

# **Water Policy Issues of Egypt**

## **Country Policy Support Programme (CPSP)**

Project funded by

Sustainable Economic Development Department  
National Policy Environment Division  
The Govt. of The Netherlands  
(Activity No.WW138714/DDE0014311)



**ICID•CIID**

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE (ICID)  
NEW DELHI

December 2005

International Commission on Irrigation and Drainage (ICID) was established in 1950 as a Scientific, Technical, Non-commercial, Non-Governmental International Organization (NGO) with headquarters at New Delhi, India. The Commission is dedicated to enhancing the worldwide supply of food and fiber by improving water and land management, especially the productivity of irrigated and drained lands. The mission of ICID is to stimulate and promote the development and application of the arts, sciences and techniques of engineering, agriculture, economics, ecological and social sciences in managing water and land resources for irrigation, drainage and flood management using research and development, and capacity building. ICID aims to achieve sustainable irrigated agriculture through integrated water resources development and management (IWRDM). ICID network spreads to 105 countries all over the world.

Country Policy Support Program (CPSP) was launched by ICID in 2002 to contribute to develop effective options for water resources development and management to achieve an acceptable food security level and sustainable rural development. The program is implemented in five countries viz. China, India, Egypt, Mexico and Pakistan and is funded by Sustainable Economic Development Department, National Policy Environment Division, The Govt. of The Netherlands as Activity No.WW138714/DDE0014311.

ISBN. 81-89610-05-8

## ACKNOWLEDGEMENTS

The present study was conducted as part of Country Policy Support Program (CPSP) initiated by the International Commission on Irrigation and Drainage (ICID) with the financial assistance from Sustainable Economic Development Department, National Policy Environment Division, the Government of The Netherlands.

ICID acknowledges the support it received for the conduct of the various studies under CPSP from many water related International Organizations by way of their participation in consultations and dialogues during the different phases of the study. The outcomes of studies made in the CPSP participating countries (China, Egypt, India, Mexico and Pakistan) were shared with IWMI, FAO, WWF, IUCN and GWP from time to time. Their contributions are gratefully acknowledged.

ICID acknowledges the continual guidance and support it received from President Peter Lee and Presidents Honoraire Ir. Keizrul bin Abdullah and Prof. dr. Bart Schultz in overall implementation of the program in participating countries. The initiative of Dr. C D Thatte, Secretary General Honoraire enabled to conceptualize the activities and an impetus to CPSP initiatives.

Thanks are due to Mr. A D Mohile, former Chairman, Central Water Commission, India and Mr. L N Gupta, former Executive Director, WAPCOS (India) for their valuable contribution to the development of a Basin-wide Holistic Integrated Water Assessment (BHIWA) model and active participation in CPSP studies.

ICID assigned the CPSP study to Egyptian National Committee on Irrigation and Drainage (ENCID). ICID acknowledges the support of Dr. M.H. Amer, Chairman, ENCID and Dr. H. Fahmy, Director, Drainage Research Institute (DRI) for their leadership in carrying out the present study successfully and for preparing the draft report. Sincere thanks are also due to Prof. Dr. Mohamed Bayoumi Attia, Consultant, Ministry of Water Resources and Irrigation (MWRI), Prof Dr. Maha Tawfik, Director, Survey Research Institute (SRI), Dr. (Ms.) Dalal El- Naggat, Director of the Regional Center for Training and Water Studies (RCTWS), Dr. Hussein El- Atfy, Head of Sector, Minister's Technical Office, MWRI, Secretary, ENCID for their valuable input and support. At the Central Office, ICID, Dr. S.A. Kulkarni, Director (I) ably coordinated the execution of various CPSP activities since its inception and edited the report for printing. Their contributions are duly acknowledged.

ICID acknowledges the donors for reposing their confidence in ICID in assigning the task of exploring strategic directions to support country level policy support addressing water supply and demand issues of all the three sectors in an integrated, holistic and sustainable manner with food security and rural development as the main focus.

December, 2005

**M Gopalakrishnan**  
*Secretary General*

## PREFACE

Egyptian National Committee on Irrigation and drainage (ENCID) would like to express its gratitude to ICID for selecting Egypt as one of the participating country of the 'Country Policy Support Program (CPSP)'. ENCID would like to thank the Government of the Netherlands for providing the financial support for this program. The Central Office of ICID at New Delhi has facilitated and provided the technical support for the program. Thanks are also due to Mr. M. Gopalakrishnan, Secretary General and Dr. S.A. Kulkarni, Director (I) for their review and comments on this report.

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## ACRONYMS / ABBREVIATIONS

BCM	Billion Cubic Meter
BHIWA	Basin - wide Holistic Integrated Water Assessment
CAPMAS	Central Agency for Public Mobilization and Statistics
CD	Central Directorate
CDWD	Central Directorate for Water Distribution
CPSP	Country Policy Support Programme
DRI	Drainage Research Institute
EFR	Environmental Flow Requirements
ENCID	Egyptian National Committee on Irrigation and Drainage
FAO	Food and Agricultural Organization
GD	General Directorate of Irrigation
HAD	High Aswan Dam
ICID	International Commission on Irrigation and Drainage
IIP	Irrigation Improvement Project
IWRDM	Integrated Water Resources Development and Management
IWRMESD	Integrated Water Resources Model for Egypt's Sustainable Development
MALR	Ministry of Agricultural and Land Reclamation
MWRI	Ministry of Water Resources and Irrigation
NWRC	National Water Research Center
NWRP	National Water Resources Policy
SIWARE	Simulation of Water Management in the Arab Republic of Egypt
SRI	Survey Research Institute
SRU	Strategic Research Unit
TDS	Total Dissolved Solids
WFFRD	Water for Food and Rural Development



## EXECUTIVE SUMMARY

Water is a finite resource that is essential for agriculture, industry, and human existence. In arid and semi-arid countries, where water resources are quite limited, challenges for achieving the highest possible water use efficiency are particularly difficult. It is important to save and conserve water while providing necessary quantities to satisfy social and economic requirements as well as conserve the environment. However, due to the increase in population and associated rise in the standards of living and human economic and social activities, the demands of water are significantly intensifying. Decision-makers have adopted several planning tools to secure water allocation and distribution. Simulation and optimization mathematical models are proven examples of such planning tools.

In order to analyse the supply and demand issues of all the three sectors, namely food, people and nature in an integrated manner, ICID initiated a 'Strategy for Implementation of Sector Vision on Water for Food and Rural Development' in the year 2000. ICID also felt the need to mobilise strong international support for strategies and policies in water sector to achieve food security and reduce poverty in developing countries through independent water assessments. In line with this, ICID launched a project titled "*Country Policy Support Programme (CPSP)*", with a funding support from the Government of The Netherlands. A model called Basin-wide Holistic Integrated Water Assessment (BHIWA) was specially developed by ICID to address the problems of integration of sectoral water needs and evaluate impacts of land and water use on the basin water resources. The main purpose of the BHIWA model is to serve as a computational framework in the evaluation of water related policies in the ICID member countries for achieving food security and sustainable rural development with due consideration to environment and ecology. The model is developed to demonstrate the benefits gained from the adoption of integrated water resources development and management (IWRDM) approach in achieving sustainable development.

The Egyptian National Committee on Irrigation and Drainage (ENCID) organized a workshop on 3 August 2004 to present and discuss the results of the application of BHIWA model in the selected river basins of India and China.

An Orientation Workshop on CPSP was held in Delhi, India in December 2004. Representatives from the National Committees of India, Pakistan, Egypt and Mexico participated in the workshop. The CPSP India study Team presented the structure of BHIWA model and illustrated its calibration procedures. The participants from the three participating countries viz. India, Egypt and Mexico presented general status of the water resources and water policies in their respective countries. CPSP-India Study Team explained the data organization and preparation for BHIWA model followed by its application to Sabarmati basin. The participants from Egypt and Mexico performed simple, applications of BHIWA model. The preliminary results of the application were reviewed and discussed. Efforts were made to extrapolate the results of basin assessment to country scale. Identification of policy options at country level for Mexico and Egypt were also preliminary discussed. However, it was concluded that the BHIWA model in its current formulation may not capture some of the peculiar characteristics of the Egyptian water resources system, particularly the drainage and reuse of drainage water.

A Task Force comprising experts on planning and management water resources was formulated according to the recommendation of the 'Inception Workshop' held in August 2004 at Cairo. The Task Force devoted time to examine the applicability of BHIWA model to Egypt. A detailed report containing description of the model (structure and mathematical formulation, inputs, outputs, software platform and finally its capabilities and limitations) was prepared.

A 'National level Consultation' was held on 26<sup>th</sup> February 2005 in Cairo. A variety of stakeholders participated in the workshop. The main objectives of the workshop were as follows:-

- ❑ To present the BHIWA model with its capabilities and the limitations, and
- ❑ To collect feed back of the participants on future application, development and use of the model to suit the Egyptian conditions.

The overall conclusions and recommendations were:

- There was a difficulty in applying the BHIWA model under Egyptian conditions as the model is to be used for an entire basin and not separately for each sub-

basin. In the present version, division into five sub-basins is provided for. The connectivity amongst the sub-basins can be prescribed. However, the Nile basin is too large and interest of ENCID was to model the water situation in Egypt alone, without modeling whole basin. **Some modifications in the model to allow modeling of a part of the basin would however, be desirable.**

- In Egypt, the environmental concerns are receiving high priority. Although, the BHIWA model can consider the monthly EFR requirements as prescribed by the user, it cannot internally estimate environmental flow requirements. **The development of a separate model for this purpose would be beneficial.**
- The BHIWA model as currently available provides for returns from irrigation into the river and groundwater system. However, in Egypt, there are proposals for directly using the returns by diverting the drainage water without allowing to flow into the river system. **Some modification of the model may be required to depict such possibilities.**
- It emerged during the National Consultation that for understanding the policy related issues, it would be necessary to model the socio-economic components, aqua-culture components, the water needs of the livestock, the climate change possibilities, and the financial implications of alternative water development. The BHIWA model considers the livestock water requirement. Climate change can be externally specified by prescribing different rainfall and evapo-transpiration needs and changed water inflow situation in either country (water transfers). **However, the socio-economic and aquatic components are not currently modeled and linked with the BHIWA.**
- The strength of the BHIWA model was acknowledged. The model is found to be simple to use, the software platform is inexpensive and accessible. The model considers the surface water and groundwater in conjunction explicitly by modeling interaction. It considers the demand of the three main use sectors viz. nature, food and people. The model can yield good answers on the impacts of future scenarios in which the water availabilities, water demands of different sectors and the water allocated to these sectors could be much

different from the present. The data requirements are simple. The data are available with several organizations in Egypt.

- The BHIWA is a general overall basin study model for checking different future water scenarios and water management strategies. It is not a detailed basin-wise water management model. ENCID has a particular interest in obtaining or developing such a detailed basin-wise water management model. Such a model could be based on a GIS platform. ENCID's particular concern regarding re-allocation of water under extreme hydrologic events can not be well answered by the present BHIWA model.
- The CPSP study reports pertaining to India and China clarifies that the BHIWA model is not supposed to be used as a detailed basin planning and management tool. For this purpose, detailed model somewhat in line with Decision Support Systems Model of the type of IWRMESD or the model based on GIS platform could be used. However, for broadly understanding the implications of large future changes, such as large changes in land and water use in upper parts of the basin, different provisions for environmental flows, change strategies for using internally generated water resources of Egypt etc., the BHIWA model could be of considerable use. In this regard, ENCID proposes three alternatives, namely:
  - 1) To use the model, with minor adjustment, to simulate alternate scenarios and management policies and evaluating their impacts on surface and groundwater regime.
  - 2) To strengthen the BHIWA model to provide greater flexibility to deal with more complex hydrologic, irrigation and drainage systems and concepts.
  - 3) To redevelop the modified model in an object oriented environment which can enhance the basic concepts of the BHIWA model and its reusability and expandability.

**A separate funding support will be required to undertake them and the National Consultation resulted in a recommendation to extend the CPSP Phase I studies (to CPSP Phase II covering Egypt to look into some of the unresolved issues that stand identified).**



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## CHAPTER 1

# COUNTRY POLICY SUPPORT PROGRAMME (CPSP)

### 1.0 Introduction

Water is a finite resource and is essential for agriculture, industry, and human existence. In arid and semi-arid countries, where water resources are quite limited, challenges for achieving the highest possible water use efficiency are particularly significant. It is important to save and conserve water while providing necessary quantities to satisfy social and economic requirements as well as sustainable environment. However, due to the increase in population and associated rise in the standards of living and human economic and social activities, the demands on water are significantly intensifying.

Water resources policy analysis deals with the protection of people from the harmful effects of water and assurance of a constant, adequate supply of usable water. Population and regulatory pressure, political and economic instabilities, and climatic variation can all be expected to further stress water supply resources. Developing policies for managing water systems for human needs in such an environment is difficult, slow and very costly.

Decision-makers have adopted several planning tools to secure water allocation and distribution. Mathematical models for simulation and optimization are proven examples of such planning tools. The development of a reliable model to be used within the water policy analysis framework that relates development plans in the different socio-economic sectors with water as a natural resource, at the national strategic level, is a very elaborate task. For a country like Egypt where socio-economic development is solely dependable on scarce water resources, this task becomes more complex. Water policy analysis requires a set of modeling principals to guide and simplify the mode of development, and reduce the dimensionality problem.

### 1.1 Background to Country Policy Support Programme (CPSP)

The World Water Vision on Water for Food and Rural Development (WFFRD) for year 2025, formulated through extensive consultations held in over 43 countries, was facilitated by International Commission on Irrigation and Drainage (ICID) and a few other International Organisations. The theme document presented at the 2<sup>nd</sup> World Water Forum held in The Hague in 2000 projected a substantial increase in the global water withdrawal, water storage and irrigation expansion for the pre-dominant “food sector”. (*largely consumptive*). A majority of these projections of large increases related to the developing countries. However, the integrated overview Water Vision Document scaled down these requirements in an attempt to consolidate conclusions and recommendation of various other themes. It also did not reflect quantification of water needs for the “people sector” (*largely non-consumptive*) and the “nature sector”. Water needs of the food sector depend on the population, the changing dietary preferences and the income levels. Likewise, the water needs of the people sector also depend, apart from population, on the quality of life, income levels and the general economic growth including the industrial growth. The water needs of the nature sector, including the need of the terrestrial and aquatic eco-systems depend on the land use as also on the preferences of the society in trade offs between the uses and ‘non-use’ of water.

In order to analyse the supply and demand issues of all the three sectors, namely food, people and nature in an integrated manner, ICID initiated a ‘Strategy for Implementation of Sector Vision on Water for Food and Rural Development’ initiative in the year 2000. ICID also felt the need to mobilise strong international support for

strategies and policies in water sector to achieve food security and reduce poverty in developing countries through independent water assessments. In line with this, ICID launched a project titled “Country Policy Support Programme (CPSP)”, with a funding support from the Government of The Netherlands.

China, Egypt, India, Mexico and Pakistan having 43% of the world population and 51% of the world irrigated areas were chosen as participating countries in the CPSP. To begin with, detailed assessments were planned and implemented for the selected sample basins for the two most populous countries of the world, viz.; China and India considering their population growth and rate of urbanisation which factors have strong bearing on water demands. Multi-stakeholder consultations at the respective basins and national level, were held in India and China to discuss the outcome of detailed assessments, including extrapolation to country level. Findings from such consultations were used to identify elements in the national policies requiring changes in the context of integrated and sustainable use of this vital natural resource. This experience in assessments was used for a similar exercise at a lesser scale in the remaining three countries, namely; Egypt, Mexico and Pakistan.

Two river basins each in India and China were selected for detailed assessment of water resources. A model called Basin-wide Holistic Integrated Water Assessment (BHIWA) model was specially developed by ICID to address the problems of integration of sectoral water needs and evaluate impacts of land and water use on the basin water resources.

The main purpose of the BHIWA model is to serve as a computational framework in the evaluation of water related policies in the ICID member countries for achieving food security and sustainable rural development with due consideration to environment and ecology. It is developed to demonstrate the benefits gained from the adoption of integrated water resources development and management (IWRDM) approach in achieving sustainable development.

## 1.2 Workshops and Consultation on CPSP

A workshop on CPSP was held in Cairo, Egypt on 3<sup>rd</sup> August 2004 to present and discuss the results of the BHIWA model application in the different river basins chosen in India and China. Representatives of the National Committees of Egypt (ENCID), Mexico (MXCID), and Pakistan (PANCID) attended a second workshop in Delhi, India in December, 2004. Detailed description of the model components and application results on basins of India and China were discussed. A national consultation was later held in El-Kanater, Egypt on 26<sup>th</sup> February 2005 to discuss the possible application of BHIWA model in Egypt. A variety of stakeholders from different sectors who deal with water issues were invited to this workshop to share their knowledge and experiences and to know the best way to apply this model in Egypt. The discussion extended further to other available options and the most appropriate model that which could better address the Egyptian Water Policy in a holistic manner (Chapter 4, *ibid*)



## CHAPTER 2

# LAND AND WATER RESOURCES OF EGYPT

### 2.0 Land Resources

Egypt is an arid country, which covers an area of about one million sq. km. of which only 4% is occupied by its population. According to the 1996 census, the Egypt's population was 62 million inhabitants of which about 99% are concentrated in the Nile Valley and Delta. One of the important issues in the future is to redistribute the population over a larger area. To reach this objective, it is essential to reclaim new lands, create new industrial regions, build new cities, hospitals, schools, etc. in order to create new jobs and provide the required food for the new communities. Agricultural water demand is more than 80% of the total demand. In view of the expected increase in water demand from other sectors, such as municipal and industrial uses, the development of Egypt's economy strongly depends on its ability to conserve and manage its water resources.

Most cultivated lands are located close to the Nile banks, its main branches and canals. Currently, the inhabited area is about  $12.5 \times 10^6$  feddans<sup>1</sup> (5.25 Mha) and the cultivated agricultural land is about  $7.85 \times 10^6$  feddans (3.3 Mha). The per capita cultivated land declined from about 0.23 feddans (0.097 ha) in 1960 to about 0.13 feddans (0.055 ha) in 1996. The per capita cropped area declined from 0.4 feddans (0.17 ha) in 1960 to about 0.2 feddans (0.08 ha) in 1996. The sharp decline of the per capita of both cultivated land and cropped area resulted in the decrease of the per capita crop production. This affects directly the food security at the individual, family, community and at country levels.

Three main land reclamation projects have been launched to form the base for population redistribution

and further economic development. The first is the El-Salam canal west of the Suez Canal and El-Sheikh Jaber east of the Suez Canal to reclaim about 620,000 feddans (260,400 ha). The second project is the El-Sheikh Zayed Canal, which will reclaim some 500,000 feddans (210,000 ha) in the south of the New Valley. The third major project is the south valley development project (Toshka Project). These projects require large investments but they do have major social, economic and institutional benefits. Limited water availability is the main constraint to implement these projects.

### 2.1 Water Resources

Water resources in Egypt are limited to the Nile River, rainfall and flash floods, deep groundwater in the deserts and Sinai, and potential desalination of sea and brackish water. Each resource has its limitation on use, whether these limitations are related to quantity, quality, space, time, or exploitation cost. Figure 1 shows the Nile River Basin.

Egypt receives about 98% of its fresh water resources from outside its international borders. This is considered to be the main challenge for water policy and decision makers in the country as the Nile River provides the country with more than 95% of its various water requirements. The average annual yield of the Nile River is estimated at 84 billion cubic meters (BCM) at Aswan. The discharge of the Nile River is subject to wide seasonal variation. The natural river flow can be divided into two periods: 1) A short 3-month long high muddy flow season, and 2) A longer 9-month long flow clear season. According to the 1959 Agreement with Sudan, Egypt's annual share of the river water is determined as 55.5 BCM. The agreement also allocated 18.5 BCM for Sudan, while about 10 BCM

<sup>1</sup> 1 Feddan = 1.04 acre = 0.42 hectare

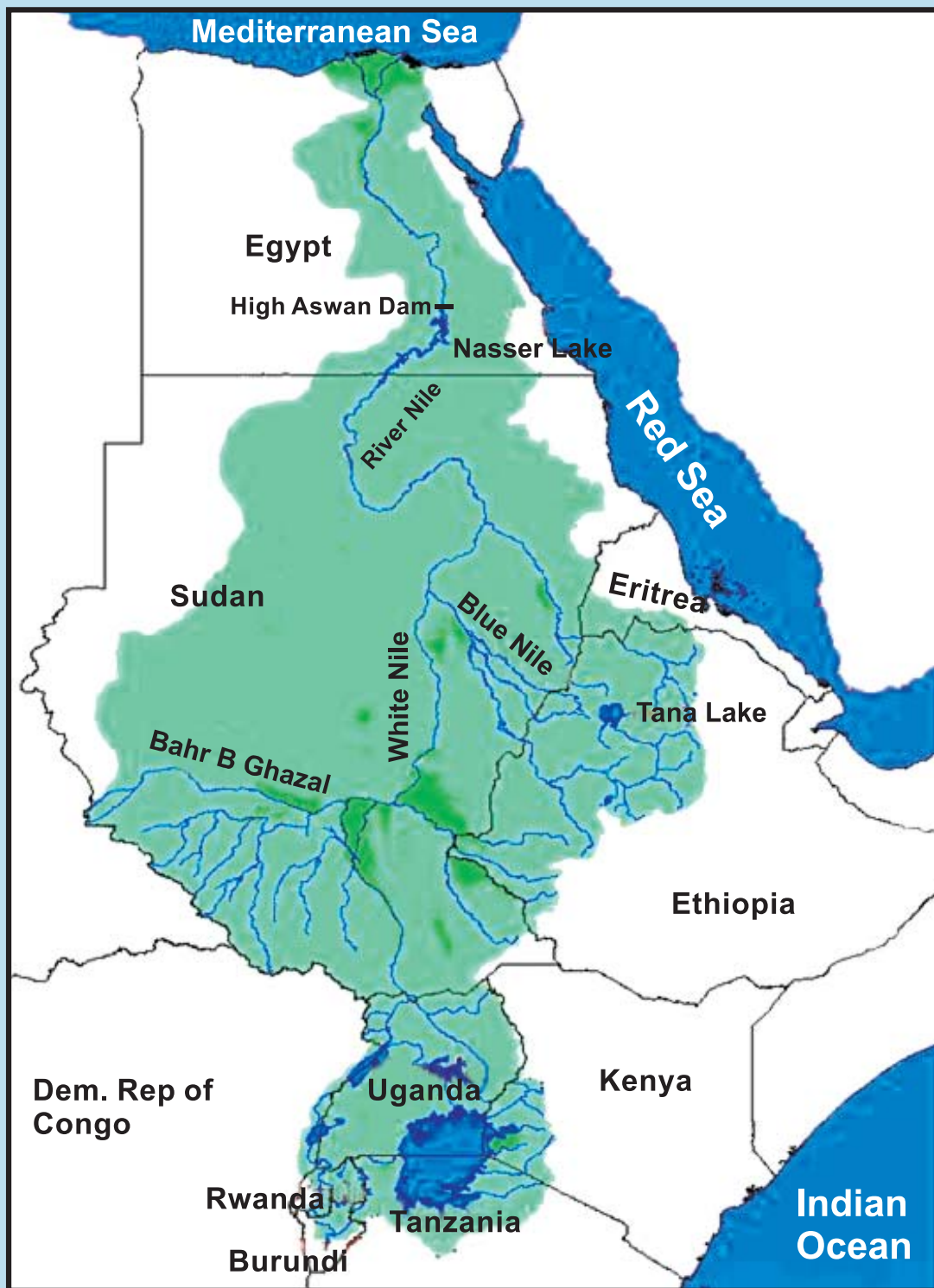


Figure 1. The Nile River Basin

are considered as various water losses at the High Aswan Dam (HAD) reservoir site. Figure 2 depicts the High Aswan Dam.

Egypt is an arid country that receives an amount of rainfall that seldom exceeds 200 mm per year along the northern coast, declines very rapidly from these coastal areas to inland, and becomes almost nil south of Cairo. Also, rainfall along the Mediterranean coast decreases

The groundwater aquifers in the valleys of Sinai are recharged from rainfall and especially from heavy storms. The annual rainfall on Sinai varies from 40 mm to 200 mm/year. Although most of the shallow aquifers in Sinai are renewable, only 10 to 20% of the deep aquifers are recharged by rainfall and flash floods. The total amount of groundwater abstraction in the Western Desert in 1997/98 was estimated to be about 0.817 BCM while it's only 0.09 BCM in Sinai.

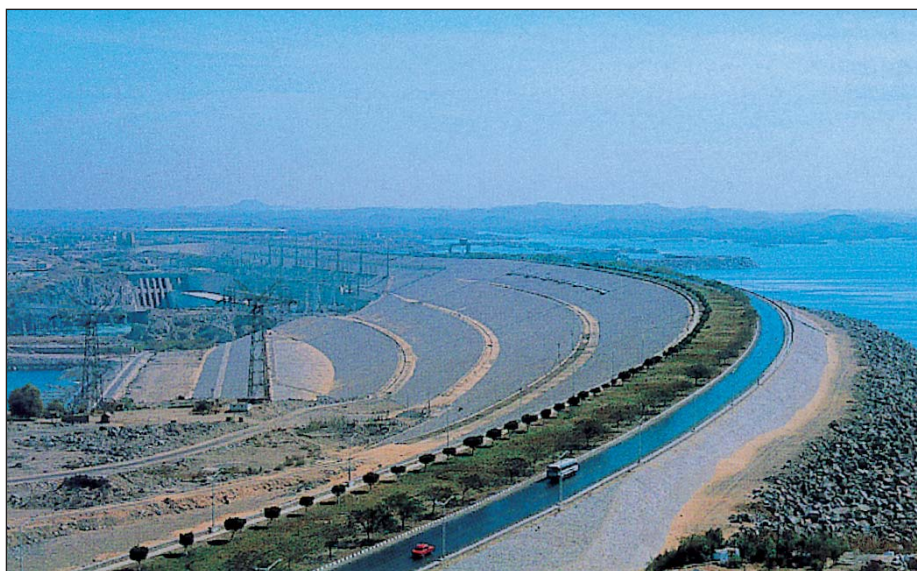


Figure 2. The High Aswan Dam on the Nile River

eastward from 200 mm/year at Alexandria to 75 mm/year at Port Said. The average annual amount of rainfall water that is effectively utilized is estimated to be around 1-3 BCM per year. On the other hand, flash floods occurring due to short-period heavy storms are considered a source of environmental damage especially in the Red Sea area and Southern Sinai. This water could be directly used to meet part of the water requirements or it could be used to recharge the shallow groundwater aquifers.

Groundwater exists in the Western Desert in the Nubian sandstone aquifer, which extends below the vast area of the New Valley Governorate and the region east of Owaynat. It has been estimated that about 200,000 BCM of fresh water are stored in this aquifer. However, such groundwater exists at great depths and the aquifer is generally non-renewable. Therefore, its utilization depends on pumping costs and depletion rate versus the potential economic return on the long run.

Desalination of seawater in Egypt has been given low priority as a water resource because the cost of treatment is high compared with other sources. Desalination is actually practiced in the Red Sea coastal area to supply tourist villages and resorts with adequate domestic water supply where the economic value of the water is high enough to cover the treatment costs. It may be crucial to use such resource in the future if the growth of the demand for water exceeds all other available water resources. However, its use will depend on technological development in this field.

There exist other non-conventional sources of water which include the renewable groundwater aquifer underlying the Nile Valley and Delta, the reuse of agricultural drainage water, and the reuse of treated sewage water.

The groundwater aquifer underlying the Nile valley and Delta is a renewable aquifer. This aquifer can be used

as a source of water to meet part of the water demands at peak periods and then recharged again during low demand periods. Current abstraction from this aquifer is estimated at 6.1 BCM in 1997/98. The amount of water that returns back to drains from irrigated lands is relatively high (about 25 to 30%). The agricultural drainage of the southern part of Egypt returns directly to the Nile River where it is mixed automatically with the Nile fresh water to be used for different purposes in the downstream. The total amount of such direct reuse in addition to unofficial reuse done by farmers themselves, if they are short of canal water, is estimated to be about 4.0 BCM in 1997/98. The total amount of official reuse of agricultural drainage water was estimated to be 3.5 BCM in 1997/98. Reuse of agricultural drainage water is limited by the salt concentration of the drainage water. Therefore, more efficient irrigation, inevitably, leads to the same amount of salt dissolved in a smaller volume of drainage water. That means a more efficient distribution system will result in smaller quantities of reusable drainage water. The total amount of drainage water that was pumped to the sea was estimated to be 15.4 BCM in the year 1997/98.

Treated domestic sewage is being reused for irrigation with or without blending with fresh water. The increasing demands for domestic water will increase the total amount of sewage available for reuse. It is estimated that the total quantity of reused treated wastewater in Egypt is about 1.4 BCM in 1997/98. Table 1 and Figure 3 show the available Water Resources in Egypt in the year 1997/98.

A note on land and water resources of Egypt is kept at Annex 1.

Egypt's water requirements is increasing with time due to the increase in population and the improvement of living

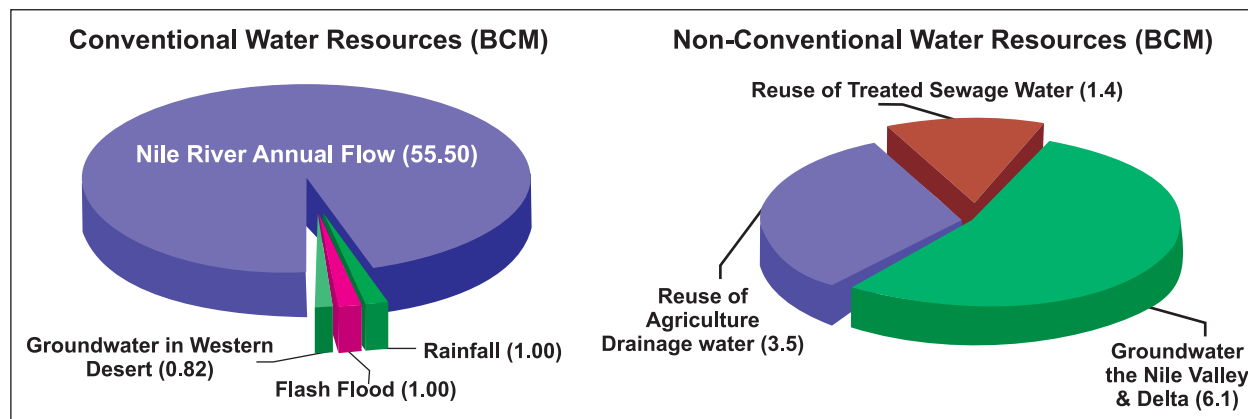
**Table 1. Water Resources of Egypt, BCM (1997-98)**

Conventional Water Resources	
• River Nile Annual Flow	55.5
• Rainfall	1.0
• Flash Flood	1.0
• Groundwater in Western Desert	0.817
Non-Conventional Water Resources	
• Groundwater in the Nile Valley & Delta	6.1
• Reuse of Agriculture Drainage Water	3.5
• Reuse of Treated Sewage Water	1.4

standards as well as the government policy to reclaim new lands and encourage industrialization.

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 the year 1997/98 was estimated to be 36.20 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 1997/98, was about 57.5 BCM. The water policies of the 1970 and early 1980's gave a significant advantage to new lands development.

Egypt's national water balance for the year 1997/98 is illustrated in Figure 4. This figure shows the different water supply sources in relation to the demands. Currently release from High Aswan Dam (HAD) is estimated to be 55.5 BCM.



**Figure 3. Water Resources of Egypt**



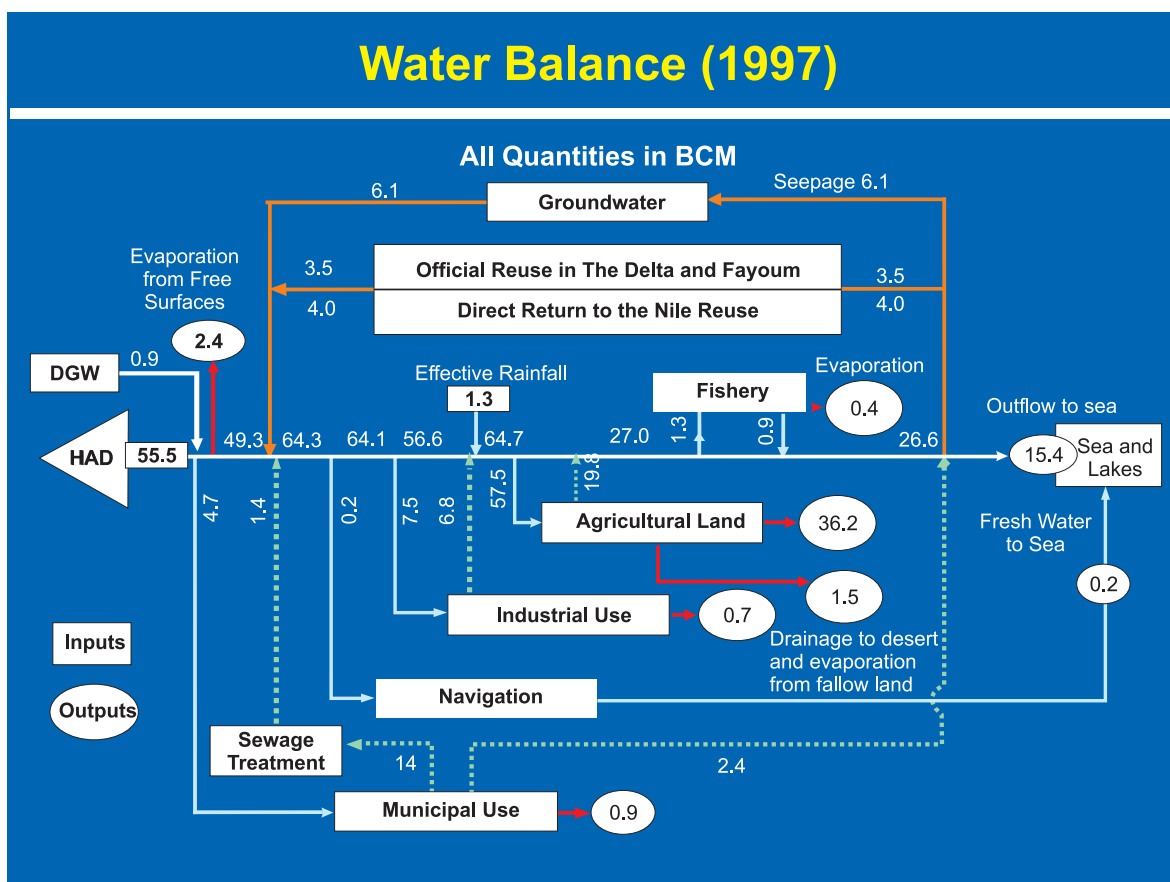


Figure 4. Egypt's National Water Balance for the Year 1997/98

Currently groundwater abstractions from the Nile aquifer amount to 6.1 BCM. An amount of 3.50 BCM of drainage water has been reused either directly or after mixing with fresh water in the Delta.

## 2.2 Population

Population growth is certainly among the most pressing challenges that Egypt is facing in its development. The Central Agency for Public Mobilisation and Statistics (CAPMAS) held its first census in 1960, followed by the second one in 1966. Since then the Population, Housing and Establishments censuses are carried out at 10-year intervals, the latest in 1996. In that year, the total population in Egypt was 59.3 million. By mid-2003 it has increased to 72.5 million (irrespective of nationality, not counting the more than 2 million Egyptians living abroad). The annual population growth rate decreased from 2.8% in the period 1976-1986 to 2.1% in the period 1986-1996, and has decreased further to 1.9% (2003 estimate). In relation to

arable land and water, Egypt's population density is among the highest in the world: 99 % of the population lives in the Nile Valley and Nile Delta, which covers only 4% (40,080 sq. km) of the total area of Egypt, resulting in an average population density of 1,435 persons per sq. km. According to the 1996 census, Greater Cairo had a population of 10.7 million. According to official figures, urbanisation in Egypt had reached 43% by 1996. The population is expected to be about 95 million by the year 2025.

## 2.3 Water for Food

Since 1987, the Ministry of Agriculture and Land Reclamation (MALR) is not interfering with the farmers' crop choice, except for rice and sugar cane. Egypt currently imports about 50% of its wheat and varying proportions of other agricultural commodities and processed food, whereas rice, potatoes, cotton and citrus are exported. Although Egypt is one of the world's largest food importers, this import accounted for only about 27% of the total import bill in 1997 (NWRP, 1999a).

Food self-sufficiency can be defined as the ratio between the production and consumption and can be shown as follows:

$$\text{Food self sufficiency} = \frac{\text{Consumption of food in the country}}{\text{Production of food in the country}}$$

tackled by promoting exports rather than by curbing (food and fodder) imports. Thus, food policy should focus on making the best use of all productive resources, which for agriculture include: land, water, labour, climate and the proximity to vast export markets by growing crops for which it has a comparative advantage (NWRP, 1999a). Figure 5 shows the self-sufficiency in major food items in 2000. It should be noted that the self-sufficiency figures based on

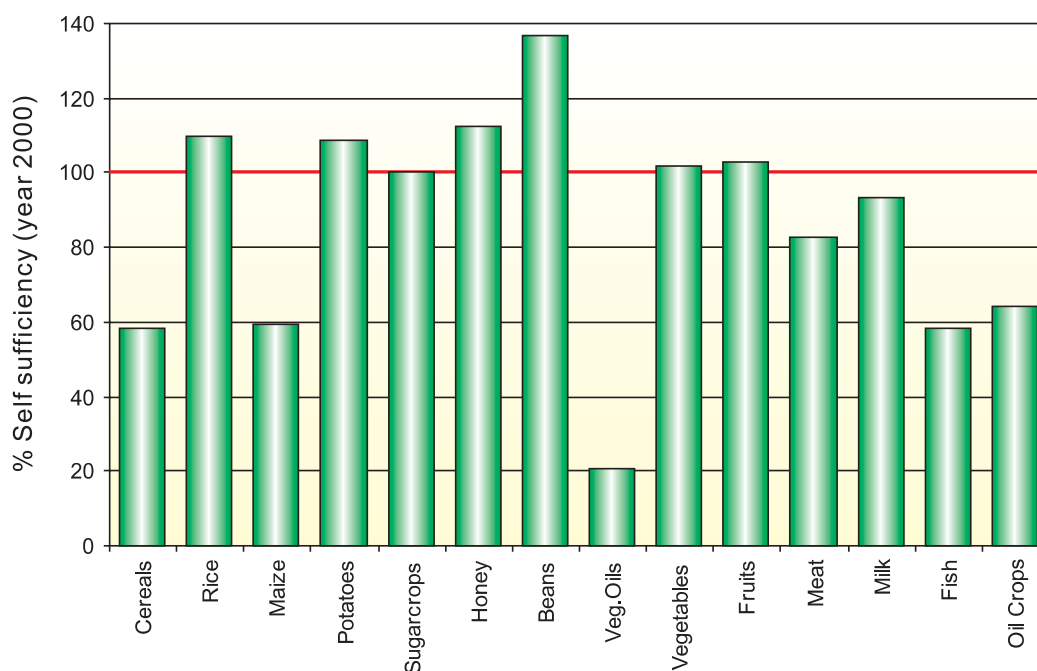


Figure 5. Sufficiency in Major Food Items (2000)

The present agricultural strategy is not based on self-sufficiency but on food security, using Egypt’s competitive advantages (APRP, 1998). Maximising food self-sufficiency in 2017 through measures would result in the production of large quantities of basic staple grains, which are relatively low-value in the international market.

Egypt is increasingly in a position to produce higher value food crops (e.g. fruits and vegetables) and non-food crops (e.g. flax and cotton) and trade them to purchase staples and have additional revenue and employment as well. Maximizing national income is therefore considered a more reliable approach to food security than self-sufficiency. The large discrepancy in the balance of payments between the import bill and export proceeds is probably a larger threat to economic sustainability and thus to food security. This trade imbalance could best be

FAO food balance sheets are somewhat different from those presented here.

### 2.4 Water for People

The supply of sufficient water of good quality is an important element of the national water policy in Egypt. Compared to the agricultural water demand the municipal water demand is small, but given the health aspects involved, this supply will receive priority over all other users. Municipal water demand includes water supply for major urban and rural villages and was estimated as 4.6 BCM in 1999/2000.

A part of municipal water comes from the Nile system and the other part comes from groundwater sources. A small portion of the diverted water (about 1 BCM) is actually

consumed while the remainder returns back to the system. The major factor affecting the amount of diverted water for municipal use is the efficiency of the delivery networks. The studies showed that the average efficiency is as low as 50%, and even less in some areas. The cost of treating municipal water can be reduced significantly if the efficiency of the distribution network is improved upon.

The health aspects are, in particular, important in the urban centres that will grow as a result of the growing population and the increase in urbanization (from 43% in 1996 to estimated 48% in 2017). Cairo ranked 25<sup>th</sup> among urban agglomerates in the world in 1950 with 2.4 million inhabitants, and has moved up to 17<sup>th</sup> in 2000 already. It is projected that the city will be ranked 14<sup>th</sup>, close to Los Angeles, by 2015. Directly related to the supply of drinking water is the collection and treatment of the municipal wastewater.

## 2.5 Water for Nature, including Environmental and Ecological Concerns

The river Nile main channel and part of the irrigation network are being used for navigation. Water demand, specifically for navigation, occurs only during the winter closure period (*when the discharges to meet other non-agriculture demands are too low*) to provide the minimum draft required by ships. This water goes directly to the sea as fresh water. After changing the winter closure system by dividing the country into 5 regions instead of two, the amount of water released for navigation is considered to be insignificant. However, in the year 1999/2000, an amount of 6.517 BCM of fresh water went directly to sea because of the high flood occurred this year and the preceding two years. Due to leakage from barrages gates, fresh water is lost to sea estimated as about 0.26 BCM per year (1995/96).

Although the water quality in the Nile is reasonably good at present, water quality problems do occur locally, caused by effluents from larger urban areas and industries. The water quality conditions in local drains are more severe. Many drains are highly polluted and this poses a direct health risk, especially in and around villages and towns in densely populated rural areas. If no additional measures are taken, the situation in the rural areas will deteriorate seriously in the future; more canals as well as larger parts of

the Nile River could become unsuitable as a source for drinking water.

In the oases, including Fayoum, the drainage water discharges into lakes or evaporation ponds. Although the actual production of pollutants may not be very high, the absence of a drainage outflow creates an accumulation of substances, which results in unhealthy conditions.

Each element of the water system whether it is an input or output has a certain salt concentration. The total salt load input to the system is estimated to be about 19.8 million tons while the total amount of salt leaving the system is estimated at 31.43 million tons. It is obvious that the system is unbalanced concerning salt loads where the output exceeds the inputs by more than 11 million tons. This imbalance might be due to various reasons, e.g. seawater intrusion in Northern Delta is considered a major source of salt loads entering the system

## 2.6 Water Quality

The water quality of the Nile is affected by agricultural drainage water, containing salts, nutrients, pesticides, herbicides, and industrial and municipal effluents from all towns and villages of Upper Egypt that drain either directly or indirectly into the river.

Water quality surveys carried out along the Nile showed that the distribution of the values of quality parameters is nearly uniform from Aswan to Cairo. The suspended sediment concentrations increase gradually along the Nile in the downstream direction. Total Dissolved Solids (TDS) ranges from 130 mg/l in Lake Nasser to 200-250 mg/l at the Delta barrages. The pH increases from 7.7 at HAD to 8.5 in the Nile Delta. The BOD as a result of human activities mainly shows a variable distribution but only occasionally exceeds the standard (especially in the downstream sections) of 6 mg/l. The variability is the result of point discharges and self-purification of the river. As a result the dissolved oxygen only drops in exceptional cases below the limit of 5 mg/l. Nitrate and ammonium hardly exceed the current standards, except for ammonium at one location in Upper Egypt. The spatial distribution of fecal coliform varies strongly. The standard is significantly exceeded during the summer months at a few locations in Upper as well as Lower Egypt.

So far the Nile is observed to maintain its self-purification capacity. However, significant amount of pollutants loads are released to drainage and irrigation systems. The extent of the sediment contaminated due to pollutants accumulation, is not accurately quantified. In the Nile branches the water quality deteriorates in a northward direction due to disposal of municipal and industrial effluents and agricultural drainage as well as decreasing flow.

Irrigation canals have sparsely been covered by water quality monitoring since they are supposed to have a quality similar to that at the point of diversion from the Nile. Some of these canals are major sources for downstream drinking water treatment plants. However, many canals are suffering from the following inputs:

- ❑ Industrial and domestic wastes (liquid and solid) from canal banks, as in the case of the Mahmoudia and Ismailia canals.
- ❑ Residuals from fertilizers, molluscicides (snail killer, for instance for the control of Bilharziasis) and herbicides which find their way to the irrigation water system.
- ❑ Agricultural, domestic and industrial wastewaters at locations where reuse pump stations add drainage water to the canals.

The open drain system receives the excess irrigation water that flows through the soil or via sub-surface drainage systems. The quality of drainage water is affected by the type of soils, toxic substances used for pest or herb control and domestic effluents from the banks. Most of the drainage system of Upper Egypt discharges the wastewater in the river Nile, while most of the drains in the Delta ultimately discharge into the Northern Lakes and the sea.

## 2.7 Institutional Framework for Water Resources Development and Management

Egypt is administratively divided into 26 Governorates. While, irrigation system in Egypt is divided into 18 Central Directorates (CD). Each CD represents Ministry of Water Resources and Irrigation (MWRI) in the region under its control where it is responsible for managing all water resources aspects under the supervision of the Irrigation Sector in the Ministry's Headquarters. Each CD includes one or more General Directorate of Irrigation (GD). There are 27 GDs covering all Nile Delta and valley governorates where each governorate is represented by one or more GD depending on the complexity of its local irrigation network.

The boundaries of the GDs are defined by specific control structures on the irrigation network; therefore, it is different than the administrative boundaries of the governorates. The organization chart of Ministry of Water Resources and Irrigation (MWRI) is shown in Figure 6.

There is one Central Directorate for Water Distribution (CDWD) under the Head of the Irrigation Sector. The main function of CDWD is to coordinate with all the Central Directorates for water resources and irrigation all over the country to estimate the annual water requirements for different uses at the Irrigation Directorates' level. These requirements are then transferred to a water budget for each Irrigation Directorate and accumulated together to estimate the annual water requirement for Egypt. Subsequently, the CDWD transfers these requirements to a schedule of 10-days period releases from High Aswan Dam and specific control structures on the irrigation network that separate between the GDs. The High Aswan Dam Authority is responsible for operating the HAD to meet these planned releases and communicate on a daily basis with the CDWD to adjust the daily releases from HAD based on the actual requirements. The Drainage Authority is responsible for maintaining the drainage network and implementing the new drainage projects to upgrade and enhance this network. The Mechanical & Electrical Department is responsible for operation and maintenance of the irrigation and drainage pump stations according to the schedule of releases prepared by the CDWD.

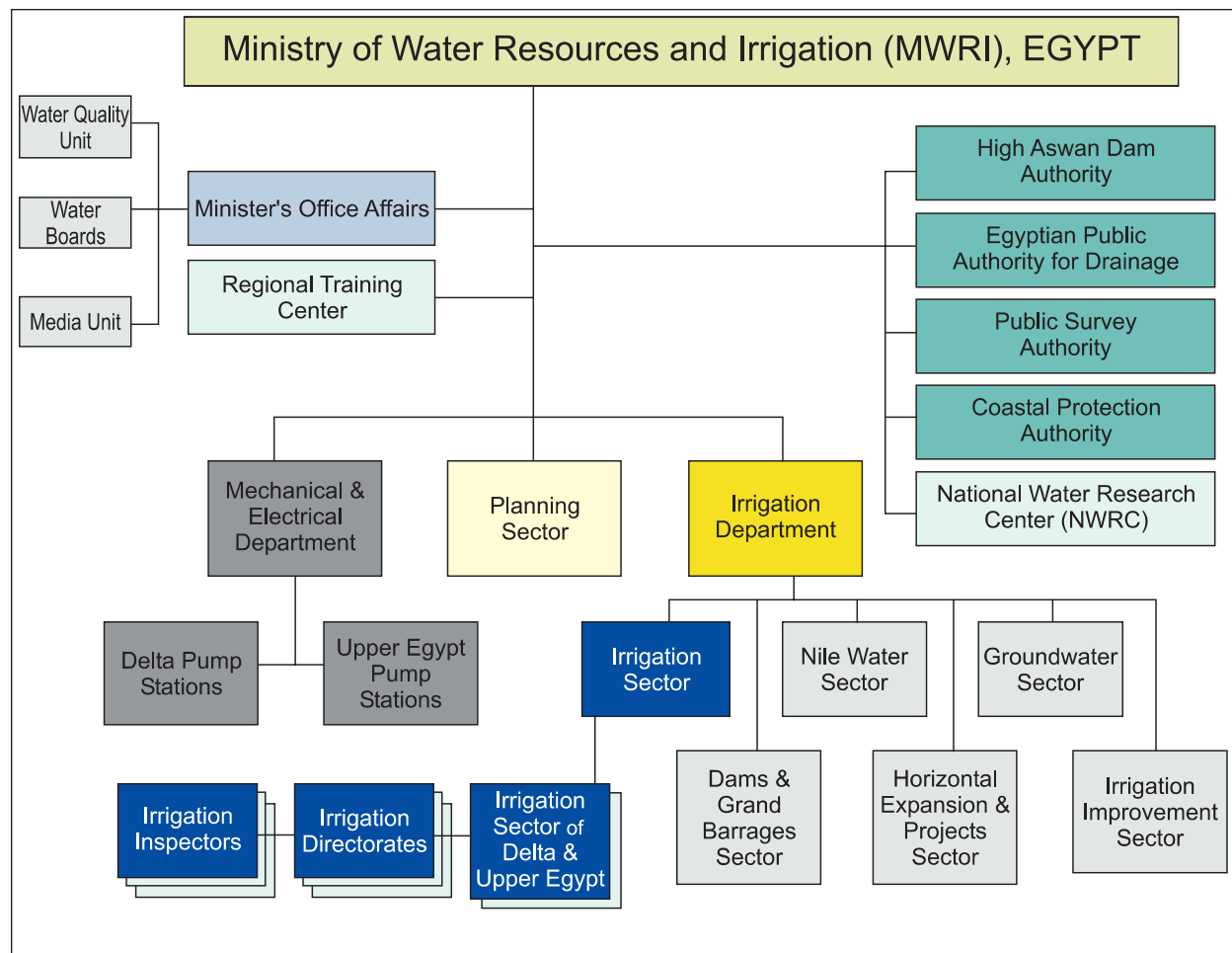


Figure 6. Organization Chart of Ministry of Water Resources and Irrigation (MWRI), Egypt

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## CHAPTER 3

# POLICIES AND VISION FOR INTEGRATED WATER RESOURCES MANAGEMENT IN EGYPT

### 3.1 Water Policies in Egypt

After the completion of the High Aswan Dam, a series of water resources policies have been developed in Egypt to have better management of the available water resources in order to match the currently and projected water supply and demand for all sectors. Most of the national water policies were not flexible, consequently, they could not cope with uncertainties. One source of uncertainty is the lack of provisions in addressing future changes in these policies - whether in technology or in the country's priority issues that may affect the behavior of water users. One of the major changes was the government decision to shift from the central planning economy to the free market economy allowing free cropping patterns based on market needs. Another source of uncertainty is nature itself. These policies could not reflect changes that happen naturally like long spells of drought or floods. One technique that copes with uncertainties in forecasting and estimating policies is to generate different scenarios, which simulate the different changes that may occur in the future and estimate different values for policy parameters. Therefore, the policy will have different scenarios reflecting the different predictable changes.

Several policies have been formulated in Egypt to manage the water resources. Following is a list of these policies since 1975 till 2002.

- Water Policy for the year 1975
- Water Policy for the year 1980
- The Egyptian Water Master Plan, year, 1982
- Water Policy for the year 1986

- Water Policy for the year 1990
- Water Security Project, 1993
- Water Policy for the year 1999
- The National Water Resources Policy, 2002 (NWRP)

### 3.2 National Water Resources Policy (NWRP, 2002)

A few years ago, attention was mainly given to 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 challenges. A more integrated management approach requires much closer coordination among concerned government institutions and the active participation of water users in planning, management and operation of water collection and distribution systems. It also necessitates the establishment/enhancement of the legal basis for water allocation, conservation and protection as well as user participation in water management.

Training and capacity building of the MWRI and other stakeholders is also essential to face these challenges, and to be able to manage the ongoing, as well as the anticipated reform activities of the water policies. To cope up with these challenges, the MWRI has developed a national policy with three major pillars viz. 1) increasing water use efficiency; 2) water quality protection; and 3) pollution control and water supply augmentation.

The National Water Resources Plan describes how Egypt will use its water resources in a sustainable and responsible way from a socio-economic and environmental point of view. The planning horizon covers a period of 20 years since the start of the project in 1997 i.e. the year 2017. With the rapid growth of population and new land development for agriculture, there is a threat of more pollution. There is a need therefore to (i) reduce water use (demand management), (ii) optimize the supply (supply

management), and (iii) abate water pollution (pollution control).

The Draft Plan also comprises of an investment plan, completed in March 2004. The Plan addresses all water related activities and considers both the technical, managerial and institutional interventions. Important decisions on allocation of resources and priority setting of interventions are indicated.



## CHAPTER 4

## POSSIBLE APPLICATIONS OF THE BHIWA MODEL TO EGYPT

## 4.1 Inception Workshop

The Egyptian National Committee on Irrigation and Drainage (ENCID) organized a workshop on 3<sup>rd</sup> August 2004 to present and discuss the results of the application of the BHIWA model in the different river basins of India and China. The main recommendations of this workshop were as follows:

- Formulating a Task Force to evaluate the BHIWA model according to the Egyptian Conditions, and
- Inviting stakeholders to a another workshop to discuss the ability and the constraints of applying the BHIWA model in Egypt

A list of presentations made in the Inception Workshop is given in Annex II. A list of participants in the Workshop is kept at Annex III.

## 4.2 Orientation Workshop

An orientation workshop on CPSP was held in Delhi, India from 12 to 17 December 2004. Representatives from the National Committees of India, Egypt and Mexico participated in the workshop. The 'CPSP India Study Team' presented the structure of BHIWA model and illustrated its calibration procedure. The participants from Egypt, Mexico and Pakistan presented the general status of the water resources and water policies in their respective countries. CPSP-India Study Team explained the data organization and preparation for BHIWA model followed by its application to Sabarmati basin. The participants from Egypt and Mexico performed simple applications of BHIWA model on their choice basins. The preliminary results of the application were reviewed and the possibility of an extrapolation of basin assessment to country scale was discussed. Identification of policy options at country level for Mexico, Egypt and Pakistan were also discussed

in a preliminary manner. However, it was concluded that the BHIWA model in a preliminary manner its current formulation may not capture some of the peculiar characteristics of the Egyptian water resources system particularly the drainage and reuse of drainage water.

## 4.3 Task Force Findings

Task Force comprising experts on planning and management water resources was formulated according to the recommendation of the first workshop held in Cairo in August 2004. This Task Force concentrated on the applicability of BHIWA model to Egypt. A detailed documented report containing description of the model (structure and mathematical formulation, inputs, outputs, software platform and finally its capabilities and limitations) was prepared for the consideration by Task Force Experts.

## 4.3.1 Capabilities of the BHIWA Model

The Basinwide Holistic Integrated Water Assessment (BHIWA) model is capable of capturing the hydrologic effects of land use changes and the resulting changes in the water regimes of the basin (surface water and groundwater). Annex IV gives a brief of the BHIWA model.

The capabilities of the BHIWA model, in a nutshell are:

- Modelling in a simplified way the entire land phase of the water cycle including the anthropogenic changes through surface and ground water withdrawals for meeting the requirements of agricultural, domestic and industrial water uses and the return of the unused water to the surface and ground water.



- Accounting for evapo-transpiration by the use sectors, and further categorising it as beneficial and non-beneficial component.
- Calculation of surface and groundwater balances separately and allowing depiction of interaction between them as well as impacts of storage and depletion through withdrawals.

#### 4.3.2 Limitations of the BHIWA Model

BHIWA model, as adopted currently, suffers from limitations due to its mathematical formulation and software platform. Although the model uses numerous land use parcels, it is not a distributed model. It does not depict the spatial variation within sub-basins for different parcels with same land use. The model does not depict the water quality and takes it into account only indirectly in terms of proportion of flows. Evaluation of the water and land use policy impacts takes place in the hydrologic domain. Other domains such as socio-economic and environmental domains need to be considered as well.

The use of Microsoft EXCEL as a software platform for the model development is very limiting compared with object oriented simulation software like STELLA. Since the flexibility to make changes to the model is very limited its usability in terms of changing system configuration is difficult

#### 4.4 National Consultation

A national level consultation was held on 26<sup>th</sup> February 2005 in Cairo. A variety of stakeholders were invited to this workshop. The main objectives of the workshop were as follow:-

- To present the BHIWA model with emphasis on its capabilities and the limitations, and
- To collect feed back of the participants on future application and the development and use of the model to suit the Egyptian conditions.

A list of participants, group formation in the Consultation is shown in Annex V and VI, respectively. Questions posed as regards the applicability of the BHIWA model under Egyptian conditions is given in Annex VII.

The main conclusions of the workshop were as follow:-

- The model in its present form is not able to capture and simulate all the components of the Egyptian

water resources system due to the absence of several other important components (e.g., irrigation and drainage interaction besides socio-economic, aqua-cultural, and other changes);

- The current model outputs and indicators therefore may not be sufficient for evaluating the water resources policy interventions in Egypt; The environmental and socio-economic aspects and the drainage water re-use and farm management in particular are the more prioritized items for the development of the policies.

The specific recommendations were as follow:-

- The optimal and most suitable geographic coverage of the application of the model could be at the national scale and for the whole Nile basin for the long term future;
- The spread sheet platform is not adequate for the future modifications so it is recommended to use kind of object oriented language program or other advanced programming languages such as (C++, Stella,...etc);
- The strategic research unit (SRU-NWRC) and the planning section of the Ministry of Water Resources and Irrigation may be entrusted with the application of this model (or any other model that may be developed) to meet special requirements of Egypt.

#### 4.5 Conclusions and Recommendations

1. There was a difficulty in applying the BHIWA model under Egyptian conditions as the model is to be used for an entire basin and not to be used separately for each sub-basin. In the present version, division into five sub-basins is provided for. The connectivity amongst the sub-basins can be prescribed. However, the Nile basin is too large and interest of ENCID was to model the water situation in Egypt alone, without modeling whole basin. Some modifications in the model to allow modeling of a part of the basin would however, be desirable.
2. In Egypt, the environmental concerns are receiving high priority. Although, the BHIWA model can consider the monthly EFR requirements as prescribed by the user, it cannot internally estimate these requirements. The development of a separate model for this purpose would be beneficial.
3. The BHIWA model as currently available provides

for returns for irrigation into the river and groundwater system. However, in Egypt, there are proposals for directly using the returns by diverting the drainage water without allowing to flow into the river system. A slight modification of the model may be required to depict such possibilities.

4. ENCID is of the opinion that for understanding the policy related issues, it is necessary to model the socio-economic components, aqua-culture components, the water needs of the livestock, the climate change possibilities, and the financial implications of alternative water development. The BHIWA model considers the livestock water requirement. Climate change can be externally specified by prescribing different rainfall and evapotranspiration needs and by prescribing changed water inflow situation to the country (water transfers) and outflows, if any.
5. ENCID recognizes the strength of the BHIWA model, generally. The model is simple to use, the software platform is inexpensive and accessible, and the model considers the surface water and groundwater in conjunctive use explicitly by modeling the interaction. It considers the demand of the three main use sectors viz. nature, food and people. The model can give answers to future scenarios in which the water availabilities, water demands and the water allocated to these sectors could be much different from the present. ENCID also recognizes that data requirements are simple and data can be obtained from several organizations in Egypt.
6. Although, BHIWA model is a broad model for checking different future water scenarios and water management strategies, it is not a detailed basin-wise water management model. ENCID has a particular interest in obtaining or developing such a detailed basin-wise water management model. Such a model could be based on a GIS platform. ENCID's another concern is regarding re-allocation of water under extreme hydrologic events. This concern is currently not being answered by the BHIWA model.
7. The CPSP study reports pertaining to India and China clarifies that the BHIWA model is not supposed to be used as a detailed basin planning and management tool. For this purpose, detailed model somewhat in line with Decision Support

Systems Model of the type of IWRMESD or the model based on GIS platform could be used. A note on 'IWRMESD for Sustainable Development of Egypt' is kept at Annex VIII. However, for broadly understanding the implications of large future changes, such as large changes in land and water use in upper parts of the basin, different provisions for environmental flows, change in strategies for using internally generated water resources of Egypt etc., the BHIWA model could be of considerable use. In this regard, ENCID has considered three alternatives as briefly stated in following para.

#### 4.6 The Way Forward

It is suggested to apply the BHIWA model on the Nile Delta and Valley (35,000 sq.km.). The BHIWA model may be utilized to simulate alternative development scenarios and management policies and evaluating their impacts on the surface and groundwater regime. The total study area can be divided into five sub-basins: East Delta, Middle Delta, West Delta, Lower Egypt, and Upper Egypt. Application of the BHIWA model could take different alternative routes as briefly stated below:

The *first alternative* is to apply BHIWA with some minor adjustment to the mathematical formulation and utilization of the Excel platform with no modification. This alternative will utilize the BHIWA with its limitations and will not take into account the accumulated modeling experiences that were developed over years in MWRI in utilizing other mathematical models, where more Egyptian planning detailed and operational models have been developed. Examples of these models are: Agro-economic model, Operational Planning Distribution model, SIWARE, RIBASIM, IWRMESD, and others. Most of these models utilize and include more advanced concepts and methods (suiting to Egyptian conditions) than what have been used in BHIWA, including the software platform.

The *second alternative* is to strengthen the BHIWA to provide greater flexibility to deal with more complex hydrologic, irrigation and drainage systems and concepts. This can be done through reviewing the available models to extract the useful concepts, indicators, estimation methods. These methods and indicators will be incorporated into BHIWA mathematical formulation without jeopardizing the BHIWA simplicity. Such modifications can be implemented through the current MS Excel platform with introduction of some automated macros and interfaces that can facilitate the user's mission.

Although this alternative will strengthen the BHIWA mathematical capabilities and adaptation to the Egyptian conditions, it will have its limitation concerning the use of Microsoft excel as a software platform for model development. The flexibility to make changes to the excel version of model is however very limited. Its reusability in terms of changing data or applying it to other basin is difficult.

The *third alternative* is to redevelop the modified model in an object oriented environment which can enhance the basic concepts of the BHIWA model and its reusability and expandability. This alternative will not only adapt it to the Egyptian conditions but it will add socio-economic and other advanced features for a more comprehensive assessment. However, it will require more time and resources to be implemented compared to the other two alternatives. Therefore, it is recommended to formulate a project for implementing this alternative where it can provide all the required resources for its implementation. The final product of this project will be an advanced version of the BHIWA model that will be

tested and verified on all the 5 Egyptian regions, as identified. Another major output for this project will be a well trained Egyptian staff on the operation and maintenance of that model.

This project considers the technology transfer and training component to be a key activity in its framework. In general, technology transfer refers to all activities related to the transfer of knowledge and skills, in combination with available tools, to Institutions and individuals. The main objective of the training and technology transfer in this project is to establish a well trained operational and sustainable tool.

This tool is capable to test the various scenarios and their impacts on the water resources management in Egypt. The training and technology transfer activities may include: i) institution support to different sectors of the MWRI, ii) practical on – the – job – training , and iii) joint execution of the project. A chosen alternative can be implemented in the Phase II of the CPSP. The proposed activities for CPSP phase II are outlined in Annex IX.



## ANNEXURES

### ANNEXURE I

#### A NOTE ON LAND AND WATER RESOURCES OF EGYPT

In Egypt, being an arid country with hardly any rainfall, water management is of particular importance. Water management aims to develop and protect the resource. Without a proper management, water will become a constraining factor in the socio-economic development of the country.

The government of Egypt is committed to develop and manage its water resources in the interests of the country. To this end the Ministry of Water Resources and Irrigation (MWRI) has since many years developed water policies and guidelines for this management. These policies and guidelines are dynamic in nature to allow for changing conditions. The underlying **National Water Resources Plan** provides an update of earlier policies and plans. The intention of this plan is to guide both public and private actions in the future for ensuring optimum development and management of water that benefits both individuals and the society at large. It is based on an Integrated Water Resources Management approach, which makes this plan a real national plan and not only a plan of the MWRI. The policy aspects involved in this plan are highlighted in a separate **Policy Document** which will be discussed in Parliament and which will provide binding objectives and guidelines for all Ministries and other Governmental Agencies.

#### Integrated Water Resources Management

In line with current global thinking on how to solve present water resources problems, Egypt has adopted an Integrated Water Resources Management (IWRM) approach. IWRM is defined as a process which promotes the coordinated

development and management of water, land and related resources, in order to maximize the resulting economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. IWRM is based on several principles. Implementation of these principles is situation and culture dependent. In the context of Egyptian water management the following principles in particular are important:

- Fresh water is a **finite and vulnerable resource**, essential to sustain life, development and environment; it should be considered in a holistic way, simultaneously taking into account quantity and quality, surface water and groundwater; and
- Water development and management should be based on a **participatory approach**, involving users, planners and policy-makers at all levels.

Adopting an IWRM approach means that this National Water Resources Plan is oriented towards the socio-economic development goals of Egypt and, besides direct water needs, also addresses issues such as health, employment and general well-being of the people. Representatives of relevant stakeholders have been involved in developing this plan, both at a horizontal level (the various Ministries involved) as well as vertically (Governorates, Water Boards, various User Groups, etc.).

#### The Challenge

The growing population of Egypt and related industrial and agricultural activities have increased the demand for water to a level that reaches the limits of the available

supply. The population of Egypt has been growing in the last 25 years from a mere 38 million in the year 1977 to 66 million in 2002 and is expected to grow to 83 million in the year 2017. The present population of Egypt is strongly concentrated in the Nile Valley and the Delta. Ninety nine percent of the population lives on 4% of the land of Egypt. To relieve the pressure on the Nile Valley and Delta, the government has embarked on an ambitious programme to increase the inhabited area in Egypt by means of horizontal expansion projects in agriculture and the creation of new industrial areas and cities in the desert. All these developments require water.

However, the water availability from the Nile River is not increasing and possibilities for additional supply are very limited. Up till now Egypt had sufficient water available and the current management is very successful in distributing the water over all its users. Thanks to the enormous capacity of Lake Nasser to store water, the supply of water to these users is every year guaranteed and nearly constant. Now that Egypt is reaching its limits of exploiting available water, the country will have to face variable supply conditions.

Moreover, the population growth and related industrial developments have resulted in a severe pollution of the water. This pollution is threatening public health and reducing the amount of good quality water even further. Major programmes are already being implemented to provide good drinking water to the population and to treat domestic and industrial sewage water. Still, those programmes are not sufficient yet and water quality in many areas is below standard.

The government of Egypt has to face these challenges. It will have to further develop its activities to improve the performance of the water resources system, to ensure that the national economic and social objectives are achieved and that environment and health are protected.

The Ministry of Water Resources and Irrigation plays a key-role in the development and management of the water system in the country. This plan tries to achieve the national objectives by developing new water resources, improving the efficiency of the present use and to protect environment and health by preventing pollution and by treatment and control of polluted water. Many of these activities are carried out in co-operation with other ministries such as the Ministry of Agriculture and Land Reclamation, the Ministry of Housing, Utilities and New Communities, the Ministry of Health and Population and the Ministry of Environment.

### The Main Issues

The main issue involved is how Egypt can safeguard its water resources in the future under the conditions of a growing population and more or less fixed water availability. Assuming that all available additional resources will be developed, the main questions with respect to water quantity that have to be answered are:

- How can the efficiency of the various uses be increased?
- How can the agricultural expansion policies of the government be supported and what are the priorities and limitations in this expansion, given existing water resources, optimum efficiency and priority for drinking and industrial water use?
- How should Egypt manage its water resources system under variable supply conditions?

With respect to water quality, health and environmental aspects the key questions to be answered are as follows.

- What is the best mix of prevention, treatment and protection measures that result in a water quality that complies with reasonable standards?
- What is the level of investment needed to provide all people with safe drinking water and adequate sanitation facilities?

Implementation of the answers to these questions leads to the following institutional question:

- What institutional mechanisms should be developed that can best cope with the increased pressure on the water resources in the country?

### The Strategy - Facing the Challenge

The National Water Resources Plan is based on a strategy that has been called '**Facing the Challenge**' (FtC). The FtC includes measures to develop additional resources, make better use of existing resources, and measures in the field of water quality and environmental protection.

The possibilities to develop **additional resources** are limited. Deep groundwater withdrawal in the Western Desert can be increased to 3.5 BCM/year, but, being fossil water, this is not a sustainable solution and should be carefully monitored. Small amounts of additional resources can be developed by rainfall and flash flood harvesting and the use of brackish groundwater. Co-operation with the riparian countries of the Nile Basin may eventually lead to additional inflow into Lake Nasser.

**Measures to make better use of existing resources** aim at improving the efficiency of the water resources system. They include a careful evaluation of planned horizontal expansion projects and a scheduled implementation of the projects in relation to the availability of water. The water use efficiency in agriculture can be improved by many measures, in particular by continuing the Irrigation Improvement Project (IIP) and Drainage Improvement activities and by reviewing the present drainage water reuse policy, e.g. by applying intermediate reuse and by allowing the use of water with a higher salinity content. Moreover, a different water allocation and distribution system that will be based on equity will decrease the losses in the system. To implement such a system and to improve operation and maintenance (O&M) it will be required to have a good institutional structure with strong Water Boards and Water Users Associations. The municipal and industrial water use efficiency can be improved by a mix of infrastructural and financial incentives or measures. Various research topics are formulated to identify further options to increase the efficiency of the system.

The strategy on **protecting public health and environment** includes several packages in which infrastructural, financial and institutional measures are combined. Priority is given to measures that prevent pollution. This includes reduction of pollution by stimulating clean products and relocation of certain industries. Agriculture will be encouraged to use more environmentally friendly methods and products. If pollution can not be prevented, treatment is the next option. The plan includes a considerable increase in treatment of municipal sewage and wastewater. Domestic sanitation in rural areas requires a specific approach. In both cases cost recovery is needed to maintain the services. The last resort will be to control the pollution by protecting the people and important ecological areas from direct contact with this pollution. Additional attention is required to protect sensitive areas, e.g. around groundwater wells and intakes of public water supply.

The strategy also includes a number of general **institutional measures**. The already initiated process of decentralisation (to Water Boards) and privatisation will be strengthened, including a restructuring of the role of MWRI, e.g. by establishing integrated Inspectorates at local level. Cost-sharing and cost-recovery mechanisms will be implemented to make the changes sustainable, in particular with respect to operation and maintenance. The planning

process at national level will be continued as an ongoing exercise, including the improvement of data and information exchange among different authorities and the co-ordination of investments. Finally, the role of the real stakeholders in water resources management, i.e. farmers and citizens should be enhanced by involving them better in the various water management tasks but also by strengthening their 'ownership' feelings towards public property. The specific role of women in water management issues is acknowledged and receives special attention.

#### **Expected Results of the New National Water Resources Plan**

Implementing the strategy '**Facing the Challenge**' will improve the performance of the water resources system. More water will be available for the various uses and the water quality will improve significantly. The agricultural area will increase by 35% as a result of horizontal expansion and the two mega projects in Toshka and the Sinai. Living space in the desert will be created for more than 20% of the population as a result of these projects. The implementation of the strategy will support the socio-economic development of the country and provide safe drinking water to its population. The access of the population to safe sanitation facilities will double from the present 30% to 60%, thus safeguarding the objective of water supply up to the year 2017.

However, at the same time it should be realized that by implementing all these measures, in particular all the planned horizontal expansion projects, the water resources system has reached its limits of what it can support. Water availability per feddan and average cropping intensity are already decreasing. Moreover, farmers should expect that the year-by-year availability of water will be more variable than has been the case so far. This is not very particular in Egypt only, farmers all over the world are dependent on the variability of rainfall and river discharges. The management of the system should be adapted to cope with this variability.

The strategy FtC follows an integrated approach to cope with this increasing pressure on the water resources system in Egypt and contains a wide range of measures and policy changes up to the year 2017. It is a real challenge to implement this strategy. Further development of the system after 2017 may require that some drastic policy decisions are made at the national level, e.g. accepting some limitations in growth of the agricultural sector and increasing the developments and corresponding

employment in the industrial and services sectors. An increase in the Nile water supply will ease the situation somewhat and should be pursued. A limited increase is not unrealistic, either as a result of water conservation projects in Sudan, changes in reservoir operation of Lake Nasser or (in the very long run) as a result of climate change.

The integrated approach of FtC assumes that all measures are indeed implemented. Failure to implement some measures may have severe consequences for the overall strategy. This is in particular the case for the expected improvement of the water quality. An insufficient improvement of the water quality will mean that the increase in reuse of water will be much less than expected with the consequence that there will be less water available for agriculture, leading to even less water available per feddan and a further lowering of cropping intensities.

### The Implementation of the Strategy

The strategy FtC will be implemented till 2017. Many stakeholders are involved in this implementation process and the National Water Resources Plan provides the guidelines for this process. The actual implementation will be done by the various stakeholders. They will translate FtC into concrete actions to be included in their regular 5-year and annual planning cycles. A National Water Council will monitor the progress and coordinate activities where needed.

The total investments needed in FtC amounts to BLE 145 for the period 2003-2017. The major shares in this investment are taken by the Ministry of Housing, Utilities and New Communities (63%) and the Ministry of Water Resources and Irrigation (32%). The private sector will take care of about 5% of these investments.

The total recurrent costs in the same period 2003-2017 are BLE 41. These costs include the operation and maintenance costs of the system but exclude the personnel costs of the government agencies. The municipalities take by far the biggest share of the O&M costs (70%) for the operation and maintenance of the drinking water treatment plants and the waste water treatment plants. The Ministry of Water Resources and Irrigation will cover 12% while the private sector will take care of about 15%.

### Required Institutional and Social Setting

Implementing the strategy FtC is much more than just applying some technical measures. Technical measures are

needed and are very essential. Drinking water purification plants and wastewater treatment plants have to be built, the Irrigation Improvement Project (IIP) has to be continued and many other technical and managerial actions should be taken. However, these actions will only be effective and sustainable if they are placed in an institutional and social setting that supports these measures.

First of all a proper **enabling environment** is needed. This enabling environment is basically formed by the national and regional policies and legislation that enable all stakeholders to play their respective roles in the development and management of the water resources; and the fora and mechanism, including information and capacity building to facilitate and exercise stakeholder participation. The role of the government is crucial in this respect. The traditional prescriptive, central approach should be replaced by the creation of a framework within which participatory and demand-driven sustainable developments can take place. This includes decentralisation and privatisation while the national government would act more as regulator and controller. Water legislation should be developed to enable this changing role. Further development of Water Boards and Water Users Associations is important and will be pursued. Finally, the political will should be there to enforce these developments.

Second, the **institutional roles**. In such a changing institutional environment the role and functions of the organizations at different levels should be clearly described. This includes the creation of effective co-ordination mechanisms between the different agencies and the development of financial structures that enable these agencies to perform their task efficiently. The Institutional Reform Unit established within MWRI will play a major role in this respect.

Finally, the more traditional **management instruments** will have to be developed further. This includes the technical and economic measures described above for developing new resources, making better use of existing resources and measures to protect health and environment. In addition, this includes a continuous assessment of supply and demand and the further development of advanced research and a water resources knowledge base in the various ministerial research institutes. ■

## ANNEXURE II

### LIST OF PRESENTATIONS IN THE INCEPTION WORKSHOP

No.	Title of Presentation	Name of the Presenter (s)
1.	Future Role of Water Management in Food Production and Sustainable Rural Development	Er. M. Gopalakrishnan
2.	Egypt's Water Resources Assessment, Policies and Applicability of CPSP	Dr. Mohamed Hassan Amer, and Dr. Maha Tawfik
3.	CPSP Water Resources Assessment Model and its Application	IAH-ICID Team
4.	Egyptian Water Policies: 1939 to 2017	Dr. Hussam Fahmy
5.	Presidio River Basin: A Proposal from MXCID for CPSP	Dr. Jaime Collado
6.	Integrated National Water Resources Plan in Egypt	Dr. Hussein El-Atfy
7.	Regional Center for Training and Water Studies	Dr. Dalal El-Naggar
8.	NWRP-Decision Support System (NWRP-DSS)	Dr. Nader El-Masry



### ANNEXURE III

#### LIST OF PARTICIPANTS IN THE INCEPTION WORKSHOP

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## ANNEXURE IV

### BRIEF DESCRIPTION OF BHIWA MODEL

#### INTRODUCTION

Basin-wide Holistic Integrated Water Assessment (BHIWA) model was developed as a part of the ICID's 'Country Policy Support Programme (CPSP)'. The model is useful for water policy planners and other professionals who are interested in projecting the water scene at basin level under different policy options / philosophies for use of water and related resources. The model considers the entire water cycle and takes into account all types of water uses. Once the model is calibrated, it enables the user to analyse scenarios of water resource development and management with respect to policy options at river basin scale. The model has been conceived mainly to address the issues of integration of water use under the three sectors namely water for nature, water for people, and water for food. The model has been developed using MS Excel as well as in Visual Basic to run on a personal computer.

The model runs on a simulation mode and does not enable users to directly set targets/goals. However, scenarios can be developed in terms of changes in land use, crop areas under rain fed and/or irrigated agriculture, cropping patterns, irrigation efficiencies, imports and exports of water, surface (reservoirs) storage, source-wise (surface and groundwater) withdrawals, etc. By simulating past conditions of little or no water use in the basin, the model can also help in setting up minimum reference flows for maintenance and enhancement of river ecology and environment. Comparison of such flows with projected future river flows help in determining indirectly limits on water withdrawals, including decline in groundwater tables to meet environment flow requirements. The model takes into consideration complex interaction between numerous factors including surface and ground water, land use and water supply, storage and water withdrawals and returns, through separate surface and groundwater and overall water balance at basin/sub basin level. Figure A1 represents the schematic of the model.

#### The Rationale

The need for depicting the entire land phase stems from basic hydrologic premise that precipitation constitutes the primary resource, and that evapo-transpiration management to increase the flows in rivers / aquifers is a potential development strategy which could be encouraged through

policy intervention, either for improving river flows or the traditional resource.

A simple water assessment model was developed to meet the following needs

- Expansion of irrigation to new lands and conversion of barren lands to forestlands, and agricultural lands.
- Influence of rainwater harvesting and soil & water conservation practices both in irrigated and non-irrigated (or rain fed) conditions on the total as well as inter-distribution of surface and groundwater.
- Impact of internal changes in policies and programmes in regard to soil and water conservation.

#### Scope

The scope of the model is:

- Basin/Regional/Country/Global scale
- Assessment of sectoral demands of water
- Whether integrated and holistic
- Effects of land and water use and climate changes on resources
- Development and analysis of scenarios to evaluate effects of water policies
- Linkages with socio-economic and environmental aspects

#### Purpose

The model can be used effectively for the following purposes:

- Understanding resources and needs
- Analyse development and management options
- Creating and improving knowledge base for meaningful and transparent dialogue

#### Attributes, Capabilities and Limitations

The model has the following attributes:

- Simplicity, in concept.
- Capability to deal with the entire land phase of the hydrologic cycle, from precipitation to evapo-

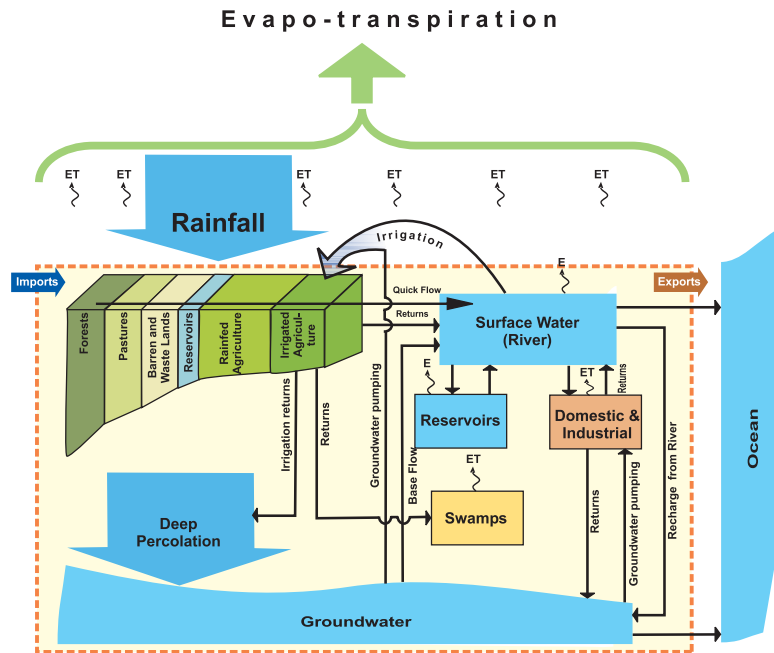


Figure A1. Schematic Diagram of BHIWA Model

transpiration and outflow to sea including withdrawals and returns.

- Flexibility, to allow depiction of changes in land use, as also human interventions through irrigation capability to depict surface and groundwater balances separately, interaction between them, as also impacts of storage and depletion through withdrawals.

The main capabilities of the model are:

- Quantification and integration of sectoral needs.
- Water balances for surface and ground water systems and for the overall basin.
- Interaction between surface and ground water systems.
- Effects of land use changes on supplies.
- Impact of sectoral policies.

Limitations of the model are:

- Not a distributed hydrologic model
- Not a basin planning tool
- Additional modules are needed to evaluate socio-economic impacts.

#### Data Required

For using the model, a river basin is first to be divided into sub basins and each sub basin is to be divided into several homogeneous land parcels. The working of the model is scenario-wise. For each scenario, the land use pattern for each parcel in each sub basin should be identified and data should be prepared accordingly for input to the model. The model provides for a maximum of 5 sub basins and 25 parcels for each sub basin. A maximum of 10 scenarios can be studied at a time in the model.

The following types of data are required for input to the model:

- *Hydrological* - Monthly data on rainfall, reference evapo-transpiration, runoff data at locations near sub basin outlets, groundwater information on recharge, fluctuation etc.
- *Land Use* - Areas of forests, grasslands, barren and fallow lands, reservoirs and agricultural lands.
- *Crops Statistics* - Gross and net areas under agriculture and irrigated agriculture; crop-wise compositions of both; cropping calendar; source wise composition of irrigated area.
- *Agronomic Data* - Soil moisture capacities, K factors (crop coefficients).

- Information about *withdrawals and returns* for irrigation use and D&I use.
- *Demographic* information including growth rates.
- *Water Development* related - Surface storage changes, Imports and exports
- *Water Use Related Parameters* – Irrigation system efficiencies for surface and groundwater; distribution of return flows to swamp evaporation, surface and groundwater.
- *Environmental* – Monthly Environmental Flow Requirements (EFR)
- *Other Parameters* – Proportion of excess flow to surface; Index for soil moisture balance; Recession coefficients of linear ground water reservoir.

## WORKING OF THE MODEL

The Basin-wide Holistic Integrated Water Management (BHIWA) model as evolved for CPSP has nine computation modules. The model is developed in Microsoft EXCEL software and has a number of spreadsheets. The model works, initially, in the calibration mode using the observed data. After obtaining a generally satisfactory calibration mode, it is worked as a tool for assessing the possible status of the basin, under different scenarios in the simulation mode. A logical sequence of the BHIWA model is depicted in Figure A2. For using the model, a river basin is first to be divided into hydrologically homogeneous sub- basins and each sub- basin into a number of land parcels each depicting a particular category/subcategory of land use. The model accommodates a maximum of 5 sub- basins and each sub-basin can be divided into a maximum of 25 land parcel types. The hydrologic computations are first performed for each land parcel in terms of water depth in millimeter over the area and then aggregated in volume units (million cubic meters) at the sub- basin level. A number of modules are used for calculations and are briefly described as below.

### Module 1: Computation of Actual ET, Quick Runoff and Natural Recharge

The model calculates water balances for the upper and lower zones viz. soil profile and groundwater system for each land parcel, given soil moisture holding capacity of the parcel, and area averages of rainfall, and reference evapo-transpiration for the sub-basin. The soil profile component of the model partitions the rainfall into actual

evapo-transpiration (AET) and excess water. The actual ET is calculated as a function of potential ET and the actual moisture availability, as proportion of the root-zone soil moisture capacity for each land use type. These functional relations depict how the actual ET reduces with reduction of soil moisture availability, or indirectly the tension in the root zone. The excess water is further divided into deep percolation (natural recharge to groundwater) and quick runoff from land areas to the river. The quick runoff from all land parcels is aggregated into a single entity to represent natural contribution from rainfall to the river system. Likewise, natural recharge to groundwater under various land categories is lumped into a single groundwater entity representing the natural contribution of rainfall to the groundwater.

### Module 2: Computation of Irrigation Withdrawal

This module calculates the requirement of additional water for each of the irrigated land parcels using data from previous module on shortfalls to meet the PET requirements. Net and gross irrigation requirements are computed source- wise using data on irrigation system efficiencies and proportion of surface water irrigation. For parcels having paddy crop, net water requirements are calculated taking into account user prescribed monthly percolation. Estimates of withdrawals for irrigation are arrived at finally considering “deficit irrigation” specified, if any.

### Module 3: Computation of Irrigation Returns

These are computed separately for surface water and groundwater irrigation systems using user specified information on potential return from the total water withdrawn, in excess of the actual evapo-transpiration (AET) and that part of the wasteful return, that will be lost as ET from swamps/waterlogged areas with in cropped lands. The difference between the potential and the wasteful return is further divided into the components returning to surface and groundwater system.

### Module 4: Accounting for Evapo-transpiration (ET) by Sector

This module is designed for accounting ET by different use sectors. This is achieved through sectoral identification of each land parcel type. Agriculture land parcels are further divided into rain-fed and irrigated parcels. Parcel ET is designated as beneficial, if it is productive from

consideration of sectoral water use. Otherwise it is classified as non-beneficial.

#### **Module 5: Computation of Domestic and Industrial Withdrawals, Use and Returns**

In calibration mode, this module is run on directly fed data. However, in simulation mode, D&I module is used first to project population and water requirements in the targeted “future” year from the user given information on base year, intermediate blocks, population growth rates and proportion of urban population to total population. Withdrawals are next computed in the model using rural and urban water supply norms and source-wise proportion of supplies. Information on consumptive use fraction and returns is used to calculate the total return as well as its components to surface and groundwater systems.

#### **Module 6: Computation of the River Water Balance**

It aggregates all inputs to the river including quick run off, base flow and returns from irrigation, D&I withdrawals and computes balance flow taking into account given values of storage changes and requirements of environmental flow. Provision exists to account for adjustments in surface water withdrawals through assumption of induced recharge from the river flow to groundwater in cases where the estimated groundwater withdrawal is found to be unsustainable. This module also has a provision to ensure that the river flow in any month is not less than the specified EFR, or zero, if no EFR is specified.

This is achieved through extra pumping from groundwater reservoir to take part of the demands on surface water.

#### **Module 7: Computation of Groundwater Balance**

The input part of the module facilities aggregation of input from deep percolation from natural rainfall, return from irrigation and D&I withdrawals and as well as induce recharge if any required from the river. The output components of groundwater system include base flow to river and withdrawals through pumping from ground water reservoir as also pumping into canals to meet the surface water shortages, if there be any. In the simulation mode, the module is designed to achieve a stable groundwater regime under average conditions by adjusting the initial groundwater reservoir storage. Where the total annual input to groundwater is detected to be less than the estimated withdrawals including natural out flow (base flow) to the river, there exists a provision to manually balance groundwater through artificial recharge from surplus river flows for achieving a sustainable or balanced groundwater regime. Consequences of modifications in groundwater reservoir system are carried forward to modify the river water balance. In addition to the above modules, there are worksheets to facilitate data inputs, and generation of aggregated results in the form of tables and charts. The model runs on a monthly time step simulating average hydrological year. In the calibration mode, however, a model can be applied either to a single year (good, average or dry) or to a sequence of years (maximum length 5 years).■

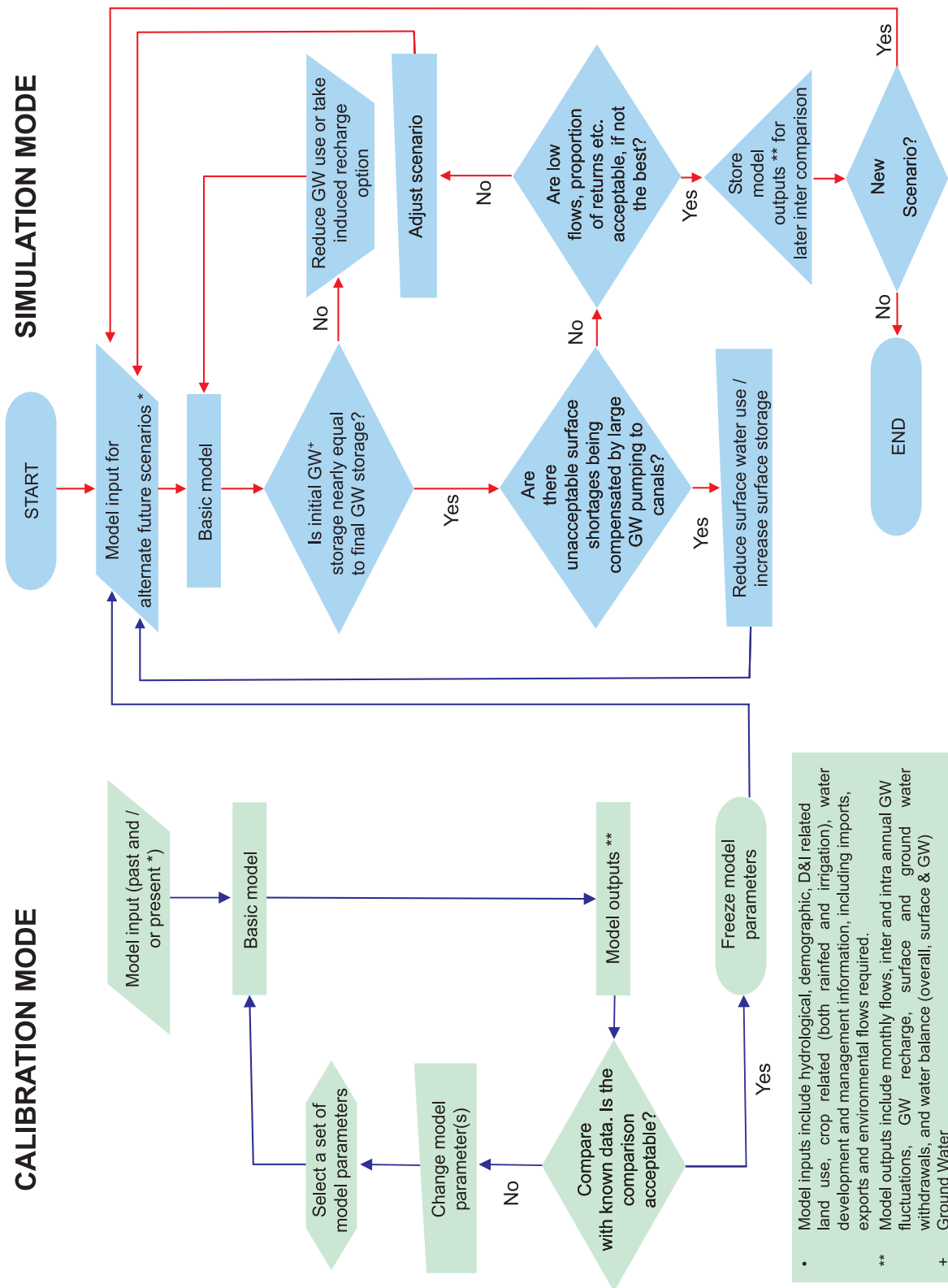


Figure A2. Logical Sequence of BHIWA Model

## ANNEXURE V

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## ANNEXURE VI

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## ANNEXURE VII

### QUESTIONS POSED IN THE NATIONAL CONSULTATION

1. Do you think that the BHIWA model in its current mode can be directly applied to the Egyptian water resources system? Give reasons.
2. Are the components of the existing model capable of capturing and simulating all the components of the Egyptian water resources system? Are there any relevant components that have to be incorporated in the model? Mention these components if any.
3. What should be the smallest calculation unit within the BHIWA model?
4. Are the data requirements for the model available or easy to acquire for the proposed calculation unit? What kind of procedures (arrangements) should be considered for acquiring missing data?
5. Are the current model outputs and indicators sufficient for evaluating the water resources policy? What are your suggestions for other indicators or evaluation procedure (approach)?
6. How can Egyptian expertise with respect to developing and utilizing models and decision support tools be associated within the model? What are the proper mechanisms to achieve the most benefit of the model application using this expertise?
7. What are the priorities for the development and adaptation of the BHIWA model?
8. What in your opinion the main weakness and strength of the BHIWA model?
9. What is the optimal and most suitable geographic coverage for the application of the BHIWA model?
10. What are the necessary modifications required in the BHIWA model to better suit the Egyptian environment?
11. Do you think that the spreadsheet of the model is adequate for the application in Egypt? What other software platform can be used to optimally utilize such a model?
12. What should be the institutional setup for the agency in charge of executing the BHIWA model? Elaborate on your choice.
13. What criteria can be used to evaluate the performance of the model with regard to efficiency and accuracy?
14. What constraints may hinder the success of the BHIWA model application? Elaborate.

## ANNEXURE VIII

## A NOTE ON IWRMESD FOR SUSTAINABLE DEVELOPMENT OF EGYPT

An integrated framework for the analysis of Egypt's water policies has been formulated as a research activity. The integrated framework utilized the simulation approach and was developed using an object-oriented environment. The model represented Egypt as one global system. The object oriented environment allowed for addressing other water related issues such as economic, social, and environmental issues when drafting Egypt's future water policy. A pre-processor expert system was developed to assist in the scenario generation. A post-processor multi-criteria analysis procedure was also implemented to analyze the simulation results and evaluate different scenarios simulated by the model. Because the model was implemented in an object-oriented environment, it was easy to view and evaluate its produced graphical outputs. The framework captured policy analysis process through the following set of tasks: (1) structure development (objects and links), (2) selection of policy variables, (3) selection of policy evaluation indicators, and (4) dynamic system simulation.

The proposed framework is applied to build a reliable policy analysis model for Egypt viz., the **Integrated Water Resources Model for Egypt's Sustainable Development (IWRMESD)**. The model relates various development plans in the different socio-economic sectors with water as a natural resource at the national (strategic) level. Agriculture, industry, domestic demand, power and navigation are the five socioeconomic sectors that depend directly on water. Development plans in these sectors involve large number of decision (policy) variables and inputs. Satisfying these plans from the different water resources pertains to another set of policy variables. The Egyptian Ministry of Water Resources and Irrigation (MWRI) controls only some of these policy variables. Integration between policy variables and their impacts are monitored through a diversity of state variables (indicators) in the social, economic, and ecological domains. The number of policy variables involved, level of control of MWRI, and diversity of the indicators made the structure development of IWRMESD a very elaborate task. Aggregation and hierarchical decomposition principles are adopted to guide and simplify the model development and to reduce the problem size. Clearly, aggregation of the data to the macro or national level masks some temporal and spatial variability. Nevertheless, it still preserves the general trends and helps get some quick simple answers to questions usually asked by policy makers. In principle,

the hierarchical decomposition of each socio-economic sector into smaller units is against aggregation principle. Therefore decomposition of the main sub sectors should be avoided unless it is extremely necessary. It should be also noted that hierarchical decomposition principle is used only to facilitate the conceptualization and model development process.

The main objective of IWRMESD development is evaluation of water process formulated to satisfy long-term socio-economic plans on the national level in five sectors. The time horizon of most socio-economic plans is 25 to 30 years. Known conventional and non-conventional water recourse should be modeled. Evaluation of the water policies is carried out using several indicators in the areas of water availability, ecosystem quality, social standard of living, and economic growth. Having a large complex problem (in terms of the number of input/output variables) necessitated the use of aggregate data. On the time scale the model time increment is chosen to be 1 year. No geographical distribution is assumed; that is, Egypt is modeled as one geographical unit rather than dividing it into regions.

Although spatial and temporal variability was reduced to a large degree through aggregation, the complexity of modeling all socio-economic sectors and linking them to the water sector is very high. The hierarchical decomposition is implemented in modeling the socio-economic development in each of the five sectors and the water resources sector separately. Some of these sectors have been decomposed to sub sectors and/or smaller basic components. Each sub sector is then modeled, using crops as basic components. The agriculture sector is decomposed into two sub sectors because of the significant difference in the characteristics with respect to cropping pattern, soil type, and irrigation system. The sub model of the water resources sector is used as an integration module that is linked to each socio-economic sector through two variables: total water requirement and the return flow from the sector.

Water use sectors are not connected except through demands placed on water. This assumption is made to reduce the degree of complexity. For example, the agro-food industry is not linked to the agriculture production. It is obvious that such a relationship is very important if the model is economically oriented, but it is less significant in the case of water use orientation. In terms of water, priority

is given to domestic and industrial sectors and then to agricultural. Navigation and hydropower generation are given the lowest priority as they are almost non-consumptive uses. Practically, water shortages occur in the agriculture sector only. Therefore the model is designed to have an automatic feedback from the water balance sector to the agriculture sector. The purpose of this feedback link is to linearly reduce the agriculture water use by the percentage of water shortage with respect to the total agriculture water requirements.

Most of the water sources are conceptualized in the model as reservoirs with no maximum storage capacity. On the basis of the storage available in each one of them, there is a constraint on the level of withdrawal. The available storage depends mainly on the inflow to these reservoirs. In the case of desalination the inflow is infinite. In the case of surface water resource the inflow is finite and comes from the release made by HAD, return flow from agriculture in Upper Egypt, and industrial and domestic effluent. Return flow, as percentage of different water uses is computed on the basis of the ratio derived from the most recent annual national balance. This ratio, as non-policy variable, is assumed to be constant over the planning horizon.

The model comprises six sectors: the five socio-economic sectors that depend on water and the water sector. A model sector is a system that is formally defined as :

$$MS_i(I_{pc}, I_{pu}, I_{np}, t) \rightarrow O_i(O_{env}, O_{wat}, O_{econ}, O_{soc}, t)$$

Where;

- MS is the Model Sector
- i* is the model sector number (*i*=1, 2, 3, ...6)
- $I_{pc}$  is the policy input variable controlled by MWRI

- $I_{pu}$  is the policy input variable uncontrolled by MWRI
- $I_{np}$  is the non-policy input variable
- t* is the time domain
- $O$  is the output vector
- $O_{env}$  is the environmental indicator
- $O_{wat}$  is the water security indicator
- $O_{econ}$  is the economic indicator
- $O_{soc}$  is the social indicator

MWRI controls mostly the water supply variables. Demand side policy variables and inputs are totally or partially controlled by other stakeholders. The entire policy variables are dynamic variables; that is, they take different values over the planning time horizon. Non policy variable are assumed to be deterministic, the known values over the planning horizon, and should remain unchanged from a model run to another process. They are classified as uncontrolled policy variables (for example, population growth rate, and inflow to HAD). Theoretically, there is no limitation on identifying variables as policy or non policy. It is the user's choice to determine which input variables are policy variables and which are not on the basis of the nature of model application.

The water policies are assessed using a set of indicators. Following Table A-1 lists these indicators covering various aspects of water resources.

Each step of the modeling process is visible and clearly explained, providing the user with an opportunity to comprehend the modeling knowledge with ease. This by itself helps planners and policy makers increase the public awareness of the water resource related issues and acquire wide range of support for suggested solutions.

**Table A1 Different Indicators Used for the Evaluation of Water Policies**

Sector	Economic ( $O_{econ}$ )	Social ( $O_{soc}$ )	Environmental ( $O_{env}$ )	Water Security ( $O_{wat}$ )
Agriculture	Net return, present value	Employment, food sufficiency	Fertilizers and pesticides use	Agriculture water requirements
Domestic	Net return, present value	Employment, health	Total load of pollutants and/or water quality index	Domestic water requirements
Industrial	Net return, present value	Additional employment, power satisfaction	Total load of pollution	Industrial water requirements, industrial efficiency
Power generation	Net return, present value	Employment, power satisfaction	Total load of pollution	Power water requirements, effluent of thermal power
Navigation water	Net return, present value, water resources cost	Employment	Total load of pollution	Losses to sea, water balance

## ANNEXURE IX PROPOSED ACTIVITIES FOR CPSP PHASE II

Following are the proposed activities for the application of the BHIWA model under Egyptian conditions in Phase II of CPSP for a period of two years:

1. Detailed assessment to actual model structure
  - a. Determination of model inputs
  - b. Determination of model outputs
  - c. Determination of the most appropriate application unit (coverage)
2. Data collection
  - a. Hydrological data
  - b. Demographic data
  - c. Domestic and industry related land use
  - d. Crop related (both rain fed and irrigation)
3. Detailed assessment of the model platform
  - a. Reviewing of the model platform
  - b. Testing new platforms
  - c. New design to the model platform
4. Model calibration and verification
  - a. Determination of the model parameter
  - b. Calibration stage
  - c. Verification stage
5. Model application
  - a. Scenarios formulation
  - b. Outputs assessment
6. Reporting
  - a. Interim report
  - b. Final report

A 'Tentative Time Schedule' for completion of the proposed CPSP Phase II activities in Egypt is shown below:

ITEM	YEAR 1				YEAR 2			
	1	2	3	4	1	2	3	4
<b>Detailed assessment to actual model structure</b> Determination of model inputs Determination of model outputs Determination of the most appropriate application unit (coverage)								
<b>Data Collection</b> Hydrological data Demographic Data Domestic and industry related and use Crop related (both rain fed and irrigation)								
<b>Detailed assessment of the model platform</b> Reviewing of the model platform Testing new platforms New design to the model platform								
<b>Model calibration and verification</b> Determination of the model parameter Calibration stage Verification stage								
<b>Model application</b> Scenarios formulation Outputs assessment								
<b>Reporting</b> Interim report Final report								

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