national and regional levels:

- The **PNUEA** ("Plan for efficient use of water"), made public in September 2001, before the NWP official approval, is framed not only by the RBP's and the NWP, but also by the PEAASAR ("Plan on efficient use of water on urban water systems"), presented in April 2000, during the phase of elaboration of those Plans. It aims to promote the sustainability of water demand, one of the (seven) "axes of action" established by the NWP, by means of the efficient use of water on urban, agricultural and industrial sectors, aiming to contribute to minimise water stress situations. A set of actions was established in order to achieve the established efficiency goals for those three sectors over a ten-year period.
- The **INSAAR** ("National assessment of urban water systems") was launched in 2002 and will be finished by the first trimester of 2004, in order to solve the detected insufficiency of basic data and also of physical and economic information needed to assess, periodically, urban water systems. It will also help to assess the PEAASAR implementation and support the characterisation of all water uses, to be finalised by the USAP in 2004.
- The **USAP** will first analyse, update and correct the information furnished by the RBPs and by the NWP and the one existent on National and Regional Water Administrations (namely DRAOTs), and then complete it based on field work. This will enable to produce, namely, accurate:
    - Indicators of state, pressures and responses on water resources;
    - Quantification of water uses by sector of economic activity and costs associated to water services.

Both the INSAAR and the USAP follow the "programmes of measures" established by the NWP and aim: (i) to validate and update the information of the RBPs and of the NWP; (ii) to produce reliable electronically available databases and correspondent GIS; (iii) to produce indicators on the use and utilisation of water; (iv) to produce statistical information, adequate to the efficient management of different water uses; and, (v) to support the application and implementation of the WFD. In fact, currently the aims of the WFD are always taken into account in all scheduled plans of actions and measures to implement the RBPs and NWP.

Stakeholders and actors

Major stakeholders and actors involved in decision-making in Ribeiras do Algarve are:

- The **Ministry of Cities, of Land-use Planning and Environment (MCOTA):** This Ministry has two consulting councils to support it in policies definitions: The National Council for Environment and Sustainable Development (CNADS) and the National Water Council (CNA). The CNA has particular responsibilities in the elaboration of the National Water Plan (PNA) and the River Basin Water Management Plans. The Ministry has the task to define, co-ordinate and execute environmental policy and territory ruling. In particular, its main responsibilities are to:
    - Manage national water resources on a global and integrated way in order to achieve a temporal balance between water availability and demand and control pollution, safeguarding the aquatic environment, and
    - Guarantee integrated and sustainable coastal management, based on different institutions, as INAG, DRAOT (now CCDR), DGA and ICN.
- **National Water Institute (INAG):** It is the institution from the MCOTA responsible for the national policies on water resources and water supply and drainage, namely to:
    - Develop information systems on national water availability and needs,
    - Promote integrated planning on a river basin scale, and coastal zones,
    - Promote conservation of national water resources on quantity and quality, etc.
- **Commission for Regional Coordination and Development of Algarve (CCDR Algarve):** The Commission for Regional Coordination and Development of Algarve is one of the five CCDR's recently created (end of 2003), and integrates DRAOT Algarve. CCDR Algarve is an official body of the Ministry of Cities, of Land-use Planning and Environment (MCOTA), responsible for the examination of regional policies on environment, land-use, and economical and social planning, taking into consideration the integrated regional development of the Algarve Region. It is responsible for the elaboration of studies, programmes and coordination of public investments in the region. CCDR Algarve also undertakes the elaboration of regional river basin management plans, regional and municipal land-use plans, regional development plans and coastal zones plans. CCDR Algarve is further responsible for the macroeconomic and social impact evaluation process of the multiple programmes, interventions and large regional development projects. DRAOT Algarve, integrated in CCDR Algarve, has as main action the implementation of the national policy and objectives in the area and of the environmental and land-use planning policy, aiming to ensure environmental quality, the adequate organization and utilization of the territory and conservation of nature, and the execution of the necessary measures for a correct utilization and exploitation of resources. It also has to assure the:
    - Elaboration of the Regional River Basin Plans,
    - Articulation, in strict collaboration with the services of other ministries, between environmental, land-use and urbanism policies and the sectoral policies,
    - Coordination and supervision of the execution of the environmental policy, and
    - Collaboration in the preparation of integrated programs for regional development.

- **National Institute of Rural and Hydraulics Development (IDRHa):** This Institute is a central service of the Ministry of Agriculture, of Rural Development and Fishing (MADRP). Its main responsibilities are to:
  - Develop information systems on water needs and current utilisation of water resources in agriculture,
  - Support water resources conservation and use and hydro-infrastructure development on agriculture.

  The institute also has a very important role in the administration of the four Public (State) Irrigation Sites and develops joint work with the existing farmers associations in the region (see below, Farmers Associations).
- **Águas do Algarve, S.A.:** This Company is integrated in the "Águas de Portugal" Group, a holding company (with major public capital, under private right statutory rules). Águas do Algarve is shared between the Águas de Portugal Group (51%) and the Municipalities of Algarve (49%). Created in 2000, resulting from the union of "Águas do Barlavento Algarvio" and "Águas do Sotavento Algarvio", Águas do Algarve Company has the concession for the already operational Multi-municipal primary water and wastewater drainage (expected to be operational by 2006) systems. Being responsible for the primary water system, the company supplies fifteen of the eighteen municipalities in the river basin.
- **Association of Municipalities of Algarve (AMAL):** The river basin is divided in eighteen municipalities, and fifteen of those comprise the Association of Municipalities of Algarve. Each of the municipalities is responsible for the secondary (domestic) networks of urban water supply as well as of wastewater drainage and treatment. The main purpose of this association is economic, social and cultural development. The AMAL is involved in the elaboration of common development programmes for the municipalities and in the management, planning, promotion and financing of their execution. The Commission for Regional Coordination and Development of Algarve, recently created, also has an important role in the decentralization process dynamics. In fact, CCDR Algarve supports the municipalities in the juridical, economical, financial and technical fields, paving the way for endowing them with better operational and technical capacities.
- **Farmers Associations:** They represent the farmers of the Public Irrigation Sites existing in the River Basin. They manage water resources and plan their utilisation in the area of the irrigation site. One can identify three major farmers associations:
  - Farmers Association of the Mira Public Irrigation Site;
  - Farmers Associations of the Alvor Public Irrigation Site;
  - Farmers Association of the Silves, Lagoa and Portimão Public Irrigation Site.
- **Tourism:**
  - **Algarve Tourism Office:** The Algarve Tourism Office has administrative, financial autonomy and its own patrimony. It is responsible for defining the tourism policy of the region and for planning and executing of all the actions that can promote Algarve as a tourist destination. It also has the mission of tourism characterisation of Algarve, elaborating regional plans of actions and collaborating with the local administrative entities.
  - **Hotel Industry Association:** The Hotel Industry Association ("Associação dos Industriais Hoteleiros e Similares do Algarve – AIHSA") represents the major undertakers of the tourism sector in the region.

These different parties have responsibilities at different levels; however, all are interrelated through the need for supporting the implementation of different options and instruments from the national to the regional level and from the regional to the local level.

Formulated and evaluated Strategies – Summary of analysis outcomes

Following stakeholder consultation, and the evaluation of the different options, two strategies were formulated, aimed at:

- Meeting 95% of domestic, particularly in the West part of the Ribeiras do Algarve River Basin, and solving localized deficits in irrigation;
- Promoting measures that prevent degradation of environmental resources focusing on aquifers overexploitation. These measures apply particularly to coastal aquifers, where overexploitation increases salinisation risks;
- Promoting measures that enable to attain the economic efficiency and environmental sustainability of water use through the evaluation of direct and environmental costs and rate of cost recovery optimization taking into account the cost recovery principle.

The structuring of both Strategies (1 and 2) reflects the concerns of stakeholders in trying to respond to above pre-defined goals, adopting two distinct approaches. While Strategy 1 comprises structural and global water management measures, Strategy 2 includes alternative, decentralised options for solving water shortage issues on a local scale.

In more detail, **Strategy 1** translates the preferential use of structural options aimed at solving water deficiency problems. The most important intervention is the construction of the Odelouca dam that follows the current trend in the region through the increase of surface water exploitation. The other measures considered are in accordance with the Ribeiras do Algarve River Basin Plan. In particular, measures incorporated in Strategy 1 are:

- New abstraction boreholes ($M1_1$)
- Primary supply system expansion ($M2_1$)
- Irrigation method improvements ($M3_1$)
- Dam construction ($M4_1$)
- Reduction of losses in secondary distribution networks ($M5_1$)

Strategy 2 does not represent a shift from structural to non-structural options. In the Ribeiras do Algarve River Basin, stakeholders have been considering alternatives to previously adopted measures aiming only to increase water availability. However, these new measures are more related with a new approach of the problems faced: the effort to solve problems at smaller, local scale rather than introducing regional, traditional options. Water management measures like desalination, water re-use and conservation measures translate this new approach. Measures incorporated in Strategy 2 are:

- Water reuse ($M1_2$)
- New abstraction boreholes ($M2_2$)
- Primary Supply System expansion ($M3_2$)
- Desalination ($M4_2$)
- Irrigation method improvements ($M5_2$)
- Conservation Measures in the domestic sector ($M6_2$)
- Reduction of losses in secondary distribution networks ($M7_2$)

The undertaken analysis portrayed that both strategies are effective in meeting the predefined goals. Moreover, Strategy 2 performs better as the same levels of effectiveness are reached through lower direct, environmental and resource costs. After the development of a cost recovery strategy, aiming to assist to the achievement of the Water Framework Directive Goals, Strategy 2 appears to hold an additional advantage compared to Strategy 1.

Therefore, one of the overall conclusions drawn from the analysis is that the combination of localised, non-conventional measures allows achieving the same domestic demand coverage levels while presenting lower values of direct and environmental costs.

From evaluation to implementation – Additional considerations

Table 8 and Table 9 present some additional considerations for the implementation of the measures incorporated in the two strategies. Measures dealing with enhancement of water supplies (i.e. boreholes, expansion of the primary water supply system, and construction/operation of the Odelouca dam) fall under the responsibility of Águas do Algarve S.A. However, enhancement of both surface and groundwater supplies should be performed in collaboration with the Commission for Regional Coordination and Development of Algarve (CCDR Algarve) and the National Institute of Rural and Hydraulics Development (IDRHa). Implementation of water reuse falls under the responsibility of CCDR Algarve, but also under the authority of Águas do Algarve S.A., since the company currently has concession for the construction and operation of the primary sewerage network as well.

Table 8 Additional considerations for implementing Strategy 1 in Ribeiras do Algarve, Portugal

Strategy measures	$M1_1$	$M2_1$	$M3_1$	$M4_1$	$M5_1$
Responsible authority for implementation	Águas do Algarve, S.A.; CCDR-Algarve; IDRHa	Águas do Algarve, S.A.	CCDR-Algarve & IDRHa	Águas do Algarve, S.A.; CCDR Algarve; INAG	CCDR Algarve; Municipality
Education/awareness efforts required	Yes	No	Yes	Yes	Yes
Administrative/legislative reforms required	No	No	No	No	No
Timeframe of application	Immediate	2-3 years (minimum)	1-2 years	5 years (minimum)	Scheduled along 15 years
Cost considerations	Low	Medium	High	High	Low
Impact mitigation required	Serious	None	None	Serious	None

The serious opposition experienced in the past for the construction of the Odelouca dam indicates that efforts to elucidate the public for the benefits derived from its construction are needed. Similar awareness effort is required so at to promote the replacement of secondary distribution networks in municipalities, for the promotion of water reuse and for the abstraction of new boreholes, which will be used for domestic supply instead of irrigation. Serious impact mitigation is considered to be a prerequisite for the increase of groundwater abstractions (measures $M1_1$ and $M2_2$), and for desalination. The latter consideration is preliminary and associated with potential impacts from brine discharges and sea or brackish water intakes.

Finally, it should be noted that water reuse ($M1_2$) and desalination ($M4_2$) have never been implemented in Ribeiras do Algarve, or in Portugal in general. Therefore, the implementation of these requires implementation of rules and relevant legislation with regard to operation/exploitation, effluent disposal and water quality standards.

Table 9 Additional considerations for implementing Strategy 2 in Ribeiras do Algarve, Portugal

Strategy measures	$M1_2$	$M2_2$	$M3_2$	$M4_2$	$M5_2$	$M6_2$	$M7_2$
Responsible authority for implementation	CCDR-Algarve, Aguas do Algarve S.A.	Águas do Algarve, S.A.; CCDR-Algarve; IDRHa	Águas do Algarve, S.A.	CCDR-Algarve	CCDR-Algarve & IDRHa	CCDR-Algarve	CCDR Algarve; Municipality
Education/awareness efforts required	Yes	Yes	No	Yes	Yes	Yes	Yes
Administrative /legislative reforms required	Yes	No	No	Yes	No	No	No
Timeframe of application	Immediate	Immediate	2-3 years (minimum)	2-3 years (minimum)	1-2 years	1-3 years	Scheduled along 15 years
Cost considerations	Low	Low	Medium	High	High	Low	Low
Impact mitigation required	None	Serious	None	Serious	None	None	None

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