Water infrastructure in Libya and the water situation in agriculture in the Jefara region of Libya

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Abstract: Information about the current state of water institutional frameworks, water infrastructure and water management policies in Libya enable the identification and evaluation of a range of options for improving water use efficiency in agriculture and the potential role of water pricing in achieving sustainability of water sources. This paper begins with an overview of the agricultural sector. In order to assess the current water situation in Libya, the water infrastructure will be examined through a review of water legislation, its institutional framework and the infrastructure surrounding the various water resources. The national strategy for the management of water resources and the suggested plans to address the inefficient use of water in the Jefara Plain Region (JPR) will be discussed. The last section will be devoted to the Great Man-made River Project (GMRP) and water investment in JPR's agriculture, and conclude by identifying the problems and obstacles facing the outcomes for these investments.

Keywords: Libya; Jefara Plain Region; JPR; water management policies; water use efficiency; water resources management; water legislation; water institutional frameworks.

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1 Introduction

With about 93% of Libya's land surface receiving less than 100 mm/year rainfall, desertification and very limited natural fresh water resources are the current and significant environment issues in Libya (CW, 2001b). The average annual rainfall for the whole country is only 26 mm. Rain usually occurs during the winter season, but varies greatly from place to place and from year to year. The highest falls are recorded in the Jabal Nafusah, Jabal al Akhdar and JPR regions, making them the only areas of the country exceeding the minimum value of 250–300 mm considered necessary to sustain rainfed agriculture (Aquastat, 2006). About 95% of Libya is desert, with only 1.2%, about 2.2 million ha, able to be cultivated (Aquastat, 2006).

Until the early 1960s, the Libyan economy had a strong agricultural base. Agriculture provided the raw materials for the industrial sector, exports, and trade, and contributed about 30% of the GDP. After the discovery of petroleum, Libya became a classic example of a dual economy (CW, 2001a, 2001b). By 2007, oil was contributing 71% of GDP where as agriculture's contribution was only 2%. Little by little the Libyan economy had been transformed from a poor, largely agricultural economy to one of Africa's stronger and wealthiest economies based on the oil and gas industries (European Commission, 2009). The Libyan economy has remained still largely controlled by the state and heavily dependent on the oil sector (Otman and Karlberg, 2007).

The total population of Libya reached 5,673,031 in 2006 (Otman and Karlberg, 2007). With a population growth rate of more than 3% annually, Libya is one of the 26 countries in the developing world whose population could conceivably double in the next 25 years. This will necessitate a sharp increase in water drawing over time, in response to the continuous population growth and water requirements for the domestic, industrial and agricultural sectors. The rates of renewable water and surface water per capita in Libya are the lowest in the Near East and North African Region. In the context of the estimated water availability and the forecasted population growth in Libya, the per capita renewable water and surface water rates show a steady decline. Alongside, the low level of food self-sufficiency acute water shortage is a key problem of agriculture in Libya (European Commission, 2009).

2 Agriculture in Libya

The agricultural sector's importance to Libya's economy has been in steady decline, contributing only 4.3% to Libya's GDP in 2002 (Table 1). By 2007, the figure had dropped to just 2% of GDP, with just 135,700 people working in the agricultural sector out of a total of 1.8 million workers in Libya (OBG, 2008). In common with other oil producing countries in the Near East and North African Region, agriculture has become a marginal sector (Casas, 1999) and Libya currently exports only about 0.3% of its agricultural produce (European Commission, 2009).

Table 1 The sectoral distribution of GDP (percent), 2002–2007

Sector	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
Oil sector	50.1	57.6	64.1	69.5	72.3	71.6
Agriculture, fishing and forestry	4.3	3.6	2.8	2.2	2.0	2.0
Manufacturing	2.2	1.9	1.7	1.3	1.1	1.2
Electricity, gas and water	2.2	2.0	1.5	1.3	1.2	1.1
Construction	6.4	4.8	4.5	4.0	3.9	4.3
Trade, hotels and restaurants	5.7	4.9	4.4	3.9	3.4	3.4
Transportation, communication and storage	5.0	4.7	3.9	3.5	3.3	3.3
Financing, insurance and business services	1.7	1.5	1.3	1.0	1.0	1.0
Housing	12.5	10.0	8.0	6.3	5.6	5.2
Public services	9.9	9.0	7.7	6.8	6.2	6.8
Other services	0.1	0.1	0.1	0.1	0.1	0.1

Source: Adapted from IMF (2008) and WBG (2012)

Many of the rural poor depend on household use food production, sold locally or for local consumption, with low productivity and limited access to markets. They coexist with large farms that are more highly mechanised, using more agricultural inputs with relatively less amounts of labour (European Commission, 2009). About 95% of Libya is desert, which leaves only 1.2% or 2.2 million ha, of cultivatable land (OBG, 2008). Most arable land lies in the Jefara Plain Region (JPR) on the west coast and Jabal al Akhdar Region on the east coast (CW, 2001a, 2001b). Annual crops account for 1.8 million ha, permanent crops for only 300,000 ha and permanent pastures for 13.3 million ha (OBG, 2008).

Libya relies heavily on imports to satisfy food requirements (Aquastat, 2006). Agricultural imports have accounted for more than 25% of the total import bill (Casas, 1999). Domestically, however, Libya is 80% self-sufficient in vegetables, fruit, eggs and meat, and is able to meet about 25% of the demand for wheat, barley, olives, dates, citrus fruits, vegetables, and peanuts. As the growing population will require an increase in food consumption to meet domestic needs, the poor soil and climatic conditions in some areas will limit production. Because the population growth and food demand is soaring, keeping up with growing demand given the current food supply presents a huge challenge for the local agricultural sector (OBG, 2008).

3 Water infrastructure in Libya

According to the American Society of Civil Engineers (ASCE, 2009) infrastructure is the combination of physical and organisational activities that support the physical, economic, environmental and social human activities. It includes those systems such as energy production, transportation and communication, management of water resources, provision of commodities, and environmental protection that improve the living conditions of society, as well as the basic facilities, services, and installations which a country or organisation uses in order to work effectively. Any discussion of water infrastructure in Libya, therefore, entails an examination of water resources and their management, as well as the water legislation and institutional frameworks.

3.1 Water legislation

Libya's first water law to regulate the exploitation of water resources was issued in 1965 and later amended by Law No. 3 of 1982. The legislation has since been complemented by a number of laws, decrees and regulations and in theory addresses all water resource issues in Libya, such as water ownership, usage, responsibilities for control and management, licensing, water quality and penalties. In practice, however, much of the legislation remains formal and has not been applied, despite the availability of the necessary judicial bodies, because of difficulties, obstacles and mismanagement at the institutional and local level (LG, 1999). This study attributes the failure to fully apply the legislation to three major factors, social and cultural, planning and economic.

- Social and cultural considerations

  The continuing subdivision of farmland by inheritance or sale has encouraged the drilling of new wells, new constructions and the cultivation of high water consuming crops for a quick return. Self-interest, rather than public interest, has been given priority; a situation fostered by a general lack of awareness about of the seriousness of the water situation, and a failure to apply sanctions for water law violations.

- Planning considerations

  The absence of an integrated agricultural policy, in particular in relation to marketing, has led to fluctuating prices encouraging farmers to illegally consume more water for quick, guaranteed profits. At the same time, a lack of coordination between the General Water Authority (GWA) and other authorities, such as with the Ministry of Agriculture, Industry and Facilities, has led to inefficient planning and management of water resources. For example, agricultural land has been reclaimed and industries and new housing schemes set up in areas where the use of water resources is restricted. In addition, a proliferation of legal authorities, with a consequent overlapping of responsibilities and lowering of their capacities, has exacerbated the problem.

- Economic considerations

  There has been an expansion of irrigation at the expense of rain-fed land to gain a better return. There has been little incentive for farmers to change their behaviour and cropping patterns to contribute to water saving, when there is no compensation for any damages or losses incurred from their conforming to water conservation legislation. In addition, a failure to protect the market and control prices has led to a rise in the price of some high water consuming crops, such as watermelons, peanuts, tomatoes and oranges, to the extent that farmers are encouraged to plant them in contravention of the legislation.

Fees collection systems have been reviewed and new legislations have been issued[1] to impose Great Man-made River Project's (GMRP's) water use charges for all purposes. The General Water Supply and Sewage Company (GWSSC), for example, is at present reorganising the collection of water fees for household and non-household (except agricultural) use (CPPAP, 2003).

3.2 Water institutional framework

Five major institutions in Libya are responsible for the development, management and monitoring of water resources and policies: the GWA, the Authorities of Implementation and Management and Water Utilisation of the GMRP, the General Company of Water Desalination (GCWD), the GWSSC and the General Environment Authority.

- The GWA

  The GWA was established in accordance with Law 26 of 1972 and re-organised by government decisions: 249 of 1989, 757 of 1990, and 695 of 1991. The GWA conducts studies and research into water, and proposes general water policy. It is responsible for implementing national water resources policy, proposing the priorities of all water related projects, programming the use of water, and monitoring the quantitative and qualitative changes in water resources. It is also responsible for issuing well drilling licenses and approving the design and construction of dams (LG, 1999).

- The Authorities of Implementation and Management, and Water Utilisation of the GMRP

  a The Authority of Implementation and Management of the GMRP (AIMG) was established in accordance with Law No. 11 of 1983. The AIMG has responsibility for laying out plans and programmes, and conducting the contracts for the implementation of actions that achieve the objectives of a project. The authority manages and operates the main project and its accessories to transfer the water from their resources until it is delivered to investors (LG, 1999).

  b The Authorities for the Utilisation of the GMRP systems was originally established as one body in 1990 to invest the water of GMRP. In 1995 to 1996, it was divided into three authorities; the Authority for the Utilisation of Jabel Hasawna – Jefara Water System of the GMRP (AUJHJWSG), the Authority for the Utilisation of the First Phase of Benghazi Plain Region and the Authority for the Utilisation of the First Phase of the Middle Region. These authorities organise the exploitation and investment of the GMRP water, and are responsible for the establishment and management of agricultural projects directly or in partnership, as well as providing the machinery, equipment and supplies needed for the projects (LG, 1999).

- GCWD

  This GCWD is an offshoot of the Ministry of Electricity, Water and Gas (MEWG), set up by the Government Resolution 924 of 2007. The GCWD assumed the task of implementing plans and programmes related to water desalination from the MEWG. Since 28th October 2007, the company has been responsible for the management and operation, maintenance and renewal of desalination plants under the supervision of the MEWG. It also collects the sale fees of desalinated water from the GWSSC in favour of the MEWG, with a price of 0.860 LYD the cubic metre (GCWD, 2012a).

- GWSSC

  The GWSSC was established under Law 8 of 1997. Its role was to invest in water and preserve the large investments that are employed in water and sanitation facilities by rationalising consumption and increase the efficiency of operating. The company also aims to achieve set standards for local and international drinking water and sanitation. The GWSSC specialises in the management, operation and maintenance of all water facilities and sanitation, including wells and networks, pumping stations and treatment (LG, 1998, 1999).

  As the water supply in Libya is a public good, the Government Decision 367 of 1998 determined the formal water selling prices for the GWSSC, with the water prices for domestic consumers set at 0.250 LYD/m^3, and 1.300 LYD/m^3 for companies, plants and commercial markets. This decision provides for the adjustment of water prices in response to changes in conditions having a direct effect on the cost per cubic metre such as electricity and fuel costs and GMRP water prices (LG, 1998).

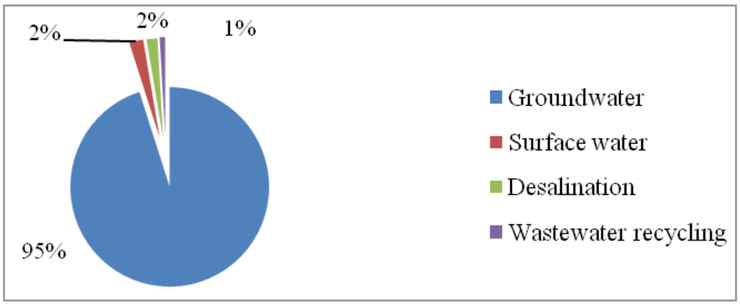
- General Environment Authority

  The General Environment Authority was established by Resolution 263 of 1999 with the aim of protecting the human environment including water, soil, air and food sources. The authority proposes environmental protection plans and programmes and supervises their implementation. It helps raise public awareness about the need to protect the environment from pollution and responsible disposal of waste materials through information campaigns. International cooperation is a priority, and the authority follows international conventions and treaties for the removal of pollution (LG, 1999; Wheida and Verhoeven, 2007).

3.3 Water resources in Libya

Water sources in Libya come from four sources: groundwater, providing almost 95% of the country's needs; surface water, including rainwater and dam constructions; desalinated sea water; and wastewater recycling (Wheida and Verhoeven, 2007).

Figure 1 Percentages of available water in Libya in1998 (see online version for colours)



Source: Adapted from Wheida and Verhoeven (2007)

3.3.1 Groundwater

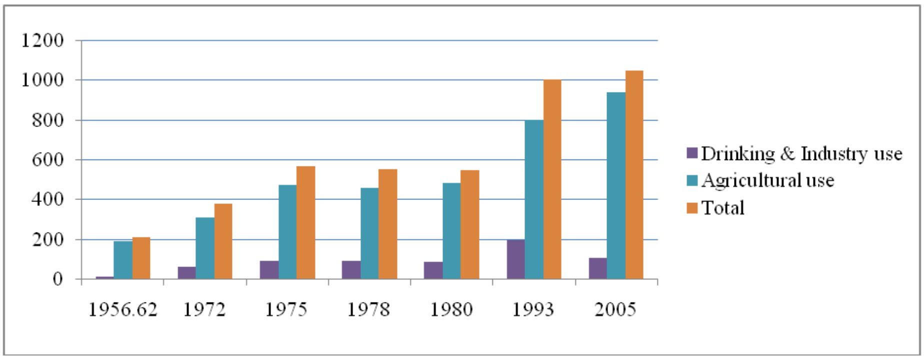
The major sources of groundwater in Libya come from five water basins: Jabal a l-Akhdar, Kufra/as-Sarir, the JPR, Nafusah/al-Hamada and Murzek. Groundwater in the country can be divided into renewable resources, mostly found in shallow aquifers, and the non-renewable resources (fossil water) encountered in deep aquifers. Groundwater reservoir characteristics are summarised in Table 2.

Table 2 Groundwater reservoirs characteristics

Basin	*Area,*	*Renewable*	*Non-renewable*	*Total dissolved*
characteristics	$(km)^2$	10^6 m^3	10^6 m^3	Solids, mg/l
Jabal al-Akhdar	145,000	200	50	1,000–5,000
Kufra/as-Sarir	700,000	–	1,800	200–1,500
JefaraPlain Region	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

Source: Adapted from Wheida and Verhoeven (2007)

Figure 2 Average underground water drawings in JPR (see online version for colours)



Note: Amount of water by million m^3/year

Source: Adapted from GAFI (2008), GWA (2006)

The amount of water drawing has increased sharply over time, and will undoubtedly increase in the future in response to continuous population growth and corresponding increases in water requirements for the domestic, industrial and agricultural sectors. Figure 2 summarises the increase in the past five decades in the JPR, the research area of interest and one of the most important territories in the country, population wise.

3.3.2 Surface water

In northern Libya, the annual rainfall varies between 200–300 mm (GWA 2006), with totals gradually decreasing towards the southern regions and almost no rain falling in Kufra, Murzek and Sarir (LG, 1999). The surface water resources existing in the northern regions of the country have been mobilised to a certain extent by the construction of a few dams (Wheida and Verhoeven, 2007). The total amount of surface water annually available is 60×10^6 m^3; however, the dams have been designed for storage capacity of 389×10^6 m^3 because of a continuing decline in rainfall levels, leakage and the need for maintenance. Table 3 shows the potential storage capacity and the existing storage of the dams.

Table 3 Dam capacity and storage in Libya

Region	*Dam name*	*Location*	*Designed capacity*	*Existing storage,*
			10^6m^3/year	*10^6m^3/year*
Jabal al-Akhdar:	Wadi Qattara	Benghazi	135.00	12.00
	Wadi Qattara-2	Benghazi	1.50	0.50
	Mrks	Ras-hlal	0.15	0.15
	Zara	Aloqurea	2.00	0.80
	Derna	Derna	1.15	1.00
	Abomansour	Derna	22.30	2.00
Kufra/as-Sarir	Garif	Sirt	2.40	0.30
	Zhawia	Sirt	2.80	0.70
	Ziud	Sirt	2.60	0.50
	Benjuid	Benjuid	0.34	0.30
	Wadi Zgar	Jufrah	3.65	0.20
Jefara Plain	Wadi Mejnean	Ben-Gashir	58.00	10.00
	Wadi Ghan	North Gharyan	30.00	11.00
	Wadi Zart	Rabta	8.60	4.50
Nafusah/al-Hamada	Wadi Ekaamm	Zliten	111.00	13.00
	Wadi libda	Homes	5.20	3.40
	Wadi Tibreat	Zliten	1.60	0.50
	Wadi Edkaar	Zliten	1.60	0.50
Total storage capacity (million m^3)			*389.89*	*61.35*

Source: Adapted from GAFI (2008) and GWA (n/d)

The flow of natural springs in Libya is variable and dependant on rainfall. Thirty-nine springs have a productivity of more than 5 litres/second, with a total of about 2,612 litres/second (LG, 1999).

3.3.3 Desalination

The population of Libya is unevenly distributed and concentrated in the fertile land and zones of industrial activities along the Mediterranean coastline, resulting in considerable water supply deficits in these areas. In the 1960s, Libya turned to desalination as an additional source of water (Wheida and Verhoeven, 2007), becoming one of the largest users of both thermal and membrane desalination technologies in the Mediterranean region (Abufayed and El-Ghuel, 2001). Table 4 shows the technical details for the larger water desalination plants in Libya in 1999.

Table 4 1999 technical details of water desalination plants in Libya with a capacity of more than 4,000 m^3/day

Location	*Design capacity* m^3*/day*	*Existing capacity* m^3/day	*Operation year*	*Remarks upon existing capacity*
Benghazi	19,200	-	1969	Out of order
Zuara	13,500 + 4,500	-	1974–1979	Out of order
Derna	9,000	4,000	1975	-
Al-Brega	7,200	-	1975	No data available
Benghazi	48,000	10,000	1976+1978	-
Sirt	9,000	-	1976	Out of order
Zilitn	13,500 + 4,500	-	1975–1978	Out of order
Tripoli-West	23,000	4,600	1976	-
Tobruk	24,000	8,000	1977	-
Sousa	13,500	2,500	1977	-
Zuitina	5,500	-	1977	Out of order
Benjwad	6,000	-	1978	Out of order
Tobruk	6,000	-	1979	Out of order
Homes	40,000	25,000	1980	-
Ras-lnof	24,000	-	1983	No data available
Sirt	9,000	-	1982	Out of order
Al-Brega	4,800	-	1982	No data available
Benwlid	7,000	-	1982–1983	No data available
Zuitina	30,000	-	1983	Out of order
Tajoura	10,000	One unit	1984	No data available
Ras-lanof	8,400	-	1984	No data available
Misrata	30,000	30,000	1987	-
Bomba Gulf	30,000	18,000	1988	-
Misrata	10,000	–	1984	Out of order

Source: Adapted from LG (1999)

Table 4 1999 technical details of water desalination plants in Libya with a capacity of more than 4,000 m^3/day (continued)

Location	*Design capacity m^3/day*	*Existing capacity* m^3/day	*Operation year*	*Remarks upon existing capacity*
Sirt	10,000	9,000	1986	-
Zilitn	30,000	20,000	1992	-
Zuara	30,000	-	-	Not implemented
Tobruk	40,000	-	-	Under construction
Sousa	10,000	-	-	Under construction
Tripoli-West	10,000	-	-	Under construction
Total of capacities	*539,600 m^3/day*	*131,100 m^3/day*		

Source: Adapted from LG (1999)

Table 5 The quantities of desalinated water produced in 2009 in Libya

The area	*The plant*	*The produced quantities*
Jefara Plain Region	Homes	3,794,396
	Zuara	4,822,703
Total of Jefara Plain Region	8,617,099	
Rest of the	Tobruk	13,008,873
	Bomba Gulf	4,173,885
	Sousa	3,590,242
Libyan coast	Abo-Traba	12,759,569
	Zuitina	39,510
	Zilitn	8,526,124
	Derna	717,373
Total of the rest of the Libyan coast		*42,815,576*
Overall total		*51,432,675*

Source: Adapted from GCWD (2012b)

Despite these installations having an annual production of around 47,851,500 m^3 of desalinated water, the supply has been relatively insignificant in proportion to the total demand, covering only part of the municipal and industrial water requirements of communities in areas experiencing water shortages (Wheida and Verhoeven, 2007). Other problems in supply and production have stemmed from only a small part, 24%, of the total design capacity being available, with many installations either out of order or working at reduced levels due to a lack of regular maintenance, difficulties in providing spare parts, obsolescence and the need for further development (Aquastat, 2006).

According to GCWD statistics, the total production of desalinated water in 2009 was 51,432,675 m^3 or about 140,911 m^3/day. Comparing these figures with total capacities for 1999 (Table 4), it is clear that the sector has seen no noticeable improvement or development over the past decade (1999–2009). Table 5 shows desalinated water production details for 2009.

In the period 2009/2010, the GCWD targeted the completion, implementing and operation of some plants, as well as researching and planning the construction and expansion of number of other plants. More details are shown in Table 6.

The data shows that the total amount of desalinated water from plants under construction and under study in the JPR were projected to reach 1,120,000 m^3/day.

Table 6 Targeted water desalination projects in 2009/2010 in Libya

Target	*The plant*	*The capacity (m^3/day)*
Completion and operation	Derna	40,000
of plants during 2009	Sousa	40,000
	First unit of Zawua in JPR	Part of 80,000
Completion and operation	Rest units of Zawua in JPR	Rest of 80,000
of plants during 2010	Zuara in JPR	40,000
Total		*200,000*
Plants under development	Homes in JPR	50,000
	Tripoli-Eest in JPR	500,000
	Jefare in JPR	300,000
	Zawua in JPR	100,000
	Zuara in JPR	50,000
	Tobruk	150,000
	Bomba Gulf	50,000
	Derna	100,000
	Sousa	100,000
	Abo-Traba	50,000
	Sirt	100,000
	Benghazi	300,000
	Misrata	100,000
	Zilitn	50,000
Total		*2,000,000*
Overall total production		*2,200,000 m^3/day*

Source: Adapted from GCWD (2012c)

3.3.4 Wastewater recycling

The rapid increase in population has necessitated a large increase in construction, imposing the establishment of apposite infrastructures, large water and sewage networks, and water treatment plants. Wastewater treatment has been implemented at varying levels of interest in Libya from the 1970s to the early 1990s for the purposes of agriculture and environmental protection (LG, 1999). The existence of larger plants in major cities surrounded by agricultural areas (summarised in Table 7) makes the cost of treated water conveyance minimal (Wheida and Verhoeven, 2007).

Table 7 Technical details of wastewater treatment plants in Libya

Treatment plants	*Installation year*	*Design capacity m3/day*	*Existing capacity m^3/day*	*Remarks*
Ejdabya	1988	15,600	5,000	–
Benghazi A	1965	27,300	-	Out of order
Benghazi B	1977	54,000	-	Provisional test
Al-merg A	1964	1,800	-	Out of order
Al-merg B	1972	1,800	-	Out of order
Al-beada	1973	–9,000	-	Under construction
Tobruk A	1963	1,350	-	Out of order
Tobruk B	1982	33,000	-	Out of order
Derna	1965	4,550	-	Out of order
Derna	1982	–8,300	-	Under construction
Sirt	1995	–26,400	-	Under construction
Abo-hadi	1981	1,000	600	–
Al-brega	1988	3,500	2,700	–
Zwara	1980	41,550	-	Not used
Sebrata	1976	6,000	-	Out of order
Sorman	1991	–20,800	-	Under construction
Zawia	1976	–6,800	-	Under construction
Zenzour	1977	6,000	-	Not used
Tripoli A	1966	27,000	-	Out of order
Tripoli B	1977	110,000	20,000	–
Tripoli C	1981	110,000	-	
Tajoura	1984	1,500	500	–
Tarhouna	1985	3,200	1,260	–
Gheraan	1975	3,000	-	
Yefren	1980	1,725	173	–
Meslata	1980	3,400	-	Not used
Homes	1990	8,000	-	Not used
Ziliten	1976	6,000	-	Out of order
Misrata A	1967	1,350	-	Out of order
Misrata B	1982	24,000	12,000	–
East Garyat	1978	500	-	Out of order
West Garyat	1978	150	-	Out of order
Topga	1978	300	-	Out of order
Shourif	1978	500	-	Out of order
Sebha A	1964	1,360	-	Out of order
Sebha B	1980	47,000	24,000	–
Total of capacities		*546,435*	*66,233*	

Source: Adapted from Wheida and Verhoeven (2007)

The proportion of the existing capacity to the designed capacity in treatment plants (except for those under construction) is just 12%. Wastewater treatment has faced recent technical challenges from the substandard condition of most water pumping stations, plants coming to the end of their operational life and the need for spare parts and maintenance (Aquastat, 2006). At the same time, the stations require a highly skilled workforce to enable them to function efficiently (LG, 1999). Another factor has been the reluctance of farmers and consumers to use treated wastewater, having a negative effect on its use as a significant and reliable water source (Wheida and Verhoeven, 2007).

It is worth mentioning that in 1998 just 6,000 hectares of the areas of agricultural projects were irrigated by treated wastewater in Tripoli and Benghazi (Table 8). The development plan for the water sector in 2007 to 2010[2] does not include any mention to wastewater recycling.

The production from all water development projects in dams, wastewater recycling and water desalination does not cover the deficit of water in Libya (Mustafa, 2001).

Table 8 Agricultural projects irrigated by treated wastewater in 1998

Project location	*Stage*	*Discharge capacity, m3/day*	*Irrigated area, hectare*
Tripoli	1st stage	27,000	2500
	2nd stage	110,000	1500
Benghazi	1st stage	27,000	360
	2nd stage	27,000	658
	3rd stage	27,000	1000

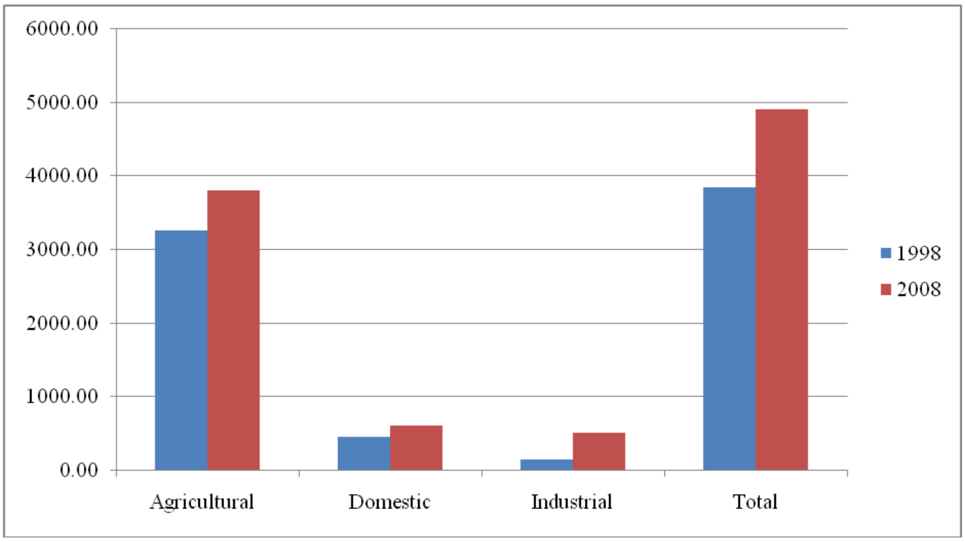
Source: Adapted from Wheida and Verhoeven (2007)

4 The water situation in Libya

The severity of the water scarcity situation in Libya necessitates cooperation between all the specialised authorities in the formulation of water policy and the determination of the quantities of allowed drawings from ground reservoirs so as to exploit them economically and reduce their poor use in agriculture, where water overuse in irrigation has led to the deterioration of the agricultural production rates, high salinity levels in the soil, and the deterioration of irrigation facilities, all causing degradation of the environment (Bouzid, 1996). The total water withdrawal for agricultural, domestic and industrial purposes is estimated at 3,843 mm^3 in 1998 (Wheida and Verhoeven, 2007), increasing to 4,903 mm^3 in 2008 (GAFI, 2008).

The excessive use of water in 1998 resulted in the withdrawal of 1,154 million cubic metres more than the estimated available water (Wheida and Verhoeven, 2007). It is clear from Figure 3 that agriculture has the highest water consumption of all sectors, about 80%. In 1998, the total irrigated area covered 309,258 hectares, with the irrigation water needs amounting to 3,259.27 mm^3 (Wheida and Verhoeven, 2006). In 2007, sources of irrigation, numbers and areas of agricultural fields ware distributed as in the Table 9.

Figure 3 Water use in 1998 and 2008 (see online version for colours)



Note: Amount of water by million m^3/year.

Source: 1998 adapted from Wheida and Verhoeven (2007) – 2008 adapted from General Authority For Information (GAFI, 2008)

Table 9 Number and area of agricultural fields in 2007

Source of irrigation	*No.*	*Area*
Irrigated by rain	123,560	509,662
Irrigated by well	135,215	281,221
Irrigated by dam	464	1,135
Irrigated by a spring of water	1,191	2,145
Irrigated by well of the state	4,054	44,730
Irrigated by other sources	3,835	13,226
Not mentioned	15,213	49,463
Total	283,532	901,582

Note: Area in hectares

Source: GAFI (2008)

It can be seen that the irrigated area increased from 309,258 to 901,582 hectares between 1998 and 2007. The required quantities increased from 3,259.27 mm^3 to estimated quantities[3] of 5,129 and 5,794 mm^3 in 2005 and 2010, respectively (CPPAP, 2003).

Urban consumption includes water consumed by house holders, gardening, hospitals, schools, universities, public offices, hotels, cafes, and commercial markets (Wheida and Verhoeven, 2006). Increases in urban water use are inevitably linked to population growth, as in Libya. Domestic water use in Libya is about 12%, and is the second ranking sector for consumption (GAFI, 2008). Urban water comes from three sources: GMRP; local groundwater in each region; and desalination. The reliance on local groundwater has decreased significantly in the period 1999 to 2008. Table 10 highlights the crisis of local groundwater in Libya and the increased reliance on the GMRP, and to a lesser extent, desalination.

Table 10 Water sources for urban purposes in 2008 compared to 1999

Source	*1999*	*2008*
GMRP	42%	53%
Local groundwater	54%	36%
Desalination	4%	11%

Source: 1999 adapted from Wheida and Verhoeven (2006) – 2008 adapted from General Authority For Information (GAFI, 2008)

Table 11 The water situation in Libya 2005–2025

Year \ *Item*		*2005*	*2010*	*2015*	*2020*	*2025*
Population "in millions"		6.7	7.8	9	10.3	11.7
The Available Water (Supply)	Surface water	170	170	170	170	170
	Renewable groundwater	650	650	650	650	650
	Total	820	820	820	820	820
	Cubic meter per capita	122	105	91	80	70
	Non-renewable groundwater	3000	3000	3000	3000	3000
Total of the available water (Supply)		3820	3820	3820	3820	3820
Irrigated areas "1000 hectare"*		450	500	550	600	650
Consumed Water (Demand)	Agricultural	4342	4825	5307	5790	6272
	Domestic	573	708	870	1060	1280
	Industrial	214	261	318	386	470
Total of the consumed water (Demand)		5129	5794	6495	7236	8022
Water deficit		-1309	-1974	-2675	-3416	-4202

Notes: Water in million cubic metres per year.

Source: Adapted from CPPAP (2003)
*According to GAFI 2008, Statistics Book, Tripoli., the actual irrigated area in 2007 was amounted 901,582 hectares

Industrial water consumption encompasses its use in air conditioning and refrigeration, manufacturing and the infrastructure and operations of factories, with a total use of 135.64 mm^3. A major use of industrial water is in the oil industry, (injection, processing and some domestic use) (Zidan, 2007), about 76% of the total (Wheida and Verhoeven, 2006).

CPPAP (2003) predicts that the population in Libya will reach 11.7 million by the year 2025. The total estimated quantity of available water for investment (excluding desalinated water and wastewater) is estimated at 3,820 mm^3, comprising 170 mm^3 surface water, 650 mm^3 renewable groundwater and 3,000 mm^3 non-renewable groundwater (including GMRP water). The rates of renewable water and surface water per capita in Libya are the lowest in the NENAR region. In the context of the estimated water availability and the forecast population growth in Libya, the per capita renewable water and surface water rates show a steady decline from 170 m^3 in 1995 to a projection of 70 m^3 in 2025.

Population growth in Libya has been accompanied by a growth of irrigated agricultural areas, making an increase in the volume of water used in agriculture inevitable, as well as increasing domestic and industrial water consumption. Using data from a 2003 (CPPAP) report, Table 11 summarises the projected water situation in Libya 2005 to 2025, highlighting the size of the problem and its evolution over time.

The water deficits shown in Table 11 represent the difference between water demand and supply at the level of the entire country. It does not reflect the situation within each region.

According to the MEWG (2007) Report on the water sector development scheme, the overall total of investments in the water sector for the period 2005 to 2010 amounted to 5,027,200,000 LYD. Table 12 summarises the scheme in detail.

Table 12 Total investments in the development plan for water sector 2007–2010

Project	*Cost in LYD*
Water desalination stations:	
Under construction	574,500,000
Under contracting	1,469,000,000
Total	*2,043,500,000*
Water transport:	
Under construction	307,100,000
Under contracting	1,176,600,000
Total	*1,483,700,000*
Water distribution (virtual)	1,500,000,000
The overall total of investments in water sector:	*5,027,200,000*
Total of investments in US$ approx	*3,921,216,000*

Note: Costs in Libyan dinar

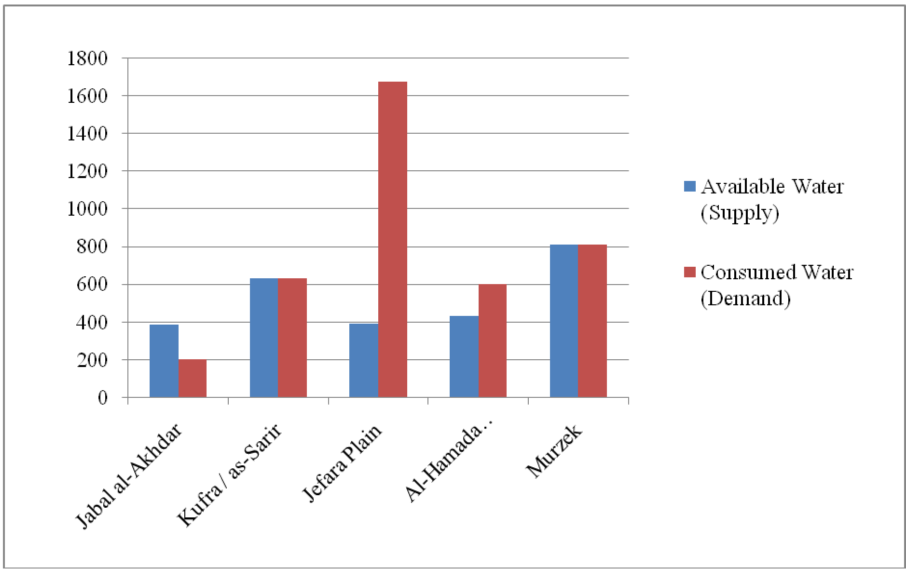
Source: MEWG (2007)

5 Inefficient water use in the JPR and suggested plans

The problem of water scarcity varies from one area to another in Libya. As such the attention given to resolving water scarcity also varies. According to the study of the water situation by LG (1999), the actual water deficit in 1998 in the JPR alone was 1,281 mm^3/year. The highest agricultural water use was found in this region as well, amounting to 1,402.86 mm^3 (Wheida and Verhoeven, 2006), and exceeding the security drawing borders by 561%. Figure 4 shows the size of the water deficit in the Jefara basin compared to other basins in Libya.

There has been wastage and inefficiency in using water resources of nearly 60% in agricultural crop irrigation in the JPR (Almontaser, 2009). According to Almontaser (2009), a different crop composition in the JPR could economise the volume of water use by 60% with an accompanying increase in farmer's income. Already in 1994, the Libyan National Consulting Bureau and Mott MacDonald of the UK (NCBMM)[4] acknowledged significant losses taking place in groundwater stock in the JPR as a result of the over-exploitation of water, with the volume of withdrawals exceeding the recharge by four to six times. For example, withdrawals for 1993 were estimated at 1,002 mm^3 (NCBMM, 1994), and 1,300 mm^3 for 2000 (WTNWR, 2003), with the recharge rate estimated at about only 200 mm^3/year, and coming from rain, the flooding of valleys and flowing quantities derived from irrigation systems and water supply systems. Average water use for typical needs, according to the water efficiency standards, should be 6,293 m^3/hectare/year in the JPR. However, the actual average use in 2007 amounted to 9,880 m^3/hectare, and water losses due to inefficient use was 3,587 m^3/hectare (Almontaser, 2009). Over-exploitation of water has led to groundwater pollution and the deterioration of their quality along the Libyan coast as a result of seawater overlapping (LG, 1999). In addition, agricultural and industrial pollution have exacerbated the problem, with chemicals from factories, sewage from treatment plants and the run-off from agricultural fertiliser and pesticides contaminating groundwater sources (Abdulaziz, 1999). A 1994 (NCBMM, 1994) study concluded that if the water withdrawals were to be halted, the JPR would require 200 years for the quality of water in the groundwater reservoir to recover and reach levels prior to the deficit caused by the negative imbalance between withdrawal and recharge. The severity of the water crisis can only be reduced with a commitment to the recommended security level of withdrawals from groundwater stock. Groundwater should be used efficiently to prolong its life span, and in this context, its use should be limited (CPPAP, 2003). Water quality and its levels will not stabilise in the ground reservoirs until withdrawals are reduced to reasonable limits. This is considered critical to achieve irrigation sustainability in the JPR in the long-term, taking into account population and economic growth.

Figure 4 1998 water deficits in Libyan basins (see online version for colours)



Source: Adapted from LG (1999)

6 The national strategy for the management of water resources in Libya

According to the General Planning Council in the CPPAP (2003) Report, the continuation of development and its sustainability require following a development strategy that can be implemented, and by laying down a balanced, integrated plan to develop the country's resource productivity (CPPAP, 2003; LG, 1999). The national strategy for the management of water resources in Libya, for the period 2000 to 2025, aims to lay the foundations for sustainable development that can ensure plugging the water deficit (quantitative and the qualitative) for current generations and secure the rights of future generations in water resources. The most important aspects of this strategy are:

1. Developing human and institutional capacity in the preparation and implementation of the national strategy for the management of water resources.
2. Reducing water deficits through good management of the water demand, reviewing agricultural policy as the agriculture is the biggest consumer of water, and restricting the amount of water used in urban and industrial purposes.
3. The setting up of advisory bodies, education and information awareness programmes, as well as introducing a water pricing system, to sensitise people to the value of water for life.
4. The development of both conventional water resources and non-conventional, such as dams and springs, and the provision of funding sources for desalination and wastewater recycling plants, and other water conservation projects.
5. The protection of the environment and protection of water resources from pollution by: the rationalisation of the use of chemical for agricultural purposes; cleaner and more efficient industrial techniques in relation to the environment and water resources; the imposition of fees on polluters; and giving support to the regulators and the judiciaries responsible for the protection of the environment.
6. Directing water policies to recover the costs of providing water and to secure the necessary finance to develop water resources.
7. The modernisation and development of valid water legislations in Libya and the activation of its role.
8. The development of technical cooperation with Arab organisations, regionally and globally, in the fields of water resource management.

The technical committees examining the water situation in Libya faces some complex challenges requiring careful handling and determination to manage the crisis. Prevailing concepts and practices are not conducive to water conservation. Significant challenges include a lack of expertise, transition possibilities and monitoring, analysis and water treatment techniques. The situation is made more difficult by the extremely limited availability of accurate, reliable and full information and data concerning water resources.

7 The GMRP

The GMRP was established under Law No. 11 of 1983, and is considered one of the largest projects, in the world for transferring and distributing water (GMRP, 2011). The project involves the transfer of groundwater from southern Libya to the fertile northern regions where the population is concentrated. Groundwater existing in deep aquifers under the desert sands in the south of the country with a volume of $3,850 \times 10^6$ m^3 is fossil water, is therefore a non-renewable resource. The GMRP project was established for the purpose of providing water for urban uses, industrial facilities and converting of thousands of hectares of arid land into productive agricultural areas (Mustafa, 2001). It is designed to transfer more than 6 mm^3/day of water through the GMRP systems after all stages are completed (GMRP, 2011; Zidan, 2007).

Investment opportunities are available in the agricultural sector, where up to 20,000 hectares of large farms irrigated by the GMRP are being offered for foreign investment within the framework of state policy and economic and social development objectives (GMMRA, 2010). Abdulaziz and Ekhmaj (2007) have identified the main objectives of the GMRP as follows:

1. Political goals to achieve food security through investment in the water for agricultural purposes to achieve self-sufficiency in key and strategic commodities.
2. Economic goals to increase the contribution of agriculture in GDP and improve the trade balance by reducing agricultural imports and increasing the exports.
3. Social goals to provide employment opportunities and improved health services, as well as the achievement and maintenance of stable populations in areas affected by water shortages.
4. Environmental goals to address the problems of overlapping seawater, desertification and deterioration of the vegetarian overlay.

GMRP construction began in 1984. Costing an estimated $US25 billion, it is expected to take 25 more years to complete (GMMRA 2010). However, substantial delays have occurred in construction due to problems in financing and management, as well as the circumstances surrounding the Libyan revolution and the resultant radical changes in the political system. The project has an expected life span of 50 years of irrigation to coastal areas (EON, 2010). Consisting of more than 1,300 wells, more than 500 m deep (Zidan, 2007), the GMRP was designed in five phases, each largely independent, that will eventually combine to form an integrated system. Five major systems are available for the transfer of water (GMRP, 2011):

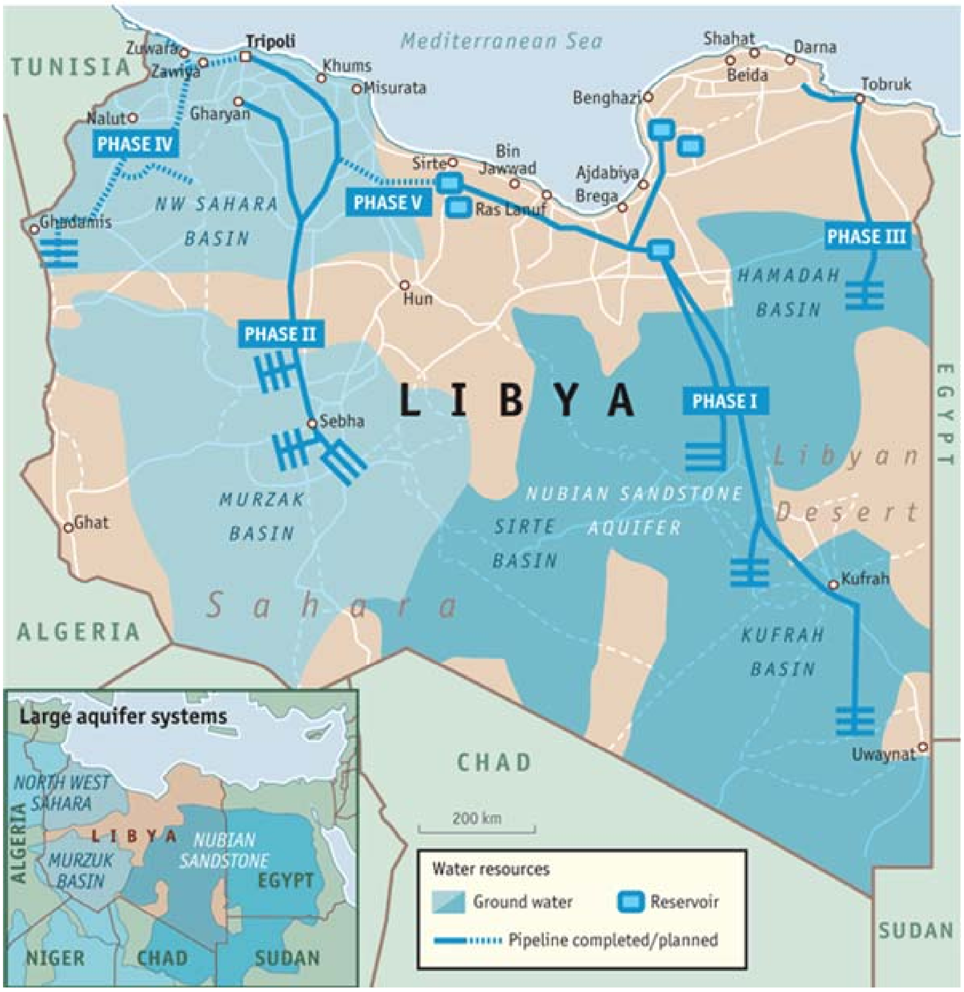
- Sarir – Sirt/Tazerbo – Benghazi System.
- Jabel Hasawna – Jefara WaterSystem.
- Ghadames – Zwara – Zawia System.
- Kufra – Tazerbo System.
- Ajdabya – Tobruk System.

Although the current production capacity of the GMRP is about 4 mm^3/day, it produces only 1.6 mm^3/day due to lack of readiness of subsystems and some agricultural projects.

The average operational cost per cubic metre of GMRP water is estimated at 0.089 LYD/m^3. With the capital cost estimated at 0.146 LYD/m^3, the total cost per cubic metre is 0.235 LYD (GMRP, 2011). According to GMRP (2011), in comparison to other water supply resources, the GMRP currently remains the best economic alternative.

Water pricing for the first phase of GMRP was set by the government in Resolution No. 218 on the 26/04/1994. The selling prices were subsidised for agriculture and urban use while for industrial use was value-added more than twice as follows: 0.048 LYD/m^3 for agricultural use; 0.080 LYD/m^3 for urban use; and 0.796 LYD/m^3 for industrial use. These prices were also adopted for the JHJWSG (Aljuhawy, 1997; LG, 1999).

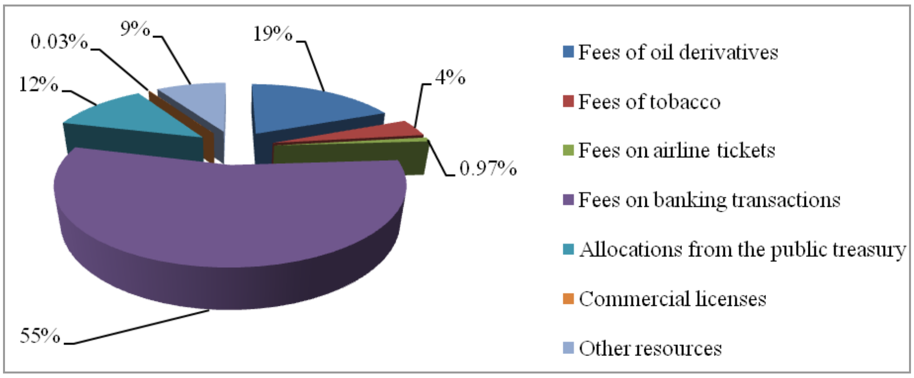
Figure 5 Configuration of the GMRP on a map of Libya (see online version for colours)



Source: http://www.gmmra.org

Due to the importance of the GMRP and the magnitude of its capital investment, the government issued multiple laws to finance it (GMRP, 2011). The legislation determined the resources to fund the GMRP such as fees on documentary credits and bank transfers, fees on tobacco products, and fees on the derivatives of oil and gas. Funds collected from the beginning of the project until 31/12/2010 amount to 11,554,251,000 LYD and are distributed as shown in Figure 6 and Table 13.

Figure 6 Funds received from the beginning of the GMRP to 31/12/2010 (see online version for colours)



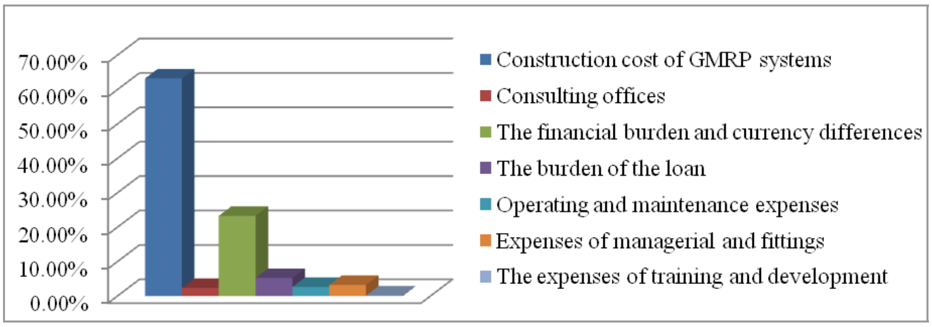
Source: Adapted from GMRP (2011)

Table 13 Funds received from the beginning of the GMRP to 31.12.2010

Item	*Amount*	*Ratio %*
Fees of oil derivatives	2,164,812,000	19.00%
Fees of tobacco	515,226,000	4.00%
Fees on airline tickets	99,129,000	0.97%
Fees on banking transactions	6,299,087,000	55.00%
Allocations from the public treasury	1,379,037,000	12.00%
Commercial licenses	3,987,000	0.03%
Other resources	1,092,973,000	9.00%
Total	11,554,251,000	100%

Source: Adapted from GMRP (2011)

Figure 7 GMRP expenditure from the beginning of the project until 31/12/2010 (see online version for colours)



Source: Adapted from GMRP (2011)

The cost of all phases of the GMRP from the beginning until 31/12/2010 amount to 10,914,811,000 LYD and are distributed as shown in Figure 7 and Table 14.

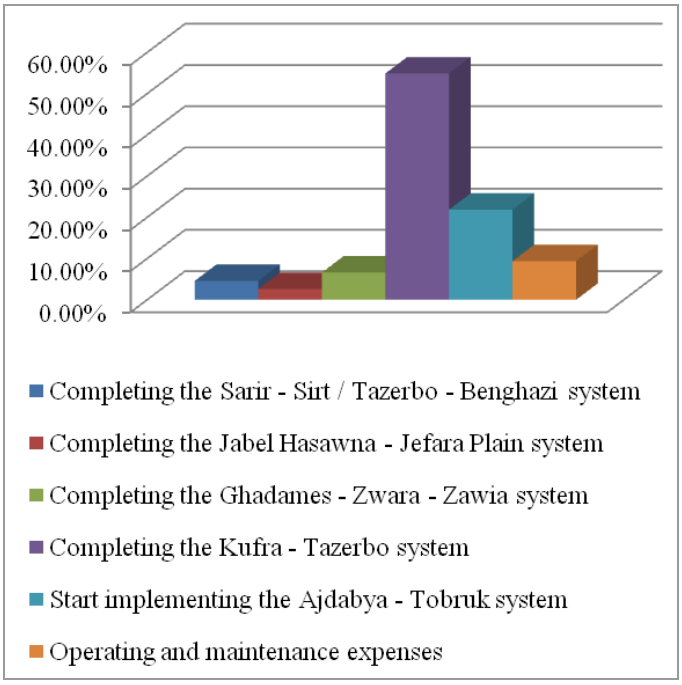
Table 14 GMRP expenditure from the beginning of the project until 31.12.2010

Item	*Amount*	*Ratio %*
Construction cost of GMRP systems	6,901,854,719	63.20%
Consulting offices	254,023,389	2.30%
The financial burden and currency differences	2,541,484,708	23.00%
The burden of the loan	570,988,739	5.10%
Operating and maintenance expenses	284,924,377	3.00%
Expenses of managerial and fittings	348,217,558	3.00%
The expenses of training and development	13,317,510	0.10%
Total	*10,914,811,000*	*100%*

Source: Adapted from GMRP (2011)

The funds required to complete the project are estimated at 5,110,259,000 LYD for the period 2012 to 2017, distributed as shown in Figure 8 and Table 15.

Figure 8 The funds required to complete the GMRP during the period 2012 – 2017 (see online version for colours)



Source: Adapted from GMRP (2011)

According to Alghariani (2003), the increasing cost of pumping water from greater distances and greater depths, combined with the falling costs of desalination, has recently reduced the cost-effectiveness of the GMRP as compared to desalination. Alghariani's

(2003) research indicates that the average cost of GMRP water cubic metre could escalate to more than 1.112 LYD (0.83 US dollars) per cubic metre, and that as the exploited aquifers are non-renewable, when sustainability is taken into account by considering 'the depletion cost', with costs conceivably reaching 3.153 LYD (2.35 US dollars)/m^3. While the cost of water cubic metre of GMRP was competitive with the cost of seawater desalination 20 years ago, in 1999 the situation shifted in favour of seawater desalination where costs have dropped to less than 0.738 LYD (0.55 US dollars)/m^3 (Alghariani, 2003).

Table 15 Funds required completing the GMRP during the period 2012–2017

Item	*Amount*	*Ratio*
Completing the Sarir – Sirt/Tazerbo – Benghazi System	235,037,000	4.60%
Completing the Jabel Hasawna – Jefara Water System	134,044,000	2.62%
Completing the Ghadames – Zwara – Zawia System	338,069,000	6.62%
Completing the Kufra – Tazerbo System	2,806,428,000	54.92%
Start implementing the Ajdabya – Tobruk System	1,117,581,000	21.87%
Operating and maintenance expenses	479,100,000	9.38%
Total	*5,110,259,000*	*100%*

Source: Adapted from GMRP (2011)

Responding to these claims, the authority of implementation and management of GMRP points out that the average cost of a cubic metre of GMRP water is only 0.329 LYD (0.245 dollars), and argues that depletion costs should not be taken into account as GMRP water comes from uninhabited areas, and that, according to hydrological surveys, the water reserves are massive. Further, the price of a cubic metre of GMRP water includes production and transfer costs. In contrast, the price of desalinated water is for production only, and does not include water transfer and distribution costs. Consideration of these factors could conceivably double the cost per unit of desalinated water. At the same time, the authority recognises the key role of social and political factors in relation to the continuing construction and completion of the remaining phases of the GMRP. In this context, the Libyan government itself is aware that the GMRP is not a panacea for the country's water supply, and in 2003 began a programme to build 11 new desalination plants (European Commission, 2009). The water sector authority has included 228 wells, costing 69 million Libyan dinar (53.82 million US$) in the water sector development plans for 2007 to 2010 (MEWG, 2007).

With GMRP water beginning to flow, the vastness of the country led the government to establish three major authorities for GMRP water investment (LG, 1999):

- The Authority for the Utilisation of Jabel Hasawna – Jefara WaterSystem established by Resolution No. 230 of 1995.
- The Authority for the Utilisation of the First Phase of Benghazi Plain Region established by Resolution No. 246 of 1996.
- The Authority for the Utilisation of the First Phase of theMiddle Region established by Resolution No. 247 of 1996.

The general goals of these authorities are to optimise water yield through producing a maximum of major agricultural products, so as to achieve food security, encourage investment in the agricultural field and contribute to the creation of job opportunities in the agricultural sector (AUJHJWSG, 2005; GMRP, 2011), in addition to achieving environmental protection goals. The existent infrastructure of areas along the coastline affected by water shortages should be integrated and rehabilitated, enabling the delivery of the water supply required to maintain agricultural soils and enhance agricultural production, thus contributing positively to economic activity (AIMG, 2008).

7.1 Jabel Hasawna – Jefara Water System of GMRP (JHJWSG)

The JPR is located in the north-western part of Libya, covering a triangular area of approximately 20,000 km^2. It is a bounded in the north by the Mediterranean Sea, the Tunisian border on the west; and on the south by a line running from the foot of Nefusa Mount on the Tunisian border to Homes, a coastal city on Mediterranean to the north-east of the capital Tripoli (GWA, 2006). The population of the region was estimated at 2.66 million in 2000 (CPPAP, 2003).

The JHJWSG targets to transfer 2 mm^3/day of water (with a maximum capacity of 2.5) from the fields of wells in the Jebel Hasawna region to the west coast, the JPR and Nefoussa Mount (Aljuhawy, 1997),with 67.3% of this amount allocated for agricultural purposes (AUJHJWSG, n/d.). The system began partial operations in August 1996 with a capacity of 250,000 m^3/day, with a current available production capacity of 2 mm^3/day. The system currently produces about 750,000 m^3/day, with the water transferred up to December 2010 amounting to 2,471,429,601 m^3. JHJWSG began full operations in 2006 when the available productivity reached 2 mm^3/day (GMRP, 2011). The components of JHJWSG as follows:

- Wells fields with 484 wells.
- Four water pumping stations.
- A water collection pipeline system from the well fields with a total length of 753 km, and pipe diameters ranging from 0.30 metres to 4 metres.
- Main pipeline along the 983 km with diameters 3.6 and 4 m.
- Six break pressure tanks.
- Two stations to control the flow.
- A fibre optic cable communications system linking the well fields with the public telecommunications system, enabling the transfer of control signals for all JHJWSG facilities.
- A system of monitoring and controlling the balance between supply and demand, which includes a main control room in the Bin-Ghashir region in addition to four sub-control rooms linked to the pumping stations mentioned above.
- Eleven electricity stations for the transmission and distribution of electric power.
- Three support centres for operations and maintenance in the Bin-Ghashir, Alchuirv and Hasawna regions.

The estimated capital costs to set up all the components of Jabel Hasawna – Jefara Water System amounts to 3,273,169,000 LYD. The system is designed for a maximum production capacity of 2.5 mm^3/day (Aljuhawy, 1997). The estimated cost of annual operation and maintenance of the system, assuming maximum production capacity, would amount to 77,506,000 LYD. Assuming a targeted capacity of 2 mm^3/day, however, the annual expenditure would amount to 64,245,000 LYD (Aljuhawy, 1997). Table 16 shows details of the estimated costs of a water cubic metre, for both targeted and maximum capacity.

Table 16 The estimates costs of the water cubic meter of the JHJWSG

Item	*The annual cost on the basis of production and transport 2 mm^3*	*The annual cost on the basis of production and transport 2.5 mm^3*
The estimated capital costs	3,273,169,000	3,273,169,000
The estimated operating and maintenance costs for 50 years	3,212,250,000	3,875,300,000
The estimated costs for replacement of the system equipment after 25 years	416,075,000	416,075,000
The estimated total cost for 50 years	6,901,494,000	7,564,544,000
The water amount supposed to transfer for a period of 50 years ‘assuming 350 days/year’	35,000,000,000	43,750,000,000
The estimated cost per cubic meter	0.200LYD	0.170 LYD

Source: Adapted from Aljuhawy (1997)

According to Aldarrat et al. (2003), the estimated cost of JHJWSG water amounts to 0.454 LYD per cubic metre of water assuming an operational efficiency of 85%, or 0.377 LYD, assuming a 100% operational efficiency.

7.2 Water investment plans in agriculture in JPR

Complementing the general goals of the GMRP water investment administrators, the Authority for the Utilisation of Jabel Hasawna – Jefara Water System aims to support existing agricultural projects and farms in the JPR and to achieve population stabilisation. It also encourages local and foreign investment, with the goal of providing a competitive environment to facilitate the introduction of modern techniques in irrigation and raise the level of production quality and quantity (AUJHJWSG, 2010a).

The NCBMM (1994) developed a master investment plan for the Jabel Hasawna – Jefara Water System administration in the spring of 1994, with the goal of creating a balance between maximising the realisable irrigated area and raising water use efficiency levels. The plan aimed to improve agricultural production for the JPR and protect aquifer water in the region from degradation. According to the NCBMM (1994) plan, aquifer reservoir conditions would be fixed and stabilised at the levels and quality of 1993 by reducing the amount of groundwater withdrawals from 1,002 mm^3/year to 250 mm^3/year. The deficit would be covered by the water from the Authority for the Utilisation of Jabel Hasawna – Jefara Water System. Table 17 summarises the 1994 plan as compared to the situation in 1993.

Table 17 A comparison between the master plan of NCBMM (1994) and the water situation in 1993 in Jefara region of Libya in million cubic metres annually.

Type of supply		*Supplies according to the master plan*			*Actual groundwater supply*
		Hasawna system	*Local groundwater*	*Amount*	
Agricultural	Projects of agricultural Scheme and coastline	481.9	–	481.9	220.0
	Bin-Ghashir and Sawani region	248.1	–	248.1	215.0
	Other regions	–	200.0	200.0	367.0
Municipal supplies		182.5	50.0	232.5	200.0
Total		912.5	250.0	1162.5	1002.0

Source: Adapted from NCBMM (1994)

The 1994 NCBMM plan provided for the prohibition of all water withdrawals for irrigation on the coastline and the Bin-Ghashir region, as well as an interdiction on the issue of any new licenses for the drilling or deepening of wells in the rest of Jefara Plain. Aljuhawy (1997) believes that the Jefara Plain water needs could be even greater than the actual amount produced and transferred by the Authority for the Utilisation of Jabel Hasawna – JefaraWater System, with estimated needs in 1997 amounting to 3,265,670 m^3/day. The NCBMM (1994) plan proposed the construction of wastewater treatment facilities in urban areas on the coast. In this context, the Electricity, Water and Gas Company signed two contracts to desalinate sea water for urban use as part of the water sector development plan 2007 to 2010 for the Jefara Plain: a contract to construct the Zawia plant with total a capacity of 80,000 m^3/day, and a contract to expand the Zwara plant to a total capacity of 40,000 m^3/day. The GCWD plan for the period 2009 to 2010 included the construction of new desalination plants in the Jefara Plain east of the Tripoli, Homes and Jefara regions and the expansion of the Zawia and Zwara plants. The total designed capacity of the targeted plants is 1,000,000 m^3/day.[5]

In its recommendations, the NCBMM (1994) plan identified an urgent need to develop policies to conserve water. Users should be aware of the problem of water scarcity and encouraged to take bold steps to conserve water, for example, by changing crop patterns and raising the level of efficiency in irrigation systems, such as with the use of drip irrigation systems. Farmers could be financially compensated to change their current practices as a policy of raising prices for water use is implemented. The use of desalinated water to irrigate grain and fodder crops could reduce the burden on fresh water use, while still providing farmers with access to a good productivity (Sholuak and Abo-Zweek, n/d.).

AUJHJWSG has been assigned the task of managing water investment. According to its establishing Resolution, it is responsible for maximising the return on water in established and integrated projects and individual farms (AUJHJWSG, 2005). The

AUJHJWSG sells the water with value of 0.060 LYD/m^3, that with the added value of the purchase price of the authority of implementation and management of GMRP, 0.048 LYD, comes to 0.012 LYD/m^3 (AIMG, 2008). In 2003 the Government published a list of existing projects, new projects and their water allocations included in the investment plan of AUJHJWSG (WTNWR, 2003). This list was updated in 2011 by the Authority for the Utilisation of Jabel Hasawna – Jefara Water System of the Great Man-Made River. Details of the projects are shown in Table 18.

Table 18 AUJHJWSG projects

Project		*Irrigated area/Ha*	*Number of farms*	*Allocations of water*	
				m^3/day	*mm^3/day*
A	Existing projects				
	Tomeena and Al krareem project	2,844	898	70,000	25.55
	Al daavniah and Naima project	2,352	503	50,000	18.25
	Imhammid Al mgrreef farm	275	1	14,000	5.10
	Garhabuli agricultural project	4,438	1497	94,527	34.50
	Beer Atterfas agricultural project	2,365	473	30,603	11.20
	Al wadi Al hay agricultural project	3,504	418	60,000	21.90
	Abu Shebah agricultural project	1,851	121	40,000	14.60
	Al heera agricultural project	2,679	484	69,891	25.50
	Wadi Al mjineen agricultural project	360	72	10,109	3.70
	Jndooba agricultural project	1,521	318	24,430	8.90
Partial total of the existing projects		22,189	4785	463,560	169.20
B	The affected areas of the coastline				
	Private holdings	76,870	19676	1,053,020	384.40
C	New projects				
	Abu Aisha agricultural project	3,320	664	80,000	29.20
	Tarhouna agricultural project	950	173	25,000	9.13
	Wadi Tajmaut agricultural project	700	5 fields	20,000	7.30
	Souf Al gene agricultural project	2,000	24 fields	95,000	34.67
	Grarat Algataf agricultural project*	2,000	27 fields	Groundwater	Groundwater
Partial total of the new projects		8,970	893	220,000	80.30
D	Water tanks				
	The rural and pastoral areas	-	73 tanks	65,000	23.73
Total		*108,029*	*25,354*	*1,801,580*	*657.63*

Note: *Based on the use of Sparkling local groundwater.

Source: Adapted from AUJHJWSG (2010a) and WTNWR (2003)

The investment plans of the Authority for the Utilisation of Jabel Hasawna – Jefara Water System of the GMRP are of two types:

7.2.1 Projects supervised directly by the AUJHJWSG

The authority has opened the agricultural projects of Abu Aisha, Tarhouna and Graart Al Gtaff to foreign and domestic investment in the agricultural field (Abdulaziz and Ekhmaj, 2007; AUJHJWSG, 2007, 2010a; WTNWR, 2003). Table 19 shows the investment details.

Table 19 Investments in AUJHJWSG agricultural projects

Agricultural project	*Investor*	*Investment area/Ha*	*Authority's share*
Abu Aisha	National Individuals and Companies	330.5	Fees of water use and the network maintenance services
	Assanabel Addahabia Company	20.0	35%
	Almutahida Company	37.5	-
	AUHJWSGP?	983.0	100%
Tarhouna	TechnoFarm International LTD	315.0	60%
	Andalusia Agritechnique Company	414.0	70%
	AUHJWSGP?	157.0	100%
Grarat Algataf	TechnoFarm International LTD	390.0	70%

Source: Adapted from AUJHJWSG (2010a)

In addition to water and arable land, the AUJHJWSG's participation and contribution to projects varies from one to another, variously providing such items as agricultural machinery and equipment, irrigation instruments, fuel and electric power, while their partner takes responsibility for planting and agricultural work, and the delivery of the crop in its final form (AUJHJWSG, 2007). The GMRP's encouragement of foreign investment in water is aimed at introducing advanced and efficient technologies, improved seeds and good management in the agricultural sector. It contributes to the financing of operating and maintenance requirements, as well as helping in the establishment of the infrastructure of transport, storage, coolers, food industries, packaging and packing. Improving efficiency through foreign investment in the natural resources of water, soil and others should be seen from the perspective of sustainable development. The cost of damage to the environment must be passed on to the investor (Abdulaziz and Ekhmaj, 2007).

Contracts with national individual companies provide them with the land and a water allowance of 120 m^3/day per five hectares at the farm gate. The investor pays the fees of operating, maintenance and land rent for the duration of the contract in advance. The water use fee is 0.060 LYD/m^3.

7.2.2 Projects and private holdings managed by owners and beneficiaries

This type of project is of two kinds: farms owned by farmers, by purchase or inheritance; and Government confiscated lands held by agricultural projects and re-delivered to other beneficiaries by utilisation contracts forever (AUJHJWSG, 2008). The AUJHJWSG provides the owner of a farm or the beneficiary with a certain amount of water a day, depending on the size of the farm. The user pays a water use fee of 0.060 LYD/m^3. Table 20 shows the authority's revenue during the period from 01/01/2010 to 31/12/2010.

Table 20 Miscellaneous revenue statement for the period 01/01/2010 to 31/12/2010

Revenue	*Amount(LYD)*
Olive oil sale	45,386.000
Crops sale	473,404.990
Investment	1,415,586.542
Seedlings sale	1,024.500
Water use	379,876.564
Miscellaneous revenues	127,395.000
Assets sale	525,841.700
Total	2,968,515.296

Source: AUJHJWSG (2010a)

7.3 Problems and obstacles faced the investment plans in JPR

The implementation of some investment contracts has been delayed by objections from citizens, who have had their lands confiscated under government sanctioned decisions of expropriation in the public interest, arguing their own legal ownership of the land. These lands would normally have been delivered in the form of farms to beneficiaries by utilisation contracts forever (AUJHJWSG, 2010a). Another obstacle, according to AIMG (2008), is the lack of a clear, binding and effective legal mechanism for the collection of water fees in the AIMG and the authorities for the utilisation of water systems, including the AUJHJWSG. Other problems are farmer debt, which amounted to 201 million dinars at the end of 2007, and the faltering of new contracts to provide farmers with water (AUJHJWSG, 2010b). These circumstances have resulted in a deficit to cover operating expenses, despite the Water Pricing Decision No.218 of 26/04/1994 requiring these expenses be covered from water sale revenue (AUJHJWSG. 2007). One of the reasons for farmer non-payment for water use in full is the failure to achieve good economic returns, especially in small farms. This report acknowledges this and identifies some of the problems experienced by farmers, such as the need for agricultural guidance and education and training to implement the modern and efficient agriculture methods and practice. There is a real need for agricultural cooperative associations to provide farmers with agricultural equipment and the production supplies such as seeds, fertilisers and pesticides. Farmers require grants and soft loans to enable the production of strategic crops that can achieve high economic returns. NCBMM (1994) has identified these same problems, as well as the additional problems of marketing constraints, inadequate import controls and the need to stimulate exports.

8 Conclusions

The water scarcity problem in Libya is exacerbated by a growing population and its dominant arid geography and desert climate. An increasing reliance on oil revenues has seen agriculture decrease to only 2% of GDP by 2007, and facing significant challenges, with domestic food supplies unable to meet demand and cultivation limited by a lack of arable land and water. Despite an institutional framework supported by legislation, water sector governance has been poor and water development projects unable to cover Libya's water deficit.

Political, social, cultural, planning and economic factors underlie the mismanagement, in particular, inefficient farming practices and a lack of expertise, transition possibilities, water monitoring and treatment techniques, and water fee collection in the AIMG. Poor economic returns, marketing constraints and the faltering of new water contracts have also led to significant levels of farmer debt. Agricultural education, training and funding are needed to implement modern and efficient methods and practice.

The target should be achieving sustainability of water flows by considering the operating expenses for as long as possible at optimal use. The water quality and levels in ground reservoirs will not stabilise until withdrawals are reduced to reasonable limits. This is critical to achieve irrigation sustainability in the JPR in the long-term, taking into account both population and economic growth.

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Notes

1 They are described in turn and in details later.

2 More details about this plan will be stated later in this section.

3 There is no data about the actual quantities in 2007 can be used for the comparison.

4 The (NCBMM) are two organisations have put the General Plan for Utilisation of the GMRP Waters phase (2) in spring of 1994.

5 More details about these plants are to be found in the desalination section of this paper.