PROGRESS IN WATER RESOURCES MANAGEMENT: EGYPT

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Abstract

Throughout the last fifty years the population of Egypt has grown by more than three folds while, on the other hand, the available renewable water resources remained the same. Consequently, the annual per capita share of renewable water resources (mainly provided by the Nile) is dramatically reduced from more than 2500 cubic meters at the year 1950 to less than 900 cubic meters at the year 2000, and is further projected to fall to about 500 m^3/cap/yr by the year 2050, as depicted from Figure (1). The challenges facing the water sector in Egypt are enormous and require the mobilization of all resources and the management of these resources in an integrated manner. It is believed that *business-as-usual* scenarios are no longer adequate in meeting the current challenges. Changes in the way water resources are currently allocated and managed are inevitable. Accordingly, the Ministry of Water Resources and Irrigation has recently launched a National Water Resources Plan for Egypt (NWRP). The latter is a comprehensive document which describes how Egypt will safeguard its water resources in the future, both with respect to quantity and quality, and how it will use these resources in the best way from a socio-economic and environmental point of view. Furthermore, to confront the prevailing water scarcity, Egypt has endorsed several policies to achieve both integration and decentralization of water management to the lowest possible level. Several strategic initiatives are currently implemented to fulfill the later objectives including the establishment of water user associations, the transfer towards integrated water management districts, and matching irrigation demands systems. A common pre-requisite for the success of any of these approaches is the availability of reliable data and information, the provision of proper analysis for such data, and equally essential, accessibility to appropriate decision support tools.

1. Introduction

It has been traditionally known that Egypt is the Gift of the Nile as stated by Herodotus of Halicarnassus, fifth century BC, who is considered as the world's first historian. The banks of the Nile hosted the first unified country in the history of the world which lasted as an independent and united country for more than 3000 years. Nevertheless, there have been times where the Nile was experiencing a vast range of variations between low flows and high flows, which rendered the livelihood along the river banks to be temporary and unstable. During such times the high flow season was accompanied by excessive flooding and ponding while the low flooding season was associated with reduced water levels in the river and accordingly inappropriate accessibility. Groundwater must have been a more reliable water resource to support man and animal communities under such circumstances. This fact is supported by surviving evidence, Figure 2, still printed on the walls of caves, oasis, and monuments belonging to first Paliolithic man (more than thirty thousand years ago) who has been centered around natural springs and depressions which have been effective in collecting rain water. Hunting has been predominant, yet evidence of early agriculture exists. Until that time, residing by the Nile banks has not been practiced yet.

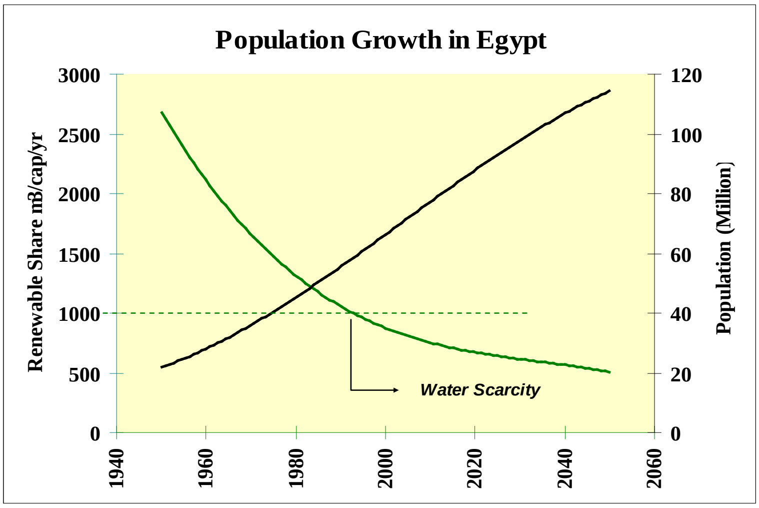

Figure 1: Water Scarcity in Egypt

Ten thousand years ago and near the end of the quaternary period, a new period witnessing high climate variability started. Aridity has been a dominating feature during this period despite the existence of few sub-pluvial (rainy) periods. Ancient Egyptians (Neolithic men) started to convert to agriculture to account for the decrease in green coverage as a result of aridity. The increase in water demand, along with sharp climate changes (higher temperature and less rain) have led to drastic natural and socioeconomic implications. Water availability at depressions where man used to live is gradually reduced.

Figure 2: Pluvial Time Drawings

Several perennial wadies have turned into ephemeral ones while others have completely dried out, filled by air-born depositions, and transformed into paleo-channels. Several Oases also vanished. Previously existing green coverage is gradually transformed into harsh desert environments. Man and animal are united in looking for more favorable living locations with more water potential, thus several immigration moves has been initiated. Looking for a more sustainable water source Figure 3), Egyptians began to cluster around flowing springs, at the edges (high lands) of Wadies, then at the main stream of the Wady (low lands), then finally towards the banks of the Nile River, which by then must have been more stabilized. This marks the early beginning of the Egyptian Dynasties which established the greatest civilization of the world.

2. Freshwater Supply

Currently, the overall average annual rainfall in Egypt is about 18 mm mainly occurring at the northern coast which receives about 150 mm of precipitation per year. In the southern Upper Egypt, Sinai, and along the Red sea coast events of measurable rainfall may be encountered once every 5 to 9 years, sometimes developing into very short, but destructive, flash floods. Precipitation which occurs in winter and late autumn accounts for 1.3 BCM/yr of internal renewable water resources recharging shallow aquifers.

Figure 3: Map of Egypt

The Nile River supplies about 97% of the annual renewable water resources in Egypt. Out of the Nile's average natural flow of 84.0 km^3/yr reaching Aswan, a share of 55.5 BCM/yr is allocated for Egypt according to the Nile Water Agreement (1959). The Agreement also allocates a share of 18.5 BCM/yr to Sudan; while about 10 BCM/yr is lost in evaporation from the high dam reservoir (Lake Nasser), Figure 4 Wagdy (2009), FAO (2007), NWRP (2007). Thus the total renewable water resources of Egypt are estimated at 56.8 BCM/yr. The latter amount of supply is constant and incremental possibilities are not foreseen for the short term. This accounts for an average per capita share of about 800 m^3/cap/yr as of year 2004, while projections forecast a share of about 600 m^3/cap/yr by the year 2025.

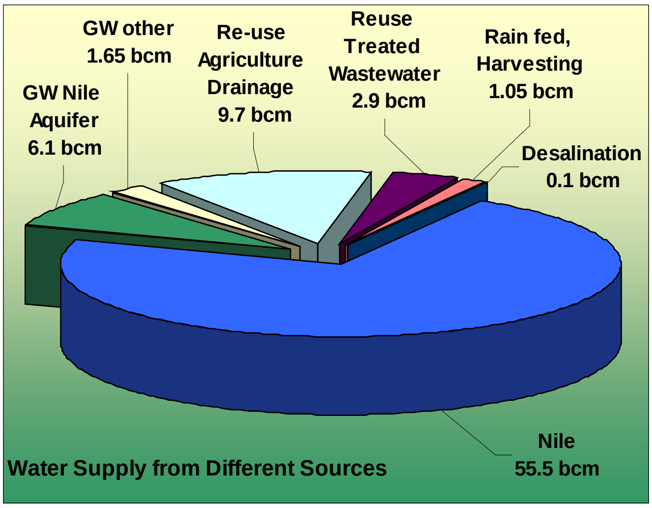

Figure 4: Sources for Water Supply

Fossil groundwater is hosted in deep aquifers as non-renewable water resources. Also, non-conventional resources include agricultural drainage water reuse, sea water desalination, municipal wastewater reuse, rain harvesting, and brackish water desalination. Fossil water exploitation is estimated at a rate of 1.65 BCM/yr, mainly concentrated at the oases of the Western Desert. The municipal wastewater reuse capacity is currently of the order of 2.9 BCM/yr, while the agricultural drainage reuse is projected to be around 9.7 BCM/yr in the Nile Valley and delta.

Groundwater utilization has been steadily increasing in Egypt for the last twenty years. A designated sector for groundwater management has been established at the Ministry of Water Resources and Irrigation to coordinate, develop, and rationalize the national groundwater utilization. There are four major groundwater systems in Egypt, Figure (5), namely; the Nile Aquifer, the Nubian Sandstone Aquifer, the Moghra Aquifer, and the Coastal Aquifer. The Nile aquifer is renewable and underlies the Nile Delta and is characterized by its high productivity and shallow depth of the groundwater table allowing the abstraction of large quantities of water (100-300 m^3/hr) at low pumping cost. Conjunctive use of surface and groundwater is widely practiced by farmers, especially during periods of peak irrigation demands. About 6.1 BCM/yr are annually extracted from the aquifer. Being a shallow aquifer it is extremely vulnerable to pollution by surface induced sources. The aquifer is directly connected to the Nile River system, and thus will be directly affected by programs for reducing conveyance losses in waterways.

The Nubian sandstone aquifer is shared by four countries namely; Egypt, Sudan, Chad, and Libya. The whole aquifer contains about 150,000 BCM of fossil water at depths reaching 2000 m. Pumping costs and economies of scale control the development of groundwater from the Nubian Aquifer. The Nubian Aquifer extends also beneath the Eastern Desert. Recent studies show that the shallow aquifers at the middle and south of the desert are connected to the deep aquifer, thus providing a good potential for groundwater development. In the Moghra aquifer, the groundwater flow is in general directed towards the Qattara Depression. The aquifer is recharged by rainfall and lateral direct inflow from the Nile aquifer. Due to the sharp increase in abstractions for groundwater-based reclamation projects in the Egyptian Western Desert and industrial and municipal supply, notably in the Western fringes of the Nile Delta, the water quality and sustainability of this resource is at risk. The Coastal aquifers exist near the western northern coast of Egypt and are recharged by rainfall on the western coast. Quantities that can be abstracted are limited due to the presence of saline water underneath the fresh water layers.

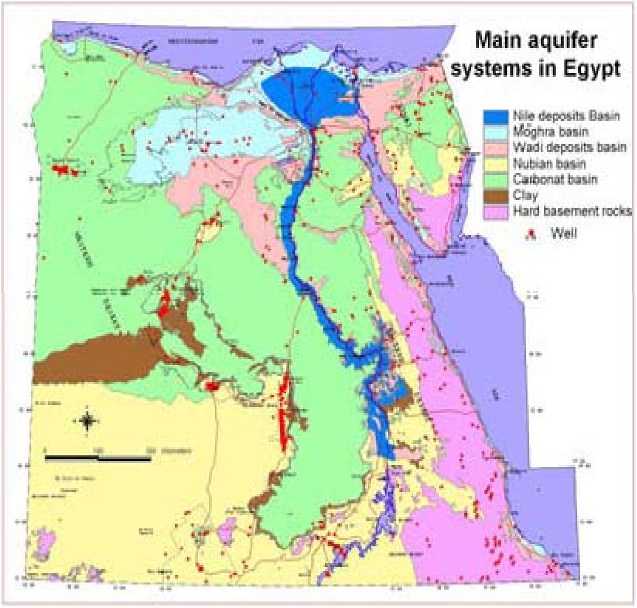

Figure 5: Main Aquifers in Egypt

3. Water Demand

Various demands for freshwater are exerting excessive pressure on the available water supply. The agricultural sector (including fisheries) is the highest freshwater consumer, utilizing about 78% of the available supplies (excluding recycling), while the domestic and industrial sectors consume 7% and 7.6% of the total natural supplies, NPI (2008). The navigation and energy (i.e. hydropower) sub-sectors are "instream" users; meaning that they utilize the Nile/irrigation distribution system, but they are not net consumers of the water resources. Drainage water spilled to the Mediterranean Sea and the desert fringes of the Nile system contributes the water needed to maintain the ecosystem/habitats of the northern Delta/Lakes. Evaporation losses from the 31,000 Km-long water conveyance network is estimated at about 2.4 BCM/yr, Figure (6), Wagdy (2009), IDSC (2007).

Water resources management, hydraulic control, channel design, distribution networks, and water discharge monitoring has been practiced by Egyptians for over 5000 years. The total dam capacity is about 169 km3 mainly attributed to the reservoir of the Aswan high dam. About 90% of the Nile's hydro-potential has been exploited to generate about 12 Twh. The irrigation potential is estimated as 4.4 million ha. Agricultural drainage through primitive pumping stations and excavation of main drains has been practiced in Egypt as early as 1898. Ditch drainage has been introduced in 1938 followed by sub-surface drainage in 1942. The Egyptian Public Authority of Drainage Projects (EPADP) has launched a comprehensive drainage construction/rehabilitation program in Egypt that covers 8.0 Million feddan of agriculture lands since late seventies. EPADP accomplished 7.2 Million feddan with surface open drainage till end of 2004. Parallel with that, EPADP introduced a long-term planning for flexible construction of subsurface drainage in an area of 6.4 million feddan, which widely enabled the use of mechanized pipe-laying, plastic pipes and synthetic envelope materials by public and private contractors. EPADP accomplished 5.4 Million feddan of subsurface drainage till end of 2004.

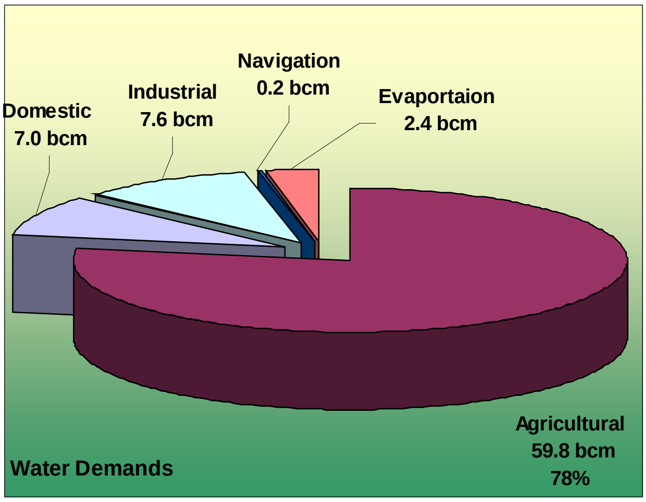

Figure 6: Sectoral Water Demands

Drinking water requirements for major urban towns and rural villages have been estimated to be 4.6 BCM in 99/2000 where approximately 97% of urban population and 70% or rural population of Egypt relies on piped water supply. The major cities in Egypt (217 city) enjoy full potable water coverage (100%). Sanitation services, however, lag behind water supply, where approximately 52% of urban population is covered by collection and treatment sanitation systems while about 11% of rural population in villages is connected to the sewerage system. Municipal water is diverted from two sources: surface water which supplies about 83% of total municipal demand and groundwater, which supplies about 17% of total demands. The total municipal demand (drinking water) is calculated to increase by a factor of 1.4 between 2000 and 2017. The total industrial water utilization is expected to increase by a factor of 2.0 throughout the former period.

Fisheries rely greatly on water resources and are directly affected by water allocation policies. The total fish production in Egypt reaches 725 thousand tons in the year 2002 where 18% of it came from marine fisheries. A population of about 700,000 fishermen earns their living from inland fisheries and related activities. It is estimated that a minimum of 8.5 BCM/yr of fresh and drainage water is required to sustain the present ecological conditions including fish production from the Delta lakes.

4. Water Quality

In general, surface water quality exhibits deterioration as we move downstream with the worst pollution occurring at the northern lakes. The domestic water demands result into more than 4.0 BCM/yr of waste water being discharged into the Nile, out of which 35% are treated. Pathogenic pollution of surface water has been recorded to increase during the 1980s and to decrease gradually throughout the 1990s and in all cases it exists in restricted localized areas. The government comprehensive plans to extend sanitation coverage and waste water treatment to rural areas are expected to eliminate significant pathogenic pollution by year 2017. Industrial effluents contribute to about 1.3 BCM/yr of untreated waste water being discharged to surface waters. Food industries contribute to 45% of total effluent discharge and to 67% of the total BOD load introduced. BOD levels in the Nile, at mid stream, are still below 6 mg/L. The Nile branches experience more Oxygen depletion which may reach a Dissolved Oxygen value of 3 mg/L at downstream end presenting potential hazard to aquatic organisms. Industrial effluents contribute to the increased levels of trace elements especially after the construction of the high dam where the potential for flushing the contaminated sediments during the flood period was eliminated. Drainage return flow to the Nile result into an increase in salinity of the water from 130 mg/L at Aswan (far upstream) to 250 mg/L near the delta barrage. Nitrogen fertilizers whose consumption has doubled between 1980 and 1993 present another source of pollution. Water hyacinth flourishing at the downstream of water ways due to increased nutrients lead to clogging of canals and is combated with mechanical and biological technologies. Despite of the flourishing fish production in Egypt, only 17 species remain as of 1995 out of 47 species which used to be available in 1948.

5. Water Sector Governance in Egypt

Three major governmental entities influence the management of water resources in Egypt. These are: (i) The Ministry of Water Resources and Irrigation, (ii) The Ministry of Agriculture and Land Reclamation, and (iii) The Ministry of Housing. The former is in charge of development, distribution and management of water resources, and development and O&M of the associated water works. The Ministry is also responsible for collection and disposal of agricultural drainage water, monitoring and assessment of water quality of the various water sources, and protecting the coastal lakes and the shoreline. The Ministry of Agriculture and Land Reclamation (MALR) is involved in improving agricultural activities and land reclamation, including water management at the on-farm level. The Ministry of Housing, Utilities and New Communities (MHUNC), provides water supply and sanitation services to the municipal and industrial subsectors. Some other ministries participate by different degrees in auxiliary management and operation of part of the irrigation and drainage systems such as Ministry of Health and Population (MoHP), the Ministry of State for Environmental Affairs, and the Ministry of Local Development (MoLD). Figure 7 represents the structure of MWRI.

Agriculture's share of the GDP fell from 34.3 % in 1955 to 16.7% in 2000, while its share of employment fell from 56% to 29.6 % over the same period (World Bank, 2004). Nevertheless, agriculture remains the most important sector of the Egyptian socioeconomic structure. The main impediments to agricultural development in Egypt are classified under: (i) policies, (ii) institutions, resources, and technology (Rami 2005). In 2003, MWRI started a program to support improved environmental and water resources management focusing on the *decentralization* and *integration* of water resource management at the irrigation *district level* (IRG, 2004).

Introduction of Integrated Water Management Districts (IWMD) is adopted as a strategic solution. A typical IWMD is an independent government irrigation operation and maintenance organization, at the district level, that has sufficient manpower, material, and financial resources to operate and maintain all water resources under its jurisdiction. Implementing integrated water management at the district requires integration of staff, facilities, stakeholders, information, users, and water resources. Effective information management is recognized as a must for appropriate operation of IWMD along with relevant databases as supportive tools.

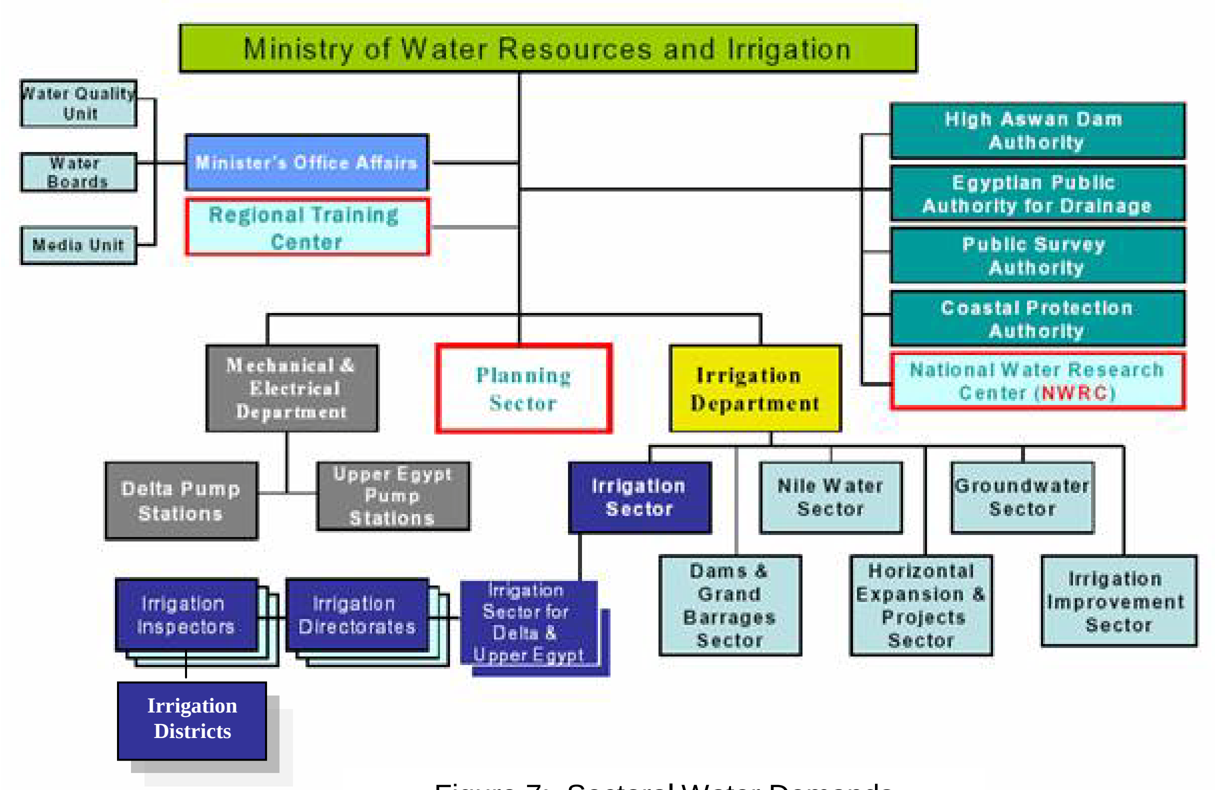

Figure 7: Sectoral Water Demands

6. Existing National Water Policies and Strategies

Five main socio-economic sectors are dependent on the available scarce water resources for their development; namely the agricultural, industrial, municipal, navigation, and power generation sectors. The cultivated and cropped areas have been increasing over the past few years and will continue increasing due to the Government policy to add more agricultural lands. The largest consumers of irrigation water are Rice and Sugarcane because they have high water requirements in addition to occupying a considerable area. The average crop consumptive use for year 99/2000 was estimated to be 41.441 bcm. The total diverted water to agriculture from all sources (surface, groundwater, drainage reuse, and sewage reuse), which includes conveyance, distribution, and application losses, in 99/2000, was about 60.731 bcm. The water policies of the 1970 and early 1980's gave a significant advantage to new lands development. However, recent changes in price and other policies particularly the reduction/elimination of government fertilizer and energy subsidies place farmers in the new land at a disadvantage (ICID 2004).

During the seventies and early eighties of the last century policies have been directed towards water supply management. At present, integrated water resources management, which seeks an efficient blend of all available resources (fresh surface water, ground water, precipitation and drainage water) to meet demands of the full range of water users (including agriculture, municipalities, industry and in-stream flows) is becoming an integral part of MWRI's policy vision to meet these challenges. An extensive coordination effort among concerned government institutions and the active participation of water users in planning, management and operation of water collection and distribution systems is required. Integration also necessitates the establishment/enhancement of the legal basis for water allocation, conservation and protection as well as user participation in water management. To cope with these challenges, the MWRI has developed a national policy with three major pillars of: 1) increasing water use efficiency; 2) water quality protection; and 3) pollution control and water supply augmentation (NWRP 2004).

7. Challenges and Responses

At present, there are significant challenges to water resources development and use in Egypt. Beginning with a single source of water – The Nile – uncertainties in climate, developments upstream, and population growths have characterized efforts to anticipate potential future water constraints. Municipal and industrial water use is being readily met and agricultural water use yields high levels of production with about 200% cropping intensity. However, the costs for water services for the next 15 years will be more than triple the current expenditures. Future public sector allocation for such high costs presents a heavy and unsustainable burden for the government budget. Moreover, water quality in a closed system is deteriorating because of pollutants being retained in as part of the recycling and reuse of drainage water, along with poor treatment and regulation of urban and rural sanitation. Stakeholders at the local level are organizing water users associations and water boards to confront the issue and have their voices heard on irrigation and rural sanitation issues.

Thus, the main drivers for water management reform at both the central and regional levels include (i) the need to meet supply/demand imbalances for the future; (ii) water quality deterioration and associated health and environmental risks; and (iii) weak service delivery, reliability, and transparency and associated quantity and quality measurements along with financial sustainability and cost recovery issues.

In addressing the main issues and the way forward, The Minister of Water Resources and Irrigation has stated that: *"…the challenges facing the water sector in Egypt are enormous and require the mobilization of all resources and the management of these resources in an integrated manner. This is especially true as the amount of available water resources is fixed, meanwhile water demands continue to grow in the years ahead due to population growth, increased food demand, and expansion and modernization of the industrial base, and improved standards of living.."* :[1]

8. Concluding Remarks

In essence, the challenges faced by the Government of Egypt include meeting the water demands of a growing society, rising living standards, food policy to feed a growing population, water quality degradation and environmental problems and health issues. Given a constant supply and growing demand, there is increasing competition for water from multiple uses. These challenges necessitate changes in the way water is currently allocated and managed. Consequently, the Ministry of Water Resources and Irrigation has prepared a National Water Resources Plan for Egypt (NWRP, 2004) that focuses on the physical improvements necessary to satisfy the supply-demand imbalance. The totality in the approach to water resources/agricultural/urban water management is expressed throughout the plan. The National Water Resources Plan is based on a strategy that has been called 'Facing the Challenge' (FtC). FtC includes measures to develop additional resources, make better use of existing resources, and measures in the field of water quality and environmental protection. Nevertheless, there is a need for an in-depth IWRM analysis to reflect the recent strategic orientation of the water sector on previous policies and strategies and their impacts on district level water management.

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