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BACKGROUND NOTE

TUNISIA'S EXPERIENCE IN WATER RESOURCE MOBILIZATION AND MANAGEMENT

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TUNISIA'S EXPERIENCE
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Introduction

Water is scarce and it is also highly variable. In addition to its long history of earthquakes, hailstorms and plagues of locusts, Tunisia has always suffered from droughts and floods. They are hard to predict as they do not follow any clear cyclical pattern. For more than a century (1640–1758), Tunisia had no droughts, whereas in modern times, it has had approximately thirty. The same applies to floods. Over the centuries, the successive civilizations that have lived in Tunisia have developed management systems to cope with the risks of floods and droughts. They were not always successful. A series of severe droughts in the area that is now Tunisia lasted for about a decade from 870 BCE. By the end of these droughts, the local administrator wrote that prices of wheat had increased steeply; food had become scarce, to the extent that people had resorted to cannibalism.[1]

Managing this scarce and variable water is critical for Tunisia's development. The country engages in extensive political debate and strategizing and the Government has invested heavily in measuring, mobilizing, and managing resources as well as in getting the maximum value from each cubic meter of water used. This paper aims to highlight Tunisia's progress in managing water, showing the evolution from traditional practices to large government-led investments to store and transfer water (which could be characterized as "physical engineering"), leading to third stage, that began around the turn of the millennium which continues physical investments but puts an increased and heavy emphasis on water management (could be characterized as "institutional engineering"). Many aspects of Tunisia's experience could be improved, but, on the whole, this paper suggests that Tunisia's experience is an example of good planning and management.

Availability of Water Resources

Tunisia is considered to be one of the countries in the Mediterranean basin least well-endowed with water resources. The potential volume of available water, 4,864 million m^3 per year, is less than 500 m^3 per inhabitant per year. This ratio will decline to 360 m^3 in 2030, when the population will have grown to approximately 13 million.

To manage variable supplies, Tunisia balances surface and groundwater stocks and flows within and between years. It uses dams and groundwater reserves to store surplus water in wet years and uses those stocks in dry years.

[1] L'Emirat Aglabite, Mohamed Talbi. Edition Dar Gharb Islami Beyrout 1985. page 112.

It also has to distribute the water between different parts of the country. Maintaining a regional balance has been and will remain an essential element in Tunisia's water supply planning and management. The population is concentrated along the coasts, where cities as well as industry and tourism are well developed. Agriculture is the largest water user, and is located throughout the country except in the southern desert. However, the country's water supplies come mainly from in the north and the interior of the country. Transfers are also a strong feature in Tunisia's long history from the Roman aqueduct at Zaghouan (built in 72 AD) to the modern-day Mejerda - Cap Bon canal (1982), with distribution networks going all the way to Sfax.

On a national scale, water resources are distributed unequally. Table 1 illustrates the geographic distribution of different categories of water in Tunisia.

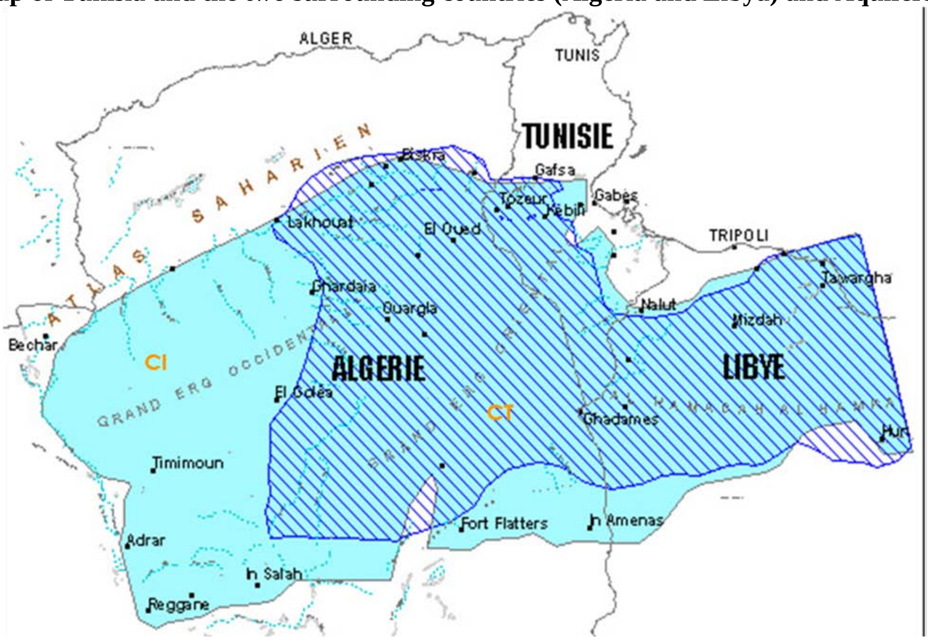
Table 1: Spatial Distribution of Water Resources in Tunisia [million cubic meters]

	Far North	North	Center	South	Country total
Regional surface *(%)*	3			62	100%
Supply of surface water *(millions m^3)*	960	1230	320	190	2700
Groundwater *(millions m^3)*		395	216	108	719
Deep groundwater *(millions of m^3)*		269	326	822	1417
Total potential resource *(millions of m^3)*		**2854**	**862**	**1120**	**4836**
%		**59**	**18**	**23**	**100**

Source: DGRE 1995.

Tunisia shares *international surface water* in the form of some rivers along the length of the western border with Algeria. The two countries have reached agreements on how to mobilize and use that water, including agreeing the annual volume available in the relevant basins, and how to distribute it between the two countries. They have also established a monitoring system, which allows both countries to track pollution as well as water volumes for the main international river, the Mejerda.

Figure 1: Map of Tunisia and the two surrounding countries (Algeria and Libya) and Aquifers extension



Source : Observatory of the Sahara (OSS), 2004

The country also has a considerable volume of international groundwater, located in the Djeffara coastal basin shared between Libya and Tunisia and, most importantly, in the Northwest Saharan Aquifer System, shared between Algeria, Libya, and Tunisia (see Figure 1). The latter is more than one million km^3 of water with very limited recharge, of which some 80,000 km^3 are in Tunisia. Three countries have established a commission to monitor this aquifer, and agreed to cooperate on its management in order to minimize cross-border impacts. This is one of only two such agreements in the world. Tunisia uses this water for irrigation of greenhouse vegetables and of dates (see Figure 2)

Figure 2: Cooling tower bringing geothermal water from the Sahara down to a temperature useable in irrigation

Source: Julia Bucknall

Tunisia's water policy aims to contribute to progressive and sustainable socioeconomic development while balancing two conflicting facts.

a. Limited water supplies and increasing cost of generating or storing and transferring additional resources.
b. Growing demand for water. In the interior, the country has established a minimum quantity necessary. It takes into account conflicting uses and the pressure on resources, and the risk of worsening water quality making its use un-sustainable.

Potential conventional water resources for the country as a whole are estimated at 4,670 million m^3/year. Of these, an average of 2,700 million m^3/year are surface water and 1,970 million m^3/year are underground water. The variability is huge. Over the past few decades the maximum potential volume of surface water was 11 billion m^3 in 1969–70 and the minimum 780 million m^3 in 1993–94. Variability is high everywhere but much higher in the south. In the north, the wettest year was nine times wetter than the driest year. In the South, it was 180 times more water was available in the wettest year than in the driest.

As monitoring has improved and particularly as hydrogeologists have discovered larger volumes of groundwater available, the estimates of the amount of water potentially available in Tunisia grew substantially between 1968 and 2007 (table 2).

Table 2. Tunisia Potential water supplies (million cubic meters)

	1968	1972	1980	1985	1990	1996	2000	2005	2007
Surface water	2000	2000	2580	2630	2700	2700	2700	2700	2700
Groundwater	160	230	490	590	670	720	737	745	745
Deep groundwater	600	900	1030	1100	1170	1250	1399	1419	1419
Total	**2760**	**3130**	**4100**	**4320**	**4540**	**4670**	**4836**	**4864**	**4864**

Source: DGRE, MARH.

Despite the increase in known resources, on a per capita basis, water availability has declined (see Table 3). For ground water, the calculation of water available refers to an assessment of the maximum volume of water that can be extracted annually from the country's groundwater resources under prevailing technical and economic conditions without leading to the long-term exhaustion of the underground resource base. For surface water resources, the calculation takes into account resources available 95 percent of the time. In other words, it shows the proportion of surface resources available for annual extraction for 19 years in any consecutive 20-year period, or during at least 95 percent of the year included in a longer period of consecutive years. This figure therefore measures the average long-term availability of surface water for human usage.

Table 3. Tunisia: change in per capita long-term water availability (million cubic meters)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Surface water *(mm^3)*	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2200
Groundwater *(mm^3)*	720	720	720	720	720	737	737	737	737	737	745
Deep groundwater *(mm^3)*	1211	1217	1217	1225	1377	1399	1403	1403	1397	1411	1420
Total Resources *(mm^3)*	4031	4037	4037	4045	4197	4236	4240	4240	4234	4248	4365
Population *(mil.)*	8,957	9,089	9,215	9,333	9,456	9,563	9,65	9,75	9,84	9,93	10,03
Availability by inhabitant *(m^3/inhabitant)*	**450**	**444**	**438**	**433**	**444**	**443**	**439**	**435**	**430**	**428**	**435**

Source: INS and MARH.

As mentioned above, supplies are concentrated in the north. Eighty one percent of the country's resources are in the north, 11 percent in the center and only 8 percent in the south.

This irregular supply affects the country in the form of often devastating floods, which can be difficult to manage. At the same time, the country's water requirements are always at risk from shortages of varying levels of seriousness. However, the infrastructure available has in recent decades enabled it to mitigate the impact of most floods by storing and transferring the water and to reduce the impact and manage the risks of drought.

Tunisia has water quality problems as well as the quantity and variability issues described above. Less than half of the country's resources have less than 1.5 g/l of salt, and therefore meet health and agronomic standards. Of this water with reasonable salinity levels, 72 percent is surface water, 20 percent deep groundwater, and scarcely 8 percent ground water (Table 4). Surface water is therefore used both for direct consumption and to improve the quality of other categories of water. In the Mejerda basin, salinity varies between 1g/l to 1.5 g/l depending on the season, whereas the water in the Ichkeul and Zouara basins varies between 0.6 g/l and 1.00 g/l. The salinity of the water in the extreme north of the country never exceeds 0.7 g/l, regardless of the season or the level of drought.

Table 4. Breakdown of Salinity of Water Resources *(%)*

	Salinity<1,5g/l	**1,5<Salinity>3g/l**	**Salinity>3g/l**	**Total**
Surface water	72	22	6	100
Groundwater	8	32	60	100
Deep groundwater	20	57	23	100
Total	**47**	**34**	**19**	**100**

Sources: A.Mamou, 1993: Principal Outline of National Planning, Environmental Limits 1996.

In absolute terms and in millions of m^3 in relation to total potential water supply, we arrive at the proportions shown in Table 5.

Table 5. Breakdown of water resources regarding salinity in relation to total potential resources (million cubic meters)

	Salinity<1,5g/l	**1,5<Salinity>3g/l**	**Salinity>3g/l**	**Total**
Surface water	1944	594	162	2700
Groundwater	58	230	431	719
Deep groundwater	283	808	326	1417
Total	2285	1632	919	4836
%	**47**	**34**	**19**	**100**

Sources: A.Mamou,1993: Principal outline of national planning, environmental limits 1996.

Thus, looking at total potential supply, more than 80 percent of water resources have salinity levels of less than 3 g/l. Given that it is used directly or occasionally blended with other resources to improve the latter's salinity levels, this water does not often require specific treatment.

Difficult as it is to manage Tunisia's water resources now, the job is only going to get harder in the future. Studies show that Tunisia can expect an increase in average annual temperature (2 degrees C on average), a modest fall in average precipitation (approximately 5 percent by 2030) and increased volatility in the climate.[2] In particular, extreme phenomena (droughts, floods, strong winds) will increase in both frequency and intensity, with very dry years likely to occur more often in the future. These changes will have serious consequences for water resources, ecosystems, and agriculture, fur urban dwellers and therefore for the entire economy and society.

Investments to Store and Transfer Water in Tunisia

For the past three decades, Tunisia's water resource management policy has been based mobilizing water resources. These have drawn up at the level of complementary hydrological systems (catchment areas, systems of aquifers) connected through transfer networks, and through a framework of sector-based strategies. These strategies have included agricultural

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[2] Strategy for Adapting to Climate Change, 2006

water, rural and urban drinking water, urban sanitation, and the reuse of treated wastewater for agricultural purposes.

The Tunisian Ministry of Agriculture and Water Resources has developed a model to help operate the country's water systems and manage the risks associated with both droughts and floods. It compares the available resources with the expected needs under various planning scenarios including estimates of when different major infrastructure investments will begin operation. This model simulates all the foreseeable demands and allows the government to ensure that needs are met, and to plan infrastructure needs well in advance. The tools used to create the simulations are constantly updated and enhanced to account for variables related to demand levels, performance of modern technology, and perverse effects of reality. The model consists of a number of separate information systems:

First, the Optimal Water Resource Management model (known with its French acronym as G.E.O.R.E.) The idea of developing integrated water information systems was first proposed in a study that the government developed over the period 1990-95. This study, *"WATER ECONOMY 2000"* was intended to enable the country to respond to water demand on a national level over the coming decades (first to 2010, then 2030). It collected, analyzed and synthesized all significant data and information pertaining to water resources and requirements, both qualitatively and quantitatively. In this way, relational databases covering resources and supply were established. All the country's water resources (conventional and non-conventional) were identified at both a regional and a national level. For the first time in this type of study in Tunisia, a geographic information system (GIS) was developed and used to identify and localize where water resources were located and used. The GIS was connected to numerical databases and simulation and optimization models. Thus it enabled a review of the water management system under diverse planning scenarios and over different geographic areas. The optimization models that were developed based on dynamic stochastic programming enabled the assessment of the performance of the existing and projected future water system. The models calculated fluctuations in both resources and consumption at varying scales and using various assumptions. By combining the relational database with the GIS assessments of the supply/demand balance, models were drawn up to determine the likely instances of over- and undersupply going forward in time and on a regional basis. Based on these results and on statistical analysis, a critical load scenario was developed to serve as the basis for determining future measures to be taken. From there, measures were defined that would enable identified shortfalls to be made up or reduced and their economic costs and environmental impacts to be evaluated. The specified measures were organized by timing and location in the form of a series of alternative strategies from which a national water management strategy would be derived.

The second information system is the agricultural map of the country, which was completed in 2004. This map is in fact a series of regional maps, which give an overview of the agricultural area of each governorate, its resources, development potential, and strengths and weaknesses. The agricultural was combined into a GIS, comprising close to 50 levels of geographic data. The maps have the following objectives:

- To ascertain in a reliable and dynamic manner the status of a particular location regarding natural resources (land, water, forests), basic infrastructure (hydraulics, transport), and economics (processing, refining, and harvesting facilities for agricultural products)

- To ascertain the status of land allocation regarding the outcome of technical and economic decisions of operating production systems
- To identify the gap between the current and optimal land use, by comparing the land use map with the agro economic potential map
- To simulate and spatially visualize decision-making scenarios based on the modification of a certain number of parameters, such as cost of entry, production prices, yields, and incentives.

The third information system is the National Water Information System, known by its French acronym as SINEAU. This is still being completed and is expected to be publicly available. It combines three different water information systems, one on ground and surface water, one on water pollution and one on soil quality. The SINEAU links these three using a horizontal system of reference and a unified spatial location. It will establish standards for describing data and sharing it with different stakeholders as well as a system for managing and referencing the relevant data.

Over the past three decades, Tunisia as developed a significant amount of water infrastructure aimed at meeting its ever-increasing demand for drinking water and for irrigation right across the country. Storage or transfer facilities, situated primarily in the north of the country, have been designed to respond to regional requirements. Decisions regarding the type and size of these facilities and the manner of their use were guided by a number of key constraints:

- The geological nature of the landscape. This constraint led decision makers to come up with different types of facilities (multiple-arch concrete dams, buttressed dams, single-arch dams, gravity dams, compressed rolled concrete dams).
- The lithology of the landscape. Through which the water flows naturally guided the conception of certain facilities and the way in which they are managed. In the Mejerda basin (the largest basin in northern Tunisia) several Triassic outcrops are largely responsible for the water's increased salinity. These outcrops exist exactly on the sites chosen for the dams (which have the best topographical features). Thus, the outcrops have influenced decisions regarding the height of the facilities and, as a result, the volume of water held behind the dam (Sidi Salem is a case in point).
- The location of demand. Most water consumption takes place in different locations from where the water is available, making transfer systems inevitable.
- Hydrological analysis. Hydrological analysis of the country's different catchment areas shows a high level of heterogeneity from the point of view of both water quality and regularity of natural supply. In addition, the level of water shortage does not have the same impact on the four large neighboring basins. The impact is felt much more acutely in the Mejerda basin in the north of the country.

This network of facilities had two purposes: To respond to different usage priorities and to enable the flexible management of this network. To ensure that water quantity is available in the place and at the time required and to improve water quality through dilution, the infrastructure was planned using three guiding principles:

a. Allowing inter-annual storage to enable supplies to be regularized from year to year, taking into account the historical frequency of occurrence of years of drought (including repeated droughts).

b. Creating interconnected dams situated in the same catchment areas to so that the system can capture any overflows of the dams in wet years
c. Allowing water to be transferred from dams in one catchment to dams in another to both balance stock levels in periods of regional drought and improve water quality in particular reservoirs.

From a hydrological point of view, the initial conception of the detailed Northern Water Plan was based on a series of monthly supply observations over 34 years. The average supply figure served as a reference point for deciding the size of the facilities.

After these water facilities had been in operation for a number of years, several complementary steps presented themselves as potentially useful for improving the system's performance. These actions centered around four key points:

- To minimize the effect of cyclical droughts and to take advantage of the years of excess rainfall, 11 other sites for medium-sized dams have been identified and earmarked for construction in the medium term. Although the water supply from these dams was taken into account when the original dams were designed, these facilities will fill up primarily during rainy years. These medium-sized structures also will safeguard the large dams from excessive silting.
- To raise the height of specific existing facilities to increase their storage capacity and offset the effects of progressive silting.
- To create small hydraulic subsystems at a local level. This idea spawned and governed the elaboration of a national strategy of water mobilization via hillside dams (structures fewer than 10 meters high with a storage capacity of fewer than 5 million m^3). These facilities lengthen the active life of the major water facilities and enable the creation of smaller local development centers. The total number of these facilities in existence is 225 units. They make available 200 million m^3 of water.
- To extend the geographic range of these transfer systems. This extension was a key component of the second phase of the national water usage strategy. It basically enabled the establishment of an integrated WRM structure (covering the use of both surface and ground water resources).

The hydraulic system for surface water in Tunisia was conceived essentially for the northern part of the country as shown in Figure 3. In the system, 13 linked dams already are in place, and an additional 14 should be online by 2015, for a total of 27 interconnected dams. Their configuration is based on the fact that water demand can be divided into two basic demand categories, depending on the number of reservoirs that supply it: "local" or "shared." Local demand sources its water from one specific reservoir, whereas shared demand is supplied by more than one reservoir. Tables 6, 7 and 8 give details of the reservoirs and the areas that use the water from those reservoirs as well as of the transfer schemes. Where the dam serves more than one area, this is shown in bold type in Table 6

Table 6. Tunisia's Reservoirs and Associated Demand (Number)

Dam	Bou heurtma	Ben Metir	Joumine	Kasseb	Lakhmess	Mellegue	Rmil	Sidi El Barrak
No. of areas served	5	3	7	1	1	3	1	2

Dam	Sejnane	Siliana	Sidi Salem	Zerga	Zouitina
No of areas served	6	1	18	1	2

Source: Louati, 2005: Optimization of management rules for multiples reservoirs considering risk

7. Tunisia's reservoirs that serve multiple uses

	Sejnane	Joumine	Ben Metir	Mellegue	Bouheurtma	Kasseb	Sidi Salem
Irrigation Ben Arous and Nabeul	X	X					X
Bizerte (drinking water)	X	X					
AG02				X	X		
Grand Tunis (drinking water)	X	X	X			X	X
Cap Bon (drinking water)	X	X	X				X
Sahel and Sfax (drinking water)	X	X					X

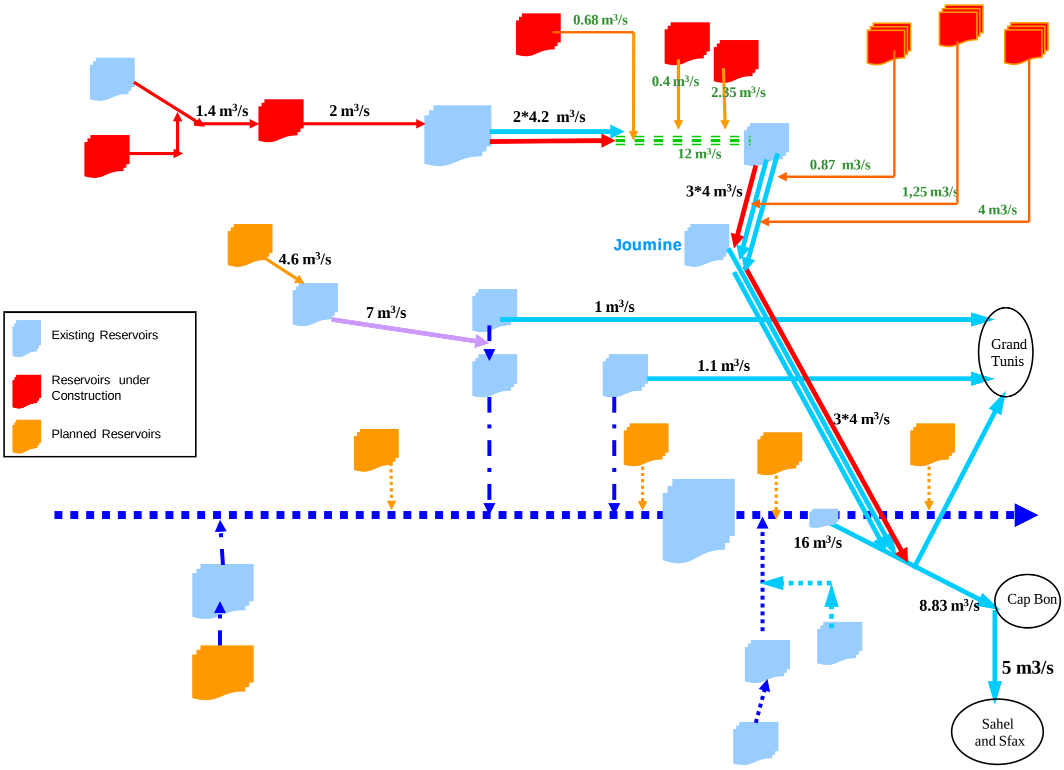
Source: Louati, 2005: Optimization of management rules for multiples reservoirs considering risk

Table 8. Tunisia's Main Water Transfer Systems and its characteristics

Name of structure	Length (km)	Flow(m3/s)	Diameter (mm)
Pipelines from Sidi El Barrak-Sejnane	18 km over 2 lines	4 to 4.6 m3/s per line	1800 mm
Pipelines from Sejnane to Taref station	13 km over 2 lines	12 m3/s	1800 mm
Pipelines from Taref station to Sidi M'barek	23 km over 3 lines	12 m3/s	1800 mm
Piplelines M'barek-Bejaoua	47 km over 3 lines	12 m3/s	1800 mm
Mejerda Cap Bon canal	120 Km	16 to 8.8 m3/s	
Ben Metir pipeline	135 km	1.3—1.1 m3/s	1250 mm
Kasseb pipeline	121 km	1.1—09 m3/s	1190—1250 mm
Belly-Sahel pipeline: -Belly-Sousse -Sousse-Sfax	96 km (2 files) 118 km	1.5—2.3 m3/s (1st file) 3.6 m3/s (2nd file) 1.35 m3/s	1400—1200 mm 1600 mm 1400—1000 mm
Jilma-Sfax pipeline Sbeitla-Sfax pipeline	151 km 148 km	0.73 m3/s 0.3 m3/s	1100—600 mm 600—325 mm
Pipelines from Kairouanais -Sidi Saad dam -El Haoureb dam -El Houareb -S.Saad (projected)	18 km right bank 10 km left bank 12 km 24.8 km	1.935—1.5m3/s 0.5—0.335m3/s 1.0 m3/s 1.0 m3/s	1600—1250 mm 600—400 mm 1000—300 mm 1100 mm
Nebhana pipeline	126 km	2.1—0.350	1400—600 mm

Source: Ministry of Agriculture and Hydraulic Resources: "Water Conservation 2000": Resource assessments, requirements and strategy for water management

Figure 3. Scheme of existing and planned infrastructure to Mobilize and Transfer Tunisia's Surface Water Resources



Source: Ministry of Agriculture and Hydraulic Resources - GTZ, 2004: Guide Plan Concerning the Implementation of Real-Time Water Resource Management; Project to optimize management of water resources.

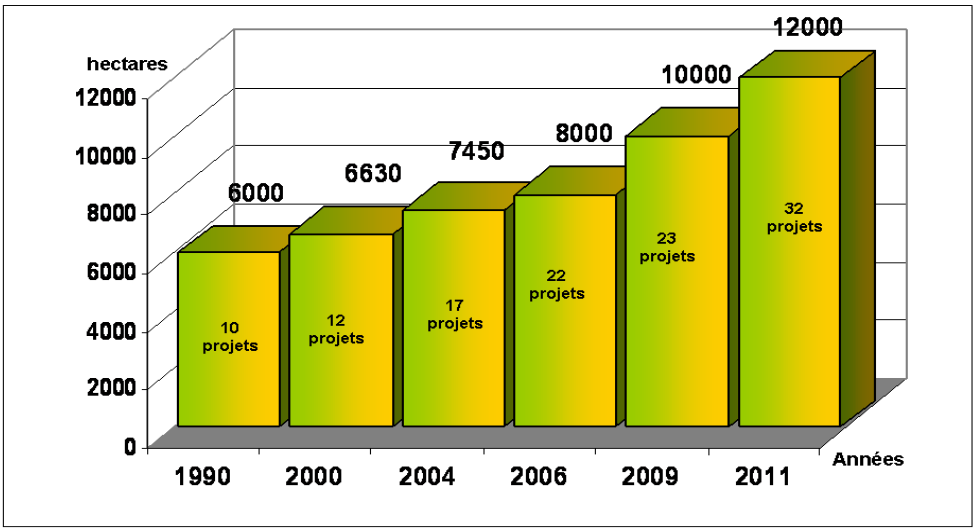
Non-conventional Water and artificial aquifer recharge

To supplement its scarce natural supplies, Tunisia has a long experience of generating *non-conventional water* and of innovative investments. The experience in reuse of treated wastewater, desalination of salt and brackish water and in artificial recharge of aquifers are instructive and indicate a concern for an integrated management of the entire water cycle.

Since the 1970s Tunisia has been formally *re-using treated wastewater* in agriculture and now has one of the world's highest rates of re-use. Almost all of Tunisia's 194 million m^3 per year urban wastewater generated is treated to adequate standards.[3] Around thirty percent of it is used in agriculture supplying around 7,000 ha of fruit trees and fodder, following strict sanitary standards. Experience indicates difficulties ensuring cost-recovery for this type of water, and the service is subsidized at present. The country plans to invest in significantly increasing that share over the next decade (see Figure 4). In addition, Tunisia uses treated wastewater for environmental purposes, in one case using it to ensure flows to an ecologically important wetland.

[3] National Sanitation Office (ONAS), Data from 2004.

Figure 4: Growth in treated wastewater used in agriculture, Tunisia



Source: Ministry of Agriculture

Despite being a country not endowed with energy resources, Tunisia also has experience with *desalination of brackish and saline water*. In the south, an important volume of brackish groundwater represents a potential source of useable water. The authorities have been able to use reverse osmosis technology to convert this into drinking water. Desalination began in 1983 in Tunisia. The national agency responsible for drinking water, SONEDE, has capacity of 58,800 m^3 per day, as shown in Table 8. Private operators have an additional capacity of 44.000 m^3/jour, mostly for tourism, although with some capacity in industrial enterprises and high-value agriculture.

Table 8. Desalination Capacity in Tunisia

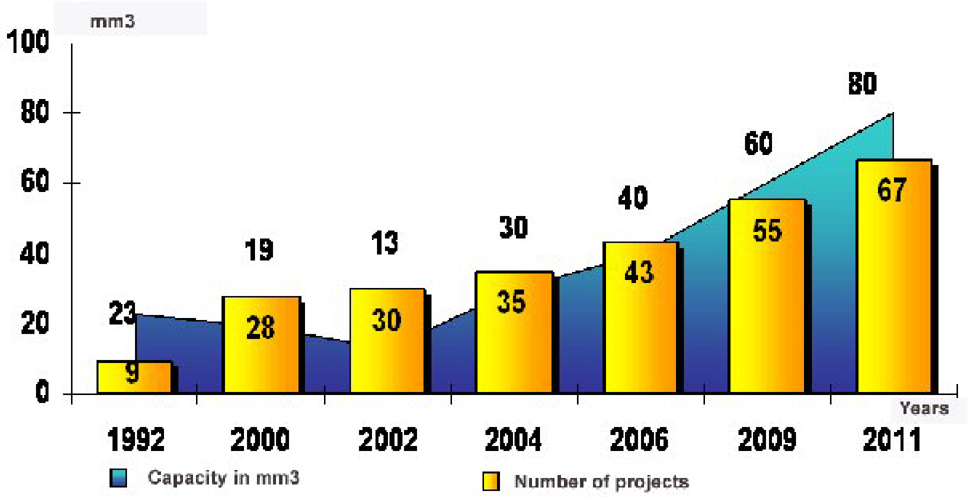
Station	Capacity (m3/day)	Year operation started	Technologie	Feed water (g/l)	Number of membranes
Kerkenah	3300	1983	Reverse osmosis	3.6	144
Gabes	25500	1995	Reverse osmosis	3.2	1188
Zarzis	15000	1999	Reverse osmosis	3.2	1188
Jerba	15000	2000	Reverse osmosis	6.0	756
Total	**58800**				**2844**

Source : SONEDE , MARH 2004

The government subsidizes the private sector to invest in desalination and considers this technology a key part of the long term water management strategy for the country. It plans to increase public sector installed capacity to 50 million meters cubed per day by 2030.

In addition, the country has long experience of *artificial groundwater recharge*. This is a way to use the surplus water from one season to store the water for use during dry periods. The program described above of construction of small dams also included some spate irrigation infrastructure which channels flood water. In addition to helping manage surface water flows, these two types of investment had a major impact on aquifer recharge (see Figure 5). Furthermore, Tunisia has projects using quarries, old wells and direct injection to increase aquifer recharge including in some cases recharge with treated wastewater. To avoid potential contamination, these schemes are usually towards the mouth of the aquifers. One trial scheme uses treated wastewater at the mouth of the aquifer to protect against saline intrusion. The government plans to increase the volumes of artificial aquifer recharge to more than 200 million m3 per year in 2030 through small dams, check dams and soil and water conservation investments in upper watersheds.

Figure 5. Growth in volumes and schemes for artificial aquifer rechagarge in Tunisia



Source: LOUATI M.H., 2008: Blue Plan, Efficiency of water utilization, national studies—the case of Tunisia

Use of Water Resources

The irrigation sector consumes close to 80 percent of Tunisia's water that is extracted. The sector now uses approximately 2 billion m^3 per year and demand should stabilize at 2.1 billion m^3 by 2010. The lack of good-quality water is becoming increasingly acute in the wake of unpredictable climate patterns and the lower performance levels of the irrigated sector. Thus the country needs to find a way to better maximizing the value of the water allocated to the agricultural sector is required.

Tunisia has about 420,000 ha of land that could potentially be irrigated through both public and private schemes of which 400,000 is actually irrigated. The government's strategy aims to serve these lands with water, assuming the water is available, by 2010 using the different policy and investment elements in the strategy. Water conservation constitutes a key component of Tunisia's long-term strategy. A technical, economic, organizational, institutional and legislative framework has been set up to maximize the country's irrigation potential and to supply drinking water as efficiently as possible.

Groundwater extraction has increased continuously since 1997, rising from 2,161 million m^3 to 2,638 million m^3 in 2006—an increase of approximately 26 percent over 15 years (see Table 9). Yet withdrawals are becoming unsustainable, while exploitation of deep groundwater is increasing slowly because of the strategic nature of the resource and the very limited recharge. In contrast, there is potential for more or better use of surface water. In rainy years, farmers demand relatively small quantities of water but much more in dry years. However, in the last decade, overall usage rates of surface water have been low.

Table 9: Tunisia evolution of water consumption (mm^3)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Surface water	399	361	445	499	248	561	510	464	688
Groundwater	757	764	771	778	778	778	778	778	807
Deep groundwater	1005	1014	1031	1078	1119	1135	1109	1127	1143
Total	**2161**	**2139**	**2247**	**2355**	**2145**	**2474**	**2397**	**2369**	**2638**

Source: DGRE- Ministry of Agriculture and Hydraulic Resources, 2007: Directory of exploitation of deep aquifers. DGRE- Ministry of Agriculture and Hydraulic Resources, 2007: Directory of exploitation of shallow aquifers.

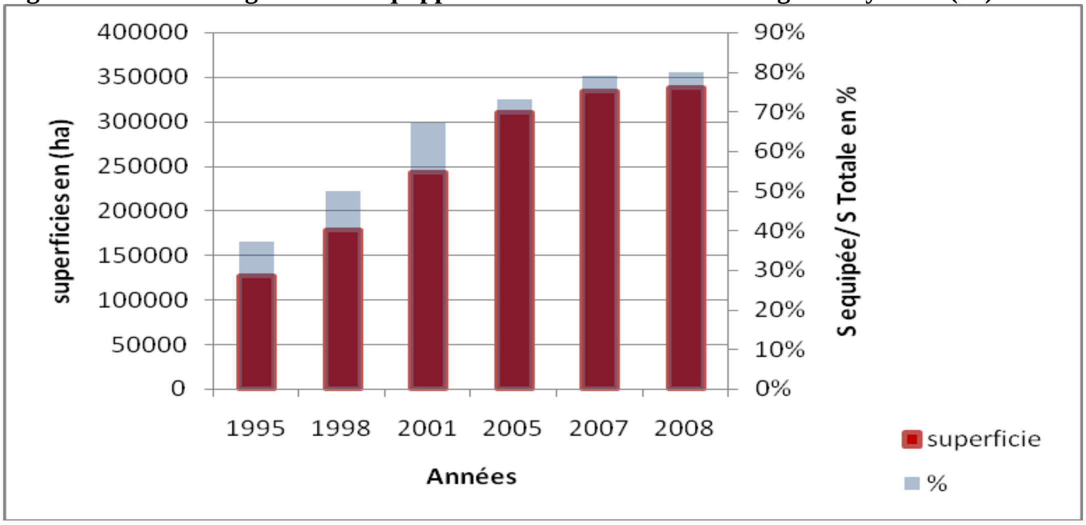
Since the end of the 1980s, average consumption of water per ha of irrigated land has shown a net decrease. Since the introduction of conservation measures across irrigated areas, specific consumption per ha has begun to decline sharply, falling from 6,200 m^3/ha in 1990 to approximately 5,500 m^3/ha in 2005.

In 1995 Tunisia's water administration adopted a National Program of Irrigation Water Conservation (PNEEI), which aimed to rationalize the use of water in all sectors, in particular, reserves of drinking water and irrigation, to ensure that the maximum economic value is derived from irrigation and to keep water demand at a level compatible with available resources, which are considered insufficient to guarantee the sustainability of these resources. It has the following broad goals

- Reinforce knowledge of adapted technologies to ensure optimal water use
- Ensure that regional services have a better grasp of techniques and methods that are adapted to local conditions to conserve irrigation water
- Encourage consumers to adopt water conservation methods and techniques
- Make available to citizens the knowledge and technical support required for them to put these techniques into practice,
- Rapidly extend the introduction of on-farm water-saving equipment; transfer public irrigated areas (PPI) to agricultural development groups (GDA) under appropriate operating conditions.

In irrigation the program provides a subsidy for installation of efficient on-farm equipment for 40 percent, 50 percent, and 60 percent of the investment cost, depending on the category of agriculture. The program aimed to install efficient on-farm irrigation equipment on 90 percent of Tunisia's 400,000 ha of irrigated land by 2006 and improving irrigation efficiency to a level of at least 75 percent by the end of 2006. As of June 2006, the irrigated area with conservation systems in place (upgraded gravity irrigation, sprinkler irrigation, and drip systems) covered close to 310,000 ha, representing 75 percent of the total irrigated area. The implementation rate has been running at 15,000–25,000 ha per year. Figure 6 shows the take-up of the irrigation systems and Figure 7 shows how water allocations per hectare have been changing.

Figure 6: Tunisia irrigated area equipped with efficient on-farm irrigation systems (%)



Source::DGGREE- Ministry of Agriculture and Hydraulic Resources, 2007: Report on the preparation of the Investment Project in the Water Sector.

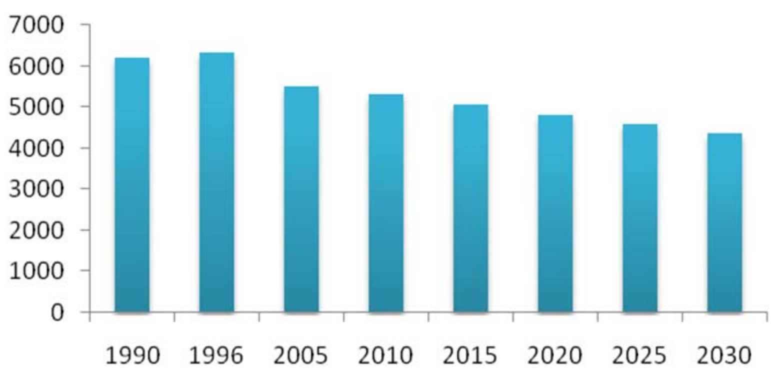
The breakdown according to irrigation method is:

- 98,000 ha of drip irrigation (or 21.6 percent of the total irrigable area)
- 106,000 ha of sprinkler irrigation (26.7 percent)
- 106,000 ha of upgraded gravity irrigation (25 percent).

Drip irrigation accounts for close to 25 percent of the total irrigable area, whereas it accounted for just 3 percent in 1995.

Regional action plans have been put in place by the Regional Agricultural Development Commissions with a goal of covering 100 percent of the irrigated area by 2009. The implementation of the water conservation program in irrigated areas is expected to cause a continued decline in consumption per ha in the coming decades, falling to a level close to 4,000 m^3/ha by 2030.

Figure 7: Evolution of mean water allocations per irrigated hectare *(m^3/ha)*



Source: DGGREE- Ministry of Agriculture and Hydraulic Resources, 2007: Report on the preparation of the Investment Project in the Water Sector.

The National Authority for Water Exploitation and Distribution (SONEDE), the operating body tasked with producing and distributing drinking water, has set up a strategy aimed at ensuring judicious water usage by both public and private facilities and institutions. The changes in water allocated to SONEDE are shown in Table 10 below.

Table 10: Evolution of production and consumption of drinking water(mm^3)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production of drinking water	309	317	326	337	346	373	373	394	403	420	439	453
Consumption of drinking water	230	247	258	272	285	301	297	306	315	339	340	348
Specific consumption (liters consumed and billed/day/ inhabitant connected to the system)	65	68	69	71	73	75	75	75	76	78	80	82

Source: SONEDE, 2008: Statistics on SONEDE's water production since 1994, databases.

Payment rates for drinking water gradually are moving to a point at which they will completely cover running and financing costs, plus a significant portion of equipment costs. The current coverage is approximately 87 percent.

Irrigation payment rates have improved considerably in recent years. However, these rates still do not factor in O&M costs incurred in the production and distribution of water. The costs of initial investment, infrastructure maintenance and major repair work, plus financing fees are still borne completely by the state. As a result, the overall payment rates run the risk of being well below average costs. Furthermore, the operating costs do not take into account the capital or operating costs of the bulk infrastructure nor the value of the resource itself.

Complementary Measures Undertaken and Policies Adopted

Regulatory Measures

The wording of laws relating to investment incentives, the legislative and regulatory framework aimed at promoting investment, and the rationalization of the water management system have been the object of several reforms focused on the water sector in general and water conservation in particular. The Water Code was promulgated in 1975. Particularly its articles 12, 15, 16, 86, 102, 106, 90, and 96 relating to resources, planning and development, tariff rates, and reuse and conservation of water were modified and completed by new laws in 1987, 1988 and 2001.

Technical Measures

In addition to the mobilization programs that have been put in place, significant initiatives aimed at improving the efficiency of communal irrigation and drinking water networks have been set in motion. The three main results of these initiatives follow:

1. The water conservation project in small and medium-sized water-consuming areas in central Tunisia aims to restore and modernize public networks, promote on-farm water-saving equipment, and transfer the management of these operations to farmer groups (known by their French acronym as GICs). This project covers 11,000 ha of irrigated land at a cost of 24 million dinars.
2. The project to improve irrigated areas in the Southern oases that encompasses 23,000 ha. The project aims to to make earthen canals more watertight by constructing concrete canals or laying underground PVC piping and to install a drainage system to remove excess water and leach salts.
3. The modernization project in the old irrigated areas of the Lower Mejerda Valley, which is underway. The project aims to modernize an initial 4,300-ha portion of the old irrigated areas, of a total surface area of 27,000 ha.
4. The water conservation program concerning public drinking water networks and facilities has several components. They include installing new means of metering and regulation, tracing leaks, renovating meters and dilapidated connections, and regulating pressure in the system.

Measuring the volume of water produced and distributed plays a key role in water management. The government’s strategy is to equip every hydraulic system with an appropriate means of measurement and to divide the networks into sections through the installation of local metering systems. This consistent coverage with meters will ensure an effective mechanism for tracing leaks. As of 2007, all the reservoirs producing drinking water were equipped with either meters or means of measuring outflows.

Metering policy is centered on three key initiatives. The first consists of replacing jammed meters to reduce or even eliminate the need to issue pro-rata bills, ten replacing unclassified meters. The second is rehabilitating degraded connections and networks by replacing dilapidated pipes and fittings to reduce leaks. In 1998 SONEDE began inventorying these connections (329,000 in total) and scheduled their replacement within 10 years. The proportion of water consumers served by degraded connections fell from 24 percent in 1998 to 6 percent in 2007. The third initiative involves resizing meters to bring them up to the necessary capacity. Regulation at the water system level consists of equipping the drinking water supply systems (gravitational or reversed-flow) with the appropriate means of regulation (cut-off valves, ballcocks, altimetric water gates, and pilot lines, radios) to avoid wasting water through overflows and leaks. Leak detection uses either correlation or the acoustic method. Part of this detection work is done in-house following a pre-established program; part is subcontracted. During 2007, some 8,300 km of the distribution network were inspected, and 2,011 leaks or broken pipes were detected—equivalent to one leak or breakage every 3.3 km. Table 11 shows the scale of investments in improving leak detection and metering for drinking water.

By 2007, 96.6 percent of supply systems (gravity and reverse-flow) had been fitted with suitable means of regulation. In addition to preventive maintenance work, in 2007, 35 new regulatory equipment systems were installed. The government intends to equip all drinking water supply systems with a suitable means of regulation.

Table 11. Number of water supply meters replaced or improved (meters)

Year	2004	2005	2006	2007
Number of meters jammed repaired or replaced	41134	37586	34267	51082
Number of degraded meters replaced	71 232	40 727	16 349	9 611
Number of meters resized	1419	1671	578	316

Institutional Measures

Tunisia's experience of self-management of communal water systems goes back to the 1900s, during which user-owner associations were created. Among these associations were the irrigation syndicates created between 1901 and 1906 to exploit the water of the wadis in central Tunisia. Examples are the irrigation syndicate at the Sbiba wadi, created in 1901, and the irrigation syndicates at the Zroud and Marguellil wadis, which were created in 1906.

Between 1912 and 1919, owner associations were created to develop the southern Tunisian oases. In 1987 the aforementioned associations of owners and consumers were converted into communal interest groups. Their function was to develop public water resources; construct, maintain, and use public water works; irrigate and decontaminate farmland; and develop drinking water supply systems.

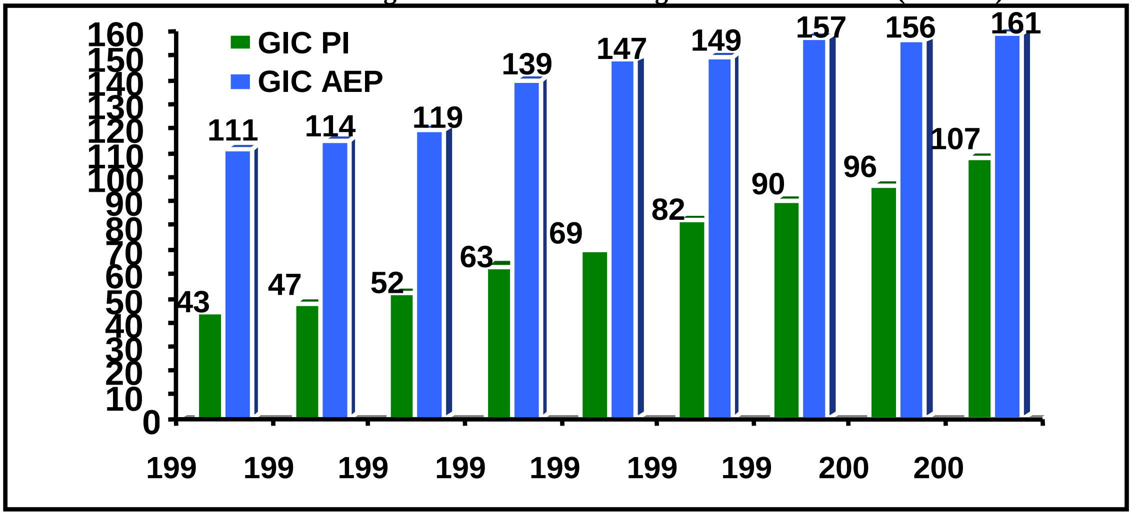
Regional committees to assess and ensure the implementation of the water conservation program were set up in March 1992 at the regional administrative level (Regional Offices for Agriculture Development, known by their French acronyms as CRDAs). Inaugurating the committees coincided with the launch of a program of training and promotion of water conservation in the irrigation sector. Regional strategies and a water conservation assessment and implementation system at a national level have been in place since 1993.

In 1987 the management of all drinking water supply systems and of borehole irrigation on public land was transferred to the GICs. In 1988 the GIC program was extended to public land irrigated by large dams. By 2001 the program covered 124,000 ha spread across a dozen governorates. The aim was to eliminate the then-"duality" in the management of public irrigated land. Areas irrigated by boreholes were run by the associations, but large areas serviced by major dams were still under public control. Through the efforts of the CRDAs, 50,000 ha of the land irrigated from the large dams were transferred to the control of the GICs before 2001, equivalent to 40 percent of the total area. From 2001–05 an additional 25,000 ha were transferred to farmer management. By the end of 2005, public areas serviced by large dams whose control was transferred to the GICs reached 75,000 ha. These public areas accounted for 53 percent of the total area of GPPIs in Tunisia, which in 2005 stood at 141,000 ha.

In 2001 PISEAU (Water Sector Investment Project) got underway to mobilize the regional bodies to transfer the management of the irrigation land to farmer groups (whose name had changed to agricultural development groups, known by their French acronym as GDAs). The project financed 10 technical assistance initiatives in 8 of the country's governorates to transfer 31,000 ha of the land irrigated from the large dams to GDAs and to reinforce the capacity where GDAs were already in place (16,000 ha).

Separately, a technical assistance project for the GDAs in areas irrigated by boreholes also was implemented, again to encourage water conservation in Tunisia's small and medium-sized irrigated areas. This 7-year project (1999–2006) involved approximately 60 GDAs and cost roughly €1 million. Two additional TA projects were put in place to strengthen the technical capacity of the regional services and of the GDAs involved in the supply of drinking water. The first to be launched began in 1997 and was due to conclude in 2008. It covered approximately 800 drinking water GICs spread across 8 governorates. The second initiative due to last 5 years (2006–10) aims to boost the technical capacity of 160 drinking water GICs located in an additional 17 governorates. The evolution of the transfer of the management of irrigated land to GDAs is shown in figure 8**.**

Figure 8: Evolution of Transfer of Management of Tunisia's Irrigated Land to GDAs (number)



Source: DGREE- Ministry of Agriculture and Hydraulic Resources, 2006: Statistics concerning communal interest groups in the irrigation sector and drinking water in rural areas.

Performance Indicators

Several types of indicators have been adopted to evaluate the water resource mobilization and management programs that have been set in motion. Efforts have been make to overcome the irregular nature of the country's available water resources by constructing dams that guarantee the security of annual supply. The effectiveness of the dams at regulating the flow is measured by the calculation of a Regulation Index (as shown in Table 12). This indicator is defined as the relation between the sum of the irregular water flows that are offset by the water stored within the dams (on an annual average basis) and the average yearly irregular flows (internal and external).

Table 12: Evolution of effectiveness of dams at regulating irregular flows (mm^3)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Average annual irregular flows (Mm^3)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Regularizable irregular flows (Mm^3)	1342	1342	1342	1647	1647	1647	1647	1652	1660	1682
Regularized irregular flows Mm^3)	1030	1228	1221	1316	1292	1300	1465	1521	1601	1587
Regulation index *(%)*	49,05	58,48	58,14	62,67	61,52	61,90	69,76	72,43	76,24	75,57

Source: Ministry of Environment and Sustainable Development, 2007

The development of water resources thus is evaluated according to an index that measures the relationship between the pressure relating to annual withdrawals of water (P) on conventional, renewable natural resources of soft water (R) as shown in Table 13. Annual withdrawals of conventional, renewable natural water for all uses include losses incurred when the water is transported. “R” denotes the average annual flow of conventional, renewable natural water. This flow corresponds to the renewable water resources available annually for consumption.

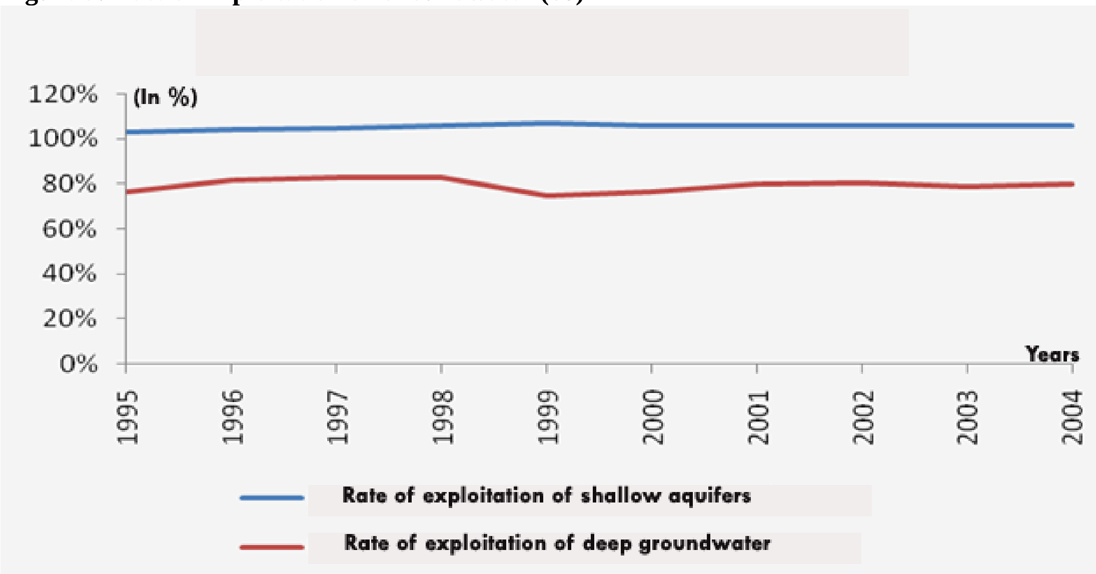
Table 13:. Evolution of rate of exploitation of water resources in Tunisia

	1997	1998	1999	2000	2001	2002	2003	2004
Withdrawals of renewable underground water (million m^3)	1098	1117	1137	1184	1206	1230	1207	1216
Withdrawals of surface water (million m^3)	399	361	445	499	248	561	510	464
Available renewable underground resources (million m^3)	1273	1284	1432	1423	1408	1408	1430	1498
Available surface resources (million m^3)	1030	1228	1221	1316	1292	1300	1465	1521
Index of total exploitation of renewable resources	**65,00%**	**58,84%**	**59,63%**	**61,45%**	**53,85%**	**66,14%**	**59,31%**	**55,65%**

Source: National Statistics Institute and Ministry of Agriculture and Water Resources.

The rate of groundwater exploitation is consistently above 100%, while for deep groundwater it is on the increase; while it hasn’t yet reached the level indicated when it potential was upgraded in 1999, it is currently at about 80%. This is shown in Figure 9.

Figure 9: Rate of Exploitation of Groundwater (%)

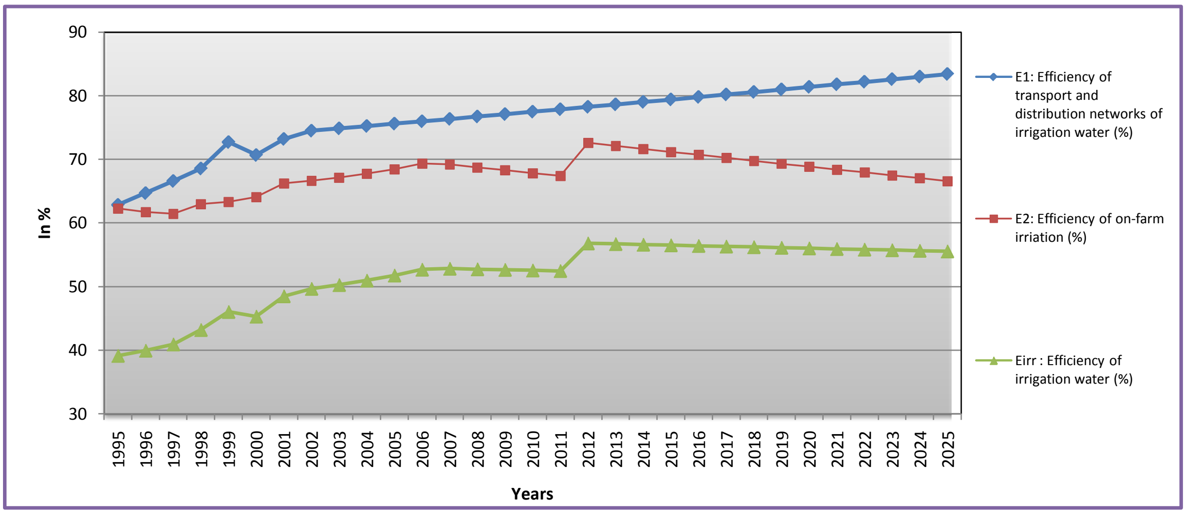


Source: DGRE- MARH, 2004

The system for evaluating and monitoring water conservation, along with a land survey carried out in 2001 based on certain techno-economic development indicators, has enabled a mid-term assessment of the National Water Conservation Program. The results confirmed both its effectiveness and its economic viability in the agricultural sector. In particular, the results of the evaluation show an extremely dynamic response from the key development players that has led to a significant increase in the area of land equipped with water conservation systems. Promotional campaigns using a variety of means of communication have contributed greatly to water conservation in irrigation.

The growth in efficiency of the irrigation sector, as measured from 1994 to 2007 and projected to 2025, is shown in figure 10.

Figure 10: Growth in Efficiency of Tunisia's Irrigation Networks *(%)*



Source: M.H. LOUATI, 2008: Blue Plan, Efficiency of water utilization, national studies—the case of Tunisia.

The overall yield of the water systems reached 77.3 percent in 2007, with distribution networks reaching 83.4 percent and conveyance networks 92.2 percent.

Table 14 tracks the evolution of average yields for drinking water systems between 1997 and 2007. The overall network yield slipped from 78.2 percent in 2006 to 77.3 percent in 2007, equivalent to a drop of 0.9 percent. This fall resulted from a 0.5-point drop in yields from conveyance (92.2 percent in 2007 and 92.7 percent in 2006) and a 0.6-point drop in yields from distribution networks (83.4 percent in 2007 vs. 84 percent in 2006).

Table 14. Evolution of Average Yields for Drinking Water Systems in Tunisia, 1997–2007. (mm^3)

Designation	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Volume consumed	246.7	256.9	271.6	285.1	301.3	297.4	305.8	313.9	327.3	340.1	348.1
Service plant volume (Vss)	0.8	0.169	0.705	1.665	1.65	1.537	1.142	1.062	1.785	2.486	3.492
Conveyance plant volume (Vsa)										1.6	0.026
Volume of briny water (Vsm)	1.9	2.324	3.597	5.328	5.08	5.058	5.561	5.9186	5.3	5.9	6.9196
Plant entry volume (VES)	321.7	329.67	342.95	357.25	380.13	380.01	400.52	410.03	427.1	447.59	463.78
Overall network yield (Rg) *(%)*	77.5	78.7	80.4	81.7	81.0	80.0	78.0	78.3	78.3	78.2	77.3

Source: SONEDE, 2008: Statistics on sonede's water production since 1994, databases.

To gauge the efficiency of transfer networks, the transfer network yield is calculated (. In 2007 this yield figure reached **99.5** compared with 92.2 for the conveyance networks and 83.4 for distribution networks.

Conclusions and Recommendations

The inevitable future challenge facing Tunisia is the necessity to develop its capacity to conserve and derive maximum benefit from its limited water resources. Conservation will be far more productive than looking for ways to secure new reserves. The substantial future economies that will be required will have to come from the major water-using sectors, among them agriculture, which consumes almost 80 percent of Tunisia's available water resources.

Tunisia's future envisages water shortages exacerbated by more frequent droughts and climate change. Consequently, water supply management increasingly must improve the operation of the hydraulic infrastructure and harness technology to make optimal use of existing resources.

Beyond direct improvement to the efficiency of water usage in irrigation, the creation of new irrigated areas is worth examining in the context of a macroeconomic strategy with due regard to realistic assumptions about economic viability and taking into account future water demands.

Technical considerations apart, the implementation of a demand-based water management strategy will advance the case for an adequate readjustment of the institutional instruments in the water sector.

Studies of Tunisia's water management system often highlight gaps or weak points in the system, particularly in planning and operations that relate primarily to private consumers. The political tendency favors *participatory management*. Thus, all levels of the administration have made great efforts to help the farmer organizations (GICs/GDAs) to take control of operating and maintaining their water distribution facilities. It is important that regulatory texts reflect this trend toward greater participation by the beneficiaries/stakeholders. General water management planning and the nature of its implementation will see improved performance with increased participation of the principal customers.

In this regard, serious thought needs to be given to the ways in which these customers can be brought in to participate in defining Tunisia's water management policy and strategy. New mechanisms need to be drawn up and set in motion to institutionalize the participation of different consumers in the water management system in Tunisia at the most important stages of planning and operation.

Increasing consumers' participation in the water management system should enable projects to be planned and managed based on genuine knowledge of the needs and constraints of both parties—the state, which holds the resources and guarantees their continuity; and the consuming groups, who are responsible for the viability and sustainability of their own activities.

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