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Abu-Zeid M.

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Major Policies and Programs for Irrigation Drainage and Water Resources Development in Egypt

Mahmoud Abu-Zeid
Water Research Center (WRC), Cairo (Egypt)

Abstract. This chapter deals with the present and future water resources in Egypt, including surface water (River Nile), ground water as well as the non-conventional water resources. Expectations of the water situation of the country is discussed in view of the changing supply and demands. Some information on the irrigation and drainage systems in Egypt is given. The policies and programs adopted by the state for the management and improvement of water resources in the country are also discussed. In this respect, some specific projetcs are reviewed. Morevover, the chapter focuses on the research programs and projects carried out by the various water research institutes in Egypt.

Keywords. Water resources – Nile River – Ground water – Drainage/Irrigation methods – Development projects

Résumé. *Dans ce chapitre, il s'agit de présenter la situation actuelle et l'avenir des ressources en eau de l'Egypte : le fleuve Nil, l'eau souterraine et les autres ressources non conventionnelles. Après avoir présenté la situation en fonction des changements dans l'offre et la demande, on décrit rapidement les systèmes d'irrigation et de drainage en Egypte, ainsi que les politiques de l'Etat en matière de gestion des ressources en eau. L'accent est mis sur les projets et les programmes de recherche menés par les différentes institutions de recherche en Egypte.*

I – Introduction

Agriculture through irrigation in Egypt is as old as history. There are much more than one physical evidence that flood Egyptians have used long-term storage reservoirs, flood control dams, irrigation structures, drainage net works, and water management techniques. The main source of water was, and will continue to be, the Nile River. Due to the pressing need to provide water for the increasing number of inhabitants, it was necessary to plan and set out policies for an optimum utilization of the available water resources and to promote them to the greatest extent.

This paper presents Egypt's present and future water resources and describes its irrigation and drainage requirements. To satisfy these requirements, efforts and strong support are provided by the national research institutions, such as the Water Research Center (WRC) whose activities and programs are briefly given.

II – Present and Future Water Resources of Egypt

1. Surface Water Resources

Egypt is an arid country with little rainfall rarely exceeding 200 mm/yr along the North Coast. The rain intensity decreases quickly away from the coastal area and scattered showers can hardly be depended upon for agricultural production.

The main source of fresh water in Egypt is the Nile River. The 1959 treaty with Sudan fixes Egypt's share from the Nile at 55.5 milliard m^3/yr. About 85% of this water is driven from the Ethiopian Plateau and the remaining part comes from the Equatorial Plateau. *Table 1* summarizes the flow from the different sub-basins of the Nile and their contribution to the flow at Aswan. Before the construction of the Aswan High Dam (AHD), the river used to rise to high levels during the flood season, from July to September. The supply during this period was greater than the demand and the extra amount of water was lost to the sea. On the contrary, the low flow during the period from November to June was far below the quantity demanded. After the construction of AHD, the discharge ratio of the dam has become more or less uniform proportional to the demand.

Table 1. Mean of Annual Flow of the Sub-basins of the Nile River

Source	**Discharge** (milliards m^3/yr)	
	At Sub-basin Exit	**At Aswan**
A) Equatorial Plateau		
1. Bahr El Jabal and Bahr El Zaraf	15.0	*
2. Bahr El Ghazal	0.5	*
Subtotal (A)	*15.5*	*13.0*
B) Ethiopian Plateau		
1. Sobat	13.5	11.5
2. Blue Nile	54.0	48.0
3. Atbra	11.9	11.5
Subtotal (B)	*79.4*	*71.0*
Total (A) + (B)	**94.9**	**84.0**

*unavailable

Egypt's share from the Nile can be increased through implementing the Upper Nile basin projects. These projects will decrease the loss of water through evaporation and seepage in the swamps. Conservation schemes aiming at saving such tremendous losses of water in certain sub-basins of the Nile River have been implemented. The losses occurring in the sub-basins of Bahr El Jabal and Bahr El Zaraf of the Equatorial Plateau amounts to not less than 14 milliard m^3/yr. It is possible to save as much as 9.0 milliard m^3/yr of this water at Malakal by implementing the two phases of the Jonglei Canal Project which will be shared equally between Egypt and Sudan. Aswan will obtain about 4.0 milliard m^3/yr of the saved water in the first phase and 7.0 milliard m^3/yr after the second one. Thus, Egypt's share after the implementation of the Jonglei Canal Project will increase to 59.0 milliard m^3/yr.

The discharges of Bahr El Ghazal (another sub-basin of the Equatorial Plateau) into the streams are usually about 14.0 milliard m^3/yr of which only 0.6 milliard m^3 reaches the White Nile at lake No while the rest is lost in the swamps. Proposed schemes for conserving the water of Bahr El Ghazal are expected to preserve 12 milliard m^3/yr at Malakal or roughly 10 milliard m^3/yr at Aswan. If this net gain is divided equally between Egypt and Sudan, Egypt's share will go up to 64 milliard m^3/yr.

The water lost in the Sobat and tributaries amounts to 5 milliard m^3/yr. Until now no definite plans are laid down or even proposed for conserving this water as it has been done for Bahr El Jabal, Bahr El Zaraf and Bahr El Ghazal. The total loss in the Machar swamps by evapotranspiration is about 10 milliard m^3/yr. Conservation schemes in this sub-basin is expected to yield an average gain of 4.4 milliard m^3/yr at the White Nile or about 4.0 milliard m^3/yr at Aswan. An equal division of this gain will make the share of Egypt in the Nile water increase to 66 milliard m^3/yr.

The above estimates of water gain which are obtain from the conservation projects in the Upper Nile sub-basins imply that a total of 21.0 milliard m^3 of water will be driven to Aswan each year. However, further conservation estimates brought this amount down to 18.0 milliard m^3/yr. In this case Egypt will get 9.0 milliard m^3/yr and its total share will be 64.5 milliard m^3/yr.

At present, about 2.3 milliard m^3/yr of the Nile water flows to the sea during the period of least crop water requirement. This coincides with the winter season when evapotranspiration is at a minimum rate. However, most of this water is lost during the closure period when the irrigation system is shut down for about three weeks for maintenance. These amounts of water can be saved for future use during the peak periods of irrigation. In fact, there are some serious efforts for allocating this water efficiently.

2. Ground Water Resources

Ground water is found virtually everywhere in the sandy and gravely layers (aquifers) underneath the Nile flood surface and the nearby desert areas. Groundwater can be pumped to surface and used for irrigation. However, pumping ground water depends on the depth and quality. For instance, brackish water which is pumped from a great depth is, generally, less attractive than fresh ground water at a shallow depth.

The main water layer (or aquifer) is formed by the Quaternary alluvial deposits in the Delta and Nile Valley Basin between Aswan and the Mediterranean Coast. The Nile is divided into two branches. One goes to the east to El-Fayoum Depression and the other towards the West to Wadi El-Tumilate Depression which goes to Ismailia. The central areas of the Valley Basin and the Delta basin, the Quaternary alluvial aquifer system, is overlain by a thin silty clay layer which acts as an aquifer in order to allow for local confinement. This clay cap is intensely segmented by the Nile River and its tributaries and irrigation and drainage canals as well.

In the Nile Valley, the maximum thickness reported from the alluvial aquifer system is in the order of 300 m near Assiut. It declines remarkably southward and northward. The recharge to the aquifer is continuous through the irrigation canals, usually from the Nile channel and occasionally from the dry streams *(wadi)* during the rainy seasons. The recharge rate is more than 3.5 milliard m^3/yr. The total available groundwater storage in the Nile Valley aquifer is about 200 milliard m^3. The aquifer is highly productive with an average salinity of 800 ppm and the natural discharge takes place through the Nile channel and the evaporation process.

In the Delta basin the aquifer thickness increases along the coastal zone to more than 500m, but looses most of its water bearing characteristics and changes into clay layers. Also, the salinity increases from 1,000 ppm near Cairo to 5,000 ppm at 50 km from the Mediterranean Coast. The aquifer continues eastward to Sinai and westward into Wadi El Natrun. In the area of the flood plan, the aquifer is essentially recharged in the South by infiltration from irrigation water and its network through the silty clay layer. It is also recharged partially through lateral seepages from the same aquifer in the west of Egypt. The total amount of ground water stored in the Delta aquifer is about 300 milliard m^3. The aquifer underneath the Delta is characterized by salt water intrusion due to the hydraulic connections with the Mediterranean Sea and the Suez Canal and upward seepage in the northern parts.

Although the total ground water stored in the Nile Valley and the Delta is about 500 milliard m^3, the present abstraction is only about 2.6 milliard m^3 every year for drinking, irrigation and industrial uses. The pumping of ground water can be raised to 4.9 milliard m^3/yr which is equivalent to the annual recharge. This rate maintains the water balance of the ground water reservoir and prevents further salt intrusion into the Delta. However, it is possible to increase the abstraction of ground water occasionally, up to 5.0 milliard $m^{3,}$ during drought years when shortage of surface water supplies occurs.

The potentiality of ground water for development can be achieved through promotion of the quantity and quality. The analysis of potentiality is based on an integrated evaluation of several parameters such as the type and the appropriate thickness of the aquifer, its productivity, the cost of pumping, the existing abstraction rate and the suitability for the anticipated use. The development plans in the Delta includes the increase of ground water abstraction in the East (Sharkia, Qualyoubia, and Dakahlia) and in the West (Behaiyra) to irrigate about 200,000 acres of newly reclaimed lands. More ground water can be pumped if certain drawn down and salt water intrusion limits are adjusted to use ground water with salinity more than 1,000 ppm in irrigation. The implementation of any of these policies would imply the drilling of about 1,500 wells in the Delta.

The ground water in the deep aquifers in the Western Desert is not renewable and available mostly at great depth. The total capacity of ground water reservoir is about 40,000 milliard m^3 subject to the cost of pumping and the economic return over a fixed time period after which water levels may drop below the economic levels of pumping. Researches and studies carried out at the New Valley proved that about 1,042 million m^3/yr of groundwater can be used for irrigation at an economical rate of return. The irrigated area is estimated to be 150,000 acres of which 43,000 acres are already cultivated. An additional 190,000 acres can be also irrigated at the East Ewainat area using ground water. The amount which can be abstracted within the safe yield of the aquifer is about 4.7 million m^3/day. More studies are under way to assess the ground water possibilities within the regional Nubian Sand Stone aquifer. The work is carried out in co-operation with the neighbouring African countries.

Ground water in Sinai exists in different aquifers at varying depths and with different qualities. Shallow aquifers in the northern coastal areas are replenished by seasonal rainfall. The thickness of the aquifer varies between 30 and 150 m and its salinity increases from 2,000 ppm up to 9,000 ppm near the coast. In the North and central parts of Sinai, ground water aquifers are formed due to recharge by rainfall and collected water in the valleys. Deep aquifers with non-renewable water exist in Sinai where wells are drilled to a depth of 1,000 m in order to supply water to the villages. The availability of deep ground water is still subject to investigations.

The El-Arish-Rafah coastal area in North Sinai has always been of importance. Since 1960, the quaternary aquifer system in this area was subject to geological, geophysical and hydrogeological investigations. The principal aquifer system in the area of El-Arish-Rafah consists of dune sands accumulation system along the coastal plans, the Wadi El-Arish younger alluvial sand and gravel system which is the major exploitable aquifer in the area, the old beach deposits system between Sheikh Zuwauid and Rafah which constitute a potential water bearing formation and the calcareous sandstones *(kurkar)* system which dominates the whole coastal area of the east.

The present ground water extraction rate from the quaternary aquifer at El-Arish area is estimated at 51,700 m^3/day. This extraction rate is pumped by 145 wells which provide 25,000 m^3/day for domestic purposes and 26,700 m^3/day for irrigation. The present ground water extraction rate in the area between El-Sheikh Zuwayied and Rafah is estimated at 43,320 m^3/day and is pumped by 280 productive wells existing in the area. A total of 20,790 m^3/day is presently extracted from the dune and old beach deposits formations, of which a total of 10,420 m^3/day is used for domestic purposes and 10,370 m^3/day for irrigation.

The occurring ground water resources in the El-Arish area is facing a state of quality deterioration in space and time. In the coastal area between El-Arish and Rafah, the system is exploited with no adverse effects but still needs to be safely managed within its available ground water potentials. A plan is prepared to conduct studies in order to determine the most convenient and secure extraction programs in the long-run.

Ground water investigations in South Sinai included several shallow and deep reservoirs which have a promising potential for future development. At the El-Qua plain, in the southwest of Sinai, the depth of the ground water reservoir ranges between 50 and 1,000 m. It consists of free water stable shallow aquifer which may reach a depth of 150 m and is underlained by a semi-confined aquifer 300 m deep. Both aquifers are hydraulically connected. They are recharged from the mountains to the East at a rate of 15.8 million m^3/yr. The total storage capacity of the reservoir is 2.5 milliard m^3 with salinity varying between 400 and 4,000 ppm. About 25 wells were drilled at El-Toor area which raised the abstracted ground water quantity up to 13,040 m^3/day in 1988.

An additional 42 shallow wells (5–23 m) were drilled by individuals for private use at the El-Wady Village. Their total discharge is about 5,000 m^3/day.

A number of shallow ground water reservoirs exist at Wadi Wateer in South Sinai. A geophysical and geological analysis helped to identify six reservoirs. Test wells will be drilled to determine the potentiality of ground water in this area. Similar investigations are underway in the Sharm El Sheikh area, south of Sinai, and at Taba to the east.

The development of deep ground water reservoirs in the south of Sinai includes the Wadi Feran area, El Kontella and Wadi Shaera. A well was drilled to a depth of 800 m at Wadi Feran where a water bearing strata of 500 m thickness was found. The production of the well is relatively high (100 m^3/hour) and of good quality (salinity 900 ppm). Drilling and investigations are under way in these areas.

3. Non Conventional Water Resources

Agricultural drainage water in Upper Egypt is discharged into the Nile River. This slightly affects the quality of the Nile water as its salinity increases from 250 ppm at Aswan to 350 ppm in Cairo. The drainage water of the Nile Delta, of a lower quality, is collected through an intensive drainage network and disposed to the sea. The annual discharge of agricultural drainage water estimates varies due to different factors, such as the management of the irrigation system, crop pattern and irrigation efficiency.

The effect of reducing the quantity of water released from the AHD on the quantity and quality of drainage water is shown in *Table 2*. The decrease in the Nile water flow downstream AHD was due to the shortage in supply caused by the drought in the Horn of Africa. The Ministry of Public Works and Water Resources (MPWWR) imposed strict policies for the release and distribution of the Nile water downstream AHD. Further decrease in drainage water quantity and increase of its salinity will occur when the irrigation efficiency is improved both in the conserving system and at farm level.

Table 2. Nile Water Flow Downstream AHD and Drainage Water Flowing to the Sea

Year	Nile Water Downstream AHD (milliard m3)	Drainage Water Quantity (milliard m3)	Drainage Water Salinity (mmhos/cm)
1984–1985	56.40	14.12	3.71
1985–1986	55.52	13.86	3.68
1986–1987	55.19	13.03	3.64
1987–1988	52.86	11.87	4.15
1988–1989	53.24	11.13	4.63

Survey and monitoring of the quality and quantity of the agricultural drainage water in the Delta proved that it is possible to reuse part of this water in irrigation. This water has salinity which ranges between 500 and 1,500 ppm. Drainage water with low salinity is used directly, or is mixed with fresh Nile water. The drainage water with high salinity or contaminated by municipal and industrial wastes cannot be used in irrigation. Under any circumstances, a substantial portion of drainage water must be discharged into the sea to maintain the salt balance in the Delta.

The amount of drainage water presently recycled in irrigation is about 4.7 milliard m^3/yr. About 2.6 milliard m^3/yr of drainage water is recycled in the Delta, and 0.95 milliard m^3/yr is reused in Fayoum. The remaining part is the drainage water flow back to the Nile in Upper Egypt. The drainage water recycled in irrigation is expected to be increased gradually to reach 7.0 milliard m^3/yr by the year 2000. The quantity of drainage water used in irrigation since 1984 is shown in *Table 3.*

Table 3. Recycling Drainage Water in the Delta

Year	Quantity (milliard m3)	Salinity (mmhos/cm)
1984–1985	2.88	1.36
1985–1986	2.79	1.33
1986–1987	2.93	1.37
1987–1988	2.65	2.01
1988–1989	2.63	2.10

Drainage water is used in irrigating a number of land reclamation projects. It will be drawn from El-Salam Canal to the east and west of the Suez Canal. It is currently used in irrigating 1,600 acres directly from the Bateekh Canal, and 6,400 acres from the Bahr El Baqar drain to the East of the Delta. In the West of the Delta, drainage water from Edko drain is used directly or after being mixed with fresh water to irrigate the Edko reclamation project area. The El-Hamoul reclamation area at the center of the Delta is irrigated by drainage water from a drain.

A potential water resource to be considered in the future is treated sewage water. Recycling of sewage water after primary treatment, has been practised since 1925 at Jabal Al-Asfar, north-east of Cairo, in an area of 4,000 acres. The completion of the new Greater Cairo Sewers will allow a treatment of 1.5 milliard m^3/yr of sewage water which will serve for the irrigation of 400,000 feddans in the desert lands.

Sewage water effluent from other major cities in Egypt may increase the total treated sewage water up to 2.5 milliard m^3/yr. The environmental impact of recycling waste water in agriculture has to be taken into consideration with special emphasis on: health aspects, chemical and physical effects on soil, ground water, crops and individuals involved in treating and using this type of water.

4. Water Supplies and Demands

The available and expected future water resources in Egypt are summarized in *Table 4.*

Table 4. Egypt Water Resources

Water Resources	**Quantity** (milliard m3/yr) 1990	Year 2000
Nile River Water	55.5	*57.5
Ground Water**	2.6	4.9
Agricultural Drainage Water	4.7	7.0
Municipal Sewage Water	__	***2.5
Total	**62.8**	**71.9**

* Assuming the first stage of the Jonglei Canal is completed.
** Not including groundwater in Sinai and the Western Desert.
*** Sewage water use is still subject to study and evaluation.

Table 5. Present and Future Water Demand

Use	**Quantity** (milliard m3/yr) 1990	Year 2000
Irrigation (old & new lands)	52.5	*61.1
Drinking and Municipal	4.1	5.6
Industrial	2.9	5.0
Navigation, Power and Regulation	2.7	0.2
Total	**62.2**	**71.9**

* Includes the irrigation requirements of an additional 2.0 million acres to be reclaimed during this period.

Shortage of water resources due to an increasing demand will be covered in the future through promoting the use of the available water resources to optimum level allocating, and conflict these resources efficiently. This is achieved through improving the efficiency of irrigation, recycling water, the full exploitation of water resources, decreasing water losses in the Upper Nile basin and the reliable forecasting of the river flow.

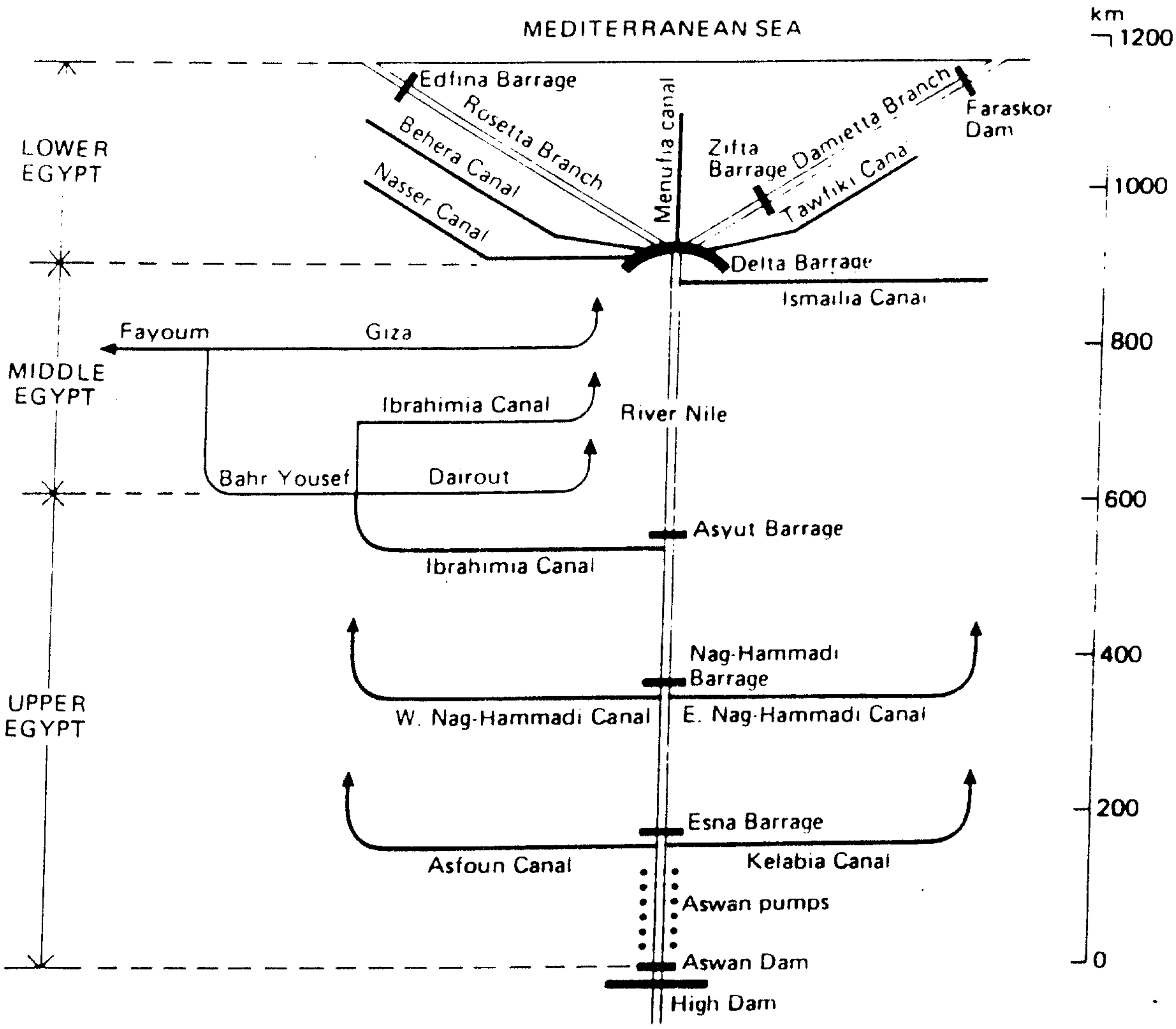
III – Irrigation and Drainage in Egypt

1. Dams and Barrages

Control and management of the Nile water has become possible only after the construction of a number of dams and barrages on the Nile and its branches. The old Delta barrages were completed in 1881 and the new ones in 1939. Other barrages on the Nile were built at Esna, Naga-Hammadi, Assiut, Zifta and Edfina as shown in *Figure 1*.

The old Aswan Dam was built in 1902 and was the first major structure for storing water annually. Its original storage capacity was 1,000 million m^3 which increased to 2,500 million m^3 in 1912 and finally to 5,300 million m^3 in 1933. This dam, together with other storage reservoirs on the Blue and White Nile, have made the flow of the Nile partially regulated from Aswan to the Mediterranean Sea.

Figure 1. Hydraulic Works on the Nile in Egypt



As a result of the continuous population increase in Egypt and the need for further development in the agricultural and industrial sectors, it was necessary to have a long term storage of the Nile water to reliably meet the demand. The Aswan High Dam (AHD) which is an earth-fill, multipurpose dam, was completed in 1965. It is one of the largest man-made lakes in the world. It has a dead storage of 31 milliard m^3 corresponding to a water surface level of 147 m above the mean sea level. The live storage between the elevations of 147 m and 175 m is 90 milliard m^3. The maximum possible storage is up to 183 m, allowing an additional 41 milliard m^3 storage for flood control purposes. The total storage capacity of the reservoir is thus 162 milliard m^3.

2. Irrigation System

The modern history of irrigation practices started in Egypt at the beginning of the nineteenth century by Mohamed Ali. Main irrigation canals and irrigation networks were constructed to introduce new crops with high economic return, such as cotton and sugarcane. Irrigation practices have changed in the Delta, from basin to perennial irrigation. Pumping stations for irrigation purposes were constructed at the beginning of the twentieth century. Since then regular efforts have been made to improve the efficiency of the irrigation system and increase its capacity. The result was an increase in crop production and a great impact on the economy. The agricultural lands, which occupied 2,516 million acres in 1806, increased in 1952 to 5,598 acres through perennial irrigation which led to a high crop intensity (165%).

Since 1952, land reclamation was largely resorted to for increasing the agricultural lands in Egypt—which is around 3% of the country's total area. Before the construction of the AHD, 49,6000 acres were reclaimed. This area was irrigated by water from the surplus of the old Aswan Dam storage, ground water, drainage water, and the economic management of its proper irrigation water. The construction of the AHD allowed long term storage which helped in reclaiming more lands. Till 1972, the total area reclaimed using AHD water was 942,000 acres, mostly in the Delta and Upper Egypt.

The expansion of land reclamation was accomplished through the modifications in the irrigation system, and the construction of new main irrigation canals and pumping stations. The most important new canal for land reclamation areas is the El-Nasiry canal in the West of the Delta. Due to the light nature of the soil in the newly reclaimed lands, the traditional flood irrigation was replaced by sprinklers and drip irrigation systems, which are more suitable given the type of crops, the climate, the topography and operational conditions in these areas. The Five-Year Plan (1982–87) included the further reclamation of about 637 acres irrigated by water from the Nile as well as ground water through new networks of irrigation canals.

The cultivated area in the Delta and Nile Valley was estimated by the end of 1988 to be 7.2 million acres, compared with 6.02 million acres in 1963. The 1988 survey is based on satellite images, aerial photographs and ground survey. The main increase in the areas under cultivation is within the Governorates of Bihaira, Alexandria, Sharkiya, Ismailia and Kafr El-Sheikh. Obviously, these are the governorates where most of the land reclamation was accomplished during the past twenty-five years. However, the cultivated areas of Sinai and the Western Desert are not included in these estimates. The National Land Master Plan identified that 2.8 million acres could be possibly reclaimed and irrigated by the Nile water while 0.55 million acres could be developed by ground water. The current policies for developing Egypt's water resources proceeds from taking into consideration the horizontal expansion of agriculture by 600,000 acres in 1991–1992 and another 1.08 million acres by the year 2000.

Egypt's irrigation system extends over 1,200 km south of Aswan to the Mediterranean Sea, and this makes it possible for a year round cropping. These farms are served by 31,000 km of public canals, 80,000 km of field channels *(mesqas)*, and 17,000 km of public drains. The canal system is designed, operated, and maintained by the MPWWR. The Ministry has four departments (Irrigation, Finance, Planning and Mechanization), four authorities (Drainage, High Dam, Coastal Protection, and Survey), six public sector companies, and WRC. The Irrigation Department administers the system through 19 administrating offices which tend to coincide with governorate boundaries, 48 supervision offices and 167 districts.

The main features of the irrigation system are:

❏ operation and control of the water based on the elevation of the water upstream or downstream of the off-take structures;

❏ water supplied to farmers, on a rotation basis, varies according to the season and cropping patterns rather than to the precise crop requirements of water;

❏ requirement of farmers to lift water once, either from the canal to the *mesqa* or from the *mesqa* to the farm ditch, as a way of discouraging over-irrigation;

❏ a drainage system for removing excess water from cultivated land consisting of open drains, tile drains, and pump stations.

Farm sizes in the Delta and Nile Valley are relatively small. The traditional method for irrigation is to divide the farmer's land into small basins, so that he can irrigate his plots adequately. The operation and maintenance (O&M) of *mesqas* (sub-branch canals) is carried by farmers. However, large *mesqas* are being systematically supervised by MPWWR for O&M.

3. Drainage System

The natural drainage has become increasingly incapable to meet drainage requirements in the agricultural lands since the introduction of perennial irrigation. The side effects of perennial irrigation have increased canal seepage and field losses causing an increased ground water recharge and a rise in turn in the water table. Moreover, the increased cropping intensity and wasteful use of water contributed to the rapid rise of water table. The severe water losses in some land reclamation areas aggravated the problem even more. Salinity of irrigated lands is a product of high water table and lack of adequate drainage in the cultivated lands.

The project of constructing a main open drain was started in 1933, and a huge network of open drains and pumping stations was established. Main open drains supplied 1.9 million acres until 1952 and this supply increased up to 3.2 million acres in 1966. When open drains were first excavated, they were designed to provide drain water at a level of 1.5 m below ground surface. In 1942, it was observed that this level was not sufficient to provide adequate field drainage. Thus, it was decided to keep the water level in the open drains at 2.5 m below ground surface, according to a new policy issued and enforced in 1958. The length of open drains was thus increased from 12,200 km in 1952 to 16,200 km in 1965.

Since 1922, the introduction of field drainage was foreseen and some studies were carried out. In 1938, open field drainage networks were established in an area of 12,000 acres. It was showed that open fields drains, apart from consuming around 10% of the surface area, split the area into small plots and complicated agricultural operations. Moreover, the maintenance of open drains proved difficult; in addition, they became a favorable environment for weeds. In 1938, studies were carried on fifteen fields scattered away all over the country using tile drainage which showed that an area of 19,000 acres was provided with tile drains made of clay pipes till 1948.

An increase in crop yield was noticeable after installing tile drainage: the yield of maize increased by 46%, cotton by 23% and wheat by 22%. In 1949, Law 35 was issued to stipulate that the state would implement tile drainage projects on all agricultural lands and farmers would be charged for the costs. Until 1953, tile drainage projects were carried out on various areas totalling 47,000 acres. During the first five-year plan (1960–65), about 250,000 acres were provided with tile drains and, by 1970, 400,000 acres. A World Bank support program started in 1970 to provide a total area of 5.5 million acres with tile drains through a series of projects.

IV – Policies and Programs

MPWWR is responsible for managing, developing and maintaining Egypt's water resources. To this end, MPWWR is undertaking and implementing several short and long-term programs to be able to supply and provide water for the present and in the future. The high rate of population growth and the limited available water resources require the adoption of bold and ambitious policies. The objectives of these policies are being set to allocate available water resources efficiently, to provide irrigation for the existing agricultural lands and newly reclaimed areas, to supply water for municipal and industrial use, to maintain navigation through the river and to generate and develop hydropower.

The present five-year plan (1987–92) of MPWWR includes several major projects and programs directed towards achieving the goals and objectives of the ministry. The on-going development programs are handling all sectors and activities within the scope and responsibility of MPWWR. They are serving and supporting the overall development plan of the country particularly in agriculture. The following is a short summary of the main projects and programs of the MPWWR.

1. Irrigation Improvement Projects

While the MPWWR is responsible for delivering water to the farm turnouts, it is necessary to improve on-farm water management to achieve the required efficiency and effectiveness of water delivery. As there was no past experience or involvement by MPWWR in on-farm water management, a project for irrigation improvement, the Egypt Water Use and Management Project (EWUP) (1977–82), proceeded in two phases.

In the first phase, past experience and knowledge have been used to formulate plans for expanded irrigation improvement programs in Egypt. The general objective of the project was to improve the social and economic conditions of Egyptian small farmers through the development and use of improved irrigation, water management, and associated practices which increase agricultural production, promote efficient water use and decrease drainage problems.

The EWUP project was implemented at three locations distributed on a geographical and climatological basis. It was based on an interdisciplinary approach which included engineers, agronomists, sociologists and economists working together to increase crop production and promote efficient water use. It this stage, the project developed, implemented and tested improved on-farm water management programs in order to evaluate their technical applicability, farmers' acceptability and organizational replicability.

The Egyptian government initiated, in 1984, a national program to improve and rehabilitate irrigation canal networks in the new as well as old lands of the Nile Valley and Delta. The National Irrigation Improvement Program (NIIP) is based in a great part on the successful results of the EWUP project. The USAID support program enhanced the development of the project until it become an on-going activity. The present phase of the program, which started in 1989, is entitled "The Regional Irrigation Improvement Program (RIIP)". The RIIP concept is to adopt the ideas generated in the EWUP project and develop them into practical plans that will be applicable for a number canal commands within different regions in Egypt. Methodologies developed by RIIP are applied within the National Program.

The RIIP program will cover an area of over 300,000 acres during the life of the project. It will establish and field test an organizational structure within the MPWWR, capable of providing technical assistance, construction assistance, economic analysis, on-farm development assistance and user involvement to remodel selected irrigation canal commands. The objective is to make the system more responsive to farmers' needs and to assure that water is available in the quantities required at that time to support increased agricultural output. The project will develop a multidisciplinary approach to problem identification within canal commands, ensure the development of cost effective and economic solutions, and the implementation and evaluation of selected interventions.

2. Irrigation Management System

The RIIP project described above is a component of an overall project entitled "The Irrigation Management System (IMS)". The IMS project was originated in 1981 and expanded in 1984 to promote its impact and take advantage of the past experience of six years of research carried out under the USAID support project (EWUP). The IMS project receives an Economic Support Fund from USAID. The project grant was brought to U.S. $340 million in 1987 and the Egyptian's Government contribution was equivalent to U.S. $421 million. The expected life of the project was of ten years (1981–91) and was expected to be extended to 1995. The goal of this project was stated as "effective control of the Nile water for all uses and particularly for their optimal allocation to and within agriculture as a means of helping increasing agricultural production and productivity". In order to achieve this goal, the IMS project includes, in addition to miscellaneous technical assistance and commodities, the following eight components:

A. Structure Replacement (SR)

This major component is meant to improve the maintenance capability of the MPWWR. It was initiated along with six other components started in 1981. The SR project aimed to minimize the structures of the irrigation system, improve their quality and check that they are built according to MPWWR specifications. Under this project, 3,000 structures were replaced or rehabilitated in the first phase. An additional 6,500 structures will be replaced during the second phase which started in 1989.

B. Preventive Maintenance (PM)

Preventive maintenance had not been a common practice in the field units of the MPWWR and has resulted in an undesirable state of maintenance of most of the irrigation system. The initial phase of the PM project is the establishment of a preventive maintenance organization in the Gharbia Directorate. Once operating, this unit can act as a model for extension to the other 18 Directorates in the irrigated areas. The objective is to plan and implement a preventive maintenance system for the public canal and drainage system. Associated with this program, an International Bank for the Reconstruction and Development (IBRD) assistance package is proposed to strengthen the Channel Maintenance. The IBRD assistance includes a soft loan of U.S. $45 million to implement the canal maintenance project in four years (1989–1993).

C. Main System Management (MSM)

Management decisions of water flows at key points throughout the irrigation delivery system will be improved by a telemetry data collection system. This system will provide real time data needed to improve the management and to reduce wastage and shortage of irrigation water. The initial phase of the telemetry system will provide detailed data (basically water levels) on the hydrology and other details of 255 specific points in the irrigation system. This will also assist the MPWWR in experimenting with automation of control gates in a pilot area (Salheya Canal command) of the irrigation system.

D. Planning Studies and Models (PS & M)

The MPWWR has developed a number of computer models designed to increase the operating efficiency of the whole irrigation system. Some of these models deal with the inflow simulation to predict the flows in Lake Nasser and the operating rules of the Aswan High Dam. Other models are concerned with the water delivery system subject to agricultural policies and programs. The development of these models has been assisted by UNDP since 1977. The objective of the new IMS component is to benefit from the basic sets of models and develop them to an integrated operational stage at which decision makers may use them to test the impacts of various policies.

E. Project Preparation (PP)

The project preparation Unit (PPU) was created by MPWWR to conduct advanced economic and technical feasibility analyses of investment options for MPWWR and to prepare English reports to be submitted to international funding agencies and foreign donors. The PPU also serves the staff capacity for the development problems of the Ministry. The PPU has turned out a number of studies which present their proper methodology and importance in funding decisions.

The PPU has recently been upgraded to a department level and become a Project Preparation Department (PPD). It has been supported by additional staff. These changes, along with technical assistance, training and professional development activities, have been and will be provided by the IMS project. Based on the previously mentioned developments, the target of self-sufficiency should be achieved. At that point, the PPD will be carrying out feasibility studies at international standards without outside technical assistance.

F. The Water Research Center (WRC)

The scope and complexity of the MPWWR responsibilities concerning the irrigation system involve a wide range of scientific disciplines and numerous subject areas. The WRC was created by the MPWWR to conduct basic research and to serve as a data bank for all the aspects of the irrigation system. To achieve this purpose, the WRC with its eleven research institutes were created and became fully operational in 1975. They carry out research to provide solutions to the problems facing the MPWWR in its activities to control, use and develop the water resource of the country for achieving its economic and social development.

The objective of the WRC component of the IMS project is to develop the former's capabilities in the long term. WRC's research institutes should provide the MPWWR and Egypt with solutions to irrigation problems and water resources. Thus, the project will finance the WRC and its eleven institutes for expatriated technical assistance and training. The training comprises twenty-six Ph.D's, forty-four M.Sc. scholarships and four hundred and sixty-eight “person/month” for non-degree training outside Egypt. Furthermore, it will provide a procurement plan to consolidate the laboratories, experimental stations, the central library and to install a mini-computer and establish a computer network for common use of data and for better interaction and communication among the research staff.

G. Survey and Mapping (S & M)

The *Survey of Egypt* was established in 1894 to carry out a program of survey and mapping. Geodetic control networks were established through the Nile River Basin. Most of cadastral and topographic maps currently in use for planning and designing irrigation projects were prepared between 1900 and 1945. Nearly all these maps are inadequate for preparing feasibility studies or detailed project plans. In addition, accurately scaled aerial photography is not available for the irrigated areas of Egypt.

The Egyptian General Survey Authority (EGSA) was established in 1971. The major task of EGSA is to prepare high quality maps needed for planning irrigation improvements and maps for detailed design of irrigation projects and for maintaining cadastral records. The EGSA is also responsible for all cadastral surveying in Egypt. In addition, accurate measurement of the nation's crop areas is needed for the development and calibration of complex models of irrigation system. The aerial photographing techniques provide such accuracy.

The objectives of the S & M component of the IMS project is to make maps and aerial photographs of high quality available for use in irrigation improvement and for other development purposes. The project will provide a series of contracts that will acquire mapping products (aerial photography, orthophoto or digital maps) and institutional improvement of EGSA itself through equipment and training.

H. Professional Development

The Training and Manpower Development (TMD) unit within the Water Research Center provides a program of short courses to promote the capabilities of the MPWWR staff, within the framework of an in-service training program. The training requirements of the MPWWR subject to the current training facilities of the country require the establishment of a National Irrigation Training Institute (NITI). NITI will provide a structured in-service training program for the technical staff of MPWWR and some staff of the Ministry of Land Reclamation. The objective of this component of the IMS project is to institutionalize a multidisciplinary training program to meet the needs of the MPWWR through establishing NITI.

3. Drainage Water Recyling Projects

A. El Salam Canal

The El-Salam Canal project started in 1985. It is planned to irrigate about 400,000 acres to the east of the Suez Canal and 200,000 acres to its west. It is going to be fed with fresh water from the Damietta Branch upstream of Farskour Dam and will be supplemented with drainage water from the Lower Serw pumping station and Bahr Hadous drain. The drainage water will be mixed with fresh water at a ratio of 1:1 to reduce the salinity level to about 800 ppm. This salinity level is reasonable for crop producing in sandy soils. It is planned to add 1.5 milliard m^3/yr of drainage water to similar quantity of fresh Nile water during the first and second phases of the project. The mixed water will be used to irrigate 165,000 acres in the first phase in Port Said Plateau, South Husseinia and South Salhia. The second phase covers the irrigation of 200,000 acres extending along the northern coast of the Sinai peninsula from the west of Al-Arish.

B. Omum drain Project

The objective of the project is to direct the drainage water from the three catchments of Omum drain (Abu-Hummos, Shereishra and Truga) to a channel which flows in an opposite direction to the drain. This collection of water will then be mixed with fresh water from the Nubariah Canal. At this stage, the canal serves an area of reclaimed lands of about 500,000 acres. Its flow will be about 5.0 milliard m^3/yr and the quantity of drainage water to be used in the project is about 1.0 milliard m^3/yr. The expected salinity of water after mixing will be about 800 ppm.

C. Batita Pumping Station

This pumping station is located on the main Gharbia drain on the downstream side of the Samatay pumping station. It is planned to pump partially the water delivered by both the station and the Segaiya pumping station to Zawia Canal. The discharge of the two pumping stations is planned to be 250 million m^3/yr at an average salinity of 900 ppm, which can be reduced to 600 ppm by adding and equal quantity of fresh irrigation water.

4. The Land Drainage Project

A comprehensive drainage program was initiated in the early seventies. It includes the construction of new main open drains, remodelling of existing main open drains and the construction of a drainage pumping station. The National Plan is aiming at supplying a total area of 6.59 million acres with main open drains. The area supplied by the main open drainage was 6.03 million acres till the end of 1989. The main drainage system is planned to be completed by the end of the Five-Year Plan (1987–92). Pumping stations are constructed to improve the drainage conditions in the flat areas and low-level lands. The drainage program has brought the total capacity of pumping drainage stations in Egypt to 2.459 m^3/sec. to serve a total area of 6.59 million acres.

The drainage system program also includes the provision of a subsurface field drainage system to a total area of 5.5 million acres in the Delta and the Nile Valley. A series of World Bank (WB) support projects started in 1970. The WB loan covered the cost of imported machinery and raw materials for plastic tubing production. Other major on-going drainage projects include: 65,000 acres in the north of the Northern Delta supported by the EEC; 80,000 acres in Dakahlia Governorate within the Canadian support project (ISAWIP); and 48,000 acres within the newly reclaimed lands on both sides of the Delta. The areas provided by subsurface drains till the end of 1989 is about 3.4 million acres. A number of drainage pipes manufacturing plants were constructed to produce the pipes and tubing required for land drainage in Egypt.

Extensive areas in the old lands of the Nile Valley and Delta have become water logged and salinized desert lands. It is estimated that the water logged area in the Nile valley has covered 50,000 acres since the beginning of desert reclamation in the early seventies. There are at least five areas near West El Fashn, West Samalut, West Tahta, West Esna and Kom Ombo in Upper Egypt reclaimed desert areas that have severe water logging and salinity problems. In the Delta, the affected area is even larger particularly in the Western Delta.

The present policy of the MPWWR is to solve the drainage problems in the above mentioned area in Upper Egypt with tube well drainage. In this respect, studies have already been made in the West El Fashn, West Tahta and West Samalut areas. Forecasting and using simulation models showed that tube well drainage is technically feasible and economically attractive for drainage. These studies resulted in well field designs for drainage purposes. In West El Fashn and West Samalut, the designs have already been implemented resulting in a well field of 63 wells in West El Fashn and one of 74 wells in West Samalut. These 137 wells are not yet operated due to the lack of pumps, engines and power supply connections. It is expected that the well field in West Tahta will be provided soon with pumps and engines through a co-operative project with the Italian Government.

5. The Esna New Barrage

The first Esna Barrage was completed in 1908 as one of the main control works for regulating the Nile water. It has 120 gate openings, 5 m wide each, placed across the whole river section. It was constructed to allow a flood discharge up to 14,000 m^3/sec. A lock (12m x 64 m) on the west bank was also included in 1948 and carried out to increase the head to 5.1 m.

However, it may be noted that the barrage has been operated at full design head only for a limited period, since the AHD was included in the operation.

Due to the deteriorating condition of the Esna Barrage and the need to improve navigation between Esna and Aswan and to produce more hydropower, the old structure required either to be replaced of renewed. It was more convenient to construct a new dam with a spillway, a power house in the main river course and a new lock located on the east bank. The spillway will have a discharge capacity of 7000 m^3/sec. A power station will be constructed to generate a total installed capacity of 102 MW.

The new structure which is now under construction will replace the old Esna Barrage. It will improve the navigation conditions in the area between Esna and Aswan which used to be a bottle neck, especially during the winter closure period. The newly constructed lock at Nagaa Hammadi together with the lock at Esna will eliminate all navigation problems in Upper Egypt and will, in turn, improve and encourage river transportation and tourism. The generated power from the new Esna Barrage will raise the country’s power supply for industrial and domestic uses even further.

6. Use of the Winter Closure Nile Water

The water released from the AHD during minimum irrigation requirements and winter closure is mainly used for navigation purposes and hydropower generation. The part of this water which used to flow directly to the sea without being used in irrigation was about 6.0 milliard m^3/yr. Since 1987–88, the water discharged into the sea was decreased to 2.8 milliard m^3/yr through rationalizing and improving management of the Nile water during the closure period. However, it will be necessary to conserve this quantity for meeting additional demands arising from future expansion in agriculture. Therefore, it was necessary to update some old plans for storing the Nile water flowing to the sea during the period of minimum requirements and winter closure in the northern lakes. The stored water can be used later in irrigation whenever needed during the year.

Two schemes are planned for conserving the Nile water from being wasted to the sea during the winter closure. They would make this water available at the proper time for irrigation. The first scheme is to store 0.8 milliard m^3 of water during the winter closure each year in the Manzala lake. This quantity will be used to supply partially the El-Salam Canal. It will be supplemented by the Nile water from the Damietta Branch and the recycled drainage water to irrigate 200,000 acres west of Suez Canal in the second phase. The second scheme is to store 1.5 milliard m^3 of water during the winter closure of the Burullos Lake. Part of this water will be used for irrigating 55,000 acres south and west of the lake. These areas form part of the land reclamation plan which will be implemented soon. Another part of the stored water will be used to irrigate the command area of the East Reshidia Canal in Kafr El-Sheikh. The rest of the stored water will be discharged into the Rosetta Branch, upstream Edfina Barrage, to meet the peak irrigation requirements during the summer.

7. The Hydrological Forecasting and Monitoring Center

Egypt's dependency on the Nile River as its major important water resource makes the necessary monitoring very difficult during the period of unpredictable flood conditions. Thus sufficient lead-time is essential and vitally important for properly managing the river flow and establishing adequate water distribution policies.

For the improvement of flood prediction, the MPWWR is working towards establishing a center for forecasting of short-term and long-term variations of the river flow in real time. A FAO project financed the establishment of the center which will produce both deterministic forecasts and extended stream flow predictions through monitoring, forecasting and simulation of the Nile River basin.

The adopted techniques are expected to improve the lead-time available rather than the present forecasts procedures based solely on stream flow data. The increased lead-time should be gained through simulating the Upper Basin response to rainfall, accounting for the moisture balance of the soil ground water system and long range climatic signals based on perceptive forecasts. In order to achieve these capabilities, the system will include different components such as data acquisition, remote sensing, hydroclimatic analysis, and diagnosis and predictions.

8. The Jonglei Canal Project

The main objective for constructing the Jongli Canal is to increase the Nile water resource from losses to the swampy areas of the Equatorial Lakes. The total annual water losses is estimated at 14.3 milliard m^3/yr. The first stage of the project includes the construction of a canal of 360 km long which connects Bahr El Jabal at Bor Straight to about Malakal on the White Nile. The canal capacity at that stage will be 30 million m^3/day. Regulator and navigation works will be carried out in the original river channel at the connection of the canal with the Sobat River.

The second phase of this project includes the construction of a dam at the exit of the Albert Lake to increase the storage capacity of the Equatorial Lakes. The Jonglei Canal capacity will increase to 43 million m^3/day.

The implementation of the project started in 1978. However, work stopped in 1983 due to political problems in the south of Sudan after the contractor has completed 75% of the earth work within 270 km of the canal length. It was planned to complete the first stage in 1985, which was supposed to increase Egypt's share from the river by 2.0 milliard m^3/yr.

V – Research Programs

1. The Water Research Center

The Water Research Center (WRC) was established in 1975 in an attempt by the MPWWR to cope with the rapid world-wide development in the field of water management. Thus, one of the major objectives of WRC is to outline and implement long-term policies for managing the water resources in Egypt in order to cope with the national demand at present and in future. WRC also aims at solving the technical and applied problems associated with the general policies for irrigation and drainage. Moreover, WRC is concerned with the extension of agricultural lands and the assessment of surface and ground water resources. Its goal is to find the means to utilize Egypt's water resources in the most efficient and cost-effective manner.

The research activities of the WRC are carried out by eleven institutes. Their names and mission are:

❑ **Water Distribution and Irrigation System Research Institute.** It deals with researches relevant to distribution of irrigation water, modern irrigation systems, assessment of plant water requirements, improvement of the irrigation delivery network, increasing irrigation efficiency and minimizing water losses.

❑ **Aquatic Weed Control and Channel Maintenance Research Institute.** Its major concern is to safely control the growth of harmful aquatic weeds in water channels by manual, mechanical, chemical or biological means. It is also responsible for conducting researches on the maintenance of channels and drains and their re-design after construction of the High Dam.

❑ **Drainage Research Institute.** It conducts researches on surface and subsurface drains, developing and testing new technologies for construction and maintenance of subsurface drains, analysis of drainage water on a national scale, recycling drainage water for irrigation, salt balance studies for improving drainage conditions in different regions, monitoring and evaluating the economical and environmental impact of the drainage projects.

❑ **Ground Water Research Institute.** It is responsible for the assessment of the capacity of underground water reservoirs in both Delta and Upper Egypt, determination of the extent of sea-water intrusion in coastal aquifers, developing hydrological map for the Delta and Nile Valley regions, as well as the use of mathematical models and computer assisted programs in the different ground water researches.

❑ **Water Resources Development Research Institute.** It works in the field of water resources development, conducting studies on the possible projects to be implemented in the upper tributaries of the Nile River and in the Sinai Region, in addition to the establishment of a complete network of recording devices to be used in designing dams and other control structures.

❑ **High Dam Side Effects Research Institute.** It is responsible for studying the impact of the change in discharge regime resulting from the High Dam along the whole source of the Nile River and submission of proposals for control structures required for channel protection in regions subject to degradation, bank erosion or sedimentation. The Institute regularly makes cross-sectional analyses using computer and mathematical models. It reports about overall degradation, bank erosion and sedimentation along the Nile River of its channel.

❑ **Hydraulics and Sediment Research Institute.** This Institute concentrates on the use of hydraulic models to solve problems of degradation and sedimentation in the Nile River channel; hydraulic models are also used to arrive to the most appropriate design for canal intakes, power stations, barrages and other major irrigation structures.

❑ **Survey Research Institute.** The institute is involved with programs for determining the geodetic surface in Egypt and studying the movement of the earth crust in Asia, Africa and the earthquake region at Aswan. It also provides survey supporting services for the other institutes.

❑ **Mechanical and Electrical Research Institute.** It is mainly concerned with mechanical and electrical activities associated with the operation of the gates at water control structures, such as barrages, and the operation of pumps and protection from corrosion.

❏ **Coastal Protection Research Institute.** The institute's main activity is the hydrographic scanning of the shore line and measurement of the sea flows, wind and waves, as well as the recording of tides and changes of water level throughout the year. This helps planning for the necessary coastal protection measures.

❏ **Soil Mechanics and Foundation Research Institute.** The goal of this institute is to study soil mechanics problems relevant to the foundations and seepage problems of the hydraulic structures and canals constructed and maintained by the MPWWR.

2. Research Projects

Several ongoing research programs are implemented by the WRC and its research institutes. The programs are oriented towards solving problems and answering questions related to the current plans for irrigation, drainage and water resources development. Some of the ongoing research activities are carried out with support and in collaboration with different international development agencies and Research organizations. In this respect, the WRC established strong connections and relationships with many international organizations. Some of the research projects which are now under way are:

❏ **River Nile Protection and Development Project.** The project started in 1988 and continues until 1992 with support from the Canadian International Development Agency (CIDA). A ten million Canadian dollars grant is offered to implement the project in a four-year period (1988–92) The project's activities are aimed at the Nile River System with objectives of rational utilization of available Nile water resources, mitigation of side effects and promoting the efficiency of present uses and future development. This project is concerned with the Nile and its branches from the Aswan High Dam to the Mediterranean sea.

The project's activities include gathering and consolidating technical and research information on river regime and sedimentation processes, establishing pilot schemes for river bed and bank protection against degradation, studying the effect of erosion on the existing hydraulic structures and controlling the Nile River pollution. The project is implemented by the High Dam Side Effects Research Institute.

❏ **River Nile and Hydraulic Structures Studies.** A three-year project started in 1988 in co-operation with the Dutch Government to study and analyze problems related to river draining, siltation, degradation, navigation and pump and canal intakes using hydraulic models. The project has introduced the Mobile Bed Model Technology to improve the research on sedimentation processes and degradation problems. The Dutch Government offered a grant of DF 3.6 million for implementing this project, in three years (1988–91). The project is implemented by the Hydraulic and Sediments Research Institute.

❏ **The Egyptian-Dutch Panel Program.** A research program was initiated in 1976 by the Egyptian Government represented by the MPWWR and the Dutch Government represented by the Ministry of Foreign Affairs. The executive agency is the WRC through its Drainage Research Institute and Ground Water Research Institute. Technical support is being provided from several Dutch specialized institutions such as ILRI, ICW, RIJP and IWACO. The objective of establishing the Panel is to provide the Government of Egypt with integrated approach in order to control water logging and salinity. Under the umbrella of the Panel, five separate research projects have been formulated. They are:

(i) The Pilot Areas and Drainage Technology Project. This project is concerned with the planning, design, implementation, operation and maintenance of subsurface drainage systems. It implements pilot areas to develop and verify drainage design criteria, test drainage materials and new construction and maintenance technology. The project is managed by the Drainage Research Institute (DRI). The project's fisrt phase (1988–1991) benefitted from a DF 3.6 million grant.

(ii) The Recycling of Drainage Water Project. Field surveys were conducted within the framework of this project to determine the quantity and quality of drainage water available in the Delta and their spatial and time variations. The project analyzed the data to classify the drainage water according to its quality and suitability for re-use in irrigation. The project developed also a regional water management mathematical model for predicting the future changes in the quantity and quality of the drainage water in response to possible changes in irrigation practices, water management, or crop pattern. The project is implemented by DRI in phases of which the final phase is of three years (1988–91) with a DF 1.75 million grant.

(iii) The Fayoum Water and Salt Balance Model Project. The objective of this project was to assess the state of water management and its constraints as well as evaluate the effects of water management alternatives on the water balance of the Fayoum area and the levels. It was terminated in 1987. The pro-

ject is implemented by DRI.

(iv) The Vertical Drainage Project. The technical and economical feasibility of tube-well drainage has been studied in pilot areas in Upper Egypt. Well fields were designed to meet irrigation requirements along with solving drainage problems. The project was phased in two stages and expected to be completed by the end of 1991. A grant of DF 1.3 million was provided for the second phase.

❏ **The Hydrogeological Map of Egypt.** The aim of this project is to produce an atlas for the ground water reservoirs in the country. The project is implemented by the Ground Water Research Institute in co-operation with the United Nations Development Program (UNDP). A 2,000,000 scale regional map has been developed, along with other detailed maps at a 100,000 scale. The project's duration is four years (1987–91). Other projects under the same program for producing maps with different scales or maps to cover other areas in the country are under way in co-operation with the Dutch Government, the USAID IMS project and the Egyptian Academy of Science.

❏ **The Regional Nubian Sandstone Aquifer Project.** National project on the regional major aquifer in Northeast Africa is designed to control desertification through proper agricultural and other forms of land and water management. The project is implemented in co-operation with the Italian Government. It will start in 1990 and the expected output would be to identify the Nubian sandstone aquifer in the Western Desert, to evaluate ground water potentialities and to establish optimum policies for ground water development.