Developing Strategies for Integrated Water Resources Management in Water Deficient Regions

Methodological Approach and Case Studies

Preface

This volume outlines a methodology for the formulation and evaluation of improved and integrated water management strategies for water deficient regions, which was developed 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*.

A strategy is defined as *"a carefully devised plan of action to achieve a goal, or the art of developing or carrying out such a plan"*. On the other hand, tactics are defined as *"the dispersing and manoeuvring of forces to accomplish a limited objective or an immediate end"*. Throughout the analysis presented in this report, a strategy is considered to be *"the employment of all policies/ options available in a Case Study Region for the accomplishment of the objectives of Integrated Water Resources Management and the mitigation of water stress conditions"*.

Water stress problems in the arid and semi-arid regions of Southern Europe are different to those faced by Northern European countries. The decline of water resources, in combination with increasing demand for freshwater, causes conflicts among competing users, even in comparatively water rich areas. Until now, water planners and managers have mainly focused in the identification and coverage of growing demands for water primarily through long-range demand projections and the construction of large facilities for the storage, conveyance and treatment of water. Appropriate water management tools and decision-making practices, along with well-planned interventions aiming at increasing the availability of supply and/ or managing the growing demand, are necessary to solve the problems related to water deficiency.

Responding to the above challenge, this document disseminates a step-by-step procedure that, through stakeholder participation, can lead to the development of new strategies for improved water resources management. The methodology consists of a number of steps for the identification and selection of the stakeholders, a procedure for stakeholder consultation in order to identify objectives, goals and responses, the evaluation of different options, and the formulation of a new strategy founded on the principles of Integrated Water Resources Management. The approach is complemented through the development of appropriate cost recovery strategies taking into account the principle for the recovery of costs and the adequate contribution of water use sectors, in line with the requirements of the Water Framework Directive.

This volume is structured in two Parts.

Part I (Chapters 1 to 8) elaborates on the principles and the methodology developed for the formulation and evaluation of improved, integrated water management strategies. Chapters 3 to 7 present the validation of this methodology, and the results from its application in five Case Studies of the WaterStrategyMan project: Paros Island (Greece), Belice Basin (Italy), Tel Aviv region (Israel), Limassol region (Cyprus), and Ribeiras do Algarve (Portugal). Chapter 8 presents some concluding remarks.

Part II is dedicated to the presentation of the outcomes of a building block of this methodology, elaborating on results from the evaluation of different applicable options in the analysed regions. The aim of this evaluation, in the broader objective of Strategy Development, was to select, out of a range of proposed management methods, those that can be most effective and efficient in alleviating water scarcity related issues.

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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Part I
Developing Strategies for Water Deficient Regions
Methodological Approach and Case Studies

Chapter 1 Introduction

The goal of the WaterStrategyMan project ("Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions") was the study of the differences between quantity and quality dimensions in water management, and the development of alternative options and long-term scenarios, under the perspective of water stress problems experienced in arid and semi-arid regions. Those objectives were undertaken through the establishment of a broad framework on the existing knowledge on Integrated Water Resources Management practices, while highlighting the importance of regionalization and the relevant cultural context in the participating countries.

The adopted research approach was based on the successive generalization resulting from systematic analysis of specific conditions (Figure 1-1). On the basis of a generalised concept for aridity, the analysis of specific regions provided "lessons" that were used to develop Regional Models, to be further analysed through Case Studies.

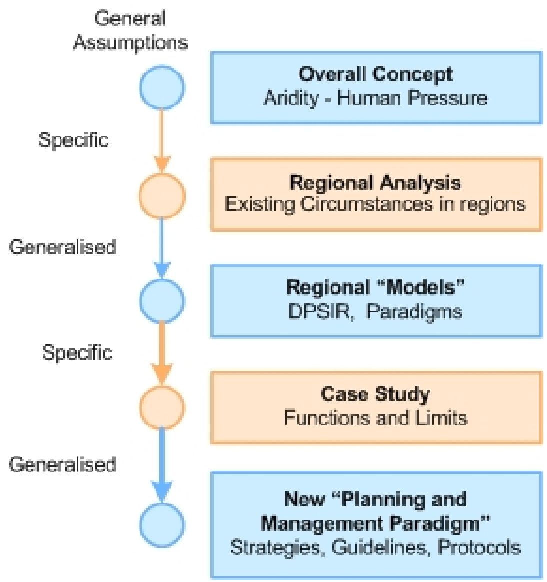


Figure 1-1 The research approach adopted in the WaterStrategyMan project

Following from the completion of the Strategies, the final outcomes of the WSM Project were the development of Guidelines for Integrated Water Management, and the development of Protocols of Implementation. Strategy Guidelines are a set of instructions that analyze the actions required within the available water management options in a given strategy, set within a suitable but flexible time framework. The Guidelines for Integrated Water Management (WaterStrategyMan, 2005a) provide:

- The applicability and parameters for each separate examined option,
- The hands-on experience in the case-study regions for each option, and
- The simulation experiences in the case-study regions for each option.

A protocol is defined as a comprehensive set of measures for regulating human activities and preserving the environment. On the basis of Integrated Strategies, formulated in the course of the WaterStrategyMan project, the Protocols of Implementation presented an initial analysis of regional requirements for their implementation, primarily classified in terms of institutional reforms, education and awareness campaigns, cost recovery issues and impact mitigation requirements (WaterStrategyMan, 2005b).

Typology Definition and Identification of Paradigms

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

This spectrum of circumstances, with particular emphasis to water stress issues was analysed in 6 countries (Greece, Italy, Israel, Cyprus, Portugal and Spain) and within 15 specific regions (WaterStrategyMan, 2004a). The main observation made was that aridity should be understood in a wider context encompassing both natural and man-made processes. Various concepts have been used to exemplify a prevailing confusion among such terms which signify dry environments or water deficiencies. The terms vary all the way from the extremes of desert to aridity, to drought and to temporary water shortages (Vlachos, 1982; Bailey, 1998). There are four different terms that are important to the initial separation between physical and social conditions with regard to what one can summarily label water deficiencies:

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

The range of circumstances in the 15 regions was analyzed on the basis of a series of well-defined indicators describing various issues of water management, such as water availability, water quality, use patterns and types of demand pressures (seasonal, permanent), pricing systems and tariffs, social capacity building, and institutional framework (water competent authorities, decision making processes and development priorities). On the basis of the spectrum of water management circumstances in the 15 regions, a typology for water stress conditions was proposed (Figure 1-2). The typology categorises the 15 regions into four broad Types with respect to the processes leading to water stress, and to the water stress context - man-made or natural processes, causing temporary or permanent water deficiency. These were further elaborated, to distinguish between the dominant regional socio-economic characteristics and sectors mostly affected by water stress and permanent deficiencies (see Table 1-1 below).

At the same time, responses to water deficiency problems, technological and social, as well as legal mechanisms for carrying out management schemes tend to fall under the following four major categories:

- Strong incentives for efficient or new uses, including economic benefits, redefinition of the doctrine of beneficial use, etc.
- Structural changes, such as new organizational arrangements, creation of new water agencies, etc.
- Regulatory counter incentives, such as stricter enforcement and pricing policies.
- Changes in water lifestyles and cultural practices.

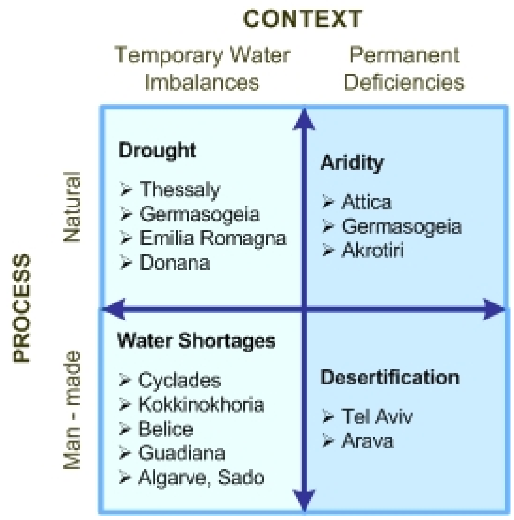


Figure 1-2 The proposed typology of water stress conditions

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

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

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

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

The DPSIR approach (Walmsley, 2002; Smeets et al., 1999), which is often used for the assessment of water management systems using indicators describing the existing Drivers, Pressures, State, Impacts and Responses, lends itself to a new interpretation in the description of Paradigm formulation (Figure 1-3). The Drivers and Pressures and their impact of water stress on the system are defined in terms of a Typology (see Table 1-1), whereas the Paradigm corresponds to the dominant responses used to mitigate water stress.

The process of eco-adaptation means that the regional Paradigms are not static, as they both influence and are influenced by the regional characteristics in a continuous cycle. The responses employed to modify the water system are subject to the judgment of the local society; the most successful of these will be used again, and combined with any "new" methods that have been shown to be effective under similar circumstances. This new combination of responses constitutes an "Emerging Paradigm" that may in turn become dominant after it has been proven effective.

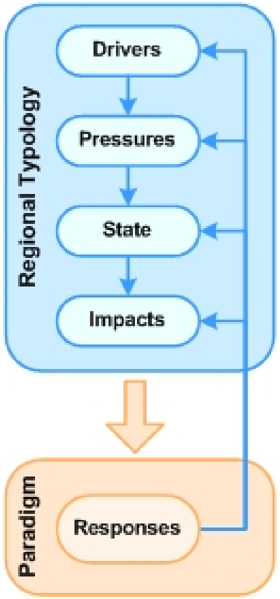


Figure 1-3 Paradigm development in the DPSIR context

In this context, and according to the above premises, six regions were selected out of the total of 15 analysed, and developed as Case Studies for the formulation and analysis of improved water management practices. These are Paros island in the Cyclades complex, Greece, Belice Basin in Sicily, Italy, Limassol Region in Cyprus, the region of Tel Aviv in Israel, the island of Tenerife in Canary Islands, Spain and the Ribeiras do Algarve river basin in Portugal. A brief description, focusing on typology of water use, current and emerging water management issues, and dominant responses to water deficiency is presented below, and summarised in Table 1-1.

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

- *Typology:* Predominantly tourist (Type II), insular.
- *Dominant Paradigm:* Since the water demand started to grow significantly in the 1980s, the residents of Paros have attempted to cover the water deficit through the construction of private and public drills, a small dam, seven interception walls and a small (1,450 m^3/day) desalination plant. However these have not been the subject of a systematic effort, and as such the policies followed have led to a number of problems in terms of both hindering economic development and exerting pressure to the environment. The dominant Paradigm on the island shows a strong tendency towards small-scale structural supply enhancement solutions.

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

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

demand. The Dominant Paradigm in the region is focused on the construction of large-scale supply enhancement infrastructure.

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

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

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

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

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

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

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

- *Typology:* Predominantly tourist (Type II), regional.

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

Table 1-1 Summary presentation of identified types

Typology	Description of underlying conditions	Regions
I (Predominantly Urban)	▪ Regions including metropolitan/large urban centres. ▪ Main economic activities largely belong in the tertiary sector, although secondary sector activities are also present. • Water deficiency is either: • Permanent, due to insufficiency of resources for the existing population, or • Seasonal due to meteorological / hydrological fluctuations. ▪ Some price elasticity in water supply.	Tel-Aviv
II (Predominantly Tourist {insular / regional})	▪ Regions or islands dependent on tourism, with small to medium sized urban centres and large seasonal population fluctuation. ▪ Dependence on agriculture as well but the main source of income is tourist activities. ▪ Seasonal water deficiency as a result of the population fluctuations due to the tourist industry's peak in the summer months. ▪ Price elasticity is variable, depending on the local conditions.	Paros, Tenerife (insular) / Limassol, Algarve (regional)
III (Predominantly Agricultural)	▪ Regions dependent on agriculture, with small to medium sized urban centres and limited population fluctuation. ▪ Dependence on secondary and tertiary sector activities is often limited compared to agriculture, which is the main source of income. ▪ Usually seasonal water deficiency as a result of increased crop requirements of water in the summer time. ▪ Price elasticity is variable, depending on the local conditions.	Belice Basin

Analysis of Water Resource Systems – The WSM DSS approach

In the framework of IWRM, *"The concept of water resources assessments should be interpreted to imply a holistic view of the water resources situation and its interaction with societal use in a country or region. The assessment should address the occurrence in space and time of both surface- and groundwater quantities and associated qualities, and give a tentative assessment of the water requirements for the assumed development. In this respect there is a distinct need for comparative measures of water use efficiency and intensity in use (i.e. product per drop)."* (Global Water Partnership, 2000).

Taking the above into consideration and with regard to the specific characteristics of the analysed regions, the identified paradigms and the selected Case Studies, a GIS-based Decision Support System was developed, the WSM DSS. The aim was to provide an integrated Decision Support System for the systematic evaluation of water management interventions for a long time horizon, simulating long-run accumulative effects and anticipating potential future changes and uncertainties. It should be noted that a variety of models and systems have been developed for water allocation and quality estimations, such as MIKE BASIN by DHI, or WEAP by the Stockholm Environment and Tellus Institute. However, the need emerged for the development of a prototype DSS which could combine the multidisciplinary information needed for the analysis of strategies and evaluation of their effects, taking into account economic, hydrologic and environmental interrelationships in the context of the economic principles of the Water Framework Directive.

The developed prototype GIS Decision Support System of the WaterStrategyMan project aims to assess the state of a water resources system in terms of sources, usage, water cycles (pathways) and environmental quality in a simulation environment that responds realistically to external and internal modifications (WaterStrategyMan, 2004b). It has the potential to evaluate the effects of actions and measures proposed or adopted, on the basis of the different scenarios, alternatives and policies. Within the simulation, water resources are allocated according to a set of demand and supply priorities reflecting the pricing system, social preferences, environmental constraints and developmental priorities. Among the many ways of classifying implementation approaches or policy options, social system responses are of particular importance for the WSM DSS, being conceived as four types of management options:

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

Key words in the WSM modelling approach are: *Description*, *Assessment*, *Strategy*, *Forecasting* and *Evaluation*. They reflect the main functions of the DSS, which, through the assistance of Geographical Information Systems (GIS) and properly customised databases, aim at:

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

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

Under this context the WSM DSS played a fundamental role in the formulation and analysis of improved and integrated water management strategies in the undertaken Case Studies, providing a coherent framework for their articulation, modelling and systematic evaluation.

The Context for Regional Strategy Development

A water resources management strategy is different to the master plans that countries and/or regions develop. Master Plans tend to be project-oriented, and the product of a master plan is often a specific set of projects to be undertaken, with the corresponding investments. Master plans can follow an accepted strategy, as a set of interventions planned within its framework of the strategy; however without reference to a specific strategy, a master plan can easily disregard the long-term issue of building water management capacity (Le Moigne and Subramanian, 1994).

On the other hand, the product of strategy formulation on a national level is not a specific set of projects. It is a set of medium- to long-term action programmes to support the achievement of development goals and to implement water-related policies that does not include project identification, ranking, or financing. A strategy should address a wide variety of aspects of water resources management, including the institutional and human resources framework and the enhancement of water management capacity.

Usually, four levels of administration in planning and management of water resources can be distinguished (Webster and Le-Huu, 2003):

(i) **National water resources planning / management.** This may be the function of a single coordinating agency (e.g. a National Water Authority or Committee), different Ministries etc.

(ii) **Sectoral level planning / management.** This involves inter-agency cooperation in one sector, e.g., potable water supply. Even within a sector, there may be many agencies operating because of duplication, functional sub-division of the sector, or creation of separate agencies for different geographic areas.

(iii) **Single organization planning /management**, e.g. an urban wastewater authority or an irrigation authority.

(iv) **Sub-national (Regional or River Basin) area-based planning/management**. Examples would include competent authorities on a River Basin District Level, or authorities managing particular ecosystems. These organizations/authorities may have broad powers and operate essentially as a single agency (similar to case iii above) or may be more coordinative in function, more closely resembling case i).

Priorities that should be addressed in strategic planning differ, according to the level of administration. An example is outlined in the Table 1-2.

According to the World Bank (2002), the core objective of new strategies for water management and planning should be the development and management of water resources in ways that contribute to the stimulation of sustainable economic growth and poverty reduction at both national and regional. Under this concept, such a strategy should be built upon the following:

- There is a major need for more effective management of water resources, to ensure increased benefits across sectors while taking into account the diverse interests of stakeholders.
- There is need for greater attention to water allocation, demand management, water rights and the use of pricing and other economic instruments.

- There is a major need for improving the benefits from existing infrastructure, and for developing institutional and financial arrangements for sustainable rehabilitation and maintenance.
- Appropriate management and institutional actions need to be complemented by major investments in new hydraulic infrastructure. These investments require long-term financing, and financing requirements will only continue to grow as costs increase.
- As demands for water services rise, increases in supply will require use of ”next generation” technologies, including demand management, inter-basin transfers and sharing of benefits from transboundary waters. Together, these result in significant increases in (financial and transaction) costs of delivery.
- Potential returns to packages of management and infrastructure investments are large. In many countries, investments in water resources management infrastructure potentially have high direct and indirect economic growth and development payoffs (including mitigation of climate change impacts on the poorest and conflict prevention). There are risks, but there are also high returns.
- Sound water resources management is a significant public good (flood control, inter-basin and transnational issues) and is part of an effective strategy for poverty reduction (employment generation, health and livelihood enhancement).

Table 1-2 Priorities for Strategic Planning and Management of Water Resources (Webster and Le-Huu, 2003)

At the National Level	
Priority 1	(1) to provide frameworks and directions for: overall development, water sector and organizations (2) to facilitate coordination among: agencies, sectors and stakeholders (3) to improve implementation: funding, accountability monitoring, resources mobilization
Priority 2	(1) to bridge the present and future: to identify problems, to overcome present weakness (2) to respond to uncertainties and to enhance flexibility
Other	(1) *Management:* to share water among sectors & regions (2) to achieve the targets within a specified timeframe
At the Sectoral Level	
Priority 1	(1) to take into consideration different institutions, stakeholders, agendas of the different sectors (e.g. forestry, environment, lands, mines, protected areas) and encourage their participation (2) to achieve expected outcomes within an anticipated timeframe (3) to identify common objectives and a shared vision
Priority 2	(1) to enable rapid development competing from limited resources (2) to provide criteria for allocation of limited budgets (3) to provide guidance in achieving tangible expected outcomes (4) to coordinate long term/short term activities
Other	(1) to improve the legal framework, reconciling many laws (2) to re-audit performance (3) to conserve water resources for sustainable use (4) to address needs of different target groups with different abilities to pay
At the Organizational level	
Priority 1	(1) to establish an effective action plan (2) to identify clear goals and to create partnerships to achieve the mission
Priority 2:	(1) to establish success (target) indicators (2) to strengthen internal environments

Many of these issues are complex, contentious and longstanding, and are beyond the scope of formulating water management strategies on a regional/organisational level. At the regional level water related issues are managed in different families and units, with varying degrees of cohesion and coordination. However, this fuzzy organizational arrangement is not a drawback. Water is a cross-cutting issue and as such it would likely be counterproductive to centralize its management. At the same time, however, communication between stakeholders and decision makers in the different sectors is of high importance, for identifying and dealing with cross-sectoral issues, such as water allocation between sectors, pollution control in an upstream-downstream dimension, and the multi-purpose use of water infrastructure. Therefore, issues that need to be addressed in regional strategic planning can be:

- Sub-regional analysis of the economic, social and environmental feasibility of irrigation rehabilitation, the energy/water nexus, water and salt strategies, and water and wastewater strategies in industrialized areas;
- Continuing work on mitigating the effect of environmental pressures by improving living conditions and reducing poverty;
- Improving soil and water conservation and watershed protection in rain fed agricultural areas, rangelands and forested areas;
- Support to wetland, grassland and fisheries restoration in the delta areas;
- Continued assistance to address the legacy of water pollution from mining and industrial wastes;
- Support to end-user associations for the management of on-farm irrigation and drainage infrastructure, and for strengthening and improving transparency of the financial management of water delivery institutions;
- Restructuring water utilities in major urban areas, in order to improve service levels and move towards financial viability;
- The use of both advisory and investment tools for the facilitation of benefit sharing on international rivers;
- Acting where there are powerful forces demanding solutions, and not in response to an idealized notion of how a sector should be managed;
- Understanding that the reform process is dialectic and never final – each “success” gives rise to a new, and hopefully “higher” form of challenge;
- Providing reforming policies in accordance to international best practice;
- Fostering the synergies that can be created when members of different parts and members of different families work together on water issues;
- Improving the efficiency of water use in agriculture (and, in particular, a focus on reducing “real losses” – water lost through evapotranspiration – rather than “paper losses” – water which percolates down into the aquifer);
- Reinforcing strong traditional community-based management systems for the management of flash flood flows in the coastal rivers;
- Improving the efficiency of urban water supply;
- Addressing the enormous task of sustainable management of selected aquifers.

The achievement of the above is strongly linked with the organizational level, which has as an ultimate goal to allocate water in quantity and quality terms for different purposes. The process for achieving IWRM involves resource assessments, planning, decision making, implementation and policing on allocations and use of water resources with and based on the interest of stakeholders. These processes are time and location specific, requiring among others (a) problem analysis (b) activity analysis (c) demand analysis and demand forecasting (e) formulation of objectives and constraints (f) design of alternative water resource systems (g) System analysis (h) system simulation and/or optimization (i) multi-criteria and multi constraint trade-off analysis, and (k) simulation and analysis of conditions (Savenije, 1997).

While formulating, simulating and evaluating strategies on a regional level, the primary aim of the WSM Case Studies was to underpin issues that influence the decision making process, and formulate improved responses that could efficiently mitigate water stress, in line with the prevailing cultural and environmental context. The developed methodology for meeting the above requirements in planning and decision making, and eventually formulating regional water management strategies is presented in the following chapter.

Chapter 2 Methodology for Strategy Development

Introduction

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

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

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

Methodology Overview

In order to achieve the desired integrated approach to water resources management, it is necessary to take into account not only the allocation of the water and the related direct and environmental costs in keeping with the IWRM principles, but also to incorporate the issue of the recovery of costs, one of the key points of the WFD.

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

A key factor was the participation of Stakeholders and end-users, an important aspect that distinguishes the process of strategy formulation. Stakeholder participation involves those who are affected by or involved in water resource management decision making. In the process of strategy formulation, it ensures transparency and accountability for decisions and promotes commitment to the decisions made. It provides unique insight and hands-on experience in the issues of the region in question, and a range of responses potentially unidentified under different circumstances. It is important however to avoid the over-politicization of issues.

The first step of the methodology was therefore to approach stakeholders and decision makers, and to collect their opinions on Water Management in their regions, discuss the regional development goals, which should guide the entire process of formulating the strategy, as well as their own perception of the problem and its solutions. They were able to provide a wide overview of the specific issues that they have had to deal with, as well as identify solutions that they have successfully (and unsuccessfully) employed. They also proposed their own specific development goals in their respective sectors, which are valuable in projecting the future demand.

After collecting all the opinions from the various stakeholders, the next step was to integrate those solutions proposed into a list of options provided by experts that incorporates the IWRM principles. A comprehensive list of options should include technical measures for the enhancement of supply, institutional measures or reform, environmental measures, and demand management options inclusive of pricing instruments, water saving technologies and educational and public awareness campaigns to promote conservation.

This was followed by a thorough examination of the strategy goals and of forecasts for the future; quantitative and qualitative projections were developed for the supply and for the demand in the various sectors. Timing is an important issue to determine, as issues may need to be addressed in different timeframes. Having a clear goal in sight, the options provided could then be ranked to produce a sequence of acceptable/available measures, which formed the proposed strategies.

The evaluation of the developed Strategies was effected using the WSM DSS developed for meeting the Case Study requirements. The model allocates water from available and user-defined sources to user-defined uses, taking into account user-defined priorities for each use and the selected strategy under different scenarios, and assesses the quality of the available resources. The WSM Decision Support System can be used to estimate how much water is needed and to determine what interventions, as well as when and where, are necessary, and their cost. It can provide indicators of performance for the selected strategy under every given scenario, and rank those scenarios.

The following two paragraphs on *Stakeholder Consultation* and *Comprehensive Scenario Analysis* aim to provide a brief overview of the methodology adopted and elaborated for two major building blocks for strategy development: the identification of targets and available, feasible and most importantly, accepted management options and the evaluation of these under different assumptions on availability and demand patterns (evolution of Pressures). Subsequently, the step-by-step- methodology for the development of regional water management strategies is presented.

Stakeholder Consultation

Until recently, central and regional administration developed “master plans” for managing 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 view of affected parties (Le Moigne and Subramanian, 1994). In many cases strategies formed this way, even if they seemed to be essential, failed to win stakeholders’ acceptance. Their implementation raised significant opposition, or they were never implemented at all. The reply to this is that conflicts of interest can be great among the different stakeholders regarding issues of quantity, quality and implementation timetable (Collentine et al., 2002). A participatory program involving stakeholders at appropriate levels and times may have lower risks, while stakeholder participation in water resources management can maximize the successful implementation, operation and maintenance of a proposed strategy (Mirghani and Savenije, 1995). However, a critical question arises during the determination of the groups of stakeholders to be consulted, as stakeholders are all those who affect, and / or are affected by the policies, decisions or actions of a water resources management plan.

Under this context, and as summarised in the Methodology Overview section, stakeholder involvement was one the key aspects in identifying both water management issues and responses. The procedure followed, presented in Figure 2-1, was split in two tasks:

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

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

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

The next step was the identification of potential stakeholder groups and actors to be approached. Stakeholders can be all those that are affected by, have interest in, or can influence decisions regarding water production, allocation and use. The different levels of involvement were a decisive factor of the final selection, and during this step two categories of stakeholder groups were distinguished and consulted (Tillman, 2001):

- Stakeholder groups that promote the water resource system;
- Stakeholder groups that benefit from the system.

Since both categories and groups interact and influence both decisions and the overall socio-economic environment, another key aspect of the work undertaken was the definition of mechanisms and governance structures that allow for such interaction.

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

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

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

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

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

The procedure undertaken in the following stages is analysed in the sections that follow.

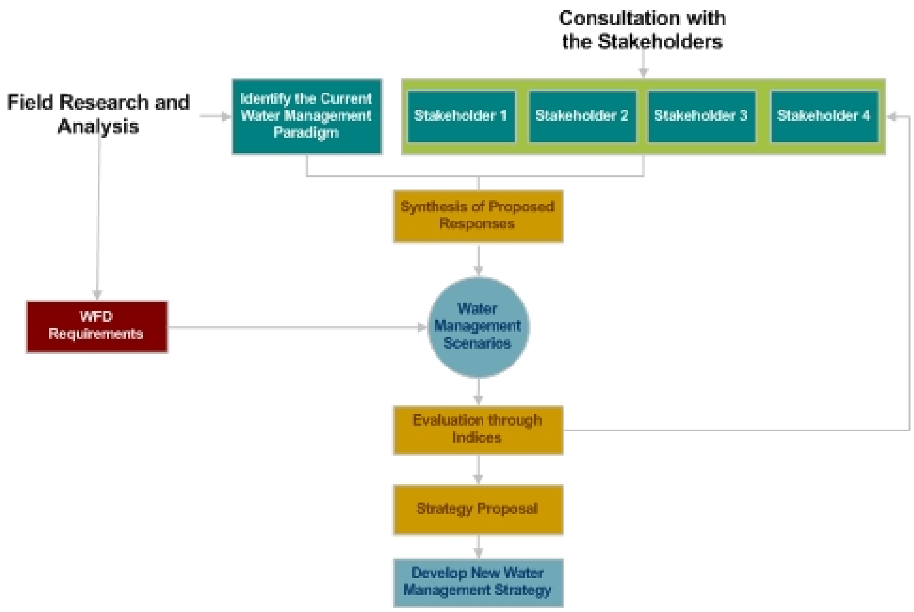


Figure 2-1 A methodological approach in defining new IWRM strategies

Comprehensive Scenario Analysis

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

The main objectives of scenario analysis were to determine the options that could be effective in meeting the targets of each Case Study analysis, and estimate their potential extent, cost and environmental impact. These water management instruments were combined in order to meet the targets for each Case Study analysis as Strategies. Under this context, the analysis process was based on the concept of a **"comprehensive scenarios"**, which has been defined as a combination of (Figure 2-2):

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

2. A selected **water management option** to be evaluated, one of a set of alternative supply or demand side management measures available.

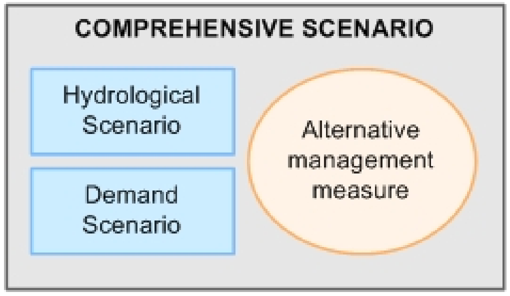


Figure 2-2 Components of Comprehensive Water Management Scenarios

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

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

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

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

The following paragraphs present the methodology for the formulation of each component of comprehensive scenarios, as this was perceived in the framework of the WSM DSS and the Case Study approaches.

Formulation of water availability scenarios

The formulation of water availability scenarios was based on the *Water Availability Module* of the WSM Decision Support System. The module estimates the amount of water that is available in a water resource system, to be allocated to the existing uses and users. Water sources considered comprise surface water, such as artificial or natural lakes and the river network system, and groundwater, renewable or not. Scenarios for availability were formulated in two distinct ways, depending on data availability:

(1) by defining a set of customized years to be repeated in time, based upon the real observations at existing monitoring stations, and

(2) by estimating runoff and natural recharge from a surface water balance performed on a monthly time step.

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

Formulation of water demand scenarios

The analysis of water demand and the formulation of projections are strictly functional to the allocation of water resources. Hypothetical demand scenarios, which along with availability assumptions constitute the basic and discriminating factor in the distribution of water from the sources to uses and users, were formulated using the *Water Demand Module* of the WSM DSS.

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

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

On the basis of observed trends, existing or own forecasts, scenarios were generated by specifying appropriate growth rates to the key variables (drivers) that govern the water demand for each modelled water use. The formulation of demand scenarios entailed a thorough data collection on the current demand patterns, consumption, losses and pricing incentives, determining demand elasticity.

Management options

In the process of the WSM project, a number of potential policy options and interventions were identified for the management of water resources in arid and semi-arid regions. These were identified in the literature and through field work, and were modelled in the DSS following the development of suitable methodology. A summary is presented in Table 2-1.

Additional options that were not available in the DSS, such as subsidisation of cistern construction in Paros island, Greece, were modelled through changes to the network modelling structure or function (e.g. the introduction of cisterns in a settlement is modelled as a small reservoir with total capacity equal to that of the sum of the individual cisterns, set just outside the settlement).

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

- Measures related with Supply Enhancement, introducing new structural interventions to increase water availability;
- Demand Management Measures, aiming to regulate and limit water demands;

- Regional Development measures, affecting the socio-economic preferences given to certain types of water use with respect to others and finally,
- Institutional policies, such as changing water pricing.

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

Table 2-1. Management options identified and used in the DSS

Management option	Description
Change in regional developmental policy	Implementation of changes in the regional developmental policy, such as shifting the local economy towards another sector that is less water-intensive. This is effected either through different priorities for the water sectors or through different growth rates.
Introduction of new crop types	Substitution of existing crops with other crop species or varieties that have either lower irrigation requirements, or require irrigation during the less water-stressed season.
Construction of surface Storage Reservoirs	Construction of water storage facilities that will be able to collect and hold water to be used later.
Desalination unit construction	Construction of desalination units that will process sea or brackish water to produce drinking-quality water.
Groundwater exploitation	Sustainable exploitation of underground aquifers through the drilling of new boreholes, pumping from existing boreholes and wells.
Importing	Importing of water from nearby or remote areas by transporting it through any means or container possible such as pipelines, water barges etc.
Water reuse	Transport of varying quality effluents for use to sectors where that quality is acceptable (e.g. treated wastewater used for irrigation of certain crops).
Conservation measures in household use	Application of water-saving devices and measures in the home, such as fitting flow-restrictors to faucets, insulating water pipes, outfitting garden hoses with shut-off nozzles etc.
Irrigation method improvement	This Action involves changes in irrigation practices in order to improve irrigation efficiency and reduce water losses (e.g. changing from flood to drip irrigation).
Process change in industry	Implementation of changes in industry processes, in order to reduce the amounts of water required during processing and production (e.g. new processes, recycling etc).
Quotas	Restriction of the amounts of water available per user, either directly through the allocation of a set volume to each user, or by limiting the duration of time that the water flow is available to users.
Reduction of network losses	Repair and/or replacement of old networks in order to reduce the water losses that are a direct result of the network aging.
Pricing	Control of the elastic water demand through the application of varying pricing levels.

Evaluation in the 'Comprehensive Scenario' context

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

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

For this purpose, a series of indicators was selected to be used for all Case Studies, based on the typology of regions outlined in the Introductory Section. Those are:

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

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

A Step-by-Step Approach for Strategy Formulation

As mentioned above, both Stakeholder Consultation and Comprehensive Scenario Analysis were two building blocks of an overall process, aiming to lead to the formulation of improved water management strategies, taking into account economic efficiency, environmental sustainability and social equity. The achievement of the aforementioned goals and purposes was pursued though a process illustrated in Figure 2-3. The overall approach includes 7 steps, grouped in two major stages, which are further elaborated below.

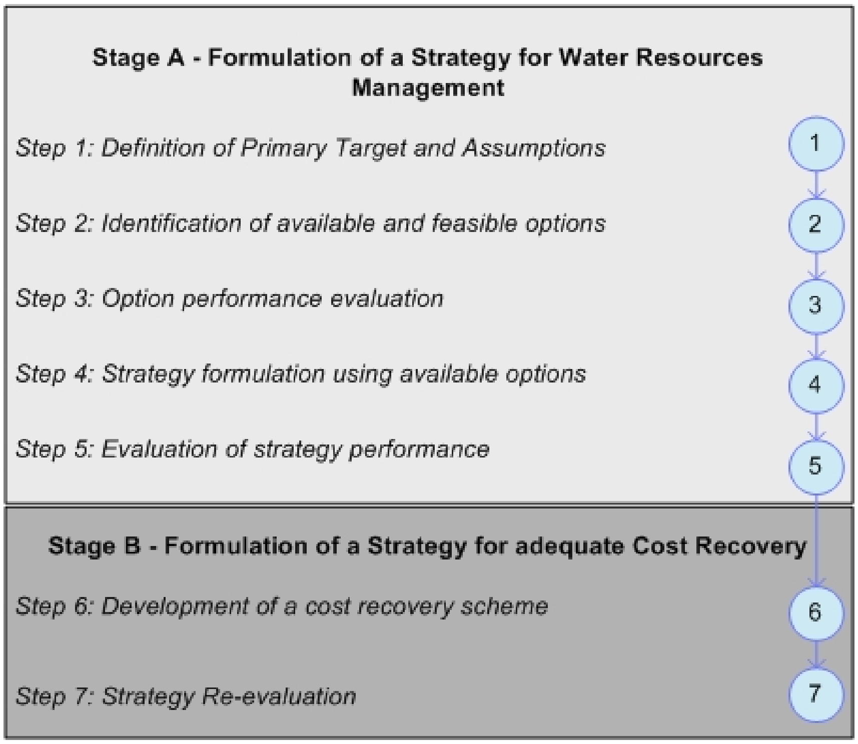


Figure 2-3 The process for Strategy Development

Stage A – Formulation of a strategy for water resources management

Step 1: Definition of primary target and assumptions

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

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

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

Step 2: Identification of available and feasible options

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

Step 3: Option performance evaluation

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

Step 4: Strategy formulation using available options

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

In more detail, the first Strategy (Strategy 1) reflects the traditional **“hard-path”** approach, involving:

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

The second Strategy (Strategy 2), referred to as a **“soft-path”** approach involves:

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

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

Step 5: Evaluation of strategy performance

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

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

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

Stage B - Formulation of a strategy for adequate cost recovery

Step 6: Development of a cost recovery strategy

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

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

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

Step 7: Strategy re-evaluation

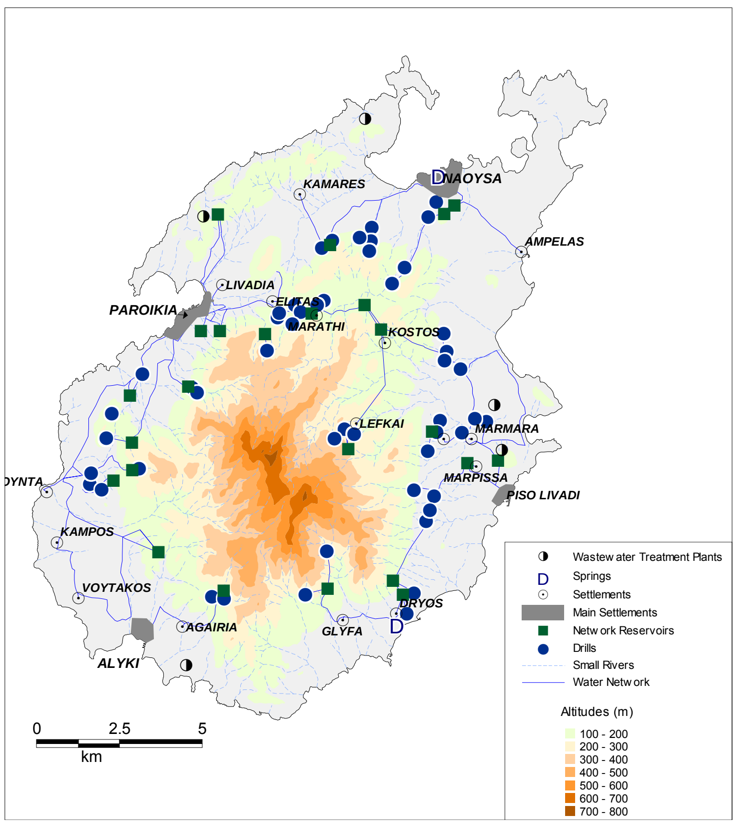
As the pricing system changes and water charges are increased, the price elasticity of demand will determine the degree to which the demand will be affected. Any significant drop in demand will need to be taken into account in the planning of interventions, as it will also affect the required supply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

The next chapters present the step-by-step approach followed and validated in five Case Studies. Each section aims to provide a summarised overview of the work undertaken for Scenario evaluation and Strategy development. The outcome of this process was the definition of a set of approaches that are suitable for the improvement of water management practices on a regional level, integrating different social, economic and environmental considerations, always in view of the WFD implementation process. Each chapter ends with a discussion and a set of recommendations on measures, options, principles and actions that should be undertaken for the region. The outcomes of the overall process, in terms of methodology and indicators used, are further elaborated in Chapter 8.

Chapter 3 Water Management Strategies for Paros Island, Greece

Introduction

The island of Paros, with an area of 196 km^2 is one of the most popular tourist destinations in the Cycladic Complex in Greece, and has a registered permanent population of 12,800 that is increased by as much as 300% during the summer months. The rapid development of the tourist industry in the last 30 years made the creation of new infrastructure necessary to cover the ever-increasing needs of the visitors and the lodging owners. The little-by-little infrastructure development was done without proper 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. At the same time, the agricultural activities that had been abandoned to a large extent were enhanced by the tourist development, and the demand for local traditional products (for example local wines) was boosted, triggering an increase in irrigation demand.



Map 1 Domestic water network in the island of Paros

The intense supply coverage problems that are faced during the summer tourist season due to insufficient planning can be solved through adequate, suitable Strategies that will promote the solution of the temporary shortage problems without adversely affecting the prosperity of the Island. The available water resources are abundant, easily surpassing the winter demand, and on a yearly basis there appears to be no significant deficit to speak of; it is the concentration of significant demand for irrigation and the tourist industry within a short period of time in the summer that has given rise to the current problems. Traditionally, these problems would be faced through the construction of large-scale infrastructure, such as a dam and additional water networks, while recently there has been a trend in areas facing similar difficulties to adopt modular solutions, and particularly seawater desalination. However, the relative abundance of water resources in Paros dictates that it could be possible to minimize the required infrastructure through the adoption of an integrated strategy that could effect the efficient allocation of the resource not only spatially, but also temporally.

Target definition

Given the strong seasonality of demand in Paros and stakeholder perceptions and expectations, as outlined below, 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. An additional target involved the achievement of a more sustainable exploitation of groundwater resources, expressed in terms of environmental costs associated with groundwater exploitation (always taking into account data availability constraints).

The **primary target** was defined for Paros island as:

- Meeting at least 80% of the domestic and irrigation needs in the peak summer period, and
- Meeting 100% of the domestic and irrigation needs during the rest of the year.

These are imperative, if any strategy developed is to resolve the social conflicts arising between users, supporting the main income producing tourism-related activities that are considered a priority by most local stakeholders and users, while maintaining the traditional agricultural activities of the island.

Identification of Available and Feasible Options

The identification of options that could be effective in mitigating the peak water shortages experienced on the island was performed through close collaboration with stakeholders and actors on a **local level**. It should be noted that 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.

On a local level, the groups of stakeholders and actors that have been consulted are:

- The **Municipality of Paros**, which constitutes the local authority 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 and the Union of Rent-Room Owners**. Both are considered to be representatives of the two main conflicting uses (and users), agriculture and tourism. Both farmers and hotel/rent-room owners are directly affected by decisions concerning water allocation, development of water supplies and overall administration of water resources and water works.

The following paragraphs are dedicated to a brief presentation of the stakeholder consultation outcomes, and to a synthesis of the proposed options into a new strategy framework.

Stakeholder consultation

For the **Municipality of Paros**, and according to a recent formulation of a water management plan (Markantonatos, 2000), water management should concentrate mainly on supply enhancement through structural interventions, such as boreholes, interception dams and desalination.

For the Municipality, the fundamental target of all strategic approaches is to adequately meet the domestic and irrigation needs, without however incurring additional costs to consumers. For this purpose, large-scale infrastructure should be financed by the government. Ultimately, such a strategy would lead to the promotion of the local tourist industry while at the same time keeping the public satisfied. Their perceptions are summarised in Figure 3-1.

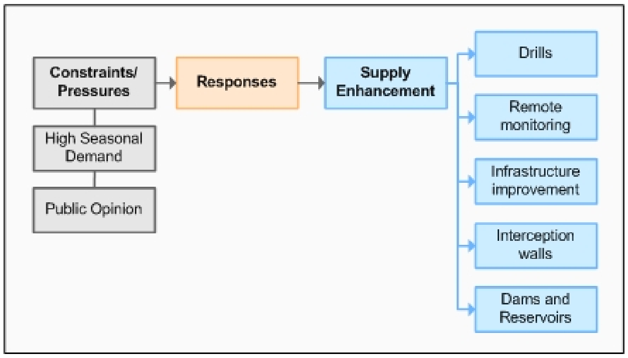


Figure 3-1 Perceptions of the Municipality of Paros, as derived from the current Water Management Plan (Markantonatos, 2000)

Although under the control of the Municipality, the perception of the **Municipal Office of Water Supply and Sewerage** (the local Water Utility) is quite different. They hold the opinion that new measures should concentrate on the more efficient use of water resources, through technological adjustments, conservation campaigns and regulation of groundwater abstractions. They as well recognize the necessity for structural interventions; they would like however to promote more technical solutions, such as desalination, without abandoning the traditional practices of groundwater exploitation (Figure 3-2).

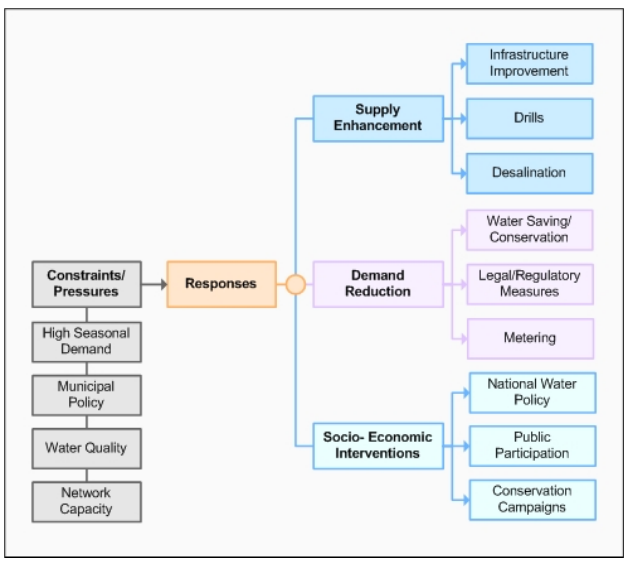


Figure 3-2 Perceptions of the Municipal Company for Water Supply and Sewerage (local Water Utility) of Paros

The **Union of Agricultural Associations** and the **Union of Hotel Room Owners** have similar points of view. Both consider that an expansion of desalination capacity would be an efficient solution for dealing with the water scarcity problems. They are increasingly aware of the limited available supply and recognize the benefits of technological adjustments and rationalization of water usage.

Synthesis of proposals for improved water management strategies

A synthesis of the current management policies, the perceptions of the local stakeholders, and of additional, imposed instruments applicable to Paros island is presented in Figure 3-3. Of these instruments only a number can be modelled through the Decision Support System, and were examined in the context of “Option Evaluation”. The rest, expressing the governance and capacity building mechanisms (e.g. institutional mobilization, clarity of vision), were addressed on a preliminary basis on the analysis of Protocols.

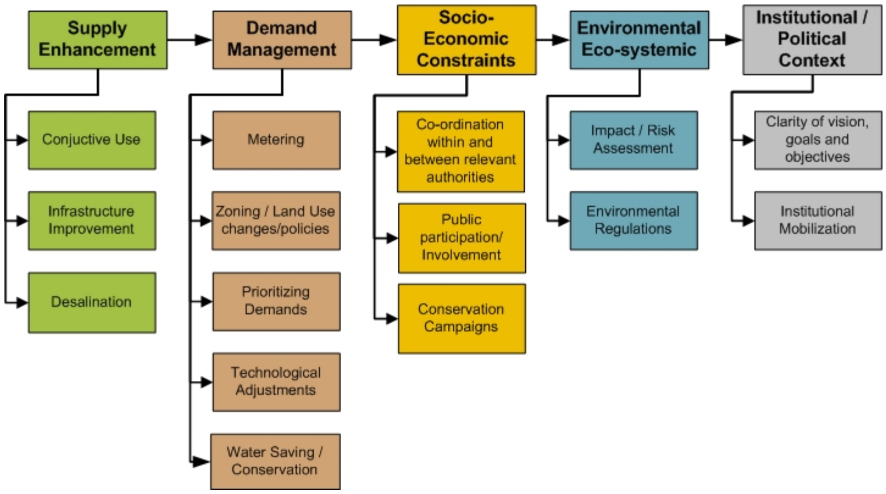


Figure 3-3 Summary of management options

In more detail, examined options pertain to three major categories:

- **Structural options** for supply enhancement, including:
  - *Network Unifications***,** aiming at the integration of the fragmented water networks of the island;
  - *Desalination unit(s) construction*, to provide additional water supplies particularly during the peak consumption periods;
  - *New Boreholes*, in areas where groundwater exploitation is below the sustainable level;
  - *Storage Reservoirs (and interception dam) construction* to provide a means of storing run-off during low consumption periods to be used later;
  - *Reduction of Network losses*, through replacement of old and damaged piping in the island towns (structural intervention);
- **Demand management options**, including:
  - *Cistern construction* subsidization in households, for better regulation of the network flow between peak and low consumption times/periods;
  - *Conservation Methods* in households and hotels;
  - *Improvement in Irrigation Methods*, for better irrigation efficiency and savings in water consumption;
- **Socio-economic measures** in the form of adjusted *Pricing* aiming to examine to what extent a difference of pricing structures would influence the water system.

The next section summarises the outcomes of the scenario development process and the results obtained from the evaluation of the different water management options in the framework of the Strategy Development Process.

Evaluation of Water Management Options

The evaluation of the different water management options was performed in two steps. First, alternative scenarios of demand and availability were formulated and combined; secondly every option was simulated under each combination and compared to each reference scenario (i.e. the system under the combination of the two demand and availability projections, including planned interventions that will be implemented in the near future). The following paragraphs provide a summary of this two-stage process. Detailed results are presented in the respective Chapter 9 of Part II.

Formulation of demand and availability scenarios

The development of **Demand Scenarios** focused on the elaboration of domestic demand projections and more specifically on permanent and seasonal population evolution. Agricultural demand was assumed to be stable over the examined period. For developing a Business As Usual scenario, it was assumed that during the period examined (2004 – 2030) the population will continue to increase with a steady yearly rate equal to the average of the previous decades. Seasonal population is assumed to follow a similar trend, as the permanent population increase should be supported by a proportional economic growth, which – at present – is strongly related to tourism development. Under this context, three different potential trends were distinguished, forming the potential scenarios for domestic demand, i.e.: (i) a scenario where demand increases at a steady rate, corresponding to the currently observed trends (BAU); (ii) a scenario where demand stabilises after a point in time, when the carrying capacity of the island is reached; and (iii) a scenario where demand decreases after a point in time.

The formulation of **Availability scenarios** was based on the sequence of years with respect to rainfall. Sequences that were developed and entered in the WSM DSS were composed of average, wet (values in the top 30 percentile of observed) and dry years (values in the bottom 30 percentile of observed). In particular, the hydrology scenarios that were used reflected, for a period of 30 years: (a) a high frequency of dry years; (b) a high frequency of wet years; and (c) a period of 30 average availability years, which signifies the assumption of standard water availability.

In order to be able to assess the behaviour of the water system under a best case scenario, a worst case scenario and a business as usual scenario as intended, the combinations of availability and demand scenarios under which the different management options have been evaluated were the following:

- A combination of high demand with a high frequency of dry years (**BAU+HD**), reflecting the worst case scenario of water shortage,
- A combination of reduced demand with a high frequency of wet years (**LD+HW**), reflecting the best case scenario, and
- A combination of high demand with a series of average years (**BAU+Normal**), in an effort to reflect the current trends of the system in a “business as usual” context.

The developed scenarios were combined, in order to assess the behaviour of the water system under different conditions. Combinations that were developed and used for option simulation were: (1) A combination of high demand with a high frequency of dry years (**BAU+HD**), reflecting the worst case scenario of water shortage, (2) A combination of reduced demand with a high frequency of wet years (**LD+HW**), reflecting the best case scenario, and (3) A combination of high demand with a series of average years (**BAU+Normal**), in an effort to reflect the current trends of the system in a "business as usual" context.

Summary of option evaluation outcomes

This section summarises the results of the evaluation of the different management options identified through stakeholder consultation and review of current approaches for the island of Paros. Results from this evaluation are presented in Table 3-1 and Table 3-2. The detailed analysis is presented in Chapter 9.

The effectiveness of each option was approached through the evaluation score obtained by the WSM DSS, from the performance with respect to domestic and irrigation demand coverage, assuming a weight of 0.5 for each indicator, and a satisfactory range of values from 80 to 100%.

The major environmental problem faced by the island lies in the overexploitation, depletion and salinisation of aquifers; therefore, the selected indicator for environmental sustainability (environmental cost) was associated with pollution loads from households and unsustainable groundwater abstractions. Economic efficiency, the ability to produce more with less, was expressed through the total direct cost in present value terms. For obtaining the Performance Matrix of Table 3-1 results for each option under the three scenarios were averaged, in order to account for the impacts of each option on the water system under variable scenarios of Pressures.

Table 3-1 Option Performance Matrix

Option	Effectiveness (Relative Sustainability Index for Demand Coverage)	Direct Cost (PV in million €)	Total environmental cost (PV in million €)
Reference	0.008	27.43	40.66
Network Unifications	0.154	27.90	42.16
GW Exploitation	0.213	27.80	42.24
Desalination	0.366	35.57	37.61
Storage Reservoirs	0.214	34.38	37.79
Losses	0.172	26.63	37.57
Cisterns	0.033	29.32	41.68
Domestic Conservation	0.050	27.10	35.26
Irrigation Method Improvements	0.253	37.59	38.61
Domestic Pricing	0.218	25.39	37.53
Irrigation Pricing	0.313	28.10	36.67

In order to rank the examined options, a normalisation of results was performed for a scale ranging from 0 to 5, where 0 corresponds to the worst value and 5 to the best value. The normalised Option Performance Matrix is presented in Table 3-2.

From Table 3-2 it is obvious that a new strategy for Paros cannot rely on the application of a few measures only. Desalination seems to occupy an advantageous position in terms of technical, economic and environmental sustainability. However, the very high cost associated with the option and technical limitations which do not allow for the installation of a capacity exceeding 5,000 m^3/d renders the “massive” application of the option impossible. If a strategy that is developed relies predominantly on desalination, it should also incorporate measures to improve efficiency of domestic and irrigation uses and to promote conservation of the island’s vulnerable resources. Required installed capacity can also be decreased if the option is combined with small-scale structural interventions that can improve the use of existing resources. Such interventions are network unifications, the interception dam, and a reduction of network losses.

Table 3-2 Normalised option performance matrix

Option	Relative Sustainability Index for Demand Coverage	Direct Cost	Environmental cost
Reference	-	****	-
Network Unifications	**	****	-
GW Exploitation	***	****	-
Desalination	*****	*	***
Storage Reservoirs	***	*	***
Losses	**	****	***
Cisterns	-	***	-
Domestic Conservation	*	****	*****
Irrigation Method Improvements	***	-	***
Domestic Pricing	***	*****	***
Irrigation Pricing	****	****	****

It therefore becomes apparent that in the scope of Integrated Water Resources Management, in addition to the common practice of supply enhancement-based approaches, we need to examine strategies incorporating “softer” measures. In doing so, we can maximise efficiency improvements in the water network with minimal cost, effected through demand management, public participation and awareness, and incorporate complementary supply enhancement methods to ensure adequacy of supply where necessary.

Strategy Formulation and Evaluation

Assumptions

The strategies that were formulated aim at medium to long-tem planning, and therefore will take into account a 25 year horizon, spanning the period 2005 – 2030. Design and planning assumed average and constant availability conditions. The demand trend used is the Business-As-Usual demand scenario, assuming a 1.5% yearly increase for population & tourism growth. Details on the selected scenario are presented in Chapter 9.

Formulation of alternative water management strategies

Following from the evaluation results, the two alternative Strategies can be formulated based on the emerging and shifting Paradigms, and evaluated against each other and against the reference case. **Strategy 1**, the "hard-path" approach reflects the Dominant Paradigm, incorporating the newest techniques and methods applied and proposed. These in the case of Paros are strongly related with the construction of additional desalination plants, to supply areas with high tourist influx, and interception dams, aiming to improve aquifer replenishment, and yield. **Strategy 2** incorporates additional interventions that aim to increase the productivity of water use ("soft" approaches), while at the same time trying to maintain groundwater abstractions at sustainable levels and guarantee the provision of adequate water supply to the dominant economic activities through small-scale decentralised solutions.

Strategy 1 – The "hard-path" approach

Strategy 1 is focused on small to medium scale structural interventions shown to be effective and efficient in the case of Paros. These interventions have been selected on the basis of the currently adopted water management responses, portrayed in Figure 3-4, and include:

- Further groundwater exploitation using boreholes abstracting sustainable quantities of water;
- An interception dam to prevent the loss of runoff and improve aquifer balance;
- Network improvements throughout the island targeting a reduction of network losses;
- Small desalination plants, to supply highly populated tourist areas.

Figure 3-5 presents a tentative timeframe for the application of these interventions. Its formulation was based on stakeholder perceptions, technical considerations and the performance of each option, as summarised in the respective paragraph and analysed in detail in Chapter 9.

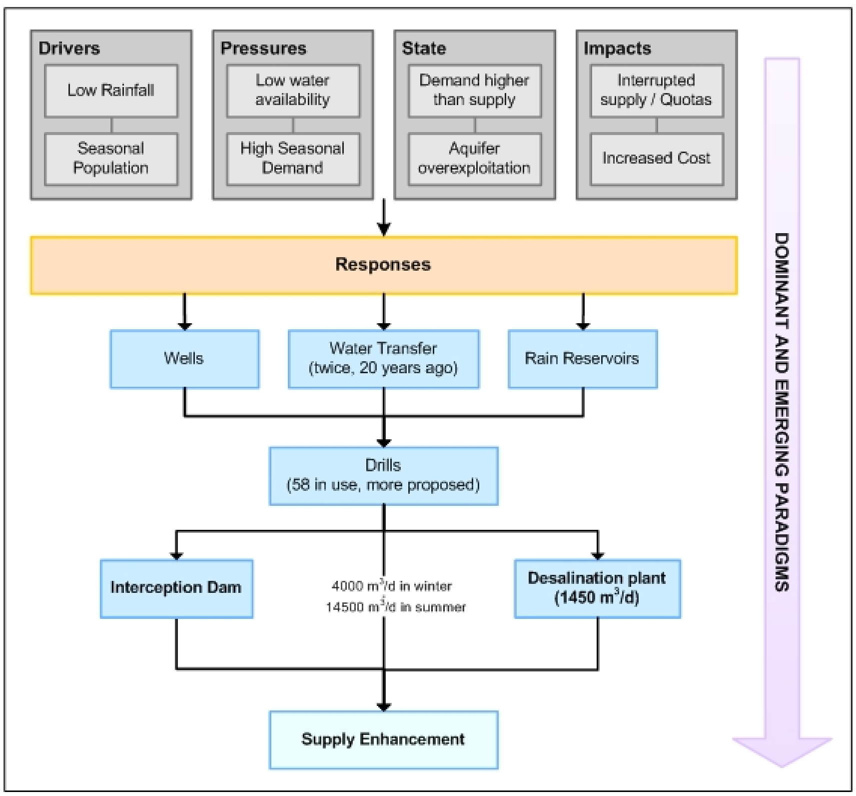


Figure 3-4 DPSIR indicators and the selected responses for Paros

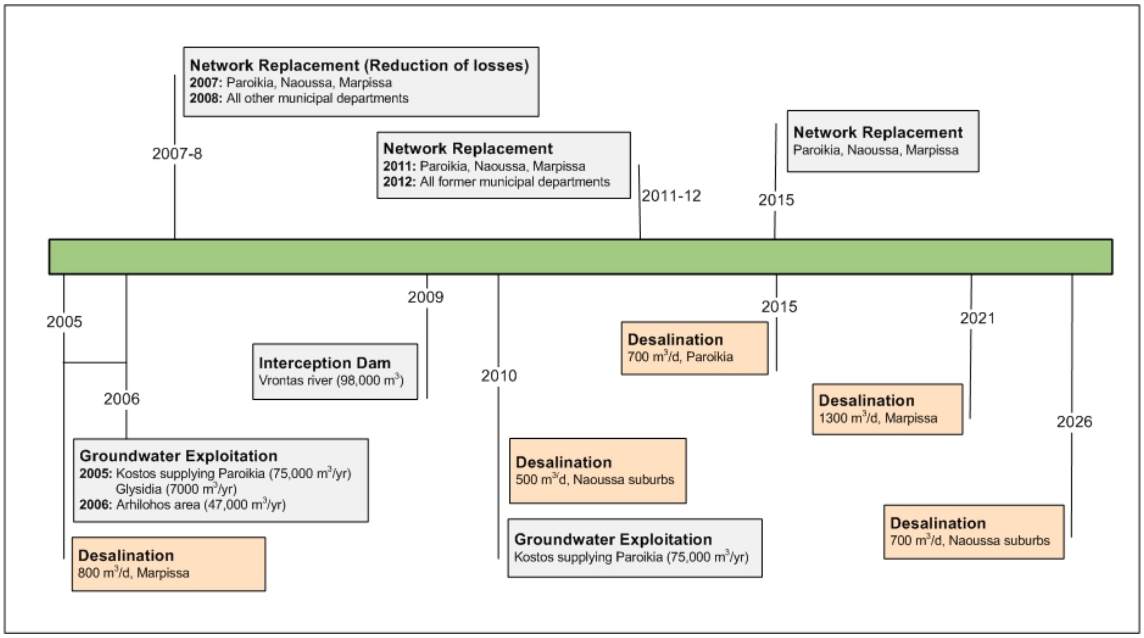


Figure 3-5 Tentative Timeframe of interventions within Strategy 1

In summary, the interventions specifically applied were the following:

- **Groundwater Exploitation option:** A total of 4 additional boreholes, yielding, on average, 204,000 m^3/yr. Three of these boreholes were assumed to be constructed in 2005, while the fourth one is foreseen for 2006. The application of this option is considered immediate, in order to cope with the strong deficits projected in Paroikia and Marpissa region.
- **Surface water exploitation option**, through the construction of an interception dam on Vrontas river. The dam, with a capacity of 98,000 m^3 was assumed to be operational from 2009 and onwards, taking into account a construction period of four years.
- **Reduction of Network Losses** through improvement in secondary distribution networks. This is assumed to be performed gradually (years 2007-2008, and 2011-2012, and 2015), with emphasis being given in the distribution networks in the larger municipal departments of Naoussa, Paroikia and Marpissa. The achieved reduction of losses was assumed as follows:
    - From 25 to 18 % in the larger municipalities;
    - From 25 to 20 % in the smaller ones.
- **Desalination.** Currently only one brackish desalination unit (capacity of 1,450 m^3/d) operates on the island, supplying only the settlement of Naoussa. In the framework of this strategy, desalination is considered to be the emerging solution to the proliferating water shortage problems. The total additional capacity required for meeting the targets of the analysis is as follows:
    - 1,300 m^3/d in 2010;
    - 2,000 m^3/d in 2020;
    - 2,700 m^3/d in 2030.

Strategy 2 - The "soft-path" approach

The second strategy developed attempts to reconcile the supply and demand in Paros without resorting to hard interventions where possible, reflecting a shift in the traditional practices of water management of the island. 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.

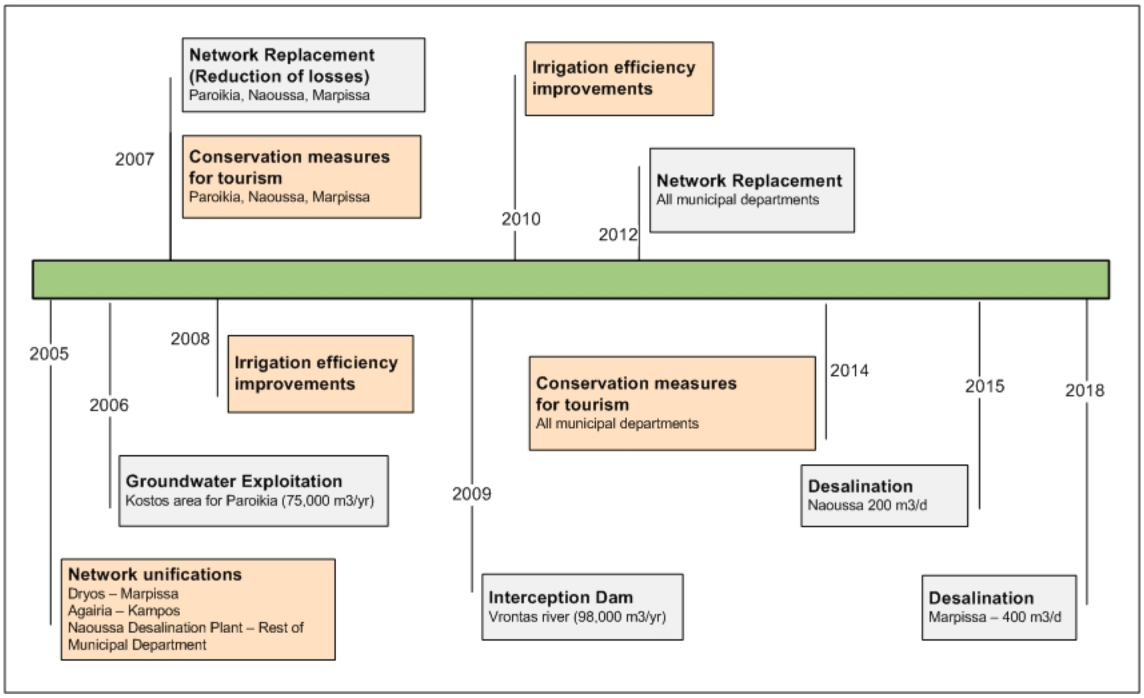


Figure 3-6 Tentative Timeframe of interventions within Strategy 2

To that end, the interventions that were included in the strategy, shown in the tentative timeframe of Figure 3-6, were determined to be:

- **Conservation measures** in the tourist sector, and particularly use of low flow taps in hotels. Such measures, considered to be subsidised by the local Water Utility, are applied in two phases, and are estimated to yield a total reduction in consumption of 16%.
- **Irrigation Method Improvements** through the gradual application of drip irrigation in all municipal departments.
- **Reduction of Network Losses**, currently estimated at an average 25% to 19% in major municipal departments and to 20% in smaller municipal departments.
- **Network Unifications** between neighbouring municipal departments and settlements to enable the allocation of available resources throughout the island.
- **Exploitation of groundwater** at a sustainable rate, through one additional borehole, yielding 75,000 m^3/yr.
- **Exploitation of surface water** through the construction of an interception dam at Vrontas with a capacity of 98,000 m^3, and
- **Two desalination plants**, yielding a total additional capacity of 600 m^3/d in 2020.

It should be noted that the eventually required desalination capacity in this case is significantly lower than the one foreseen under Strategy 1. This is due to the fact that the applied conservation and efficiency improvement options assist to a more sustainable exploitation of resources and therefore assist in the building of strategic groundwater reserves that can help in alleviating future water deficits.

The following paragraphs present the results from the evaluation of the two strategies and their comparison with the reference case, i.e. the assumed demand and availability scenarios combination, which incorporates the interventions and actions already foreseen by the local authorities.

Strategy evaluation

After the formulation and simulation of the two strategies in the WSM Decision Support System, they were evaluated against each other, and against the reference case. Figures 3-7 to 3-10 present the results obtained from the simulation of the two strategies, addressing the two primary targets set at the beginning of this analysis, with respect to domestic and irrigation demand coverage, and the improvement achieved for the respective deficits.

From Figure 3-7 it is evident that both strategies can stabilise domestic demand coverage at a rate above 95% thus meeting the target for domestic demand coverage.

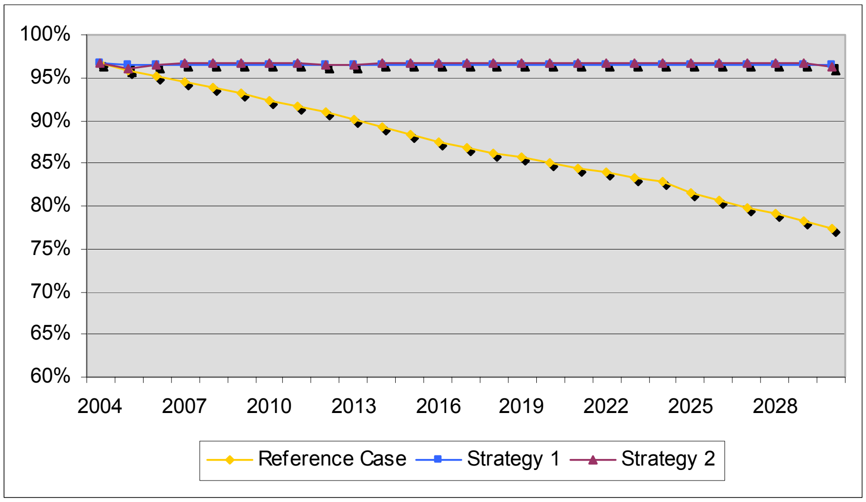


Figure 3-7 Domestic Demand Coverage (%)

The same conclusions can be drawn for domestic deficit improvement (Figure 3-8). Both strategies significantly reduce domestic deficit and present the same improvement, escalating with demand growth. From the same Figure it is evident that slightly better results (2% difference from 2007 and up to the end of the simulation period) can be achieved with Strategy 2.

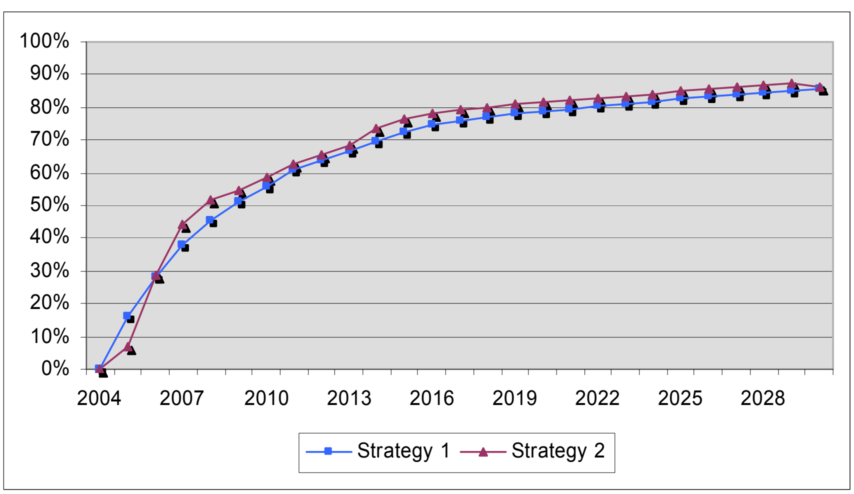


Figure 3-8 Domestic deficit improvement with respect to the reference case (%)

Figure 3-9presents the obtained results for irrigation demand coverage. Again, both strategies can meet the target of the analysis, achieving coverage above 80%. However, here Strategy 2 performs better, especially after the full introduction of measures that target the agricultural sector (i.e. irrigation method improvements) and limit domestic water consumption. This is more evident when inspecting Figure 3-10 that portrays the relative improvement of irrigation deficits with respect to the reference case (20% difference between the two strategies). Therefore, one a preliminary conclusion that can be drawn from the analysis is that agricultural use can be best supported through measures targeting wasteful water use for both sectors.

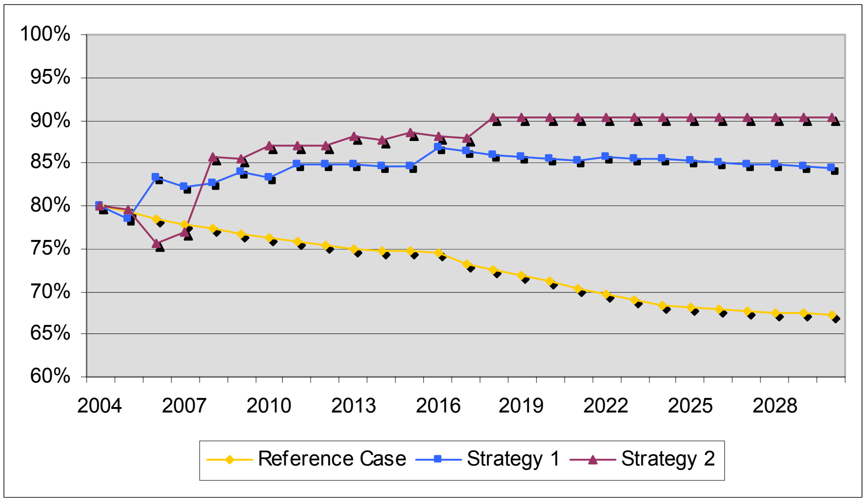


Figure 3-9 Irrigation Demand Coverage (%)

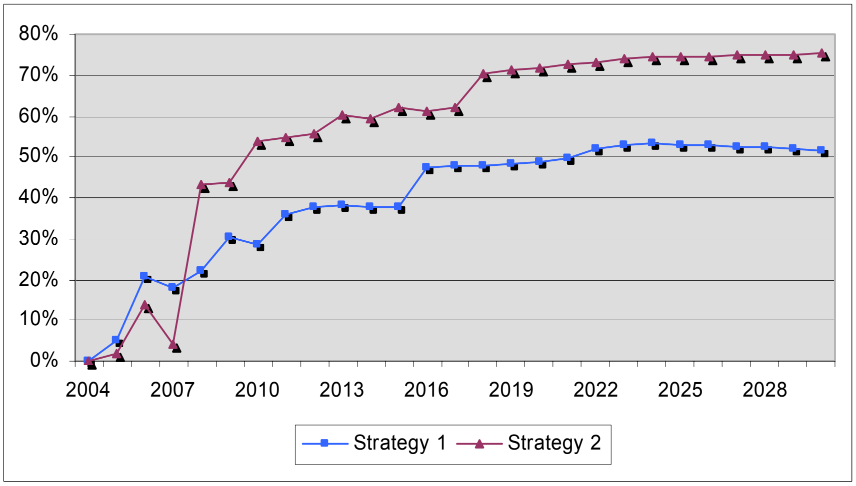


Figure 3-10 Irrigation deficit improvement with respect to the reference case (%)

The evaluation of the two strategies was performed with respect to four criteria; Relative Sustainability Index for Demand, computed from the evaluation scores for domestic and irrigation demands assigning a weight of 0.5 to each indicator. Additional economic indicators concerned the present value of direct and environmental costs, and total value to users, which on a second level can be used to derive the social welfare surplus resulting from the application of these interventions. The evaluation scores are presented in Table 3-3, from where it is again evident that both strategies have a similar performance with respect to demand coverage.

Table 3-3 Strategy evaluation table

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Total value to users (PV – million €)
Reference case	0.000	27.59	36.07	159.6
Strategy 1	0.503	33.99	35.89	176.9
Strategy 2	0.504	30.33	33.84	178.1

Figure 3-11 presents the present values for the cost components considered in the analysis, i.e. direct costs, environmental and resource costs. Direct costs considered in this assessment comprise the costs for domestic water supply, through the local water utility, and abstraction costs from private (irrigation) boreholes. Inspection of Figure 3-11 leads to the observation that Strategy 2 presents lower values for direct, environmental and resource costs due to:

- Lower investment requirements since the installed desalination capacity is significantly smaller;
- Reduced annual operational and maintenance costs, since both groundwater abstractions and desalination production requirements are lower, thus lowering energy costs;
- Lower groundwater (over)abstractions, since in most aquifers the abstractions considered "unsustainable", i.e. exceeding the safe yield are significantly lower.

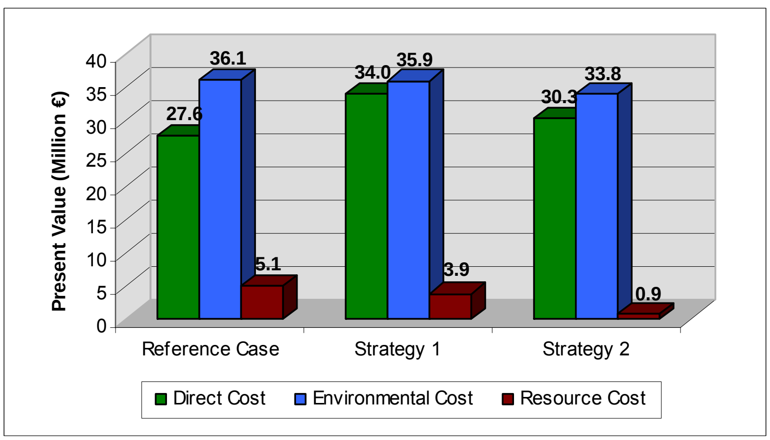


Figure 3-11 Present values of direct, environmental and resource costs (Million €)

Figure 3-12 presents the total direct costs from the operation of the water system, including both costs of the local Water Utility for domestic water provision and own production costs (private users), which are associated with agriculture. The difference between the costs for Strategy 1 and Strategy 2 is evident, while the graph also depicts that costs from a potential application of Strategy 2 are, at least in the short term, similar to those of the reference case.

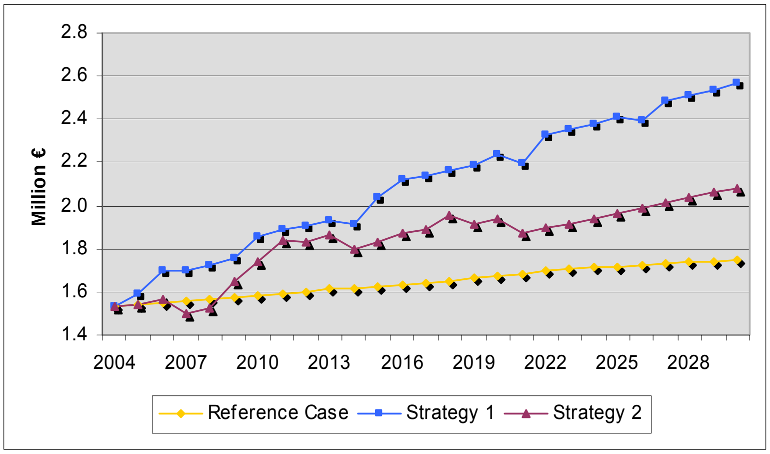


Figure 3-12 Total direct costs (Million €)

Figures 3-13 and 3-14 present the environmental costs allocated to domestic use and agriculture. For domestic use both strategies present similar environmental costs, with Strategy 2 performing better at the beginning of the simulation and Strategy 1 at the end of the simulated period, due to the higher desalination capacity. However, environmental costs associated with irrigation water supply are significantly lower for Strategy 2. This is due to the fact that this Strategy includes measures that target the agricultural sector, thus directly influencing irrigation demand and consecutively groundwater abstractions.

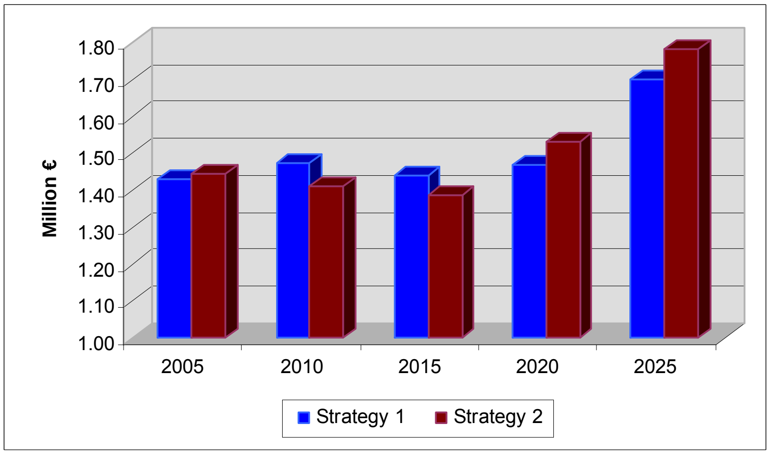


Figure 3-13 Environmental Costs - Domestic use (Million €)

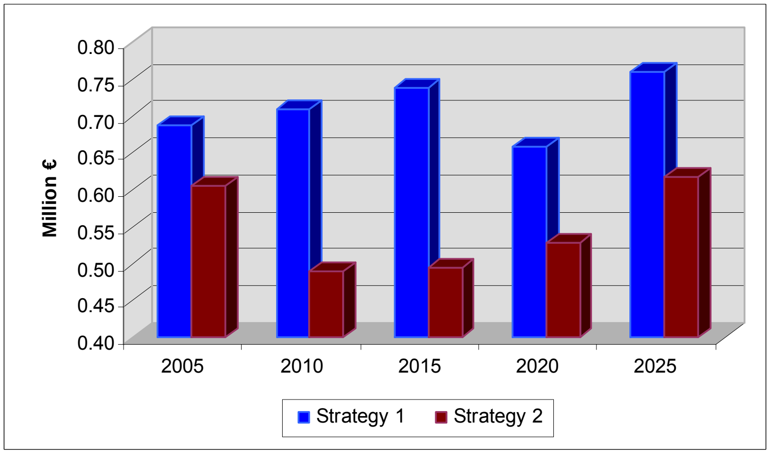


Figure 3-14 Environmental Costs - Irrigation water provision (Million €)

Development of a Cost Recovery Strategy

The Cost Recovery Rate (CRR) under Strategies 1 and 2 was estimated taking into account direct and environmental costs, and revenues from water billing which are associated with domestic use only. Environmental costs were estimated on the basis of groundwater overabstractions, i.e. abstraction volumes that exceed the safe yield, and pollution incurred from domestic use. Resource costs were not included in the estimation of the CRR. This is due to the fact that still in the Greek institutional framework there is no mechanism for their recovery, neither on a River Basin District Level (Region of Southern Aegean) nor on a local level. In addition, such mechanisms are not foreseen in the Law 3199/2003 which resulted from the transposition of the WFD in the Greek Law.

The initial estimation of CRR for domestic water provision was based on the current pricing system of the island, where the average weighted tariff, estimated according to the volume of water sales, in approximately equal to 1.45 €/m^3. It should be noted that prices are not uniform throughout the island, but vary per municipal department and on a seasonal basis, with the highest prices being charged in the municipal departments of Paroikia (1.57 €/m^3), of Naoussa (1.54 €/m^3), and of Marpissa (1.52 €/m^3). The initially estimated CRR for domestic water provision is presented in Figure 3-15. Since irrigation water supply is not metered and charged, and incurred direct costs are covered by the users, the cost recovery rate for direct costs is always 100% while for environmental costs CRR is equal to 0%.

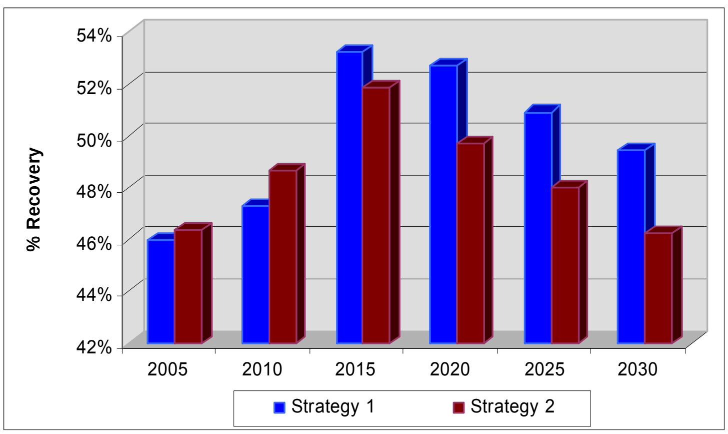


Figure 3-15 Initial cost recovery rate for domestic water provision before the application of cost recovery strategies

In order to achieve an adequate cost recovery for both domestic and irrigation water provision, two cost recovery strategies were developed. The first one targets only the domestic sector, and aims to ensure full recovery of direct costs and partial recovery of environmental costs. The second targets environmental costs associated with irrigation water provision, and is built in addition to the first cost recovery strategy for the domestic sector. Under the second scheme, environmental costs resulting from groundwater overabstractions are recovered in the form of abstraction charges. Assumptions and targets for each cost recovery scheme are outlined in the following paragraphs.

Formulation of cost recovery strategies

Cost Recovery Strategy A – Domestic water provision

The scheme developed was not tiered; instead prices were estimated as flat-rate average volumetric prices to be readjusted after 5-year periods. The set cost recovery targets, to be achieved through a gradual increase of prices, were:

- A 100% recovery of direct costs for the total duration of the examined period (2005-2030),
- An initial (in the year 2005) recovery of 50% of the associated environmental costs, and
- A targeted (in the year 2030) recovery of 70% of the associated environmental costs.

Figure 3-16 presents the total costs that have to be recovered from domestic water provision. These according to the water billed volumes, taking into account losses and unmetered supplies, initially yield the prices of Figure 3-17.

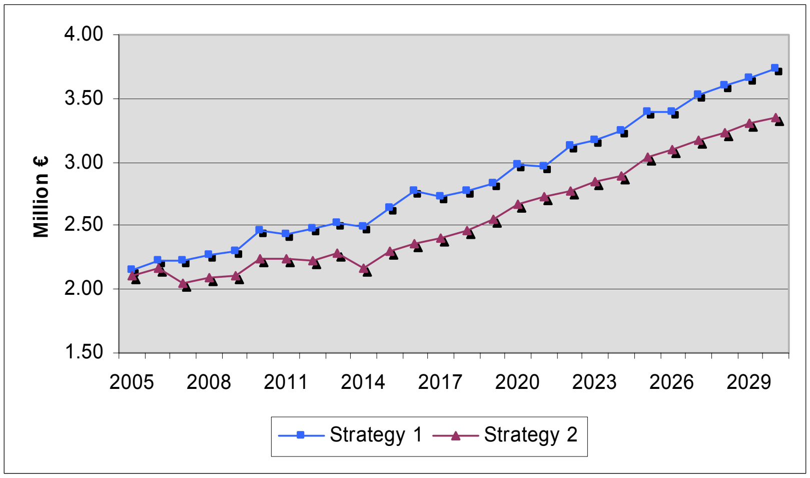


Figure 3-16 Total costs to be recovered - Domestic Use (Million €)

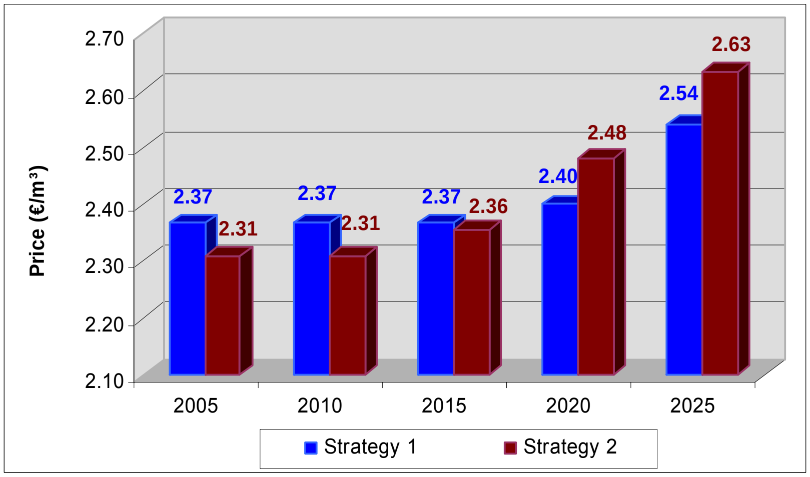


Figure 3-17 Initially estimated average volumetric price for domestic water (€/m^3)

From the inspection of the two figures it becomes evident that although Strategy 2 (the "soft-path" approach) results in lower direct and environmental costs for the entire simulation period, resulting (initial) prices are higher for the periods 2020-2025 and 2025-2030. This is due to the lower volume of water sales, due to the applied conservation measures which lead to a reduction of consumption in households but most importantly the hotel sector.

Cost Recovery Strategy B – Irrigation water provision

As previously stated, the development of a cost recovery strategy for costs incurred by irrigation water provision is only tentative. In the examined case, assumed recovery of environmental costs resulting from groundwater abstractions is based on the estimation of an abstraction charge, effective when the safe yield of the aquifers is exceeded. The actual application of such an instrument would involve specification, by a competent authority, of limits for abstraction volumes per borehole, and the metering of water quantities extracted from each.

The targets set for the recovery of environmental costs associated with irrigation water supply were set as follows:

- An initial (in the year 2005) recovery of 30% of environmental costs, and
- A targeted (in the year 2030) recovery of 60% of environmental costs.

This cost recovery strategy was applied in combination with Cost Recovery Strategy A, in order to analyse the effect that a potentially more equitable allocation of costs to water uses would have on the water system of the island.

Figure 3-18 presents the total environmental costs to be recovered, and Figure 3-19 the resulting abstraction charge, assuming that quantities abstracted for irrigation are metered.

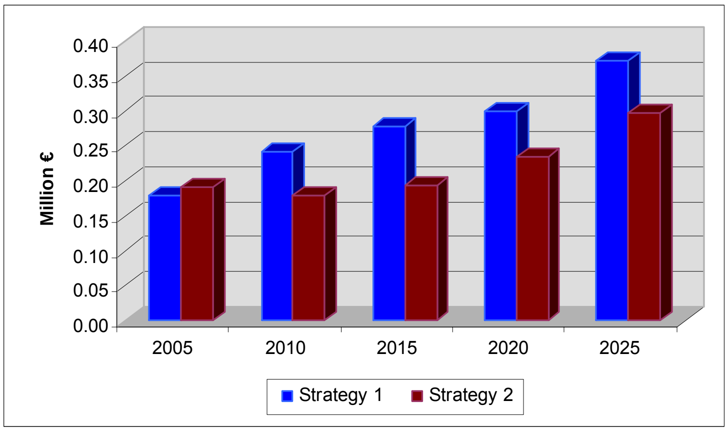


Figure 3-18 Total costs to be recovered – Irrigation Water Supply (Million €)

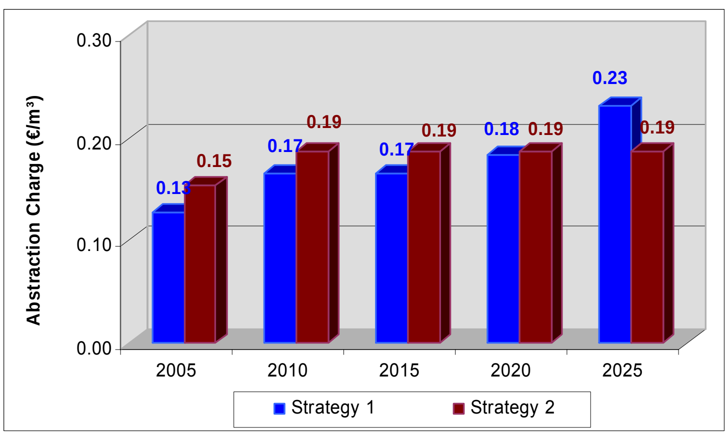


Figure 3-19 Initially estimated average abstraction charge for irrigation abstractions (€/m^3)

Re-evaluation of strategy options and performance

Cost Recovery Strategy A – Domestic water provision

Given the demand elasticity for the domestic use in Paros, estimated at -0.2, the introduction of pricing is expected to affect the demand considerably. Therefore an iterative process was used in order to redefine the extent for the application of options, their costs, and the prices required for the targeted cost recovery. By this process, the final prices for domestic supply in the year 2030 were determined at 2.32 €/m^3 for Strategy 1 and 2.32 €/m^3 for Strategy 2 (Figure 3-21).

Figure 3-20 presents total domestic demand, before and after the application of the pricing scheme. Figure 3-21 portrays the evolution of prices for each 5-year period from 2005 to 2030.

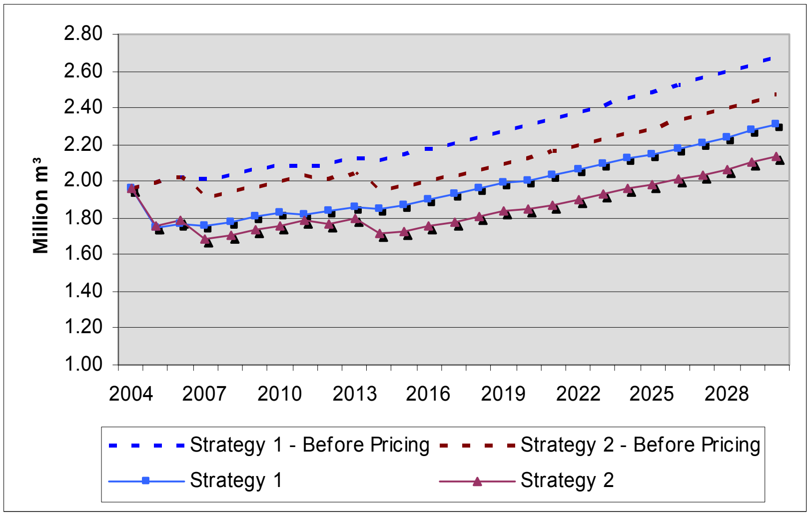


Figure 3-20 Domestic Demand (Million m^3)

One conclusion that can be drawn from the resulting prices is that given the assumed elasticity, Strategy 2 eventually incurs lower costs to consumers than Strategy 1, since it involves smaller infrastructure, and reduced investment costs. The reduction of prices for achieving the targeted recovery ranges between 7 and 10% between the first iteration and the final estimation.

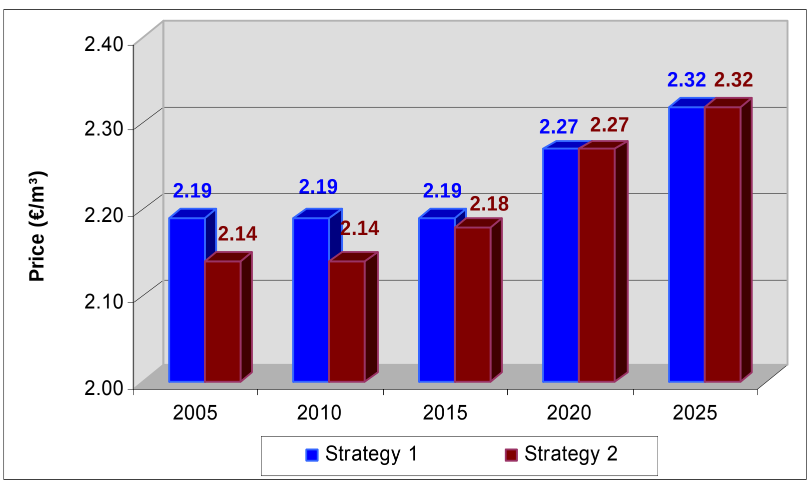


Figure 3-21 Final prices for domestic water provision (€/m^3)

Following the re-adjustment of the two Strategies to reflect the effects of pricing, their performance was re-evaluated; the re-evaluation results are shown in Table 3-4 below. Values in brackets present the results obtained before the application of the first cost recovery strategy.

Table 3-4 Adjusted Strategy evaluation table (under Cost Recovery Strategy A)

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Resource Cost (PV – million €)
Reference	0.000	27.59	36.07	5.10
Strategy 1	0.507 (0.503)	31.04 (33.99)	31.58 (35.89)	3.15 (3.90)
Strategy 2	0.503 (0.504)	27.67 (30.33)	29.9 (33.84)	0.68 (0.90)

According to the results presented in Table 3-4, domestic pricing has a significant effect, both in terms of direct costs and more importantly environmental costs, which are significantly reduced. Reduction of direct costs is attributed to the lower annual operational costs, which are primarily associated with domestic water provision. In more detail the demand decrease, as a result of the increasing prices, lowers anticipated supply production and consecutively incurred costs are reduced. The decrease of environmental costs is associated with the reduction of groundwater overabstractions, which for both uses drop to more sustainable levels. Finally it should be noted that resource costs are not significantly affected from the developed pricing scheme. This is expected, taking into account that the priorities of the two uses lead to a solution that approximates the economically optimal allocation.

Cost Recovery Strategy B – Irrigation water provision

For the re-evaluation of the two strategies under a potential cost recovery scheme for environmental costs resulting from irrigation groundwater overabstractions, the demand elasticity for the different crop types was assumed to be -0.4 for annual cultivations and -0.2 for permanent. The iterative process that was followed on the re-evaluated strategies under Cost Recovery Strategy A, determined a charge of 0.13 €/m^3 for Strategy 1 and 0.12 €/$m^3$for Strategy 2.

Figure 3-22 presents total irrigation demand, as a result of the applied pricing schemes, while Figure 3-23 portrays the evolution of the abstraction charges for each 5-year period from 2005 to 2030.

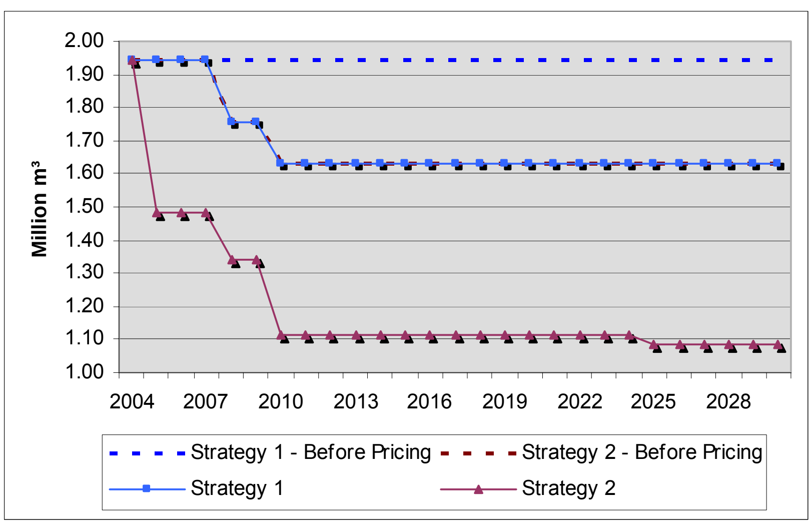


Figure 3-22 Irrigation Demand (Million m^3)

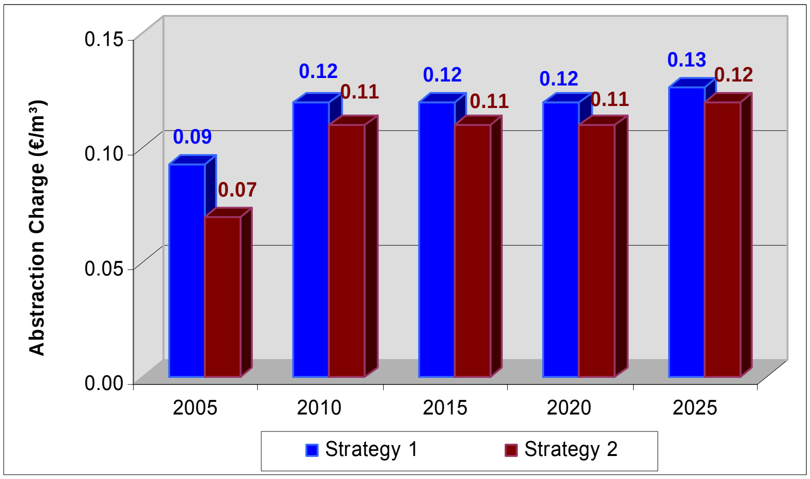


Figure 3-23 Resulting abstraction charges for irrigation water supply

The re-evaluation of the two strategies yielded the results presented in Table 3-5. Values in brackets in this case correspond to the Cost Recovery Strategy A.

Table 3-5 Adjusted Strategy evaluation table (under Cost Recovery Strategy B)

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Resource Cost (PV – million €)
Reference	0.000	27.59	36.07	5.10
Strategy 1	0.503	27.67 (31.04)	29.96 (31.58)	1.80 (3.15)
Strategy 2	0.508	27.01 (27.67)	22.05 (29.90)	0.60 (0.68)

From the adjusted evaluation table the following conclusions can be drawn:

- With irrigation pricing environmental cost for Strategy 1 drops significantly, while for Strategy 2 the reduction is much smaller. Eventually, both values are almost equal to those of the reference case. From this it can be induced that a large part of the planned infrastructure may not be required if a drastic reduction is applied in agricultural demand.
- Similarly, environmental costs present considerably lower values for both strategies. The effect is much more pronounced in Strategy 2, where due to the already applied irrigation method improvements, the demand drops to approximately 50% of the one of the reference case.
- Resource costs do not vary significantly, and still constitute a small component of the total cost for the reasons explained above.

It should be underlined that the above results and observations are valid only if the assumed elasticities for irrigation demand are realistic and can model realistically the response of end-users to the estimated price increase. In practice, and given the relative socio-economic and environmental (landscape preservation) importance of the sector, and the current institutional framework it is doubtful whether such charges can be effectively applied.

Discussion and Recommendations

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

The evaluation results for Strategy 2 compared to the reference case and Strategy 1 emphasise that the high temporal water imbalance in the island of Paros can best be solved through a combination of small-scale structural interventions and soft interventions aiming to increase the efficiency and productivity of water use. The further use of Institutional measures, aiming to centralize the decision-making process for the allocation of resources and costs could make a significant contribution to the solutions of the Problems that are faced on the Island.

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

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

Chapter 4 Water Management Strategies for Belice Basin, Italy

Introduction

The area of **Garcia-Arancio Irrigated Districts** under study is located in the Western part of the Italian Sicily region and is comprised of the hydrological basin of the Belice River, which extends almost from the Southern to the Northern coast of the island in the territories of Palermo, Trapani and Agrigento, and of the four irrigation districts Castelvetrano, Menfi, Sambuca di Sicilia and Sciacca that lie along the Southern coast, between the provinces of Trapani and Agrigento. It also includes the catchment of the artificial Arancio Lake, a valuable resource for the agricultural use of water.

The water resources of the Belice Basin are mostly represented by the artificial Garcia Lake, built during the years 1977-1985 on the left branch of Belice and having a present useful capacity of 63 hm^3. Water from the Garcia is used both for irrigation purposes and for providing the urban settlements, inside and outside the basin, with drinkable water.

With respect to urban water use, the Belice resources rely on the main two networks of the Montescuro aqueduct and the Favara di Burgio aqueduct, which constitute the water source with the first priority for the settlements of the area.

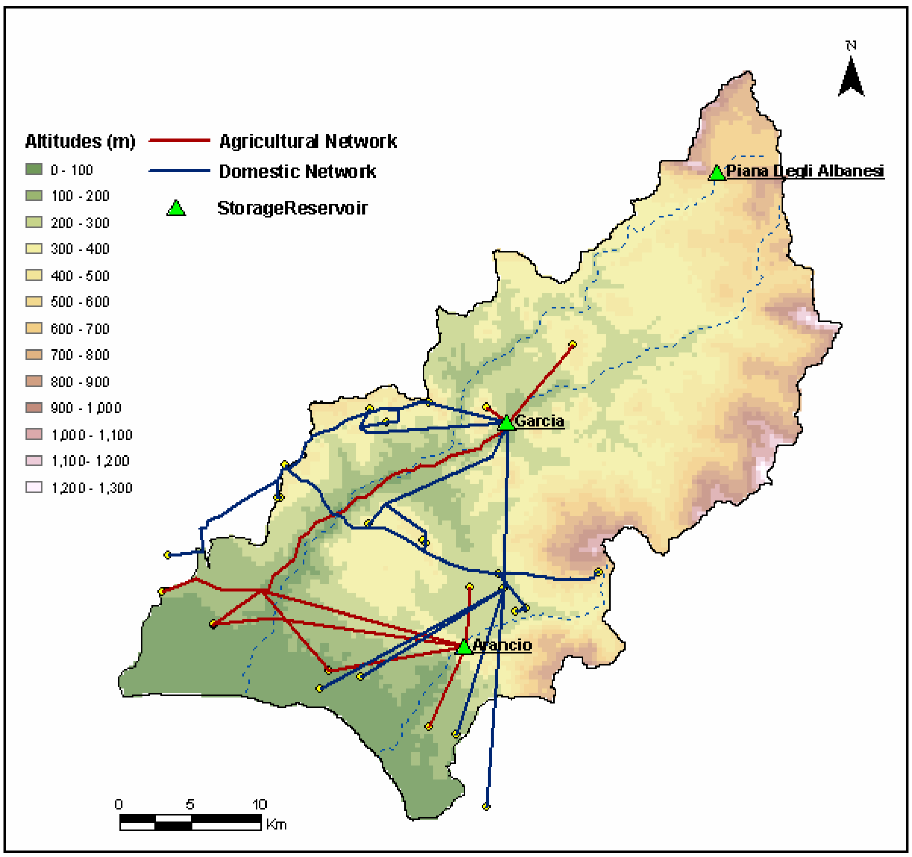


Figure 4-1 Domestic and agricultural networks in the Garcia-Arancio Districts and Belice Basin

Montescuro originates from the springs of the Sicani Mountains, outside and east of the examined area, and goes across the Belice Basin from East to West. It covers 65% of its urban demand. Within the case study area, it supplies the settlements of Castelvetrano, Gibellina, Montevago, Partanna, Poggioreale, S. Margherita Belice, Salaparuta and Sambuca di Sicilia.

Outside the examined area, water is conveyed to some territories of Palermo, Trapani and Agrigento. Favara di Burgio is supplied by the water springs in the town of Caltabellotta and covers 67% of the water demand. It supplies Menfi and Sciacca within the area and other territories of Agrigento outside.

In terms of irrigation, the Garcia Lake serves the cultivated lands under the competence of the Co-operative no.2 - Palermo, Co-operative no.1 -Trapani and Co-operative no.3 -Agrigento, this latter being responsible for the four *Garcia –Arancio districts* of the case study.

These districts can rely on their own water source, the Arancio Lake, which has a useful capacity of 30 hm^3, and is entirely used for irrigation. This lake, however, is not sufficient to cover the crop requirements during the summer period, and the withdrawals from the Garcia are fundamental to the survival of the cultivations. The role of Garcia is not limited to the water supply during summer: it also has the task to recharge the Arancio during the winter months. But although in winter water is available for all users and uses, both irrigation and urban, it is in the summer that the water resources of Belice Basin have to be shared and deficits may arise. Although the construction of the Garcia Reservoir was promoted in 1969 with the scope of irrigating the nearby lands, and only in 1986 it started being used for urban needs, the latter have the highest priority. As a result, the shares for the exploitation of the reservoir water, established as percentages of the existing volume, are bound to that priority.

The goal of the formulation of scenarios and strategies for the Garcia-Arancio districts area is to verify the policy measures that are under implementation by the local authorities, which concern improvement of distribution efficiency, both for domestic and agricultural users, and further exploitation of existing surface water. This analysis addresses the potential solutions for a complete satisfaction of the agricultural demand under a negative trend of the climatic conditions, precipitation decrements and temperature increments, and under a forecasted rise of the urban consumption.

The dominant philosophy of the past concerned the constructions of new reservoirs, the interconnection of existing ones and the mutual integration between different water sources such as lakes, springs and local boreholes. At the time being, some projects for waste water re-use are under examination and others are being carried out. On the side of irrigation practices, several steps have been made towards an efficient distribution of water since 1957, when the first cultivated lands of the area were provided with water through a network of open surface canals. They have been progressively replaced by pipelines, and the use of irrigation methods such as drip is even more increasing. Demand management options, such as reduction of network losses or application of quotas, are also to be implemented to balance the growing consumption rates for the urban water users, which are forecasted to double in 30 years.

Target definition

The targets set for strategy formulation is to meet specific water needs for irrigation and domestic purposes. This can primarily be achieved by improving the efficiency of water distribution networks in the integrated water supply system. However, the costs of the interventions should be borne by the local population.

The **Primary Target** as defined for the Belice Basin case study is the following:

- To meet irrigation demand, especially in the period from May to October (when plants growth occurs);
- To lower water deficit in domestic use.

Identification of Available and Feasible options

The potential policy options identified in the course of the WSM Project were subsequently analysed in their applicability to the Garcia-Arancio region through consultation with the local stakeholders. Major stakeholders in the region that were consulted were:

- **The Consortium 3 – Agrigento for Land Reclamation;**
- **The EAS, Ente Acquedotti Siciliani.**

The following paragraphs present the outcomes of the stakeholder interviews. These were used to define a synthesis of applicable options that – according to their perception– could be effective in mitigating water deficiency and related environmental problems in the Garcia-Arancio region.

Stakeholder consultation

The Consortium 3 – Agrigento for Land Reclamation is in charge of the water resource management and water service for irrigation purposes of the case study area. For this agency the critical circumstances for irrigation that can appear during dry climatic conditions appear with the enlargement of the pumping station on Belice. At present this plant supplies the nearby lands with water, but it has the major task of recharging the Arancio Lake during the year. Its development would increase the amount of exclusive water the irrigated sites can rely on, given that the volumes transferred by Garcia are constrained to the first priority of use of the settlements. The required energy to pump more water would be provided by wind power plants that are being designed. Another structural option they are working on is the construction of facilities which allow using the treated urban waste water in order to supply the cultivated lands. They are planning to deliver the treated effluents to the irrigated districts directly during summer, and to recharge the Arancio during winter. From the demand management side, the replacement of high water demand crops with others with smaller requirements is to be excluded, because it would be against the development policy of the past forty years. Instead of that, the measures of the agency relate the improvement of the irrigation efficiency through an overall increased use of the drip method in place of the sprinkler until covering the entire cultivated land with that.

The EAS, Ente Acquedotti Siciliani, is the regional authority in charge of the aqueducts in Sicily, but all their competences pass to the new founded *Sicilia Acque* (summer 2004). The EAS manages the Garcia reservoir, in collaboration with the Consortium 2 – Palermo for Land Reclamation, and the network of Montescuro Ovest that gives water to many settlements inside and outside the Belice basin. The infrastructure of this aqueduct is currently under replacement, an activity whose scope is to assure lower distribution losses so as to cover, with the same output of the springs, a higher percentage of the total domestic consumes. On the other side, the agency is also going to boost the Garcia reservoir, a water source that presently integrates the Montescuro supplies: a water plug will be constructed on the right branch of the Belice and connected through pipelines to the storage reservoir, on the left branch. The next project will then regard the development of the Drinking Water Treatment Plant of Sambuca di Sicilia, in order to make available an effluent of 1,200 l/s to be supplied to the Montescuro and outside the case study area to the Favara di Burgio aqueduct. From the socio-economic and institutional side, the regional agencies for domestic water supply have to satisfy the urban demand with first priority while at the same time try to recover the cost of service, the direct cost for the new infrastructure mostly. Education and conservation campaigns always appear on the agenda and the water prices are set according to the tiered pricing method, thus discouraging the waste of water. In spite of that, the first objective is still the augmentation of the available water resources.

Synthesis of proposals for improved water management strategies

Based on the outcomes of the stakeholder consultation and own experience, a synthesis of the current management policies and of additional, imposed measures applicable to the area of Garcia-Arancio district is presented in Figure 4-2.

The options/measures that were examined for the case study pertain to three major categories:

- **Structural options** for supply enhancement, including:
  - *Construction and expansion of pumping stations***,** aiming at the augmentation of water available at the Garcia reservoir;
  - *Connection to irrigation sites of existing treatment plants*, to provide additional water supplies particularly during the peak consumption periods;
- **Demand management options**, including:
  - *Reduction of Network losses*, through replacement of the fifty year old Montescuro distribution network (structural intervention);
  - *Improvement in Irrigation Methods*, in order to consider the current trend in substituting the current sprinkler systems with drip irrigation;
- **Socio-economic measures** in the form of an increasing water selling price for the domestic sector, under assumptions on demand elasticity, in order to examine what influence such a policy would have in the water allocation in the system.

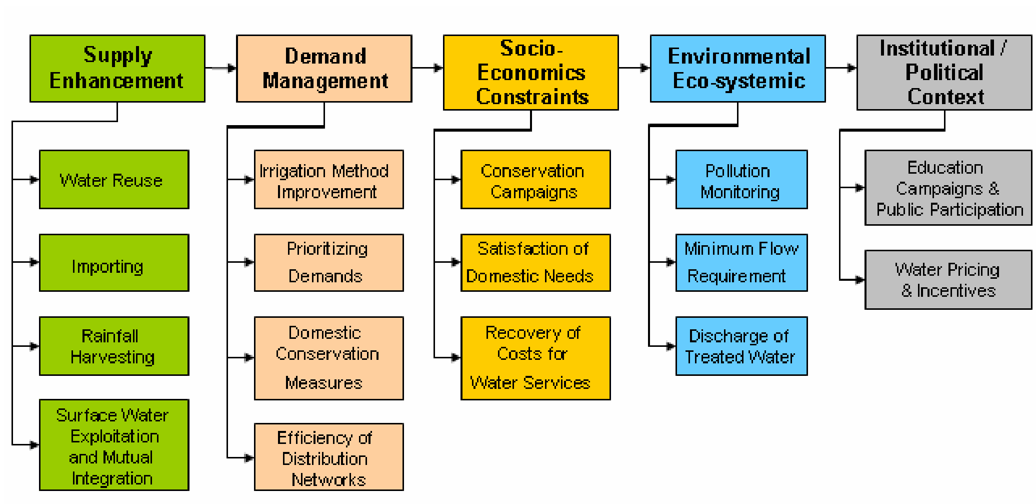


Figure 4-2 Summary of management options

Evaluation of Water Management Options

The evaluation of the different management options was performed following a two-stage process:

- First, alternative future demand and availability scenarios were formulated, in order to assess the current and foreseen state of the water system. The combinations of these, depicting a normal state, a high shortage and a low shortage state were used as reference scenarios for the evaluation of the different options.
- Then each option was evaluated and compared against each respective reference scenario. The aim of this process was to assess the extent to which each option can be effective in mitigating the shortage situation and the related incurred costs from a potential application.

The following paragraphs aim to provide a summary of the outcomes of this process, analysed in further detail in Chapter 10, along with more general data and assumptions on the estimation of costs and the selection of appropriate indicators for option evaluation.

Formulation of demand and availability scenarios

The formulation of **Demand Scenarios** for the Garcia-Arancio districts involved four types of water demand: residential and tourism demand, agricultural demand, and demands that have to be supplied outside the region that is being studied (both agricultural and domestic). Their formulation was based on the following data and assumptions:

- Available information on agricultural development is only short-term and limited. Therefore, corresponding projections in every developed scenario were of the same importance.
- The two Consortia for Land Reclamation of Trapani and Palermo are planning an expansion of their irrigation systems from 2004 and onwards (INEA, National Institute for Agricultural Economics).
- The construction of two tourist facilities of minor importance is being planned for the immediate future, influencing, thus, tourism demand.

However, the core of the formulation of **Demand scenarios** for the Garcia-Arancio district was assumptions on the trends in urban consumption rates. Such projections were based on data provided by the relevant study of SOGESID, covering the period 2005-2032. On the basis of these, three different scenarios were formulated for the period 2001-2020: one depicting a growing demand, one assuming an urban demand that is stabilised after 2015, and one assuming a constant, “permanent” demand which presumes that population, urban consumption and agriculture will be constant throughout the examined period.

Availability Scenarios and consecutively projected values for run-off and aquifer recharge were formulated on the basis of a detailed hydrological balance, applying the Rainfall Scenario Module of the WSM DSS. First of all, three scenarios of rainfall and three of temperature were defined, namely Normal, Wet and Dry for the former, and Normal, Hot and Cold for the latter. Then these were combined, in order to perform a soil water balance at the watershed level and obtain availability scenarios of runoff and recharge. In order to maintain consistency with past historical events, the forecasted availability scenarios have been built taking into account the negative rainfall trends of the past forty years, from 1951 to 1990.

Summary of option evaluation outcomes

The selection of appropriate indicators in order to rank the above options reflects the responsibility of the water agencies to assure the coverage of the domestic demand, and the objectives of the Consortium no.3 Agrigento that requires a sufficient yearly amount of water to satisfy crop requirements during the irrigation season. These water uses are also in conflict during the summer because they share the surface water of Garcia Lake, but domestic supply is of first priority. As a consequence the analysis of options was formulated around the **coverage of domestic and irrigation demands**. Therefore, the effectiveness of an option relates the level of domestic and irrigation demand coverage that was reached; it is approached by a relative index obtained by the evaluation module of WSM DSS, assuming a weight of 0.5 for each coverage indicator, and a satisfactory range of values from 70 to 100%. Environmental sustainability is expressed through the total environmental cost for each option, which, in the Garcia Arancio case study, was associated with surface water abstractions from reservoirs and river reaches of interest. This criterion takes into account the costs that the local authorities should have to pay in order to replenish the overexploited surface water resources with treated waste water. Economic efficiency, the ability to produce more with less, is expressed through the total direct (financial) cost. Both the environmental and the direct cost were expressed in present value terms for the evaluation.

Chapter 10 presents the overall evaluation procedure for each option, as well as the demand and availability scenarios that were formulated for their analysis. Table 4-1 and Table 4-2 present the final results of the option evaluation for the Belice Basin Case Study in numerical values and normalized form, for a normal (average) availability scenario and a business-as-usual demand scenario, hereafter mentioned as the reference case.

Table 4-1 Option Performance Matrix

Option	Effectiveness (Relative Sustainability Index for Demand Coverage)	Economic Efficiency (Direct Cost – PV – million €)	Environmental Sustainability (Total environmental cost – PV in million €)
Base Case	0.0308	506.5	960.7
Waste Water Reuse	0.0306	512.6	965.6
Exploitation of Belice	0.0006	550.9	980.5
Irrigation Methods Improvement	0.0137	619.6	941.6
Water Pricing	0.0206	505.6	936.8
Reduction of losses	0.0205	487.0	935.8

From the point of view of effectiveness, Table 4-1 shows that the options simulated separately do not help in meeting the overall needs for domestic and irrigation supply. In fact the demands are not 100% covered under the Reference situation and the value of effectiveness remains more or less close to or slightly below the reference case even with the strategic options. All the options analysed in the case study aim at improving the agricultural effectiveness, which is the primary goal of the water strategy in the case study of Garcia-Arancio. These options include interventions that act directly in favour of the irrigation requirements, such as the waste water reuse, the Belice exploitation and the irrigation method improvements, but also measures that act in favour of the domestic water needs and should have an additional positive effect on the irrigation demand coverage, e.g. reduction of distribution losses and water pricing. Both irrigation sites and domestic users need water, but urban users have a higher priority. As a consequence all policy measures which seem to indirectly bring an advantage to the agricultural sectors are nullified. In conclusion, although the analysis of the single graphs of domestic and irrigation effectiveness (Chapter 10) portray that the options can help in impact mitigation it seems clear from that only their integration in a strategic plan can lead to a more significant result.

Among the best options examined is waste water reuse, which reaches a good score from an effectiveness and economic efficiency point of view. This is the option that involves and influences the districts directly more than others and its positive effects do not depend on the competing domestic user or on the reduced availability scenarios. The low performance score of the Belice exploitation option) underlines that in general structural interventions should account for the forecasts of water inflows at river reaches and reservoirs, because an expansion of a structure that will never work at its maximum is not worth it. Besides, if a few structural interventions are to be combined together, the possibility that increased supply allocated to a category of users could decrease amounts allocated to others should be investigated and preferably avoided.

Table 4-2 Normalised option performance matrix

Option	Effectiveness	Economic Efficiency	Environmental Sustainability
Waste Water Reuse	*****	****	**
Exploitation of Belice	*	***	*
Irrigation Methods Improvement	***	*	*****
Water Pricing	****	****	*****
Reduction of losses	****	*****	*****

This first approach to the demand and availability scenarios and to the evaluation of proposed feasible water solutions for the Garcia-Arancio case study has pointed out that institutional policy, such as water pricing, and demand management options, like the replacement of old aqueducts and pipelines to lower the losses, are the best strategic options, as they reach the highest score for the three criteria of effectiveness, economic efficiency and environmental sustainability.

Strategy Formulation and Evaluation

Assumptions

Strategies were formulated on a medium-long term of 20 years, starting from the year 2001 up to 2020; the design and planning assumed average availability conditions. More specifically, the availability scenario consisted of a randomly generated series of "normal" hydrological years (years during which rainfall values do not fall in the top or bottom 30 percentile of the observed values). The demand trend applied was based on a Business-As-Usual demand scenario.

Formulation of alternative water management strategies

Following the results obtained from the evaluation of the different options, summarised above, two alternative strategies were formulated, and evaluated against each other and against the reference case. **Strategy 1** reflects the current approach, incorporating management options and measures either already in use or emerging in the area as newest techniques and methods applied or proposed. **Strategy 2** simulates a "soft-path approach" including small-scale decentralized solutions, and measures aimed at increasing the efficiency in water use. The formulated strategies are briefly analysed in the paragraphs that follow.

Strategy 1 – The "hard path" approach

Responses adopted in the framework of Strategy 1 are dominantly structural and involve construction and rehabilitation of large scale infrastructure. 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;
- The expansion of the drinking water treatment plant of Sambuca di Sicilia;

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

Figure 4-3 shows the DPSIR indicators and the subsequently selected responses for Belice basin. An initial timeframe for the application of the interventions, formulated according to their technical characteristics and performance is presented in Figure 4-4.

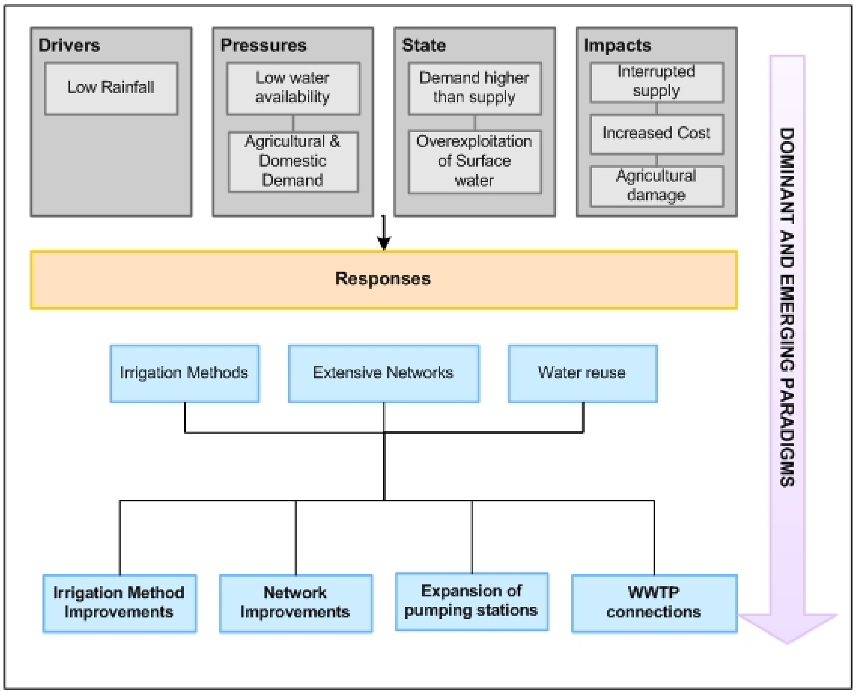


Figure 4-3 DPSIR indicators and the selected responses for Belice

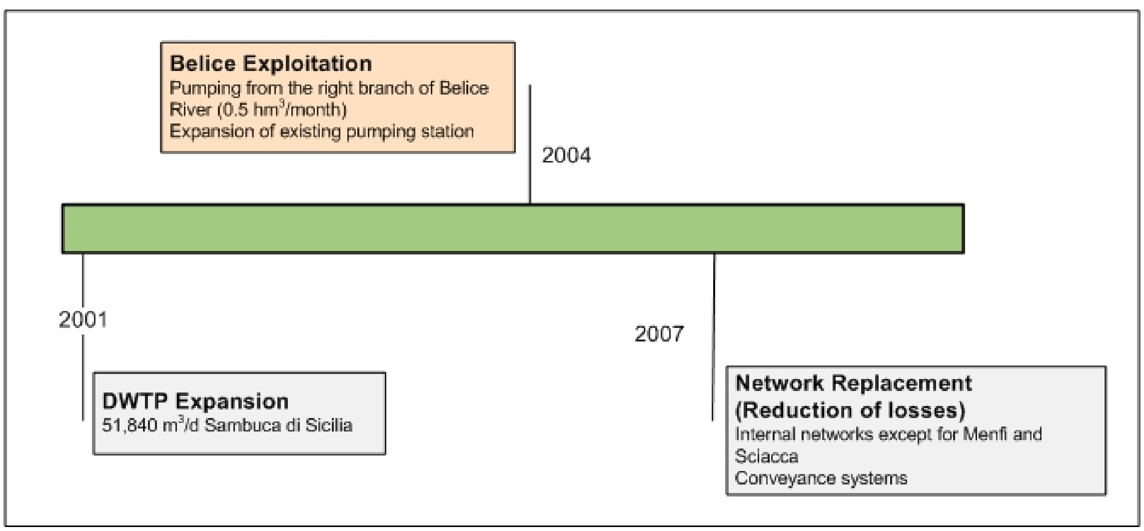


Figure 4-4 Tentative Timeframe of interventions within Strategy 1

In summary, the interventions specifically applied were the following:

- The option of further exploiting the surface water of Belice river, through:
  - Pumping from its right branch a quantity of 6 hm^3/yr
  - Expansion of the existing station on Belice working from January to April and yielding 7 hm^3/yr
- Reducing distribution network losses through network re-construction. Estimated loss reduction that can be achieved is:

  - From 40 to 21 % in the internal networks of municipalities;
  - From 40 to 21 % in the pipelines which convey water from the drinking water treatment plant to settlements.
- Expansion of the drinking water treatment plant of the region, by doubling its capacity (from 25920 m^3/d to 51840 m^3/d, starting from 2001).

Strategy 2 – The "soft path" approach

The second Strategy was developed under the objective to reduce deficit for domestic and irrigation users. The interventions adopted aim at increasing water availability, and promoting a more equitable and functional water distribution. For the reduction of domestic deficit the quantity of fresh water allocated to the irrigation districts should be replaced by equal quantities of treated effluent produced in the local waste water treatment plants. In addition, the flow capacity of the existing pipeline connecting Garcia Lake to the Drinking Water Treatment Plant of Sambuca di Sicilia should be doubled. This measure is to be effected in combination with the expansion of the drinking water treatment plant in 2001. The Strategy formulated within this framework is then highly dependent on efficiency improvements.

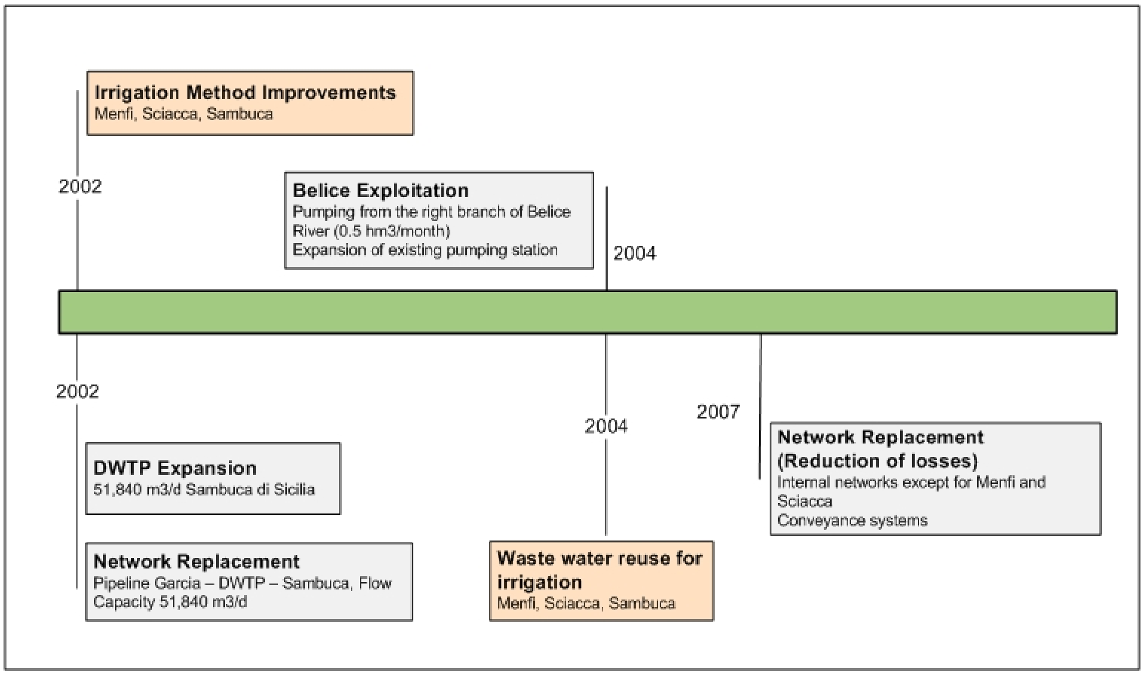


Figure 4-5 Tentative timeframe of interventions within Strategy 2

In more detail, the interventions included in the strategy and shown in the tentative timeframe of Figure 4-5 were the following:

- Expansion of the drinking water treatment plant (DWTP) of Sambuca from 25,920 m^3/d to 51,840 m^3/d;
- 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;
- Irrigation method improvements through the application of drip irrigation for the areas of Menfi, Sambuca di Sicilia and Sciacca;
- 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;

- Exploitation of surface water from Belice River. This, similarly to Strategy 1, 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;
- 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.

Strategy Evaluation

The two formulated strategies were simulated in the WSM DSS and evaluated against each other and the reference case. The percent demand coverage in the domestic and irrigation water use is presented in Figures 4-6 and 4-7 respectively. It should be noted that in Figure 4-7 the curves for both strategies coincide, since irrigation demand coverage was the main target for strategy formulation.

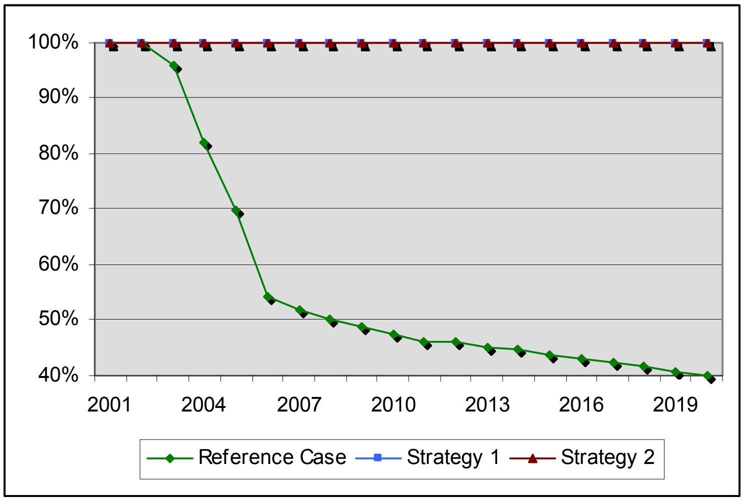


Figure 4-6 Domestic Demand Coverage (%)

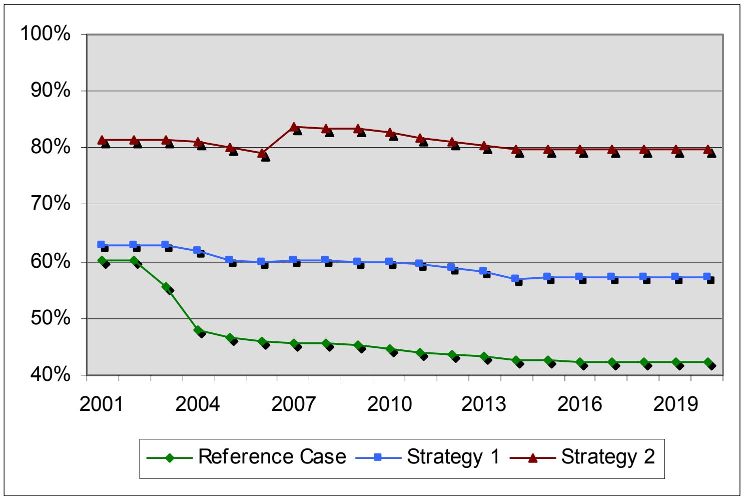


Figure 4-7 Irrigation Demand Coverage (%)

Table 4-3 shows the scores obtained by comparing the two Strategies with the application of four indexes: Relative Sustainability Index for Demand, computed from the evaluation scores for domestic and irrigation demands assigning a weight of 0.5 to each indicator, Direct and Environmental Costs, and total value to users.

Table 4-3 Strategy evaluation table

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Total value to users (PV – million €)
Reference case	0.000	413.6	1672.6	1934.1
Strategy 1	0.494	636.3	2617.9	9249.8
Strategy 2	0.593	669.5	2700.1	9257.1

Finally, in Figure 4-8 the present values for direct, environmental and resource costs are depicted. It should be noted that both strategies present similar direct and environmental costs. The major difference lies in resource costs, where Strategy 2 indicated significantly lower values. Figures 4-9 to 4-11 illustrate the variation of total direct and environmental costs associated with freshwater provision for the two uses.

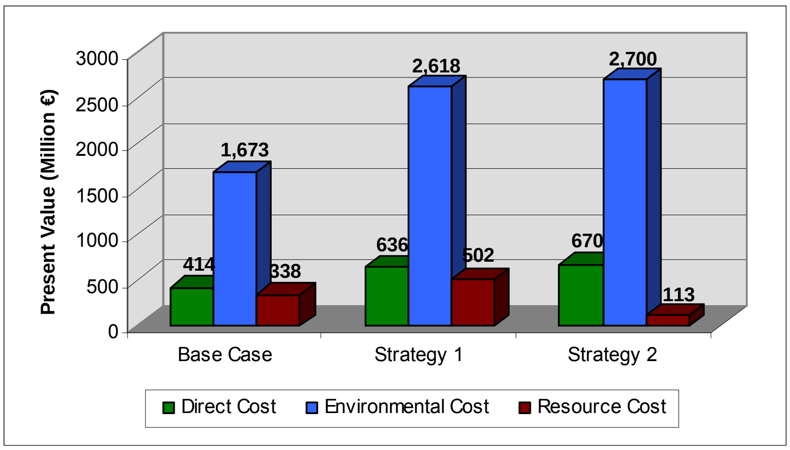


Figure 4-8 Present Values of direct, environmental and resource costs

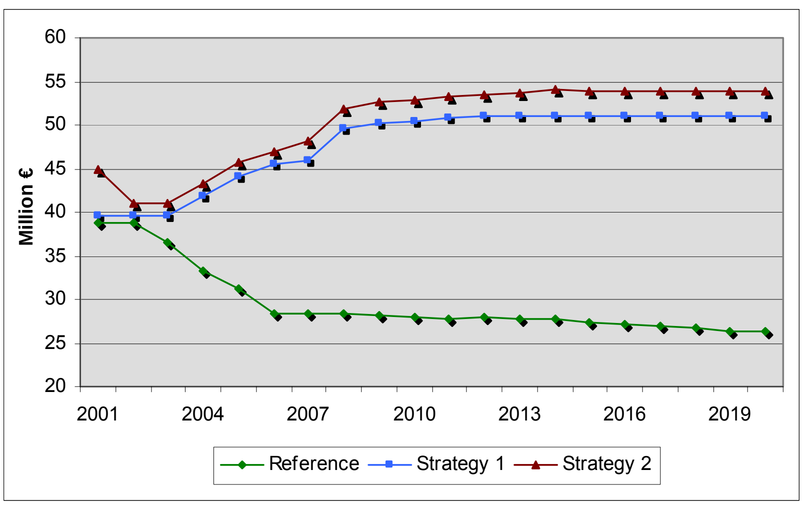


Figure 4-9 Total Direct costs

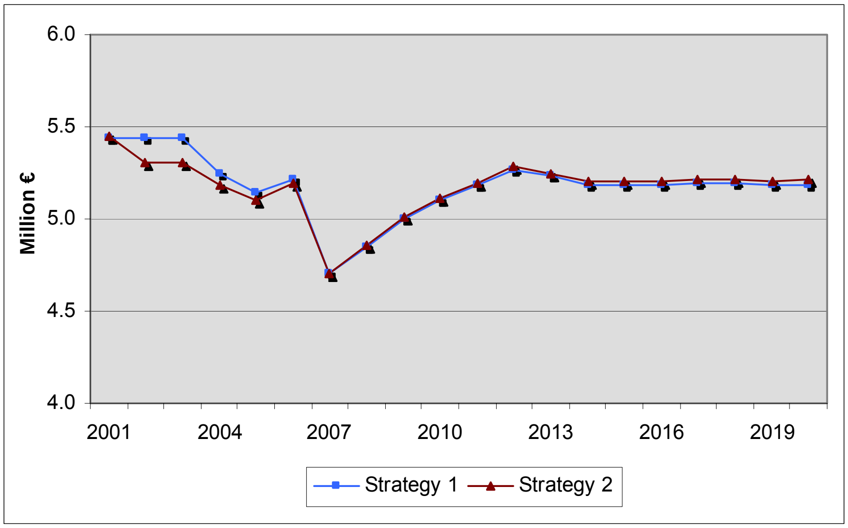


Figure 4-10 Environmental costs allocated to domestic use

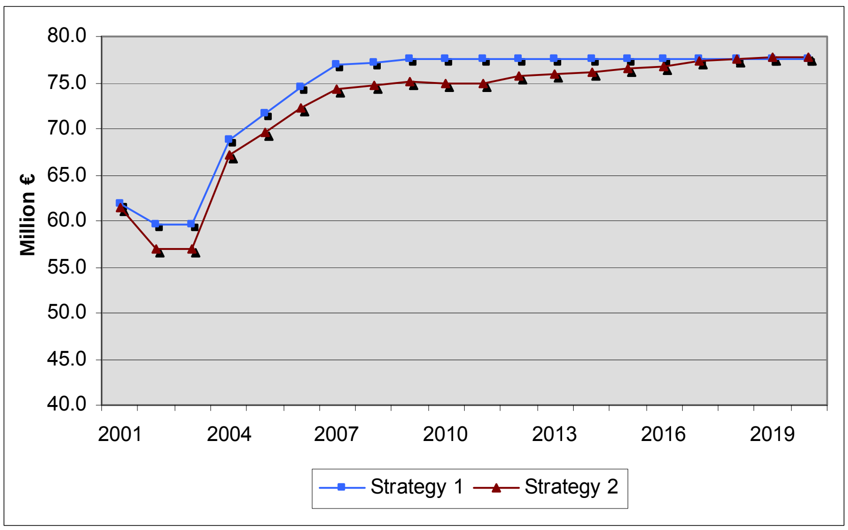


Figure 4-11 Environmental costs allocated to agriculture

Development of a Cost Recovery Strategy

Formulation of cost recovery strategies

Development of cost recovery strategies was based on achieving a recovery for total direct costs. The two formulated Strategies have been further analysed on the basis of proposed pricing schemes targeting domestic users. Two different solutions have been suggested: the first (Strategy A) is based on indications provided by local authorities, while the second (Strategy B) is formulated taking into account National and European prices, as well as a minimum target for cost recovery.

Cost Recovery Strategy A

The schemes developed were based on a gradual increase of water prices. The price is assumed to increase at a yearly rate of 2.7% for the entire scenario duration, from an initial value of 0.8 €/m^3 to a final 1.2 €/m^3, achieved after twenty years. Water demand elasticity for domestic users is assumed equal to -0.2 for residential demand and -0.35 for tourist demand. The increasing price function for both strategies is the same, shown in Figure 4-12.

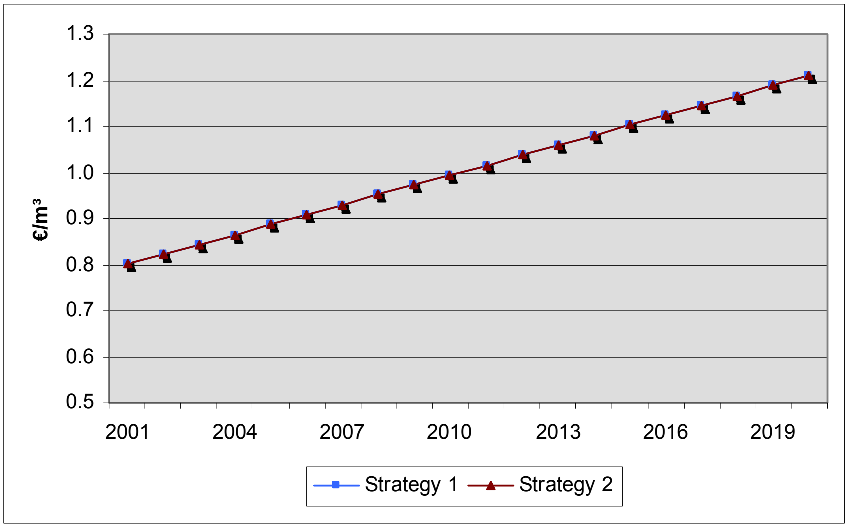


Figure 4-12 Increasing price for domestic use

Cost Recovery Strategy B

This strategy aims at recovering at least 50% of total direct costs, by increasing water price for domestic and irrigation use over a five-year period. According to the results obtained from the two strategies, total costs to be recovered are presented in Figure 4-13.

More specifically, the progress of the water selling price increase is expected to be the following:

- Water price for domestic use rises by 0.50 €/m^3 every 5 years: the price increases from 0.8 €/m^3 in 2001 to 2.3 €/m^3 in 2020;
- Water price for irrigation purposes rises by 0.05 €/m^3: the price increases from 0.14 €/m^3 in 2001 to 0.28 €/m^3 in 2020. Elasticity is assumed to be equal to -0.1.

The increase of water selling prices throughout the scenario duration is portrayed in Figure 4-14.

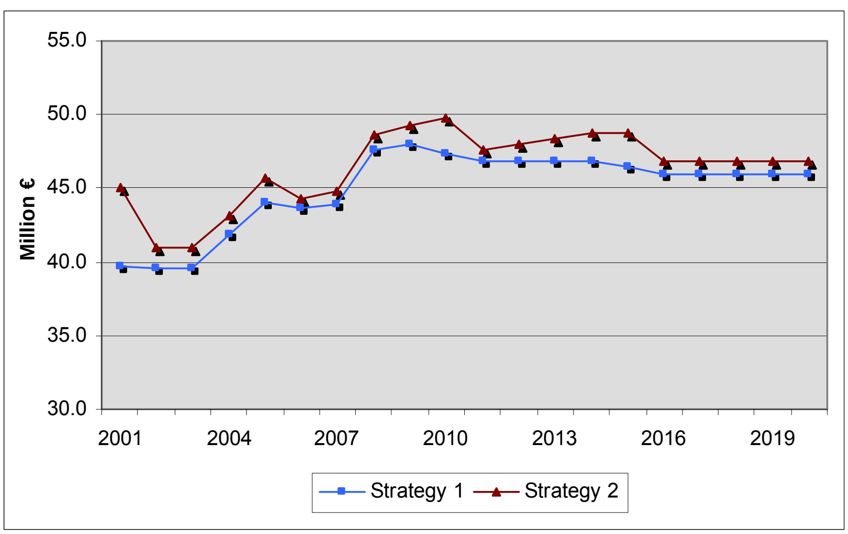


Figure 4-13 Total direct costs to be recovered

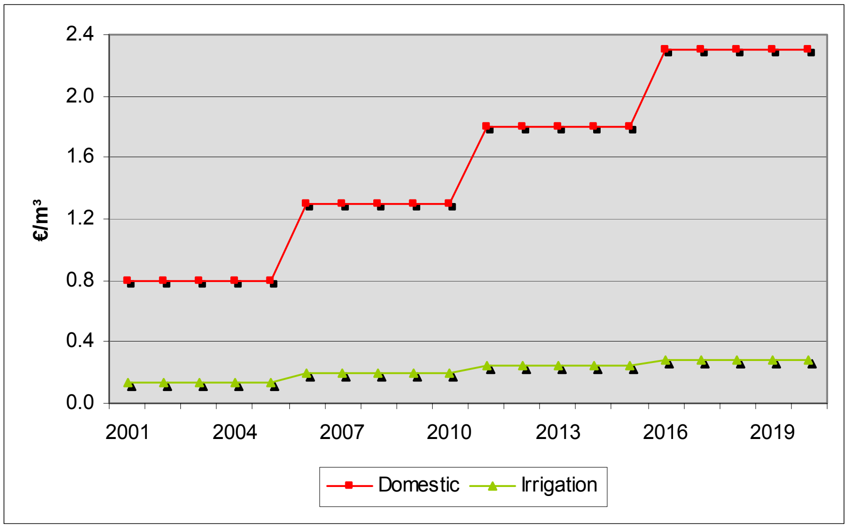


Figure 4-14 Growing price for domestic and irrigation use

Re-evaluation of strategy options and performance

The high values of demand elasticity assumed for the Belice Region (-0.2 for residential demand, -0.35 for tourism demand and -0.1 for irrigation purposes) suggest that an increase in water price could result in a reduction in water demand. The following results confirm this hypothesis: an increase from 1.2 €/m^3 to 2.3 €/m^3 in 2020 causes a decrease of approximately 30% in water demand (40% if compared to the scheme where no further pricing is applied). Table 4-4 and Table 4-5 show the obtained evaluation results for each of the four indicators after the application of the two strategies and the different economic policies.

Table 4-4 Adjusted Strategy evaluation table (under Cost Recovery Strategy A)

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Total value to users (PV – million €)
Reference Case	0.000	413.6	1,672.6	1,934.1
Strategy 1	0.494	631.2	2,618.2	9,285.2
Strategy 2	0.644	661.0	2,697.8	9,251.7

Table 4-5 Adjusted Strategy evaluation table (under Cost Recovery Strategy B)

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Total value to users (PV – million €)
Reference Case	0.000	413.6	1,672.6	1,934.1
Strategy 1	0.494	604.0	2,551.7	8,833.1
Strategy 2	0.639	624.8	2,597.3	8,873.6

Figure 4-15 and Figure 4-16 present the results obtained by applying the first Cost Recovery Strategy (Strategy A), in comparison to the reference case. Domestic demand reduction appears the same for both strategies because of the same policy applied.

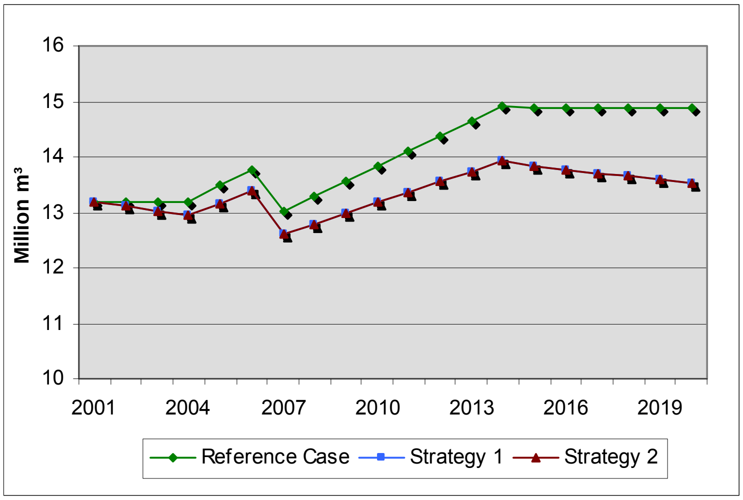


Figure 4-15 Domestic demand under Cost Recovery Strategy A

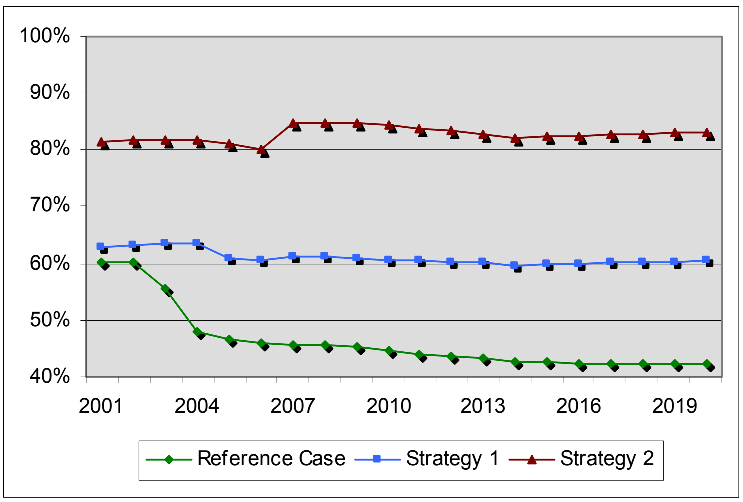


Figure 4-16 Domestic Demand Coverage under Cost Recovery Strategy A

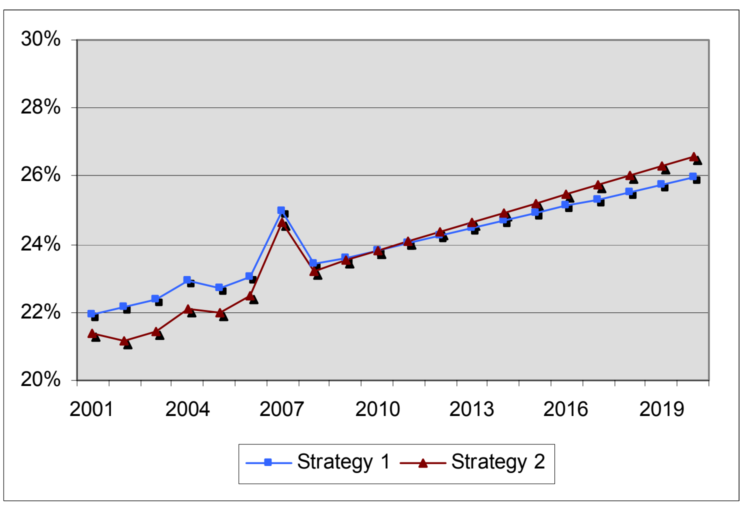


Figure 4-17 Achieved recovery rate for direct costs under Cost Recovery Strategy A

The results obtained with Strategy B are presented in the figures below. It should be noted that some segments of the two curves in Figure 4-18 coincide.

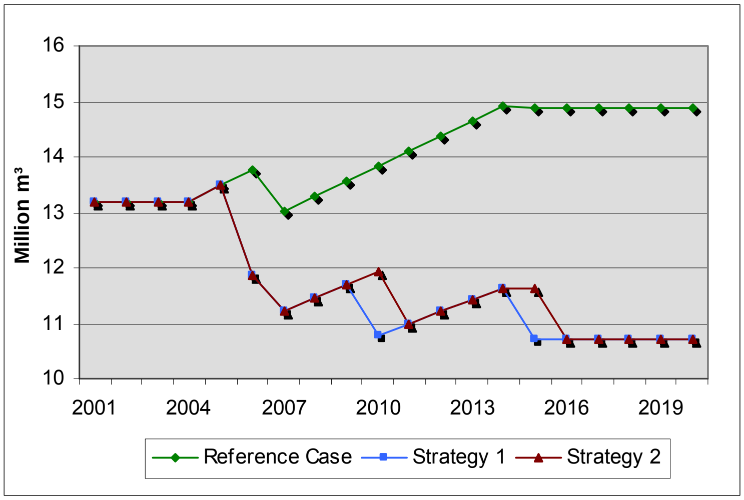


Figure 4-18 Domestic Demand under Cost Recovery Strategy B

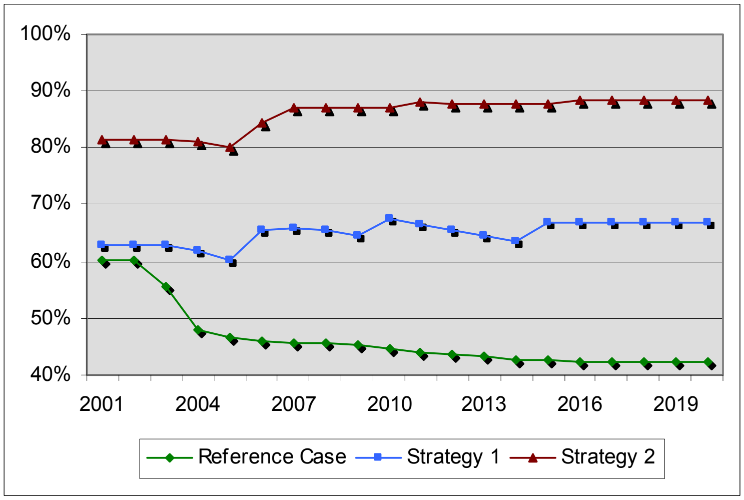


Figure 4-19 Domestic Demand Coverage under Cost Recovery Strategy B

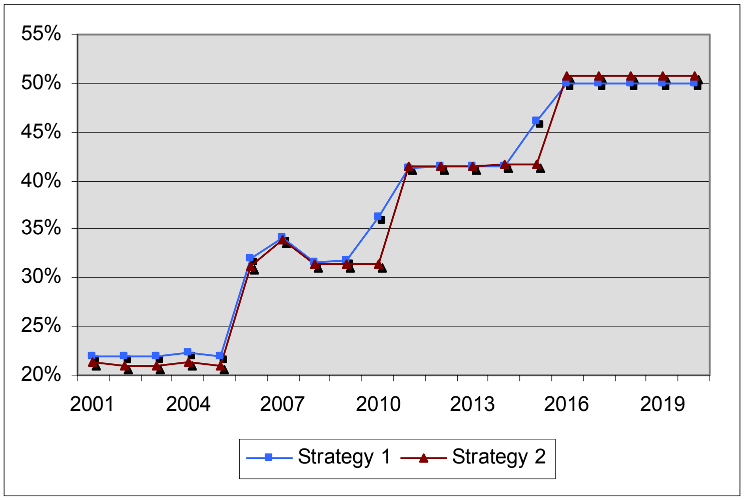


Figure 4-20 Achieved recovery rate for direct costs under Cost Recovery Strategy B

Finally, in Figure 4-21 the cost recovery rate of total direct costs achieved under the two alternative pricing policies is compared.

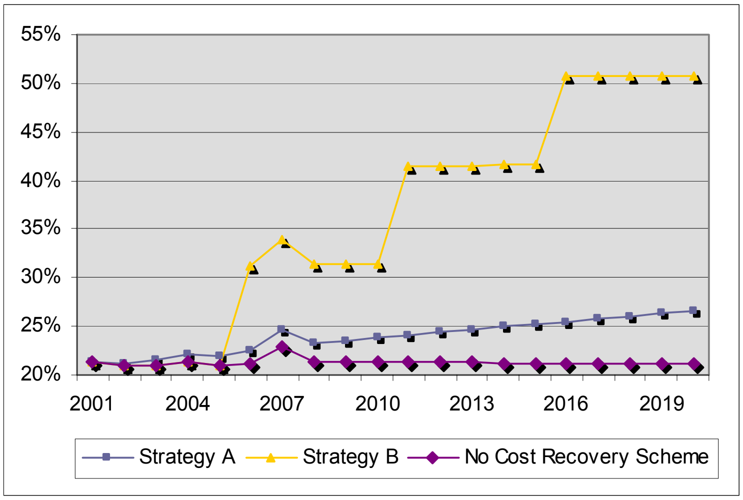


Figure 4-21 Cost Recovery Rate achieved under the two cost recovery strategies

Discussion and Recommendations

The analysis of the two Strategies portrays that the suggested interventions can possibly meet local water need for irrigation use, while domestic demand can be met only with Strategy 2. Domestic supplies are 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 two reservoirs and the Montescuro Ovest aqueduct. If interventions on conveyance and treatment systems are realised, the analysis suggested that nearly 90% of domestic water needs can be effectively met.

The suggested increase of water prices does not always affect water demand, provided that local authorities adopt a relatively gradual and “mild” price increase. If a ‘hard’ (but politically less desirable) approach is adopted, such as the one analysed under Strategy B (Figure 4-18), a drastic reduction in water demand is likely to be expected. However, one should note that results are biased from the high demand elasticities assumed in the analysis of cost recovery strategies.

Moreover, the analysis of the results of the two pricing policies shows that total direct costs can be hardly recovered, unless unpopular measures are adopted. Apparently, only with Strategy B at least 50% of total direct costs are likely to be recovered (instead of 27% cost recovery with Strategy A); this percentage drops to only 9% if total costs are considered (Resource and Environmental costs).

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

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

- Improvement of the efficiency of water distribution networks, by reducing water losses in the secondary network and along the main pipelines;
- Waste water reclamation and reuse, and improvement of irrigation efficiency;

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

Chapter 5 Water Management Strategies for Tel Aviv Region, Israel

The Israeli Water Economy

The Water Crisis

Chronic scarcity of water is a fact of life in Israel where aggregate demand exceeds the supply of fresh water in a largely semiarid environment. The commonly agreed upon policy of maintaining a long-term balance between potential available water and the utilization of water resources has not been able to keep up with consumer pressure, especially the pressure from the agricultural sector. The Israeli water economy is in the midst of a crisis, the main features of which are a shortage of fresh water and a steadily increasing deficit, poor and declining groundwater quality (gradual salinisation), and pollution of most of the streams by untreated urban , industrial and agrochemical effluents (Zaslavski, 2001).

The main quantitative expression of the crisis is a sharp decrease in the ability to pump groundwater without crossing predetermined red lines, where the agricultural sector bears the brunt of the necessary cuts. Since all significant natural water resources in Israel are largely overexploited, attention is being increasingly focused on the development of unconventional water resources, namely, desalination of sea water and recycling of sewage effluents. The supply of reclaimed sewage is expected to grow substantially due to increases in water supply for the growing domestic and industrial sectors, and the expansion of irrigation with recycled effluents. Indeed, a large-scale transition in agricultural water use, from good-quality water to treated wastewater, is expected to occur within the next few years. This shift requires the development of many more environmentally safe water-treatment plans, reservoirs and conveyance systems. Treated wastewater can also be used for river restoration.

There is a total 351,460 hectares of cultivated land in Israel, 196,998 ha of which are irrigated (56% of the total cultivated area). The continuing scarcity is an excellent economic incentive for breakthroughs in irrigation technologies that were invented in Israel, such as drip irrigation and micro sprinklers, which have reduced water loss by 20%. Computer-assisted irrigation management enhances these results. Despite the modest role of agriculture in the national product (less than 2% of the GDP), irrigation consumes about 60% of the nation’s limited freshwater supply for own production and exports (water-intensive crops such as cotton and citrus are exported). There is a consensus among policy makers and water experts that the supply of potable water (i.e. urban consumption) should receive top priority. Nevertheless, some water experts point out that, while water used by industry or tourism is many times as productive as that used by agriculture, water is made available to farmers at about 65% of its price at the cities’ gates.

Among the many factors contributing to the water crisis are population growth and economic development, resulting in increased domestic and industrial consumption of fresh water. Additional crucial factors contributing to the crisis are inefficient institutional and administrative mechanisms for water allocation and control, and a poor decision-making culture (hydro-politics). The next sections are dedicated to a brief presentation of these factors.

Institutional and Administrative Framework

There is no private ownership of water in Israel. The Israeli Water Law of 1959 states that all water sources are publicly owned and that their utilization is controlled by the Water Commissioner. A single government-owned company, Mekorot, operates the National Water Carrier (NWC)[1] and provides approximately 60% of the total water supply; regional cooperatives and municipalities and private well owners supply the rest.

The allocation is administrative: the Water Commission issues permits for production (extraction) to suppliers as well as allocations (quotas) for agricultural consumers. In the past, these quotas constrained the use of water in agriculture. However, more recently, with higher prices for water and lower prices for agricultural products, the agricultural sector fails to exploit all of its allocation. Households, on the other hand, were never constrained in their consumption and formal quotas for this sector were abolished several years ago. The current water laws do not permit trading in water quotas, and the transfer of water rights between sectors such as agriculture and industry is unlawful.

Water pricing practices

Prices of water delivered by the national company Mekorot are set by the parliamentary finance committee, and are based on recommendations of the Ministry of Finance, the Ministry of Infrastructure and the Ministry of Agriculture. The prices are determined in consultation with the Water Council 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 of improving income distribution, water charges depend on the type of use: farmers pay the lowest charges, industry pays higher charges and households pay the highest ones. Within each sector, charges do not depend on location: users in all parts of the country face the same charges, regardless of the supply price of water (Kislev, 2002). Private water producers set prices independently.

Tiered pricing exists for agricultural users who pay a reduced price of $0.19 for the first 50% of their quota, a higher price of $0.23 for the additional 30%, and the full price of $0.31 for the rest of their quota (which in most cases is not fully utilized). Industries pay an average of $0.33 per m^3 and cities and towns pay $0.45 at the "city gate". Neither industries nor municipalities pay tiered charges. Households in cities face tiered charges, paying about $0.68 for the first block (typically 8 m^3 per household per month), $1.0 for the second block (typically 7 m^3 per household per month) and $1.47 per m^3 for any additional consumption. In other words, in addition to the prices that they pay to Mekorot for water, the municipalities impose two layers of surcharges on their households: one for the water-distribution system and for sewage removal, and the other in the form of taxes to help finance general municipal operations. This policy may be beneficial for the city in the short run but it might be very harmful in the long run, when funds will be required for reinvestment and renewal of the old water-delivery and treatment systems (Kislev, 1993). Water prices vary with quality. Water with over 400 mg of chlorides per litre is charged at a lower rate than fresh water according to its salinity level, with the average price being $0.16 per m^3. The charges for recycled waste

[1] The NWC, which is made up of canals and pipelines, was constructed almost 40 years ago, and is designed to divert the Jordan water from the Sea of Galilee to the center of the country and to Negev desert, thus enabling the settlement of this extremely arid region. The uniqueness of this carrier goes beyond the transference of water from the north to the arid south. It has become an operational tool, connecting all three major water sources into one system (Kislev, 1993). During the wet winter season, when even the southern part of Israel gets some precipitation, water is still being pumped from the Sea of Galilee and injected into the Coastal Plain and the Mountains aquifers, to recharge the declining water tables. During the summer time, irrigation all over the country is a must, because there is no precipitation between May and November and water is pumped from both the Sea of Galilee and the aquifers.

water are according to a two-tiered pricing system: the first 50% of the quota is provided at the higher rate of about \$0.15 per m^3 and the rest at the lower rate of \$0.11 per m^3. The largest treatment plant of wastewater in Israel is the **"Shafdan"**. It is a plant for the treatment of urban and industrial effluents from the greater Tel-Aviv metropolitan area (which includes more than 30% of the country's population), and is responsible for conveying **all** of its recycled water, about 90-100 hm^3 per year, to the southern region (western and northern Negev) for agricultural use, which are located 100 – 150 km away from this plant. The Shafdan is operated by Mekorot; the capital, operation and conveyance costs are about 0.30 $\$/m^3$, almost double than the price charged for the agricultural consumers. In short, recycled water from the Shafdan is highly subsidized.

The prices charged by Mekorot are subsidized by the Government which covers approximately 20% of the cost of supplying the water. In the past, part of the subsidy was implicit. While Mekorot operated the government-financed NWC, its capital cost was not reflected in the water prices. However, since 1993 Mekorot has been working according to a "cost agreement" under which it purchases the capital assets of the water economy, and their depreciation becomes a recognized component of its costs. Governmental support has therefore become explicit.

Hydro-politics and major stakeholders

As already noted, decisions on water prices are made in the political arena and are affected by pressures applied by interest groups, each of which attempts to affect public decisions in its favour. The farmers' main interest lies in receiving a large allocation of water supply at the lowest attainable price. Water is a significant input in agricultural production in arid and semiarid regions like Israel, and many farmers strongly support their representatives in the political arena. The agricultural lobby is very well organized and until now, its influence on water policies and pricing decisions has been significant. The share of water costs in household budgets or in manufacturing costs is relatively small. Therefore, urban and industrial water users have little incentive to organize political lobbies and, in effect, they do not offer up any strong opposition to the agricultural lobby (Kislev, 2002). The consequences of the success of the agricultural lobby have been the over-utilization of water for many years, hydrological deficits, the intrusion of sea water into the coastal aquifer, the contamination of reservoirs, and a reduction in the carry-over capacity of the system. These detrimental effects are among the major reasons for the current water crisis.

Although still very influential, the agricultural lobby has lost some of its political power in the last two decades. Agriculture in Israel is seen by many as an enterprise whose national value exceeds its contribution to the GNP via food production, which justifies governmental support (Netanyahu, 2000; Zaslavski, 2001). It contributes to security by protecting the country's lands, especially in peripheral areas, and by supplying food in times of emergency; it also contributes to the environment by protecting open spaces and preserving the natural and social landscape. In addition, its use of various qualities of water from various sources has been, and still is flexible, and it can serve as a safety net for the supply of water to local authorities (i.e. households) in times of emergency since it utilizes a large amount of fresh water.

Major stakeholders in the Israeli water economy

Decision-making and management relating to the water economy take place in many forums and are greatly affected by special interest groups, each pulling in its own direction (Soffer, 2001). The main stakeholders in the water arena which are relevant to our analysis 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 this body's 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).

(3) **Mekorot** is Israel’s national water company, responsible for most of the supply and maintenance activities, including the operation of the National Water Carrier and the Shafdan. In effect, Mekorot is the only entity with significant financial and operational abilities in the field of water resources. Its role in the overall financial turnover of water resources reaches about 80% of the sector’s business activity, since it operates a water system at high costs, conducts water for long distances and pumps water to elevated locations.

(4) **The Ministry of Agriculture**. The Minister of Agriculture is in charge of implementing many water laws, and can promulgate secondary legislation, such as determining norms for agricultural water use. His influence on decisions related to water pricing and on the Water Commissioner's decisions (regarding the allocation and distribution of water quotas) is crucial. **The Financial Committee of the Parliament** is in charge of determining water prices.

(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 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 the purification for all water types and their uses. This includes authorizing recycled wastewater irrigation of lands overlying groundwater aquifers. The **Ministry of Environmental Quality** is responsible for preventing water pollution and protecting water resources from contamination.

(7**) Farmers** (agricultural water users). As already mentioned, decisions on water prices are made in the political arena and are affected by pressure from special interest groups, each attempting to affect public decisions in its favour. The farmers' representatives are the strongest and most influential of such groups. The farmers' main interest lies in receiving large allocations of water, to be supplied at the lowest attainable price. The agricultural lobby is very well organized, and its influence on water policies and pricing decisions has been significant.

(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 sewage activities. Urban water consumption has the highest priority in the allocation of freshwater resources. The industrial sector also has high priority.

The large number of parties involved in the arena of water management hinders initiatives and changes, yielding a bureaucratic maze and a lack of synchronization of the different needs that the water economy has to fulfil.

Overview of the region of Tel Aviv

Case Study Selection

In principle, and in terms of water management, Israel can be examined as a single geographic entity for the following reasons:

(a) **Freshwater:** As mentioned, the National Water Carrier (NWC) connects all major sources of freshwater into a single network. Water can be transferred from one region to another, so that water from one aquifer may be used in a different geographical region. In addition to the NWC which transfers water from the Sea of Galilee in the north to the center and the south of the country (Negev), there are some additional major pipelines:

- (i) Connection of the coastal aquifer (in the west) to the Jerusalem metropolis,
- (ii) Connection of the NWC to the Northern Coastal Plain and Western Galilee (in the north), and
- (iii) Connection of the Hula Valley (near the source of the Jordan River) to the Mountains of Galilee.

(b) **Recycled water:** The Shafdan, a plant for the treatment of urban and industrial effluent of the greater Tel Aviv metropolitan area (home to more than 30% of the country's population), is responsible for transferring recycled water to the southern region (Western and Northern Negev) for agricultural use. Two large additional networks convey recycled effluent from the Jerusalem metropolis to the Negev Plain and from the Haifa metropolis to the Western Jezreel Valley, respectively.

(c) **Pricing policy**: Water prices by quality and sector (agricultural, industrial, urban) are more or less uniform throughout the country.

The current assessment focuses on the **Tel-Aviv region, a core part of the national water system.** The following paragraphs aim to provide a brief description of the current water economy of the region.

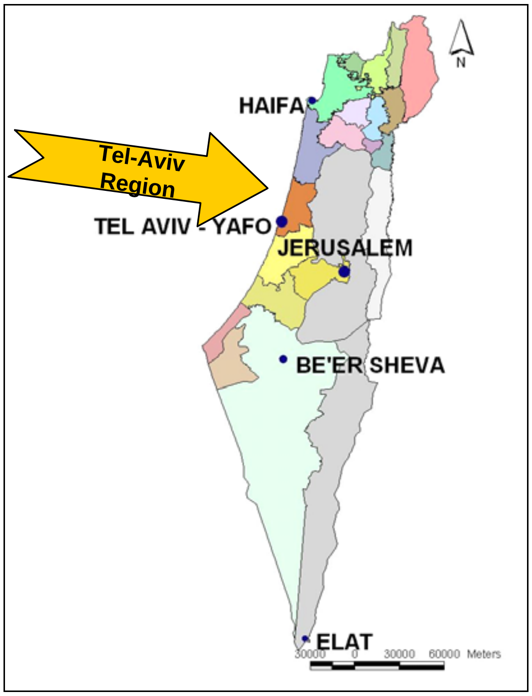


Figure 5-1 Map of Israel and the selected region

The region of Tel Aviv is located in the coastal plain on the eastern shore of the Mediterranean Sea (Figure 5-1) and it lies above the Coastal Aquifer[2]. It is characterised by a Mediterranean climate, with an average annual precipitation of 450 mm. The region is semi-arid with the Aridity Index ranging from 0.05 to 0.2.

In terms of population, the Tel Aviv region is the largest in Israel, concentrating 30% of the total population (approximately two million persons - Table 5-1[3]). The region has 14,700 hectares (ha) of cultivated agricultural land, 5% of the total cultivated land in the country.

Table 5-1 Distribution of Population by Type of Settlement

Type of Settlement	Tel-Aviv	
	thousands	%
Metropolitan areas (Pop. exceeding 200,000)	352	18
Big cities (Pop. 100,000-200,000)	902	47
Mid-sized cities (Pop. 20,000-100,000)	485	25
Small towns and cities (Pop. 2,000-20,000)	149	8
Villages and communities	42	2
TOTAL	**1,930**	**100**

Therefore, the water economy is characterized by relatively high domestic and industrial consumption and relatively low agricultural consumption, as detailed below.

Natural water sources in the area are mostly supply from the National Water System, operated by the national water company Mekorot. Freshwater is either extracted from the coastal aquifer, above which the region lies, or supplied from the Sea of Galilee via the NWC.

Table 5-2 Aggregate water supply for an average year

Source	Type	Quantity (hm^3)
National System	Fresh	40
	Recycled	16
	Total	56
Local System	Fresh	267
	Total	267
TOTAL	Fresh+ Desalinated	307
	Recycled	16
GRAND TOTAL		**323**

[2] The Coastal Aquifer underlies the coastal plain, adjacent to the Mediterranean Sea, and is composed of sandstone. The aquifer is bounded to the east by the foot hills of the mountain belt, in the north by the Carmel Mountain, in the South by the Sinai Desert, and in the west by the Mediterranean Sea. The major flow of the reservoir is toward the Mediterranean Sea where it eventually interfaces with seawater. The Coastal Aquifer is valuable storage basin since the sandstone layers hold water efficiently. The available storage capacity is 20,000 hm^3. Average chloride concentrations range from 50-250 mg/l but reach 600 mg/l in some part of the coast. The aquifer has a mean annual recharge of 250 hm^3 in addition to 50 hm^3 of agriculture drainage.

[3] Data in all tables refer to the year 2000.

In addition, part of the fresh water (some 35%) 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. It is important to emphasize that most of the urban and industrial waste water produced in the region are **not** utilized for agricultural irrigation within the region itself. Most of this water is treated in the Shafdan plant (90-100 hm^3 per year) and the treated water is exported to the southern region (western and northern Negev) for agricultural use, located 100-150 km away from this plant. Aggregate supply is summarized in Table 5-2.

The total aggregate water supply in the region reaches to 323 hm^3 per an average year. 82% of the total supply is produced by the Local system and the remaining 18% of the total supply is produce by the National system. Only 5% of the total supply (16 hm^3) is recycled water which is used only by the agricultural sector (i.e. irrigation). The quality of the fresh water is good, with a salinity level of 150-250 mg chlorine per litre. The future use of desalinated water should lead to an improvement in water quality. The region's large population creates the potential for a large supply of recycled water for agriculture.

Water demand and actual consumption

Summary of water demand and actual water consumption by sector and water type are presented in Table 5-3 and Table 5-4 respectively.

"Demand" for water may differ from "actual consumption" of water. In this case study the difference is limited to the agricultural demand and consumption of recycled water. Specifically, the demand for recycled water in Tel Aviv region is 49 hm^3; while actual consumption is only 16 hm^3, since it cannot exceed the available supply (Table 5-2).

The division of actual consumption of each sector between water supplied from the national water system and from the local system (i.e., pumping of fresh water from the coastal aquifer plus recycled wastewater) is presented in Table 5-5.

Table 5-3 Water Demand by Sector and water type (hm^3/yr)

	Fresh water	Recycled	Total
Domestic	191	---	191
Industrial	58	---	58
Agricultural	25	49	74
Total	**274**	**49**	**323**

Table 5-4 Actual Water Consumption by Sector and water type (hm^3/yr)

	Fresh water	Recycled	Total
Domestic	191	---	191
Industrial	58	---	58
Agricultural	58	16	74
Total	**307**	**16**	**323**

With an average annual consumption of 100 m^3 per capita, which is similar to the national average, the total domestic consumption in the region reaches 191 hm^3 per year. 87% of the total domestic consumption is produced by the Local system and the remaining 13% of the total consumption is produced by the National system.

The total industrial consumption in the region reaches 58 hm^3 per year. 88% of the total Industrial consumption is produced by the Local system and the remaining 12% of the total consumption is produce by the National system. The entire industrial consumption is derived from fresh water (there are no saline water or recycled water in use).

Table 5-5 Division of Actual Water Consumption by Source of Supply (hm^3/yr)

	National System	Local System	Total
Domestic	25	166	191
Industrial	7	51	58
Agricultural	24	50	74
Total	**56**	**267**	**323**

The total agricultural consumption in the region reaches to 74 hm^3/yr. 68% of the total Industrial consumption is produced by the Local system and the remaining 32% of the total consumption is produce by the National system. Unlike the other sectors (Domestic and Industrial), 21% of the total Agriculture consumption is obtained from recycled water (16 hm^3) which is delivered by the National system.

As Tel-Aviv is part of the national water system, prices charged to the consumers of the region are determined within the national framework. Private producers are subject to a system of public compensations/production levies if their production and operation costs exceed/fall short of the administrative price charged by Mekorot to its consumers. The aim of this public intervention is to equate the prices charged to the consumers of the private water suppliers to the prices charged to the consumers of Mekorot.

Land prices in this area are among the highest in the country. The region is therefore subject to further urbanization and a reduction in agricultural area. Agriculture in this region has value as a public good in conserving open areas and providing “green lungs”.

Identification of Available and Feasible Options

Stakeholder consultation

The relatively extensive, face-to-face discussions with representatives of almost all the above-mentioned stakeholders resulted in identifying some of the dominant perceptions, goals and actions in the process of formulating water management policies and strategic plans. Although some of this information refers to the Israeli water economy in general, they also affect water management in the region of Tel Aviv, as part of the National Water System of the country. The main outcomes of these discussions are summarised below.

The Water Commissioner and the Head of the Planning Department in the Water Commission

The Water Commissioner's interest is to preserve the current institutional situation under which the vast majority of Israeli water resources are managed at the national level. Plans for the future (with execution subject to severe budget constraints), include: (i) increasing the flexibility of water transfer between the various regions around the country; (ii) increasing the reliability of supply to all sectors; (iii) increasing the available storage; (iv) transportation systems for recycled waste water for agricultural use; and (v) raising the required purification level of the waste water to be used for irrigation above unconfined aquifers (including desalination of waste water); allocating massive funds for sea water desalination plants (the plan is to desalinate about 400 hm^3/yr no later than 2010).

The Chairman, the Chief Engineer and the Head of the central region of the National Water Company, Mekorot

Mekorot is the national water company, which operates the nationwide water system. It is a governmental company which operates on the principal of "cost plus". As water prices (determined in the political arena and not controlled by Mekorot) paid to the company by its agricultural, industrial and urban consumers do not fully cover the costs of water production and transfer, the company is subsidized by the government. The subsidy is equal to the uncovered costs plus a "fair benefit" for the company. Mekorot's role in the overall financial turnover of water resources reaches about 80% of the industry's business activity, since it operates a water system at high cost, conducts water for long distances and pumps water to regions with high altitude. Currently, the company is the only entity with significant financial and operational abilities in the field of water resources, i.e. it is a powerful monopoly. The current institutional situation under which all major water sources are operated by Mekorot within a framework of one very large national system helps the company to preserve its monopoly power and the company objects to any major institutional changes. The company's major aims include: (i) supplying the demands of all consumers in a reliable way according to the priorities set by the Water Commissioner (the consumers with the highest priority are the general public for domestic consumption, the industrial sector also has high priority; agricultural consumers are of the lowest priority); (ii) improving the quality of fresh water as well as that of recycled waste water; (iii) increasing the market share of the company in the plants for recycling wastewater; (iv) winning at least some of the public contracts to build and run sea water desalination plants; and (v) connecting as many private (as yet non-existent) desalination plants as possible to the National Water System.

The General Director and the Head of the Planning Department of the Ministry of Agriculture

Agriculture in Israel is seen by many as an enterprise whose national value exceeds its contribution to GNP via food production, a fact that justifies governmental support. It contributes to security by protecting the country's lands, especially in peripheral areas, and by supplying food in times of emergency. It also contributes to the environment by protecting open spaces and preserving the natural and social landscape. In addition, its use of water has been and still is flexible, utilizing water from various sources and at various levels of qualities. Thus, it can serve as a safety net for supplying water to local authorities (i.e. households) in times of emergency, since it utilizes a large amount of fresh water. Some of the major goals of the Ministry of Agriculture relevant for the present analysis are: (i) setting uniform agricultural water prices in all regions of the country; (ii) increasing the current purification level of recycled wastewater to suit irrigation of all crops and over all soil plots; (iv) charging the additional associated costs to the producers of the wastewater (i.e. to the cities); (v) preserving the current size of the agricultural sector, especially in peripheral areas (water subsidy is an important policy tool in obtaining this goal); (vi) preserving open agricultural spaces and natural landscapes (in the absence of a water subsidy, some of the green lungs may turn yellow); and (vii) "fighting" the wide coverage in the written and electronic media of the recent water crisis (coverage which has emphasized increased tension between farmers and local authorities concerning the fairness of uneven water pricing, with farmers paying about 50% of the price paid by the urban sector).

The referee for water and sewage in the budget department at the Ministry of Finance

The Ministry of Finance is responsible for the overall budget and for the allocation of financial resources (including subsidies) to the water economy and Mekorot. Structural changes and major developments (such as massive recycling of sewage and desalination of sea-water) cannot be carried out without the approval of this ministry. The traditional position of the economists in the budget department of the Ministry of Finance is that there is no water shortage in Israel, and all that is required is to increase water prices so that demand does not exceed available supply. They constantly call for basing the water allocation on an efficient price system that includes the shadow price or scarcity rent of water and does not vary by sector. In addition to the reduction of subsidy for agricultural water, the expected reduction in agricultural water consumption associated with increased water prices may ease public pressure for an urgent and large scale investment in expensive desalination plants partially subsidized by the Government, and a consequent reduction of governmental expenses. The Ministry of Finance recognizes the special contribution of agriculture to the national goals of protecting the country’s lands and the open spaces and preserving the natural and social landscape, and therefore agrees to keep subsidizing it, but not through the medium of water.

The Ministry of Health's southern district sanitation engineer and the vice General Director of the Ministry of Environmental Quality

The sanitation engineers of the Ministry of health are responsible, among other things, for granting permits to farmers to irrigate with recycled waste water and to prohibit irrigation of agricultural crops and irrigation of soil plots overlying groundwater aquifers by recycled waters that were not treated appropriately. In practice their requirements significantly affect farmers' plans regarding irrigation with treated wastewater. The Ministry of Environmental Quality is responsible for preventing water pollution and protecting water resources from contamination. The Ministry promulgates regulations, prohibitions and restrictions on the location and establishment of polluting facilities over or near water resources and determines the quality of water for various purposes including the quality of floodwater and recycled waste water used for rivers rehabilitation.

Active farmers and farmers' representatives

Most farmers do not adopt the economic point of view represented by the Ministry of Finance, and they act to advance their short run goals. They request a quota-based allocation of potable water and water price adjustments (i.e. subsidy) based on the ability to pay. At the same time, they advocate the expensive expansion of supply, mainly by sea water desalination, in order to reduce water shortage. Some farmers claim that agriculture will collapse if it had to pay the full cost of water production. Some farmers’ representatives claim, based on past experience, that any “final” agreement on water pricing with the Ministry of Finance is just an opening for endless future negotiations and they do not trust this Ministry to fulfil its promises in the long run.

Farmers are complaining about the monopoly power of Mekorot and claim that the company's costs (especially the capital costs) are too high. They also claim that the majority of the recent investments in the National Water System were made in order to guarantee a reliable stable supply of good quality water for the urban sector while the agricultural sector benefits nothing from these investments but is asked to share the costs (via an increase in water prices). As for irrigation with recycled wastewater, the interviewed farmers pointed out the competition between farmers in the central and in the peripheral regions. Most of the urban and industrial sewage is “produced” in the coastal plain (which includes the region of Tel Aviv), in the centre of the country, while most of the irrigated areas are located in the periphery. The costs of constructing new networks to transport the recycled water (assuring that it will not be mixed with freshwater) and the costs required to prepare new facilities to store excess treated water from winter to summer are of major importance. The spatial distribution of aquifers and the environmental costs associated with irrigation that may pollute the underlying groundwater, should also be considered for the allocation of wastewater. There is also strong conflict between the agricultural and the urban sectors regarding the purification standards for disposal set for the cities by the Government. Another conflict is on the allocation of costs and benefits associated with recycling between the generators of sewage (the municipalities) and the agricultural users.

The vice director of Tel Aviv's city council - head of the city water department

The municipality’s major interest is to supply high-quality drinking water with a low level of chlorides and at a low cost. Therefore, Tel Aviv prefers to obtain its water supply mostly from local drillings, using water from external sources as little as possible (transported by Mekorot from the Sea of Galilee via the National Water Carrier). Tel Aviv is willing to build and operate its own desalination project (because desalinated water is of the best quality), but only if this is economically justifiable, i.e. less expensive than buying water from Mekorot.

Emerging issues from the stakeholder consultation

As a result of the aforementioned consultation, a series of foreseen/proposed approaches, responses and questions arise that can give ground for the introduction of improved water management practices in the region of Tel Aviv. These are:

- Intensifying the reclamation of wastewater for agricultural irrigation and for river rehabilitation: A large scale transition in agricultural water use from good quality water to reclaimed urban and industrial waste water is expected in the forthcoming years. This shift requires the development of many more environmentally safe water treatment plants, reservoirs and conveyance systems. The urban water economy from the city gate to the consumers, to the treatment plant and to final disposition is becoming as big as the economy of fresh water and it is growing steadily. The current trend calls for stricter adherence to water purity standards. An inter-ministerial committee of director-generals recently issued a report recommending substantially stricter purification standards for recycled wastewater in the near future. Cost-benefit analysis of the above-mentioned large-scale transition should take into consideration:
- The spatial distribution of aquifers and the environmental costs associated with irrigation above them, which may pollute the underlying groundwater.
- The question of how the costs and the benefits associated with recycling should be allocated between the generators of sewage (the municipalities) and the agricultural and ecological users.
- The question of how municipalities can be assured that the farmers will not reduce usage suddenly (due to an economic crisis for example) and leave the cities with treated water that they cannot dispose of.
- At the farm level one should investigate farmers' incentives to adapt crop varieties to water of lower quality and evaluate the negative environmental externalities associated with sustained use of treated wastewater.
- Reform in water allocation practices - Allocation by prices: The goals of a reform in water pricing are to increase the overall efficiency of water allocation to the agricultural sector, by raising water prices to an "economically efficient" level, and at the same time to give farmers incentives, via adequate land-dependent cultivation subsidies, to strive towards the national goal of protecting the land and preserving the landscape. The efficient prices should reflect the long run costs of water supply,

including the scarcity value of water, and the environmental costs associated with water production and/or water use. More specifically, the analysis of the reform in water pricing should cope with the following questions:

- How should prices vary by water quality? The quality requirements for urban consumption are much higher than the requirements for agricultural use, but water in Tel Aviv's region is supplied via the same national conveyance system. Should the prices for the agricultural and the urban sectors be identical? Should farmers pay the extra costs required to meet the standards of urban use?
- How should prices vary by reliability of water supply? The supply to the urban and industrial sectors in Israel is reliable while the supply of fresh water to the agricultural sector is reduced in dry years. In other words, weather uncertainty implies uncertain supply to the agricultural sector.
- How should the spatial variation of water prices reflect the spatially variable extraction and transportation costs? If equity considerations imply a homogeneous price for water of a given quality, one should evaluate the "efficiency cost" of the equity requirement. It should be noted that a homogeneous price implies cross-subsidization among users in different regions.

In addition to sending signals to water users about the full cost of water supply, prices should also cover the costs of supply. In the case that total revenues collected by the suppliers exceed (fall short of) the total costs of supply, rebate to users (governmental subsidy to water producers) should be considered.

Selection of options to be further analysed in the Strategy Formulation Process

Given the above, and taking into account the fact that prices levied on the consumers of Tel Aviv region form a part of the National Water Policy, the analysis focused on four management options that could form part of future measures adopted by the national and regional authorities. These are:

(a) Increasing the annual supply of recycled waste water by 12 hm^3 through the connection of additional cities in the region to the existing wastewater-treatment plants (hereafter denoted as **R**).

(b) Increasing the annual supply of fresh water by establishing one desalination plant, capable of desalinating 50 hm^3 of sea water annually, in the second year of the time horizon, and then establishing an identical desalination plant in the seventh year of the planning period. The plants are operated only in periods of freshwater shortage (hereafter denoted as **D**).

(c) Increasing the annual supply of fresh water by over-pumping of groundwater from the coastal aquifer. The significant environmental costs associated with the option were taken into account assuming a cost of 0.64 €/m^3 (hereafter denoted as **OP**).

(d) Reducing gross annual domestic demand for water by 20% through investments in water conservation (hereafter denoted as **WC**).

Evaluation of Water Management Options

Formulation of demand and availability scenarios

The evaluation of the impact of the described management options was based on a thorough examination of their performance under a business-as-usual demand scenario (Bau) and two different water availability scenarios, which denote an average and a high shortage state respectively.

The projection of the future **Demand scenario** for the region was based on the recent Master Plan for the development of the Israeli water resources in the years 2002 to 2010, prepared by the planning department of the Water Commission. Specifically, it is assumed that:

- **Domestic demand** steadily increases at a constant annual rate of 0.5% due to population growth (the consumption per capita is assumed to be stable over time);
- **Agricultural and industrial demands** are stable over time (the land in the region is very expensive, agricultural lands are under pressure from urbanization processes and it is very unlikely that additional land will be allocated for agricultural production).

With regard to freshwater availability, two major scenarios have been assumed in the analysis:

- A sequence of 15 years with a stable supply of fresh water equal to the annual long-term average supply (the Stable or **Normal Scenario**), and
- A cyclical sequence of 15 years with fluctuating supply, where three consecutive years with average supply are followed by three consecutive dry years with a supply that is 30% lower than the average (the **Cyclic Scenario**).

In the analysis of management options, the business as usual (BAU) scenario under the above fluctuating or cyclical weather conditions, denoted by **BauC**, was used as a reference scenario. It was found that during the drought periods (2003-2005, 2009-2011 and 2015), the demands of all the sectors could not be satisfied. In fact, during the dry years, the agricultural and industrial sectors do not receive fresh water at all, a situation that is socially unacceptable, and cannot be left unaddressed. The results for the aforementioned management options utilized to overcome this situation are discussed in length in the respective Chapter 12 and are summarized below.

Allocation (supply and demand) priorities

The assignment of demand and supply priorities for modelling water resource allocation for the Tel-Aviv case study was based on basic economic principles, i.e.: (a) the cheaper sources should be used prior to the more expensive ones, and (b) when supply shifts from one resource to the next (starting from the least expensive one), it should first be allocated to the demand with the highest value, then to the demand with the second highest value, and so on. Based on these principles, the priorities of Table 5-6 were assumed and analysed hereafter:

The highest priority ("1") is to allocate fresh water from local wells (the least costly resource) to local domestic consumers. Then, water from local wells should be allocated to industrial consumers and to livestock: priority "2".

The same high priority ("2") is assigned to the allocation of fresh water imported to the region through the NWC, which costs more than water from local wells, to local domestic consumers and to domestic consumers who live in the southern region of the country (via water export). In fact, most of the fresh water imported to the region via the NWC (an annual average of 270 hm^3 per year) is exported to southern consumers and only 14% (40 hm^3) is consumed within the region. Relatively high priorities ("3" and "4") are assigned to the allocation of imported fresh water to industrial consumers and livestock in Tel Aviv and to the export of recycled effluents to southern farmers (produced in the Shafdan treatment plant).

The lowest allocation priorities are assigned to the agricultural activities in the region. Among these activities, the highest priorities ("5"-"7") are the allocation of recycled effluents (which cannot be used for domestic or industrial consumption or for irrigating vegetables and flowers) to orchards, citrus and field crops. The lowest priorities are assigned to the allocation of fresh water for the irrigation of field crops (priorities “12” and “13”); and to the export of fresh water from local wells to domestic and/or agricultural consumers in the south (priorities “14” and “15”).

Table 5-6 Supply and Demand Priorities

Supply Source/Consumer	Imported Fresh Water (NWC)	Fresh Water from Local Wells	Recycled Water
Domestic Sector	2	1	
Domestic Users in Southern Regions (exported water)	2	14	
Agricultural Users in Southern Regions (exported water)	4	15	
Industry	3	2	
Agricultural Demand			
Livestock	3	2	
Citrus	11	10	6
Orchards	9	8	5
Field Crops	13	12	7
Vegetables	9	8	
Flowers	9	8	
Exported Recycled Water (Shafdan)			4

Summary of option evaluation outcomes

The final results of the evaluation of management options are summarised below. Results in this section refer only to the performance of the examined measures under cyclic weather conditions and the Business-As-Usual demand scenario. Criteria used for this evaluation are: (i) Private Welfare Surplus (PWS), (ii) Social Welfare Surplus (SWS), (iii) Total environmental cost, and (iv) Total Direct Cost.

Table 5-7 Evaluation of Management Options Financial Indicators: NPV PWS, SWS, Environmental and Direct Costs (Million €)

Scenario	Total Unmet Demand	PWS	SWS	Environmental Cost	Direct Cost
	hm^3	Net Present Values, Million €, 4%			
BauC	1,374	990.2	1,194.5	35.1	1,596.1 (616)
BauC+R	1,222	1,021.5	1,230.7	29.3	1,611.1 (629)
BauC+D	741	1,110.4	1,175.1	25.2	1,875.6 (1,027)
BauC+OP	0	1,292.3	958	618.7	1,800
BauC+WC	795	1,254.5	1,324.4	21	1,635.1 (610)

Calculation of the direct costs in Table 5-7 requires an additional explanation. Large amounts of fresh water are imported to the region from the Sea of Galilee (Lake Kinneret) through the National Water Carrier (NWC). Some (relatively small) amount of this water is used within the region while the remaining amount is exported (again, via the NWC) to the southern regions of the country. In the analysis of the different management options, direct costs include the costs associated with the **gross** amount of imported water. However, most of this water just passes through the region on its way south. The value of the fresh water exported out of the region was added to the benefits (or values) accrued to the region from water use, assuming that the value of 1 m^3 of water exported to the south via the NWC is equal to the direct costs of the imported water. **An alternative approach, which will be utilized hereafter**, is to levy the direct costs associated with water supplied to the region via the NWC only on the **actual or net** amount of water used within the region (import minus export). This will significantly reduce the calculated total direct costs but will not affect the SWS.

The principal conclusions drawn from the evaluation of options are:

(a) With the exception of scenario BauC+OP (over-pumping), none of the management options meets targets (a) and/or (b) (meeting 100% of the domestic and industrial demands and at least 70% of the agricultural demand).

(b) **The net present value of the total Social Welfare Surplus (SWS)** in the region [defined as the present value (calculated at a discount rate of 4%) of the annual differences between the total value or benefit accrued by water consumers and the total direct and environmental costs] has been selected as **the best criterion to rank the various scenarios.** Obviously, a management option implying a high SWS value is preferred to one implying a lower value. **Total private welfare surplus (PWS),** accrued to water consumers, is defined as the present value (calculated at a discount rate of 4%) of the annual differences between the total value or benefit accrued by water consumers and the water prices charged to the various consumers. While both SWS and PWS depend on the value of water for the various consumers, the former also depends on the actual, direct and environmental costs of supplying the water, whereas the latter depends on the prices charged to the consumers. Since in many cases water prices differ from water costs, it may well be that the PWS and SWS for a specific group of consumers do not coincide.

(c) The source of the environmental costs associated with scenario BauC+OP, which are assumed to be equal to 0.64 €/m^3, is **over-pumping** of groundwater from the coastal aquifer. The source of the environmental costs for all other scenarios (where over-pumping is not an option) is the reduction in cultivated area resulting from an agricultural water deficit. The environmental cost associated with a cut of 1 m^3 of irrigation water demanded by the agricultural sector—a cut which yields a reduction in cultivated area—is assumed to be 0.09 €/m^3.

(d) Since the option of enhancing supply via over-pumping (BauC+OP) yields the highest PWS value, it will be preferred by the regional consumers (their demand is completely satisfied and the prices they have to pay are lower than the total costs of over-pumping). However, **from a social point of view, it is the least desirable option**. It involves the lowest SWS and the highest environmental cost, and it violates the target number (minimizing the long-run impact to the coastal aquifer via over-pumping). Thus, **hereafter** the management option of **over-pumping will not be considered** as a building block in any of the potential management strategies (presented further on). The management option to reduce gross domestic demand via water conservation, BauC+WC, yields the highest SWS, which is about 8% higher than the SWS of the second-best scenario, BauC+R. The environmental costs associated with the former are lower than those associated with the latter, so the green lobbies will probably also prefer BauC+WC to BauC+R.

(e) The option of increasing the supply of recycled water and/or reducing gross domestic demand (by 20%) via water conservation seems to hold the advantage in terms of SWS and environmental costs. Although it involves the highest direct costs, the option to increase supply via seawater desalination, which improves social welfare and has no negative environmental impacts, cannot be rejected a priori.

Strategy Formulation and Evaluation

Definition of target and assumptions

The approach that has guided the water supply sector in Israel for decades, and in particular the last decade, has been one of brinkmanship, including deferment of sea-water desalination to the latest possible date. This approach is guided by short-term economic considerations, according to which maximum empty storage capacity must be ensured for large natural replenishment occurrences, in order to prevent or minimize overflows and discharge to the sea. The implementation of this policy for so many years is one of the reasons that the Israeli water economy is in the midst of a crisis, characterised by a shortage of fresh water and a steadily increasing deficit, combined with poor and declining groundwater quality (gradual salinisation). Rainfall variability and the associated fluctuations in annual replenishment in Israel are quite large, with series of dry years being a frequent occurrence. About 4 years ago, **the policy of brinkmanship was abandoned and replaced by one that is aimed at preventing shortfalls in water supply and lack of control over water resources, in order to ensure the stabilization of the country's water supply system in the future, especially during periods of consecutive dry years.**

To examine the impacts of the above policy change under relatively unfavourable future weather conditions, we assume hereafter a time horizon of 15 years with a fluctuating replenishment series, in which three consecutive years of average natural supply of water (estimated from long-term values) are followed by three consecutive dry years with a supply that is 30% lower than the average.

The main targets of strategies aimed at improving this reference scenario (BauC) are:

(a) Meeting 100% of domestic and industrial demands during each of the 15-year time horizons.

(b) Meeting at least 70% of the agricultural demand during each of the 15-year time horizons (the fulfilment of this goal guarantees that none of the mature orchard groves in the region will “dry out”).

(c) Increasing the Social Welfare Surplus **(SWS)** in the region. The total present value of SWS in the region is defined as the difference between the discounted stream of annual values or benefits accrued by water consumers, and the total direct and environmental costs. Following consultation with stakeholders and decision-makers in the water economy of Israel, we came to the conclusion that for the Israeli case study, the SWS is a good criterion to rank the various scenarios. Obviously, a management option implying a high SWS value is preferred to one implying a lower value.

(d) Minimizing the long-term overexploitation (overpumping) of the coastal aquifer that leads to its salinisation.

(e) Reducing dependencies and cross-subsidies between the region of Tel Aviv and the national water system (in an extreme case the Tel Aviv region can be completely disconnected from the national system and managed as a single economic entity).

Formulation of alternative water management strategies

It is apparent that within the scope of integrating management scenarios into promising water-management strategies, we should seriously examine the impacts of various combinations of the management options already analyzed to enhance supply via recycling and/or desalination of sea water and to reduce domestic demand via water conservation (Emerging Paradigm Strategy). One of the aims of the analysis is also to evaluate the option of creating a partial institutional and economic separation of Tel Aviv’s water resources from the national water system and operating them as a balanced economic entity with respect to the industrial and domestic sectors.

With regard to the options already briefly discussed and analysed in detail in Chapter 12, in the strategy formulation process we change some of the assumptions with respect to the scenarios that are used as building blocks in the Strategies. Specifically:

(a) Water conservation in the domestic sector: the 20% reduction in gross annual domestic demand for water via investment in water conservation is reduced hereafter to only 7% (scenario **BauC+WC**). This was done following consultation with water experts in the city of Tel Aviv who insisted that a 20% reduction cannot be obtained in the near future, whereas 7% is a realistic figure.

(b) In the analysis of the different options, we examined the impacts of enhancing the annual supply of fresh water by establishing two desalination plants (scenario **BauC+D**), each capable of desalinating 50 hm^3 annually, one in the second year and the other in the seventh year of the time horizon. In spite of desalination, the region still suffered from water shortages during the dry periods. This was especially true for the first dry period when only one desalination plant is available. Therefore, hereafter it is assumed that the first desalination plant, established in the second year of the time horizon, is capable of desalinating 100 hm^3 (rather than 50 hm^3). The assumptions with respect to the second plant are left unchanged.

Within the scope of integrating management scenarios into promising water-management strategies, we need to have examined the impacts of **all** possible combinations of the management options BauC+R, BauC+D (revised, see above) and BauC+WC (revised, see above).

A grand combination of all three management options was found to be the best alternative. It meets 100% of the domestic and industrial demands and more than 70% of the agricultural demand, and it yields the highest present value of SWS, 1,340 million €.

Given the above, two alternative strategies have been formulated and evaluated against each other and against the reference case, BauC. **Strategy 1 (Emerging Paradigm Strategy)** is the grand combination of the management options BauC+R, BauC+D (revised) and BauC+WC (revised), preserving the current institutional setting under which a significant amount of water in the region is supplied by Mekorot, and the water economy is managed at the national level and subject to the current pricing practices. **Strategy 2** reflects a new paradigm of 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 (see below). As in Strategy 1, the grand combination of the management options BauC+R, BauC+D (revised) and BauC+WC (revised) was found to perform better than all other partial combinations.

Strategy 1 – Current Institutional Setting

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. Specifically:

(a) **Grand combination of management options**: {Increasing the annual supply of recycled wastewater (through the connection of additional cities in the region to the existing wastewater treatment plants) by 12 hm^3 } + {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 time horizon, and an additional plant in the seventh year of the planning period capable of desalinating 50 hm^3} + {Reducing gross annual domestic demand for water by 7% via investment in water conservation}.

(b) **Preservation of the current institutional setting** under which prices of water delivered by the national company Mekorot are set by the government and depend on water type. Moreover, water charges depend on the type of use: farmers pay the lowest charges, industry pays higher charges and households pay the highest. Within each sector, charges do not depend on location: users in the entire country pay the same charges, regardless of the supply price of water. Private water producers set prices independently. Under the current situation, Tel Aviv is connected to the national water system and a significant part of its fresh water is imported via the NWC [with average weather conditions, net import of 40 hm^3 (= import of 270 hm^3 from the Sea of Galilee minus export of 230 hm^3 to the south of the country). In dry years, the import is reduced in our analysis from 270 to 189 hm^3 while water export remains 230 hm^3].

Strategy 2 – Partial Institutional and Economic Separation

The second strategy assumes the same grand combination of management options assumed for the first strategy. However, it differs from Strategy 1 by the assumed institutional setting. Specifically, we assume here 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. We assume termination of the option to import and export water via the NWC, and determine water prices for the industrial and domestic sectors so that the **average** CRR (cost recovery rate) value over the assumed time horizon is equal to 100%. Agricultural water prices are subsidized at the national level and are left unchanged in this strategy.

Strategy Evaluation

The two formulated strategies were simulated in the WSM DSS and evaluated against each other and the reference case, with respect to the targets defined in Step 1 of the analysis. The percent demand coverage in the domestic, industrial and agricultural sectors is presented in Figures 5-2, 5-3 and 5-4, respectively.

As can be derived from Figures 5-2 and 5-3, the target to meet 100% of domestic and industrial demands is fully satisfied under both strategies. The target of meeting at least 70% of agricultural demand during each 15-year time horizon is fully satisfied under Strategy 2 (Figure 5-4). This target is only partially met under Strategy 1; during the last two years of the first dry period of the time horizon (2004-2005), less than 40% of the agricultural demand is satisfied. The major reason for this difference between the two strategies for the coverage of agricultural demand is the cutting off of the region's (imported and exported) water conveyed through the national system under Strategy 2. As mentioned, under Strategy 1 fresh water is imported to the region via the NWC and exported out of the region to the southern part of the country through the same carrier. During 10 years of the time horizon, the amount of imported water exceeds the amount of exported water; however in 6 years of the simulated period (2004-2005, 2009-2011 and 2015), the opposite occurs (negative net import). In total, the net import (gross import minus export) of water via the NWC is positive and equal to 73 hm^3.

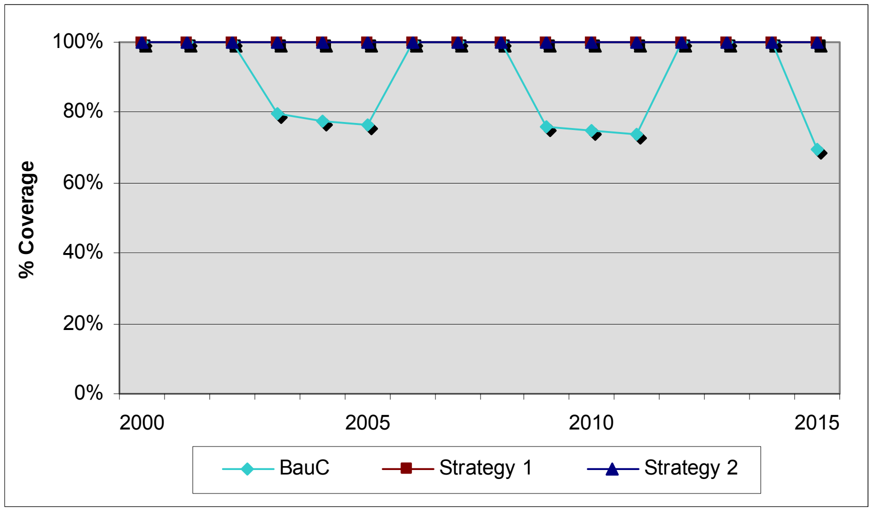


Figure 5-2 Domestic Demand Coverage (%)

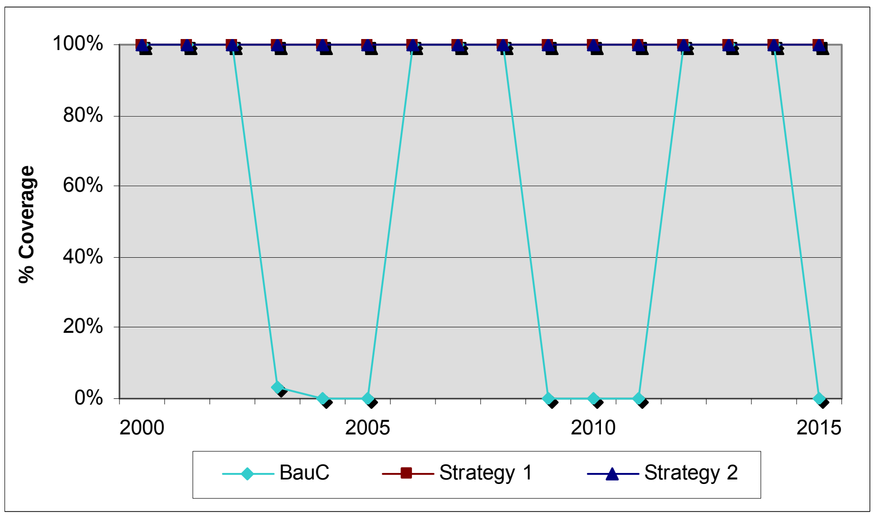


Figure 5-3 Industrial Demand Coverage (%)

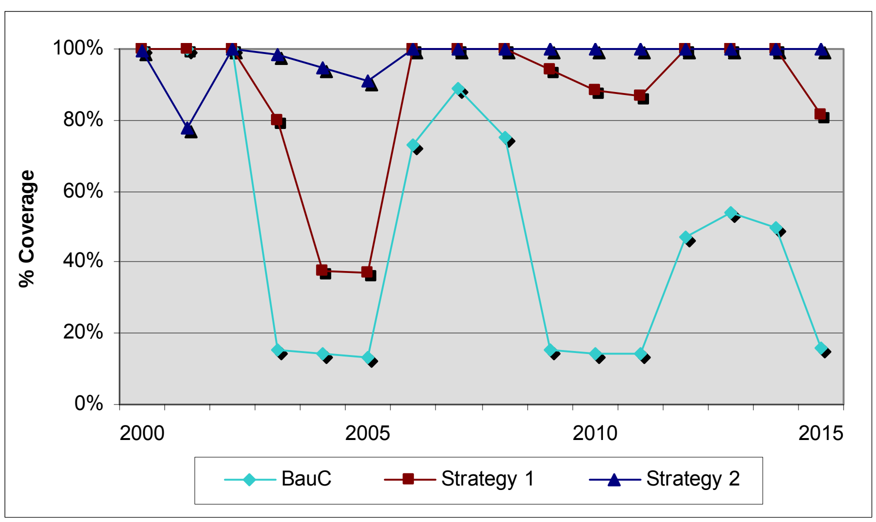


Figure 5-4 Irrigation Demand Coverage (%)

The two highest **negative** net imports (41 hm^3) occurred in the years 2004-2005 and 2010-2011. The fact that during 2004-2005 only one desalination plant is operating, coupled with the assigned allocation priorities (under which domestic and industrial demands are of higher priority than agricultural demand), explain the low (less than 40%) rate of irrigation demand coverage during this period under Strategy 1.

The criteria of total unmet demand, SWS and PWS, and direct and environmental costs are summarized in Table 5-8 and Figures 5-5 to 5-8.

It should be noted that the unacceptable level of unmet demand under the base BauC scenario is reduced dramatically: by about 90% and 98% under strategies 1 and 2, respectively. Total unmet demand under Strategy 1 (142 hm^3) is about fivefold the one of Strategy 2 (28 hm^3). As mentioned, the main reason for the difference is the **negative** net import of fresh water via the NWC, obtained under Strategy 1, which cannot be balanced by the supply from all other sources, whereas under Strategy 2, net imports are zero by assumption.

Table 5-8 Strategy Evaluation Table

Scenario	Unmet Demand	PWS	SWS	Environmental Cost	Direct Cost
	hm^3	Present Values, Million €, 4%			
BauC	1374	990	1.194	35	616
Strategy 1	142	1,322	1,340	9	949
Strategy 2	28	1,431	1,332	2	1,014

The present values of SWS (calculated at a real discount rate of 4%) associated with Strategies 1 and 2 are higher by 11.5% and by 12.3%, respectively, with respect to the reference case BauC. The present value of SWS obtained under Strategy 2 is higher than the one obtained under Strategy 1, but the difference is relatively small. The annual levels of SWS are depicted in Figure 5-5. The sharp reduction in SWS during the dry periods is quite large.

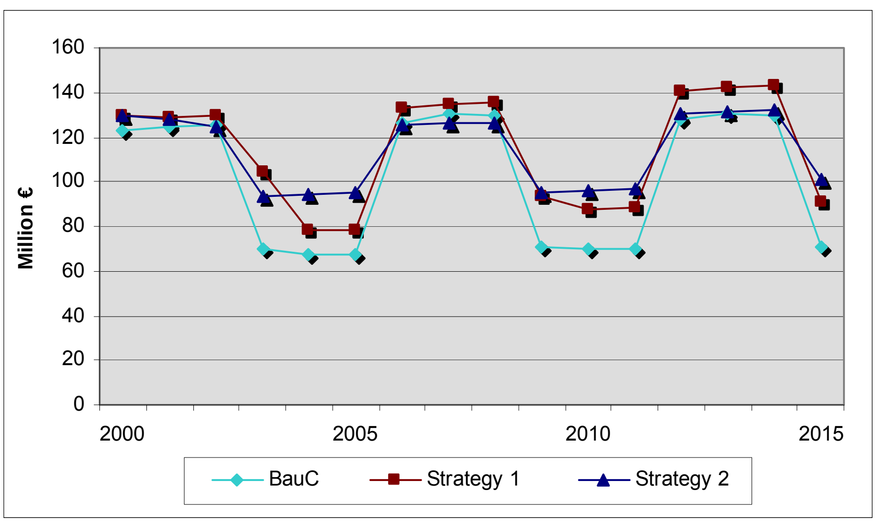


Figure 5-5 Annual Values of SWS in Million €

For the Israeli case study, the present value of the Social Welfare Surplus (SWS) was considered the appropriate criterion for ranking alternatives. Additionally in the scope of integrating management options into promising water management strategies, the impacts of **all** possible combinations of the management options (BauC+R, BauC+D, and BauC+WC) have been examined, and it was established that the grand combination of all three management options is the best one. For example, under the Emerging Paradigm Strategy

(Strategy 1), combinations of only two management options yield present SWS values significantly lower than 1,340 million € (1,274 million € for the combination of recycling and seawater desalination, and 1,297 million € for the combination of recycling and domestic water conservation).

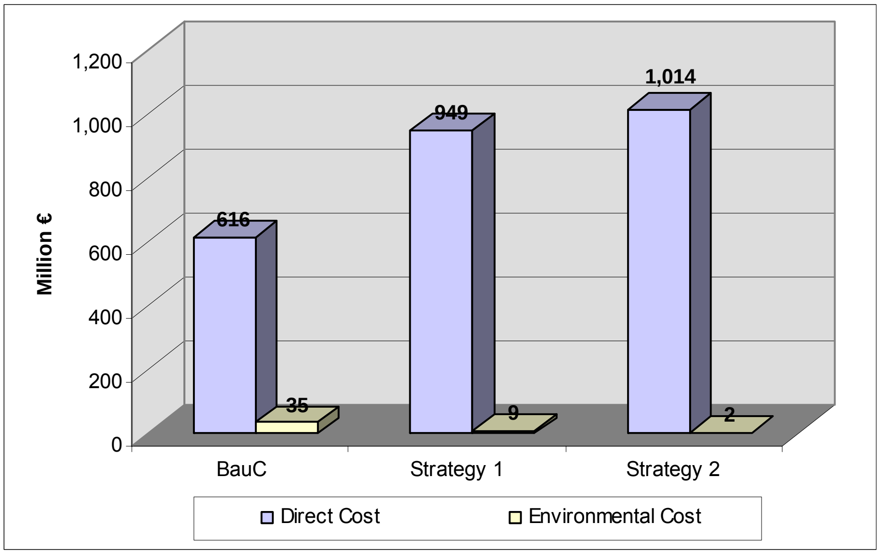


Figure 5-6 Present Values of Direct and Environmental Costs in Million €

Present values of direct and environmental costs are depicted in Figure 5-6. The annual values of these cost components are presented in Figure 5-7 and Figure 5-8 respectively. The present value of the direct costs associated with Strategy 2 is about 7% higher than the one associated with Strategy 1. The total quantity of **net** fresh water import from the NWC under Strategy 1 (73 hm^3) does not exist under Strategy 2. However, the total amount of desalinated water under Strategy 2 (987 hm^3) is higher by 187 hm^3 than the respective amount under Strategy 1 (800 hm^3). The difference (187-73 = 114 hm^3) is equal to the difference between the unmet demands of the two strategies (142-28=114 hm^3). The direct costs associated with Strategy 2 are higher since the costs of producing and supplying desalinated sea water are higher than the cost of water imports.

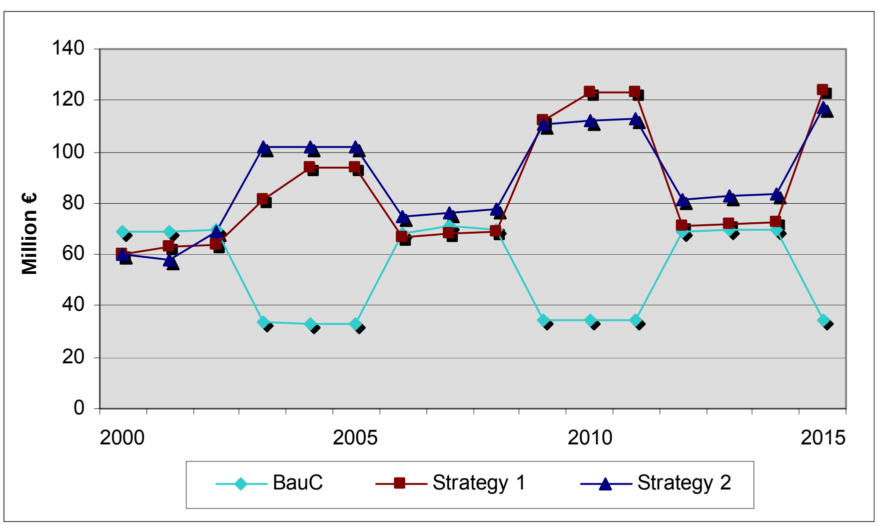


Figure 5-7 Total Annual Direct Costs in Million €

As already noted, agriculture in the Tel Aviv region has value as a public good in terms of preserving landscape and providing "green lungs". For the reasons discussed in the analysis of water management options (Chapter 11), the only relevant source of environmental costs in our analysis is the one associated with the unmet agricultural demand. The estimation is based on studies conducted in Israel which estimated the environmental value of cultivated land (in relation to non-cultivated land) and the average amount of irrigation water (m^3/ha) applied in the region. Specifically, the environmental costs associated with a cut of 1 m^3 in the irrigation water demanded by the agricultural sector—a cut which yields a reduction in that cultivated area—are assumed to be 0.09 €/m^3. The relatively low levels of unmet demand under Strategy 1 and, especially, under Strategy 2 explain the negligible level of environmental costs.

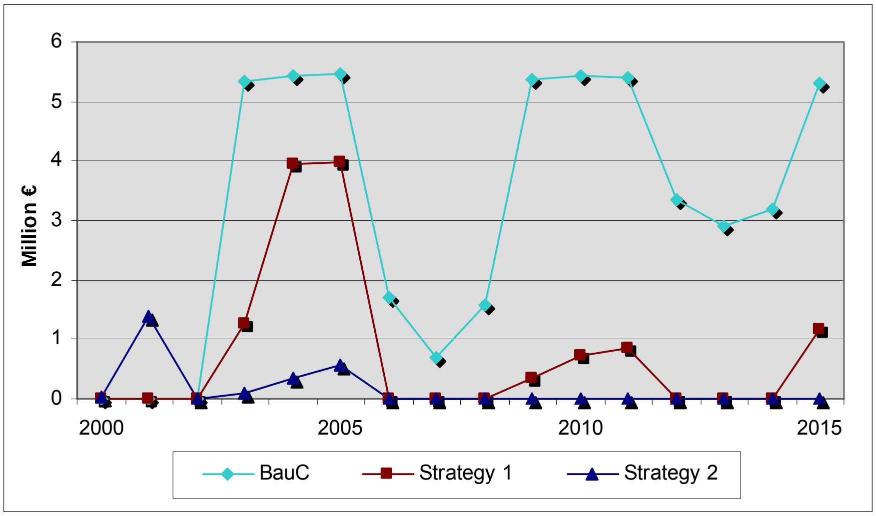


Figure 5-8 Total Annual Environmental Costs in Million €

Analysis of Cost Recovery Issues

Total annual costs to be recovered from domestic, industrial and agricultural uses are presented in Figures 5-9, 5-10 and 5-11 respectively.

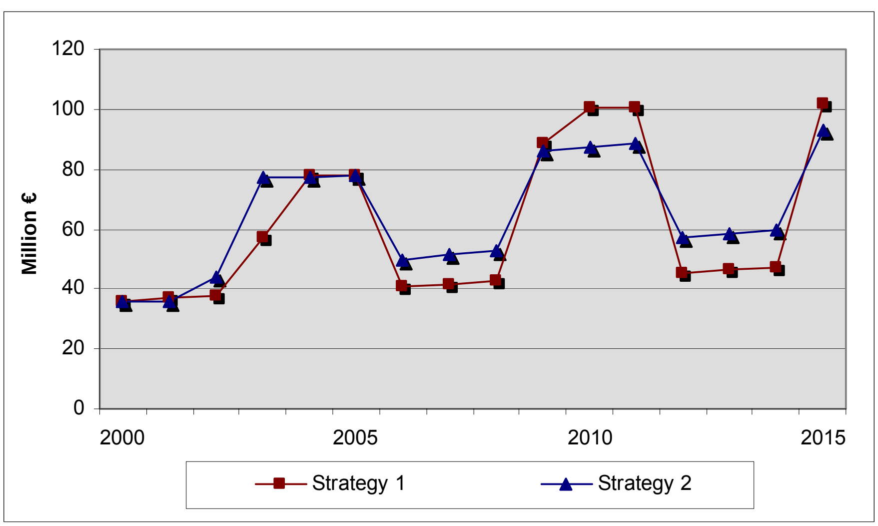


Figure 5-9 Annual Direct Costs to Be Recovered in the Domestic Sector (Million €)

The cost recovery rate (CRR) measures the percentage of the total costs associated with the production and supply of water that is covered by total water charges paid by the various consumers. Water prices in Israel are determined in the political arena and depend on the type of use: farmers pay the lowest charges, industry pays higher charges and households pay the highest ones. Within each sector, charges do not depend on location: users in all parts of the country face the same charges, regardless of the supply price of water. Most of the fresh water consumed in the region is from local wells, and the direct costs of its production and supply, 0.20 €/m^3, are lower than the prices charged to domestic and industrial consumers, and only 2 cents lower than the agricultural water prices. Thus, for most of the years of the time horizon, the total water charges collected from the region's consumers exceed total costs and the “overall" CRR exceeds 100%. Water charges that exceed water costs are not rebated to consumers, implying that domestic and industrial consumers in the Tel Aviv region subsidize consumers in other regions of the country (in most of the other regions, average CRR is lower than 100%).

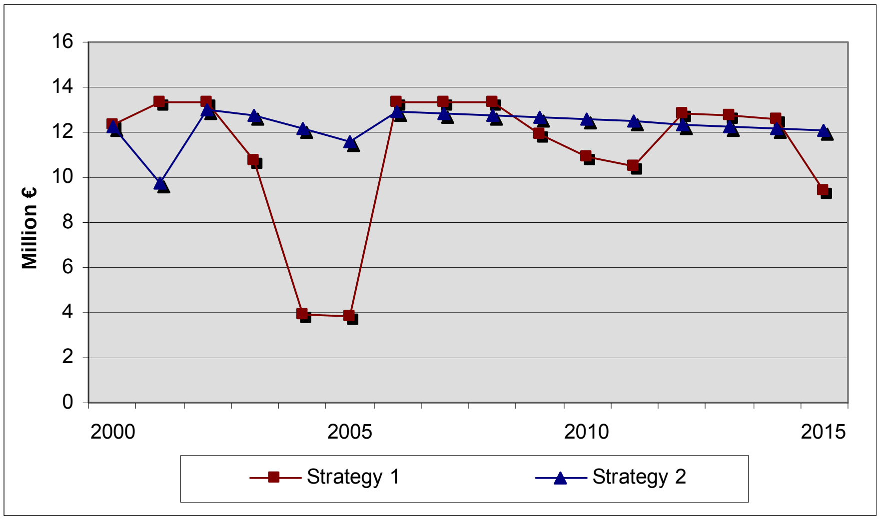


Figure 5-10 Annual Direct Costs to Be Recovered in the Industrial Sector (Million €)

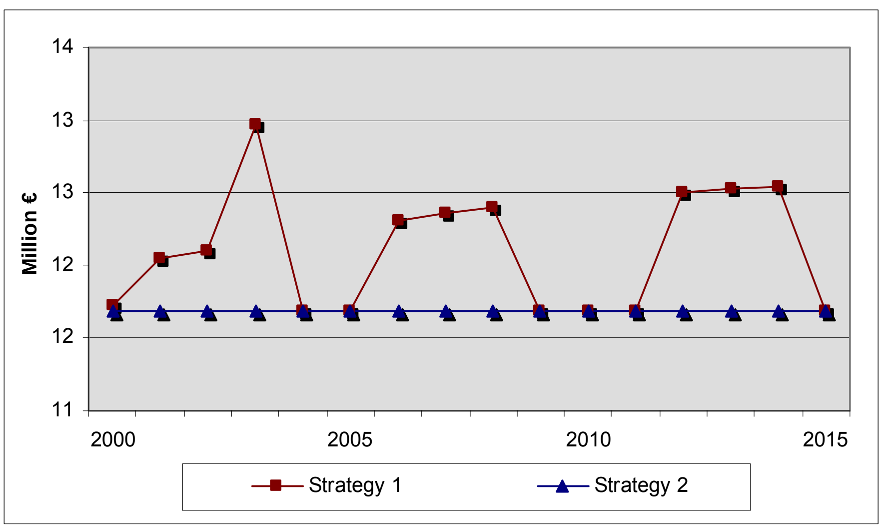


Figure 5-11 Annual Direct and Environmental Costs to be recovered in the Agricultural Sector, Million €

The annual CRR values for domestic, industrial and agricultural consumers are presented in Figures 5-12, 5-13 and 5-14, respectively. From Figure 5-12 it is evident that under both strategies, the cost recovery rate for domestic consumers is higher in “normal" years, with average weather conditions, than in “dry" years. This is due to the fact fresh water prices to a specific consumer are independent of the water source, and the cost of desalinated water is three times higher than the cost of local drills and almost twice as high as the cost of imported water. Thus, the larger the share of desalinated water in the total supply to a specific use, the smaller the CRR value associated with that use. Indeed, in dry years, the supply of imported water (in Strategy 1) and of water from local wells (in Strategies 1 and 2) is cut off and is substituted by expensive desalinated sea water.

Under the Shifting Paradigm Strategy (Strategy 2), the average CRR values over the time horizon for the domestic and industrial sectors are constrained to 100%. A CRR value of 100% can be obtained by a reduction in the prices of fresh water charged to domestic and industrial consumers. The imposition of a CRR= 100% implies a price reduction of 0.02 (=0.31-0.29) and 0.07(=0.27-0.20) €/m^3 for the domestic and industrial consumers respectively. The lower prices under Strategy 2 explain why the (yellow) CRR curves under Strategy 2 in Figure 5-12 and Figure 5-13 lie below the CRR curves under Strategy 1. Under Strategy 2, the industrial sector receives water from only one freshwater source, local drills, while the domestic sector receives water from two sources, local drills and desalination. Thus, the annual values of CRR associated with industrial consumption are always equal to 100% (Figure 5-13) while those associated with domestic consumption fluctuate around the imposed **average** of 100% (within the range of 60%-155%, Figure 5-12).

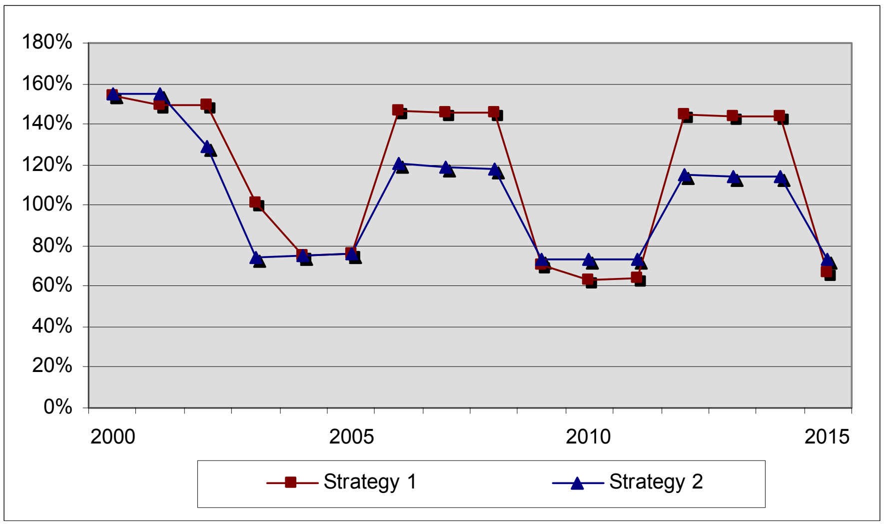


Figure 5-12 Annual CRR Values for Domestic Consumers (%)

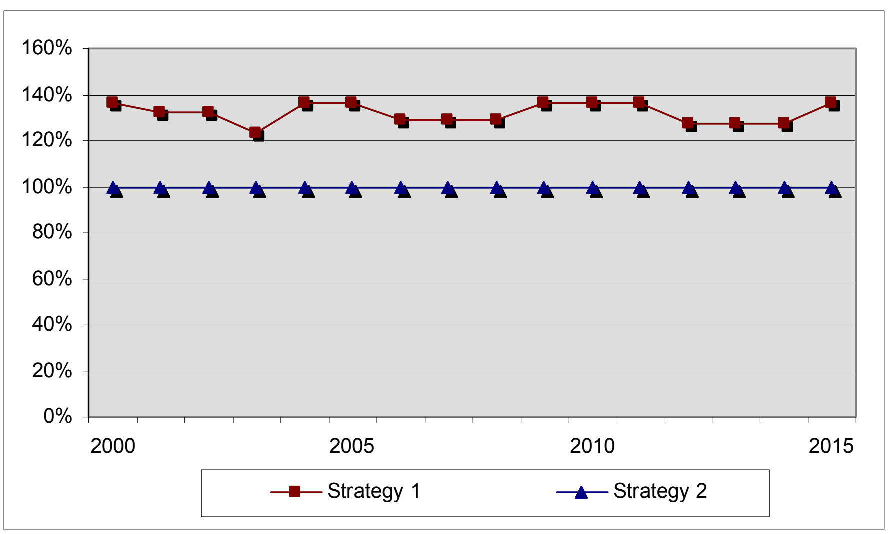


Figure 5-13 Annual CRR Values for Industrial Consumers (%)

The CRR values associated with the agricultural sector are presented in Figure 5-14. Agriculture is supplied by recycled water—the price of which (0.09 €/m^3) is lower than its cost (0.14 €/m^3)—and fresh water, the price of which (0.18 €/m^3) is also lower than its cost. Thus, the values of the CRR for agricultural consumers are lower than 100%, implying that even in the Tel Aviv region, agricultural consumption is slightly subsidized. With the exception of a few dry years in the beginning of the time horizon (2003-2005), the CRR values under both strategies are almost identical. Under Strategy 1, CRR values are lower during the dry years (2003-2005) because the portion of recycled water out of the total water consumption by the agricultural sector increases and the price paid for that water is much lower than the cost of supplying it.

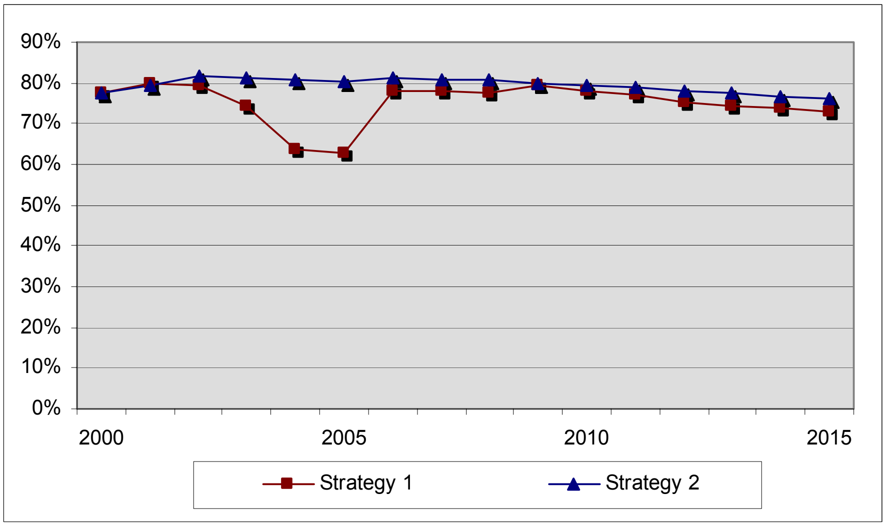


Figure 5-14 Annual CRR Values for Agricultural Consumers (%)

The aggregate CRR values for all the consumers in the region are presented in Figure 5-15.

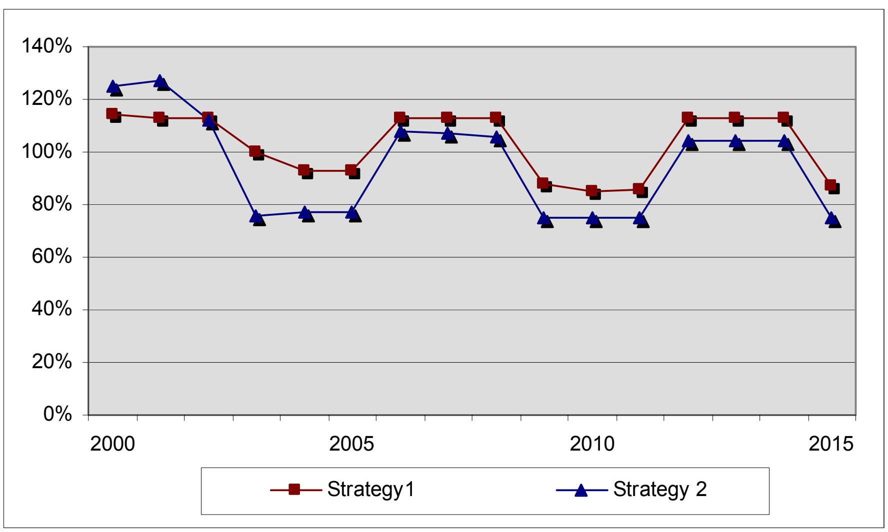


Figure 5-15 Annual Aggregated Cost Recovery Rate (%)

Summary and Concluding Remarks

The evaluation results for Strategies 1 and 2 as compared to the reference case suggest that a **grand combination of the three management options**—sea water desalination, wastewater recycling and fresh water conservation in the domestic sector—**is to be preferred to any partial combination of these options**. It meets 100% of the domestic and industrial demands and more than 70% of the agricultural demand, while it yields the highest present SWS value, 1,340 million €.

The present values of SWS associated with strategies 1 and 2 are higher by 11.5% and 12.3% respectively, with respect to the reference case BauC. However, it is important to note that the welfare criterion does not capture all the differences between the two institutions under consideration. With respect to the current centralized institutional setting (Strategy 1), the Shifting (separation) Paradigm (Strategy 2) has several advantages:

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

(b) Under the current institutional setting, the amount of fresh water exported from the Sea of Galilee and conveyed to the southern consumers via the 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) While the present value of SWS under Strategy 1 is slightly higher (by 8 million €) than the one under Strategy 2, the relationships are reversed with respect to the present values of PWS. The present PWS value under Strategy 2, with lower water prices for domestic and industrial consumers, is 109 million € higher than the one obtained under Strategy 1. 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.

The present value of environmental costs associated with each of these two strategies is much lower than those obtained under the reference scenario. The costs under Strategy 2 (2 million €) are practically negligible and the costs under Strategy 1 (9 million €) are reasonably low. Neither of these strategies is likely to be opposed by the environmentalists (or green lobbies).

Based on the above findings, **the Shifting Paradigm Strategy (Strategy 2) appears to hold the advantage.** Although its associated SWS is slightly lower relative to Strategy 1, it involves a negligible level of unmet demand (28 hm^3 versus 142 hm^3 under Strategy 1) and a negligible level of environmental costs. However, the feasibility of its political application is questionable. On the one hand, as stated above, the PWS of the consumers in the region will increase with respect to Strategy 1 and they are likely to exert political pressure on the relevant decision-makers to adopt such strategy. However, 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.

Chapter 6 Water Management Strategies for Limassol region, Cyprus

Introduction

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

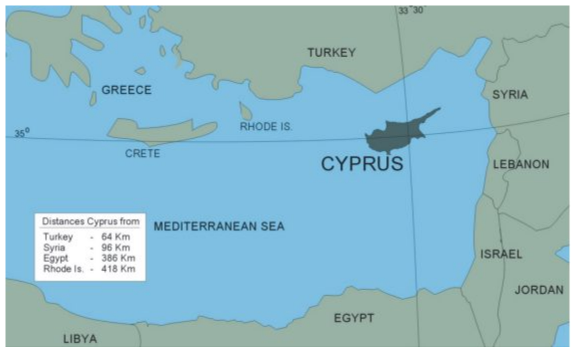


Figure 6-1 Cyprus in the Mediterranean

Although a large number of various water supply investments and interventions have been made such as surface water dams, groundwater exploitation, inter-basin 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 demand and the dynamic competitive tension between agriculture, urban growth including tourism, and the environment are challenging the existing water management practices in the island. With this in mind, the objective in the formulation of the scenarios and strategies for the Limassol Region is to meet the growing demand for water exerted by the permanent and seasonal population without affecting detrimentally the traditional agricultural demand which appears to have been stabilized. At the same time, the scenarios attempt to ensure stability of supply and maintain the groundwater exploitation to sustainable levels achieving thus environmental protection of the local aquifers.

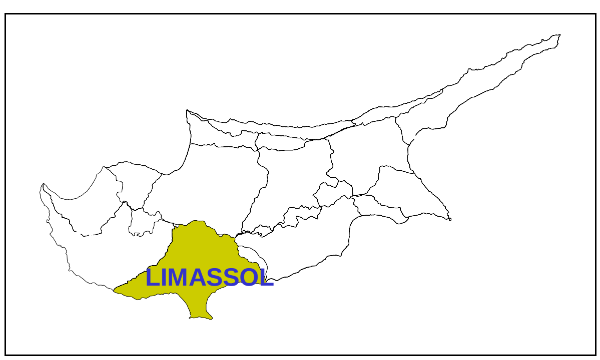


Figure 6-2 The selected Limassol region

The Limassol region (Figure 6-2) is a typical representative study region for the formulation of scenarios and strategies to address the competing and conflicting water uses in the island, since:

- The region is one of the main tourist destinations in Cyprus,

- The agricultural production in the area accounts for more than 25 % of the fruit trees, 6% of the vegetable and 20% of the table grapes production of the country
- The water system of the region is very complex (Figure 6-3 a and b)

The domestic consumption of the region accounts for almost 12.8 hm^3, whilst the domestic water consumption for tourism (seasonal population) accounted for 3.6 hm^3 in 2000 which is almost 26 % of the island's total seasonal consumption. The domestic consumption 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). Irrigation water demand in the region accounts for almost 31 hm^3 of which 24 hm^3 were supplied from the major Government Irrigation Schemes (Figure 6-1). In addition the annual water demand for animal husbandry in the region accounts for 820,000 m^3 and the industrial demand for 1.5 hm^3 or 43% of the total industrial demand of the island. Environmental demand in the region accounts for 4 hm^3.

The sources of water supply in the region include:

- Surface water stored in the three dams of the region, namely the Kouris Dam (of a total capacity of 115 hm^3), the Polemidhia Dam (of a total capacity of 3.4 hm^3) and Germasogeia Dam (of a total 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 capacity of 40,000 m^3/day with a potential capacity of 80,000 m^3/day. 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 extraction from a number of boreholes to be used for domestic and irrigation purposes.
- Treated effluent from the Limassol Sewerage Board Treatment Plant used for agricultural and landscape irrigation.

The irrigated areas in the region fall in two categories: Areas within the Major Government Irrigation Schemes of the region (Akrotiri West and Germasogeia-Polemidhia) and areas outside the Government Irrigation Schemes.

Water from the Kouris Dam (the biggest dam in Cyprus) is transferred to the eastern part of Cyprus (Kokkinokhoria region) through the pipeline of the Southern Conveyor Project (Figures 6-3a and b).

Target definition

Since the water management practices in the region reflect the competing demand and the dynamic competitive tension between agriculture, urban growth including tourism, and the environment, the formulation of the strategies will be based upon the following objectives:

- To meet at least 80% of domestic and irrigation needs in the peak summer period
- To meet 100% of domestic and irrigation needs during the rest of the year

The above targets are justified taking into account the perceptions of the stakeholders (see below) regarding a strategy that aims at a more efficient use of the region's and the island's water resources. Furthermore, reservations dictate, among others, that the coverage of the domestic demand as well as the sustainable distribution of the water at a national level should be guaranteed, while on the other hand, the agricultural activities should be maintained for socioeconomic reasons.

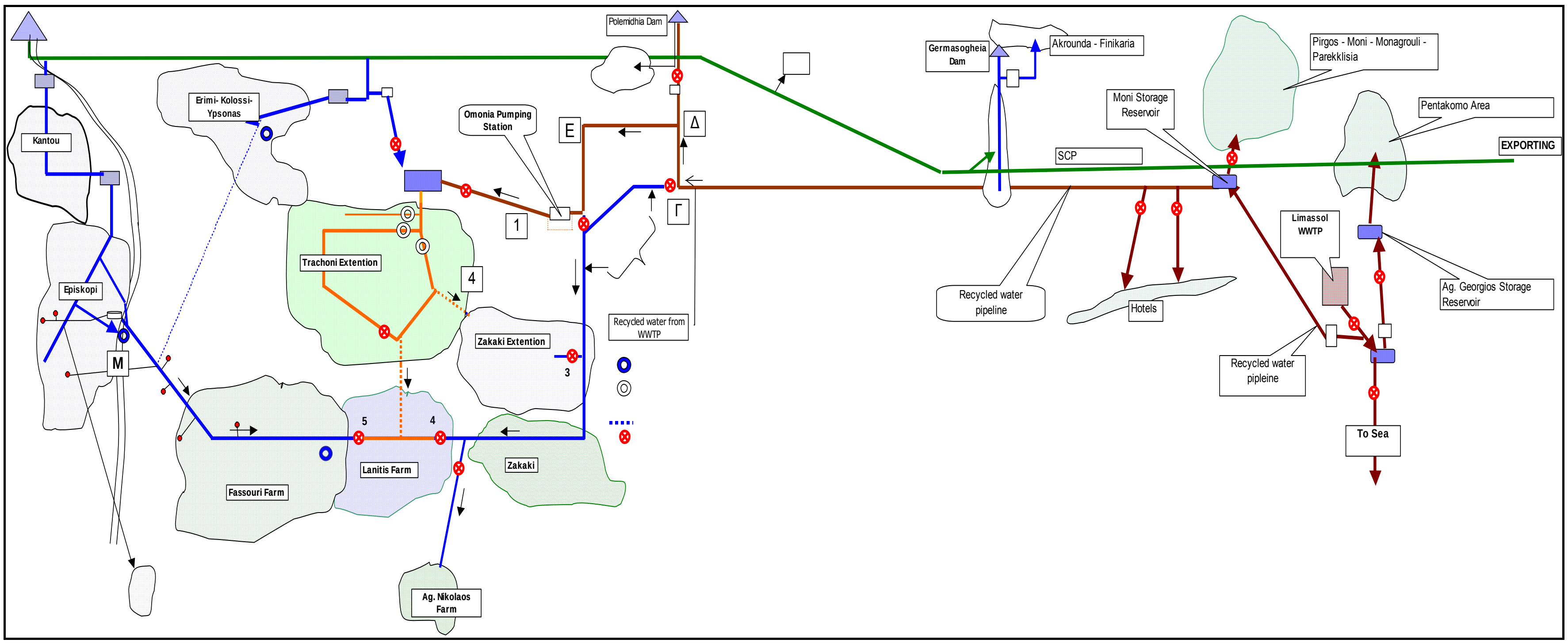


Figure 6-3a The irrigation system of the region

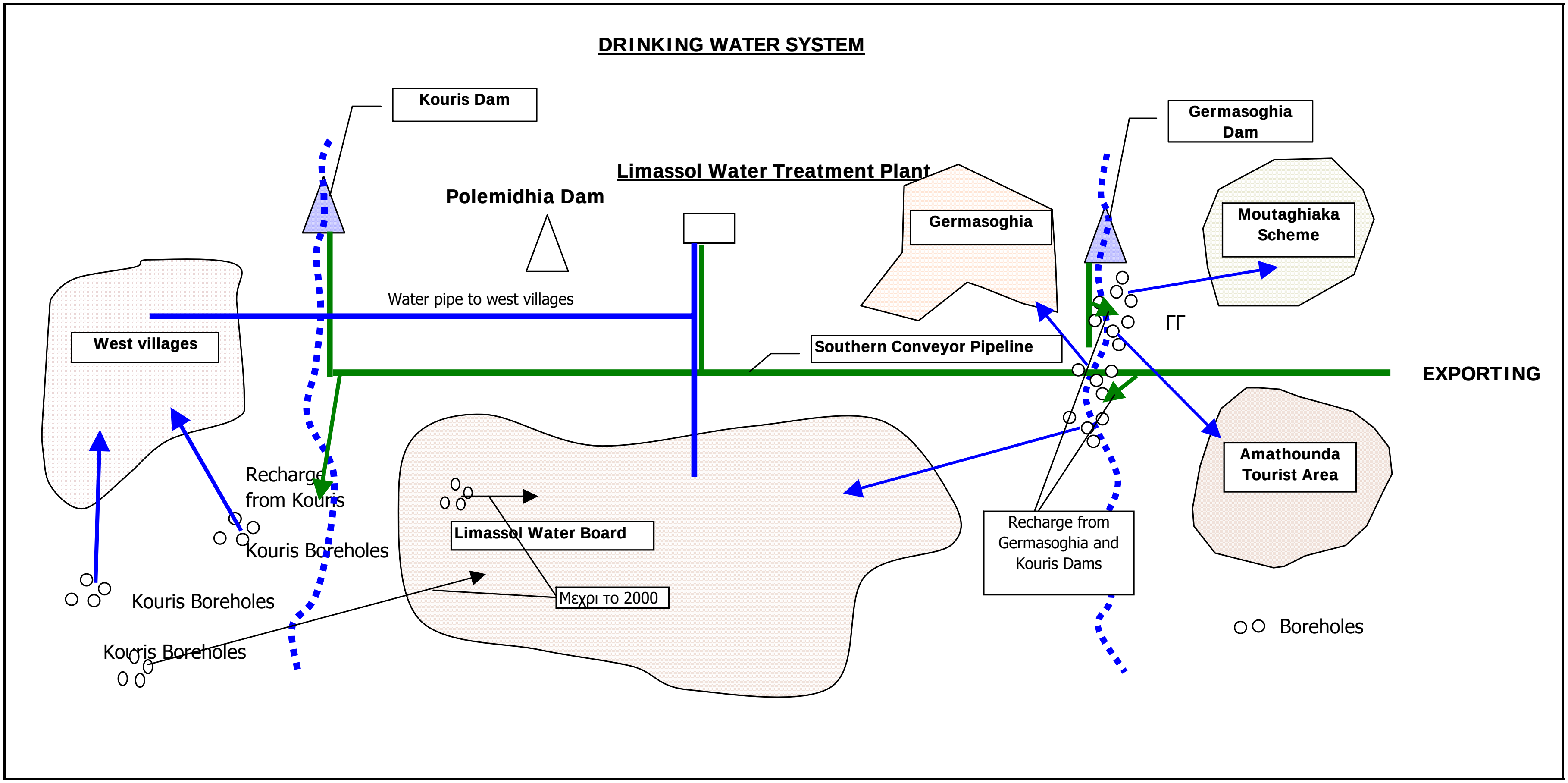


Figure 6-3b The irrigation system of the region

Identification of Available and Feasible Options

Applicable management options and measures derived from a synthesis of the current responses regarding water management, the responses proposed by the stakeholders and the requirements of the Water Framework Directive that can be implemented in this specific area. Throughout this identification, stakeholder consultation played a key role in the definition of constraints and possibilities that could have a substantial effect in the mitigation of water management issues in the region.

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-Amathus (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 **Fassouri Agricultural Estate**.

The approached stakeholders proposed different (alternative) solutions to the problems of water deficit and groundwater quality. Proposed solutions strongly depended on the problems faced, and their awareness on the impact that measures would have to the island as a whole, and the region in particular.

Stakeholder Consultation Outcomes

Perceptions of the Water Development Department (Ministry of Agriculture, Natural Resources and the Environment)

For WDD, additional options that could be applied both in the region of Limassol, and in Cyprus as a whole are:

- Interventions on the supply side:
    - Increase of available supply through enhancement of the use of treated wastewater,
    - Building groundwater quantities – maintain strategic reserves.
- Interventions on the demand side:

    - Demand reduction for irrigation through adjustments in cropping pattern,
    - Water saving, achieved by a further reduction of water losses.
- Interventions related to the overall socio-economic environment, and institutional instruments:
    - Need for public participation in order to improve water conservation,
    - Incentives and disincentives to conciliate water availability with demand,
    - Groundwater pricing mechanism to discourage preference on this resource,
    - Water tariffs for irrigation to reflect true costs allowing an adequate cost recovery.

Perceptions of the Water Board of Limassol

The perceptions of the Water Board of Limassol concentrate on a more efficient use of the water resources of the region and the island in general. Their proposals, perceptions, and reservations are:

- Priorities and interventions on the supply side:
    - First priority on the provision of adequate drinking water,
    - Sustainable water allocation on a national level,
    - Objections for the construction of new desalination plants,
    - Utilisation of treated wastewater in the agricultural and tourism sectors (golf courses and landscape),
    - Elimination of water abstraction from boreholes, and shift towards surface water (provision of equal quantities from the Water Treatment Plant of Limassol).
- Interventions on the demand side:
    - Demand reduction through adjustment of cropping patterns, and substitution of local agricultural production with imports,
    - Water saving, through further reduction of network losses.
- Considerations for the overall socio-economic environment:
    - Water tariffs for agricultural purposes are very low,
    - There is need for public participation in order to improve water conservation,
    - Water tariffs for potable water should be reasonable.

Perceptions of the Sewerage Board of Limassol

The Sewerage Board of Limassol – Amathus holds the opinion that supply-side interventions should focus on the improvement of recycled water quality, in order to promote its acceptance and use by farmers and municipalities. With regard to the institutional context, they believe that provision of recycled water should be effected through a company operating on a national level, independently of the Government.

Perceptions of Municipalities

Local municipalities object towards two interventions proposed by the Government: they raise concerns for the recharge of the Kouris Delta aquifer with treated wastewater, and for the construction of a new desalination plant. Additional interventions should focus on the improvement of the treated wastewater quality, and they think that there is need for public participation and awareness campaigns regarding the operation of the WWTP, in order to promote the use of treated wastewater in agriculture.

Perceptions of End Users

The end-users (farmers) that were contacted, expressed the following as potential measures/perceptions:

- Necessity for a National Water Authority,
- Public participation/involvement,
- Pricing mechanism for treated wastewater,
- Subsidies for irrigation freshwater,
- Campaigns to increase awareness for the safe use of the treated water for irrigation,
- Coverage of the seasonal demand (tourism activities) with desalinated water,
- Need to ensure the good and stable quality of treated wastewater,
- Improvements of the distribution system,
- Prioritisation of demands.

Synthesis of proposals for improved water management strategies

Figure 6-4 illustrates a set of practices which will be combined to formulate strategies aiming at balancing the various pressures on water demand due to the conflicting water uses pertinent in the region (domestic – agricultural– tourist use). The approach was based on the thorough consideration of environmental, social and economic constraints.

A number of the above proposed interventions were analyzed using the WSM Decision Support System, and the results of this analysis are presented in the following text. The examined interventions fall into three main categories, described in Table 6-1.

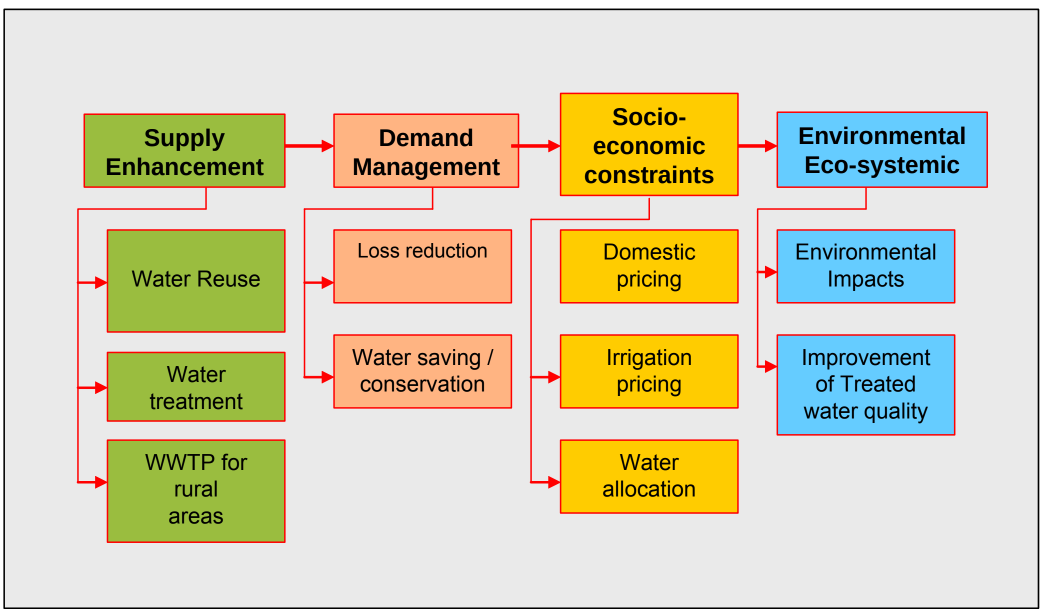


Figure 6-4 Summary of management options

Table 6-1 A synthesis of management options for Limassol region

GOALS	INTERVENTIONS
Interventions related to Supply Enhancement	
Domestic and tourist demand will be met by surface water – Agricultural demand will be met by surface water reducing the burden on groundwater.	SE1: Minimization of groundwater abstraction for drinking water. SE2: Upgrade Program of the existing Water Treatment Plan.
Maintain irrigated agricultural practice using water from dams and treated water only, to allow aquifers to recover.	SE3: Construction of a WWTP for the western rural areas. SE4: Minimization of groundwater abstraction for irrigation
Interventions related to demand management	
Adjustment of cropping pattern to less water demanding crops suitable for the climatic and water conditions of the country. Consequent promotion of high income crops Prioritizing irrigation demands during droughts	DM1 : 1st priority permanent crops 2nd priority seasonal crops
Interventions related to the socio-economic context	
Discouragement of groundwater resource preferences.	SE1: Increment of groundwater tariffs to the level of surface water charges.
Reflection of true water costs on water tariffs allowing an adequate cost recovery.	SE2: Review of irrigation water allocation criteria.
Conciliation of water availability with demand.	SE3: Gradual increase of irrigation water prices to reflect true costs (cost recovery). SE4: Introduction of incentives and disincentives to conciliate water availability with demand
Interventions related to the Environmental Eco-Systemic Context	
Improvement of treated water quality.	E1: Additional infrastructure at the WWTP.

Evaluation of Water Management Options

Formulation of demand and availability scenarios

The formulation of demand scenarios for the region of Limassol was based on existing projections and data (the relevant FAO study for the island), and a selection of appropriate variables, aiming to reflect the competing demands and the dynamic competitive tension among agriculture, urban growth including tourism, and the environment. More specifically, the formulation of demand scenarios addressed permanent and seasonal population growth, increase in the domestic consumption rates for both the seasonal and the permanent population, and growth in agricultural demand. The formulated scenarios correspond to the normal (Business-As-Usual) conditions, conditions of high demand, and conditions of low demand, according to data provided from FAO, the Water Development Department, the Limassol Water Board etc. Detailed reference on the above can be found in Chapter 12.

The formulation of availability scenarios was based on detailed data on water flows that were available for the region. The main assumption for their formulation was based on the sequence of years with respect to water inflows. Three different hydrological scenarios were used, reflecting the business as usual conditions (standard water availability) – BAU, the high frequency of dry years conditions (DRY) and high frequency of wet years (WET).

Each of the identified options was examined with respect to combinations of the above scenarios, which depicted a “normal shortage state”, a “low shortage state” and a “high shortage state”. Detailed results from the evaluation, as well as conclusions drawn regarding the applicability of the options can be found in Chapter 12. The following paragraphs present the evaluation outcomes for the high shortage state, which served as the basis for the strategy formulation, as described below.

Summary of option evaluation outcomes

The selection of the appropriate options was based on their performance with respect to a number of indicators including coverage of domestic and irrigation demand, direct cost as well as environmental costs, associated with groundwater exploitation. The results of the option evaluation process are presented in Table 6-2, in normalised form under a scale ranging form 1 (worst performance) to 5 (best performance).

Table 6-2 Normalised performance matrix of the studied interventions (HD+DRY scenario)

Option	Effectiveness	Economic Efficiency	Environmental Sustainability
Water reuse	***	*	***
Water treatment plant expansion	*	*	*****
Waste water treatment plant construction	***	*	*****
Reduction of Losses (Distribution network improvement)	*****	**	*
Conservation measures	***	*****	*
Irrigation water pricing	*****	*	*
Domestic water pricing	***	*****	*

From the normalised matrix it is apparent that the examined options do not have the same performance with respect to the three adopted indicators. Soft measures perform better in relation to demand coverage and economic efficiency, while they have a poor performance with regard to the environmental sustainability (associated in this case with abstractions from vulnerable aquifers). On the other hand, the structural options (water reuse – water treatment plant – wastewater treatment plant) perform better with respect to environmental sustainability and effectiveness while a poor performance is indicated with regard to economic efficiency indicators. It is therefore evident that a more integrated approach is required, incorporating not only structural interventions, but also demand management, conservation and economic incentives to reach solutions that could be effective in mitigating water stress while at the same time not incurring excessive costs to consumers.

Strategy Formulation and Evaluation

Assumptions

The formulated and assessed strategies refer to medium to long-term planning (period 2002 – 2030) and to the worst case scenario with regard to water availability conditions (high frequency of dry years) and water demand (high demand scenario). It is assumed that domestic population increases annually, throughout the planning period, by 0.5%, seasonal population by 0.5-1%, irrigation demand by 10% and domestic and seasonal consumption rates by 2% and 1.5%, respectively.

Formulation of alternative water management strategies

The strategy formulation, based on the available feasible options, summarized above, involves three steps:

- Selection of measures based on a thorough examination of the strategy goals and of forecasts for the future;
- Determination of the time for their application;
- Scheduling of a sequence of acceptable/available measures.

The next level of action included the evaluation of the selected Strategies using the Decision Support System. The DSS optimally allocates water from available and user-defined sources to user-defined uses, taking into account user-defined priorities for each use and the selected strategy under different scenarios. It also assesses the quality of the available resources. The Decision Support System was used to estimate how much water is needed and to determine what interventions are necessary, when and where they are needed, as well as what their cost is. It provided indicators of performance for the selected strategy under each given scenario, and it ranked those scenarios.

Thus, the overall approach followed a thorough examination of the strategy goals and forecasts for the future, developing quantitative and qualitative projections for supply and demand in the various sectors. Uses were ranked in order of importance, so as to enable efficient allocation of resources to the sectors which are characterized by the highest use value. Scheduling was another important point, since different issues should be addressed in different time frames.

Following the aforementioned steps, two strategies were formulated:

(i) **Strategy 1**, which was based on the current approach, including already applied and tested measures (hard measures), and

(ii) **Strategy 2**, which involves options not currently used or accepted, relying mostly on measures aiming to increase the productivity of water use and “soft” responses.

Strategy 1 – The “hard-path” approach

Strategy 1 includes already applied and planned for the future measures which, based on the experience of the various stakeholders, are expected to be effective and efficient for the Limassol water system. These measures and interventions are mostly structural, focusing on expansions of the existing system and the construction of wastewater treatment plants and reuse infrastructure.

The interventions incorporated in Strategy 1 include:

- **The construction of a new Waste Water Treatment Plant to serve the West Rural Areas.** The realization of this intervention is scheduled for the year 2007, and includes the following technical aspects:
    - A new 4000 m^3/day WWTP will be constructed to treat the effluent of the villages Polemidhia, Ypsonas, Erimi, Episkopi and Kolossi.
    - The tertiary treated effluent will partially cover the needs of the Episkopi and Fassouri farms.
- **Water Reuse**, which is scheduled for the year 2007, and includes the following:

- Recycled water during winter months (when the irrigation demand is minimum) will be stored in Polemidhia dam and/or will recharge the Kouris Delta aquifer. Under these circumstances, the Kouris Delta aquifer may not be used for domestic purposes.
- The pipeline from the WWTP will be connected to the existing network to transfer water to Zakaki Ext., Ag. Nikolaos, Lanitis and Fassouri farms.
- A new pipeline will connect Ypsonas reservoir with Zakaki farm so that fresh water is transferred from the Kouris dam in order to meet the irrigation demand of the farm. The cost of the pipeline is estimated to be approximately 250,000 €.
- A new 5 km pipeline will connect the existing network with the Kouris Delta aquifer. The cost of the new pipeline is estimated to be 1.7 million € approximately.

- **Water Treatment Plant.** The realization of this intervention is scheduled for the year 2010, with the following technical aspects:
  - Upgrade of the existing Water Treatment Plant to reach a capacity of 80.000 m^3/d.
  - Minimisation of groundwater abstractions from the Garyllis aquifer for domestic supply.

The tentative timeframe of the selected interventions is presented in Figure 6-5.

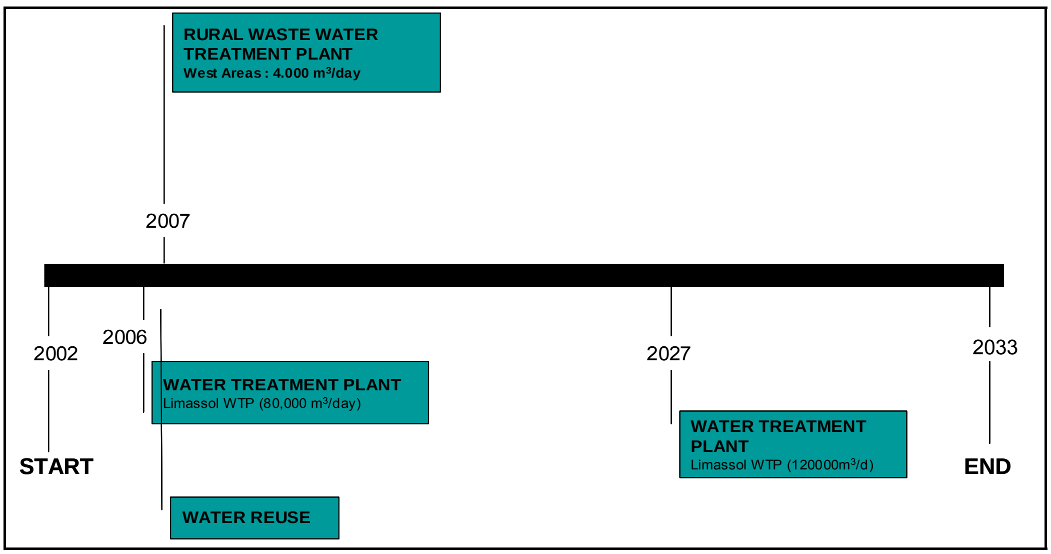


Figure 6-5 Tentative timeframe of interventions under Strategy 1

Strategy 2 – The "soft-path" approach

The second strategy attempts to reconcile the supply and demand through soft interventions reflecting a shift in the traditional paradigm of water management in Cyprus. The strategy formulated is highly dependent on efficiency improvements dealing with water reuse, conservation measures, domestic and irrigation pricing complementary to the planned structural measures but making them of a smaller size and extending the application timeframe. Additional interventions, with respect to Strategy 1 are the following:

- **Reduction of distribution network losses (domestic sector).** The realization of this intervention is scheduled for the year 2006, with the following technical aspects:
  - Reduction of the losses to 15% (through successive network replacements) for the three biggest settlements in area under examination which are Lemessos Municipality, Lemessos Tourist Part and Germasogeia Municipality.

- **Conservation measures for domestic use**. The realization of this intervention is scheduled for the year 2010, with the following technical aspects:
    - o Reduction in the domestic demand of 10% (excluding the seasonal demand).
- **Domestic Pricing.** An increase in bulk domestic water tariffs has already been effected by the WDD in 2004. Similar increases are also applied in 2017, with the following details:
    - o Application of block structured water tariffs with an average price of 0.77 €/m^3.
    - o An elasticity of –0.25 was assumed for residential consumption.
- **Irrigation Pricing**. The realization of this intervention has already been planned and applied by the Water Development Department since 2004, with the following considerations/ assumptions:
    - o This option examines the case of raising the irrigation water prices from 0.12 €/m^3 to 0.19 €/m^3 within a period of three (3) years according to the tentative timeframe shown in Figure 6-6.
    - o Data for demand elasticities are available for individual cultivations and are provided in the following table.

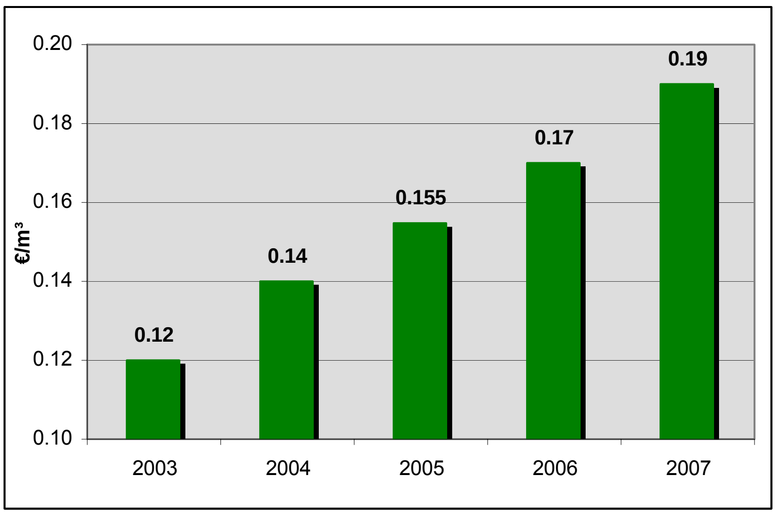


Figure 6-6 Timeframe of irrigation pricing

Table 6-3 Agricultural products price elasticities (Eri Nicolaides, 2000)

Product	Price Elasticity
Potatoes (spring)	-0.33
Tomatoes (greenhouse)	-0.70
Cucumbers (greenhouse)	-0.58
Water melons (open)	-0.50
Oranges	-0.02
Grapefruits	-0.02
Lemons	-0.01
Mandarins	-0.02
Grapes	-0.02

The tentative timeframe of the selected interventions is presented in Figure 6-7.

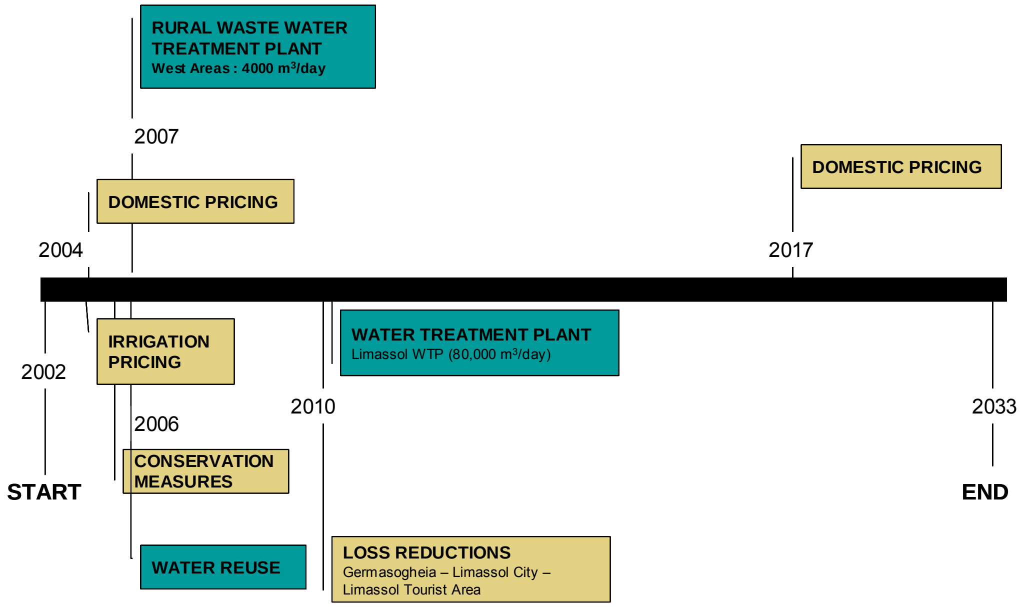


Figure 6-7 Tentative timeframe of interventions under Strategy 2

Strategy Evaluation

Under both strategies domestic and irrigation demand coverage reaches almost 100% on an annual basis, as depicted in Figures 6-8 and 6-9 respectively. Therefore, it can be concluded that the main target set for strategy development (i.e. 100% coverage of domestic and irrigation needs) can be achieved with both approaches (and timeframes).

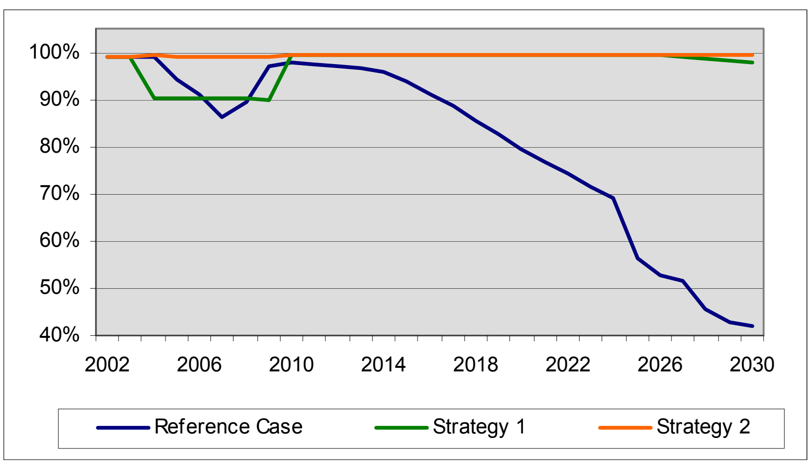


Figure 6-8 Domestic demand coverage (%)

The developed strategies were evaluated through a series of indices and indicators describing the actual range of the activities applicable to the region reflecting the perception of the locals towards economic development, social and environmental sustainability. Since it is widely acceptable that future economic growth of the area is to rely on tourism, the analysis of options was assessed on the ground of the **coverage of domestic needs.** On the other hand due to the importance of the agricultural sector (social, economic and environmental), the options formulation was also assessed on the basis of the **irrigation demand coverage** presented in Figure 6-9**.**

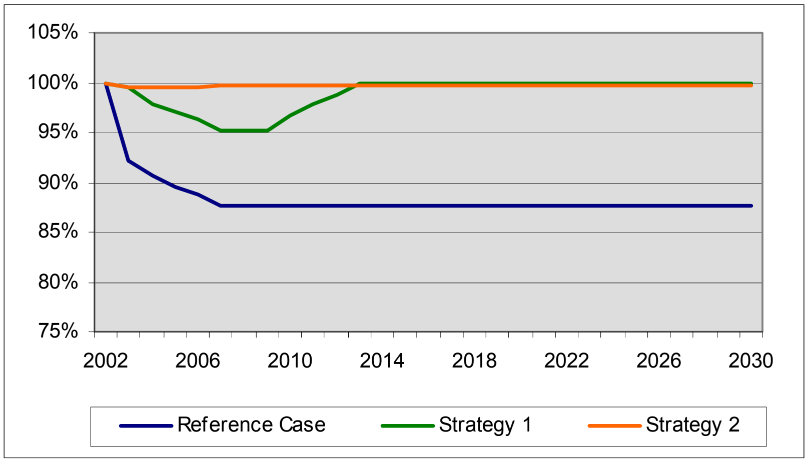


Figure 6-9 Irrigation demand coverage (%)

Table 6-5 presents the results of the comparison of the two strategies against the reference case, while Figure 6-10 presents the resulting costs (direct, resource and environmental) in present value terms.

Table 6-4 Strategy evaluation table

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)
Reference case	0	389	342
Strategy 1	0.741	359	118
Strategy 2	0.751	350	109

With regard to the evaluation scores obtained through the WSM DSS it should be noted that both strategies are characterized by a similar performance in terms of demand coverage. Another important conclusion is that under both strategies environmental and resource costs are lower. This difference is minor on what concerns environmental costs, but becomes significant in terms of resource costs which fall to approximately 10% of these in comparison with the reference case.

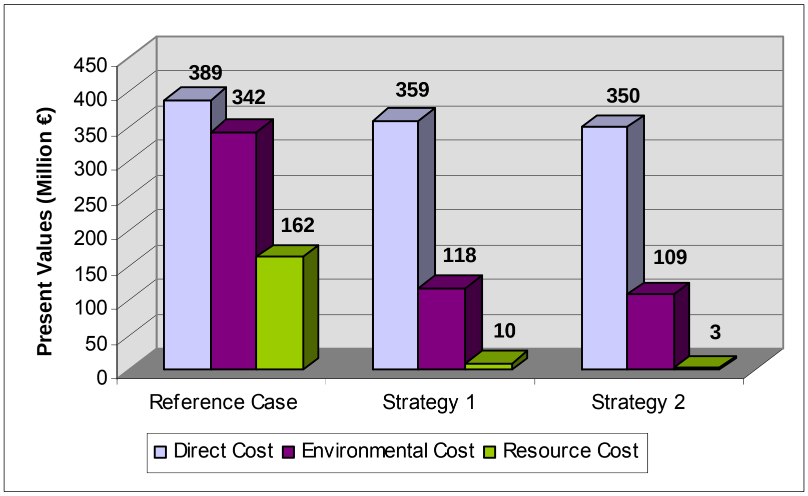


Figure 6-10 Present Values in million €

The evolution of direct costs, resulting from the simulation of the two strategic plans is portrayed in Figure 6-11, where a drop appears in the total cost after 2014. This decrease is associated to the end of the amortisation of the existing drinking water treatment plant.

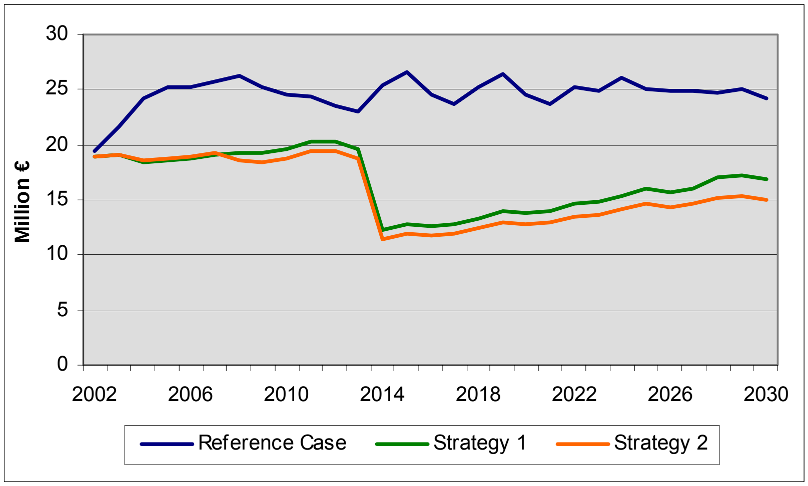


Figure 6-11 Total Direct Costs

Development of a Cost Recovery Strategy

The development of a cost recovery strategy is strictly interrelated with the provisions of the WFD, requiring recovery of costs associated with the provision of water services and the adequate contribution of the water uses and users to these costs. Taking into account the fact that the WSM Decision Support System allocates costs to each use (user) proportionally according to the volume of water allocated/ pollution incurred from each, the achieved cost recovery rate for the two strategies is portrayed in Figures 6-12 and 6-13. The estimated cost recovery includes only the incurred direct (financial) costs associated to freshwater provision.

Formulation of cost recovery strategies

Concerning domestic use during the period from 2010-2030, the cost recovery rate under Strategy 2 is expected to be slightly greater than 90% while for irrigation use, it is expected to be slightly greater than 80%. One conclusion drawn from the examination of the two graphs is that that full cost recovery under the assumed availability conditions cannot be achieved, even though Strategy 2 includes the currently implemented pricing measures by the Government.

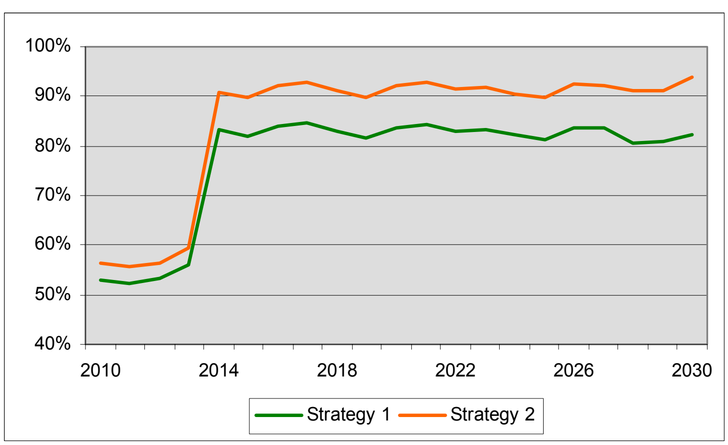


Figure 6-12 Cost recovery rate for domestic water provision

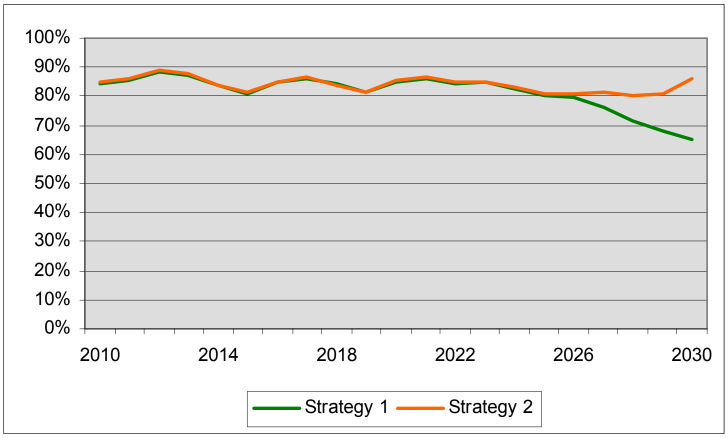


Figure 6-13 Cost recovery rate for irrigation water provision

In order to examine and analyze the difficulties which could be encountered if the provisions of the WFD were applied in the Limassol region, a cost recovery pricing scheme was developed for both Strategies for the domestic and irrigation uses.

The developed strategy was considered a flat-rate average volumetric price scheme to be readjusted on a periodic basis. The set targets regarding the rate of cost recovery were:

- **Domestic water provision:** after year 2015 the recovery of direct costs should be more than 80% reaching 100% by 2030, with average volumetric prices readjusted every 5 years
- **Irrigation water provision:** 100% recovery of direct costs, by 2030, with average volumetric prices readjusted every 5 years

In Figures 6-14 and 6-15 the resulting costs that have to be recovered are presented.

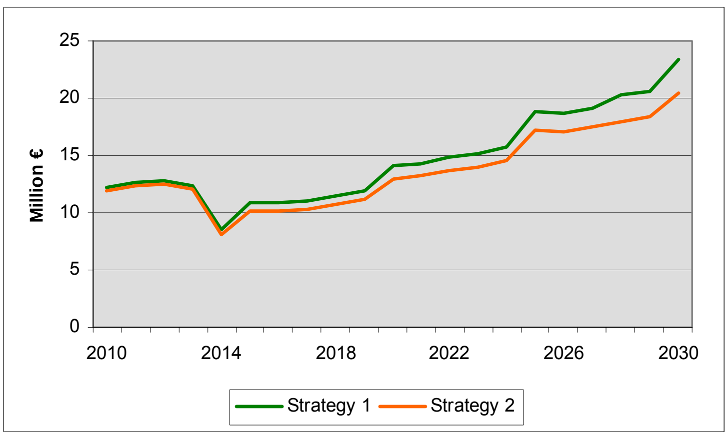


Figure 6-14 Total costs to be recovered – Domestic water provision

Given the demand elasticity for the domestic and irrigation demand in Cyprus (for the domestic use estimated at –0.2 and for the irrigation related to the different crops – seasonal and permanent) the introduction of pricing is expected to significantly affect the demand. Therefore an iterative process was used in order to redefine the extent for the application of options, their costs, the timeframe of application, and the prices required for the targeted cost recovery.

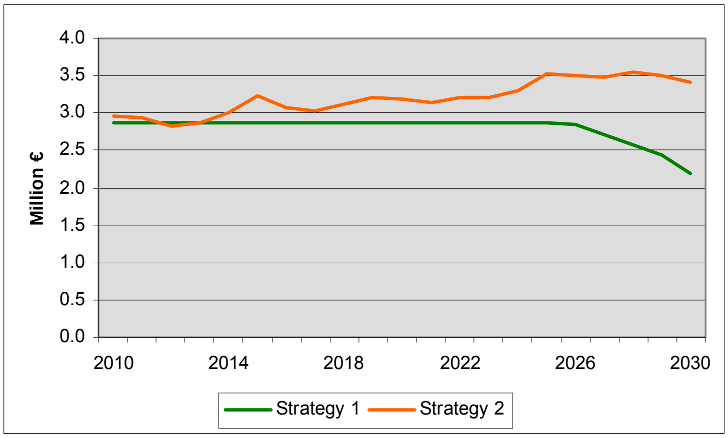


Figure 6-15 Total costs to be recovered – Irrigation water provision

The applied volumetric prices for domestic and irrigation water that resulted from this process for the period 2010-2030 are:

- For domestic (potable) water:
  - For Strategy 1, from 0.77 €/m^3 from 2010 to 2025, to 0.83 €/m^3 for the period 2020-2025 and escalating to 0.94 €/m^3 in 2030.
  - For Strategy 2, the tariff increase is effected much earlier, in 2023 with the tariff reaching 0.9 €/m^3 and remaining constant for the rest of the examined period.
- For irrigation water:
  - For Strategy 1, from 0.15 €/m^3 from 2010-2025, 0.2 €/m^3 from 2025 to 2030 and reaching 0.25 €/m^3 in 2030.
  - For Strategy 2, the estimated volumetric price remains constant, and equal to 0.17 €/m^3 throughout the examined period.

Re-evaluation of strategy options and performance

As it was mentioned before, given the elasticity for the domestic and irrigation use in the area, the demand was affected significantly as a result of the introduction of the new pricing policy (Figure 6-16).

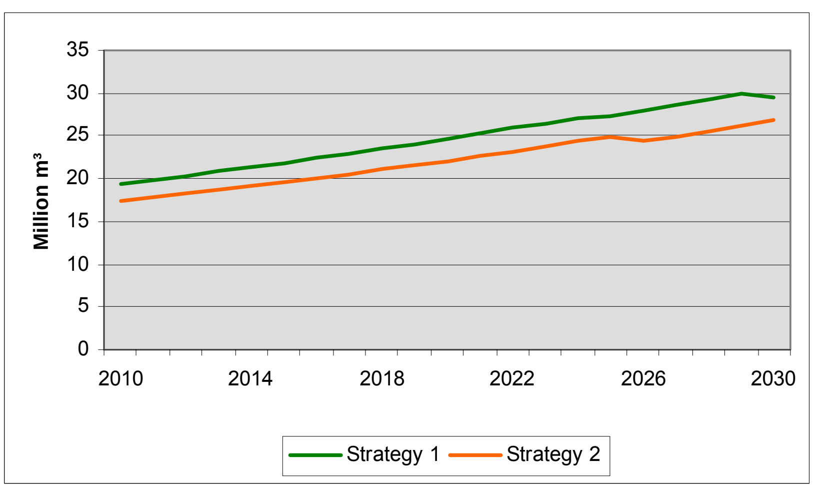


Figure 6-16 Domestic demand under cost recovery strategy

For the same reason, the performance of the two Strategies was also affected resulting in the evaluation scores presented in Table 6-5. However, it should be noted that the simulation of the pricing policy incurred slight differences both in terms of demand coverage (resulting evaluation score), and in terms of direct and environmental costs.

Table 6-5 Adjusted Strategy evaluation scores under cost recovery strategy

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)
Reference case	0	389	342
Strategy A	0.742 (0.741)	353 (359)	113 (118)
Strategy B	0.757 (0.751)	345 (350)	108 (109)

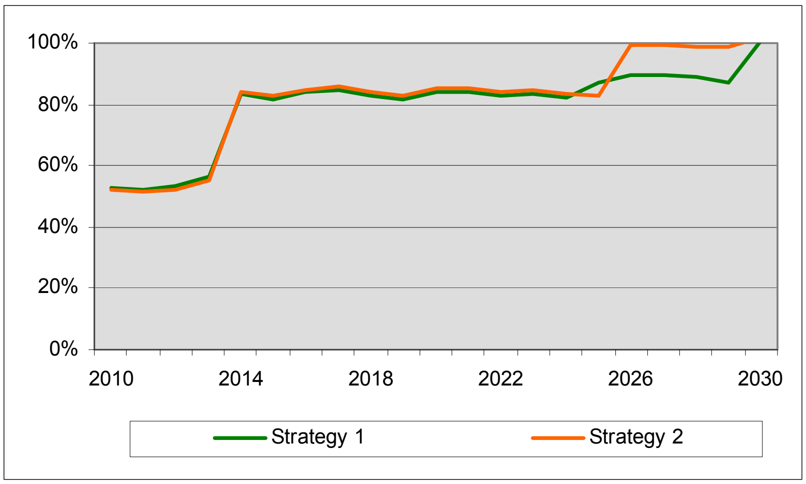


Figure 6-17 Cost recovery rate – domestic water provision (under cost recovery strategy)

Figure 6-17 and Figure 6-18 present the achieved cost recovery rates for domestic and irrigation water provision. The targeted 100% recovery is achieved only for potable water provision, while for irrigation water only 80% can be achieved, as a result of affordability issues.

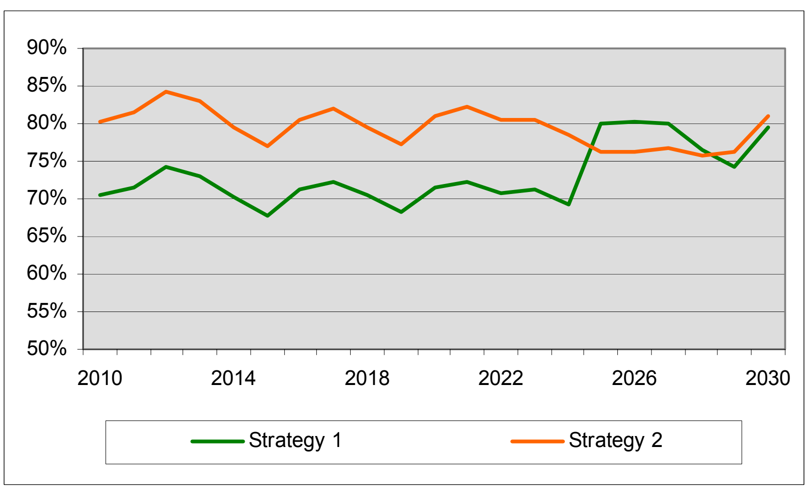


Figure 6-18 Cost recovery rate – irrigation water provision (under cost recovery strategy)

Discussion and Recommendations

Both strategies achieve to meet local water needs for domestic and irrigation use since they both reach 100% demand coverage for both uses.

The analysis of the two economic policies adopted shows that total direct costs can be fully recovered for the domestic use (in line with the requirements of the Water Framework Directive), and up to 85% for irrigation water provision. Strategy 1 (that also included pricing measures), achieved better results than Strategy 1(which was based only on structural measures); this is an indication that the adoption of soft measures, like pricing, can contribute to the recovery of the full cost of the water for domestic use, in line with the suggestions of the WFD.

In terms of economic performance, Strategy 2 appears to be more effective and more attractive after cost recovery strategy is applied, resulting in smaller average volumetric prices for domestic and irrigation use.

The average volumetric price for domestic use under the cost recovery strategy was determined at 0.95 and 0.9 €/m^3 for Strategies 1 and 2 respectively, while the average volumetric price for irrigation under the cost recovery strategy was determined at 0.25 and 0.17 €/m^3 for Strategies 1 and 2 respectively.

Chapter 7 Water Management Strategies for Ribeiras do Algarve, Portugal

Introduction

The Ribeiras do Algarve River Basin, with an area of 3837 km^2 and including 18 Municipalities (Figure 7-1), is the most popular tourist destination in mainland Portugal. The region has a registered permanent population of around 365,000 inhabitants (2001), which is increased on average by approximately 200% during the summer months due to tourist influx. However, that percentage increase is different for each Municipality (Figure 7-1): Albufeira = 571%, Aljezur =288%, Almodôvar = 0%, Castro Marim = 557%, Faro = 54%, Lagoa = 365%, Lagos = 227%, Loulé = 204%, Monchique = 43%, Portimão = 252%, São Brás de Alportel = 41%, Silves = 104%, Odemira = 0%, Olhão = 70%, Ourique = 0%, Tavira = 152%, Vila do Bispo = 186% and Vila Real de Santo António = 25%.

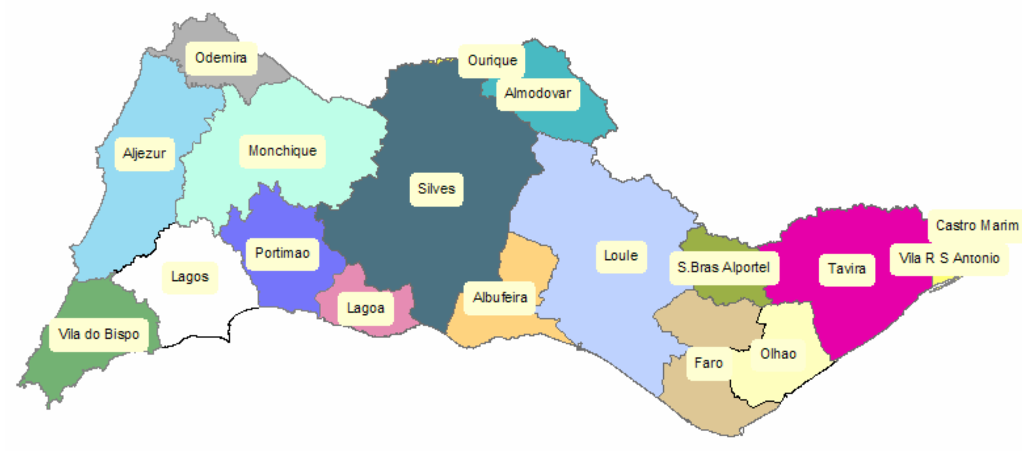


Figure 7-1 Municipalities located within the Ribeiras do Algarve River Basin

The Ribeiras do Algarve River Basin has undergone, in the last decades, deep changes in its demography, mostly due to the important development of tourism activity that created a new reality. In the 1980s, one could identify a productive structure based on three economic activities: agriculture, fishing and tourism. Nevertheless, in recent years the backbone activities of Algarve's economy have shifted towards tourism and the associated tertiary activities. One of the most specific demographic characteristics of the River Basin is the quite unequal population distribution. Most of the inhabitants are living in the coastal zone and the hinterland is suffering from depopulation process associated with significant ageing of the remaining inhabitants. Consequently, the pressure on water resources exerted by the seasonal population is very intense, leading to water shortage during the summer months.

Traditionally, domestic and agricultural demands were supplied by groundwater resources, which supported the development of tourism and irrigated agriculture. However, the combination of natural processes and aquifers overexploitation led to groundwater salinisation and water quality deterioration. Therefore, aquifers progressively became a non-reliable source of water supply, causing a shift from groundwater to surface water, which now constitutes the major source of public water supply. This change in the supply sources enabled the recovery of some aquifers.

From 1995 and onwards, the management of the water supply has been based on surface water abstractions. Initially two Inter-Municipal companies were created: one for the west part of the basin, "*Águas do Barlavento Algarvio*" and one for the east part, "*Águas do*

Sotavento Algarvio". In 2000, the two companies merged forming *"Águas do Algarve, S.A."* company which has the concession of the Primary Water Supply system (Figure 7-2) and guarantees the supply of the municipal secondary network systems of the region. The two previously existing systems were connected, constituting the Primary Water Supply System as known today. This connection allows transferring a maximum of 7 hm^3 from one side to the other. Since 2001, this Company also has the concession for the primary network for sewage collection, drainage and wastewater treatment.

More specifically, the Primary Water System of Águas do Algarve is based (Figure 7-2):

- In the East part of the Ribeiras do Algarve River Basin, "Sotavento" region, on the Odeleite-Beliche system (located in the Guadiana River Basin) and
- In the West part, "Barlavento" region, on Bravura and Funcho dams.

Figure 7-2 Supply Nodes of the Primary Water Supply System of Águas do Algarve

However, restrictions are imposed on abstractions from these reservoirs, dictated by agreements made with INAG during the concession period. This way, Águas do Algarve Company is limited to abstract the volumes from the existing storage reservoirs presented in Table 7-1.

Table 7-1 Volume available in the storage reservoirs for urban supply

Storage Reservoir	Volume (m^3)	
	Minimum	Maximum
Bravura	4,000,000	6,000,000
Funcho	12,000,000	23,000,000
Odeleite-Beliche		69,000,000*[4]

Nevertheless, agriculture is still the most important water use (about 67% in 2000) and presently both surface (SW) and groundwater (GW) are used for irrigation. According to the River Basin Plan the agricultural area represents about 32 000 ha, i.e. approximately 8% of non-urbanized area of the basin. Although groundwater is still the main supply source, supplying 85% of the irrigated areas, the overall efficiency of water in agriculture use is low (about 60%). Two types of users, public and private, exist. Public users are mainly supplied with surface water and farmers are members of farmer associations to which they pay for water supply. On the contrary, private users rely on groundwater for irrigation and undertake

[4] Water volume treatment capacity of Tavira's Water Treatment Plant

all costs related to construction, operation and maintenance. Additionally, golf courses represent an important economic activity and are mainly located along the coastline. The salinisation of the aquifers necessitates finding an alternative to supply those, by re-using wastewater treatment plants effluent or by eventually using desalinised water, implying an important increase of the associated costs.

Figure 7-3 presents the different irrigation sites and golf courses that were considered in the analysis.

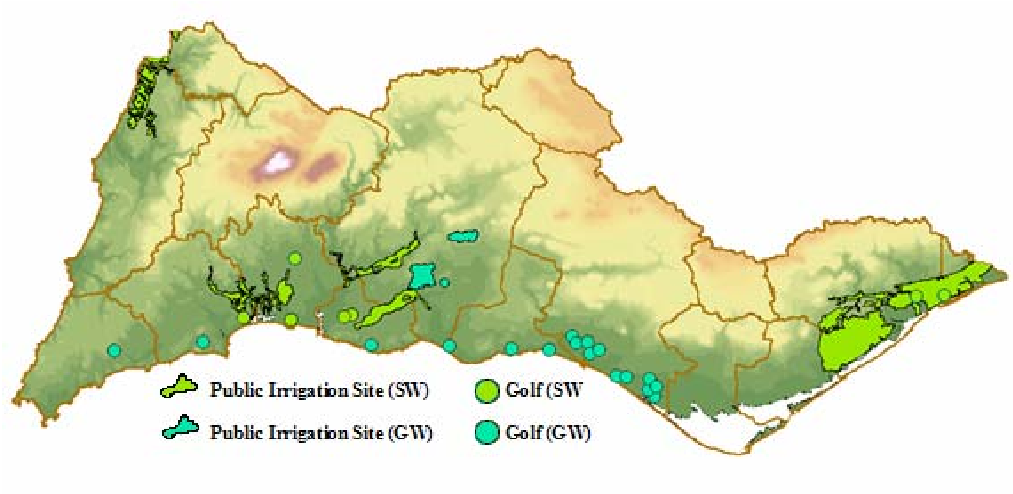


Figure 7-3 Public irrigation sites and golf courses

In brief, water management issues identified in Ribeiras do Algarve River Basin consist of conflicting interests between tourism and agriculture, mostly during the summer months. Additional issues are related to infrastructure deficiencies, poor groundwater quality in some areas, high values of secondary water supply network losses (16% to 61%) and inadequate irrigation methods. These urge for the implementation of management measures that could solve and prevent conflicts between users, and led to the definition of the targets outlined below.

Target definition

According to the current water management issues the targets that were defined for the formulation of water management strategies in the Ribeiras do Algarve River Basin were to:

- Meet 95% of domestic demand, particularly in the West part of the Ribeiras do Algarve River Basin, and solving localized deficits in irrigation;
- Promote measures that prevent degradation of environmental resources focusing on aquifers overexploitation. These measures apply particularly to coastal aquifers, where overexploitation increases salinisation risks;
- Promote 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 definition of targets also emerged from the perceptions and expectations of the different stakeholders, which are presented in the following paragraphs.

Identification of Available and Feasible options

One of the tasks performed for defining major water management issues and identifying available and feasible options for their mitigation was Stakeholder Consultation, which was performed at national, regional and local level. One of the outcomes of this process was that besides conflicting interests, all consulted parties and actors had a different approach to water problems, according to their level of intervention. In the framework of Strategy Development stakeholders that were consulted were:

- The **National Water Institute (INAG)**, which is the institution responsible for the formulation of national policies on water resources, water supply development and environmental protection.
- The **Commission for Regional Coordination and Development of Algarve (CCDR Algarve),** which is the official body of the Ministry of Cities, of Land-Use Planning and Environment (MCOTA), responsible for the elaboration of regional policies on environment, land-use, and economic and social planning, taking into consideration the integrated regional development of the Algarve Region.
- The **National Institute of Rural and Hydraulics Development (IDRHa),** the central service of the Ministry of Agriculture, of Rural Development and Fishing (MADRP), responsible among others for supporting conservation of water resources, and development of infrastructure in the agricultural sector.
- **Águas do Algarve, S.A.,** the company that has concession for the operation and maintenance of the Primary Water Supply System, as described above.
- The **Association of Municipalities of Algarve (AMAL),** which is involved in the elaboration of common development programmes for the municipalities and in the management, planning, promotion and financing of their execution.
- **Farmers Associations,** which represent the farmers supplied from the public water supply system of the basin.
- The **Algarve Tourism Office**, responsible for the tourism policy of the region and the **Hotel Industry Association.**

The following paragraphs provide an overview of the outcomes of this consultation process and the synthesis of proposals to be examined in the evaluation of single, stand-alone options and strategy development.

Stakeholder consultation

At the national level, the **National Water Institute (INAG)** was consulted as the main authority responsible for water resources management. The main objectives identified were related to urban water supply and economic activities, as tourism and agriculture. Solving existing shortfalls in water supply and guaranteeing that water of good quality is delivered has, thus far, been a crucial goal. In that way, the Odelouca dam can be considered an important intervention, which will allow a significant improvement in domestic demand coverage. Odelouca dam will also, indirectly, enable the reinforcement of irrigation supply, since at present irrigation water sources (Funcho dam) are mostly used for urban water supply. Regarding demand management, emphasis is given to the achievement of irrigation demand coverage of 80% through a better knowledge of the irrigation situation, promotion of a more efficient management of irrigation supply and improvement of taxes. Other, more general, objectives that have been identified are:

To guarantee the economic and financial sustainability of all water uses and services,

- To encourage the participation of the users in conservation efforts and the management of water supply systems in general.

At the regional level, **Águas do Algarve S.A.** was involved, as a stakeholder, from the very beginning of the strategy development phase. As mentioned above, the real change regarding water management in the region occurred at the beginning of the 2000s with the implementation of the Primary Water Supply System. Consequently, the major interventions proposed by Águas do Algarve S.A. concentrate on supply enhancement, through the further development of the water supply system. Towards that direction, the main foreseen interventions and improvements are:

- Increase of the coverage of the water supply system (from 82% in 1998 to 95% in 2006),
- The integration in the system, for emergency situations, of some, already existing, municipal wells, which are considered adequate in quantity and quality. If there is a problem in the primary water supply system, these wells should be able to substitute, at least partially, surface water supply.

Again, the construction of the Odelouca Dam was proposed as a solution, since it was mentioned that it will be possible to provide urban water supply to 95% of the population in the east side of Ribeiras do Algarve Basin. Thus, the dam will constitute the major supply source of the existing primary system. In addition, the sharp degradation of groundwater water quality and the insufficient supply capacity of aquifers in dry years render their substitution by surface water into a real priority. The Odelouca Dam will additionally assure the regularization of surface flow: a connection between Odelouca dam and the already existing Funcho dam, will allow the transfer of water to the Alcantarilha Water Treatment Plant. However, at present there is delay in the construction of the dam putting the achievement of the goal for network coverage at stake. In addition, Águas do Algarve has the concession for the primary drainage system and treatment facilities. Consequently, it will be possible to improve the percentage of population served by wastewater treatment plants and the quality of return flows from urban uses.

On the other hand, **Farmers Associations** and the **IDRHa** insist on an improvement in irrigation water supply. For example, Funcho dam, currently being used for domestic water supply, was also built for irrigation purposes. Farmers demand reallocation of its supply sources to agriculture. The extensive use of groundwater for irrigation supply is considered an important issue since salinisation of the aquifers is a real problem in Algarve.

CCDR Algarve as the official body of coordination has an overall view concerning existing problems and the different goals of the several entities involved. In addition to the objectives already referred, an imperative necessity was mentioned to reduce losses in the secondary urban water supply network systems (at Municipality level) and in the different irrigation systems. Moreover, Municipalities still own drills that were used for urban supply before the construction of the Primary Water Supply System. These are at present inactive (except Albufeira and Lagoa which, according to Águas do Algarve S.A., still use some of their drills to provide a small fraction of the water supply). It appears as a necessity, according to Municipalities point of view that they should be allowed to use their drills complementing water supplied from Águas do Algarve.

Finally, **Tourism Institutions** have overall the same objectives and expectations as the Municipalities. Supply enhancement and reduction of losses were referred as the best ways to face water shortages during the summer period.

Synthesis of proposals for improved water management strategies

Figure 7-4 presents a synthesis of the options defined from the stakeholders. Based on these outcomes, a series of options was selected to be further analysed using the WSM Decision Support System:

- **Structural options** for supply enhancement, including:
  - **Dam construction** aiming to reduce domestic demand deficit in Algarve River Basin, in the Municipalities supplied by Águas do Algarve company;
  - **Network Enhancement** to improve domestic demand coverage by increasing the number of Municipalities supplied by the Primary Water Supply System (currently, 30 out of 51 secondary network systems are supplied by Águas do Algarve, S.A.);
  - **Desalination unit construction,** to solve water deficit and/or water quality problems in domestic use (Aljezur Municipality) and golf courses;
  - **Water Reuse,** through the use of treated wastewater for golf courses
- **Demand management options**, including:
  - **Reduction of Network Losses**, through replacement of old and damaged pipes of all the Municipal secondary water supply systems (structural intervention);
  - **Improvement in Irrigation Methods**, for better irrigation efficiency and savings in water consumption;
  - **Conservation measures in the tourism sector** in order to reduce seasonal population water consumption, covering only some Municipalities. This option, relies on the assumption that 1/3 of the hotels located in the Municipalities with higher ratio of overnight stays per room would adopt new low flow taps and flowing cisterns.
- **Socio Economic measures**, more specifically the impact of a new pricing structure for irrigation and for settlements supply.

Figure 7-4 Summary of management options, as outcomes of the stakeholder consultation process

Evaluation of Water Management Options

Formulation of demand and availability scenarios

One primary step for the evaluation of the different selected management options was the definition of appropriate demand and availability scenarios.

For identifying the business as usual scenario (BAU) for demand, it was assumed that during the period examined (2000 – 2035) the permanent population will continue to increase with a steady yearly rate. Growth rates for the different Municipalities were estimated for permanent population according to the projections presented in the Ribeiras do Algarve River Basin Plan for 2000-2020 (Table 7-3). For seasonal population, the growth rate was set equal for all the Municipalities and estimated upon the projection from 2000-2020. Irrigation demand scenarios were based on the projections presented in the River Basin Plan for 2000-2020. Two additional scenarios were formulated under the assumption that after a point in time the population in Ribeiras do Algarve River Basin will reach its carrying capacity regarding tourism development. In one of them, this is followed by stabilization of population, while a more pessimistic scenario assumes a small decrease of tourism and population growth.

Under this context, three different potential trends have been distinguished, forming the potential scenarios for domestic demand:

I. A scenario where demand increases at a steady rate, equal to that currently observed, and corresponding to a "business as usual" situation (BAU),

II. A scenario where demand is stabilized 10 years after the reference year (Stabilized Demand, SD)

III. A scenario where the demand decreases 15 years after the reference year (Low Demand, LD).

Table 7-2 Business as usual scenario, growth rates

	2000	2020	2035
Permanent population	Differentiated for each Municipality[5]		
Seasonal population	2.3%		
Private irrigation sites	1.3%		0
Public irrigation sites	Differentiated for each public irrigation site[6]		0
Golf courses	0		

The formulation of the availability scenarios was based on the sequence of years with respect to rainfall presented by INAG (National Water Institute) for the 13 meteorological stations considered. Three hydrological scenarios were considered:

- The Normal Scenario (Normal) represents a period of 35 years defined in accordance with the historical sequence that occurred between 1970 and 2000.

[5] Albufeira: 2.01%; Aljezur: 0.19%; Almodôvar: -1.59%; Castro Marim: -0.87%; Faro: 2.01%; Lagoa: 1.07%; Lagos: 1.07%; Loulé: 1.07%; Monchique: 1.59%; Odemira: 0.87%; Olhão: 0%; Ourique: -1.59%; Portimão: 2.01%; São Brás de Alportel: 0.18%; Silves: 1.07%; Tavira: 0.18%; Vila do Bispo: 0.18% and Vila Real de Santo António: -0.87%.

[6] Silves . Lagoa and Portimão: 0.5%; Mira, Benaciate, Sotavento: 3 .4%; Alcantarilha and Vale da Vila: 7.2%.

- The High Frequency of Wet Years Scenario (HW) was defined considering a 25% increase of the Normal scenario's precipitation.
- The High Frequency of Dry Years Scenario (HD) was defined considering a 10% decrease of the Normal Scenario's precipitation.

Details regarding data for the formulation of these scenarios complemented by the analysis of the behaviour of the water system on their combinations are provided in Chapter 1.

Summary of option evaluation outcomes

This section aims to summarise the results of the evaluation of the different management options considered applicable in Ribeiras do Algarve. Results from this evaluation are presented in Table 7-3 and Table 7-4, while the detailed analysis is presented in Chapter 13.

The effectiveness of each option is approached through the evaluation score obtained, from the behaviour with respect to domestic and irrigation demand coverage, assuming a weight of 0.4 and 0.3 respectively. Although initially, and in Chapter 13, environmental sustainability was expressed through the performance with respect to the groundwater exploitation index, the final selection based environmental sustainability estimates on the overall environmental cost (in present value terms). The latter was associated with surface and groundwater abstractions. The economic efficiency was expressed in terms of direct costs.

Table 7-3 Option performance matrix

Option	Effectiveness (Relative Sustainability index for demand coverage)	Economic efficiency (Direct cost-PV, million €)	Environmental Sustainability (Environmental cost - PV, million €)
Reference case	0.300	1690.1	692.5
Dam construction	0.475	1885.4	722.3
Conservation measures	0.300	1669.8	687.3
Network enhancement	0.300	1676.0	687.3
Desalination	0.307	1846.9	689.3
New abstraction boreholes	0.493	1808.4	735.5
Reduction of network losses	0.300	1690.5	689.9
Irrigation method improvements	0.300	2143.9	673.8
Water re-use	0.300	1680.0	685.2
Domestic pricing	0.305	1536.2	661.9
Irrigation pricing	0.300	1632.4	656.4

Under BAU+Normal scenario, among all the management options and in terms of Relative Sustainability Index for Demand Coverage (RSIDC), the options which present a better performance are the "dam construction" and the "new abstraction boreholes" (Table 7-3 and Table 7-4). The component associated to the domestic use of the RSIDC determines the overall indicator value. Although differences are verified in the behaviour in terms of effectiveness for irrigation between "dam construction" and "new abstraction boreholes", the overall values for RSIDC remains high for both options (Table 7-3). "Desalination" and "domestic pricing" options present similar score values to the value corresponding to the “reference case” (Table 7-3) therefore, only the normalized scores of “dam construction” and the “new abstraction boreholes” present relevant normalized performance values (Table 7-4).

Concerning the options “network enhancement”, “reduction of network losses”, “irrigation method improvements” and “water re-use”, the scores for RPIDC are equal to the reference case, presenting similar variation trends of (global demand coverage) effectiveness along the period of simulation. The same value is also obtained for the “irrigation pricing” option, although there are differences in the effectiveness trends for irrigation use when compared to the reference case. This can possibly be explained by the fact that only public irrigation sites and golf courses were considered in this option, since private users do not pay a real tariff for the water consumed/abstracted.

The decrease in demand, caused by the tariff increase, in public irrigation sites and golf courses, combined with no improvement of unmet demand in private irrigation sites, resulted into a similar trend of the irrigation coverage variations along the period of simulation between this option and the reference case.

Table 7-4 Normalised option performance matrix

Option	Effectiveness (relative Sustainability index for demand coverage)	Economic efficiency (Direct cost-PV, million €)	Environmental Sustainability (Environmental cost - PV, million €)
Reference case	-	****	***
Dam construction	*****	**	*
Conservation measures	-	*****	***
Network enhancement	-	****	***
Desalination	-	**	***
New abstraction boreholes	*****	***	-
Reduction of network losses	-	****	***
Irrigation method improvements	-	-	****
Water re-use	-	****	***
Domestic pricing	-	*****	*****
Irrigation pricing	-	****	*****

Concerning the present value of environmental costs, the values of socio economic measures (“domestic pricing” and “irrigation pricing” options) appear to be the most favourable, i.e., lower ones, followed by the “irrigation method improvements” option. Nevertheless, the latter option indicates the highest value in terms of direct costs whereas the socio economic measures are still the ones presenting lower values. Concerning direct costs and environmental costs, “domestic pricing” option proves to be the most favourable, since it originates from a decrease in demand and therefore a decrease in both operation and maintenance costs and environmental costs (Table 7-3).

Strategy Formulation and Evaluation

Assumptions

The strategies that were formulated aim at a medium to long term planning and therefore will take into account a 35-year horizon, spanning the period 2000-2035. The availability scenario is the **"Normal scenario"**, defined in accordance with the rainfall historical sequence that occurred between 1970 and 2000 and was provided by the National Water Institute (INAG). The demand trend used is a Business-as-Usual (BAU) demand scenario, assuming: (i) a permanent population yearly growth rate differentiated by Municipality according to the RBP; (ii) a seasonal population yearly growth rate of 2.3%. Regarding agriculture, a 1.3% yearly growth rate for private irrigation sites, and differentiated growth rates for cultivable area in public irrigation sites, between 2000 and 2020, are considered applicable (PBHRA, 2001).

Formulation of alternative water management strategies

The selection of options to be integrated into water management strategies was based on the results of the option evaluation procedure, taking into account the different management options already implemented by the relevant authorities. Two strategies were formulated, each one based on a different concept, and compared against each other and against the reference case. In particular, **Strategy 1 (the "hard path approach")** reflects the current trends in the application of structural options, and focuses on the further exploitation of surface water resources. **Strategy 2** represents a shift to the application of **"soft instruments"**, and although it does not correspond to radical changes in the already adopted approach, reflects the necessity to consider:

- Other alternatives to conventional water supply sources;
- The implementation of small scale, localized solutions as an alternative to the application of measures at a regional, more global scale; and
- The sustainable combination of surface and groundwater resources exploitation, which can increase current demand coverage.

Strategy 1 – The "hard path" approach

As previously referred, Strategy 1 translates the currently adopted "hard-path" approach through the preferential application of structural options. The primary aim is to increase supply by means of essentially using surface water. According to that, the most important measure is the construction of the Odelouca dam, starting to operate by 2010, which translates the current trend of implementing large-scale structural options. Additionally, abstractions from the Querença-Silves aquifer are considered in order to satisfy most of the domestic water demand until the Odelouca dam starts operating. Improvement in irrigation methods and Reduction of network losses are in accordance with the schedule presented in the River Basin Plan of Algarve. In that way, Figure 7-5 shows the tentative timeframe of interventions and Table 7-5 succinctly describes all the management options considered.

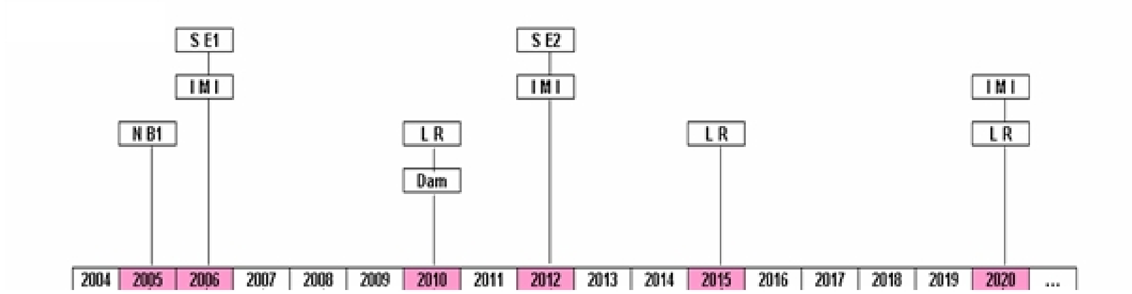


Figure 7-5 Tentative timeframe of interventions within Strategy 1

Table 7-5 Water management options description and identification in Strategy 1

Abbreviation	Water management option		Description
NB	New boreholes	NB1	Abstraction in Querença-Silves aquifer (0.6 hm^3/month, until 2010)
SE	System enhancement	SE1	System enhancement in Loulé Municipality
		SE2	System expansion in Aljezur and Monchique Municipalities
IMI	Irrigation method improvements		Differentiated for public and private irrigation sites
LR	Losses reduction		5% reduction
Dam	Dam construction		Construction of the Odelouca dam

Strategy 2 – The "soft-path" approach

On the other hand, Strategy 2 shows the necessity of a sustainable and combined use of both surface and groundwater. In that way, demands can be completely met and the dependence on surface water is reduced. The options chosen in this case intend to solve shortage problems at a localized level.

Thus, Strategy 2 reflects the need to consider alternatives to conventional water supply sources, namely desalination and the implementation of small scale, localized management measures, against the application of measures at a regional scale. According to that, options like "water re-use" for golf courses, "desalination", and "conservation measures" are here implemented. Figure 7-6 shows the tentative timeframe of interventions under Strategy 2 and Table 7-6 briefly presents all the management options considered.

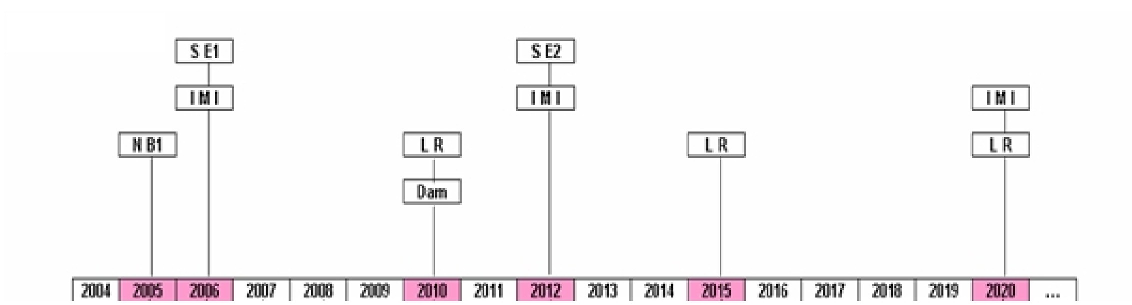


Figure 7-6 Tentative timeframe of interventions within Strategy 2

Table 7-6 Water management options description and identification in Strategy 2

Abbreviation	Water management option		Description
NB	New boreholes	NB2	Abstraction in Querença-Silves aquifer (1 hm^3/month)
WRU	Water re-use		In 4 golf courses
SE	System enhancement	SE1	System enhancement in Loulé Municipality
		SE3	System expansion in Monchique Municipality
IMI	Irrigation method improvements		Differentiated for public and private irrigation sites
Des	Desalination	Des1	Desalination unit in Aljezur Municipality for domestic use (seawater)
		Des2	Desalination unit in Loulé Municipality for golf courses (seawater)
		Des3	Desalination unit in Portimão Municipality for domestic use (seawater)
CM	Conservation measures		In 1/3 of the hotels through the substitution of taps and flushing cisterns
LR	Losses reduction		5% reduction

Strategy Evaluation

Figure 7-7 and Figure 7-8 depict, for both strategies, the time evolution of the domestic demand coverage and the improvement of domestic demand deficit, respectively.

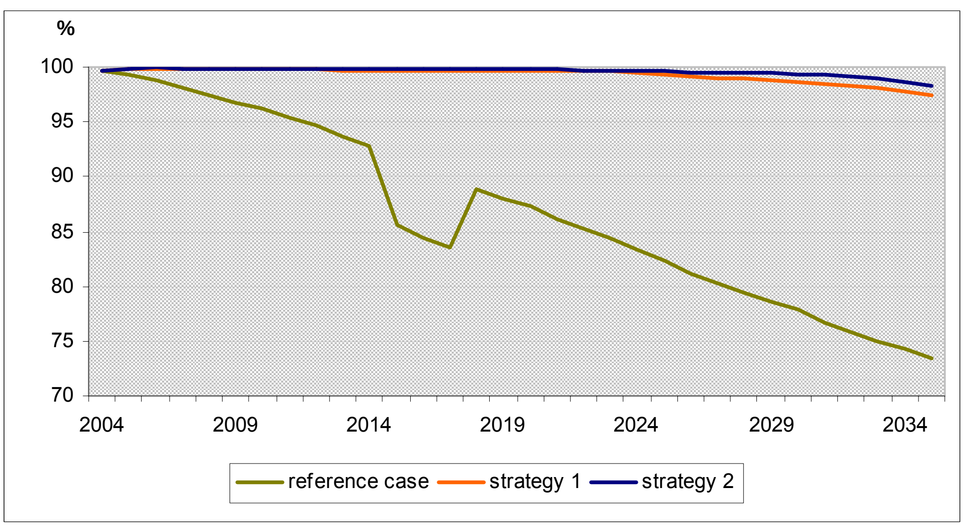


Figure 7-7 Domestic demand coverage

With respect to domestic use, the reference case is compared with both strategies. Analyzing Figure 7-7, it is denoted that by the end of the simulation period a domestic demand coverage of 73% can be observed for the reference case against a percentage of 98% achieved by both strategies. It is important to note that the observed peak in 2015-2017 (dry period) is related to the insufficient supply capacity problem of Arade dam, which is solved through the application of these two strategies. The comparison of the two strategies from 2030 and on shows a slightly better performance of Strategy 2 as far as domestic demand coverage is concerned. This is due to the application of “conservation measures”, which results in a decrease of domestic demand.

In more detail, as far as Strategy 1 is concerned, the improvement of domestic demand coverage by 14.5% on average for the simulation period is mostly associated to the application of structural options based on surface water. More specifically the construction of the Odelouca dam results in achieving 95% coverage of the domestic demand. In fact, domestic demand coverage, based on groundwater use, shows only a marginal increase of 0.4% on average over the simulation period, which is predominantly associated to the application of the “losses reduction” option.

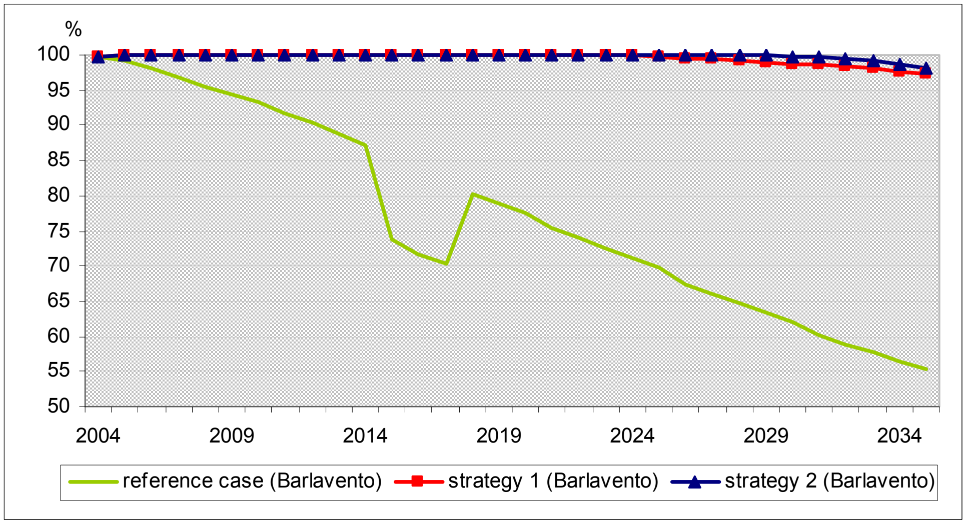


Figure 7-8 Domestic demand coverage in Barlavento region through surface water exploitation

With respect to the Barlavento region, the 95% goal of domestic demand coverage, one of the targets set by Águas do Algarve S.A. is also achieved. The average improvement over the simulation period is equal to 23%, attaining a maximum of 42% in 2035. This is mostly achieved by increasing surface water use (Figure 7-8).

For Strategy 2, the results are similar to those obtained by Strategy 1. This leads to the conclusion that the absence of strong regional structural options (Odelouca dam) can be counterbalanced by smaller options, solving problems at local level.

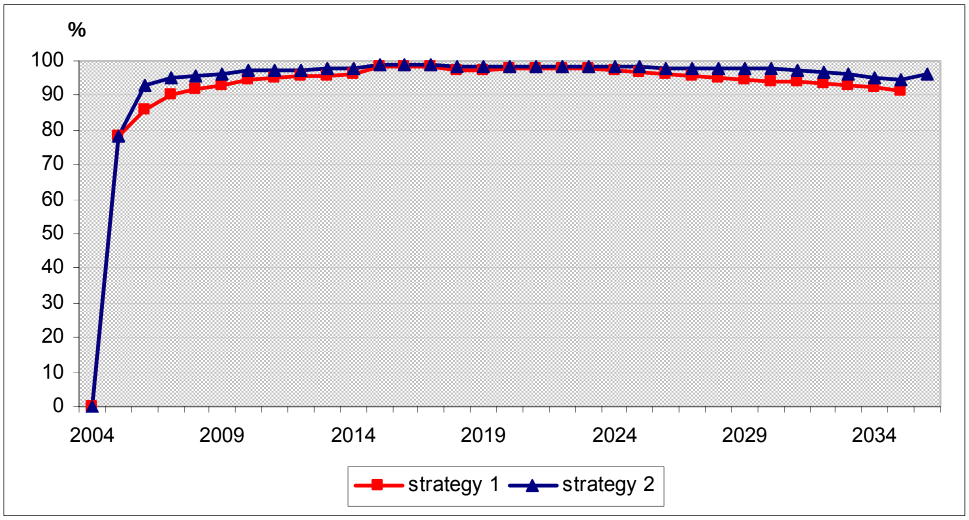


Figure 7-9 Domestic demand deficit improvement for Strategy 1 and Strategy 2

In terms of domestic demand deficit improvement (Figure 7-9), only slight differences can be observed between the two strategies. Strategy 2 however always presents a slightly better performance: the maximum differences of 7.3% in 2006, and 2.9% in 2035 result from the introduction of water management options.

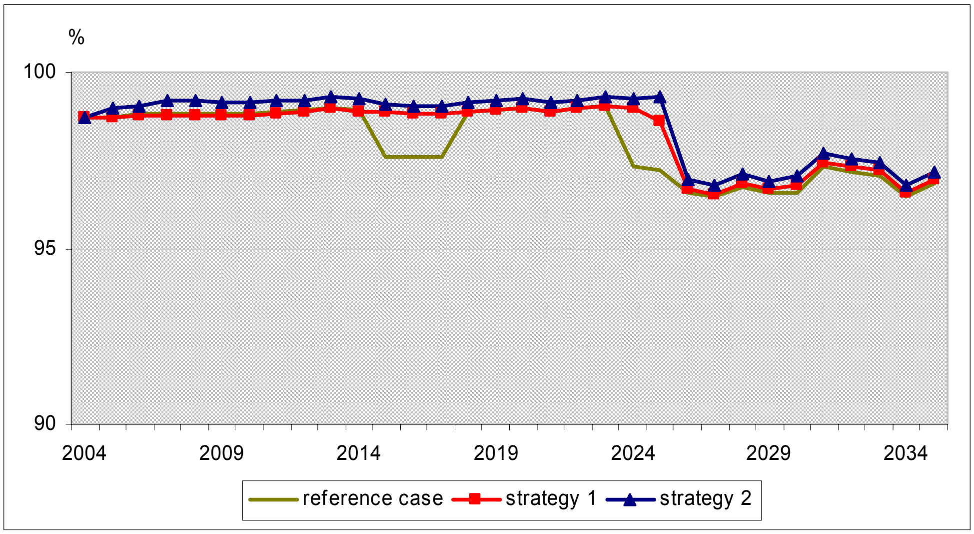


Figure 7-10 Irrigation demand coverage (%)

With regard to efficiency in meeting irrigation needs, some differences can be observed between the two strategies and the reference case. Both strategies increase the irrigation demand coverage in less than 1.5% during the period 2015-2017. This solves shortage problems anticipated in the reference case due to the previously existing deficit in Silves, Lagoa and Portimão public irrigation sites. Additionally, as far as the reference case is concerned, the decrease observed in 2024, and related to Monchique private irrigation needs is delayed due to the application of both strategies. This results in an increase of irrigation demand coverage of 1.7% and 1.9%, for Strategies 1 and 2 respectively. It should be emphasized that irrigation demand coverage is always above 95% for both the reference case and the two Strategies, even in the case of dry periods. The highest percentage is achieved with Strategy 2 (Figure 7-10).

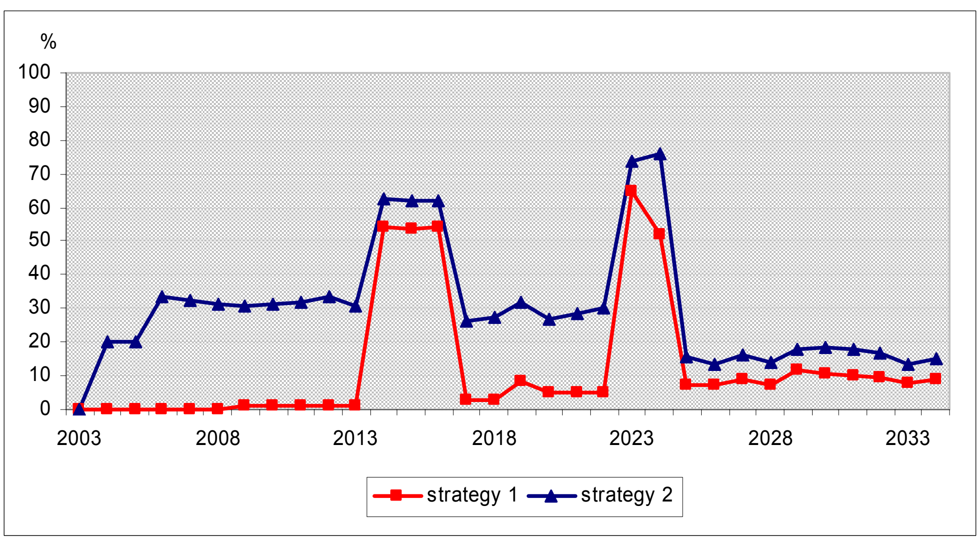


Figure 7-11 Irrigation demand deficit improvement for Strategy 1 and Strategy 2

Analyzing Figure 7-11, two peaks for irrigation deficit improvement can be observed in the periods 2015-2017 and 2024-2025. In the first peak Strategies 1 and 2 are characterized by an average deficit improvement of 54% and 62%, respectively. In the second peak an improvement of 75% on average is observed for Strategy 2, approximately 16% higher than the correspondent value for Strategy 1. This difference derives from the earlier application of the “System expansion” option to Monchique Municipality in Strategy 2 (2008) than in the case of Strategy 1 (2012). This in turn results in an increase of the available groundwater of Monchique aquifer, which is then used for irrigation purposes.

Furthermore, the irrigation deficit improvement achieved by Strategy 2 is always higher than the result of Strategy 1 (almost 17.5% on average during the simulation period). Nevertheless, the major differences in the results of the two strategies during the periods 2005-2014 (29% on average) and 2018-2023 (24% on average), are attributed to the following additional supplies of Strategy 2:

- In Herdade dos Salgados golf course that is supplied with treated wastewater (application of the “water re-use” option in 2005), and
- In Quinta do Lago-Ria Formosa golf course that is supplied with desalinated water (application of the “desalination” option in 2007).

Following the application of the two strategies, the WSM DSS tool offers their evaluation with respect to four criteria: Effectiveness, expressed by the relative sustainability index for demand coverage, Direct and Environmental costs, and Total Value to Users. Table 7-7 summarises the performance indicators of the two strategies and the reference case.

Table 7-7 Strategy evaluation table

	Effectiveness (relative sustainability index for demand coverage)	Economic efficiency (Direct cost, PV-million €)	Environmental Sustainability (Environmental cost, PV-million €)	Total value to users (PV, million €)
Reference case	0.3	1,690	692	9779
Strategy 1	0.57	2,361	700	10206
Strategy 2	0.63	2,253	667	10078

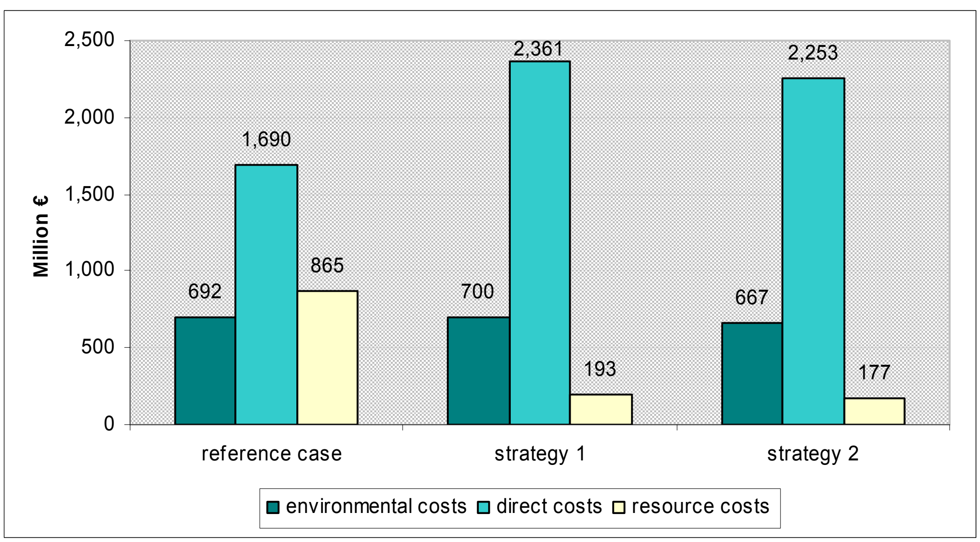


Figure 7-12 Present values (million €)

As a result of the enormous amount of investments in the Ribeiras do Algarve River Basin, the application of Strategies 1 and 2 causes an increase of the Present Value (PV) of direct costs in comparison with the reference case (40% and 33% respectively Figure 7-12). The difference observed in the PV direct costs between the two strategies is about 4.5% (108 million €). The major investment in the basin is related to the "irrigation method improvements" option which is applied under both strategies. In Strategy 2, the desalination units present higher values of specific O&M costs, approximately 0.50 €/m^3 against 0.05 €/m^3 for the dam construction adopted in Strategy 1.

With respect to the Present Value of environmental costs, the lower value corresponds to Strategy 2 (667 million €), representing a 1% (8 million €) decrease against the reference case, and 5% (33 million €) against Strategy 1 (Figure 7-12). The main reason for this decrease is the substitution of Odelouca dam construction by the application of options that resulted in a reduction in both surface and groundwater abstraction costs i.e., "desalination" units construction, "water re-use" and "conservation measures". This last option also causes a reduction in pollution costs because of the reduction of domestic demand.

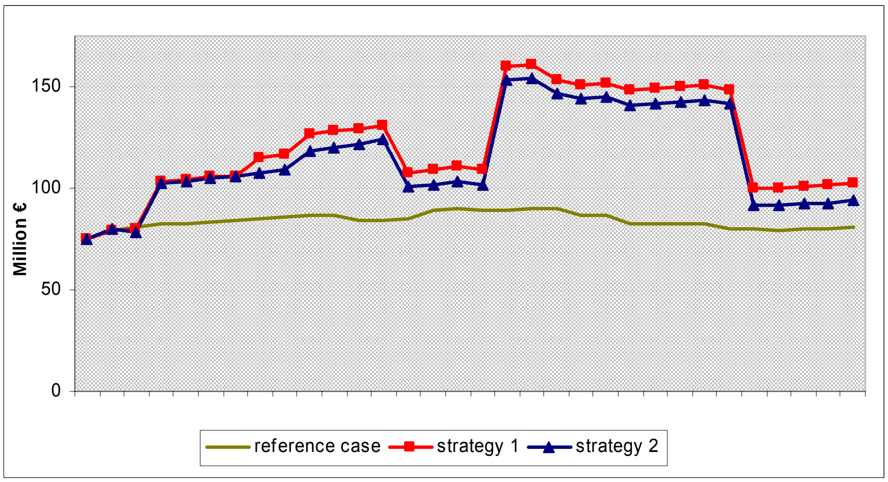


Figure 7-13 Total direct costs (million €)

The increase of direct costs observed under Strategies 1 and 2 along the simulation period corresponds, as stated previously, to the estimated required amount of investments (Figure 7-13). More specifically, the increase observed between 2005 and 2017 and from 2020 to 2031 corresponds to the application of the "irrigation method improvements" option. Additionally, the slightly higher direct costs observed in Strategy 1 comparatively to Strategy 2 after 2010 (approximately 4% on average), are associated with the construction and exploitation of the Odelouca dam (Figure 7-13).

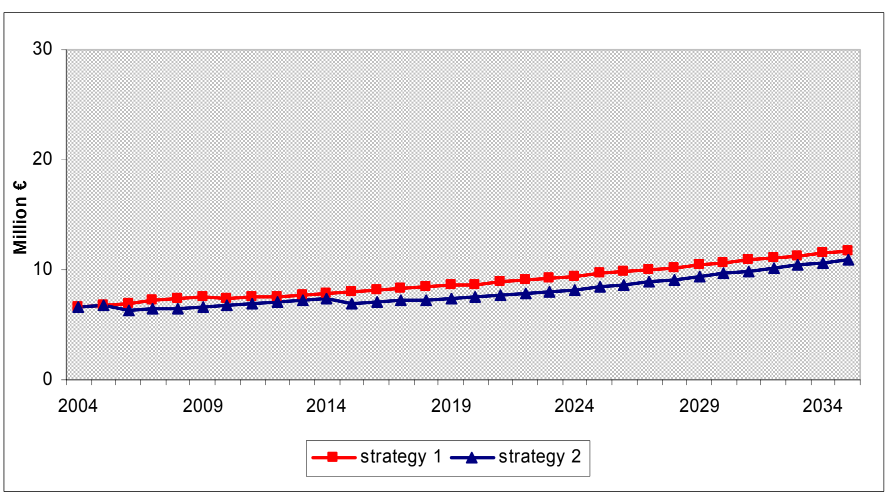


Figure 7-14 Environmental costs allocated to Domestic use (million €)

Regarding domestic use, the environmental costs present an increasing trend along the simulation period. This is due to population growth, and consequently to freshwater demand and consumption increase (Figure 7-14). The slightly lower values under Strategy 2 are mainly associated to the application of the "conservation measures" option in 2006.

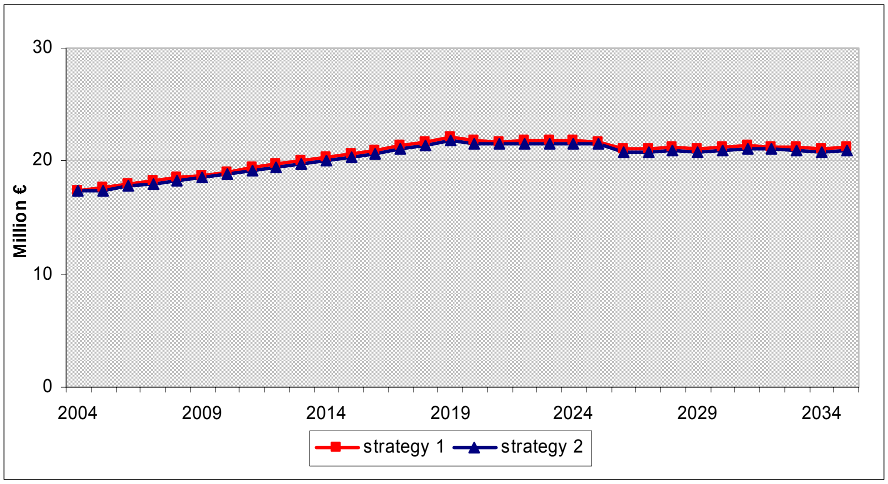


Figure 7-15 Environmental costs allocated to Agriculture (Million €)

Environmental costs associated with agriculture are approximately the same under both strategies, because the only additional management measure applied in the framework of Strategy 2 is "water reuse" for golf courses in 2005 (Figure 7-15).

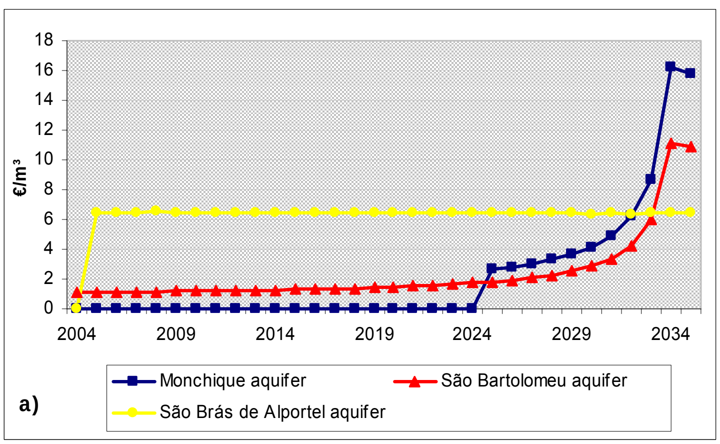


Figure 7-16a Scarcity rent for groundwater (€/m^3) in Strategy 1

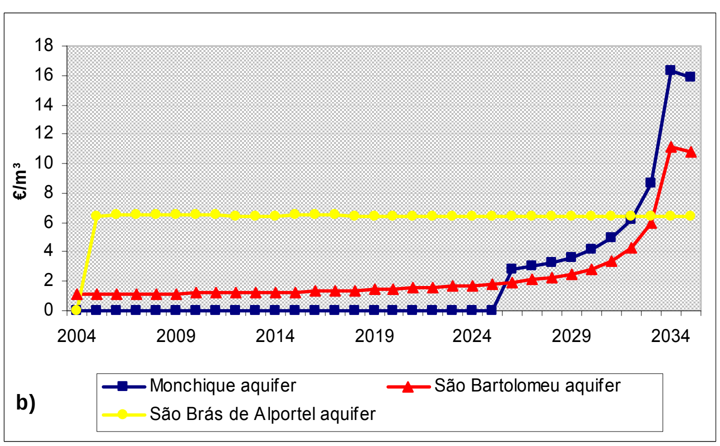


Figure 7-16b Scarcity rent for groundwater (€/m^3) in Strategy 2

Scarcity rent values for groundwater and surface water sources induced by shortages in Algarve region, for both strategies, are presented in Figure 7-16 and Figure 7-17 respectively.

As it can be observed in Figure 7-16 a) and b), the scarcity rent values for groundwater sources under both strategies are very similar. In São Brás de Alportel aquifer, the value of scarcity rent is constant during the whole simulation period (approximately 6 €/m^3). Regarding São Bartolomeu aquifer, the value of scarcity rent, under 2 €/m^3 until 2026, is rapidly aggravated at the end of the simulation period due to the overexploitation of this aquifer, reaching more than 11 €/m^3 in 2034. As far as Monchique aquifer is concerned, a steep increase due to overexploitation is also verified after 2025 for Strategy 1, while this value of scarcity rent is expected to be zero up to 2024. With regard to Strategy 2, this increase appears after 2026, as a consequence of anticipating the application of the "system expansion" option to Monchique Municipality (see comments of Figure 7-11).

Concerning surface water, under both strategies (Figures 7-17a and b), the values of scarcity rent associated to storage reservoirs exploitation are generally lower than the ones associated to groundwater. The scarcity rent value of approximately 2.0 €/m^3, observed along the whole simulation period for both strategies. The value associated with Odeleite-Beliche dams reflects the structural deficiencies of the primary water supply system, which prevent the provision of adequate water supply for users directly dependant on this dam. Under Strategy 1, the scarcity rent values associated to Odelouca and Bravura dams increase after 2023, corresponding, thus, to structural limitations in the primary water supply system which is unable to cope with the demand increase (Figure 7-17 a).

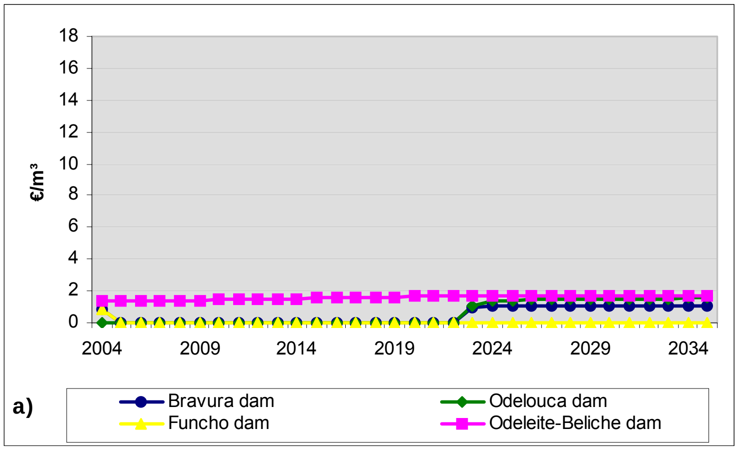


Figure 7-17a Scarcity rent for surface water (€/m^3) in Strategy 1

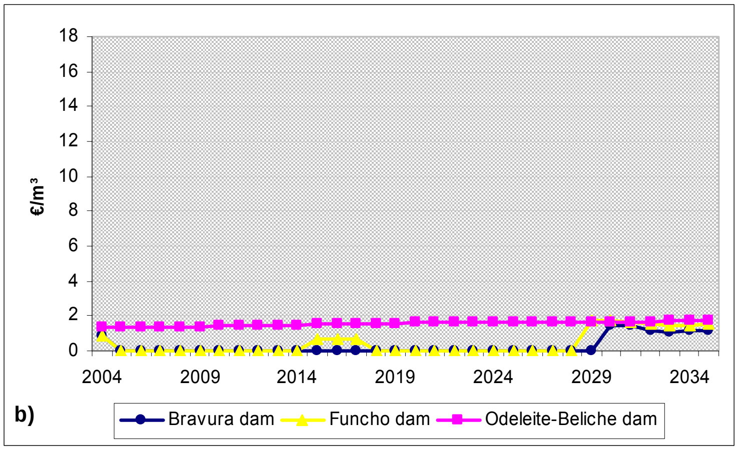


Figure 7-17b Scarcity rent for surface water (€/m^3) in Strategy 2

For Strategy 2, the higher values verified between 2014 and 2017 are associated to water unavailability at Funcho and Bravura dams (Figure 7-17 b). The construction of Odelouca dam under Strategy 1 prevents this increase from occurring in Funcho dam (Figure 7-17 b). Finally, from 2028 onwards, the increase in scarcity rent associated with Funcho and Bravura dams reflects once more the inability of the primary water supply system to cope with the increasing demand.

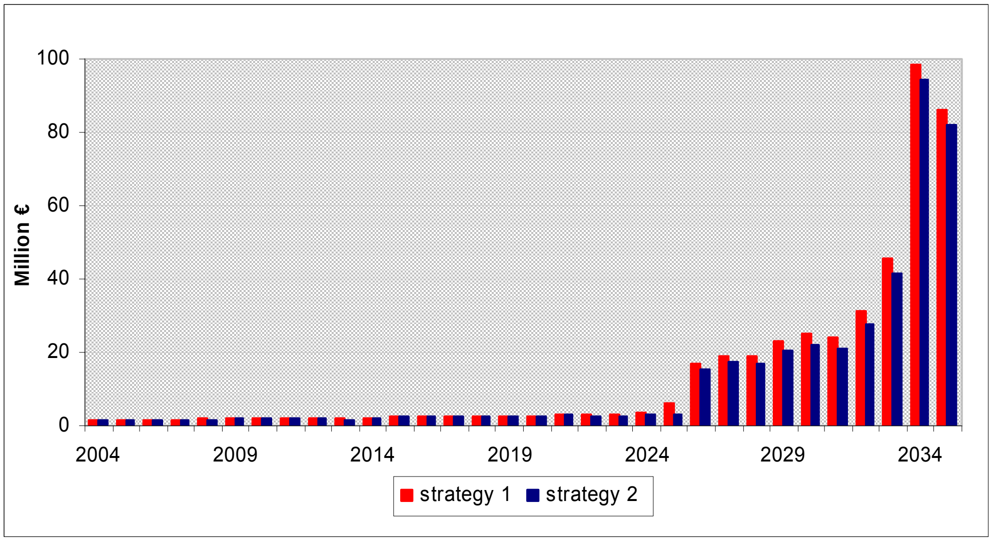


Figure 7-18 Resource costs (million €)

The resource costs increasing trend after 2026, reflects essentially the water demand deficit affecting groundwater users which rely on Monchique aquifer (Figure 7-18). In fact, the high values of both scarcity rent in Monchique aquifer and total unmet demand affecting the aquifer users (Figures 7-16 a and b), result into the aforementioned increasing trend. In more detail, the resource costs associated to Monchique users represent on average 70% of the total resource costs after 2026.

Development of a Cost Recovery Strategy

The cost recovery rate (CRR) under Strategies 1 and 2 was estimated taking into account direct, environmental costs and resource costs. The initial estimation was based on the water tariffs presented in the National Water Plan, under the assumption that these are constant. Although a large amount of investments is envisaged for the basin, most, like the construction of "new abstraction boreholes", "system enhancement", "dam construction" and "desalination" units construction, will also contribute to an increase in revenues from the provision of water services. Nevertheless, the CRR is always lower than 70% up to the end of the simulation period under both strategies (Figure 7-19). The slightly lower values for Strategy 1 (5% on average with respect to Strategy 2) are related to the amortisation of the Odelouca dam investment costs. Figure 7-20 presents the total costs to be recovered from domestic users throughout the simulation period.

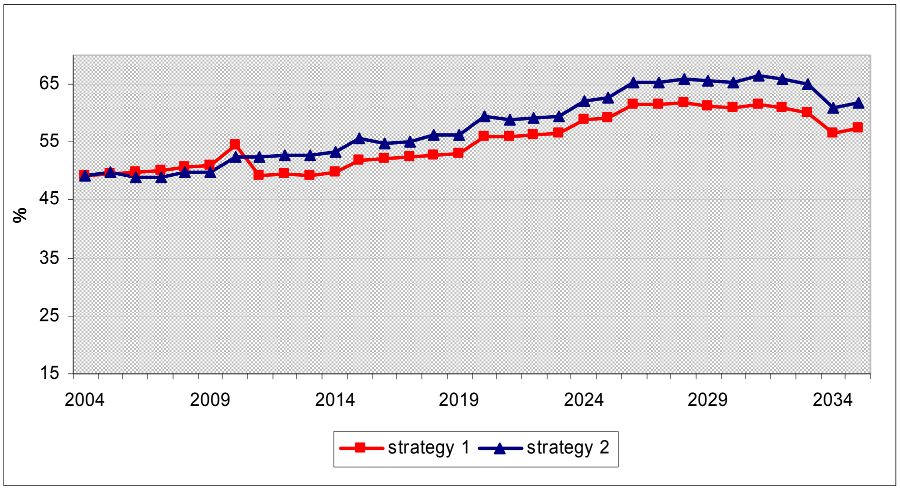


Figure 7-19 Cost recovery rate for domestic water provision (%)

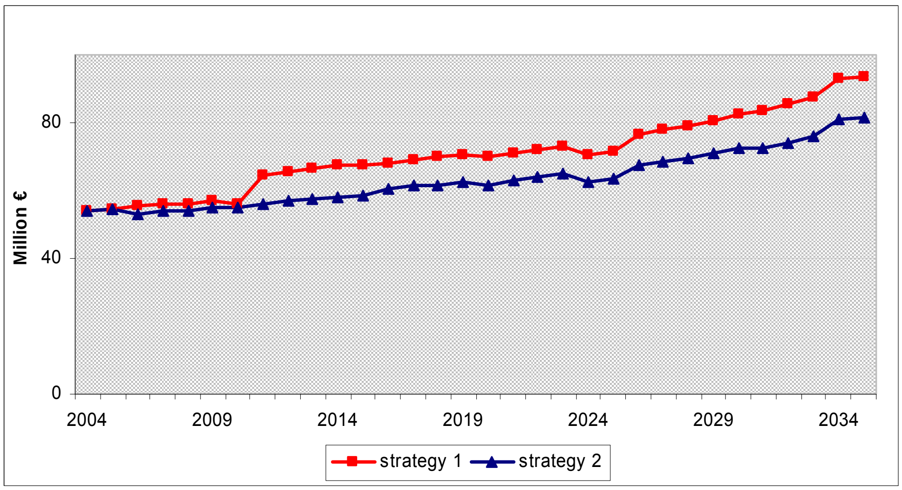


Figure 7-20 Total costs to be recovered from domestic users (million €)

The highest increase in total costs to be recovered corresponds to the Odelouca dam investment costs (69 million € by 2010) under Strategy 1.

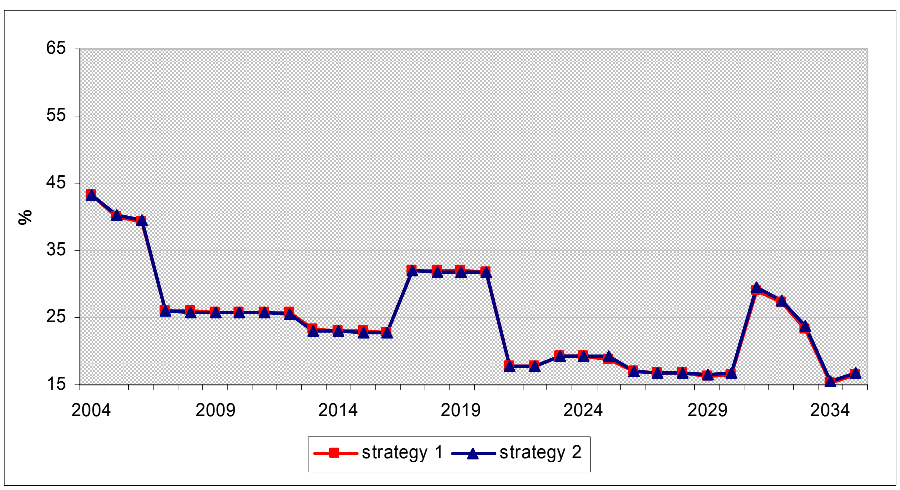


Figure 7-21 Cost recovery rate for irrigation supply provision (%)

The cost recovery rate for irrigation is always lower than 50% until the end of the simulation period under both strategies (Figure 7-21). Costs correspond to the application of the "irrigation methods improvement" option which affects the entire river basin and represents the higher investment costs within both strategies. Moreover, the particularly high values of resource costs observed from 2026 to 2035 (Figure 7-18) cause a further decrease by the end of the simulation period. Since the same investments are simulated within the same timeframe of application for both strategies, the obtained values do not differ.

Formulation of cost recovery strategies

The cost recovery strategies were developed according to the economic interest of the basin taking mainly into consideration the high investments in the basin between 2005 and 2020, i.e.:

- Under **Strategy 1**, the construction of Odelouca dam;
- Under **Strategy 2**, the construction of a high capacity desalination plant and
- Under both **Strategies**, the improvement of irrigation methods.

The cost recovery strategy was based on the development of a pricing scheme for domestic use. The current average weighted price for domestic supply provision in the Ribeiras do Algarve River Basin is, according to data from the National Water Plan (PNA, 2000), 0.68 €/m^3. This value varies between the different Municipalities from 0.41 €/m^3 in Vila do Bispo Municipality to a maximum price of 1.04 €/m^3 in the Municipality of Aljezur.

Although the impact of both "domestic pricing" and "irrigation pricing" options has been studied individually, during the evaluation of the different options, only "domestic pricing" is considered for the formulation of the cost recovery strategies. Two main reasons lie behind this choice:

(iii) the agricultural sector has been long dependant on subsidies, and

(iv) no charges are applied to private irrigation activities, although such are foreseen in the current legal framework.

In addition, the inclusion of "irrigation pricing" within the cost recovery strategies would imply considering additional changes to the institutional framework and/or policy which are considered unrealistic at this time.

Cost recovery targets to be achieved through the increase of water tariffs for domestic users, are:

- A 100% recovery of direct costs from 2020 onwards, and
- A targeted minimum cost recovery of 70% associated to environmental costs by 2025.

Demand elasticity was assumed to be equal -0.5, in absence of any specific studies for the Algarve River Basin, and in accordance with Águas do Algarve S.A. water company.

An iterative process was initiated in order to find a water price that would enable to achieve the rate of cost recovery targets set for both strategies. Thus, a differentiated increase in water prices for domestic users is planned to take place every 2 years from 2005 to 2015 (increase of 8% to 10% for Strategy 1 and 7% to 8% for Strategy 2). As a result of this process, the final water prices calculated for domestic use in the year 2035 are on average:

- 1.21 €/m^3 for Strategy 1 (ranging between 0.65 €/m^3 in Vila do Bispo Municipality and 1.56 €/m^3 in Aljezur Municipality);
- 1.12 €/m^3 for Strategy 2 (ranging between 0.62 €/m^3 in Vila do Bispo Municipality and 1.56 €/m^3 in Aljezur Municipality).

Figure 7-22 shows the average volumetric price for domestic use according to the domestic water tariff increase adopted.

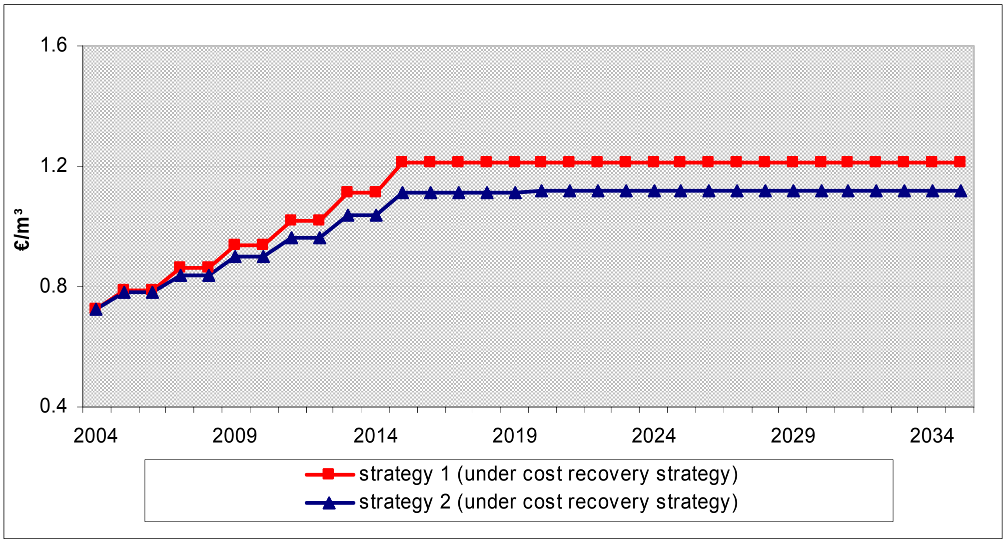


Figure 7-22 Average volumetric price for domestic users (€/m^3)

Re-evaluation of strategy options and performance

The increase in domestic water prices results in a reduction of domestic demand, as depicted in Figure 7-23.

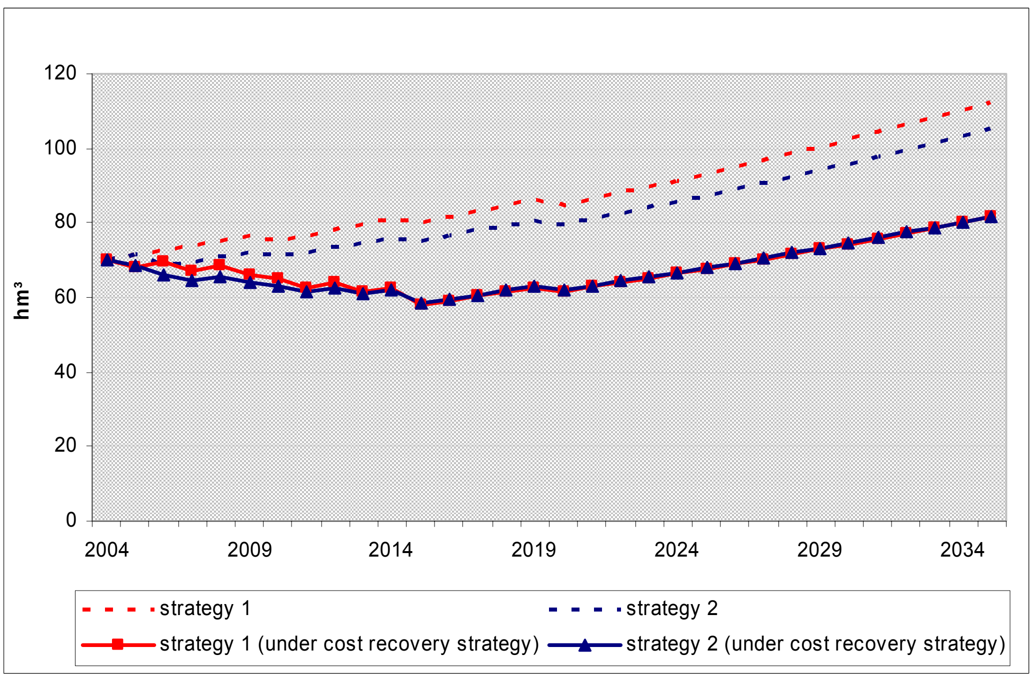


Figure 7-23 Domestic demand before and after the application of the cost recovery strategy

Comparing domestic demand before and after the application of the cost recovery strategy, the reduction in domestic demand observed for both strategies, 20% on average for Strategy 1 and 15% for Strategy 2 derives from the assumed value of demand elasticity. It should be noted that the demand decrease is higher for Strategy 1 as a result of a higher price increase.

An inflection in this trend is observed after 2015, resulting from both water tariff stabilization and population growth (Figure 7-23).

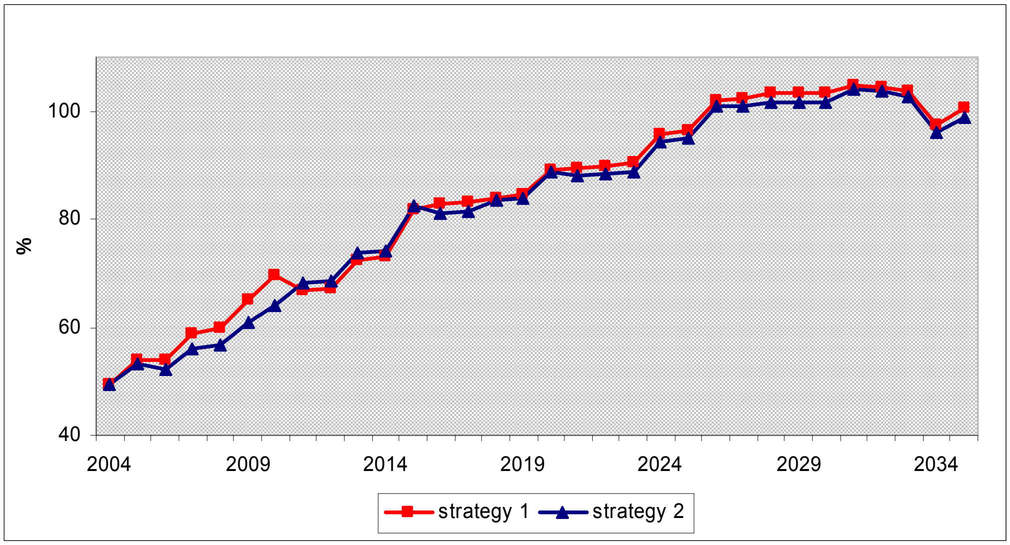


Figure 7-24 Cost recovery rate for domestic supply provision after the application of the cost recovery strategy

For both strategies, the optimized price increase enables to accomplish an overall rate of cost recovery of 89% by 2020. This figure corresponds to a 100% recovery of direct costs. In addition, an overall rate of cost recovery of 97% is achieved in 2025. The foreseen rates are in line with the recovery goal of 100% of direct costs and approximately 70% of environmental costs and resource costs (Figure 7-24).

Following this process, the two strategies are re-evaluated against each other and against the reference case (Table 7-8). Values in brackets denote the results obtained before the application of the cost recovery strategy.

Table 7-8 Adjusted strategy evaluation table after the application of the cost recovery strategy

Option	Effectiveness (Relative Sustainability index for demand coverage)	Economic efficiency (Direct cost - PV, million €)	Environmental Sustainability (Environmental cost PV, million €)	Total value to users (PV, million €)
Reference case	0.3	692	1,690	9,779
Strategy 1	0.7 (0.57)	647 (700)	2,137 (2,361)	9,681 (10,206)
Strategy 2	0.7 (0.63)	628 (667)	2,074 (2,253)	9,679 (10,078)

The decrease of domestic demand, incurred from the adjustment of water prices, results in an increase in domestic demand coverage. Consequently, and in comparison to the situation before the application of the cost recovery strategy is applied, the PV of environmental costs decreases by 7.5% for Strategy 1 and 5.8% for Strategy 2). This is mainly due to lower surface and groundwater abstractions for supplying domestic users. Similarly, the decrease observed in terms of the PV direct costs (9.5% for Strategy 1 and 7.9% for Strategy 2) is due to a decrease in specific operation and maintenance costs associated to water treatment and conveyance. Finally, a reduction in domestic demand and therefore in water supplied to domestic users causes a decrease in the total value to users (Table 7-8).

It should be noted however that the obtained results reflect a cost recovery strategy under the established targets are primarily based on an assumption of the value for demand elasticity. A more rigorous definition of this value would be of benefit for complementing this analysis.

Discussion and Recommendations

The structuring of both strategies reflects the concerns of the stakeholders that are trying to respond to the pre-defined goals, by adopting two distinct approaches. While Strategy 1 comprises structural and global water management measures, Strategy 2 includes alternative options aiming at solving water shortage issues on a local scale.

The undertaken analysis portrayed that both strategies can be 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.

Therefore, one of the overall conclusions drawn from the analysis is that the combination of localised, non-conventional measures allows for alleviating water stress issues through a more cost-effective manner.

After the development of a cost recovery strategy, aiming to assist to the achievement of the Water Framework Directive cost recovery principles, Strategy 2 appears to hold an additional advantage compared to Strategy 1, since within such framework lower – and more socially acceptable – water prices can be defined.

Chapter 8 Instead of Conclusions

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

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

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

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

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

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

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

Part II
Analysis of water management options in the Case Study Regions

Chapter 9 Analysis of Water Management Options for Paros Island, Greece

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.

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, in the summer, creating conflicts between uses and problems with water supply adequacy during peak consumption. Paros 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. Under this context the goal for formulating scenarios and strategies in the island of Paros was to reconcile supply and demand both temporally and spatially, achieving a more equitable distribution of resources and ensuring future economic growth.

The next sections of this Chapter paragraphs present the analysis of water management options, performed in the framework for comprehensive scenario analysis. The outcomes of this process were used to develop guidelines on the future applicability of the examined measures and instruments, and to select appropriate responses for the strategy formulation process.

Demand and Availability Scenario Components

Formulation of Demand Scenarios

Data

Given the growing economic importance of the tertiary sector and especially tourism, the formulation of demand scenarios for Paros was based primarily upon assumptions for permanent and seasonal population growth. For this purpose, a variety of data and estimations have been collected and analysed from associations and the local and governmental authorities, regarding population fluctuations, consumptions, network losses and unaccounted consumptions. Table 9-1 presents the authorities that have been contacted, and the data that have been collected from each one.

Table 9-1 Available information on domestic demand components

Authority	Available Information
Municipal Office of Water Supply and Sewerage (Water Utility)	• Water Supply Provision and Fluctuation • Consumption Fluctuation
National Statistical Service	• Permanent Population • Tourist Arrivals, Departures and Overnight stays
Local Administrative Authorities	• Seasonal Population
National Tourist Organisation	• Number of Hotels, Rooms and Beds • Occupancy • Overnight stays
Room/Hotel Owners Association	• Number of Hotels, Rooms and Beds • Occupancy • Overnight stays

One important conclusion that was drawn from data cross-referencing concerned the real permanent population of the island. The registered population according in the 2001 census was 12,783 inhabitants. However, during the winter months local authorities estimate that actual (permanent) residents are only 35% of the recorded, being mostly permanent employees and farmers or stockbreeders. The rest are either indigents who live permanently in the mainland and have seasonal occupations in Paros or people with a second (country) residence that visit the island for summer vacations. Two types of seasonal population have also been distinguished: the low season visitors, mostly families and pensioners who visit Paros during Easter, May and June, and the peak season tourists (from the mainland and abroad) who visit Paros during August and constitute the massive inflow that creates the summer peak of 54,000 visitors. The yearly population fluctuation is presented in Table 9-2.

Table 9-2 Monthly variation of permanent and seasonal population in Paros

Month	Permanent Population Fluctuation[7]	Seasonal Population Fluctuation[8]
January	35%	0%
February	35%	0%
March	55%	5%
April	55%	30%
May	70%	35%
June	100%	50%
July	100%	75%
August	100%	100%
September	78%	40%
October	55%	20%
November	35%	0%
December	35%	0%

[7] Share of registered population (12,783)
[8] Share of the seasonal population during August (54,000)

The uneven spatial distribution of tourist population per municipal department is presented in Figure 9-1. The municipal departments of Paroikia and Naoussa, with their traditional settlements and developed tourist facilities and accommodation, concentrate the largest part (about 70% of the total). The departments of Marpissa and Agairia, currently under tourism development, come second with 15 and 10% respectively. Kostos and Lefkes exhibit very small tourism activity, with their total share not exceeding 5% of the total seasonal population.

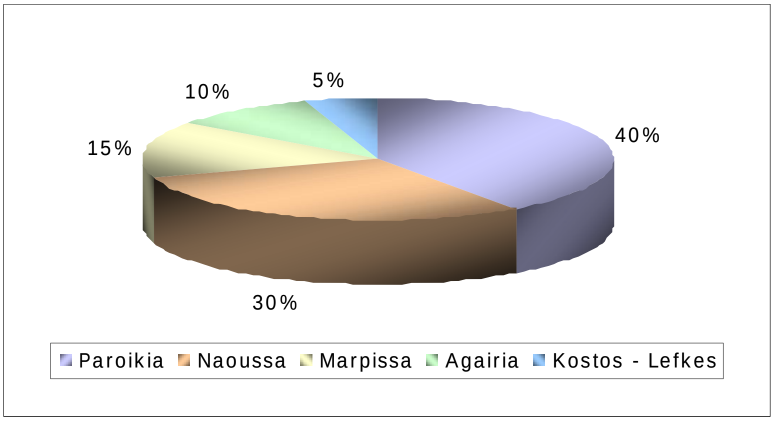


Figure 9-1 Spatial distribution of seasonal population

Estimation of demand parameters, such as consumption rates and loss coefficients, was performed using data obtained from the Water Utility of Paros, using the flowchart presented in Figure 9-2.

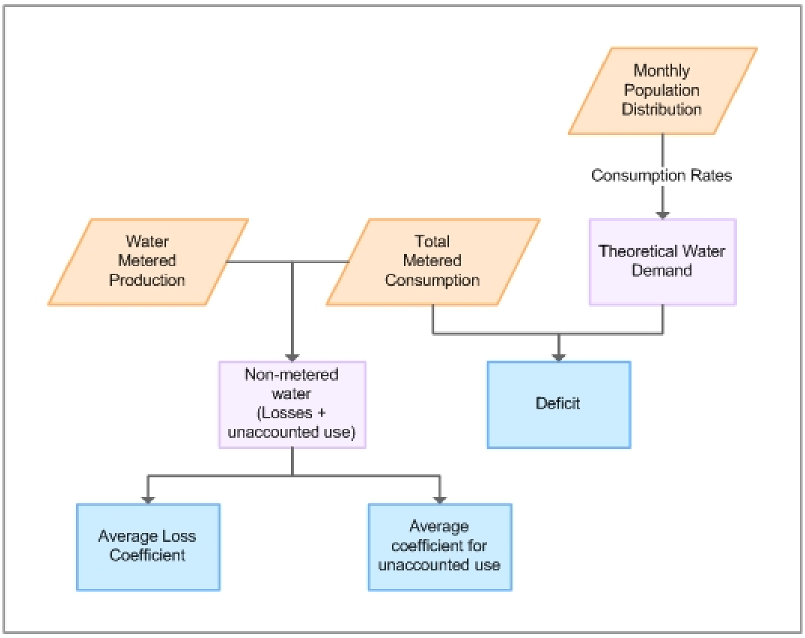


Figure 9-2 Flowchart for the estimation of demand parameters

Domestic consumption rates, estimated on the basis of real consumption and excluding losses, were estimated at approximately 130 and 180 l/capita/day for permanent and seasonal population respectively. The relatively low rates (with respect to the international standards of 200 and 350 l/capita/day) are attributed to the rural character of the majority of residential population and the conservation campaigns that have increased the awareness of both inhabitants and tourists on periodical water stress conditions. Unaccounted for water use was estimated as the difference between the metered (charged volumes) and the delivered supply, on the basis of data and estimates provided by the Water Utility. Average network losses account for about 25% of the delivered supply volumes.

Projections

The economic development, which began in the 1970's, resulted in increasing permanent population growth rates (Table 9-3). For identifying a business as usual scenario, it was assumed that during the period examined (2004 – 2030) the population will continue to increase with a steady yearly rate equal to the average of the previous decades. Seasonal population is assumed to follow a similar trend, as the permanent population increase should be supported by a proportional economic growth, which is nowadays strongly related to tourism development.

Table 9-3 Growth of registered permanent population (National Statistical Service)

Year	Registered permanent population	Yearly Growth Rate (%)
1971	7,314	-
1981	7,881	1%
1991	9,591	2%
2001	12,783	3%

Two other scenarios formulated for the period analysed assume that after a point the island has reached its carrying capacity regarding tourism development. This would be followed by stabilization of population while a more pessimistic scenario assumes a small decrease of tourism that is followed by minor emigration trends towards the mainland.

Under this context, three different potential trends were distinguished, forming the potential scenarios for domestic demand (Table 9-4):

I. A scenario where demand increases at a steady rate, equal to that currently observed, and corresponding to a "business as usual" state (**BAU**),

II. A scenario where demand is stabilized after a point in time, in this case taken to be 15 years after the reference year (**Stabilized**),

III. A scenario where the demand decreases after a point in time, in this case taken to be 25 years after the reference year (**LD**).

Table 9-4 Population trends for the three scenarios

Scenario	Period	Growth Rate (%)	
		Permanent Population	Seasonal Population
BAU	2001 – 2030	1.5	1.5
Stabilized Demand	2001 – 2015	1.5	1.5
	2016 – 2030	0.0	0.0
Low Demand	2001 – 2015	1.5	1.5
	2016 – 2025	0.0	0.0
	2026 – 2030	-0.5	-0.5

The three domestic demand scenarios are depicted in Figure 9-3. It should be noted that due to the continuous decline of agricultural activities, irrigation and animal breeding demands are assumed to be stable over time and equal to 2.51 and 0.04 million m^3 respectively. A very small quantity (7,000 m^3/yr) is exported to the nearby island of Antiparos during the peak months of July and August.

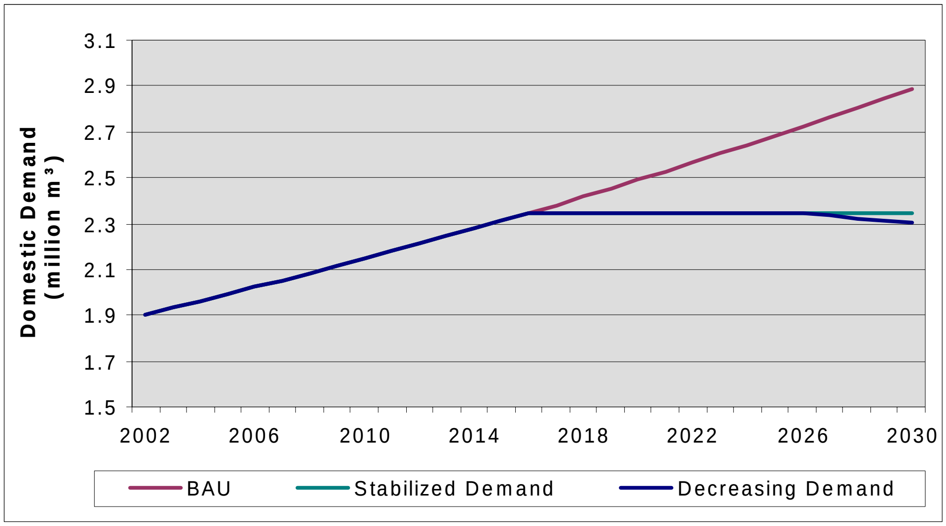


Figure 9-3 Domestic Demand Scenarios

Formulation of Availability Scenarios

Data

The climate in Paros, as in all the islands of the Cycladic complex, is temperate Mediterranean. The average temperature is 16.5 – 19.5 °C. The average annual rain height is 480 mm according to the last 50 year measurements from the meteorological stations of Naxos and Paroikia.

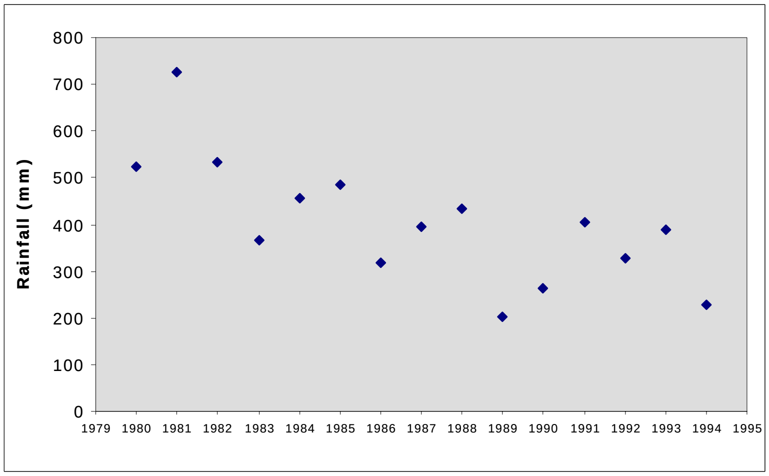


Figure 9-4 Rainfall measurements from the Naxos meteorological station

Rainfall monthly variation is presented in Figure 9-5. Highest rainfall values are observed during the winter, while during the summer season, from May to August, precipitation is very rare, not exceeding 5 mm/month.

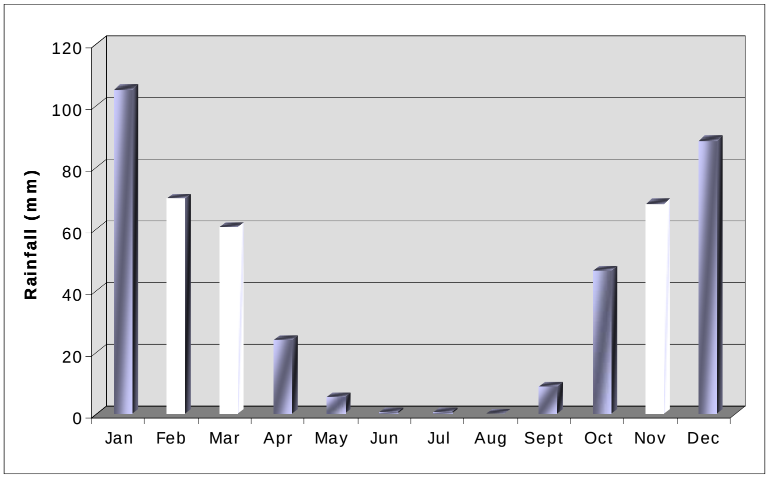


Figure 9-5 Average monthly rainfall in Paros

Scenarios

The main variable in the formulation of availability scenarios was the sequence of years with respect to rainfall. Sequences that were developed and entered in the DSS were composed of average, wet (values in the top 30 percentile of observed) and dry years (values in the bottom 30 percentile of observed). The hydrological scenarios that were used reflected:

IV. a period of 30 years with a high frequency of dry years (**HD**),

V. a period of 30 years with a high frequency of wet years (**HW**),

VI. a period of 30 average water availability years, which signifies the assumption of standard water availability, reflecting the baseline scenario (**Normal**).

The three availability scenarios are depicted in Figure 9-6.

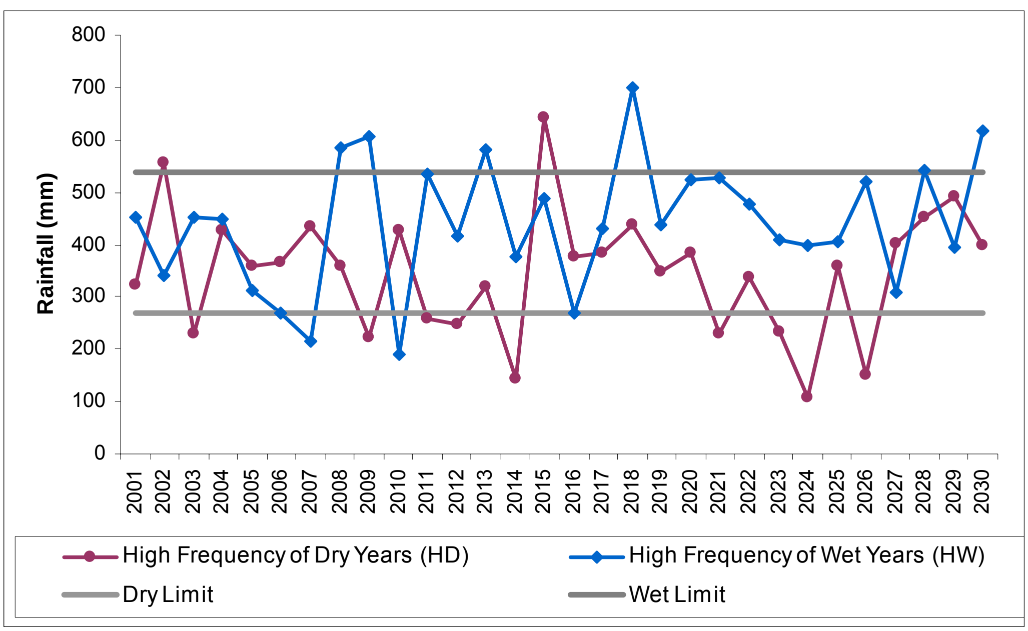


Figure 9-6 Water Availability Scenarios

Combinations of Availability and Demand scenarios

In order to be able to assess the behaviour of the water system under a best case scenario, a worst case scenario and a business as usual scenario as intended, the combinations of availability and demand scenarios under which the different management options have been evaluated were the following:

- A combination of high demand with a high frequency of dry years (**BAU+HD**), reflecting the worst case scenario of water shortage,
- A combination of reduced demand with a high frequency of wet years (**LD+HW**), reflecting the best case scenario, and
- A combination of high demand with a series of average years (**BAU+Normal**), in an effort to reflect the current trends of the system in a “business as usual” context.

Figure 9-7 presents the overall domestic deficit under the three scenarios.

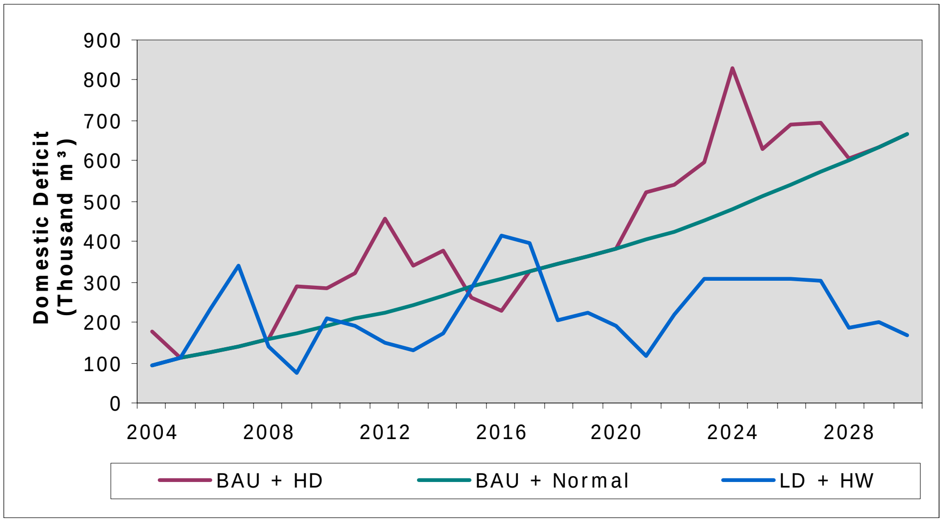


Figure 9-7 Estimated domestic deficit under the selected demand and availability scenario combinations

From the temporal and spatial variation of domestic shortages throughout the island, the following are concluded:

- The municipal department of Paroikia and the towns of Marpissa and Piso Livadi face permanent water deficiency. This is due to the large tourist influx in those areas and the limited available groundwater resources. Aquifers supplying those areas are on the verge of overexploitation.
- The current desalination capacity is adequate to meet both residential and tourist water needs of the town Naoussa up to 2023. However, the rest of the municipal department, mainly supplied through boreholes, faces small water shortage problems. Groundwater exploitation is very high mainly due to the irrigation activities of the area, facilitating the advance of the sea intrusion front. During recent years efforts have been made to limit groundwater abstractions to sustainable levels and enhance the Naoussa aquifer through the construction of small interception dams.
- The municipal department of Arhilohos faces small, periodic water shortages, aggravated by seasonal droughts.
- The exploitation of the aquifer of Agairia at the southern part of the island is rather low. The hydro-geological survey of the island has concluded that, due to the impermeable geologic structures, further exploitation is possible without endangering the water balance of the area.

- The municipal departments of Agairia and Lefkes do not face deficiency for the entire simulation period.

In all cases peak shortages are observed during the month of August when both domestic and irrigation requirements reach their peak. For domestic use, deficit reaches 174, 288, and 67 thousand m^3 in 2009 in a normal (average), dry, and wet year respectively under the three scenarios (Figure 9-8).

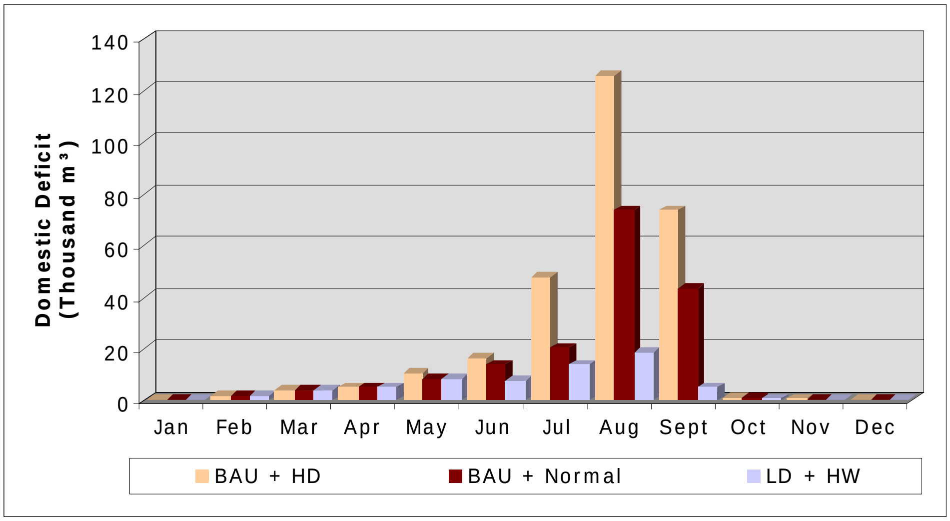


Figure 9-8 Monthly domestic deficit under the three scenarios (year 2009)

Cost Estimations

The estimation of **direct costs** for the island of Paros consists of:

- Amortization of capital expenditures associated with new infrastructure;
- Additional operating costs incurred from the use of new infrastructure for both domestic and irrigation purposes;
- Costs associated with the application of demand management options, which are supposed to be in the form of subsidies provided to the pertinent sector.

In addition, and in order to cope with the lack of relevant data, and appropriate information, the following assumptions have been made in order to estimate the total annual costs from the operation of existing infrastructure:

- **For domestic use,** an additional unit cost of 0.6 €/m^3 of supply delivered has been assumed, in order to account for the operating expenses of the Water Utility. This cost was derived assuming that for the year 2001 the cost recovery rate, computed on the basis of annual operating costs and revenues from water billing, was equal to 90%.
- **For irrigation water provision,** which is performed mainly through private boreholes, the provision of water supply was considered not to entail capital costs. No data have been made available for irrigation abstractions, borehole number and depth etc. Therefore a unit cost of 0.1 €/m^3 was considered applicable, according to previous estimates regarding groundwater abstractions in the island.

Environmental costs for the case of Paros are associated with:

- Groundwater abstraction
- Pollution generated from domestic uses.

Groundwater abstractions are associated overabstractions originated from the major aquifers of the island, i.e. the Ksiropotamos-Naoussa aquifer, the Prodromos – Tourlos – Dryos aquifer and the small aquifers of Alyki. The selected reference period runs from May to September and the average costs incurred from abstraction were set equal to 0.5 €/m^3.The vulnerability of each aquifer to overabstraction was effected through the use of area coefficients that are summarized in Table 9-5.

Table 9-5. Area coefficients used for groundwater abstraction environmental costs

Groundwater Body	Area Coefficient
Ksiropotamos - Naoussa	2.0
Prodromos – Tourlos – Dryos	1.8
Alyki	1.5

With respect to pollution, environmental costs have been estimated as equal to the operating expenses of a secondary wastewater treatment plant. Since no particular environmental problems have been recorded in terms of aquifer, stream or coastline degradation, the relevant coefficients were set equal to 1. It should be noted that pollution environmental costs are related to the activity levels and not on the volumes of water abstracted and disposed. Therefore, they do not vary for all water management options that have been examined in the current analysis

Present values have been estimated for the period of 2004 to 2030, using a discount rate of 4%.

Analysis of Water Management Options

The management options that were analysed in the Case Study for Paros Island have already been described in Chapter 3 and are listed here for completeness. In total 9 options were evaluated under the three scenario combinations, pertaining to three major categories, i.e. Supply Enhancement (structural responses), Demand Management and Socioeconomic measures in the form of adjusted pricing schemes for domestic and irrigation water provision. Specifically, measures and instruments analysed were (i) *Network Unifications***,** aiming at the integration of the fragmented water networks of the island; (ii) *Desalination unit(s) construction*, to provide additional water supplies particularly during the peak consumption periods; (iii) *New Boreholes*, in areas where groundwater exploitation is below the sustainable level; (iv) *Storage Reservoirs (and interception dam) construction* to provide a means of storing run-off during low consumption periods to be used later; (v) *Reduction of Network losses*, through replacement of old and damaged piping in the island towns (structural intervention); (vi) *Cistern construction* subsidization in the households/hotels, for better regulation of the network flow between peak and low consumption times/periods; (vii) *Conservation Methods* in households and the hotel sector; (viii) *Improvement in Irrigation Methods*, for better irrigation efficiency and savings in water consumption; (ix) Socio-economic measures in the form of adjusted *Pricing* aiming to examine to what extent a difference of pricing structures would influence the targeted indicators of the analysis.

Simulation assumptions and results for the simulation of each option under the three scenario combinations are presented in the next paragraphs. The *Summary and Conclusions* section of this chapter summarises the analysis outcomes, and performs a comparison between the options in terms of effectiveness, incurred direct and environmental costs.

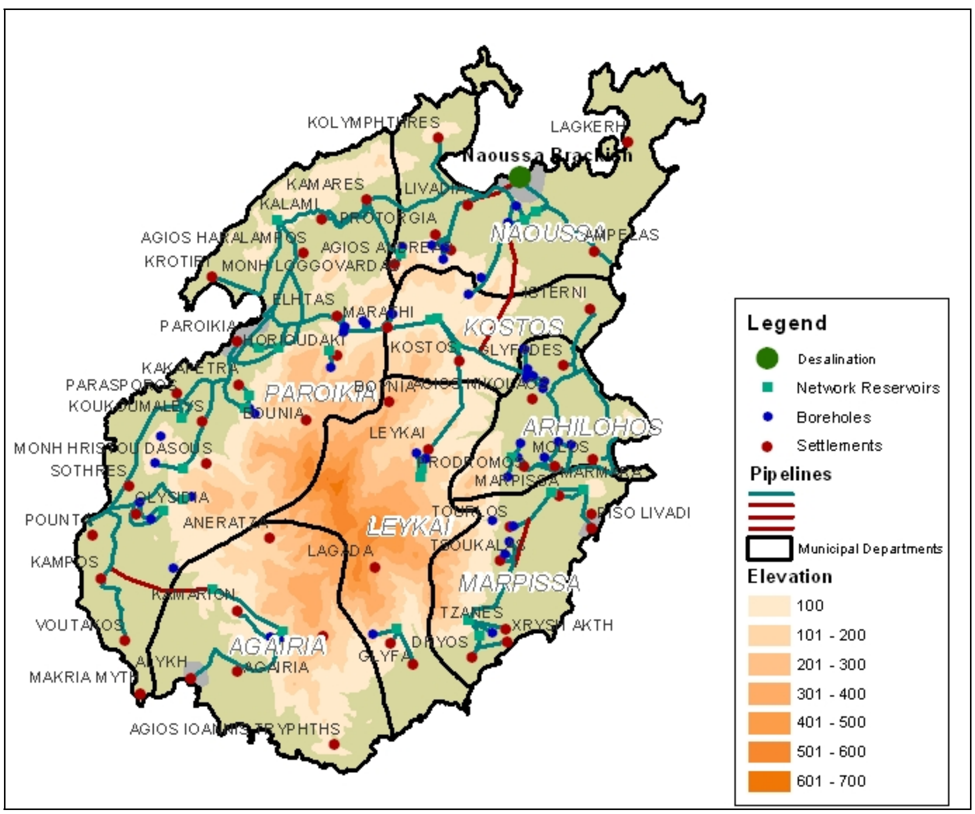
Structural Options

Network Unifications

The water supply network of Paros is highly fragmented, due to the past administrational structures governing the water supply. As a result, there are a number of separate water supply networks that are each supplied by local resources, some in the most heavily populated parts of the island facing water shortages during the summer peak. Other regions are more water-rich and could contribute towards alleviating the problems where these are faced through the implementation of network connections and unifications. A combination of four feasible interventions has been identified, in terms of water availability and existing deficits, and technical feasibility (Map 9-1):

- A connection between the water networks of Alyki and Kampos.
- A connection between the water networks of Dryos and Marpissa.
- A connection between the water networks of the town of Naoussa and its suburbs.
- Finally, a connection between Kostos and Naoussa.

The first three of the proposed connections are considered necessary, since the areas to be supplied face permanent water shortage problems. Between scenarios it is the appropriate connection years that will vary and that will be assessed. The cost of the new connections, estimated according to their length and pipeline diameter, is presented in Table 9-6, while the year for each connection is presented in the Annex.



Map 9-1 Proposed network unifications

Table 9-6. Network unification costs

Connection	Construction Cost (€)
Agairia – Kampos	9,000
Naoussa – Naoussa Suburbs	44,000
Dryos – Marpissa	18,000
Kostos - Naoussa	400,000
Total	**471,000**

Under normal (average) water availability conditions, the first three connections are applied for 2005. Since the settlement of Naoussa does not face deficiency problems before the year 2021, the connection should be made much later, in 2028. Figure 9-9 presents the total volume of water transferred by each connection under the BAU + Normal scenario.

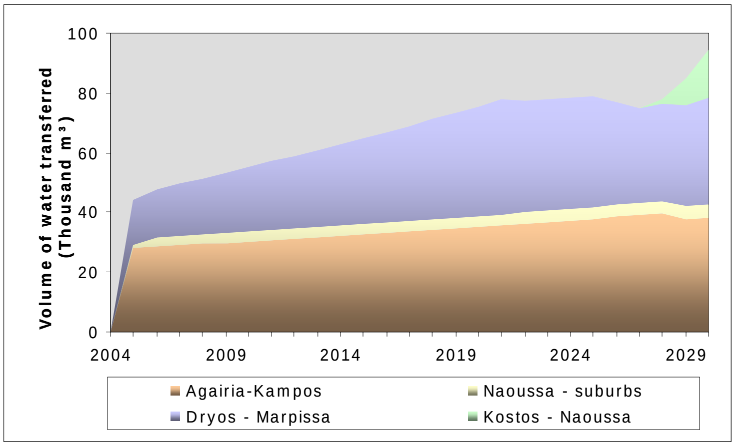


Figure 9-9 Volume of water transferred from each connection (BAU + Normal scenario)

In dry years transferred volumes normally increase during the summer months, with the provision that local water needs are always satisfied before any transfer is made. Monthly distribution differs for average or wet years. In some areas (e.g. Paroikia) already existing infrastructure is adequate to meet water needs up to the peak month of August. After that however, local resources are depleted, and additional water transfers are required for meeting the demand.

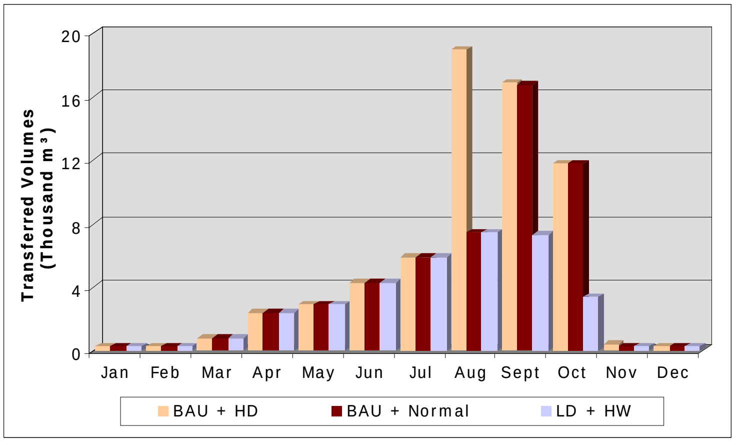


Figure 9-10 Monthly volumes of water transferred for the three scenarios (year 2009)

Under average availability conditions, the unification of the island's fragmented networks can lead to an increase in domestic demand coverage. Overall, when water availability is increased due to increased precipitation, there is a significant effect on the domestic demand coverage, due entirely to a better allocation of the available resources (Figure 9-10 and Figure 9-11). The effect becomes smaller as demand increases, since larger water quantities are required for satisfying local needs before making water transfers through the new connections, and since no additional water supply sources have been introduced in the system.

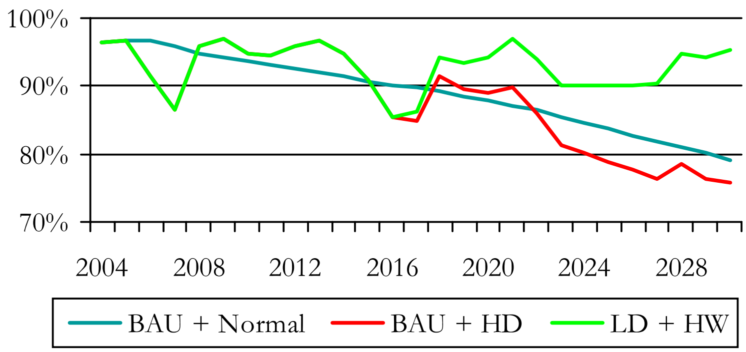


Figure 9-11 Percent demand coverage effectiveness of Network Unifications to Domestic use

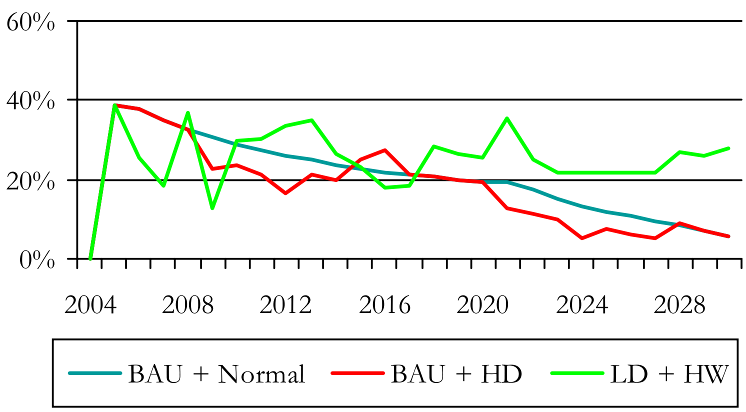


Figure 9-12 Percent Improvement of deficit in Domestic use with respect to the reference scenarios

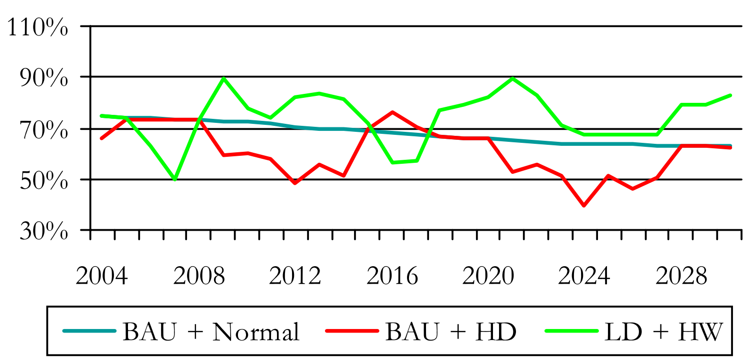


Figure 9-13 Percent demand coverage effectiveness of Network Unifications to Irrigation use

Network unifications have a positive effect only in domestic demand coverage, which is higher under a high frequency of wet years (LD + HW scenario). Irrigation demand coverage (Figure 9-13 and Figure 9-14) is overall decreased over time due to the increasing demand for domestic use. A similar pattern of effectiveness improvement as with the domestic use is observed where the overall water availability is significantly increased due to increased precipitation.

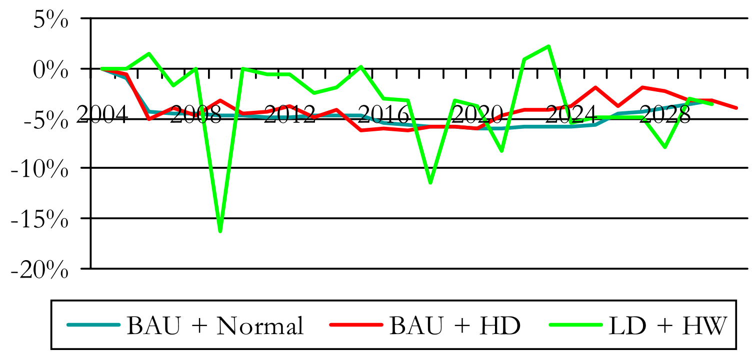


Figure 9-14 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios

Overall the option is not very expensive, since the unifications proposed are between neighbouring municipal departments and construction costs are low (Table 9-6). Additional cost is incurred from the augmentation of water distributed through the network but in any scenario this increase does not exceed 5% of the respective reference scenario direct cost, expressed in present value terms (Figure 9-14). The present value increase of the option under the LD+HW scenario is much lower, since the most expensive connection between Kostos and Naoussa is not required.

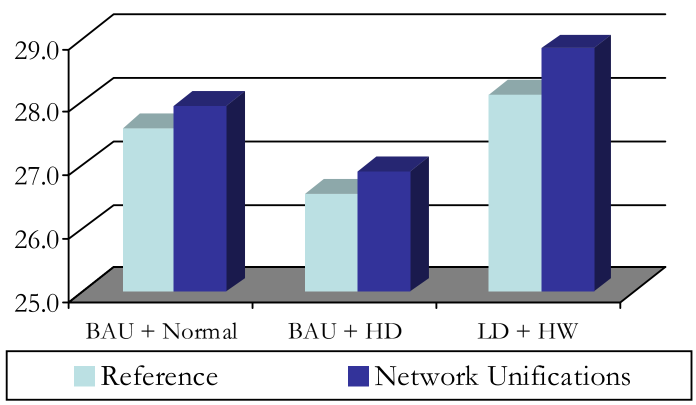


Figure 9-15 Total direct cost difference of the Network Unifications option under the three scenarios (Present Value – Million €)

An additional remark is related to the most expensive connection between the municipal departments of Kostos and Naoussa. This connection is used only after 2028, when the installed desalination capacity cannot meet the demand, and is required only under normal or dry conditions. Additionally, the unification creates problems in the provision of water supply to the Paroikia municipal department. Therefore, the connection should - if realised - be combined with the construction of new boreholes or other supply enhancement measures in order to stabilise the supply delivered to the other regions from the boreholes of Kostos area.

The total environmental costs for network unifications do not vary significantly between the intervention scenario and the reference conditions for each availability/demand scenario

(Figure 9-15); this is due to the fact that the environmental cost is calculated at the level of the resource and on the basis of total abstraction levels. The option does not affect groundwater abstraction levels; all available water resources are considered exploited and the increase of domestic abstractions is followed by a decrease of irrigation abstractions. Therefore, the total volume of water abstracted from each aquifer remains at the same level as with the reference scenario, and total environmental costs are more or less constant.

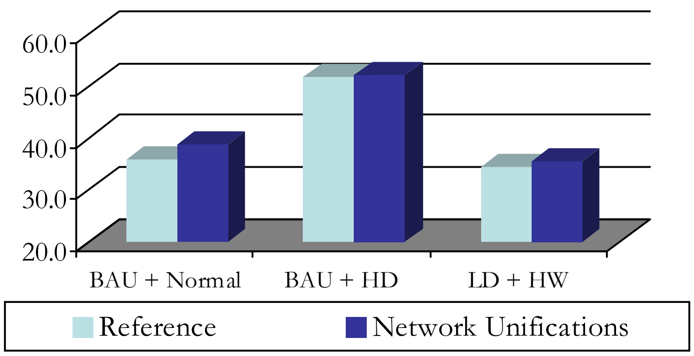


Figure 9-16 Total environmental cost difference of the Network Unifications option under the three scenarios (Present Value – Million €)

Desalination

Desalination is a water supply enhancement option of increasing popularity in the Greek islands and worldwide. A brackish water desalination plant already exists in Paros, with capacity of 1,450 m^3/d, and supplies only the settlement of Naoussa.

Based on the water demand patterns and the seasonal peaks observed on the island, the intervention evaluated involved the construction of four additional desalination units, aimed to supply:

- The town of Marpissa and the tourist settlement of Piso Livadi (Marpissa unit),
- The town of Paroikia (Livadia unit),
- The southern part of the municipal department of Paroikia (Livadia and Parasporos units)
- The suburbs of Naoussa and potentially after 2023 the town of Naoussa as well (Naoussa suburbs unit).

The desalination units were designed to have a lifetime of 15 years, and their capacity was estimated so as to meet approximately 95% of the domestic water needs in the selected regions. Units are replaced with increased capacity in 2021. Initially required capacity (year 2005) ranges from 2,300 m^3/d (LD+HW scenario) to 2,750 m^3/d (BAU+HD scenario). Details on the capacity for the each of the four units under the three scenarios can be found in the Annex.

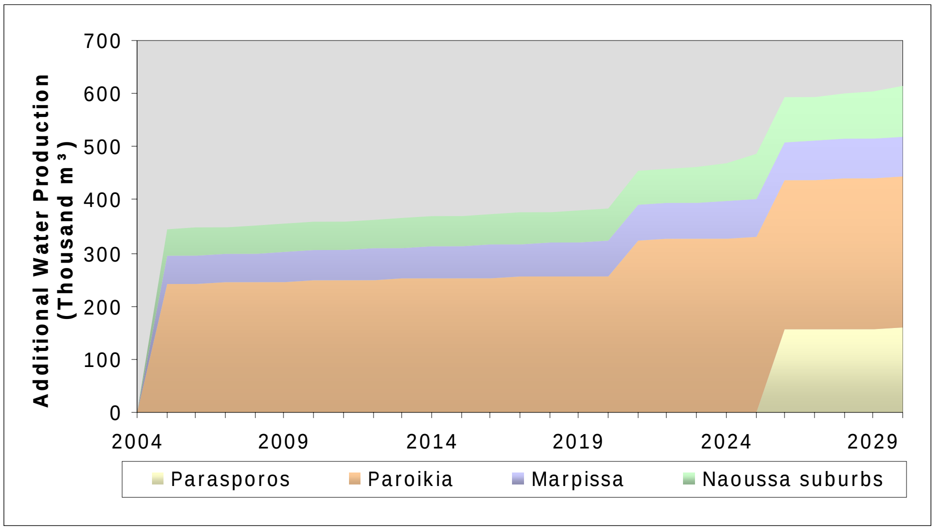


Figure 9-17 Water production from the four new desalination units (BAU + Normal scenario)

In all cases desalination is used as a primary supply source, with the aim to limit groundwater exploitation and indirectly improve coverage of irrigation water requirements. Figure 9-17 presents the water produced from the four units in the BAU + Normal scenario. Although desalination in all four areas is used as a primary resource, units operate in full capacity only during August. During the winter operation falls to approximately 25 % of the installed capacity (Figure 9-18).

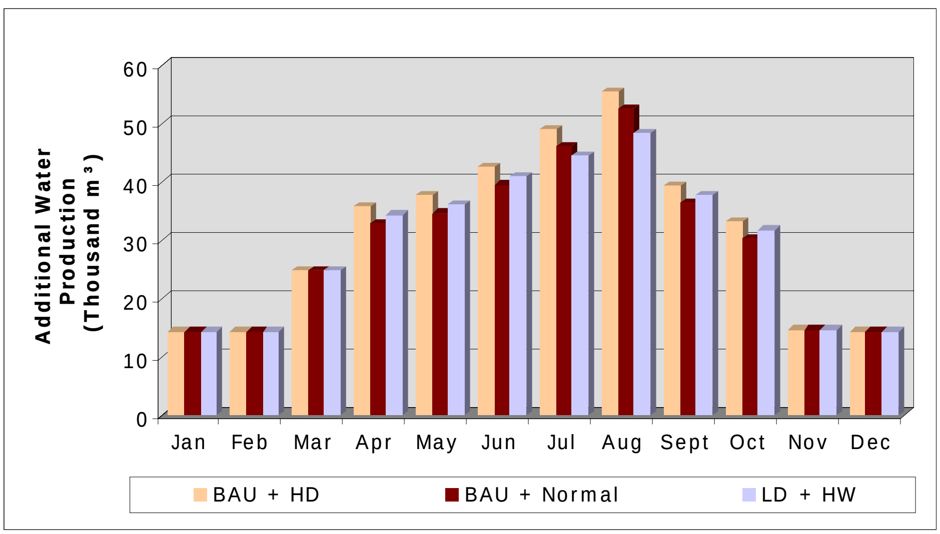


Figure 9-18 Monthly water production from the new desalination plants for the three scenarios (year 2009)

Desalination is the structural solution that performs the best among all examined. Due to the design specification, domestic demand coverage does not fall below 95% with the exception of a dry period in the BAU+HD scenario, where the effectiveness to domestic use is approximately equal to 92% (Figure 9-19). The domestic deficit improvement with respect to each reference scenario is subject to the high hydrological variations; improvements are lower under the LD+HW scenario where due to high water availability and decreasing demand trends, the domestic deficit is lower. Under the two other scenarios domestic deficit improvements can reach even 80% with respect to the reference scenario (Figure 9-20).

The domestic use relies more on desalination, and the smaller dependency to groundwater resources helps in the alleviation of irrigation shortages (Figure 9-21). Desalination units have been designed so as to meet domestic deficits, and not to completely substitute the use of groundwater resources; therefore, irrigation deficit improvements decrease as domestic demand increases and domestic use dependence on groundwater resources becomes higher (Figure 9-22).

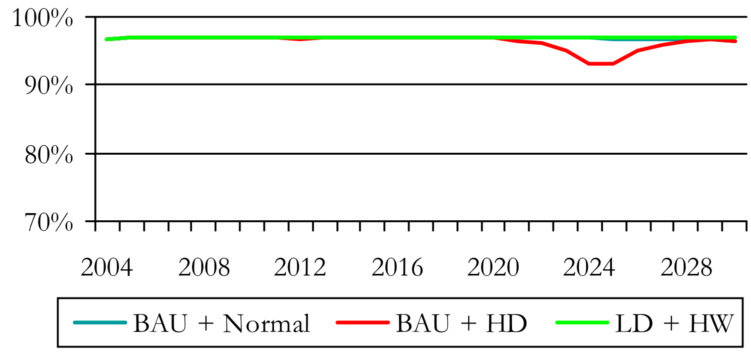


Figure 9-19 Percent demand coverage effectiveness of Desalination to Domestic use

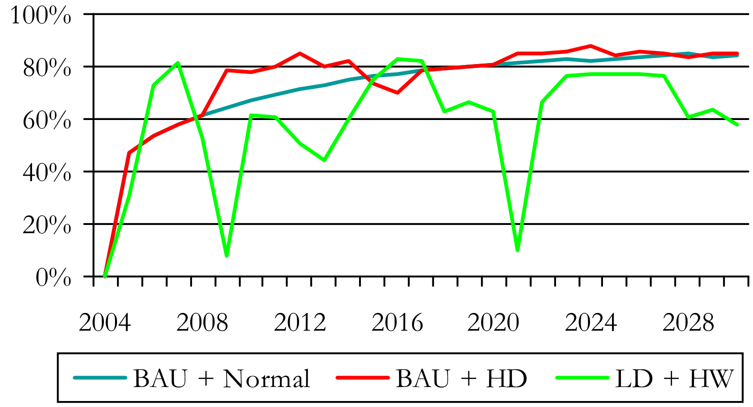


Figure 9-20 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Desalination option)

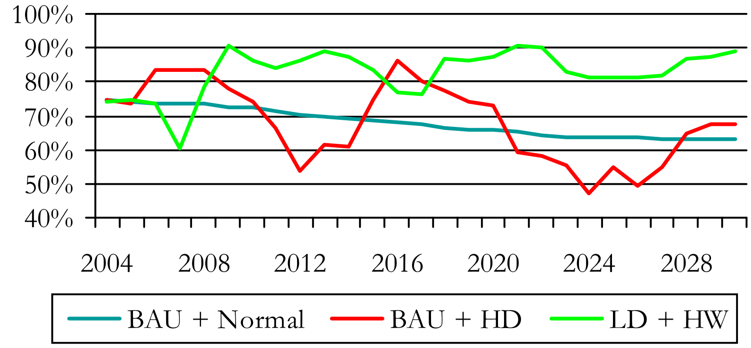


Figure 9-21 Percent demand coverage effectiveness of Desalination to Irrigation use

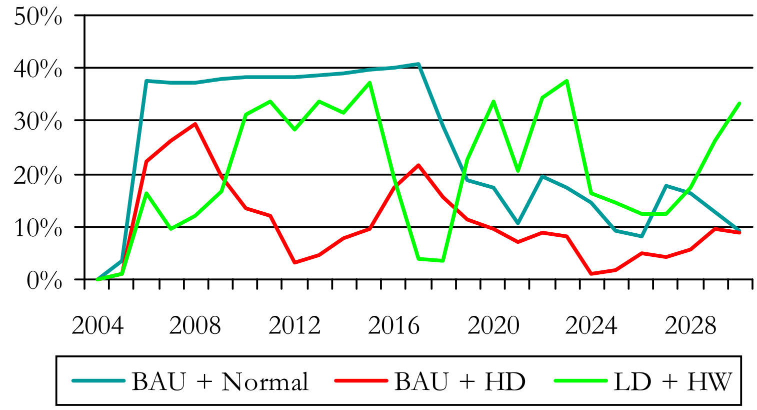


Figure 9-22 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Desalination option)

Despite the observed improvement and the recent technological advances, which lower energy consumption and costs, desalination remains a very expensive solution. Figure 9-24 presents the present value of direct cost between the three scenarios that were examined. In all cases an at least 30% increase of costs is anticipated if a strategy shall predominantly rely on desalination. A combination of the option with other, mostly non-structural solutions should therefore be preferred in an effort to limit the required capacity, and avoid incurring very high additional costs to consumers.

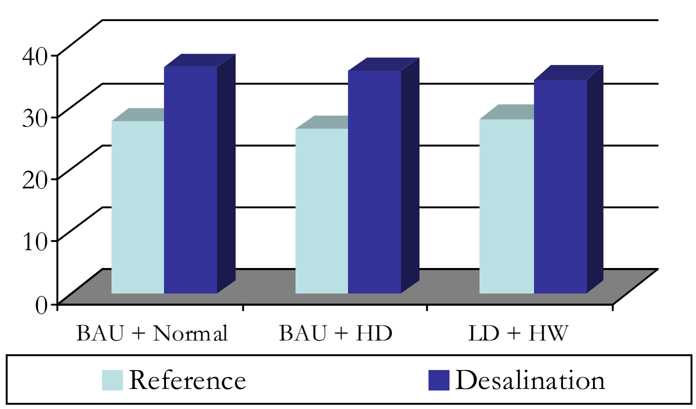


Figure 9-23 Total direct cost difference of the Desalination option under the three scenarios (Present Value – Million €)

The environmental costs, presented in Figure 9-23, again do not present significant variation within the BAU+Normal scenario, and within the BAU+HD scenario, for the reference case and the addition of Desalination. Under the BAU+HD scenario however, the environmental cost is significantly reduced where Desalination is introduced, due to the significant reduction in groundwater abstractions that exceed the safe yield of the Naoussa-Ksiropotamos aquifer.

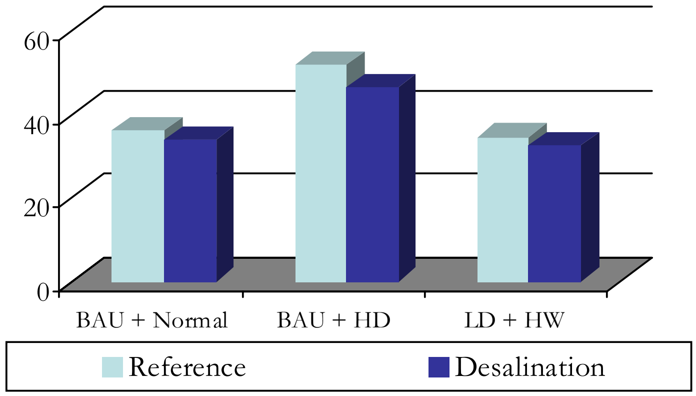


Figure 9-24 Total environmental cost difference of the Desalination option under the three scenarios (Present Value – Million €)

Groundwater Exploitation

The construction of new boreholes to provide additional water supply is the method that has been used most frequently in the case of Paros, as until recently the groundwater reserves were adequate, the costs entailed in the use of boreholes are significantly lower than those of major structural solutions, such as reservoir construction or desalination, and the solution was quick and easy to implement. As a result, the island today is perforated by a large number of boreholes, most being used for irrigation purposes. The size of this potential water management intervention as a component of the comprehensive scenarios for Paros was defined in the basis of the local geological structures and the current exploitation patterns. Since little or no data are available for abstracted water volumes from irrigation, the option is examined for domestic use only. Very low priority is given to the new supply source.

As in the case of Network Unifications, the size of such an intervention cannot be varied on the basis of demand conditions, since it depends more on available quantities for abstraction. Thus it was the scheduling of interventions (see Annex) that was defined by the demand – availability conditions in the area, and formed the extent for the application of the option.

The locations that could be selected for the application of this intervention were:

- The Agairia – Alyki area. This area does not face water deficit, and thus can provide water for other parts of the island. However, this can only be effected in conjunction with network unifications, as this water network is currently isolated.
- The Archilohos area. This area faces small, periodic deficits, and exhibits low water exploitation. An additional borehole yielding about 47,000 m^3/yr can be constructed.
- The Kostos area, in order to supply water to the main town of Paroikia and its suburbs. A maximum of two new boreholes can be constructed here, based on current estimates, yielding about 75,000 m^3/yr each.
- The Glysidia area. However, the local aquifer is non-productive and vulnerable to salinisation; to that end, it is estimated that a borehole yielding only 7,000 m^3/yr should be constructed.

Yields and costs are summarized in Table 9-7. Figure 9-25 presents quantities abstracted from the new drillings for the BAU+Normal scenario. The month variation of water production for a normal, dry and wet year (2009 under the three scenarios) is presented in Figure 9-26.

Table 9-7 Yield and construction costs for new boreholes

Borehole	Yield (m³/yr)[9]	Construction Cost (€)
Arhilohos	47,000	40,000
Glysidia	7,000	20,000
Kostos 1	75,000	40,000
Kostos 2	75,000	40,000
Total	204,000	140,000

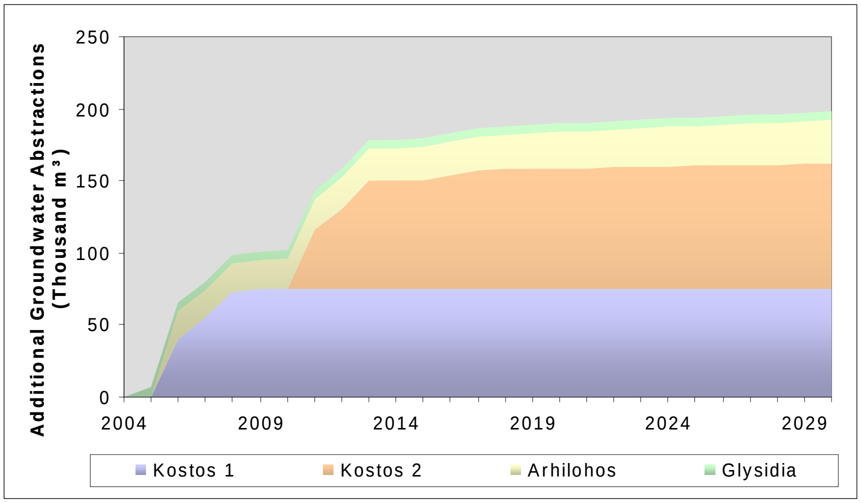


Figure 9-25 Additional Groundwater Abstractions (BAU+Normal scenario)

The new boreholes are assigned a very low supply priority with respect to existing supply sources. For this reason, under all three scenarios the new boreholes operate after the peak summer months, when the traditional supply sources have been depleted. During the peak season, supply normally originates from the existing groundwater drillings.

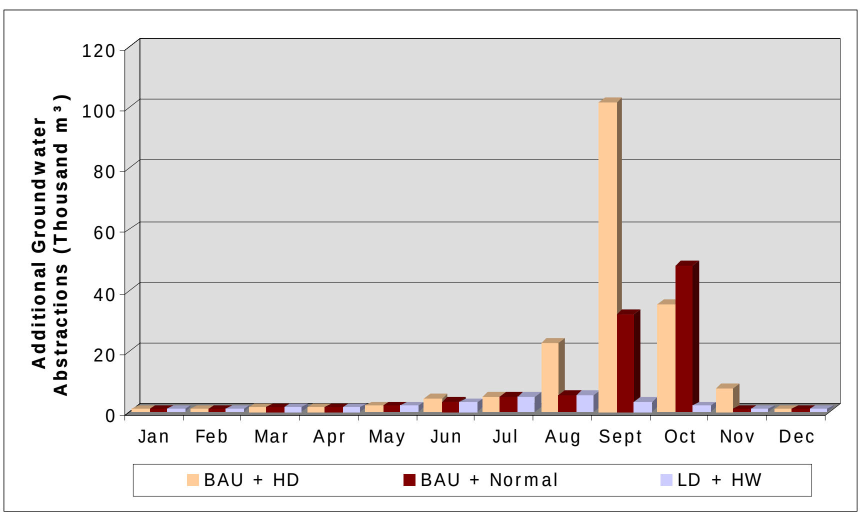


Figure 9-26 Monthly variation of abstractions from the new boreholes (2009)

[9] Yields refer to an average (normal) year.

The coverage of Domestic demand shows some improvement where the option is applied, which is once again diminished as the demand grows over time (Figure 9-27). Although the traditional practice of groundwater exploitation can assist in meeting some domestic requirements, this effect is almost diminished in cases of drought, as it is depicted from the results of the BAU+HD scenario (Figure 9-28). Although the traditional practice of groundwater exploitation can assist in meeting some domestic requirements, this effect is almost diminished in cases of drought, as it is depicted from the results of the BAU+HD scenario. In general, irrigation deficits are not significantly affected, with the exception of the high dry scenario.

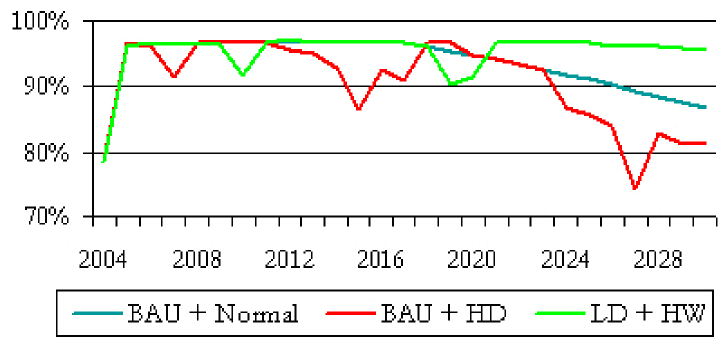


Figure 9-27 Percent demand coverage effectiveness of Groundwater exploitation to Domestic use

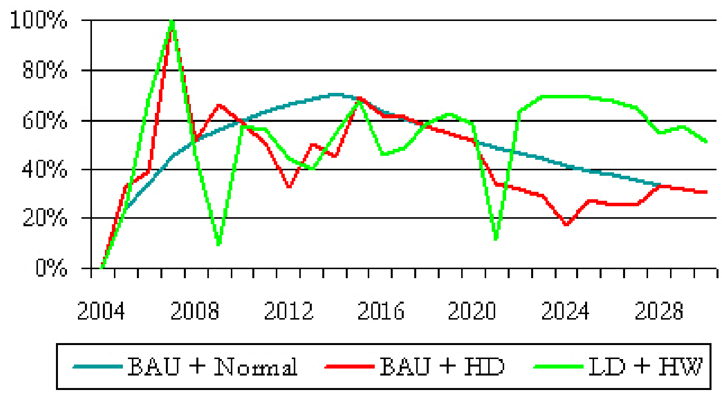


Figure 9-28 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Groundwater Exploitation option)

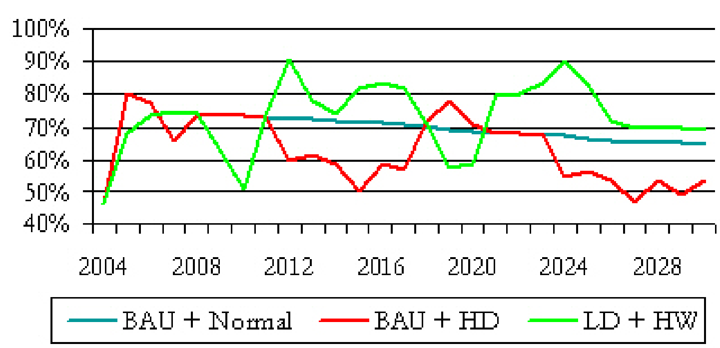


Figure 9-29 Percent demand coverage effectiveness of Groundwater exploitation to Irrigation use

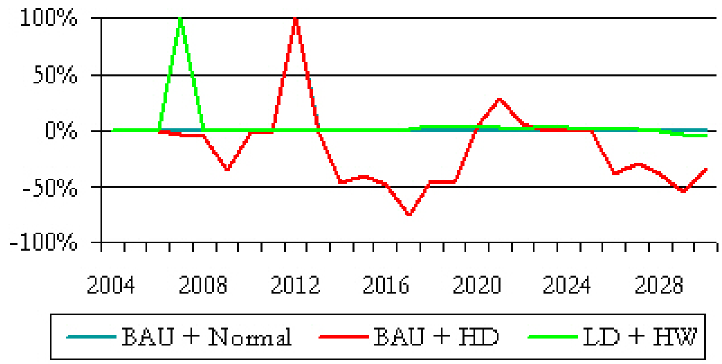


Figure 9-30 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Groundwater Exploitation option)

Direct cost increases are similar to those of the network unification option. A small average increase of about 3.5-5% is common among all three scenarios. Infrastructure construction costs are low; the increase is due to the augmentation of water abstracted and delivered to domestic use, which incurs a proportional increase in annual operating costs.

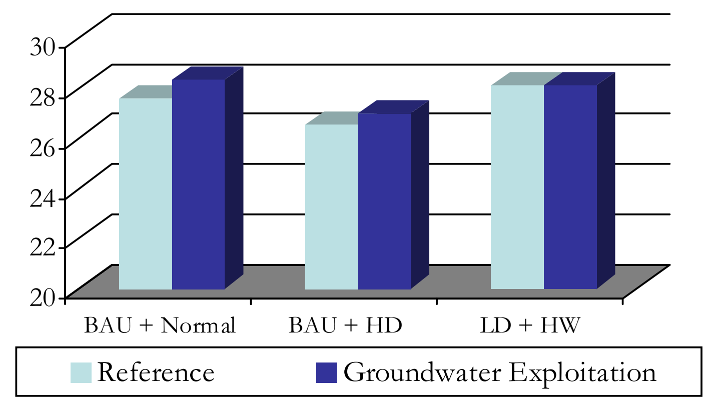


Figure 9-31 Total direct cost difference of the Groundwater exploitation option under the three scenarios (Present Value – Million €)

The total environmental cost records a substantial increase due to the increase of groundwater abstractions. In all cases, it is higher than the respective reference case, with the highest values recorded for the high dry scenario.

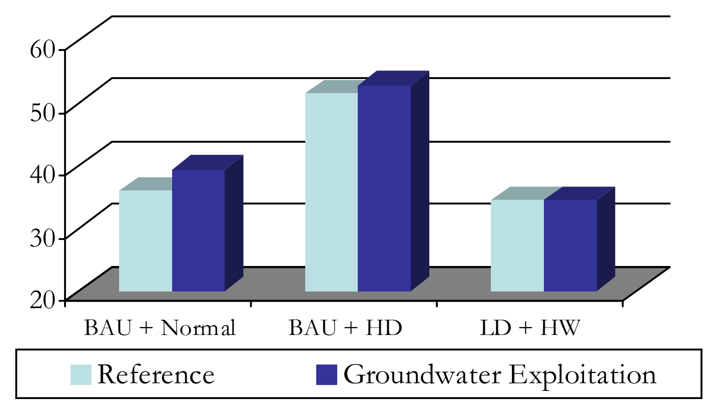


Figure 9-32 Total environmental cost difference of the Groundwater exploitation option under the three scenarios (Present Value – Million €)

Storage Reservoirs

In recent studies undertaken, two separate proposals have been made for the construction of storage reservoirs; the first was for the construction of a dam at Kavouropotamos river (Markantonatos, 2000), and the second the construction of an interception dam at Vrontas River.

The Kavouropotamos River is located in the southern part of the island. The water of the proposed dam, with a capacity of 450,000 m^3 (dead volume equal to 30,000 m^3), would be intended for domestic supply only, and a drinking water treatment plant of capacity 7,500 m^3/d would be necessary. Extensive distribution networks to supply the entire island have been proposed by the study. The cost specifications of the dam and related waterworks are presented in Table 9-8.

Table 9-8 Cost components for Kavouropotamos dam (Markantonatos, 2000)

Cost Component	**Cost (million €)**
Dam	4.70
Drinking water treatment plant	0.01
Connections	
From DWTP to Syrigos (Agairia)	1.42
From Syrigos to Paroikia	1.18
From Paroikia to Naoussa	0.72
From Naoussa to Marpissa	1.11
From Marpissa to Dam	0.96
Total	9.13

The construction of an interception dam at Vrontas River, which is located in the eastern part of the island, would contribute to the enhancement of local aquifers and therefore enhance domestic and irrigation supplies while inhibiting sea water intrusion. The specifications of the dam were:

- Capacity: 98,000 m^3.
- Dead volume: 30,000 m^3.
- Construction cost: 1.1 million €.

Construction for both dams starts in 2005 and it is estimated that they will be fully operational in 2009. In the scenario that was examined, Kavouropotamos dam was connected to the areas of Agairia, Marpissa and Paroikia, since the perimetric connection that was proposed is considered too costly and high energy heads are required to transfer water up to the northern settlement of Naoussa. Figure 9-33 presents the abstraction from Kavouropotamos dam and the groundwater recharge from Vrontas dam under the BAU + Normal scenario.

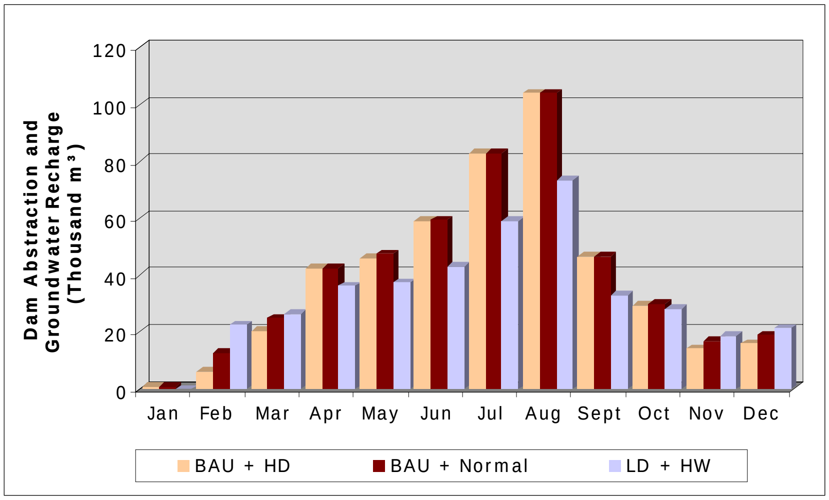


Figure 9-33 Monthly abstractions from Kavouropotamos and Vrontas dams for the three scenarios (year 2009)

The construction of storage reservoirs can be an effective solution in meeting domestic needs while at the same time increasing irrigation demand coverage, as can be seen in Figure 9-34 to Figure 9-37. Under normal (average) availability (BAU+Normal scenario), the effect of the option is similar to the one of desalination. However, the option performs much worse in the case of dry years, when inflows to both dams drop to 30% of normal (average) ones.

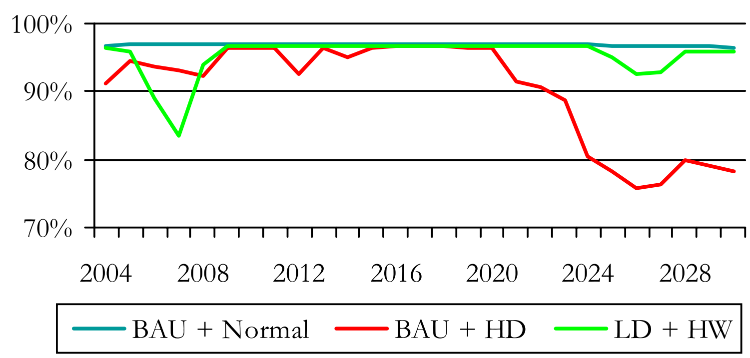


Figure 9-34 Percent demand coverage effectiveness of Storage Reservoirs to Domestic use

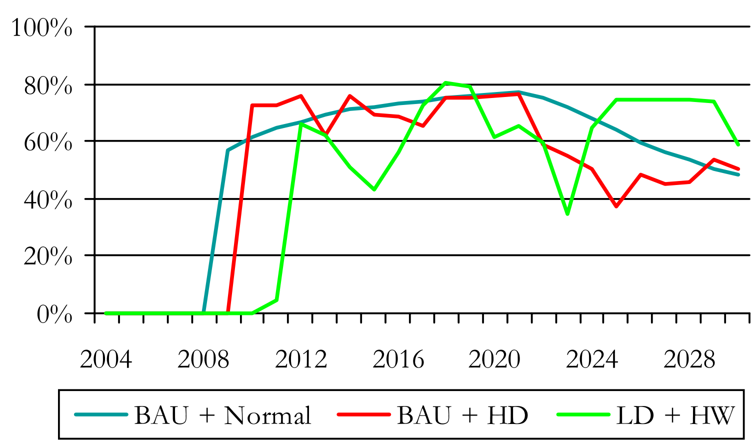


Figure 9-35 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Storage Reservoirs option)

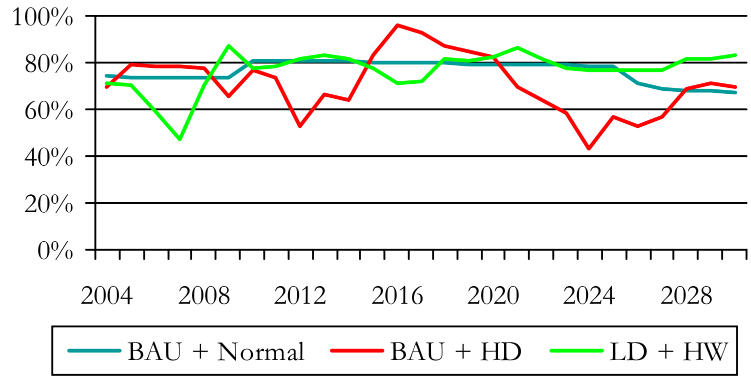


Figure 9-36 Percent demand coverage effectiveness of Storage Reservoirs to Irrigation use

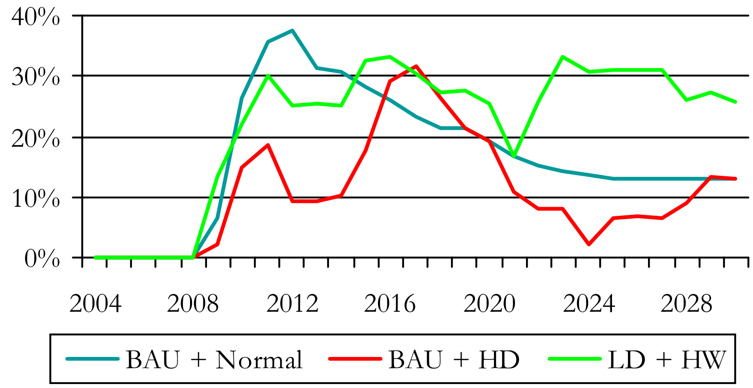


Figure 9-37 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Storage Reservoirs option)

Since alternative financing schemes are not examined at this stage, the Kavouropotamos dam is considered to be too expensive (even without including the operational costs of the system, such as pumping requirements).

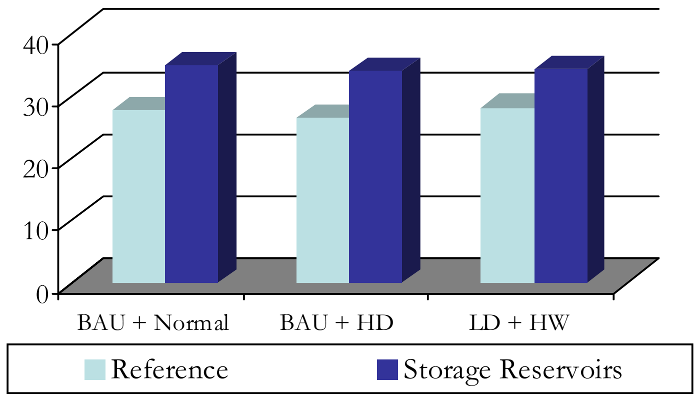


Figure 9-38 Total direct cost difference of the Storage Reservoirs option under the three scenarios (Present Value – Million €)

Another disadvantage concerns the operation of such an extensive network rather vulnerable to failures, which also renders the construction of a remote monitoring system for leakage control, and the facilities to support this, necessary. At the same time, the interception dam at

Vrontas can with significantly lower costs help in the mitigation of the overexploitation of the aquifer and assist in sustaining the irrigation of the traditional vineyards in the municipal department of Naoussa.

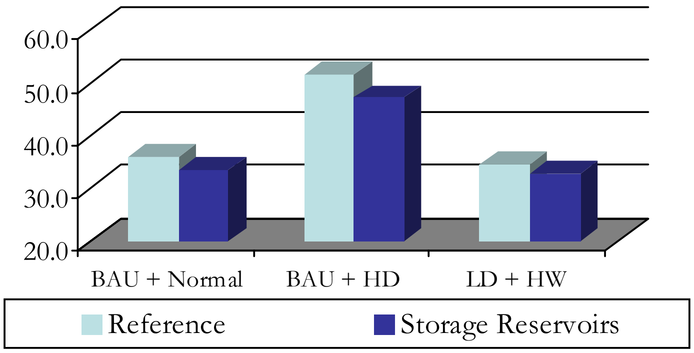


Figure 9-39 Total environmental cost difference of the Storage Reservoirs option under the three scenarios (Present Value – Million €)

Given that the levels of abstraction are reduced and the recharge is increased due to the introduction of the interception dam, the environmental costs show a perceptible reduction, which becomes significant under the BAU + HD conditions (Figure 9-39).

Reduction of Network Losses

The current estimated level of network losses in Paros is in the range of 25% of the total supply. The option that was explored was a gradual reduction of losses from 25% to 15%, through successive network replacements. The application of this intervention was made on the assumption that internal network replacement will be gradually applied in the different municipalities. First priority was given to the larger municipalities, Paroikia, Naoussa and Marpissa and secondary to the minor ones, Agairia, Arhilohos, Kostos and Lefkes. The assigned scheduling of network replacements was made on the basis of demand size, current network status and observed deficits.

The process of network replacement has been estimated to last approximately 3 years, with an even distribution of costs throughout this time. The total cost of the option is presented in Table 9-9. In the case of the traditional settlements of Paroikia and Naoussa, where the internal distribution network is particularly old, extended and in some cases even undocumented, replacement may last up to 4 years.

Table 9-9 Network Replacement Costs (Markantonatos, 2000)

Municipal Department	Total Network Replacement Cost (€)
Paroikia	450,000
Naoussa	202,000
Marpissa	94,500
Arhilohos	51,000
Agairia	61,500
Likes	133,500
Kostos	50,100
Total	1,042,600

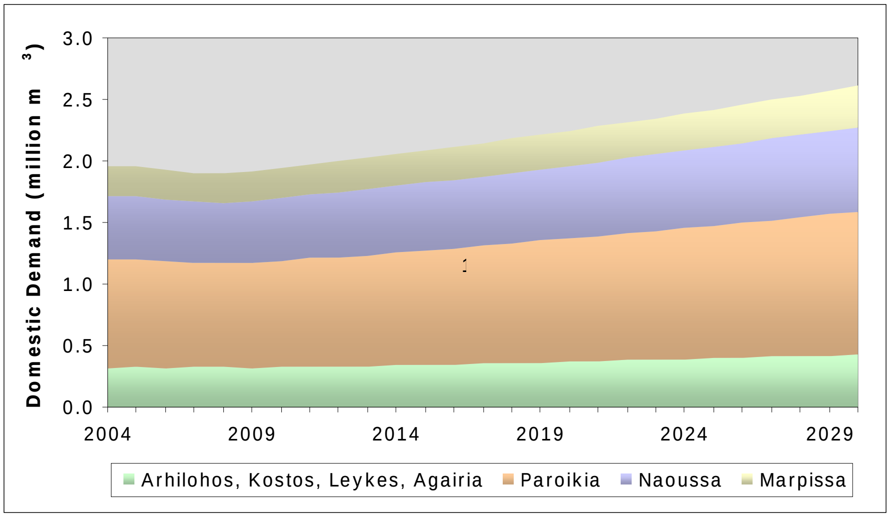


Figure 9-40 Domestic demand per municipal department under the network loss reduction option (BAU + Normal scenario)

Figure 9-40 presents the new demand for each municipal department under the BAU – Normal Scenario. Network replacements for Paroikia and Naoussa occur during the period 2005-2008, for Marpissa from 2005 to 2007 and for the other municipal departments in 2006, 2009 and 2012.

Scheduling of replacements does not differ much for the other two examined scenarios. The application of the option can be delayed in the smaller municipal departments with the exception of Kostos, whose boreholes are used to supply the department of Paroikia. More details on the simulation of the option are presented in the Annex.

Reduction of losses through distribution network replacements shows a significant improvement in terms of both domestic and irrigation demand coverage. The reduction of losses results in improved efficiency in the supply of water towards the domestic use (Figure 9-41 and Figure 9-42). As with all measures targeted to promote conservation, some improvement in irrigation demand coverage is observed; this is due to the decline in domestic groundwater abstractions resulting in higher water availability for agricultural purposes (Figure 9-43 and Figure 9-44). Since no additional supply sources are introduced in the system, the effect of the option for domestic and irrigation water provision, decreases as domestic demand becomes higher due to population growth. This is not of course the case for the LD+HW scenario where, after 2015 demand stabilises.

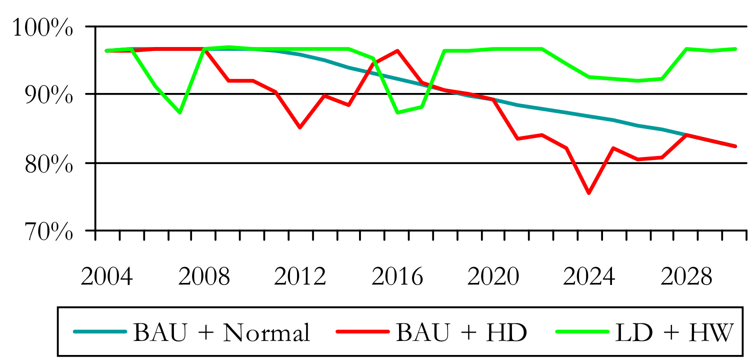


Figure 9-41 Percent demand coverage effectiveness of Reduction of Network Losses to Domestic use

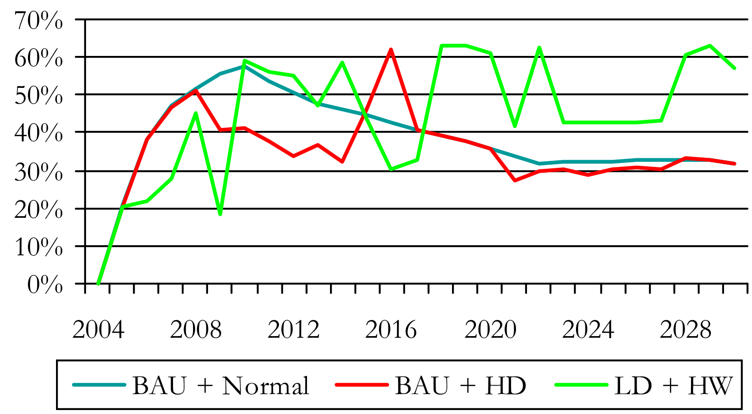


Figure 9-42 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Reduction of network losses option)

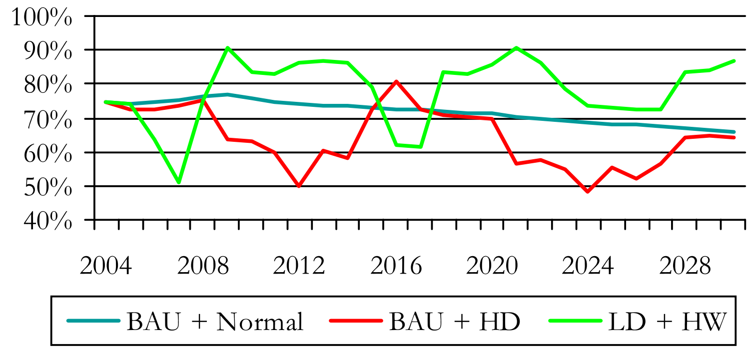


Figure 9-43 Percent demand coverage effectiveness of Reduction of Network Losses to Irrigation use

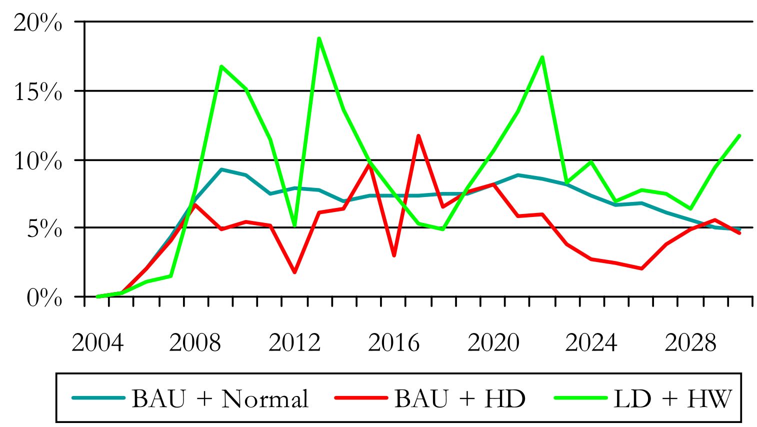


Figure 9-44 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Reduction of network losses option)

Figure 9-45 presents the direct cost (expressed as the present value over the period 2004-2030) between the three scenarios after the application of the scheduled network replacements. An average reduction of direct costs of about 1 to 2% is common between all three scenarios.

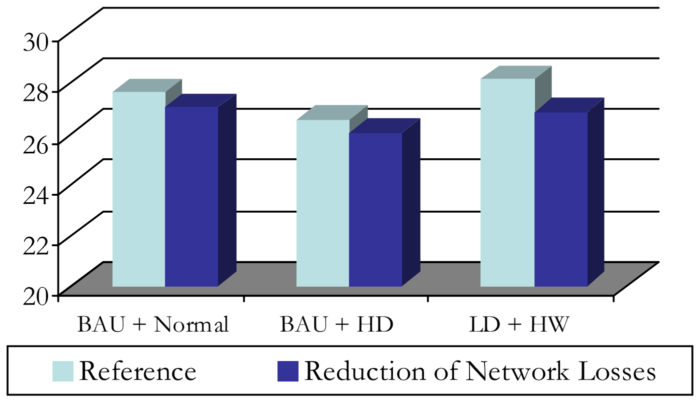


Figure 9-45 Total direct cost difference of the Reduction of Network Losses option under the three scenarios (Present Value – Million €)

Additionally, in all three cases direct costs are smaller than those of the respective reference scenario, since the volume of water delivered to domestic users is significantly lower. This reduction of annual operational costs adequately covers the expenses of the network replacements. The effect of the option is less significant under a high dry frequency; however the relatively low cost makes the measure a candidate for selection in strategy formulation.

As the introduction of network improvements does not directly affect the level of abstraction, the environmental costs within each scenario show no significant variation, with the exception of the LD+HW and BAU+HD scenarios, where the preferential abstraction from less vulnerable aquifers means an improvement in overall environmental performance (Figure 9-46).

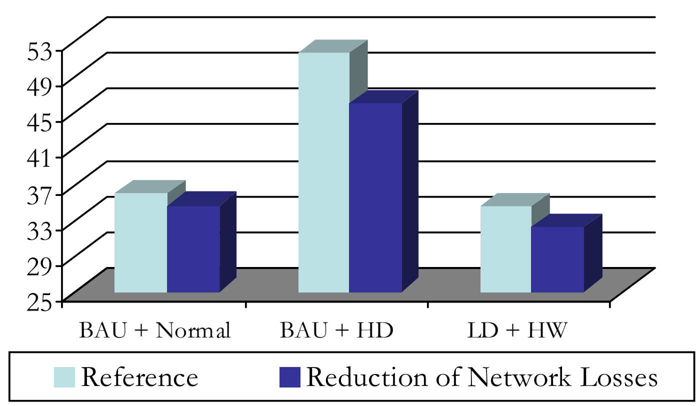


Figure 9-46 Total environmental cost difference of the Reduction of Network Losses option under the three scenarios (Present Value – Million €)

Demand Management Options

Cisterns

A traditional method for household water management is the use of cisterns that collected rainwater to be used later for various domestic uses. Today this method can be adapted to promote rational use of water resources in each household, by providing a means of storing water during the low-consumption times and alleviating pressure on the water network during peak times. The use of a cistern functioning as a water tank in each building to provide a buffering effect in the spatial and temporal distribution of the water supply could make a significant difference in the coverage of demand in areas facing problems of seasonal deficits and reduced flow at peak consumption times.

The proposed scenario assumed the existence of a state subsidy for the construction of household cisterns in areas with seasonal deficits. In order to enable modelling of this option in the DSS, it was assumed that the construction of cisterns was represented by the construction of a small storage reservoir set on the water network of each area selected for application. Each of these reservoirs was set with a capacity reflecting the total of the proposed cisterns, and the corresponding cost. The capacity of the reservoirs was estimated according to the permanent population of each area, assuming an initial penetration of the intervention at the range of 50% of households. A possibility for expanding this capacity by 20% after 5 years or more was also considered. Initial capacity and associated capital cost for each municipal department are presented in Table 9-10.

Table 9-10 Estimated capacity and cost for cisterns

Municipal Department	Permanent Population (2001)	Number of cisterns	Initial Capacity (m^3)	Capital Cost (thousand €)[10]
Paroikia	5812	937	20,150	2,063
Marpissa	984	159	4,000	350
Arhilohos	910	147	3,150	323
Naoussa	3027	488	10,500	1,075
Kostos	374	60	1,300	133
Total	11107	1791	39,100	3944

The total volume of water stored and used during the summer is presented in Figure 9-47.

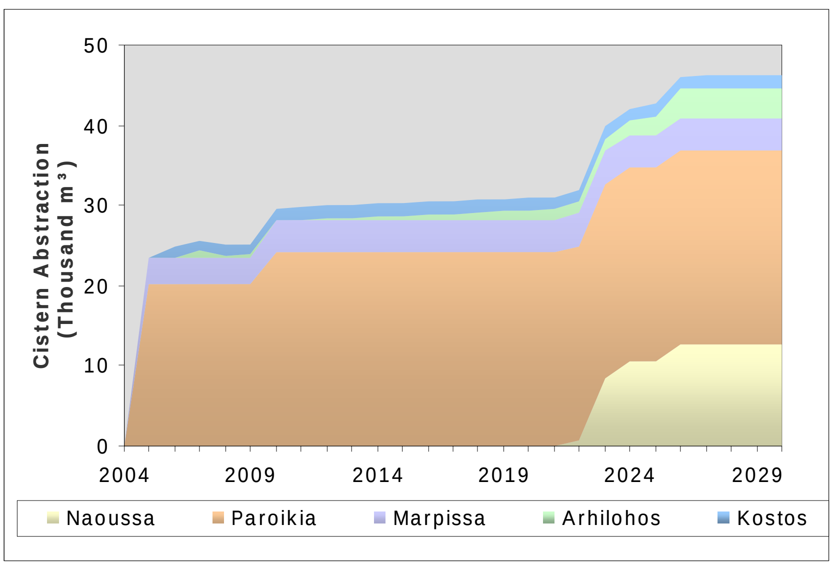


Figure 9-47 Cistern abstractions under the BAU + Normal scenario

[10] Assuming an average cost of approximately 2,200 €/cistern

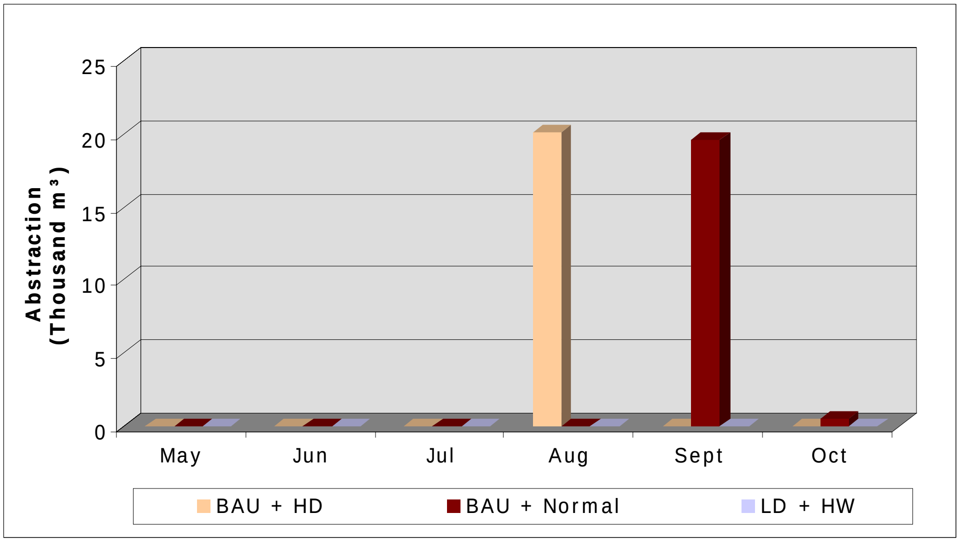


Figure 9-48 Abstractions from Paroikia cisterns under the three scenarios (2009)

This abstraction may vary according to the water availability for each year. Figure 9-48 presents abstractions from the cisterns in the Paroikia municipal department for the three scenarios in year 2009. For an average year, cisterns are used during September and October, since available supply is adequate to meet the August peak. In cases of drought and limited available resources, abstraction takes place in August, while for wet years cisterns are not needed at all.

Domestic deficit does not present any significant improvement; as demand escalates, the initial improvement of 10% falls to approximately 3% in 2030 (Figure 9-49 and Figure 9-50). The small increase in groundwater abstractions, used to fill up the cisterns, results in a similar deterioration of irrigation deficit and decreases in effectiveness (Figure 9-51 and Figure 9-52).

Overall, the option can help to alleviate some pressure on available resources during the high demanding summer months while improving the reliability of domestic supply. Of course the small capacity cannot adequately meet the structural deficit appearing in some municipal departments, and an expansion of the application of the option in the hotel sector is considered unrealistic. Additionally, the measure is not effective in cases of drought and escalating demand.

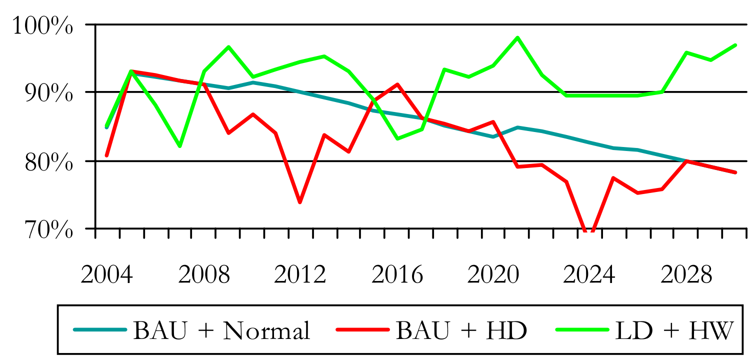


Figure 9-49 Percent demand coverage effectiveness of Cisterns to Domestic use

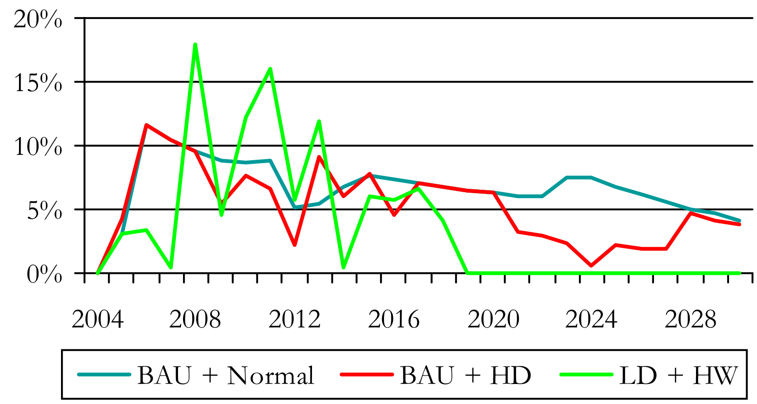


Figure 9-50 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Cisterns option)

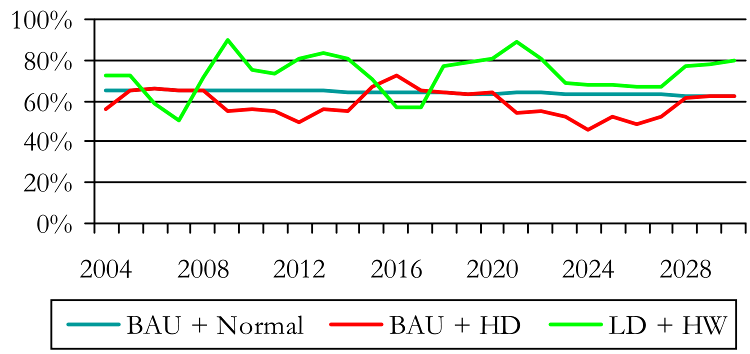


Figure 9-51 Percent demand coverage effectiveness of Cisterns to Irrigation use

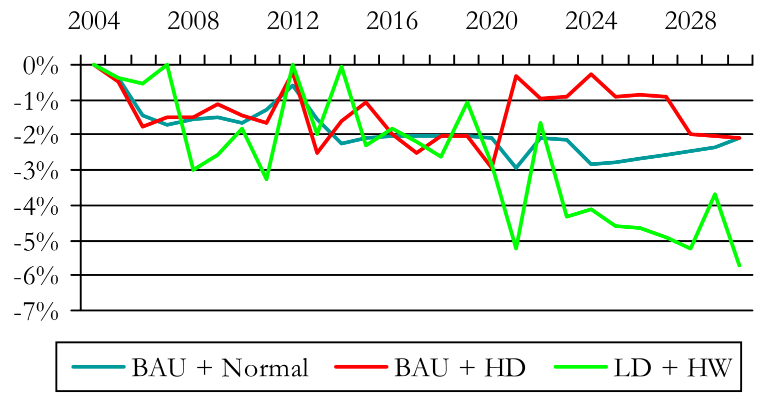


Figure 9-52 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Cisterns option)

Figure 9-53 presents the direct cost (expressed as the present value over the period 2004-2030) between the three scenarios after cistern construction. In two cases, direct costs increase about 8-10% due to the high subsidies for allowing the penetration of cisterns into the supply system.

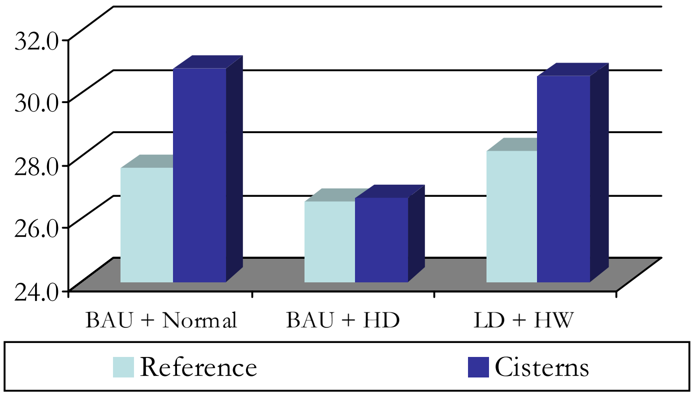


Figure 9-53 Total direct cost difference of the Cisterns option under the three scenarios (Present Value – Million €)

Environmental costs present a marginal increase, due to the augmentation of groundwater abstractions, which are used for filling up the cisterns during the low peak months (Figure 9-54).

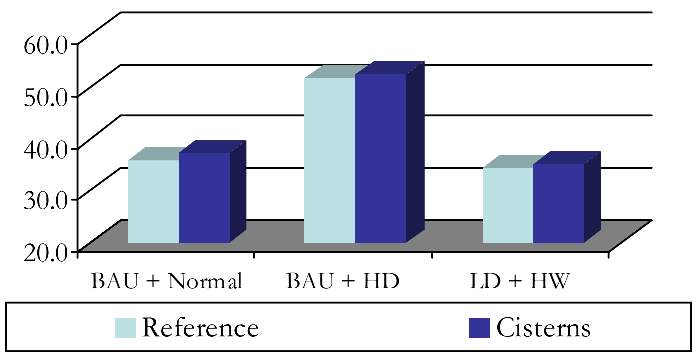


Figure 9-54 Total environmental cost difference of the Cisterns option under the three scenarios (Present Value – Million €)

Improvement in Irrigation Methods

Although agriculture in Paros Island is not the major economic activity, it is vital to the local economy and social structure. The climatic conditions on the island demand that any crops need to be irrigated, for at least part of the year; the season of highest irrigation demand coincides with the peak tourist season, creating strong conflicts. At the same time, farmers have neither been educated on how to improve irrigation efficiency, nor are they offered any significant incentives to reduce their water usage. Current irrigation efficiency is estimated to be in the range of 50%.

The scenario that has been evaluated for improvement of irrigation methods assumes a transition from the currently used irrigation methods, which mostly involve furrow irrigation, with drip irrigation that is most efficient, for all crop types with the exception of cereals (in the case of garden vegetables or pulses it is assumed that cultivation takes place in greenhouses).

The improvement was applied gradually in 4 time steps, with time intervals of at least two years between each. Initial application corresponded to 2005, with cost estimated at 0.45 €/m^2. The maximum feasible penetration was defined by the crop cultivation patterns in each area. Figure 9-55 presents the scheduling for the application of drip irrigation in the municipal department of Agairia under the three scenarios.

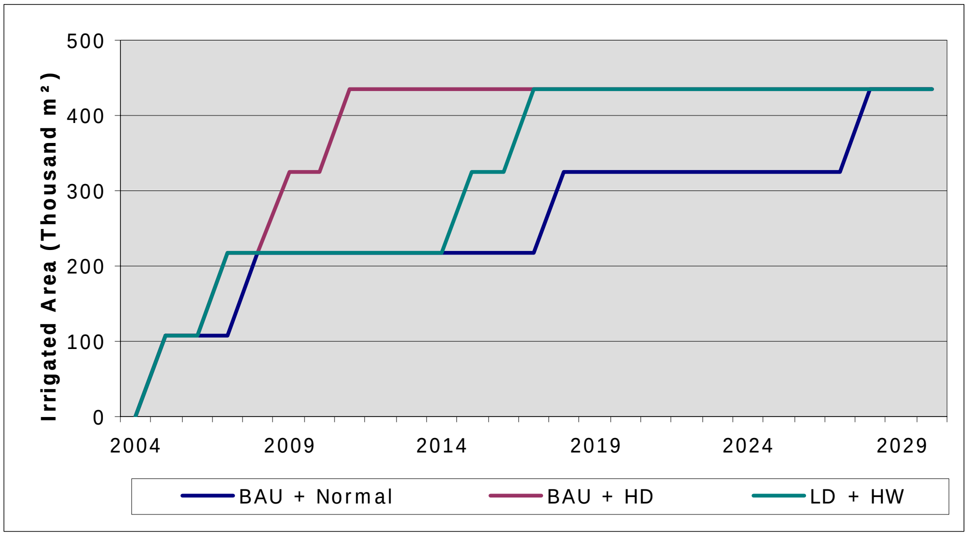


Figure 9-55 Application of drip irrigation in Agairia under the three scenarios

Effectiveness to domestic demand coverage presents minor increases under all three scenarios and exhibits a decreasing trend as the demand escalates (Figure 9-56). The improvement of domestic deficit with respect to each reference scenario is minor, with maximum values ranging from 12% (BAU+Normal) to 35% for the wet periods of the LD+HW scenario (Figure 9-57). This is due to the reduction of irrigation demand and therefore groundwater abstractions during the low peak months, which results in higher groundwater availability for the prioritised domestic use during the peak summer period.

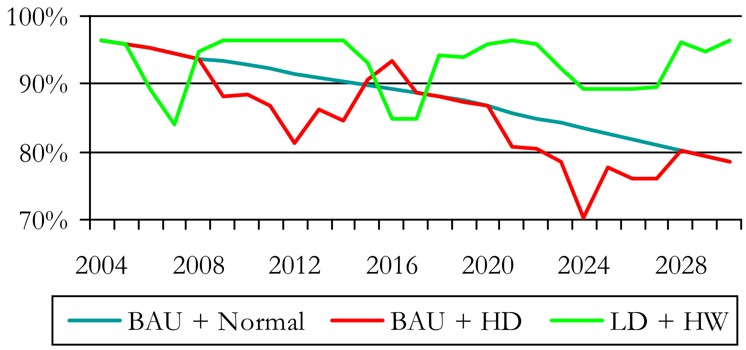


Figure 9-56 Percent demand coverage effectiveness of Improvement of Irrigation Methods to Domestic use

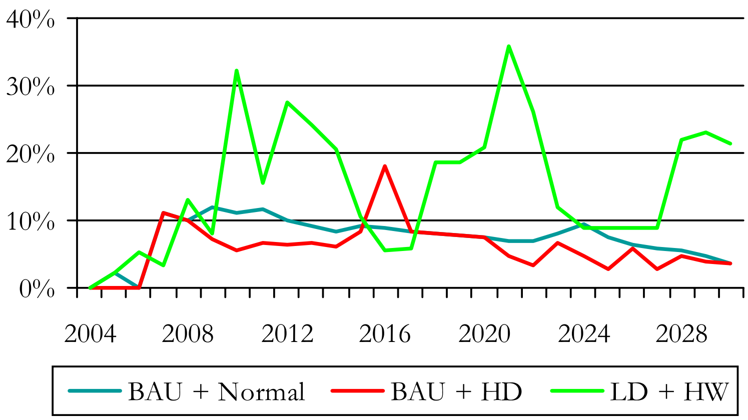


Figure 9-57 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Irrigation Method Improvement option)

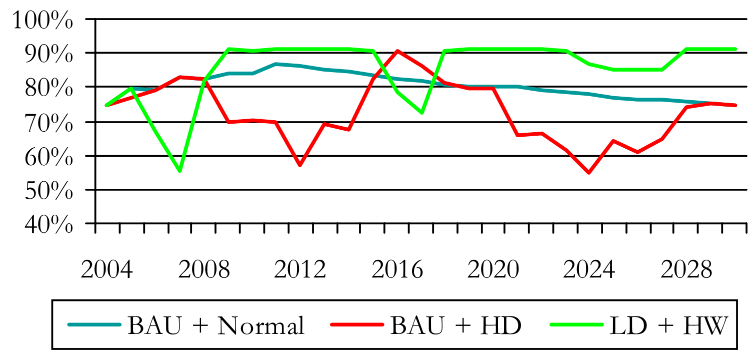


Figure 9-58 Percent demand coverage effectiveness of Improvement of Irrigation Methods to Irrigation use

Improvement in irrigation demand coverage is of course very important, reaching a maximum of 90% in terms of effectiveness and of approximately 65% in terms of relative deficit improvement (Figure 9-58 and Figure 9-59). However, it should be emphasised that even after irrigation method improvements, irrigation demand is not fully met. Additionally, irrigation deficit improvement is much lower in cases of drought, when available supply is low and a higher priority is given to domestic uses.

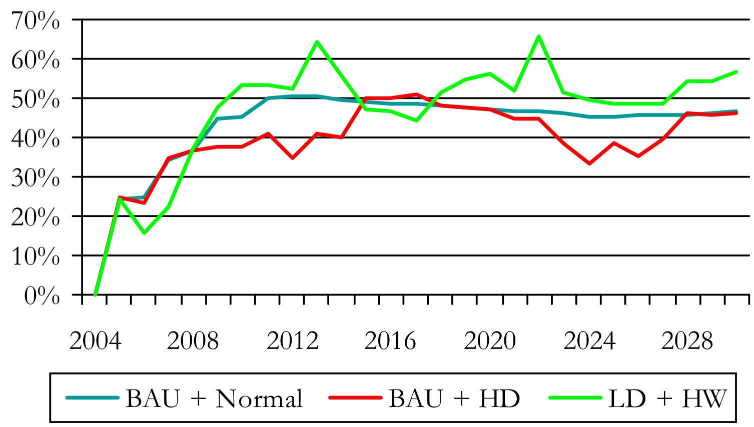


Figure 9-59 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Irrigation Method Improvement option)

Direct cost increases are significant, of the order of 25% (Figure 9-60). This augmentation is due to the increase of two cost components:

- Capital costs, which are associated with the provision of subsidies to farmers for the implementation of the option;
- Increase of operating costs due to the marginal increase of domestic water consumption during the peak summer months.

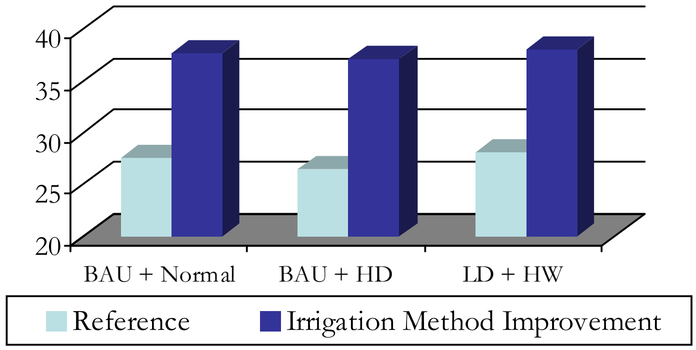


Figure 9-60 Total direct cost difference of the Improvement of Irrigation Methods option under the three scenarios (Present Value – Million €)

The total environmental cost does not differ much after the application of the option, presenting only a small decrease with the exception of the BAU+HD scenario. Since both domestic and irrigation demands are not fully met, all available resources are exploited; thus environmental costs associated with groundwater abstraction remain constant with small variations (Figure 9-61).

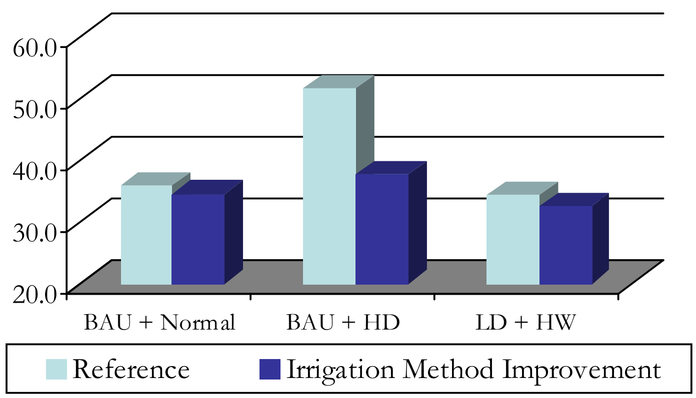


Figure 9-61 Total environmental cost difference of the Improvement of Irrigation Methods option under the three scenarios (Present Value – Million €)

Conservation Measures in Domestic Use

A large proportion of the water consumed by the domestic sector is never actually used and eventually wasted, particularly so in the case of tourist services. Some of this is due to lack of awareness, while a large amount is due to inappropriate or faulty equipment - high pressure showerheads, large volume flushes, leaky or dripping faucets to name a few. In addition to increasing awareness about water issues, there are also several technical methods for effecting a decrease of water consumption in the domestic sector, such as dual/reduced flow flushes, low-flow taps, and water meters.

The scenario evaluated for the application of conservation methods in the domestic sector, including in this case the tourist industry, assumed a state subsidy for the installation of low flow taps in households and in hotels. The initial penetration of the measure was assumed to be 40% of all households, a figure doubled and reaching 80% at the point in time where a large water deficit was estimated to appear. Figure 9-62 presents domestic demand after the successive applications of conservation measures.

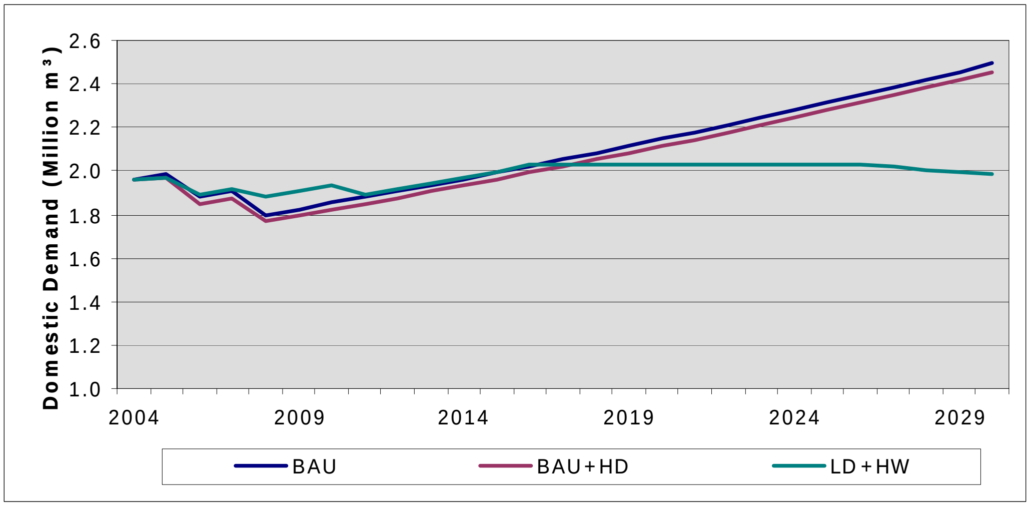


Figure 9-62 Domestic demand after the application of conservation measures for the three scenarios

Domestic conservation can be an effective response in terms of domestic demand coverage, since it can stabilise the effect of domestic demand increase for a period of approximately 10 years (Figure 9-63). The maximum improvement in domestic use deficit is reached under high wet conditions, while under a normal (average) water availability sequence, this reaches a maximum of 47% in year 2015 (Figure 9-64). After that, the effect of the application of the option gradually reduces as demand escalates. The same improvements, although more decreased, stand for the effectiveness to irrigation demand coverage and the improvement of irrigation deficits, with a more pronounced effect under the LD+HW scenario (Figure 9-65 and Figure 9-66).

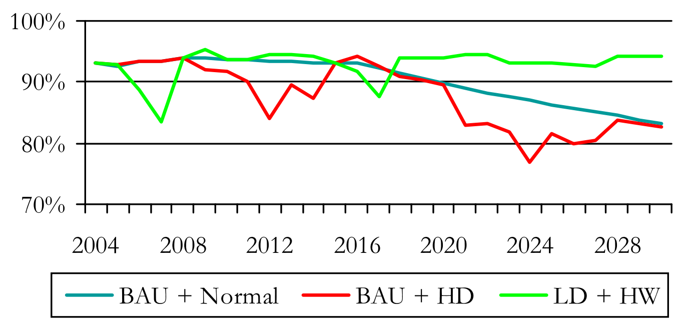


Figure 9-63 Percent demand coverage effectiveness of Domestic use Conservation measures to Domestic use

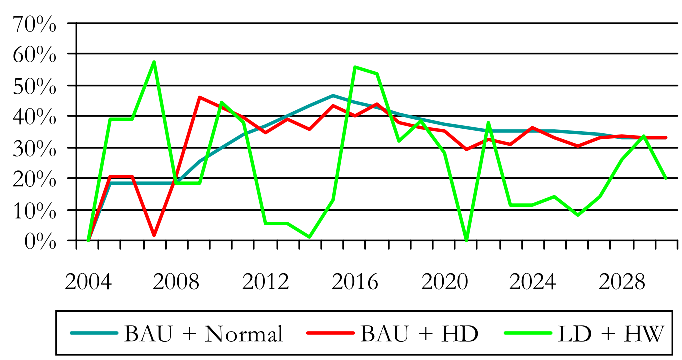


Figure 9-64 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Domestic conservation option)

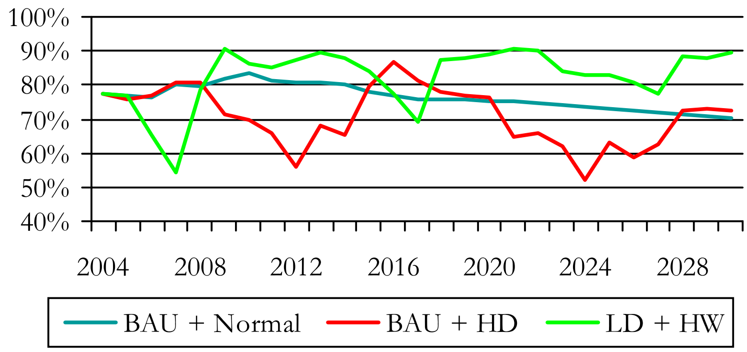


Figure 9-65 Percent demand coverage effectiveness of Domestic use Conservation measures to Irrigation use

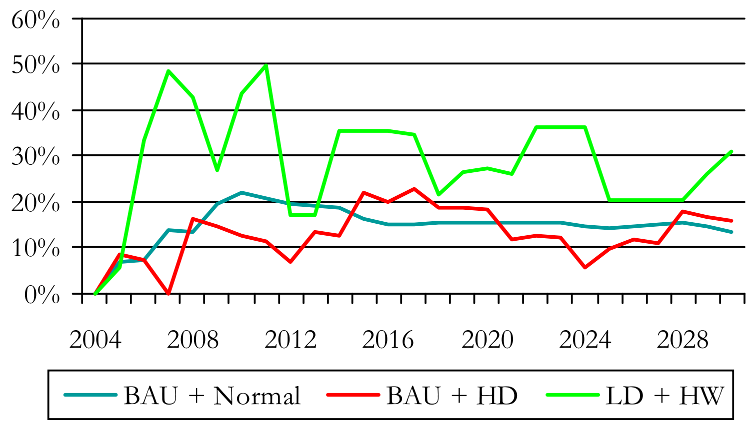


Figure 9-66 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Domestic conservation option)

As with all measures aiming to enhance the efficiency of domestic usage, conservation results in a decrease of the total direct cost of the system, of about 8-10%, due to the reduction of operating costs associated with domestic water supply (Figure 9-67). The effect is more intense than the one associated with network loss reduction, since the cost of conservation is much lower than the one associated with network replacements.

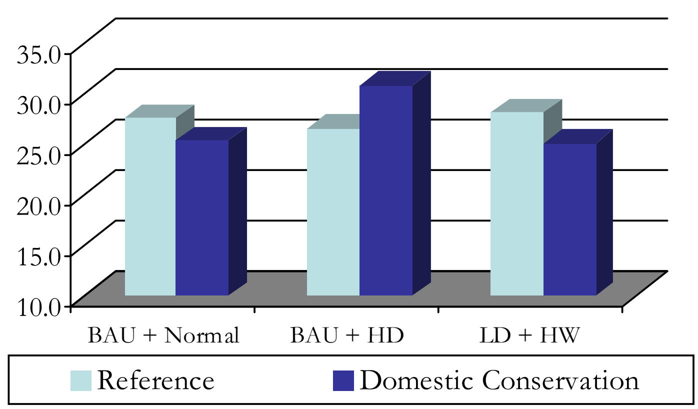


Figure 9-67 Total direct cost difference of the Domestic use Conservation measures option under the three scenarios (Present Value – Million €)

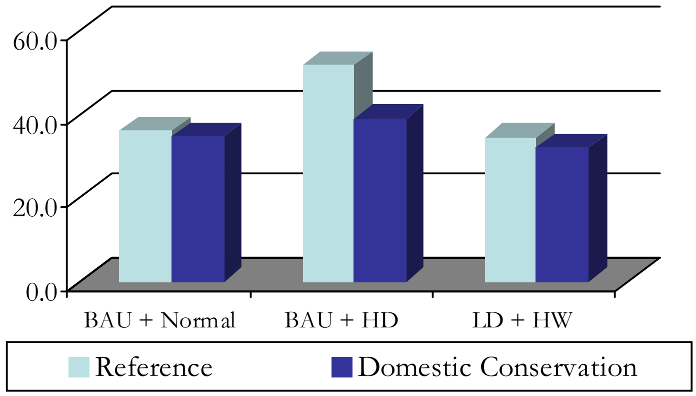


Figure 9-68 Total environmental cost difference of the Domestic use Conservation measures option under the three scenarios (Present Value – Million €)

Similarly to the reduction of network losses, domestic conservation does not directly affect groundwater abstraction volumes. Therefore, with the exception of the LD+HW scenario, environmental costs do not show significant variation (Figure 9-68).

Pricing

Domestic Water Pricing

Although the management of domestic water supplies is the responsibility of one single authority, prices throughout the island are not uniform. The current weighted average selling price is at approximately 1.45 €/m^3 with the highest prices being charged during the summer period. Water is most expensive in the municipal department of Naoussa (1.57 €/m^3), Paroikia (1.54 €/m^3) and Marpissa (1.52 €/m^3), while the lowest prices are charged in the water-rich departments of Arhilohos (0.73 €/m^3) and Lefkes (0.42 €/m^3). No data exist on the conservation incentives of the existing tariff system, making it hard to estimate an elasticity of the demand on price.

In the scenario examined for domestic pricing, the goal was not of course to lower consumption in order to achieve a better coverage of domestic needs, but to estimate the effect that a price increase would have on demand. For this purpose, and since consumption rates are relatively low, a small elasticity of -0.2 was assumed for residential and tourist consumption. The pricing scheme that was examined was a gradual increase (every two years) of average prices from 1.6 €/m^3 to 2.5 €/m^3. Figure 9-69 presents the new domestic demand under the examined pricing scheme for the BAU scenario.

The domestic demand decrease, due to the rather large augmentation of prices directly affects domestic demand coverage effectiveness (Figure 9-70). Especially under the LD+HW scenario, domestic pricing stabilises effectiveness above 90%. Similarly, domestic deficits present a significant improvement, reaching almost 80% under the BAU+Normal and LD+HW scenario (Figure 9-71). Similar trends are observed for irrigation water use. After a point, the gradual increase of domestic demand, due to population growth results to the gradual decrease of irrigation effectiveness (Figure 9-72). The same observation stands for the relative improvement of irrigation deficits. However, the effect under the LD+HW scenario is much more pronounced, in some cases exceeding even 20% with respect to the reference case (Figure 9-73).

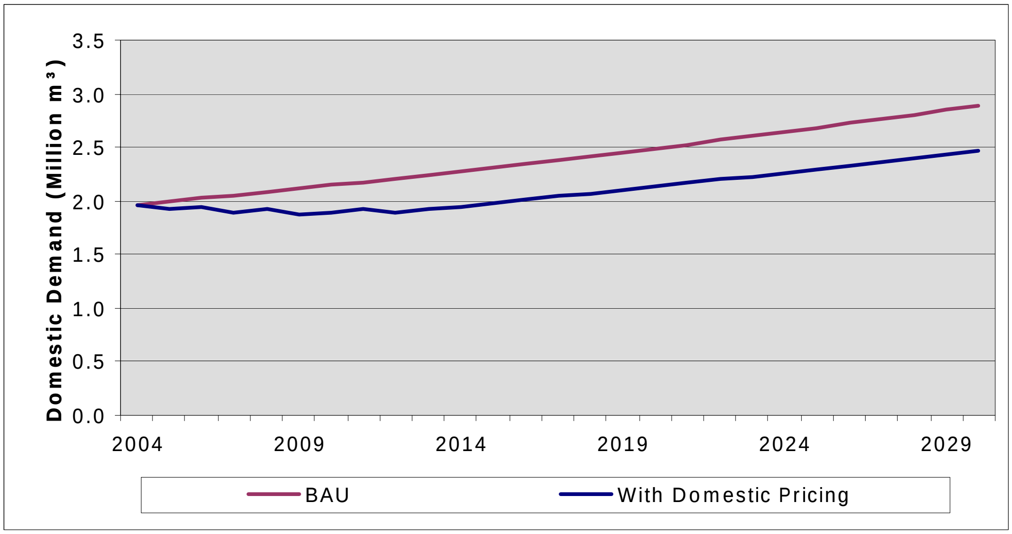


Figure 9-69 Domestic demand before and after pricing application (BAU demand scenario)

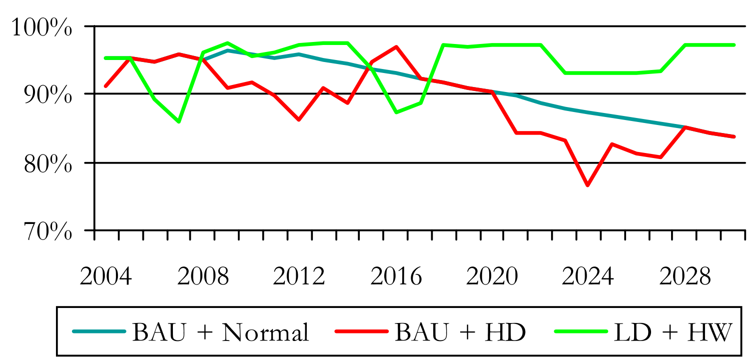


Figure 9-70 Percent demand coverage effectiveness of Domestic Use Pricing to Domestic use

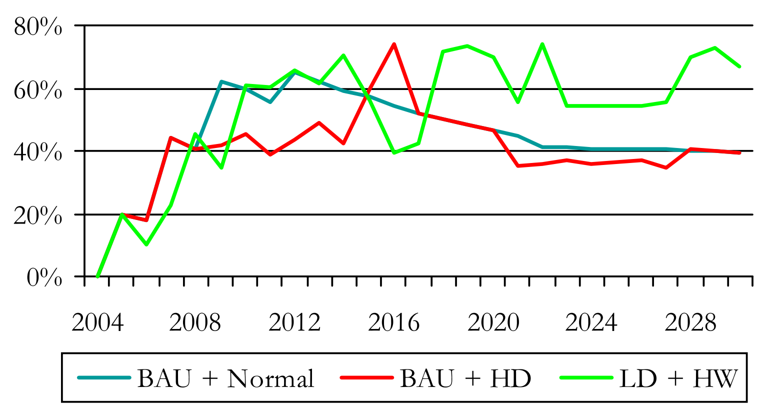


Figure 9-71 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Domestic use pricing option)

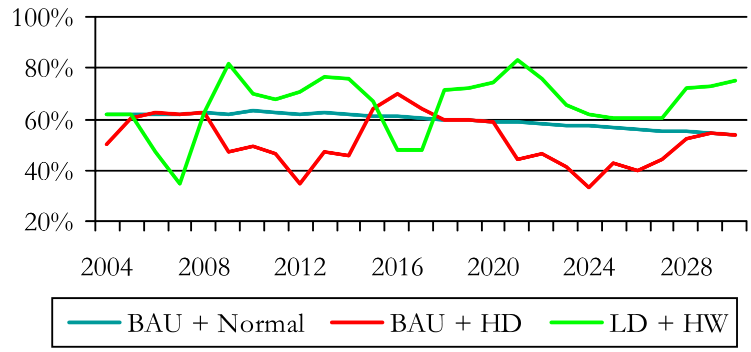


Figure 9-72 Percent demand coverage effectiveness of Domestic Use Pricing to Irrigation use

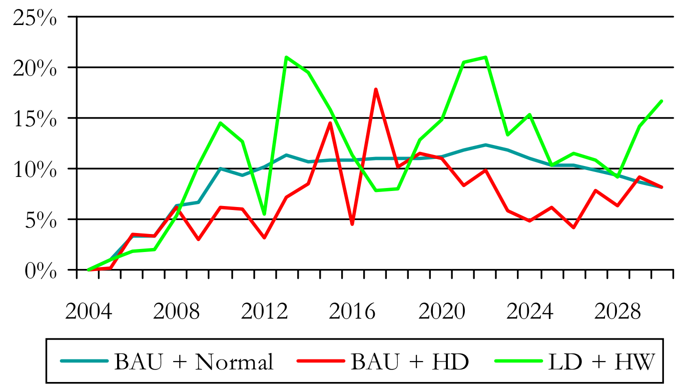


Figure 9-73 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Domestic use pricing option)

In all cases the option results in a significant decrease of direct costs (Figure 9-74). This is due to the fact that operational costs are primarily associated with domestic use. Consequently, the reduction of supply delivered to domestic use incurs a direct cost decrease, which is more pronounced under the BAU+Normal and LD+HW scenarios.

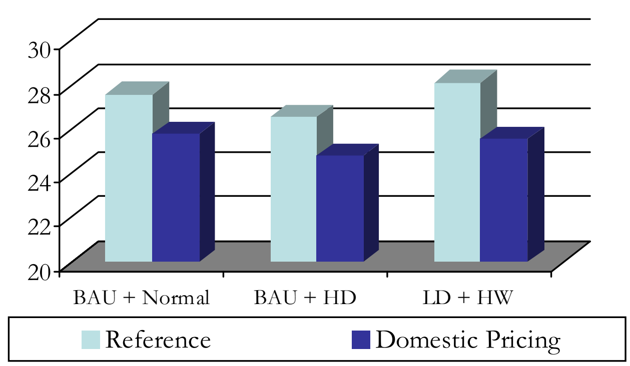


Figure 9-74 Total direct cost difference of the Domestic Use Pricing option under the three scenarios (Present Value – Million €)

Total environmental costs present a marginal decrease, since in some aquifers unsustainable groundwater abstractions are reduced. However, the total volume of groundwater abstractions more or less remains constant, and therefore, the decrease of the total environmental cost is very low (Figure 9-75).

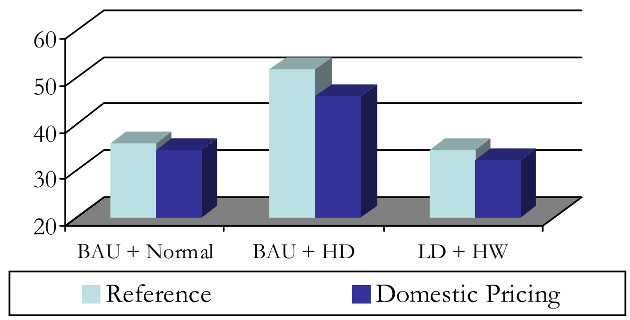


Figure 9-75 Total environmental cost difference of the Domestic Use Pricing option under the three scenarios (Present Value – Million €)

Irrigation Water Pricing

As in most places in Greece, irrigation water is not charged or an area charging system is used. In the case of Paros, with the exception of the municipal department of Naoussa, there is no central irrigation system and normally irrigation activities are supported through private boreholes operated by the farmers themselves or by farmer associations. Although no data exist either for prices or for demand elasticities, an assumption is made for estimating the impact that a small pricing system would have on irrigation demand. For this purpose it is assumed that initially (2004) prices for irrigation are set at 0.07 €/m^3 and they are gradually increased by 0.02 €/m^3 every two years during the period 2005-2009. The elasticity of demand on price is assumed to be equal to -0.4 for annual crops and -0.2 for permanent crops. Irrigation demand under the selected pricing scheme is presented in Figure 9-76.

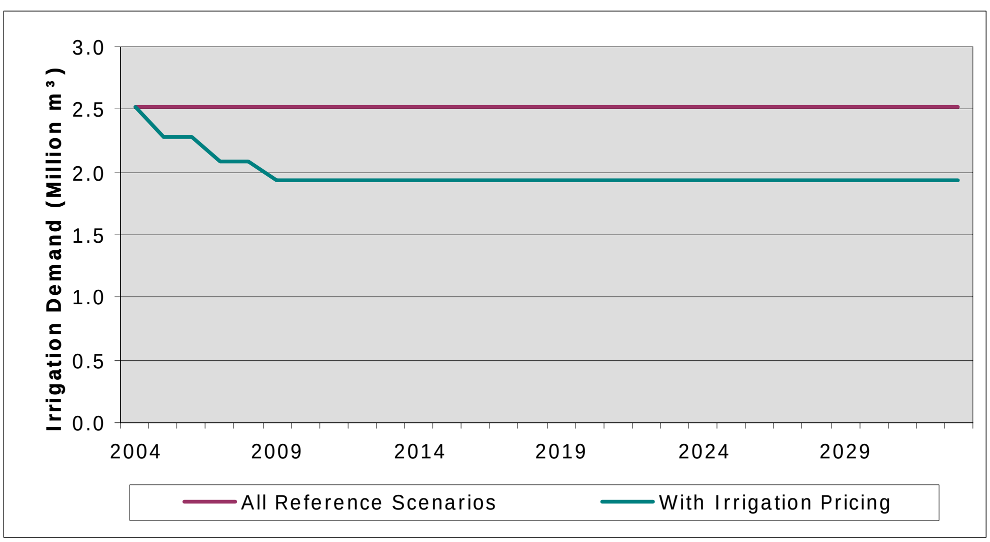


Figure 9-76 Irrigation demand before and after the application of a pricing scheme

As with domestic pricing, irrigation water pricing has a significant impact on agricultural demand. The high price increase and the relatively high tentative elasticity assumed lead to a considerable improvement of domestic and irrigation deficits. This improvement is adequate to stabilise the effectiveness to domestic demand coverage up to the year 2010, provided of course that water availability is constant (Figure 9-77). Similarly, the improvement of domestic deficits reaches a maximum of 15% during the same period (Figure 9-78).

The impact on the effectiveness to irrigation demand coverage is higher (Figure 9-79). It reaches approximately 90% under the LD+HW scenario, while under the BAU+Normal scenario it drops at 80% due to the increase of domestic demand. The improvement with respect to each reference case shows a stabilising trend, around 50%.

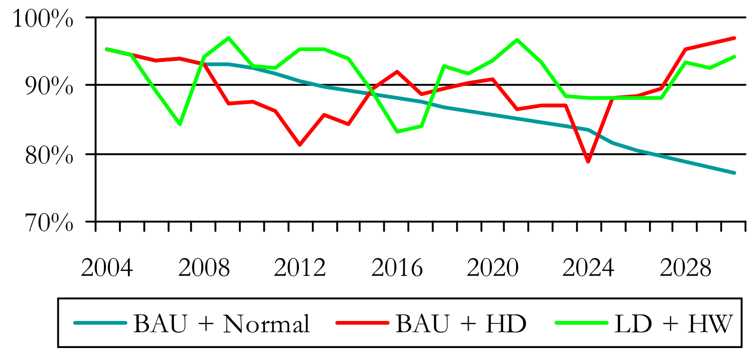


Figure 9-77 Percent demand coverage effectiveness of Irrigation Pricing to Domestic use

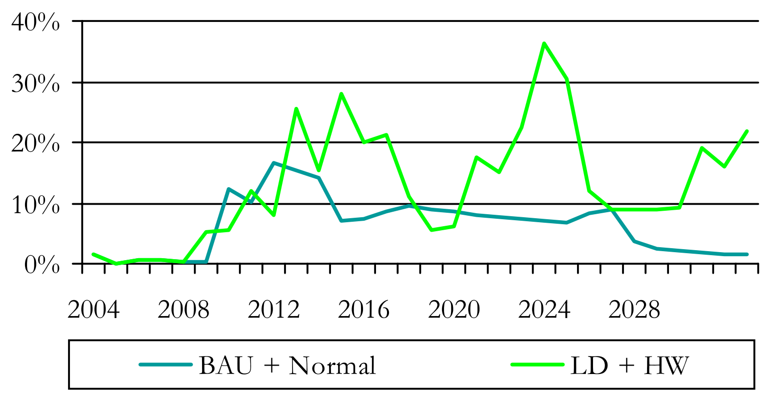


Figure 9-78 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Irrigation pricing option)

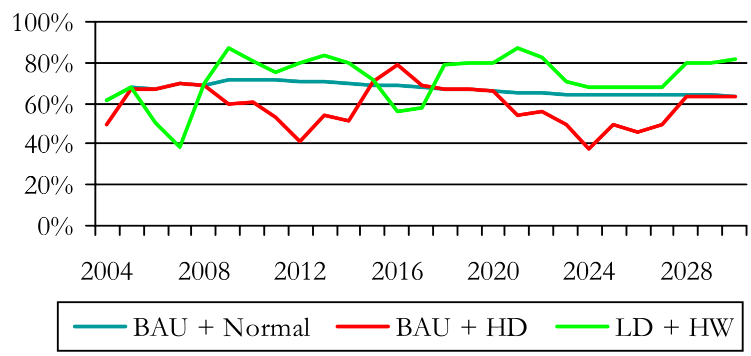


Figure 9-79 Percent demand coverage effectiveness of Irrigation Pricing to Irrigation use

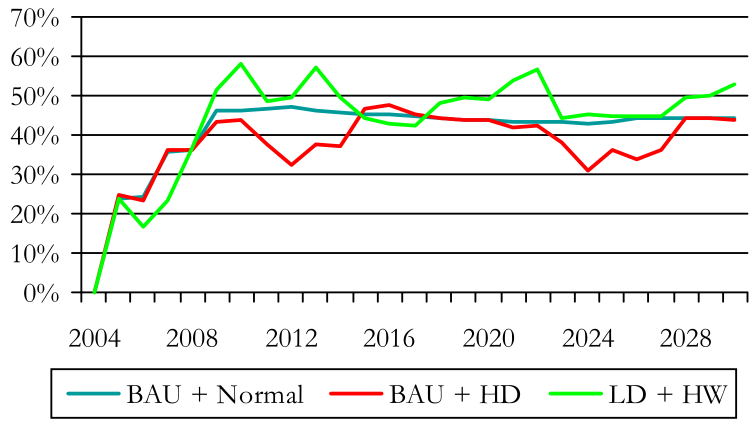


Figure 9-80 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Irrigation pricing option)

Reduction of irrigation demand results in the augmentation of supply delivered to domestic uses. This in turn, increases the operating costs of the system and leads to an average increase of about 2-3% on direct costs (Figure 9-81).

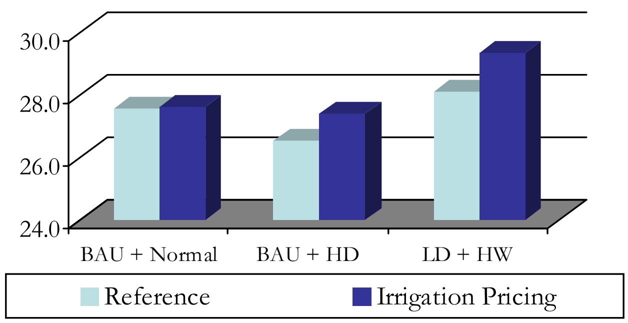


Figure 9-81 Total direct cost difference of the Irrigation Pricing option under the three scenarios (Present Value – Million €)

A rather important decrease can be observed in environmental costs, after the application of the irrigation pricing option. The lower value is observed for the BAU+Normal scenario (7%), while higher reductions are evident under the variable availability conditions of BAU+HD and LD+HW scenarios (approximately 10%, Figure 9-82).

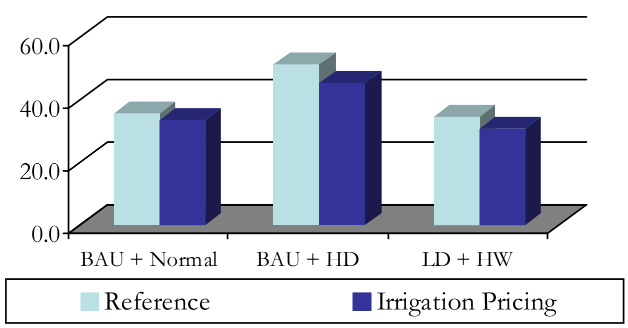


Figure 9-82 Total environmental cost difference of the Irrigation Pricing option under the three scenarios (Present Value – Million €)

Summary and Conclusions

The selection of options considered applicable for the formulation of strategies for the island of Paros was based on the Performance Matrix derived from the simulation results of the examined measures and instruments.

The following paragraphs present a summary of the outcomes of the comprehensive scenario analysis. The derived Matrix, is presented at the end of this Chapter where a final comparison is made between the examined methods, and some considerations are given with regard to the potential effect that each option could have when integrated into a strategic plan.

Network Unifications

For network unifications the scenario analysis focused on the effect from the application of network expansions in order to unify the distribution networks of neighbouring municipal departments. The analysis did not incorporate the integration of additional supply enhancement options, such as boreholes or storage reservoirs, but mainly aimed to analyse the extent to which scarcity problems could be alleviated by a more equal spatial distribution of resources. Under average availability conditions, the analysis on unification of the island's fragmented networks showed that such an option can lead to an increase of about 40 % in domestic demand coverage. This effect becomes smaller as demand increases, since larger water quantities are required for satisfying local needs before making water transfers through the new connections. Overall, the measure had a positive effect only in domestic demand coverage, an effect that is higher in water-rich years and high availability conditions. However, benefits observed are not great and are highly dependent on the yearly water availability.

All in all the option is not exceedingly expensive, with direct cost increasing only marginally. This stands only for the assumption that the unifications proposed are between neighbouring municipal departments. Those results demarcate that through combination with other, small-scale structural solutions, network unifications may prove to be an effective solution for alleviating water scarcity problems.

Desalination

The option that was examined was the construction of four additional desalination units, mainly aimed to supply tourist areas. The total required capacity can range from 2,750 m^3/d in 2005 to 4,000 m^3/d in 2021. Desalination is the structural solution that performs the best among all those that have been examined. Units were designed to meet 95% of the observed domestic deficits, under all availability conditions. Under this assumption, the evaluation of the option depicted that at throughout the examined horizon (period 2005-2030) the improvement of domestic demand coverage can even reach 85% with respect to the BAU (Business as usual) scenario. The lower dependence of domestic use to groundwater resources results in higher volumes of water available for irrigation, thus improving irrigation demand coverage up to 25%. Despite the observed improvement and in spite of recent technological advances, which lower the energy cost, desalination remains a very expensive solution. A 30% increase of costs (in present value terms) is anticipated if a water management strategy predominantly relies on desalination. A combination of this option with others, mostly non-structural solutions should be therefore preferred in an effort to limit the required capacity and avoid incurring very high additional costs to consumers.

Groundwater Exploitation

The additional use of 4 boreholes for sustainable abstraction in selected sites proposed by the hydro-geological study of Paros (Bezes, 1996) was examined, for the augmentation of the available water supply in the months following the summer peak. The total yield of the new boreholes was equal to 204,000 m^3/yr[11] and they were mainly intended to supply the important tourist areas and some small villages. Additional groundwater exploitation is the option that has the worst performance among the examined structural interventions. Although it may assist in meeting some domestic requirements, this effect is almost diminished in cases of drought and increasing demands. Another impact is strongly related to the aggravation of irrigation deficits; more intensive abstraction for domestic use leaves fewer quantities available for irrigation consumption. Consequently, the irrigation deficit can increase by as much as 20% with respect to a normal water shortage scenario. The generally low financial cost and the high environmental cost of groundwater exploitation are reflected also in the scenario analysis. Construction and operational costs are low; however, due to the augmentation of water abstracted and delivered to domestic users, annual direct costs increase by 5 to 7%.

Storage Reservoirs

In recent studies, two separate proposals have been made for the construction of storage reservoirs; the first involved the construction of a dam for domestic supply and the second the construction of an interception dam. The first storage reservoir, which through a drinking water treatment plant and a perimetric network would be able to supply the entire island, would store water from nearby springs as well as runoff. The total capacity of the reservoir was estimated at 450,000 m^3. The second is an interception dam would be used for aquifer enhancement in an area with significant groundwater exploitation for both agricultural and domestic purposes. The capacity of the dam was estimated at 98,000 m^3.

Scenario analysis demarcated that storage reservoirs are an effective solution in meeting domestic and irrigation needs, with maximum improvements similar to those of desalination (almost 75 and 30 % respectively[12]). This however is valid under the assumption of average/normal availability conditions. Run-off and hence storage are strongly dependent on precipitation levels. Therefore the sole dependence of a supply system on storage reservoirs was found to make the system vulnerable to periodic droughts. Since alternative financing schemes were not examined at this stage, the costs associated with the application of the option were considerably high. Even without including additional operational costs for pumping and treatment, the construction of the dam for domestic supply incurred very high capital costs. This resulted in an overall increase of direct costs around 30 %. In terms of cost, this ranks this option as similar to desalination, which is a much more flexible solution in terms of supply and reliability. However, the interception dam can, with significantly lower costs, help in the mitigation of the impacts of aquifer overexploitation, and assist in sustaining the irrigation of the traditional vineyards in the nearby areas.

Reduction of Network Losses

The option that was explored was a gradual reduction of losses from 25 % to 15 %, through successive network replacements. The application of this intervention was made on the assumption that internal network replacement will be gradually applied in the different municipalities. The network replacement program was estimated to last around 4 years, with

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[11] Under average availability conditions

[12] Under average availability conditions.

the assigned scheduling of network replacements being made according to demand size, and current network status. Reduction of losses through distribution network replacements shows a significant improvement in terms of domestic and irrigation demand coverage as well as groundwater exploitation. The effect is much more evident under normal/average availability conditions, reaching almost 60 % in domestic deficit coverage, but it decreases as demand gradually grows. The improvement of irrigation demand coverage and groundwater overexploitation is much lower, of about 10 %. As with other measures that limit domestic water consumption, network replacement results in a decrease of direct costs. Therefore, capital expenses associated with network improvements can adequately be met through the reduction of annual operational costs associated with domestic abstractions.

Cisterns

The subsidisation of cistern construction in households of Paros was examined, assuming an initial penetration of the intervention at the range of 50% of households (initial capacity of 39,100 m^3) and the possibility for expanding this capacity by 20% after 5 years or more.

Overall, the option can help to alleviate pressure on available resources during the high demand summer months while improving the reliability of domestic supply. However, the small capacity of cisterns renders the impact of the option minor, with a maximum improvement of 10%. It should be noted that an expansion of the application of the option in the hotel sector is considered unrealistic, given the current legislative and socio-economic environment. Additionally the measure was not effective in years of low water availability and drought, while the initial noted improvement diminished as demand escalated. The high subsidies required for allowing the penetration of cisterns into the supply system are reflected in direct costs, which on an annual basis may increase up to 30 %.

Improvement in Irrigation Methods

The measure examined in this case was the transition from the currently used irrigation methods, which mostly involve furrow irrigation, with drip irrigation that is most efficient, for all crop types with the exception of cereals. The improvement was scheduled to be applied gradually in 4 time steps, with time intervals of at least two years between each, and the maximum feasible penetration was defined by the crop cultivation patterns in each region of the island. Under all shortage conditions examined, improvement in irrigation deficits is significant, ranging from 25 to 50 % (under high demand and average and low availability conditions respectively). However, although it would be expected that efficiency improvements would have a significant impact in terms of environmental performance, this is not the case. Even after such assumptions, irrigation demand was not fully met. Additionally, the effect of irrigation improvements was further diminished in cases of drought, when available supply is low and a higher priority is given to domestic uses. However, the option is the only identified means of modernizing irrigation and ensuring the preservation of agricultural activities for the island.

Conservation Measures in Domestic Use

The scenario evaluated for the application of conservation methods in the domestic sector, in this case including the tourist industry, assumed a state subsidy for the installation of low flow taps in households and in hotels. The initial penetration of the measure was assumed to be 40% of all households, a figure doubled and reaching 80% at the point in time where a large water deficit was estimated to appear.

Reduction of domestic demand through the use of water saving devices was found to directly improve, besides domestic deficit, irrigation demand coverage, since smaller quantities are abstracted to supply domestic water use. Such an improvement of the order of 40 to 60 % is indicative of the effect that soft conservation measures could have on the performance of the supply system. Environmental performance was found to exhibit an improvement of about 5 to 8%.

As with all measures aiming to enhance the efficiency of domestic usage, conservation results in a decrease of the total direct cost of the system. This reduction is due to the reduced water production, and associated running costs of the system. The effect is more pronounced than other types of efficiency improvements, since the cost associated with the application of the option is much lower.

Pricing

The domestic water pricing scheme that was examined was a gradual increase of average prices up by 50%. Additionally, for estimating the impact that a small pricing system would have on irrigation demand, it was assumed that initially prices for irrigation would be set at 0.07 €/m^3, gradually increased by 0.02 €/m^3 every two years during the period 2005-2009. In both cases and in absence of estimates, high elasticities have been assumed.

Domestic pricing performs better under average or high availability conditions, while the limited water availability under a drought diminishes the effect of the pricing scheme, even with an assumed high demand reduction. Similar, but smaller improvements are observed for irrigation demand coverage, and groundwater exploitation (around 25 and 10% respectively).

As with domestic use, irrigation pricing has a significant impact on agricultural demand. The high price increase and the relatively high tentative elasticity assumed led to a considerable improvement of domestic and irrigation deficits, and groundwater exploitation. Although one would expect that improvements would be of the same magnitude as those of domestic pricing, this is not the case. The low priority of irrigation compared to domestic demand coverage renders the use more vulnerable to availability variations, and almost diminishes the effect that pricing would have on the alleviation of the respective deficit and groundwater over abstraction. Since direct costs are associated with domestic use only, domestic pricing results in a significant decrease of direct costs. The opposite stands for irrigation pricing, where the minimisation of irrigation consumption results in higher water availability for the domestic sector.

Comparison of Options

The final selection of options that were further analysed during the strategy formulation phase depended on the performance of the options examined regarding the indicators that were presented throughout the analysis.

Results are summarized in Table 9-11. The effectiveness of each option is approached through the evaluation score obtained by the WSM DSS, from the performance with respect to domestic and irrigation demand coverage, assuming a weight of 0.5 for each indicator, and a satisfactory range of values from 80 to 100%.

Table 9-11 Option Performance Matrix

Option	Effectiveness (Relative Sustainability Index for Demand Coverage)	Direct Cost (PV in million €)	Total environmental cost (PV in million €)
Reference	0.008	27.43	40.66
Network Unifications	0.154	27.90	42.16
GW Exploitation	0.213	27.80	42.24
Desalination	0.366	35.57	37.61
Storage Reservoirs	0.214	34.38	37.79
Losses	0.172	26.63	37.57
Cisterns	0.033	29.32	41.68
Domestic Conservation	0.050	27.10	35.26
Irrigation Method Improvements	0.253	37.59	38.61
Domestic Pricing	0.218	25.39	37.53
Irrigation Pricing	0.313	28.10	36.67

Environmental sustainability is expressed through the total environmental cost for each option, associated with pollution generation and unsustainable groundwater abstractions. It should be noted that the major environmental problem faced by water management authorities in Paros lies in the overexploitation and salinisation of aquifers. Economic efficiency, the ability to produce more with less, is expressed through the total direct cost in present value terms. Results obtained for each option under all three scenarios were averaged in order to take also into account the behaviour of each measure under variable availability and different demand scenarios.

The normalisation of the results obtained in Table 9-11 under a scale ranging from 0 to 5 yields the Normalised Option Performance Matrix of Table 9-12.

From the normalised matrix presented in Table 9-12 it is obvious that a new strategy for Paros cannot rely on the application of a few instruments only. Desalination seems to occupy an advantageous position in terms of technical, economic and environmental sustainability. However, the very high cost associated with the option and technical limitations which do not allow for the installation of a capacity exceeding 5,000 m^3/d, renders the “massive” application of the option impossible. If a strategy that is developed relies predominantly on desalination, it should also incorporate measures to improve efficiency of domestic and irrigation uses and to promote conservation of the island’s vulnerable resources. Required installed capacity can also be decreased if the option is combined with small-scale structural interventions that can improve the use of existing resources.

Table 9-12 Normalised option performance matrix

Option	Relative Sustainability Index for Demand Coverage	Direct Cost	Environmental cost
Reference	-	****	-
Network Unifications	**	****	-
GW Exploitation	***	****	-
Desalination	*****	*	***
Storage Reservoirs	***	*	***
Losses	**	****	***
Cisterns	-	***	-
Domestic Conservation	*	****	*****
Irrigation Method Improvements	***	-	***
Domestic Pricing	***	*****	***
Irrigation Pricing	****	****	****

Annex

Hydrological Sequences

Table A9-1 Intra-annual rainfall variation

Year Type	Factor Relative To Normal Year											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dry	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.0	0.7	0.7	0.7	0.7
Wet	1.3	1.3	1.3	1.3	1.3	1.3	1.0	1.0	1.3	1.3	1.3	1.3

Table A9-2 Dry rainfall scenario (figures in mm)

Year	Dry		Wet		Year	Dry		Wet	
	Rainfall	Type	Type	Rainfall		Rainfall	Type	Rainfall	Type
2004	426.7	NORMAL	450.2	NORMAL	2018	439.2	NORMAL	700.0	WET
2005	357.1	NORMAL	311.2	NORMAL	2019	346.8	NORMAL	437.1	NORMAL
2006	364.3	NORMAL	269.3	DRY	2020	384.3	NORMAL	522.0	WET
2007	434.6	NORMAL	215.2	DRY	2021	229.0	DRY	526.1	WET
2008	360.1	NORMAL	584.9	WET	2022	336.8	NORMAL	478.2	NORMAL
2009	220.9	DRY	605.9	WET	2023	234.0	DRY	407.4	NORMAL
2010	427.7	NORMAL	189.9	DRY	2024	108.5	DRY	396.7	NORMAL
2011	259.6	DRY	534.1	WET	2025	359.9	NORMAL	404.9	NORMAL
2012	246.9	DRY	417.1	NORMAL	2026	150.0	DRY	518.8	NORMAL
2013	319.1	NORMAL	581.1	WET	2027	402.2	NORMAL	306.9	NORMAL
2014	142.2	DRY	375.1	NORMAL	2028	453.0	NORMAL	541.4	WET
2015	642.8	WET	486.6	NORMAL	2029	490.1	NORMAL	395.1	NORMAL
2016	377.7	NORMAL	268.8	DRY	2030	396.9	NORMAL	617.4	WET
2017	384.0	NORMAL	432.0	NORMAL					

Network Unifications' Parameters

Table A9-3 Construction years for network unifications

Connection	Year		
	BAU + Normal	BAU + HD	LD + HW
Agairia – Kampos	2005	2005	2005
Dryos – Marpissa	2005	2005	2005
Naoussa – suburbs	2005	2005	2005
Kostos – Naoussa	2028	2021	-

Desalination Parameters

Table A9-4 Capacity and construction cost for the BAU+Normal scenario

Unit	Capacity (m^3/d)		Construction Cost (€)	
	2005	2021	2005	2021
Paroikia	800	1,100	790,000	1,050,000
Naoussa suburbs	450	850	480,000	830,000
Marpissa	1,400	1,500	1290000	1,365,000
Parasporos13	-	500	-	523,000
Total	*2,650*	*3,950*	*2,560,000*	*3,768,000*

Table A9-5 Capacity and construction cost for the BAU+HD scenario

Unit	Capacity (m^3/d)		Construction Cost (€)	
	2005	2021	2005	2021
Paroikia	900	1200	873,000	1,123,000
Naoussa suburbs	450	1100	480,000	1,041,000
Marpissa	1,400	1,500	1,290,000	1,365,000
Parasporos	-	600	-	612,000
Total	*2,750*	*4,400*	*2,643,000*	*4,141,000*

[13] The Parasporos unit in the BAU + Normal scenario is constructed in 2026 and supplies the southern part of the municipal department of Paroikia and a part of the tourist facilities of the settlement

Table A9-6 Capacity and construction cost for the LD+HW scenario

Unit	Capacity (m^3/d)		Construction Cost (€)	
	2005	2021	2005	2021
Paroikia	850	850	830,000	830,000
Naoussa suburbs	250	250	285,000	285,000
Marpissa	1,200	1,200	1,123,000	1,123,000
Parasporos	-	-	-	-
Total	*2,300*	*2,300*	*2,238,000*	*2,238,000*

Groundwater Exploitation Parameters

Table A9-7 Simulated construction years for the new boreholes for the three scenarios

Borehole	Simulated Construction Year		
	BAU – Normal	BAU – HD	LD – HW
Arhilohos	2006	2006	2007
Glysidia	2005	2005	2005
Kostos 1	2005	2006	2006
Kostos 2	2011	2007	2007

Reduction of Network Losses Parameters

Table A9-8Scheduling of network replacements

Municipal Department	BAU + Normal	BAU + HD	LD + HW
Paroikia	2005-2008	2005-2008	2005-2007, 2009
Naoussa	2005-2008	2005-2008	2005-2008
Marpissa	2005-2007	2005-2007	2005-2007
Kostos	2006, 2007, 2009	2006, 2007, 2009	2006, 2007, 2009
Arhilohos, Lefkes, Agairia	2006, 2009, 2012	2006, 2009, 2010	2006, 2007, 2015

Cisterns Parameters

Table A9-9 Simulation Construction and expansion years for cisterns

Municipal Department	Simulation Construction Year[14]		
	BAU + Normal	BAU + HD	LD + HW
Paroikia	2005 (2010)	2005 (2010)	2005 (2010)
Marpissa	2005 (2010)	2005 (2010)	2005 (2010)
Naoussa	2022 (2026)	2021 (2026)	2022 (--)
Kostos	2006 (2011)	2005 (2010)	2006 (2011)
Arhilohos	2007 (2026)	2006 (2011)	2006 (2011)

Table A9-10 Parameters for the cistern expansion scheme

Municipal Department	Number of Cisterns	Capacity (m^3)	Capital Cost (thousand €)
Paroikia	187	4,030	413
Marpissa	30	680	70
Naoussa	100	2,100	215
Kostos	12	260	27
Arhilohos	30	630	65
Total	172	3670	377

Irrigation Method Improvements Parameters

Table A9-11 Total penetration of drip irrigation per municipal department

Municipal Department	Maximum Penetration (%)
Paroikia	65%
Marpissa	77%
Naoussa	68%
Kostos	43%
Arhilohos	64%
Agairia	46%

[14] Capacity expansion years are presented in the brackets

Table A9-12 Scheduling of irrigation method improvements

Municipal Department	BAU + Normal	BAU + HD	LD + HW
Paroikia			
Marpissa			
Naoussa		2005,2007,2009,2011	
Kostos			
Arhilohos			
Agairia	2005,2007,2018,2028	2005,2007,2009,2011	2005,2007,2015,2017

Chapter 10 Analysis of Water Management Options for Belice Basin, Italy

The Belice basin is characterised by strong water scarcity originating from low rainfall, especially during the summer, when water demand for agriculture is higher and the existing infrastructure is inadequate to cope with urban and irrigation demand growth.

In fact the Arancio Reservoir was built to address local water requirements, but rainfall scarcity does not allow the provision of sufficient supply of water. Because water in the Arancio reservoir is often at a minimum level, it was considered necessary to abstract additional water from Basso Belice. In order to improve the local water supply system, new irrigation techniques have been developed and applied, along with interventions aimed at using water produced in the waste water treatment plants of this territory.

Moreover, even though water is conveyed from the Garcia reservoir to supply Montescuro aqueduct, significant water losses still constitute a major issue in the region. Local authorities have adopted new measures so as to improve the efficiency of water distribution systems.

This chapter aims to provide insight to the research undertaken for the formulation of demand and availability scenarios. In addition, it presents a thorough analysis of the options analysed and evaluated for the Case Study of Belice Basin, in terms of effectiveness, direct and environmental costs. The chapter ends with a summary of the outcomes of this process with the aim to denote interventions that could be effective and reliable in meeting the emerging water management issues of the region.

Demand and Availability Scenario Components

Formulation of Demand Scenarios

Data

The formulation of demand scenarios for the Garcia-Arancio districts involved the four types of nodes: Settlement, Irrigation Site, Exporting and Tourist Site. Except for the agricultural scenarios, which were based on assumptions on the growth of cultivated land, the others involved forecasts of consumption rates, rather than growth rates of population. The necessary data was provided by the agencies shown in Table 10-1.

Table 10-1 Available information on demand components

Agency	Available Information
Land Reclamation Consortium 3 - Agrigento	Water Supply Provision for irrigation, development of new areas equipped for irrigation, constructions of tourist sites and number of beds
National Statistical Service	Permanent Population
University of Palermo + AMAP local agencies for water services (AMAP and SOGESID)	Permanent and Seasonal Population, growth rates
INEA (National Institute of Agricultural Economics)	Land reclamation of areas included into agricultural exporting nodes

According to official analyses made for the preparation of the local water resource management plans, both permanent and seasonal population of the area are not expected to increase in the next three to four decades, while the consumption rates are estimated to double during the same time. The monthly fluctuation of permanent population is not significant with seasonal variations while seasonal population is significant only during the summer period, from June to August, with almost the same monthly distribution. The total population for each settlement is presented in Table 10-2.

Castelvetrano, Menfi and Sciacca have the highest population among the settlements considered in the case study area, but their water supply sources are different. While the two latter obtain water from the Garcia Lake, the Castelvetrano relies on valuable local boreholes that cover 80% of its monthly demand, obtaining the remaining 20% from the Montescuro aqueduct. In general, the more populated sites are those having water available locally, such as Sambuca di Sicilia, S. Margherita Belice, Castelvetrano and Partanna.

The domestic consumption rates are estimated at about 170 and 200 l/capita/day for permanent and seasonal population respectively. Average network losses are rather high, varying from 33% to 44% of the delivered supply volumes.

As regards the irrigated districts, the available information about the land reclamation process, and the related equipment of new cultivable areas for irrigation with internal and external distribution networks, refers only to short time forecasts. Agricultural expansion involves the two irrigated districts of Menfi and Sciacca, and the operational start of a brand new district in the territory near the settlements of Montevago and S. Margherita Belice that will be served by the Garcia Lake. In the simulation of the case study, the cultivated land in the other districts of Castelvetrano and Sambuca di Sicilia is assumed not to increase.

Table 10-2 Permanent and seasonal population in settlements and use of local resources

Settlements	Permanent Population	Permanent (% over the total)	Seasonal Population	Seasonal (% over the total)	Use of local resources
Sciacca	40,220	34.81%	21,173	27.08%	no
Castelvetrano	27,243	23.58%	41,000	52.44%	yes
Menfi	12,760	11.04%	9,429	12.06%	no
Partanna	11,376	9.85%	2,616	3.35%	yes
Santa Margherita Belice	6,474	5.60%	500	0.64%	yes
Sambuca di Sicilia	6,159	5.33%	2,000	2.56%	yes
Gibellina	4,675	4.05%	500	0.64%	no
Montevago	3,096	2.68%	700	0.90%	no
Salaparuta	1,835	1.59%	200	0.26%	no
Poggioreale	1,711	1.48%	60	0.08%	no
TOTAL	**115,549**	**-**	**78,178**	**-**	**-**

With reference to the water demand outside the Garcia-Arancio districts, the exporting nodes being taken into account in the area symbolize urban and agricultural needs. Water transferred outside the area for urban use is requested by the exporting nodes *Urban_Agrigento, Urban_Trapani* and *Urban_Favara di Burgio*. Node *Urban_Agrigento* stands for the settlements of Agrigento served by the Montescuro aqueduct, such as Giuliana, Chiusa Sclafani and Palazzo Adriano. They have an overall population of 8,729 inhabitants, who consume a monthly volume of 44,517 m³. Exporting node *Urban_Trapani* stands for some settlements in the territories of Palermo and Trapani served by the Montescuro after it exits Belice basin at the west. They include Calatafimi, Vita, Salemi, S. Ninfa and Campobello di Mazara. The full amount of permanent and seasonal population is 59,571 inhabitants and the monthly water volume delivered is 303,812 m^3. The scenarios for these two external demands are driven by the consumption rates that tend to double in the next twenty-thirty years in the same way as the ones of internal settlements do. The third urban exporting node of *Urban_Favara di Burgio* represents the water from Garcia that is treated in the drinking water treatment plant of Sambuca di Sicilia and integrates the resources of the Favara di Burgio aqueduct, namely the water springs of Caltabellotta, in the territory of Agrigento. The annual water volume required from the treatment plant is about 2.8 hm^3.

Projections

The available information about the agricultural development is only short-term and limited. For that reason, the corresponding projections were considered in every simulated scenario to have the same weight. Projections for cultivated areas under the competence of Consortium no.3 Agrigento are shown in Table 10-3. The district of Menfi will increase by 2000 ha in the next years. The growth was assumed to take place during four years, from 2004 to 2007, with a 500 ha of increment per year. The increment for the district of Sciacca is lower: its total additional area will be 300 ha during the period of 2004-2006. The new district of Montevago-S. Margherita Belice is assumed to increase by 2500 ha in a period of four years from 2005 to 2009, with a growth of 500 ha per year.

Table 10-3 Growth of cultivated areas (Land Reclamation Consortium 3 –Agrigento)

District	Period of development	Actual Cultivated Land (ha)	Total Additional Land (ha)
Menfi	2004-2007	6,490	2,000
Sciacca	2004-2006	3,925	300
Montevago-SMB	2005-2009	0	2,500

According to data from INEA, National Institute of Agricultural Economics, the two Consortiums for Land Reclamation of Trapani and Palermo are planning an expansion of their areas equipped for irrigation from 2004. The areas of Trapani would constitute a brand new irrigated zone of 16,051 ha, in the areas 1/D and 1/C that are west to the Castelvetrano irrigated district. In Palermo two areas for a total 2,712 ha would be developed in a period of three years from 2005 to 2007. The forecast annual demands are presented in Table 10-4. Although the expansion of cultivated area is planned by the two Consortia, it was not considered in the latest simulation of the case study water network, because of not being realistic in the actual context of water scarcity and of unmet domestic demands. The irrigation demands for the exportation of these users were kept constant, and were also reduced upon the present simulated inflows to the Garcia Lake. The considered values are 7.9 hm^3 and 5 hm^3 per year for Trapani and Palermo respectively.

Table 10-4 Growth of cultivated areas outside the case study (not incorporated in the analysis)

Exporting	Period of development	Actual Annual Demand (hm^3)	Annual demand after expansion (hm^3)
Irrigation_Trapani	2005-2020	0	9.4
Consortium 2_Palermo	2005-2007	8.9	10.4

The construction of two minor tourist facilities was planned. A site is under construction in Menfi, with a total capacity of 3,000 beds, which is assumed to grow progressively by 1,000 beds per year from 2004, to be operational at 100% in 2006. The other tourist site relates to the territory of Sciacca and a total capacity in 2007 of 20,000 beds to be operational in four years. In terms of overnight stays, which is the variable driving the demand scenarios for this kind of water user, the relevant values refer to the three summer months of June-August and are presented in Table 10-5. These forecasts of tourist presence are considered in every demand scenario as it is for the agricultural growth.

Table 10-5 Growth of overnight stays for Tourist sites

District	Period of development	Total overnight stays
Menfi	2004-2006	270,000
Sciacca	2004-2007	1,800,000

The trends of urban consumption rates are the core of the demand scenarios for the Garcia-Arancio case study. The projections made by the Sogesid agency from 2005 to 2032 estimate an average growth rate from 170 l/capita/day to 280-300 l/capita/day, which means an average annual increase of 2.31% for the case study settlements. The trends affect the residential population only, the consumption rate of the seasonal and tourist being assumed to remain constant at 200 l/capita/day. The annual increase rates and the final consumption rates in 2020 for the settlements are presented in Table 10-6. Similarly for the exporting nodes, representing urban demand, the assigned rate is the average over the single settlements aggregated into the exporting: 2.39% is applied to *Urban_Trapani* and 1.89% to *Urban_Agrigento* and *Urban_Favara di Burgio*.

Table 10-6 Increase of consumption rates for settlements

Settlements	Annual Increase Rate (%)	Consumption Rate in 2020 (l/cap/d)
Sciacca	2.73%	235
Santa Margherita Belice	2.31%	225
Sambuca di Sicilia	2.31%	225
Salaparuta	1.89%	215
Poggioreale	1.89%	215
Partanna	2.73%	235
Montevago	1.89%	215
Menfi	2.73%	235
Gibellina	1.89%	215
Castelvetrano	2.73%	235
Average	**2.31%**	**225**

Three different scenarios were distinguished upon the domestic demand of settlements and exporting nodes (Table 10-7):

I. A “growing demand” (**GD**) scenario where urban demand increases from 2005 to 2020 at a steady average rate of 2.31% for settlements and 2.39% and 1.89% for the exporting nodes;

II. A "stabilized demand" (**SD**) scenario where demand is stabilized after a point in time, in this case 14 years after the reference year;

III. A constant, "permanent demand" (**PD**) scenario, which assumes that not only will the population stay the same, as is confirmed by recent studies, but also that the rates of consumption and agricultural expansion will be fixed in time.

Table 10-7 Consumption rate trends for the two scenarios

Scenario	Period	Annual Growth Rate (%) (Average over the settlements)	Annual Growth Rate (%) (export urban)
Growing Demand	2001 – 2004	0.0	0.0
	2005 – 2020	2.31	2.39% and 1.89%
Stabilized Demand	2001 – 2004	0.0	0.0
	2005 – 2014	2.31	2.39% and 1.89%
	2014 – 2020	0.0	0.0

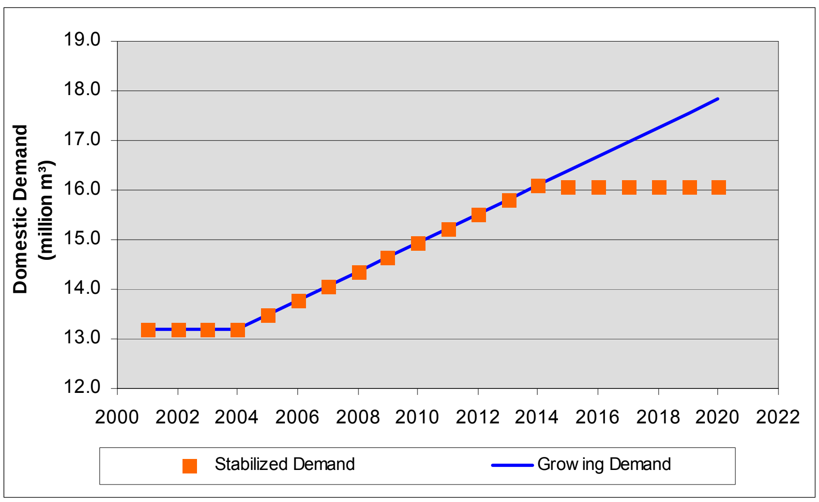


Figure 10-1 Domestic Demand Scenarios in Belice Basin

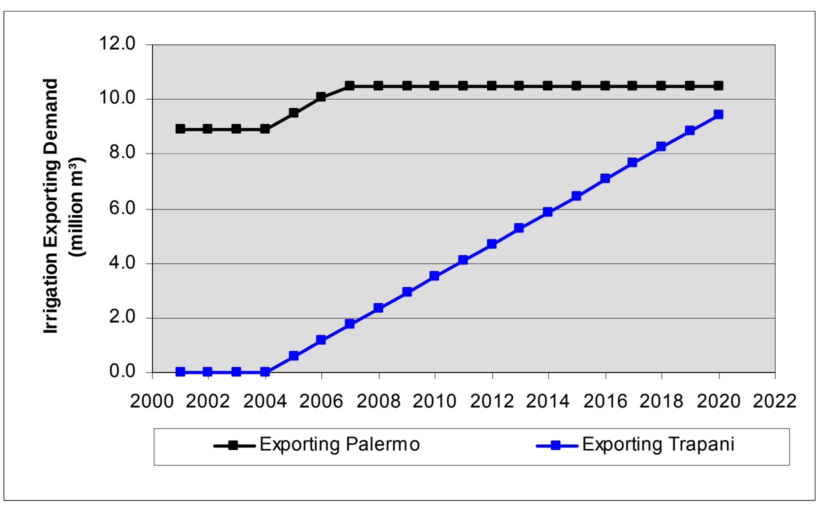


Figure 10-2 Irrigation Demand Scenarios for areas supplied by Belice Basin sources, outside Belice Basin (not incorporated in the analysis)

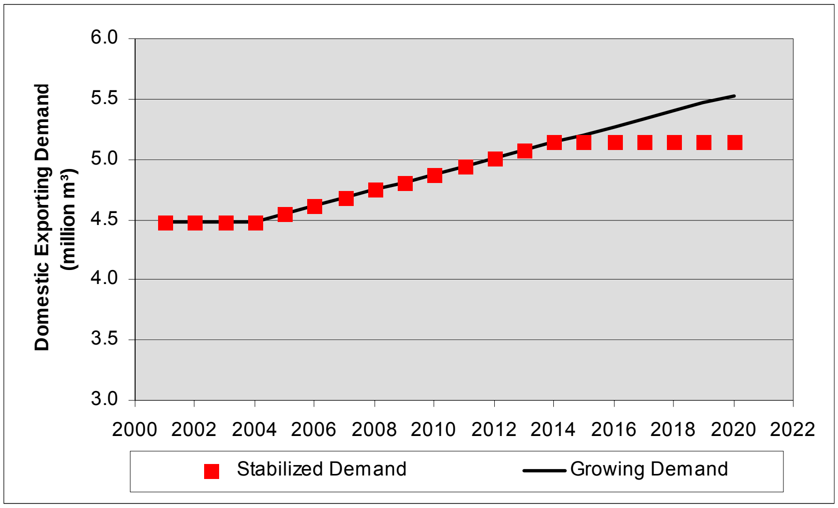


Figure 10-3 Domestic Demand Scenarios for areas supplied by Belice Basin sources, outside Belice Basin

Formulation of Availability Scenarios

Data

Daily recorded time series of rainfall, temperature and runoff are available for the Belice basin. The data were analyzed and aggregated both in time, i.e. at monthly and yearly time step, and spatially, over the area of the basin.

According to the humidity index of Thornthwaite, 54% of the case study area is defined as semi-arid, whereas 44% is dry to sub-humid and 2% is sub-humid to humid. The annual precipitation is about 500-600 mm and is unevenly distributed during the year with the 85% concentrated between October and March. The average annual evapotranspiration ranges from 800-900 mm to 1000 mm along the coast. The average annual temperature falls between 10-11 °C in the inland areas and between 17-19 °C in the coasts. The maximum values appear in summer and are about 30-31 °C.

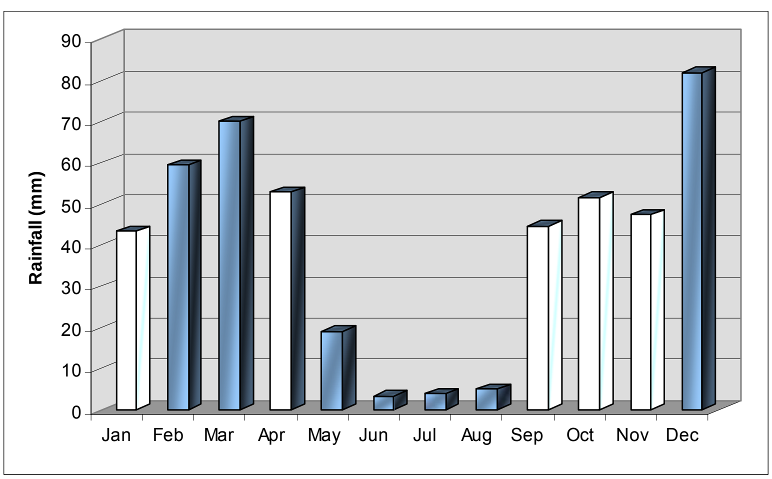


Figure 10-4 Average monthly rainfall in the Garcia-Arancio districts

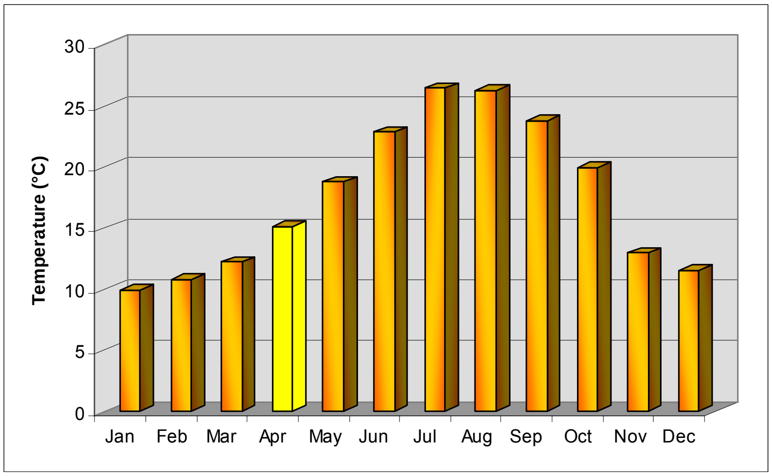


Figure 10-5 Average monthly temperature in the Garcia-Arancio districts

Scenarios

The availability scenarios of runoff and aquifer recharge have been built with the Rainfall scenario module of the WSM DSS. First of all, three scenarios of rainfall and three of temperature were defined, namely Normal, Wet and Dry for the former, and Normal, Hot and Cold for the latter. Then they have been combined together in order to perform the soil water balance at the watershed level and obtain availability scenarios of runoff and recharge. The generated availability scenarios express:

a) a period of 20 years with a high frequency of wet years and low temperatures (**WET scenario**),

b) a period of 20 years with a high frequency of dry years and high temperatures (**DRY scenario**),

c) a period of 20 years comprised of Normal Rainfall and Normal Temperature (**NORMAL scenario**),

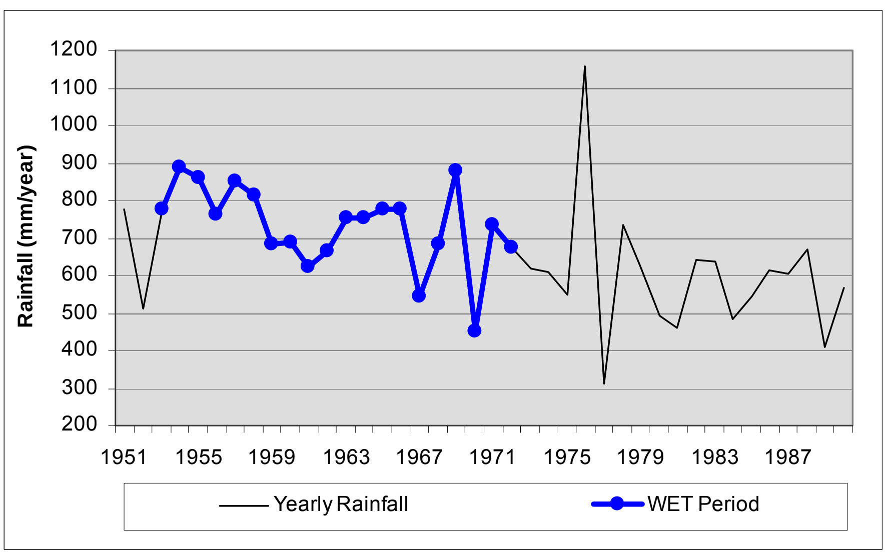


Figure 10-6 Historical wet period

In order to be consistent with past historical events, the forecast availability scenarios were built by following the negative rainfall trends of the past forty years, from 1951 to 1990. The time frames of continuous data with the higher frequency of dry and wet years were identified in the past events. Then the deviations from the general trend of those time frames were applied to the forecast trend. The dry period for rainfall is from 1966 to 1985, and the wet from 1953 to 1972 as depicted in Figure 10-6 and Figure 10-7.

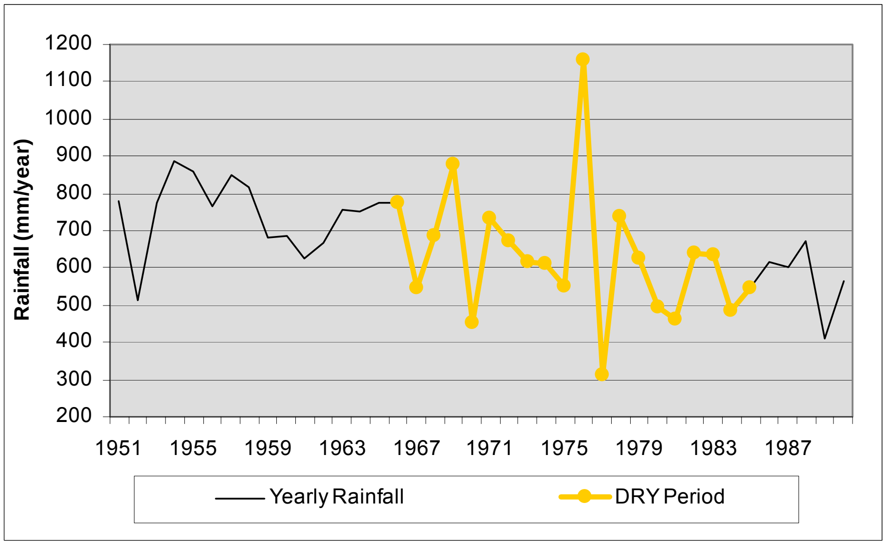


Figure 10-7 Average Historical dry period

In the generation of the time series of rainfall and temperature the trends of each single month were also accounted for, that is, the tendency of the months of January, the months of February etc., in order to maintain a variation within the year while considering the specific historic behavior of each month and its tendency in the future.

Combinations of Availability and Demand scenarios

In order to be able to assess the behaviour of the water system as intended under a best case scenario, a worst case scenario, and a business as usual scenario, the combinations of availability and demand scenarios under which the different management options have been evaluated were the following:

- A combination of the *Growing* Demand Scenario with the *Dry* Availability Scenario (**GD+DRY**), reflecting the worst case scenario of water shortage,
- A combination of the *Stabilized* Demand Scenario with the *Normal* Availability Scenario (**SD+NORMAL**), reflecting the current trends of the system in a "business as usual" context, and
- A combination of the *Permanent* Demand Scenario with the *Wet* Availability Scenario (**PD+WET**), reflecting the best case scenario.

As regards the water resource system that was simulated and evaluated, there is a overall and generalized condition of water scarcity in the Garcia-Arancio districts, which depends on the very limited amount of water that is considered to enter the system in terms of runoff. In addition to that, the system was simulated by taking into account the real forecasts on the rates of consumption for the urban use and the projects of land expansion as related to the agricultural practice. After the first simulations it was immediately clear from the collection of the relevant data that the system is to be considered non sustainable, at least according to the information that is available at the time of writing this paper. In particular:

- The Arancio lake should be the primary water source for the districts but it is always at its minimum storage because of the low inflows that do not assure a sufficient recharge;

- All the irrigated districts are facing a permanent deficit every year from May to October, during the season of irrigation. Their demands are satisfied just for the three-four years of the simulation, until the Garcia reservoir can provide the Arancio and some of the districts with water;
- From the introduction of the urban demand of settlements within the simulated water resource system, the overexploitation of the Garcia appeared to be the first cause of the overall condition of deficit, because too much water is expected to be abstracted yearly to integrate the Montescuro aqueduct, coming from outside the region;
- The settlements facing the higher unmet demands are Castelvetrano and Partanna, which are located west of the area and are the latest to be supplied by the urban distribution network. Second highest are Menfi and Sciacca that are in the territories administrated by the agency for land reclamation but receive water only by the Garcia reservoir: as a consequence of the critical drought conditions of the reservoir they are subject to a basic deficit of 120,000 cubic metres, exacerbated to 160,000 from June to August;
- From institutional constraints the two land reclamation agencies of Trapani and Palermo are legitimated to take a fixed yearly amount of water from the Garcia reservoir, but it seems to be incongruent with the real allocation of water. Their role in the resource system will be further investigated during the next strategy formulation phase.

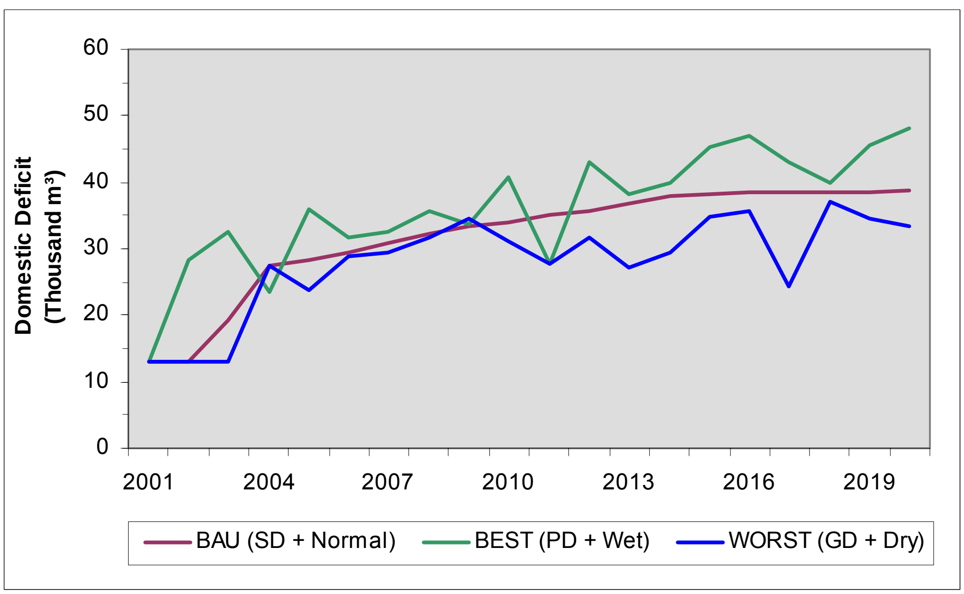


Figure 10-8 Estimated domestic deficit under the selected demand and availability scenario combinations

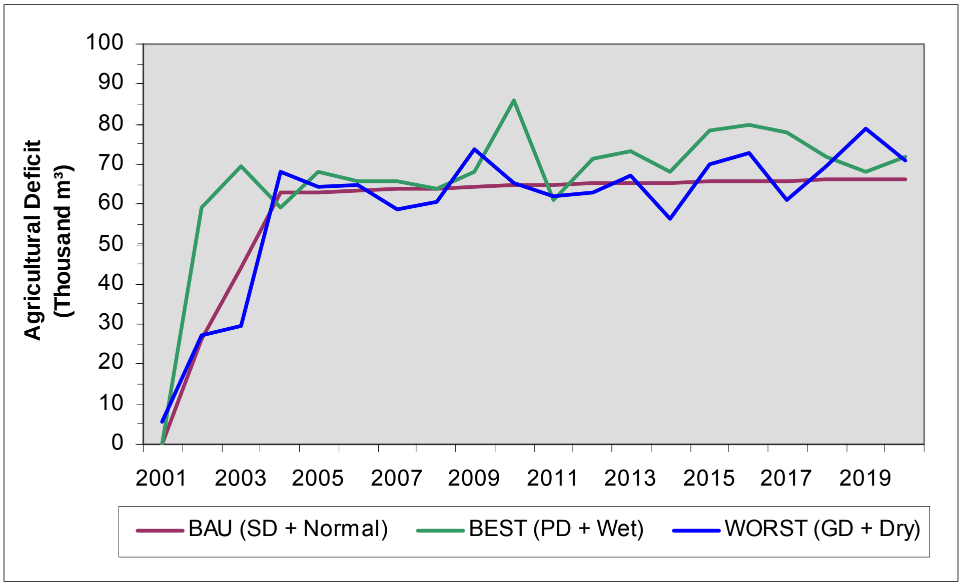


Figure 10-9 Estimated irrigation deficit under the selected demand and availability scenario combinations

Cost Estimations

The estimation of **direct costs** for the Garcia-Arancio Districts consists mostly of depreciation of capital expenditures and running costs associated with both existing and new infrastructure.

Since the appropriate information was not available for some infrastructure, an additional direct cost was considered per m^3 of water distributed, 2 €/m^3 for domestic use, and 0.5 €/m^3 for irrigation use respectively.

Environmental costs for the case of Garcia-Arancio Districts are associated with surface water abstraction and consumption. The surface water bodies involved are the two storage reservoirs of Garcia and Arancio and the Belice river reaches that supply them seasonally.

The selected reference period runs from May to September and the average costs incurred from abstraction and consumptions were set equal to 0.7 €/m^3. The vulnerability of the examined surface water bodies to overabstraction is quite high and was expressed by appropriate area coefficients that are summarized in Table 10-8.

Table 10-8 Area coefficients used for surface abstraction environmental costs

Surface Water Body	Area Coefficient
Garcia	2.0
Arancio	2.0
Belice River Reach 18	1.5

Present values have been estimated for the period of 2001 to 2020, using a discount rate of 4.5%.

Analysis of Water Management Options

The water management options/ measures elaborated in this section were based on the outcomes of the stakeholder consultation process, as briefly described in Chapter 4. They pertain to the following three major categories:

- **Structural options** for supply enhancement, including:
  - *Construction and expansion of pumping stations***,** aiming at the augmentation of water available at the Garcia reservoir;
  - *Connection to irrigation sites of existing treatment plants*, to provide additional water supplies particularly during the peak consumption periods;
- **Demand management options**, including:
  - *Reduction of Network losses*, through replacement of the fifty year old Montescuro distribution network (structural intervention);
  - *Improvement in Irrigation Methods*, for the consideration of the current trend in substituting the current sprinkler systems with drip irrigation;
- **Socio-economic measures** in the form of an increasing water selling price for the domestic sector, under assumptions on demand elasticity, in order to examine what influence such a policy would have in the water allocation in the system.

The above mentioned options were ranked though a number of appropriate indicators the selection of which was based on the responsibility of the water agencies to ensure the coverage of the domestic demand, and the objectives of the Consortium no.3 Agrigento requiring a sufficient yearly amount of water to satisfy the crop requirements during the irrigation season. These water uses become more competitive during the summer because they share the surface water of Garcia, but settlements are to be served first. As a consequence the analysis of options is to be formulated around the **coverage of domestic and irrigation demands**. This information is presented graphically for each option in terms of “effectiveness”, together with the % improvement (reduction of the deficit) obtained with each option with respect to the reference simulation without any intervention. The satisfactory range of values and the weights assigned to the two coverage indicators are presented in Table 10-9.

The analysis of options is completed by the graphs of the **direct (financial) cost** and of the **environmental cost,** which are important to quantify the price to be paid for water management measures, and for the over-exploitation of the surface water resources of the Garcia-Arancio region.

All the presented graphs depict the effect of each option under the three coherent management scenarios representing worst conditions, i.e. **GD+DRY** scenario, “business as usual” context, i.e. **SD+NORMAL** scenario, and best conditions, **PD+WET** scenario.

Table 10-9 Satisfactory range of values and weights for the indicators of the Belice Basin case study

Indicator	Satisfactory range of values	Weight
Domestic demand coverage	70-100%	0.50
Irrigation demand coverage	70-100%	0.50

Structural Options

At present, the irrigated districts receive water from two surface sources, exclusively supplying irrigation: the Arancio Lake and a weir on the Belice River. Additional water comes from the Garcia Lake that has the double task of directly providing with water the district of Castelvetrano and partly of Menfi, and of recharging the Arancio Lake during the winter months. However, the consortium 3 has to share the available water at Garcia with the urban requirements inside and outside the Belice Basin. Since in case of water scarcity the urban users have a higher priority to be served by Garcia than the agricultural ones, the plans of the agency aim mostly at expanding their own water sources and at maximizing the irrigation efficiency. The first goal can be attained by means of structural options.

Wastewater Reuse for Irrigation

First of all, there is a project aiming at the use of the effluents of some treatment plants to feed the irrigation sites directly, or to recharge the Arancio Lake. This second alternative would be operative during the winter, whereas during the summer the critical crop requirements would use treated water with straight connections. The plants involved are those that currently serve the settlements of Castelvetrano, Menfi and Sambuca di Sicilia, and will be linked to the corresponding irrigated districts. The total additional volume the three districts can count on is about 12,497 m^3/day and will be used with first priority. This measure partially frees the Consortium Agrigento for Land Reclamation from the domestic constraint on the Garcia supplies. The total financial cost of the water reuse project is about 118.8 Million €, including the construction of the canals and/ or pipelines carrying the effluents to the internal irrigation networks of the districts. The water selling price of treated water will be 0.092 €/m^3, which constitutes an incentive to use it, as this price is lower than the price of 1.4 €/m^3 that farmers pay at the time being for fresh surface water.

As far as the simulation is concerned, the option was originally assumed to become active after 2006, but in the latest simulations it started from the beginning of the scenario horizon, i.e. 2001, in order to see the effect from the first years, where water from Garcia is still available for the agricultural use (it decreases during the years due to first priority of domestic abstractions).

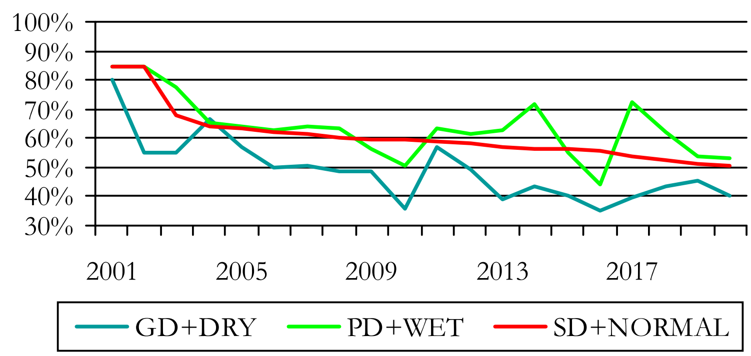


Figure 10-10 Percent demand coverage effectiveness of Wastewater Reuse to Domestic use

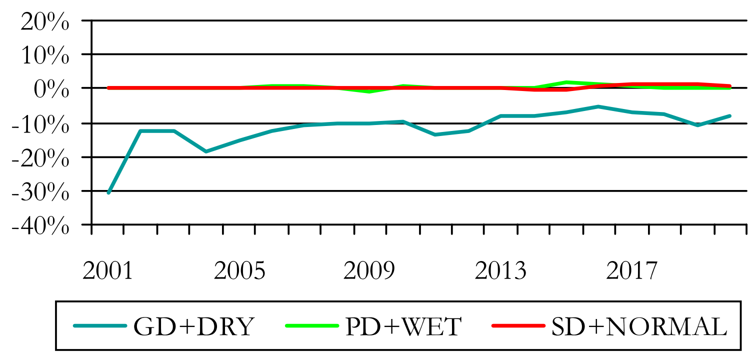


Figure 10-11 Percent Improvement of deficit in Domestic use with respect to the reference scenarios

From the chart depicting the percent improvement of deficit with respect to the reference scenarios, the effect of the waste water reuse on the irrigation deficit is clear: the three districts can rely on more, and exclusive, water and the unmet demand is reduced by 10%. The irrigation demand coverage remains inside the satisfactory range of 80-100%, except for the worst circumstances. The domestic coverage and deficit are not remarkably influenced since this option is tailored exclusively in order to meet the crop requirements.

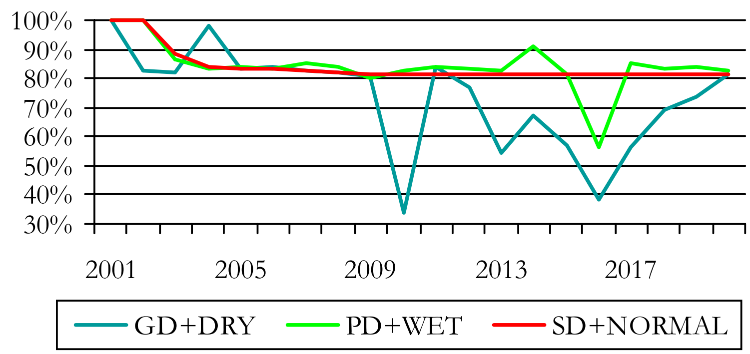


Figure 10-12 Percent demand coverage effectiveness of Wastewater Reuse to Irrigation use

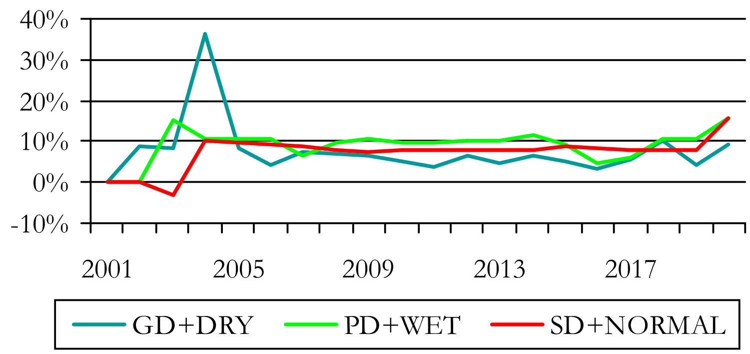


Figure 10-13 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios

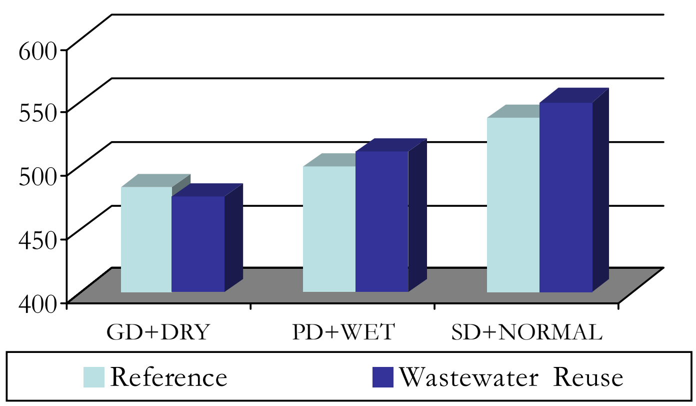


Figure 10-14 Total direct cost difference of the Wastewater Reuse option under the three scenarios (Present Value – Million €)

The direct costs increase by about 2.3 - 2.4 % both in the Best and the BAU scenarios, while the environmental cost increases by 0.5 and less in the BAU scenario.

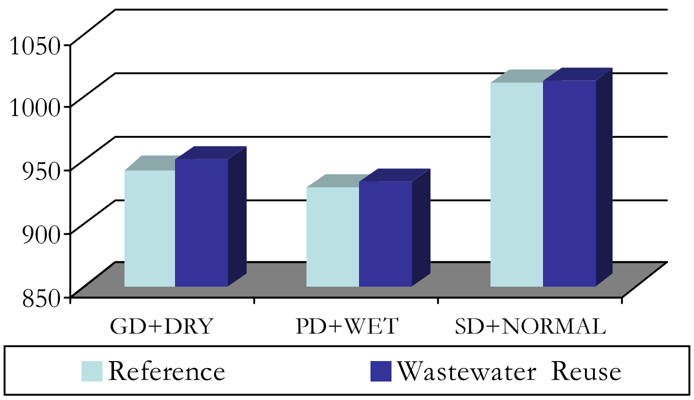


Figure 10-15 Total environmental cost difference of the Wastewater Reuse option under the three scenarios (Present Value – Million €)

Exploitation of Belice River

Another method the local stakeholders in charge of agricultural water services intend to follow in order to become more independent from the domestic constraint on Garcia is the expansion of the existing pumping station on the Belice River in the district of Castelvetrano, namely the "Basso Belice". They are working to equip the station with new pumps, which will boost the river exploitation up to 15 hm^3 of water withdrawn per month from the present 8 hm^3. This additional volume of water is allocated to the Arancio and will contribute to the coverage of the deficit for all the irrigated relevant districts such as Menfi, Sambuca di Sicilia and Sciacca. This action is to be combined with the strategy of the agencies responsible for the exploitation of the Garcia Reservoir for domestic use, as integration of the Montescuro Aqueduct. They are at present constructing a connection of Garcia Lake with the right branch of Belice, in order to take advantage of the corresponding sub-basin.

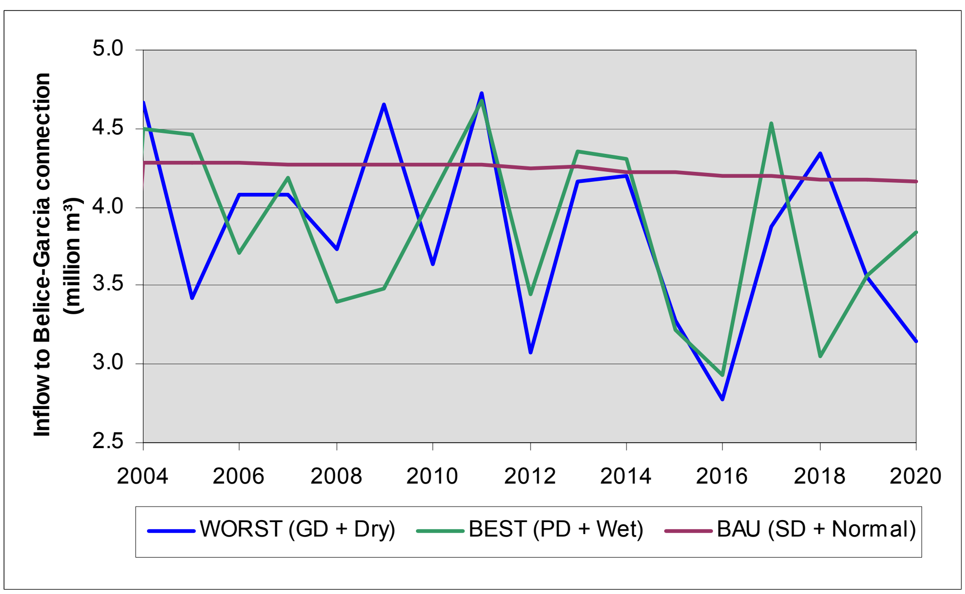


Figure 10-16 Inflows to the pipeline connecting the Garcia to the right branch of Belice River

The annual volume that will be transferred is 6 hm^3 and will represent an additional water volume to be shared between the three Land reclamation agencies of Agrigento, Trapani and Palermo, and the settlements served by the Montescuro, both inside and outside the Belice basin. The construction cost of the connection river-reservoir and of the pumping plant expansion reach a total of 47.9 million €. The application year for this combined option is

2004 for the BAU and the BEST management schemes, while it starts in reference year 2001 for the WORST.

According to the simulation results, from the application year 2004 the situation improves: domestic unmet demand decreases at approximately 20% after the transfer of water to Garcia but there is a negative trend for the scenario duration, which is due to the declining runoff available at the river reach where water is abstracted. Besides, from the analysis of the water flows in the river reach and in the new Belice-Garcia pipeline it appears that only an average yearly value of 3.8 hm^3 recharge the Garcia, compared to the 6 hm^3 of the designed structural intervention. Therefore, water is not sufficient and this availability diminishes in time also. The effect of the runoff scenario is analogous for the river reach related to the expansion of the existing pumping station: the water abstracted yearly is about 6 hm^3 against the 15 hm^3 that the new plant can manage. But in this case there is another limiting factor. In fact the supply enhancement option should permit conveying more water from the Belice to the Arancio, which means more water for all the irrigated districts. As regards the irrigation deficit, its percentage improvement is lower with a mean value of 8% and even slightly exacerbated by the strategic option in the long run, with a mean value of -20% in the last 5 years of the scenario. The reason for that is evident if we look at the geographical location of the river reach whose water is pumped to recharge the Arancio: as it is downstream the connection of Belice to the Garcia, its water flow is reduced by the abstraction towards Garcia itself.

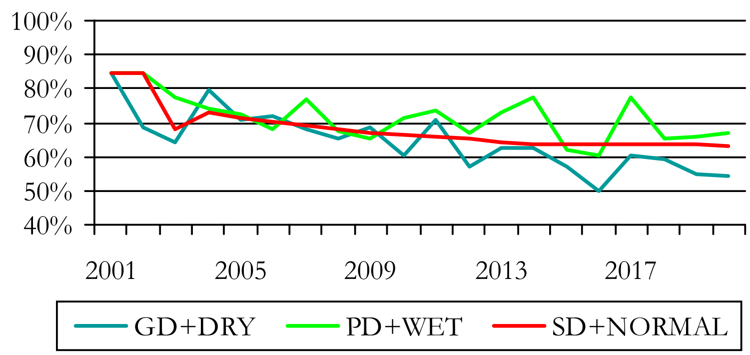


Figure 10-17 Percent demand coverage effectiveness of Belice Exploitation to Domestic use

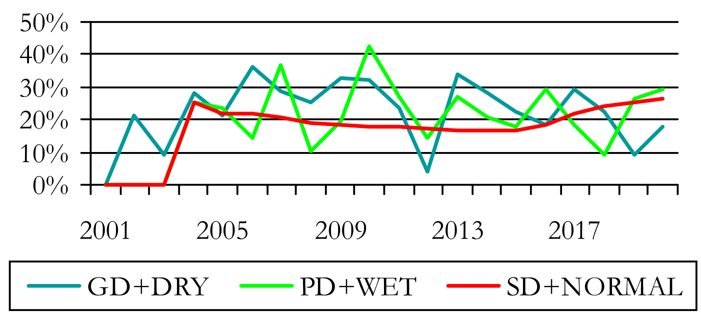


Figure 10-18 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Belice exploitation option)

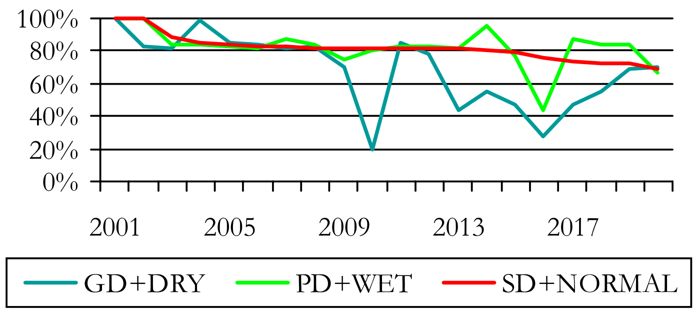


Figure 10-19 Percent demand coverage effectiveness of Belice Exploitation to Irrigation use

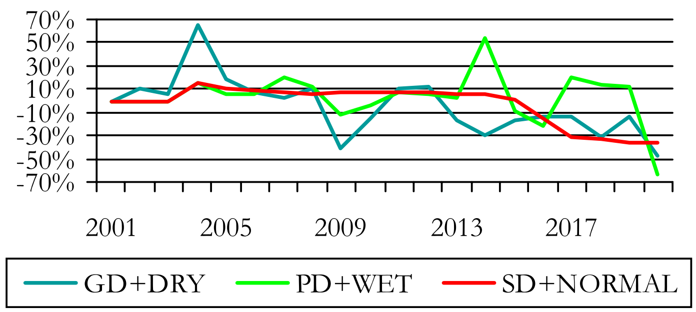


Figure 10-20 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Belice exploitation option)

The increment of the direct costs with respect to the reference scenarios is quite high, about 10%, and it is due to the capital and running cost of the two pumping stations constructed and enhanced. The environmental cost increases by 5% because of the additional amount of water abstracted from the vulnerable resources of the river reach on the Belice recharging the Arancio Lake and the Garcia Lake, which is refilled by the new pumping station on the Right Belice Branch.

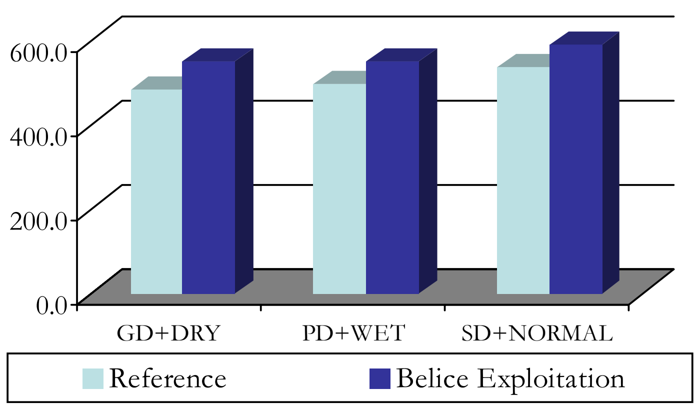


Figure 10-21 Total direct cost difference of the Belice Exploitation option under the three scenarios (Present Value – Million €)

The conclusion is that the combination of the two structural options together is not convenient because the potential advantages for the agricultural users are cancelled by the new structure built in order to provide additional water to the settlements. Besides, the exploitation of the right branch of the Belice river do not positively influence the irrigated districts because the Garcia reservoir does not have enough water to cover both urban and agricultural requirements and the additional water goes entirely to the settlements. The high direct cost introduced in the BAU management scheme from 2004 by the two options cannot be justified.

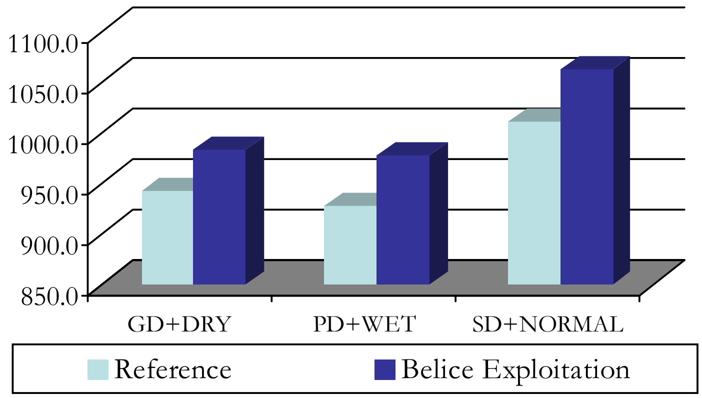


Figure 10-22 Total environmental cost difference of the Belice Exploitation option under the three scenarios (Present Value – Million €)

Demand Management Options

Improvement of Irrigation Methods

The distribution of water to the local irrigation networks of the four irrigated districts Castelvetrano, Menfi, Sciacca and Sambuca di Sicilia is very efficient: the Consortium no.3 Agrigento for Land Reclamation confirmed a factor of 0.98 that is the result of fifty years of progress of agricultural practice in the case study area. However, further water can be saved by using the drip irrigation method in place of the sprinkler. At the time being, a forty percent of the cultivated areas are irrigated by drip irrigation, but the majority is still by sprinkler. The consortium revealed that a gradual shift to a complete use of the drip method is on the agenda, and as a consequence this option was simulated with the WSM DSS to get an indication of its weight within a demand management approach to water scarcity.

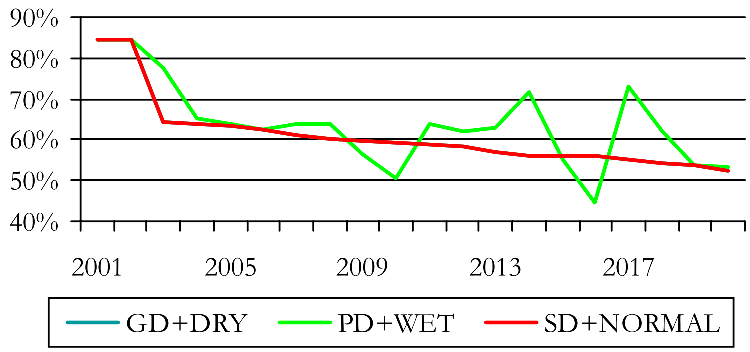


Figure 10-23 Percent demand coverage effectiveness of Irrigation Method Improvement to Domestic use

The replacement of one method with the other has been assumed to happen progressively with a tendency of +2% per year. Applied from 2005 to 2020, this means a growth of drip irrigation from 40% to 72% in sixteen years, and the correlated reduction of the sprinkler from 60% to 28%. The direct cost for this operation was not available and was not accounted for. The goal is to verify the positive effect this option should have on the coverage of irrigation demand for the three agricultural areas that take water from the Arancio Lake directly, Menfi, Sciacca and Sambuca di Sicilia.

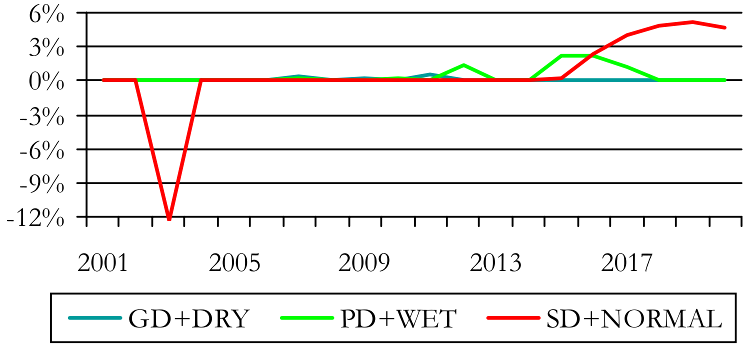


Figure 10-24 Percent Improvement of deficit in Domestic use with respect to the reference scenarios

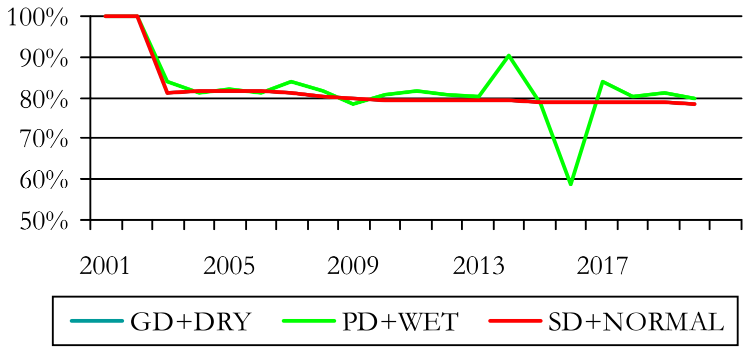


Figure 10-25 Percent demand coverage effectiveness of Irrigation Method Improvement to Irrigation use

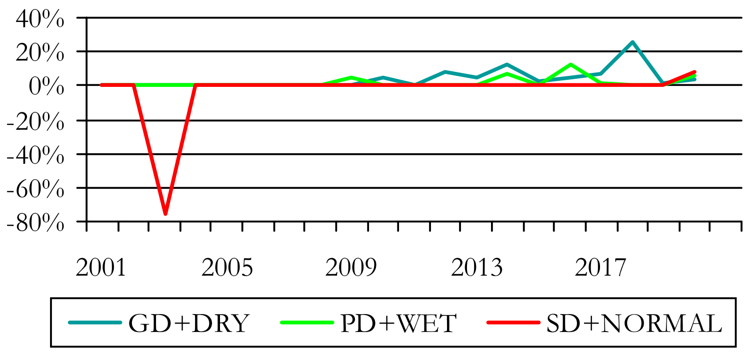


Figure 10-26 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios

From the analysis of results it emerges that this kind of action does not remarkably influence the water availability for agricultural use of the cases study. There is a slightly positive effect on the irrigation demand coverage, +2%, but it appears in the long run after 2009, and only for the worst scenario. Under this option the irrigation effectiveness lies in the satisfactory range of 80 – 100 % but on the other side the domestic needs drop to 55% at the end of the scenario horizon.

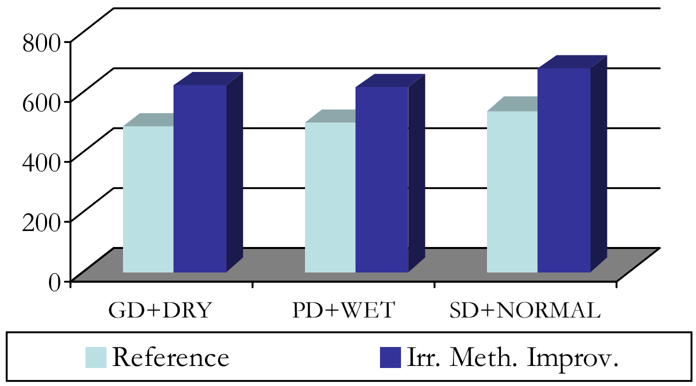


Figure 10-27 Total direct cost difference of the Irrigation Method Improvement option under the three scenarios (Present Value – Million €)

The environmental cost is reduced by -2% because less water is transferred from the vulnerable resources of the Garcia Lake and of the Belice River, since water from the Arancio Lake is supplied to the irrigation sites more efficiently. However, the additional direct cost incurred from the option application, about +20%, is very high and not acceptable compared to the minor advantages the option generates. This is a minor strategic measure for the Garcia-Arancio districts and it should be included into a group of more effective policy options.

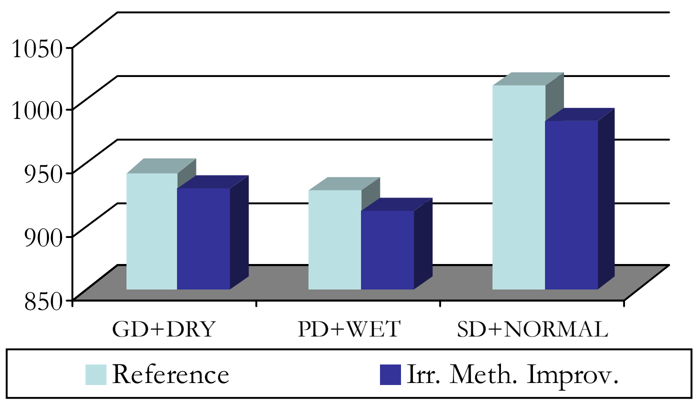


Figure 10-28 Total environmental cost difference of the Irrigation Method Improvement option under the three scenarios (Present Value – Million €)

Reduction of Distribution Losses

The major selected option from the demand management side, to be applied to the Belice basin, is the reduction of network losses. The internal networks of the settlements considered in the cases study have a pretty high conveyance loss factor, being the average value about 40 %, and respectively it is for the pipelines of the Montescuro aqueduct that carry water for 100 km crossing the Belice basin from East to West. The replacement of the fifty year old Montescuro will save a precious amount of water, which will be used to cover the increasing rate of consumption of the next twenty years. As the replacement project is planned for years 2004-2006, this option was assumed to appear in the simulation from 2007. The target efficiency to be reached is in the range of 79-90 % with the direct (financial cost) being equal to about 61.4 million €.

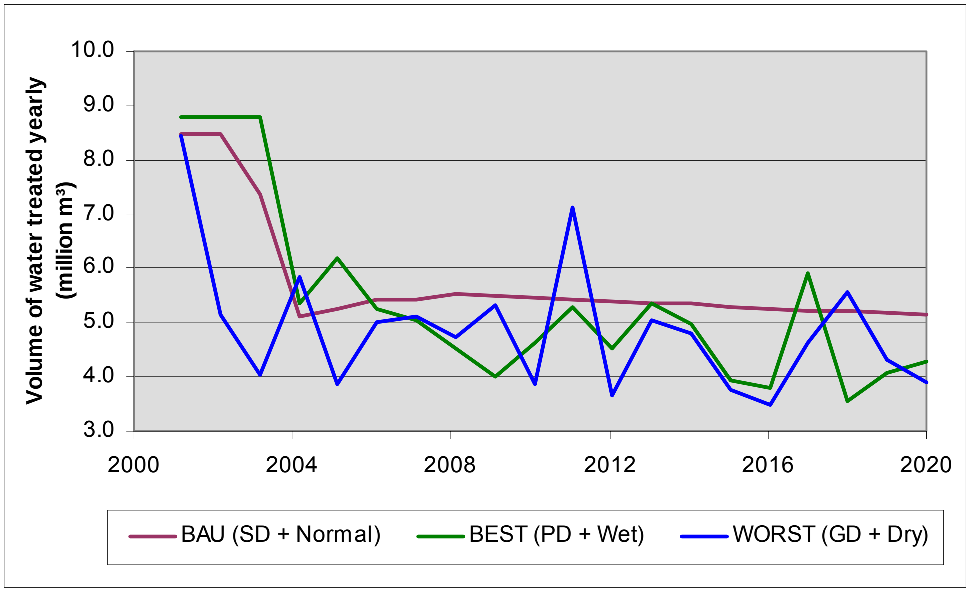


Figure 10-29 The volume of water treated by the drinking plant of Sambuca di Sicilia is always far from the designed capacity of 18 hm^3, and it evolves according to the negative trend of the inflows to the Garcia reservoir

Together with this project an expansion of the Drinking water treatment plant of Sambuca di Sicilia was also designed by the water authorities for urban use management. Currently, this plant treats the volumes coming from the Garcia and supplying the settlements of Menfi and Sciacca within the cases study area, and the Favara di Burgio aqueduct. The capacity of the plant is going to almost double, from 300 l/s to 600 l/s. This expansion was simulated within the DSS by setting the maximum monthly volume treated by the plant to a higher consistent value. In reality this project refers to years 2002-2004 but for the simulation it was assumed to be operational from the beginning of the scenario in 2001.

From the analysis of the selected indicators, the average 12% improvement of the domestic demand deficit reached after the replacement of the aqueduct network is evident, occurring in 2006. The positive increment at the beginning of the scenario and till 2004 depends on the augmented capacity of the drinking water treatment plant with respect to the reference management scheme: it is visible an immediate effect based on increased water volumes coming from the Garcia.

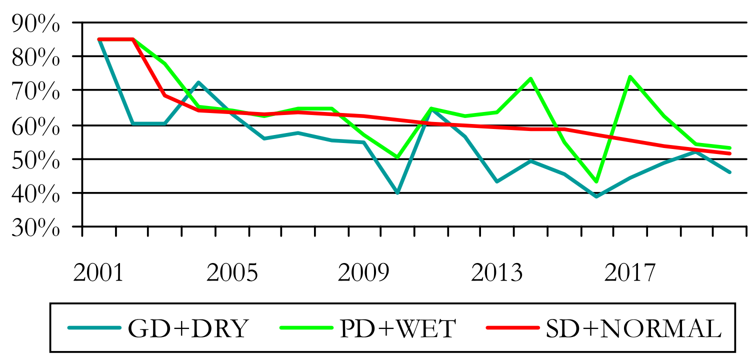


Figure 10-30 Percent demand coverage effectiveness of Losses Reduction to Domestic use

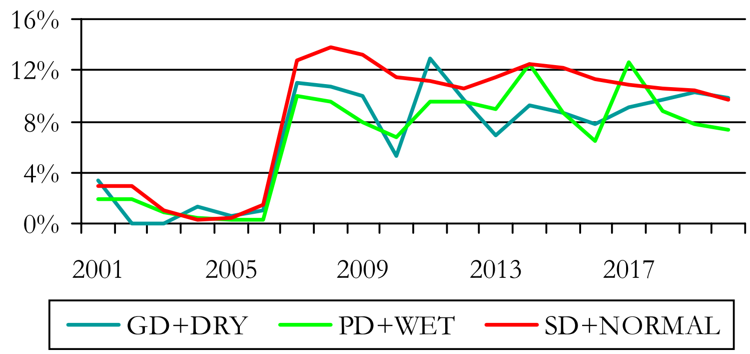


Figure 10-31 Percent Improvement of deficit in Domestic use with respect to the reference scenarios (Loss Reduction)

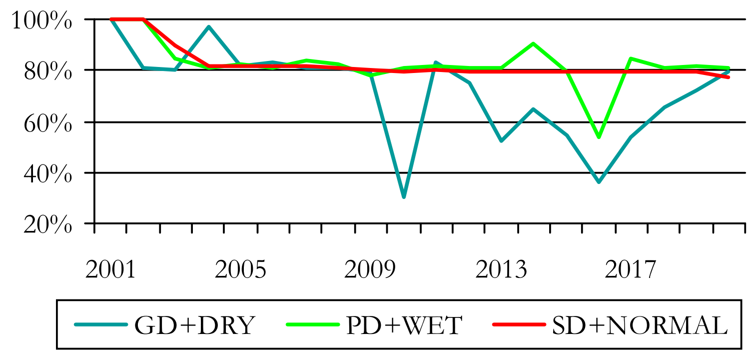


Figure 10-32 Percent demand coverage effectiveness of Losses Reduction to Irrigation use

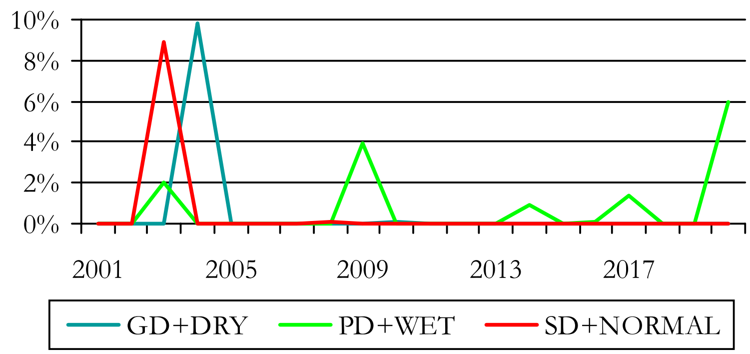


Figure 10-33 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios (Loss Reduction)

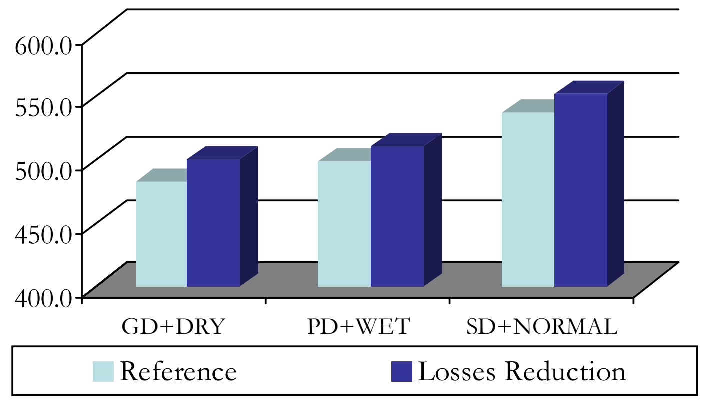


Figure 10-34 Total direct cost difference of the Losses Reduction option under the three scenarios (Present Value – Million €)

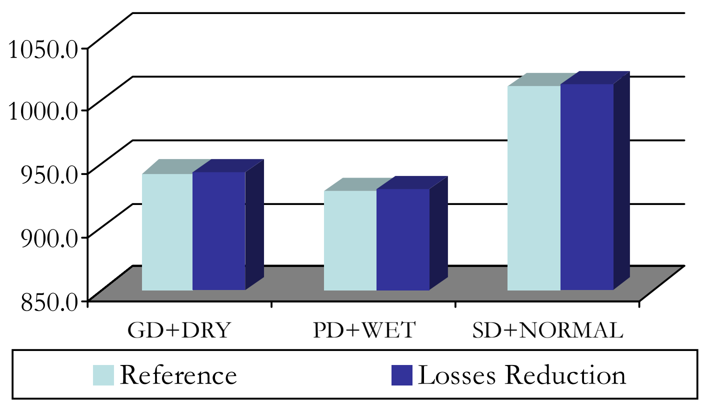


Figure 10-35 Total environmental cost difference of the Losses Reduction option under the three scenarios (Present Value – Million €)

The augmentation of direct and environmental costs is limited under the three scenarios making this option a candidate for strategy development as one that improves domestic demand coverage effectiveness. Environmental cost in particular changes slightly: the system relies more on the water of the Montescuro aqueduct that is distributed more efficiently, using less water from the already overexploited water resources of Garcia and Belice. On the other hand, this option brings no positive effect to the irrigation demand coverage, except for isolated and non-significant improvements under the best scenario. Moreover, the investigation of the water flows in the pipeline connecting the Garcia to the drinking plant pointed out that, although the new treatment capacity is about 18 hm^3, it is not exploited at its maximum due to the limited available surface water. The maximum volume of water treated is 9 hm^3, just half of the new capacity. The situation is similar to the enhancement option of the Belice exploitation, where an unhelpful availability scenario, i.e. the forecast available runoff, makes this structural option insufficient and not completely successful. It is suggested to combine it with another option affecting the irrigation effectiveness directly, such as waste water reuse.

Water Pricing

An option forecasting the growth of the water selling price for domestic users was simulated within the case study of the Garcia-Arancio. Standard values of demand elasticity were used, such as 0.2 for the permanent population of settlements, and 0.35 for the seasonal component and the tourists. The price is assumed to increase by 1.87 % each year in the scenario duration, from an initial value of 0.8 €/m^3 to a final 1.1 €/m^3 after twenty years. This kind of analysis is useful to understand to what extent a rising selling price would influence the allocation of water among the conflicting uses and the exploitation of alternate resources. This information will be used by the local agencies for water services to establish the proper price which assures recovery of the costs they have to pay to face the forecast increasing rates of consumption.

The simulation results show the evident impact of the rising price over the domestic deficit. The demand is reduced according to the elasticity demand parameter specified for the permanent and seasonal population, and as a consequence the deficit solves heavily. However this effect was expected, together with the trend of the improvement, which follows the specified growth of the selling price. Of course the unmet demand for irrigation is not touched by this option, given that no elasticity was assigned to irrigation sites. The only exception is under the worst scenario, which is characterized by a growing demand scenario and the worse conditions of rainfall and temperature: in this case the significant reduction of the domestic demand leaves more water available for the irrigation sites and an improvement of deficit appears. From the side of the costs, the reduction of direct costs of 0.8 % completes a positive effect coming out the application of this option. However, it has to be combined with others that also influence the irrigation effectiveness.

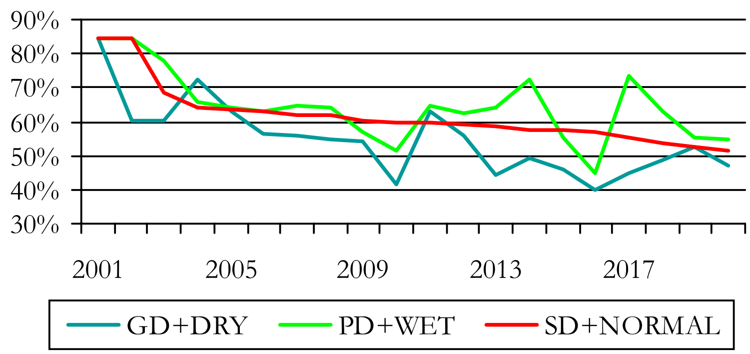


Figure 10-36 Percent demand coverage effectiveness of Water Pricing to Domestic use

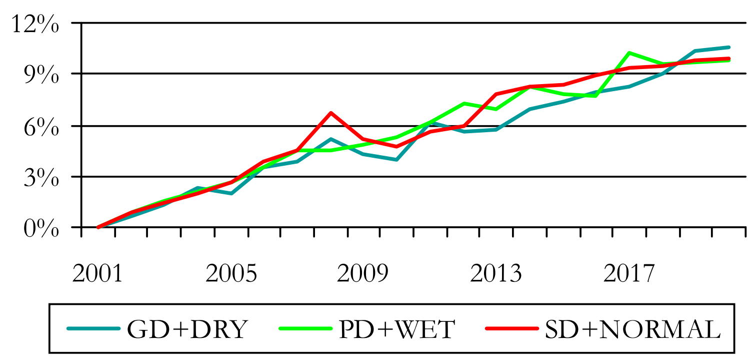


Figure 10-37 Percent Improvement of deficit in Domestic use with respect to the reference scenarios

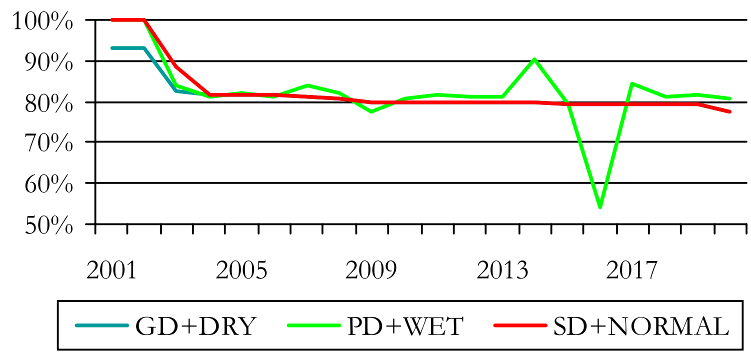


Figure 10-38 Percent demand coverage effectiveness of Water Pricing to Irrigation use

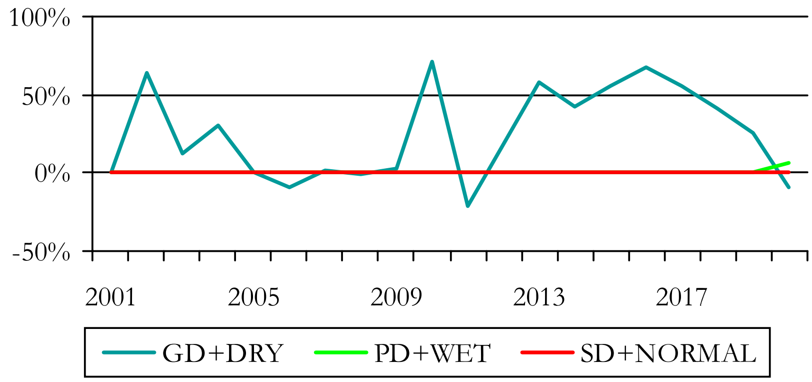


Figure 10-39 Percent Improvement of deficit in Irrigation use with respect to the reference scenarios

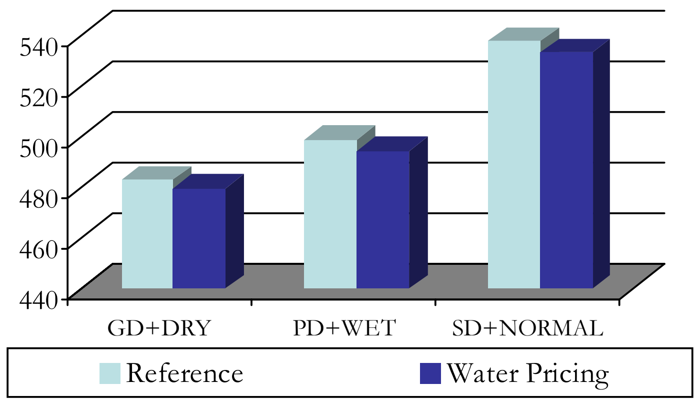


Figure 10-40 Total direct cost difference of the Water Pricing option under the three scenarios (Present Value – Million €)

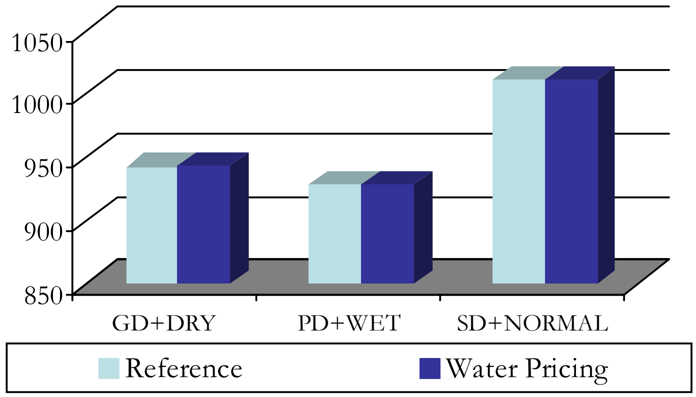


Figure 10-41 Total environmental cost difference of the Water Pricing option under the three scenarios (Present Value – Million €)

Summary and Conclusions

The final selection of options/ measures to be further analysed during the strategy formulation phase, which is presented in Chapter 4 depends on the performance of the options examined regarding the indicators that were presented throughout the analysis. The performance of each strategic option is evaluated under the three criteria of effectiveness, economic efficiency and environmental sustainability. The effectiveness of an option relates the level of domestic and with the level of irrigation demand coverage that was reached; it is approached by a relative index obtained by the evaluation module of WSM DSS, assuming a weight of 0.5 for each coverage indicator, and a satisfactory range of values from 70 to 100%. Environmental sustainability is expressed through the total environmental cost for each option, which is associated in the Garcia Arancio case study with surface water abstractions from reservoirs and river reaches of interest. This criterion takes into account the costs that the local authorities should have to pay in order to replenish the overexploited surface water resources with treated waste water. Economic efficiency, the ability to produce more with less, is expressed through the total direct (financial) cost. Both the environmental and the direct cost are expressed in present value terms. The following paragraphs summarise the conclusions drawn from the analysis of each option, with regard to its applicability, cost and environmental impact.

Wastewater Reuse for Irrigation

Wastewater reuse was initially examined for a horizon of 20 years from 2001 to 2020, but it was later preferred to apply it from 2001, to see the effect from the beginning of the simulation period, when water from Garcia Lake is still available for agricultural use (available supply decreases over the years due to the higher priority for domestic abstractions). The effect of wastewater reuse on irrigation deficits is positive. In particular, the three districts can count on additional, augmenting water supplies, and unmet demand reduces by 10 %. Domestic coverage and deficit are not significantly influenced, since this option is tailored exclusively so as to meet irrigation requirements. Under the worst circumstances of a dry climatic scenario, and a maximum domestic demand growth, the effect of the option is lower. However, even under this case, improvements in irrigation demand coverage are present. Additional financial costs due to the option application are about 2.3-2.4 %. The environmental cost, associated with the sustainable amount of water abstracted from the vulnerable and shared resource of Garcia Lake increases only by 0.5 %.

Exploitation of Belice River

The two artificial lakes Arancio and Garcia are a fundamental part of the water system of the region and play an essential role in the satisfaction of the regional water requirements. No new reservoirs were examined in the case study analysis. However, two structural interventions aimed at augmenting the exploitable storage volumes of the two lakes are being planned by the water agencies of the Belice Basin, and therefore were simulated as an alternative policy option, according to the water management plans of the Land Reclamation Authority. They are:

- The expansion of the existing pumping station on the Belice river, which recharges the Arancio lake during winter, and
- The connection of Garcia Lake with the right branch of the Belice River.

The two interventions were combined in order to evaluate the positive impact over the unmet demand that was expected for both urban and agricultural water uses. The expansion of the station recharging the Arancio Lake brings advantages to the supplied irrigated districts, while the supply to the Garcia is supposed to influence mostly the urban demands, as they have a higher allocation priority with respect to irrigation requirements. According to the simulation results, from the application year 2004 the situation improves. Unmet domestic demand decreases by about 20 % after the transfer of water to Garcia Lake; however there is a negative trend along the examined period due to the declining runoff available at the river reach where water is abstracted from. Additionally from the analysis of the water flows in the river reach and in the new Belice-Garcia pipeline it appears that only an average yearly value of 3.8 hm^3 recharges Garcia Lake against the 6 hm^3/yr of the designed structural intervention. So, water is not sufficient and availability also diminishes in time. Of course the effect of the runoff scenario is similar for the river reach related to the expansion of the existing pumping station: the yearly water abstraction is about 6 hm^3 against the 15 hm^3/yr that the new plant can manage. However in this case there is another limiting factor. In fact the supply enhancement option should permit the transfer of more water from the Belice to the Arancio Lake, which means more water for all the irrigated districts. Regarding the irrigation deficit, its percentage improvement is lower, with a mean value of 8 %, and even exacerbated by the strategic option in the long run, with a mean value of -20 % in the last 5 years of the scenario. The reason lies on the geographical location of the river reach from where water is pumped to recharge the Arancio Lake: as it is downstream the connection of Belice to the Garcia, its water flow is reduced by the abstraction towards Garcia Lake. The construction cost of the connection Belice River- Garcia reservoir is 22.9 million €, while the cost for the pumping plant expansion is 25 million €, with a total of 47.9 million €. The increment of direct costs characterizing the application of this policy option is quite high, about 10%, and it is due to the capital and running cost of the two pumping stations constructed and enhanced. The environmental cost increases of 5% because of the additional amount of water abstracted from the vulnerable resources of the river reach on the Belice recharging the Arancio Lake and of the Garcia Lake.

Reduction of Distribution Losses

Under the comprehensive scenario analysis context, the intervention was assumed to have effect from year 2007. The target efficiency to be reached was in the range of 79-90 %. The replacement of pipelines was combined with an expansion of the treatment capacity of the drinking water treatment plant of Sambuca di Sicilia, from 300 l/s to 600 l/s., which receives water from the Garcia Lake and provides the Montescuro with additional water volumes. As expected, a positive impact characterizes domestic water savings, and consequently domestic demand coverage. There is an average 12% improvement of the domestic demand deficit, which is reached after the replacement of the aqueduct network. Instead, this option brings no positive effect to irrigation demand coverage, except for isolated and not significant improvements under the best scenario. The investigation of the water flows in the pipeline connecting the Garcia to the drinking plant pointed out that, although the new treatment capacity is about 18 hm^3, it is not exploited at its maximum due to the limited surface water available. The maximum volume of water treated is 9 hm^3, just half of the new capacity. The situation is similar to the enhancement option of the Belice exploitation, where a negative availability scenario, i.e. forecast available runoff, makes this structural option not sufficient and completely successful. The direct cost for plant expansion is about 5.16 million €. The analysis of the option pointed out that the increments of direct and environmental costs are limited. Environmental costs in particular change slightly: the system relies more on the water of the Montescuro aqueduct being distributed more efficiently, using less water from the already overexploited water resources of Garcia and Belice.

Improvement of Irrigation Methods

The distribution of water to the local irrigation networks of the four irrigated districts Castelvetrano, Menfi, Sciacca and Sambuca di Sicilia is very efficient: the land reclamation agency confirmed a factor of 0.98 that is the result of fifty years of progress of agricultural practice in the case study area. However, water can be further saved by using the drip irrigation method in place of sprinklers. At the time being, 40% of the cultivated area is irrigated by drip but the majority is still by sprinklers. The agency stated that a gradual shift to a complete use of the drip method is on the agenda, and as a consequence this option was analysed under different scenarios in order to assess its potential impact within a demand management approach to water scarcity. The replacement of one method over the other was supposed to happen progressively with a tendency of +2 % per year. Applied from 2005 up to 2020, this means a growth of drip irrigation from 40 % to 72 % in sixteen years, and a correlated reduction of sprinkler systems from 60 % to 28 %.

The impact analysis reveals that this type of policy measure does not significantly influence water availability for agricultural use in the case study. There is a slightly positive effect on the irrigation demand coverage, +2%, but it appears after 2009, almost halfway in the examined period, and only for the worst scenario, i.e. in the combination of the most unfavourable weather conditions and maximum forecasted water demand growth. Under this option, irrigation effectiveness lies in the satisfactory range of 80-100 %. On the other side domestic demand coverage drops to 55 % at the end of the examined time period. Therefore, this intervention alone is not sufficient to cover the existing unmet demands of the irrigated districts.

Direct costs for this option were not available, but were approximated by an indicative value of 0.1 €/m^2. From the evaluation of the irrigation improvement option, it resulted that the environmental cost reduces by 2% because less water is transferred from the vulnerable resources of the Garcia Lake and of the Belice River, since water from the Arancio Lake is supplied to the irrigation sites more efficiently. However, the additional direct cost from the option application, about +20%, is very high and not acceptable compared to the small advantages the option generates.

Water Pricing

An increase in the water selling price for domestic users was examined for the case study of Garcia-Arancio. Standard values of demand elasticity were used, such as 0.2 for the permanent population of settlements, and 0.35 for the seasonal component and the tourists. The price was assumed to increase by 1.87 % each year in the examined period, from an initial value of 0.8 €/m^3 to a final 1.1 value of €/m^3 after twenty years.

Results show the evident impact of the price increase over domestic demand and deficit. Demand is reduced according to the elasticity demand parameter specified for the permanent and seasonal population, and as a consequence the deficit is heavily affected. However this effect was expected, along with the trend of the improvement, which follows the specified growth of the selling price. Of course the unmet demand for irrigation is not affected by this option, given that no price elasticity was assigned to irrigation sites. The only exception is under the worst scenario, which is characterized by a growing demand scenario and the low availability conditions. In this case the significant reduction of the domestic demand leaves more water available for the irrigation sites and an improvement of deficit appears. In terms of costs, a reduction of direct costs by 0.8 % completes a positive effect of the option.

Comparison of Options

Table 10-10 summarises the evaluation results, presented also in Chapter 4, as part of the strategy formulation phase.

Table 10-10 Option Performance Matrix

Option	Effectiveness (Relative Sustainability Index for Demand Coverage)	Economic Efficiency (Direct Cost – PV – million €)	Environmental Sustainability (Total environmental cost – PV million €)
Base Case	0.0308	506.5	960.7
Waste Water Reuse	0.0306	512.6	965.6
Exploitation of Belice	0.0006	550.9	980.5
Irrigation Methods Improvement	0.0137	619.6	941.6
Water Pricing	0.0206	505.6	936.8
Reduction of losses	0.0205	487.0	935.8

All the options analysed in the case study aim at improving the agricultural effectiveness, which is the primary goal of the water strategy in the case study of Garcia-Arancio. These options include interventions that act directly in favour of the irrigation requirements, such as the waste water reuse, the Belice exploitation and the irrigation methods improvements, but also measures that act in favour of the domestic water needs and should have an additional positive effect on the irrigation demand coverage, e.g. reduction of distribution losses and water pricing. Unfortunately, both the irrigation sites and the settlements need water to cover their demands, but the urban users have a higher priority and as a consequence all the policy measures which seem to indirectly bring an advantage to the agricultural requirements are nullified. In conclusion, although the analysis of the single graphs of domestic and irrigation improvements show that the options help solving the deficit impact occurring in the region, it seems clear from Table 10-10 that only a combination of them into a strategy can lead to a more significant result. This first approach to the demand and availability scenarios and to the evaluation of proposed feasible water solutions for the Garcia-Arancio case study pointed out that institutional policies, such as water pricing, and demand management options, like the replacement of old aqueducts and pipelines to lower the losses, are the best strategic options, as they reach the highest score for the three criteria of effectiveness, economic efficiency and environmental sustainability. They should therefore constitute a core part of any strategic plan, which should also integrate structural measures in an effort to increase the sustainable exploitation of available resources.

Annex

Hydrological Sequences

Table A10-1 Normal, Dry and Wet rainfall scenarios (figures in mm)

Year	NORMAL	DRY	WET
2001	512.70	545.29	407.00
2002	505.26	384.61	515.07
2003	497.82	427.24	551.44
2004	490.38	678.64	448.63
2005	482.94	286.61	493.86
2006	475.50	509.12	453.23
2007	468.06	456.94	457.33
2008	460.62	443.73	439.31
2009	453.18	437.25	305.49
2010	445.75	336.94	424.85
2011	438.31	739.49	476.90
2012	430.87	201.36	429.55
2013	423.43	435.61	436.92
2014	415.99	395.94	459.52
2015	408.55	327.21	325.60
2016	401.11	246.79	331.39
2017	393.67	438.52	604.37
2018	386.23	426.36	224.66
2019	378.79	315.33	425.33
2020	371.35	341.54	377.02

Table A10-2 Normal, Dry and Wet rainfall scenarios (figures in mm)

Meteorological data	Historic Period Selected	
	20 Years Wet/Cold	20 Years Dry/Hot
Rainfall	1953 -> 1972	1966 -> 1985
Temperature	1962 -> 1981	1955 -> 1974

Parameters for the Exploitation of Belice River Option

Table A10-3 Exploitation of surface water of Belice River

Option	Yearly Volume abstracted (hm^3)	Conveyance factor of pipelines to Garcia	Construction Cost (Million €)	Purpose
Pumping from right branch of Belice	6	0.05	22.9	Integration to all water use
Expansion existing station on Belice	7	0.05	25	Integration to irrigation

Table A10-4 Simulation year for Belice Exploitation

Options	Year		
	BAU	BEST	WORST
Pumping from right branch of Belice	2004	2004	2001
Expansion existing station on Belice	2004	2004	2001

Distribution Network Replacement Parameters

Table A10-5 Replacements of Montescuro

Construction Years	Initial average efficiency	After replacement	Cost (Million €)
2004-2006	40 %	21 %	61.4

Irrigation Methods Improvement Parameters

Table A10-6 Improvement of Irrigation Methods

Application Years	Districts involved	Yearly increment of drip over sprinkler	% at 2020	Cost (€/m^2)
2005-2020	Menfi, Sciacca, Sambuca di Sicilia	+ 2%	Sprinkler – 28% Drip – 72%	~0.1 (indicative cost)

Wastewater Reuse Parameters

Table A10-7 Wastewater Reuse for Irrigation

Application Years	Plants	Total Capacity (m^3/d)	Effluent Price (€/m^3)	Cost (Million €)
2004-2006	Menfi, Castelvetrano, Sambuca di Sicilia	12,497	0.092	118.8

Water Pricing Parameters

Table A10-8 Water Pricing Variation for Domestic & Tourist

Application Years	Demand elasticity for domestic & tourist		Yearly increment of selling price	Variation of price 2001 - 2020 (€/m3)
	Permanent	Seasonal		
2001 – 2020	0.2	0.35	+ 1.87%	0.8 -> 1.1

Chapter 11 Analysis of Water Management Options for Tel Aviv Region, Israel

The following paragraphs aim to present the results of the analysis undertaken in the region of Tel Aviv, Israel with respect to the formulation of demand and availability scenarios and the evaluation of the impact of a series of water management options that were considered applicable in the Case Study.

A detailed description of the region, in terms of geography, population and water economy is presented in Chapter 5. In this section, some characteristics are briefly described, in order to provide a brief overview of the framework used for scenario formulation and evaluation.

The region is located in the Coastal Plain on the eastern shore of the Mediterranean Sea and lies above the Coastal Aquifer. In terms of population, the Tel Aviv region is the largest in Israel, concentrating 30% of the total population (approximately two million persons). The region has 14,700 hectares (ha) of cultivated agricultural land, 5% of the total cultivated land in the country. Therefore, the water economy is characterized by relatively high domestic and industrial consumption and relatively low agricultural consumption.

Tel Aviv constitutes **a core part of the national water system** of Israel. Water supply is mostly provided by the national water company, Mekorot, and consists of groundwater extracted from the Coastal Aquifer above which the region lies and of water from the Sea of Galilee conveyed through the National Water Carrier. It is important to emphasize that most of the urban and industrial waste water produced in the region is **not** utilized for agricultural irrigation within the region itself. Most of this water is treated at the Shafdan plant (90-100 MCM per year), and the treated water is exported to the southern region (western and northern Negev), located 100 to 150 km away from the plant, for agricultural use. In addition, in the future, the region is slated to receive a significant amount of desalinated water.

As Tel-Aviv is part of the national water system, prices charged to the consumers of the region are determined within the national framework. Private producers are subject to a system of public compensations/production levies if their production and operation costs exceed/fall short of the administrative price charged by Mekorot to its consumers. The aim of this public intervention is to equate the prices charged to the consumers of the private water suppliers to the prices charged to the consumers of Mekorot.

Demand and Availability Scenario Components

The data for the analysis undertaken in the region of Tel Aviv were collected from a number of reliable and trustworthy sources, including:

- The Master Program of the Water Commission for the years 2002 – 2010 for the prediction of future domestic, industrial and agricultural demands;
- Monthly publications and reports of the national water company, Mekorot for cost estimates;
- Publication of the parliament about water prices;
- Budget sheets for various crops published by regional offices of the Ministry of Agriculture for the calculation crops values;
- Data on population and weather published by the Israeli Bureau of Statistics;
- Maps and geographical data from the GIS Centre of the Hebrew University of Jerusalem;

- Regional officers of the Ministry of Agriculture for areas planted for various crops and for data on crop budgets, as well as best management irrigation practices.

Demand

The region is characterized by relatively high domestic (191 hm^3/year) and industrial (58 hm^3/year) consumption, and relatively low agricultural consumption (74 hm^3/year). Environmental water consumption is negligible (2 hm^3/yr) and is ignored in the analysis. The prediction of the future demand scenario for the region is based on the recent Master Plan for the development of the Israeli water resources in the years 2002 to 2010, prepared by the planning department of the Water Commission. Specifically, it is assumed that:

(1) **Domestic demand** steadily increases at a constant annual rate of 0.5% due to population growth (the consumption per capita is assumed to be stable over time);

(2) **Agricultural and industrial** demands are stable over time (the land in the region is very expensive, agricultural lands are under pressure from urbanization processes and it is very unlikely that additional land will be allocated for agricultural production).

Total agricultural demand is subdivided among a few crops that represent the typical crop mix in the region: citrus, orchards (other than citrus, e.g. avocados, grapes, mangos, olives and pecans), field crops, vegetables, and flowers.

Availability (Supply)

Israel is a small and narrow country; half of its area is a dry desert. Precipitation, only in the winter, averages more than 700 mm per year in the north and less than 35 mm at the southern tip of the country. The natural supply is unstable since precipitation varies from year to year. Monthly rainfall variations in a given year are not relevant to our analysis.

As shown in Table 5-2 of Chapter 5, the water in the region of Tel Aviv is supplied from:

(1) Local wells, pumping from the coastal aquifer (annual average of 267 hm^3) and via the NWC [annual average of a net amount equal to 40 hm^3 (= import of 270 $hm^3$from Lake Kinneret minus export of 230 hm^3)];

(2) Recycled effluent for irrigation (16 hm^3), and

(3) In the near future, the region is slated to receive a significant amount of desalinated sea water.

Table 11-1 Supply and Demand in Tel-Aviv for an average, normal year (hm^3)

	Demand	Supply	
Local	323	307	Fresh water
		16	Reused water
The Southern Regions of the Country	320 (demand of domestic and agricultural consumers)	230	Fresh water (export for users in the southern regions via the NWC)
		90	Recycled water (export for agricultural users in the southern regions via the Shafdan)
Total	**643**	**643**	

Two major availability scenarios of fresh water are assumed in our analysis:

d) A sequence of 15 years with a stable supply of fresh water equal to the annual long-term average supply (hereafter the Stable or **Normal Scenario**), and

e) A cyclical sequence of 15 years with fluctuating supply, where three consecutive years with average supply are followed by three consecutive dry years with a supply that is 30% lower than the average (hereafter the **Cyclic Scenario**).

Major data on the demands of local consumers, and of consumers who live in the south and who receive water that is either exported to them from Lake Kinneret (via the NWC) through Tel Aviv or produced in the region of Tel-Aviv, are summarized in Table 11-1. Relevant supply data are included as well.

Costs, Prices and Benefits to Water consumers (€/m^3)

The relevant direct costs associated with the various sources supplying water to the region and the prices charged for agricultural, industrial and domestic consumers are summarized in Table 11-2.

Direct Costs

The direct costs (DC) associated with "local drills" are based on the cost of pumping one cubic meter from the aquifer source, through a well and into the distribution system, taking into account the (age dependent) capital cost component of constructing the wells and the water conveyance system. The "imported water" is water imported to the region via the NWC from Lake Kinneret (Sea of Galilee), whose water level is regulated between 209m and 214m **below sea level**. The high pumping costs coupled with the significant distance of water transportation -- the length of the NWC between Lake Kinneret and the region of Tel-Aviv (more than 150 km) - can explain why the costs of imported water is so much higher than water from local drills.

Table 11-2 Direct Costs and Prices Charged to Consumers (€ /m^3)

Source	Cost	Price	Consumer
Imported Water (via the NWC)	0.32	0.18	Agriculture
		0.27	Industry
		0.31	Domestic
Local Drills	0.20	0.18	Agriculture
		0.27	Industry
		0.31	Domestic
Desalination	0.60	0.31	Domestic
Recycled Water	0.14	0.09	Agriculture

The development and operation of new desalination plants is governed by a "BOT agreement" (Build, Operate and Transfer) between the Israeli government and the entrepreneurs. The agreement includes details about the financing, design, construction, operation and transfer of a seawater desalination facility with predetermined production capacity whose supply is guaranteed by the entrepreneurs. The government is committed to purchasing the predetermined production of the facility for a period of about 25 years, at a predetermined price. At the end of that period the facility will be transferred to the control of the government. The cost as per the latest tender for desalinated seawater is 0.53 US$/m^3 at the gate of the plant. Connection to the national water system and transportation add 0.15 US$/m^3, implying desalination costs of about 0.60 €/m^3.

The vast majority of the domestic and urban waste water in the region are treated in the Shafdan treatment plant and exported to the south of the country. The "recycled water" in Table 11-2 represents recycled water treated to a secondary level in relatively small, not modern, local treatment plant and used only for agricultural irrigation. The direct costs associated with this water are relatively low and are composed of only 5 € cents of transportation costs and 9 € cents of maintenance, operation and capital costs.

As mentioned above, water **prices** are determined at the national level and the water prices here considered represent actual water prices.

Environmental costs

The potential sources of environmental costs in the region are threefold:

(i) The major potential source is a gradual increase in the salinity of the groundwater aquifer located below irrigated agricultural land (a portion of the coastal aquifer). Salts are imported to the region with irrigation water conveyed from Lake Kinneret via the NWC. Even though the salt content of the Kinneret, the source for the NWC, is relatively low (200 to 240 ppm Cl), the salt brought in by the NWC gradually accumulates in the soil and ultimately percolates to the groundwater. In addition, in the "process" of domestic consumption, about 100 mg of chlorides per litre are added to the wastewater, some of which is recycled and used for irrigation within the region. However, the vast majority of domestic and industrial wastewater is treated in the Shafdan treatment plant and "exported" to southern regions of the country. We conducted a comprehensive salt-balance analysis for the region of Tel-Aviv and found that the annual amount of salts exported out of the region exceeds—by about 22,000 tons—the sum of the amount that is imported through the NWC and the amount added during the domestic and industrial consumption process. Thus, we assume that there are no salinity-associated environmental costs in this region.

(ii) Environmental costs associated with over-pumping of ground water from the coastal aquifer.

The local fresh water in the region are pumped from the coastal aquifer which is the largest reservoir of natural water in the country, situated in the coastal strip between the Carmel mountain range and the Gaza Strip region. The available storage capacity is 20,000 hm^3. The annual renewal from precipitation is 300-400 hm^3, which is also the average annual pumping rate. As a result of over-pumping during the 1990s, the surface level descended, with penetration of seawater. As a result, the salination level of the aquifer has increased, affecting several wells. The chloride level has a broad range, from 50 to 600 mg chlorine/litre. About two-thirds of the water is still beneath the 250 mg level, the maximum permitted for domestic use. The current policy is to rehabilitate the coastal aquifer, with the aim of raising the average water level and putting a stop to the deterioration in quality. This is being done by selective limitation of pumping approval in areas with severe salinity and quality problems.

So far, we (implicitly) assumed that the current supply (=actual consumption) of water from local drills, 267 hm^3/yr (Table 5-5), does not exceed the natural (plus a limited, artificial) recharge implying the absence of over pumping.

Later on, we will evaluate the option to increase the supply of fresh water in the region via over-pumping. Over-pumping involves significant environmental costs, mainly because of the expected intrusion of sea water, resulting in an increased salinity level.

The environmental costs associated with over-pumping takes into account not only the present damages to consumers associated with the consumption of saline water, but also the costs resulting from the expected future need to rehabilitate (via desalination) increasing number of areas with severe salinity and quality problems. The environmental costs resulting from over-pumping are assumed to be equal to 0.64 € cents.

(iii) Environmental costs associated with unmet agricultural demand. As mentioned above, agriculture in the region of Tel-Aviv has value as a public good in conserving open areas and providing "green lungs". The estimation of the environmental costs associated with the unmet agricultural demand is based on studies conducted in Israel (details are available by request), which estimated the environmental value of cultivated land (relative to non cultivated one) and the average amount of irrigation water (m^3/ha) applied in the region. Specifically, the environmental costs associated with a cut of 1 cubic meter of irrigation water demanded by the agricultural sector - a cut which yields reduction in the cultivated area - are assumed to be 0.09 €.

Benefits to water consumers

The calculations of the benefits gained by water consumers are less obvious and require an explanation. In the absence of any knowledge of the urban demand curve for water or the aggregate willingness of the city residents to pay for water, we approximate the marginal value of water (assumed to be identical to the average value) for domestic and industrial consumers by the marginal cost of the most expensive source that is either currently under use or should be utilized on the basis of economic considerations. In the current example, it is the cost of seawater desalination, 0.60 €/m^3.

The average value of irrigation water applied to each of the annual crops (vegetables, flowers and field crops) is approximated here by calculating the average net profits per m^3 of water applied to that crop, taking into account the alternative value of the agricultural land (measured by the net profits, in €/ha, of the best alternative non-irrigated crop, such as rain-fed wheat).

The calculation of the average value of water applied to mature citrus crops or other orchards is more complicated and its description is outside the scope of the current report. Details are available in the above-mentioned working paper. We just state that its value is composed of the sum of average net profits per m3 applied to the mature grove plus a loss term which measures the potential loss from the need to replace a mature grove by a new grove, in case the mature one is not irrigated and dry out.

The assumed water values for the various crops are summarized in Table 11-3.

Table 11-3 Assumed Water Values or Benefits (€/m^3)

Crop	Field Crops	Vegetables	Flowers	Citrus	Other Orchards	Domestic + Industrial Users
Average Net Benefits per m^3	0.17	0.44	1.03	0.39	0.84	0.60

Social Welfare Surplus (SWS) and Private Welfare Surplus (PWS)

The total social welfare surplus (SWS) in the region is defined as the difference between the total value or benefit accrued by water consumers and the total direct and environmental costs. Following consultation with stakeholders and decision makers in the water economy of Israel, we came to conclusion that for the Israeli case studies, the SWS is the best criterion to rank the various scenarios. Obviously, a management option implying a high SWS value is preferred to one implying a lower value. Total private welfare surplus (PWS), accrue to water consumers, is defined as the difference between water values (benefits) and the water costs charged to the consumers.

While both SWS and PWS depend on the value of water for the various consumers, the former also depends on the actual, direct and environmental' costs of supplying the water while the latter depends on the prices charged to the consumers. Since in many cases water prices differ from water costs, it may well be that the PWS and SWS for a specific group of consumers do not coincide.

Analysis of Reference or Business-As-Usual Scenarios

The two BAU scenarios, which are used as reference scenarios in our analysis, represent the current demand and supply conditions under the above mentioned two assumed water availability conditions:

(i) A sequence of 15 years with a stable supply of fresh water equal to the annual long-term average (normal) supply; denoted by **BauN**, and

(ii) A cyclical sequence of 15 years with fluctuating supply, where three consecutive years with average supply are followed by three consecutive dry years with a supply that is 30% lower than the average; denoted by **BauC**.

The Business-As-Usual + Normal Scenario

The stream of annual demands depicted in Figure 11-1 is based on the assumption that domestic demand is steadily increasing at a constant annual rate of 0.5% due to population growth while agricultural and industrial demands remain constant. The schedule of unmet demands is depicted in Figure 11-2. The combination of stable supply and steadily increasing (domestic) demand for fresh water results in a water shortage after five years which increases over time. Given the assumed allocation priorities, the agricultural sector bears all the necessary cuts (Figure 11-2).

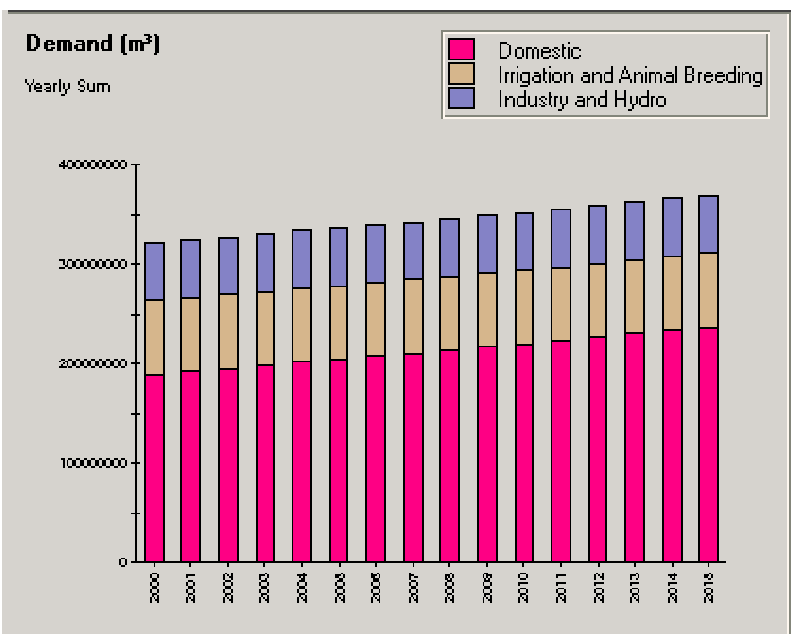


Figure 11-1 Projected water demands per sector under the BauN scenario

The (stable) annual demand of the agricultural sector is composed of 49 hm^3 of recycled water and 25 hm^3 of fresh water (Table 5-3). However, the supply of recycled water is limited to 16 hm^3 for the first year of the time horizon (Table 5-4). We assumed that the supply of recycled water increases with the increased consumption of fresh water (0.5% per year) by the domestic and industrial sectors that are connected to the treatment plants. Specifically, we assumed that 60% of the **increased** consumption is recycled. By the end of the time horizon, the quantity of recycled water available for irrigation has increased to 19 hm^3.

At the beginning of the time schedule, the agricultural demand was fully supplied by 16 hm^3 of recycled water plus 58 hm^3 of fresh water. However, the steady increase in domestic demand for fresh water coupled with the assigned priorities implied that in the fourth year of the time horizon, total demand for fresh water would exceed total supply, with the agricultural sector bearing all the required cuts. The levels of unmet agricultural demand over the last 11 years of the time horizon are depicted in Figure 11-2.

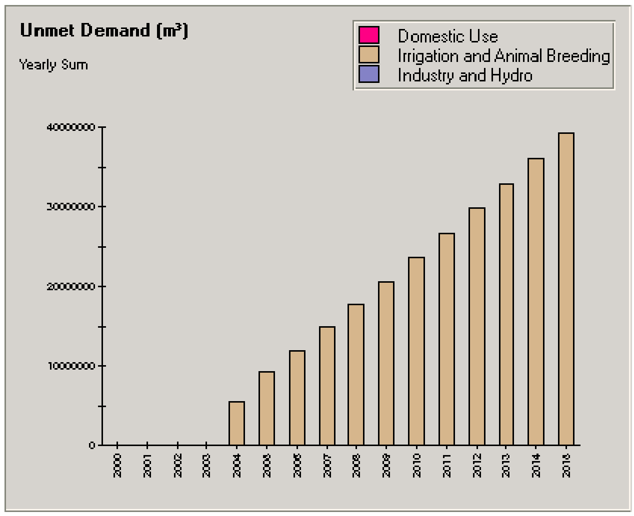


Figure 11-2 Unmet demand under the BauN scenario

Figure 11-3 illustrates the impact of water cuts on areas planted for various types of crops. The area planted for field crops is immediately sharply reduced when the water cuts take effect and vanishes completely within three years (and the land is left idle). The area planted for citrus is also reduced in the early stages until it decreases gradually and vanishes in the year 2012. These two crops are less profitable than the others. Later on, towards the end of the time horizon, the farmers are forced to give up some flowers and vegetables. Orchards other than citrus are the only crop that is kept constant over the entire time period.

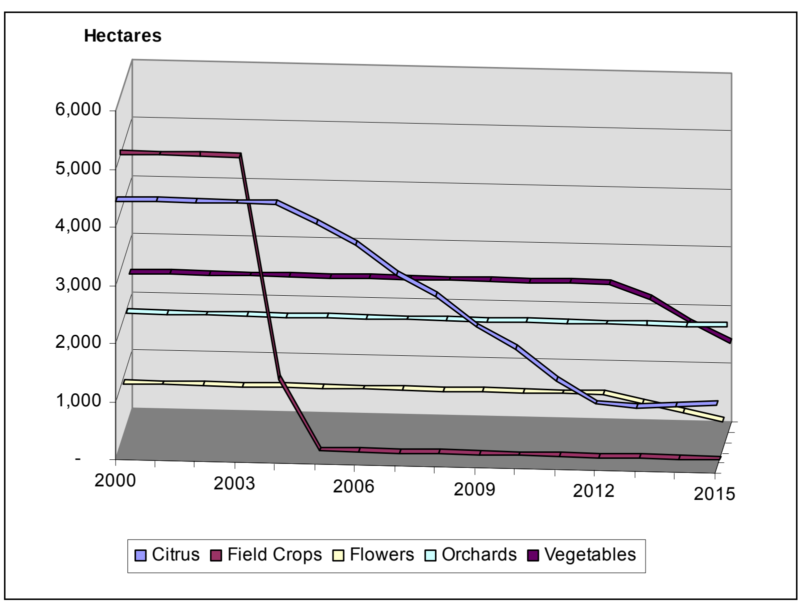


Figure 11-3 The impact of water cuts on areas planted for various crops under the BauN scenario

The total reduction in the area of cultivated land resulting from the water cut from about 14,000 ha in 2004 to only about 5000 ha in 2015 .

Cost Recovery Rate (CRR)

The CRR measures the percentage of the total costs associated with the production and supply of water to consumers that are covered by total water charges paid by the various consumers. Water prices in Israel are determined in the political arena and depend on the type of use: farmers pay the lowest charges, industry pays higher charges and households pay the highest ones. Within each sector, charges do not depend on location: users in all parts of the country face the same charges, regardless of the supply price of water. More than 87% percent of the fresh water consumed in the region is from local wells, and the direct costs of its production and supply, 0.20 €/m^3, are lower than the prices charged to domestic and industrial consumers, and only 2 cents lower than the agricultural water prices. Thus the total water charges collected from the region's consumers exceed total costs and the “total” (i.e., average) CRR (Figure 11-4) exceeds 1.1 (i.e. 110%). We also calculated the value of the CRR for each of the consumers. As can be seen from Figure 11-4, the CRR of domestic consumers, who pay the highest price for water (0.31 €/m^3) is higher than 140% and that of industrial consumers is close to 130%. Water charges that exceed water costs are not rebated to consumers, implying that domestic and industrial consumers in Tel-Aviv's region subsidize consumers in other regions of the country (in most of the other regions, including the Arava, average CRR is lower than 1). Finally, note from Table 5-4 and Table 5-5, presented in Chapter 5 that agricultural consumption is composed of 22% recycled water -the price of which (0.09 €/m^3) is lower than its cost (0.14 €/m^3) -and 78% fresh water, the price of which (0.18 €/m^3) is also lower than its cost. Thus, the value of the CRR for agricultural consumers is lower than 1 (and ranges between 80% and 73%), implying that even in Tel-Aviv's region, agricultural consumption is slightly subsidized.

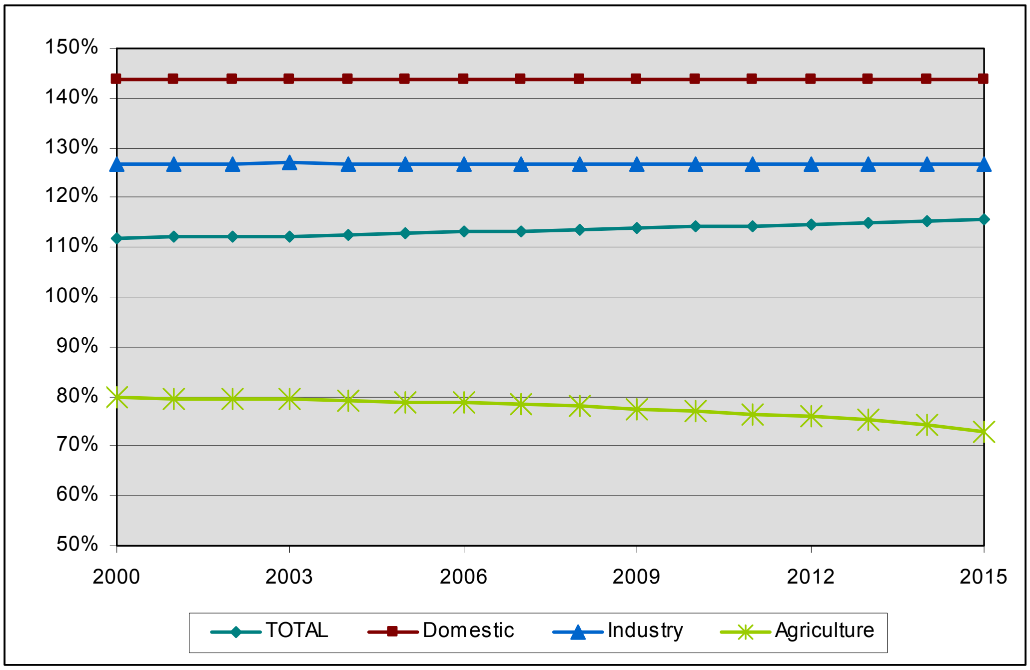


Figure 11-4 The CRR under the BauN scenario

Effectiveness

The “effectiveness” is defined as the ratio of supply delivered (i.e., actual consumption) to the level of water demanded. Since unmet demand is limited to the agricultural sector, the effectiveness for domestic and industrial uses is 100% (Figure 11-5). As can be seen from

Figure 11-2, the effectiveness for agricultural uses is 100% in the first 4 years of the planning period and then it steadily reduces, reaching level lower than 45% at 2015 (Figure 11-5).

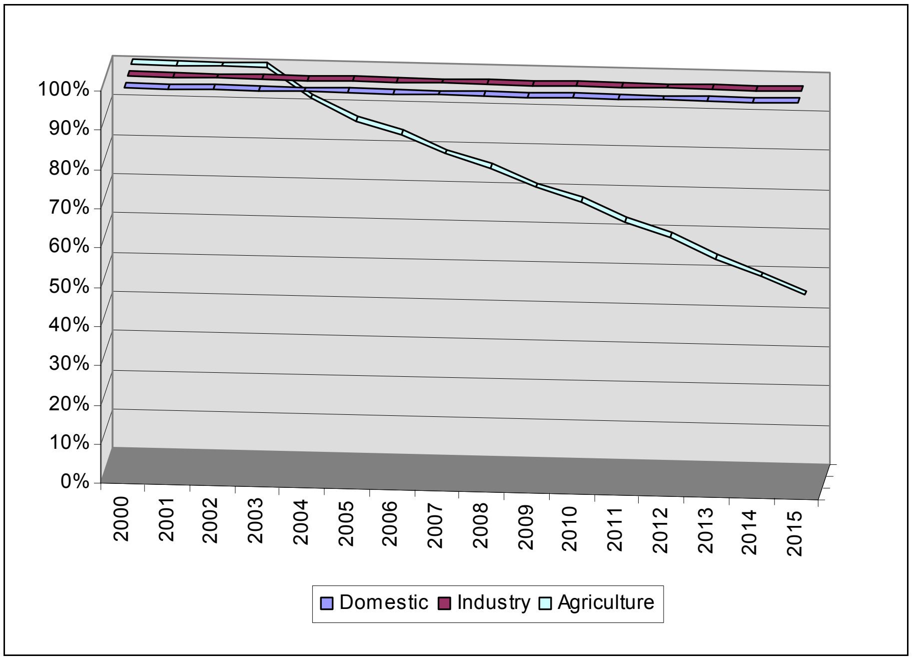


Figure 11-5 Effectiveness for Domestic, Industrial and Agricultural use under the BauN scenario

Social Welfare Surplus (SWS)

The values of Social Welfare Surplus for the 15 years of the time horizon are depicted in Figure 11-6.

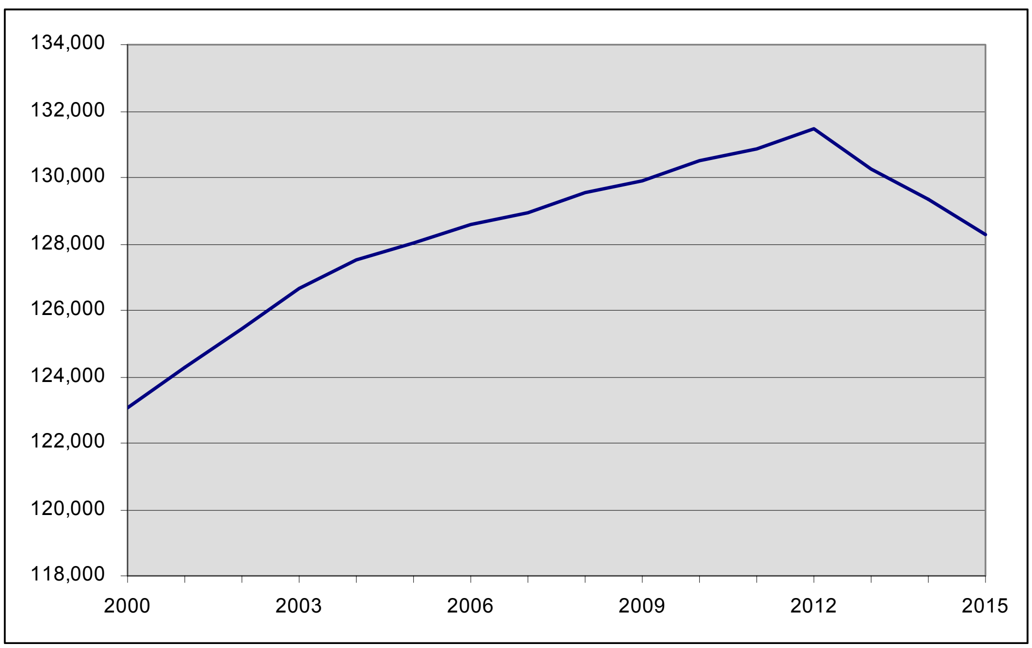


Figure 11-6 Social Welfare Surplus (SWS) under the BauN scenario

The increase in SWS over the period 2000 to 2015 is due to the positive and steady shift in domestic demand which increases the aggregate welfare of domestic and industrial users (i.e., the marginal value of water for these consumers is multiplied by larger quantities of water). In the first four years, the cultivated area is not affected by the increased domestic and industrial demand and thus agricultural consumption of water and its associated SWS are constant.

From the fifth year and on, the agricultural sector bears increasing water cuts, implying a reduction in the cultivated area and in the contribution of this sector to aggregate SWS. However, until the year 2012, the annual increase in SWS resulting from increased consumption by the domestic and industrial sectors is larger than its reduction in the agricultural sector. In the last 4 years, farmers are forced to cut the area planted for flowers, the most profitable crop (see Table 11-3). Since the average value of water applied to flowers (1.03 €/m^3) is higher than the average value attributed to domestic and industrial consumption (0.60 €/m^3), the aggregate value of SWS declines in the last four years.

For ranking purposes, we calculated for each of the scenarios the present value of the stream of SWS values, denoted by NPV (SWS). A management option implying a high value of NPV (SWS) is preferred to one implying a lower value.

In this, BauN, scenario, NPV(SWS) = 1,409.7 million € with an assumed real interest rate of r = 4%.

Present values (r=4%) of PWS, SWS, and environmental and direct costs are presented in Figure 11-7.

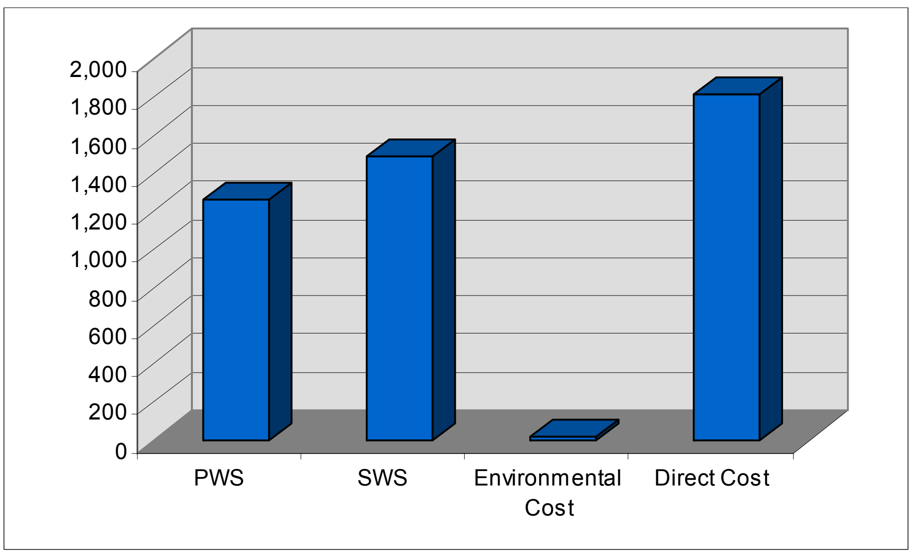


Figure 11-7 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauN scenario

With the exception of the agricultural sector, consumer prices of fresh water exceed water costs (the gap for water from local drills is the highest), implying that NPV (PWS) - 1263.7 million € – is lower than NPV (SWS). The present value of total direct costs – 1812.6 million € – is about 122 times higher than the one of total environmental costs (14.8 million €). In other words, the environmental costs caused by the water shortage, implying a reduction of water supply for the agricultural consumers and subsequently, reduction of the cultivated area, is relatively quite small under the BauN scenario.

The second reference or business as usual scenario is the BauC Scenario which is presented below.

The Business-As-Usual + Cyclic Scenario

This scenario assumes a cyclical sequence of 15 years with fluctuating supply, where three consecutive years with average supply are followed by three consecutive dry years with a supply that is 30% lower than the average. As can be seen from Figure 11-8, unmet demand in the drought periods (2003-2005, 2009-2011 and 2015) is not limited to the agricultural sector (as was the case under the BauN scenario (Figure 11-2). In fact, during the dry years, the agricultural and industrial sectors do not receive fresh water at all, a situation that cannot be tolerated by society, and cannot be left untreated.

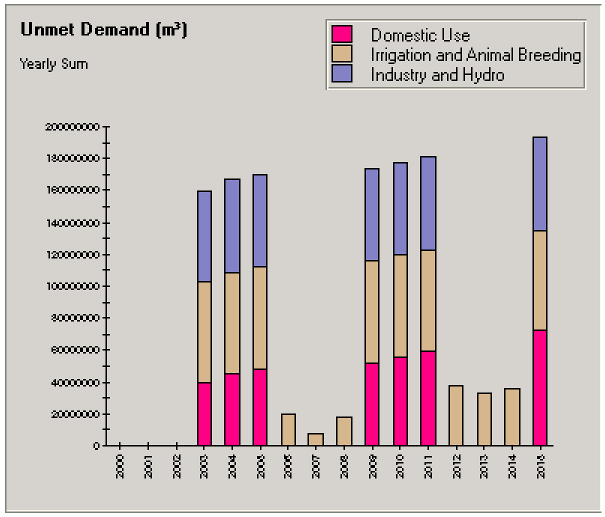


Figure 11-8 Unmet demand under the BauC scenario

The impact of water cuts on the cultivated area is presented in Figure 11-9.

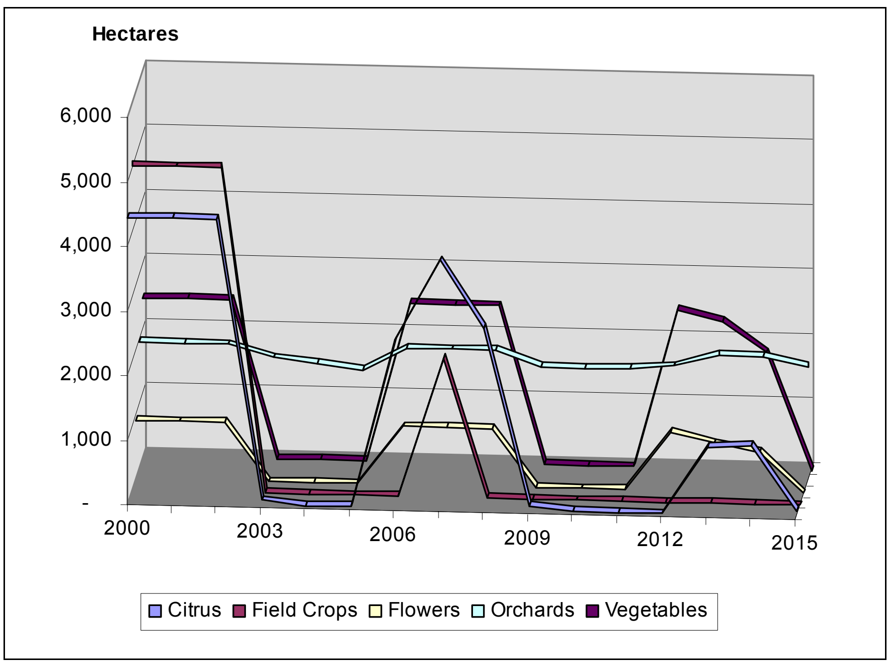


Figure 11-9 The impact of water cuts on the areas planted for various crops under the BauC scenario

The figure clearly demonstrates that during the dry periods, the areas planted for flowers and vegetables, which are irrigated with fresh water, vanish. The area planted for field crops, which are less profitable, vanishes completely from the year 2003 until the end of the time horizon. Citrus and other orchards are irrigated with recycled water and the latter are more profitable (Table 11-3). During the dry periods, all the available recycled water is supplied to the orchards, the area of which is quite stable over the time horizon. Citrus receives no water during those periods and dries out. Obviously, since citrus and orchards are perennial crops, the area planted for them cannot fluctuate sharply from year to year. While calculating the SWS value associated with the agricultural sector, we assume that a grove that is not irrigated dries out and is replaced by a new grove.

Cost recovery rate (CRR)

The CRR values are presented in Figure 11-10. The values associated with domestic consumption are higher during the dry years. This is because the supply of the relatively expensive imported water is cut off during the dry years and all consumption is satisfied from local wells. The cost of the latter is much lower (see Table 11-2) than the cost of imported water; meanwhile, urban consumers pay the same price for water from both sources. The CRR associated with the industrial sector drops to zero in dry years since it does not receive any fresh water. The CRR values associated with the agricultural sector are lower during the dry years because the portion of recycled water in total water consumption increases during these periods, and the price paid for that water is much lower than the cost of supplying it.

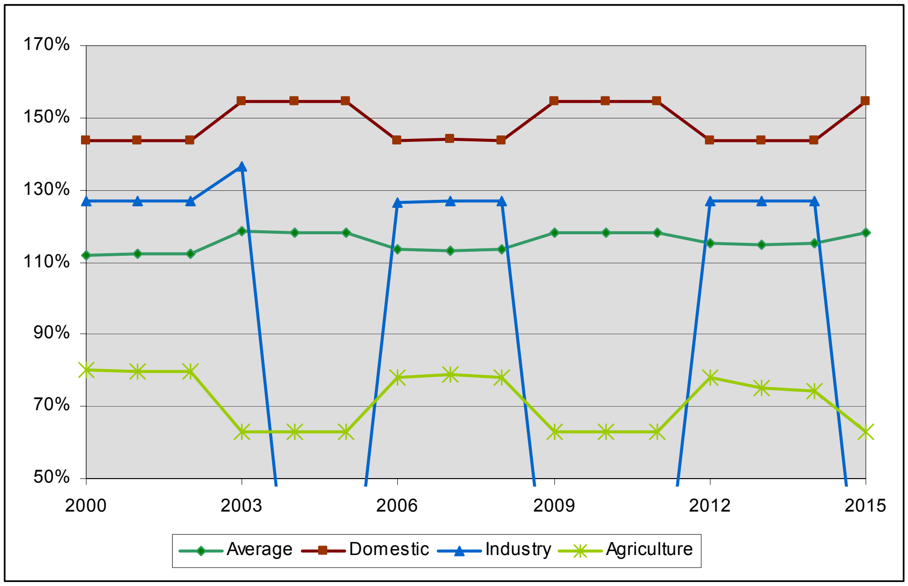


Figure 11-10 The CRR under the BauC scenario

Effectiveness

In contrast to the BauN scenario (see Figure 11-5) the "effectiveness" for domestic and industrial uses is not 100% for the whole planning horizon. Inspection of Figure 11-11 shows that during the sequences of dry years its values drop below 70% for the domestic sector and to zero for the industrial sector. The effectiveness for agricultural fluctuates, dropping to about 10% during the dry periods.

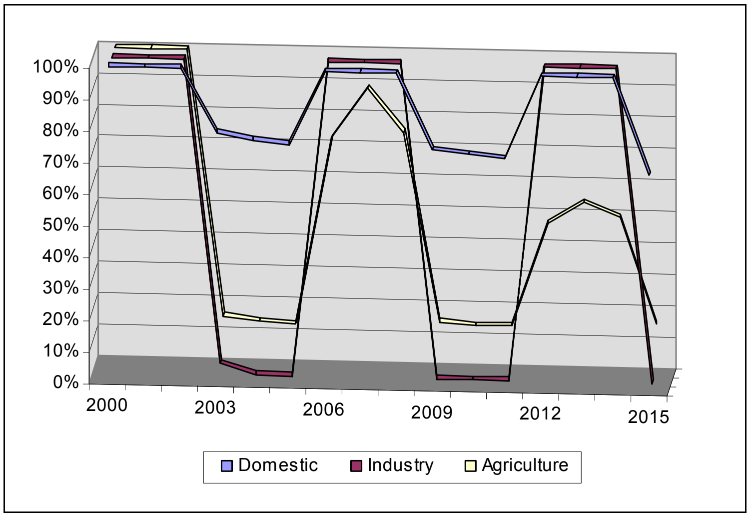


Figure 11-11 Effectiveness for Domestic, Industrial and Agricultural use under the BauC scenario

Social Welfare Surplus (SWS)

The annual SWS values for the BauC scenario are depicted in Figure 11-12. The sharp reduction in SWS during the dry periods is quite large.

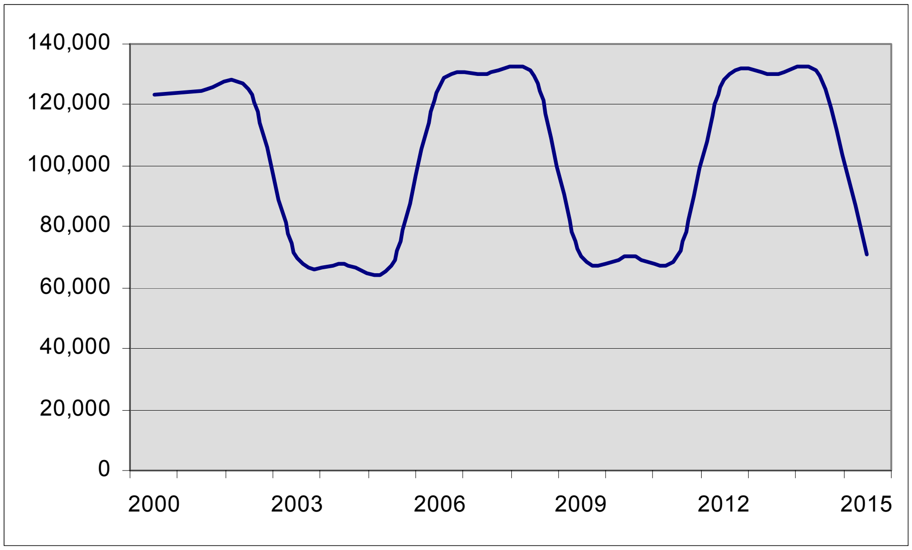


Figure 11-12 SWS under the BauC scenario

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauC scenario are presented in Figure 11-13 together with the respective values for the BauN scenario.

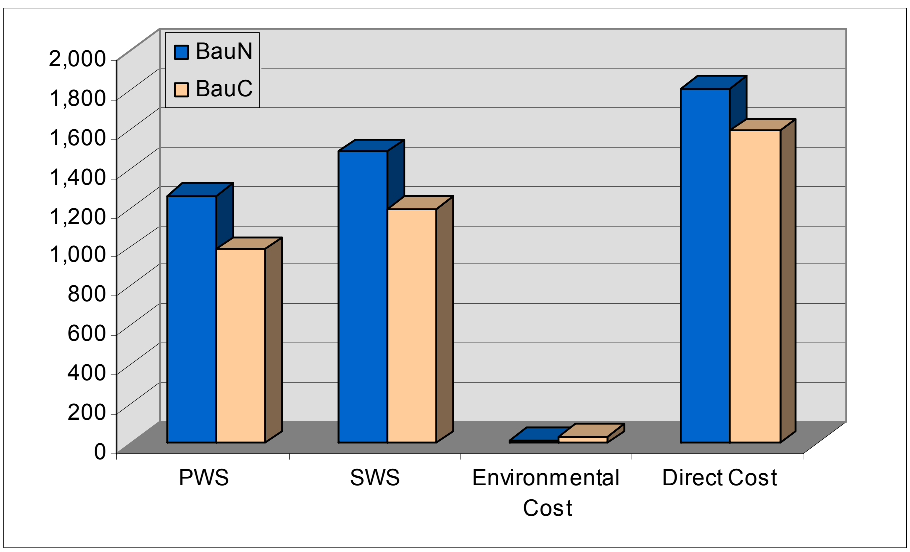


Figure 11-13 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauC and the BauN scenarios

As expected the value of both, NPV (SWS) and NPV (PWS) under the BauC scenario are lower than the respective values under the BauN scenario. Obviously, a state of nature with a sequence of 15 years with a stable supply of fresh water are preferred to a sequence with fluctuating supply, where three consecutive years with average supply are followed by three consecutive dry years. Unfortunately, the choice of the state on nature is not in the discretion of the decision makers. The present value of total direct costs – 1,596.1 million € – is about 45 times higher than the one of total environmental costs (35.1 million €). The direct costs under the BauC scenario are lower than the respective costs under the BauN scenario simply because less water is supplied in the former. On the other hand, the larger water shortage for the agricultural sector under the BauC scenario implies that its associated environmental costs are about 2.4 higher than these costs under the BauN scenario.

Analysis of Water Management Options

For each one of the aforementioned availability scenarios, we evaluated the impacts of the following management options:

a) Increasing the annual supply of recycled wastewater (via the connection of additional cities in the region to the existing wastewater treatment plants) by 12 hm^3; (scenarios **BauN+R; BauC+R**).

b) Increasing the annual supply of fresh water by establishing one desalination plant, capable of desalinating 50 hm3 of sea water annually, in the second year of the time horizon, and then establishing an identical desalination plant in the seventh year of the planning period. The plants are operated only in periods of freshwater shortage; (scenarios **BauN+D; BauC+D**).

c) Increasing the annual supply of fresh water via over pumping of ground water from the coastal aquifer, taking into account that it involves significant environmental costs assumed to be equal to 0.64 € cents; (scenarios **BauN+OP; BauC+OP**).

d) Reducing gross annual domestic demand for water by 20% via investment in water conservation; (scenarios **BauN+WC; BauC+WC**).

Before proceeding, we briefly elaborate here on the last management option for the sake of clarity. Conservation efforts in the urban sector in Israel focus on improvements in efficiency, repair, control and monitoring of municipal water systems, controlled exploitation, spatial distribution of new boreholes, promotion of household pressure reducer devices, dual flush toilets, pull handle taps and cisterns with double quantity dispensers, and increased public awareness and media campaigns.

Based on a comprehensive study that was conducted in Israel, the direct costs required to save 20% of water consumed in the domestic sector are 0.12 €.

Table 11-4 presents the acronyms for all combinations of the scenarios for Tel Aviv.

Table 11-4 Abbreviations of Assumed Scenarios for the region of Tel Aviv

Water Availability	Normal (average) Replenishment of Freshwater	Cyclical Replenishment of Fresh Water
The Current Supply Situation	BauN (reference)	BauC (reference)
Increased Supply of Recycled Water	BauN+R	BauC+R
Increased Supply via seawater desalination	BauN+D	BauC+D
Increased supply via over pumping	BauN+OP	BauC+OP
Reducing gross domestic demand via water conservation	BauN+WC	BauC+WC

Increased Supply of Recycled Water

Recycling under the Business-As-Usual+Normal Scenario (BauN+R)

Currently, only a few cities in the region are connected to wastewater-treatment plants other than the Shafdan, which supplies recycled water for agricultural irrigation within the region itself, at a level of 16 hm^3. Under the BauN+R scenario, we assume the establishment of additional treatment plant which enables the treatment of wastewater from a few additional municipalities and increases the annual amount of recycled water available for irrigation within the region (at the beginning of the time horizon) by 12 hm^3. Thus, in this scenario, the supply of recycled water is limited to 28 hm^3 for the first year of the time horizon. Then, it increases with the increasing consumption of fresh water (0.5% per year) by the domestic and industrial sectors which are connected to the treatment plants. Specifically, we assume that 60% of the **increased** consumption is recycled. By the end of the time horizon, the quantity of recycled water available for irrigation increases to 49 hm^3, which is equal to the total demand for recycled water (see Table 5-3). Figure 11-14 and Figure 11-15 depict the unmet demands and the agricultural cultivated areas, respectively.

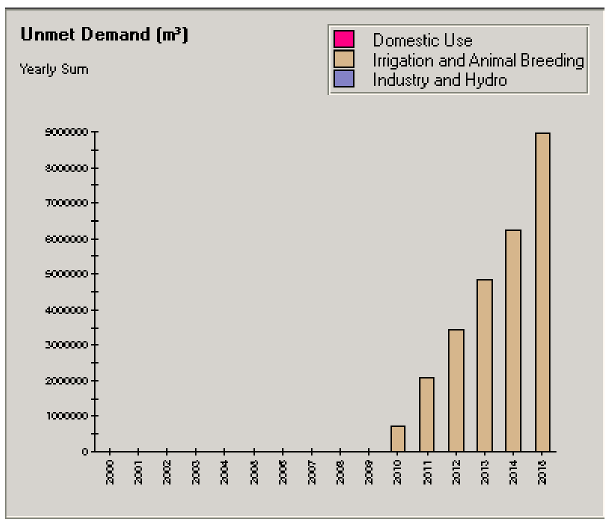


Figure 11-14 Unmet demand under the BauN+R scenario

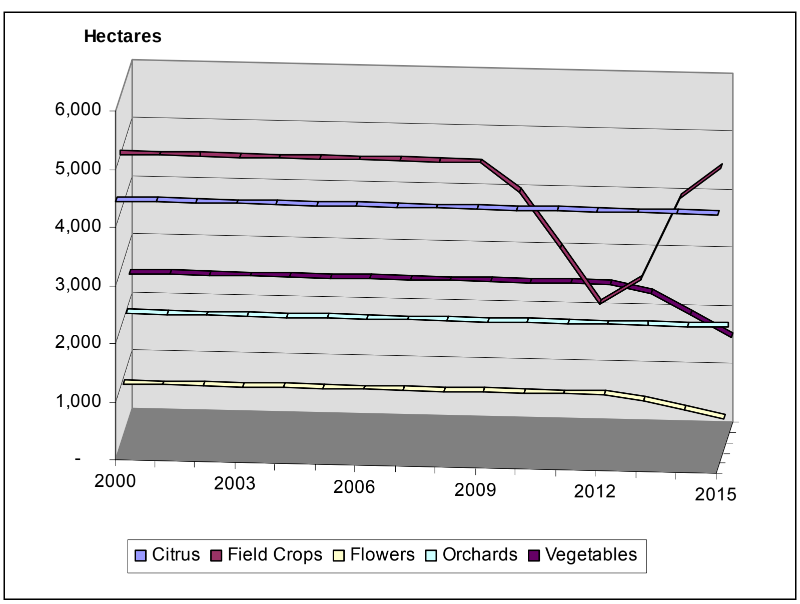


Figure 11-15 The impact of water cuts on the areas planted for various crops under the BauN+R scenario

Comparison with the corresponding Figure 11-2 and Figure 11-3 for the BauN scenario (a reference scenario) shows that the period under which agricultural demand for 74 hm^3 per year is fully satisfied increases from 4 (Figure 11-2) to 10 (Figure 11-14) years. Moreover, the level of unmet demand under the BauN scenario (i.e. about 40 hm^3 in the last year of the time horizon) is much higher than the one under the BauN+R scenario (i.e. “only” about 9 hm^3 in the last year).

Inspection of Figure 11-3 and Figure 11-15 clearly illustrates that the aggregate cultivated area under the BauN scenario is significantly smaller than the one under the BauN+R scenario for each year.

Cost Recovery Rate (CRR)

To economize space, we do not present the figures showing the annual CRRs for this scenario. We found that the CRR for domestic and industrial demand are very similar to those derived under the BauN scenario. However, for the agricultural sector, the CRR under the BauN+R scenario is lower by about 2 to 5% than the one under the BauN scenario. The gradual increase in the supply and consumption of recycled water, the price of which, for the agricultural users (0.09 €/m^3), is much lower than its costs (0.14 €/m^3), is the reason for that difference.

Effectiveness and Improvement

The “effectiveness” indices for domestic, industrial and agricultural uses for the BauN+R scenario are presented in Figure 11-16. Comparison with the corresponding Figure 11-5 for the BauN scenario shows that under both scenarios domestic and industrial demands are fully met for all the years of the planning horizon. As for the agricultural sector: the effectiveness is 100% in the first 4 years of the planning period under the BauN scenario and in the first 10 years under the BauN+R scenario. Moreover, under the BauN scenario it steadily drops to a low level of about 45% at 2015 (Figure 11-5), while under the BauN+R scenario it drops “only” to level of about 85% at 2015 (Figure 11-16).

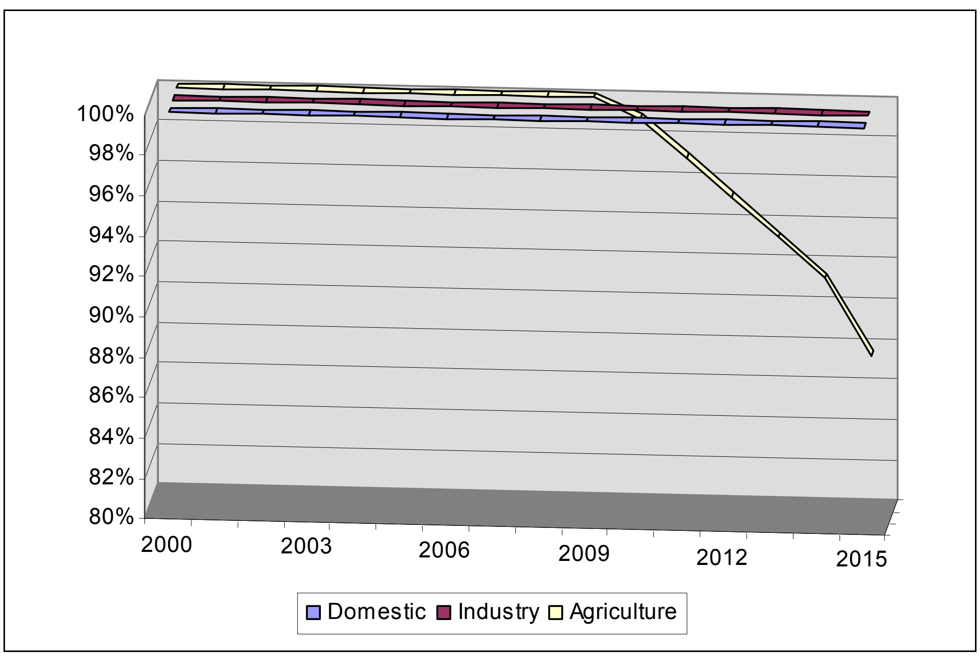


Figure 11-16 Effectiveness for Domestic, Industrial and Agricultural use under the BauN+R scenario

Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauN+R scenario with respect to the reference BauN are depicted in Figure 11-17.

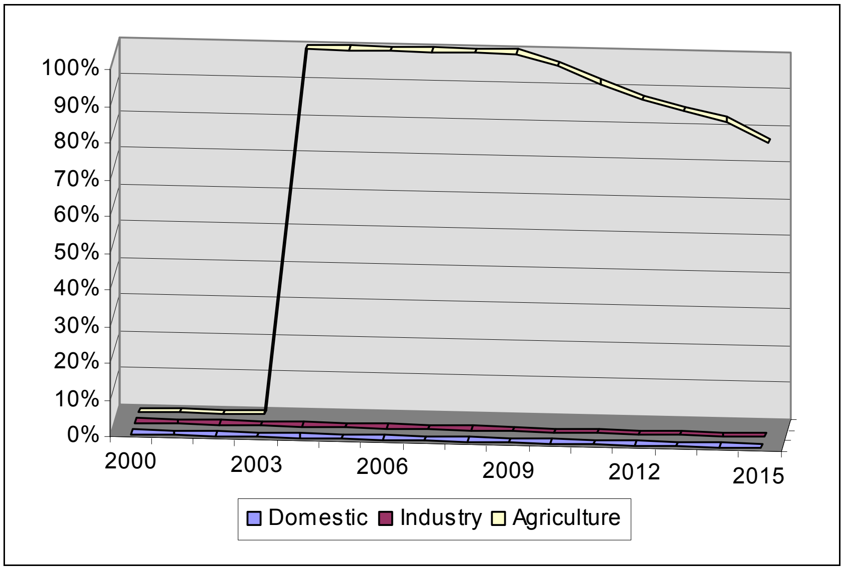


Figure 11-17 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauN+R scenario relative to the reference BauN scenario

Since unmet demand under the reference scenario is limited only to the agricultural sector, there is no improvement of deficit in the domestic and industrial uses. The improvement in agricultural deficit after the fourth year of the time horizon is very significant and equal to 100% for all the years in which agricultural deficit under the BauN+R scenario vanishes.

Social Welfare Surplus (SWS)

As for the welfare indicator, we found that the values of NPV(SWS) associated with the BauN+R scenario (1,533.5 million €) is higher by about 43 million € than the respective value under the reference, BauN, scenario. This implies that **the option to reduce agricultural water shortages by increasing the supply of recycled water is socially profitable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauN+R scenario are presented in Figure 11-18 together with the respective values for the reference BauN scenario.

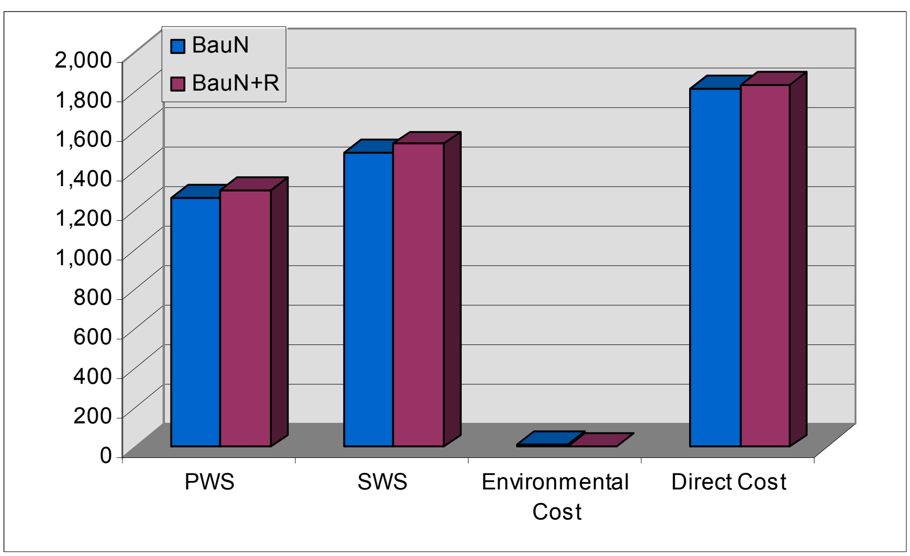


Figure 11-18 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauN+R and the BauN scenarios

The values of both, NPV (SWS) and NPV (PWS) under the BauN+R scenario are higher than the respective values under the reference, BauN scenario. The direct costs under both scenarios are similar (1812.6 and 1831.6 million € under the BauN and under the BauN+R scenarios, respectively. Due to the relatively small water shortage for the agricultural sector under the BauN+R scenario, its associated environmental costs are negligible (1.3 million €).

Recycling under the Business-As-Usual+Cyclic Scenario (BauC+R)

Figure 11-19 and Figure 11-20 depict the unmet demands and the agricultural cultivated areas, respectively. Comparison with the corresponding Figure 11-8 and Figure 11-9 for the reference BauC scenario shows an improvement in all sectors especially in the agricultural one. The period under which agricultural demand for 74 hm^3/yr is fully satisfied decreases from 13 (Figure 11-8) to 11 (Figure 11-19) years.

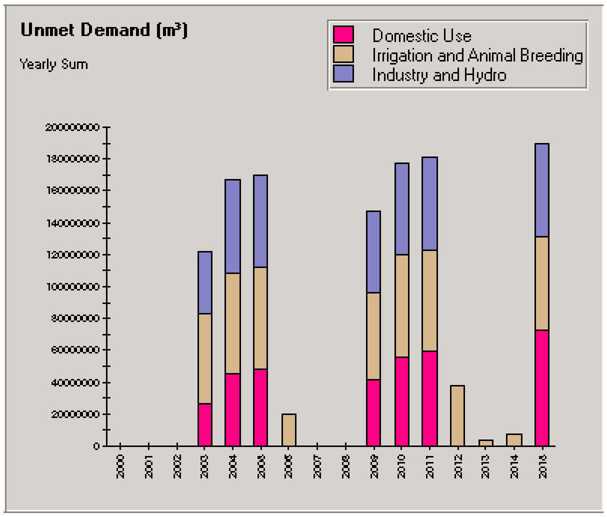


Figure 11-19 Unmet demand under the BauC+R scenario

Inspection of Figure 11-9 and Figure 11-20 clearly illustrates that the aggregate cultivated area under the BauC scenario is significantly smaller than the one under the BauC+R scenario for each year.

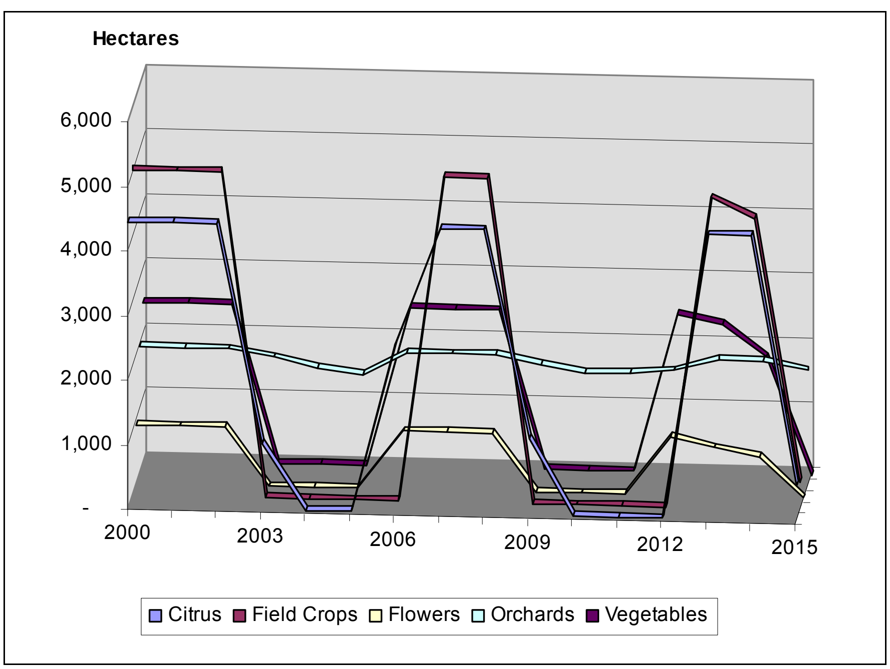


Figure 11-20 The impact of water cuts on the areas planted for various crops under the BauC+R scenario

Cost Recovery Rate (CRR)

We found that the CRRs for domestic and industrial demand are very similar to those derived under the BauC scenario. However, for the agricultural sector, the CRR under the BauC+R scenario is lower by about 2 to 5% than the one under the BauC scenario. The gradual increase in the supply and consumption of recycled water, the price of which, for the agricultural users (0.09 €/m^3), is much lower than its costs (0.14 €/m^3), is the reason for that difference.

Effectiveness and Improvement

The “effectiveness” indices for domestic, industrial and agricultural uses for the BauC+R scenario are presented in Figure 11-21. Comparison with the corresponding Figure 11-11 for the BauC scenario shows that the effectiveness related to the domestic and industrial uses are the same under both scenarios.

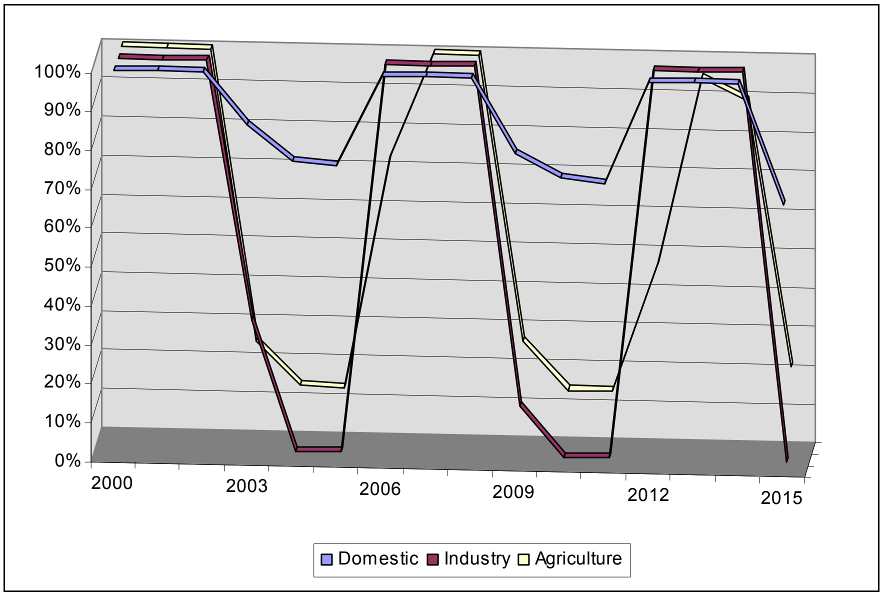


Figure 11-21 Effectiveness for Domestic, Industrial and Agricultural use under the BauC+R scenario

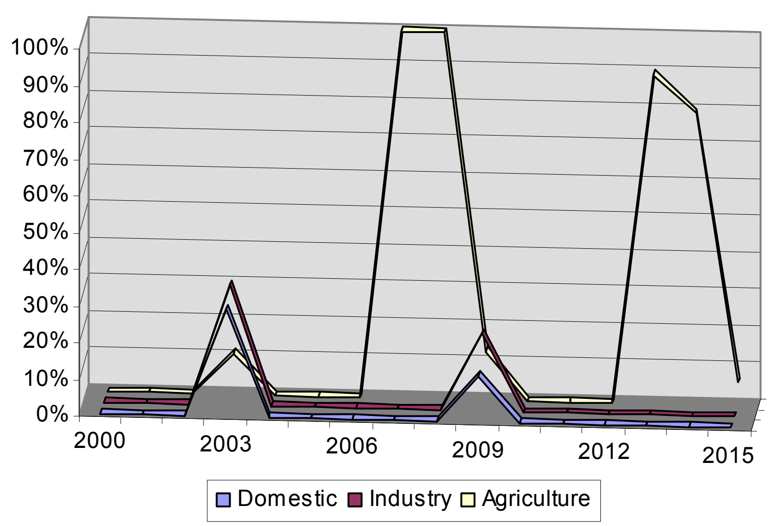


Figure 11-22 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauC+R scenario relative to the reference BauC scenario

As for the agricultural sector: the effectiveness is 100% in the first 4 years of the planning period under the BauC scenario as well as under the BauC+R scenario. From the fifth year and on the effectiveness level is much higher under the BauC+R scenario. Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauC+R, with respect to the reference BauC, are depicted in Figure 11-22.

Since unmet demand under the reference scenario is similar to that under the BauC+R scenario for both, the industrial and domestic sectors, the improvement is limited to two years. Specifically, the improvement for the industrial sector is 33% in 2003 and 21% in 2009 and the improvement for the domestic sector is 28% in 2003 and 13% in 2009. The significant improvement is in the agricultural sector especially in the years 2007 and 2008 (100%) and in the years 2013 (90%) and 2014 (79%).

Social Welfare Surplus (SWS)

As for the welfare indicator, we found that the values of NPV(SWS) associated with the BauC+R scenario (1,230.7 million €) is higher by about 36 million € than the respective value under the reference, BauC, scenario. This implies that **the option to reduce agricultural water shortages by increasing the supply of recycled water is socially profitable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauC+R scenario are presented in Figure 11-23 together with the respective values for the reference BauC scenario.

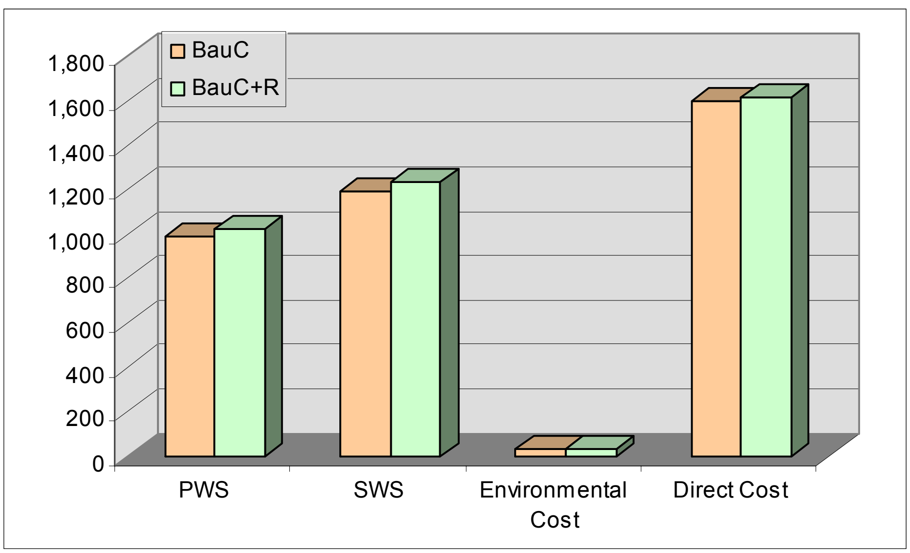


Figure 11-23 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauC+R and the BauC scenarios

The values of both NPV (SWS) and NPV (PWS) under the BauC+R scenario are somewhat higher than the respective values under the reference, BauC scenario. The direct costs under both scenarios are similar (1,596.1 and 1,611.1 million € under the BauC and under the BauC+R scenarios, respectively). Due to the relatively small water shortage for the agricultural sector under the BauC+R scenario, the environmental cost decreases by almost 17% under the BauC+R scenario (29.3 million €) comparing to the reference scenario (35.1 million €).

Increased Supply via Seawater Desalination

Desalination under the Business-As-Usual + Normal Scenario (BauN+D)

Relative to the basic BauN scenario, this one assumes an increase in the annual supply of fresh water via the establishment of one desalination plant, capable of desalinating 50 hm^3 of sea water annually, in the second year of the planning horizon and the establishment of an identical desalination plant in the seventh year of the planning period. The desalination plants are only operated in periods of freshwater shortage. We implicitly assume that the desalination plants can supply water to additional regions other than Tel-Aviv, but Tel Aviv's region has the highest priority for this water. When the consumption of desalinated water in Tel Aviv falls short of the total supply, the extra supply is conveyed to other regions (which are not included in our case study).

Under this scenario, the demand of all consumers is met for all the years of the time horizon, and all agricultural plots are fully cultivated (see Figure 11-24).

As shown in Table 11-5, only one of the two desalination plants is operated during the years 2004 to 2015, to meet the deficit in the agricultural sector. The total supply of desalinated water during the planning horizon is 267.8 hm^3.

Table 11-5 Quantities of Desalinated Water Under the BauN+D Scenario (hm^3)

Desalination Plant	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
First	5.5	9.2	12.0	14.8	17.7	20.6	23.6	26.7	29.7	32.8	36.0	39.2
Second	-	-	-	-	-	-	-	-	-	-	-	-
Total	5.5	9.2	12.0	14.8	17.7	20.6	23.6	26.7	29.7	32.8	36.0	39.2

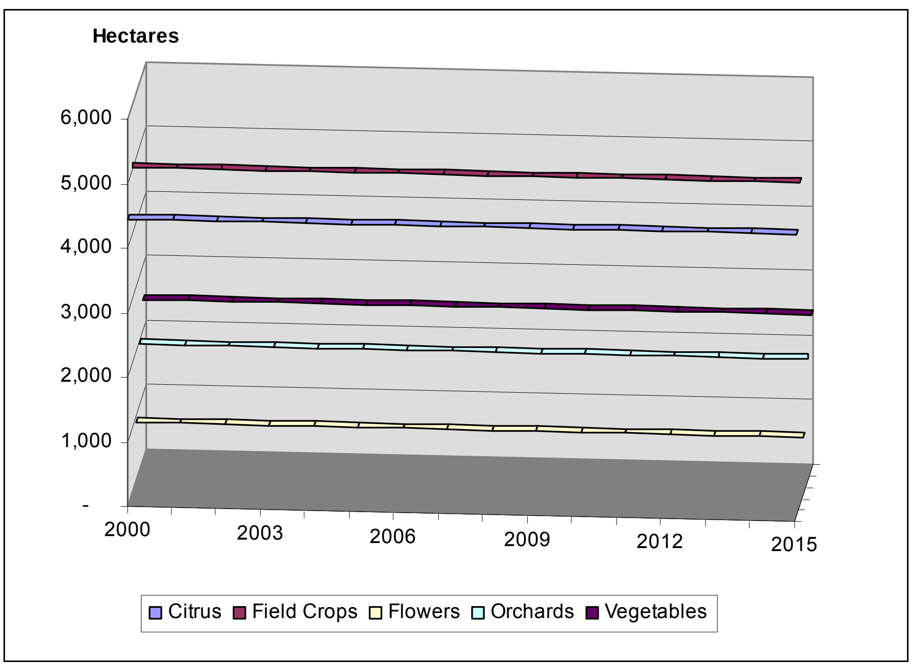


Figure 11-24 The impact of water cuts on the areas planted for various crops under the BauN+D scenario

Cost Recovery Rate (CRR)

The CRR values for the industrial and agricultural users under this scenario are quite similar to those of the reference BauN scenario, but there is a notable difference with respect to the domestic sector. Under the reference scenario, the CRR values for the domestic sector are practically stable at a level of 143%, whereas under the BauN+D scenario, they decline steadily from the fifth year of the planning horizon, when the expensive desalinated plants are being operated, reaching a level of 110% in the year 2015.

Effectiveness and Improvement

The "effectiveness" indices for domestic, industrial and agricultural uses for the BauN+D scenario are presented in Figure 11-25. Comparison with the corresponding Figure 11-5 for the BauN scenario shows that under both scenarios domestic and industrial demands are fully met for all the years of the planning horizon. As for the agricultural sector: the effectiveness is 100% in all years of the planning period under the BauN+D scenario while under the BauN scenario it steadily drops to a low level of about 45% at 2015 (Figure 11-5).

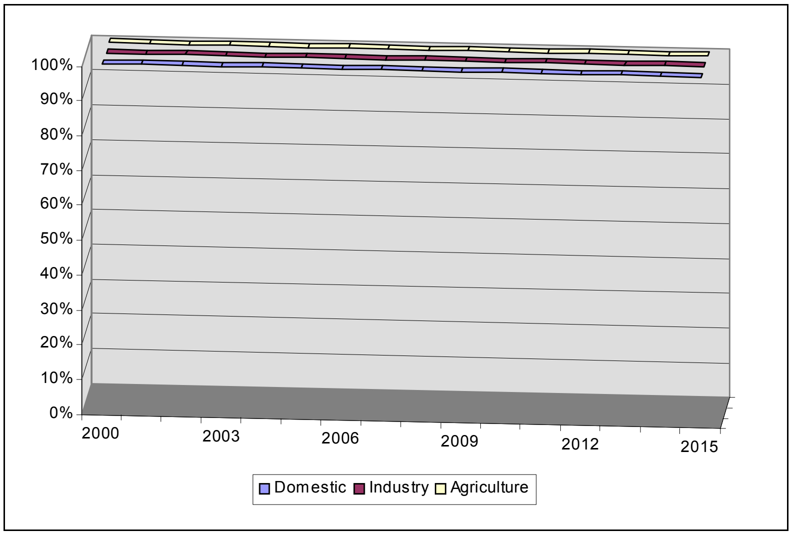


Figure 11-25 Effectiveness for Domestic, Industrial and Agricultural use under the BauN+D scenario

Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauN+D with respect to the reference BauN are depicted in Figure 11-26. Since unmet demand under the reference scenario is limited only to the agricultural sector, there is no improvement of deficit in the domestic and industrial uses. The improvement in agricultural deficit after the fourth year of the time horizon is very significant and equal to 100% for all the years in which agricultural deficit under the BauN+D scenario vanishes.

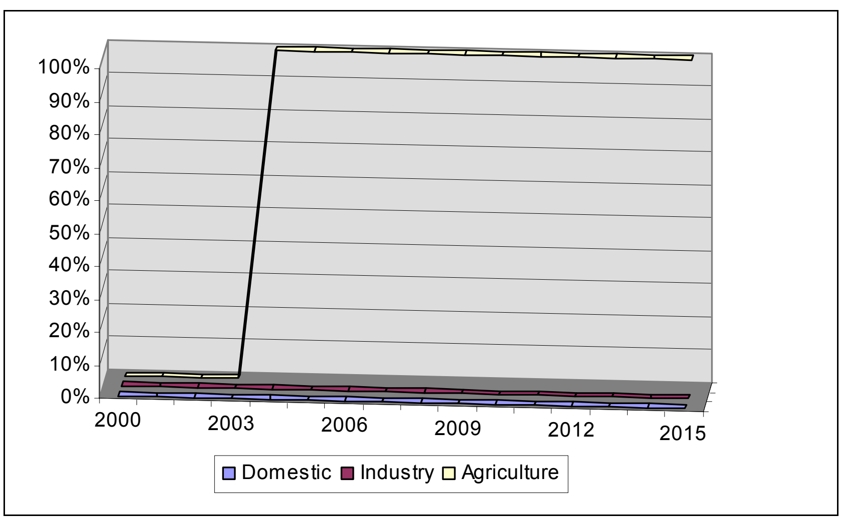


Figure 11-26 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauN+D scenario relative to the reference BauN scenario

Social Welfare Surplus (SWS)

As for the welfare indicator, the values of NPV(SWS) associated with the BauN+D scenario (1,463 million €) is lower by about 27.7 million € than the respective value under the reference, BauN, scenario. **Thus, it can be concluded that under normal weather conditions, meeting all unmet demands via the establishment of desalination plants (the BauN+D) scenario is socially undesirable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauN+D scenario are presented in Figure 11-27 together with the respective values for the reference BauN scenario.

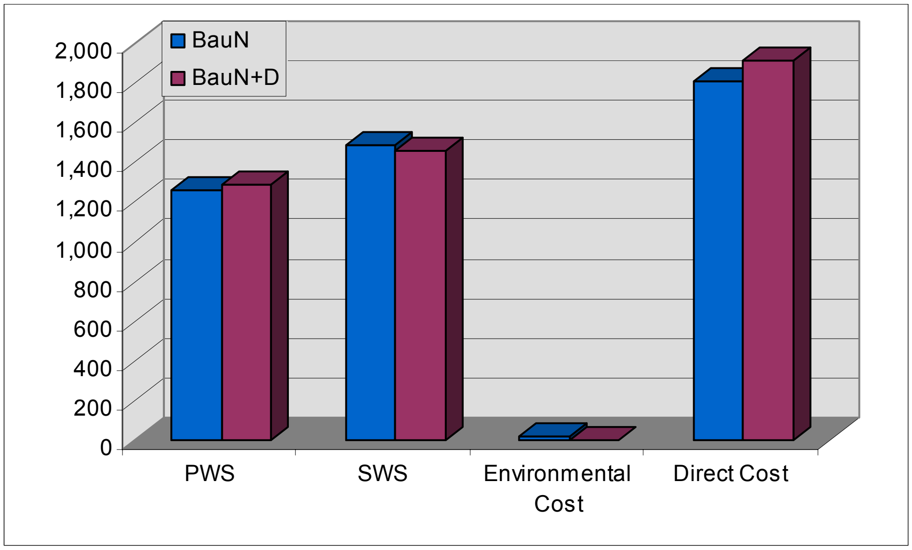


Figure 11-27 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauN+D and the BauN scenarios

While NPV(SWS) under the BauN+D scenario is smaller than the one under the reference BauN scenario, the relationships are reversed with respect to the present values of private welfare surpluses, NPV(PWS). The reduction in social welfare surplus is attributed to the utilization of costly desalinated water to overcome the water deficit in the agricultural sector. Since the price of fresh water charged to each one of the users is independent of the water source (see Table 11-2), the private welfare surplus increases (from 1263.7 million € under the BauN scenario to 1292.2 million € under the BauN+D scenario) due to the increased consumption by the agricultural sector. This result may explain the political pressure of the agricultural lobby in Israel to increase water supply via desalination without changing the agricultural water prices. The direct costs under the BauN+D scenario (1,913.8 million €) are higher by 101.2 million € than those associated with the reference scenario. Due to the absence of water shortage for the agricultural sector under the BauC+D scenario, its associated environmental cost is zero.

Desalination under the Business-As-Usual + Cyclic Scenario (BauC+D)

Unlike the parallel scenario under a stable supply of fresh water, BauN+D, where the demand of all consumers is met for all the years of the time horizon, the unmet demands in dry years under this scenario are quite large. Despite the desalination, the region still suffers from water shortages during the dry periods. This is especially true for the first dry period when only one desalination plant is available. Inspection of Figure 11-28 shows that almost all the water cuts were imposed on the agricultural sector; nevertheless, the industrial and the domestic sectors suffered some small water cuts as well.

Figure 11-28 and Figure 11-29 depict the unmet demands and the agricultural cultivated areas, respectively. Comparison with the corresponding Figure 11-8 and Figure 11-9 for the reference BauC scenario shows an improvement in all sectors especially in the agricultural sector. The period under which agricultural demand for 74 hm^3 per year is not met decreases from 13 (Figure 11-8) to 7 years (Figure 11-28). The level of unmet demand under the BauC scenario (about 19 hm^3 in the last year of the time horizon) is higher than the one under the BauC+D scenario ("only" 11 hm^3 in the last year).

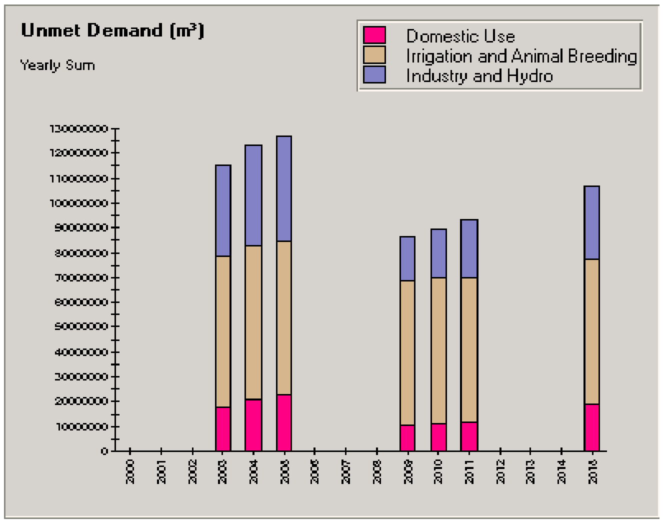


Figure 11-28 Unmet demand under the BauC+D scenario

Inspection of Figure 11-9 and Figure 11-29 clearly illustrates that the aggregate cultivated area under the BauC+D scenario is significantly larger than the one under the BauC for each year. But still, the agricultural sector faces significant water deficit during dry periods even in the presence of desalination plants.

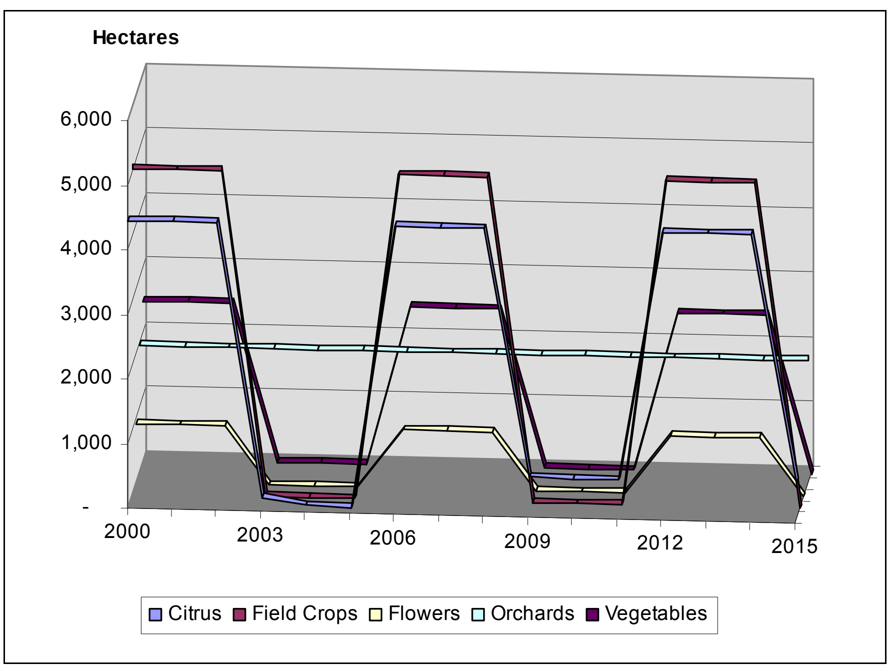


Figure 11-29 The impact of water cuts on the areas planted for various crops under the BauC+D scenario

The quantities supplied from the two desalination plants are summarized in Table 11-6.

Table 11-6 Quantities of Desalinated Water Under the BauC+D Scenario (hm^3)

Desalination Plant	2003-2005	2006	2007	2008	2009-2011	2012	2013	2014	2015
1st	50.0	12.4	-	-	50.0	-	-	-	50.0
2nd	-	-	14.8	17.7	50.0	29.9	32.8	36	50.0
Total	50.0	12.4	14.8	17.7	100.0	29.9	32.8	36	100.0

The total amount of desalinated water during the planning horizon is 692.2 hm^3, more than 2.5 times higher than the total under the reference BauC scenario. During the first series of dry years, 2003 to 2005, the first (and only) desalination plant supplied at its full capacity in each of the following two years. The same observation applies to both desalination plants during the second series of dry years, 2009 to 2011 and in 2015.

Cost Recovery Rate (CRR)

The CRR values for the agricultural sector under this scenario are quite similar to those under the basic BauC scenario; however there is a notable difference with respect to the industrial and domestic sectors.

Table 11-2 shows that while the consumer price of fresh water to a specific consumer is independent of the water source, the cost of desalinated water is three times higher than the cost of local drills and almost twice as high as the cost of imported water. Thus, the larger the share of desalinated water in the total supply to a specific consumer, the smaller the CRR value associated with this consumer. This explains why the domestic-associated CRR values dropped in dry years, to levels of about 100% during the first dry period and to about 80% during the second one, while under the reference BauC scenario, they fluctuated around 150%.

Under the basic scenario, the industry-associated CRR values drop to zero in dry years (Figure 11-11), only because the industry does not receive any fresh water. In the BauC+D scenario, it fluctuates around 130% and does not drop sharply during dry years because almost all the desalinated water is supplied to only the domestic sector.

Effectiveness and Improvement

The “effectiveness” indices for domestic, industrial and agricultural uses for the BauC+D scenario are presented in Figure 11-30. Comparison with the corresponding Figure 11-11 for the reference BauC scenario shows that under the current scenario, the level of effectiveness in all sectors is much higher than the one under the reference scenario, especially during the dry years’ period.

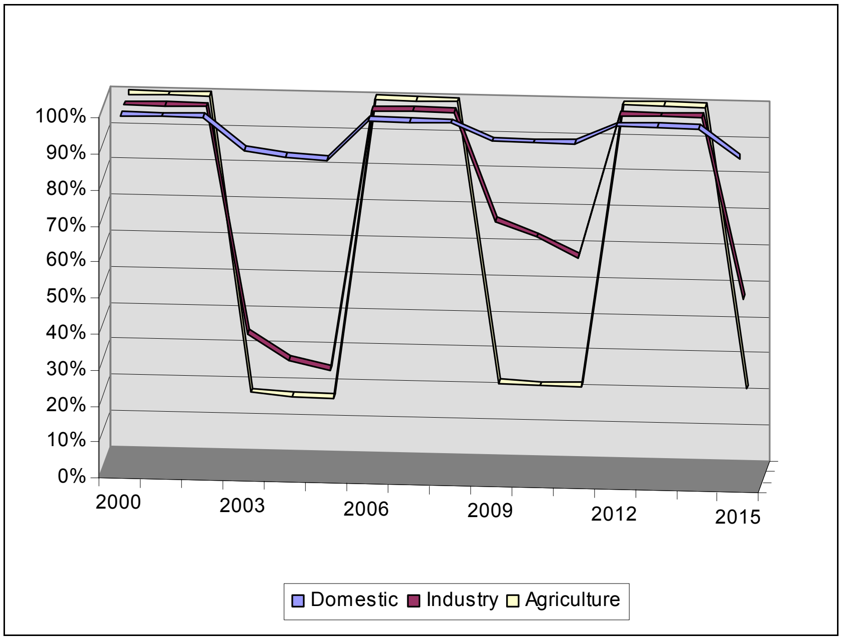


Figure 11-30 Effectiveness for Domestic, Industrial and Agricultural use under the BauC+D scenario

Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauC+D relative to the reference BauC are depicted in Figure 11-31.

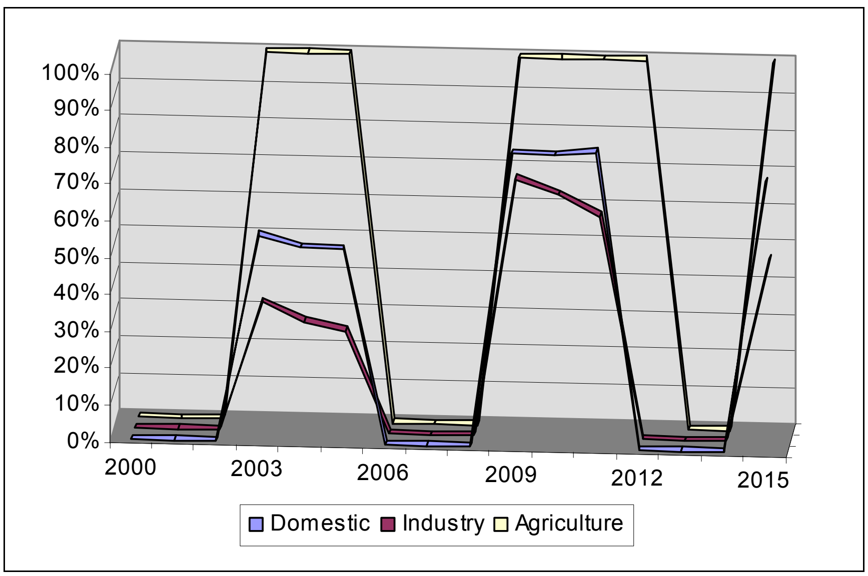


Figure 11-31 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauC+D scenario relative to the reference BauC scenario

The improvement in the deficit of all sectors during the dry periods is very significant. .

Social Welfare Surplus (SWS)

As for the welfare indicator, we found that the values of NPV(SWS) associated with the BauC+D scenario (1,175.1 million €) is lower by about 20 million € than the respective value under the reference, BauC, scenario. This implies that **the option to reduce agricultural water shortages by increasing the supply of recycled water is socially undesirable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauC+D scenario are presented in Figure 11-32 together with the respective values for the reference BauC scenario.

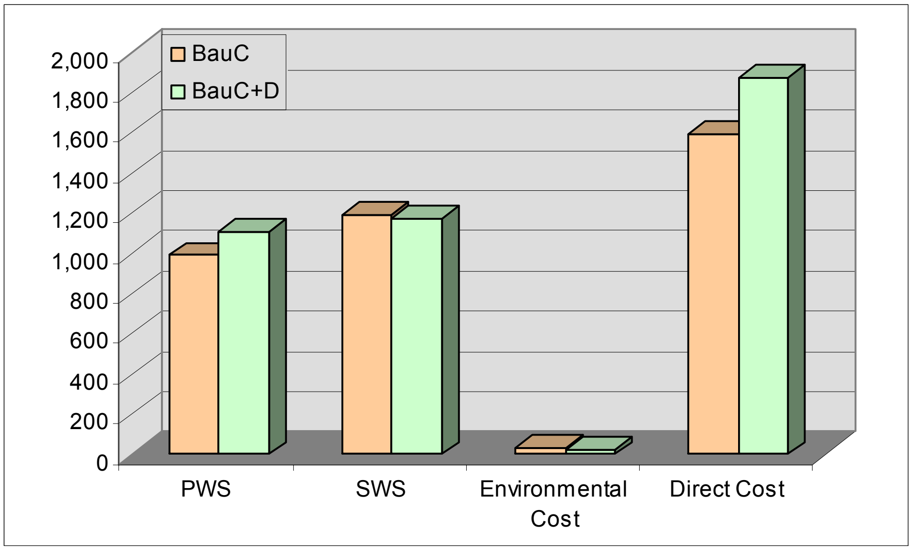


Figure 11-32 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauC+D and the BauC scenarios

As illustrated above, NPV(SWS) under the BauC+D scenario is smaller than the one under the reference BauN scenario. Like the result of the previous, BauN+D scenario, the present values of private welfare surpluses, NPV (PWS) – 1,110.4 million € – is higher than the one associated with the reference scenario. Namely, the social and the private interests diverge. The direct costs under the BauC+D scenario (1875.6 million €) are higher by 279.5 million € than those associated with the reference scenario. Due to the reduction of water shortage for the agricultural sector under the BauC+D scenario, its associated environmental cost reduced from 35.1 million € under the reference scenario to 25.2 million € under the BauC+D scenario.

Increased Supply via Over Pumping

Overpumping under the Business-As-Usual + Normal Scenario (BauN+OP)

Relative to the basic BauN scenario, this one assumes an increase in the annual supply of fresh water via over pumping of water from the coastal aquifer to overcome water deficits. Covering water shortage via over pumping involves very high environmental costs assumed to be equal to 64 € cents.

Under this scenario, the demand of all consumers is met for all the years of the time horizon, and all agricultural plots are fully cultivated (see Figure 11-33).

The quantities of over pumping are presented in Table 11-7. The total level of over pumping during the planning horizon is 267.8 hm^3, and is equal to the level of desalination under the BauN+D scenario (see Table 11-5).

Table 11-7 Quantities of Over Pumping Under the BauN+OP Scenario (hm^3)

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
5.5	9.4	11.7	15.1	17.5	20.9	23.4	26.9	29.5	32.8	36.0	39.2

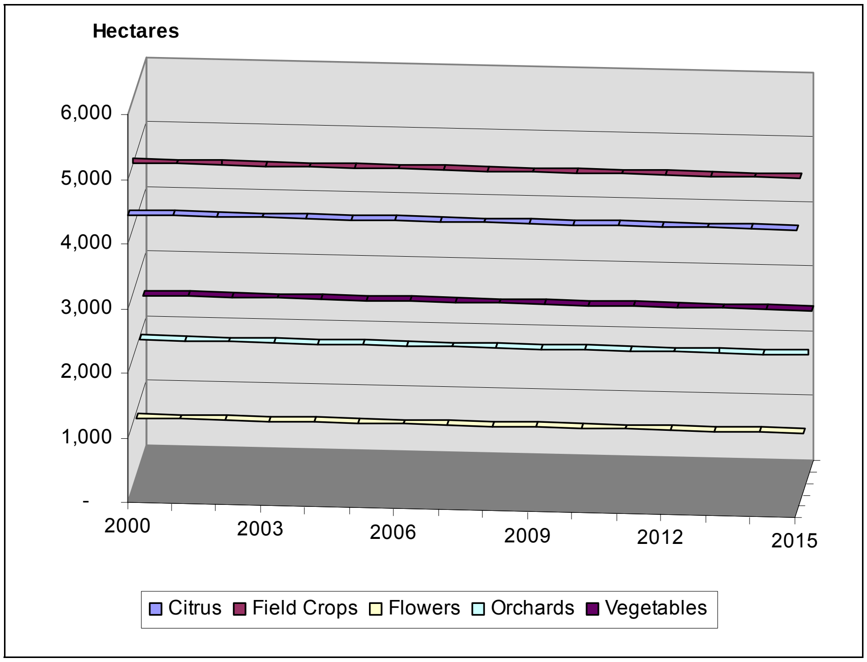


Figure 11-33 The impact of water cuts on the areas planted for various crops under the BauN+OP scenario

Cost Rcovery Rate (CRR)

The shapes of the CRR vs. time curves for all users are similar to those obtained under the BauN+D scenario. Since the cost associated with over pumping (64 € cents per cubic meter) is higher than the one associated with desalination (60 € cents), the CRR values associated with BauN+OP are somewhat lower than those associated with BauN+D.

Effectiveness and Improvement

The “effectiveness” for domestic, industrial and agricultural uses for the BauN+OP scenario is presented in Figure 11-34. The absence of water deficit for all users during the whole time horizon implies “effectiveness” of 100% for each user (Figure 11-34). Comparison with the corresponding Figure 11-5 for the BauN scenario shows that under both scenarios domestic and industrial demands are fully met for all the years of the planning horizon. As for the agricultural sector: while the effectiveness is 100% in all years of the planning period under the BauN+OP scenario it steadily drops to a low level of about 45% at 2015 under the reference BauN scenario (Figure 11-5).

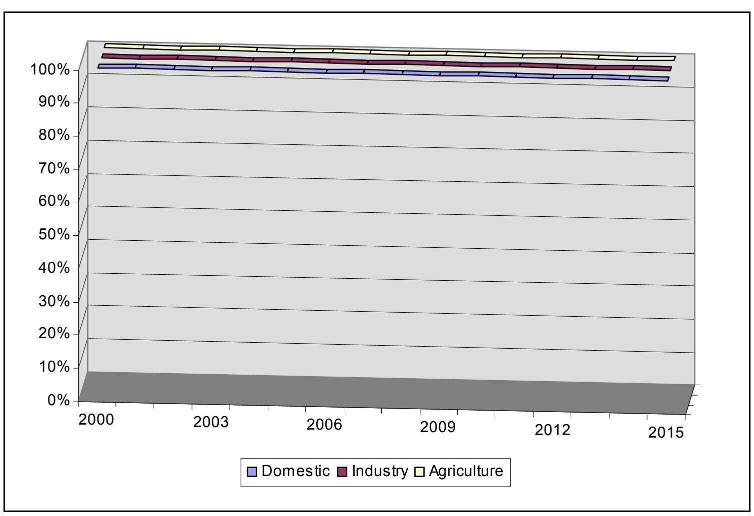


Figure 11-34 Effectiveness for Domestic, Industrial and Agricultural use under the BauN+OP scenario

Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauN+OP with respect to the reference BauN are depicted in Figure 11-35.

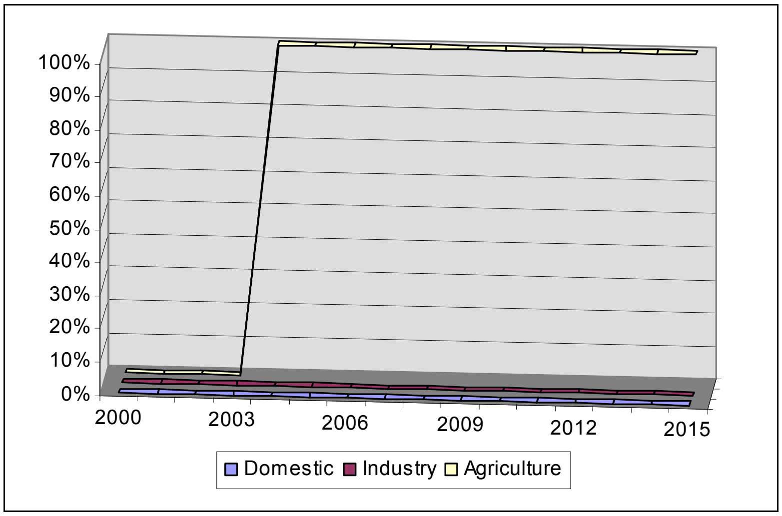


Figure 11-35 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauN+OP scenario relative to the reference BauN scenario

Since unmet demand under the reference scenario is limited only to the agricultural sector, there is no improvement of deficit in the domestic and industrial uses. The improvement in agricultural deficit after the fourth year of the time horizon is very significant and equal to 100% for all the years in which agricultural deficit under the BauN+OP scenario vanishes.

Social Welfare Surplus (SWS)

The values of NPV(SWS) associated with the BauN+OP scenario (1,422.7 million €) is lower by about 68 million € than the respective value under the reference, BauN, scenario. The high (environmental) cost associated with over-pumping explains the above reduction.

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauN+OP scenario are presented in Figure 11-36 together with the respective values for the reference BauN scenario.

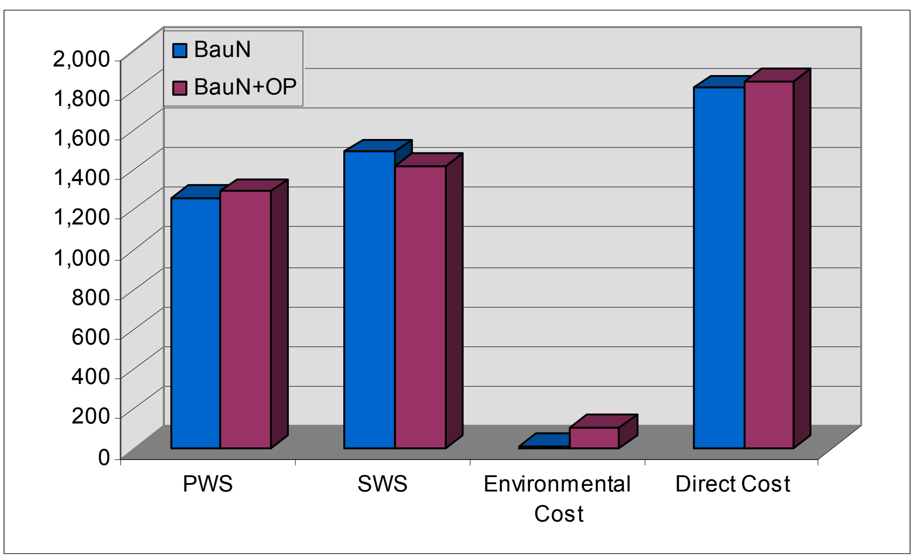


Figure 11-36 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauN+OP and the BauN scenarios

As illustrated in the figure, NPV(SWS) under the BauN+OP scenario is smaller than the one under the reference BauN scenario. The relationships are reversed with respect to the present values of private welfare surpluses, NPV (PWS). The reduction in social welfare surplus is attributed to the utilization of costly over pumped water to overcome the water deficit in the agricultural sector. Since the price of fresh water charged to each one of the users is independent of the water source (see Table 11-2), the private welfare surplus increases (from 1263.7 million € under the BauN scenario to 1292.3 million € under the BauN+OP scenario) due to the increased consumption by the agricultural sector. The values of NPV(PWS) under the BauN+D and the BauN+OP are exactly the same. The direct costs under the BauN+OP scenario (1,846.5 million €) are higher by 34 million € than those associated with the reference scenario. Due to the absence of water shortage for the agricultural sector under the BauN+D scenario, the environmental cost associated with the reduction of cultivated area vanishes. However, the environmental costs associated with **over-pumping** of ground water from the coastal aquifer are very high, 107.6 million €.

Overpumping under the Business-As-Usual + Cyclic Scenario (BauC+OP)

Like the previous scenario, in the current scenario the demand of all consumers is met during all the years of the time horizon and all agricultural plots are fully cultivated.

The quantities of over pumping are presented in Table 11-8. The total level of over pumping during the planning horizon is very large, 1,395.1 hm^3. It is much higher than the total amount of desalination under the BauN+D scenario (see Table 11-5), since annual desalination cannot exceed the capacity of the desalination plants while over pumping in our analysis is not administratively constrained.

Table 11-8 Quantities of Over Pumping Under the BauC+OP Scenario (hm^3)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
54.3	168.4	171.2	25.6	7.9	18	175.7	185.6	188.7	36.6	32.7	36	194.5

Cost Recovery Rate (CRR)

The shapes of the CRR vs. time curves for all users are similar to those obtained under the BauC+D scenario. Since the cost associated with over pumping (64 € cents per cubic meter) is higher than the one associated with desalination (60 € cents), the CRR values associated with BauC+OP are somewhat lower than those associated with BauN+D.

Effectiveness and Improvement

The absence of water deficit for all users during the whole time horizon implies "effectiveness" of 100% for each user (Figure 11-37). Comparison with the corresponding Figure 11-11 for the BauC scenario illustrates the significant impact of over-pumping on water deficits. Indeed, the percent-improvement of water deficit in all sectors under the BauC+OP scenario relative to the reference BauC scenario, especially during the dry periods, is impressive (Figure 11-38).

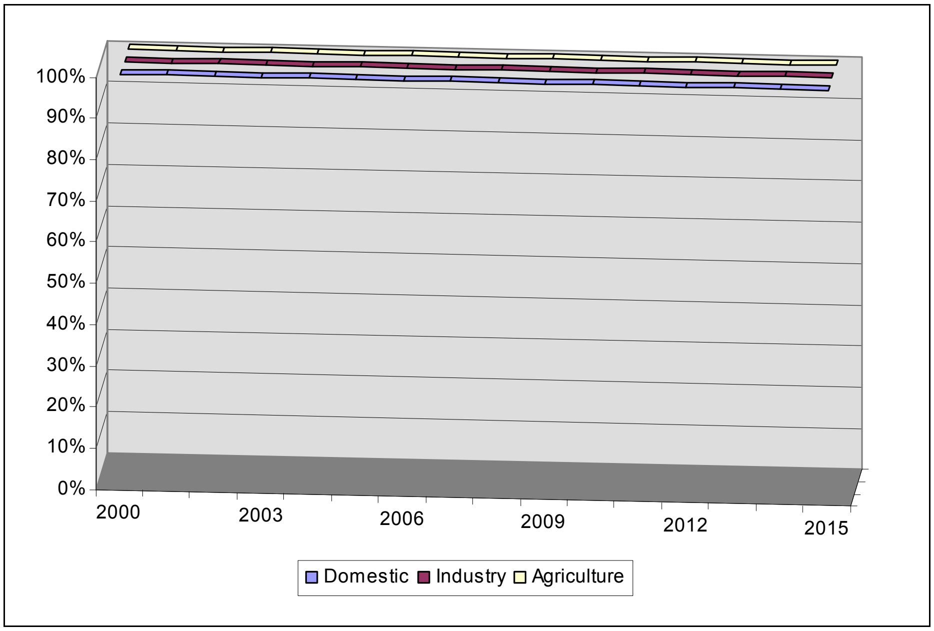


Figure 11-37 Effectiveness for Domestic, Industrial and Agricultural use under the BauC+OP scenario

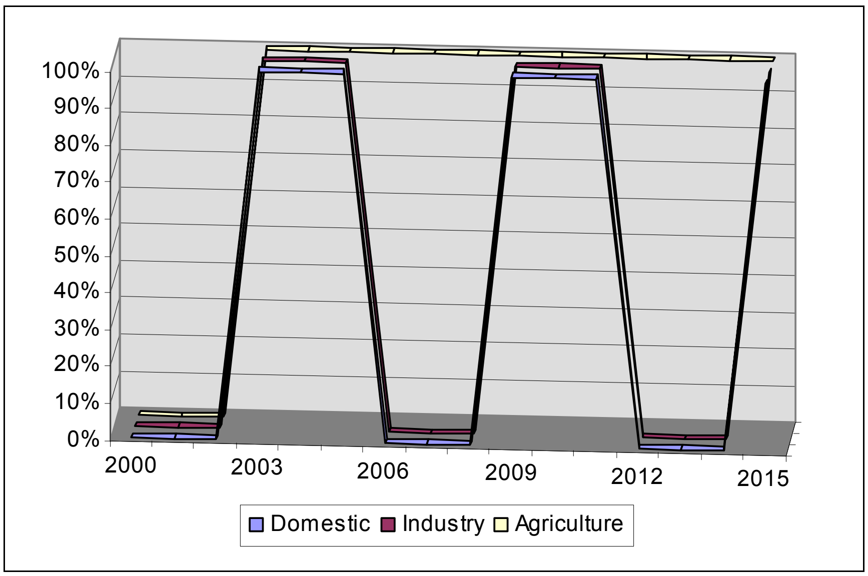


Figure 11-38 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauC+OP scenario relative to the reference BauC scenario

Social Welfare Surplus (SWS)

The values of NPV(SWS) associated with the BauC+OP scenario (958 million €) is lower by 236.5 million € than the respective value under the reference, BauC, scenario. This implies that **the option to reduce agricultural water shortages via over-pumping is socially undesirable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauC+OP scenario are presented in Figure 11-39 together with the respective values for the reference BauC scenario.

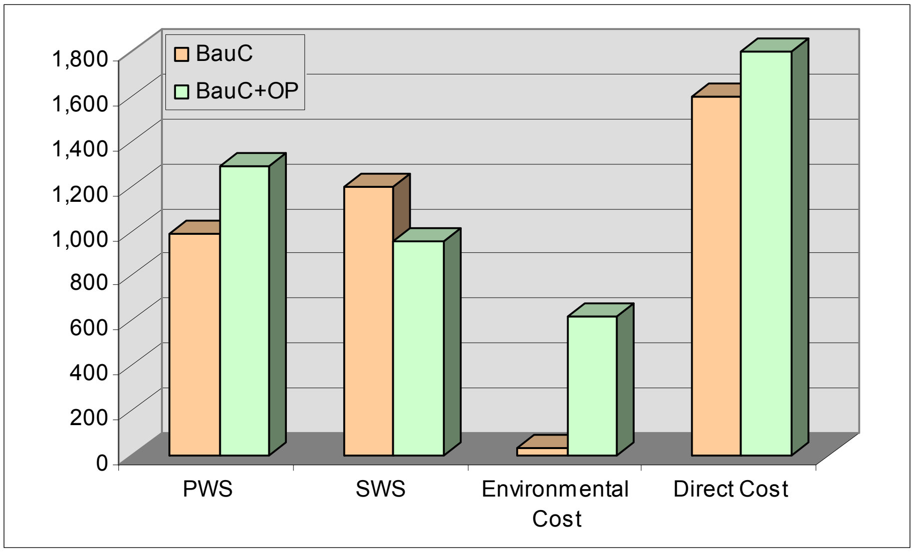


Figure 11-39 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauC+OP and the BauC scenarios

As illustrated in the Figure, NPV(SWS) under the BauC+OP scenario is smaller than the one under the reference BauC scenario. The relationships are reversed with respect to the present values of private welfare surpluses, NPV (PWS). The reduction in social welfare surplus is attributed to the utilization of costly over pumped water to overcome the water deficit in the agricultural sector. Since the price of fresh water charged to each one of the users is independent of the water source (see Table 11-2), the private welfare surplus increases significantly (from 990.2 million € under the BauC scenario to 1292.3 million € under the BauC+OP scenario) due to the increased consumption by the agricultural sector. The values of NPV(PWS) under the BauN+D, the BauN+OP and the BauC+OP are exactly the same. The direct costs under the BauC+OP scenario (1,800.0 million €) are higher by 203.9 million € than those associated with the reference scenario. Due to the absence of water shortage for the agricultural sector under the BauC+OP scenario, the environmental cost associated with the reduction of cultivated area vanishes. However, the environmental costs associated with **over-pumping** of ground water from the coastal aquifer are very big, 618.7 million €.

Reduction of Gross Domestic Demand via Water Conservation

In the next two scenarios we assume that gross annual domestic demand for water can be reduced by 20% - via investment in water conservation - **without affecting the water benefits or values accrue to domestic consumers**. A simple example can explain our assumption in the above emphasized statement. In the absence of conservation the value of water to domestic consumer who consumes a **"gross amount"** of 100 cubic meters per year from local drills is 100x(0.6) = 60 € (see Table 11-3). The direct cost associated with this consumption is 100x (0.2) =20 € (see Table 11-2). We assume that only 80% of the gross amount should be regarded as an **"effective consumption",** i.e., actually serves the consumer's needs while the remaining 20% are wasted. The waste can be avoided by increasing the efficiency of water consumption via investment in water conservation. In other words, the value accrue to the domestic consumer from the consumption of a gross amount of 100 m^3 (60 € in our example) is identical to the value obtained from the consumption of an effective amount of 80 m^3. Recalling that the direct conservation costs are 12 € cents, the total direct costs associated with the supply (from local drills) of 80 m^3 of effective water is 80x0.2+20x0.12= 18.4 € cents.

Water Conservation under the Business-As-Usual + Normal Scenario (BauN+WC)

Under this scenario, the demand of all consumers is met for all the years of the time horizon, and all agricultural plots are fully cultivated. The water deficit in the agricultural sector that existed under the reference, BauN scenario, vanishes due to the reduction in the demand of the domestic consumers.

Cost Recovery Rate (CRR)

The CRR values for the industrial and domestic users under this scenario are quite similar to those of the reference BauN scenario, but there is a small difference with respect to the agricultural sector. Under the BaucN+WC scenario, the CRR values for the agricultural sector are practically stable at a level of 80%, whereas under the reference scenario, they decline steadily from the fifth year of the planning horizon, reaching a level of 72% in the year 2015.

Effectiveness and Improvement

The "effectiveness" for domestic, industrial and agricultural uses for the BauN+WC scenario is presented in Figure 11-40. In the absence of water deficit the level of effectiveness is 100% for each one of the three sectors. Comparison with the corresponding Figure 11-5 for the BauN scenario shows that under both scenarios domestic and industrial demands are fully met for all the years of the planning horizon. As for the agricultural sector: the effectiveness is 100% in all years of the planning period under the BauN+WC scenario while under the BauN scenario it steadily drops to a low level of about 45% at 2015 (Figure 11-5). Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauN+WC with respect to the reference BauN are depicted in Figure 11-41.

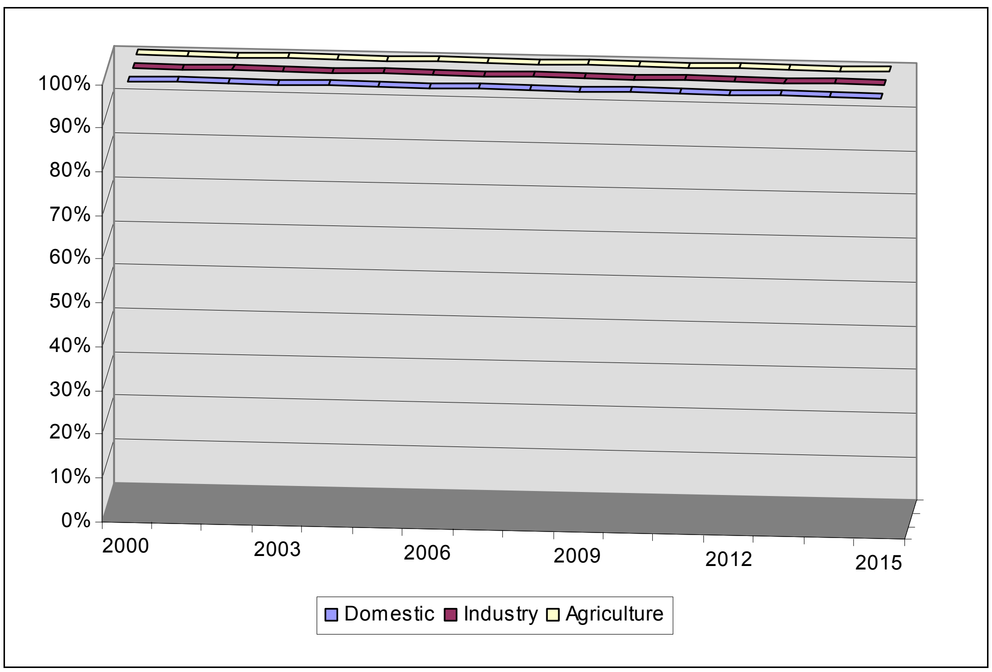


Figure 11-40 Effectiveness for Domestic, Industrial and Agricultural use under the BauN+WC scenario

Since unmet demand under the reference scenario is limited only to the agricultural sector, there is no improvement of deficit in the domestic and industrial uses. The improvement in agricultural deficit after the fourth year of the time horizon is very significant and equal to 100% for all the years in which agricultural deficit under the BauN+WC scenario vanishes.

Figure 11-41 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauN+WC scenario relative to the reference BauN scenario

Social Welfare Surplus (SWS)

As for the welfare indicator, the values of NPV(SWS) associated with the BauN+WC scenario (1,504.7 million s) is higher by 14 million € than the respective value under the reference, BauN, scenario. This implies that **the option to reduce agricultural water shortages by the water conservation approach (BaucN+WC) is socially profitable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauN+WC scenario are presented in Figure 11-42 together with the respective values for the reference BauN scenario.

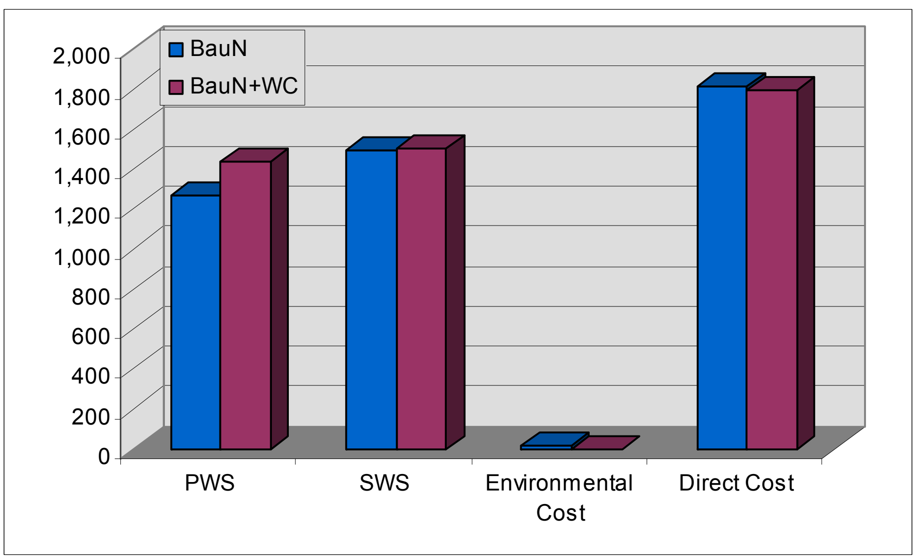


Figure 11-42 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauN+WC and the BauN scenarios

The value of both NPV (SWS) and NPV (PWS) under the BauN+WC scenario are higher than the respective values under the reference, BauN scenario, implying that the private and the social interests coincides. The direct costs under both scenarios are relatively similar (1812.6 and 1792.6 million € under the BauN and under the BauN+WC scenarios, respectively. The direct costs for the BauN+WC scenario include water conservation costs of about 61 million €. Due to the lack of water shortage for the agricultural sector under the BauN+WC scenario, its associated environmental costs are zero.

Water Conservation under the Business-As-Usual + Cyclic scenario (BauC+WC)

Unlike the parallel scenario under a stable supply of fresh water, BauN+WC, where the demand of all consumers is met for all the years of the time horizon, the unmet demands in dry years under this scenario are quite large. During the dry years, the supply was reduced to consumers of all sectors, but agricultural and industrial consumers bore the brunt of the necessary cuts. Figure 11- 43 and Figure 11-44 depict the unmet demands and the agricultural cultivated areas, respectively. Comparison with the corresponding Figure 11-8 and Figure 11-9 for the reference BauC scenario shows an improvement in all sectors especially in the agricultural sector. The period under which agricultural demand for 74 hm^3 per year is not met decreases from 13 (Figure 11-8) to 7 years (Figure 11-43).

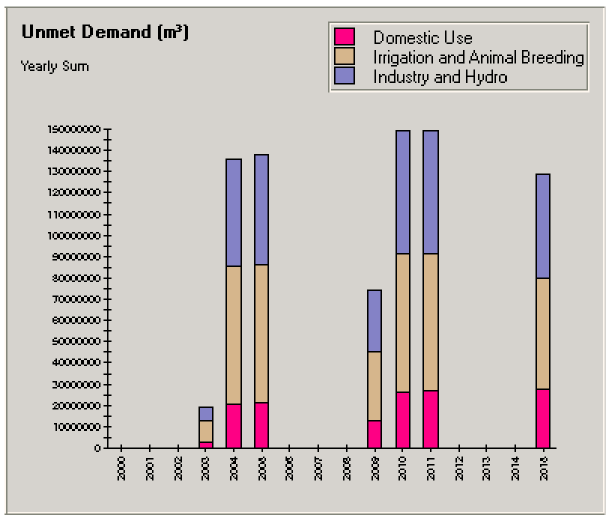


Figure 11-43 Unmet demand under the BauC+WC scenario

Inspection of Figure 11-9 and Figure 11-44 clearly illustrates that the aggregate cultivated area under the BauC scenario is significantly smaller than the one under the BauC+WC scenario for each year.

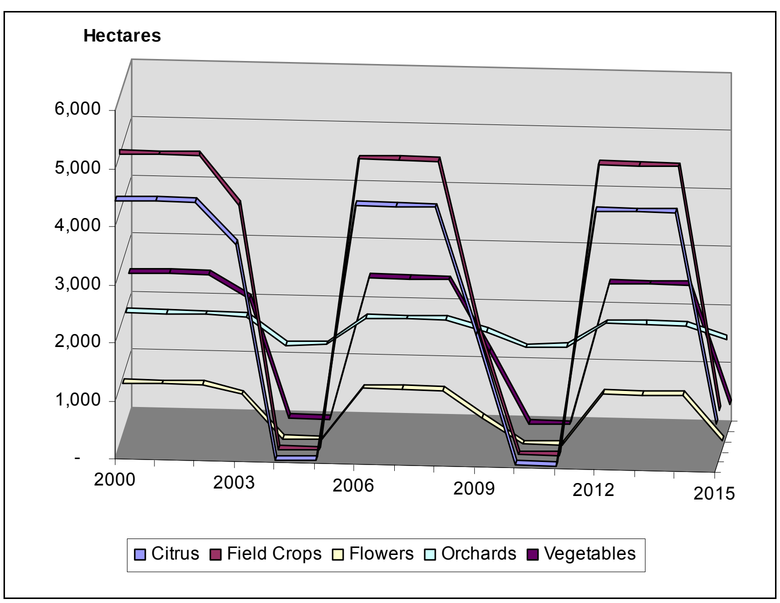


Figure 11-44 The impact of water cuts on the areas planted for various crops under the BauC+WC scenario

Cost Recovery Rate (CRR)

We found that the CRR values for each one of the consumers are similar to those obtained under the reference BauC scenario.

Effectiveness and Improvement

The “effectiveness” indices for domestic, industrial and agricultural uses for the BauC+WC scenario are presented in Figure 11-45. Comparison with the corresponding Figure 11-11 for the reference BauC scenario shows that under the current scenario, the level of effectiveness in all sectors is much higher than the one under the reference scenario, especially during the period of dry years.

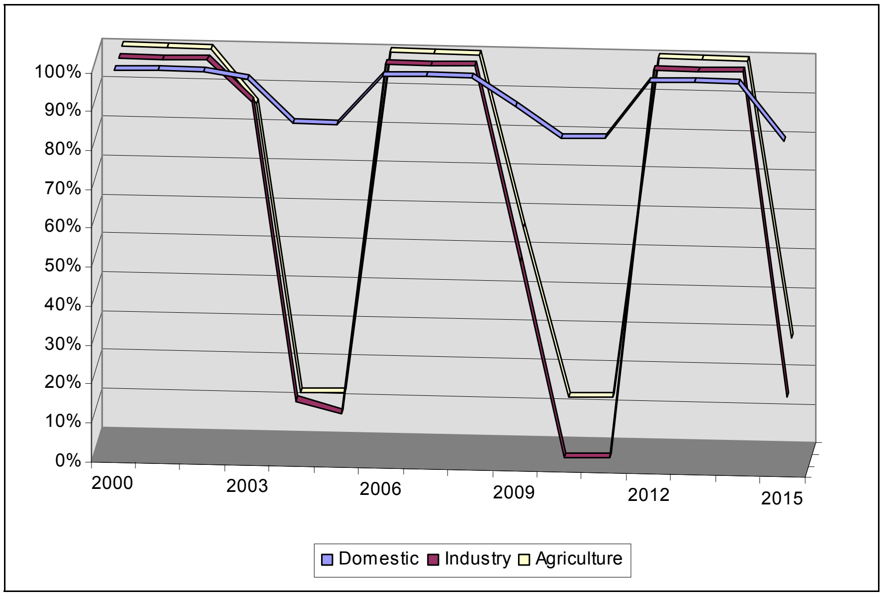


Figure 11-45 Effectiveness for Domestic, Industrial and Agricultural use under the BauC+WC scenario

Percent improvements of water deficit in the domestic, industrial and agricultural uses under the BauC+WC relative to the reference BauC are depicted in Figure 11-46.

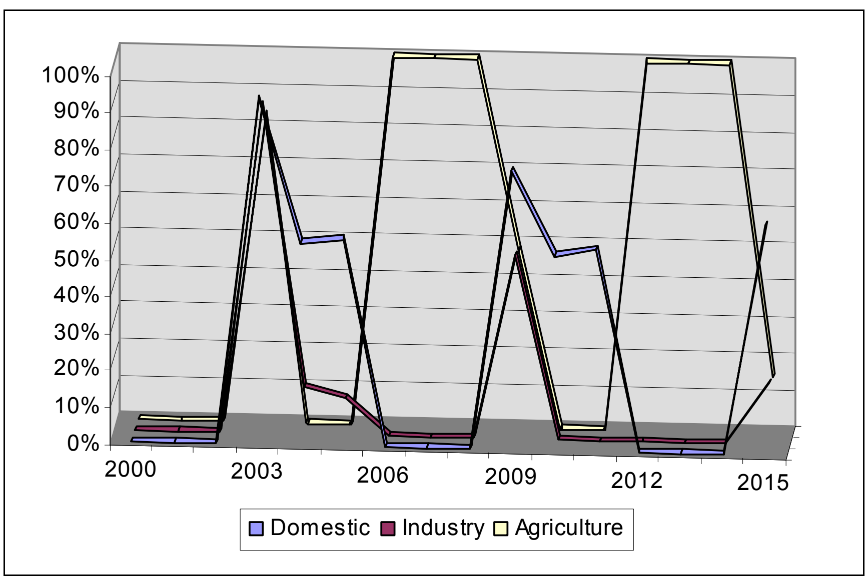


Figure 11-46 Percent improvements of deficit in domestic, industrial and agricultural uses under the BauC+WC scenario relative to the reference BauC scenario

The improvement in the deficit of all sectors during the dry periods is very significant.

Social Welfare Surplus (SWS)

As for the welfare indicator, the value of NPV(SWS) associated with the BauC+WC scenario (1,324.4 million €) is higher by about 30 million € than the respective value under the reference, BauC, scenario. This implies that **the option to reduce agricultural water shortages by the water conservation approach (BaucN+WC) is socially desirable.**

Present values (r=4%) of PWS, SWS, and environmental and direct costs for the BauC+WC scenario are presented in Figure 11-47 together with the respective values for the reference BauC scenario.

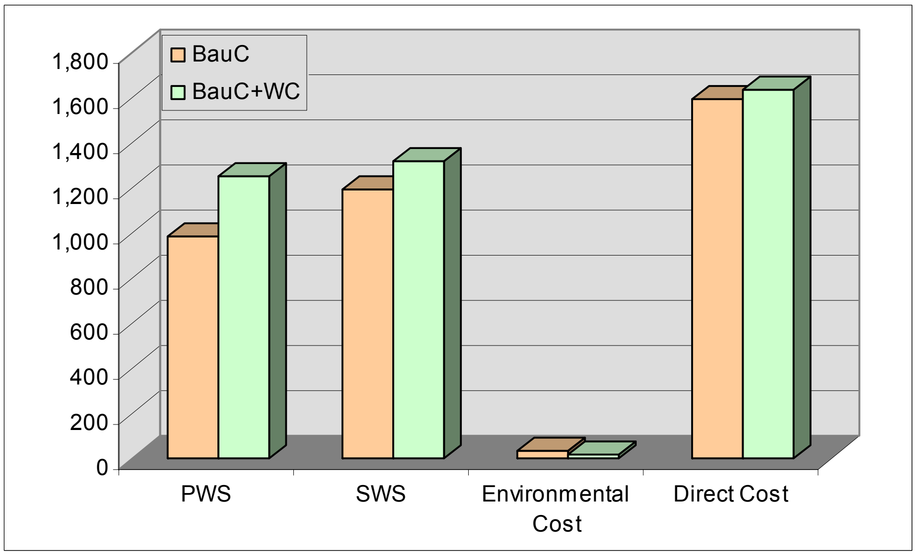


Figure 11-47 Present values (r=4%) of PWS, SWS, environmental and direct costs under the BauC+WC and the BauC scenario

The values of both NPV (SWS) and NPV (PWS) under the BauC+WC scenario (1,324.4 and 1254.5 million €, respectively) are higher than the respective values under the reference, BauC scenario. The direct costs under the BauC+WC scenario (1,635.1 million €, including 61 million € invested in water conservation) is higher by 39 million € than the respective value under the reference, BauC, scenario. The environmental cost under the BauC+WC scenario - that are associated with the reduction in cultivated area - is lower by about 14.1 million € than the respective value under the reference, BauC, scenario.

Summary and Conclusions

Results from the evaluation of the options are summarized in Table 11-9 and Figures 11-49a – 53c below. The rest of this section is aimed at comparing the performance of the various management options and identifying the scope of integrated management scenario into promising water management strategies.

The SWS and PWS Criteria

The **net present value of the total social welfare surplus (SWS)** in the region (defined as the difference between the total value or benefit accrued by water consumers and the total direct and environmental costs) **is the best criterion to rank the various scenarios.** Obviously, a management option implying a high SWS value is preferred to one implying a lower value. **Total private welfare surplus (PWS),** accrue to water consumers, is defined as the difference between water values (benefits) and the cost of water charged to the consumers.

While both SWS and PWS depend on the value of water for the various consumers, the former also depends on the actual, direct and environmental costs of supplying the water while the latter depends on the prices charged to the consumers. Since in many cases water prices differ from water costs, it may well be that the PWS and SWS for a specific group of consumers do not coincide.

Table 11-9 Evaluation of Management Options; Financial Indicators: NPV (r=4%) of PWS, SWS, Environmental and Direct Costs (Million €)

Scenario	PWS	SWS	Environmental Cost	Direct Cost
	Million €, 4%			
BauN	1,263.7	1,490.7	14.8	1,812.6
BauN+R	1,303.0	1,533.5	1.3	1,831.1
BauN+D	1,292.2	1,463	0.0	1,913.8
BauN+OP	1,292.3	1,422.7	107.6	1,846.5
BauN+WC	1,440.7	1,504.7	0.0	1,792.6
BauC	990.2	1,194.5	35.1	1,596.1
BauC+R	1,021.5	1,230.7	29.3	1,611.1
BauC+D	1,110.4	1,175.1	25.2	1,875.6
BauC+OP	1,292.3	958	618.7	1,800.0
BauC+WC	1,254.5	1,324.4	21	1,635.1

Inspection of the third column of Table 11-9 and Figures 11-48a and b imply:

Under normal weather conditions, the management option to increase the supply of recycled water, BauN+R, yields the highest SWS, which is about only 2% higher than the second-best scenario, BauN+WC. Increasing water supply via over-pumping, the BauN+OP scenario, yields the lowest SWS.

Under cyclical weather conditions, the management option to reduce gross domestic demand via water conservation, BauC+WC, yields the highest SWS, which is about 8% higher than the second-best scenario, BauC+R. As when under normal weather conditions, the BauC+OP scenario is the least preferred one.

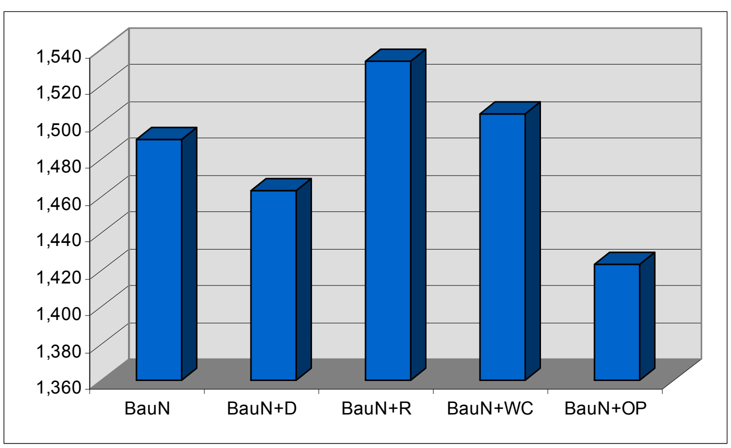


Figure 11-48a NPV of SWS for all BauN scenarios (million €)

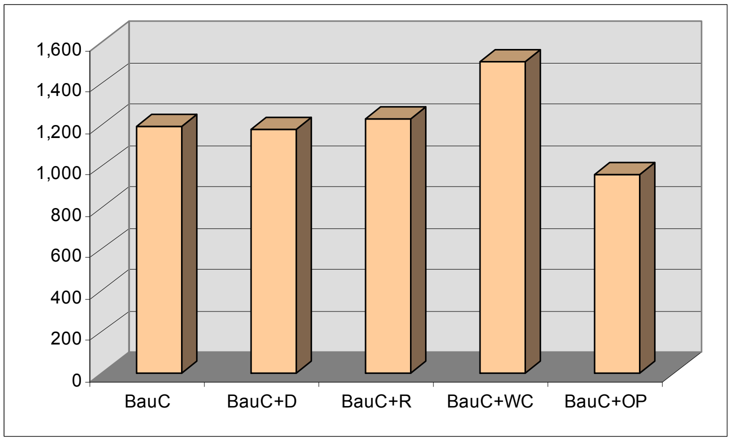


Figure 11-48b NPV of SWS for all BauC scenarios (million €)

Inspection of the second column of Table 11-9 and Figures 11-49a and b imply:

The highest private welfare surplus (PWS) under normal weather conditions, is obtained under the "second-best" BauN+WC scenario, and is higher by about 11% than the PWS associated with the socially preferred scenario, BauN+R.

The highest value of PWS under cyclical weather conditions is obtained under the BauC+OP scenario with the lowest SWS. This value is higher by about only 3% than the PWS associated with the socially preferred scenario, BauC+WC.

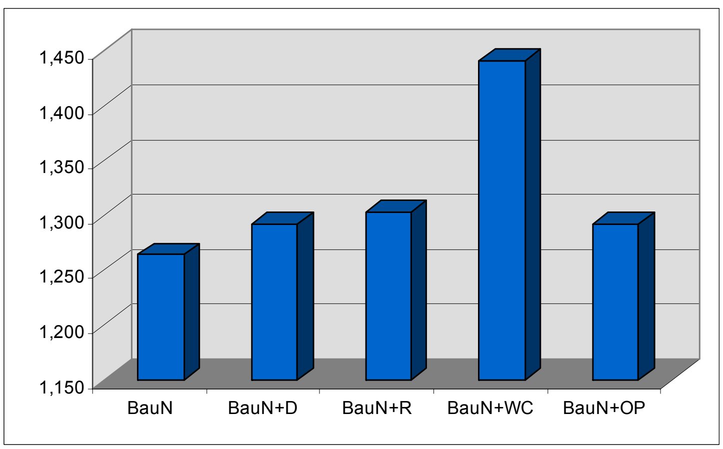


Figure 11-49 a. NPV of PWS for all BauN scenarios (million €)

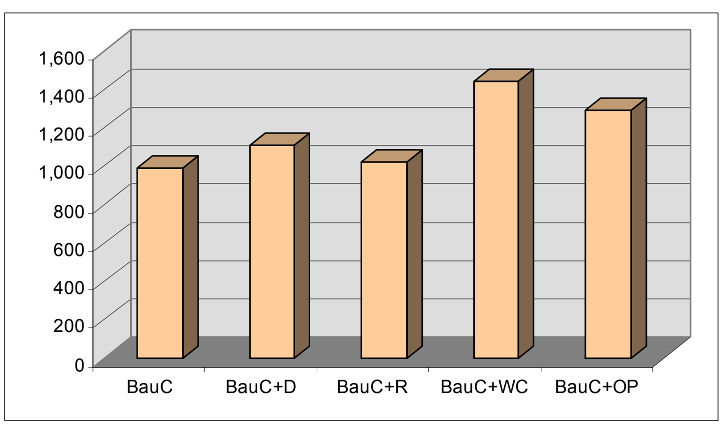


Figure 11-49b NPV of PWS for all BauN scenarios (million €)

Environmental Costs

Inspection of the fourth column of Table 11-9 and Figures 11-51a, b implies:

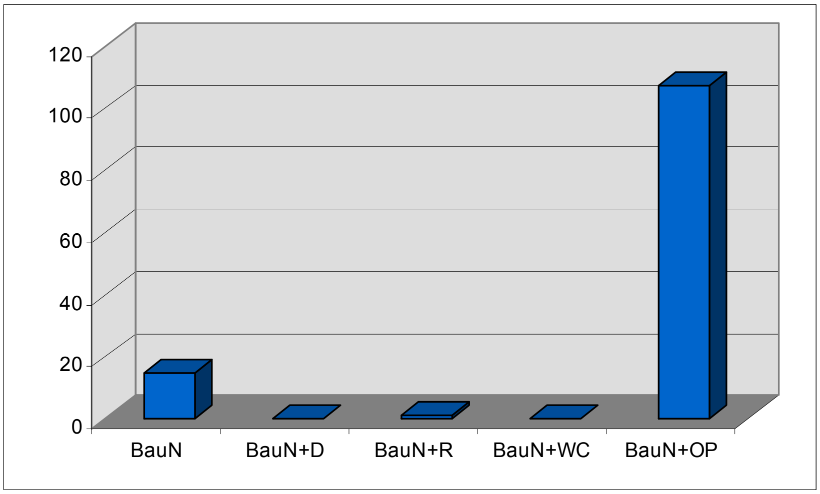


Figure 11-50a NPV of Environmental Cost for all BauN scenarios (million €)

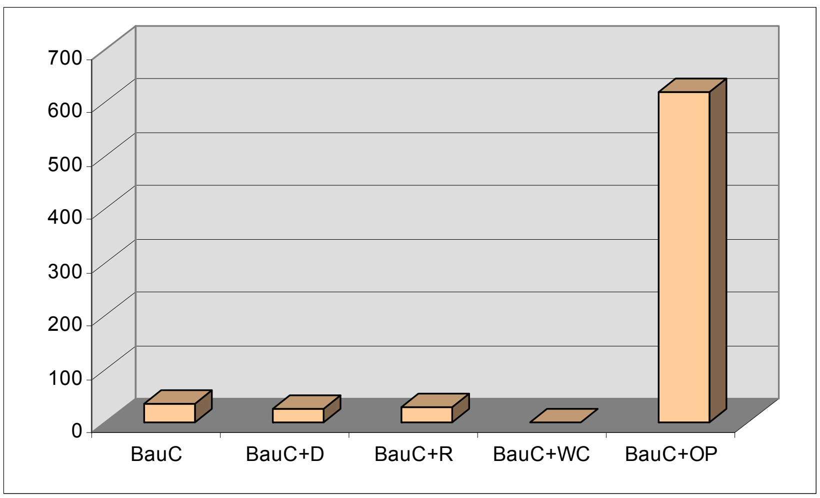


Figure 11-50b NPV of Environmental Cost for all BauC scenarios (million €)

The source of the environmental costs associated with scenarios BauN+OP and BauC+OP is over-pumping of ground water from the coastal aquifer, which are assumed to be equal to 64 € cents. The source of environmental costs for all other scenario (where over-pumping is not an option) is the reduction in cultivated are resulting from agricultural water deficit. The environmental costs associated with a cut of 1 cubic meter of irrigation water demanded by the agricultural sector - a cut which yields reduction in the cultivated area - are assumed to be 9 € cents. Since the environmental costs associated with over-pumping are 7 times higher than those associated with agricultural water shortage, it should not come as a surprise the environmental costs associated with scenarios BauN+OP and BauC+OP are much relative to all other management options. Obviously, for environmentalists or “Greens”, the increase of water supply via over-pumping is the by far the worst management option.

Under normal weather conditions, the environmental costs associated with all management options other than over-pumping are practically negligible. Under cyclical weather conditions, the environmental costs associated with the corresponding management options are low relative to the direct costs but not negligible; the costs associated with the BauC+WC are lower than those associated with BauC+D and BauC+R.

Direct Costs

Inspection of the fourth column of Table 11-9 and Figures 11-51a, and b imply:

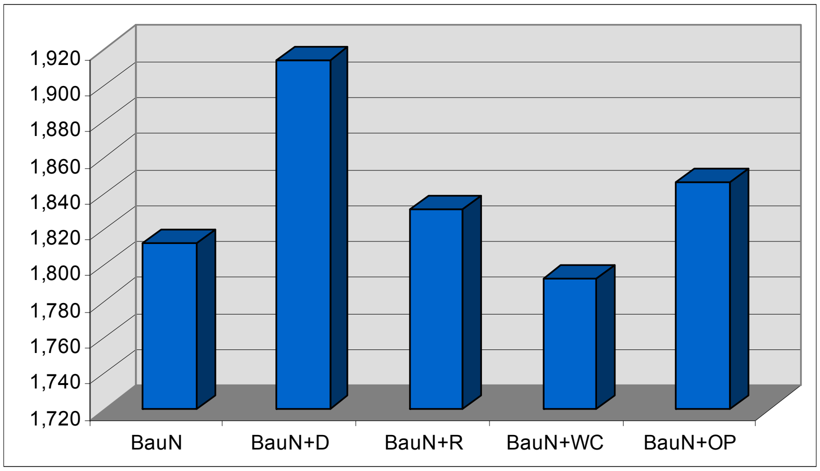


Figure 11-51a NPV of Direct Cost for all BauN scenarios (million €)

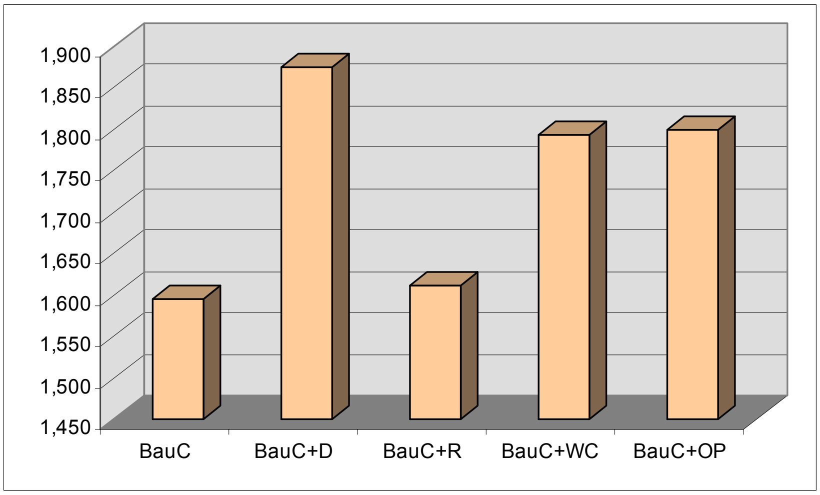


Figure 11-51b NPV of Direct Cost for all BauC scenarios (million €)

Under both normal and cyclical weather conditions the direct costs associated with the option to increase supply via desalination of seawater (BauN+D, BauC+D) are higher than those implied by all other management options. The direct costs associated with the increased recycling (BauN+R, BauC+R) are the lowest. It should be emphasized that direct costs is only one (commonly very important) component of the social welfare associate with water utilization. As long as water benefits vary between scenarios and management option, direct costs alone cannot be used as a criterion for economic efficiency.

Percent improvement of deficit in domestic, industrial and agricultural uses

Under the reference BauN scenario domestic and industrial demands are fully met, i.e., the "effectiveness" associated with each one of them is 100% (Figure 11-5). This necessarily implies a 0% improvement for theses two sectors under each of the management options BauN+R, BauN+D and Baun+WC. The agricultural supply is fully met only during the first 4 years of the time horizon (see Figure 11-2) and then it steadily increases. Thus, the effectiveness for agricultural uses is 100% in the first 4 years of the planning horizon and then it steadily decreases. This leaves a lot of room for improvement from the fifth year of the time horizon and on.

The percent improvement of deficit for the agricultural sector under normal weather conditions is presented in Figure 11-52. Inspection of this figure show that the agricultural deficit completely vanishes under the BauN+D and the BauN+OP. Under the BauN+R scenario, the deficit vanishes until the year 2009 and then it steadily increases (i.e., the percent improvement decreases).

Under the reference BauC scenario, none of the demands is fully met during the whole planning horizon, namely the "effectiveness" associated with each one of them is not 100% during all the years examined (Figure 11-11). This leaves a lot of room for improvement, especially during the dry periods.

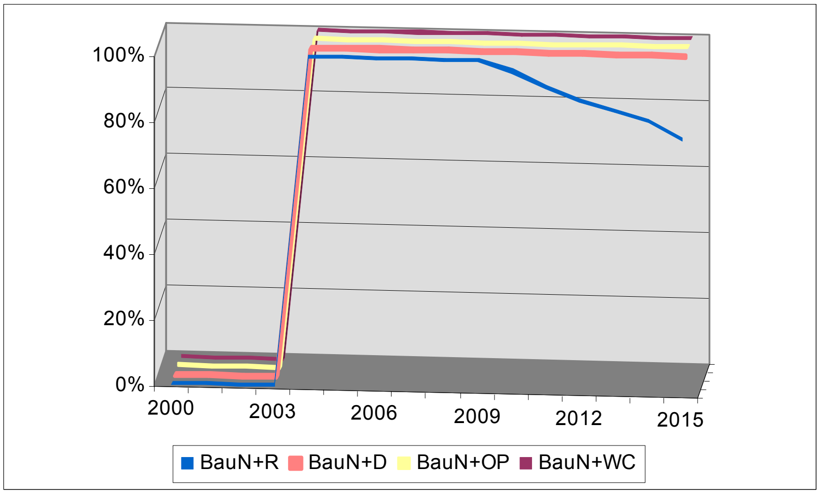


Figure 11-52 Percent improvement in agricultural deficit under the normal weather conditions (%)

The percent improvements of deficit for the domestic, industrial and agricultural sectors under cyclical weather conditions are presented in Figures 11-53a, 11-53b and 11-53c, respectively. Inspection of these depicts that:

(i) The highest percent improvement in the deficit of all sectors obtained under the BauC+OP management options which enables to increase supply (via over-pumping of ground water from the coastal aquifer) as much as needed. Under the BauC+D scenario, for example, the increased supply of fresh water is limited by the capacity of the assumed desalination plants (50 hm^3 between the years 2003 and 2008 and 100 hm^3 from 2009 and on).

(ii) The lowest percent improvement of all sectors is obtained under the BauC+R management option. This can be explained by the fact that the amount of **additional** recycling is low relative the quantity of desalinated water, the quantity of over-pumping and the reduction in domestic demand via water conservation.

(iii) The percent improvement in the deficit of the domestic and the agricultural sectors is higher under the BauC+WC scenario than under the BauC+D scenario (see Figures 11-53a and 11-53c). The ranking between the impacts of these two scenarios on the industrial sector is indeterminate (see Figure 11-53b).

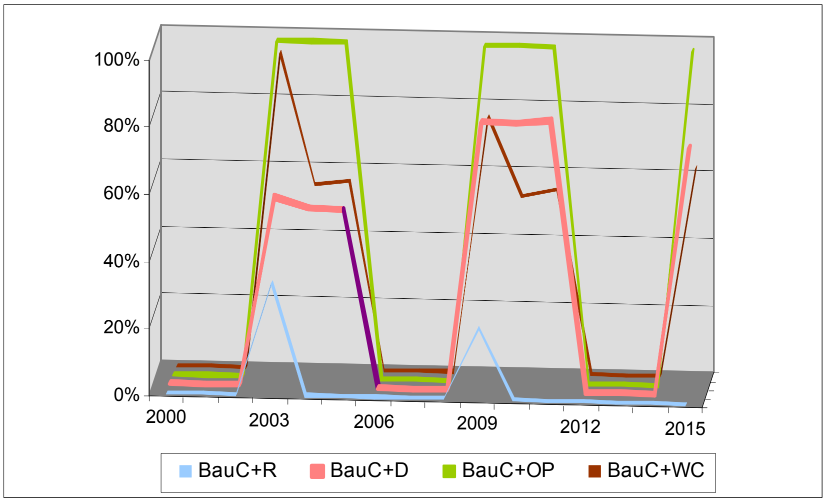


Figure 11-53a Percent improvement in domestic deficit under the cyclical weather conditions (%)

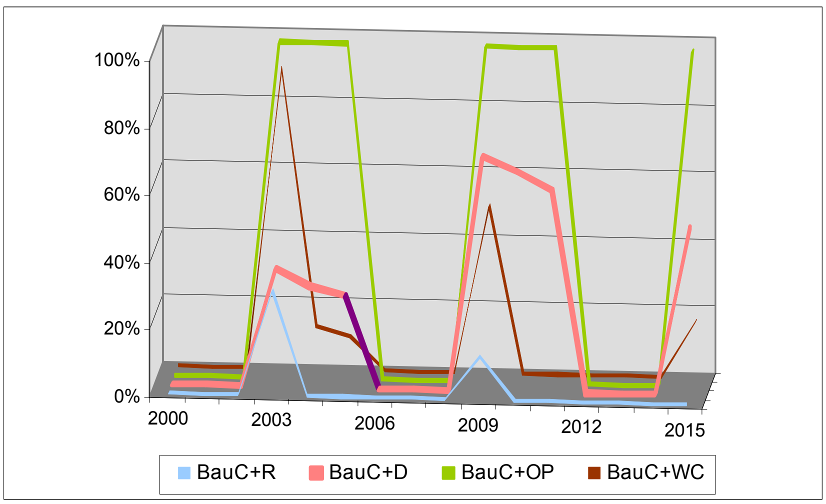


Figure 11-52b Percent improvement in industrial deficit under the cyclical weather conditions (%)

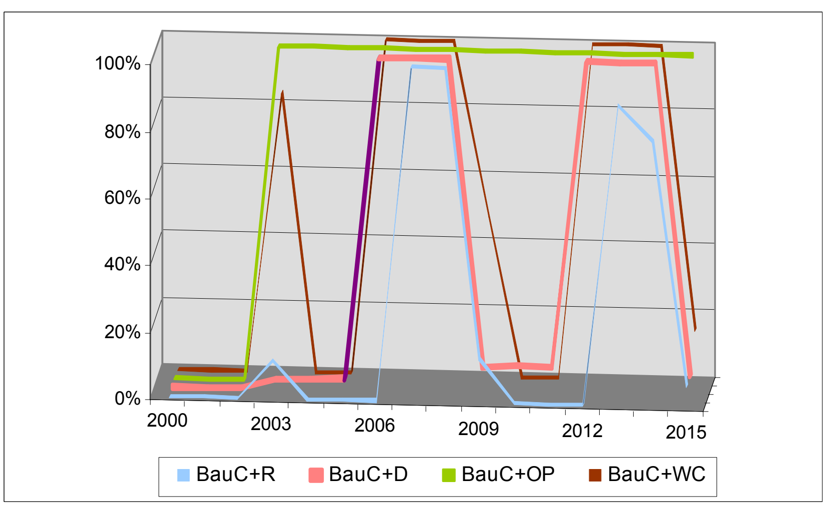


Figure 11-52c Percent improvement in agricultural deficit under the cyclical weather conditions (%)

Concluding Remarks

Normal Weather Conditions

A social planner will prefer the BauN+R management option (i.e., to increase the supply of recycled water), that yields the highest value of SWS. The environmental costs associated with this scenario are negligible, so a fierce opposition of environmentalists (or green lobbies) to this scenario is unlikely. On the other hand, this is the only management option under which agricultural supply is not fully met during all the years of the time horizon, and its associated PWS is lower than the one associated with the BauN+WC scenario. On this ground, this scenario may be opposed by the (strong and effective) agricultural lobby.

The second best scenario from social point of view is BauN+WC, with the second highest value of SWS; the lowest values of both environmental and direct costs and the highest value of PWS.

From a social point of view and from the point of view of the greens' lobby, the worst scenario is BauN+OP, with the lowest value of SWS and the highest value of environmental cost. The greens' lobby is indifferent between the BauN+D and BauN+WC scenarios, as both imply zero environmental costs.

Cyclical Weather Conditions

From a social point of view the best management option is BauC+WC and the second-best one is BauC+R. The environmental costs associated with the former are lower than those associated with the latter, so the greens' lobby will probably also prefer BauC+WC to BauC+R.

The lowest percent improvement of all sectors is obtained under the BauC+R management option. Indeed this option involves the lowest value of PWS. On this ground, this scenario may be opposed by political lobbies of all sectors.

The highest percent improvement in the deficit of all sectors obtained under the BauC+OP management options which enables to increase supply (via over-pumping of ground water from the coastal aquifer) as much as needed. Indeed this option involves the highest private welfare surplus (PWS). However it is the worst scenario from social point of view and from the point of view of the greens' lobby since it involves the lowest value of SWS and the highest value of environmental cost.

Based on the results obtained so far, it can be concluded that the option to enhance supply via over-pumping of groundwater is not desirable. It involves the lowest social welfare surplus and the highest environmental costs. The option to increase supply of recycled water and/or to reduce gross domestic demand via water conservation seem to occupy advantageous positions in terms of social welfare surplus and environmental costs. Although it involves the highest direct costs, the option to increase supply via seawater desalination, which improves social welfare and has no negative environmental impacts, cannot be rejected a-priori.

It is apparent that in the scope of integrating management scenarios into promising water management strategies, the impact of various combinations of the examined management options should be taken into account, such as supply enhancement via recycling or desalination of seawater, and reduction of domestic demand via water conservation.

Chapter 12 Analysis of Water Management Options for Limassol Region, Cyprus

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

Although a large number of various water supply investments and interventions have been made such as surface water dams, groundwater exploitation, inter-basin 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 demand and the dynamic competitive tension between agriculture, urban growth including tourism, and the environment** are challenging the existing water management practices in the island. Taking into account the above, the objective in the selection of appropriate management options and eventually of the formulation of the strategies for the Limassol Region is to meet the growing demand for water, to alleviate pressures exerted on vulnerable resources by the growing urban demand, without detrimentally affecting the traditional agricultural activities.

This chapter is dedicated at presenting the formulation of water management scenarios and the evaluation of different management options and methods considered applicable in the Limassol region. The outcomes of this analysis, summarised in Chapter 6, formed a milestone in the overall process of formulating improved and integrated water management strategies, determining the extent, cost and impact that each option could have when applied to the water system of the Limassol region.

Demand and Availability Scenario Components

Formulation of Demand Scenarios

Since the water management practices in the region reflect the competing demand and the dynamic competitive tension between agriculture, urban growth including tourism, and the environment, the formulation of the demand scenarios will be based upon assumptions for:

- Permanent and seasonal population growth,
- Domestic consumption rates, and
- Agricultural demand growth.

Data were collected from the FAO Study, as well as from other sources including the Water Development Department, the Limassol Water Board, local administrative authorities, hotel owners association, and the Cyprus Tourism Organisation.

Three different demand scenarios were formulated, responding to:

- Normal conditions (NORMAL);
- High Demand conditions (HD);
- Low Demand conditions (LD).

Population projections were based on the census of 1992 and consecutive demographic reports (Ministry of Finance, 1994). The rate of growth of population (in %) is 0.8 for 2000 – 2005 dropping to 0.7 for the period 2005 to 2010 and to 0.6 afterwards. The assumed growth rates for the local population under the various scenarios are presented in Table 12-1.

Projections concerning seasonal population growth, associated with tourism development were based on the Strategic Plan of the Cyprus Tourism Organization. Accordingly, for the period 2000-2010, the annual increase of overnight stays will be of the order of 3.4%. The assumed rate of 3.5% was maintained throughout the examined period, running from 2000 to 2030. Additionally, the normal scenario envisaged an annual increase of 1.5% of the per capita water demand.

Table 12-1 Details of Demand Scenarios

SCENARIO	Population Growth		Irrigation	Consumption rate growth	
	Domestic	Seasonal		Domestic	Seasonal
NORMAL	1%	3.5% up to 2010 1.5% from 2010	0%	2%	1.5%
LOW DEMAND	0.5%	3.5% up to 2010 1.5% from 2010	0%	2%	1.5%
HIGH DEMAND	2%	3.5% up to 2010 1.5% from 2010	10%	2%	1.5%

The corresponding domestic water demand (hm^3) is portrayed Figure 12-1.

The irrigation demand is considered to have been stabilized and according to relevant studies (FAO) future growth is not expected, due to the limitation in available water supplies, costs and competition from imported agricultural products. The anticipated increase of irrigation water tariff is also a major factor in maintaining the agricultural activity to its present levels. This has been adopted for the NORMAL and the LOW DEMAND scenarios. For the HIGH DEMAND scenario an increase in consumption rate of 10% has been assumed, indicating a change in cropping pattern towards one characterized by a higher demand of water.

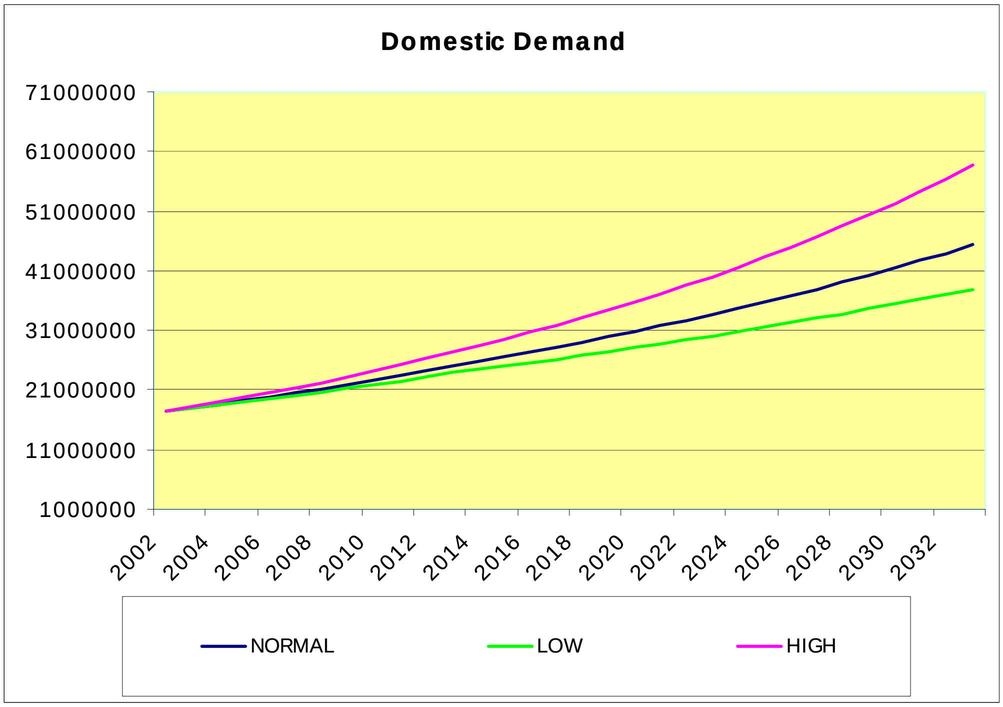


Figure 12-1 Domestic Demand Scenarios

Formulation of Availability Scenarios

Data

Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked with respect to temperature, precipitation and weather in general. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-March are separated by short autumn and spring seasons. During the last 30 years a considerable reduction of mean annual rainfall has been experienced in the island (Figure 12-2).

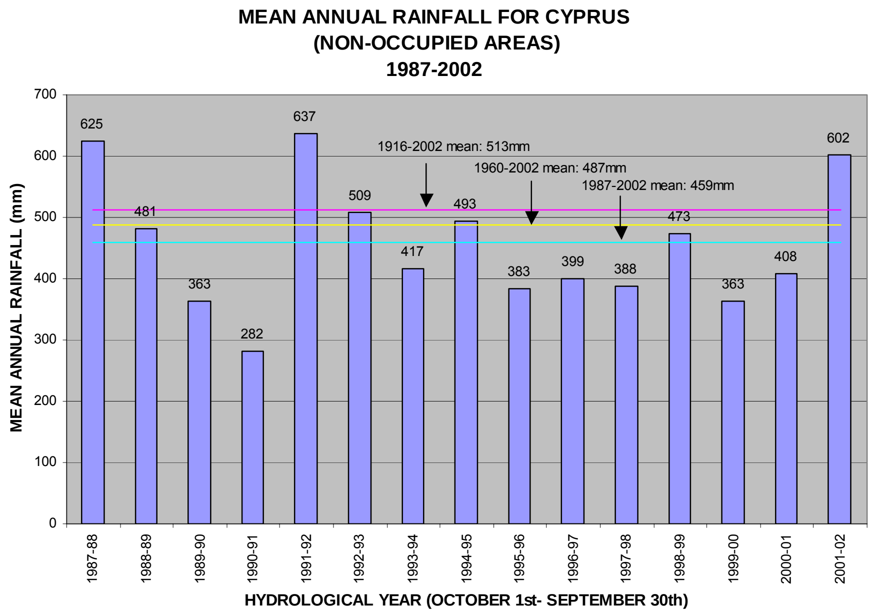


Figure 12-2 Mean annual rainfall for Cyprus (1987 – 2002)

The mean annual rainfall in Limassol is 409 mm according to the last 30 years measurements at the meteorological station of Limassol (Figure 12-3). In the same Figure 12-3, the mean rainfall throughout the region is presented. The inflows into the surface storage reservoirs (Figure 12-5) depend on the catchment rainfall and they reflect this.

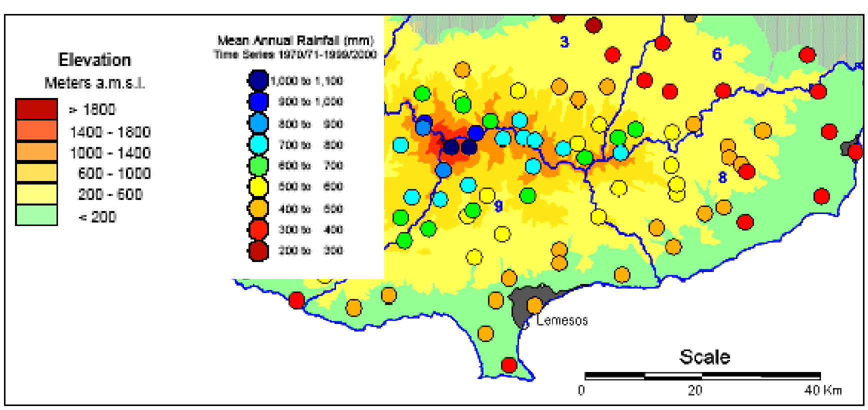


Figure 12-3 Mean annual rainfall for the Limassol region (1970 – 2000)

The distribution of the precipitation through the year is similar all over the island. In the Limassol region the mean precipitation increases to maximum in December and January. The decrease of the mean precipitation is slower than the increase, it spans over eight months from December – January to a minimum in July – August (Figure 12-4).

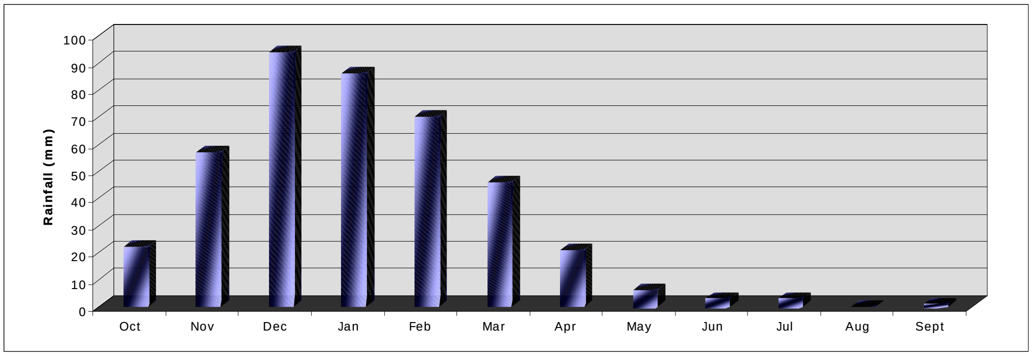


Figure 12-4 Monthly rainfall distribution in the Limassol region (average values for the period1970 – 2000)

Figure 12-5 shows the variations with time of the region's three dams inflows over the 1987/1988 – 2003/2004 periods.

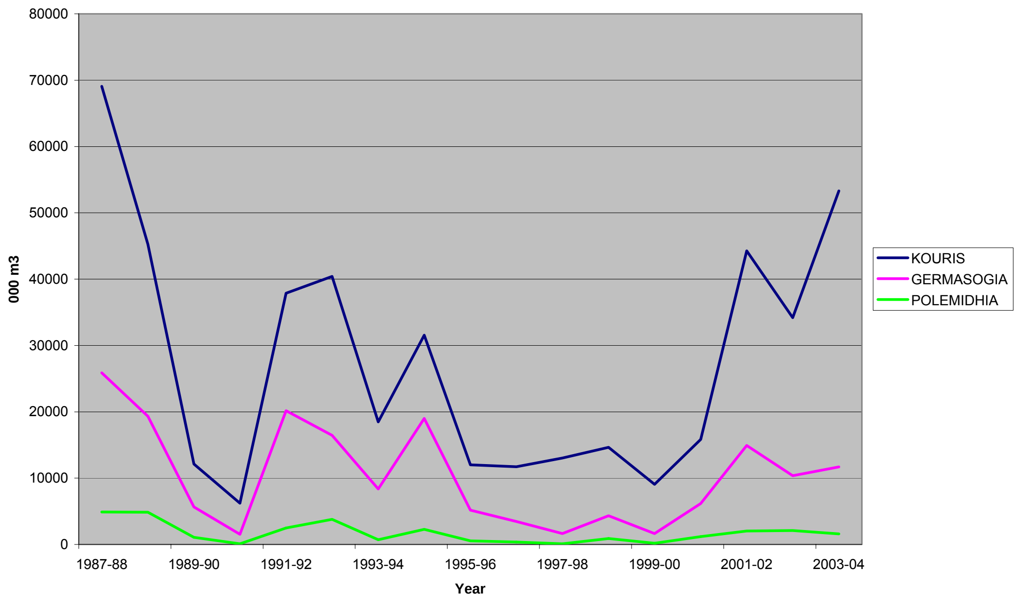


Figure 12-5 Annual distribution of the water inflows in the three dams of the region (1970 – 2000)

Scenarios

Since detailed data of water inflows were available for the region, the variable in the formulation of water availability scenarios was the sequence of years with respect to water inflows in the dams. Three different hydrological scenarios were used, reflecting the business as usual conditions (standard water availability) – BAU, the high frequency of dry years conditions (DRY) and high frequency of wet years (WET).

The three scenarios are depicted in Figure 12-6.

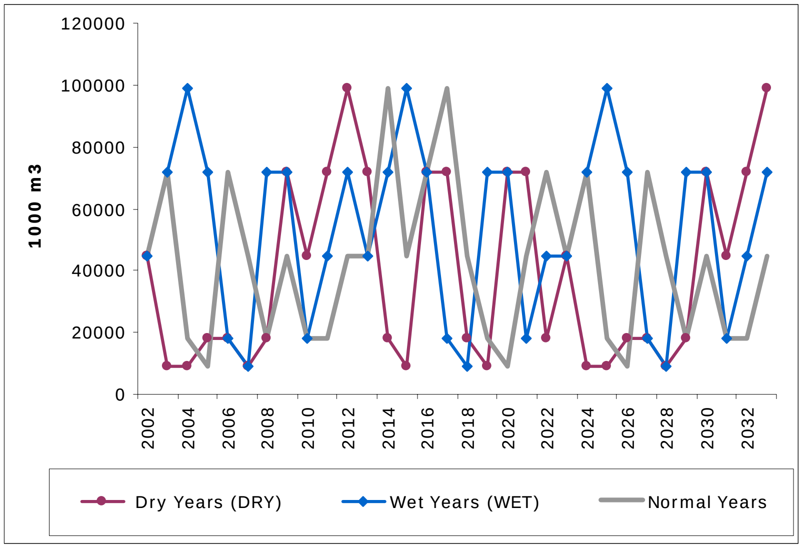


Figure 12-6 Water availability scenarios

Combinations of Availability and Demand Scenarios

In order to cover all the possible responses of the water system of the region, a number of hydrological and demand scenarios have been developed related to the business as usual case scenario (BAU), the worst case scenario (WORST) and the best case scenario (BEST).

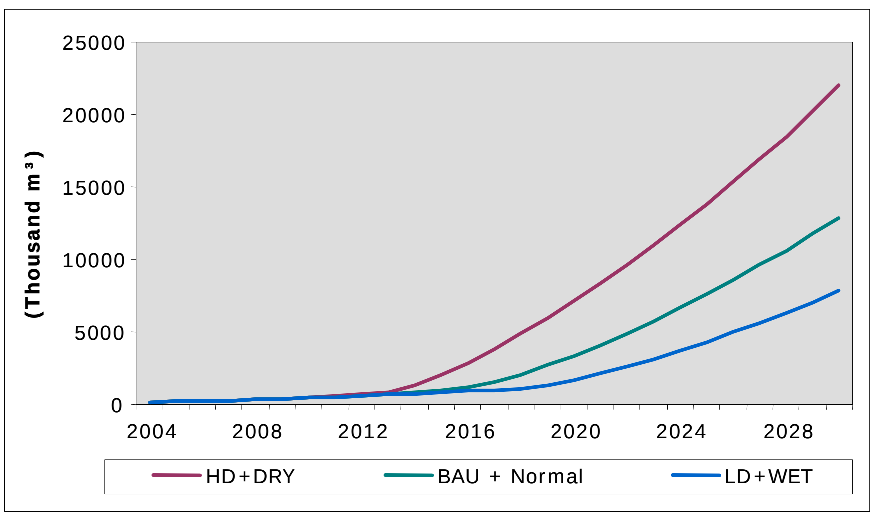


Figure 12-7 Estimated domestic unmet demand under the selected hydrological-demand combinations

The details of the adopted combinations are given in the following Table.

Table 12-2 Combinations of availability and demand scenarios

Combination Name	Availability Scenario	Demand Scenario
Business as Usual Scenario:	Normal years	Business as Usual demand
Worst case Scenario:	Dry years	High demand
Best case Scenario:	Wet years	Low demand

The domestic water deficit is characterized by a steep increase (Figure 12-7) in all three combinations after year 2012, since by that time the water production of the water treatment plant of Limassol will reach the plant's capacity (40.000 m^3/day).

There is a pronounced seasonality of domestic water deficit peaking in the summer period due to increased influx of tourists (Figure 12-8). Certain tourist destination areas experience considerable stress in meeting the water demand.

At the beginning of the simulation period (year 2002), the domestic water unmet demand is less than 0.8% of the demand, experienced mainly in Limassol Tourist Area and Akrotiri, Assomatos and Kantou villages. By the end of the simulation period nearly all settlements in the study area face domestic water deficit, which reaches up to 31% of the demand.

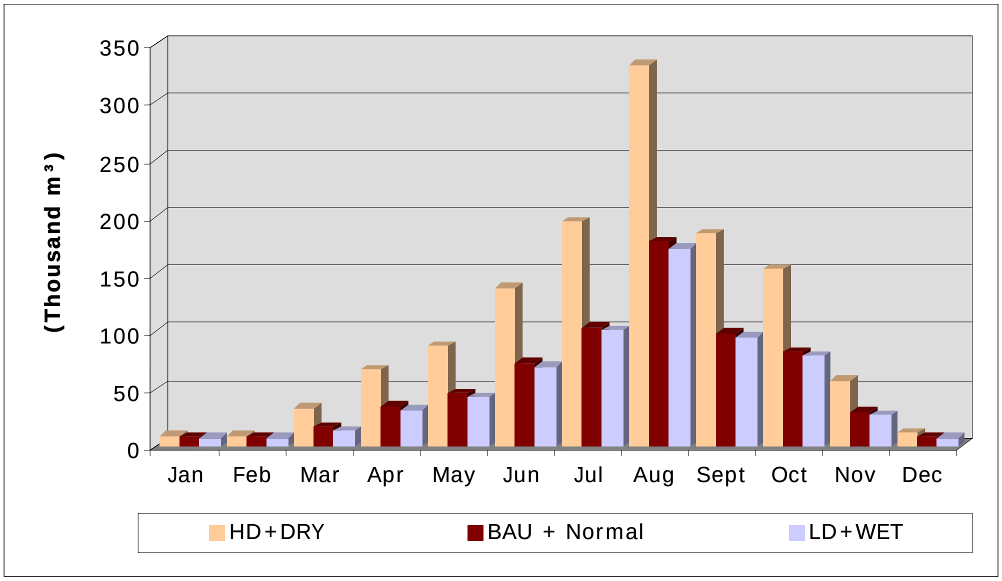


Figure 12-8 Monthly domestic deficit under the three scenarios (year 2011

Analysis of Water Management Options

The management options analysed have also been mentioned in Table 6-1of Chapter 6, and are repeated here (Table 12-4) for convenience.

The satisfactory range of values and the weights assigned to the three indicators are presented in Table 12-3. In addition to the three aforementioned indicators, it was considered necessary to incorporate also the direct costs related to the application of each option, in order to select not only efficient, but also cost effective solutions.

Table 12-3 Evaluation indicators

Indicator	Satisfactory range of values	Weight
Domestic demand coverage	90-100%	0.50
Irrigation demand coverage	80%	0.25
Groundwater exploitation index	0-80%	0.25

Table 12-4 A synthesis of management options for Limassol region

GOALS	INTERVENTIONS
Interventions related to Supply Enhancement	
Domestic and tourist demand will be met by surface water – Agricultural demand will be met by surface water reducing the burden on groundwater.	SE1: Minimization of groundwater abstraction for drinking water. SE2: Upgrade Program of the existing Water Treatment Plan.
Maintain irrigated agricultural practice using water from dams and treated water only, to allow aquifers to recover.	SE3: Construction of a WWTP for the western rural areas. SE4: Minimization of groundwater abstraction for irrigation
Interventions related to demand management	
Adjustment of cropping pattern to less water demanding crops suitable for the climatic and water conditions of the country. Consequent promotion of high income crops Prioritizing irrigation demands during droughts	DM1 : 1st priority permanent crops 2nd priority seasonal crops
Interventions related to the socio-economic context	
Discouragement of groundwater resource preferences.	SE1: Increment of groundwater tariffs to the level of surface water charges.
Reflection of true water costs on water tariffs allowing an adequate cost recovery.	SE2: Review of irrigation water allocation criteria.
Conciliation of water availability with demand.	SE3: Gradual increase of irrigation water prices to reflect true costs (cost recovery). SE4: Introduction of incentives and disincentives to conciliate water availability with demand
Interventions related to the Environmental Eco-Systemic Context	
Improvement of treated water quality.	E1: Additional infrastructure at the WWTP.

The following paragraphs present the results of the undertaken analysis for the worst hydrological/demand case scenario, which constitutes the reference scenario (or case) for both scenario evaluation and strategy development.

Structural Options

Wastewater Reuse

Cyprus has recently turned to the use of non-conventional water such as desalination and reuse of tertiary treated effluent to augment its available supplies. Within this framework the 100% utilization of the tertiary treated effluent of the Limassol Waste Water Treatment Plant has been identified as a possible policy intervention to enhance the water supply of the region and to alleviate the burden on groundwater.

The application of this intervention which is presented schematically in Figure 12-9 is scheduled for the year 2008, and includes the following technical aspects:

- Recycled water during the winter months (when the irrigation demand is at a minimum) will be stored in Polemidhia dam and/or will recharge the Kouris Delta aquifer. Under these circumstances, the Kouris Delta aquifer may not be used for domestic purposes.

- The pipeline form the WWTP will be connected to the existing network to transfer water to Zakaki Ext., Ag. Nikolaos, Lanitis and Fassouri farms.
- A new pipeline will connect Ypsonas reservoir with Zakaki farm to transfer fresh water from the Kouris dam to cover the irrigation demand of the farm. The cost of the pipeline is estimated to approximately 250,000 €.
- A new 5 km pipeline will connect the existing network with the Kouris Delta aquifer. The cost of the new pipeline is estimated to be approximately 1.7 million €.

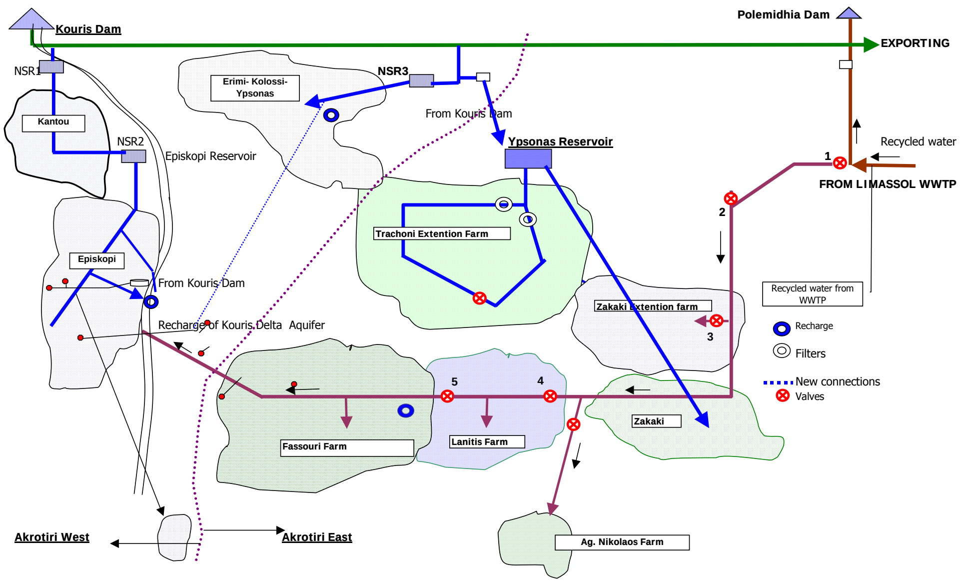


Figure 12-9 Proposed network modifications for recycled water reuse

This option results in substantial reductions (compared to the reference case where no intervention is adopted) in irrigation deficit (Figure 12-10), with a subsequent reduction in groundwater abstractions (Figure 12-11).

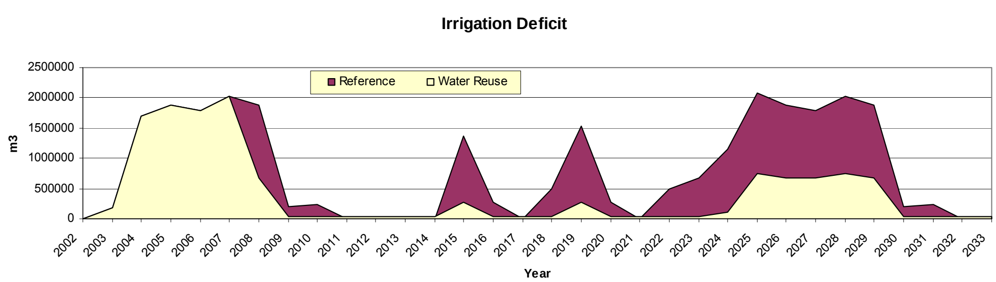


Figure 12-10 Reduction of irrigation deficit with respect to the reference scenario

As it can be seen in Figure 12-11, this intervention also has positive effects in domestic demand coverage, due to the reduction of surface water being used for irrigation purposes, and as a result there are quantities of fresh surface water available to cover domestic purposes. As it was mentioned before, this is of great importance since the Kouris Delta aquifer may not be used for domestic purposes. In this case the resulted domestic deficit is reduced because of saved surface water that would have otherwise been used for irrigation.

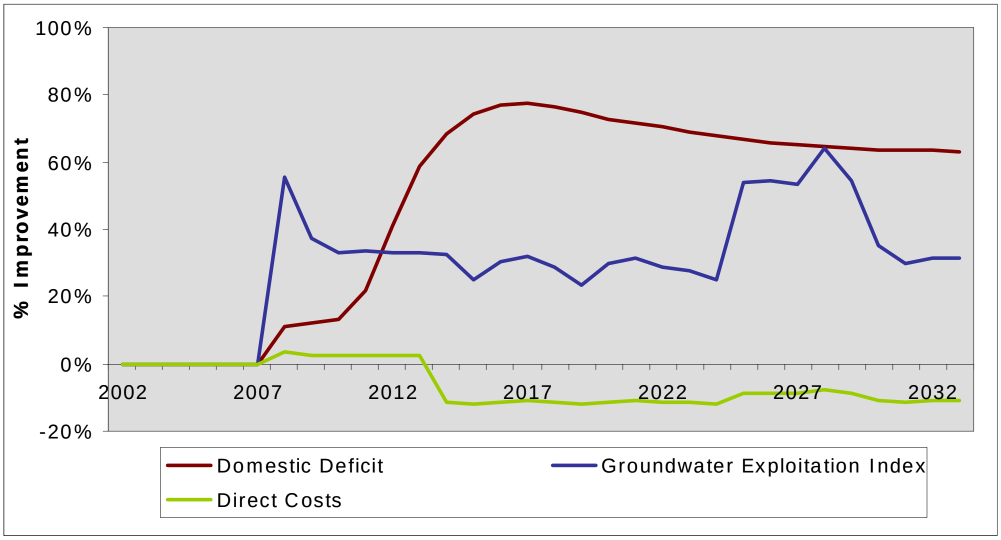


Figure 12-11 Improvement (%) with respect to the reference scenario HD+Dry

Under current conditions the 100% utilization of the recycled water can be accomplished only with the construction of a new 11 km pipeline from the Ypsonas reservoir to Kouris Delta aquifer. This alternative has a much higher cost than the examined option, and this is the reason why the examined option is promoted by the Water Development Department.

The comparison of the direct cost (present values adopting a discount rate of 10%) leads to the conclusion that in all cases the anticipated increase of costs is less than 1% in line with the previous comments. The associated increase of direct cost for the HD+DRY scenario is the highest since for the same incurred costs for the intervention, the water demand is highest and the water availability is lowest, the latter affecting also the availability of domestic water and consequently the quantity of produced treated effluent. Thus, relatively smaller quantities of treated effluent water are being recycled.

Contrary to the above, for the LD+WET scenario this change is the lowest of the three scenarios examined since it appears that in this case where the demand is lowest and water availability highest (increased treated effluent availability), full use of the intervention is made balancing the incurred cost for the intervention. This is also strongly suggested by the results shown in Figure 12-12. The evaluation of the water reuse intervention against the reference scenarios is by far highest for the LD+WET scenario. In this case the deficits for irrigation are the least, the groundwater exploitation is reduced and more water is available for the domestic sector.

In all the three scenarios the increase of direct cost appears to be very small indicating the balancing of the incurred costs for the intervention by the mobilization of sufficient quantities of treated effluent water replacing fresh water which becomes available for other use (domestic demand).

The associated environmental cost is presented in Figure 12-12. The estimation of the environmental cost was based on the French Agences de l'Eau method, and is related to renewable groundwater abstractions alone (the environmental cost for pollution was not calculated). The environmental cost after the introduction of the intervention is substantially lower than the environmental cost estimated for the reference scenario due to the substantial reduction of the groundwater abstractions for irrigation purposes (see also Figure 12-11).

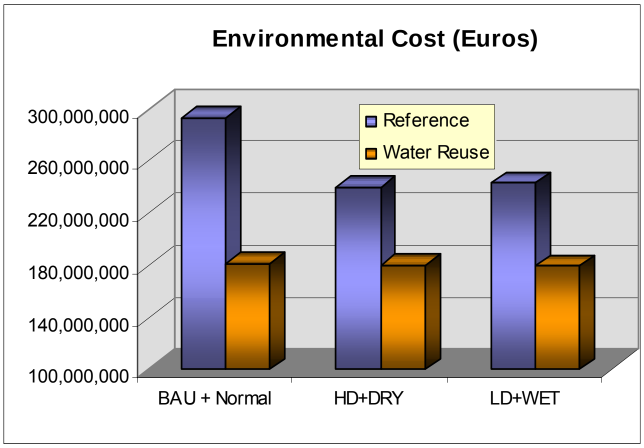


Figure 12-12 Comparison of the environmental cost of the water reuse intervention against the three reference scenarios

The obtained evaluation scores for all three cases are presented in Figure 12-13. The higher score is obtained for the best case scenario (Low Demand and Wet). In all three cases the ground water exploitation index shows the greatest improvement in line with what it was mentioned before (Figure 12-11).

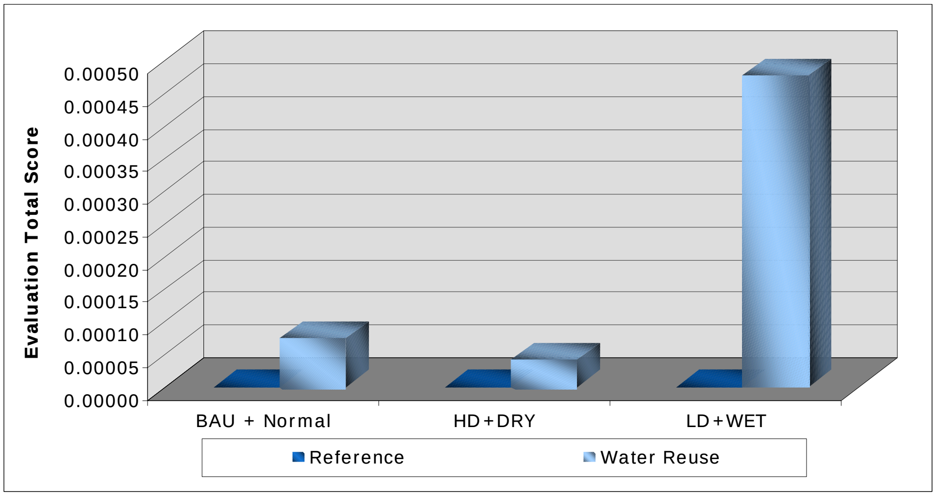


Figure 12-13 Evaluation of the water reuse intervention against the reference scenarios

Water Treatment Plant Upgrade

As it was mentioned before (Figure 12-7) by the year 2012 the demand for treated fresh water from the Limassol Water Treatment Plant will overcome the capacity of the plant.

Based on the water demand projections and the seasonality patterns of the water consumption, the examined intervention involves the following technical aspects:

- Upgrade of the existing Water Treatment Plant to reach a capacity of 80.000 m^3/d.
- Minimisation of groundwater abstractions from the Garyllis aquifer for domestic uses.

The intervention is examined coupled with the previously presented one.

Under the worst case scenario, this option results in substantial reductions in domestic deficit (Figure 12-14), with a subsequent reduction in groundwater abstractions (Figure 12-16).

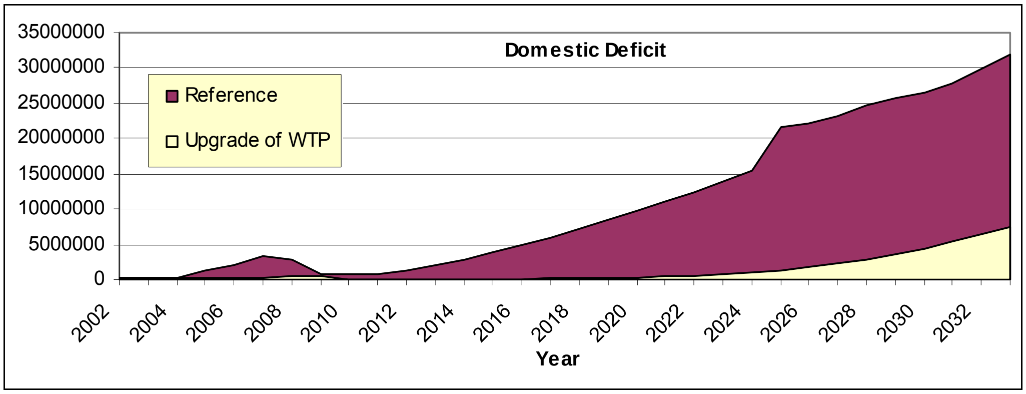


Figure 12-14 Reduction of domestic deficit with respect to the reference scenario HD+Dry

This intervention also has positive effects in irrigation demand coverage as it can be seen in Figure 12-15, because more quantities of treated effluent and groundwater are available for irrigation use.

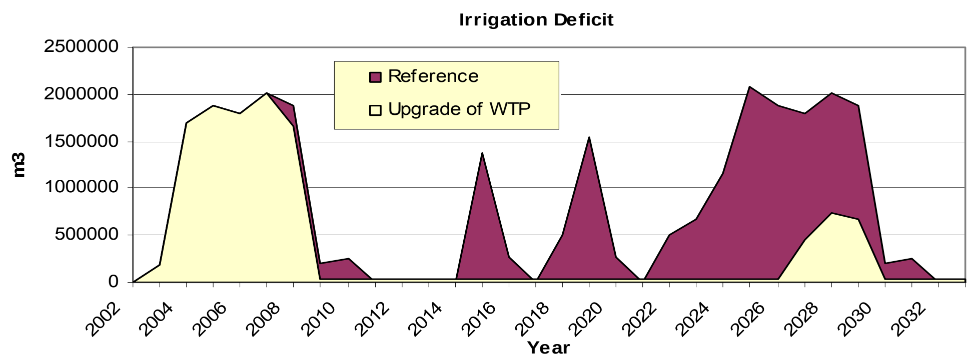


Figure 12-15 Reduction of irrigation deficit with respect to the reference scenario

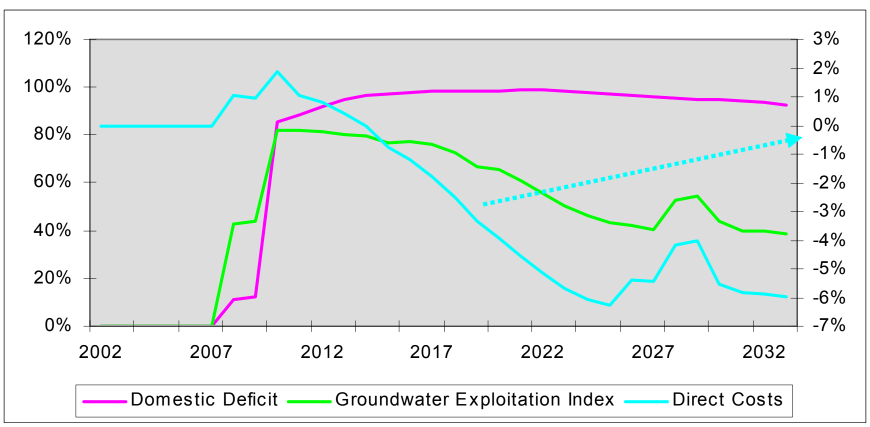


Figure 12-16 Improvement (%) with respect to the reference scenario HD+Dry

The most favourable case is the BAU+Normal scenario in which the direct costs of the intervention are outweighed by the coverage of the normal demand under normal climatic conditions. The additional costs are practically balanced for the HD+DRY scenario whilst for the LD+WET the intervention is just slightly less effective (due to the lower demand assumed) compared to the high demand and dry conditions scenario. The beneficial effect of the water treatment plant upgrade, which allows surface water to be used for domestic purposes permitting to the Garyllis aquifer (reduced groundwater exploitation) to help meet the irrigation demand, is inherent in all the three scenarios examined.

The associated environmental cost is presented in Figure 12-17. The environmental cost after the introduction of the intervention is substantially lower than the environmental cost estimated for the reference scenario, due to the substantial reduction of the groundwater abstractions for domestic purposes (see also Figure 12-16).

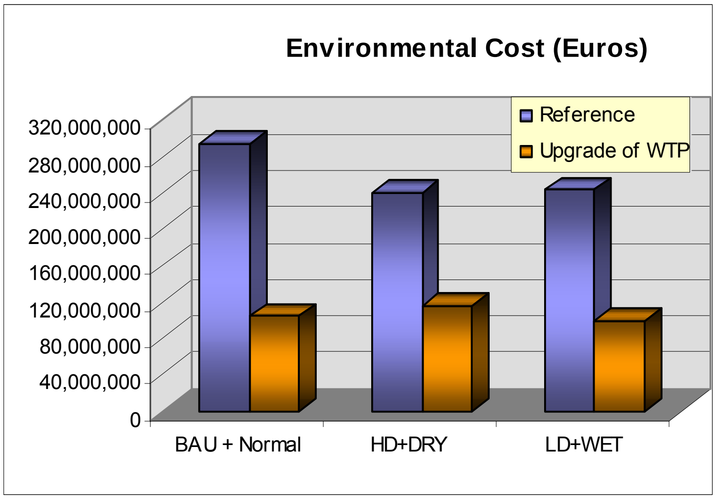


Figure 12-17 Comparison of the environmental cost of the WTP upgrade intervention against the three reference scenarios

In the LD+Wet scenario both the irrigation and the domestic demand are covered to an increased level and at the same time the groundwater exploitation is reduced. This probably is the reason for the high evaluation score attained by this scenario as shown in Figure 12-17.

The obtained evaluation scores for all three cases are presented in Figure 12-18. The highest score is obtained for the best case scenario (Low Demand and Wet).

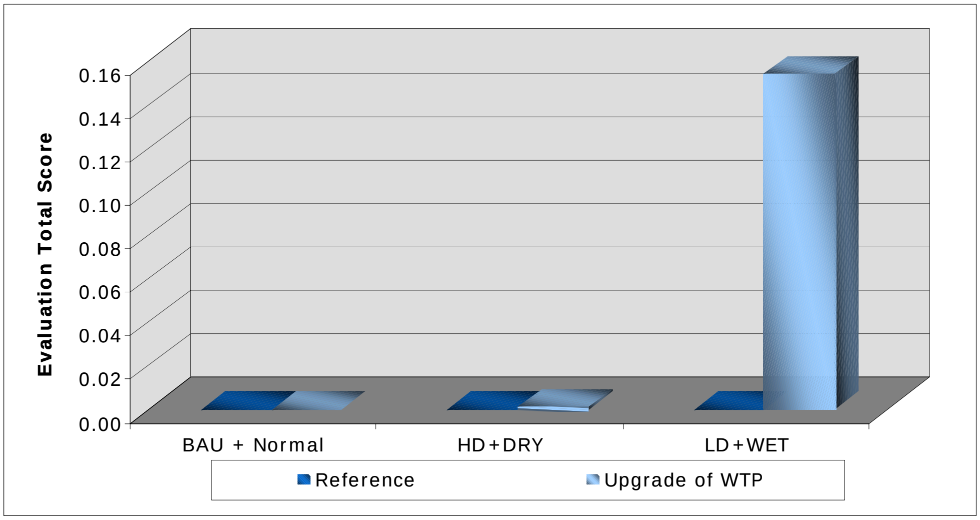


Figure 12-18 Evaluation of the water treatment plant intervention against the three reference scenarios

New Wastewater Treatment Plant for the Western Rural Areas

An additional measure to enhance the water supply of the region would be the construction of a WWTP to serve the western rural areas. According to the perceptions of the Municipalities of the region for the new water management strategy, such a solution promotes the acceptance of treated water for agriculture, since the “affected Municipalities” can participate in the operation of the plant

The realization of this intervention is scheduled for the year 2008, and includes the following technical aspects:

- A new 4000 m^3/day WWTP will be constructed to treat the effluent of the villages Polemidhia, Ypsonas, Erimi, Episkopi and Kolossi.
- The tertiary treated effluent will partially cover the needs of the Episkopi and Fassouri farms.

Under the worst case scenario, this option results in minimisation of the irrigation deficit (Figure 12-19), with a subsequent reduction in groundwater abstractions (Figure 12-20).

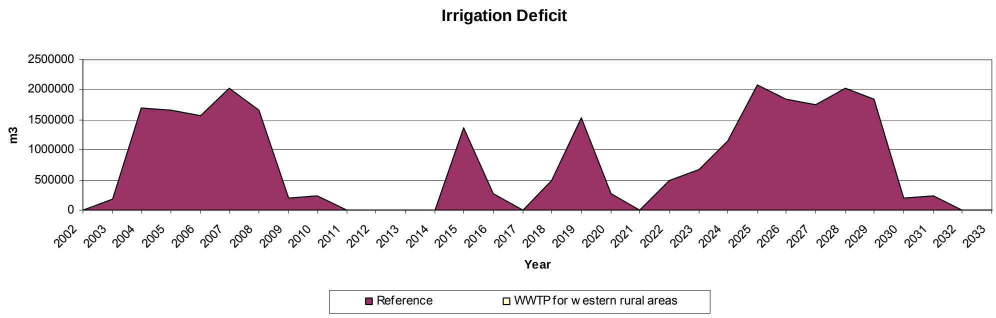


Figure 12-19 Reduction of the irrigation deficit with respect to the reference scenario HD+Dry

This intervention also has positive effects in domestic demand coverage as it can be seen in Figure 12-20. This is because, due to the reduction of the groundwater abstractions for irrigation purposes, there are available quantities of fresh water to cover domestic purposes.

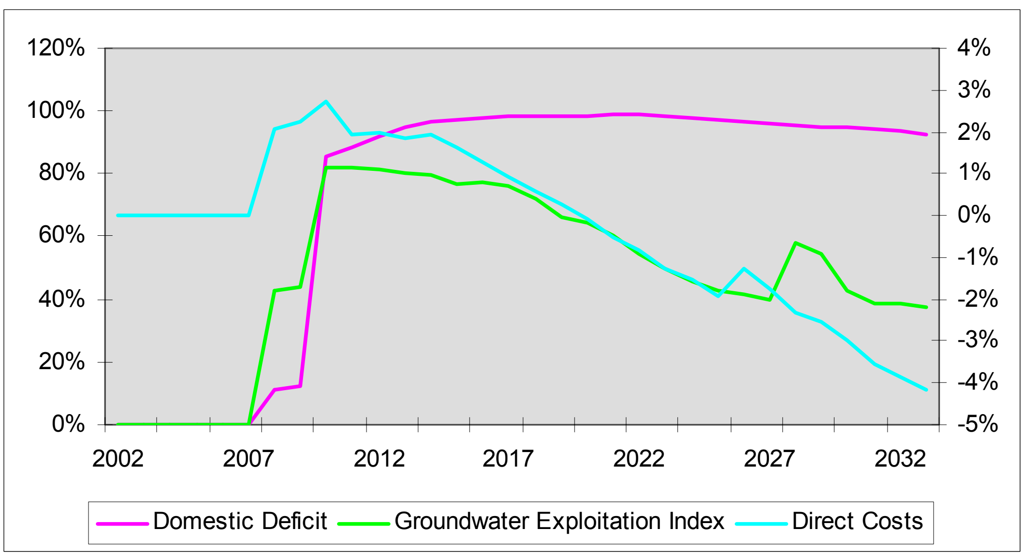


Figure 12-20 Improvement (%) with respect to the reference scenario HD+Dry

This intervention constitutes a new source of water which will be available for irrigation at reduced cost (treated effluent). Furthermore, the cost of the intervention is relatively small since the water can be used within the same general area that is being produced (no major pipelines are required). Thus, the costs are very favourable for the BAU+Normal scenario where the irrigation deficits are high. The high demand and low availability of water (less domestic supply and thus less treated effluent produced) render the relative cost of the intervention more expensive. This is also the case for the Low Demand but Wet scenario. Lower quantities of recycled water are mobilized but the meeting of the demands renders the evaluation score of this scenario the highest against the reference case. Increased irrigation demand coverage and the reduced groundwater exploitation due to this intervention provide the highest score for this scenario.

The associated environmental cost is presented in Figure 12-21. The environmental cost after the introduction of the intervention is substantially lower than the environmental cost estimated for the reference scenario, due to the substantial reduction of the groundwater abstractions for irrigation purposes.

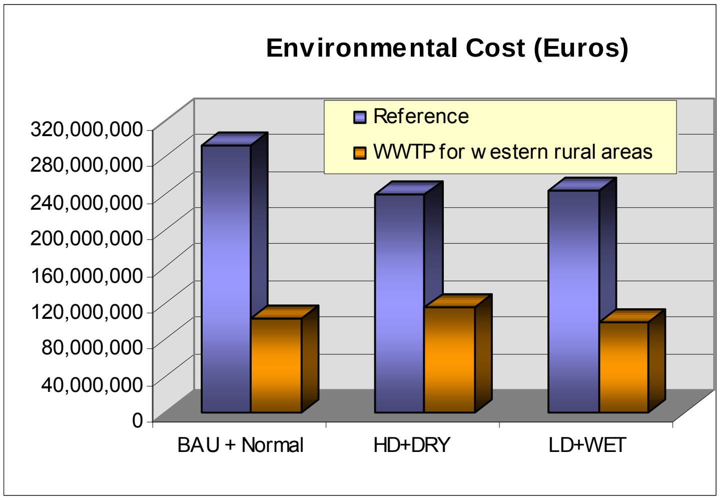


Figure 12-21 Comparison of the environmental cost of the WWTP intervention against the three reference scenarios

The obtained evaluation scores for all three cases are presented in Figure 12-22. The highest score is obtained for the best case scenario (Low Demand and Wet) for which the efficiency indicator shows the greatest improvement.

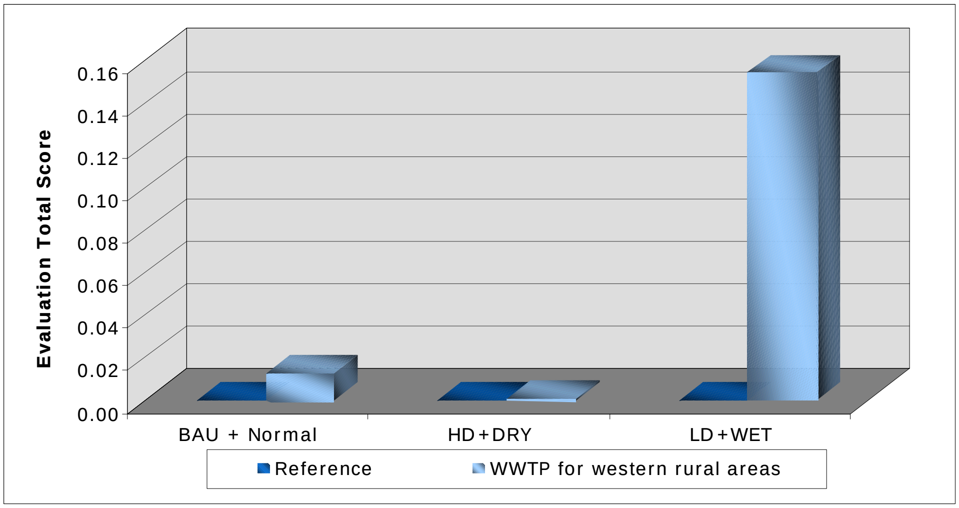


Figure 12-22 Evaluation of WWTP (western rural areas) against the three reference scenarios

Demand Management Options

Conservation Measures in the Domestic Sector

The application of conservation measures in the domestic sector was assessed assuming that a reduction in the domestic demand of 10% (excluding the seasonal demand) could be accomplished. In addition it was assumed that the measure will apply in year 2008. In Figure 12-23 domestic demand after the application of the measure is presented.

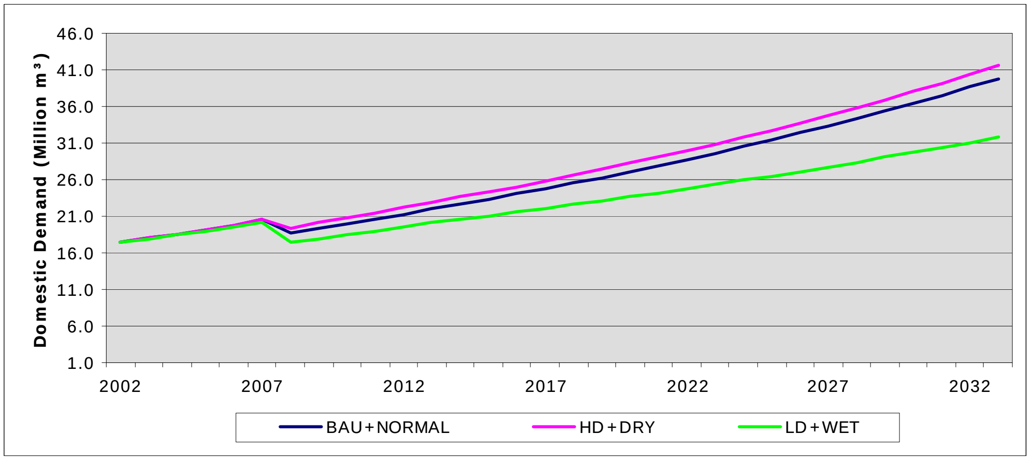


Figure 12-23 Domestic demand after the application of conservation measures for the three scenarios

Under the worst case scenario, this option results in substantial reductions in domestic deficit (Figure 12-24 and Figure 12-25).

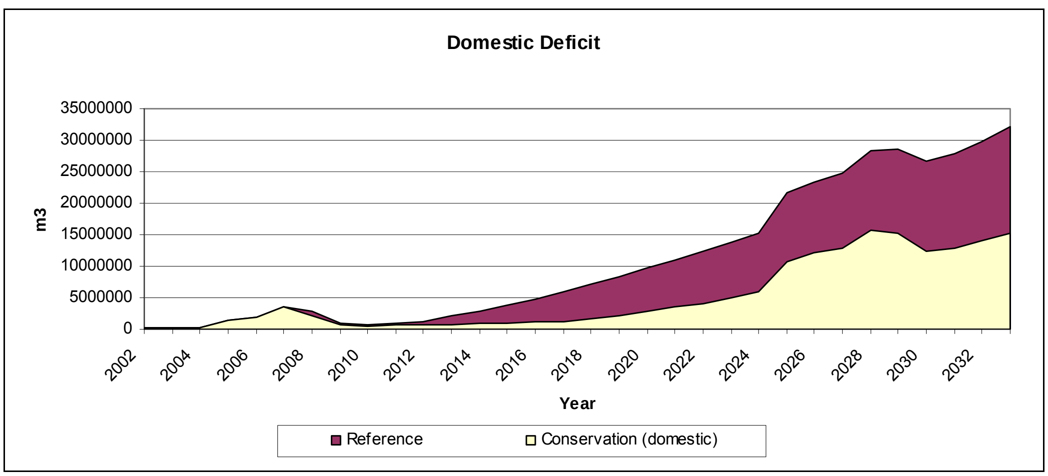


Figure 12-24 Reduction of domestic deficit with respect to the reference scenario

As it is depicted in Figure 12-25, this intervention also has positive effects in groundwater exploitation index and direct cost due to the reduction of the groundwater abstractions in order to supply domestic purposes.

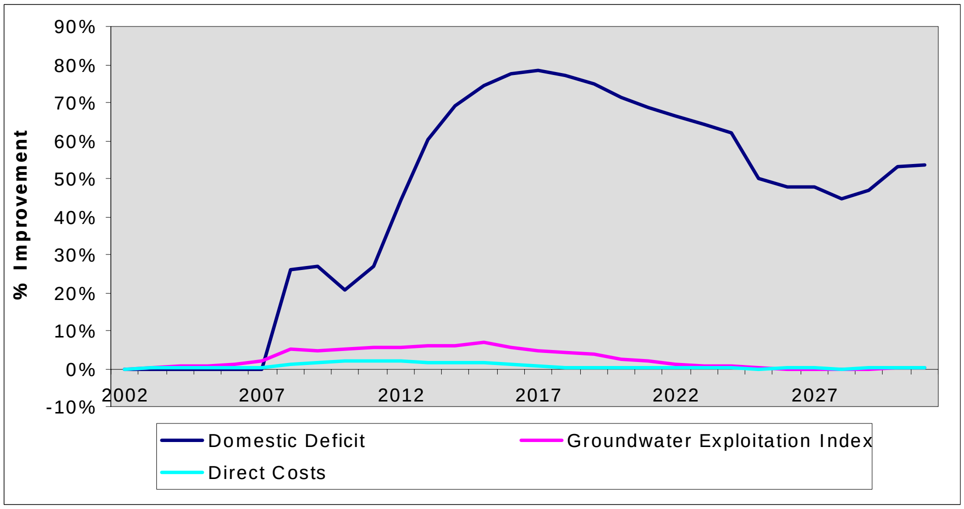


Figure 12-25 Improvement (%) with respect to the reference scenario HD+Dry

This measure alone can not ensure the coverage of the domestic needs, especially after year 2012 when the water production of the water treatment plant of Limassol is expected to reach the plant's capacity (40,000 m^3/day). In all cases the anticipated decrease of the total direct costs is less than 1%. The assumed water conservation from the intervention compared to the incurred costs renders the costs favourable for all the examined scenarios.

In the case of the HD+DRY scenario the larger quantities of water saved (due to the High Demand) are possibly counterbalanced by the lower availability of water. Thus, the intervention appears slightly more favourable for the LD+WET scenario where the large availability of water enables greater savings of water and improved demand coverage. This is probably the reason why the highest evaluation score is attained under this scenario.

The associated environmental cost is presented in Figure 12-26. The environmental cost after the introduction of the intervention is substantially lower than the environmental cost estimated for the reference scenario, due to the substantial reduction of the groundwater abstractions for domestic purposes.

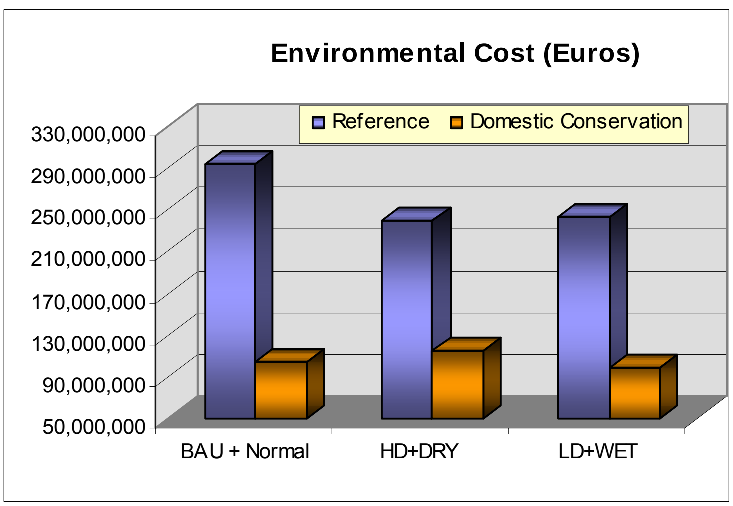


Figure 12-26 Comparison of the environmental cost against the three reference scenarios

The obtained evaluation scores for all three cases are presented in Figure 12-27. The higher score is obtained for the best case scenario (Low Demand and Wet) for which the efficiency indicator shows the greatest improvement.

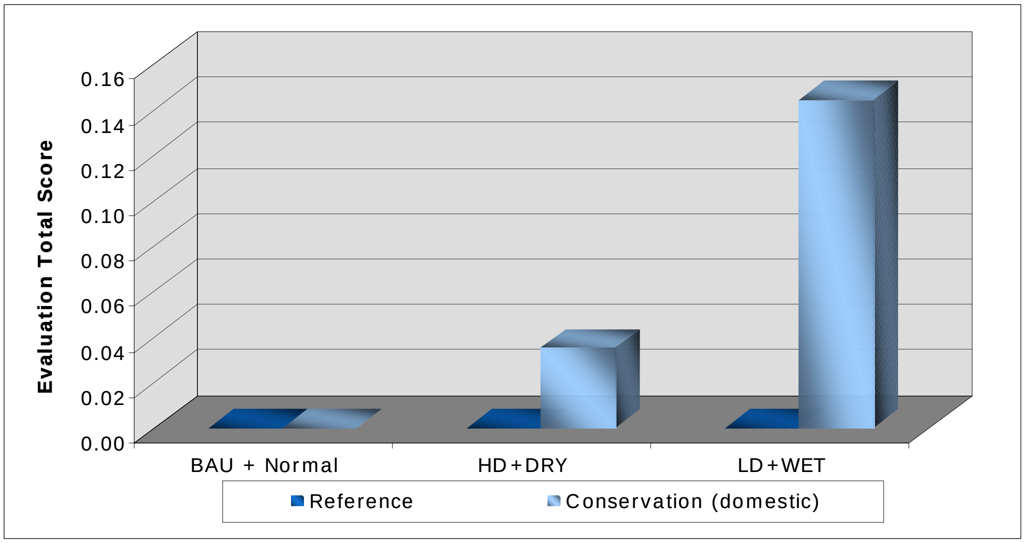


Figure 12-27 Evaluation of domestic conservation against the three reference scenarios

Reduction of Network Losses in Domestic Water Supply

Accurate data regarding the level of network losses throughout the study area are not available. Data exist for the area served by the Limassol Water Board where network losses are reported to be as low as 16%. In any case it is believed that losses can be of the order of 25% or more.

Thus, the reduction of the losses to 15% (through successive network replacements) was assessed as an alternative water management option for the three biggest settlements in the study area that is the Lemessos Municipality, Lemessos Tourist Part and Germasogeia Municipality. The new demand for each one of the settlements where the measure is applied under the worst case scenario (DRY + HD) is presented in Figure 12-28.

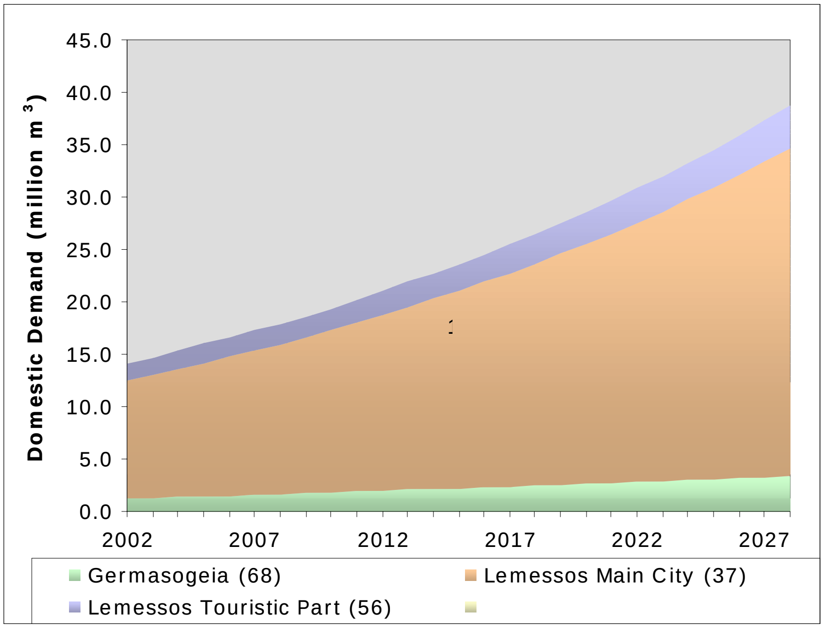


Figure 12-28 Domestic demand per municipal department under the network loss reduction option (HD + Dry)

Under the worst case scenario, this option shows an improvement in domestic deficit (Figure 12-29), and to a lesser extent in groundwater exploitation index. Again this measure alone cannot ensure the coverage of the domestic needs, especially after year 2012 when the water production of the water treatment plant of Limassol is expected to reach the plant's capacity (the improvement after 2012 falls from 25% to less than 5% in year 2033).

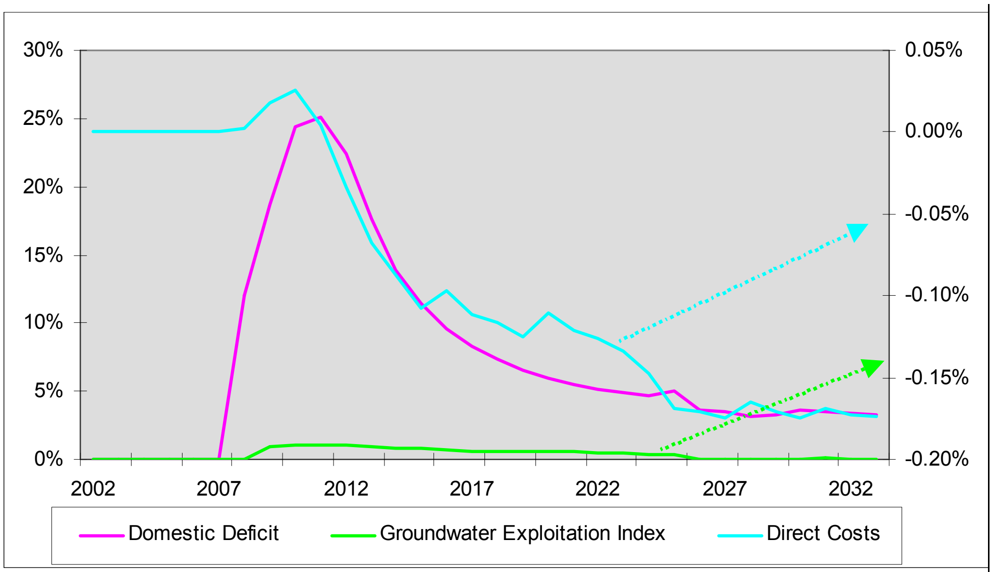


Figure 12-29 Improvement (%) with respect to the reference scenario HD+Dry

The irrigation deficit reduction is slightly influenced by this option, as it can be seen in Figure 12-30.

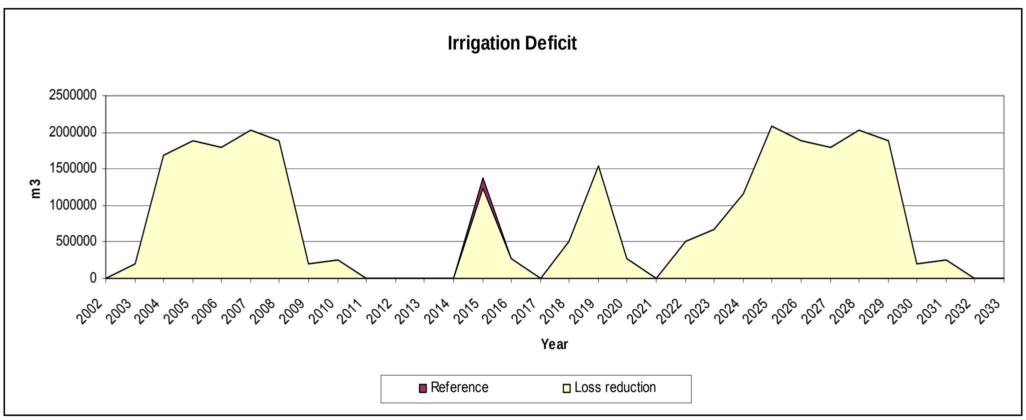


Figure 12-30 Improvement of irrigation deficit with respect to the HD+Dry scenario

In the HD+Dry scenario less water is available and thus less water is expected to be saved by this intervention, thus in this case the associated direct cost is slightly higher than the cost of the reference case. The difference among the three scenarios examined is very small due probably to the small change of the domestic water demand and the supply, irrespective of the climatic conditions.

The associated environmental cost is presented in Figure 12-31. The environmental cost after the introduction of the intervention is slightly lower than the environmental cost estimated for the reference scenario, due to the small influence of the intervention on the reduction of the groundwater abstractions (see Figure 12-29 groundwater exploitation index). Moreover the environmental cost (calculated based on the to renewable groundwater abstractions alone) is much higher than the estimated environmental cost of the previously described interventions, for the same reason.

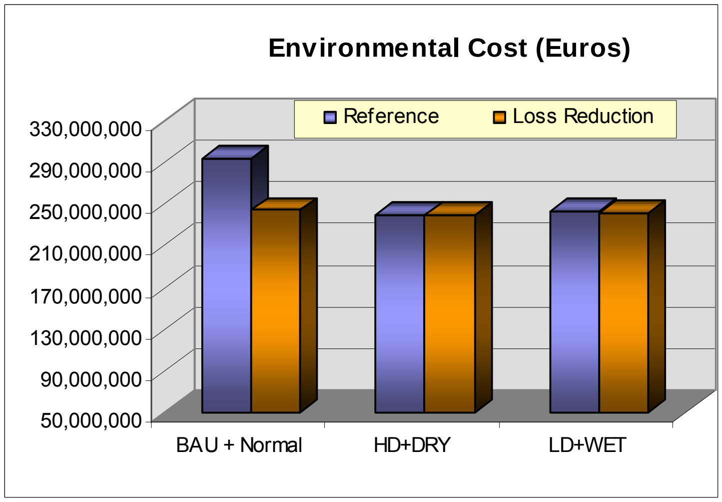


Figure 12-31 Comparison of the environmental cost against the three reference scenarios

Both the HD+Dry and the LD+Wet scenarios attained a high evaluation score for the reasons stated above, the high water demand in the first case and the large availability of water in the second and the fact that the demand coverage is improved. In both cases relatively larger quantities of water are mobilized and thus more water is saved.

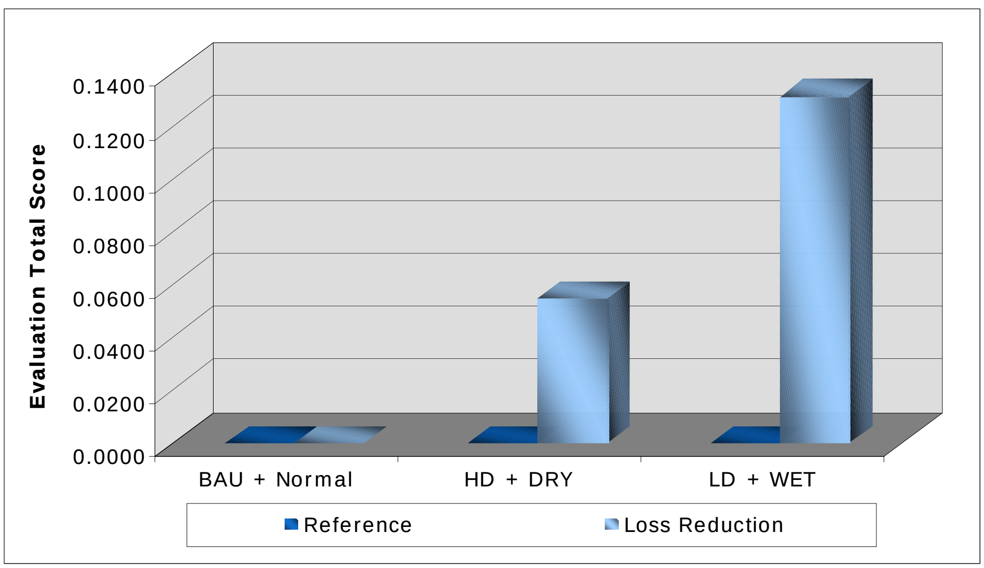


Figure 12-32 Evaluation of loss reductions against the three reference scenarios

Pricing

Irrigation Water Pricing

Contrary to the costs of domestic water that is almost full charged to customers, the price of irrigation water covers neither the full financial nor the economic costs. The present tariff for the study area is Cy £0.07 /m^3 which is equivalent to 22.3% of the weighted average unit cost of water, although the Loan Agreements with the World Bank dictate that the price of the water should be at least 38% of the weighted average unit cost. As a result the WDD is examining the case to revise the prices upwards to reflect the true cost of the water. This will promote efficiency and water conservation measures contributing towards a sustainable water management alleviating the current water shortage problem. Such an approach complies also with the provisions of the new Water Framework Directive of EU, although it is well understood that its implementation will be very difficult.

This option examines the case of raising the irrigation water prices from 0.07C£/m^3 to 0.11 C£/m^3 within a period of three (3) years. Data for demand elasticities are available for individual agricultural products and are presented in the following table.

Table 12-5 Agricultural products price elasticities (Eri Nicolaides, 2000)

Product	Price Elasticity
Potatoes (spring)	-0.33
Tomatoes (greenhouse)	-0.70
Cucumbers (greenhouse)	-0.58
Water melons (open)	-0.50
Oranges	-0.02
Grapefruits	-0.02
Lemons	-0.01
Mandarins	-0.02
Grapes	-0.02

As it can be seen in Table 12-5 the value of the elasticities for the permanent crops is much lower than the seasonal crops. This is reasonable given that the production decisions for permanent crops are much more complicated and long term than in the case of annual/ seasonal crops.

The application of this simple irrigation pricing scheme results in a reduction of irrigation demand of approximately 1,500,000 m^3 or 10% of the total irrigation demand (Figure 12-33).

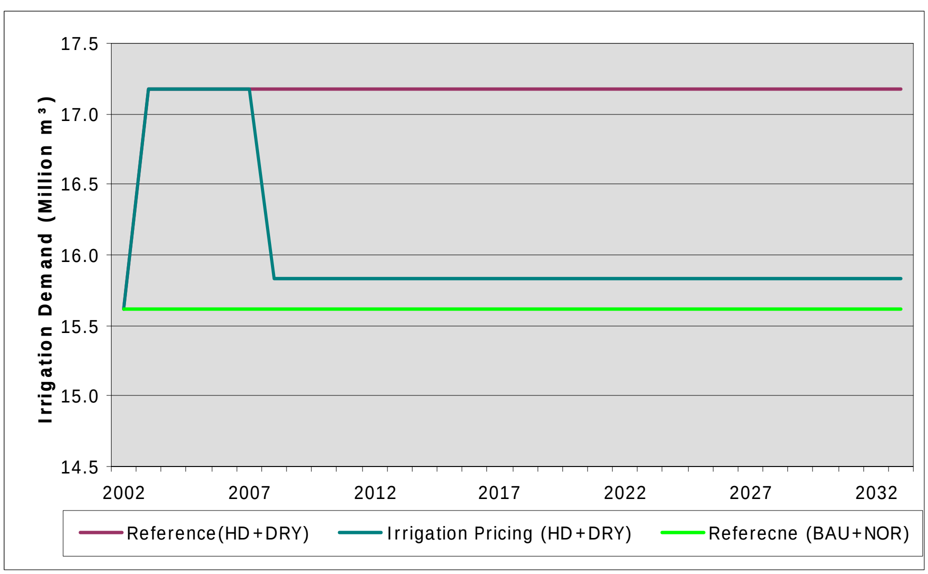


Figure 12-33 Irrigation demand under reference scenarios and irrigation pricing intervention

Under this management option the irrigation deficit throughout the simulation period (2002 – 2033) is reduced by almost 23%, from 24,489,795 m^3 to 19,684,766 m^3 (Figure 12-34).

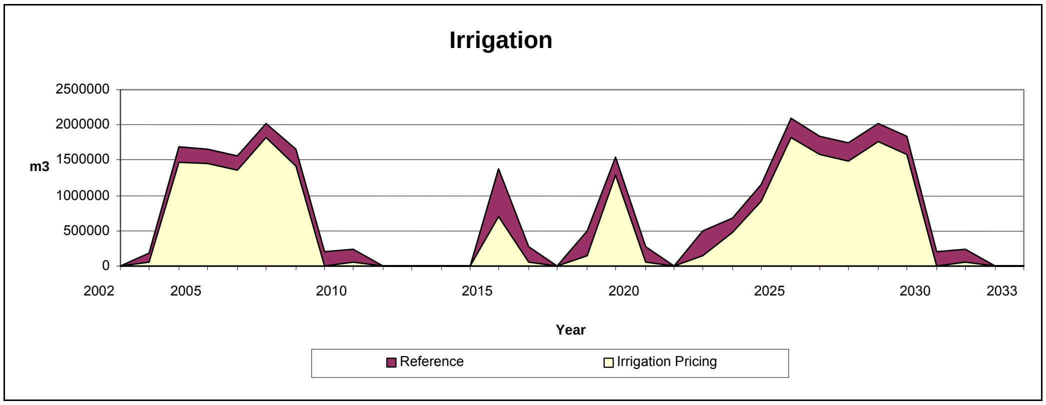


Figure 12-34 Improvement of irrigation deficit with respect to the reference scenario HD+Dry

This intervention has small positive effects in groundwater exploitation index but does not affect the domestic deficit (Figure 12-35).

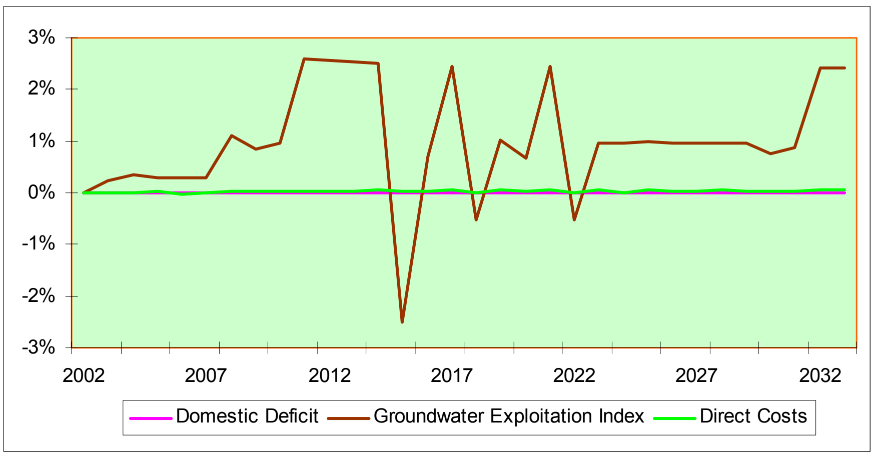


Figure 12-35 Improvement (%) with respect to the reference scenario HD+Dry

In all three scenarios the change in direct cost is favourable but very small, since this is a non structural intervention which does not involve real costs (see also Figure 12-35). It promotes water saving since water attains a price closer to its true value.

The associated environmental cost is presented in Figure 12-36. There are no observed differences compared to the reference cases, due to the small influence of the intervention on the reduction of the groundwater abstractions (see Figure 12-35 groundwater exploitation index).

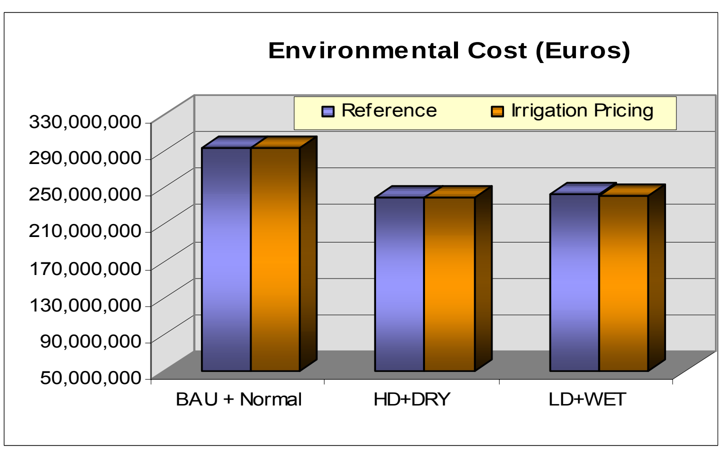


Figure 12-36 Comparison of the environmental cost against the three reference scenarios

The obtained evaluation scores for all three cases are presented in Figure 12-37. The higher score is obtained under the best case scenario (Low Demand and Wet). Higher irrigation demand coverage and reduced groundwater exploitation are also contributing to the higher score of this scenario.

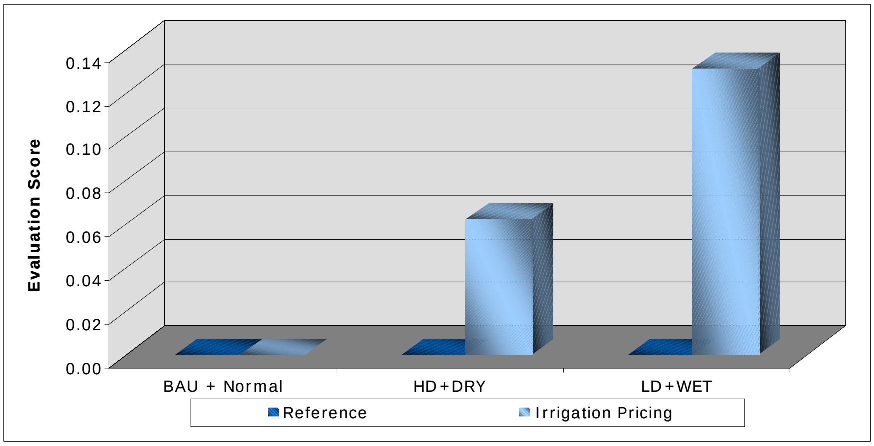


Figure 12-37 Evaluation of irrigation pricing against the three reference scenarios

Domestic Water Pricing

The domestic water supplies in the study area are managed by the Limassol Water Board as well as the Municipalities, Improvement Board and Village Water Committees.

A block structured water tariff is applied in the study with an average cost of C£0.5 per m^3. The present water tariff charged by the Water Development Department to the three major city Water Boards is only C£0.27 per m^3, while charges to the Municipalities and Village Authorities is C£0.335 per m^3.

Although there is no relative data, it is believed that domestic demand is inelastic with regard to water tariffs. However, in order to investigate the effectiveness of such an option (in case water demand is not inelastic to water tariffs) this option was assessed based on the following assumptions / parameters:

- a 60% increase in the water tariffs will be imposed after 2008
- an elasticity of –0.25 was assumed for residential consumption

In Figure 12-38 the new domestic demand under the examined pricing scheme for the worst case scenario (DRY + HD) is presented.

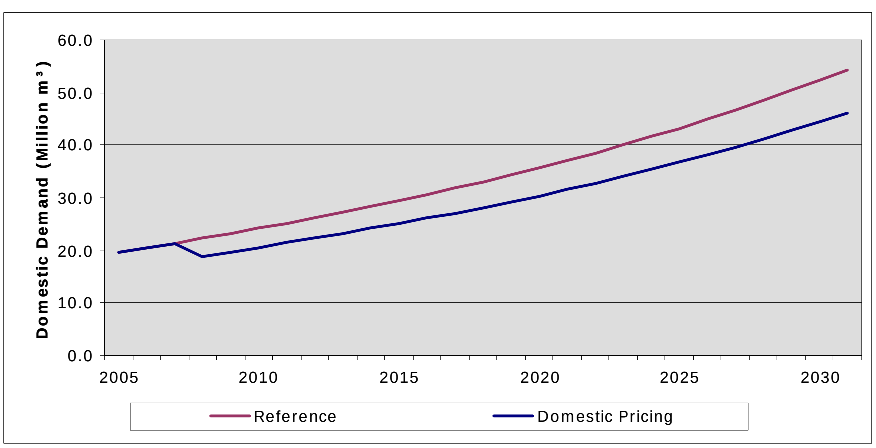


Figure 12-38 Domestic demand under reference scenarios and domestic pricing intervention

Under this management option the domestic deficit throughout the simulation period (2002 – 2033) is reduced by almost 38%.

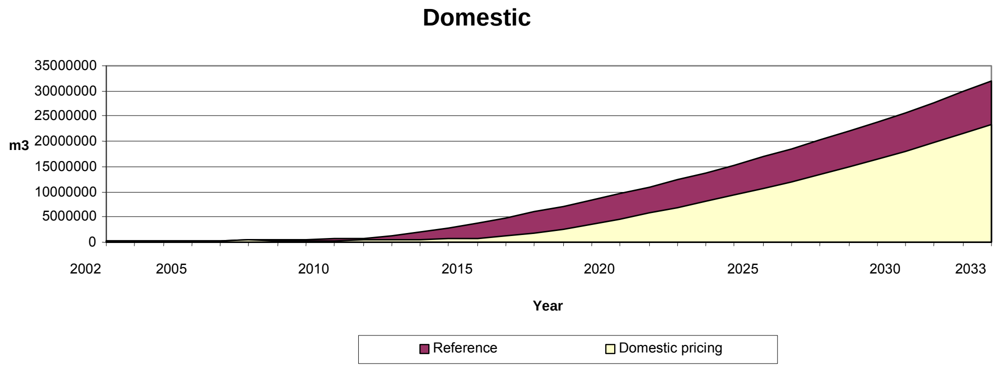


Figure 12-39 Improvement of domestic deficit with respect to the HD +Dry scenario

This measure alone cannot ensure the coverage of the domestic needs, especially after year 2012 when the water production of the water treatment plant of Limassol is expected to reach the plant's capacity (40,000 m^3/day).

This intervention has also positive effects in groundwater exploitation index and total direct costs (Figure 12-40).

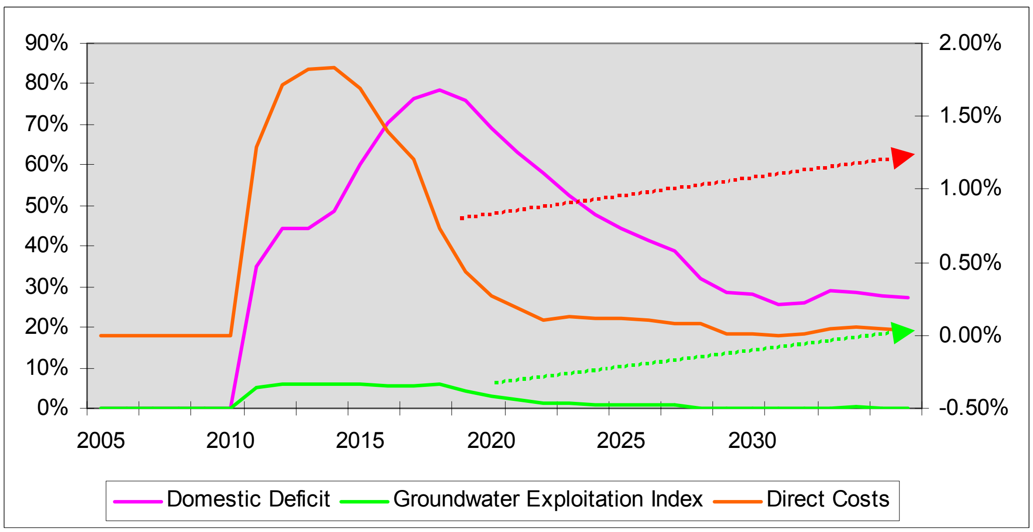


Figure 12-40 Improvement (%) with respect to the reference scenario HD+Dry

In all cases the option results in a reduction of direct costs, due to the fact that costs are only associated with domestic use. Consequently, the reduction of domestic water supplies inhibits a direct cost decrease of an order of 1% of the reference case present value.

The intervention appears to be most effective in the case of the HD+Dry scenario where the water demand is the highest and the climatic conditions are not favourable. This is also indicated by the evaluation score for the three examined scenarios, based on which the HD+Dry scenario is characterized by the highest value since the demand coverage is increased, within the reduced proportion allowed by the prescribed price elasticity.

The associated environmental cost is presented in Figure 12-41. Small differences are observed compared to the reference case, due to the small influence of the intervention on the reduction of the groundwater abstractions (see Figure 12-40 groundwater exploitation index).

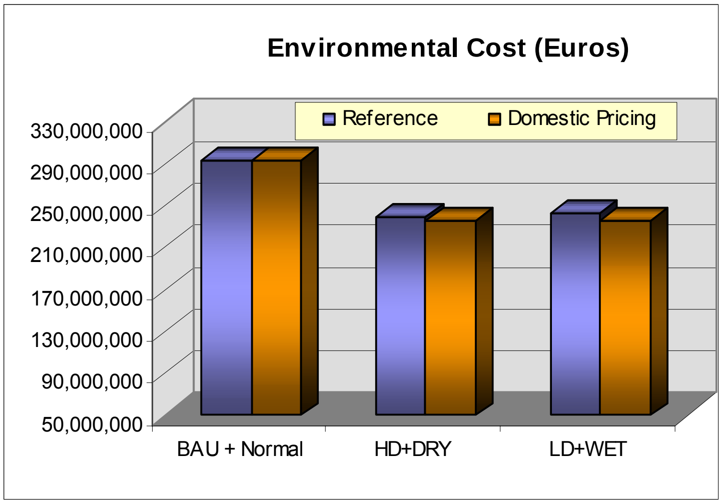


Figure 12-41 Comparison of the environmental cost against the three reference scenarios

The obtained evaluation scores for all three cases are presented in Figure 12-42. The higher score is obtained under the worst case scenario (High Demand and Dry).

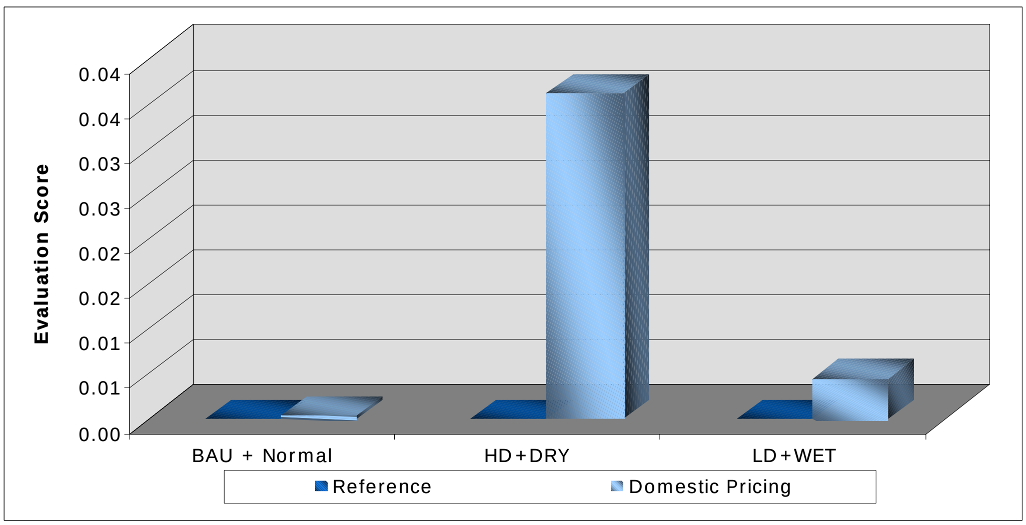


Figure 12-42 Evaluation of domestic pricing against the three reference scenarios

Summary and Conclusions

The Strategies that were developed and presented in Chapter 6 depended on the performance of management options with respect to the selected indicators that were presented throughout the analysis, and summarised in the respective paragraph of this section. The following paragraphs summarise the performance of the examined options, as well as critical parameters that were entered in the WSM Decision Support System for their analysis.

Wastewater reuse

Under a scenario with a high sequence of dry years, water reuse can result in substantial reductions in irrigation deficit, with a subsequent reduction in groundwater abstractions. It also affects positively the domestic demand coverage since there are quantities of fresh water available to cover domestic purposes as a result of the reduction of the groundwater abstractions for irrigation purposes.

Reduction of Network Losses in Domestic Water Supply

Accurate data regarding the level of network losses throughout the study area are not available. Data exist for the area served by the Limassol Water Board where network losses are reported to be as low as 16%. In any case it is believed that losses can be of the order of 25% or more. Thus, the reduction of the losses to 15% (through successive network replacements) was assessed as an alternative water management option for the three biggest settlements in the study area that is the Limassol Municipality, Limassol Tourist Part and Germasogeia Municipality. The measure will be applied in 2008.

Under the worst case scenario, this option shows an improvement in domestic deficit and to a lesser extent in groundwater (over)exploitation. This measure alone cannot ensure the coverage of domestic needs, especially after 2012 when water production of the water treatment plant of Limassol is expected to reach the nominal plant capacity (the improvement after 2012 falls from 25% to less than 5% in year 2033). Reduction of irrigation deficits is also slightly affected by this option.

Conservation Measures in the Domestic Sector

The application of conservation measures in the domestic sector was assessed, assuming that a reduction of 10% in the domestic demand (excluding the seasonal demand) could be accomplished. In addition it was assumed that the measure will be applied in 2008.

Under the worst case scenario, this option results in substantial reductions in domestic deficit. It also has positive effects in groundwater exploitation index and direct cost, due to the reduction of the groundwater abstractions in order to supply domestic users. This measure alone cannot ensure the coverage of the domestic needs, especially after 2012 when the water production of the water treatment plant of Limassol is expected to reach the nominal capacity (40,000 m^3/d).

Irrigation Pricing

This option examines the case of raising the irrigation water prices from 0.07 CY£/m^3 to 0.11 CY£/m^3 within a period of 3 years. The adopted values of the elasticities for the permanent crops are much lower than the seasonal crops. This is reasonable given that the production decisions for permanent crops are much more complicated and long term than in the case of annual/ seasonal crops.

The application of this simple irrigation pricing scheme results in a reduction of irrigation demand of approximately 1,500,000 m^3 or 10% of the total irrigation demand. Under this management option the irrigation deficit throughout the simulation period (2002 – 2033) is reduced by almost 23%, from 24,489,795 m^3 to 19,684,766 m^3. This option also has positive effects in groundwater exploitation index but does not affect the domestic deficit.

Domestic Pricing

The domestic water supplies in the study area are managed by the Limassol Water Board and by the Municipalities, Improvement Board and Village Water Committees. A block structured water tariff is applied in the study with an average cost of 0.5 CY£/m^3. The present water tariff charged by the WDD to the three major city Water Boards is only 0.27 C£/m^3, while charges to the Municipalities and Village Authorities are 0.335 C£/m^3. Although there is no relative data, it is believed that domestic demand is inelastic with regard to water tariffs. However, in order to investigate the effectiveness of such an option (in case water demand is not inelastic to water tariffs) this option was assessed based on the following assumptions/parameters:

- A 60% increase in the water tariffs will be imposed after 2008.
- An elasticity of –0.25 was assumed for residential consumption.

Under this management option the domestic deficit throughout the simulation period (2002 – 2033) is reduced by almost 38%. This measure alone can not ensure the coverage of domestic needs, especially after 2012 when the water production of the water treatment plant of Limassol is expected to reach the plant's capacity (40,000 m^3/day). This option has also positive effects in groundwater exploitation index and total direct costs.

Comparison of Options

The premises for the comparison of measures and options and the final selection of instruments that formed the core of the formulated strategies were presented in Chapter 6 and it is analysed in more detail here. The effectiveness of the options was assessed on a combination of the evaluation scores obtained for domestic and irrigation demand coverage. This is due to the fact that future economic development is, according to the perceptions of all stakeholders, related to tourism.

However, the agricultural sector is still important on the region, both on social and on environmental terms. In addition, it was considered necessary to incorporate in the options evaluation process the direct costs related to the application of each option, in order to select not only efficient, but also cost effective solutions. Environmental protection was assessed through the groundwater exploitation index and the resulting environmental costs, since a large part of the domestic water supply in the area relied upon groundwater from the existing aquifers until recently. The major Akrotiri aquifer has been experiencing overdraft in the last 20 – 25 years since a major portion of the natural replenishment has been cut off by the Kouris dam. The levels of pumping haven't changed after the construction of the dam due to the water price differential between surface and groundwater, the latter being much cheaper. The results of the options performance evaluation process are presented in Table 12-6

Table 12-6 Performance evaluation of the studied interventions (HD+DRY scenario)

Option	Effectiveness (Relative Sustainability Index for Demand Coverage)	Economic Efficiency (B/C Ratio)	Environmental Cost (PV – million €)
Water reuse	0.0793	3.14	180
Water Treatment Plant	0.08	3.18	115.5
Waste Water Treatment Plant	0.08	3.19	115.6
Loss Reduction	0.134	3.31	239
Conservation measures	0.115	3.73	234.2
Irrigation Pricing	0.142	3.18	239.6
Domestic Pricing	0.116	3.65	235.1

Table 12-7 presents the normalised results of the performance evaluation (presented in Table 12-5) under a scale ranging from 1 to 5 (worst performance: 1 – best performance: 5).

Table 12-7 Normalised performance matrix of the studied interventions (HD+DRY scenario)

Option	Effectiveness (Relative Sustainability Index for Demand Coverage)	Economic Efficiency (B/C Ratio)	Environmental Cost (PV – million €)
Water reuse	*	*	***
Water Treatment Plant	*	*	*****
Waste Water Treatment Plant	*	*	*****
Loss Reduction	*****	**	*
Conservation measures	***	*****	*
Irrigation Pricing	*****	*	*
Domestic Pricing	***	*****	*

From the normalised matrix it is apparent that the studied options have a different performance with respect to the three adopted indicators. Soft measures perform better in relation to the relative sustainability index for demand coverage and economic efficiency, whilst they have a poor performance with regard to the environmental sustainability (groundwater abstractions). On the other hand the structural options (water reuse – water treatment plant – waste water treatment plant) perform better in relation to environmental sustainability but are characterized by the weakest performance in relation to effectiveness and economic efficiency indicators.

Chapter 13 Analysis of Water Management Options for Ribeiras do Algarve, Portugal

The Ribeiras do Algarve River Basin has undergone, in the last decades, deep changes in its demography, mostly caused by the important development of the tourism activity. In addition, agriculture still is the most important water sector consumer, using mostly groundwater resources. In the 90's, a shift in urban supply, from groundwater to surface water, took place in the Ribeiras do Algarve River Basin, by means of the construction of the primary urban water supply system. This latter allowed minimizing the continuous and intensive exploitation of the groundwater resources.

With the aim of solving the conflicting interests which coexist on water resources between the tourism sector and agriculture and the localized water shortages occurring mainly during summer months, it is crucial to find alternatives in water management. Moreover, the infrastructure deficiencies, the poor groundwater quality in some areas, the high values of secondary water supply network losses (16% to 61%) and the inadequate irrigation methods reinforce the necessity of finding solutions in order to solve and prevent conflicts between users.

The following paragraphs present the formulation of water management scenarios and the evaluation of different management options and methods considered applicable in the Ribeiras do Algarve basin. The outcomes of this analysis, summarised in Chapter 7, formed a milestone in the overall process of formulating improved and integrated water management strategies, determining the extent, cost and impact that each option could have when applied to the water system of the River Basin.

Demand and Availability Scenario Components

Formulation of Domestic Demand Scenarios

For permanent and seasonal population, a variety of data and data estimations have been collected and analysed from several institutions and governmental and non-governmental organisations (Table 13-1). These concern population fluctuation, consumptions, network system description, network losses, water sources and abstractions (surface and groundwater), irrigation efficiency, types of irrigated cultivations, and costs associated with water distribution and drainage.

Table 13-1 Available information on domestic demand components

Authority	Available Information
Águas do Algarve S. A.	a) Served population with water supply and water drainage and treatment; b) Consumption Fluctuation; c) Costs associated to Primary Network System
National Statistical Institute (INE)	d) Permanent Population; e) Seasonal Population; f) Tourist Arrivals, Departures and Overnight stays
National Water Authority (INAG)	g) Permanent Population; h) Overnight stays; i) Consumption Fluctuation; j) Served population with water supply and water drainage and treatment; k) Network losses; l) Rainfall data
National Tourist Institute	m) Seasonal Population

The permanent population was estimated to be approximately 365,000 inhabitants by 2001. The monthly variation of seasonal population is presented in Table 13-2.

Table 13-2 Monthly variation of seasonal population in Ribeiras do Algarve River Basin

Month	Seasonal Population Fluctuation[15]
January	19%
February	26%
March	53%
April	55%
May	65%
June	66%
July	77%
August	100%
September	73%
October	55%
November	28%
December	25%

The uneven spatial distribution of tourist population per Municipality in August is presented in Figure 13-1. The coastal Municipalities (Albufeira, Aljezur, Castro Marim, Faro, Lagoa, Lagos, Loulé, Portimão, Olhão, Tavira, Vila do Bispo and Vila Real de Santo António) represent 97% of the seasonal population in August whereas the inland ones (Monchique, São Brás de Alportel and Silves) represent only 2%.

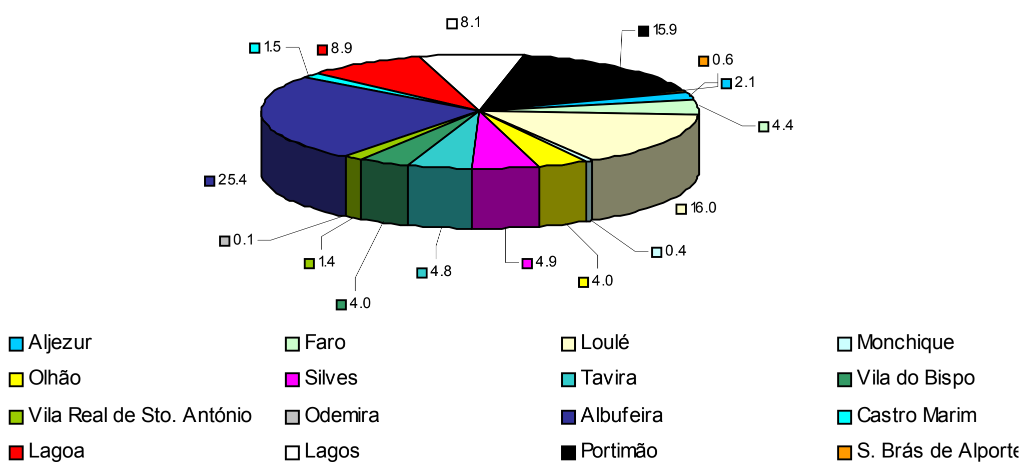


Figure 13-1 Distribution of the seasonal population in August by Municipality, in percentage (2001 data)

Nevertheless, the areas of the Municipalities belonging to the Ribeiras do Algarve River Basin differ significantly and therefore the seasonal population density (seasonal population in August divided by the area) for each Municipality (hab/km^2) may show even better the

[15] Share compared to the seasonal population during August (709,756) in 2001

uneven distribution of tourist population. In August 2001, Castro Marim and Albufeira were the Municipalities with the highest population density value, 1314 hab/km^2 and 1280 hab/km^2 respectively (Figure 13-2). In that month, in Loulé, although seasonal population density was not one of the highest, it was 10.5 times higher than the permanent population. This observation may be justified by the fact that Loulé has, after Silves, the second highest area of all Municipalities in Ribeiras do Algarve River Basin, and the seasonal population is mainly concentrated by the sea.

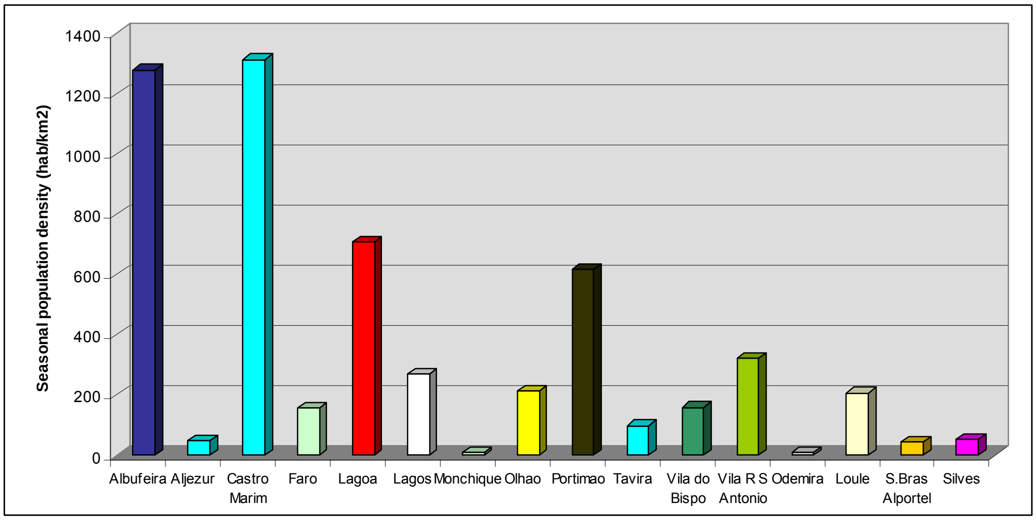


Figure 13-2 Seasonal population density (inhabitants/km^2) in August for each Municipality (2001 data)

The population in 2000 was considered to be the same as in 2001, using the results from the 2001 Census. Finally, domestic consumption rates were estimated based on the real supply delivered by Águas do Algarve Company to the different settlements in 2002.

Projections

For identifying the business as usual scenario (BAU), it was assumed that during the period examined (2000 – 2035) the permanent population will continue to increase with a steady yearly rate. Growth rates for the different Municipalities were estimated for permanent population according to the projections presented in the Ribeiras do Algarve River Basin Plan for 2000-2020. For seasonal population, the growth rate was set equal for all the Municipalities and estimated upon the projection from 2000-2020. Seasonal population growth rate is higher than the one set for permanent population (Table 13-3) and this fact is related to the seasonal population increase, the tourism development and the permanent population decrease due to a reduction in the birth rate.

The two other scenarios formulated for the analysed period assume that after a point in time the population in Ribeiras do Algarve River Basin will reach its carrying capacity regarding the development of tourism. In one of them, this is followed by stabilization of population, while a more pessimistic scenario supposes a small decrease of tourism and birth rate.

Under this context, three different potential trends have been distinguished, forming the potential scenarios for domestic demand:

I. A scenario where demand increases at a steady rate, equal to that currently observed, and corresponding to a “business as usual” situation (BAU),

II. A scenario where demand is stabilized 10 years after the reference year (Stabilized Demand, SD),

III. A scenario where the demand decreases 15 years after the reference year (Low Demand, LD).

The annual growth rates for permanent and seasonal population considered for each demand scenario were set as presented in Table 13-3. The differentiation by Municipality is considered equal for the three scenarios, “Business as Usual” (BAU), “Stabilized Demand” (SD) and “Low demand” (LD).

Table 13-3. Population trends for the three scenarios

Scenario	Period	Growth Rate (%)	
		Permanent Population	Seasonal Population
BAU	2000 – 2035	differentiated for each Municipality[16]	2.3
Stabilized Demand	2000 – 2010	differentiated for each Municipality[3]	2.3
	2011 – 2035	0.0	0.0
Low Demand	2000 – 2010	differentiated for each Municipality[3]	2.3
	2011 – 2015	0.0	0.0
	2016 – 2035	-0.5	-0.5

The demand evolution corresponding to the three scenarios is presented in Figure 13-3.

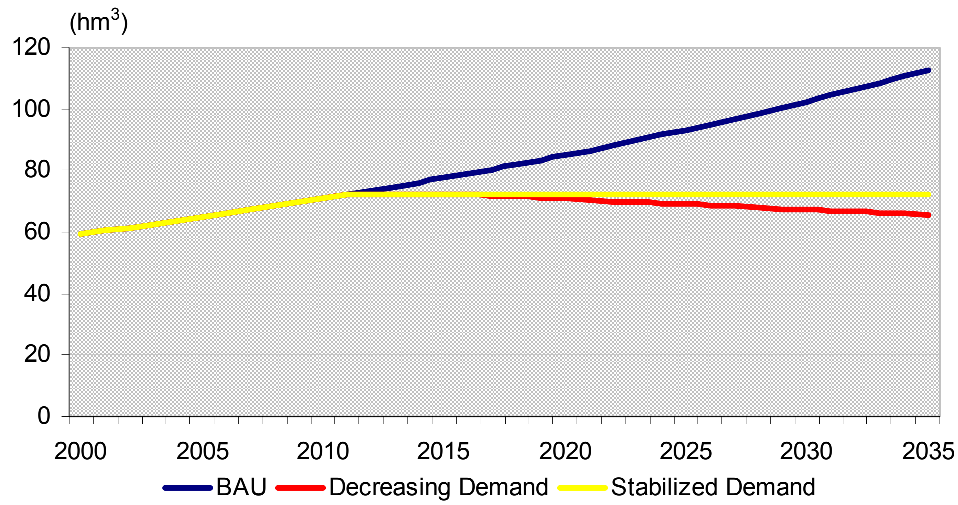


Figure 13-3 Domestic demand scenarios

It should be noted that the consumption rates for permanent and tourist population were set according to the River Basin Plan (differentiated by Municipality) and considered constant for all the period of the simulation.

Formulation of Irrigation Demand Scenarios

Concerning irrigation demand, it is important to note that it is very difficult to gather accurate data. In fact, the information uncertainty is major drawback. The cultivated area is estimated to be around 32,000 ha, however, the different Institutions contacted about this matter are not

[16] Albufeira: 2.01%; Aljezur: 0.19%; Almodôvar: -1.59%; Castro Marim: -0.87%; Faro: 2.01%; Lagoa: 1.07%; Lagos: 1.07%; Loulé: 1.07%; Monchique: 1.59%; Odemira: 0.87%; Olhão: 0%; Ourique: -1.59; Portimão: 2.01%; São Brás de Alportel: 0.18%; Silves: 1.07%; Tavira: 0.18%; Vila do Bispo: 0.18% and Vila Real de Santo António: -0.87%.

able to provide a consistent evaluation of the water volumes involved in this activity. The stakeholder consultation showed, as expected, the existing uncertainty regarding agriculture consumption. Nevertheless, the data introduced in the DSS results from the analysis of different sources of information, attempting to adopt a coherent and reliable approach (Table 13-4).

Table 13-4 Available information on irrigation demand components

Authority	Available Information
DGA of Algarve (Ministry of Agriculture, Rural Development and Fishing)	General Information about Irrigation Sites, Crops and Irrigation Methods
Farmer Association of Alvor	Irrigation Sites Characteristics, Crop Types and Irrigation Methods concerning the Public Irrigation Site of Alvor
Farmer Association of Silves, Lagoa and Portimão	Irrigation Sites Characteristics, Crop Types and Irrigation Methods concerning the Public Irrigation Site of Silves, Lagoa and Portimão
IDHRa (Rural Development Institute)	Irrigation Sites Characteristics, Crop Types and Irrigation Methods concerning the Public Irrigation Site of Sotavento Algarvio Irrigation Sites Characteristics, Crop Types and Irrigation Methods concerning the Public Irrigation Site of Benaciate Costs associated to Public irrigation sites
CCDR Algarve	Information of the River Basin Water Management Plan, especially on Private Irrigation Sites and groundwater exploitation (see Annex) Data on Golf Courses
Ribeiras do Algarve River Basin Plan	Irrigation sites (public and private) areas and demand Crop types and cultivated areas Costs associated to public and private irrigation

Projections

As for the irrigation demand scenarios, according to the projections presented in the River Basin Plan for 2000-2020, the growth rates considered for public and private irrigation sites and golf courses are presented in Table 13-5.

Table 13-5 Growth rates considered for irrigation sites and golf courses

	Period	Growth Rate (%)
Private irrigation site	2000 – 2020	1.3
	2021 – 2035	0.0
Public irrigation sites	2000 – 2020	differentiated for each public irrigation site[17]
	2021 – 2035	0.0
Golf courses	2000 – 2035	0.0

[17] According to the River Basin Plan

Furthermore, a growth rate of 0.5% was considered for animal breeding sites until 2020 and no growth rate for industrial sites. The demand scenarios considered hereafter entitled the reference case, are the combination of one of the domestic demand scenarios and the irrigation and industrial demand scenarios.

Formulation of Availability Scenarios

The climate in Ribeiras do Algarve River Basin is Mediterranean temperate, characterized by rainy winters and dry summers. The average temperature is 18 ºC and the average annual precipitation is around 750 mm. However, there are differences between the corresponding values of the six sub-basins identified (Figure 13-5): a maximum of 813 mm/year in the "Costa Ocidental" sub-basin and a minimum of 565 mm/year in the "Costa Sul". Those differences reflect not only spatial but also temporal different precipitation distribution (Figure 13-4).

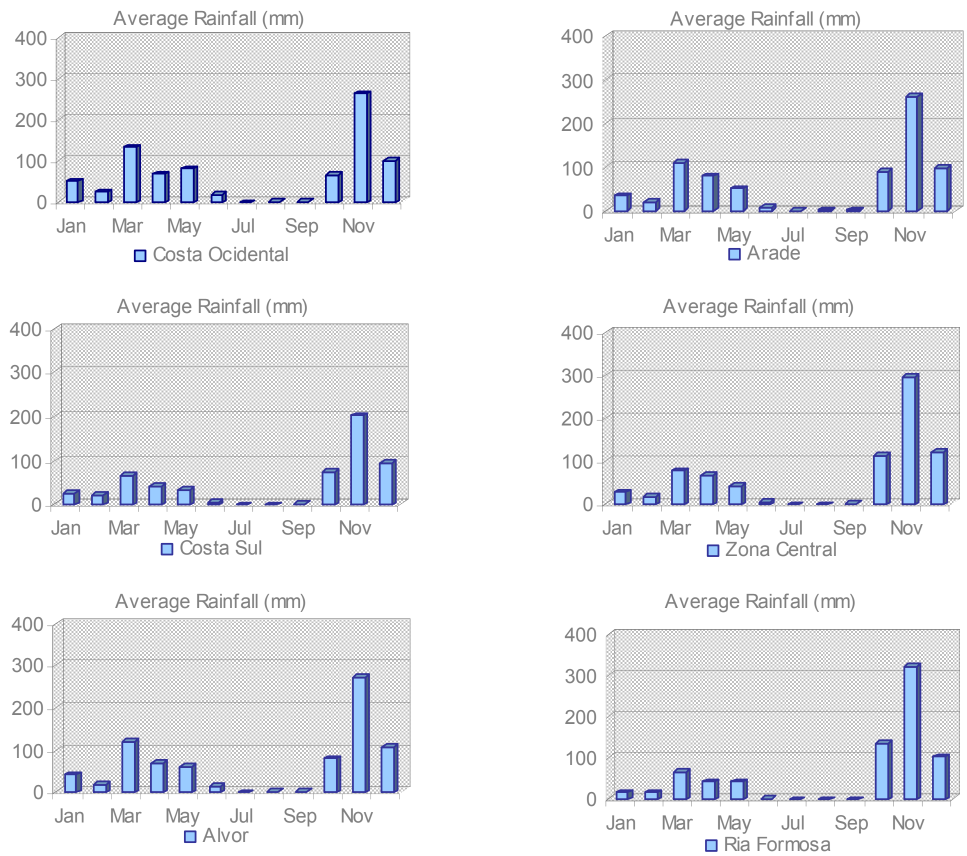


Figure 13-4 Average monthly rainfall in the different sub-basins

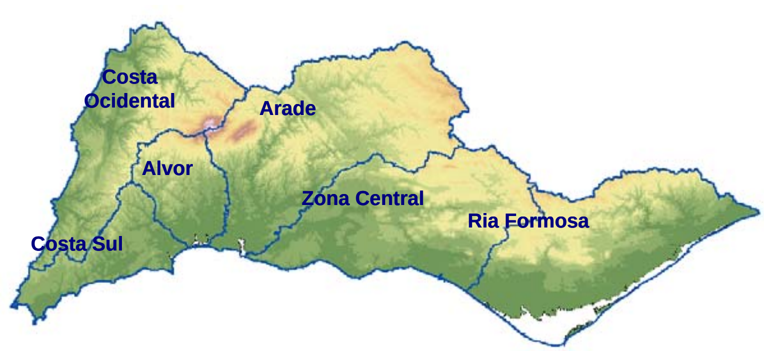


Figure 13-5 Ribeiras do Algarve sub-basins

Scenarios

The formulation of the availability scenarios (Figure 13-6) was based on the sequence of years with respect to rainfall presented by INAG (National Water Institute) for the 13 meteorological stations considered (Table A13-2 and Figure A13-1 of the Annex to this Chapter). Three hydrological scenarios were considered:

f) The **Normal Scenario (Normal)** represents a period of 35 years defined in accordance with the historical sequence that occurred between 1970 and 2000.

g) The **High Frequency of Wet Years Scenario (HW)** was defined considering a 25% increase of the Normal scenario's precipitation.

h) The **High Frequency of Dry Years Scenario (HD)** was defined considering a 10% decrease of the Normal Scenario's precipitation.

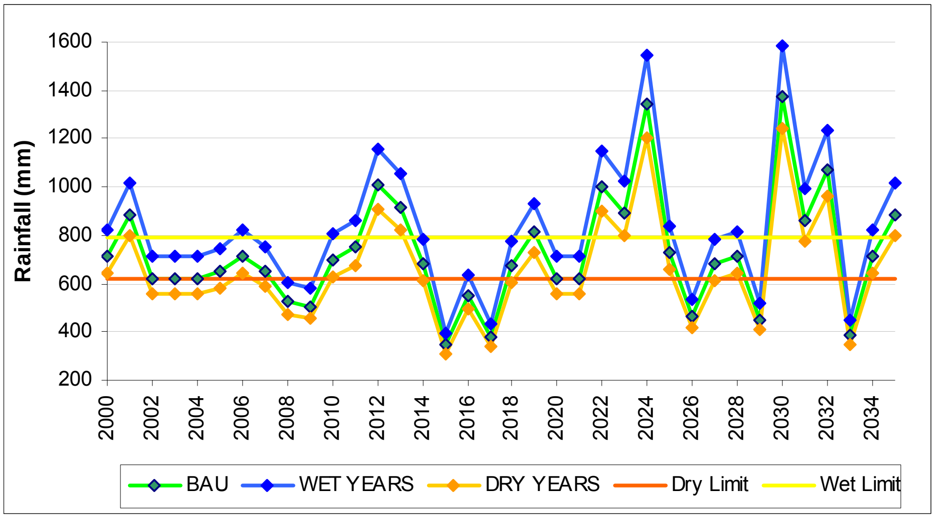


Figure 13-6 Water availability scenarios

The intra-annual rainfall variation coefficients considered (Annex, Table A13-1), in order to determine the monthly rainfall variation, were defined following the analysis of the hydrological data series provided by the National Water Institute. The three water availability scenarios presented in Figure 13-6 (BAU, Wet Years and Dry Years scenarios) were used to formulate the three water year sequences defined in the corresponding Table A13-3 of the Annex of this Chapter. Nevertheless, the obtained results anticipate an aggravation of water deficit problems in the Ribeiras do Algarve Region by means of the simulations already developed and hereafter described.

Combination of hydrological and demand scenarios

Besides the availability scenarios defined previously, it is important to establish different scenarios to evaluate the behaviour of the overall water system. The different management options that have been evaluated are the following:

- A combination of Steady Demand Increase with a High frequency of Dry years **(BAU+HD)**, reflecting a severe scenario of water shortage, according to the River Basin Plan,
- A combination of Low Demand with a High frequency of Wet years **(LD+HW),** reflecting the best case scenario, and

- A combination of Steady Demand Increase with a series of average years **(BAU+ Normal)**, in an effort to reflect the current trends of the system in a "business as usual" context.

It should be emphasized that the simulation period considered begins in 2000 as inferred from the scenarios formulation. This way, one includes the year 2000 used as reference in the National Water Plan and the Ribeiras do Algarve River Basin Plan and also follows the infrastructural evolution of the Primary Water Supply System previously described.

After defining the demand and availability scenarios, one can for instance, through the DSS, estimate the overall domestic deficit and irrigation deficit under the three chosen scenarios. Those results for the reference case (i.e., with no implementation of management options, defined in 9.3. for the three different scenarios) are presented in Figure 13-7 and Figure 13-10.

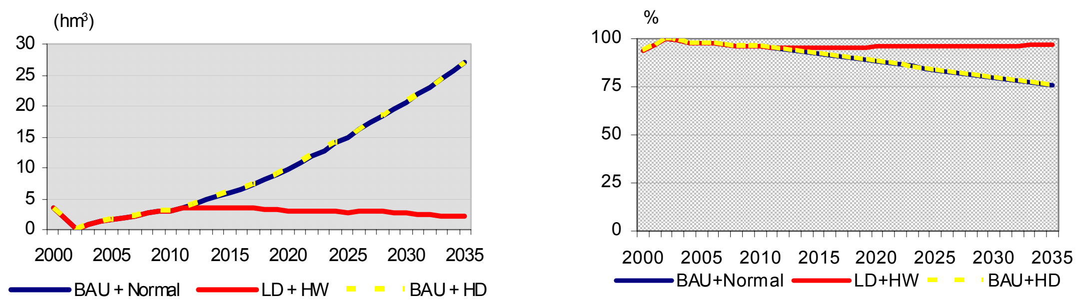


Figure 13-7 Reference case: a) Estimated domestic deficit and b) Estimated domestic demand coverage under the selected demand and availability scenario combinations

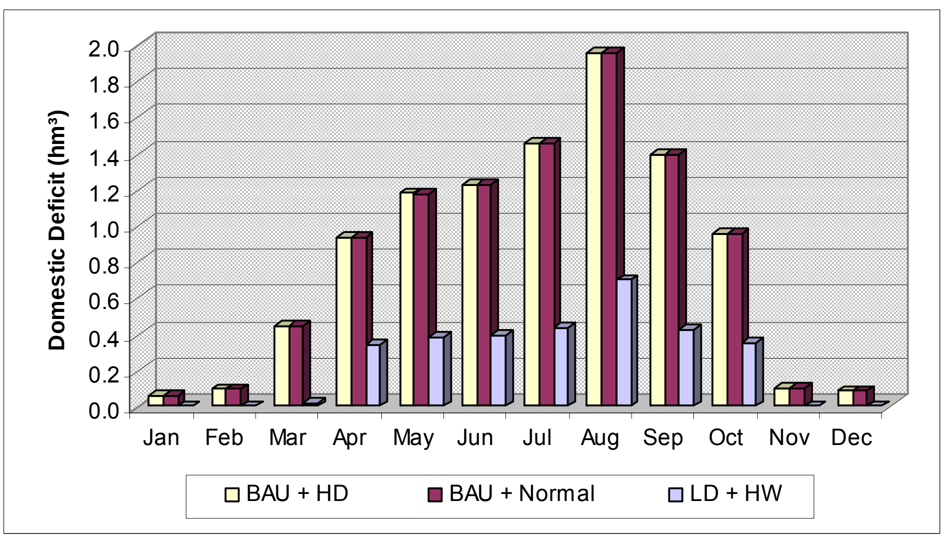


Figure 13-8 Reference case: Monthly domestic deficit (year 2020)

As one can observe, from Figure 13-7.a, the domestic deficit under the BAU+Normal and BAU+HD scenarios is approximately equal. As said previously, most of the Ribeiras do Algarve River Basin, namely the settlements where the permanent and seasonal population are higher, is supplied by surface water. In Sotavento, the capacity of Odeleite-Beliche system is sufficient to assure the domestic demand. However, in Barlavento, according to the agreement made with INAG (Table 7-1), the maximum volume available in Funcho storage reservoir for domestic supply is not enough to assure all the demand associated to the BAU scenario, increasing significantly the deficit observed. That way, the deficit is owed not to an insufficient recharge of the Funcho reservoir but to the limitation imposed by the agreement. Therefore, the effect extent of the sequences of dry years defined in the HD hydrological scenario on the deficit is almost nonexistent. For the LD+HW scenario, the domestic deficit is always below 5 hm^3, representing, on average, less than 4% of the domestic demand considered for this scenario. Figure 13-7.b presents the estimated domestic demand coverage under the selected demand and availability scenario combinations. As one can observe, for the BAU+Normal and BAU+HD scenarios, the domestic demand coverage drops to 75% by the end of the simulation period.

As previously explained, domestic supply is assured by surface and groundwater. Figure 13-9 shows the domestic deficit according to the type of supply: 99% of this deficit is due to surface water, almost all of it in Barlavento (95%).

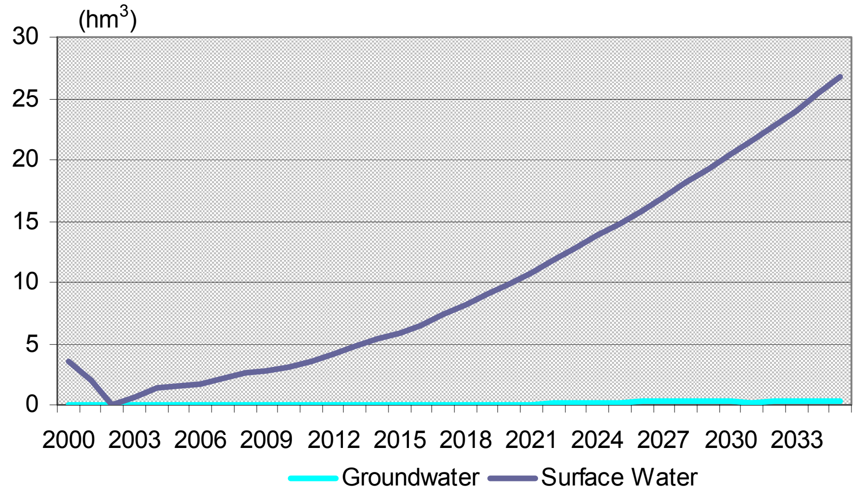
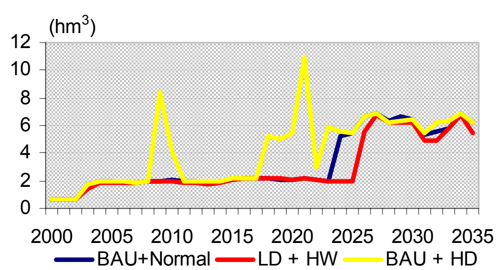


Figure 13-9 Reference case: Domestic deficit according to the type of supply (BAU+HD)

It should be noted that the domestic deficit may not only represent an effective shortage of water but may also be a consequence of inadequate pipeline diameter, because of the required flow transfer not being assured. One should stress that deficits due to pipeline diameter have been identified by Águas do Algarve and that the substitution of these pipelines is already scheduled. Moreover, the value of domestic deficit concerning urban supply by surface water from 2000 to 2003 is due to the scheduled construction of the network reservoirs.



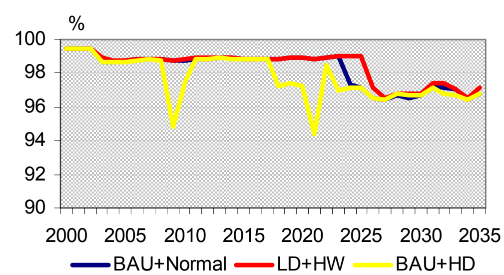


Figure 13-10 Reference case: a) Estimated irrigation deficit and b) Estimated irrigation demand coverage under the selected demand and availability scenario combinations

Contrarily to settlements, most of the irrigation sites are supplied with groundwater and therefore dependant on its availability. The estimated irrigation deficit is consequently higher for the BAU+HD scenario and lower for the LD+HW scenario (Figure 13-10.a). However, for the BAU+HD scenario the peaks observed in 2010 and 2021 are due to water deficiency in the Silves, Lagoa and Portimão (SLP) Public irrigation site which is supplied by surface water from Funcho storage reservoir. The increase of the deficit occurring in the first years is due to a sequence of dry years that affect the aquifers and consequently the irrigation deficit. Figure

13-10.b presents the irrigation demand coverage under the selected demand and availability scenario combinations are in accordance with what was explained above.

Figure 13-11 shows the monthly deficit existing for irrigation in 2020. As one would expect, the peaks occur during the summer months, when the crop requirements are higher.

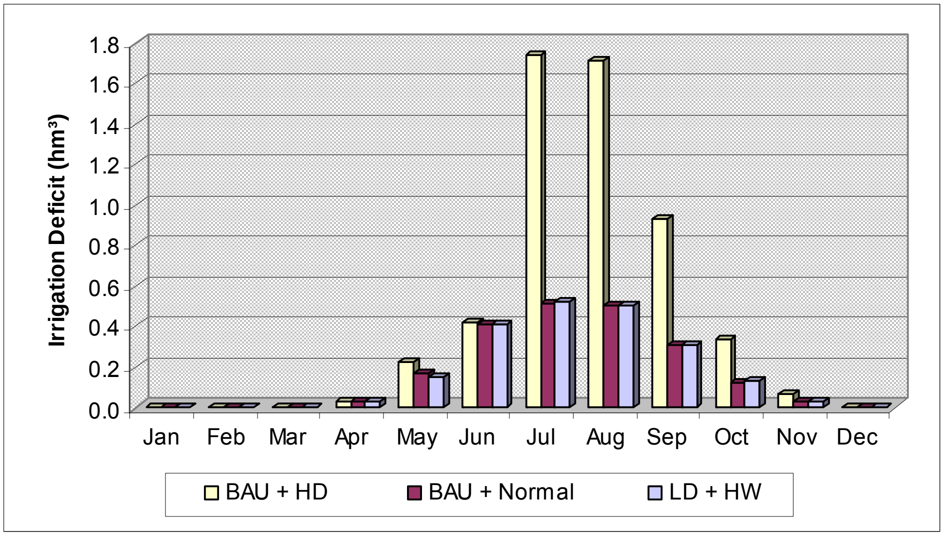


Figure 13-11 Reference case: Monthly irrigation deficit under the three scenarios (2020)

Cost Estimation

The estimation of direct costs for the Ribeiras do Algarve River Basin was based on the evaluation of:

- Amortization of capital costs associated to past and new investments, for both domestic irrigation and industrial uses,
- Operation and maintenance costs of new and existing infrastructures, for domestic, irrigation and industrial purposes.

For domestic use, the capital and specific operation and maintenance costs of the primary network system were estimated according to information of Águas do Algarve S.A. Company. Concerning secondary network systems, if the settlements were supplied with groundwater, the values were estimated according to specific bibliography of National Laboratory of Civil Engineering (Lencastre, 1994). For settlements supplied with surface water direct costs have been estimated by means of expert consultation.

Concerning revenues from water billing, there are two levels of water service supply in the Basin. On the first level, Águas do Algarve Company is responsible for the Primary Water System and charges a water price to each municipality. On a second level, each Municipality is responsible for providing water and to each settlement network. There is an exception to this scheme for Aljezur and Monchique Municipalities, entirely supplied by groundwater, where the Municipality is the unique water service provider. For all the settlements water selling prices were estimated according to information of the Water National Plan (PNA, 2000).

For irrigation use, specifically for public irrigation sites, operation and maintenance costs were set according to the River Basin Water Plan (PBHRA, 1999) and to data provided by Silves, Lagoa and Portimão (SLP) and Sotavento Algarvio farmers associations (IHERA, 2001). Revenues from water billing were calculated according to information of the National Water Plan (PNA, 2000) and farmers associations (IHERA, 2001).

For Private irrigation sites (defined as sites supplied by private boreholes), capital, operation and maintenance costs for borehole construction and irrigation method implementation were set according to the River Basin Water Plan (PBHRA, 1999), using information from experts and hydraulic infrastructure implementation companies. Although farmers owning this type of irrigation sites do not pay for water use, in terms of overall economical analysis of the Ribeiras do Algarve River Basin the water selling price was considered as being equal to private irrigation sites operation and maintenance costs (PBHRA, 1999).

For industrial use, network capital and specific operation and maintenance costs were set according to Águas do Algarve S.A. Company and expert consultation. For industrial units using groundwater the direct costs were estimated according to bibliography of National Laboratory of Civil Engineering (Lencastre, 1994). Revenues from water billing were calculated by means of the Water National Plan (PNA, 2000).

Present values have been estimated for the period 2000 to 2035, using a discount rate for hydraulic works of 3.33% set by decree.

Analysis of Water Management Options

As described in Chapter 7, management options analysed in the context of comprehensive water management scenarios context were:

- **Structural options** for supply enhancement, including:
  - **Dam construction** aiming to reduce domestic demand deficit in Algarve River Basin, in the Municipalities supplied by Águas do Algarve company;
  - **Network Enhancement** to improve domestic demand coverage by increasing the number of Municipalities supplied by the Primary Water Supply System (currently, 30 out of 51 secondary network systems are supplied by Águas do Algarve, S.A.);
  - **Desalination unit construction,** to solve water deficit and/or water quality problems in domestic use (Aljezur Municipality) and golf courses;
  - **Water Reuse,** through the use of treated wastewater for golf courses.
- **Demand management options**, including:
  - **Reduction of Network Losses**, through replacement of old and damaged pipes of all the Municipal secondary water supply systems (structural intervention);
  - **Improvement in Irrigation Methods**, for better irrigation efficiency and savings in water consumption;
  - **Socio Economic measures**, more specifically the impact of a new pricing structure for irrigation and for settlements supply. New pricing structures are not analysed in this chapter; however they are included in the overall option evaluation, performed as part of the Strategy Formulation process.

The selection of appropriate indicators for ranking the above options reflects the perception of the local stakeholders towards economic development, social and environmental sustainability. Since it is widely acceptable that future economic growth is to rely to tourism, the analysis of options is to be formulated around **coverage of domestic needs**. For Ribeiras do Algarve River Basin this indicator expresses the efficiency of the operation of the water resource system, and to a large extent the technical sustainability. This last though is also demarcated by **irrigation demand coverage**. Although agriculture is not currently the primary economic activity, agricultural activities are major consumers of water at Ribeiras do Algarve River Basin. Aquifer overexploitation and salinisation are among the key environmental problems that threaten not only the provision of supply but also the future resources of the Basin. That way, environmental protection is expressed through the **groundwater exploitation index** and the **non sustainable groundwater production fraction**. Finally, the cost analysis is taken into account through the consideration of the **rate of cost recovery**.

The satisfactory range of values and the weights assigned to the chosen indicators are presented in Table 13-6.

Table 13-6 Satisfactory range of values and weights for the indicators of the Ribeiras do Algarve Case Study

Indicator	Satisfactory range of values	Weight
Domestic demand coverage	95-100%	0.50
Irrigation demand coverage	80-100%	0.25
Groundwater exploitation index	0-80%	0.075
Non sustainable groundwater production fraction	0-35%	0.075
Rate of cost recovery	100-120%	0.1

The following paragraphs aim to present the detailed analysis of each option/method, with regard to its impact on the water system of Ribeiras do Algarve. Results are presented in comparison to each reference scenario, derived from the respective combinations for demand and availability projections.

Structural Options

Surface Water Exploitation - Dam Construction

As said previously and considering the population growth rates presented in Table 13-3, there is always a deficit in urban supply for any range of the scenarios considered. The major deficit is due to the limitation existing in the Funcho storage reservoir that will not be able to guarantee the necessary volumes for urban water supply, in Barlavento Municipalities.

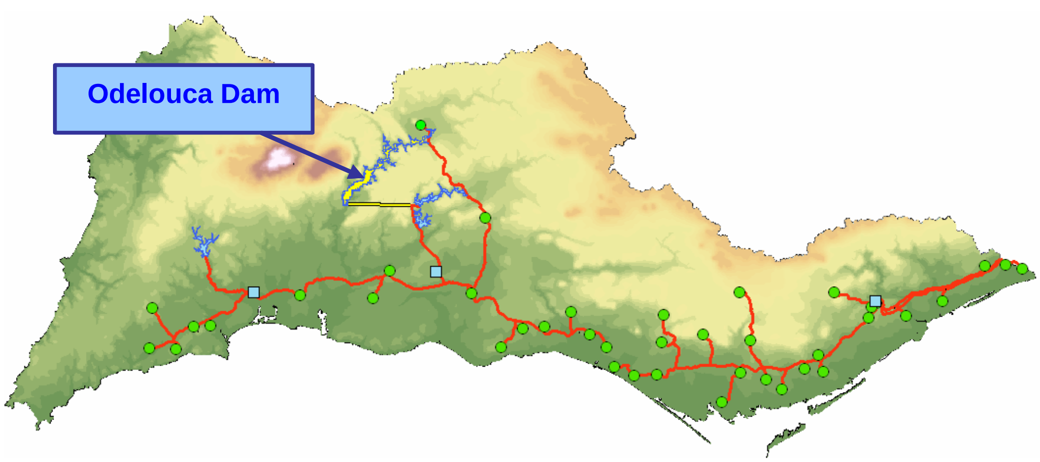


Figure 13-12 Odelouca dam location

That way, it appears reasonable to consider a new supply source to provide water to the West area of Algarve, Barlavento: Odelouca dam may start operating in 2008, with a capacity of 157 hm^3 and dead volume of 23 hm^3. In fact, the construction of Odelouca dam has already begun and its main goal is to assure domestic demand coverage in the Barlavento, above 95%. This construction has now been stopped, expecting developments at the financial, environmental and social sustainability level. Figure 13-12 shows the foreseen location for Odelouca dam and Table A13-4 (Annex) presents the capital costs associated to the project construction.

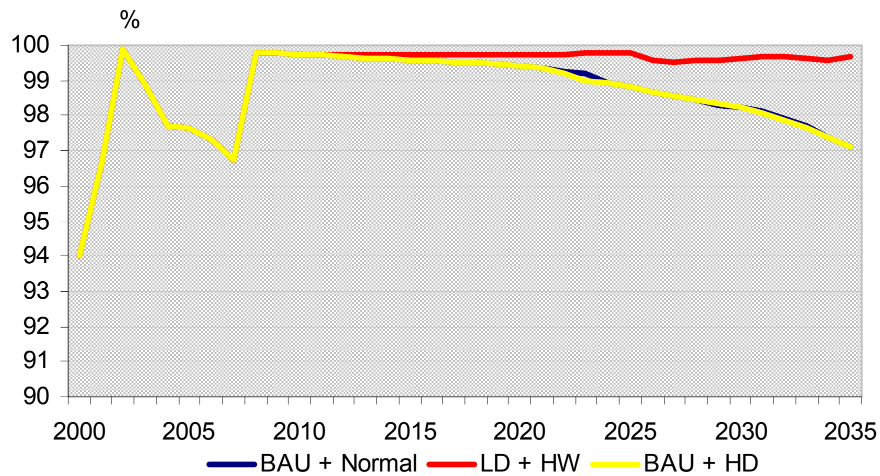


Figure 13-13 Percent demand coverage effectiveness of Odelouca dam to domestic use

Figure 13-13 shows the domestic demand coverage evolution over time, for the different scenarios analysed with the DSS.

This coverage is always above 94% but is expected to decrease between 2002 and 2008 when Odelouca dam is expected to start operating. With the introduction of this option and under the LD+HW scenario the domestic demand coverage rises to almost 100%, for all the simulation period. As expected, under the BAU+Normal and BAU+HD scenarios, the demand coverage is lower, as the water requirements in BAU demand scenario are higher. By 2022 the differences observed between the latter referred scenarios is due to unmet demand related to groundwater supply sources, namely at Monchique aquifer.

It should be noted that in Barlavento, the domestic demand coverage obtained with this option is 99% in average, showing that the goal of the Odelouca dam construction is achieved.

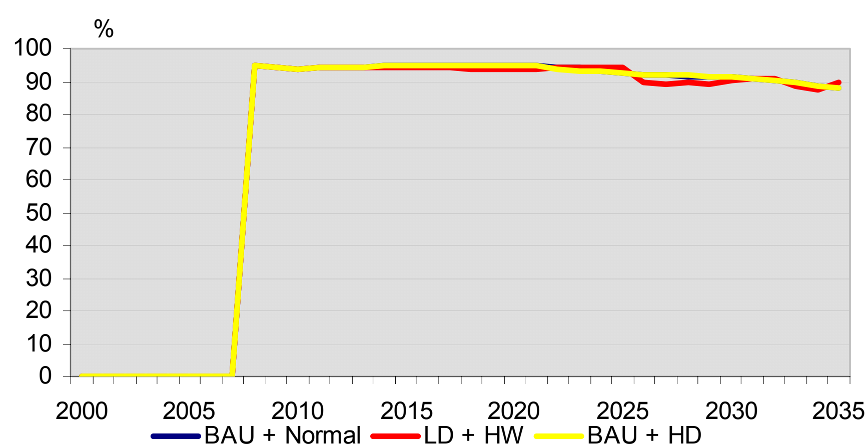


Figure 13-14 Percent improvement of deficit in domestic use with respect to the reference scenarios

As previously referred (Figure 13-9), 95% of the domestic demand deficit is related to Barlavento, the West part of the Ribeiras do Algarve River Basin. Figure 13-14 shows that the domestic deficit improvement achieved with this option is above 93%, on average, from 2008 until the end of the simulation.

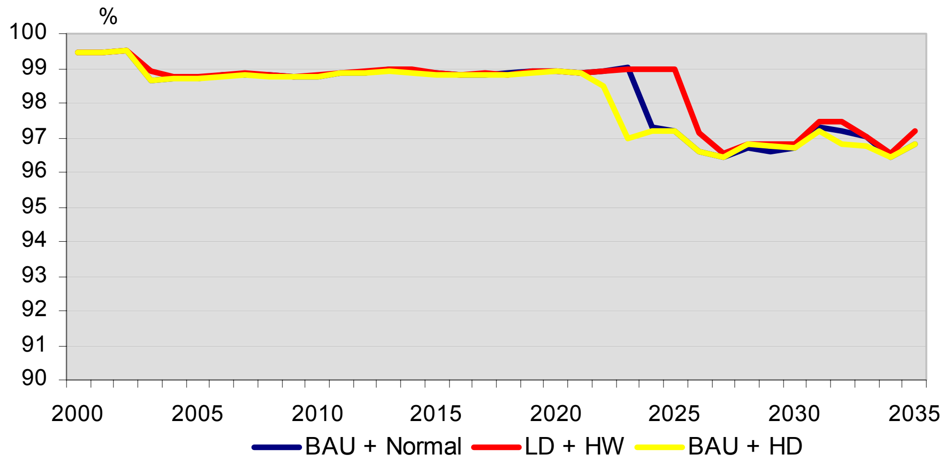


Figure 13-15 Percent demand coverage effectiveness of Odelouca dam to irrigation use

Concerning irrigation use, in the first 5 years of the period of simulation, one can observe a small reduction of the demand coverage effectiveness due to a considered sequence of dry years that affects a specific aquifer (São Bartolomeu). The introduction of the Odelouca dam has indirect influence on agriculture as, with this option, Funcho dam is re-allocated to agriculture from 2008 onwards. For the BAU+HD scenario the percent demand coverage effectiveness goes down from 2021 on due to Monchique aquifer being unable to satisfy all the abstraction needs. For the BAU+Normal scenario this failure happens in 2023 as the groundwater availability is higher. In the LD+HW scenario, it only happens in 2025 as this scenario is associated to higher groundwater availability and less demanding conditions (Figure 13-16).

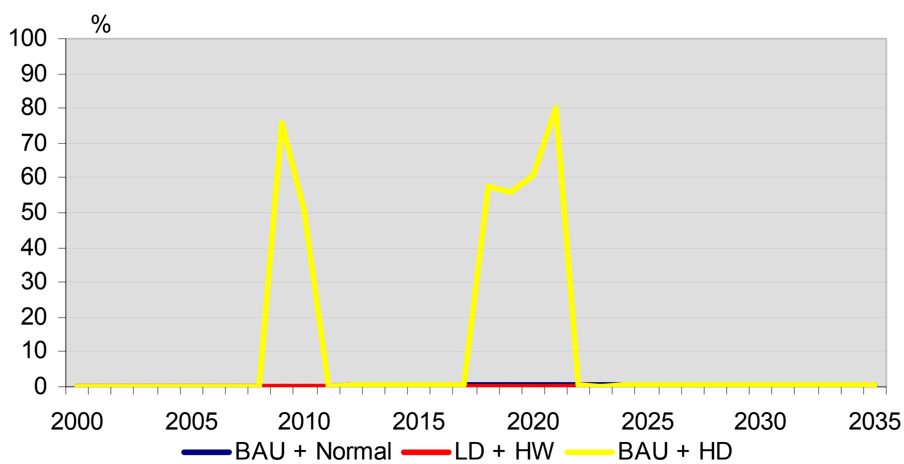


Figure 13-16 Percent improvement of deficit in irrigation use with respect to the reference scenarios

At first sight, the improvement in the irrigation deficit shown in Figure 13-16 is outstanding. The peaks observed for the BAU + HD scenario are due to the Silves, Lagoa and Portimão (SLP) public irrigation site (see Figure 13-10), currently supplied by surface water based on Funcho dam. With the introduction of Odelouca dam, Funcho dam will be consequently fully allocated to agriculture, allowing the mitigation of the BAU +HD scenario deficit.

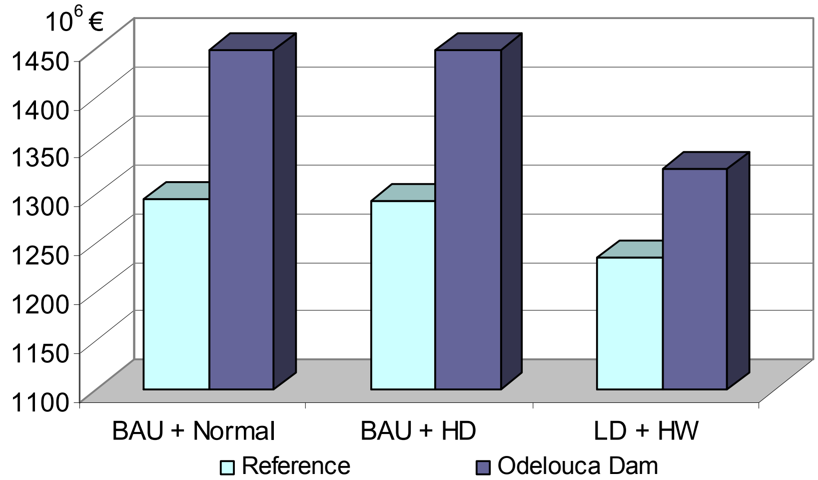


Figure 13-17 Total direct cost difference of the Odelouca dam option under the three scenarios (Present Value – Million €)

Overall the dam construction option is the most expensive of all the simulated ones, in terms of capital costs (Table A13-4 of the Annex). Nevertheless, under the BAU + Normal and BAU + HD scenarios the dam construction represents an increase in terms of present value of only 12%. Furthermore, under BAU+Normal and BAU+HD the present value differs less than 1% between them. This result reflects the importance of surface water in domestic use directly affected by this option. Water flowing within the Network System is closely dependant on the demand scenario rather than with the hydrological scenario. As a consequence, the present value increase of the option under the LD + HW is much lower (7%), since the quantity of water supplied to each consumer is lower, therefore decreasing specific operation and maintenance costs.

Network Enhancements

Águas do Algarve Company, through the concession of the Primary Water Supply System, has been committed to cover 95% of urban water supply users. Presently, this percentage is above 90%. That way, new expansions represent more important investments, as they intend to serve smaller settlements farer from the main pipeline.

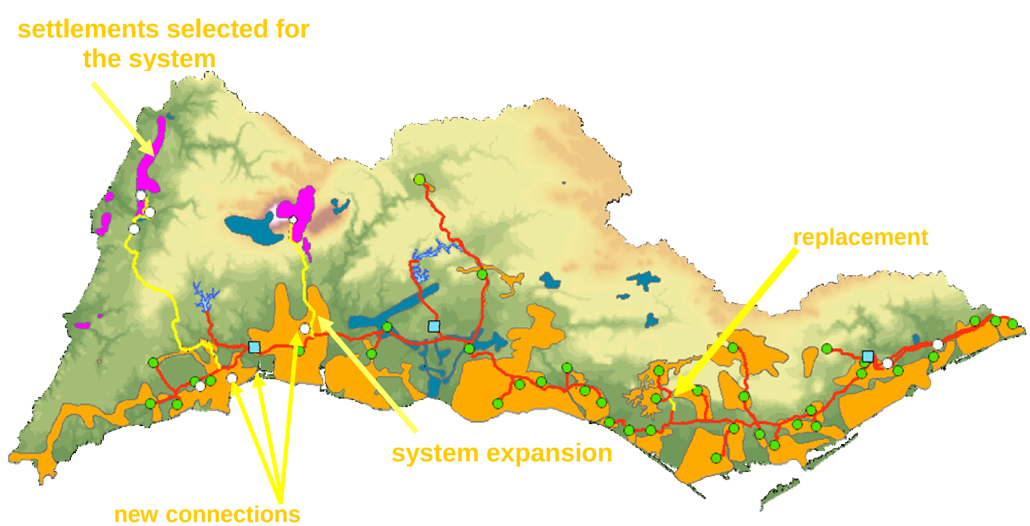


Figure 13-18 Primary Network System: expansion, enhancements and replacements

As referred by the Águas do Algarve Company, two major connections are planned to be realised soon, and those will benefit two Municipalities, Aljezur and Monchique. In addition, new connections and one replacement are considered to be benefiting other Municipalities as Albufeira, Portimão, Lagos, Loulé and Tavira, increasing network coverage percentage. Figure 13-18 shows the location of the new reservoirs and pipelines. Tables A13-5 and A13-6 of the Annex present the cost estimation associated to the system enhancement.

Table A13-7 of the Annex to this Chapter presents the new connections scheduling. Figure 13-19 shows the demand coverage effectiveness for domestic use with the network enhancement option.

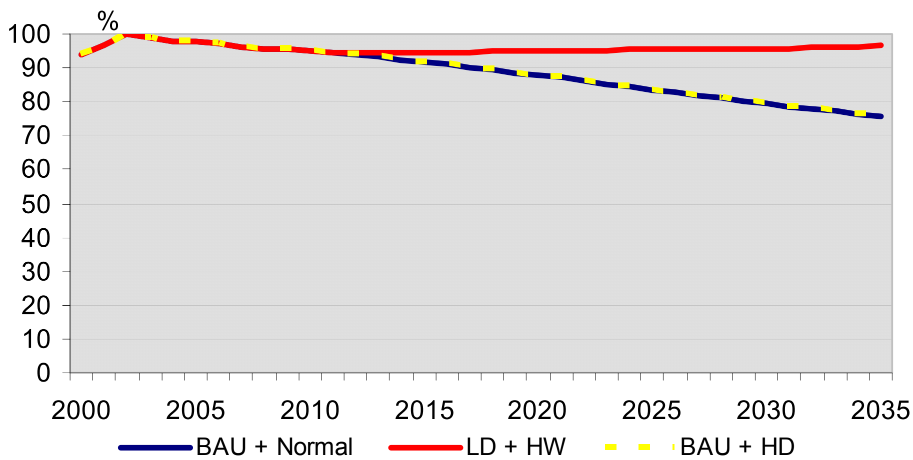


Figure 13-19 Percent demand coverage effectiveness of network enhancement to domestic use

The demand coverage effectiveness is lower than in the reference case as some settlements in Aljezur, for example, that were previously supplied by groundwater are now connected to the Primary Water Supply System and consequently, have a deficit as the available quantity is the same and the population to supply has increased (Figure 13-19).

There are no observed differences between the BAU+Normal and BAU+HD scenarios because, as explained in the "Formulation of availability scenarios", the demand coverage variation depends on demand scenario rather than on the availability scenario. As expected, the demand coverage effectiveness is higher for the LD+HW scenario.

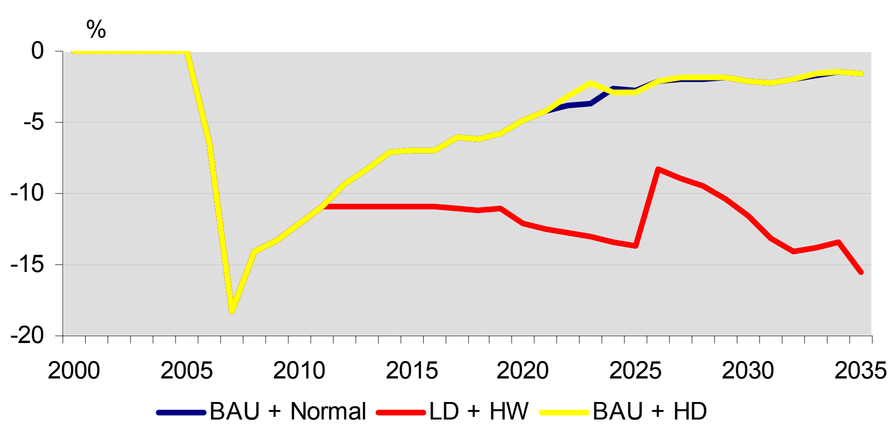


Figure 13-20 Percent improvement of deficit in domestic use with respect to the reference scenarios

With this option, more Municipalities are supplied by the Primary Water Supply System, but the water quantity that is distributed is the same as of the reference case. Therefore, the overall domestic deficit increases (Figure 13-20), with a maximum of almost 20% in 2006 under BAU+Normal and BAU+HD scenarios. Furthermore, 12% of the latter value is concentrated in Barlavento Algarvio, in Monchique and Aljezur Municipalities, where the new connections are implemented.

Although the differences observed between the domestic deficit before and after the option implementation under all scenarios are the same (on average 0.4 hm^3) the demand under BAU+HD and BAU+Normal scenarios is higher than under LD+HW scenario. Consequently, although negative improvements are observed for the three scenarios, under LD+HW scenario the value is lower (-12%, on average) than for the other two scenarios (-5.7%, on average).

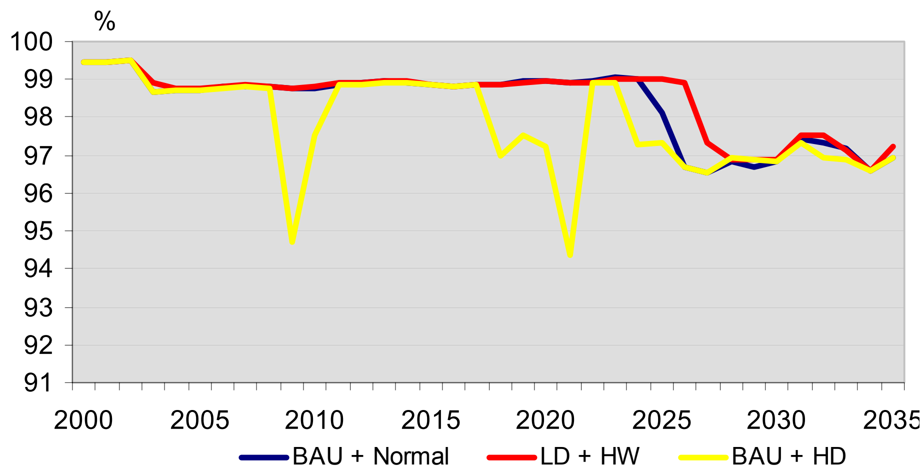


Figure 13-21 Percent demand coverage effectiveness of network enhancement to irrigation use

Regarding irrigation use, concerning demand coverage effectiveness (Figure 13-21), in 2009, the greater unmet demand percentage is observed in the BAU+HD scenario, in Silves, Lagoa and Portimão (SLP) Public irrigation site. The deficit in that irrigation site is exclusively due to Funcho storage reservoir use, with the abstractions needed for public water supply being higher as a result of the new network enhancements.

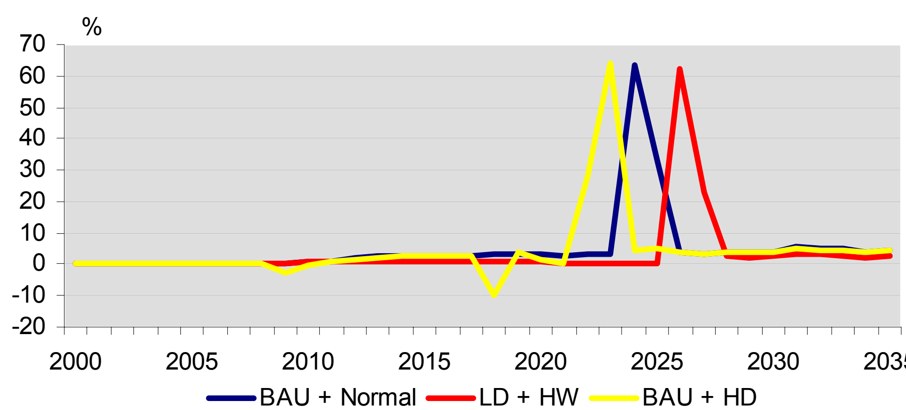


Figure 13-22 Percent improvement of deficit in irrigation use with respect to the reference scenarios

As previously stated, this option increases the water availability for this purpose as settlements that were previously supplied by groundwater, are now supplied by the Primary Water Supply System, through surface water. Therefore groundwater previously available for settlements supply is now available for irrigation use. The best example is Monchique aquifer where a major improvement of the deficit (65%) observed (Figure 13-22) for the year 2023 is observed. The deficit improvement depends on the availability scenario considered, i.e., in LD+HW where higher quantity of groundwater is available, deficit in that scenario is delayed (2023).

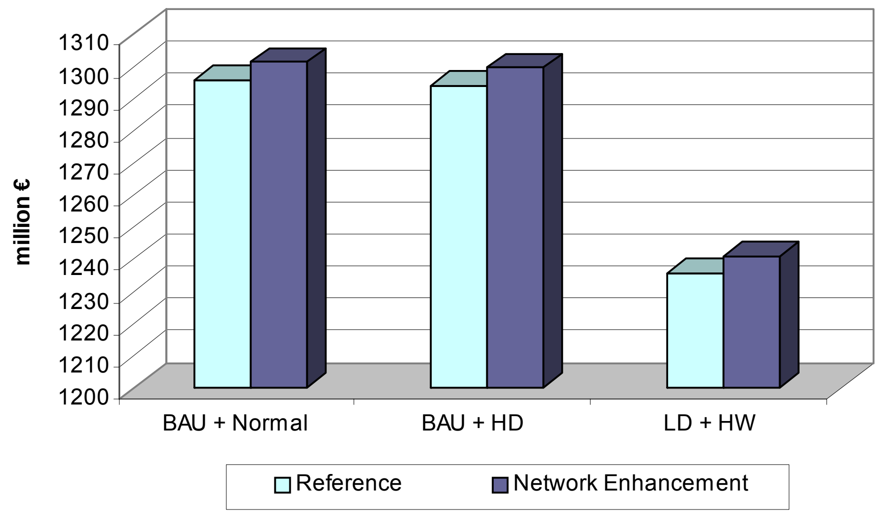


Figure 13-23 Total direct cost difference of network enhancement option under the three scenarios (Present Value – Million €)

Under all three scenarios, the additional cost incurred corresponds to the change from groundwater to surface water at Aljezur and Monchique Municipalities and the increase of network coverage at Albufeira, Portimão, Lagos, Loulé and Tavira. System expansion, replacement and new connections costs increase total direct costs by 0.5% for the whole region and up to 37% in the Aljezur and Monchique Municipalities (in terms of present value). In fact, the present value increase is mainly associated to the capital cost depreciation. By the end of depreciation period (2032) the specific operation and maintenance costs, at the Municipalities of Aljezur and Monchique, are shown to be 65% lower than when those Municipalities were supplied by groundwater.

Desalination

Desalination is a water supply enhancement option that has still not been used in the Ribeiras do Algarve River Basin. Two types of desalination units, with different purposes and characteristics were considered:

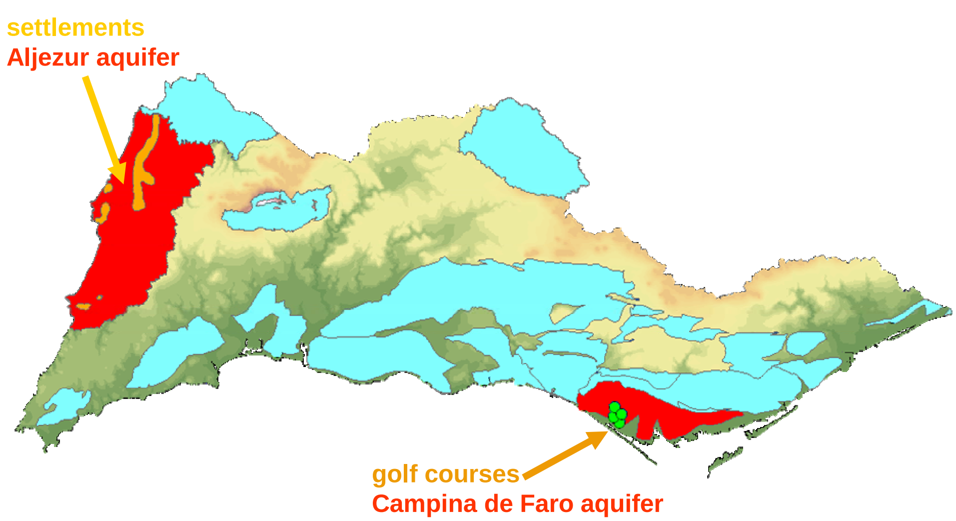


Figure 13-24 Location of the two desalination plants considered

Aljezur Municipality, currently supplied with groundwater, was chosen as a site to construct a desalination plant (Figure 13-24), in 2006, using seawater, because the Aljezur aquifer presents quality problems such as high concentration of chlorides. This desalination plant will produce 0.45hm^3 in 2006, 0.55hm^3 in 2020 and 0.71hm^3 in 2035. This unit aims to solve water quality problems, particularly in Aljezur, Bordeira, Carrapateira, Vale da Telha/Arrifana, Monte Clérigo/Espartal settlements.

Also, the construction of desalination units for the irrigation of golf courses would allow abstracting groundwater from Campina de Faro aquifer, which presents high concentrations of nitrates and chlorides. Thus, another unit, processing brackish water, will be located in Loulé Municipality (Figure 13-24) and start operating by 2006. The water treated in this unit will be used for irrigation purposes in four golf courses (Quinta do Lago, Quinta do Lago - São Lourenzo, Quinta do Lago - Ria Formosa and Quinta do Lago - Pinheiros Altos) and its capacity will be 11500 m^3/day in 2006. For Quinta do Lago - São Lourenzo and Quinta do Lago - Ria Formosa golf courses, the connection to a wastewater treatment plant will be substituted by the connection to the desalination unit. Moreover, Table A13-8 of the Annex presents the desalination associated costs.

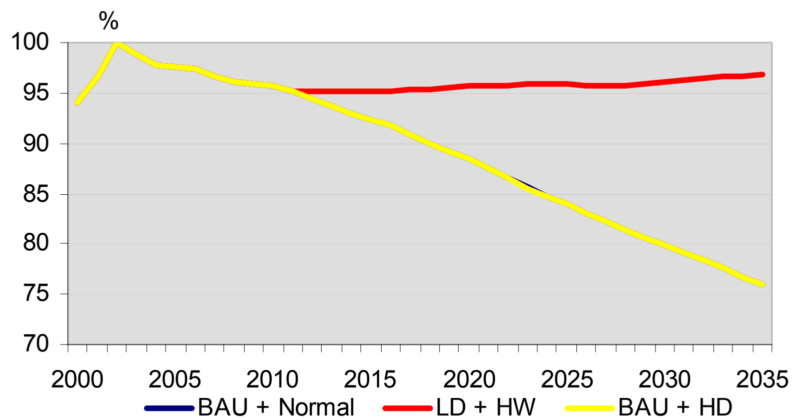


Figure 13-25 Percent demand coverage effectiveness of desalination to domestic use

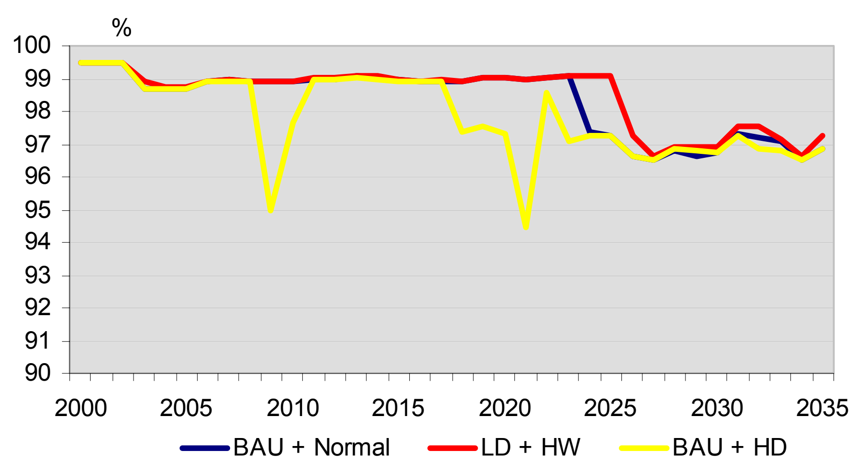


Figure 13-26 Percent demand coverage effectiveness of desalination to irrigation use

Concerning the domestic use, the desalination unit was designed in order to supply Aljezur Municipality population with better water quality giving up abstractions for domestic water supply, from Aljezur aquifer. As the desalination unit was foreseen to provide the same quantity of water as the Aljezur aquifer and there was no domestic deficit in the reference case, no graph for domestic deficit improvement, which is inexistent, is provided.

There are small differences in irrigation coverage between the reference case and the introduction of the desalination units as one of the desalination plants is for golf courses. This option eliminates the existent deficit (on average 42%) in Quinta do Lago – Ria Formosa golf course, which resulted from the link to Quinta do Lago wastewater treatment plant (Figure 13-26).

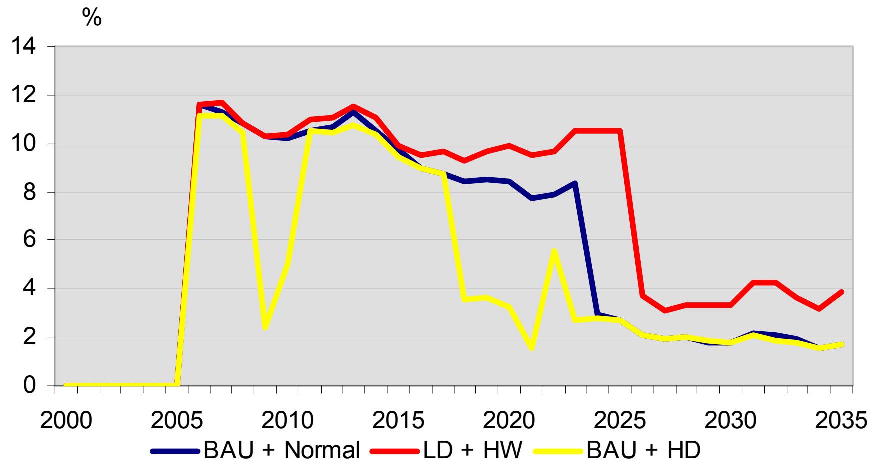


Figure 13-27 Percent improvement of deficit in irrigation use with respect to the reference scenarios (desalination option)

Under all scenarios, this option represents approximately an improvement of only 0.1% in irrigation coverage for the entire Ribeiras do Algarve Basin (Figure 13-27).

On average, the implementation of the desalination unit for the irrigation of golf courses causes a deficit improvement in the golf courses of 8% under LD+HW (the scenario where more water is available), 7% under BAU + Normal and 5% under BAU + HD scenarios (Figure 13-27).

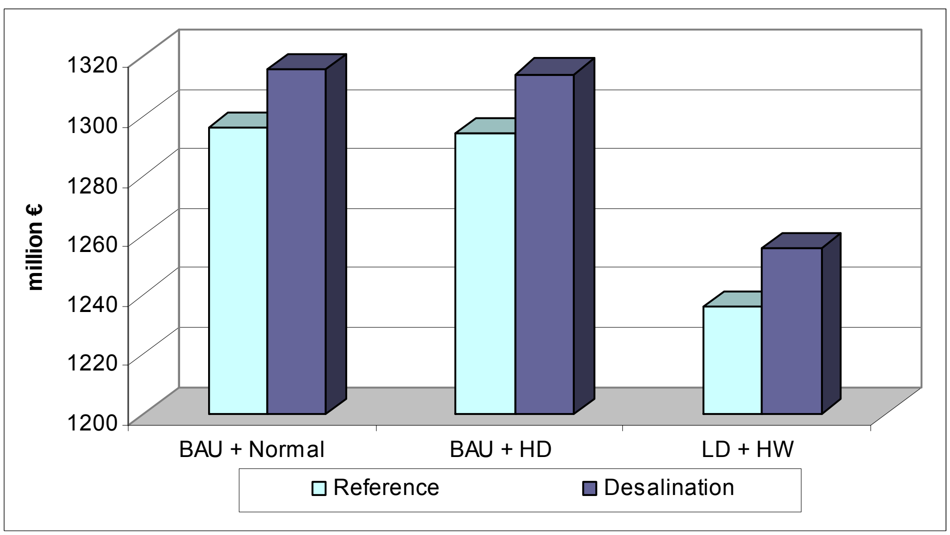


Figure 13-28 Total direct cost difference of the desalination option under the three scenarios (Present Value – Million €)

Figure 13-28 compares the present value of total direct cost of the three scenarios that were studied. In all three cases the construction of the two desalination plants to supply the Aljezur Municipality settlements and golf courses in Quinta do Lago only represent a 1.5% increase of costs for the three scenarios. In fact, the construction of desalination plants are localized measures and the overall increase of direct costs when considering the whole basin is small.

Although, focusing only to the Aljezur Municipality settlements and to the golf courses supplied by the desalination units, the present value presents a 250% increase when comparing the BAU + Normal scenario with the implementation of desalination units' scenario.

Wastewater Reuse

Nowadays, Quinta do Lago - São Lourenzo and Quinta do Lago - Ria Formosa golf courses are using treated water from wastewater treatment plant. The Algarve Commission of Coordination and Regional Development has delimited a critical area (Figure 13-29) where aquifers, as a result of the proximity of the sea, are subjected to salinisation unless protected and where new water boreholes are not allowed except if employed for domestic use.

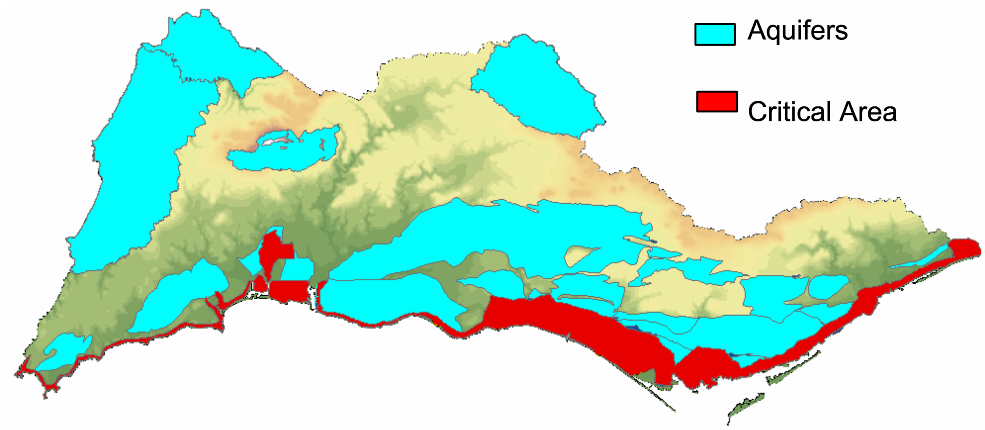


Figure 13-29 Critical area location

In this option, golf courses situated within the critical area were connected to a wastewater treatment plant, WWTP, at a distance of less than 2000 m from the golf course to be supplied. The WWTP holds secondary treatment and therefore tertiary treatment will be implemented and capital costs supported by each golf course benefited with this option.

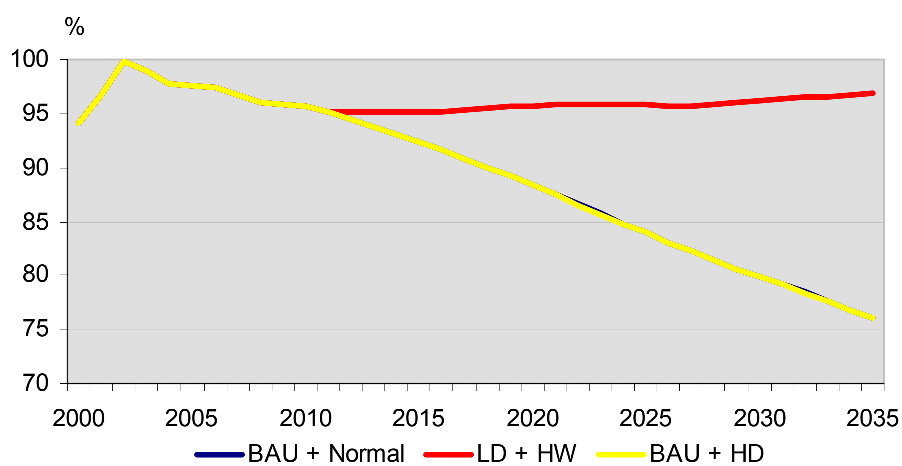


Figure 13-30 Percent demand coverage effectiveness of water reuse to domestic use

In 2006, six golf courses were selected to adopt this type of water supply. In Loulé Municipality: Vilamoura – Millennium, Vilamoura – Laguna Course, Vale do Lobo – Ocean Golf Course and in Albufeira Municipality: Balaia Village, Herdade dos Salgados and Pine Cliffs. Table A13-10 of the Annex presents the yield and construction costs for water reuse.

The reuse option only deals with golf courses in Municipalities where settlements are supplied with surface water. Therefore, domestic effectiveness presents no differences before and after the option implementation (Figure 13-30) and no domestic deficit improvement is observed.

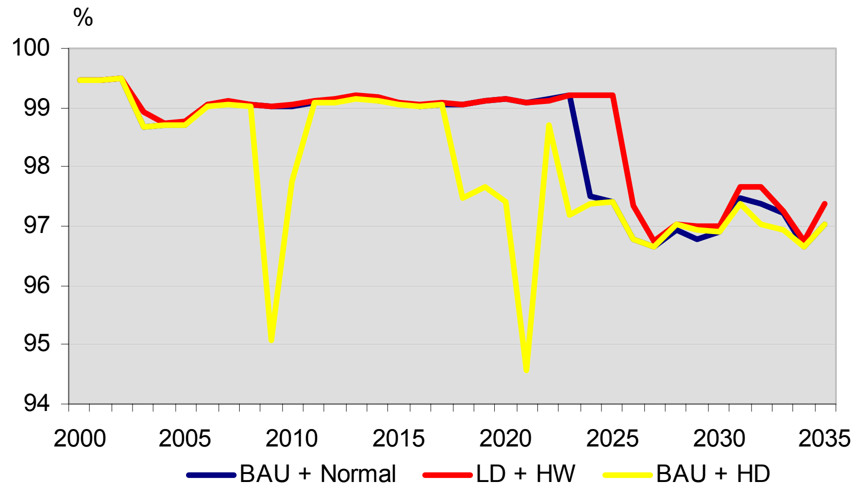


Figure 13-31 Percent demand coverage effectiveness of water reuse to irrigation use

The differences in irrigation demand coverage for the whole Ribeiras do Algarve River Basin, between all three scenarios and the base case, are on average 0.26%, i.e. there is almost no distinction between the data presented in Figure 13-31 and the percent demand coverage effectiveness to irrigation use in the base case. Similarly, in Loulé and Albufeira Municipalities where water reuse is carried out, the differences in irrigation demand coverage, between all scenarios and base case, are on average 2%. As stated before, the peaks in percent demand coverage effectiveness for irrigation under BAU + HD scenario are due to water deficit at Arade dam. Implementing this option implied just a shift from groundwater supply to water reuse in golf courses and a decrease in the groundwater volume exploited in the critical area.

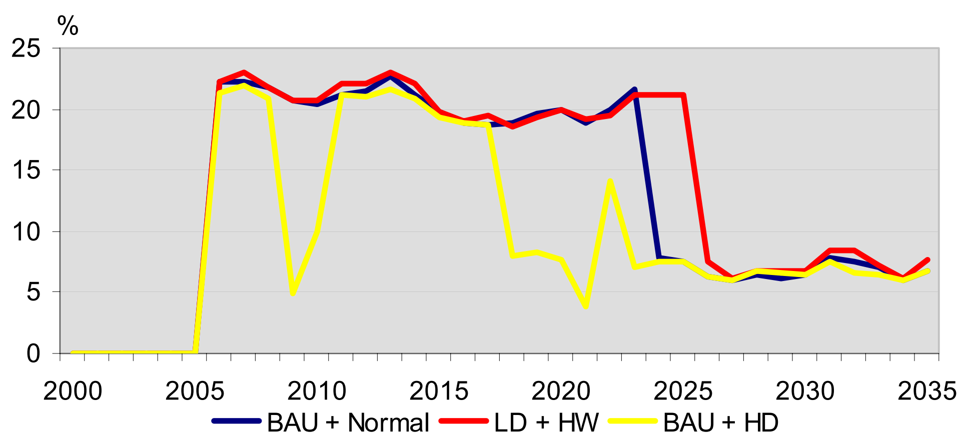


Figure 13-32 Percent improvement of deficit in irrigation use with respect to the reference scenarios (water reuse)

The improvement of the irrigation deficit is only observed in Herdade dos Salgados golf course where the deficit, which was 415 m^3 in 2005, becomes inexistent after 2006. The small fluctuations observed are caused by the sequence of hydrologic years selected for each scenario (Figure 13-32).

Demand Management Options

Reduction of Network Losses

The current estimated level of network losses in the Ribeiras do Algarve River Basin settlements ranges from 16 to 61% for the total domestic water supply. The option that was explored was a gradual reduction of losses of 15% in 15 years for each Municipality (Table A13-9 of the Annex). These losses reductions will be achieved through successive network interventions (upgrade, replacements, maintenance). The application of this option was based on the assumption that internal network interventions will be implemented in different Municipalities, in three phases: from 2005 onwards at a 5% rate until 2010, 5% from 2010 to 2015 and 5% from 2015 to 2020.

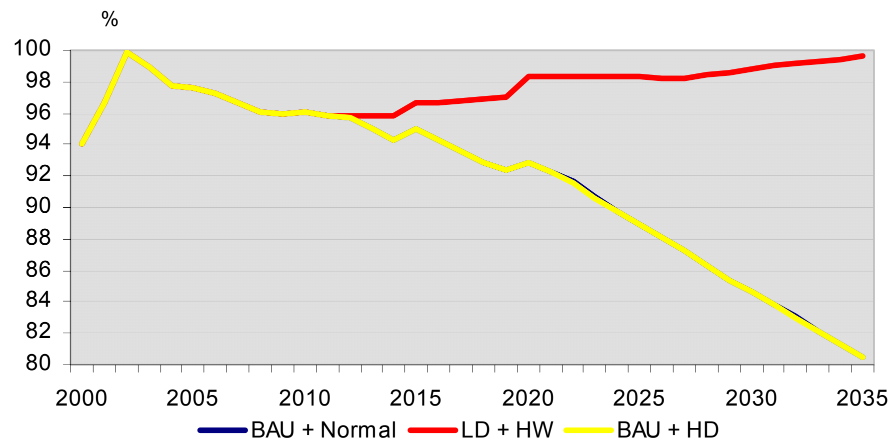


Figure 13-33 Percent demand coverage effectiveness of losses reduction to domestic use

Analyzing Figure 13-33, one can observe that the domestic demand coverage for LD+HW scenario, after the year 2015, is always above 96%, almost reaching 100% for the last year of the simulation period.

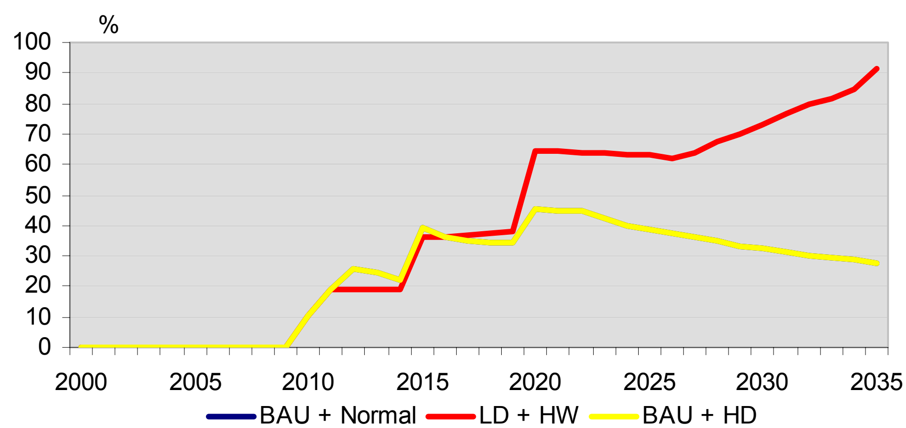


Figure 13-34 Percent improvement of deficit in domestic use with respect to the reference scenarios (losses reduction)

For the other scenarios (BAU+Normal and BAU+HD), the domestic demand coverage decreases to values under 90% in 2024, mostly due to Barlavento. The deficit in Barlavento represents 95% of the total existent deficit in the Algarve mainly as a result of Funcho dam surface water abstraction limit of 23 hm^3.

In terms of domestic deficit, the LD+HW scenario performs better for the analyzed option, presenting an improvement of 54% on average, for the period of simulation, reaching 97% in the last year. An average improvement of 33% of the water deficit, after 2010 and a maximum value of the improvement (45%) in 2020 are observed under the BAU+Normal and BAU+HD scenarios. In those scenarios, as the reduction of losses ends in 2020, the decreasing of the domestic use deficit improvement is due to the continuous increasing of demand (Figure 13-34).

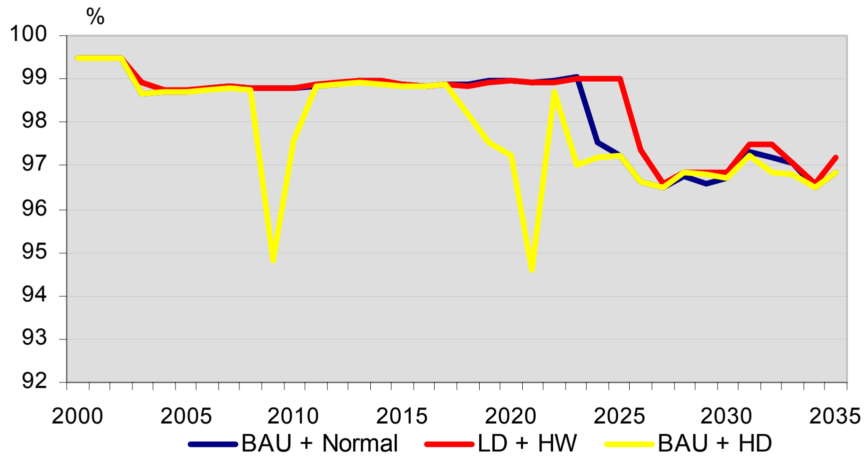


Figure 13-35 Percent demand coverage effectiveness of losses reduction to irrigation use

For the worst case scenario, BAU+HD, and although the irrigation coverage is on average 98% along the simulation period, this parameter presents values of 94.8% and 94.6% in 2009 and 2021 respectively (Figure 13-35). The major share comes from Silves, Lagoa and Portimão public irrigation site, which achieves irrigation coverage values of 41% in 2009 and 26 % in 2021, because of severe water shortage in Funcho dam. The Monchique private irrigation site is particularly affected, showing a deficit of 62% under BAU+Normal and LD+HW scenarios by 2024 and 2026.

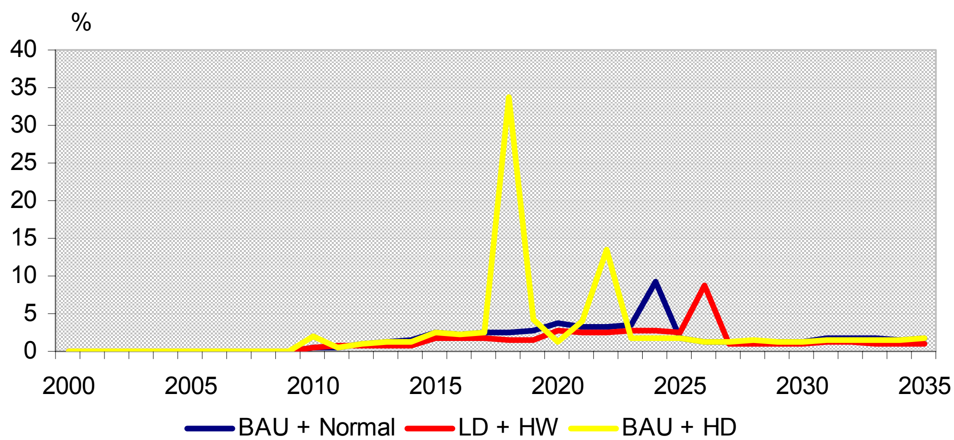


Figure 13-36 Percent of improvement of deficit in irrigation use with respect to the reference scenarios (losses reduction)

Although this option is directed towards the domestic supply network systems, it also influences agriculture indirectly, namely public irrigation sites supplied by surface water. As stated before, domestic use and Silves, Lagoa and Portimão public irrigation site, are mostly supplied by surface water from Funcho dam. Thus, the option considered affects significantly the latter irrigation site particularly under the BAU+HD scenario (Figure 13-36).

Under the BAU+Normal and LD+HW scenarios, the overall deficit improvement, after the option is implemented, is 2%. Specifically, under LD+HW scenario the irrigation deficit decreases 9.3% in 2024 and 8.3% in 2026 (Figure 13-36).

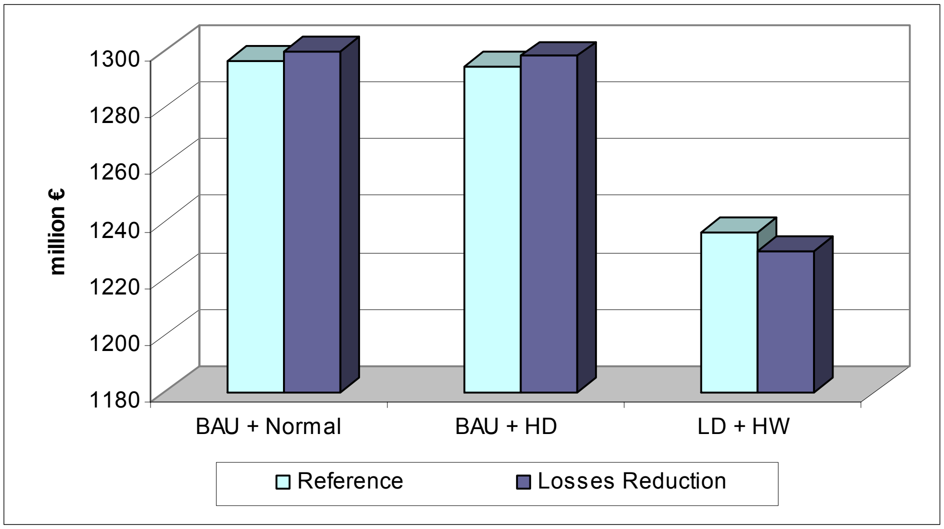


Figure 13-37 Total direct cost difference of the losses reduction option under the three scenarios (Present Value – Million €)

This option presents the lower present value among all options. Under BAU+Normal and BAU+HD scenarios, losses reduction causes domestic deficit decrease consequently, the volume of water supplied increases and specific operation and maintenance costs increase. Contrarily, under the LD+HW scenario present value decreases after the scheduled network interventions. Under this scenario the domestic unmet demand is lower; losses reduction decrease the volume of water delivered to domestic users and operational costs are lower.

Improvement in Irrigation Methods

Agriculture represents the most important water consumer in the Algarve. The irrigation sites represent 123.7 hm^3 (approximately 67%) of the total water consumption at the Ribeiras do Algarve River Basin. From this volume, 96.9 hm^3 correspond to groundwater consumption. The irrigated area growth rate varies either for public and private irrigation sites, causing an increase in water need and therefore enhancing irrigation water deficit. Moreover, it is predicted that an area of 10 650 ha of public irrigation sites is to be implemented by 2006.

In order to diminish losses in agriculture, which represented a maximum of about 27 hm^3 (22% of the supply volume used for irrigation) for BAU+Normal scenario in 2000, alterations in irrigation methods (furrow and sprinkler) were implemented both in public and private irrigation sites. Hence, furrow irrigation method implementation area percentage will be decreased, whereas sprinkler irrigation method implementation area percentage will consequently increase.

Table 13-7 presents the application percentage (% area) change from furrow to sprinkler irrigation method for public and private irrigation sites.

Table 13-7. a) Irrigation methods application extent (% area), for public irrigation sites

Public irrigation sites	2005		2006	
	Furrow	Sprinkler	Furrow	Sprinkler
Silves, Lagoa and Portimão	100%	0%	0	100%
Mira	100%	0%	0	100%
Alvor	100%	0%	100%	0%
Vale da Vila*[18]	-	-	0	100%
Alcantarilha*	-	-	0	100%

b) Irrigation methods application extent (% area), for private irrigation sites

	2006		2012		2020	
	Furrow	Sprinkler	Furrow	Sprinkler	Furrow	Sprinkler
Private irrigation sites	20%	80%	15%	85%	10%	90%

As part of the option, the efficiency of furrow and sprinkler irrigation methods will be enhanced (Table 13-8), for example by means of repairing.

Table 13-8. a) Irrigation methods efficiency improvement, for public irrigation sites

	2006		2012		2020	
	Furrow	Sprinkler	Furrow	Sprinkler	Furrow	Sprinkler
Public irrigation sites	65%	85%	65%	85%	70%	85%

b) Irrigation methods efficiency improvement, for private irrigation sites*[19]

Regadio privado	2006		2012		2020	
	Furrow	Sprinkler	Furrow	Sprinkler	Furrow	Sprinkler
de Aljezur	65%	85%	65%	85%	70%	85%
de Almodôvar	65%	85%	65%	85%	70%	85%
de Lagoa	65%	85%	65%	85%	70%	85%
de Monchique	-	-	65%	85%	70%	85%
de Odemira	65%	85%	65%	85%	70%	85%
de Ourique	65%	85%	65%	85%	70%	85%
de S. Brás Alportel	-	-	65%	85%	70%	85%
de Vila do Bispo	65%	85%	65%	85%	70%	85%

[18] operation start 2006
[19] For the remaining private irrigation sites no other than these modifications in efficiency were implemented

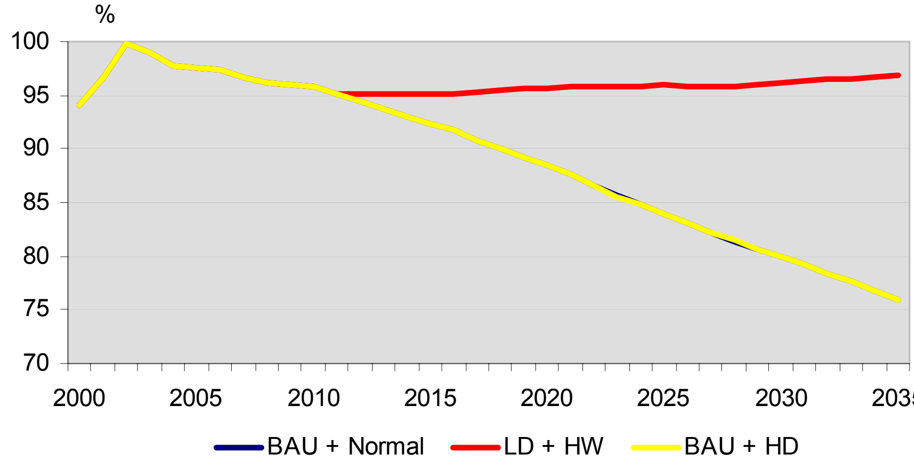


Figure 13-38 Percent demand coverage effectiveness of Improvement in Irrigation methods to domestic use

From Figure 13-38, under the LD+HW scenario, the domestic coverage is always higher than 95%. For the other scenarios, the domestic coverage presents a decreasing trend, reaching values lower than 80% from 2030 onwards. Consequently, no changes are observed.

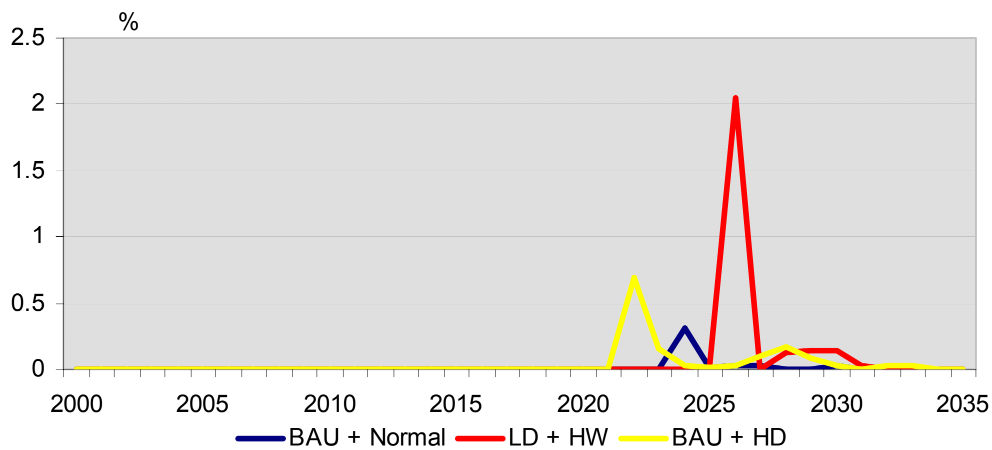


Figure 13-39 Percent improvement of deficit in domestic use with respect to the reference scenarios (improvement in irrigation methods)

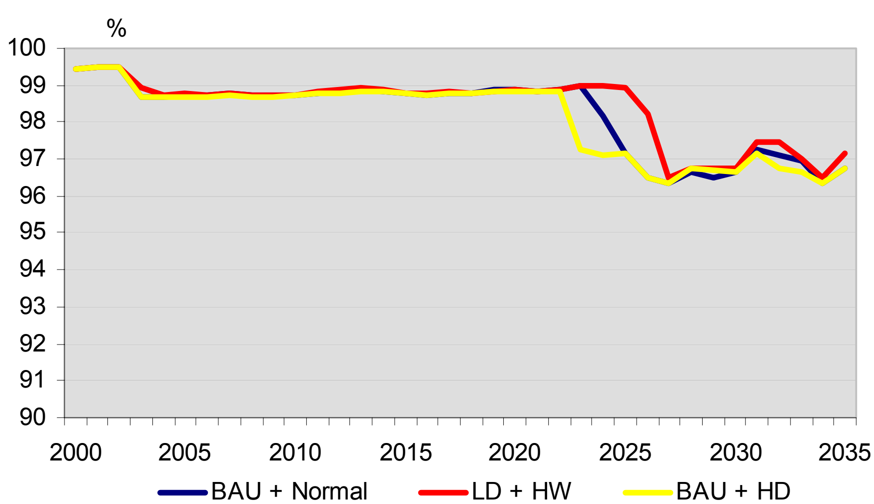


Figure 13-40 Percent demand coverage effectiveness of improvement in irrigation methods to irrigation use

The observed domestic deficit improvement is indirectly related to the change from furrow to sprinkler method. Under BAU+HD scenario, the deficit observed in settlements supplied with groundwater abstracted from S. Bartolomeu in 2021 and Monchique in 2023 aquifers decreases.

For the BAU+HD scenario the percent demand coverage effectiveness decreases from 2021 due to Monchique aquifer being unable to satisfy all the necessary abstractions. For the BAU+Normal and LD+HW scenarios this failure happens in 2023 and 2025 respectively as these two scenarios are associated to less demanding conditions (Figure 13-40).

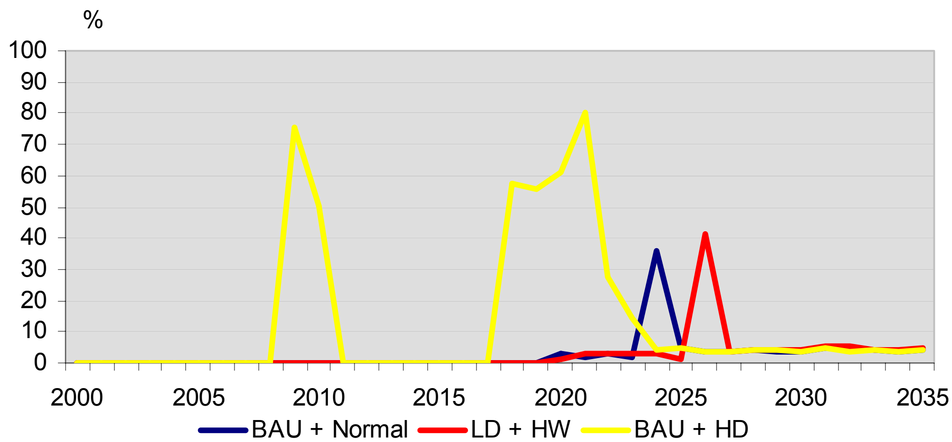


Figure 13-41 Percent improvement of deficit in irrigation use with respect to the reference scenarios (improvement in irrigation methods)

Under BAU+HD scenario there is an irrigation deficit improvement which reaches almost 80%, from 2009 to 2011 and from 2017 to 2021 (Figure 13-41). The latter is due to the mitigation of the unmet demand in Silves, Lagoa and Portimão public irrigation sites. There is also a deficit improvement observed in 2024 under BAU+Normal and in 2025 under LD+HW which is due to the overexploitation of S. Bartolomeu and Monchique aquifers.

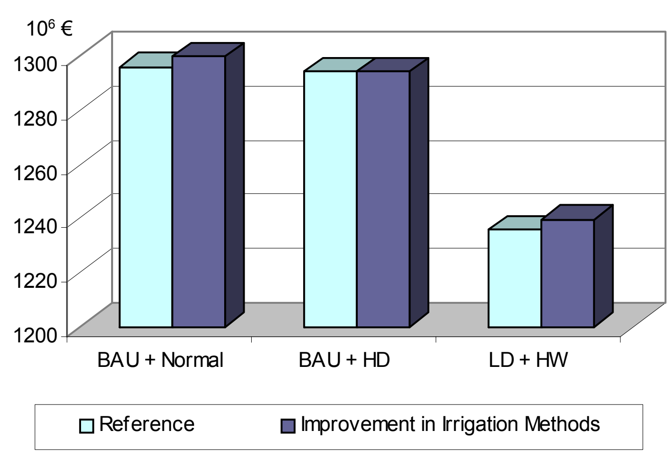


Figure 13-42 Total direct cost difference of the improvement in irrigation methods option under the three scenarios (Present Value – Million €)

Only costs at public irrigation sites were considered because, at this stage, only data concerning these types of irrigation sites was available. Consequently, the increase in terms of present value reflects the capital costs associated to the implementation of new irrigation methods at public irrigation sites. Therefore, although the irrigation deficit decreases (Figure 13-42) at private and public irrigation sites, the specific operation and maintenance costs increase are associated to public irrigation sites.

Summary and Conclusions

The final selection of options to be further analysed depended on the performance of the measures analysed with respect to the indicators that were presented throughout the analysis. The following paragraphs present a summary of the outcomes of this analysis for each option considered, while at the end of this chapter a final comparison is made between the examined methods, and some considerations are given with regard to the potential effect that each option could have when integrated into a strategic plan.

Dam Construction – Odelouca dam

Results concerning the evaluation of surface water exploitation, through the construction of the Odelouca dam, pinpoint that such a measure can guarantee 95 % of the domestic demand coverage in the Barlavento. This target will be reached even during the dry periods. Scenario analysis demarcated Odelouca storage reservoir as an effective solution in meeting domestic coverage, with an improvement of up to 25% by 2035 under severe shortage conditions. The expected domestic demand coverage in Barlavento above 95% is achieved under all scenarios examined. With regard to irrigation, the construction of the Odelouca dam, for domestic supply purposes diminishes the unmet irrigation demand verified in the Silves, Lagoa and Portimão public irrigation sites in 2010, 2018 and 2021. The unmet demand peaks that are predicted for those years are addressed, as water from Funcho dam is reallocated to agriculture purposes. The Odelouca dam capital cost is, in total, 69.9 million €. Odelouca dam construction and operation will increase direct costs up to 11 % in terms of present value, while the overall cost recovery rate will decrease by 5% until 2033. From this year onwards and because the storage dam capital cost is totally depreciated, the excess of water supplied to the system causes a residual increase of 0.3% of the cost recovery rate, making it a profitable investment considering the storage reservoir lifetime.

Network Enhancements

The implementation of network expansions will be carried out in order to provide surface water to Aljezur Municipality, Monchique Municipality and other small settlements. The analysis did not include the integration of additional supply enhancement options, such as boreholes or storage reservoirs, but mainly aimed to analyse the extent to which scarcity problems could be solved by a more equal spatial distribution of resources. The system expansion causes a slight improvement on domestic demand coverage up to 0.5%, whereas domestic demand coverage increases up to 2%. However, the dependence on surface water resources increases, and this option can be effective in minimising groundwater exploitation, while allowing for the replenishment of local aquifers. In fact, the groundwater exploitation analysis showed a decrease ranging from 5 to 10 %, depending on availability and demand. Hence, the system expansion option can be perceived as a measure that could help in the mitigation of environmental impacts associated with water abstractions. System expansion, replacement and new connections costs increase total direct costs by 0.5% for the whole region, and up to 37% in the Aljezur and Monchique Municipalities (present value estimates). On the other hand, after the capital cost depreciation for network expansions (2032), direct costs decrease up to 33 % by 2034. Cost recovery rates decrease by 1% for the whole Ribeiras do Algarve region.

Reduction of Network Losses

Losses reduction were applied to water supply (secondary) network systems in all settlements of Ribeiras do Algarve River Basin, supplied with surface and groundwater. A reduction of 15 % in 15 years from 2005 to 2020 was examined. A reduction in settlements network losses causes, under shortage conditions, an average improvement of 33 % in domestic deficit after the application of the measure. This improvement is associated with the eastern part of Algarve (Barlavento) where the measure has a higher impact. It should be noted that this part of Algarve is strongly dependent on the Funcho storage reservoir, which is affected by availability conditions. However, as demand increases and supplied volumes remain constant, the effect of the option becomes less pronounced. Consequently, this measure improves the irrigation deficit on a smaller extent, about 3 %. This improvement is attributed to the public irrigation sites Silves, Lagoa and Portimão that also depend on the Funcho storage reservoir. Losses reduction, (not accounting for implementation periods), decrease direct costs by 1 % and increase cost recovery rates by 10% with respect to low availability and high demand reference conditions.

Desalination

The construction of new desalination plants will allow the development of new golf courses. The option that was examined was the construction of two desalination units: one unit is implemented in the Aljezur Municipality, and the other in the Quinta do Lago settlement. The latter will additionally prevent further water quality degradation of the Campina de Faro aquifer; groundwater is already presenting high concentrations of nitrates, sulphates and chlorides. The potential construction of a desalination unit enables a decrease of 0.22 hm^3 (11%) of the overall irrigation unmet demand at Ribeiras do Algarve River Basin. The problem of the water deficit that existed in Quinta do Lago - Ria Formosa Course, which was supplied inefficiently by a wastewater treatment plant, could be solved. The total capital cost of the Aljezur desalination unit is 4.595.005 €, including maintenance and operation costs of 0.55 €/m^3. The other desalination unit (Quinta do Lago) has a total capital cost of 5.413.165 € and specific maintenance and operation costs of 0.37 €/m^3. In total, the construction of the two desalination plants corresponds to only a 1.5% increase of costs (in terms of present value). Nevertheless, focusing only in the Aljezur Municipality and the golf courses supplied by the desalination units, there is a 250 % increase in the direct costs (in terms of present value) relatively to the worst-case scenario. In fact, the construction of desalination plants are localized measures and the overall increase of direct costs when considering the whole basin is small.

Improvement in Irrigation Methods

The option of irrigation method improvements comprises a shift from furrow to sprinkler irrigation methods through the development of a programme of application. The scenario foresees that for private irrigation sites there will be a gradual decrease of surface irrigation method percentage coverage from 20 % in 2006 to 15 % in 2012 and to 10 % in 2020, and an increase of sprinkler irrigation method percentage coverage from 80 % in 2006 to 85 % in 2012 and to 90 % by 2020. Efficiency improvements will be introduced in private irrigation sites whenever these are lower than 65 % by 2006 and 70 % from 2020 onwards, for furrow irrigation method, according to the Ribeiras do Algarve River Basin Plan. Concerning public irrigation sites, Mira and Silves, Lagoa and Portimão, a change in percentage coverage from 100% furrow into 100% sprinkler, was applied by 2006. For the latter irrigation sites, the irrigation method efficiency will increase from 65% to 70% in 2020.

Between 2006 and 2035, the irrigation deficit improvements at the whole River Basin, obtained from the application of this option, are on average 16%. The extra water volume accumulated in the Funcho/Arade storage reservoir can therefore be used during dry periods at the Silves, Lagoa and Portimão irrigation sites. Particularly at this irrigation site, the irrigation deficit improvement after the introduction of this option reaches 80% in 2021. Direct costs will increase by 0.4% in terms of present value relatively to the worst-case scenario. Particularly at the irrigation sites where this option is implemented, this increase is of 11% relatively to the same scenario. The overall rate of cost recovery for the whole Ribeiras do Algarve River Basin also decreases in 2006 by 14%, year of the new irrigation system implementation, and there is practically no difference in the following years

Wastewater Reuse

The option considered was the connection of golf courses that are at distance of less than 2000 m from a WWTP and situated in the "critical area" previously defined in the analysis of the desalination option. In 2006, 6 golf courses will adopt this kind of water supply in Loulé Municipality: Vilamoura – Millennium, Vilamoura – Laguna Course, Vale do Lobo – Ocean Golf Course; and in Albufeira Municipality: Balaia Village, Herdade dos Salgados and Pine Cliffs. The demand for these golf courses is 2.1 hm^3.

Water reuse can solve some problems by decreasing unmet demand (66% in 2035), protect aquifers from overexploitation, abandon poor groundwater quality supply and enable sustainable development of golf courses. These improvements are mainly observed in Herdade do Salgados golf course, which, in this option, has been connected to another WWTP in order to eliminate previous supply deficiencies. Similarly to current practice, capital costs, operation and maintenance costs and analytical control are considered to be totally supported by the golf courses that implement this method. Nevertheless, data have not yet been evaluated.

Comparison of Options

Results are summarized in Table 13-9. The effectiveness of each option is approached through the evaluation score obtained by the WSM-DSS, from the behaviour with respect to domestic and irrigation demand coverage, assuming a weight of 0.5 and 0.25 respectively.

Table 13-9 Comparison of options

Option	**Relative Sustainability Index for Demand Coverage**	**Economic Efficiency**		**Relative Sustainability Index for Environment Resources**
		Rate of Cost Recovery Index	**(Direct Cost – PV- million €)**	
Base Case (BAU+Normal)	0.250	0	1296	0
Dam Construction	0.524	0	1448	0
Network Enhancement	0.250	0	1301	0.15
Desalination Unit Construction	0.250	0	1315	0.075
Reduction of Network Losses	0.251	0	1230	0
Improvement in Irrigation Methods	0.250	0	1300	0.15
Water Reuse	0.250	0	No data	0.075

Environmental sustainability is expressed through the performance with respect to Non Sustainable Water Production Fraction and Groundwater Exploitation Index, assuming weight of 0.075 for each indicator. Economic Efficiency is expressed through the evaluation score obtained by the WSM DSS, from the performance with respect to rate of cost recovery, assuming weight 0.10 and through total direct cost, expressed in present value terms.

All the rate of cost recovery values are zero (Table 13-9) because at any time throughout the simulation period the index value is higher then the lower limit (100%). Nevertheless, the option that presents higher average rate of cost recovery values is the dam construction, since a higher quantity of water is sold. A pricing measure is therefore needed in order to achieve this objective. Due to the complexity and size of the Ribeiras do Algarve River Basin, it is often difficult to observe some clear differences in the indicators when a management option is only applied locally to a specific Municipality or Settlement of the Basin. This situation applies to Aljezur where, for example, the effect of introducing desalination plant is not distinguished in the evaluation total score.

It could be inferred that the application of one option by itself is unsatisfactory since it cannot simultaneously fulfil the criteria of effectiveness, economic efficiency and environmental sustainability. A structural, large-scale option such as dam construction has an advantageous position in terms of effectiveness; however the rank with respect to economic efficiency and environmental sustainability is unsatisfactory. If a strategy is developed, these options should incorporate other options to improve economic and environmental performance, like hard options such as network enhancement or softer ones like improvement in irrigation methods.

Annex

Hydrological Sequences

Table A13-1 Intra-annual rainfall variation

Water Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Dry	0.9	0.8	0.8	0.8	0.6	0.6	0.7	0.6	0.6	0.7	0.8	0.8
Normal	1	1	1	1	1	1	1	1	1	1	1	1
Very Dry	0.7	0.7	0.7	0.7	0.6	0.5	0.6	0.4	0.5	0.6	0.7	0.6
Very Wet	1.6	1.6	1.4	1.3	1.7	2	4.9	5.6	2.1	1.6	1.5	1.7
Wet	1.1	1.1	1.2	1.1	1.3	1.2	1.7	2	1.2	1.3	1.2	1.2

Table A13-2 Meteorological stations considered

Station Number	Name
30E/01	Aljezur
30E/02	Marmelete
30E/03	Barragem da Bravura
30F/05	Vidigal
30G/01	Alferce
30G/03	Barragem do Arade
30H/03	São Bartolomeu de Messines
30H/05	Paderne
30L/03	Faz-Fato
31I/01	Loulé
31J/01	São Brás de Alportel
31K/01	Santa Catarina/Tavira
31E/01	Lagos

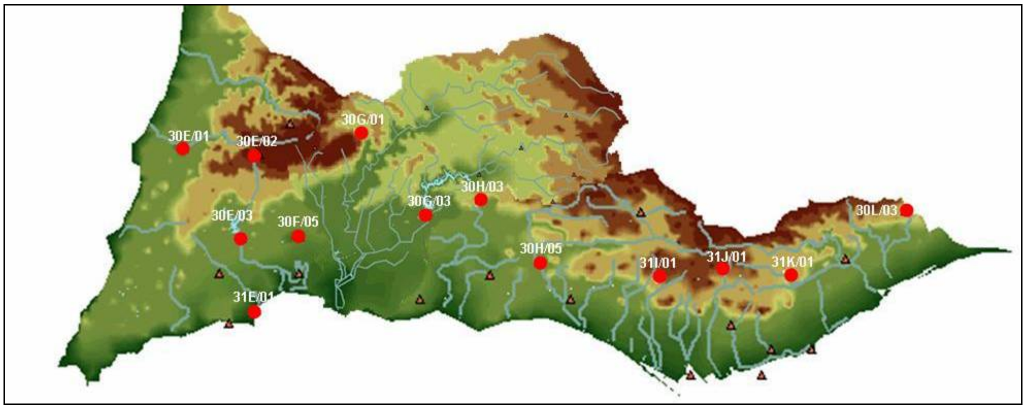


Figure A13-1 Map of the meteorological stations considered

Table A13-3 Dry, Normal and Wet availability scenarios

Year	Dry	Normal	Wet	Year	Dry	Normal	Wet
2000	normal	wet	normal	2018	normal	normal	dry
2001	wet	very wet	wet	2019	wet	wet	normal
2002	dry	normal	dry	2020	dry	normal	dry
2003	dry	normal	dry	2021	normal	normal	dry
2004	dry	normal	dry	2022	very wet	very wet	wet
2005	normal	normal	dry	2023	wet	very wet	wet
2006	normal	wet	normal	2024	very wet	very wet	very wet
2007	normal	normal	dry	2025	normal	wet	normal
2008	dry	dry	very dry	2026	very dry	dry	very dry
2009	dry	dry	very dry	2027	normal	normal	dry
2010	normal	wet	normal	2028	normal	Wet	normal
2011	normal	wet	normal	2029	very dry	dry	very dry
2012	very wet	very wet	wet	2030	very wet	very wet	very wet
2013	wet	very wet	wet	2031	wet	very wet	normal
2014	normal	normal	dry	2032	very wet	very wet	wet
2015	very dry	very dry	very dry	2033	very dry	very dry	very dry
2016	dry	normal	dry	2034	normal	wet	normal
2017	very dry	very dry	very dry	2035	wet	very wet	wet

Dam Construction Parameters

Table A13-4. Cost Estimation for Odelouca dam project

Cost Component	Cost (million €)
Dam and accessibilities Tunnel Land Expropriations	39.8 25.8 4.3
Total	**69.9**

Network Enhancement Parameters

Table A13-5 Pipeline connection construction costs (connections)

Cost Component	Cost (€)
Aljezur	
Ocidental R3	2,747,073.45
Ocidental R2	480,384.72
Ocidental R1	462,413.48
Portimão	
Ocidental Morgado dos Reguengos/Monchique-Ginjeira	163,591.62
Ocidental Morgado dos Reguengos	94,661.30
Albufeira	
Oriental Cerro de Ouro	2,359,256.90
Monchique	
Ocidental Monchique-Ginjeira	2,110,868.39
Lagos	
Ocidental Final RXVI	141,774.14
Ocidental Final RVII	214,917.39
Loulé	
Oriental Quintinhas	56,656.91
Tavira	
Nascente Cumeada	40,128.17
Nascente Santa Margarida	48,846.75
Total	**8,920,573.22**

Table A13-6 New network cost estimation for the system enhancement (reservoirs)

Cost Component	Cost (€)
Aljezur	
R3	6,679.00
R2	6,451.00
R1	37,768.00
Portimão	
Morgado dos Reguengos	5,444.00
Albufeira	
Cerro de Ouro	354,525.00
Monchique	
Monchique-Ginjeira	11,273.00
Loulé	
Oriental Quintinhas	7,977
Tavira	
Cumeada	134,611.00
Total	564,728.00

Table A13-7 Construction years for network unifications

<table>
<tr><th>Municipality</th><th>Reservoir</th><th>Settlement</th><th>Year</th></tr>
<tr><td rowspan="5">Aljezur</td><td>R1</td><td>Aljezur (sistema norte)</td><td>2006</td></tr>
<tr><td rowspan="2">R2</td><td>Vale da Telha/Arrifana</td><td>2006</td></tr>
<tr><td>Monte Clérigo/Espartal</td><td></td></tr>
<tr><td rowspan="2">R3</td><td>Bordeira</td><td>2006</td></tr>
<tr><td>Carrapateira</td><td></td></tr>
<tr><td rowspan="2">Monchique</td><td rowspan="2">Monchique-Ginjeira</td><td>Monchique</td><td>2007</td></tr>
<tr><td>Caldas de Monchique</td><td></td></tr>
<tr><td>Albufeira</td><td>Cerro de Ouro</td><td>Albufeira</td><td>2006</td></tr>
<tr><td>Portimão</td><td>Morgado dos Reguengos</td><td>Portimão</td><td>2006</td></tr>
<tr><td rowspan="3">Lagos</td><td>RVII</td><td rowspan="3">Lagos/Luz</td><td rowspan="3">2006</td></tr>
<tr><td>RXVI</td></tr>
<tr><td>Sargaçal</td></tr>
<tr><td>Loulé</td><td>Quintinhas</td><td>Vilamoura</td><td>2006</td></tr>
<tr><td rowspan="2">Tavira</td><td>Cumeada</td><td>Conceição</td><td>2006</td></tr>
<tr><td>Santa Margarida</td><td>St.º Estevão</td><td>2006</td></tr>
</table>

Desalination Parameters

Table A13-8 Capacity and construction cost for the all scenarios

	Type	Capacity (m^3/day)	Capital cost (€)	O&M costs (€/m^3)
Aljezur	Seawater	6000	4 595 005	0.55
Quinta do Lago	Brackish water	11500	5 413 165	0.37

Reduction of Network Losses Parameters

Table A13-9 Scheduling of network replacements

Municipalities	Current Losses (%)	Reductions %			Losses in 2020 (%)
		2010	2015	2020	
Aljezur	30	5	5	5	15
Almodôvar	30	5	5	5	15
Castro Marim	30	5	5	5	15
Faro	30	5	5	5	15
Lagoa	30	5	5	5	15
Loulé	32	5	5	5	15
Monchique	30	5	5	5	15
Odemira	30	5	5	5	15
Portimão	30	5	5	5	15
Tavira	30	5	5	5	15
Vila Real St.º António	28	5	5	5	15
Lagos	60	5	5	5	45
Olhão	61	5	5	5	45
S. Brás de Alportel	56	5	5	5	45
Silves	59	5	5	5	45
Albufeira	16	5	5	5	1
Vila do Bispo	43	5	5	5	28

Table A13-10 Yield and construction costs for water reuse

Golf course	WWTP	Demand (2006) (10^3 m^3)	Tertiary treatment capital cost (10^3 €)
Balaia Village	Vale Faro – Zona Nascente	294	60.3
Herdade dos Salgados	Galé	458	93.9
Pine Cliffs	Pinhal do Concelho	150	30.7
Vilamoura Millennium	Vilamoura	406	83.2
Vilamoura – Laguna Course	Vilamoura	406	83.2
Vale do Lobo – Ocean Golf Course	Vale do Lobo	353	72.4

Groundwater

Considering the difficulties in getting data for the aquifers in the Ribeiras do Algarve River Basin due to lack of research in this field, a criterion has been developed in order to estimate the Yield Factor and NonSustainable Groundwater Production Fraction of each aquifer.

Firstly, the capacity of each aquifer was calculated, based on its area, saturated area and storage coefficient. All these parameters have already been defined in River Basin Plan.

Capacity of aquifer (m^3) = Area (m^2) x Saturated Height (m) x Storage Coefficient

Following that, the Yield Factor was defined as:

Yield Factor= Available volume / Groundwater availability volume

with

Available Volume = Water Available (m^3/year/km^2) x area (km^2)

The “available volume” is the groundwater volume that is available for abstraction, being smaller than the volume stored in aquifers. Furthermore it is necessary to preserve the aquifers sustainability assuring that the necessary quantity for its protection is maintained.

It was assumed that the Yield Factor was equal to 1 (100%), allowing the total aquifers storage volume to be abstracted. The aquifers sustainability is therefore preserved by setting a fraction of recharge that limits the volume that can be abstracted.

In this way, the Sustainable Factor was defined as:

Sustainable Factor = DHS / Recharge (per aquifer per year)

The DHS is the groundwater sustainable volume as defined by the Water National Plan, i.e, the groundwater volume associated to the recharge, which is available in the aquifer. However improvements in the determination methodology of this parameter are being made.

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