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WATER GLOBAL PRACTICE

Securing Potable Water Supply under Extreme Scarcity

JUNE 2018

Philippe Marin,
Bambos Charalambous,
and Thierry Davy

Lessons and Perspectives from the Republic of Cyprus

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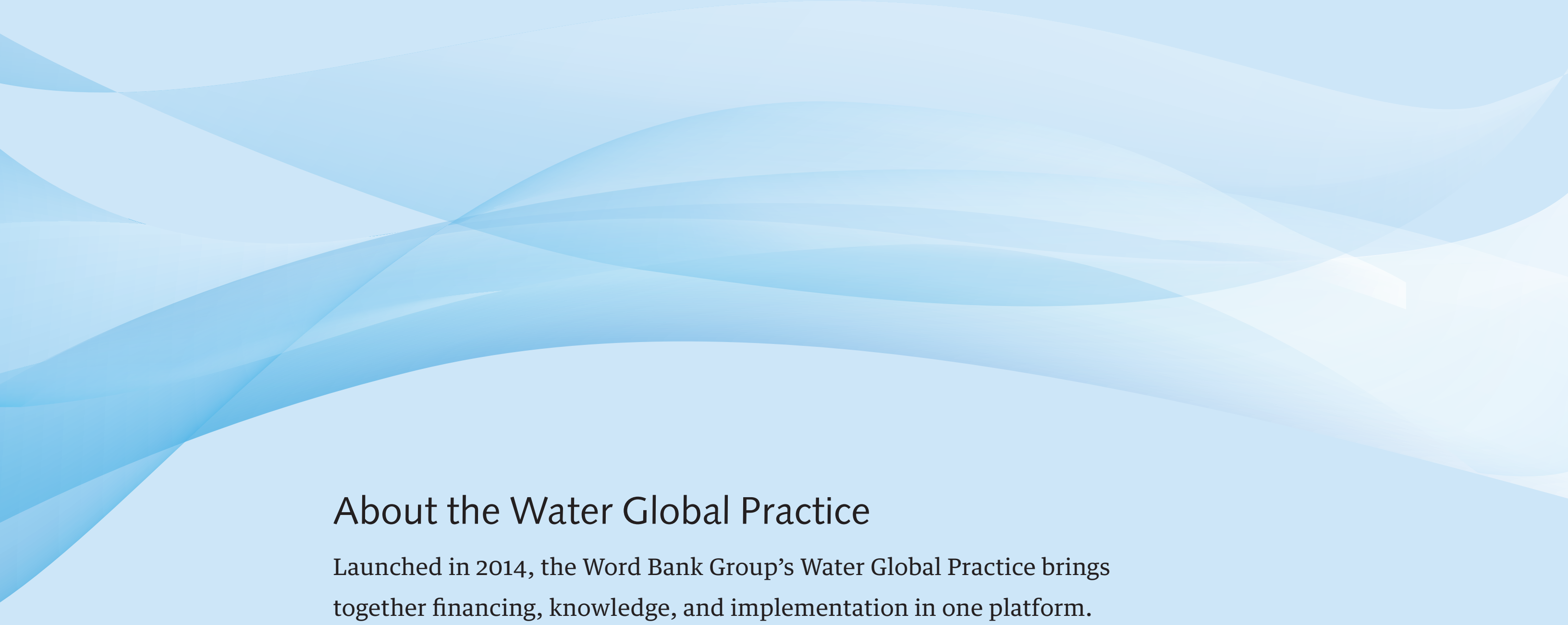

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Το νερόν εν το γάλα της γης τζαι χαράς’ τον που το έσιει
“Water is the milk of earth, and blessed is the one that has it.”

Introduction

The objective of this report is to document the key achievements and lessons learned from the water management experience of the Republic of Cyprus, for the benefit of other countries around the world facing increasing challenges in dealing with water scarcity, in a context of climate change.

Over the past decades, the Republic of Cyprus has managed to achieve **potable water security despite extreme water scarcity, in particular with the massive development of nonconventional water resources (desalination and wastewater reuse) under public-private partnership (PPP) schemes.** In a global context of climate change and increased water stress, **this experience holds valuable lessons for many other countries around the world.** While focusing on potable water security, the report will also address other aspects of water management under scarcity, including irrigation and groundwater management, and the special experience of Cyprus in applying the EU water legislation under extreme water scarcity.

Considering the peculiar geopolitical situation of Cyprus (with the *de facto* partition of the island since the 1974 invasion of the northern part by the Turkish army, and subsequent displacement of populations), **this report focuses on water management in the areas under government's control**—that is, the southwestern part of the island, which represents 60 percent of the territory with a permanent population of about 850,000 people belonging mostly to the Greek Cypriot community. It does not address water management in areas outside of the government's control, though a brief snapshot of the situation there is provided in box 4.1, at the end of the concluding chapter of the report.

The report has been structured around four successive chapters:

- **The first chapter provides an overview of the water resources in Cyprus,** highlighting the situation of extreme water scarcity and presenting the key institutional players.
- **The second chapter analyzes in detail how potable water security was achieved in the Republic of Cyprus.** It presents how all rainwater was captured in a first phase through massive infrastructure investment in dams and a 110-km water conveyor (until the 1990s), and how the switch to desalination was carried out in the past two decades. It discusses the water losses performance of potable water services, as well as tariffs levels and demand management. Finally, it discusses the situation of sewerage services and how the urban water cycle was successfully closed through massive development of wastewater reuse (both for irrigation and aquifer recharge).
- **The third chapter discusses other aspects of water resources management under scarcity.** This includes discussions about how water allocations between users is arbitrated each year between dams and desalination plants, the situation of irrigated agriculture (the "poor parent" in water management), aquifers management and recharge, and how the EU legislation was successfully leveraged upon in a context of extreme water scarcity.

- **The fourth and concluding chapter summarizes what has been achieved—**moving from the 1970s-90s motto “not a drop of water to the sea” to the new motto “not dependent on rainfall any more”—**and also discusses what still remains to be done**. Despite its undeniable successes, the Republic of Cyprus still faces some remaining challenges for water reforms and moving toward sustainable water management. The report identifies four strategic priorities for public policies, which are suggested to be dealt with in the near future: focusing on demand management, modernizing the financial and institutional framework, achieving compliance with the EU wastewater directive, and defining a viable strategy for irrigated agriculture in line with sustainable aquifer management.

Abbreviations

BOR	built-operate-remove
BOT	build-operate-transfer
CAP	Community Agricultural Policy
CAPEX	capital expenditure
CAPO	Cyprus Agricultural Payments Organization
DBO	design-build-operate
DMA	district metered area
DMP	drought management plans
EAC	Electricity Authority of Cyprus
EC	European Commission
EU	European Union
GCC	Greek Cypriot community
GDP	gross domestic product
IAS	individual appropriate sanitation
ILI	Infrastructure Leakage Index
IWA	International Water Association
MAR	managed aquifer recharge
MARDE	Ministry of Agriculture, Rural Development and Environment
NRW	nonrevenue water
NVZ	nutrient vulnerable zones
O&M	operation and maintenance
PBC	performance-based contracts
PE	population equivalent
PPP	public-private partnerships
RBMP	river basin management plans
ROT	rehabilitate-operate-transfer
TCC	Turkish Cypriot community
TWW	treated wastewater
UFR	unmeasured flow reducers
UNDP	United Nations Development Programme
UWWTD	Urban Wastewater Treatment Directive
VAT	value added tax
WDD	Water Development Department
WFD	Water Framework Directive
WSS	water supply and sanitation
WWTP	wastewater treatment plants

Executive Summary

The Republic of Cyprus is one of the most water-scarce countries in the world, with only 390 m^3 per capita of utilizable freshwater on average every year (government-controlled areas). It is also, along with Malta, one of the two "water poor" countries of Europe. The negative impact of global climate change can already be felt acutely, with a 20 percent reduction in average rainfall since the early 1970s.

Historically and in the absence of any perennial rivers, the island has relied essentially on groundwater to meet potable water and irrigation demand. Growing population during the 20th century led to the overexploitation of aquifers, with saline intrusion in coastal areas. Following the independence from UK in 1960, **a massive dam development program was carried out under the motto "not a drop of water to the sea."** Over three decades, more than a hundred dams (of which 56 were large dams) were built in the central Troodos Mountains, providing a total storage capacity of 332 million cubic meters and making Cyprus the European country with the largest number of dams per capita.

This massive development of dams was accompanied by the construction of a 120-km bulk water conveyance infrastructure (the "Southern Conveyor") to transfer water from the main dams to the three urban and tourist areas of Nicosia, Larnaca, and Limassol, as well as a series of public irrigation perimeters on the Southern coast. Both the dams and the Southern Conveyor were developed and are operated by **the Water Development Department (WDD), which has been for more than a century the "operational arm" of water management in Cyprus**. The WDD is also responsible for providing potable water in bulk to local utilities that distribute water to the population—the urban water boards of Nicosia, Larnaca, and Limassol as well as municipal water departments and local community boards.

However, this supply-side policy centered on developing dam storage started to prove its limitations in the 1990s, due to high interannual rainfall variability combined with the impact of demand growth (population and tourism) and of climate change. In addition to extreme water scarcity, Cyprus also suffers from high rainfall variability—with rainfalls oscillating between as much as 270 million cubic meters in a wet year to as low as 20 million cubic meters in the driest year—and successive years of drought are not uncommon. Since 1990, the volume of rainwater captured in dams each year has oscillated between 12 and 192 million cubic meters—and on average only 30 percent of the total dams' storage capacity has been used.

A major drought occurred during 4 successive years in 1997–2000, and proved a first turning point for Cyprus water policies. Drastic rationing measures had to be implemented—both for potable water distribution in large urban centers and for public irrigation systems. These motivated the WDD to initiate the development of nonconventional water resources—both desalination and reuse of treated wastewater—using public-private partnership (PPP) schemes with the private sector. The first two desalination plants were put in operation in 1997-2001 under build-operate-transfer (BOT) contracts. The first wastewater reuse pilot was initiated in 1997, using treated effluents from the Limassol Wastewater Treatment Plant (WWTP) developed under a design-build-operate (DBO) contract.

The second turning point for Cyprus water policies was the catastrophic drought of 2008–09, whose consequences were exacerbated by poor decision making in the two previous years. The 1997-2000 drought was followed by three consecutive exceptionally wet years in 2002–04, and water stored in the dams was at record levels. As this provided a (false) sense of security, plans for further development of desalination plants were delayed. Even though the drought returned in 2005 and then continued in 2006 and 2007, political considerations (with, among other things, the upcoming 2008 presidential elections) led the government to delay taking unpopular rationing measures, especially for farmers. Unfortunately, the drought continued for a fourth year, during the winter of 2007–08, with the dams at critically low levels at the beginning of 2008. This provoked a major water crisis on the island, especially in the city of Limassol, which did not have yet a desalination plant. The severe rationing measures introduced in early 2008 (with water three times a week, 36 hours in total) came too late and proved insufficient—forcing the government to finally take unprecedented emergency measures. At the peak of the crisis, water tankers had to be brought in on a daily basis from Athens to Limassol during 8 months—for a total of 8.4 million cubic meters of potable water, at the prohibitive cost of 6.7 euros per m^3. Three emergency desalination plants were also installed with private concessionaires under build-operate-remove (BOR) schemes.

The 2008–09 drought demonstrated that massive recourse to seawater desalination rainwater was a must for Cyprus to achieve potable water security in the face of high rainfall variability, growing demand, and climate change. Two other large desalination plants were put into operation under BOT schemes in 2012 and 2013, to reinforce supply in the western part of the Southern Conveyor (especially for Limassol). The four desalination plants are all connected to the Southern Conveyor, with a total production capacity of 220,000 m^3/day—sufficient to supply all the potable water needs of the Nicosia, Larnaca, Limassol, and Famagusta areas even during peak summer months. A fifth desalination plant is to be put in operation in 2018–19 in the city of Paphos, on the western coast. Over the past two decades, Cyprus has developed a solid expertise in the development and supervision of desalination BOTs, with well-designed contracts including various operational modes (standard, standby, additional volume) and flexible concessionaire fees' structure—allowing the WDD to optimize production based on demand. The contractual price (standard operating mode) for desalinated water is in the range of 0.70 to 0.90 euros/m^3, and the private sector has financed close to 250 million euros for the desalination plants' construction.

In parallel with the development of desalination, **Cyprus has also embarked on the massive development of treated wastewater reuse**—as the second pillar of its nonconventional water strategy. After joining the EU in 2003, the Republic of Cyprus had to harmonize with the EU water legislation, including *inter alia* compliance with the Urban Wastewater Treatment Directive (UWWTD). The cost of the massive investment required in sewerage collection and treatment infrastructure was estimated at about 1.4 billion euros. Leveraging on this legal obligation, Cyprus made the decision to develop all its WWTPs with tertiary treatment capacity—which represented a rather marginal additional cost over the UWWTD requirement, but allowed for the reuse of treated wastewater for agriculture and aquifer recharge.

Acknowledging that tertiary wastewater treatment is technically challenging, most of the WWTPs were developed under PPPs, following the DBO scheme. This effectively transferred operation and maintenance (O&M) and compliance risks to the private sector, while investment was still financed with public funds. The wastewater reuse program also involved major investments in conveyance networks and winter storage reservoirs, as well as efforts to facilitate acceptance by farmers. As of 2016, about 30 million cubic meters of treated wastewater was reused,[1] mostly for irrigation but also for aquifer recharge—with less than 10 percent being discharged to the sea (a key factor for the excellent bathing water quality of Cyprus beaches).[2] The "no discharge to the sea" objective is expected to be reached in 2018.

Through its wastewater reuse program, Cyprus has effectively succeeded to "close" the urban water cycle: every m^3 of desalinated seawater produced is being used twice: first for potable water, and second through wastewater reuse. Although farmers were initially reluctant to use treated wastewater, it has now become well accepted, and demand for treated wastewater—which is viewed as the most reliable water source for farmers on the island—far exceeds supply.

As of 2018, the Republic of Cyprus has now successfully achieved potable water security—a remarkable achievement for one of the most water-scarce countries in the world. Its strategic supply of potable water to the populations (domestic, hotels, and industry) is no longer dependent on the vagaries of highly variable rainfall. Well-designed PPPs with the private sector (under BOTs for desalination and DBO for tertiary WWTPs) have proved instrumental in the successful development of nonconventional water resources—effectively transferring construction, O&M, and compliance risks to the private sector (plus financing risk in the case of the desalination BOTs) with strong incentives for efficient construction and sustainable operation. Over the past two decades, about 250 million euros have been brought by the private concessionaires for financing the construction of desalination plants.

The massive development of nonconventional water sources is now allowing the WDD to allocate more water to meet farmers' demand for irrigation—both from dams and wastewater reuse. Traditionally, irrigation has been the "poor parent" of water management in Cyprus, serving as a buffer for water shortages during drought years, and hindering the development by farmers of high value crops. Most of the food in the Republic of Cyprus is imported—making importation of "virtual water" through food one key element of its strategy to deal with extreme water scarcity. At the same time, being able to allocate more water from dams to irrigation may also bring in the future much needed **relief to overexploited aquifers**. This shall be reinforced by recent measures to foster sustainable groundwater management under the European Union (EU) Water Framework Directive (WFD), with the recent introduction of compulsory permits for private well owners and of raw water abstraction charges—though actual implementation and enforcement is expected to be a long process.

However, achieving potable water security has come at a price—not just financial but also environmental. The massive development of dams in the 1960-90 period had already led to the destruction of many natural habitats in the Troodos Mountains. Today, the four large desalination plants consume about 9 percent of all the electricity generated in the Republic of Cyprus, with an emission of greenhouse gases estimated at 436 thousand tons per year. Desalination is costly, especially as the Republic of Cyprus is entirely dependent on expensive oil-fired plants for its power generation. Still, the recent discovery of large offshore gas reserves gives hope that it may become self-sufficient in energy in the future—allowing it to reduce both the desalination bill and its environmental impact. Experiments are also being carried out with renewable energy for desalination.

Despite these worthy successes, Cyprus faces several important remaining challenges for reforms—in order to move toward fully sustainable water management. Most of the efforts so far have been focused on the "supply side" of water policies (increasing capacity for water storage and desalination), and several aspects of water management (especially with regard to financial sustainability and operational efficiency) remain to be optimized. The analysis in this report has allowed for the identification of four **priority pillars for potential future policy actions**.

Priority Pillar 1: Starting to Focus on Demand Management

Demand management should now become a priority, after decades of water policies that have largely focused on the supply side of the water balance. This is especially the case for potable water, where with a domestic per capita consumption estimated at 140 liters per day in the large urban areas, there is significant scope for making the Cypriot population more water savvy. A revised WSS tariff structure with, among other things, a higher proportion of volumetric charges, would send a stronger market signal to domestic users about the true value of water—which is a must in a country suffering from extreme water scarcity (though this may also require putting in place a targeted social tariff for the poor). Significant scope for water savings also exists in the tourism industry.

Priority Pillar 2: Modernizing the Financial and Institutional Framework

There is an urgent need to rethink and optimize the financial framework of the water sector in Cyprus—especially now that most potable water comes from expensive seawater desalination plants. The water sector is still significantly subsidized, and there is also still a lack of accountability and incentives for performance of the various players. Unless necessary additional reforms are implemented, the newly achieved potable water security may be threatened in the long run.

The current institutional and regulatory framework for WSS providers should be reformed with *inter alia* better ring-fencing from local politics and agglomerations of providers (for scale economy and to deal with capacity gaps)—so as to move further toward full cost recovery through tariffs, and reduce the current burden of the sector on the national budget. Reducing water losses in distribution networks should become a top national priority, and could be supported by PPPs such as performance-based contracts (PBCs), building on the successful track record with BOT-DBO over the past two decades.

In parallel, **the structure and institutional status of the WDD should be modernized** so that it can better play its role as the "operational arm" of water management.

Priority Pillar 3: Complying with the Urban Wastewater Treatment Directive

Although significant efforts have already been made for compliance with the UWWTD in large urban areas, **the required development of sewerage infrastructure in smaller agglomerations and rural areas remains to be completed**. This will require major efforts—not just financial but also efforts to deal with the local capacity gaps and special challenges associated with sanitation in rural areas. Valuable lessons could be learned from other, more advanced EU countries.

Priority Pillar 4: Developing a Sustainable Strategy for Irrigated Agriculture

As the newly achieved potable water security is allowing to allocate more water resources from dams to farmers, this provides an opportunity to **rethink the social and economic contribution of irrigated agriculture.** This should be done in the context of a **new national irrigation strategy that should fully address sustainable aquifer management.** This will mean addressing *inter alia* several difficult trade-offs—such as the need to drastically reduce abstractions in overexploited aquifers while also meeting demands from farmers—and shall require developing a vision of what the future role of irrigated agriculture in Cyprus should be.

Notes

1. Including the Mia Mila bicommunal WWTP, operated as a DBO under the supervision of UNDP, and which treats mostly sewerage effluents from the capital Nicosia but is located downstream outside of the government-controlled areas.

2. In government-controlled areas.

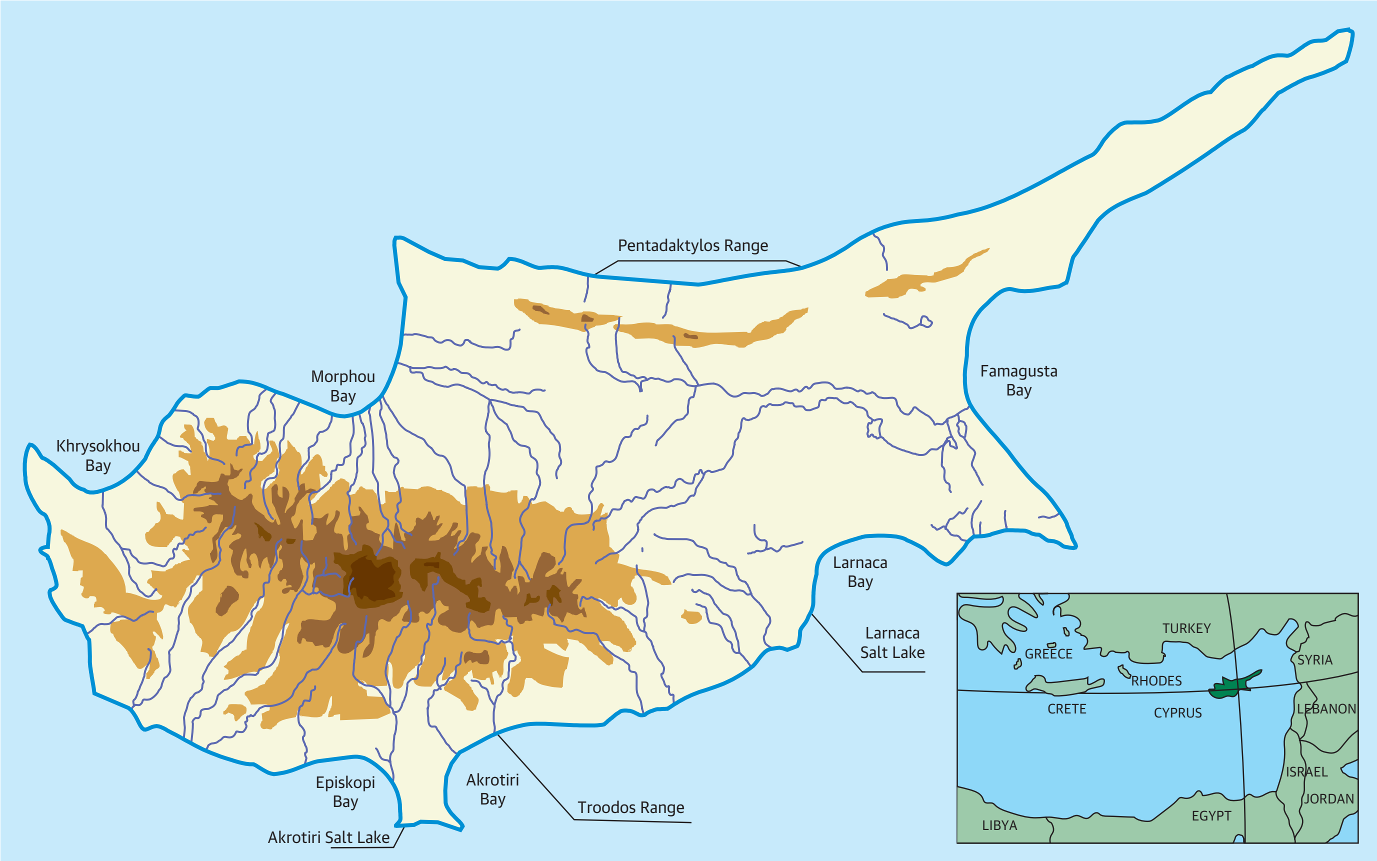
Chapter 1 Overview of Water Management in Cyprus

1.1. Geopolitical Situation: Areas under Government Control

The island of Cyprus is located in the Eastern Basin of the Mediterranean (map 1.1). It is the third largest island in the Mediterranean after Sicily and Sardinia—with a surface area of 9.251 km^2. **The Republic of Cyprus was established in 1960**, when the island gained its independence from Great Britain. However, the invasion in 1974 of the northern part of the island by the Turkish army, and ensuing internal displacement of populations, has led to a *de facto* partition of the island (map 1.2). Since then, it has been separated along ethnic divides between the so-called Greek Cypriot community (GCC) in the south and Turkish Cypriot community (TCC) in the north.[1]

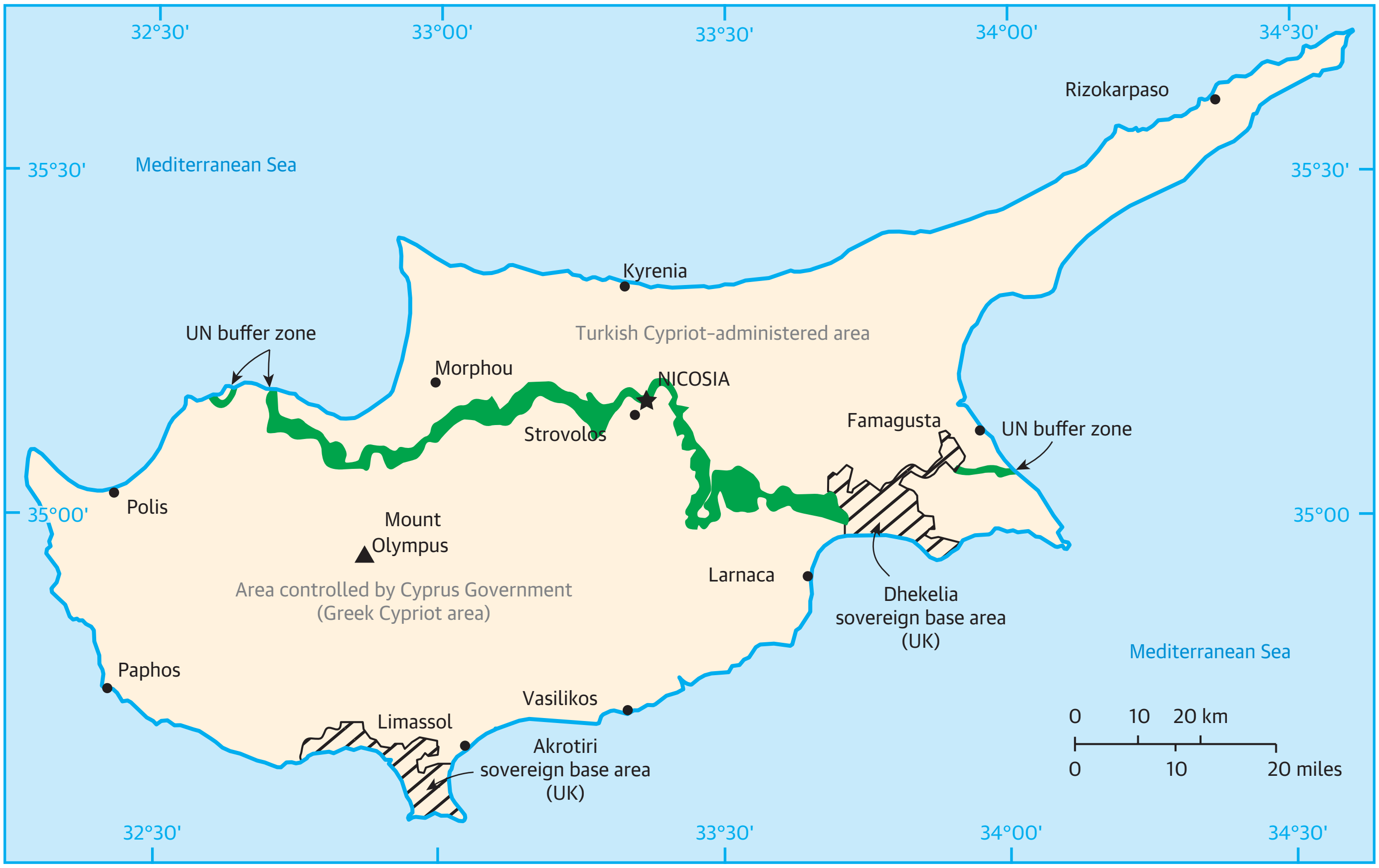
Since then, the Republic of Cyprus has been controlling only the southern 60 percent of the island. It is the only internationally recognized government of the island. In 2004, it became a member of the European Union (EU) and adopted the euro in 2008. The north of the island (about 37 percent

MAP 1.1. Physical Features and Location of Cyprus



Source: WDD.
Note: Mountainous areas in brown.

MAP 1.2. **Map of the Island of Cyprus with Green Line Divide**



Source: World Bank 2004.

of the territory) falls outside of the government's control. The island division is materialized by a buffer zone or "green line" under the control of the United Nations. Although many efforts have been made in the past decades under the auspices of the United Nations to settle the Cyprus issue, the country still remains sadly divided. Box 1.1 outlines the current geopolitical situation.

This case study focuses on the water management experience of the Republic of Cyprus—that is, the southern part of the island (GCC), which is under the government's control. It has a permanent population of 855,000 (Eurostat 2017) plus almost 3 million tourist arrivals per year. Water management in the areas outside of government control in the north of the island[2] is outside the scope of this study, but will be briefly described in box 4.1 at the end of this report.

Together with Malta, Cyprus is considered one of the two "water poor" countries of Europe. Faced with acute water scarcity, over the past three decades, the Republic of Cyprus has implemented, in the southern area under its control, a series of actions to improve the efficiency of water management and ensure the security of potable water supply. This includes major water infrastructure investments, combined with operational practices and reforms that include wide recourse to public-private partnerships (PPP) for the development of desalination and wastewater treatment plants.

BOX 1.1. Cyprus's Geopolitical Situation

Status under international law. In 1960, Cyprus achieved independence from the United Kingdom—which has kept two sovereign military bases there (3 percent of the territory). Since 1974, the island has undergone a *de facto* partition between the southern part of the island, dominated by the Greek Cypriot community, and the northern part, dominated by the Turkish Cypriot community. A military invasion by Turkey in 1974 led to the continuous occupation by Turkish forces of the northern part of Cyprus. In 1983, the Turkish Cypriot administration in the North unilaterally declared its independence. The statehood of the northern part of Cyprus is only recognized by Turkey. The UN Security Council resolution 541 stated that the declaration was legally invalid. The UN Security Council further instructed UN members to continue to recognize the sovereignty, independence, and territorial integrity of the Republic of Cyprus as the only internationally recognized state on the island.

EU membership of Cyprus. The Republic of Cyprus formally applied for membership in the EU in 1990. After signing the Treaty of Accession in 2003, it became an EU member state on May 1, 2004. On January 8, 2008, Cyprus also became a member of the Eurozone. A separate protocol of the Treaty of Accession regulates the status of the northern part of Cyprus as "areas of the Republic of Cyprus in which the Government of the Republic of Cyprus does not exercise effective control." The effectiveness of EU laws is suspended in the northern part of Cyprus until the EU Council unanimously decides otherwise. Turkish Cypriots (as opposed to Turkish settlers) are considered EU citizens even though they live outside of the government-controlled areas.

Peace talks between the two communities. The "Cyprus Problem" has the longest standing UN blue helmet mission in UN history (since 1964). Throughout its presence in Cyprus, the United Nations has provided assistance to the two communities in their attempts to bridge their differences. The last attempt to reach a comprehensive settlement for the "Cyprus Problem" failed in July 2017 in Crans Montana. As of the writing of this report, both sides are still reflecting the way forward.

In addition to lessons on how to deal with extreme water scarcity, Cyprus also provides a unique case for analyzing the application of EU water directives in such context. Being part of the EU, Cyprus is subject to the EU "environmental acquis," which includes a rather stringent and complex body of water legislation. This includes several elements linked to water scarcity, such as, among other things, the requirement to ensure sustainable management of aquifers under the Water Framework Directive (WFD). This also includes legislation that has had a major indirect impact, as with the Urban Wastewater Treatment Directive, which requires massive development of sewerage collection and wastewater treatment infrastructure, and has been leveraged in Cyprus to develop treated wastewater reuse.

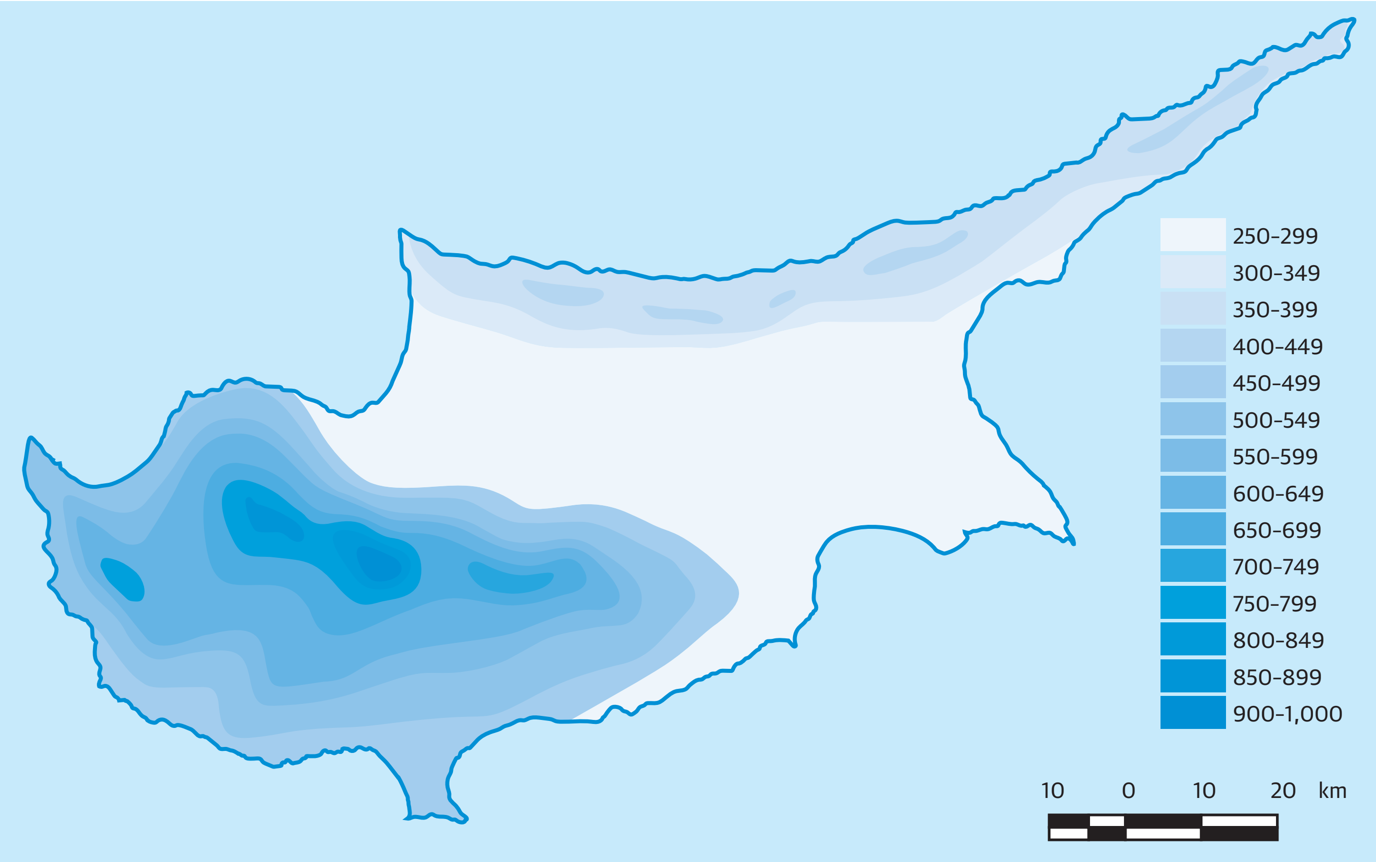
All these experiences—as well as several continuing challenges—hold a wealth of lessons for the many other countries around the world facing growing water scarcity. These will be described and analyzed in detail in this report. The focus of the analysis will be on how the Republic of Cyprus has been able to achieve potable water security over the past decade, but the issues of irrigation for agriculture and how to promote sustainable groundwater management will also be discussed.

1.2. Water Resources under Scarcity

1.2.1. High Variability of Rainfall and Frequent Droughts

The climate in Cyprus is typically semi-arid Mediterranean, characterized by hot dry summers and rainy, changeable winters. The mean annual precipitation stands at about 460 mm, but precipitation in Cyprus is confined to the winter season between November and March. Rainfall is unevenly distributed geographically, with maximum precipitation (over 1,000 mm) falling on the two mountainous masses and minimum precipitation (less than 300 mm) observed in the eastern plain and the coastal areas where the large urban centers are located (map 1.3).

MAP 1.3. Annual Rainfall Distribution (mm) in the Troodos Mountains



Source: WDD.

The rainfall regime is characterized by extreme variability, both between parts of the island and between successive years.

Because of its semi-arid climate and limited size, Cyprus does not have any river with perennial flow. There are only a few streams that can flow during the winter rainy season only. The island's topography is dominated by two mountain ranges, the Troodos Range in the central-western part of the island and the Pentadaktylos Range (outside of government-controlled areas) in the north. Between the two ranges lie the Morphou and Mesaoria plains, which, together with the narrow alluvial plains along the coast, make up the bulk of the agricultural land of the island. Most of the rivers have their sources in the Troodos Mountains, which rise to 1,952 meters (Mount Olympus) and create a natural barrier for clouds—thereby receiving most of the rainfall (photograph 1.1).

Drought periods occur frequently, and it is not unusual to experience two or three or even up to six consecutive dry years, with extremely low rainfall. Historically, droughts have occurred every 2-3 years, but in the past 50 years they have increased both in magnitude and frequency. In the past two decades, three severe drought periods—meaning droughts that span over more than 1 year—were observed, which severely affected the country: in 1990-91 (2 years), in 1996-2000 (5 years), and in 2006-09 (4 years). In the past, these droughts were dealt with in an emergency mode through severe water restrictions that involved cutting supply for farmers in government-irrigated perimeters, rationing potable water distribution in urban areas, and mobilizing some low-quality (brackish) water. The worst year was 2008, when the

PHOTOGRAPH 1.1. Nonperennial River in the Troodos Mountains

Source: WDD.

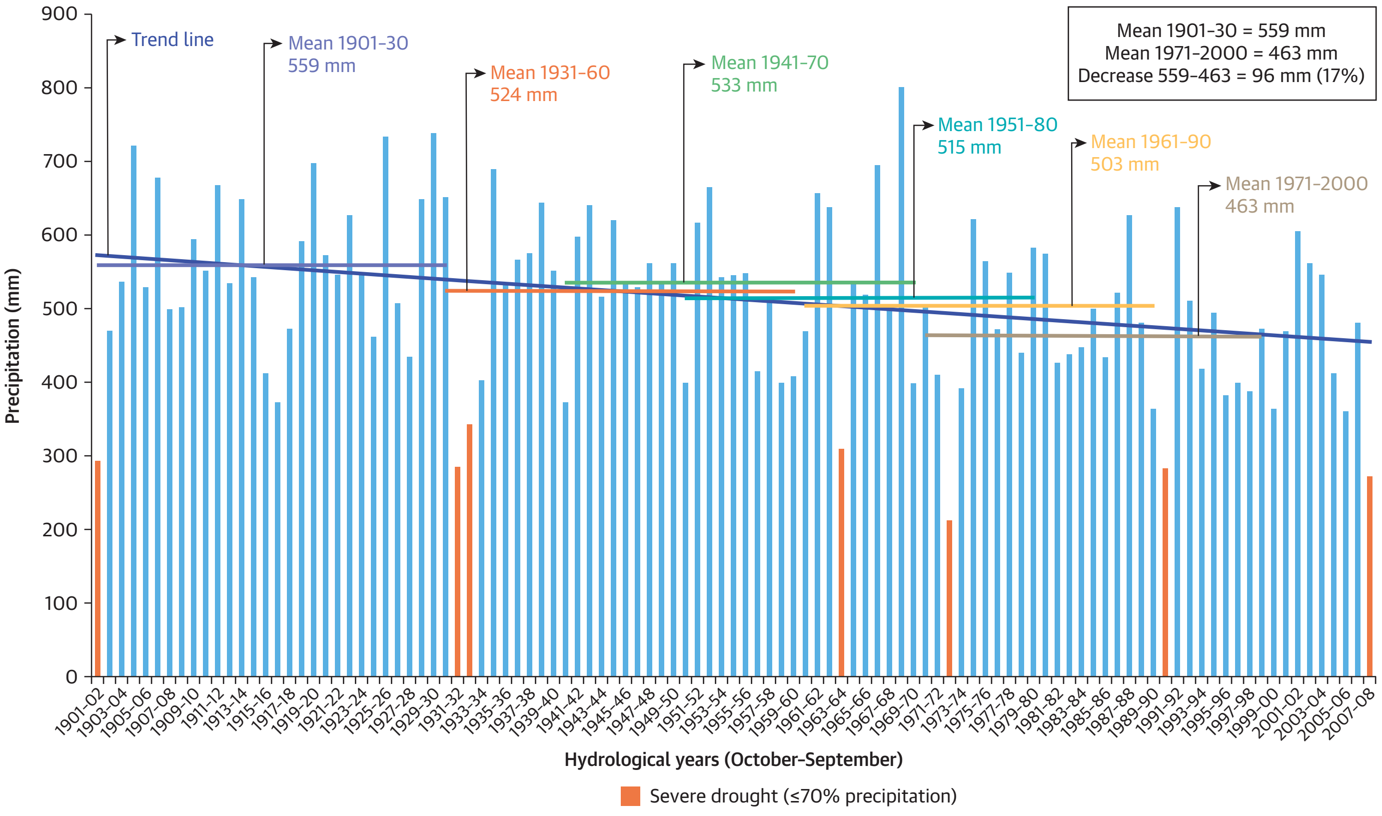
drought reached catastrophic proportions and water had to be brought in (on a daily basis for many months) from Athens by tankers to ensure potable water supply in urban and tourist areas during the summer. However, and thanks to the construction of desalination plants, the last droughts in 2014 and 2016 did not result in any rationing in potable water supply—as **Cyprus has now achieved *de facto* water security for potable water supply**.

Water scarcity in Cyprus is already aggravated by the impact of climate change. The effect started to be felt as early as the 1970s, with increasing rainfall variability and frequency of droughts. Statistical analysis shows a **20 percent drop in the mean annual precipitation since the early 1970s**, compared to precipitation records over the past 100 years. While the mean annual precipitation over a 30-year period of the last century (1901-30) amounts to 559 mm, it has dropped down to only 463 mm during the past 30-year period (1971-2000) (figure 1.1). This reduction in rainfall has been accompanied by a parallel increase in average temperature (figure 1.2), with parallel negative impact on evapotranspiration in agriculture (with higher crops consumption).

1.2.2. Cyprus Is One of the Most Water-Scarce Countries in the World

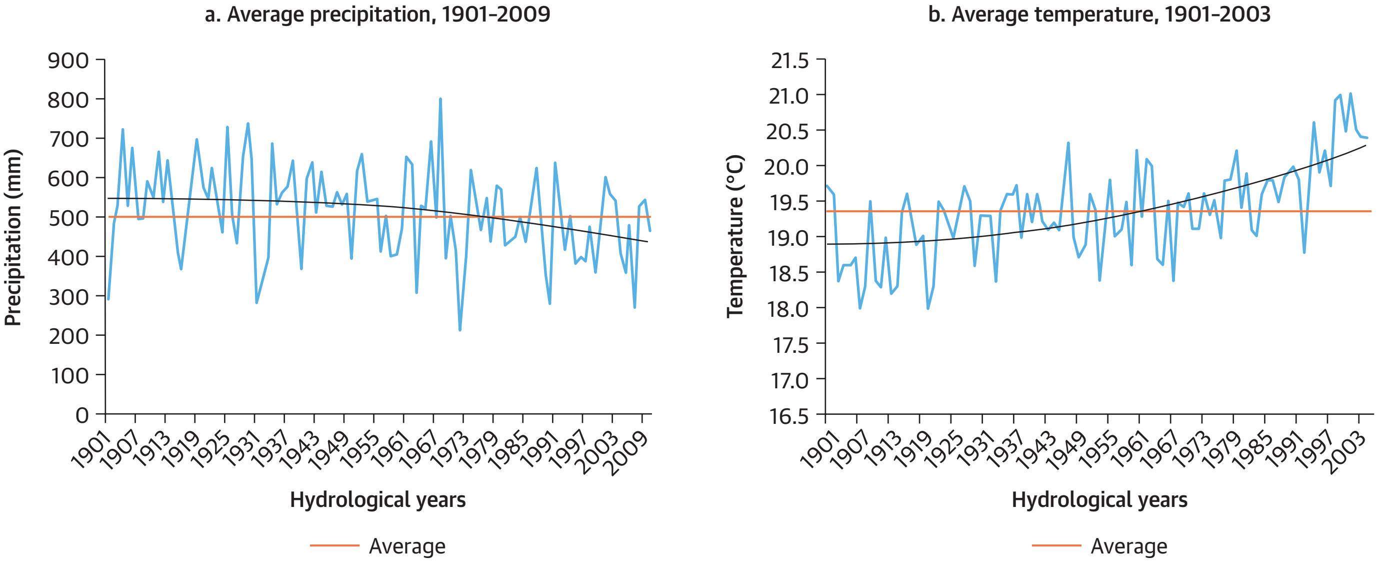
Out of an average total annual water supply of 2,670 million cubic meters/year (government-controlled areas) coming from rainfall, it is estimated that as much as

FIGURE 1.1. Average Annual Precipitation in the Government-Controlled Areas of Cyprus, 1901-2008



Source: WDD.
Note: mm = millimeters.

FIGURE 1.2. Evolution of Average Precipitation and Temperature in Cyprus, 1901–2009



a. Average precipitation, 1901–2009

b. Average temperature, 1901–2003

Source: WDD.

86 percent is lost to the atmosphere through evapotranspiration. The remnant 14 percent that does not evaporate represents **only about 370 million cubic meters, available as useable water on average each year—yet with considerable between-year variations**.

As already mentioned, **Cyprus is, together with Malta, one of the two most water-scarce countries of the EU**. Availability of renewable natural freshwater stands at **only 390 m³ per capita per year** in the government-controlled areas, which receive more water than the northern part of the island (because of the central Troodos Mountains) but are also more densely populated. **Cyprus is below the standard threshold for extreme water scarcity of 500 m³ per capita per year** (the normally accepted threshold for water scarcity being at 1,000 m³ per capita per year).[3]

Because of acute water scarcity and high variability of rainfall, the Cypriot population has been forced for time immemorial to develop technologies and practices to manage water efficiently and deal with the lack of water. Every year, and for as long as human memory goes, the populations on Cyprus have been anxiously awaiting the return of the short winter rainy season—as it entirely determines their livelihood in the following year. How much water would fall each year between December and March would determine how much food could be grown, and even whether humans and cattle would have enough potable water to drink. One of the most dramatic droughts recorded in historical memory took place 13 centuries ago—in 306 CE—when almost all of the island's population had to be evacuated after 17 years of consecutive drought. Archeological remains are witnesses of the elaborate systems developed by the ancient Greek civilizations on the island to harvest and conserve rainwater (photograph 1.2).

PHOTOGRAPH 1.2. Pictures of Archeological Remains of Water Infrastructure in Cyprus

a. A cistern at Vouni Palace

b. Stone aqueduct at Agios Serghios for the conveyance of water from Kyrenia to Salamina

Source: Department of Antiquities Archive.

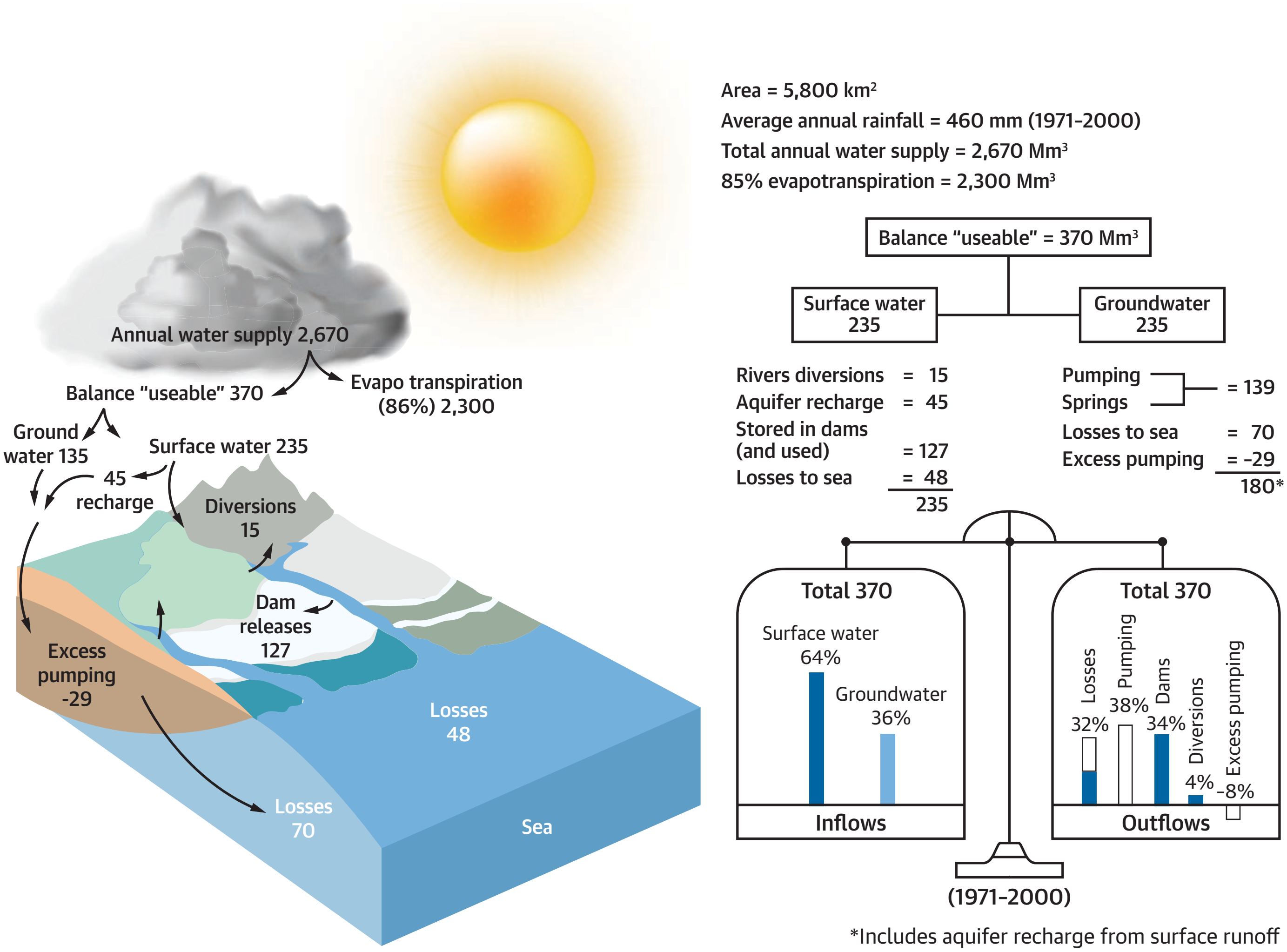
1.2.3. The Water Balance in Cyprus

The overall water balance for Cyprus (government-controlled areas) is presented in figure 1.3. As already mentioned, out of the 2,670 million cubic meters that comes from rainfall on average, only 370 million cubic meters (14 percent) is left available after evapotranspiration. Of these, **135 million cubic meters per year goes to replenish the aquifers** through soil infiltration, and **235 million cubic meters per year flows as surface water through seasonal streams** and run-off. It is important to highlight that these figures are based on average rainfall and do not reflect the situation of acute scarcity that occurs during drought years.

Because of the absence of permanent superficial water bodies, the Cypriot population relied entirely on groundwater until the mid-20th century. This has been true from time immemorial and did not change under British rule, despite significant population growth in the 20th century, as no major investments were made to develop dams in the central mountain region and growing water demand kept being met by groundwater extraction. As a result, at the time of independence in 1960, the aquifers were already overexploited, with serious salinization on the coastal aquifers. The situation became worse in the following decades due to continued population growth and increased demand from tourism. A 2002 study carried out by the Water Development Department (WDD) and FAO concluded that the Cyprus aquifers were at very low levels, partially intruded by saline water, and were overexploited by 40 percent (Katsikides et al. 2005).

To reduce the pressure on aquifers and to satisfy growing demand, **an ambitious program of construction of dams** (see section 2.1.1) **was implemented since independence in the 1960s to capture the surface water**, which was until then largely lost to the sea through surface runoff. Even though Cyprus has developed its dams potential close to the limit, it is estimated that still only about 54 percent of the utilizable freshwater is captured into the dams—the rest being lost to the sea or used for spade irrigation. Since most of the rainfall evaporates

FIGURE 1.3. Freshwater Balance for Cyprus Areas under Government Control



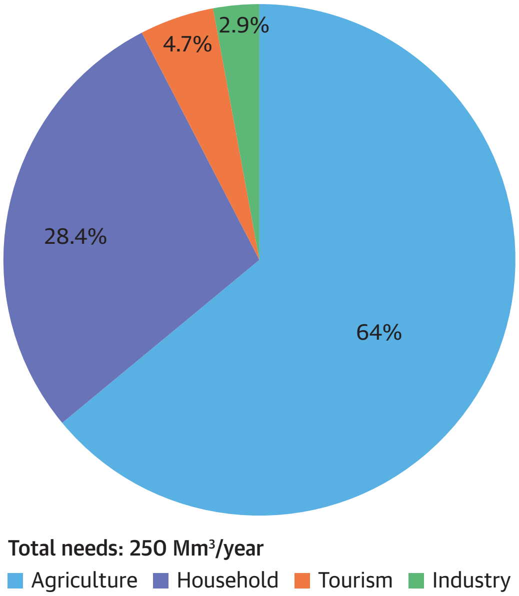
Source: WDD 2003.

a. Includes aquifer recharge from surface runoff.

(86 percent), it results that from the average rainfall supply, **only 4.75 percent is captured into the dams—or about 127 million cubic meters on average**.

The total volume of water usage in the government-controlled areas has been estimated at about 250 million cubic meters per year. The breakdown between the different users is at about 61 percent for irrigation, 3 percent for livestock, 28 percent for domestic use, 5 percent for tourism (14 percent of all potable water), and 3 percent for industries (figure 1.4)—but again this breakdown is only an estimate for illustration purposes, because in practice the percentage of water allocated each year to agriculture varies greatly because irrigation is used as a buffer to compensate for rainfall variability, and also because the actual amount used each year for irrigation is not known since a large portion comes from private boreholes. It is important to realize that this volume must not be equated with the total

FIGURE 1.4. Water Usage in Cyprus, by Sector



Source: WDD.
Note: Mm³ = million cubic meters.

demand, which is higher because irrigation demand is almost never satisfied (since 1996, this happened only one year, in 2004, when the dams were full and overflowing). The **two main users—domestic potable water and irrigated agriculture (figure 1.4)—both have significant seasonality,** which poses additional challenges in a context of extreme water scarcity for managing water resources during the dry summer months.

The average volume of rainfall water stored in dams (127 million cubic meters) represents less than half the current annual water demand for all usages. But in practice, as will be seen in more detail in section 2.1.1, the high variability of rainfall from one year to the next results in considerable variations in the total volume stored at the beginning of each year: **from as low as 20 million during the worst drought years, to as much as 270 million cubic meters in the wettest years.** The network of dams that has been built in Cyprus, albeit of considerable magnitude, is therefore insufficient to meet demand in a context of overexploited aquifers. More importantly, the volume of water available from freshwater sources—both stored in dams and in the aquifers—is insufficient to guarantee that potable water supply can meet demand during drought years.

In this context, a program of massive development of nonconventional water resources—both desalination and treated wastewater—was implemented over the past two decades. The objective has been to reduce the pressure on overexploited aquifers and guarantee the supply of domestic potable water. **Desalination now supplies half of total domestic potable water** on average, and the existing total capacity of the desalination plants provides enough cushion to guarantee that domestic demand can be met even during drought years.

In addition, **70 percent of treated wastewater is now reused in agriculture**. Cyprus is one of the few countries around the world (together with Malta, Israel, and Singapore) to have made massive investments in nonconventional water resources in order to achieve potable water security under extreme water scarcity, while also closing the urban water cycle through wastewater reuse. How this was achieved over the past two decades will be discussed in chapter 2.

1.3. Institutional Framework of the Water Sector

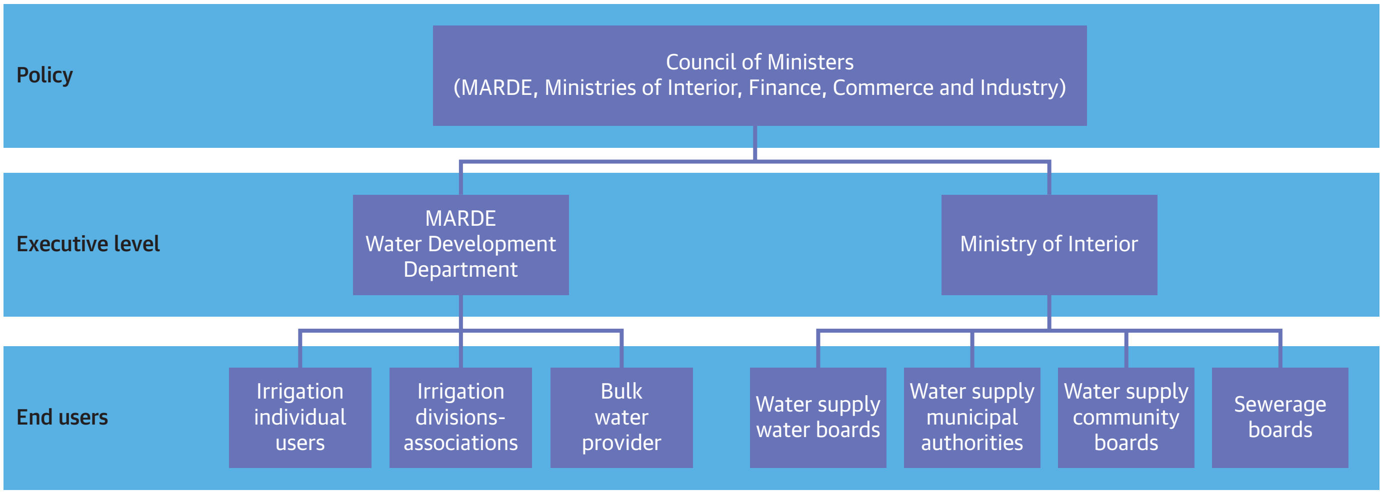
1.3.1. Governmental Organization

The institutional structure of the water sector in Cyprus is shown schematically in figure 1.5. **At the policy level, the lead ministry is the Ministry of Agriculture, Rural Development and Environment (MARDE),** who is responsible for the formulation of water policies, which must be approved by the Council of Ministers. As will be discussed later, all decisions related to water policies in Cyprus—including tariff changes for domestic supply and irrigation, or annual allocations of water from dams and other sources—are made at the level of the Council of Ministers. This reflects the strategic importance of water management in a context of extreme water scarcity.

At the executive level, responsibility is divided between MARDE and the Ministry of the Interior. Other important ministries are the Ministry of Finance (which *inter alia* approves budgets), the Ministry of Health, and the Ministry of Commerce, Industry, and Tourism.

- The **WDD** is the department inside MARDE in charge of the water sector and is responsible for both water policies and managing the large water infrastructure of the island (government-controlled areas). This includes (a) operation of dams, bulk water

FIGURE 1.5. Institutional and Administrative Structure of the Water Sector



Note: MARDE = Ministry of Agriculture, Rural Development and Environment.

conveyance and treatment and public irrigation perimeters; and (b) the supervision of the desalination plants operated by private concessionaires.

- **The Ministry of the Interior** supervises all local authorities (municipalities and villages administrations) through the district officers. As such, it directly **oversees the various WSS providers**, such as the water boards, sewerage boards, and local water municipal services.

1.3.2. The Water Development Department

The WDD is the operational arm of the government in the water sector, and has been leading water management in Cyprus for more than a century. It was established more than a century ago (in 1896) as a section of the erstwhile "Public Works Department," initially responsible for the development and operation of domestic water supply and irrigation. In 1939, it was set up as an independent government department called the "Water Supply and Irrigation Department" and adopted its present name in 1954. With the establishment of the Republic of Cyprus in 1960, the WDD was restructured into several divisions with responsibility for implementing the water policy of the newly established republic.

In addition to the responsibility for implementing water policies at the national level and protecting water resources (integrated water resources management), **the WDD is in charge of the construction, operation, maintenance, administration, and management of all government water works relating to fresh water provision**, including dams, bulk water conveyance, potable water treatment, public irrigation perimeters, as well as desalination plants under PPPs. The WDD is the main purveyor of bulk water supply for both domestic potable and agriculture on the island.

Map 1.4 shows the magnitude and wide geographical spread of the water infrastructure operated by the WDD. It will be discussed in more detail in the following chapters. The development of such large water infrastructure was supported by massive public resources, and for several years, the WDD expenditure accounted for about 20 percent of the total infrastructure development budget of the Republic of Cyprus. It must be noted that, historically, many construction works were carried out directly by the WDD with its own staff (with low-skilled hourly employees), but the practice has gradually been abandoned. For all water infrastructure, the WDD now focuses on planning, design, tendering and construction supervision, and subsequent operation and maintenance (O&M)—either directly or through PPP with the private sector.

Despite its extensive operational mandate, the WDD remains a ministerial department—with all the functional limitations that this entails. It absorbs more than half of the total annual budget of the ministry (55 percent in 2013), yet it does not have financial autonomy and all its costs—including *inter alia* staff salaries, suppliers, and water purchased from desalination plants—are paid through central budget allocations. It is also subject to public procurement rules, and all its staff are civil servants. In 2017, the WDD had a total of about 840 staff, including many

MAP 1.4. **Large Water Infrastructure Operated by the Water Development Department**

Source: WDD.

engineers and technicians working on planning and water quality monitoring, but also about 500 field workers employed in the operation of the dams, bulk water conveyor, water treatment plants, and irrigation perimeters. Since the 2012-13 financial crisis in Cyprus, the number of employees has decreased due to an overall hiring freeze across all ministries for hiring new civil servants (as part of the agreement with EU and International Monetary Fund), and this is starting to create some operational issues with the recent retirement of many qualified staff.

The WDD is also responsible for the implementation and enforcement of the EU water directives that have all been translated into national legislation. Of special importance is the WFD, which fosters sustainable water management at the basin level through implementation of sound tariff policies based on cost recovery, and the Urban Wastewater Treatment Directive (UWWTD) (91/271/EEC), which requires extensive development of sewerage collection and wastewater treatment infrastructure. For the UWWTD, it is responsible for the National Implementation Plan of the Directive, which includes (a) planning and periodic reporting to the European Commission; (b) for rural communities and municipalities: design, tendering, and supervision of the construction of wastewater infrastructure; and (c) for urban areas: coordination with the urban sewerage boards.

To support the implementation of the WFD, the **Integrated Water Management Law came into force in 2010**, and it constitutes an important milestone for water management in Cyprus. It replaced the previous legislation that had evolved on an ad hoc basis based on the 1991 Water Law (called "water saving law"), resulting in complex legislation with fragmented responsibilities. The 2010 Integrated Water Management Law clarified responsibilities by **assigning to the WDD the integrated management of all water sources** (surface, underground, desalinated, and treated wastewater), along with mandates to ensure sufficiency of water for domestic, agricultural, and other uses; address the imbalance between supply and demand in a sustainable manner; and ensure long-term protection of all water resources.

1.3.3. Water Supply and Sanitation Service Providers

All potable water and sanitation providers (as well as the nongovernmental irrigation schemes not managed by the WDD)[4] **fall under the jurisdiction of the Ministry of Interior**. These include the urban water boards, the municipal water supply departments, the village commissions for domestic water supply, and the sewerage boards for wastewater collection and treatment.

The proportion of the population served by the three types of potable water operators—the urban water boards, the municipal water supply departments, and the community boards—is shown in table 1.1. There is 100 percent coverage for domestic potable water supply in Cyprus, with all consumers being connected to the water supply network, including in the small isolated villages in the Troodos Mountains.

More than half of the population (46,000 people) is served by the three water boards of Nicosia, Limassol, and Larnaca. These are ring-fenced public utilities with strong central government presence on the Board of Directors,[5] and they cover several municipalities in the three largest urban centers on the island. It is important to highlight that the urban water boards are not corporatized utilities; rather, they have a quasigovernmental status with

TABLE 1.1. **Percentage of Total Population Served by Domestic Water Service Providers**

Water service provider	Population		Volume produced		
	Number	Percent of total	Mm^3	Percent of total	Liters per capita/day[a]
Water Board of Nicosia	210,000	25	17.0	22	222
Water Board of Limassol	170,000	20	16.0	21	274
Water Board of Larnaca	60,000	7	4.4	6	200
Municipal water supply departments (9)	160,000	19	18.3	24	312
Community boards (146)	250,000	29	21.5	27	235
Total	**850,000**	**100**	**77.2**	**100**	**249**

Note: Mm^3 = million cubic meters.

a. Based on overall consumption including industries, commerce, and tourism, not domestic consumption.

similar regulation as the central government entities for staff and public procurement regulations. They do have, however, financial autonomy: their budget is approved by their respective boards (and not by the central government) and they are operated without subsidies from the central government. The tariffs are also approved by the board, with a view to cover operating expenses and investments, but without allowance for profits.

Overall, **the three urban water boards in Cyprus compare relatively well in terms of operational performance with large water utilities from other EU countries**. The key characteristics of each urban water board are provided in table 1.2. Labor productivity stands at between 1 and 1.5 staff per thousand connections (only for potable water services); all customers are metered and receive continuous 24/7 water supply. The issue of water losses (NRW) and demand management—crucial in a context of water scarcity—will be reviewed in detail in section 2.1.

There are nine municipal water supply departments that provide service to about a quarter of the population (160,000 people) in cities and towns not covered by the water boards. This includes cities located outside of the three large urban areas (Paphos and Polis on the western coast), as well as peri-urban municipalities in the vicinity of urban water boards but have so far chosen to remain autonomous (especially in the surrounding of Nicosia).

The remaining 29 percent of the population (about 250,000 people) is provided potable water through 146 community boards in small villages in rural and peri-urban areas. In both cases of municipal water departments and community boards, the water services are not ring-fenced from the municipal budget, tariff levels are set by local authorities and cover only a portion of operating costs, and there is often a serious lack of technical and operational capacity.

TABLE 1.2. Key Characteristics of the Water Boards in Limassol, Larnaca, and Nicosia, 2013

Description	Unit	Water Board of Limassol	Water Board of Larnaca	Water Board of Nicosia
Population		**170,000**	**60,000**	**210,000**
Connections (water meters/customers)	No.	98,000	33,400	120,000
Average potable water tariff	**Euro/m^3**	**1.00**	**1.70**	**1.30**
NRW	Percent	28.3	17.0	16.5
Total staff	**No.**	**110**	**50**	**140**
Staff/1,000 connections	No.	1.12	1.50	1.16
Per capita dotation (supplied into the system)	l/c/d	256	215	222
Per capita consumption	l/c/d	184	178	178
Per capita domestic consumption	l/c/d	145	125	140
Total volume billed	Mm^3	11.4	3.8	13.7
Total sales	**Million Euros**	**18.3**	**6.6**	**22.9**

Note: Mm^3 = million cubic meters; No. = number; NRW = nonrevenue water.

The difference between municipal water supply departments and community boards is linked to the respective financial autonomy of local authorities, and to how water investments are financed. For municipal water supply departments, infrastructure investments are financed by transfers from the municipal budget, while for community boards they are fully subsidized by the central government. In addition, the WDD used to carry out maintenance for community boards with its own staff and budget, but the practice has been phased out recently due to budget constraints.

The organization of sewerage services is somewhat different from potable water services, with five urban sewerage boards. They cover the urban areas of Nicosia, Limassol, Larnaca, Paphos, and Ayia Napa/Paralimni with a total population of close to 600,000 people (70 percent). Like the urban water boards, they are ring-fenced public utilities subject to similar procurement and staffing rules as government, but with financial autonomy. In rural areas, sanitation systems are largely undeveloped but investments are proceeding to comply with the UWWTD under the leadership of the WDD (which provides financing, design, and supervision of civil works), and four rural sewerage boards were recently created.

Notes

1. Following the invasion, a total of 165,000 Greek-Cypriots lost their homes and were displaced to the southern part of the island that remained under the government's control, while 45,000 Turkish-Cypriots were displaced to the northern part (United Peacekeeping Forces in Cyprus, UNFYCIP). In 1974, the population on the island was estimated at about 640,000, of which Greek Cypriots represented about 85 percent of the total.

2. The population currently living in Northern Cyprus in the areas outside of the government's control has been a contentious issue, due to a large proportion of Turkish settlers. In 2011, the population was reported at 285,000, excluding the Turkish troops stationed in military bases (more than 30,000), of which the majority were Turkish settlers, but higher figures have been circulated.

3. Based on the World Business Council for Sustainable Development (2005): a country should have at least 1,700 m^3/capita/year to be water-sufficient. Between 1,000 and 1,700 m^3/capita/year a country experiences water stress. Water scarcity starts below 1,000 m^3/capita/year with less than 500 m^3/capita/year characterizing extreme water scarcity.

4. Local Irrigation Divisions formed by landowners and Irrigation Associations formed by water-right owners.

5. Three members of the Board of Directors are appointed by the Council of Ministers; the Chairman of the Board is the District Officer of the administrative region in which the board is located, the Accountant General of the Republic, and the Director of the Water Development Department. The rest of the board members are the mayors and councilors of the local municipal areas served by the water boards.

Chapter 2

Ensuring the Security of Potable Water Supply

2.1. Mobilizing All Available Rainwater through Dams and National Conveyor

2.1.1. Massive Investments in Dam Development in the 1980s

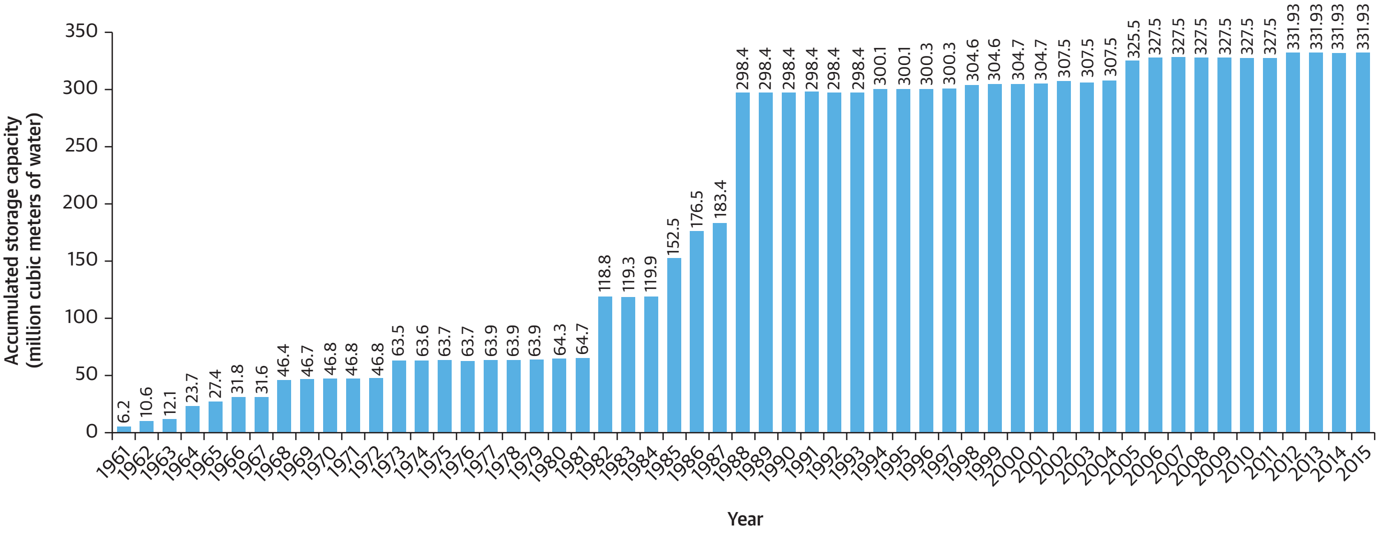
Until the 1960s, potable water supply (as well as irrigation) on the island was almost entirely dependent on aquifers. **After independence, the slogan "not a drop of water to the sea" was adopted by the Cypriot government and determined the national water policy for the ensuing decades.** The underlying rationale was that, in a context of extreme water scarcity, all available renewable freshwater water had to be mobilized. The development of dams was, at that time and in a context of fast-growing demand with economic development (population growth, tourism, and agriculture), the only way to reduce the overexploitation of aquifers (with those in coastal areas already suffering from saline intrusion).

As a result, the Water Development Department (WDD) embarked into a massive program of dams construction, most of which were of the earth-fill type. The water storage capacity went up from a mere 6 million cubic meters in 1961[1] (figure 2.1) to about **332 million cubic meters** in 2015 (310 million cubic meters in the 56 large dams). Most of the storage capacity increase took place during the 1980s. Dams are used for potable water supply, irrigation, and aquifer recharge. Contrary to most other countries, there are **no hydropower dams in Cyprus**: extreme water scarcity has always made meeting demand for domestic supply and agriculture the sole priority.

At present, Cyprus has more than 100 dams, including as many as 56 large dams. Most of these dams are dedicated to supplying small to medium irrigation systems spread across the island. Recharge dams were constructed to mitigate overexploitation in the coastal aquifers.[2] There are **11 large dams used for potable water supply, which represent together 84 percent of the total storage capacity**, of which the Kouris Dam with 115 million cubic meters is by far the largest.[3] Several dams are used for both irrigation and potable water supply. The location of all larger dams on the island is shown in map 2.1.

Cyprus is quite unique in terms of the magnitude dam development, with a ratio of **50 large dams for every 10,000 square kilometers.** It is **ranked first among European countries for dam density.** It is considered that the dams' potential in Cyprus has now been largely developed to its maximum potential. The **total storage capacity per capita stands at more than 400 m^3 per capita**, which is about the same as the total average volume of renewable freshwater available each year. Over the past two decades, the maximum volume stored at the beginning of the year following a wet summer was at about 275 million cubic meters (2004 and 2012), while during drought years (1991, 1998, 2000-01, and 2008) the volume of water stored went down to less than 30 million cubic meters. Photograph 2.1 shows aerial views of the two largest dams in Kouris (potable water and irrigation) and Asprokremmos (irrigation and some potable water supply).

FIGURE 2.1. Storage Capacity in Dams Constructed between 1961 and 2015



Source: WDD.

MAP 2.1. Location of Major Dams and Ponds in Cyprus

Source: WDD.

PHOTOGRAPH 2.1. Aerial Views of Two Large Cyprus Dams

a. Asprokremmos Dam

b. Kouris Dam

Source: WDD.

BOX 2.1. How the Island's de facto Partition in 1974 Affected Future Water Policies of the Republic of Cyprus

The water policies of the Republic of Cyprus over the past decades were heavily influenced by the consequences of the Turkish military invasion and subsequent de facto partition of the island. **At the time of the partition, about 70 percent of the economic resources of Cyprus (including tourism facilities) were located in the areas which fell outside of government control, and so were also most of the arable lands**. This included in particular the two highly developed regions (agriculture and tourism) of Famagusta (in the East) and Kyrenia (on the northern shore). As a result, the Greek Cypriots, which represented at the time about 85 percent of the population on the island, were left with a smaller (and mostly mountainous) territory (60 percent) that had only about one-third of the economic resources of the island at the time. Furthermore, a large refugee population had to be attended to because since 165,000 Greek-Cypriots were evicted from their homes and displaced to the south of the island that remained under the government's control.

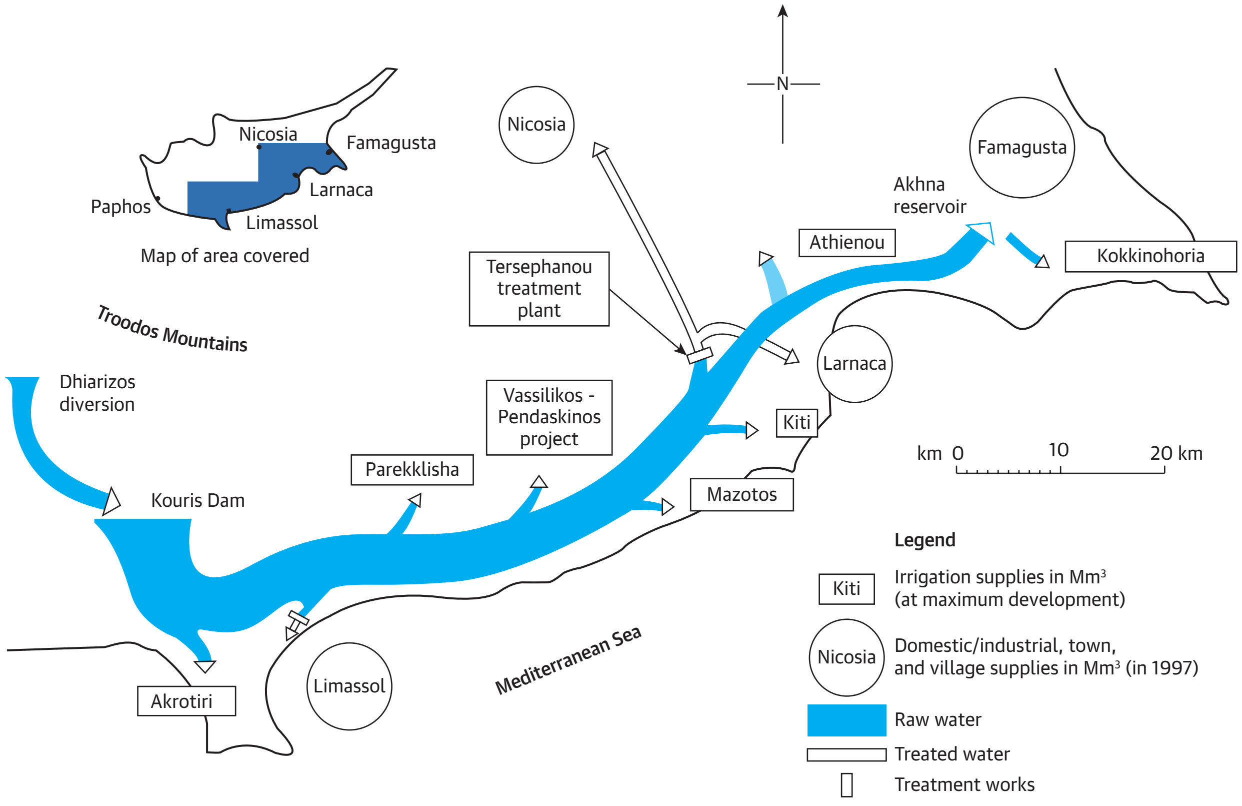
As a consequence, **the entire economy of the Republic of Cyprus had to be largely reconstructed, and water was a major constraining factor in a semi-arid climate with high rainfall variability**. This largely explains the massive recourse to supply-driven water policies in the following decades, with the aim of exploiting virtually all opportunities to capture available rainfall in the Troodos Mountains through dams—in an emergency effort to meet the growing demands from a larger population living on a smaller territory, from new tourism resorts, and for rebuilding an agriculture sector in the few arable lands still under government control.

2.1.2. Southern Bulk Water Conveyor

In parallel with the development of dam storage capacity, **a major bulk water transmission network was built—the Southern Bulk Water Conveyor—interconnecting the main dam (Kouris) with the largest urban centers and tourist areas on the island** (namely Limassol, Larnaca, the capital Nicosia, and the tourist area around Famagusta) as well as the public irrigation perimeters on the southern coast. In addition, the new bulk water conveyor allowed a series of new public irrigation perimeters to be developed in the southern plain around Famagusta area, where the coastal aquifer could not be used anymore for agriculture due to saline intrusion. Construction of phase 1 started in 1984 with the Kouris Dam and main conveyor (110 km length). The schematic of the bulk water transmission system is represented in figure 2.2.

The Southern Conveyor project was initiated in 1984 and was built over two successive construction phases, which were finally completed in 1999. The total cost for the two phases was 157 million CYP in 1999—equivalent at that time to about **270 million euros.** The first phase was completed in 1994 and involved the construction of the Kouris Dam, the 110-km main

FIGURE 2.2. Schematics of the Southern Bulk Water Conveyor



Source: WDD.
Note: Mm^3 = million cubic meters.

conveyor, and irrigation infrastructure covering almost 10,000 hectares. The second phase involved digging a 14.5 km tunnel through the Troodos Mountains for river diversion into the Kouris Dam, extending the conveyor with a 36.5 km pipeline to Nicosia, and the construction of the Limassol and Tersephanou water treatment plants. Since then, more infrastructure such as the desalination plants have been gradually added and interconnected. Two new pipelines are planned for next year to keep reinforcing the interconnection: from Vassilikos to Nicosia (55 million euros) and from the Dhekelia desalination plant to a resort area (20 million euros).

The Southern Conveyor allows interconnection of raw water sources from the associated large dams dedicated mainly to domestic potable water, along with a series of other dams dedicated initially to irrigation (map 2.2). In practice, **the bulk water is mixed in the transmission pipe** (photograph 2.2) and is distributed among the three potable water treatment plants (serving Limassol, Larnaca, Nicosia, the Akrotiri UK military base area, and the Famagusta tourist area) and the various public irrigation perimeters developed along the conveyor. The WDD

MAP 2.2. Links of Transmission Network with Dams and Water Treatment Plants

Source: WDD (only one desalination plant is represented).

PHOTOGRAPH 2.2. Laying of Main Conveyor's Pipeline

Source: WDD.

operates not only the dams and the entire conveyor transmission system, but also the WTPs that provide water in bulk to the urban water boards and municipal water supply departments (and which were built before the construction of the Southern Conveyor) and the public irrigation perimeters along the conveyors.

The hydraulic operation of the Southern Conveyor (map 2.2) has been designed to be mostly gravity based so as to minimize operating costs. In normal conditions, the pressure resulting from the intake at the Kouris Dam is sufficient for water conveyance (with three pressure-break tanks located along the main pipeline), but when the Kouris Dam is too low, a pressure-boosting station immediately downstream of the dam has to be put into operation. Also, water conveyance to Nicosia, located in the center of the island, requires the water to be pumped from Larnaca half way to a storage reservoir (from there it is transported by gravity).

Overall, **64 percent of the total dam storage capacity that could be used for potable water in Cyprus is interconnected with the Southern Conveyor**—equivalent to 55 percent of the total dam storage capacity. Table 2.1 provides the list of the dams used for potable water (only or shared with irrigation), with each respective year of commencement of operation and capacity, and whether each is connected to the Southern Conveyor.

Currently, the city of Paphos on the western coast (a major tourist resort) **is the only large urban area not connected to the Southern Conveyor**—due to the mountainous topography of the coastline. Table 2.2 provides the list of the potable water treatment plants in operation on the island (government-controlled areas).[4] They are all supplied by dams and operated by the WDD. Three large water treatment plants are connected to the Southern Conveyor,

TABLE 2.1. Potable Water Dams in Cyprus and Connections to the Southern Conveyor

Dam	Location of the dam (district)	First year of operation	Capacity (Mm³)	Connected to Southern Conveyor
Kannaviou	Paphos	2005	17.2	No
Evretou	Paphos	1986	24.0	No
Asprokremmos	Paphos	1982	52.4	No
Arminou[a]	Paphos	1998	4.3	Yes
Kouris	Limassol	1988	115.0	Yes
Germasogeia	Limassol	1968	13.5	Yes
Kalavasos	Larnaca	1985	17.1	Yes
Lefkara	Larnaca	1973	13.9	Yes
Dhipotamos	Larnaca	1985	15.5	Yes
Tamassos	Nicosia	2002	2.8	No
Klirou—Malounta	Nicosia	2007	2.0	No
Total water storage capacity			**253.7 Mm³**	**179.3 Mm³**

Note: Mm³ = million cubic meters.
a. Water is transferred to Kouris Dam.

TABLE 2.2. Potable Water Treatment Plants in Cyprus

Treatment plant	Capacity m³/day	Supplied water from	Area served	First year of operation
Kornos	30,000	Southern Conveyor	Nicosia	1984
Limassol	80,000	Southern Conveyor	Limassol and surrounding communities	1994—40.000 m³/day 2007—80.000 m³/day
Tersephanou	60,000	Southern Conveyor	Mainly Nicosia, partly Larnaca and Famagusta	1997
Paphos	30,000	Asprokremmos Dam	Paphos	2003
Kannaviou	10,000	Kannaviou Dam	Communities northwest of Paphos	2012

Source: WDD.

PHOTOGRAPH 2.3. General View of the Limassol Water Treatment Plant

Source: WDD.

while two other large plants are dedicated to supplying potable water to the Paphos area. The largest potable water plant is located in Limassol (photograph 2.3).

2.2. The Switch to Desalination for Potable Water Supply

2.2.1. Rainwater Is Too Unreliable for Securing Potable Water Demand

Because of large rainfall variability and continuous demand growth, it became gradually evident that **the massive development of dam storage capacity could not be enough to achieve potable water security.** The large rainfall variability has been made worse by the 20 percent mean reduction in average rainfall that has been measured since 1970.[5] However, the consequence of this reduction in rainfall is of even higher magnitude in terms of the water that can be captured, with a reduction in mean annual runoff into the dams ranging from 24 percent to 58 percent with a mean value of about 40 percent.

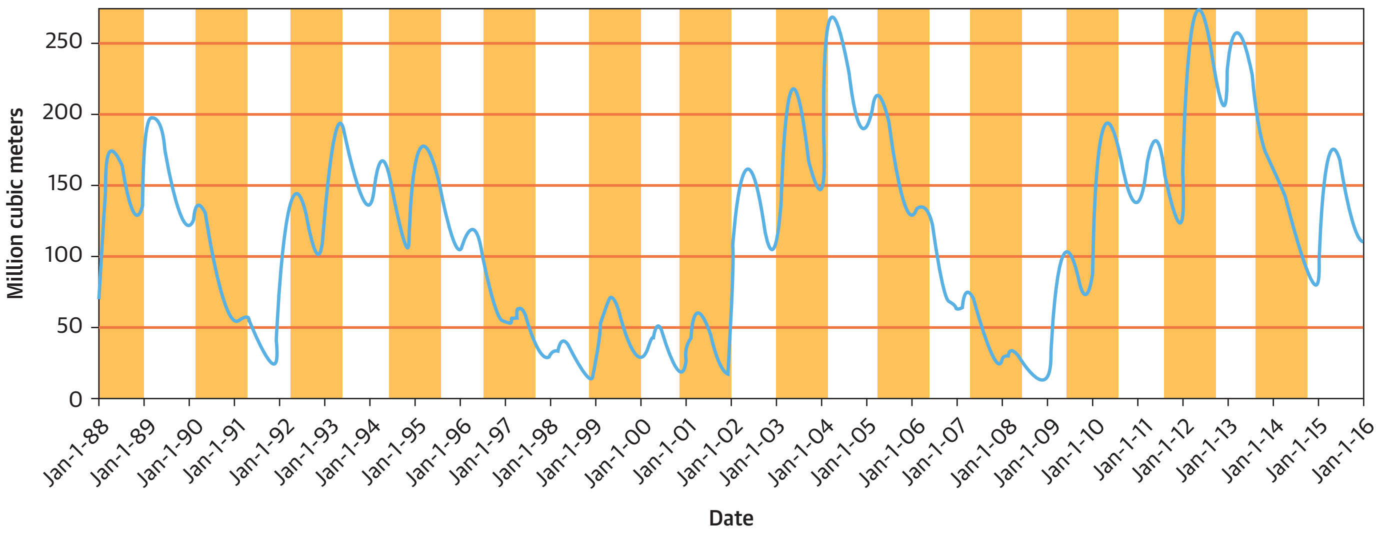
The average total volume of water stored in dams for the period 1988–2014 amounts to 100.4 million cubic meters—only about 30 percent of the total storage capacity—with considerable interannual variations. This is well illustrated in figure 2.3, which shows the variation in the total volume of water stored during the period 1988–2016. There are considerable variations in the amount of water stored as reserve at the end of the rainy winter season each year—from as little as 20 million cubic meters in the driest years (1992, 1999–2002, 2008–09) to a peak of as much as 270 million cubic meters in the wettest years (2005 following three successive years of abundant winter rainfall). It is worth noting that even during this peak, still only about 85 percent of the dams' total water storage capacity in Cyprus was being used. The other years when the dams' storage reached such high levels were 2012 and 2013, as a combination of heavy rainfall in 2012 and the fact that the desalination program was already at full speed (more in the next section).

The negative impact of the combination of rainfall variability and reduction in runoff on the total volume of water captured in dams over the past three decades can be seen from figure 2.4, which indicates the amount of rainfall that was stored each year from runoff into the dams. Again, the periods 1989-91 (three years), 1995-2001 (five years), and 2004-08 (four years) stand out as consecutive years with extremely low rainfall and ensuing runoff into the reservoirs. The considerable dam storage capacity developed in Cyprus was never fully utilized because in practice the total volume of **water captured in dams ranged from 12 million cubic meters (1990–91 and 2013–14) to about 192 million cubic meters (2011–12)—a factor of 1 to 16**. Even in the year 2012, when the dams started at their maximum historical level, the total stored volume captured was only 60 percent of total storage capacity.

Another recurrent problem is the **high levels of evaporation in the dams, due to the high temperatures during the summer dry months** in Cyprus. A study by the WDD found in 2014 that for 19 dams for which data were available, the quantities of water evaporated amounted to 9.6 million cubic meters. The overall rate of evaporation from dams of the Southern Conveyor Project is estimated at 8 percent.[6]

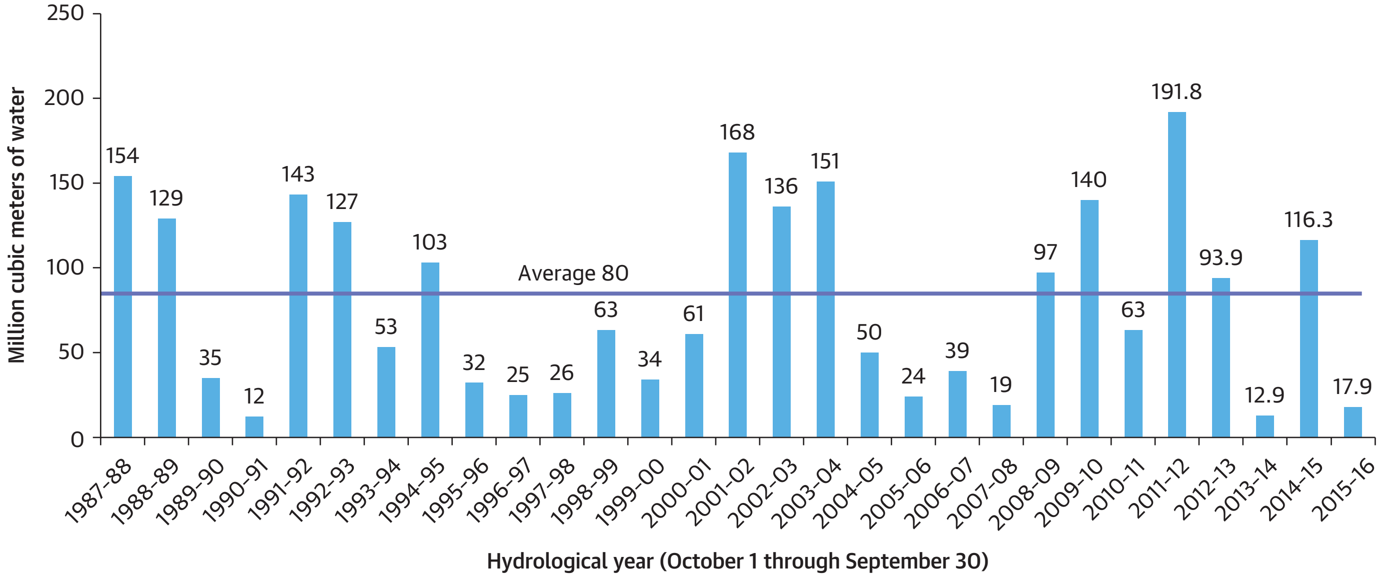
The succession of several dry years has been particularly problematic during the past two decades, starting with four successive dry years from 1997 to 2000 that kept the dams at very low levels. The government was forced to announce in early 1997 a reduction in water allocation of 20 percent for potable water and 40 percent for irrigation. In 1998, the water situation became worse and the reduction was increased to 28 percent and 56 percent, respectively. As a consequence, potable water rationing was imposed in urban areas that were supplied in bulk by the WDD; for instance, in Limassol, water supply was rationed for 12 hours every 48 hours. These measures were in force until the end of 2000.

FIGURE 2.3. Water Storage Curve for All Dams, 1988–2016



Source: WDD.

FIGURE 2.4. Water Inflow to Dams, 1987/88-2015/16

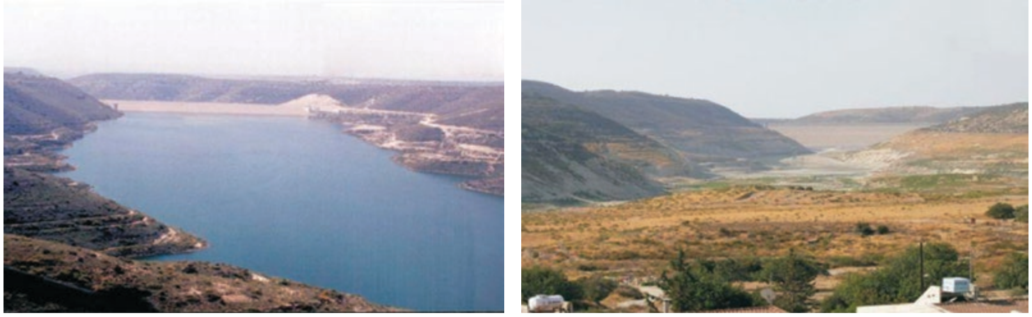


Source: WDD.

A few years later, the 2008-09 drought in Cyprus was the worst in modern history. One might have thought that after four years of drought and water rationing, drastic measures would have been taken in the early 2000s to ensure that in the future at least potable domestic supply could be guaranteed. However, and unfortunately, this major drought event was followed by three successive wet winters in 2002-04, with the volume of water stored in dams achieving record levels. Unfortunately, the dry years then returned and the large reserves ended up being depleted by four consecutive dry years. Because of upcoming elections in 2008, the government had been reluctant to impose water-saving measures early on—betting on a return of the rains during the 2007 winter—but this did not happen and the dams were at critical levels at the beginning of 2008.

This provoked a major water crisis in the southern part of the island, forcing the government to take drastic measure to ensure potable water supply, especially for the city of Limassol, which normally relied entirely on the Kouris Dam (see photograph 2.4 with pictures of the Kouris Dam, before the drought and at the end of the 2008 summer, when it was totally dry). Severe rationing measures were reintroduced in early 2008, with domestic water supply available only three times a week for 36 hours in total. Several small removable desalination plants were installed in the emergency. The most spectacular (and desperate) measure was to transport water from Athens via tankers to Limassol on a daily basis (see photograph 2.5). A total of 8.4 million cubic meters were transported over an eight-month period at a total cost of 56 million euros—at the prohibitive price of about **6.7 euros per m^3**. Farmers also suffered major losses.[7]

PHOTOGRAPH 2.4. View of Kouris Dam in 2004 and at the Worst of the 2008 Drought



a. April 2004

b. September 2008

Source: WDD.

The catastrophic 2008–09 drought was a turning point, driving the government's decision to finally embark on a massive desalination program to secure potable water supply. The three successive wet winters of 2001-02, 2002-03, and 2003-04 had proved a false blessing because they had given the illusion that the water shortage problem had been solved. As will be seen in the next section, desalination plants were starting to be developed in the early 2000s, but the development of additional desalination plants that had been agreed upon after the 2000 drought were postponed to save money, while a large portion of the water stored in the dams was freed for agriculture (CLICO). The 2008-09 drought came as a brutal wake-up call, prompting the government to adopt a new water production strategy whereby virtually all urban residential water needs would be met by water generated from desalination plants—the aim being that (a) **water supply for domestic, commercial, industrial, and touristic use should become independent of weather conditions;** and (b) renewable freshwater from **rainfall captured in dams should become solely dedicated to the agricultural sector** in order to gradually restore groundwater reserves.

2.2.2. Developing Seawater Desalination Plants under Build-Operate-Transfer Schemes

The first large seawater desalination plant in Cyprus started operation in April 1997 at Dhekelia (photograph 2.5) to cover the urban centers of Larnaca and Nicosia, plus the Famagusta resort area (photograph 2.6). Though the initial capacity was 20,000 m^3 per day, due to the prevailing water crisis situation at the time, the plant capacity was doubled to 40,000 m^3 per day the following year. It was developed under a public-private partnership (PPP) arrangement with the WDD as off-taker, following a build-operate-transfer (BOT) contractual structure whereby a private concessionaire undertook the design, financing, construction, and subsequent operation of the plant.

The operation and maintenance (O&M) period for this first desalination BOT in Dhekelia was initially for only 10 years, but it was followed in 2007 with a new contract, after an international tender, for an O&M period of 20 years. The new contract involved both the rehabilitation of the plant and a capacity extension to 60,000 m^3/day (more details in subsequent

PHOTOGRAPH 2.5. **The Dekhelia Desalination Plant**

Source: WDD and Caramondami.

PHOTOGRAPH 2.6. **Supplying Potable Water to Limassol via Tankers from Greece**


a. Construction of sub-sea supply pumping main

b. A tanker connected to the supply buoy

Source: WDD.

text)—and was therefore a rehabilitate-operate-transfer (ROT) contract. The Contractor who had initially built the plant was a joint venture between Cypriot company Caramondani and Spanish company Cadagua, but the subsequent refurbishment, extension, and 20-year O&M was undertaken by the Cypriot company alone.[8]

The second desalination plant is located near Larnaca international airport and started operation in July 2001, supplying the Larnaca, Famagusta, and Nicosia urban centers. It was also developed following a BOT approach, and with an initial 10-year O&M period. Like in the case of the Dhekelia plant, a new contract was awarded in 2014 following international tender including refurbishment and upgrading to 60,000 m^3 per day of the plant and a 25-year O&M period. The contractor who built the plant was IDE Technologies (Israel), but the second contract (ROT) was undertaken by MN Larnaca Desalination, a consortium of Mekorot Development & Enterprise (a subsidiary of Israel national bulk water company Mekorot), and Cypriot company Netcom Ltd.

The third large desalination plant started operation in 2012 near Limassol (photograph 2.7) with a capacity of 40,000 m^3 per day. It followed again the BOT contractual model, but this time with a 20-year O&M period—the WDD having drawn the lesson from the first contracts in Dhekelia and Larnaca that a 10-year O&M was unnecessarily short. The concessionaire that was awarded the contract was the same Israeli-Cypriot consortium already operating the Larnaca desalination plant for a decade.

The fourth permanent seawater desalination plant started operation in the summer of 2013. It is located on the premises of the Vassilikos power plant which is owned and operated by the Electricity Authority of Cyprus (EAC). With a capacity of 60,000 m^3 per day, it serves a wide area including Larnaca, Nicosia, the Famagusta resort area, and a number of the eastern villages of Lemesos. The contractual arrangement is slightly different from the first three desalination plants: the WDD has a bulk water purchase contract with EAC, which is the off-taker in a BOT contract with a private concessionaire. The BOT contract was awarded with a 20-year O&M period to IDE of Israel, the same company who had built the first desalination plant in Larnaca.

The total desalination capacity with the four seawater desalination plants under BOTs with private concessionaire now stands at 220,000 m^3 per day. All the desalination plants are based

PHOTOGRAPH 2.7. View of the Limassol Desalination Plant

Source: Logicom Group. Logicom.net.

on reverse osmosis, and their geographical location is shown in map 2.3. They are all interconnected with the Southern Conveyor, allowing water to be transferred as required to Limassol, Larnaca, the Famagusta area, and Nicosia. The **annual combined production capacity of 80 million cubic meters is broadly equivalent to the combined demand from the various urban users** (residential, commercial, industrial, and tourism).

In practice, the seawater desalination plants do not operate at full capacity throughout the entire year. The capacity has been set so as to allow for future demand increases, as well as for an operational cushion to be used only during the summer peak demand. Also, the WDD arbitrates each year for bulk water supply between desalination and treatment of raw water stored in the dams, depending on how much water has been captured from rainfall so as to reduce overall water production costs. The three potable water treatment plants in Kornos, Limassol, and Tersephanou that are connected to the Southern Conveyor with a combined capacity of 170,000 m^3 per day for treating raw water from the dams, are still fully in use. How the WDD arbitrates in practice between desalination and dams for meeting the domestic water demand is discussed in more detail in section 3.1.

MAP 2.3. Location of the Permanent Desalination Plants

Source: WDD.

2.2.3. Contractual Features of Desalination Build-Operate-Transfer Schemes

Table 2.3 summarizes the key characteristics of the various BOT contracts that have been implemented over the past decades for the four desalination plants. It includes total capacity and minimum average daily production, dates of tender closing and plant commissioning, total capital expenditure (CAPEX), and contractual prices (the four desalination BOT contracts currently in execution are shaded in blue in the table). In all cases, the cost of land was borne by

TABLE 2.3. Key Characteristics of Cyprus Permanent Desalination Plants

Description	Desalination plant owner						
	WDD	**WDD**	**WDD**	**WDD**	**WDD**	**WDD**	**EAC**
Main areas served	Larnaca Famagusta Nicosia —	Larnaca Famagusta Nicosia —	Larnaca Famagusta Nicosia —	Larnaca Famagusta Nicosia —	Larnaca Famagusta Nicosia —	**Lemesos** — — —	Larnaca Famagusta Nicosia Eastern villages of Lemesos
Plant and contract	**Dhekelia**	Dhekelia refurbishment	Dhekelia Extension	**Larnaca**	Larnaca refurbishment	Episkopi	**Vassilikos**
Plant capacity (m³/day)	20,000 (1997) 40,000 (1998)	**40,000**	**20,000**	52,000	**60,000**	**40,000**	**60,000**
Normal daily production (m³)	—	36,000	45,000	46,500	54,000	36,000	54,000
Type of contract	BOT	ROT-BOT	ROT-BOT	BOT	ROT	BOT	Bulk purchase-BOT
Tender closing date	05/1995	06/2005	09/2007	06/1998	04/2011	05/2008	01/2010
Date of operation	04/1997	05/2007	07/2008	07/2001	Summer 2014	07/2012	07/2013
Construction consortium	Caramondani Desalination Plants Ltd and Cadagua (Cyprus and Spain)	Caramondani Desalination Plants Ltd (Cyprus)	Caramondani Desalination Plants Ltd (Cyprus) —	IDE (Israel)	MN Larnaca Desalination Co (Mekorot Development & Enterprise Ltd of Israel and Netcom Ltd of Cyprus)	MN Limassol Water Co (Mekorot Development & Enterprise Ltd, Israel and Netcom Ltd, Cyprus)	IDE (Israel)
Duration of O&M	10 years	20 years		10 years	25 years	20 years	20 years
Total CAPEX	€62.9 M	€13.1 M	€14.1 M	n.a.	€6.0 M	€45.8 M	€50.3 M
Contractual price (€/m³)	0.92 —	0.64 —	0.64 up to 40.000 m³ 0.82 for additional 20.000 m³	0.68 —	0.594 —	0.8725 —	0.813 —
Adjusted price (inflation and electricity) for 2016 (€/m³)	—	—	**0.83**	—	**0.47**	**0.92**	**0.77**

Note: — = not available; BOT = build-operate-transfer; CAPEX = capital expenditure; EAC = Electricity Authority of Cyprus; m³ = cubic meter; n.a. = not applicable; O&M = operation and maintenance; ROT = rehabilitate-operate-transfer; WDD = Water Development Department.

the public off-taker. Each BOT contract includes a required total capacity—corresponding to the maximum volume that the plant can produce—and a standard production capacity corresponding to the normal operating mode (when not on standby).

The prices of desalinated water for the two newest desalination plants in Limassol and Vassilikos, whose BOTs were tendered in 2008 and 2010, stand at about 0.85 euros per m^3. It is important to note, however, that this is the contractual price as submitted for the tender, which was based on a theoretical unit price of electricity.[9] In practice and as will be explained in the next paragraphs, although each contract set a target for energy efficiency, the unit price paid by the concessionaires to the EAC is a pass-through and varies therefore each year according to the industrial electricity tariff of EAC, itself dependent on oil prices volatility.

The current contractual price for the older desalination plants in Dhekelia and Larnaca is lower—at around 0.65–0.70 euros per m^3. This partly reflects the fact that the current contracts are not BOTs but ROTs, and a portion of the investment cost of these plants had already been amortized over the 10-year O&M period of the first BOT contracts (the plants had started operation in 1997 and 2000).

Overall, the price of desalination water in Cyprus is among the lowest in the world—when taking out the impact of higher unit cost of electricity. It compares well with the price of desalinated water in Israel, which is also produced through large BOTs for seawater reverse osmosis, and is in the range of 0.55 to 0.85 US$ per m^3. The cost of investment financed by the private concessionaires can be estimated at close to 250 million euros.[10]

The contractual design of the BOTs has created strong financial incentives for the private sector to come up with the most efficient technical solution for reducing energy consumption. This was of crucial importance because electricity typically represents between half and two-thirds of the cost of desalinated water (based on international benchmarks). Furthermore, the four desalination plants in Cyprus represent about 9 percent of all the national electricity consumption government-controlled areas), and power generation on the island is entirely based on imported fuel. Each tendered contract included a target energy efficiency in kWh/m^3 for calculating the energy portion of the remuneration. While the unit cost of electricity is a pass-through, if the actual efficiency of a plant is below the contractual energy efficiency target, the private concessionaire has to pay a financial penalty equivalent to the difference with what the energy cost would have been, had the target been achieved. Conversely, if the energy efficiency is higher than the contractual target, it is allowed to keep the savings as bonus.

As a result, **seawater desalination plants in Cyprus have achieved a high level of energy efficiency, which is reported to currently stand at about 4.5 kWh/m^3—**though the actual energy efficiency figures achieved by the private concessionaires are confidential and may be closer to 4 kWh/m^3. This compares well with other top performing countries such as Malta (about 4 kWh/m^3) and Israel (though the best performing Israeli plant in Sorek has been reported to achieve a power efficiency of 3.6 kWh/m^3). The case of the Dhekelia plant, which is the oldest on the island, illustrates the constant progress that has been achieved over time. The energy efficiency of the original plant commissioned in 1997 was 5.5 kWh/m^3—including both the desalination process per se and the energy required for associated processes, that is, seawater intake, brine discharge, and intake into the distribution network. Following the refurbishment of the plant and new contract that started in 2007, the overall energy efficiency went down to 4.6 kWh/m^3 with the introduction of pressure exchangers technology. Since then, minor process improvements have reduced this energy efficiency ratio further.

Another lesson incorporated in the design of the BOT contracts currently in operation, from the earlier ones signed in 1995 and 1998, is the **importance of having contractual provisions allowing the off-taker to put the desalination plant in partial (or full) standby mode.** The normal operating mode (contracted volume) of the plants corresponds on average to 86 percent of the total capacity, but the WDD has the option for each plant to request that a portion of the contracted capacity be switched to standby (paying only the related fixed costs of the plant), or that an additional volume be produced while paying only the marginal cost. This is of crucial importance in the specific context of Cyprus with the high variability of rainfall. In wet years, the amount of water stored in dams may be considerable, and allocating a large portion of it to domestic consumption allows for reducing significantly the overall potable water production cost for the WDD because the production cost of filtration plants supplied from dams is much lower than desalination.

To this end, **the payment formula of the desalination BOTs gives flexibility to the WDD for optimizing the production level of the plants based on demand.** The unit price of desalinated water is based on a structure that includes **three operational modes: normal operation, standby, and additional quantities; and four cost components: CAPEX, energy, and fixed and variable O&M.** This is outlined in table 2.4, while table 2.5 illustrates how this is applied in the case of the Limassol BOT contract. In the event that the concessionaire is not able to deliver the full volume of water required, it is obligated to pay a financial penalty to the WDD for the quantity of water not delivered, equivalent to the corresponding purchase price under the contract.

The contractual design of the new desalination BOT in Paphos, whose tender was launched in November 2017, will introduce a new enhancement in the payment formula. This will be the fifth largest desalination plant, with a capacity of 15,000 m^3 per day to supply the large city of Paphos on the western coast (which is not connected to the Southern Conveyor). The payment structure for this new 25-year BOT contract has been modified by the WDD, drawing lessons from its experience of the difficulty of arbitrating between desalination and dams for potable water production, in a context of extreme rainfall variability. The proportion of standby capacity is being increased to 30 percent, and **two standby modes will be introduced**, with different unit prices for short- and long-term standby modes. The underlying rationale is that after the wettest years, the dam supplying the Paphos potable water filtration plant may be able to cover the water demand for up to two years, in which case putting the plant in long-term standby mode will allow for reducing some of the normal fixed costs (e.g., reducing staffing).

TABLE 2.4. Price Structure Components for the Desalination Build-Operate-Transfer Contracts

Unit cost components	Unit price according to operating mode
C: Capital expenditure	Unit price for normal operation: C + OM + E
OM: Operation and maintenance (fixed + variable)	Unit price for standby mode: C + SOM
E: Energy	Unit price for additional quantities: OM + E
SOM: Standby operation and maintenance (fixed)	

TABLE 2.5. Constituent Components of the Unit Price for One of the Desalination Build-Operate-Transfer

Component	Description	Percent of cost
C	Percent of total cost per cubic meter of desalinated water for the recovery of capital investment	36
OM	Percent of total cost per cubic meter of desalinated water to cover the cost of O&M in operating mode (fixed and variable portions)	18
E	Percent of total cost per cubic meter of desalinated water to cover the cost of Energy, based on a pass-through for the electricity tariff in euros per kWh and a target efficiency of 4.04 kWh/m^3	46
SOM	Percent of total cost per cubic meter of desalinated water to cover the cost of OM in standby mode (fixed portion only)	9

Unit Price of desalinated water produced and delivered (C+OM+E) = 100 percent

Unit Price of desalinated water when plant is in Standby Mode (C+SOM) = **45 percent**

Unit Price of desalinated water for additional quantities (OM+E) = **64 percent**

Note: C = capital expenditure; E = energy; OM = operation and maintenance; SOM = standby operation and maintenance.

Another noteworthy experience with desalination was the use of **built-operate-remove (BOR) schemes to install several small desalination plants, on a temporary and emergency basis, to deal with the 2008 drought**. A total of three plants were built under this approach (two serving Lemesos and one serving Paphos) using reverse osmosis. Only two plants used seawater, while a third was designed to remove nitrate and salt from groundwater in the Lemesos coastal aquifer. These contracts were for three to five years only, and at completion all equipment was removed by the private operators. Key characteristics of these plants are given in table 2.6. The prices for desalinated water for these emergency plants are, understandably, higher than for the BOT contracts, except for the Garyllis plant which was not using seawater but brackish water (salt and nitrates removal) from the Lemesos aquifer (this scheme had to be discontinued due to lack of environmentally sustainable solutions for disposing of brines).

2.3. Potable Water Distribution: Water Losses and Demand Management

2.3.1. Water Losses of Water Services Providers

As already mentioned, **the WDD is responsible for supplying potable water in bulk to most of the water service providers on the island** (government-controlled areas). This includes the

TABLE 2.6. Key Characteristics of the Temporary Desalination Plants Operated under BORs, 2008–10

Description	Desalination plant		
Areas served	Lemesos	Lemesos	Paphos
Plant location	Moni	Garyllis	Paphos
Plant capacity (m^3/day)	20,000	13,000	30,000
Minimum daily production (m^3)	18,000	11,700	27,000
Minimum annual production (m^3)	6,570,000	3,482,592	9,855,000
Type of contract	BOR	BOR	BOR
Tender closing date	08/05/2008	14/07/2008	21/05/2009
Date of operation	December 2008	2009	November 2010
Name of construction consortium	Silnir Cyprus LTD	Nirosoft IND. LTD	Mesogeos SA
Duration of O&M	3 years	5 years	3 years
Total CAPEX (cost of construction)	€9.7 million	€1.9 million	€12.1 million
Price (€/m^3)	1.39	0.29	1.22
Adjusted price for electricity (€/m^3)	—	0.35	1.70
Key technology	Reverse osmosis	Reverse osmosis (brackish water)	Reverse osmosis

Source: WDD.
Note: — = BOR = built-operate-remove; CAPEX = capital expenditure; m^3 = cubic meters; O&M = operation and maintenance; WDD = Water Development Department.

three urban water boards that serve Limassol, Nicosia, and Larnaca; the municipal boards; and many community boards. In addition to the Southern Conveyor, the WDD also operates transmission pipelines for the supply of the city of Paphos with two water filtration plants. There is no reliable estimate from the WDD of the level of **losses in the bulk water transmission systems** (both raw water and treated potable water). A significant number of community boards in villages located in rural and mountainous areas rely on their own water sources—either boreholes or springs with treatment limited to disinfection.

Even though analyzing the water losses in potable water distribution is a crucial topic for a country suffering from extreme scarcity, **access to nonrevenue water (NRW) data in Cyprus is a challenge**. There are no official audited data with regard to NRW performance of the Water Service Providers in Cyprus, except for references in some annual reports of the Auditor General of the Republic with data limited to the urban water boards and some municipal boards, and no data for community boards supplying villages.[11] The latest year for which NRW data were available is 2013. A search of the Auditor General's Annual Reports from 2002 to 2013 yielded only limited information.

As part of this study, estimates for the level of NRW for the various types of water supply providers in Cyprus have been calculated for 2013 and are shown in table 2.7. Although these estimates are subject to several limitations, and can be considered relatively broad

TABLE 2.7. **Nonrevenue Water for the Water Services Providers as a Percentage of System Input Volume, 2013**

Water service provider	System input volume	Nonrevenue water (NRW)			
	Mm³	Mm³	Percent	liter/con./day	ILI
Water Board of Nicosia	17.0	3.4	**20**	120	2.6
Water Board of Limassol	16.0	4.5	**28**	174	3.5
Water Board of Larnaca	4.4	0.8	**18**	66	1.3
Municipal water departments	18.3	6.4	**35**	—	—
Community boards	21.5	8.6	**40**	—	—
Overall NRW	**77.2**	**23.7**	**31**	—	—

Note: — = not available; ILI = Infrastructure Leakage Index; Mm³ = million cubic meters; NRW = nonrevenue water.

concerning the municipal departments and community boards, they do provide nonetheless an overview of the current situation of water losses in the distribution networks. These figures are all based on universal coverage and continuous 24/7 water supply. The NRW level has been calculated with three different indicators: percentage of input volume, volume lost per connection per day, and Infrastructure Leakage Index (ILI) as defined by the International Water Association (IWA)—so as to allow for a better analysis of the water losses situation.

The **overall NRW level for potable water distribution in Cyprus can be estimated at 31 percent.** While this is broadly in line with the NRW levels at the national level of potable water providers in other southern European Union (EU) countries such as Italy, France, Spain, and Portugal, this is still **relatively high for a country suffering from extreme water scarcity.** While a portion of the NRW corresponds to commercial losses, that is, undermetering of actual consumption, the total volume **lost every year from water leakages in distribution networks is probably in the range of 16 to 20 million cubic meters.**[12]

Water losses reduction has been a top priority for the three water boards of Nicosia, Limassol, and Larnaca for almost three decades. In the early 2000s the urban water boards embarked on a major program of modernization of their water distribution network, which included division of the distribution network into pressure zones and district metered areas (DMA).[13] SCADA (supervisory control and data acquisition) systems were installed to allow for continuous monitoring of flows and pressures. A 2008 study commissioned by the three water boards concluded that the networks hydraulics and current DMAs framework were well designed overall.[14]

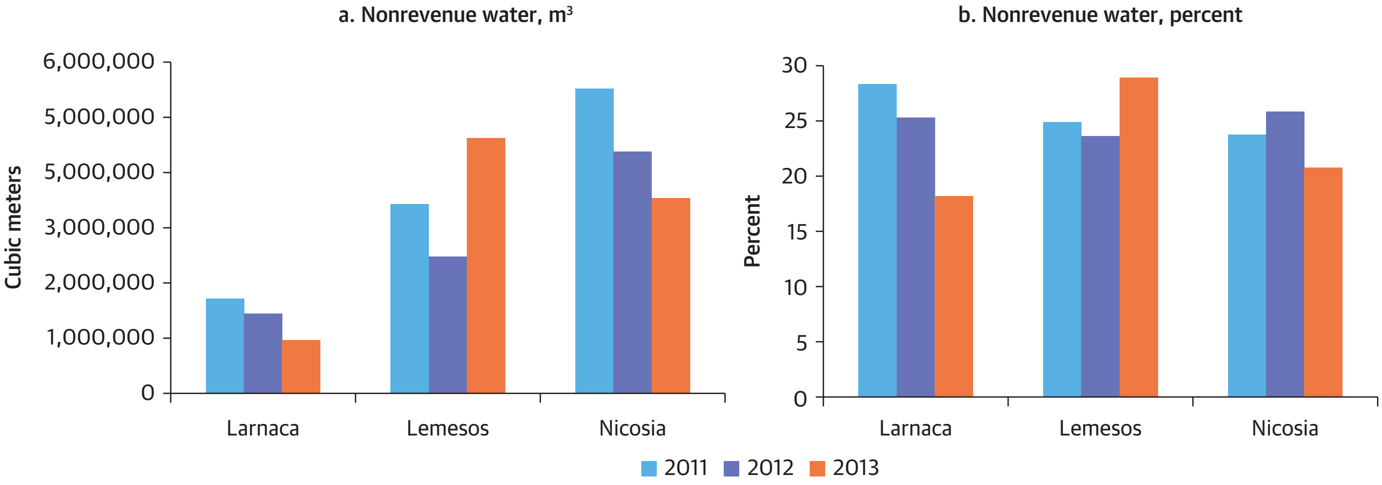
The Larnaca Water Board stands out for achieving a very good NRW performance, with NRW at 18 percent in 2013 and an ILI indicator of only 1.3. The volume of water lost per connection stands at only 66 liters per day. The ILI indicator, which was developed by the IWA as part of its NRW expert taskforce, measures the relative proportion of physical losses to a notional level of "unavoidable losses," which corresponds to the level of water leakages below which further effort to reduce leakages would be technically too challenging.[15]

The ILI methodology calculation suggests that in Larnaca, the utility has managed to reduce the level of water losses not far from the minimum technical level given the specificities of its network conformation—a fact rarely achieved except by the best-performing water utilities in Western Europe, and in line with what should be expected from a well-performing water utility operating under water scarcity constraints and distributing expensive desalinated water.

The NRW performance of the Nicosia Water Board is satisfactory, standing at 20 percent in 2013, but the ILI calculation suggests that some further reduction in water losses may be achieved. This underlines the importance, when analyzing the NRW performance, to look not just at the percentage figure but also at other indicators. Even though the NRW percentage is comparable to the one in Larnaca, the volume of water lost per connection is almost twice as high, and the ILI indicator at 2.6 suggests that some gains may remain to be made in terms of reducing water leakages. However, the complexity of the water distribution system in Nicosia—with hilly topography, old pipelines, many pipes located in old streets in historic neighborhoods, and the demarcation line and no-man's land currently dividing the city—explains why reducing water losses further in Nicosia is more challenging than in Larnaca.[16]

In contrast, the NRW performance of the Limassol Water Board is unsatisfactory, at 28 percent and with an ILI of 3.5 based on 2013 data. The 2013 Auditor General's report also provided the evolution of the percentage of NRW for the three water boards for the three successive years 2011, 2012, and 2013. Results are depicted in figure 2.5. Although water losses in Nicosia and Larnaca have been on a positive downward trend, this is not the case for Limassol where water losses have been increasing.

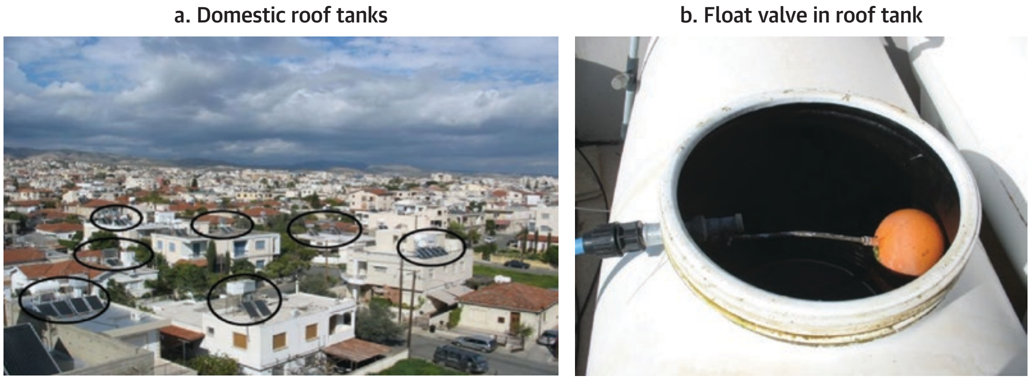
FIGURE 2.5. Nonrevenue Water in the Three Urban Water Boards of Larnaca, Limassol, and Nicosia, 2011–13



The poor NRW performance in Limassol is a recent phenomenon, partly due to the consequences of the 2008–09 drought, since it used to have a satisfactory NRW level similar to the two other water boards. Limassol was by far the hardest-hit city, having to be supplied by water tankers from Athens once the Kouris became dry. The utility was forced to impose rationing and adopt an intermittent distribution mode for eight months. This considerably damaged the networks, due to the repetitive pressure surges generating multiple breaks and leakages, most of them invisible. Once the drought was over and distribution restored to a continuous 24/7 supply, the level of **NRW had increased by about nine percentage points compared to the predrought level**. The consequences of the drought and intermittent supply on water losses will be further analyzed in the next section. Since then, **the Limassol Water Board seems to have been unable to restore the physical condition of its distribution network back to its pre-2008 condition**, with a backlog of invisible leaks (pipes and connections) that kept growing. Another reason for the relatively poor performance may have been the incorporation in 2013 of another peri-urban municipality in the water board, whose water network was previously operated by a municipal department and which was in poor shape.

It is worth highlighting that private roof tanks can generate significant meter underregistration, which is a notable component of NRW in Cyprus (photograph 2.8). Roof tanks are widespread in countries affected by water scarcity; they allow customers to adjust to the inconvenience created by intermittent water supply and rationing. In Cyprus, although now a continuous 24/7 supply is guaranteed for all domestic customers thanks to the desalination program, most houses are still equipped with roof tanks, as a legacy of the past and especially the last major droughts in 1999–2002 and 2008–09. The problem stems from the fact that the ball valves in roof storage tanks cause meter underregistration, especially at very low flows. Tests carried out in Limassol showed that **undermetering due to roof tanks accounted for between 3 and 5 percentage points in the overall NRW figure**.

PHOTOGRAPH 2.8. Limassol—Domestic Roof Tanks on Houses and Valve Closing System



a. Domestic roof tanks

b. Float valve in roof tank

Source: Bambos Charalambous.

The study also showed that installing flow control devices (called unmeasured flow reducers or UFR) was an efficient solution to solving this common problem faced by water utilities in water-scarce countries—a valuable lesson for countries in arid climates facing similar situations.

The level of water losses in the municipal water supply departments is much higher than for the three water boards—at an estimated average of 35 percent. NRW figures are reported for only a limited number of municipal water departments and vary between 28 percent and 45 percent indicating relatively high water losses. Even though they represent a combined production volume comparable to the Nicosia Water Board, the volume of water losses is almost double, estimated at 6.4 million cubic meters in 2013. This is **an issue of major concern—not just in terms of efficient water management under scarcity but also of financial sustainability**—because with the exception of Paphos, all these Municipal Water Departments are supplied in bulk by the WDD, and most of the potable water comes from expensive desalination plants. As for Paphos, the Asprokremmos Dam has become insufficient to guarantee potable water supply, and although a fifth desalination plant is being developed by the WDD, the rationale for putting effort in leakage reduction is equally strong. Even though the concerned municipalities have financial incentives for taking NRW reduction seriously, this is not yet happening, possibly because of a lack of technical capacity and managerial incentives.

Very little data are available on the community boards in rural villages, and the level of NRW probably varies between 30 percent and more than 50 percent. A study commissioned by the WDD in 2009[17] found that in most cases the basic data necessary to calculate a NRW figure—system input volume and metered consumption—did not exist, especially because not all customers are properly metered. In the few cases where such data were available, a level of NRW of 26 percent was calculated for 2008 based on 60 community boards. Yet this figure is not representative because obviously only the best performers were able to provide the needed data. The study concluded that NRW in rural villages varied from 30 percent, where the distribution networks were relatively new (financed and installed or replaced by the WDD), up to 40 percent or more where the networks are older. These community boards have little or no capacity to deal with NRW—depending entirely on the WDD for technical issues. Overall, it can be estimated that the level of **water losses in community boards is in the range of 8 to 10 million cubic meters per year**—a considerable figure which is close to 40 percent of the total estimated water distribution losses. The impact, however, in terms of water resources management is unclear, since many rely on boreholes and springs, and the aquifers in the Troodos Mountains (where many rural villages are located) are not in situations of stress, unlike those on the coastline.

2.3.2. Rationing under Drought: Impact of Intermittent Water Supply

It is well known that intermittent supply has severe effects on the integrity of water distribution networks. Because of the continuous emptying and refilling of the network, the pipes are subject to constant pressure surges (the "hydraulic hammer" effect) that increase the frequency of breaks. Intermittent supply is often adopted by water utilities faced with water shortages in an attempt to control water consumption and reduce losses—but **this results in a vicious cycle**. The deterioration of the network generates more breaks and leakages, and the number of hours of service has to be reduced to avoid losing more water through distribution losses. Supplying less quantity in an intermittent manner causes such deterioration to the network, that if and when continuous supply is reestablished, additional quantities are lost through increased leakage. Furthermore, domestic demand is largely inelastic, and in arid countries where households are often equipped with private roof tanks, the effect of intermittent supply on households' consumption is minimal.

This has been **fully confirmed by the 2008–09 drought in Cyprus, where extensive data are available from the Limassol Water Board**. As already mentioned, Limassol was the hardest-hit urban area in Cyprus, having to be supplied by water tankers from Greece for eight months. As a consequence, the utility had to impose rationing and switch into intermittent supply for about two years, during the worst point of which customers were supplied only 36 hours per week. Data collected on the adverse effects on the networks, as well as the financial repercussions on the utility, after the drought ended and the distribution mode was restored to continuous 24/7 supply, are presented below.

As a result of the deterioration of the network during these two years of intermittent supply, **there was a large increase in the number of reported pipe breaks once continuous supply was reestablished,** when compared with the predrought period. A statistical comparison was made for 20 large DMAs, before and after the drought (first year after rationing was lifted). The number of reported breaks (visible leakage) went up by 200 percent in the distribution pipes as a consequence of intermittent supply. For visible leakage in service connections, the increase was 100 percent. The results are shown in table 2.8.

The increase in water losses after reestablishing continuous supply is evident when comparing the Minimum Night Flow in the various DMAs before and after. The combined Minimum Night Flow measured at the entry of all DMAs is presented in figure 2.6 members for the years 2007 and 2010. The difference corresponds to increased water distribution losses as a consequence of the many breaks and leakages generated by the intermittent supply mode.

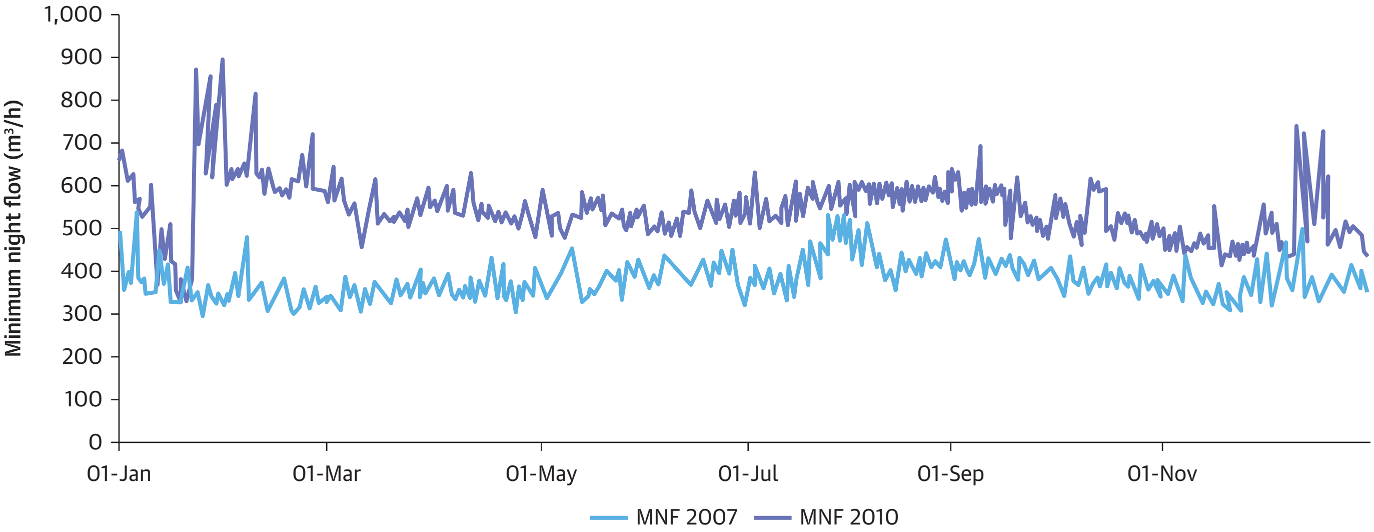
The overall increase in water leakage in Limassol after two years of intermittent supply was measured at nine percent—equivalent to an additional volume of **losses of 1.65 million cubic meters per year**. For the purpose of drawing lessons for other countries, it is important to note that the increase in leakage would have been much higher if the Limassol utility did not have

TABLE 2.8. Effect of Intermittent Supply on Reported Pipe Bursts in Limassol

Description	Number of reported breaks		
	Before drought	After drought	Percent increase
Mains	14 per 100 km	42 per 100 km	**200**
Service connections	15.5 per 1,000 connections	29.7 per 1,000 connections	**100**

Note: km = kilometers.

FIGURE 2.6. Minimum Night Flow for All Reservoirs, 2007 and 2010



Source: Water Board of Limassol.
Note: m³/h = cubic meters per hour; MNF = minimum night flow.

at that time a well-designed network with DMAs, and more than a decade of experience in active leakage control. Further evidence of the impact of intermittent supply is shown in table 2.9, with the evolution of the system input volume and metered consumption before, during, and after the drought (2007-10). Intermittent supply allowed during 2008-09 to reduce both system input volume and consumption, by about 20-25 percent. But **once continuous supply was reestablished, the system input volume had to be increased by 13 percent compared to 2007**, even though consumption went down slightly.

The 2008-09 drought experience in Limassol also shed valuable light for estimating the "hidden" costs of intermittent supply. These include losses in revenue and additional operating costs during the rationing period, as well as the cost of the additional water lost due to increases in leakages once continuous supply was reestablished. The figures as calculated by the Limassol Water Board are presented in table 2.10. The revenues shortfall during the 2008-09 represents about one million euros, and the cost of the additional losses due to intermittent supply were estimated at about 1.3 million euros per year. Because the Limassol Water Board has not succeeded in repairing the backlog of additional leakages generated in 2008-09, this last figure has become a recurrent additional cost every year. The **accumulated incurred costs of the two-year intermittent supply can therefore be estimated to have reached a total of about 9 million euros by 2015**.

2.3.3. Tariffs and Demand Management

To foster water conservation, **potable water tariffs of water boards and municipal departments—which serve about 70 percent of the population—are based on a progressive blocks structure**, with all customers being metered. Customers are differentiated by categories, with

TABLE 2.9. System Input Volume versus Customer Consumption in Limassol, 2001–10

Year	Distribution mode	System input volume (%)	Customer consumption (%)
2007	Continuous 24/7	Baseline zero	Baseline zero
2008	Intermittent	−17,5	−9,2
2009	Intermittent	−9,1	−8,9
2010	Continuous 24/7	+12,8	−1,2

TABLE 2.10. Costs of Intermittent Supply in Limassol during the 2008–09 Drought

	euros
Reduction in water sales for 2008–09	300,000
Additional costs for staff overtime in 2008–09	365,000
Cost of repairs additional breaks in 2008–09	325,000
Cost of additional water lost in 2010–12	1,325,000
Total incurred cost over 2008–15 in Limassol	8,940,000

commercial customers and hotels paying higher rates to cross-subsidize domestic customers.[18] Different rates are applied to monthly consumption tranches. The water tariff structure for domestic customers in the three water boards and two municipal departments (in the Paphos and Larnaca areas) is shown in table 2.11. For domestic customers, the fixed charge is in the order of 3 to 5.5 euros per month. The first discounted consumption tranche typically covers the first 10 m^3 per month. There are steep rate increases for consumption above 21 m^3 per month—between twice and three times the rate of the first tranche. To ensure affordability for large families, special tariffs are available for households with more than five members.

The **sewerage charges for the five sewerage boards (Nicosia, Larnaca, Limassol, Paphos, and the Famagusta resort area) have two components**, with one being **a volumetric charge based on water consumption which therefore directly impacts water demand**. This is a flat volumetric fee with no increasing blocks charged through the water bills by the water boards or municipal departments. **The second component is a fixed sewerage tax charged annually based on residential values.**[19] The prevailing sewerage tariffs (sewerage collection and wastewater treatment) in 2017 as charged by the urban sewerage boards are provided in table 2.12. The domestic sewerage tariff in urban areas varies between 0.34 and 0.71 euros per m^3, which is low compared to other European countries, but does not include the portion paid through the annual sewerage property tax (which can represent half of the sewerage bill).

Overall, **urban water supply and sanitation (WSS) tariffs in Cyprus** (both water boards and municipal departments) **are lower than in most other European countries.** In addition,

TABLE 2.11. Domestic Potable Water Tariffs in the Three Urban Water Boards of Lemeos, Larnaca, and Nicosia and in the Municipalities of Paphos and Geroskipos, 2017

		Domestic water tariffs				
		Limassol	**Larnaca**	**Nicosia**	**Paphos**	**Geroskipos**
Fixed (€/month)		4.00	3.50	3.50	4.00	4.00
Maintenance (€/month)		1.50	2.00	0.00	0.00	0.00
Consumption						
From (m^3)	To (m^3)					
0	5	0.90	0.90	0.90	0.81	0.65
6	10	0.90	1.00	1.05	0.81	0.65
11	15	1.40	1.40	1.25	0.90	0.85
16	20	1.40	1.50	1.40	1.10	1.10
21	25	2.35	1.80	2.20	2.00	1.90
26	30	2.35	2.50	2.90	4.00	3.00
31	and over	5.00	5.00			3.50
31	35			3.60		
36	40			3.80		
41	and over			5.00		
31	36.67					
36.67	and over					

Note: m^3 = cubic meters.

customers benefit from large value added tax (VAT) rebates: no VAT on the water bill and only 5 percent VAT on the sewerage bill. The average WSS bill for a family of four (based on 17 m^3 per month) served by one of the water boards is in the range of 18 to 22 euros per month (2017)—**between 1.07 and 1.27 euros per m^3**. For the same family living in Paphos and served by a municipal water department and a sewerage board, the WSS monthly bill stands at 12 euros, or about **0.70 euros per m^3**. To this must be added the sewerage annual tax based on property value, which for a property valued at 200,000 euros represents about 10-12 euros per month—**or about one-third of total WSS cost**. Tariffs tend to be lower in urban areas served by municipal departments because water charges are set solely by local authorities, whereas for urban water boards the central government has significant power to push for water charges closer to full cost recovery.

The **domestic consumption per capita for the urban areas of Limassol, Nicosia, and Larnaca stands at 140 liters per day on average**. This is broadly in line with per capita domestic consumption in other Southern European countries such as Spain, France, Italy, Portugal, and Greece—but significantly more than in Malta and Israel (about 85 liters per day), two other advanced Mediterranean countries that also suffer from extreme water scarcity. This consumption level includes a sizeable amount dedicated to gardening (no rainfall for more than

TABLE 2.12. **Domestic Sewerage Tariffs in the Five Urban Sewerage Boards, 2017**

Sewerage board	Tariff in euros per m³ of water used		Sewerage annual tax (Lump sum in euros)		Storm water annual tax (Lump sum in euros)		Late rate rivision
	2017	Maximum charge[a]	Charge rate × (property value)[b]	Maximum charge	Charge rate × (property value)[b]	Maximum charge	
Nicosia	0.55	0.55	0.60 ‰	0.60 ‰			2012
Limassol	0.64	0.64	1.10 ‰-hotels/factories	1.10 ‰	0.10 ‰	0.15 ‰	2017
			0.42 ‰-all other premises	0.60 ‰			
Larnaca	0.50	0.56	1.10 ‰-hotels/factories	1.30 ‰	0.16 ‰	0.30 ‰	2008
			0.56 ‰-all other premises	0.80 ‰			
Paphos	0.42	0.5	1.10 ‰-hotels/factories	2.00 ‰	0.10 ‰	0.10 ‰	2011
			0.45 ‰-all other premises	2.00 ‰			
Agia Napa	0.34	0.55	1.35 ‰-hotels	2.00 ‰			2016
			1.10 ‰-commercial bulidings	2.00 ‰			
			1.80 ‰-dwelling and other bulidings	2.00 ‰			
			0.20 ‰-unused land	2.00 ‰			
Paralimni	0.34	0.55	1.35 ‰-hotels	2.00 ‰			2016
			0.90 ‰-hotels (in residential areas)	2.00 ‰			
			1.10 ‰-dwelling and other bulidings	2.00 ‰			
			0.20 ‰-unused land	2.00 ‰			

a. The maximum charge is a cap value over which the sewerage boards are not allowed to charge.

b. The property value is taken from the Lands and Survey Department based on the latest version (1/1/2013) on all fixed assets (land and buildings).

half of the year), though many private houses also have private wells. Although no data are available for the per capita domestic consumption in areas served by municipal departments and community boards (even though they serve a permanent population of more than 400,000 people), it is likely that the per capita consumption is higher, due to both lower tariffs and less strict metering practices.

Overall, it can be said that **households in Cyprus are using water rather comfortably, considering that the island suffers from extreme water scarcity.** This can be directly attributed to the fact that **the rather low WSS tariffs are insufficient to foster much demand management by households**—reflecting the fact that the water sector is subsidized by the central budget—and it can largely explain why the per capita domestic consumption stands at 140 liters per day, despite the extreme water scarcity prevailing on the island. In urban areas, this is at least in part due to the fact that a significant portion of the sewerage cost is charged through an annual sewerage tax, based on residential value and unlinked from actual consumption.

Water tariffs are even lower for rural areas and villages served by community boards, and which represent about 40 percent of the population (government-controlled areas). Water tariffs there tend to be very low—typically between 0.10 and 0.30 euros per m³—and there is no charge for sewerage services (except in a few villages with sewerage systems). Furthermore, metering practices by community boards are very lax: billing based on estimated consumption still exists, and when meters are in place they are rarely replaced periodically and tend to show undermetering. As most villages depend on their own boreholes and springs, demand management is essentially constrained only by the local water resource.

Even though demand management through tariffs has clearly not been exploited to its maximum in Cyprus, **several significant measures have been taken over the past 3 decades to promote demand management**. Communication campaigns are carried out by the WDD on a regular basis to educate the public on the need for water conservation, and were intensified during the droughts periods of 2001-04 and 2008-09. Since 1991, using piped potable water for washing cars and cleaning verandas and pavement has been banned by law, with fines imposed by the police.[20] The water boards also have rather strict bill collection procedures, with a 10 percent surcharge on overdue bills (two months) followed by disconnection.

Since the early 2000s, the WDD had put in place subsidies for a series of water-saving measures at the household level (see appendix A). The two most important were for installing a grey water recycling system (3,000 euros) and for drilling boreholes for watering gardens (700 euros, or about half of the cost of drilling plus pump installation). A total of 7,666 boreholes subsidies were granted between 1997 and 2010. Overall, **the WDD estimated that these measures saved about 1.7 million cubic meters per year** in domestic water demand, of which 1.38 million cubic meters/year came from the borehole subsidy and 0.27 million cubic meters per year from the connection of boreholes with toilets.[21] These subsidies had to be phased out in 2013 as part of the drastic budgetary cuts applied in the aftermath of the Cyprus financial crisis.

In retrospect and with the exception of grey water recycling, these subsidies measures were questionable in a context of already overexploited underground water resources. This is because they were not directed at reducing the total water consumption of households, but rather at switching water supply partly from the piped network to the aquifers. Furthermore, using shallow boreholes for toilets increased the salinity level of sewerage collected in coastal areas, which creates challenges for further reuse of treated wastewater (TWW) in agriculture. It would have been better to subsidize the installation of water saving devices (e.g., for flush toilets and showers).

Water demand from the tourist industry deserves a special look. The total consumption of the tourist industry is estimated at about **20 percent of total urban consumption, or about 5 million cubic meters per year,** which is considerable. Even though WSS tariffs charged to hotels are considerably higher than for domestic customers,[22] the per capita water demand for tourists has been estimated at 465 liters per day (Savvides 2001), which is more than three times domestic consumption per capita. Building on the experiences in other countries, resource-saving measures targeted at the hotel industry would be worth considering.[23]

2.4. Sewerage Services and Reuse: Closing the Urban Water Cycle

2.4.1. Sewerage Services in Urban and Rural Areas

Sewerage services on the island are mostly provided through five urban sewerage boards, which serve the **urban agglomerations of Nicosia, Limassol, Larnaca, Paphos, and the Famagusta resort area** (Ayia Napa/Paralimni). Like the urban water boards, they are organized as ring-fenced utilities with quasigovernmental status. Their combined service area represents a total population of 765,000 people—with a much wider geographical scope than the three urban water boards. Their main characteristics are shown in table 2.13.

Since joining the European Union (EU) in 2004, Cyprus made considerable efforts to comply with the EU Urban Wastewater Treatment Directive (UWWTD). At that time, significant sanitation investment was still required to expand sewerage networks and wastewater treatment within the areas covered by the five large urban agglomerations on the island—Nicosia, Limassol, Larnaca, Paphos, and the Famagusta resort area. In addition, compliance with the UWWTD required Cyprus to make an unprecedented effort to provide sewerage services in rural areas, which were largely undeveloped, by developing sewerage infrastructure in a total of 50 agglomerations above 2,000 population equivalent (only 6 already had sewerage systems) as well as several smaller villages. The UWWTD implementation plan that was agreed upon in 2008 with the European Commission (EC) is shown in map 2.4.[24]

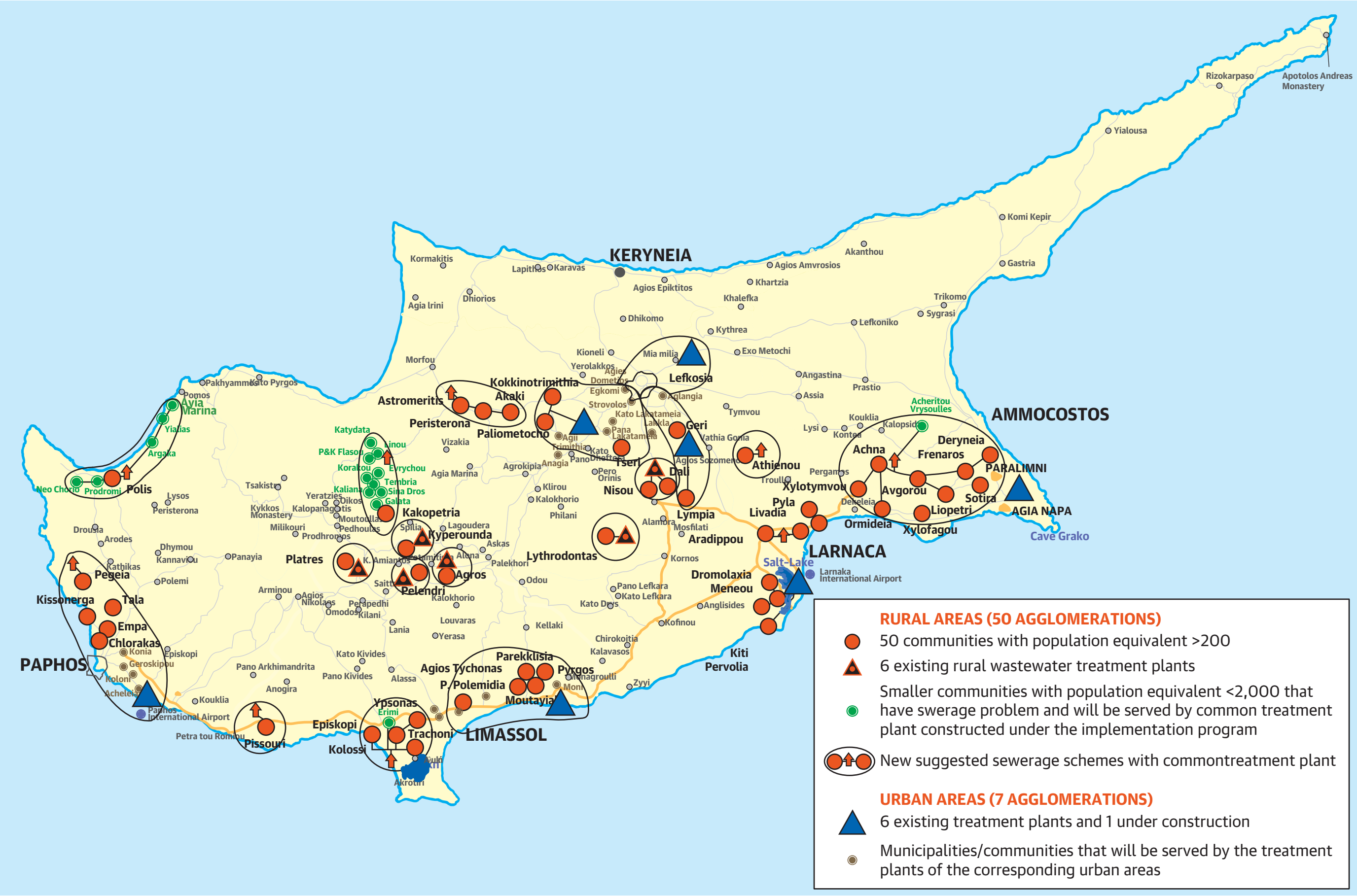
The financing and execution mechanisms for sewerage investments differ depending on the size of the agglomerations. In the five urban agglomerations of the island, the urban sewerage boards are responsible for financing, constructing, and operating the new sewerage infrastructure. Financing for infrastructure investments is carried out through borrowing from EIB or commercial banks, to be repaid through the sewerage charges (both volumetric charges through the water bill, and the annual sewerage tax based on real estate value), with only the cost of tertiary wastewater treatment being subsidized by the central government. In the rural communities, the WDD is responsible for financing (with grants from EU cohesion funds)[25] and construction, while newly created Rural

TABLE 2.13. Main Characteristics of the Five Urban Sewerage Boards, 2015

Description	Unit	Sewerage board				
		Limassol	Larnaca	Nicosia (Republic only)	Paphos	Ayia Napa, Paralimni
Population covered ('000) (current/target)	Number	130/170	40/60	255/270	105/150	115/115
Service coverage	Percent of total population	76	60	94	70	100
Treated effluent volume (current/target)	Mm^3/year	7.8/19.0	2.5/6.5	12/13	3.8/5.0	3.3
Length of sewerage pipes (current/target)	km	600/650	142/325	1,430/1,440	370/400	260

Note: km = kilometers; Mm^3 = million cubic meters.

MAP 2.4. National Implementation Program for Urban Wastewater, 2008



Source: WDD.

Sewerage Community Boards are responsible for O&M with the assistance of the WDD. The total investment for new sewerage systems was estimated at **1,430 million euros.** As only 125 million euros was earmarked from EU grants, UWWTD compliance represented a big financial commitment for a country like Cyprus.

Although sewerage investments largely came to a halt in 2013 with the Cyprus financial crisis and ensuing budgetary restrictions, most of the UWWTD objectives for the urban areas have been achieved. In the areas served by the five urban sewerage boards, the rate of coverage for sewerage collection services now stands at 84 percent—corresponding to a population of 645,000 being connected to sewerage networks. This represents a total length of about 2,800 km of sewer networks. It is estimated that an additional 270 km (less than 10 percent) would be needed to achieve full coverage based on targets set for compliance with the EU UWWTD. There are 8 large wastewater treatment plants (WWTPs), which treat all the effluent collected by the sewerage networks.[26] The sewerage systems and WWTPs in operation are shown in map 2.5.

MAP 2.5. Existing Wastewater Treatment Plants in 2015

Source: WDD.
Note: PE = population equivalent.

However, most of the sewerage investments planned for small agglomerations remains to be executed. There are only seven small WWTPs in operation for agglomerations of more than 2,000 PE[27]—compared to the target of 50 small agglomerations above 2,000 PE under the original 2008 implementation plan. Cyprus was supposed to fully comply with the UWWTD by December 2012 (interim date for compliance) according to the EU accession treaty, and is one of the EU-13 countries still facing serious UWWTD compliance issues. Based on the latest 2014 EC implementation report, the legal compliance for agglomerations above 2,000 PE stands at only 30 percent, with overall compliance based on the percentage of generated load reaching 65 percent.[28]

The Government of Cyprus has proposed to the EC an updated UWWTD plan with final compliance deadline set for 2027, taking into consideration *inter alia* the continuing budgetary constraints, and the special challenges of expanding sewerage systems in rural areas.

This revised plan aims to optimize the cost of UWWTD compliance, including through better reliance on individual appropriate sanitation (IAS) systems for rural areas where sewerage networks may not be the most economical solution.

2.4.2. Design-Build-Operate Schemes for Wastewater Treatment

One key feature of the development of WWTPs in Cyprus has been the widespread recourse to PPPs following the design-build-operate (DBO) model. All except one (in Larnaca) of the eight large WWTPs developed over the last three decades, as well as most smaller plants in rural areas, have been done under the DBO approach.

The strategic decision to rely on DBO schemes for the development of WWTPs in Cyprus was concomitant to the other strategic decisions to develop extensive wastewater treatment reuse for agriculture—as another nonconventional water resource to complement desalination. Operating WWTPs with tertiary treatment levels entails complex technological processes, with significant risks of noncompliance with the more stringent effluent standards[29] required for agriculture (and subsequent risks in terms of public health). In Cyprus, adopting the PPP approach for the development and O&M of the WWTPs has allowed to transfer these risks to private concessionaires, who are liable for financial penalties in case the treated effluents do not meet minimum standards. Like in the case of the desalination plants developed under BOTs, it was considered that the technological complexity of tertiary wastewater treatment justified adopting the PPP approach.

Under DBO schemes, and contrary to BOT schemes as adopted for desalination, the financing of the new plants was provided by the public developer and off-taker.[30] Still, the private sector remained responsible for the design, construction, and subsequent O&M of the plants. For the development of WWTPs, the DBO approach was deemed more appropriate as it allowed for achieving a lower cost of financing compared to BOTs (the urban sewerage boards were able to borrow on favorable commercial terms) and made it easier to cofinance with EU grant funding. Still, private concessionaire still had strong incentives to design and build the new plant efficiently (with no construction delays and no costs overruns) and carry out subsequent O&M in a sustainable and efficient manner.

The first WWTP DBO in Cyprus started operation as early as 1990, and by 2016, seven large WWTP DBOs for urban areas had been developed and are now in operation (out of eight large WWTPs in total—only the WWTP in Larnaca was developed under a traditional construction contract and is directly operated by the Larnaca Sewerage Board).[31] The strategy of partnering with the private sector was also extended in parallel to the few older WWTPs in some rural areas, where O&M was delegated to private operators, sometimes in combination with civil works for rehabilitation under a "rehabilitate-operate-transfer" (ROT) approach. The DBO tenders were structured so that the private sector was left with the choice of treatment technologies—focusing only on required output parameters, that is, treatment capacity and effluent quality. This has resulted in a variety of wastewater technologies being operated now on the island, with tertiary treatment achieved with either sand filters or membranes bioreactors. Table 2.14 provides a snapshot of the 7 large WWTPs, plus the Mia Milia WWTP near Nicosia which is located outside the government-controlled areas (more details below).

The largest WWTP DBO in Cyprus is located in Limassol (Moni), with a capacity of 230,000 PE (see photograph 2.9). It treats most of the sewage effluent from the Limassol urban area, and provides a good illustration of how the WWTP DBO contracts are structured and work in practice—since a standard model has been adopted across the island. The capital cost was entirely financed by the Limassol Urban Sewage Board, with exception of the CAPEX for the tertiary treatment, which was paid by the WDD. The Limassol Sewage Board pays an O&M volumetric fee to the private contractor (about 0.30 euros per m^3), while the WDD pays an additional fee for tertiary treatment. This O&M fee is adjusted for inflation, with the unit cost of electricity (euros per kWh) as a pass-through and sludge disposal as reimbursable.[32] The DBO contract includes penalties for noncompliance with effluents standards if the frequency of noncompliant tests over a month exceeds five percent, following review by the parties to establish whether the problem was due to sewage quality

TABLE 2.14. Existing Large Wastewater Treatment Plants in Cyprus

WWTP	Area/city(ies) served	Capacity m^3/day	Agglomeration served PE	Year of operation	Contract type	Duration of O&M years	Name of private contractor
Anthoupoli	Anthoupoli	13.000	50.000	2008	DBO	10	WWT, Germany
Mia Milia	Part of Nicosia	30.000	110.000	2013	DBO	10	WWT, Germany
Vathia Gonia	Nicosia city	22.000	75.000	2010	DBO	10	lacovou, Cyprus Saur, France Stereau, France
Vathia Gonia - Septage and industrial waste	Nicosia Larnaca	2.200	—	Feb 1998	DBO	98°–03 03–08 08–13** 13–18**	Biwater, UK lacovou/Saur/Stereau
Limassol	Limassol city and environs	20.000 40.000	230.000	1995* 2008**	DBO	5+5	*Kruger, Denmark Zachariades, Cyprus Kruger, Denmark Cybarco, Cyprus
Larnaca	Larnaca city and touristic strip to the east	8.000 18.000	80.000	1995 2015	Utility run	—	—
Paphos	Paphos and Geroskipos towns	19.500	100.000	2008	DBO	10	Envitec, Greece
Ayia Napa Paralimni	Ayia Napa and Paralimni towns	21.000	91.000	2006	DBO	5	Michaniki Perivallontos, Greece

Source: WDD.

Note: — = not available; * = name of private operator; ** = name of private operator; DBO = design-build-operate; O&M = operation and maintenance; PE = population equivalent.

problems at the entry of the plant or the contractor's fault. There are also penalties for not complying with the assets maintenance and renewal program.

One noteworthy project is the WWTP DBO located South of Nicosia (Vathia Gonia; photograph 2.9) dedicated exclusively to treating **the sewerage brought by tanker trucks from households' septic tanks** in the Nicosia and Larnaca areas, **as well as various types of industrial waste**. It was developed directly by the WDD and started operation in 2000 with a capacity of 2,200 m^3 per day of sludge from domestic septic tanks or industries.

The "new Nicosia" WWTP (photograph 2.10) is the second largest DBO scheme, and is worth noting as a unique collaboration between the Greek Cypriot and Turkish Cypriot communities ("bicommunal" plant) under United Nations Development Programme (UNDP). The plant was developed under the auspice of the UNDP and is located outside of the government-controlled areas. It started operation in 1980 as a pilot and was expanded as of 2013 to treat sewerage effluents from most of Nicosia,[33] both from the government-controlled areas

PHOTOGRAPH 2.9. The Limassol (Moni) and Vathia Gonia WWTPs

Source: WDD.
Note: WWTP = wastewater treatment plant.

PHOTOGRAPH 2.10. View of the "New Nicosia" Bicommunal WWTP

Source: UNDP.
Note: WWTP = wastewater treatment plant.

(about 80 percent) and from the areas outside of the government's control (Nicosia is the last divided capital city of Europe, with the demarcation line and no man's land running right through the old historic city). It delivers TWW for reuse by farmers in a nearby perimeter in the areas outside of government control. The cost of development, as well as all O&M costs, is entirely supported by the WDD with the TWW provided to farmers for free (contrary to the standard practice of charging for TWW). UNDP acts contractually as an off-taker to the private concessionaire.

The gradual development of the WWTP DBO market has led to a vibrant industry of private wastewater operators in Cyprus. This includes several joint ventures between Cypriot companies and other European water companies (e.g., Biwater, Saur, Merkel)—which operate the large urban WWTPs as well as some of the O&M contracts for smaller plants—as well as purely local companies who are active for both DBOs and O&M contracts in smaller rural plants. This has ensured that there is solid competition for tenders on new DBO projects, as well as for the renewal of O&M contracts.

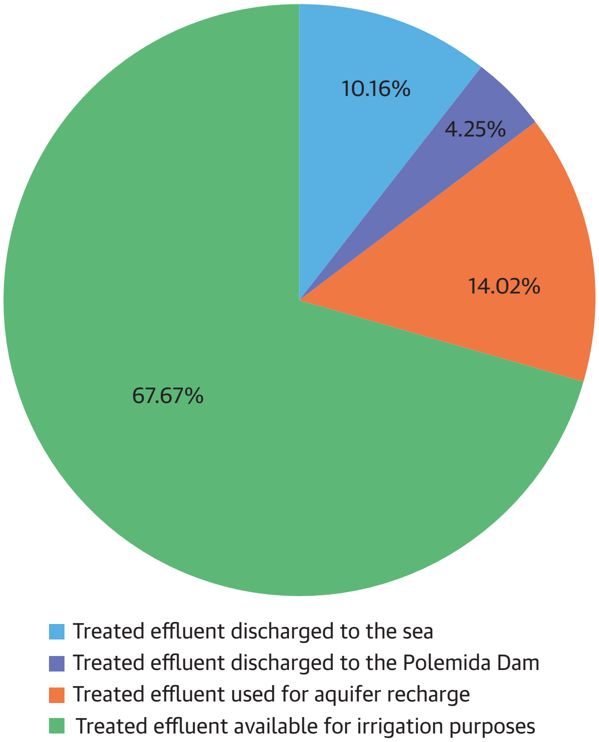
The contractual duration of WWTP DBOs has increased over time. The **first contracts were awarded with O&M periods of either 5 or 10 years**—reflecting an initial, rather cautious approach regarding the delegation of O&M to private contractors (keeping open the option of taking over O&M of the plant after a few years). As the experiences with private O&M proved largely positive, at the end of the contracts all sewerage boards decided to continue with private O&M, tendering new O&M contracts.[34] The current WDD policy for the new small WWTP DBOs to be developed under the UWWTD implementation plan is to award longer **20-year DBO contracts** with 19 years of O&M—the rationale being that private O&M has shown its benefits and the rural sewerage boards will likely never have the technical capacity to take over the operation of the tertiary WWTPs during their useful life.

2.4.3. Reuse of Treated Wastewater

About 90 percent of the TWW is now reused in Cyprus (government-controlled areas). Figure 2.7 shows the breakdown of usage for TWW in 2015. During that year, a total of 68 percent was used for irrigation, 14 percent was used for aquifers recharge, and four percent was discharged into a dam.[35] The yearly relative proportions of usage for TWW have been relatively stable in recent years since the desalination capacity came into full gear. Discharge of TWW into the sea was gradually reduced. It still amounts to 10 percent due to discharge in Limassol during the winter months, but this will be entirely phased out after 2018. This has obvious benefits not just for providing nonconventional water to agriculture, but also for improving the quality of bathing water and beaches in an island depending heavily on tourism.

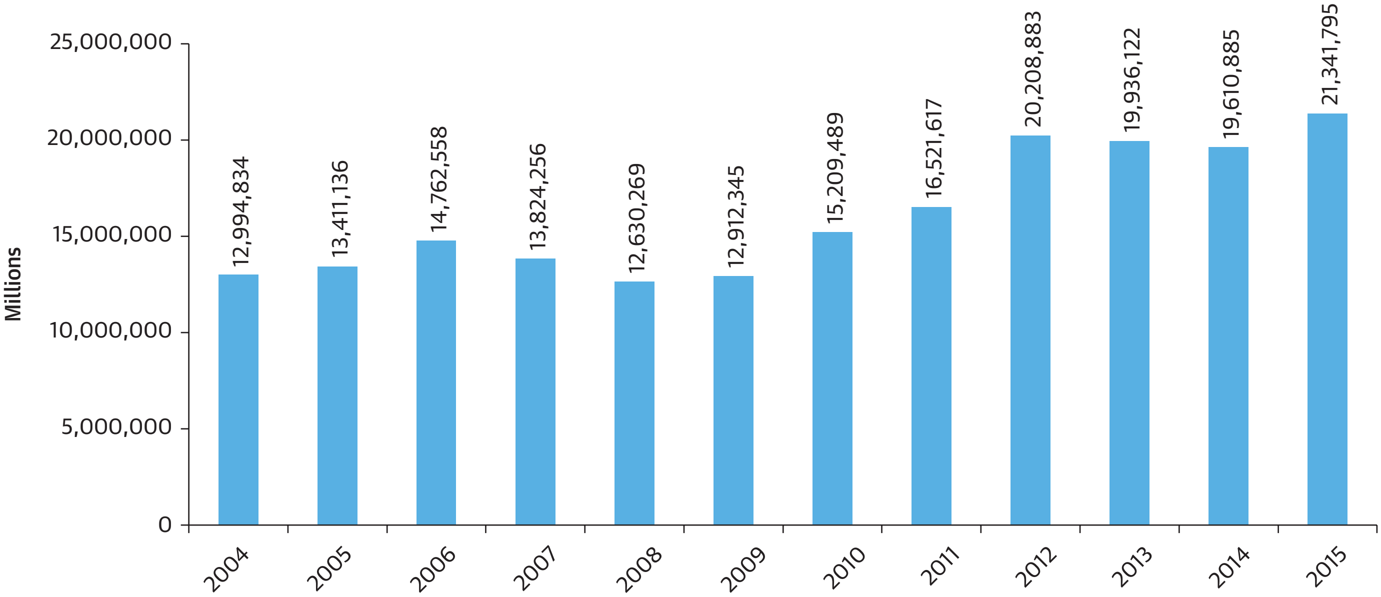
The full development of TWW reuse took about two decades, taking advantage of the massive infrastructure investments in sewage collection networks and new WWTPs driven by the need to comply with the UWWTD. Figure 2.8 shows the evolution of the volume of TWW from WWTPs in Cyprus from 2004 to 2015.[36] The need to comply with the UWWTD

FIGURE 2.7. **Reuse of Treated Wastewater in Cyprus, by Category of Usage, 2015**



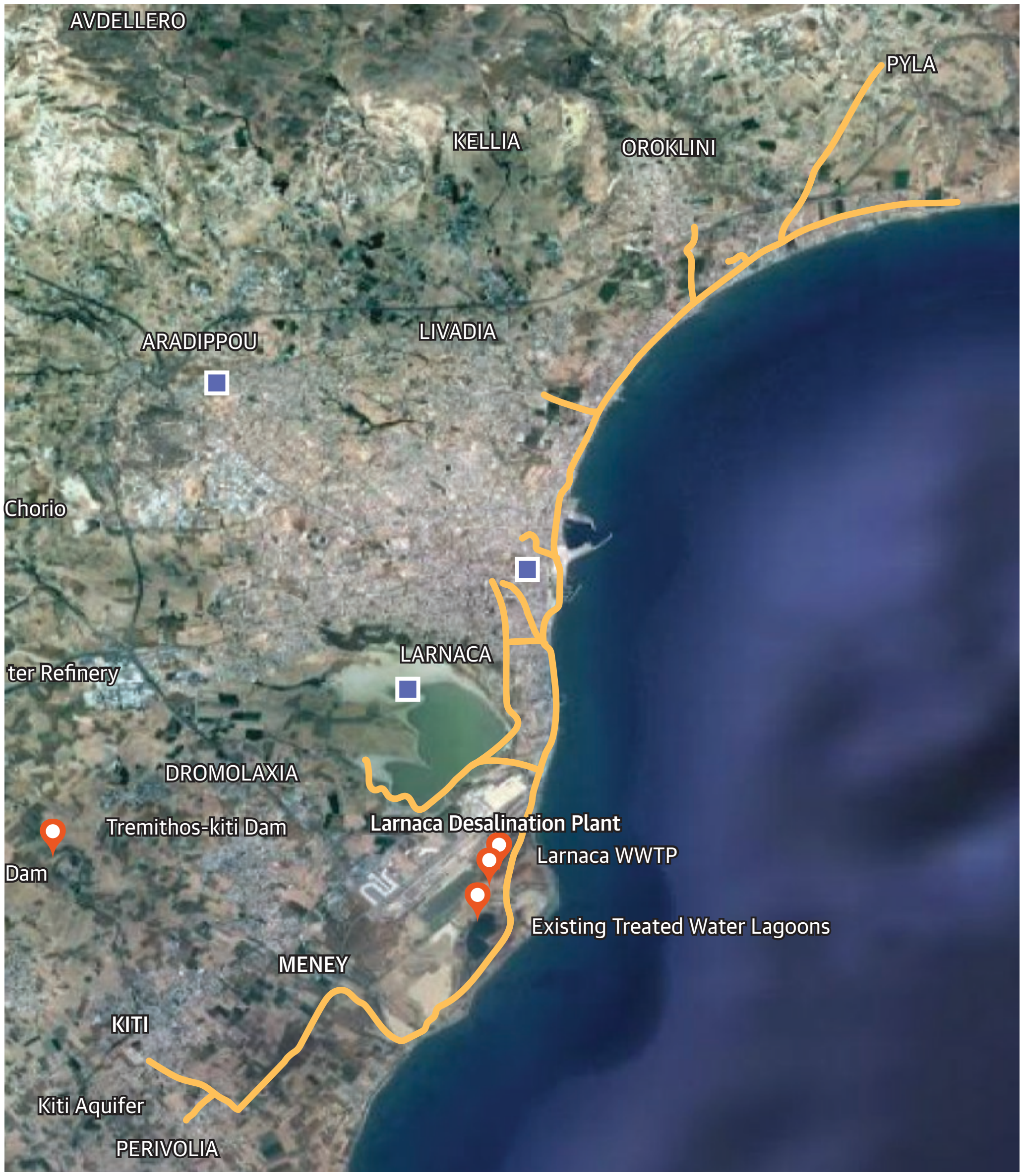
Source: WDD.

FIGURE 2.8. **Annual Quantities of Treated Effluent in Cyprus from the Urban Wastewater Treatment Plants (Except Mia Milia), 2004–15**



Source: Neocleous, WDD.

MAP 2.6. **Treated Wastewater Conveyance Network in Lanarca**



Source: WDD.

as part of joining the EU was a crucial factor for enhancing the development of wastewater reuse in Cyprus. Major investments had to be carried out to expand sewerage collection networks and build new WWTPs to capture and treat most of the pollution load on the island. The total volume of TWW available from WWTPs almost doubled—from 13 million cubic meters in 2004 to 21.3 million cubic meters in 2015.[37] In that context, the additional infrastructure investment needed for the TWW effluent to be reused represented only a portion of what it would have been otherwise, without Cyprus's obligation to comply with the UWWTD as part of its EU accession treaty.

PHOTOGRAPH 2.11. **Treated Wastewater Reservoir in the Troodos Mountains**

Source: WDD.

Another lesson from Cyprus is that **the development of TWW reuse requires major investments, not just in wastewater treatment but also to build dedicated pipelines to convey TWW to irrigation perimeters,[38] along with large reservoirs for winter storage**. Whereas in many countries irrigation reuse is often limited to lands nearby the WWTP, a large conveyance system was built in Cyprus to ensure that all the volume of TWW is used by farmers. Furthermore, TWW must be stored during the winter months when there is low demand for irrigation. This is illustrated in photograph 2.11, which shows for the case of the Larnaca area the magnitude of the dedicated conveyance networks, as well as a small TWW reservoir in the Troodos Mountains. Seven large dedicated TWW reservoirs have been built, with a current capacity of 2.36 million cubic meters that will be raised soon to 3.7 million cubic meters (allowing all discharges into the sea to stop by 2018). All the storage and conveyance infrastructure for TWW is operated by the WDD, who "own" the treated effluents produced by the WWTPs and then sell them to farmers.

Notes

1. The first dam in Cyprus was built in Paphos (Kouklia) in 1900, and 15 small dams were built during the period 1945–58.
2. The majority are located in the South-Eastern Mesaoria plain and near the Famagusta area.
3. These are the Evretou Dam (24 million cubic meters), Kannaviou Dam (17.2 million cubic meters), Asprokremmos Dam (52.4 million cubic meters), Arminou Dam (4.3 million cubic meters), Germasogeia Dam (13.5 million cubic meters),

Kalavasos Dam (17.1 million cubic meters), Lefkara Dam (13.8 million cubic meters), Dhypotamos Dam (15.5 million cubic meters), Klirou-Malounta Dam (2 million cubic meters), and Tamassos Dam (2.8 million cubic meters).

4. There are also two small temporary mobile units in operation in the West Nicosia area (Tamasos and Klirou-Malounta, of 500 m^3/day each) that shall be interconnected to the Southern Conveyor by 2020.
5. Based on the findings of a recent study carried out by the WDD in cooperation with the Food and Agriculture Organization of the United Nations (2012).
6. Report from the Auditor General of the Republic of Cyprus on water resources management, 2016.
7. The total cost of the 2008 drought on Cyprus agriculture is not entirely known, but is considerable. The national Agricultural Insurance Organization paid €19.3 million as drought compensation to farmers, while the Cyprus Agricultural Payment Organization ended up providing farmers with €2.4 million emergency state aid (CLICO).
8. It is noteworthy that, since then, the plant has been operated efficiently with constant upgrades to new technologies—indicating that a successful transfer of technology and know-how took place from foreign to Cypriot players.
9. 0.10 euros per kWh in the case of the Limassol desalination plant.
10. Total investment cost in the table is 190 million euros, the CAPEX for the first Larnaca BOT was not disclosed.
11. No data on NRW figure are publicly available from the urban water boards' website, and there is no legal obligation for water supply providers to report NRW figures to the WDD.
12. Assuming that commercial losses represent between 20 percent and 30 percent of the total NRW figure. While the urban water boards have a relatively low level of commercial losses (about 15-20 percent of overall NRW), the magnitude of undermetering is expected to be significant in municipal departments and community boards.
13. Each pressure zone downstream of a reservoir is subdivided into DMAs, which have a single metered source with physical discontinuity of pipework at boundaries.
14. In Limassol, the DMAs vary in size from 50 to 6,800 connections, with an average size of about 3,000 connections.
15. The underlying rationale behind the ILI indicator is that some leakages are unavoidable in a buried water distribution network. The calculation of the ILI indicator takes into account not just the input volume and billed metered consumption, but also a series of parameters that are characteristic of each specific water distribution network including length, density of connections, and average pipe pressure.
16. Lanarca has benefitted from flat topography on the coastline, high population density with resorts, and a large proportion of relatively recent new pipes due to fast network expansion in the past two decades.
17. Study on the "Investigation into the Status of the Water Supply Networks of all the Community Boards and Municipal Water Supply Departments." I.A.CO Ltd and ENVECO s.a., May 2010.
18. A significant portion of the revenues of the water boards and municipal boards are the large fees for new connections on new building plots. Real estate developers have to cover all the investment required to extend the networks, plus a fee based on surface as a partition in the past development cost of the existing infrastructure.
19. Based on the historical value of real estate as of January 1980, as determined by the Department of Lands and Surveys.
20. Under the 1991 Water Saving Law, any person using a hose for washing pavements, verandas, or vehicles is guilty of a criminal offense and can be imprisoned for up to three months and liable for a fine of up to 513 euros (the extrajudicial fine levied is 51 euros).
21. Other subsidies included for the installation of a hot water recirculator (€ 220), and connection of a borehole with the toilet cisterns (€ 700). Other savings were minimal: 0.03 million cubic meters/year from the installation of recycling systems and 0.05 million cubic meters/year from hot water circulators (CLICO).
22. This is especially the case for hotels located in areas served by municipal boards, such as in Paphos and the Famagusta resort area, because municipalities there have set very high water charges for hotels to compensate for domestic water tariffs that are lower than those charged by urban water boards.
23. For example, grants for low-flush toilets, efficient shower heads, A-rated washing machines, and dishwashers.

24. An inventory of 57 agglomerations was established based on administrative entities, 7 urban and 50 rural. The 7 urban agglomerations contributed to 74 percent of the total generated load (995,000 PE), whereas the 50 rural agglomerations contribute to the remaining 26 percent of the total generated load.

25. This is only for rural areas, and overall less than 10 percent of capital investments needs for UWWTD are provided by EU grants.

26. The effluent treatment plant capacity is fully developed in all sewerage boards except for Limassol and Larnaca which are planning the extension of their treatment capacity to cover additional effluent volumes from current service areas. The total installed capacity stands at 171,000 m^3/day of which 166,000 m^3/day is done through the 8 largest WWTPs.

27. in Kyperounta, Platres, Agros, Lythrodontas, Pelentri, Palechori, and Dali. There is a total of 26 small WWTPs including also four plants for PE of less than 2,000 (Alassa, Askas, Kakopetria, Agglissides), three for refugee housing estates (Kofinou, Livadia, Arediou), three for general hospitals (Nicosia, Limassol, Larnaca), and nine for army camps.

28. In Cyprus, one PE is about 60 grams of BOD5/day, and the concentration of BOD5 is estimated at about 500 mg/liter.

29. Cyprus adopted water quality standards for wastewater reuse in 2005. Standards for agriculture reuse are: BOD5 10 mg/l, suspended solids 10 mg/l, fecal coliforms (*Echerichia coli*) 5 per 100 ml, and no eggs of intestinal worms. This compares with BOD5 25 mg/l and SS 125 mg/l for effluent as required under the UWWTD standards.

30. Either the urban sewerage boards, the WDD, or for the new WWTPs in rural areas, the sewerage community boards.

31. The first DBO was for the WWTP in Tharmagostia. The largest DBO for large urban WWTPs are the ones in Moni, Limassol (230,000 PE), followed by Mia Milia (bicommunal plant, 110,000 PE—outside of government-controlled areas) and Vathia Gonia (2,200 m^3/day) near Nicosia. The Larnaca WWTP is the only large urban plant developed under a traditional construction contract and operated directly by a sewerage board. The most recent DBO started operation in 2017 for a new WWTP in Atheniou (CAPEX 7.9 million euros).

32. The rationale being that the optimal solution for sludge disposal may change over a 10-year O&M period; hence it appeared preferable to leave control of how the sludge is disposed to the sewerage board.

33. Investment cost is 29.2 million euros, of which 8.2 million is EU grant.

34. Even in the case of the WWTP DBO in Paphos where the urban sewage board recently took over direct O&M of the plant from the private contractor, the plan is to tender a new O&M contract with another operator.

35. The Polemidhia Dam located north of the town of Limassol and used for irrigation only.

36. Without the bicommunal Nicosia WWTP, whose treated effluents are reused outside of government-controlled areas.

37. These figures do not include the Mia Milia WWTP located in the TCC area and which treats a large portion of the sewerage effluents from Nicosia. When the Mia Milia WWTP is included, the total volume of treated wastewater was 19.9 million cubic meters in 2004 and went up to 33.2 million cubic meters in 2015.

38. The treated wastewater networks are separated from the Southern Conveyor which transport raw water from dams to both potable water plants and irrigation perimeters, since usage of treated wastewater is forbidden for crops that are consumed raw, crops for exporting, and ornamental plants.

Chapter 3 Water Resources Management under Scarcity

3.1. Arbitrating between Dams and Desalination Plants

The bulk water infrastructure operated by the Water Development Department (WDD)—which includes all dams, the Southern Conveyor and water filtration plants under direct management, the pipelines for transporting treated wastewater, the public irrigation perimeters, plus the desalination plants operated under BOTs—**supplies about 75 percent of the potable water demand in the government-controlled areas and 50 percent of the irrigation consumption**. The rest comes from wells, boreholes, and springs (individual farmers and associations, community water boards in villages, private households and industries). Although the **tariff of bulk potable water sold by the WDD to the water boards is relatively high at 0.82 euros per cubic meter,**[1] it is also significantly subsidized. The actual average unit cost of desalination paid by the WDD to private concessionaires depends on the total volume purchased each year, and only in 2016 was it fully covered by the bulk water selling price (see discussion that follows). Therefore, how the WDD operates this large infrastructure system and arbitrates between dams and desalination plants is crucial for efficient water management under scarcity.

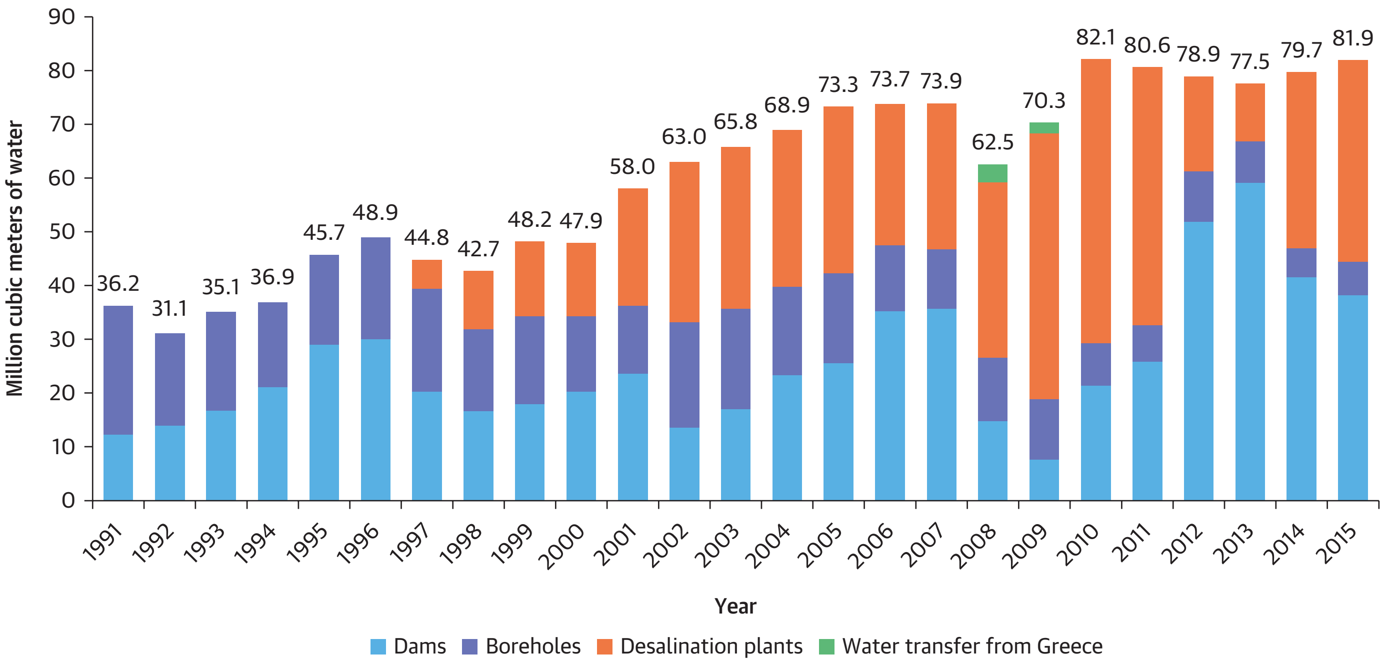
For many years before the desalination program went into full gear, water supply allocations in Cyprus was subject each year to considerable pressures and uncertainties. At the end of each rainy season, a decision had to be made regarding the year's allocation by the WDD of available water between domestic supply and irrigation, to be ratified by the Council of Ministers. It had to take into account both the demand from domestic users and agriculture, but also the target for how much water should be left stored in the dams at the end of the dry season, as security buffer for the following year. This later element was obviously sensitive because it involved taking a gamble on how much water would fall in the following rainy season, considering that several consecutive years of droughts can occur. Although demand for potable water is stable and therefore predictable, it worked the other way around for irrigation, as farmers decide how much annual crops to grow based on how water they can get each year—and lobby to get as much water as possible. As was discussed previously, poor decision making in 2005-07 (not saving enough water in dams as buffer) led to the catastrophic drought in 2008-09.

With the full desalination capacity in place, the decision-making framework for water resources by the WDD is now evolving. The capacity of the four large desalination plants supplying Larnaca, Limassol, and Nicosia (with a fifth plant to be constructed soon to supply the city of Paphos on the west coast) is now able since 2012 to cover almost all the demand for domestic potable water in urban areas.[2] In theory, this means that the WDD could allocate almost water stored in the dams to irrigation, with desalination serving as a base-load to supply most of domestic potable water needs.

In practice, water resources allocation policies during the past 5 years have been affected by the 2012 financial crisis in Cyprus. The two new desalination plants in Limassol and Vassilikos started to operate (and the Larnaca plant was also rehabilitated and expanded) at the same time of the outburst of the 2012 financial crisis in Cyprus. Since then, the Republic has been under severe budgetary constraints, with heavy-handed control by the European Commission (EC), European Central Bank, and the International Monetary Fund. This directly impacted the operational budget of the WDD as a ministerial department. As a consequence, difficult and unexpected trade-offs had to be made. The desalination plants ended up being operated well below full capacity to reduce the overall desalination bill, supplying part of the potable water need through dams, and thereby reducing the amount of water that could theoretically be made available for irrigation.

Figure 3.1 shows the **breakdown of sources of potable water for the distribution systems supplied in bulk by the WDD since 1991**. Production of desalinated water started in 1997 with 5.4 million cubic meters. Even though the installed desalination capacity went up from 41 million cubic meters per year to 77.4 million cubic meters in 2011-12 (commissioning of the new Limassol and Vassilikos plants), and then 80 million cubic meters in 2014 (expansion of the Larnaca plant), the actual volume of potable water produced by desalination plants has been only in the range of 10.7 to 37.5 million cubic meters per year since 2012. This was the lowest volume of desalinated water produced since 2001, and a figure comparable with the volume in 1998-2000 when the desalination program was initiated with just the Dhekelia plant.

FIGURE 3.1. Source Contribution to Potable Water, 1991-2015



Source: WDD.

Historically, the unit cost of desalinated water paid by the WDD to the private concessionaires has been high and well above the contractual price. This was due to fluctuations in the cost of electricity purchased from the grid, and low capacity usage in some years. Table 3.1 shows the annual quantities of water purchased and the corresponding purchase cost to the government. The **average purchase cost for desalinated water during the period 2008–2016 was at 1.36 euros per cubic meter**. However, during the peak of the financial crisis in 2012 and 2013, the average price stood as high as 2.83 and 3.29 euros per cubic meter—both because the government took advantage of heavy winter rainfall to produce cheaper potable water from dams[3] and drastically reduce the production of desalination plants (used at only 24 percent and 11 percent), and also because of a drastic jump in electricity price following the accidental explosion of the main power plant on the island.[4] The extreme budgetary constraints did not leave much choice to the government, who took advantage of the flexibility afforded by the structure of the BOT contracts (allowing to modulate production on demand) by requesting the contractors to put the plants partly in stand-by mode.

The year 2016 can be regarded as the first "normal" year under the new potable water production framework. That year, the four desalination plants were operated at 80 percent capacity overall (i.e., close to their standard operating mode), as base-load to meet most potable water needs.[5] This allowed allocation of more water to irrigation, better meeting the demand of farmers and reducing the pressure on aquifers. Thanks also to a reduction in the cost of kilowatts per hour, the average cost of desalinated water paid by the WDD went down drastically that year, at only 0.63 euros per cubic meter—confirming the efficiency of Cyprus desalination plants and of the BOT contracts that were put in place.

In the future, it is expected that arbitration between dams and desalination water by the WDD will be based on relying on desalination to meet most of the potable water demand. Before the desalination program, water management in Cyprus was essentially a matter of mitigating

TABLE 3.1. Desalination Quantities and Cost, 2008–16

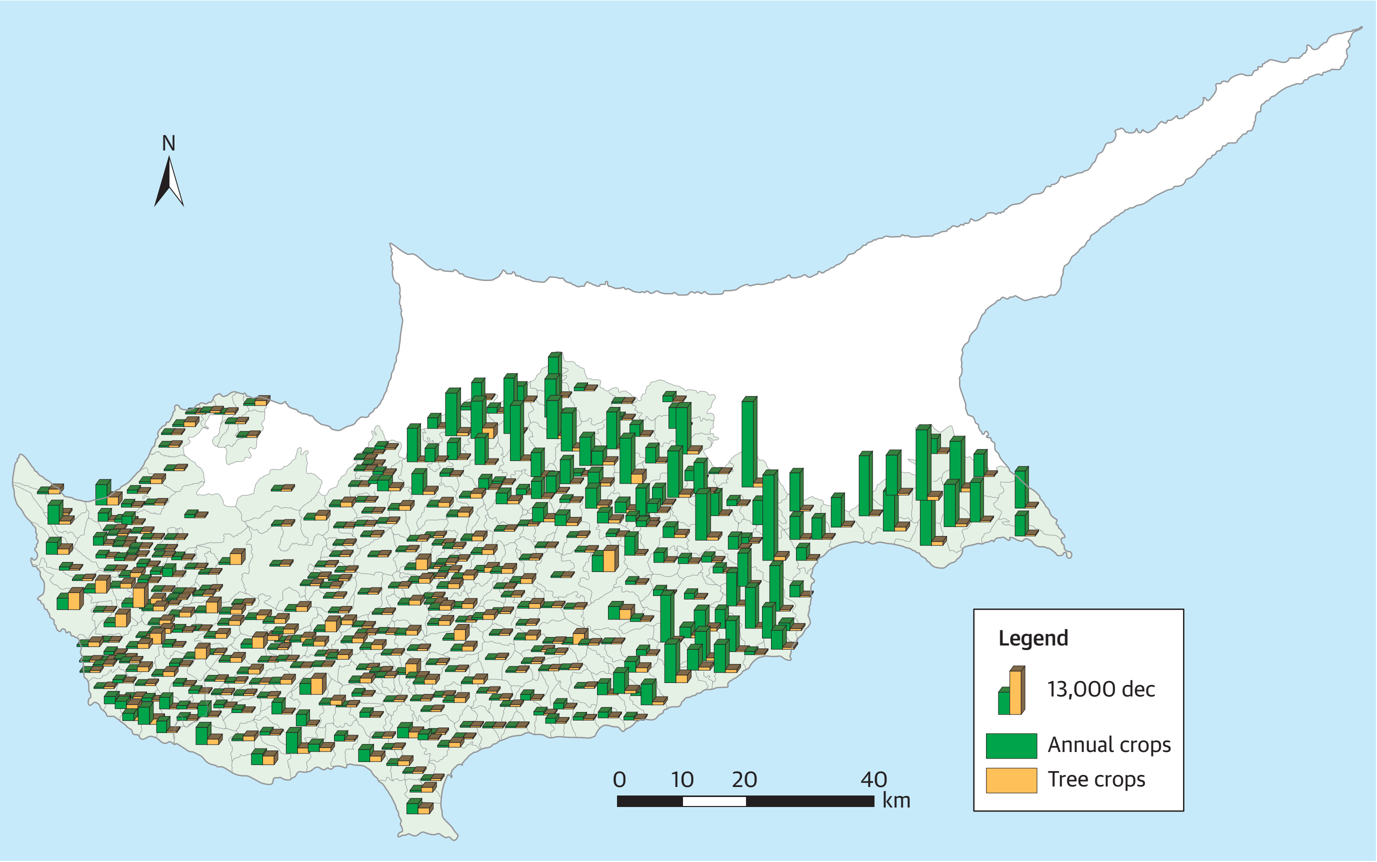
Year	Desalination capacity (Mm^3)	Capacity usage percent	Quantity purchased of desalinated water (Mm^3)	Total cost (million €)	Average purchase price (€ per m^3)
2008	34	96	32.6	65.28	2.00
2009	41 (+12)	94	49.6	63.56	1.28
2010	41 (+12)	99	52.8	62.36	1.18
2011	41 (+23)	76	48.7	74.98	1.54
2012	56 (+16)	24	17.6	49.98	2.83
2013	77 (+16)	11	10.7	35.24	3.29
2014	80	41	32.8	36.92	1.13
2015	80	48	38.1	43.83	1.15
2016	**80**	78	62.6	39.27	0.63
Total	**–**		**345.5**	**471.4**	**1.36**

Note: Mm^3 = million cubic meters.

crisis on a daily basis—with potable water rationing an ever-existing risk and agriculture demand never being met. Thanks to the new installed capacity, the desalination plants should be run as base load for domestic supply, and operated at least in standard operating mode so as to reduce the unit price paid by the WDD. This would allow for allocating more water to irrigation and reducing pressures on aquifers abstraction—the key operation decision becoming how much additional volume (above contracted volume) should be requested each year from the desalination contractors.

Thanks to the desalination program, the government can now **move toward meeting the triple goals of ensuring potable water supply, while allocating most of the water harvested in the dams for irrigation, and alleviating the pressures on overexploited aquifers**. It is worth noting in that respect that **every cubic meter of desalinated water is actually used twice in the water balance**: first to meet potable water demand, and second to meet irrigation demand through reused treated wastewater (reducing the vulnerability of agriculture to rainfall variability).

MAP 3.1. Agricultural Production in Government-Controlled Areas



Source: The Cyprus Institute.

3.2. Irrigation: The "Poor Parent" in Water Management

The actual water demand of irrigated agriculture in Cyprus is difficult to estimate. While many public irrigation perimeters have been developed, there are also many farmers located outside of these perimeters who practice irrigation—either through community users' association or independently—using private boreholes which until recently were not metered. Because of the semi-arid climate, most crops require irrigation at some point during the year, with the exception of trees (mostly olive) in the Troodos Mountains. The large public irrigation systems supplied by the Southern Conveyor and independent dams are located respectively in the southern coast and the west of the Troodos Mountains. Consequently, the annual crops on arable lands located in the north-central part of island, in the government-controlled areas, have to rely on private boreholes (map 3.1).

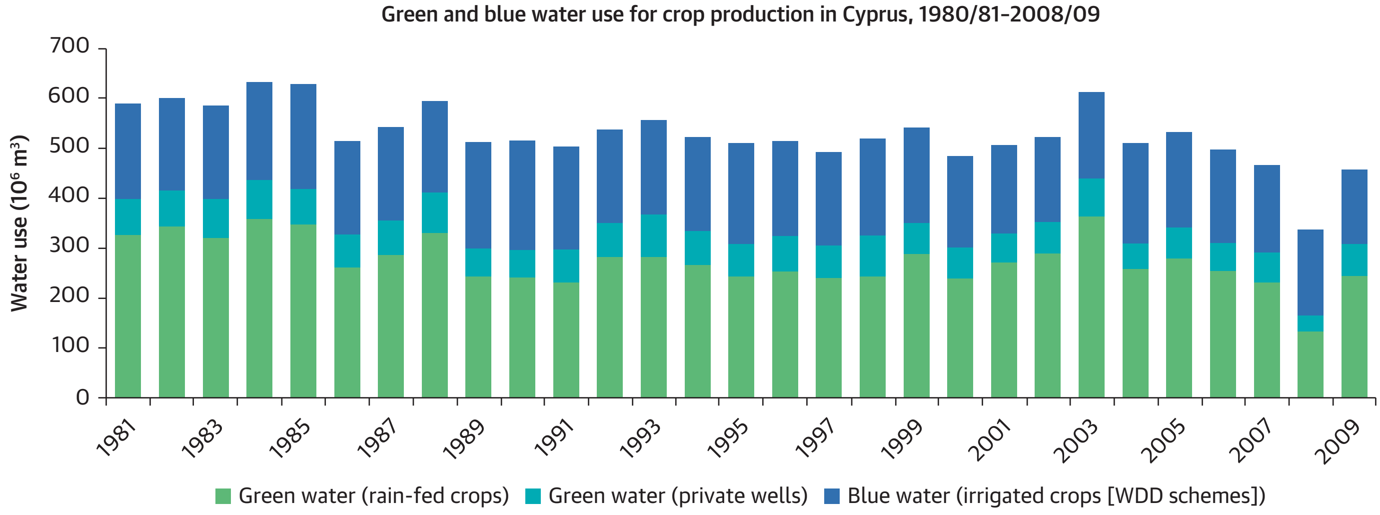
The actual volume of water used by irrigation is known only for the public perimeters operated by the WDD, and which are concentrated on the coastlines. The public irrigation perimeters managed by the WDD and supplied through the Southern Conveyor are located along the coastal plan in the South Limassol and around Famagusta, where the aquifers have become seriously depleted and suffer saline intrusion, and represent a total acreage of 13,926 hectares. The WDD also operates large perimeters on the western coast (around Paphos and Polis), as well as many small perimeters, through dams located around the Troodos Central Mountain, which were built mostly between 1970 and 1994.

However, a large portion of the agricultural production comes from the central plains area near Nicosia, which is not served by the public irrigation perimeters managed by the WDD. As shown in figure 3.2, depending on the year, it is estimated that between one-third and one-fourth of the total volume of irrigated water comes from groundwater extraction from private or community boreholes. This figure also shows the impact of the 2008 drought, with a considerable reduction in water available for rain-fed crops, as well as water abstracted from private boreholes.

The total water demand from irrigated agriculture was estimated in the past, based on crops patterns on the island (map 3.1) in the early 2000s, taking into consideration the water demand for each crop given climatic and soil conditions in Cyprus, assuming no water shortage (Klohn 2002; Savvides 2001). This led to a figure for the total volume of irrigated water demand of 174.4 million cubic meters. The large public irrigation schemes managed by the WDD used 57 percent of the total (including an estimated 15 percent for conveyance losses), while the remaining 43 percent corresponded to scattered irrigated areas developed by individuals and communities.[6]

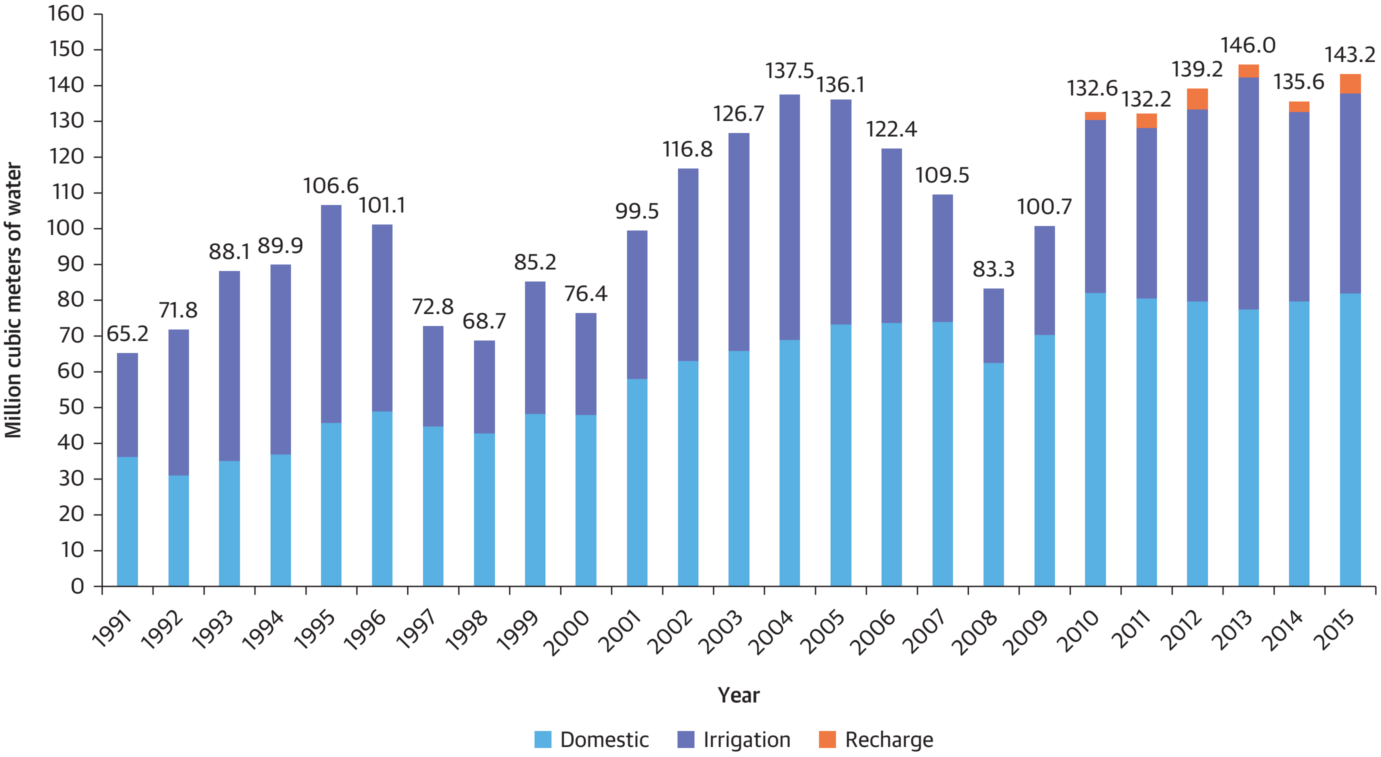
In practice, the water demand for irrigation has been satisfied only in some years, and the actual water consumption in agriculture fluctuates around 150 million cubic meters per year. Over the past two decades, the only year with no restrictions for irrigation was 2004 when all the dams in Cyprus were overflowing for the first time ever. Figure 3.3 shows the water allocation over the past 25-year period from 1991 to 2015 by the WDD. This is the allocation from the WDD, irrigation from boreholes and domestic supply from springs and wells not included. Domestic supply has been stable since 2010. Over the past 25 years, the volume

FIGURE 3.2. Volumes of Water Used for Agriculture in Government-Controlled Areas



Source: The Cyprus Institute.

FIGURE 3.3. Water Allocation by Water Development Department, 1991–2015 (No Private Boreholes)



Source: WDD.

made available by the WDD for public irrigation perimeters oscillated between 20.8 million cubic meters (during the worse drought year in 2008) and 64.8 million cubic meters. Over the past 25 years, only during five wet years (1995, 2003-05, and 2013) was the volume in excess of 60 million cubic meters and made available for farmers.

Agriculture has traditionally served as a buffer for water shortages during drought years, with rationing imposed in all irrigation perimeters and limited water available from private boreholes. The fact that potable water supply takes priority in a situation of scarcity and high rainfall variability means that the amount of water available each year to agriculture is extremely variable and unpredictable. In drought years, priority is given to permanent crops, even though only a portion of their normal water demand can be covered. The water allocated to farmers during dry years has been in the range of 30 percent to 70 percent of the normal demand, depending on the type of crop and the availability of water in each area. Already overexploited aquifers do not fully compensate for the shortfall during drought years. In 2000, which was a drought year, the total volume of water supplied by the WDD to public irrigation schemes was only 28.5 million cubic meters, while the estimated groundwater extraction was 26.0 million cubic meters.

The absence of a reliable supply of irrigation water from one year to the next has largely prevented the development of high-value crops. Farmers cannot take a long-term view on investments, especially for perennial crops. Irrigated perimeters depending on dams have seen a decline in the proportion between perennial and seasonal crops—down from 50-50 three decades ago to 30-70—as farmers are waiting to know in early spring how much acreage they can grow based on the water allocated. As a result, citrus groves have been gradually abandoned in favor of vegetables, essentially for the local market, with early-season potatoes remaining the only higher value crop earmarked for exports. The importance of low-value irrigated agriculture has been reinforced by the consequences of the 2012 financial crisis. Many unemployed people went back to farming in their villages, but they operate small acreages, lack competence in farming practices, and do not have funds to invest.

Another element is the impact of the EU Common Agricultural Policy. A large portion of farmers' revenues comes from EU subsidies, which tend to blur the normal market incentives and are not designed to foster water use efficiency. For instance, as subsidies per hectares are higher for irrigated crops, farmers have incentives to plant as much irrigated acreage as possible, even though there may not be enough water available to achieve a profitable yield under normal market conditions.

These peculiar factors explain why, even though the agriculture sector uses about 65 percent of all water resources of Cyprus on average, it contributes only a minor part to national wealth. The contribution of agriculture to national gross domestic product (GDP) stood at a mere 1.7 percent in 2015, and has been stable at this low level for many years. In many cases, agriculture is done on small plots by families who look at it as an additional—and somewhat aleatory—source of income, while they rely on other employment as their main income. The majority of arable lands on the island is located outside of government-controlled areas, and today a large portion of the food (including fresh vegetables and fruits) is imported. There are very few agricultural exports because local demand largely exceeds supply. The economy of the Republic of Cyprus has changed considerably over the past three decades, being now essentially a tertiary economy based on tourism and services (including offshore). As a consequence, most of the food is imported—with the **importation of "virtual water" becoming an important element for adjusting to extreme scarcity**.

Yet, a high level of irrigation efficiency has been achieved by Cypriot farmers in public perimeters, under the WDD guidance. Since 1965, the government has adopted a two-pronged approach to improve water efficiency in irrigated agriculture, providing farmers both with technical and financial assistance. This included investing in closed pipes for water distribution (as opposed to the traditional open canals used in most countries), launching demand-management campaigns to educate farmers in the use of modern irrigation systems, and installing water meters on all irrigation outlets for the accurate measurement and billing of water used by farmers. Currently, all irrigation water in government schemes in Cyprus is distributed through modern and highly efficient systems (closed pipes, drippers, sprinklers; photograph 3.1). Conveyance efficiencies are between 90 and 95 percent and field application efficiencies between 80 and 90 percent. Fertilizer application rules are frequently coupled with regulation of irrigation systems, and 85–90 percent of Cypriot farmers in these public perimeters apply advanced irrigation techniques, modulated to actual crop needs.

Irrigation efficiency in the public perimeters operated by the WDD is supported mostly by a strict quota system and tariff policy—with the tariff for farmers set at 0.12–0.17 euros per cubic meter. The annual quota allocation to each farm depends on crop and area irrigated. In case of overconsumption, a penalty that is a multiple of the usual tariff is applied, and the WDD is entitled to interrupt supply. The WDD water tariff for irrigation (excluding treated wastewater reuse) is shown in table 3.2.[7] The tariff for farmers was set at a relatively low level—and below full cost recovery—in order to avoid creating incentives for farmers to use private

PHOTOGRAPH 3.1. Sprinkler Irrigation and Drip Irrigation in Cyprus

Source: WDD.

TABLE 3.2. **Pricing for Irrigation Water Supplied by the Water Development Department (Updated in 2017)**

Description	€/m^3
Water supplied to irrigation associations	0.12
Water supplied to individual users	0.17
Water for industrial use	0.25
Water for livestock	0.17
Water for football grounds and golf courses	0.36
Water for green areas and parks	0.23
Water for irrigation over the quota (overconsumption)	0.45

Note: m^3 = cubic meter.

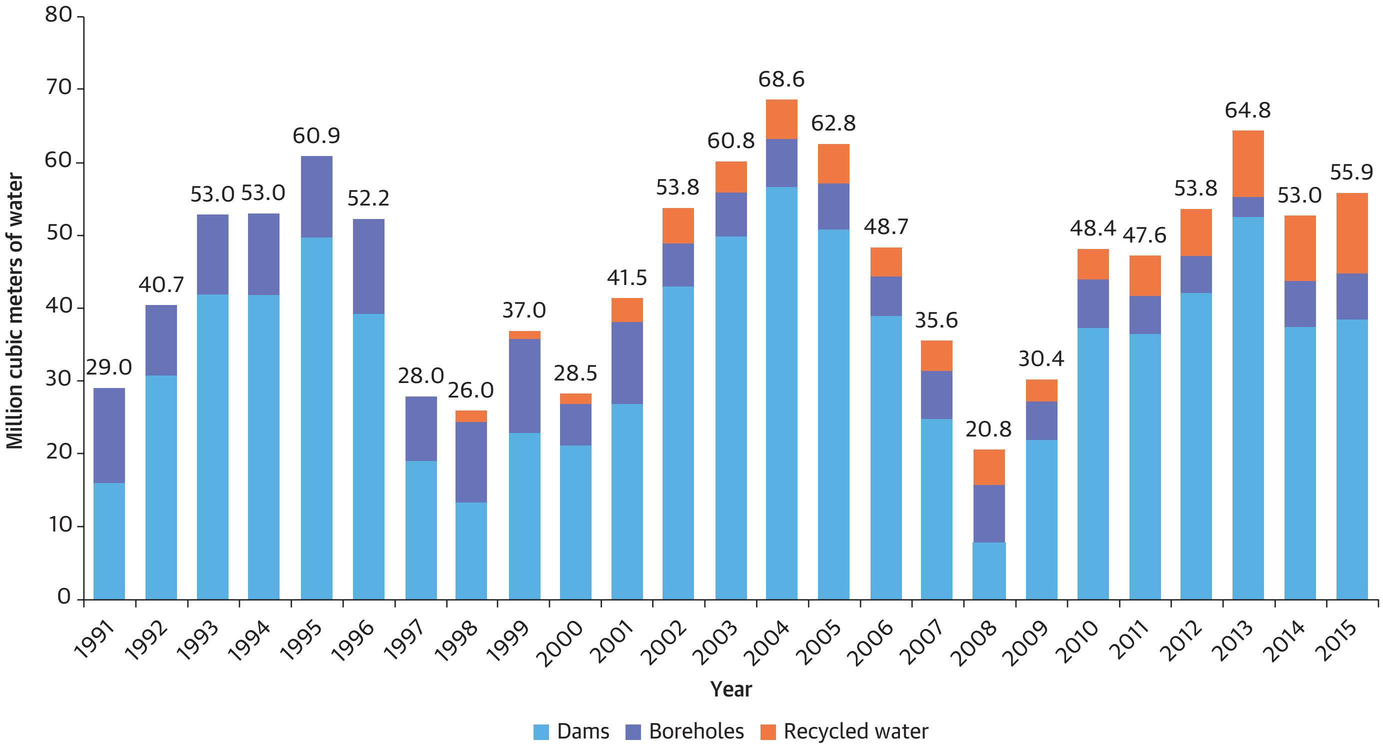
boreholes (the water table is less than 50 meters deep in the plains), but at the same time it is **based entirely on a volumetric fee** (contrary to other EU countries where irrigation tariffs include a fixed charge per hectare) so as to encourage usage efficiency.

In order to further incentivize farmers to save water, the WDD has also been subsidizing the switch to new crops that are more water savvy. One scheme compensates farmers who agree to switch from citrus trees to olive, carob, or prickly pear, by paying them a subsidy for the loss of income (400 euros per hectare) during 5 years (until the new trees are established and reach full yield).

Treated wastewater represents the only reliable supply of irrigation water, along with to a lesser extent private boreholes in noncoastal areas where aquifers have not been depleted. This is illustrated in figure 3.4, which provides the volume of water supplied by the WDD to farmers between 1991 and 2015. It shows again that water supplied from dams has been highly unreliable, but also that the volume extracted from boreholes has been halved compared to two decades ago. In contrast, the volume supplied from treated wastewater has been growing regularly every year for the past two decades. Furthermore, while reuse of treated wastewater is limited to certain crops, it does allow farmers to invest in higher value crops like citrus for which there is no limitation for reuse of treated wastewater. This is also the case for potatoes for export, which are planted in January for harvesting and exported in June to European markets.[8]

Treated wastewater now supplies about nine percent of the estimated total irrigation needs in government-controlled areas—but this was achieved over two decades and required significant efforts for gaining acceptance from farmers. There was considerable resistance from farmers back in the early 2000s, and the implementation by the WDD of several pilot projects proved crucial to demonstrate the benefits and safety of irrigating with treated wastewater (photograph 3.2). Investments in reuse infrastructure were fully funded by the WDD, for both the cost of the wastewater treatment plants' (WWTP) tertiary treatment, and the conveyance and storage infrastructure (photograph 3.2).

FIGURE 3.4. **Irrigation Water Quantities per Supply Source from Water Development Department, 1991–2015**



Source: WDD.

PHOTOGRAPH 3.2. **Irrigation with Treated Wastewater**

Source: WDD.

To incentivize the switch to treated wastewater, the reuse tariff is heavily subsidized—at about half the rate of freshwater and set for farmers at 0.05–0.07 euros per cubic meter (table 3.3). This represents about 33-44 percent of the the WDD tariff for raw water coming from dams (or boreholes), in the public irrigation perimeters. Today, demand for treated wastewater now exceeds the supply capacity of the WDD, as farmers now understand that this is their only reliable source in the face of high rainfall variability.

In addition to tariff incentives, special efforts were made to facilitate farmers' acceptance of treated wastewater. When the reuse program started back in 1997, it was met with widespread skepticism and reservations from farmers. This prompted the government to take a proactive stance. A pilot demonstration project was set up by the WDD on about 30 hectares near Limassol. The government leased the agricultural land for two years, paying for all investments (both conveyance of treated wastewater, and irrigation systems at the plot level). Sorghum, alfalfa, and corn were grown under close monitoring of the national Agricultural Research Institute. The findings were impressive—crop productivity increased by 30 percent compared to the same crop irrigated with freshwater, and the absence of health hazards was confirmed—and were then used for extensive communication and public consultation with farmers.

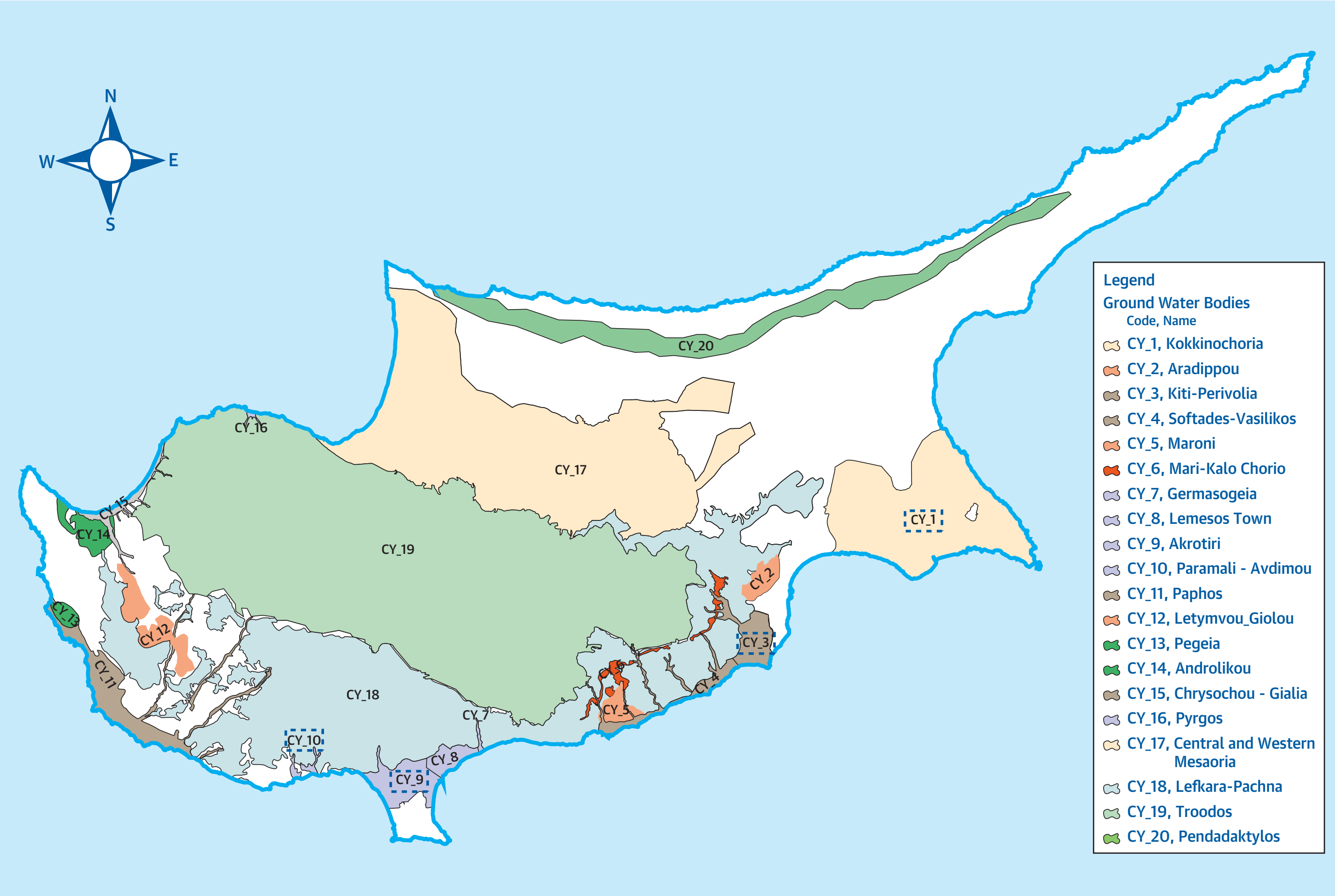
3.3. Aquifer Management and Recharge

With exception of the large mountain aquifer in the central Troodos Range, **most aquifers in Cyprus are suffering from overabstraction,** with a gradual lowering of the water table over the past five decades. Furthermore, the **coastal aquifers have deteriorated due to seawater intrusion**. Map 3.2 shows the island with locations of the various aquifers.

The country has prepared two successive River Basin Management Plans (RBMP) for the periods 2009-15 and 2016-21, as part of the implementation of the EU Water Framework Directive (WFD) (see next section). Regarding aquifers, this includes measuring and monitoring the chemical and ecological status of groundwater bodies, as well as the abstraction balance, and developing a program of measures to move toward sustainable aquifers management to prevent further deterioration of water resources, achieving "good chemical and ecological status" for all aquifers.

The RBMP process has allowed for the qualitative and quantitative condition of Cyprus's aquifers to be assessed in detail. This is summarized in table 3.4. A total of about one thousand piezometers have been installed to ensure monitoring of the water table and abstraction levels. Overall and due to the combination of overpumping, saline intrusion, and nitrate contamination from agriculture, **around 80 percent of the groundwater bodies were rated as being at risk of failing to achieve a "good status"** according to the WFD.[9] Overall, only five aquifers out of 21 were reported to be in good status—both qualitative and quantitative—in 2016. Eleven coastal aquifers were identified to be suffering from saline intrusion, while nine aquifers are affected by nitrates pollution from agriculture.

MAP 3.2. **Map of Cyprus's Aquifers**



Source: WDD.

TABLE 3.3. **Selling Rates of the Reuse-Treated Wastewater and Freshwater According to Use**

Use	Water selling price	
	Reused water	Fresh water
Water supplied to irrigation associations	2	12
Water supplied to individual users (farmers)	7	17
Water for football grounds and golf courses	12	36
Water for green areas and parks	17	23
For overconsumption	Increase by 50 percent	45

Source: WDD.

TABLE 3.4. Condition of Cyprus's Aquifers based on River Basin Management Plan Assessment, 2016

S/N	Groundwater body code	Name of ground water body	Quantitative condition	Qualitative condition	Qualitative parameters which are in excess of the allowable values	Increasing pollution trend	Qualitative parameters exhibiting increasing trend	Overall condition of the water body
1	CY-1	Kokkinokhoria	BAD	BAD	Cl^-,NO_3^-,NH_4^+,EC	YES	NO_3^-,NH_4^+	BAD
2	CY-3A	Tremithos stream bed	BAD	GOOD	n.a.	NO	n.a.	BAD
3	CY-3B	Kiti-Pervolia	BAD	BAD	Cl^-,NO_3^-,NH_4^+,EC	YES	Cl^-	BAD
4	CY-4	Softades-Vassilikos	BAD	BAD	$Cl^-,NO_3^-,NH_4^+,SO_4^=$,EC	YES	NO_3^-	BAD
5	CY-5	Maroni	BAD	GOOD	n.a.	NO	n.a.	BAD
6	CY-6	Mari-Kalo Chorio	BAD	GOOD	Cl^-	YES	Cl^-	BAD
7	CY-7	Germasogeia	GOOD	GOOD	n.a.	NO		GOOD
8	CY-8	Limassol	BAD	BAD	NO_3^-,C_2Cl_4, Pb	YES	NO_3^-	BAD
9	CY-9	Akrotiri	BAD	BAD	$Cl^-,NO_3^-,NH_4^+,SO_4^=$,EC	YES	NO_3^-	BAD
10	CY-10	Paramali-Avdimou	BAD	GOOD	n.a.	NO	n.a.	BAD
11	CY-11A	Paphos	GOOD	GOOD	Cl^-,NO_3^-	NO	n.a.	GOOD
12	CY-11B	Ezousa stream bed	GOOD	GOOD	n.a.	NO	n.a.	GOOD
13	CY-12	Letimbou-Yiolou	BAD	BAD	NO_3^-,NH_4^+,As	YES	NH_4^+	BAD
14	CY-13	Pegeia	BAD	GOOD	n.a.	NO	n.a.	BAD
15	CY-14	Androlikou	GOOD	GOOD	n.a.	NO	n.a.	GOOD
16	CY-15A	Chrysochou-Yialia	BAD	BAD	Cl^-,NO_3^--	NO	n.a.	BAD
17	CY-15B	Chrysohou stream bed	BAD	GOOD	n.a.	NO	n.a.	BAD
18	CY-16	Pirgos	BAD	GOOD	n.a.	NO	n.a.	BAD
19	CY-17	Central and Weste Mesaoria	BAD	GOOD	$Cl^v,NO_3^-,SO_4^=,NH_4^+$	YES	NH_4^+	BAD
20	CY-18	Lefkara-Pachna	BAD	GOOD	$Cl^-,SO_4^=$,EC	NO	n.a.	BAD
21	CY-19	Troodos	GOOD	GOOD	$SO_4^=$	YES	$SO_4^=$	GOOD

Source: WDD.
Note: n.a. = not applicable.

The implementation of the Nitrates Directive will gradually improve the qualitative status of the aquifers affected by nitrates pollution. It involves the identification of nutrient vulnerable zones (NVZ), the preparation of a code of good agricultural practices for farmers, and the implementation of a nitrate action plan for farmers within the NVZ. Implementation by farmers is enforced through potential reduction of EU subsidy payments (under the EU Community Agricultural Policy [CAP]) by the Cyprus Agricultural Payments Organization (CAPO), under a cross-compliance implementation system.

To comply with the WFD's good status requirement for underground water bodies (deadline 2027), it will be essential for Cyprus to drastically reduce the current overabstraction in several aquifers to reduce and stop saline intrusions. The massive development of nonconventional water resources—namely desalination (with an installed capacity in 2016 of 80 million cubic meters) and wastewater reuse (21 million cubic meters in 2015)—in order to substitute for overexploited groundwater is obviously of crucial importance and impact. However, additional measures are needed to control abstraction from private boreholes, which for irrigation alone was estimated at 74 million cubic meters (year without restriction).

To that effect, a **new "Drilling and Abstraction Law" was adopted in 2014, introducing for the first time a system of private wells permits, together with raw water abstraction fees.** This represents a crucial step in Cyprus's implementation of the WFD, with three essential requirements for private well owners:

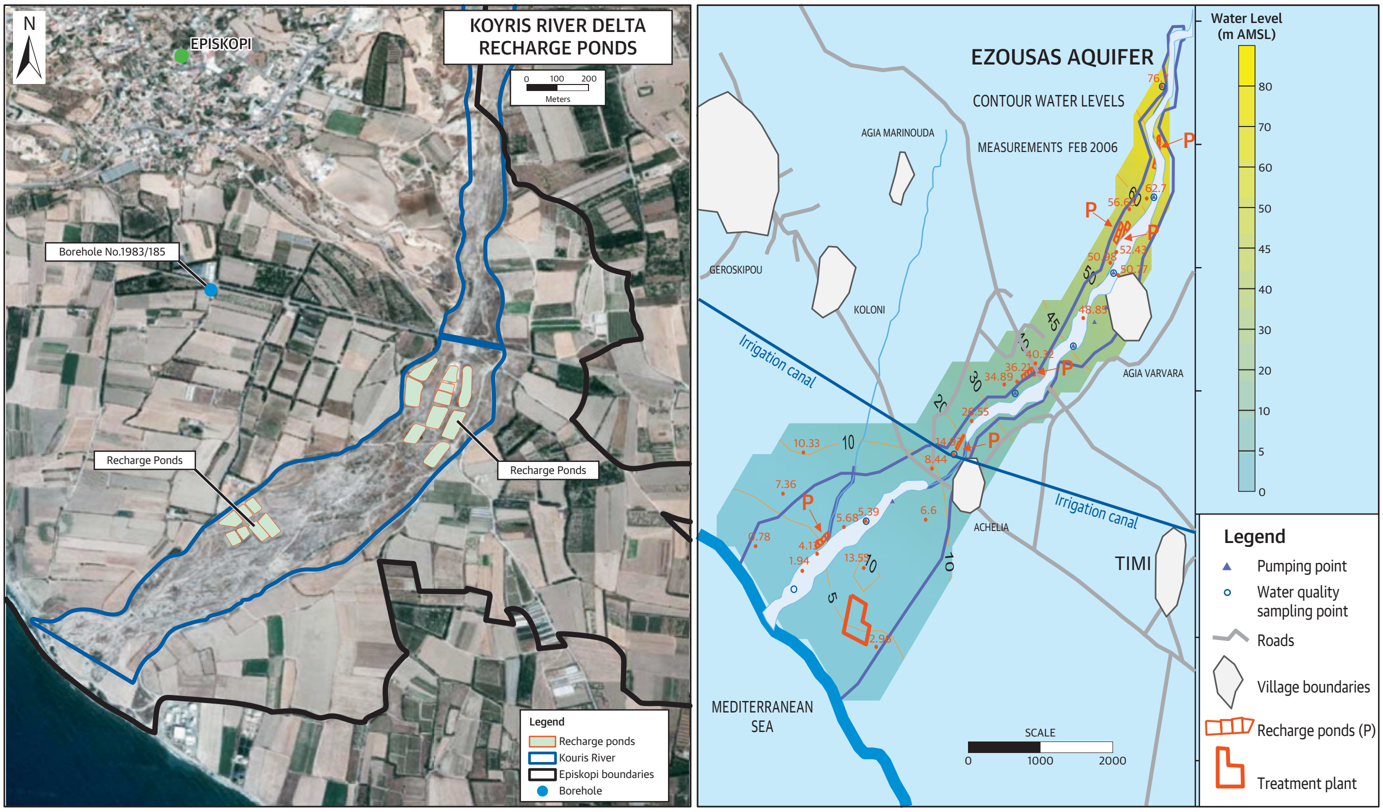
- **All private wells and boreholes must now be registered,**[10] with new drillings requiring a permit. Over the past three years, about 50,000 extraction permits licenses have been issued for existing wells, but it is estimated that about 35,000 owners of operating wells (mostly small ones, such as for household gardens) have not yet registered.
- Under the new law, **each well or borehole owner must install a meter**—but again many have not yet done so either, and the WDD anticipates that this will be a long process.
- Starting in 2017, **raw water abstraction rates have been introduced**, albeit at the modest level of only 0.01 euros per cubic meter for irrigation, and 0.05 euros per cubic meter for domestic use for water authorities and 0.12 euros for potable water for individuals.[11] Billing is based on either metering or estimate (if no meter, in which case the maximum volume recorded in the license is billed).

The **promotion of Managed Aquifer Recharge (MAR) through reuse of treated wastewater has been another notable initiative for improving aquifers management in Cyprus**. In 2016, **about 14 percent of total treated wastewater volume produced was allocated to recharge coastal aquifers** affected by saline intrusion. The recharge sites have been carefully selected based on hydrogeological conditions, availability and quality of wastewater, possible benefits, economic evaluation, and environmental considerations. **Two recharge sites have been successfully operated since 2010**.

The first aquifer recharge project is located near Paphos on the western coast, where the Ezousa aquifer is being recharged artificially with 2–3 million cubic meters of treated wastewater per year. In order to mitigate the clogging effect due to the presence of suspended solids in treated wastewater, an additional treatment is carried out before discharge with ultrafiltration through membranes. The recharged water is then used by farmers through private boreholes in the area during the dry season, without the crops limitations that normally apply to reusing the treated wastewater. Map 3.3 shows an aerial picture of the recharge area, along with a hydrographic map of the aquifer.

The second recharge project is for the Akrotiri aquifer, near Limassol, which is among the most affected on the island, with severe depletion (the water table is well below sea level) and saline intrusion. Recharge is carried out through a series of recharge ponds located in the beds of the Kouris river, 10 km west of Limassol and south of the town of Episkopi. Treated wastewater from the Limassol WWTP is discharged into the ponds during the winter months, when there is no demand for irrigation from farmers. The operation of the recharge ponds is done through alternate flooding and drying, to ensure due oxygenation in both the

MAP 3.3. Recharge Ponds in Kouris River (Ezousas Aquifer) Near Paphos



Source: WDD.

bottom of the ponds and in the infiltration soil. The maximum possible daily recharge from the existing ponds is estimated at 42,000 cubic meters per day—that is, up to a maximum of 15 million cubic meters per year. The upstream part of the Akrotiri aquifer is also recharged with some fresh water from the Kouris Dam (10 km upstream), with controlled releases of water in the river bed, depending on water availability.

3.4. Implementing EU Water Legislation under Water Scarcity

Cyprus provides a unique case for analyzing the relevance and challenge of applying the EU water legislation in a context of extreme water scarcity. The body of water laws, which as part of the "EU environmental acquis" are applied in EU member states, is admittedly the most comprehensive and stringent water legislation in the world (see outline in box 3.1). Although the implementation of various EU water directives is discussed in previous chapters, it is worth recapitulating how they have been leveraged upon to help better manage water under scarcity.

The Urban Wastewater Treatment Directive (UWWTD) has been the key driver to make possible the massive development of treated wastewater reuse. Taking advantage of the obligation under the 2004 EU accession treaty to invest massively in sewerage collection and wastewater treatment infrastructure—which can be considered a "sunk cost"—Cyprus chose to invest

BOX 3.1. EU Water Policies

The European water policy was founded through the 1972 Paris Conference, which initiated the framework of an EU common environmental policy. This led to the adoption of many directives since the mid-1970s.

The first wave: focus on pollution abatement. The first wave of EU water legislations adopted from the mid 1970s to the 1990s was focused on reducing pollution in water bodies and monitoring water quality. Some of these water directives were designed to protect the environment, such as the Urban Wastewater Directive (91/271/EEC), which aimed to reduce pollution of waters from domestic and industrial sources by requiring massive investments in sewage collection and treatment systems, and the Nitrates Directive (91/676/EC), which aimed at reducing nonpoint source pollution from agriculture. Other water directives were aimed at protecting public health and focused on monitoring—that is, the Drinking Water Directive (80/778/EEC) and the Bathing Water Directive (75/160/EEC).

The second wave: moving toward integrated water management through the WFD. By the mid-1990s, it became apparent that simply updating the existing directives would not be enough to improve significantly the quality of inland waters in Europe. The Water Framework Directive (WFD) (2000/60/EC) is a drastic change in the spirit of EU water legislation by putting in place a broader integrated water management approach, aiming *inter alia* to achieve good ecological status for all EU waters by 2015. It required member states to carry out a detailed assessment of their water resources, and put in place institutional and financial mechanisms so as to ensure sustainable water management (including moving toward full cost recovery while considering not just financial costs but also resources and environmental costs)—while leaving each country flexibility on how best to achieve the goals of good ecological status and sustainable water management. The implementation of the WFD is supported by river basin management plans (RBMP) that are updated every six years. The WFD was conceived as an "umbrella legislation" that encompasses all other existing EU water directives, which are incorporated as "basic measures" under the RBMPs.

The third wave: complementing the EU WFD. During the course of the WFD implementation, the commission and the member states have been adding new directives to address specific challenges such as climate change, floods, and groundwater pollution. It has led to the adoption of a new set of directives such as the Floods Directive (2007/60/EC) and the Groundwater Directive (2006/118/EC).

further in tertiary treatment in all its WWTPs as well as in conveyance and storage infrastructure, in order to be able to reuse the treated wastewater as a new nonconventional water resource on a large scale. In that sense and even though Cyprus is among the new member states that have not yet fully complied with their UWWTD compliance deadline (mostly for small agglomerations), it can be said that for the large portion of the sewerage investment already completed, the country has actually gone beyond the UWWTD requirements in terms of pollution abatement. As with the program of massive dam development in 1970-90, the objective again has been that **no water should be lost to the sea**—this time not for rainwater runoff but for wastewater discharge—with the ambitious goal of zero discharge of treated wastewater to the sea to be achieved by 2018. The environmental and public health benefits of this strategy cannot be overstated in a country like Cyprus, heavily dependent on beach tourism. It is also noteworthy that thanks to the development of wastewater reuse, **each cubic meter of desalinated water produced is used twice: first as potable water and again as reused treated wastewater** (for irrigation or recharge).

The implementation of the WFD has also been key for aquifers management to be put on a path toward sustainability. As in all countries with a long history of water scarcity, the political economy surrounding water rights and private abstraction from aquifers is complex, and is difficult to deal with for any elected government. The fact that the requirement to regulate private pumping from aquifers and more toward sustainable management of groundwater were part of the requirement to harmonize with the "EU environmental acquis" under the accession treaty has been instrumental for implementing some necessary yet difficult measures. Although time will be needed to reverse the course of decades of the overabstraction of aquifers, the preparation of the first two RBMPs has allowed for taking the first necessary steps: assessing the condition of the aquifers in details, establishing a reliable monitoring system (piezometers), and putting in place for the first time an obligation for private boreholes to be registered and measured, and for private users to start paying an abstraction fee. Cyprus's legal obligation for WFD compliance provides a strong incentive to take action and achieve results.

The preparation of drought management plans (DMPs) is an additional requirement under the WFD that was added in 2008 by the EC.[12] The objective is to ensure that member states would sufficiently focus on the negative impact of climate change and global warming. It requires that DMPs be prepared by each EU member state and be incorporated into the second round of RBMP (2016-21)—a new step of obviously major relevance for Cyprus, even though it is already the EU member state with the most related experience, alongside Malta. Cyprus has been one of the first EU countries to develop stand-alone DMPs, independent from the RBMPs.

In a general manner, the WFD has provided the platform for gradually moving toward sustainable management of scarce water resources on the island. It was translated into Cyprus Law in 2004.[13] One key element has been pushing for a gradual move toward water tariffs based on cost recovery, and for a financial framework allowing the long-term sustainability of all types of water services. This is a gradual process not yet completed. The "pricing and cost recovery of water services" regulation was adopted in 2014 to harmonize water tariff policy in Cyprus with article 9 of the WFD and sets the framework for moving toward full cost recovery and the inclusion of environment and resources costs ("the polluter pays principle") into water tariff policies. In December 2016, this led to the adoption by the Council of Ministers of the new WDD bulk water tariff framework as well as the introduction for the first time of abstraction fees for private boreholes. Also, all qualitative and quantitative assessments of groundwater, as required under the WFD, have been completed.

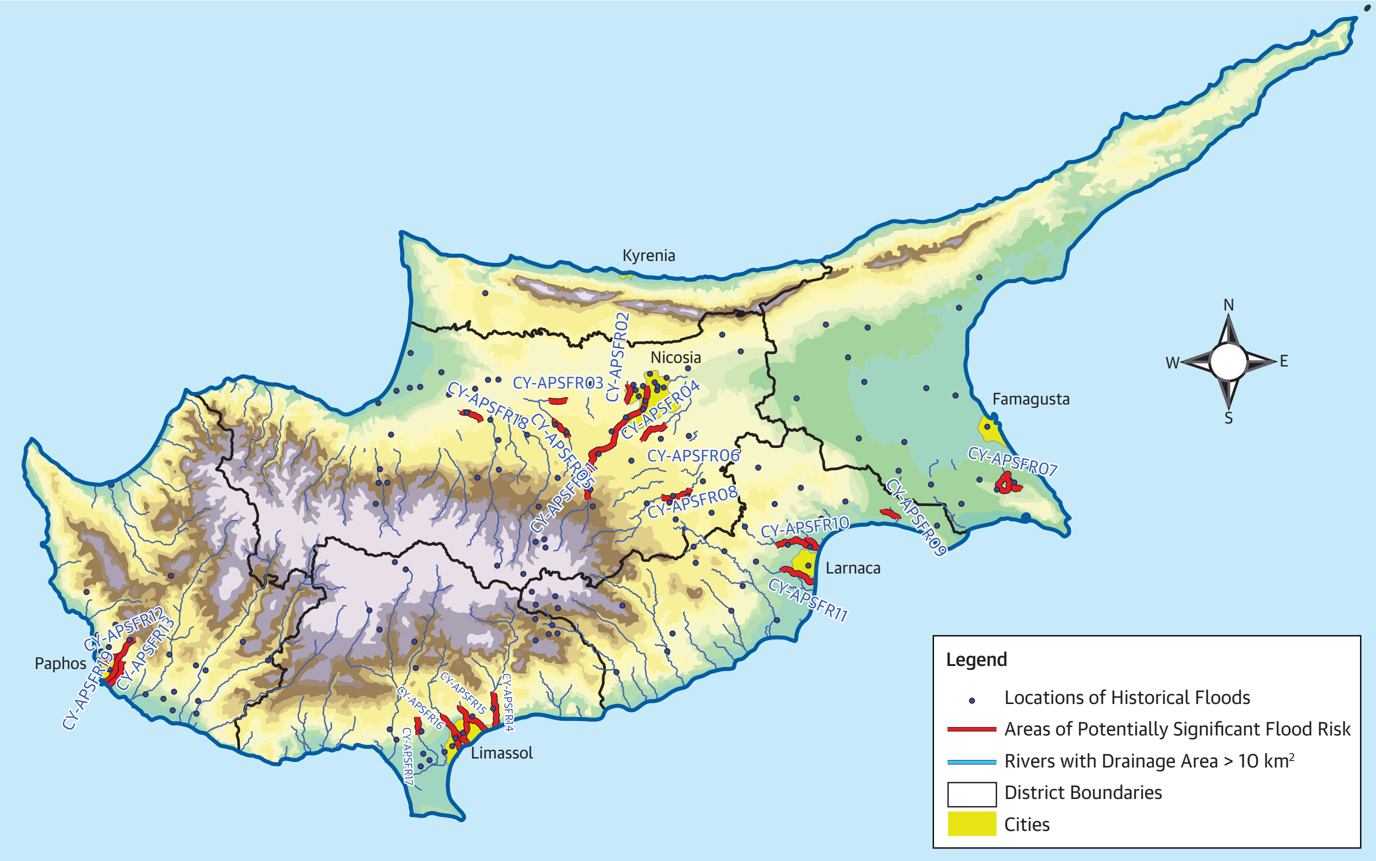
Although the EU has not yet issued specific legislation on reuse of treated wastewater, it is also worth mentioning that **Cyprus has been among the most active member states to push for the issuance of EU wastewater reuse regulation**, alongside other EU countries with strong reuse experience (Spain, Malta, and Greece). This included contributing in EC technical committees for development of wastewater reuse standards, defining required levels of treatment according to various uses.

Regarding the Bathing Water Directive, Cyprus has consistently achieved the best compliance rate of all EU countries for meeting the water quality criteria. This is directly linked to the massive wastewater reuse program, with only a small proportion of treated wastewater being discharged to the sea (about nine percent of total volume, in the winter for the Limassol area), to be entirely phased out by 2018. The 2016 report by the EC on compliance with the BWD ranks Cyprus first, alongside with Malta, for the quality of its beaches, with 99 percent of bathing sites achieving an "excellent bathing water quality" rating. This is well ahead of all other Mediterranean EU countries with many beach bathing sites: Greece (97 percent), Croatia (94 percent), Italy (91 percent), Spain (85 percent), and France (77 percent).

Under the EU Floods Directive, Cyprus has prepared a flood management plan including identification of main floods risks areas (with flood risks maps, map 3.4) and identification of mitigation measures. While the issue of flooding may seem at odds with water scarcity, this is in fact particularly relevant in the context of Cyprus's semi-arid Mediterranean climate because low average freshwater availability goes together with high variability of rainfall, which in turn increases the risk for flash floods and flooding events that can have major human and economic negative consequences.

There are also **a few aspects of the current EU water legislation which should be highlighted for being somewhat at odds with the constraints and priorities of managing water under scarcity, or for failing to address some key issues**. This is notably the case for the new dams' development, as the restrictions imposed by the WFD and other EU environmental legislations (such as the Habitats Directive and Natura 2000) on protected natural sites and avoiding alterations in the hydromorphological conditions of water bodies. While well justified on environmental protection grounds, these create major restrictions for the construction of new dams, and one must recognize that most of the storage infrastructure built in the 1970–90s would probably be very challenging to develop today.[14] Another important aspect of water management under scarcity which is not covered by EU water directives is the reduction of

MAP 3.4. **Floods Risk Areas in Cyprus Identified under Flood Management Plans**



Source: WDD.

water losses in potable water distribution networks. Also, the Floods Directive focuses on risk assessment and mitigation instead of dealing with measures such as storm water capture and urban run-off reduction (such as with green roofs), which would be relevant in a water scarcity context.

Finally, **regarding irrigation, it must also be noted that EU water policies are not fully harmonized with the EU CAP**. Under the current CAP, there is no link between access to subsidies and efficient use of irrigated water—which is a significant shortcoming for water management in a water-scarce country.

Notes

1. It was set for many years at €0.77/m^3 and increased in March 2017. Average sale price to customers by the waterboards of Nicosia, Limassol, and Larnaca is €1.14/m^3, €1.00/m^3, and €1.64/m^3, respectively.
2. Domestic potable water supply in rural villages and settlements is still provided by boreholes and local springs. These are located mostly in the western coast and central Troodos Mountains.
3. The entire Southern Conveyor is based on gravity, so water from dams provides a very inexpensive source of potable water.

4. This took place in July 2011 and destroyed a power plant with about one-third of the island's electricity generation capacity.
5. Providing 62.6 million cubic meters out of an estimated 80 million cubic meters of total demand for potable water in the government-controlled areas, which also includes the boreholes and springs operated by Community Boards in rural areas.
6. These are scattered developed areas by individuals or community schemes all over Cyprus outside the major government irrigation schemes. Almost 96 percent of this demand is satisfied by groundwater.
7. The tariff framework is different in private perimeters where users' associations manage their own supply and distribution of irrigation water (mostly from boreholes, plus some limited surface flows). Prices are set freely by the irrigation committees without government involvement, but the WDD provides subsidies for investment as well as technical assistance for O&M. Water volumes are rarely metered but estimated typically based on pumping duration.
8. Main crops using treated wastewater in Cyprus are citrus, olive trees, potatoes, corn, cow-grass, and barley.
9. The WFD requires that "good water status" be achieved by 2015—a goal which no EU member state has been able yet to comply with—but also allowing for potential exemptions on well-justified cases for two additional cycles of six years till 2027.
10. It is noteworthy that although water belongs in principle to the state, cases are found in rural areas where individuals have private water rights on surface or spring water. These rights came back when Cyprus was under Ottoman rule and were passed down through inheritance of the lands. As an example, for the construction of the Kouris Dam, the government had to acquire water rights from individuals for part of the waters being affected by the project.
11. Private domestic wells for household and garden use are still not charged (for abstraction quantity below 500 m^3/year).
12. 2008 EU guidance document on drought management plans.
13. The island is subdivided into nine hydrological regions made up of 70 watersheds—although the whole island is considered as one river basin district since there are no perennial rivers.
14. The development of three additional dams (including one for the city of Paphos, not connected to the Southern Conveyor) is currently blocked due to environmental issues.

Chapter 4

Conclusions: What Has Been Achieved and What Remains to Be Done

4.1. Potable Water Security under Extreme Scarcity Is a Remarkable Achievement

Even though the island suffers from extreme water scarcity and strong rainfall variability, potable water security has now been fully achieved in Cyprus. There was no rationing of potable water supply during the summer of 2014, even though winter rainfall had been almost as low as during the previous 2008 drought. This remarkable achievement was done thanks to massive recourse to desalination—with an installed capacity that can fully meet the needs of the three large urban centers of Nicosia, Limassol, and Larnaca—together with other investments and policies implemented over three decades to improve water management under extreme scarcity. **Cyprus has successfully moved from the 1970–90s motto "not a drop of water to the sea" to the new motto "not dependent on rainfall anymore."**

The massive development of nonconventional water resources, as well as new policies for sustainable water management, is now bringing much needed relief to overexploited aquifers (in government-controlled areas). With desalination supplying most of the potable water needs, the water captured in the large dam storage infrastructure can now be allocated mostly to agriculture, thereby reducing the need for farmers to overpump water from their private boreholes. The development of reuse of treated wastewater—whether for irrigation or for aquifers recharge—is also reducing the degradation of aquifers. In addition, the assessment of groundwater bodies, as required under the European Union (EU) River Basin Management Plans (RBMPs), as well as recent policy to regulate private abstractions (licensing and metering of private boreholes) along with the introduction of a bulk water extraction fee, is paving the way for reversing decades of overpumping and putting Cyprus's aquifers on a path toward sustainable management.

Well-designed public-private partnerships (PPPs) with the private sector have been instrumental in the successful development in Cyprus of nonconventional water resources—desalination and wastewater reuse. The government recognized two decades ago that both desalination and wastewater treatment for reuse in agriculture (which requires tertiary treatment) were complex and costly technologies, and that it would be beneficial to develop the new plants under PPP models—respectively build-operate-transfer (BOT) schemes for desalination and design-build-operate (DBO) schemes for wastewater treatment. The advantages of the PPP approach are multifold. This allows construction and operation and maintenance (O&M) risks to be passed along to the private sector, which is left with flexibility to identify the most cost-efficient technical processes over the useful life of the plant. Furthermore, under a BOT, the private sector finances the capital investment—more than 250 million euros of private financing was raised for the four desalination plants since 1997—and has incentives to optimize the combined investment and operating costs of the new plant over its entire useful life. With more than two decades of experience with BOT-DBO schemes for desalination and wastewater treatment plants (WWTP), and more than a dozen contracts in execution, Cyprus has been able to validate the benefits of the BOT-DBO approach, gradually optimizing the design of these contracts and building a solid expertise in the design, tendering, and supervision of such PPP contracts.

The development of massive water storage and conveyance infrastructure has also proved key for optimizing water resources management under extreme scarcity. This includes the large number of dams in the Troodos Mountains to capture all harvestable rainfall, the Southern Conveyor, which interconnects the main dams and production facilities (filtration plants and desalination) with the main water users (urban centers of Nicosia, Limassol, and Larnaca and irrigation perimeters on the southern coast), as well as the dedicated pipelines and reservoirs for treated wastewater for reuse. Concentrating the management of this large water infrastructure in one single institution—with the Water Development Department (WDD) as the "operational arm" of the water sector in Cyprus—has been essential for efficiently managing and optimizing the allocation of available water to various users.

Cyprus has managed to leverage the implementation of EU water legislation to improve its water management under extreme scarcity. The country went beyond the requirement of the Urban Wastewater Treatment Directive (UWWTD) by choosing to develop tertiary treatment and wastewater reuse for all its WWTPs. This allowed to gradually phase out all discharge of treated wastewater into the sea, and effectively "close the urban water cycle" with every cubic meter of desalinated water produced being used twice (first for domestic supply, and then through treated wastewater reuse). It also takes advantage of the gradual implementation of the Water Framework Directive (WFD) to move toward sustainable aquifers management, and hopefully reverse over the next decade more than half a century of overpumping of groundwater. This is remarkable, because the EU water legislation was not conceived initially to deal specifically with water-scarce environments.

It is noteworthy that Malta—the other water-scarce country in the EU—has followed a similar path, with massive development of desalination and wastewater reuse. This has also been the case for Israel, which in addition developed, like Cyprus, a national bulk water conveyance infrastructure. These international comparisons validate the massive investments made in nonconventional water resources, underlining that **the decisions made in Cyprus were the right ones**. Cyprus is now one of the most advanced countries in the world for water management under scarcity.

However, achieving potable water security in Cyprus came at a price—not just financial but also environmental. The four desalination plants consume about 9 percent of the total electricity generated in the Republic of Cyprus, with an emission of CO^2 gases estimated at about 436 thousand tons per year. This is also very costly, as electricity production on the island is entirely dependent on expensive oil-fired plants, with the governmental budget having to absorb changes in oil prices. The discharge of brine into the sea also has a local negative impact (albeit marginal). However, with the recent discovery in the Republic of Cyprus's economic zone of significant gas reserves, it is hoped that in a few years it may become self-sufficient in gas energy—which would reduce both the cost of desalination and its environmental impact. Pilot experiments are also carried out by the WDD to test the use of renewable energy for desalination. It is worth noting that the massive development of dams in the previous decades—albeit an imperative at the time to meet demand in the face of severe aquifers depletion—also had notable environmental consequences, as most of the ecosystems on nonperennial rivers disappeared.

4.2. Institutional Reforms Are Still Needed for Sustainable Water Management

Despite these worthy successes, Cyprus still faces several important remaining challenges for reforms and moving toward fully sustainable water management. As most of the efforts have been concentrated so far in infrastructure development and the "supply side" of water policies, several aspects of water management remain to be optimized. The water sector is still financially dependent on subsidies, both for investment and for O&M costs (especially for bulk potable water and wastewater reuse) coming from the central government as well as local authorities. With ever-increasing rainfall variability and scarcity due to climate change, the country may not be able to cope unless the financial sustainability of the water sector as a whole is improved—especially considering that both desalination and wastewater reuse are very expensive. Two questions in particular need to be urgently addressed:

- **Is the newly achieved potable water security financially sustainable in the long run?** The answer lies in optimizing the financial framework of the water sector, promoting *inter alia* more demand management (reducing per capita consumption), improving efficiency (including reducing water leakages in distribution networks), and moving toward full cost recovery through tariffs (reducing contributions from the national budget)—so as to reduce the water sector's dependence on subsidies from the national budget.
- **How to reconcile sustainable aquifers management with meeting farmers' demand for irrigation?** This is a challenging task at best in a context of extreme water scarcity, and it will require developing a strategy for irrigated agriculture that would *inter alia* aim at solving the inherent conflict between meeting farmer demand and drastically reducing abstraction from the overexploited coastal aquifers, in line with the requirements of the EU WFD.

Based on the analysis of this report, and under the overarching goal of **optimizing water management under scarcity in Cyprus and complying with EU water directives**, it is suggested that the future reforms and public policy actions address **four priority pillars**:

4.2.1. Priority Pillar 1: Starting to Focus on Water Demand Management

Demand management should now receive the full attention of policy makers, after decades of water policies that have focused on the supply side. With a domestic consumption of 140 liters per capita per day in the large urban areas of Nicosia, Limassol, and Larnaca (and even more elsewhere), there is notable scope for making the population more water savvy given the context of extreme water scarcity on the island. The domestic tariff levels in Cyprus (especially for half of the population, which is not served by the urban water boards) are below other EU countries, and the fact that about half of the total WSS (water supply and sanitation) bill is not linked to volumetric consumption (being either a fixed charge or linked to residential values) does not create sufficient incentives for water conservation, as would be needed in a context of extreme water scarcity.

A revised tariff structure is needed to send a clear market signal to users about the true value of water, in a country like Cyprus affected by extreme water scarcity. This should entail a higher proportion of volumetric charges, with a lower portion of fixed charges (especially for sewerage tariffs). This may also involve increasing overall tariff levels—though this may also require putting in place targeted subsidies for the poor, such as through social water tariff schemes as were put in place recently in many other EU countries (Greece, Malta, Italy, Spain, Portugal, France, Belgium, England, and Wales).

The tourism industry could be a significant source of water savings that has not been exploited so far. The water consumption per capita is considerably higher than for domestic users, and there is significant scope for improving the water efficiency of hotels and beach resorts. Lessons could be learned from specific measures implemented in other major sea tourism destinations (e.g., Spain), and they could be supported in the context of promoting a greener tourism industry in Cyprus.

4.2.2. Priority Pillar 2: Modernizing the Institutional and Financial Framework

There is an urgent need to rethink and optimize the financial framework of the water sector, now that potable water security has been achieved through the development of expensive nonconventional resources, to ensure financial sustainability. The institutional and governance model should be modernized to introduce more accountability and incentives for operational efficiency and financial sustainability, and to reduce the still high level of government subsidies to the water sector. To achieve this, a detailed review of the current financial flows, subsidies, and funding needs of the water sector should be carried out, and reform steps should be taken for both the WSS providers and the WDD.

The current institutional and regulatory framework for WSS providers must be reformed. There is an overall lack of regulation and accountability of WSS service providers for performance, and insufficient agglomeration in periurban areas (municipal water departments) and rural areas (community water boards). The municipal water departments and community boards lack ring-fencing to protect them from excessive interference of local politicians. Water supply in small rural communities is subsidized in nontransparent ways. These shortcomings are not conducive to operational efficiency, cost recovery tariffs, and the move toward financial sustainability. Mechanisms to enable further agglomeration of municipal and local services should be explored, together with recourse to PPPs such as performance-based contracts (PBC) for water losses reduction to improve operational efficiency and reduce costs—building on the successful track record of the WDD with BOT-DBO schemes over the past two decades.

In particular, the operational performance of water supply providers can and should be improved—especially for reducing water losses in distribution. This is all the more urgent now that most of potable water is being supplied through expensive desalination plants (thereby raising the cost of leakages). While the level of NRW in the urban water boards of Nicosia and Larnaca appears satisfactory, this is not the case for Limassol, or for the municipal water departments and community boards (who together absorb 57 percent of total potable water production). The good NRW performance of Nicosia and Larnaca shows that the technical and operational expertise already exists in Cyprus—and that it can be done. Priority should be given to reducing water losses in Limassol, Paphos (where a fifth desalination plant will soon become operational), and the municipal water boards supplied by the Southern Conveyor.

The structure and institutional status of the WDD should be modernized, so that it can better play its role as the "operational arm" of water management in Cyprus. The WDD plays a crucial role in water management in Cyprus, yet it is currently constrained by its status as a ministerial department, which combines responsibility for water policies, and for operating and maintaining the water resources infrastructure on the island. The absence of financial autonomy—even though it is *inter alia* the off-taker of the desalination plants—as well as cumbersome public staffing and procurement procedures generate serious financial and operational challenges. Staffing reorganization, along with separating the operational function for large water infrastructure into a separate, corporatized public company (still fully owned by the government)—as recommended in a 2014 World Bank report to the government[1]—would create better conditions for optimizing the operational and financial framework of the water sector. More recourse to the private sector through subcontracting as well as innovative PPPs could also help improve operational efficiency, foster access to technological innovations, and deal with the current staffing shortage for certain positions due to the freeze in the government's hiring.

4.2.3. Priority Pillar 3: Complying with the Urban Wastewater Treatment Directive

The development of the required sanitation infrastructure in smaller agglomerations and rural areas remains to be completed, under Cyprus's legal obligation to comply with the EU UWWTD. Although much has already been achieved for compliance in urban areas, the sewerage investment effort largely came to a halt in the aftermath of the 2012 financial crisis and ensuing major restrictions on the national budget. Compliance in smaller agglomerations and rural areas will require significant efforts, not just financially but also to address local capacity gaps. Lessons learned from the implementation of the UWWTD in other EU countries have shown that compliance in rural agglomerations poses a series of special challenges, and requires a specific approach.

BOX 4.1. Water Management in Northern Cyprus, in Areas Outside of the Government Control

Over the four decades following the island de facto partition in 1974, little had been done in the areas outside of the government's control, in the north of the island, for improving water management. Water services have been suffering from poor infrastructure management (high water losses, intermittent supply), overexploitation of aquifers, and poor institutional framework (low tariff with virtually no demand management).

In sharp contrast with the massive development of dams carried out by the Government of the Republic of Cyprus in the central Troodos Mountains, until recently **only six existing large dams** and 17 small dams were developed in the Northern Pentadaktylos range, outside of the government's control. The total capacity (until 2016) stood at a mere 20.7 million cubic meters—against 322 million cubic meters in the areas under government control (i.e., a mere six percent). Most of the rainwater falling on the Pentadaktylos range is lost to the sea. The existing dams are mostly for irrigation because potable water was, until recently, supplied mainly from groundwater extraction (annual water demand estimated at 110–120 million cubic meters), mostly from the Morphou aquifer which is now affected by severe overexploitation. Some small desalination plants have been developed for a total capacity of 11,000 cubic meters per day.

For decades, potable water services suffered from significant rationing in most northern towns. It is noteworthy that, in the portion of the capital Nicosia that is outside of government control, the Government of the Republic of Cyprus has been, through the WDD, providing for many years bulk water supply to the population at no cost to the end users, to alleviate the rationing and water shortage. In towns and villages, potable water supply is provided by municipal departments with no ring fencing. Tariffs are much lower than in government-controlled areas, well below full operation and maintenance (O&M) cost recovery, and municipalities face major difficulties to operate the infrastructure due *inter alia* to their poor financial situation and low capacity. The level of water losses (NRW) is not well known but reportedly very high.

Sewerage services in the north are seriously underdeveloped. Until 2005, only limited portions of Nicosia North and Kyrenia had a sewerage collection system, and the only WWTP was the bicommunal plant in Mia Milia built under the auspices of the United Nations Development Programme. Since then, investments sponsored by the EU have allowed sewerage collection and treatment to expand into the north of Nicosia (coverage 65 percent) and to the large towns of Famagusta and Morphou. Still, most of the population is not connected to a sewerage network, and a large portion of the collected sewerage is discharged without proper

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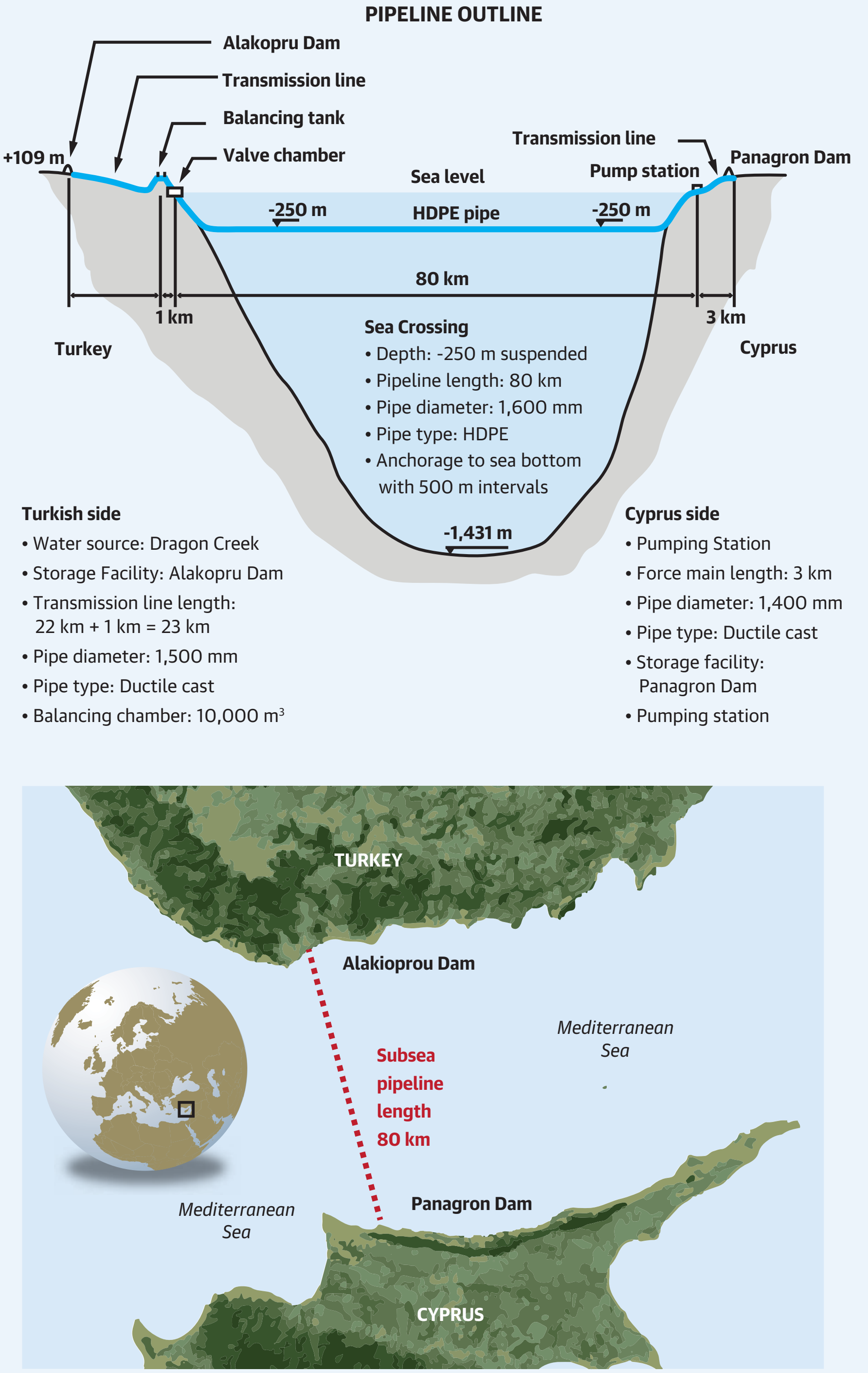
BOX 4.1. continued

FIGURE B4.1.1. Freshwater Pipeline from Turkey to Cyprus



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BOX 4.1. continued

treatment into the sea—with serious negative environmental impact (especially on the quality of the beaches).

The recent construction of an 80-km offshore water pipeline bringing raw freshwater from Turkey—a project carried out and financed entirely by the Turkish government—is now radically changing the water resources situation in the north. The project started construction in 2011 and is based on an underwater 80-km pipeline suspended at 250 meters sea depth and connecting the north of Cyprus with Turkey (figure B4.1.1). It also comprises the construction of two large dams—one in Turkey (with a 23-km adduction line) and one in northern Cyprus (Panagra, 26.5 million cubic meters)—plus pumping stations and pipes for water conveyance in the Turkish Cypriot community area. Raw water from the Dragon River in Turkey is brought by gravity through the pipeline to the Panagra Dam. The total capital investment cost is believed to be well above 450 million euros. **It started operation in 2017** and has the capacity to transfer about 75 million cubic meters per year (half to be treated for potable water use and the other half to be used for irrigation)—the avowed objective being to meet most of water demand in the areas outside of government's control for the next two decades.

While a notable technological achievement, the Turkey-Cyprus offshore pipeline project is also controversial. Given the poor state of water distribution infrastructure in the north of the island, with the low capacity of municipal departments, the sudden increase in the volume of water put into distribution systems will likely result in massive leakages, unless necessary actions are taken. When factoring all investment costs subsidized by grants from Turkey, the actual cost of water, on a per cubic meter basis, appears to be more expensive than the cost of desalinated water achieved by the well-designed build-operate-transfer schemes (BOTs) put in place in government-controlled areas. Pressures were also reported on the local municipal administrations to sign a concession contract with a Turkish private company to delegate the provision of water services to customers, in exchange for benefiting from the pipeline water supply. Finally, this project raises obviously sensitive geopolitical issues, in the context of the continued impasse for resolving the de facto division of the island and continued Turkish military occupation in the north—as it will make the northern part of the island totally dependent in the future on Turkey for such a strategic commodity as water.

Source: Nicos Neocleous, Cyprus Civil Engineers Association, 2015.

Cyprus has adopted a proactive stance in dealing with the remaining challenges of UWWTD compliance, and an extended implementation plan has been submitted to the European Commission (EC) (with a deadline in 2027). It will still require considerable investments, but it should also provide opportunities to further increase the volume of treated wastewater available for farmers locally. Appropriate solutions should be developed for dealing with the limited capacity of local authorities, and higher unit costs in small agglomerations and rural areas (such as individual appropriate sanitation)—possibly drawing on lessons from other EU countries. More attention could also be given to storm water management in urban areas, as a way to both capture more rainwater and further reduce discharges into the sea.

4.2.4. Priority Pillar 4: Developing a Sustainable Strategy for Irrigated Agriculture

The newly achieved potable water security offers an opportunity to rethink the social and economic contribution of irrigated agriculture—in the context of a national irrigation strategy that should also address sustainable aquifer management to ensure future compliance with the WFD. Now that most of the water captured in dams can be allocated in the future for irrigation, the question of how to best use this water should be raised. Whether this additional available volume will be sufficient for farmers to switch to higher value crops given the climate change risk, and what could be done to facilitate it, need to be carefully considered. This will require taking into consideration various trade-offs between the additional volume that will be generated by further development of wastewater reuse, and the need to reduce in parallel aquifers abstraction by farmers to move toward sustainable groundwater management—in a context of further reduction of rainfall due to climate change.

Note

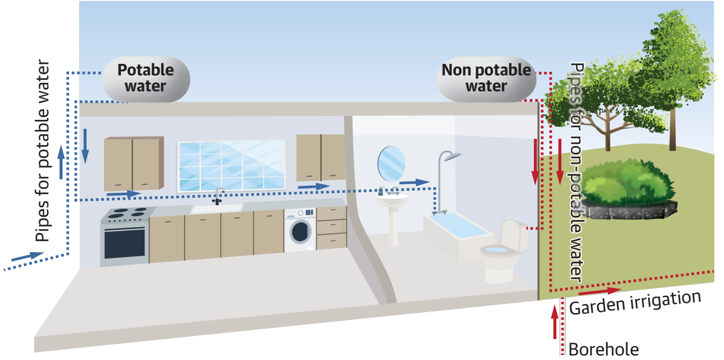
1. Analysis of the function and structure of the Ministry of Agriculture, Natural Resources and Environment (MANRE) of the Republic of Cyprus, World Bank, May 2014.

Appendix A

FIGURE A.1. Subsidies for Potable Water Conservation in Place in 2009

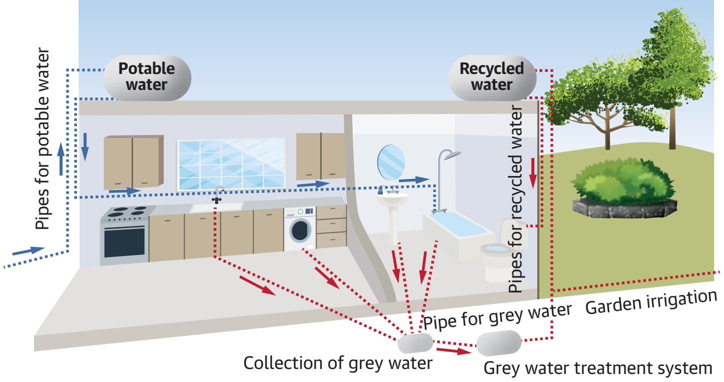
GOVERNMENT SUBSIDIES FOR THE CONSERVATION OF POTABLE WATER

BOREHOLE IN HOUSE GARDENS
CONNECTION OF BOREHOLES WITH TOILET CISTERNS



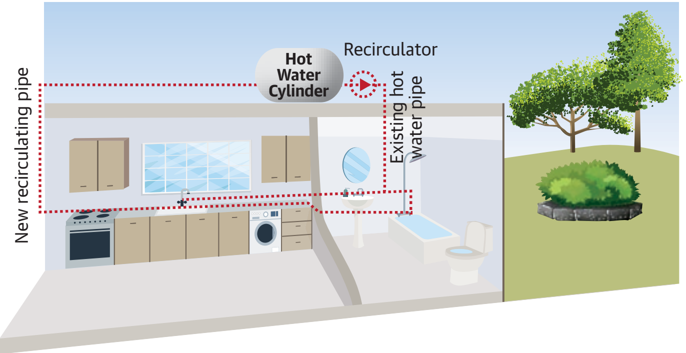
Government subsidy for borehole drilling in house garden **€700**
Government subsidy for the connection of borehole with lavatories **€700**

RECYCLING GREY WATER



Government subsidy for the installation of a grey water recycling system **€3,000**

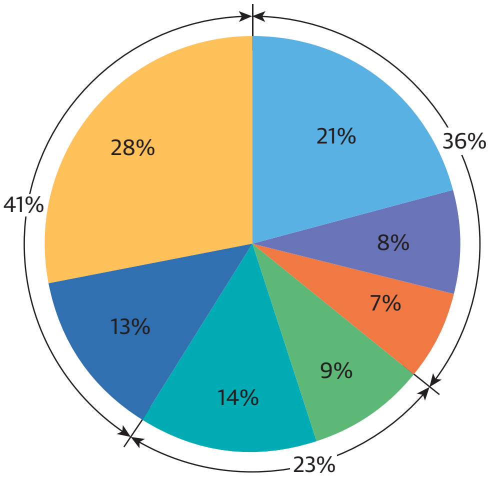
HOT WATER RECIRCULATOR



Government subsidy for the installation of hot water recirculator **€220**

The Water Development Department offers subsidies for the following potable water conservation measures:

Installation of hot water recirculator:	€220
Drilling of borehole for house garden irrigation:	€700
Connection of boreholes with toilet cisterns:	€700
Installation of grey water recycling system:	€3,000



Average consumption of water in a household

- 🟦 Bath
- 🟪 Washbasins
- 🟧 Washing machine
- 🟩 Car washing and outdoor cleaning
- 🟩 Garden irrigation
- 🟦 Kitchen
- 🟨 Toilet

For more Information please contact:
For Borehole drilling call: 22609352
the rest of the subsidies: 22609203, 22609213, 22609000

Source: WDD.

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