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HYDROLOGICAL AND ENVIRONMENTAL CHARACTERISTICS OF WETLANDS IN EGYPT

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ABSTRACT: Egyptian wetlands are classified into two broad categories: coastal and inland wetlands. The major problem of coastal wetlands, which are located in the northern part of the Nile Delta, is the environmental impacts caused by the intrusion of saline water into fresh water aquifer. Inland wetlands, which are often located in the depressions of western desert or other areas along the Nile Valley, can be further classified as either natural wetland such as Wadi Elnatrun depression, or manmade wetland such as Siwa oasis. The associated problems in manmade wetlands comprise the groundwater abstraction which often exceeds the actual need, the negative impact of upland drainage on neighboring lowland, and the rise of groundwater table in agricultural lands due to illegal alteration of irrigation systems by farmers. Another type of manmade wetlands is the riverine land, which was existed in south of Egypt after the construction of Aswan High Dam and caused dramatic migration for some living societies and relocation of some historical monuments. This review addresses the current problems faced by those coastal and inland wetlands, and illustrates the mitigation systems proposed in Egypt for tackling such problems.

INTRODUCTION

From hydrological viewpoint, wetlands can be defined as “those lands that are saturated with water from surface or ground water resources at duration sufficient to prevent growth of normal plants and crops” (Grismer 1998). Wetlands are existed in areas where there is an excess of water due to the following: 1) the rise of sea water level, 2) the drainage of water to depressions in landscapes, or 3) the excess of annual precipitation than the potential evapotranspiration. The classical classification of wetlands grouped them into two major types: natural and manmade wetlands. Natural wetlands are formed when the land falls below the sea level. Manmade wetlands are formed due to human activities through the random abstraction and exploitation of groundwater, or by the lack of management of irrigation and drainage systems in land where the groundwater table is naturally high. Another type of manmade wetland is caused when uplands are transferred into wetlands as a result of the extraordinary rise in the water level upstream of dams. For example, during the construction of Aswan High Dam in south of Egypt, several lands in the upstream side were flooded by water. Egyptian government was forced to relocate the drawn historical monuments, such as Abu Simble temple and Phialla temple to another uplands with the aid of the UNESCO.

In Egypt, the phenomenon of saline water intrusion has seriously affected on the groundwater management along the coastal land of the Nile Delta. Although this effect is partially attributed to the construction of the Aswan High Dam, the consequence decrease of the recharged fresh water into the groundwater basin in the Delta is also another major effective factor. The Delta is an important resource in the future of the Egyptian economy. Egyptian agricultural wealth amounts up to 25% of the total income, of which 70% percent

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comes from the Nile Delta area. The anticipated high population growth, together with the uncertainties of weather in relation to the Nile water resources, make the need for scientific research and exploitation of the Delta aquifer of paramount importance. The Nile Delta aquifer is considered one of the largest underground fresh water reservoirs in the world. The potential benefits of proper groundwater management include a) the increase of groundwater yield and quality, b) the avoidance of up-coning problems which may occur due to the unexpected extraction of water in the north of the Delta, and c) the maintenance of drainage system following a reduction of water head in the clay layer, which covers the whole Delta aquifer.

For inland lowlands, a spotlight is focused on manmade wetland problem selected from the Nile valley. Surface water has been available for land reclamation east and west of the Nile valley since the construction of the Aswan High Dam. About 750,000 acres of new land on the fringes of the Nile floodplain have been reclaimed since 1967 by using surface water discharged from main and branch canals. A few years later, the land was cultivated, and problems appeared in the new land as well as in the adjacent old land surrounding the riverbanks. Those problems can be summarized as the waterlogging in the lowland farms, the rise in water table in the new reclaimed upland, the shortage of irrigation water in the end reaches, the migration of farmers from lowlands to the desert side, and the high rate of groundwater abstraction in their new farms.

Another example of inland wetlands problems is the oasis waterlogging and the salinization due to the random abstraction of groundwater. This problem took place in several oases in the western desert. People dug hundreds of private wells with different water salinity in order to reclaim and cultivate this arid land. This practice has lead to the deterioration of the groundwater. The excess discharge from wells is drained forming salt lakes, which in turn affect on soil, air humidity, social life, and the stability of historical temples in the oasis. Management of groundwater in such areas is essential for better environment and quality of life.

SALINE WATER INTRUSION

Concepts and Application

Definitions

In coastal aquifers under natural conditions fresh water floats above saline water. The separating surface between the two types of water is known as the saline-fresh water interface which takes the form of a transition zone of varying salinity. The process of migration of saline water into fresh water, is an important item in the hydrological cycle in coastal regions. Coastal aquifers may be classified into four types, Figs. 1a, 1b, 1c, and 1d:

1. Unconfined (phreatic) aquifers are bounded at the top by the groundwater table and the bottom by an impervious layer.
2. Confined aquifers are bounded at both top and bottom by impervious layers.
3. Leaky aquifers are confined aquifer but one or both of the confining layers are semi-pervious with lower permeability coefficients than that of the aquifer itself.
4. Layered aquifers consist of several aquifers separated by impervious layers.

Modeling of Saline Water Intrusion

Groundwater model development involves three basic steps as any other model. The first is the identification, which involves the simplification and schematization of real system by using set of assumptions. The second is the verification, in which the identification model is

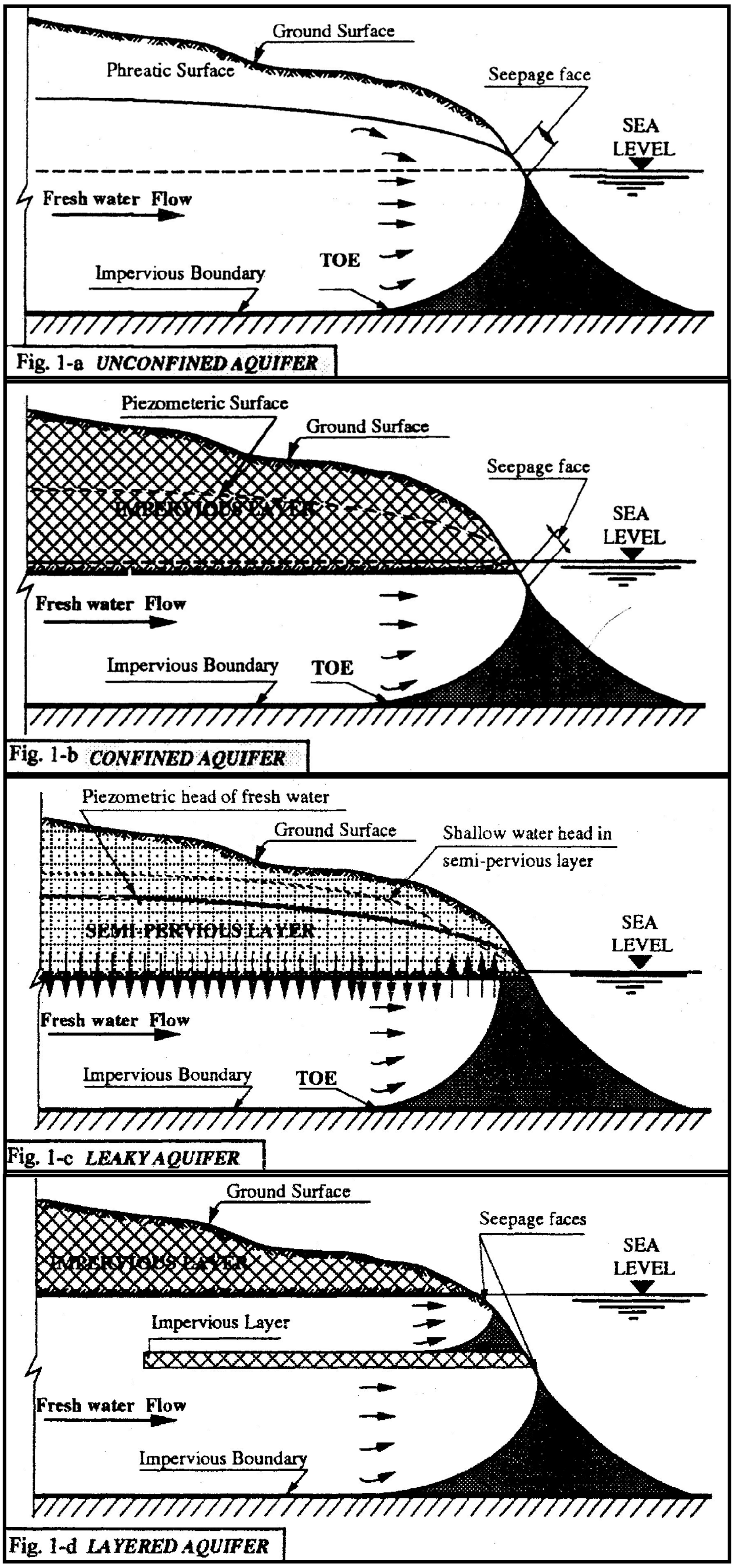

Fig. 1 Different Types of Coastal Aquifers (after Zakari, 1995)

tested under controlled conditions. The final step is the calibration of parameters in the identified model, which may be executed by trial and error method or an automatic method (Anderson et al. 1992) until best fit is achieved between the observed and computed dependent variables.

Saline water intrusion phenomenon can be simulated by one of the three types of modeling:

1. Analytical models that directly solve the equations after any necessary manipulation to eliminate or obviate certain difficulties, (Pistiner and Shapiro 1993).

2. Physical models and analogies which try to compare the model of the prototype with other physical phenomena responding to the certain mathematical principles, (Kashef 1971), and (Sugio et al. 1987).

3. Numerical (digital) models that solve the mathematical equation by approximate methods, such as finite difference (Essaid 1990), finite element (Hassan 1993), and finite volume (Rangogni and Molinaro 1994) method.

Hypothetical Approaches for Saline Water Intrusion

In each type of aquifers one of the following two approaches might be considered in modelling the interaction between fresh and saline water.

Sharp interface theory

Immiscible fluids with different properties are separated by an interface. The location and shape of the interface influences the pressure and density distributions in both fresh and saline water zones. The sharp interface approximation becomes very convenient in some practical situations when the transition zone between salt and fresh water is quite narrow compared with the overall saturated thickness of the aquifer formation. Two types of sharp interface line can be described; the first is the lens type, the second is the toe type, see Figs. 2a-2c. For applying this theory, the general form of Darcy's Law and the mass continuity groundwater flow equation are applied for each zone assuming constant densities ρ_f and ρ_s for fresh and saline water, respectively (Layla 1980).

Convection and dispersion theory

A transition fully mixed zone between the two liquids is located with a gradual decrease in salt content from saline water to fresh water, see Fig. 3. The quantity of the water and width of the transition zone depends on the convection, hydrodynamic dispersion, solid-solute interaction, various chemical reactions, and any decay phenomena may be related to the source of salt. The flux of salt per unit area due to convection only can be represented as the production of the average pore water velocity related by Darcy's law to the hydraulic gradient and the mass of solute dissolved per unit volume of the liquid. Bear and Verruijt (1992) described hydrodynamic dispersion as consisting of two independent phenomena, namely mechanical dispersion and molecular diffusion. Both types produce mixing and spreading of solute. Mechanical dispersion is caused be velocity variation at the microscopic level. The molecular diffusion represents the movement of salt due to difference of salt concentration and does not require seepage flow. The flux of molecular diffusion is governed by Fick's law.

Investigation on the Saline Water Intrusion in the Nile Delta Aquifer

The exploitation of coastal aquifers in Egypt has been limited to the local abstraction of relatively low quantities of groundwater from the coastal aquifers due to the dominance of the use of surface water from the Nile River.

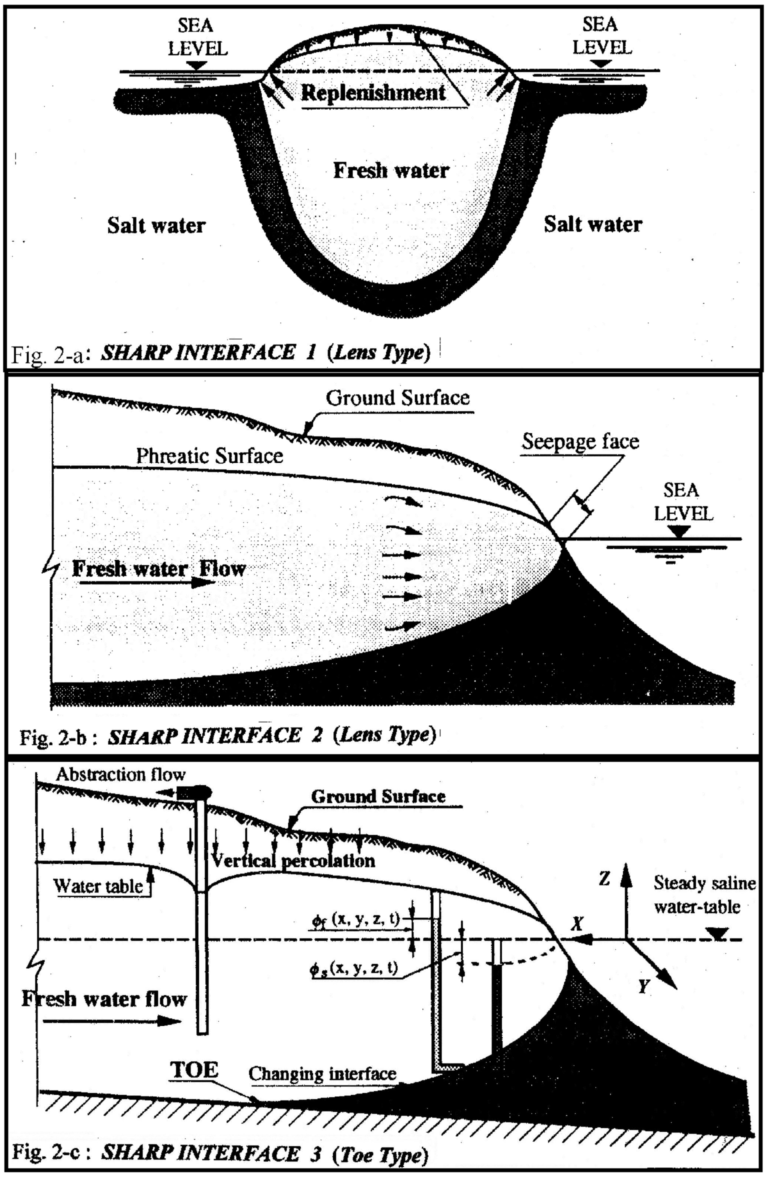

Fig. 2-a: ***SHARP INTERFACE 1 (Lens Type)***

Fig. 2-b : ***SHARP INTERFACE 2 (Lens Type)***

Fig. 2-c : ***SHARP INTERFACE 3 (Toe Type)***

Fig. 2 Diagrammatic representation of groundwater flow in the coastal aquifer

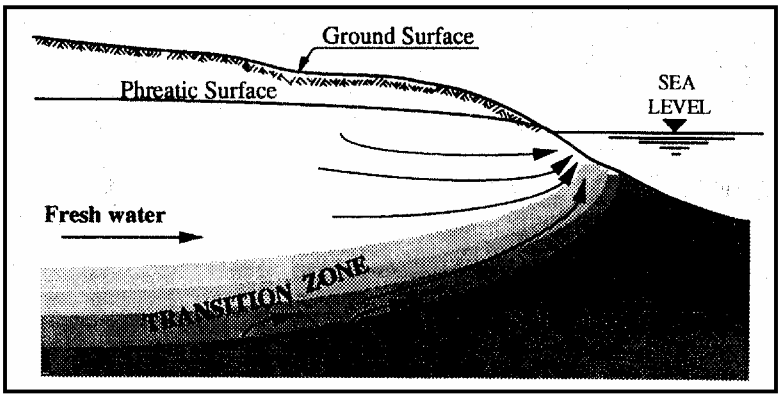

Fig. 3 Transition zone and flow patterns in homogeneous coastal aquifer

Location and geological formation of the Delta aquifer

The Nile Delta area and its fringes lie between latitudes 30° 05' and 31° 30' north and longitudes 29° 50' and 32° 15' east. The area is almost triangular in shape. The length of the base is about 275 km and the apex of the Delta lies 20 km north west of Cairo City. It is bounded by the Mediterranean sea at the north, the Suez canal at the east, desert in the west and Ismailia Canal in the south east, see Fig. 4. In the north there are several natural salt lakes, such as El-Manzala, Idko, El-Burulius, and Maryut. The area of the Nile Delta is about 2,200 km^2. The land has a gradient of about one meter every 8.5 km. Precipitation is rare, occurs in the winter and varies from average of 26 mm per year at the south of the Delta to an average of 180 mm at the Mediterranean Sea.

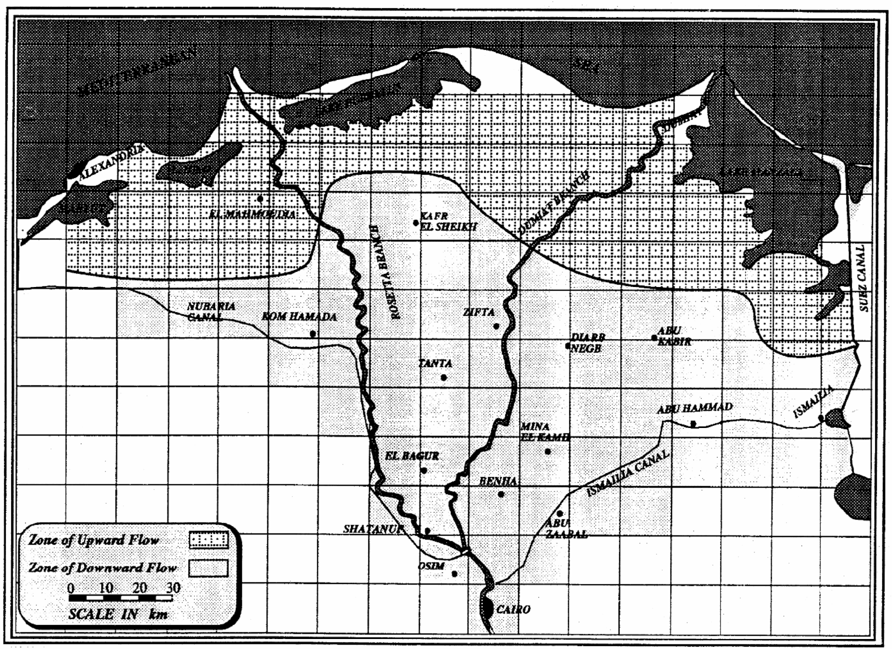

Fig. 4 Nile delta region and zones of upward and downward flow

The bulk of the aquifer consists of deltaic deposits (pleistocene, 10^6 years). The thickness of the deposits is about 900 m at the sea and it decreases gradually going to the south. There is a clay cap (Holocene, 10^4 years) in the top of the aquifer. The thickness of clay cap is about 40 m at the Mediterranean coast and about 5 m near Cairo. The Nile Delta aquifer rests on a thick clay section, which acts as an aquiclude (Impervious layer-Pliocene, $25x10^6$ years). The main part of the reservoir is considered to be leaky aquifer, confined by an aquilude (thick clay) in the bottom and a semi-previous layer (clay) at the top. Outside the branches of the Nile River, particularly at the eastside near Ismailia canal, the aquifer becomes unconfined due to the clay cap vanishing. The north side of the reservoir is bounded by the Mediterranean Sea, the east by the Suez Canal, the south by a clay aquiclude near Cairo, and the west by limestone stratum, see Fig. 5.

Porous medium properties for flow and salt transport

The records for vertical hydraulic conductivity in Delta aquifer gave average values in the range of 84 to 220 m/day (Amer 1982). The storage coefficient was found to lie in the range of 0.001 to 0.006 (Amer 1982) at the middle part of the Delta and 0.0007 to 0.0018 (Amer 1982) at the east of the Delta. The values of porosity of the Nile Delta aquifer lie within the range of 20%-25%.

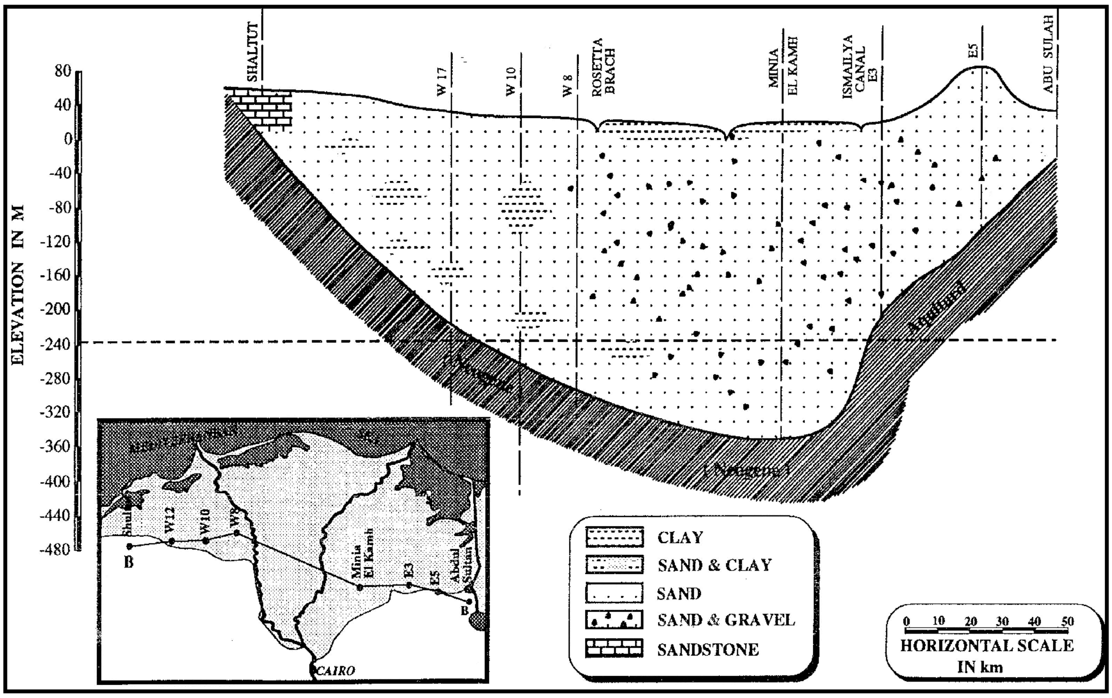

Fig. 5 Geological cross section B-B

For the clay cap, vertical permeability coefficient, k_z', is calculated by using Auger-hole, which is base on short-term stress. The recommended value for vertical permeability lies in the range 0.02-0.3 m/day. Local response tests at small selected intervals of time are used to measure horizontal permeability in the clay cap. For salt transport, the longitudinal dispersivity in the aquifer is recommended to be 100 m, and the transverse dispersivity is 10 m. The molecular diffusion is zero.

Groundwater levels and the quantity of extracted fresh water in the Delta aquifer

Generally, the main direction of groundwater flow is from the south to the north towards the Mediterranean. The groundwater also flows towards the north eastern direction. The main sources which feed the aquifer are the Nile branches (Rosetta and damietta), some Rayahs (El-Menufy, El-Tawfiky and El-Nassary), the Nubaria and the the Ismailia canals, in addition to the amount of drainage water from the land, the drains, and the rainfall. The maximum exploitation of the groundwater of the Delta aquifer lies in the western part of the Nile Delta, see Table 1. This is due to the lack of any canals network in this area and because most of the land is desert. The amount of the water is about 39.65% of the total fresh water collected.

Groundwater piezometric head in the Delta aquifer

There are two water heads in the reservoir of the Nile Delta. The first is called the shallow water head, referring to the level of water in the clay cap. The second is the pressure head, referring to the potential in the aquifer itself. The potential head in the aquifer varies from 16 m above the sea level at the south to the sea level at the north with negative value in wadi El-Natroun as shown in Fig. 6. The difference between these two pressure heads at a certain location is an indication of the amount of vertical leakage. The groundwater levels were periodically observed in several locations. It is proved that the fluctuation in water level is not more than one meter. Therefore, the flow may be treated as steady state condition. Field investigation showed that there is a zone at the north of the Delta having an upward flow where the potential in the aquifer itself is higher than the shallow water head. The iso-line of Revelle ratio $CL/(CO_3 + HCO_3)$ was determined as 250.

Table 1 Extracted fresh water in Nile Delta aquifer

Delta site	Governorate	Extracted water (m^3/year)	Regional/Total
Southern side	Cairo	238,464,000	15.16%
	Giza	66,838,154	4.25%
Eastern side	Qalyubiya	277,143,625	17.62%
	Sharkiya	142,429,462	9.05%
	Dakahliya	137,661,005	8.75%
Middle side	Gharbia	26,976,687	1.72%
	Menufiya	59,745,882	3.89%
Western side	El Tahrear	612,757,851	38.95%
	Beheira	11,033,216	0.7%
Total of extracted fresh groundwater = $1.6x10^9$ m^3/year			

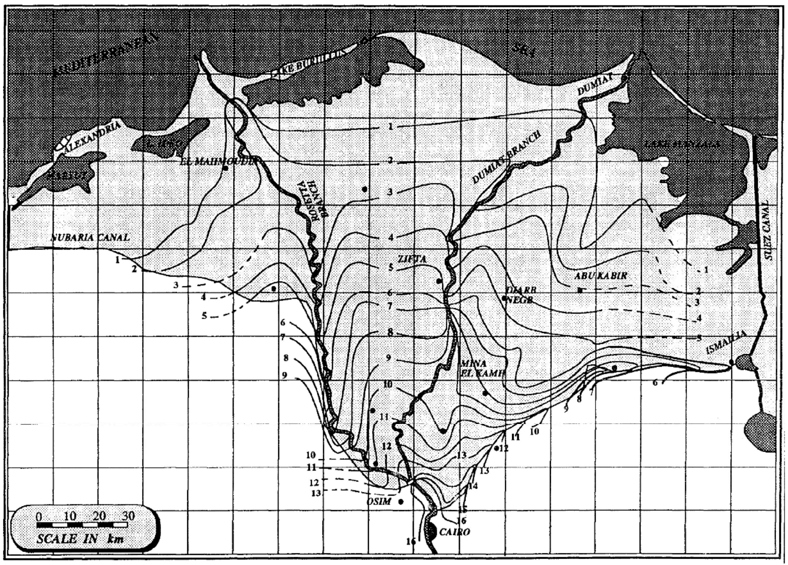

Fig. 6 Contour map of piezometric heads

Fresh water flux to the Mediterranean Sea

The groundwater reservoir loses some of the incoming water to some reaches of the river and to Wadi Natroun Depression. The rest of the water balance discharges to the sea. This amount is estimated to be $0.6x10^9$ m^3/year. It is calculated by using contour map of piezometric heads and maps of fresh water thickness.

Observations on the salinity in the Delta aquifer

The iso-salinity contour map shows that the groundwater salt content ranges between less than 320 mg/l to 45000 mg/l, see Fig. 7. High salinity, particularly at west side of the aquifer, is due to the high rate of extracted water and evaporation. The salinity concentration increases northwards.

The shape and location of the transition zone between salt and fresh water depends on the properties of the porous medium. The transition zone is defined as the zone between the iso-concentration line 1000 mg/l and the iso-concentration line 4000 mg/l. The investigation showed that the transition zone extends up to 80 km inside the Delta, and the permeability at the north is less than the permeability at the south of the Delta.

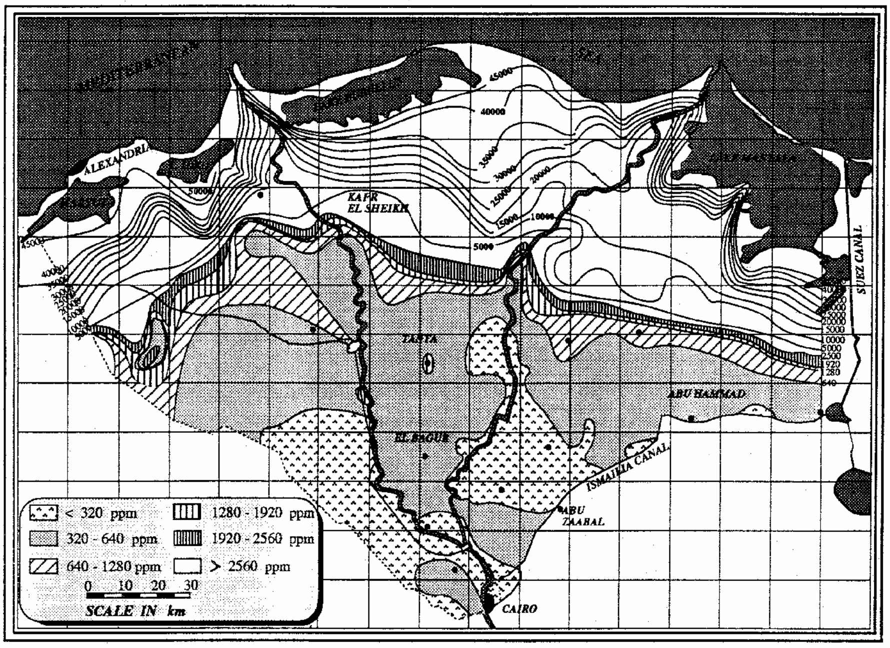

Fig. 7 Contour map of groundwater salinity.

Numerical simulation

Several finite element models have been described to simulate the groundwater flow and salt transport in the Nile Delta aquifer, (Sherif 1987) and (Hassan 1988). A three dimensional finite element model presented in Alexandria University by (Zakaria 1995) shows that the aquifer depth was varying from 100 m up to 900 m. This aquifer has two main sources of water. One source is the leakage from the river and big canals. The other source is from vertical leakage due to the difference between the shallow water level in the clay cap and the piezometric head in the aquifer itself. The dominant component of saline movement is governed by advection and dispersion. For this study, two types of aquifers were considered; leaky aquifer and unconfined aquifer. The extracted water from the wells by pumping from the aquifer (359 well) is simulated in the model. Figure 4 shows the predicted zones for upward and downward flow in the Delta aquifer. More importantly, the model successfully evaluated the recent groundwater salinity and predicted the future situation after the introduction of suitable countermeasures.

Control of Saline Water Intrusion Phenomenon

Several methods have been suggested for controlling seawater intrusion the area:

1. Construction of artificial subsurface barriers: It is possible to reduce the saline water flow inland by constructing artificial barriers with low permeability. Sheet piling, asphalt, concrete or puddle clay is considered best materials for subsurface barriers.
2. Artificial recharge: This increases the groundwater head in fresh water zone and thereby resists saline intrusion. Recharging wells are best suited for confined aquifers, while surface spreading is suitable for unconfined aquifers.
3. Pumping trough: By constructing wells adjacent and parallel to the coast, pumping would form a trough in the groundwater surface. Gradients created would limit seawater intrusion to a stationary wedge inland of the trough. This is suitable as a temporary method to reduce salinity in intruded aquifers until another method can be brought into operation.
4. Modification of pumping: In this case of saline water intrusion is controlled by the

reduction in/or rearrangement of the pattern of pumping wells in a coastal aquifer.

UPLAND RECLAMATION AND ITS IMPACT ON LOWLAND

Integrated development plans for the Nile Valley flood plain and adjacent desert fringes are essential because both regions generally share the same aquifer system. Surface water is been available for land reclamation since the construction of Aswan High Dam. About 750,000 acres on the fringes of the Nile flood plain have been reclaimed since 1967 by using surface water diverted from main canals. Most of reclaimed areas fall in the upland west or east of the Nile Valley. The old land between the reclaimed one and the Nile coarse is relatively considered lowland. After cultivation of those uplands, drainage problems appeared in several areas of the adjacent old cultivated land. The major irrigation and drainage problems are summarized as : 1) the waterlogging and soil salinization in the old cultivated area adjacent to reclaimed desert land, 2) the shortage of irrigation water in the reclaimed area at the end of the irrigation canals, and 3) the continuous increase of groundwater abstraction for irrigation in the desert which affects the sustainability of the water resources.

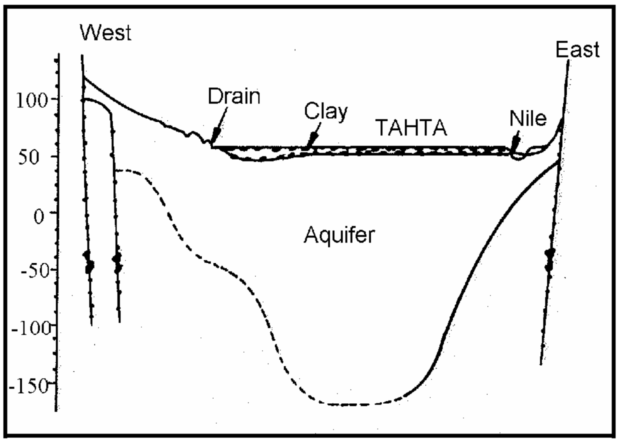

Fig. 8 Schematic Cross Section in Tahta Area.

Several studies have evaluated the groundwater development in the area of Tahta, west of the Nile River (Attia, et al. 1992). The West Tahta region includes both the Nile flood plain and the desert fringes system, see Fig. 8. This region contains variety of problems that can be solved by proper groundwater development. Nearly 4,000 acres of the desert fringes have been reclaimed. Even though the plan was prepared to use new systems for irrigation (drippers and sprinklers), the land is being irrigated with surface irrigation by the farmers. Seepage losses from the irrigation system and vertical leakage from the land are high due to the type of the subsoil. These losses caused shortage in supplied water, and increased groundwater heads in reclaimed areas. As the reclaimed areas and the adjacent old land share the same aquifer, high rates of groundwater seepage are existed and affected the adjacent old cultivated land. Accordingly, the cultivated area on the fringes was reduced (1,000 acres are bare). Furthermore, waterlogging and soil salinization problems have severely degraded some old cultivated land (1,000 acres are affected). As for social impact, farmers in waterlogged lands moved to the desert and started to dig wells and to cultivate new areas west of the present reclaimed area. The continuous increase in demands in desert areas will certainly affect the continuity of water supply both quantitatively and qualitatively.

Hydrological characteristics

Tahta is an arid region with almost no precipitation. The maximum temperature is 37.9 ^{0}C in June, and the minimum is 6.1 °C in January. The reference evapotranspiration (ET_0) varies from 3.5 mm/day to 9.9 mm/day. The soil in the desert reclaimed area consists of fine sands and silt, while in old land the soil is silty clay. The waterlogged area extends over a distance of 7.25 km with an average width 600 m covering an area of 1000 acres. The ground water table in the new reclaimed area is 10-30 m under the ground level. In the waterlogged area the groundwater table was raised from 6.5 m (1978) to 0.3 m (1989) under the ground surface level. In the reclaimed area the aquifer is recharged by seepage from unlined canals and deep percolation of excess irrigation water. In waterlogged area the recharge of the aquifer is mainly from seepage of the reclaimed area. Table 2 shows the water balance in the reclaimed area. The quality of groundwater in reclaimed and adjacent desert is brackish, the total soluble salt (TSS) is of the Na-Cl type and ranges between 1000 and 3500 ppm. The groundwater in the Nile flood plain can be associated with infiltrated surface water of the $Ca\text{-}HCO_3$ type, with TSS of the range between 400 and 800 ppm.

Table 2 Annual water balance

Component	10^6 m^3/year	mm/day
Inflow of surface water	46	9.0
Evapotranspiration	21	4.1
Outflow of surface water	2	0.4
Outflow of groundwater	23	4.5
Total outflow	46	9.0

Mitigation Procedures

The problems with reference to irrigation water shortages and waterlogging in the Nile valley are still under investigation. According to the numerical models (Attia, et al. 1992) for predicting present and future conditions, the proposed solutions may be simply divided into short-term and long-term answers. For the short-term, schemes have been devised for the improvement of irrigation and drainage through the development of groundwater. It is proposed that water wells be evenly distributed over the reclaimed area giving discharge of 13,000 m^3/day, thereby augmenting the canals and balancing land drainage and water quality. As for waterlogging, the total amount of seepage to the lowland areas was 63,000 m^3/day. The proposed irrigation well field in reclaimed area will reduce the amount of seepage to the lowland areas to 50,000 m^3/day. For the long-term solution, several ideas have been proposed for lining of canals and improving or rescheduling of the irrigation practices. However, those solutions will not relieve waterlogging problems in the immediate future. Thus, long-term schemes should be considered in parallel to the pre-mentioned short-term ones.

GROUNDWATER EXPLOITATION IN ARID LOWLANDS

Several wetlands are existed in areas that are not located along the coastal line and consequently are not influenced by saline water. Depressional wetlands are located in the landscape or where changes in the surface topography affect the groundwater discharge. The water table is normally high or near the ground surface throughout the year. The vegetation in this area can be a variety of hydric plants such as cattails, reeds, grasses, sedges, and trees. Some of these depressional wetlands fall in deserts or arid areas away of the sea or the fresh surface water. In such areas, the only source of water is the groundwater resources, which are recharged by rainfall precipitation over the adjacent mountain series. Special care is necessary to protect lowland systems from improper management practices and environmental degradation because of frequent high abstraction of water. Egypt has several depressional lowlands, such as El-Fayum, El-Qattara, Siwa,El-Baharia, El-Farafra, El-Dakhla, El-Kharga, and Baris.

Case Study of Manmade Wetland

An example of depressional wetlands in arid areas is found in Siwa Oasis in the western desert of Egypt. The water table in the area is a result of natural potential head of the groundwater in the layered aquifer, and of the abstraction of water for agricultural usage.

The Siwa Oasis is an area of great historical importance for it is here that Alexander the Great lived and left his temples and monuments buried under its sands. The Oasis is located at the farther western edge of the western desert, and forms a sort of closed basin. It is located about 65 km east of the Libyan border, and 300 km south of the Mediterranean Sea. The total area is approximately 1,000 km^2. Most of the central part of the depression lies from 15 to 20 m below the sea level. The area is characterized by extremely arid climatic conditions of a typical hot desert. The monthly mean temperature ranges from 19.6^{o}C in January to 37.3 ^{o}C in July. The monthly mean relative humidity ranges between 30% and 58%. The average annual precipitation is about 9.6 mm. The average monthly wind speed varies between 2.6 to 4.9 km/hr. The evaporation rate ranges from 5.4 mm/day in December to 16.8 mm/day in June.

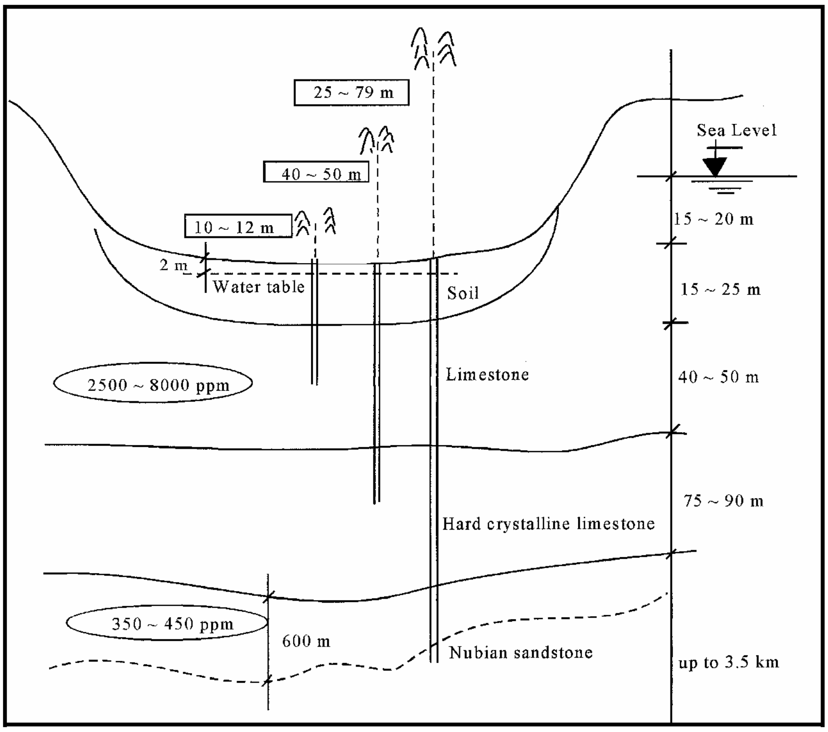

Fig. 9 Types of artesian wells in Siwa

Hydrological block

Four types of aquifer systems have been identified in Siwa. The top shallow aquifer with thickness of 15-25 m, which consists of deposits, alluvium, gravel, loose sediments, some times limestone. The normal water level of this aquifer is 2 m below ground surface, however due to the abstraction of water from deep aquifer and the improper of irrigation management and drainage systems the area suffers from waterlogging and salinization. The second aquifer is the upper limestone aquifer with thickness of 40-50 m, which consists of limestone intersected with thin layers of shale. Water level in the aquifer is under piezometric head in the order of 5 to 8 m bellow sea level. This aquifer is recharged from the percolated water of the rainfall at the western area, and from the rich deep Nubian sand stone aquifer through faults. The third aquifer is the lower limestone aquifer with thickness of 75-90 m, which consists of hard crystalline limestone. The recharge into this aquifer is from the deep Nubian sandstone water rise up through the faults. The salinity of its water is high due to the existence of salt, especially, gypsum ($Ca\ SO_4$), as the water percolates upwards through the layer. The fourth aquifer is the Nubian sandstone aquifer with thickness of 3.5 km. The upper most part of this aquifer, 600 m, is saturated with fresh water of 350 to 450 ppm. The thickness of fresh water zone in this aquifer is about 650 m. Below this depth, water becomes increasing saline with depth. This aquifer is recharged by the heavy rainfall precipitating over the mountain series at the southern part of the Libian-Chad area. The piezometric head values for this aquifer ranges from 25 to 79 m above sea level, see Fig. 9.

Water Extraction and Associated Problems

The area of Siwa has over 200 springs. Except for three, all springs in Siwa are recharged from the top shallow aquifer, which recharged in turn from the deeper upper limestone aquifer. The total estimated yield of water from the Siwa springs is about 60 million m^3/day. The total dissolved solids representing salinity ranges between 2,500-8,000 ppm. The three springs that are the exception are Ein Abu Shroof, (Q=1,200 m^3/hr, total dissolved solids =5200 ppm), Ein Koresht (Q=2,100 m^3/hr, TDS=5,500 ppm), and Ein Meshendit (Q =750 m^3/hr). These three springs are recharged from the deep Nubian Sandstone aquifer through the faults.

The Oasis has many lakes, such as El-Zaiton lake, El-Maraqi lake, Aghurmi and Siwa lakes. The source of water for the lakes is the drains, which carry the excess water from springs and cultivated lands. The salinity of the drains ranges from 3,000 ppm to 18,000 ppm.

In addition to the springs, there are about 1,760 hand dug wells extracted their water from the same top shallow aquifer, such as Aghourmy, Ain El Dakrour, Telehram, Azmoury and Ghaleit. They give a total discharge of about 450,000 m^3/day. The average salinity of the water from these wells ranges between 2,500–6,000 ppm. As mentioned above, almost of the recharged water into this top shallow aquifer comes from the underlying upper limestone aquifer. The cause of salinity is that water in its way up by means of deep cracks or faults may pass through thin layer or pockets of salts, especially those are rich with sodium chloride.

In some areas, water extraction from this region becomes faster than the velocity of internal. This is causing the decrease piezometric head. The saline water, which lies in the lower region, starts to penetrate the fresh water region causing "The upconing phenomenon". The continuity of fresh water extraction causes a gradually decrease in the piezometric head up to the worst case, where the saline water causes deterioration in fresh water quality and properties. If this happened, a quick control should be done by closing the well.

Waterlogging problem appears in some areas with high groundwater table due to the improper management of water abstraction and land reclamation with the absence of suitable drainage systems. The water losses from waterlogged areas by evaporation and evapo-transpiration were found to be 7.5 mm/day leaving a layer of salt on the top of land.

Social and Environmental Impact of Wetlands in Oasis

As been explained above, oases in Egypt are suffering from waterlogging phenomenon. An ecological study is dune in Alexandria University for several oases. One of the investigated locations was in Siwa. The population in Siwa is almost 12,000, however the number of dug wells are 1760 well. The well consists of a pipe penetrating the subsurface soil till the carrier aquifer. The discharged water from the wells is continuously drained into several lakes and it percolates through the soil particles causing rise in groundwater table. Figure 10 shows the amount of excess water comparable to the required quantity. The impact of this problem can be summarized as follows:

1. The rise of the groundwater table to a limit covering the roots of the planets is a real threat to the agricultural wealth in the oasis.
2. The collected water in the lakes evaporated by time and the salt stayed in the ground causing soil salinization, see Fig. 11 (Abd El-Motty 2000).
3. Some houses in the area are collapsed due to the rise of groundwater over the foundation level, and the salinization of soil.
4. The historical monuments and temples, which were built thousands of years ago, are severely influenced by the water and salinization of the soil due to the extension of cultivated lands around their structures, see Fig. 12 (Abd El-Motty 2000).

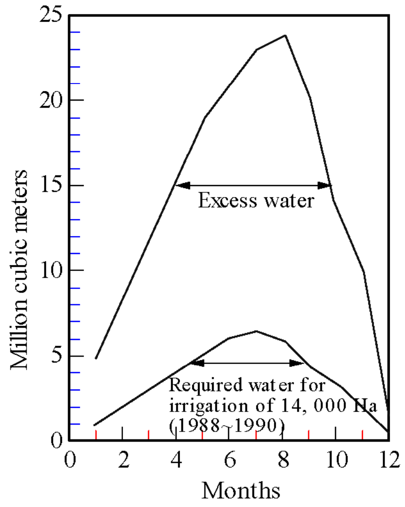

Fig. 10 Amount of excess water abstracted from wells

Fig. 11 Houses surrounded by Lakes and Vegetation

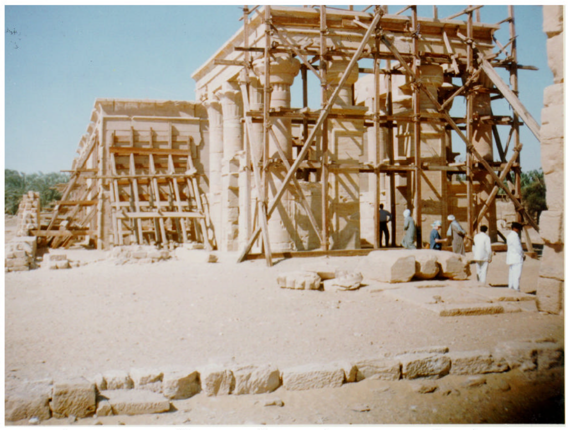

Fig. 12 Failure of Hepies Temple due to groundwater rise

Management and Restoration Considerations

One of the steps that should be undertaken for groundwater management is the institution of a systematic groundwater monitoring and pumpage control program for the basin. The monitoring/data-processing program would be responsible for the regular collection, analysis, and interpretation of groundwater data (levels, quality, and pumpag).

For the restoration of the present state and the prediction of the future situation in Siwa oasis, field and mathematical long-term studies were done in Alexandria University. One of the studies was done by using three dimensional finite difference groundwater flow model to estimate the piezometric maps, the variation of head with time, and the total volumetric budget for the oasis (Ramzy et al. 1996). Groundwater-use quotas were established for each aquifer, based on an evaluation of the safe yield in the study area. The safe yield refers to the maximum withdrawal rate from an aquifer without causing water to drop below a certain level and without allowing any saline water intrusion into the fresh water bearing formations.

For management of future water abstraction, the existed wells were plotted and several arbitrary wells were suggested with various discharges. Several proposals were suggested for the estimation of the optimum position, depth, distance, and pumping rates and periods which give suitable discharge of fresh water and at the same time helping to decrease any mixing between fresh and saline water. The study recommended that the authority should issue permits to qualified well owners and perform compliance inspection to insure that the permitted pumpage quotas are not exceeded. Further study is proposed to find the suitable solutions for waterlogging in the oasis. The study includes the improvement of irrigation and drainage networks, and lowering water table in the shallow aquifer by using vertical drainage.

CONCLUSIONS

Three major problems of wetlands in Egypt are discussed, and the following conclusions are drawn:

1. Saline water intrusion at the northern part of the Nile Delta takes place and extends to a long distance southward, especially after the decrease of the discharged fresh water after the construction of Aswan High Dam and the increase of demand for surface and groundwater.
2. Modelling of groundwater in the Nile Delta aquifer, and field observations show that the southern boundary, with a flow rate of 36.26×10^6 m^3/year, and Damietta branch, with a flow of 180.75×10^6 m^3/year, can be considered as recharge boundaries, while the Rosetta branch acts as drain with inflow rate of 35.63×10^6 m^3/year.
3. A mitigation system should be implemented, and the abstraction of groundwater should be controlled to protect the agricultural land of the Delta from contamination and salinization.
4. In the Nile valley, the aquifer underlying the desert fringes and flood plain are hydraulically interconnected. The reclaimed upland irrigation systems caused several problems to the adjacent flood plain. The waterlogging and salinization problems in the old cultivated lands can be solved by system of tube-wells to lower the water table for one meter at least. The irrigation water deficits in the reclaimed area can be supplemented by a well field from the groundwater basin instead of the surface water from the river.
5. The exploitation of groundwater in the oasis should be controlled and a network of drainage systems should be constructed to avoid the problems of deterioration of water and the waterlogging in the cultivated lands. In planning of the extension of new reclaimed areas, particular considerations should be taken for the historical structures and residential houses to avoid the problems of land subsidence, soil salinization, and construction failures.

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