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Water Security and Interconnected Challenges in Libya

Hussin Aqeil, James Tindall, and Edward Moran

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Executive Summary

This document discusses how obtaining sustainable water sources will help overcome water-security challenges in Libya. Libya is a country with vast areas of desert and dry climate conditions; a nation that suffers from water scarcity. Throughout the last three decades, Libya has given great recognition to water resources to meet the crucial demands of its growing population, as well as agricultural and industrial challenges. Scarcity of fresh-water resources is apparent, especially along the coastal strip where there are several highly populated areas that are exerting major pressure on social, economic, and environmental issues. The primary conventional sources of fresh water in Libya come from scarce, erratic rainfall and fossil groundwater that resides in four sandstone aquifers: the Kufra, Sirt, Morzuk, Hamada and the Nubian Sandstone Aquifer. Libya's fresh water is estimated to be about 3,820 million cubic meters annually. However the amount of depletion of nonrenewable groundwater is estimated to total about 3,000 million cubic meters per year resulting in a 21-percent deficit. The rate of water consumption by agriculture is about 85 percent, which is the highest rate while domestic and industrial consumption of water is 11.5 and 3.5 percent respectively. The agricultural sector does not have a significant share in the economy of Libya, especially during the last ten years, which yields a poor ROI of water and energy use. The Libyan government planned to use groundwater within deep aquifers by implementing "The Great Manmade River Project" (GMMRP), which remains in progress, but currently is stalled due to civil unrest. The construction of this project depends on funds from government collected taxes on gasoline, tobacco, and travel with no external support. There are also some non-conventional water resources such as desalination of sea water and treatment of wastewater in some parts of Libya. However, water scarcity is increasing due to continued population growth and resultant demand on water resources required for agricultural and industrial use.

There is a vital need for a water management policy that ensures and sustains a satisfactory living standard for the Libyan people and secures sustainable water resources for future generations. The policy should consider: (1) developing new water sources; (2) increasing water efficiency; and (3) implementing conservation measures. There is also a need to establish institutions with highly qualified people capable of enacting suitable implementation, management, and legislation decisions to efficiently allocate water resources. The policy of water management would be divided into three main areas: (1) water supply; (2) demand and allocation management with concentration on allocation management; and (3) the steps needed for achieving established goals. Integrated water-resource management should be directly considered with specific attention to non-conventional water resources such as desalinated sea water and treated wastewater to more adequately meet current and future demand.

Installations of more desalination plants in urban areas along the coast will provide a new water resource especially when their capacities are sufficient enough to assist in domestic water demands. Since waste water has to be treated for environmental sustainability, additional wastewater treatment plants would assist in increasing water supply sources especially for the agricultural sector. Water is currently a free resource in Libya, but it is important to consider water metering and pricing to regulate water demand and pay for required infrastructure maintenance and enhanced conveyance systems. Cost estimation of desalination plants is illustrated herein and includes the pricing for each desalination unit. The suggested costs per water unit also are estimated. By increasing non-conventional water resources, integrated water-resource management, potential institutional reform, and water pricing, as well as the creation of a national water council capable of setting overall water policy, Libya can adequately control

its water resources to provide for increasing water demand. This approach would have a number of benefits including: (1) Increasing desalination plants will increase water supply to meet increasing demand; (2) Creating a new water pricing system will be capable of regulating water consumption, reducing waste water and needed maintenance; (3) Developing a one-water institution strategy will focus ideas, assist in better decision making, create clear and united objectives, and ensure a more rapid implementation of good water management; and (4) Training and education programs will improve competencies in water management.

Introduction

Water dominates about three quarters of the earth and is the source of life for every living organism. Water availability affects all aspects of life including health, economic, political and social issues, and limits development of the social structure and civilization.[1] Thus, water should be recognized as an economic good that supports social and economic development. Fresh water is an essential factor in sustaining economic development, ecosystem functioning, and the environment. Water development and management, however, is key to maintaining water's essential factors, which includes effective policy and pricing structures.[2] Libya is a nation that has long suffered from water scarcity and increasing water demand. It is one of the driest countries in the world, with only the narrow coastal region (less than 5% of the country) receiving the majority of rainfall. In 1953 the discovery of oil in the deserts of southern Libya also led to the discovery of vast quantities of freshwater trapped in aquifers under the Libyan Desert. The Nubian Sandstone Aquifer System, the world's largest, is located under the eastern part of the Sahara desert and spans the political boundaries of Libya, Chad, Sudan and Egypt. This aquifer covers an area of just over two million square km and contains an estimated 150,000 cubic km of groundwater.

Much of Libya's water supply previously came from expensive desalination plants on the coast, which left little water to irrigate farmland—vital in this largely desert country. Additionally, the coastal aquifer historically used in Tripoli began to be severely contaminated with increasing salinity. In 1983 a massive engineering project, known as the Great Man-Made River Project (GMMRP), was created to supply water from desert aquifers to the coastal region for the majority of the Libya's 6.3m people, as well as to expand agriculture production through irrigation.

The project, of which three of five phases have been completed, is intended to supply 6.5m cubic meters of water per day through 4,000 km of pipelines and from 1,100 wells drilled into five non-renewable groundwater reservoirs. The estimated cost for the total project was $25 billion, which is approximately one tenth of the cost of desalinated water. However, with expanding populations, this non-renewable water will lead eventually to non-sustainability.

For the past 30 years, Libya has given a high priority to its developmental projects; however development is limited by the availability of sustainable water resources. Therefore, Libya considers water resources of critical importance for meeting the crucial demands of its growing population, agricultural needs, and industrial challenges. Libya has gone through severe deficiency in water resources and also suffered from the pollution of some of its water resources. Scarcity of fresh-water resources is apparent, especially along the coastal strip where there are several highly populated areas

[1] James A. Tindall, and Campbell, Andrew, A.,, *Water Security: Conflicts, Threats, Policies* (Denver: DTP 2011).
[2] Ibid.

lending to major pressure on social, economic, and environmental. Because of the country's economic situation and population sprawl into several separated areas, there is a vital need for a water management policy that ensures and sustains a means for providing a satisfactory living standard for the Libyan people for current and future generations.

This paper focuses on providing a policy for water management that is concentrated on the depletion of water supplies and the quality of water provided, especially in the coastal and highly populated areas. The policy will consider developing new water sources and increasing water efficiency by lessening water waste and implementing conservation measures. There is also a need to establish institutions with highly qualified people capable of adequate management and enacting suitable legislation and measurement decisions to allocate water resources based upon adequate pricing and conveyance structures. The policy of water management will be divided into three main parts: (1) water supply; (2) demand and allocation management, and (3) steps necessary for achieving established goals.

Water Supply Management

Libya has a population of about 5.5 million; its Sahara desert constitutes 90 percent total land area where temperatures are high and rainfall scarce. The main water resources in Libya are the scarce and erratic rainfall and the fossil groundwater that resides in four sandstone aquifers: the Kufra, Sirt, Morzuk, Hamada and the Nubian Sandstone Aquifer.[3] Rainfall average for Libya is about 56 mm per year, which varies between more than100 mm/year in the northern areas to the highest rates in the regions of Tripoli and Benghazi — about 250-300 mm/year.[4] Generally, it is the narrow coastal regions that receive the largest amounts of precipitation, which drops to about 10 mm/year in the southern areas — some areas are very dry with no rain at all.[5]

Libya's fresh water is estimated to be about 3,820 million cubic meters per year; surface water represents about 170 million cubic meters per year. The water recharged to groundwater aquifers is about 650 million cubic meters per year and the amount of depletion of the nonrenewable aquifers is estimated about 3,000 million cubic meters per year, which is unsustainable long term. Nearly all the estimated 200 million cubic meters of runoff per year evaporates due to the severely dry climate of Libya excepting for small amounts of rainfall that recharge underground aquifers, particularly those in the northern areas of the coast — the North West Sahara Basin. This leads to a limitation of 100 million cubic meters of regular renewable surface water resources per year (Table 1).

The rate of water consumption through agriculture activities is about 85 percent, which is the highest rate of use. Both Domestic and industrial consumption of water is 11.5 and 3.5 percent respectively. In 1998, water shortage was about 1,150 million cubic meters; the amount is increasing due to continual population growth and resultant increased demand for water from agricultural, domestic, and industrial uses. According to recent consumption of water, it is predicted that water requirements for the year 2025 will possibly reach from 8,200 to 8,840 million cubic meters due to the increasing number

[3] A. Otchet, "Black and Blue, Libya's Liquid Legacy " *The UNESCO Courier* 53(2000).
[4] L. Laytimi, "Agricultural Situation Report - Integrating and Strengthening the European Research Area," (2005).
[5] Verhoeven Wheida, "Desalination as a Water Supply Technique in Libya," *Desalination* 165(2004).

of population and the various industrial and agricultural needs with water shortage that could reach about 4,339 million cubic meters.[6]

Table 1: Water Resources in Libya[7]

Source	m^3 per year
Renewable water resources:	
Average precipitation	98.53×10^9 56 mm/y
Total actual renewable water resources in 2004	0.6×10^9
Total actual renewable water resources/inhabitant in 2004	106
Total dam capacity in 2000	385×10^6
Non-conventional sources of water:	
Produced wastewater in 1999	546×10^6
Treated wastewater in 1999	40×10^6
Desalinated water produced in 1999	18×10^6

Conventional Water Resources

Conventional water resources include flowing and stored surface water and groundwater. Libya has constructed storage dams to conserve surface-water resources by storing flood water in reservoirs behind these dams. These dams were constructed mainly in the northern areas where surface runoff is prevalent.[8] Libya possesses 16 dams that have about 385 million cubic meters of total storage capacity and could contain about 61 million cubic meters of annual storage capacity, however, due to some dams' dysfunction, this amount decreases to about 30-40 million cubic meters per year (Table 2).

Libya's groundwater can be divided into two main parts, renewable water resources, which are represented in the shallow aquifers that obtain water from rainfall and surface runoff and, non-renewable water resources that are called fossil water represented in the deep aquifers.[9] In the process of oil exploration in the Libyan southern desert in the middle of the twentieth century, fossil fresh water resources were accidentally discovered; trapped in large-quantity aquifers that formed five main, underground basins. The extent of these basins has been determined and their characteristics are listed in Table 3.

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[6] Laytimi, "Agricultural Situation Report - Integrating and Strengthening the European Research Area."
[7] Ibid.
[8] Wheida, "Desalination as a Water Supply Technique in Libya."
[9] Ibid.

Table 2. Dams in Libya.[10]

Dam	Reservoir capacity (10^6 m^3)	Average annual design storage (10^6 m^3/year)	Dam	Reservoir capacity (10^6 m^3)	Average annual design storage (10^6 m^3/year)
Wadi Mejenin	58	10	Zaza	2	0.8
Wadi Kaam	111	13	Derna	1.15	1
Wadi Ghan	30	11	Abu Mansur	22.3	2
Wadi Zaret	8.6	4.5	Wadi Tabrit	1.6	0.5
Wadi Lebda	5.2	3.4	Wadi Dakar	1.6	0.5
Wadi Qattara	135	12	Wadi Jarif	2.4	0.3
Murkus	0.15	0.15	Wadi Zahawuiyah	2.8	0.7
Bin Jawad	0.34	0.34	Wadi Zabid	2.6	0.5
Total				384.74	60.69

Table 3. Groundwater reservoir characteristics.[11]

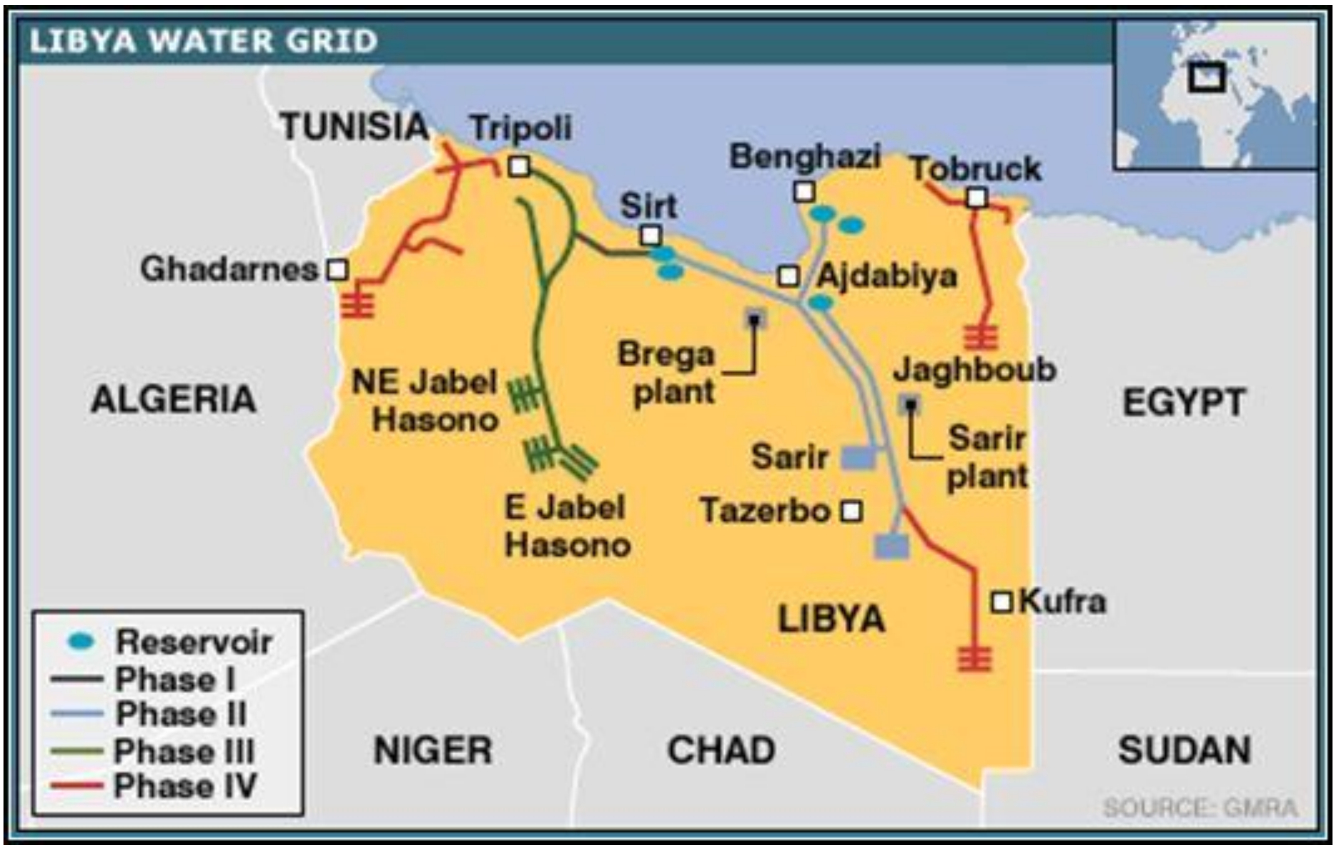
		Usable water		
Basin characteristics	Area in square Kilometers	Renewable in million cubic meters	Non-renewable in million cubic meters	Total dissolved solids
Jabal al-Akhdar	145,000	200	50	1,000 – 5,000
Kufra / as-Sarir	700,000	-	1,800	200–1,500
Gefarah plain	18,000	200	50	1,000–5,000
Nafusah / al-Hamada	215,000	250	150	1,000–5,000
Murzek	350,000	-	1,800	200–1,500

Due to the developing economy and the increase in total population, especially in the northern coastal areas, water demand for agriculture, industry and domestic use is increasing significantly. Accordingly, this has resulted in risk of potential depletion of conventional water resources in which the level of water has fallen and has resulted in salt-water intrusion of shallow aquifers along the coast of Libya. To solve the water problem and to supply the population of Libya, mostly living along the coast, the Libyan government planned to use groundwater from deep aquifers. The government designed one of the greatest, most ambitious and most expensive projects in the 1970s and started implementation; it

[10] Laytimi, "Agricultural Situation Report - Integrating and Strengthening the European Research Area."
[11] Ibid.

is called "The Great Manmade River Project" (GMMRP). This project (Figure 1) began its first stages in the 1980's utilizing funds from government collected taxes on gasoline, tobacco and travel, with no external support. The project began by laying huge pipelines and hydraulic infrastructure to link well fields where groundwater is pumped and then, conveyed to coastal cities.

Figure 1. Libya Great Manmade River Project.[12]



Libyans call the GMMRP the eighth wonder of the world. During Phase I, the project pumped and conveyed about two million cubic meters of water per day to the northern coastal areas from Benghazi to Sirt. About 700 million cubic meters of constant flowing water passes through pipelines to a 4 million cubic meter capacity storage reservoir located near the city of Ajdaba on the northern coast. Water in the reservoir is redirected into two main branches. These two branches convey the fossil water extracted from two well fields. One branch is directed to the east to convey water to the city of Benghazi and the surrounding areas; the other branch heads west to transport fossil water to the city of Sirt and surrounding areas. The second phase of the project is designed to deliver about 2.5 million cubic meters of fresh water per day. This water is conveyed from a well field through a pipeline network that is

[12] Watkins

divided into two main branches and delivered to other areas along the coast that are not included in the first phase, along with separate areas scattered along the northwestern mountain and hills.[13]

The third phase of the project began in 2010 and should deliver about 1.7 million cubic meters of fossil water daily upon completion (projected for 2015) from the Nubian Sandstone Aquifer System in the area of Al-Kufra in the north-eastern desert. This phase is designed to join with the first two phases and support them to overcome water supply deficiency to the western area called the "Gefarah plain."[14] There are two more phases that will conclude the completion of the GMMRP; the fourth phase will consist of a water-supply network to be constructed from the Gadammes area to the areas of Zawara and Zauia in the north. The fifth phase will connect the well field of Jagboub Oasis to the city of Tubruk in north-eastern Libya. The Libyan government decided in 1993 that 80 percent of the water collected in the GMMRP will be used for agriculture for the country's goal to be agriculturally self-sufficient and economically independent thus, becoming a truly sovereign state. However, 5 percent of the river's water is scheduled for industrial purposes, 12 percent for domestic use, especially in the urban areas, and 3 percent is expected to be lost during the conveyance process.[15] The latter is actually minimal compared to most large-city conveyance systems that lose about 20 percent of water in the conveyance process.[16]

Non-conventional water

Desalination of Seawater

Countries bordering coasts that possess little or limited conventional water resources generally have the option of using desalination technology for providing potable water. Desalination is widely used around the world and the number of desalination plants that currently exist is about 12,500 plants worldwide. These plants account for about 706 million cubic feet of fresh water per day. Thus, providing and supplying about one percent of the world's production of fresh water. There is a growing world market in water desalination that is expected to double due to the decline in costs for new desalination equipment and technology. The world market could potentially reach about $70 billion within the next 20 years. Ten billion dollars has already been reserved for the purpose of establishing a number of desalination units in different parts of the world. It is expected that these desalination units will produce about 187 million cubic feet of fresh water per day taking into consideration the growing demand of some countries that experience hot, arid climates such as the Middle East, Asia, the Caribbean, and even the Southwest U.S., in addition to the persistent water shortage in many countries around the world.[17]

Libya has a growing demand for fresh water and since the 1960s has considered desalination as a sufficient solution to provide for additional water resource demands.[18] Desalination of seawater can be

[13] Wheida, "Desalination as a Water Supply Technique in Libya."
[14] Business Monitor International, "Libya Infrastructure Report," (London: Business Monitor International, 2011).
[15] Wheida, "Desalination as a Water Supply Technique in Libya."
[16] Tindall, *Water Security: Conflicts, Threats, Policies*.
[17] J. Martin-Lagardette, "Desalination of Seawater," *Water Engineering & Management* 148, no. 4 (2001).
[18] Abufayed, "Desalination Process Application in Libya," *Desalination* 138(2001).

accomplished by two primary techniques, the thermal technique that includes distillation and the membrane technique, which includes reverse osmosis. In Libya, both thermal and membrane desalination techniques have been used since the early 1960s. In Libya, the population is highly concentrated on the Mediterranean coastal zones where the climate is moderate, soils are fertile, and there is presence of industrial activities. Accordingly, Libya suffers from disparate population distribution, resulting in a tremendous shortage in water supply in more populated areas. Initially, many desalination plants were constructed, but some of them are currently non-operational (Table 40).[19]

Table 4: Desalination Plants.

Location	Plant Type	Design Capacity	Number of Units	Operation Year	Year of Installation	Existing Capacity
Derna	MSF*	9000	2	1975	1973	4000
Benghazi	MSF	24000 + 24000	4 + 4	1976 + 1978	1974 + 1976	10000
Tripoli-West	MSF	23000	2	1976	1974	4600
Tubruk	MSF	24000	4	1977	1975	8000
Sousa	MSF	13500	2	1977	1975	2500
Hones	MSF	40000	4	1980	1977	25000
Misrata	MSF	30000	3	1987	1982	25000
Bomba	MSF	30000	3	1988	1984	18000
Sirt	MSF	10000	1	1986	1985	9000
Zilitn	MSF	30000	3	1992	1989	20000
Tubruk	MED**	40000	3			Under construction
Sousa	MED	10000	2			Under construction
Tripoli	MED	10000	2			Under construction
Derna	MED	5000	1			Under construction

*MSF is Multistage Flash Desalination; **MED is Multi-Effect Distillation.

New installation technologies are used in current desalination plants in the cities along the Libyan coast. However, due to the number of non-operational plants, the annual production of the existing desalination units remains in deficit to total fresh-water demand. It is important to note that surface-water supply does not fulfill the water requirements for the population living along the coast, which represents about two thirds of the total Libyan population, but only occupies about one hundred

[19] Wheida, "Desalination as a Water Supply Technique in Libya."

kilometers of the coast line of the Mediterranean Sea; this compares to the Libyan border along this coast of about 1900 km.[20]

Desalination technology was highly sought by the Libyan government because of its ability to overcome total water deficits, despite initial expense. Thus, increasing the number of plants along the coast in the most populated areas such as Tubruk, Tripoli, Sirt and Benghazi has had a positive effect and will help achieve long-term sustainability of water supply and for continued economic development. However, management of these plants has been an issue. It is therefore important to both use the latest scientific advancement for newer plants and to consider administering the development of desalination units domestically instead of through specialized international institutes, especially considering the cost of these plants (Table 5).

Table 5: Estimated Cost for Desalination Plants.

City	Design capacity in m3/day	Price per plant	
		US dollars(millions)	Libyan Dinar(millions)
Tripoli	100,000	150	191
Benghazi	80,000	120	153
Sirt	60,000	90	115
Tubruk	80,000	120	153
Total	320,000	480	612

Given costs and longer-term sustainability issues, we recommend some type of tiered pricing system for water based on a unit capacity where 1 unit = 1 m^3 of water (264 gallons-US). As an example, for domestic and industrial consumption the cost (October 2012 currency rates) of a unit system would be as follows:

From 1-4 units: 0.70 Libyan Dinar ($0.55 USD)
5-9 units: 1.00 Libyan Dinar ($0.79 USD)
9+ units: 1.50 Libyan Dinar ($1.18 USD)

As a comparison, this tiered pricing system would be less than 50 percent cost of a comparative system in the United States. However, by comparison of volume of water per unit in the U.S. (1,000 gallons), the total cost would be about 47 percent higher per unit volume, although current U.S. water prices are increasing significantly.

Wastewater Treatment

During the last 30 years, there have been many changes that include significant increases in population growth, as well as the addition of extensive urbanization of Libyan cities (a global trend due to jobs and economies) along its coast. Accordingly, the need for some critical infrastructures was lessened such as roads to fulfill the demand for urban areas, as well as rural areas. Since the 1970s,

[20] Ibid.

Libya has followed a strategy to reduce environmental problems caused by wastewater treatment. As in other countries, wastewater treatment makes a significant contribution to pollution and further reduces water-supply levels. Thus, alternatives are being sought for providing non-potable water for agricultural irrigation, golf courses, parks, public gardens, industrial cooling, fire-fighting purposes, street cleaning, and residential toilets. Solutions in these areas, following those of other countries such as Japan and cities like Shanghai, could greatly reduce potable water demand. Particularly since current water resources are very limited and the results of finding a solution will result in a sustainable water supply. Based on current water-demand trends, future supplies could incur costly financial and ecological prices, especially since recent water demand in Libya is already surpassing the country's capacity from conventional water resources. In the meantime, there is a crucial necessity for integrated water-resource management to focus more on non-conventional water resources as an alternative to conventional supply, especially wastewater treatment and reuse.[21]

Since 1963, Libya has implemented a functional wastewater-treatment plan, operation and maintenance problems. Much of the treated water has been used for agricultural irrigation. However, the cost of transferring this treated water from the plants to agricultural areas has been small since the agricultural areas directly surround existing treatment plants. But, this treated wastewater has also played an exclusive role in economic development due to agricultural revenues. In addition to supplies for agriculture, there is a need for educational-health programs to address public concern about the usage of previously treated wastewater for agricultural irrigation and the loss of confidence in the validity of products that have been irrigated by this water. Farmers also are hesitant to use treated wastewater, thus there is a need for adequate policies to help resolve these issues.

The total design capacities for wastewater treatment plants that have been installed and used since the 1960s in Libya are illustrated in Figure 2. There has been a steady increase in the rate of design capacities by nearly 6500 m^3 per day between the years 1965 and 1975. This rate increased afterward to 16000 m^3 per day between the years 1975 and 1985 and then to 484735 m^3 per day in the period between 1985 and 1998. Due to maintenance and other operational issues, the rate of design capacity began to decrease and became constant throughout the last few years. Currently, the actual implemented capacity is much smaller than it was designed to be, reaching only about 6500 m^3 per day, which is equal to the design capacity of 1975. A critical thrust must be taken to overcome the wide gap between the design capacities and those actually implemented.

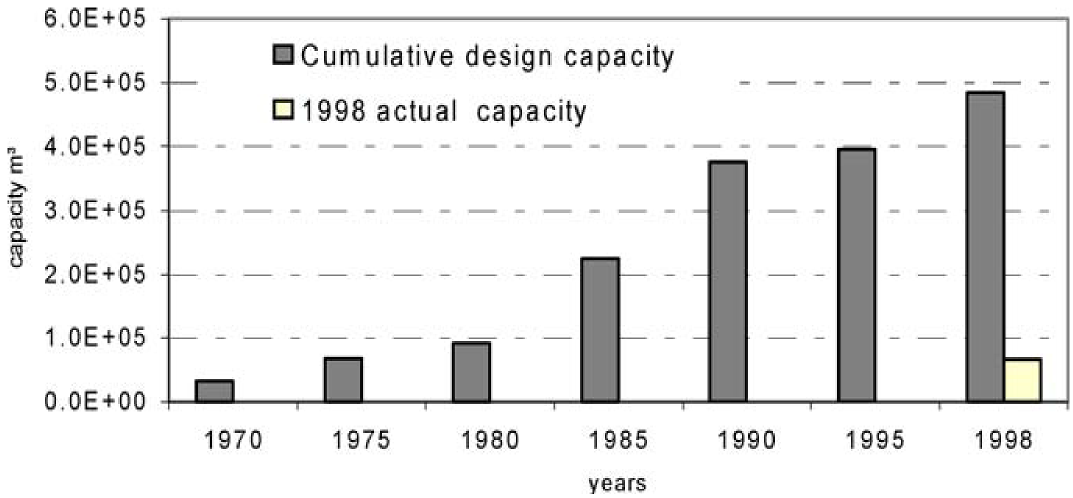
Wastewater treatment plants that started at a small scale in the 1960s began to increase in size and capacity in later years, which has increased economic development opportunities. These treatment plants are used in most northern cities and villages. It is important to note that nearly all the wastewater treatment plants are designed to provide the agricultural sector with treated water suitable for irrigation purposes. Initially, the technique used for water treatment was trickling filters (TF) installed in the 1960s; the activated sludge (AS) technique is now used in most new plants. From 1965 to 1995, 25 wastewater treatment plants were constructed; three of them remain in operation working with good

[21] E. Wheida, and Verhoeven, R.,, "An Alternative Solution of the Water Shortage Problem in Libya," *Water Resources Management* 21, no. 6 (2007).

efficiency, two with average efficiency and the rest have mostly lost their efficiency.[22] If the current civil unrest continues, remaining plants may become totally inoperable.

As illustrated in Table 6, the design capacities of wastewater treatment plants are between 150 m^3 to 110000 m^3 per day and partially treated and untreated waste water end up in the sea or in Wadi beds far from the urban populated areas. A serious problem facing all treatment plants is that they do not deliver any data about treated water quality, which is due to lack of laboratories and absence of skilled personnel.

Figure 2. Overall cumulative designed and installed capacities of wastewater treatment plants.[23]



Two main agricultural projects (fruit trees and animal fodder) benefited significantly from wastewater treatment and were established in the cities of Tripoli and Benghazi contributing to the irrigation of about 6000 hectares (Table 7), according to the National Company of Water Supply and Wastewater Treatment.

Water Demand Management

Because water demand increased so significantly, its management became more important. Near-term immediate actions should be addressed to avoid a potential water crisis, which Libya is now undergoing. Maintenance and conservation of water requires more focus on the primary consumer sectors. As previously noted, the agricultural sector consumes about 85 percent of the total water use, which will likely continue. Table 8 shows the five segments where water is used, as well as population and water demand.

[22] Ibid.
[23] Ibid.

Table 6. Wastewater treatment plants.

Treatment Plants	Installation Year	Design Capacity, m3/day	Existing Capacity, m3/day	Treatment Type	Condition
Ejdabya	1988	15600	5000	Activated sludge	
Benghazi A	1965	27300	-	Tricking filters	Inoperable
Benghazi B	1977	54000	-	Tricking filters	Provisional test
Al-merg A	1964	1800	-	Activated sludge	Inoperable
Al-merg B	1972	1800	-	Activated sludge	Inoperable
Al-beada	1973	9000	-	Activated sludge	Under construction
Tubruk A	1963	1350	-	Tricking filters	Inoperable
Tubruk B	1982	33000	-	Activated sludge	Inoperable
Derna	1965	4550	-	Trickling filters	Inoperable
Derna	1982	8300	-	Activated sludge	Under construction
Sirt	1995	26400	-	Activated sludge	Under construction
Abo-hadi	1981	1000	600	Activated sludge	-
Al-brega	1988	3500	2700	Activated sludge	-
Zwara	1980	41550	-	Activated sludge	Not used
Sebrata	1976	6000	-	Activated sludge	Inoperable
Sorman	1991	20800	-	Activated sludge	Under construction
Zawia	1976	6000	-	Activated sludge	Under construction
Zenzour	1977	6000	-	Activated sludge	Not used
Tripoli A	1966	27000	-	Tricking filters	Inoperable
Tripoli B	1977	110000	20000	Activated sludge	-
Tripoli C	1981	110000	-	Activated sludge	-
Tajoura	1984	1500	500	Activated sludge	-
Tarhouna	1985	3200	1260	Activated sludge	-
Gheraan	1975	3000	-	Activated sludge	-
Yefren	1980	1725	173	Activated sludge	-
Meslata	1980	3400	-	Activated sludge	Not used
Homes	1990	8000	-	Activated sludge	Not used
Ziliten	1976	6000	-	Activated sludge	Inoperable
Misrata A	1967	1350	-	Tricking filters	Inoperable
Misrata B	1982	24000	12000	Activated sludge	-
East Garyat	1978	500	-	Activated sludge	Inoperable
West Garyat	1978	150	-	Activated sludge	Inoperable
Topga	1978	300	-	Activated sludge	Inoperable
Shourif	1978	500	-	Activated sludge	Inoperable
Sebha A	1964	1360	-	Tricking filters	Inoperable
Sebha B	1980	47000	24000	Activated sludge	-

Table 7. Irrigated areas in Tripoli and Benghazi by treated wastewater.

Project location	Stages	Discharge capacity m3/day	Irrigation area hectare	Irrigated crops
Tripoli	1st stage	27.000	2500	Fruit trees and animal fodder
	2nd stage	110,000	1500	Animal fodder
Benghazi	1st stage	27,000	360	Animal fodder
	2nd stage	27,000	658	Animal fodder
	3rd stage	27,000	1000	Animal fodder

Table 8. Water Demand.

Segment	Population in 1995, (1000)	Population in 2025, (1000)	Water Demand, (Million m3)		
			Domestic	Industry	irrigation
Jabal Al-akhdar	1158	2637	252	20	77
Kufra As-sarir	218	841	102	51	1670
Gefarah plain	1919	4002	348	33	2718
Nufusah Al-hamada	826	2132	131	18	1266
Murzek	284	824	162	43	1949
Total	4405	10436	995	165	7680

As previously mentioned, the agricultural sector does not have a significant share in the economy of Libya especially during the last 10 years. Its contribution to the economy does not exceed 10 percent of Libya's total income, yet to become a sovereign state, Libya needs to produce most of its own food so that it is not controlled by other countries. According to this evaluation it is necessary that new measures be taken to achieve economical sustainability and, expanding agriculture is quite an important component. There must be a prompt shift from management of water supply to management of water demand. The major aspects affecting management of demand are population growth and its effects on demand and sustainable supply. This shift is imperative to balance Libya's water budget, which makes the assumption that no real economic crisis will occur. As illustrated in Figure 4, if agricultural production is reduced to 1998 levels, water consumption due to irrigation will be reduced and thus reduce total water demand accordingly.

Figure 3. Total and agricultural economic production in Libya.

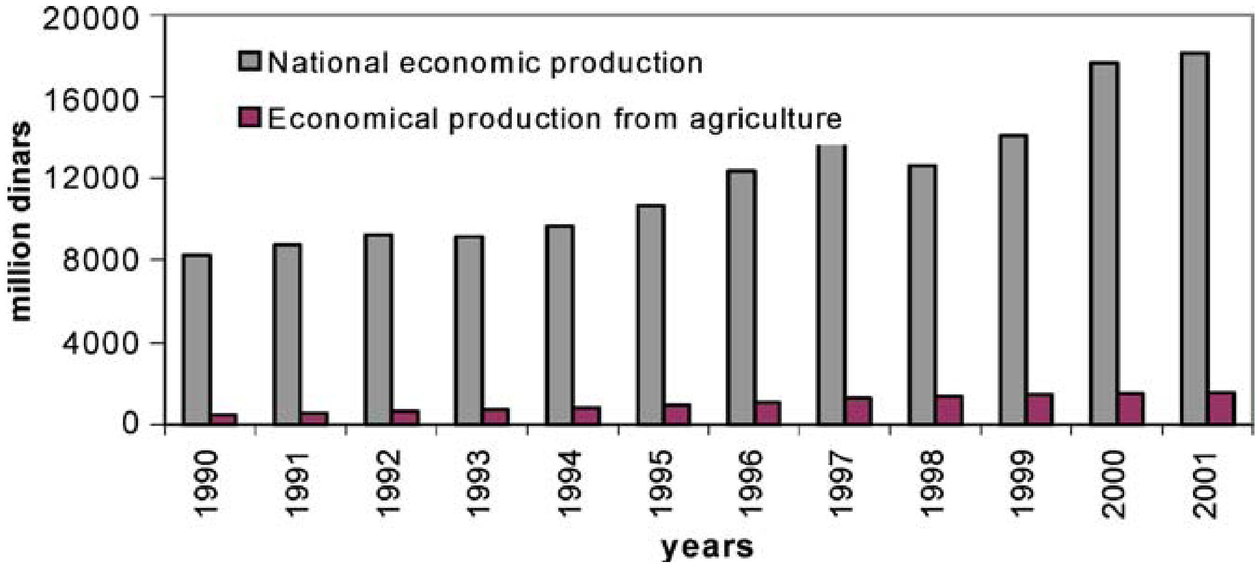
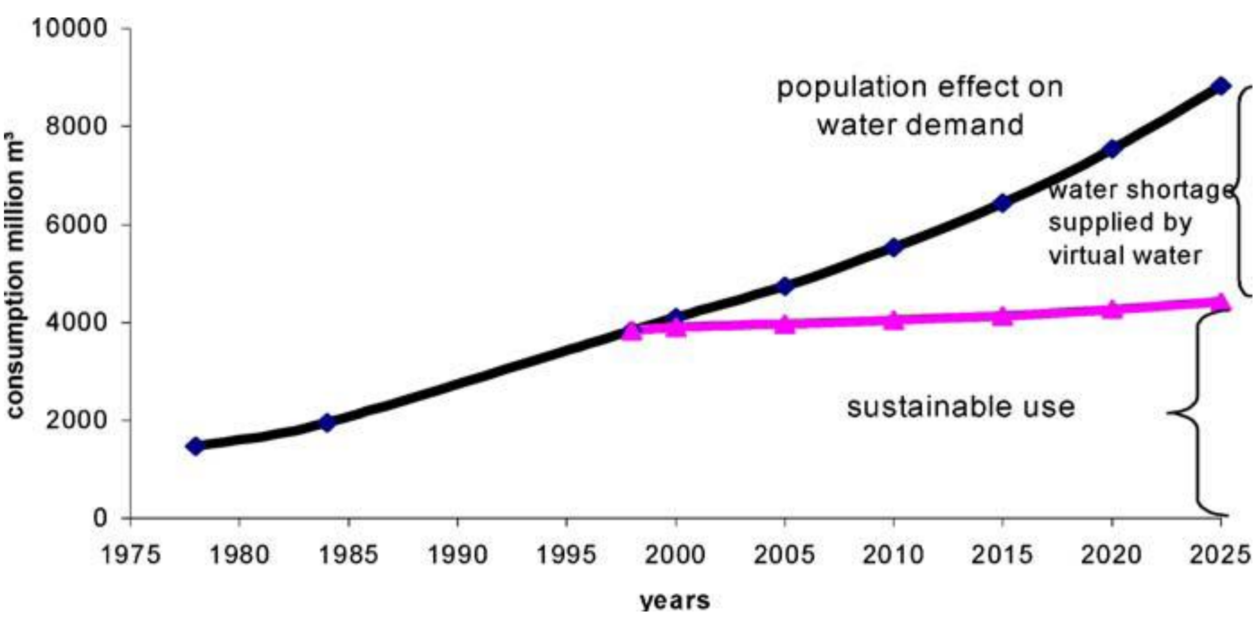


Figure 4. Stabilizing agricultural production.



Agriculture Policy Reconsideration

Libya's hot climate and scarcity of rainfall are just two reasons for the large amounts of water needed for agricultural irrigation. Precipitation is occasional, limited, and inadequate throughout Libya except for the very narrow coastline along the Mediterranean Sea. The demand of water for agriculture is also increasing due the continuous growth of the Libyan population and resulting increasing demand for food. In consideration, measures taken for water conservation could have an impact on the agricultural sector such as:

I. Discouraging increases in irrigated areas to avoid crucial reduction due to climate conditions.
II. It is currently unfeasible to adapt the policy of food self-sufficiency because costs will exceed gains, yet required for sovereignty.
III. Utilize water conservation and consumption measures to minimize the consumption of irrigation water within the agricultural sector such as:

1. *National Policy on Water Resources*

Some measures should to be considered for the future of water resources in Libya and attention given to areas where there are serious water quality and quantity problems:

a. There should be no expansion in agricultural areas or products, especially in areas that suffer from water deficiency without an increased supply of water.
b. There is a need to consider economic reforms and job reorientation for incompetent farmers.
c. Restrict well drilling for irrigation to those who have permits and or licenses.
d. Agricultural activities should be restricted by appropriate economical and technical measures.

2. *Agricultural Planning*

For the future of agriculture in Libya other measures also should be considered:

a. Food self-sufficiency and security policies should be applied in consideration of crop type and the requirements, location, and accessibility of water resources.
b. Water-resources allocation should be managed such that groundwater is used for growing fruit and vegetables while reclaimed water is used for growing animal fodder to lessen water treatment price, energy requirements, and water demand.
c. Gradual transformation from food requiring higher water consumption to lower water consumption by changing food habits and concentrating on seafood fisheries development is likely.
d. Prohibiting exportation of agricultural products since it is not reasonable to export crops while the country suffers from water deficits. This is a trade in virtual water that is not economical as is witnessed by other Middle Eastern countries, particularly Israel.
e. Following legislative actions restrict the use of groundwater in coastal areas.

f. For state sovereignty, an agricultural program sufficient to feed the general Libyan populace and avoid control from outside Libya, would work in conjunction with the above points and should be a national priority.

3. Irrigation Technique

Using advanced irrigation techniques that can reduce water consumption and provide adequate irrigation should be a priority. The technology should be suitable to both the nature of the soil and also crop types and would include training users on operating and maintaining irrigation networks, as well as encouraging the manufacture of irrigation tools locally.

4. Production Efficiency

It is mandatory to build a highly competent team of farmers through providing educational programs on modern methods of agriculture. A primary goal should be to encourage planting crops that can thrive on the limited amount of rainfall and that have the potential to use more advanced tools during plant harvesting, storage, and transportation. This will help minimize agricultural losses and increase production efficiency. A variety of crops that would be suggested are the subject of another study.

Utilization of GMMRP

A significant and rapid solution to mitigate increased water demand along coastal areas experiencing water deficit is the delivery of fossil groundwater to these areas. Fossil groundwater sources are non-renewable water resources that require high extraction costs especially for the long-term because deeper and deeper wells will need to be drilled to extract water. The use of the delivered water and water allocation could be prioritized as follows:

a. Satisfy domestic and industrial demands then allocate remaining water to the agriculture sector since treated wastewater could be used to irrigate a variety of crops.

Carefully allocate water important in areas such as the Gefarah Plain and Nafusah Al-hamada where population density and agricultural operations are higher and, in some urban areas where desalination of water resources does not adequately address domestic needs. However, extracting water from the immense Nubian Sandstone Aquifer system may cause transboundary disputes with Chad, Egypt, and Sudan and, with Algeria in relation to the Northwestern Sahara Aquifer system, which must be considered in policy and development issues.

Water Metering and Pricing

Due to the very low or no cost for water to residents in Libya, water metering and pricing should be considered. Measures need to be implemented that address the cost of water production, maintenance, infrastructure development, and future expenses for building new water resource conveyance systems such as desalination projects. Prices need to depend on water allocation and environmental costs, along with development and related costs. A fair pricing will allow and persuade water users to self regulate consumption through water price. Prices need to be fair and affordable to all users and should reflect the service presented, although this is difficult to achieve for the very poor, who will likely need subsidies. Various pricing measures that could be considered to prevent water misuse could include:

a. Control water pricing for the sectors of industry and agriculture such that price will depend on cubic meter consumption in areas where the cost of water production is affordable; in other areas of high cost, the price may require subsidy.
b. In urban areas, a fair and effective pricing program is recommended for domestic water users – a tiered system would likely be most effective.
c. Water needs to be metered for all users.
d. Water resource users should have limits on the quantity of water they can extract from any source based on needs of the sector they are classified within, i.e., domestic, agricultural, or industrial.

The pricing of water affects water demand and economics; elasticity is the change of water demand as a result of changes in price so, as prices for water increase, the demand would decrease, which shows that price is considered a demand management tool for reducing demand. As a consequence, when demand falls, water suppliers' total income drops as well.[24] The estimated price for water, as mentioned in the desalination plants' section would be according to a unit tiered system where 1 unit = 1m^3 (264 gallons – U.S.) of consumed water. Costs will vary as previously shown. As with all societies, economic income levels vary. In such instances an option for pricing could consider and economic tier for taxing water use. For example, allow users to use a specific amount each day and assess a charge for over consumption. Further, in regard to social responsibility, again, the underserved and poor will be unable to afford the tiered pricing suggested therefore, allowances need to be incorporated into policy in their behalf.

Water Allocation Management

There are regions in Libya that are blessed with natural water resources and for which legislation is not an issue because there are no problems allocating water among users. But for other regions in which water is scarce and living standards are rising, there is a greater need for water allocation among sectors. Accordingly, legislative actions to manage water usage, development and protection need to separate between the authorities who manage water allocation and the consumers. For example, the supervision of agricultural secretary on institutions such as General Water Authority (GWA) and Great Manmade River authority deprive these institutions from their responsibility for water management. However, for greater efficiency and effective management, all sectors of water management should be grouped together to ensure that their functions do not conflict.[25]

[24] Tindall, *Water Security: Conflicts, Threats, Policies*.
[25] Ibid.

Current Water Legislation

Water legislation was enacted in 1965 and updated in 1982 to regulate water use and prevent pollution. The current legislation considers: (1) Water resources as a national treasure; (2) Each citizens right for using water resources on his or her property; (3) Forbidding well drilling without licensing; and (4) The institute General Water Authority is responsible for water management. Although, water authorities have the right to monitor water quality and prevent pollution of water sources.[26]

By examining Libya's water legislative actions it could be stated that they include many areas of water-resource protection, but there is a problem applying these actions due to: (1) The obstacle of tribal social systems; (2) Negligence on applying proper actions to regulate the amount of water used that could lead to water shortage; (3) Cultivatable land is divided into small parts as a consequence of Libya's land heredity system that lends itself to illegal well drilling; (4) Fluctuation in agricultural product prices and lack of a collective marketing policy encourages agriculture to ban certain products; (5) Urbanization expansion on fertile lands leads to using more water to reclaim unfertile lands; and (6) Many areas where well drilling is prohibited are distributed by the government among farmers which leads to a deterioration of water quality.[27]

Legal Institutional Policy Framework

Many measures need to be considered in planning and implementing a national water resources strategy for Libya. Training personnel, as well as public education in areas with water problems and reestablishing and redesigning institutions capable of creating and implementing appropriate and immediate actions is necessary. This could be achieved by:

1. Developing training programs to improve personnel skills and knowledge in planning, management, monitoring, and controlling water institutions.
2. Increased public education and awareness.
3. Improving competencies in water management by creating specified educational programs.
4. Educational programs would likely need to be subsidized to guarantee the implementation of long-term water strategy and security. The success of a national water strategy will depend on the cooperation of the various authorities within the water institutional framework, i.e., it must include all stakeholders; and
5. Water-use taxing.

It is necessary to establish a water commission that has the authority to deal directly with all aspects of water including critical water resources situations, to demand and analyze government reports

[26] Salem Bakhbakhi, "Why the Great Manmade River Project?" (paper presented at the Managing non-renewable resources conference, Tripoli, Libya, 1999).
[27] Wheida, "An Alternative Solution of the Water Shortage Problem in Libya."

concerning water issues, and that requires oversight by the Libyan National Government. This water commission would be responsible for:

1. Integration of water allocation by considering limited water resources in relation to increasing water demand.
2. Future water planning should consider water deficiency and secure social and economic development, and an overall water-security strategy and framework.
3. Create a union of all water institutions with a new authority to implement needed processes for effective implementation, management, and control.
4. Water allocation should consider the needs of the domestic sector as the top priority because water directly affects public health, followed by the industrial and agricultural sectors.
5. Rapid implementation of water strategy with water projects that have long-term financial and socio-economic impacts; this is a requirement for continued economic development.
6. Create a national water council position within the system of the government responsible for applying future water policies.

Benefits

This policy will have many benefits that include:

1. Increasing the number of desalination plants that will increase water supply to meet increasing demand;
2. Creating a new, tiered water-pricing system will assist in regulating water consumption and reduce water waste thereby providing savings through conservation;
3. Creating a unified water institution strategy will concentrate ideas and decisions and help create clear and united objectives to ensure rapid implementation and effective water management; and
4. Implementing training and education programs that will improve competencies in water management and thus, help to ensure long-term sustainability.

Conclusions

Libya’s water resources are limited and as population increases, the demand for water also increases. Currently, water demand surpasses conventional water resources; additional demand will require steep financial and environmental costs. Integrated water resource management should be directly considered with specific attention to non-conventional water resources such as desalinated sea water and treated wastewater. Integrated water resource management will take into consideration that the agricultural sector contributes to high levels of water consumption with minimal contribution in Libyan gross domestic product (GDP) and economic sustainability. Transboundary issues regarding the Northwestern Sahara and Nubian Sandstone aquifer systems with Chad, Egypt, Sudan, and Algeria will also play a significant role in future water supply and allocation, which policy must consider.

The agricultural sector is considered the major source of water deficiency; expansion into reclaimed land is recommended, as well as crop expansion to develop a more sovereign Libya that does not need to rely upon other countries for the majority of its food. This is despite current water shortages, which presently minimize food self-sufficiency, but which must be overcome. Additionally, conflicts between the functions of different institutions could be ended by considering reform and creating a national water council capable of setting and governing overall water policy. Conservation of water should also be considered by using advanced irrigation technologies to reduce water waste. Coastal areas that suffer from water deficiency such as Gefarah and Nafusah Alhamada should have a priority for water allocation management by conveying groundwater from the south to the north. However, long-term use of fossil groundwater given population growth will not be sustainable thus; alternatives such as desalination need to continue to develop. The domestic sector should have the highest priority followed by the industrial and agricultural sectors. Treated wastewater from the domestic and industrial sectors could be used for agriculture and would increase sustainable supply in this area. Installation of more desalination plants near urban areas along the coast will provide a new water resource especially when their capacities are great enough to assist in domestic water demands.

Desalination plants contribute to economic-development sustainability. To supply current and future water needs inoperable plants need to be repaired and new plants constructed. Wastewater treatment is also another important water resource that feeds the agricultural areas in the northern region. Since wastewater needs to be treated for environmental sustainability, additional wastewater treatment plants will assist in increasing water supply sources, especially for the agricultural sector. Water pricing is a regulator for water demand thus; an effective water-pricing system designed for all sectors will assist in water-resource conservation but should be socio-economically tiered.

By increasing non-conventional water resources, integrated water-resource management, considering institution reform and water pricing, and creating a national water council capable of setting and governing overall water policy, Libya could have adequate control on its water resources and possess the capacity to meet future, increasing water demands.