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Balancing Productivity and Environmental Pressure in Egypt

Toward an Interdisciplinary and Integrated Approach to Agricultural Drainage

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Preface

This country study was prepared as a contribution to the project—*Agricultural Drainage: Toward an Interdisciplinary and Integrated Approach*, sponsored by the World Bank–Netherlands Partnership Program (BNPP)—Environmental Window for Water Resources Management and the Agricultural and Rural Development Department (ARD) of the World Bank. The activity was task managed by Safwat Abdel-Dayem, drainage adviser (ARD), and coordinated by Peter Mollinga, associate professor, Wageningen University. This country study is one of six parallel studies. The other studies are on Bangladesh, Indonesia, Mexico, the Netherlands, and Pakistan. Together they will provide the basis for formulating the proposed approach.

The task manager and the coordinator provided general direction for the study and contributed comments on preliminary texts. The country study benefited from the critical comments provided during the workshop held in Wageningen, the Netherlands, October 23–25, 2002, and attended by Bank staff, country officials, and representatives of international organizations, including the Food and Agriculture Organization of the United Nations, the International Progamme for Technology and Research in Irrigation and Drainage, the International Commission for Irrigation and Drainage, and the International Institute for Land Reclamation and Improvement.

We acknowledge constructive interaction with a large number of persons—both inside and outside Egypt. Although there are more, we would like to particularly mention: Ayat Soliman, Eng. Yehia Adbel Aziz, Safaa, Abd Elwahab Elhadad, Abd Eljawad, Adel Hashem, Dr. Tareq Mohie Eldin Sadek, Fawzi El Sobary, Eng. Fawzi Ibrahim, El Said El Bahwari, Eng. Toulba Ahmed Toulba, Samir Abu Elleil, Malak Abu el Kheir, Omar Ibrahim Abu El Leil, Eng. Mahmoud Tawfiq Abbas, Abd Elmoneim Hamza, Hussein Elwan, Makram Ibrahim, Laban Tamouz, Fahmy Hassanein Elnaggar, Mohamed Zakaria, Fathy Eltarawy, Hisham Kandeel, Hussein Elatfy, Suzan M.Kamel Abd Elrahman Abd Elmeguid Ali, Ahmed Fouad Abou Hadab, Nabil Fawzy Nashed, Dr. Samia Elguindi, Nader Aly El-Masry M.Sc, Magdy A. Salah El Deen, Tareq Mohamed Hussein, Tareq Abdel Latif Gad, Gamal El Din Marey, Hans van Leeuwen, Jan Bron, Jan Blum, Waleed A. Reheem, Ron Havinga, Peter Flik, and Tareq Mourad.

ARCADIS Euroconsult of the Netherlands and NSCE (North–South Consultants Exchange) of Egypt implemented this case study.

Acronyms and Abbreviations

APP	Advisory Panel Project on Water Management and Drainage
BNPPEW	Bank–Netherlands Partnership Program Environmental Window
BOD	Biological oxygen demand
COD	Chemical oxygen demand
CAP	Compliance Action Plan
CAPMAS	Central Agency for Public Mobilization and Statistics
CMRI	Channel Maintenance Research Institute, Ministry of Water Resources and Irrigation
CUA	Collector-user association
DAS	Drainage Advisory Service
DEMP	Drainage Executive Management project
DRI	Drainage Research Institute
DWIP	Drainage Water Irrigation project
ECRI	Environmental and Climatic Research Institute
EEAA	Egyptian Environmental Affairs Agency
EIA	Environmental impact assessment
EMP	Environmental Management Plan
EPADP	Egyptian Public Authority for Drainage Projects
ERR	Economic rate of return
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GARPAD	General Authority for Reclamation Projects and Agricultural Development
GIS	Geographic information system
IAS	Irrigation Advisory Services
IBRD	International Bank for Reconstruction and Development
IFAD	International Fund for Agricultural Development
IIP	Irrigation Improvement project
IIIP	Integrated Irrigation Improvement project
IMT	Irrigation management transfer
INTESP	Institutional and Technical Support Program, Netherlands funded
IRU	Institutional Reform Units
IUA	Irrigation user associations
IWMI	International Water Management Institute.
KfW	Kreditanstalt fur Wiederaufbau [German Bank for Reconstruction]
LE	Egyptian pound
MADWQ	Monitoring and Analysis of Drainage Water Quality project
MALR	Ministry of Agriculture and Land Reclamation
MCMP	Manual Channel Maintenance project
M&E	Monitoring and evaluation
MED	Mechanical and Electrical Department of Ministry of Water Resources and Irrigation
MIS	Management information system
MSL	Mediterranean sea level
MWRI	Ministry of Water Resources and Irrigation
NAWQAM	National Water Quality and Availability Management project
NDP	National Drainage Project
NSCE	North South Consultancy Exchange
NSDA	North Sinai Development Authority
NGO	Nongovernmental organization
NWRP	National Water Resource Plan
NPV	Net present value
O&M	Operation and maintenance
PE	Polyethylene

PIM	Participatory irrigation management
PVC	Polyvinyl chloride
PWM	Participatory water management
RIGW	Research Institute for Groundwater
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WRC	Water Research Center
WUA	Water user association

Executive Summary

The development of agricultural drainage in Egypt and the institutions that have developed around it is the subject of this study. It focuses on the current challenges and issues in drainage in Egypt, which lead to the conclusion that drainage must be viewed as a cornerstone of integrated water resources management.

The challenge in agricultural drainage in Egypt over the years has been to find ways of maintaining the productivity of the water resource system in a situation of increased demand and environmental pressure on the resource. The recent history of drainage begins with the failure of the cotton crop in the early twentieth century and the government's strong response to overcome waterlogging and salinity. In the late 1960s, Egypt embarked on the "national subsurface drainage project," covering almost all of the "old land" (the Valley, Delta, and Fayoum) with surface drains and horizontal pipe drains. This program has turned Egypt into the country with the most extensive drainage coverage. In 2012, the horizontal drainage plan in the old land is expected to come to an end.

Drainage development in Egypt has become a public responsibility. The Egyptian Public Authority for Drainage Projects (EPADP) was established in 1973 within the Ministry for Irrigation (now the Ministry of Water Resources and Irrigation, MWRI). EPADP was given full autonomy to develop the drainage system in the old lands. A centralized "blanket" approach was chosen—full coverage and standardized designs and procedures. Internal knowledge was considerably developed. Procedures for land acquisition, crop compensation, and capital cost recovery supported the implementation of the program. Design, construction, supervision, and maintenance (of horizontal pipe drains) were done in-house. This allowed EPAPD to develop into an effective deliverer. The reverse side is that outside EPAPD little capacity developed—which is felt as a constraint in the current drive toward user management of drainage systems in the old lands and private investment on new lands. In the new lands, EPADP never had a strong role, and a substantial backlog of drainage improvements awaits action. Particularly now that the drainage construction program in the old land is ending, the role and function of EPADP will have to be redefined.

The impact in terms of agricultural production has been significant. Monitoring, as part of the National Drainage Program, established that annual net farm income increased by US$375/ha in nonsaline areas and US$200/ha in saline areas. In addition, drainage reduced the incidence of vector-borne disease and reduced damage to built-up property. The extensive drainage network also facilitated drainage water reuse—both formal and informal. With this development, water quality in the drains has become a critical concern. The major issue is the pollution of drainage water with toxic substances, particularly bacteria, heavy metals (cadmium, lead), ammonia, and pesticide residues. Most of these originate in industrial and urban areas, through which the drains pass. Particularly where irrigation canals also serve as the source of domestic water, the discharge of contaminated drainage water from the irrigation system has been problematic. The development of the drainage network has also meant that the outflow is changing, particularly to the northern lakes, with dwindling volumes of water containing increasingly concentrated contaminants. These lakes sustain a large fishing population and serve a substantial part of the domestic market for fish, but the sustainability and safety of this activity is under threat.

The increasing complexity and interlinkages in Egypt's water system have put drainage in the context of integrated water resources management rather than in one focused only on sustaining agricultural productivity. As Egypt's policy is to meet water scarcity by doubling official reuse and as there is already substantial "unofficial" private reuse at the tail-ends of canals, drainage water quality management will only gain in importance in the near future.

A number of suggestions have been put forward to remedy the situation: continuing substantial investment in water treatment but following better location-specific priorities; reducing the use of agrochemicals by cutting subsidies and increasing awareness of their undesirable side effects; and tightening enforcement of water quality legislation with the help of public disclosure. Other solutions are in the realm of water resources management—designating special drains as sewers and moving from a centralized drainage water reuse system to an intermediate reuse system.

What appears important in this constellation is to also reinforce local water resources management—looking at the local water supply and sector-specific demand and preparing local strategies to make the most of the management of water volume and quality. Integrating irrigation and drainage services more closely at district and governorate level is already being discussed—for combined operation and maintenance (O&M) activities. This may have to go a step farther toward improved water management at this level.

The question of institutional arrangements thus arises. The blanket approach to drainage development and the technology chosen in Egypt allowed steady progress of activities but left relatively little space for user involvement in drainage or decentralized management. At the lowest level of the drainage system, collector-user associations (CUAs) were tried out, but they did not take off, as they had too little to do and were not given legal recognition.

In light of a move toward participatory water management in Egypt, water boards are being piloted in 50 secondary canal commands, their area of operations typically ranging around 750 ha. A legal amendment has been introduced in the Parliament to enable the transfer of what are now public functions to water boards, at either secondary canal or district level. The amendments would also empower water boards to collect the necessary charges and implement effective sanctions. The opening for district-level water boards is particularly important, as this may be the most viable level for user management and decentralized integrated water resources management. However, discussion is still at a very early stage—there are no integrated water resources management districts in place or water boards operating at this level. Important questions remain about the role of MWRI, the regulation of water functions, financing mechanisms. Other questions have not yet been asked.

Egypt's main challenges with respect to drainage seem to be:

- Development of drainage services in the new lands
- Implementation of a range of measures to improve drainage water quality
- Development of viable models of decentralized integrated water resources management
- Redefinition of the role of EPADP and the private sector in providing drainage services, particularly as emphasis shifts from construction to maintenance and management.

1. Introduction

In global overviews of water-stressed areas, Egypt invariably comes out on top. With rainfall ranging between virtually nil in the south to 180 mm on the North Coast, Egypt is more dependent than any other country on a single source of water, the Nile River. Nile water is intensively utilized, used and reused along its course—for water supply, inland fisheries, navigation, and irrigation. What was once flood plain and river delta is now a dense network of canals and drains.

Although the number is falling, agriculture still employs 30 percent of the labor force. Most farmers are smallholders—98 percent owning less than 2 ha of land. Because farming in Egypt depends entirely on irrigation, high water productivity and livelihood security are intricately connected in Egypt. There are no new major water resources to develop. Expansion of land is sought from increased use of groundwater and from intensified reuse of drainage water, but both have an upper limit. At the same time, urbanization is progressing in large cities as well as in small rural centers. This translates into additional demand for domestic and industrial water but, more important, into a larger pollution load and an increased need to address water quality.

Drainage development in Egypt must be viewed in this context: how to maintain the productivity of the water resource system in a situation of increased demand and environmental pressure on the resource. This is the theme of this case study. The completion of the High Dam at Aswan in 1968 made year-round irrigation possible and drastically changed the nature of water management in Egypt. To avoid salinity increases and waterlogging, undoing a large part of the gains, and to maintain high agricultural productivity, an accelerated drainage program was started that aimed at full coverage. From 1973 onward, this program developed into one of the largest of its kind globally. The drainage program in Egypt has been implemented in a "command and control" fashion. This made it possible to make much headway, but it also implied a number of choices such as a centralized organization of construction; a blanket approach to drainage, and choice of a specific technology (surface drainage combined with horizontal pipe drainage).

The extensive surface and subsurface drainage system that developed since the 1970s has "produced" large volumes of drainage effluent. Increasingly low-quality drainage water is reused for irrigation, generally after mixing it with better quality surfacewater. To help address water scarcity in Egypt, present policy promotes reuse of more than 50 percent of the drainage water. However, reuse of drainage water has also caused water quality problems in a number of places, compounded by the fact that open drains in Egypt often receive considerable raw sewerage and industrial effluent. Moreover, the ultimate discharge of agricultural production water has become a matter of concern. The northern lakes at the end of the drainage systems, for example, have been seriously degraded.

This report presents the findings of a literature review and field study on agricultural drainage in Egypt.[1] It is the authors' conviction that in Egypt as well as in other countries the growing competition for fresh quality water and the need to balance economic, social, and environmental objectives in water management create the imperative for truly integrated management of water resources. This study attempts to define where drainage fits into this larger picture. It is important to see drainage as an important intervention in water management, not as merely an infrastructural solution to a drainage problem. In Egypt, the role of drainage in securing the productivity of water resource systems, the opportunities and problems associated with drainage water reuse, and the questions surrounding the discharge of drainage effluents all underline that drainage cannot be excluded from the debate on integrated water resources management.

The terms of reference of the study attempt to develop a typology of drainage situations based on technical-physical and social-managerial criteria. The typology first occurs at the more global macro level, where Egypt presents a prime example of land drainage in an arid/semi-arid climate where drainage is practiced within canal irrigation commands to control waterlogging and soil salinity. The typology can be worked out further at the local level. Within Egypt, drainage situations are diverse, often related to the socioeconomic development of each region.

A second objective of the study is to look at the institutional models for drainage management, at users as well as at agency level. This has received relatively little thought so far. Much of the global discussion in recent years has been on user organizations in irrigation situations and on the reform of irrigation agencies. The strong focus on irrigation management transfer and participatory irrigation management in the irrigation policy debate has at times overlooked other water management functions and ignored the positive complexity of local water resource systems. As the terms of reference of the study suggest, it may be worthwhile to consider organizations that have a more integrated remit. One of the principles associated with integrated water resources management is that of *subsidiarity*, water management at the lowest appropriate level. What does this means in drainage management? What is the lowest appropriate level? Is there one appropriate level? Should it concern drainage only or integrated water management functions? Experiments and experience in Egypt over the last 15 years are important in this regard. A number of efforts, initiated by the Ministry of Water Resources and Irrigation, attempted to give farmers a role in the management of drainage—in user-controlled drainage and through the establishment of collector-user associations. This did not take off nor was it sustained. Now the establishment of user organizations on a larger scale and with broader mandates is being discussed—for example, water boards or water user federations at secondary branch or district level.

The third objective of the study is, based on a typology and assessment of institutions in managing drainage, to place drainage in a framework of integrated water resources management. This requires a better understanding of the role of drainage in food security and environmental security.

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1 This document is based on literature references, discussions, field visits and discussion during an expert meeting on 23–25 October 2002 in Wageningen. The field visit schedule is attached as appendix A.

2. Agricultural Drainage in Egypt—Typology and History

Despite its enormous land mass (1 million km^2), only a small portion of Egypt is inhabited and cultivated—8.2 million feddans (3.4 million ha), less than 4 percent of the land area. Egypt is mainly desert territory. Rainfall ranges from almost 180 mm (winter rainfall) along the north coast to almost nothing in the south. The temperature fluctuates between 9^o C (January) to a maximum temperature of 35^o C in the northern districts and reaches more than 40^o C in the south. Relative humidity ranges from 70 percent (February to October) to 80 percent in December. The evaporation rate is far in excess of precipitation: it ranges from 1,500 mm/yr in the north to 2,400 mm/yr in the deep south (DRI 2001).

People and agriculture are found where water is nearby. Viewed by satellite, the image is that of a lotus, the Nile Valley its stem and the delta the flower.

Figure 1 Satellite image of the Nile Delta

Source: http://earthobservatory.nasa.gov/.

The Nile branches, which flow through the delta have been consolidated into two main branches that reach the Mediterranean Sea at Rosetta and Damietta. The delta is bordered on the east and west by higher desert land. Near the coast, there is a large area of salt marshes and a series of lagoons (the northern lakes Maryut, Edku, Burullus, and Manzala). The delta is divided into three regions according to their position with respect to the Nile branches: the Eastern Delta for the region east of the Damietta branch, the Middle Delta for the region between the two branches, and the Western Delta for the region west of the Rosetta branch.

The delta, the Nile Valley, and the Fayoum oasis together are also called *the old lands*, as they have a millennia-long history of settlement. Together they make up more than 70 percent of the cultivated land in Egypt. The old lands generally consist of alluvial sediments, mainly clays to heavy clays (35 to 80 percent clay) with a low permeability (5 to 25 cm/day) and an extremely flat topography (northwest slope of 1 in 10,000). The northern part of the delta has developed under fluvio-marine conditions and contains heavy clays. The cultivated lands in the delta and valley are characterized by a low hydraulic gradient, responsible for a low rate of natural soil drainage.

Apart from the old lands, there are the old new lands, the new lands, and the area recently developed under the Mega projects. The term *old new lands* is reserved for the land developed before 1985, the areas on the fringes between the old lands and the higher desert as well as along the northwest coast. They are usually served by extensions of existing irrigation canals or by groundwater irrigation. In these areas, the older Nile alluvial sediments intermingle with sandy material of desert origin and colluvial packages. Adjacent to the Nile course and its branches, dunes have been formed that show clear stratification of fine-medium and coarse-textured layers. The *new lands* are the areas developed following construction of irrigation canals after 1985 such as the New Valley and recently the area served by the Mega projects—in particular Toshka Canal, Sinai, and El Oweinat. The land, often undulating, consists of mainly sandy soils.

The new areas, the old new lands, and the new lands have been developed to accommodate Egypt's fast-growing population. Egypt's total population is now nearing 64 million (2000), and demographic growth remains high at an estimated 2.3 percent yearly. In the small part of the country that is cultivated, population density is extremely high, 1,800/km². The typical image of the countryside is one of small towns, large villages, and small farm holdings. Large areas, particularly in the delta, are gradually losing their rural character to industrialization. More than 98 percent of landowners own less than 5 feddans (2.08 ha) and 70 percent less than 1 feddan.

As can be seen from table 1, only 0.2 percent of Egyptian farmers own 50 feddans (20.8 ha) or more. (PAD-NDP-II 2000). Agriculture is still the main source of livelihood for a large segment of the population. It provides employment for more than 5 million workers, some 30 percent of the labor force. The cultivated area in 2001 was 8.2 million feddans (3.4 million ha)—or, to put this into perspective, more than the irrigated area in Mexico and less than that in Sindh province, Pakistan. Yet cropping intensities (at 185 percent) are considerably higher than in the latter area. On the old lands, the cropping intensity is close to 200 percent. Due mainly to water shortages, the average cropping intensity on the new lands is much lower, with most of the area fallow in summer. Crop yields in Egypt are high—compared to other arid countries, particularly where drainage is adequate.

Table 1 Agricultural land ownership in Egypt

Land holding (feddan)	***Percent of farmers***
Less than 1	69.3
1 to 3	23.8
4 to 5	5.1
5 to 10	1.1
10 to 20	0.5
20 to 50	0.15
50 and more	0.05

One feddan equals 0.42 ha.
Source: World Bank 2000.

In 2000, agriculture accounted for 16.6 percent of Egypt's GDP, and 20 percent of its export earnings. Egypt is self-sufficient in most crops except wheat (59 percent). Winter (November–May) and summer (May–October) are the major crop seasons in Egypt. The most important crop for the delta and the valley are wheat and berseem (Egyptian clover) in winter, cotton, rice (only in the delta), and maize in summer. Many farms also grow other cash crops, especially vegetables and perennial crops, mainly sugarcane in upper Egypt and citrus in the delta.

Brief History of Water Resources Development and Drainage

The primary function of drainage, as it developed in Egypt, has been to safeguard agricultural productivity in the old and newly developed lands. Drainage serves to reduce or remove salts, to control groundwater table levels in general and, in some specific areas, to reduce waterlogging. An important benefit (often mentioned by farmers) is improved aeration. Unlike in some of the other countries in this study such as the Netherlands or Bangladesh, in Egypt drainage development has been more single-purpose and has not been strongly oriented to other water management functions, be it flood control or urban water management.

The water management and the role of drainage developed differently in Egypt from area to area, in particularly in the old lands, old new lands, and new lands. The differences are related to the physical conditions and, more importantly to the particular path-dependent histories of the old lands and new lands. First, we want to discuss the history of water development in Egypt up to 1960—when the emphasis was exclusively on what has subsequently been called the old lands. Then, we discuss water resource development after 1960. In this period, heavy investments were made in drainage in the old lands as well as in irrigation and drainage in newly developed areas, the new lands. A snapshot typology as its emerged in Egypt is given in table 2.

Table 2 Drainage typology in Egypt

Typology	*Location*	*Area (million ha)*	*Type of drainage*	*Institutional responsibility for drainage*
Old land	Nile Valley and delta	2.6	Subsurface and open	EPADP
Old new land	Desert lands on the fringe of the old land and along coast, expansion, 1960–85	0.9	Limited open drains	GARPAD/EPADP/private
New land	Desert land away from Nile Valley in Western desert and Sinai. Expansion from 1985 onward	1.5	None or under development	Private

EPADP Egyptian Public Authority for Drainage Projects; GARPAD General Authority for Reclamation Projects and Agricultural Development (GARPAD).
Source: This study.

Water Resource Development to 1960

Egyptian farmers throughout the centuries have gradually extended the cultivated area along the fringe of the seasonally flooded Nile Valley. In the beginning of the nineteenth century, the industrial revolution and the colonization policy of England and France brought a new economic drive to Egypt. The Nile water resources and proximity to Europe made Egypt an attractive place for the cultivation of cash crops such as cotton and sugarcane. A network of irrigation canals was developed to support a year-round supply of water. Once permanent infrastructure was built to ensure a perennial water flow for the high-value cash crops, the management of water resources for irrigation became a state function. The Public Works Department, established in 1836, was in charge of the development of the irrigation and other public infrastructure. With the creation of the Nizarah of Public Works, in 1857, several state functions were formally institutionalized through a number of departments, including an irrigation department. In the course of the century, the cultivated area increased more than two-and-a-half-fold. The total cultivated area increased from 2 million feddans (0.84 million ha) in 1820 to 2.6 million feddans (1.09 million ha) in 1848, 4.7 million feddans (1.97 million ha) in 1880, and 5.2 million feddans (2.18 million ha) in 1900 mainly in Middle Egypt and in the delta. All the emphasis was on building irrigation canals.

The expansion was made possible by the construction of permanent irrigation infrastructure by the Ministry of Public Works. Sale or distribution of the newly irrigated land was the prerogative of the state. Private owners, often of large estates, took charge of developing the land and supplying housing for the workers. For a long time, drainage was not part of the equation. The first open drains were introduced only in 1870 after the first delta barrage was built, replacing the age-old flood irrigation regime.

Despite such local, landowner-initiated, on-farm drainage solutions, perennial irrigation led to waterlogging and salinity of the soil. This accumulated throughout the years, triggering a spectacular collapse of the cotton crop in 1909 (Assiouti 1994). Open drains were then excavated by the ministry to resolve the problem locally. This event made it clear that drainage was also a state affair. The magnitude of the problem—intricately linked to the operation of the centrally managed water distribution system—was such that it required a comprehensive and public solution going beyond the boundaries of individual farms. In the first half of the twentieth century, the major effort was focused on improving drainage of the cultivated land, leaving aside horizontal expansion activities. Moreover, the complexity and size of key state functions related to irrigation and agriculture could no longer be handled within the legal framework of a department. In 1913, a royal decree established the Ministry of Agriculture, and in 1914 the Nizarah of Public Works became the Ministry of Public Works. Thus, the management of agricultural development and the distribution of irrigation water were separated, each now carried out by two independent organizations, presenting henceforth a challenge to maintain coordination and complementarities between these two vital organizations.

The development of nationwide solutions for drainage was endorsed as a prime responsibility by the new Ministry of Public Works. It immediately initiated a series of studies and investigations to identify and design comprehensive solutions. The design of a major drainage improvement program to cover the entire cultivated area with open drain networks and pumping stations was finalized. Construction started in the 1930s. Soon maintenance of these public open drain networks became necessary, and this task was added to the portfolio of the ministry. With Law 35/1949 in 1949, the state unambiguously established that the provision of drainage was a public responsibility. It meant to undertake drainage projects (horizontal pipe drainage and open drains) on all agricultural land. The law also established that farmers would bear the capital costs, on soft terms. This was the start of a blanket drainage approach in the Nile Delta and Valley. The area of artificially drained land—mainly by open drains—reached 2.2 million feddans (0.92 million ha) on the eve of the revolution in 1952.

The advent of the socialist system in 1952 introduced new political principles into agricultural development. It reinforced the trend toward enlarged public sector roles. There was increasing concern to maintain social equity, and the state became a major provider of subsidized agricultural inputs and regular water supply. New land development was taken up to accommodate a rapidly growing population. In socialist style, cropping patterns were regulated, and the state procured the main agricultural commodities such as wheat and cotton.

Drainage Development in the Old Lands

By 1968, a network of open drains some 17,000 km long was servicing nearly all the agricultural land, 6.9 million feddans (2.9 million ha). In 1968, the Aswan High Dam was commissioned, and perennial irrigation became possible throughout the country. Agriculture intensified dramatically with cropping intensities and yields among the highest in the world. At the same time, it became clear that the existing network of mainly open surface drains would not be sufficient to control the rising groundwater tables and the accumulation of salts transported by irrigation water.

Soon after the completion of the Aswan High Dam (1968), a large program of drainage implementation was started with funding from the national budget (Five-Year Plans), as well as international funding by the World Bank. A study by the Food and Agriculture Organization and the UN Development Programme (FAO-UNDP), implemented by NEDECO-ILACO (1966) provided the substance to the program. In subsequent programs, KfW and the Netherlands government joined as financial partners. In 1973, a central organization was established within the Ministry of Irrigation for the planning, design, installation, and maintenance of drainage works—the Egyptian Public Authority for Drainage Projects (EPADP). Drainage pipe factories were established by EPADP and specialized contractors were trained. The designs were standardized as much as possible. The choice was for horizontal pipe drains with buried manhole covers for the lateral connections, preventing as much as possible "interference" of farmers with the system (see section 3). The entire drainage program has been almost invisible, almost as if laying an electricity grid.

Box 1 Irrigation systems in Egypt

Nearly all land is irrigated from the Nile, except where groundwater is used (mainly in the Sinai and New Valley). The irrigation system in the "old lands" of the Nile Delta and Valley is a combined gravity and lift system. The main canal system takes its water from head regulators, situated upstream of the Nile barrages. The flow of water is regulated and distributed among branches and distributaries by means of cross-regulators and gated intake structures. The main system and branches have a continuous flow, while the water supply to the distributaries is allocated according to a rotation schedule of 5 days on and 10 days off. This may vary between areas and season by some days. At the tertiary intakes, water is supplied to the mesqa's (private irrigation ditches, serving an area from 10 to 300 feddan). The larger mesqa's have a subrotation along the marwas (small irrigation ditches).

Water is generally applied to the fields by means of pumping by the farmers. Most farmers replaced their traditional animal-powered waterwheels *[saqias]* with mobile diesel pumps in the 1980s and 1990s. The field application method is ponding of level basins. Every 15 days, some 120 mm to 200 mm of water depth is applied. Irrigation field efficiency is between 60 percent and 70 percent, when sufficient irrigation water is available. This is generally the case in the head reaches of the canals. In the tail ends of the canals, however, chronic shortages of irrigation water may occur. Most farmers compensate for these deficits by pumping supplemental water from a drain or from groundwater.

Source: This study.

Box 2 Drainage technology in Egypt

Main drains in the old lands

The water table in the open drains is generally maintained at 2.5 m below ground surface. The open drain system now includes 18,000 km drain length, with bed widths varying from 1 m to 30 m and depths from 2.5 m to 6 m (INTESP Report 14, 2001). The water flows from the field drains (pipe drains or open surface drains) through secondary open drains to the main drains by means of gravity. Since many parts of the Nile Delta lie below sea level or cannot be drained by gravity, drainage water is either pumped back into irrigation canals for reuse or pumped into the northern lakes or the Mediterranean. In Fayoum province, irrigation is practiced by gravity with no water-lifting system. Drainage water here accumulates in Wadi Rayan and Qaroon Lake. The first drainage pumping station started in 1898 (and still operates, Nijland 2001). There are some 130 pumping stations in the Delta with a total capacity of 2,500m^3/sec.

Subsurface drainage

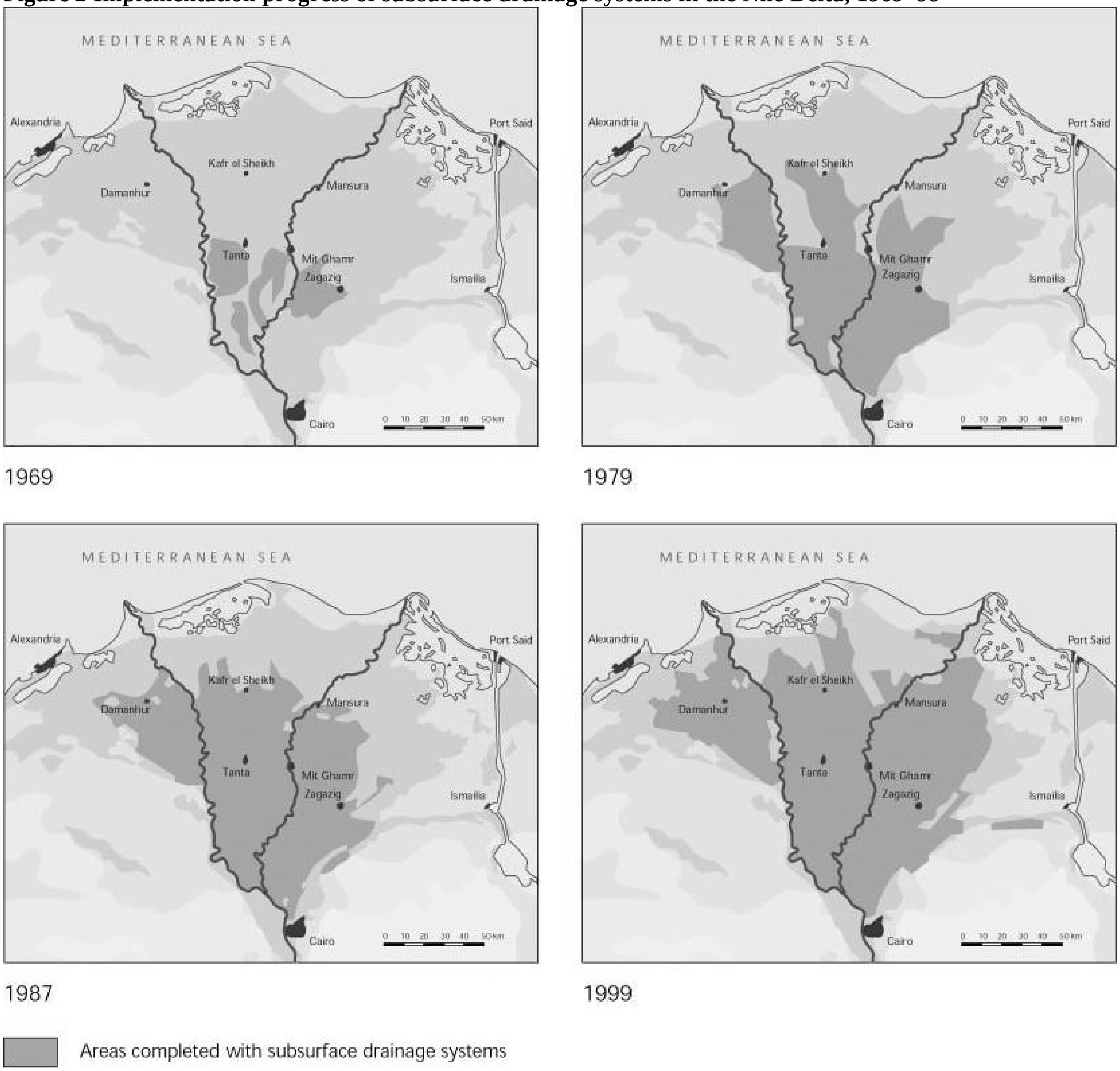
To control waterlogging and salinity, more intensive drainage was needed than only the main drainage system. In 1938, drainage tests with open field drains were run in an area of 12,000 feddan (5,000 ha). It was found that open field drains worked for drainage purposes, but they took up too much land (15 percent of the area) due to the narrow drain spacing necessary in the heavy soils in the Nile Delta and Valley. The open field drains also split the area into properties that were too small for efficient agricultural operations. Moreover, they required intensive maintenance. It was then decided to test horizontal pipe drains (closed field drains). From 1942 to 1948, an area of 19,000 feddan (8,000 ha) was provided with pipe drains (50 cm clay pipes, manually installed) and found to perform well. (Assiouti 1994: 10).

Horizontal or vertical drainage?

Horizontal pipe drainage in Egypt is a more appropriate technology than vertical drainage because of the soil characteristics in the Nile Delta and Valley. The clay content ranges between 30 percent and 80 percent, and the soils have a low to medium hydraulic conductivity and low permeability. Especially in the East and Middle Nile Delta, the soils require narrow drain spacing (Amer 1996). This would make it more difficult to use vertical drainage here, since the aquifer characteristics are not favorable. Shallow tubewells (as used in Pakistan and India) will work well only if sweet groundwater is available (for conjunctive use), which it usually is not in the delta. In the new lands, the situation is different in some places, and vertical subsurface drainage is being tested, as part of the National Drainage Project–I (Amer 1996; Attia and van Leeuwen 2000).

The rapid progress of drainage coverage that resulted from this blanket approach is shown in figure 3. It shows the increase in the area under subsurface drainage in the Nile Delta—with little interaction with farmers. Farmers paid the investment costs, but as this was translated into a surcharge on the land tax, it was almost unnoticeable. Unlike other cost-recovery systems, payment was not problematic. Moreover, as the benefits of the systems showed up as increased crop yields, the farmers did not hesitate to pay the investment costs. The crop compensation mechanism used also made for a relatively smooth implementation of the program (box 3).

Figure 2 Implementation progress of subsurface drainage systems in the Nile Delta, 1969–99



Source: Nijland 2001.

Box 3 Crop compensation

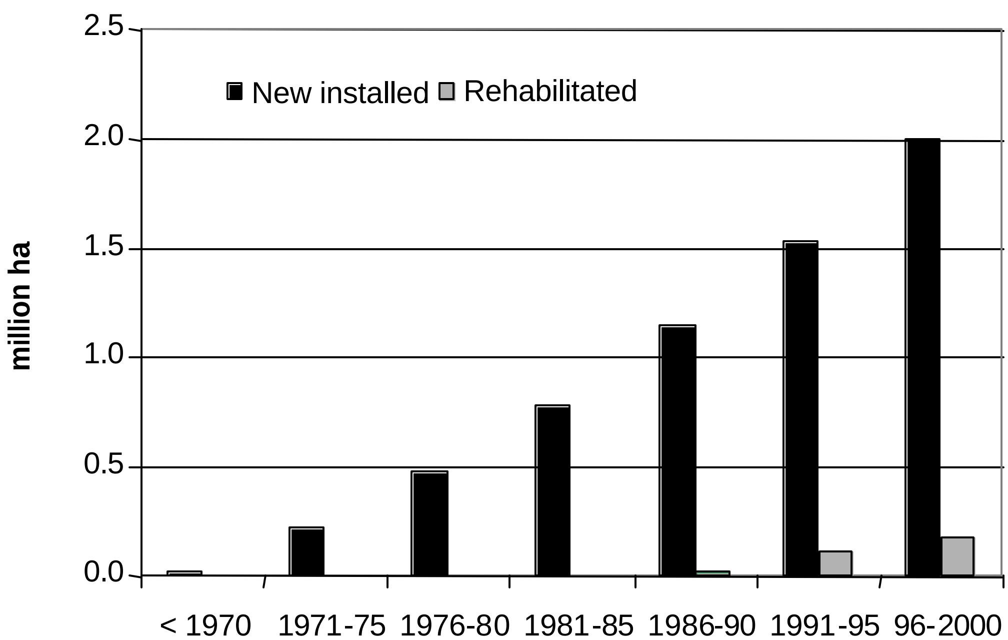
The Egyptian Public Authority for Drainage Projects (EPADP) compensates *individual* farmers for land expropriation and crops damaged during construction of open and subsurface drains. During cost recovery, this compensation is repaid by *all farmers* in the area. This is a fair way of dealing with the ticklish crop compensation issue. The individual is compensated for damage incurred and the group pays for it, including the impacted individual. This method can be exported, to India for instance.

Source: This study.

A detailed description of the drainage technology used in Egypt is given in appendix B. Initially, the choice was for clay pipes. After a period of using cement pipes, PVC pipes were chosen, which were easier to install, of better quality, and more durable. This innovation, developed by the Drainage Research Institute (DRI), was established in 1975 in support of the national drainage program. The horizontal pipe drainage systems discharged by gravity into the surface drains. This has made their operation far less vulnerable than, for instance, most subsurface systems in Pakistan and India, which depend on (small) pumping stations to lift the drainage effluent into a surface drain. The drainage program has made steady progress. For 30 years, EPADP has pursued its objectives of designing and constructing subsurface drains in 2.7 million ha and open drains in 3.1 million ha. Today, more than 75 percent of the horizontal pipe drain planned areas and more than 95 percent of the open drain areas have been completed. An annual implementation rate of over 50,000 ha is achieved (figure 3).

By 2001, a total of 18,000 km of open drains, 50,000 km of collector pipe, 400,000 km lateral pipe, and 300,000 manholes had been installed. This makes the Egyptian drainage program one of the world's largest water management interventions and the largest drainage program.

Figure 3 Cumulative area provided with horizontal pipe drainage, 1970–2000



Source: Amal, van Leeuwen, and Koopmans 2001.

Total investment under this program amounted to around US$3 billion—about three times the amount spent on the Left Bank Outfall Drain in Pakistan. Since 1985, part of the investment has gone to rehabilitating old drainage systems. Installation of another 600,000 ha of horizontal pipe drainage is foreseen under NDP-2 (with the same donors) between 2001 and 2006.

Land Reclamation in the New Lands

The policy of land reclamation—"horizontal expansion," as it has been called—took center stage starting in the 1960s. The development of new lands at that time was an integral part of the centrally planned economy. The first large land reclamation scheme took place in Upper Egypt to resettle the Nubian population displaced by the Aswan High Dam in an area east of Kom Ombo. Subsequently in the land reclamation programs, priority was given to the development of state farms to ensure national food security. Provisions were also made to offer landless farmers and jobless university graduates an opportunity to become landowners.

As in the case of the development of drainage of the old lands, strong, well-equipped public sector agencies were set up. A special agency, the Desert Development Organization (later replaced by the General Authority for Reclamation Projects and Agricultural Development, GARPAD), was entrusted with responsibility for planning, design, and implementation of the infrastructure and establishment of the social infrastructure to serve the new settlements.

Over the years, more than 2.5 million feddans (1 million ha) of land have been developed, although not all of this is actually cultivated. The Desert Development Organization, and later GARPAD, hence had a comprehensive mandate in the development of the new lands. Once the land was developed and the human settlement completed, the agency was expected to transfer the different components to the regular line agencies. In reality, transfer was usually delayed, with the temporary project status of the new schemes lingering on, which created confusion over competences.

The Old New Lands of the 1960s

Most of the newly developed lands in the 1960s were situated along the fringes of the Nile Delta, the main exceptions being the former lake-bottom soils of the northern lakes, and the remote areas of the oases in the New Valley and Bahareya depression of the Western Desert, supplied by deep groundwater. All in all, a target of 1 million feddans (0.42 million ha) of reclaimed land was set for the 1960s. Of this total, 30 percent was in fine-textured deltaic soils; the remainder in sandy, calcareous soils. The West Delta received the lion's share of the land reclamation program (40 percent), particularly in Tahrir province and Nubariya (IFAD 1990).

Drainage was generally not included in the otherwise comprehensive plans. Yet drainage problems soon became manifest in the shape of local waterlogging in the reclaimed areas and excessive seepage in the adjacent old lands at a lower elevation (table 3).[2]

Table 3 Reclaimed lands

Plan year/Area	***1952/78***	***1978/82***	***1982/87***	***1987/92***	***1992/97***	***Total (feddan)***	***Total (hectares)***
East Delta	101,761	60,010	35,330	97,600	249,100	543,801	228,400
Middle Delta	172,990	1,600	12,770	48,685	23,000	259,045	108,800
West Delta	410,540	46,920	111,383	382,775	133,000	1,084,618	455,500
Middle Egypt	89,465	-	4,900	39,650	21,000	155,015	65,100
Upper Egypt	78,944	3,850	9,697	23,900	35,300	151,691	63,700
New Valley	45,900	3,900	4,670	26,040	4,000	84,510	35,500
Sinai and West Suez Canal	12,400	7,000	11,050	232,100	4,500	267,050	112,200
Total	912,000	123,280	189,800	850,750	469,900	2,545,730	1,069,200

Source: GARPAD 1997.

Drainage problems have been addressed in the old land, but not in most of the new lands, where drainage has usually been left out of the master plan. When drainage problems emerge, it is usually up to the new settlers to find their own solutions. Some farmers have developed local solutions with field-level drainage. In some extreme cases, waterlogged and or salinity-damaged land has been abandoned. EPADP's mandate in the old land does not automatically extend to the new lands.

The case of Nubariya is illustrative in this respect. The reclamation of Nubariya, a sandy desert area west of the Nile Delta, started in 1960. Gross cultivated area today covers 350,000 feddans (147,000 ha). The area varies from flat to gently hilly. The Nasr feeder brings Nile water to the area via the Nubariya canal. Five pumping stations along the canal raise the water 40 m. Irrigation techniques vary, but sprinklers or drip systems were introduced on the nonleveled land reclaimed since the late 1970s. Many farmers abandoned these micro-irrigation systems, however, due to lack of water and repeated breakdowns of the government-operated pumps. As a result, irrigation efficiency in reclaimed desert dropped, increasing drainage problems.

[2] Major negative side-effects of desert reclamation along the fringes are waterlogging and salinization of adjacent low-lying old cultivated land. The initial leaching of desert land and excess irrigation applications cause a rise in the groundwater table, resulting in groundwater flow toward the adjacent old lands and a rise of the piezometric level. This reduces natural drainage in the old land and causes a rise in the water table and waterlogging. Next salinization of the root zone occurs through capillary rise.

The government has initiated settlements for various groups: ex-employees of privatized state farms, university graduates with no farming experience, smallholders with plots ranging from 2.5 to 6 feddan, and investors with farms ranging from 200 to 50,000 feddan. No provision for drainage facilities was made at the initial planning and design stage. Solutions were devised as the problems appeared. A network of five open main drains was designed by GARPAD and built by public companies under contract for the construction of the whole reclamation and settlement scheme. An area of 23,000 feddans (8,500 ha) was installed with subsurface drains in the early 1980s (Bangar al Sukar).

New open drain under construction in Nubariya.
Photo: A. van Achthoven

The settlement process and agricultural activities intensified in Nubariya in the mid-1980s. By the beginning of the 1990s, waterlogging had become so severe that it affected 10 percent of the cultivated land, including a large area under high-value crops. This brought both investors and graduates to the streets, claiming compensation and solutions. One investor in the Shagaa water board project installed his own horizontal pipe drainage system with good effects. He had to do it by hand since no contractors or trenching machines could be found.

The never-ending "temporary" status of the institutional and administrative set up of the new lands has been a major reason the agencies concerned such as MWRI and MWRI-EPADP have been slow to take over operation and maintenance of the water control systems in the new lands. For a long time, MALR (on behalf of GARPAD) and MWRI were unable to reach agreement. GARPAD asked MWRI to take over operation and maintenance (O&M) of the drainage infrastructure, yet MWRI's assessment was that the infrastructure had not yet reached the standard for which it could take over responsibility for operation and maintenance. This is reminiscent of transfer problems in water infrastructure in many other countries, for instance, the difficult transaction between WAPDA and the provincial irrigation departments in Pakistan and Public Works and local government in Indonesia.

In 1996 the issue was resolved. A ministerial decree was issued, and EPADP was invited in Nubariya to provide direct technical assistance to the public companies in charge of the land reclamation. The director general of a nearby drainage directorate was nominated to lead the operation with two newly recruited graduate engineers (box 4). The responsibility of the directorate in Nubariya is limited to technical services regarding the construction of the main drainage system. EPADP does not yet have full jurisdiction to undertake regular maintenance and systematically design drainage solutions for the whole area. New settlements and land reclamation projects in the West and East Desert remain under the jurisdiction of GARPAD.

Box 4 Pioneering days in drainage in Nubariya

Soon after the establishment of the new drainage directorate in Nubariya, two young graduate engineers were mobilized. An area of over 40,000 feddan around al Bustan was in critical shape: an impervious layer at a depth of 0.6 m to 1.5 m below the field had accelerated waterlogging. They did not know much about drainage when they started but learned as they worked along with the experienced director general. Although their responsibility was only to advise GARPAD on the construction of the main drains, they were approached by local farmers to help in solving on-farm drainage problems. The team worked round the clock and finished designing a network of secondary and tertiary open drains in seven months. Once the design was approved by GARPAD, the team was called in for supervision. The young engineers on the team were highly motivated to get on with their work: they sympathized with their peers, the graduate settlers, and appreciated their problems.

In addition to their work in al Bustan, the two engineers are called upon regularly by other public companies in the area to resolve specific local drainage problems. The network density of the main drains is not sufficient to ensure proper drainage of the fields. In many areas, secondary open drains are sufficient, but there are locally specific situations such as closed basins in hilly areas or subsurface impervious layers, where tailored solutions must be developed. Drainage water is often fed back into the irrigation canal as the most practical and feasible solution.

Besides work with EPADP in the smallholders-owned areas for which GARPAD is responsible for providing services, the two engineers have occasionally been involved, on exceptional basis, working with the investors. Investors faced the same waterlogging and salinity problems as the smallholders did, but they did not have access to EPADP regular services. The investors are expected to resolve their own problems, but there is no private local source of expertise they can hire. The two engineers have spent some of their weekends and spare time surveying and designing drainage systems for private farms. They are happy when they get an opportunity to do this kind of work. Asked whether they could envisage opening a private practice to expand and formalize these services in the area, they replied that it would be interesting, but that they cannot afford to buy equipment and means of transportation they would need. Nevertheless, there is still a lot of work to do to cover the 350,000 feddan (190,000 ha) of Nubariya that lacks an adequate drainage system. The young engineers are satisfied with what they are doing but would not mind getting an opportunity to reflect on this experience and learn more about drainage system planning and design.

Source: This study.

While the graduate settlers are assisted and subsidized by the Mubarak Graduates Program (part of the GARPAD support package), the investors have had to fend for themselves. With EPAPDP operating in the area, investors turned to the department engineers for technical advice and support—either pro-bono or against payment—and they have developed a partnership with the drainage authority. Earlier such know-how and support were not available to investors willing to invest in rehabilitating land and constructing their own drainage facilities. Even so, this relationship between EPADP and the investors is constrained by the investors' lack of financial resources and

Manhole on privately installed subsurface drain.
Photo: A. van Achthoven.

by ambiguity about who pays the costs—the landowners or GARPAD. The lines between shared and public infrastructure are less clear-cut than they are in the Nile Delta and Valley

The New Lands of the 1970s

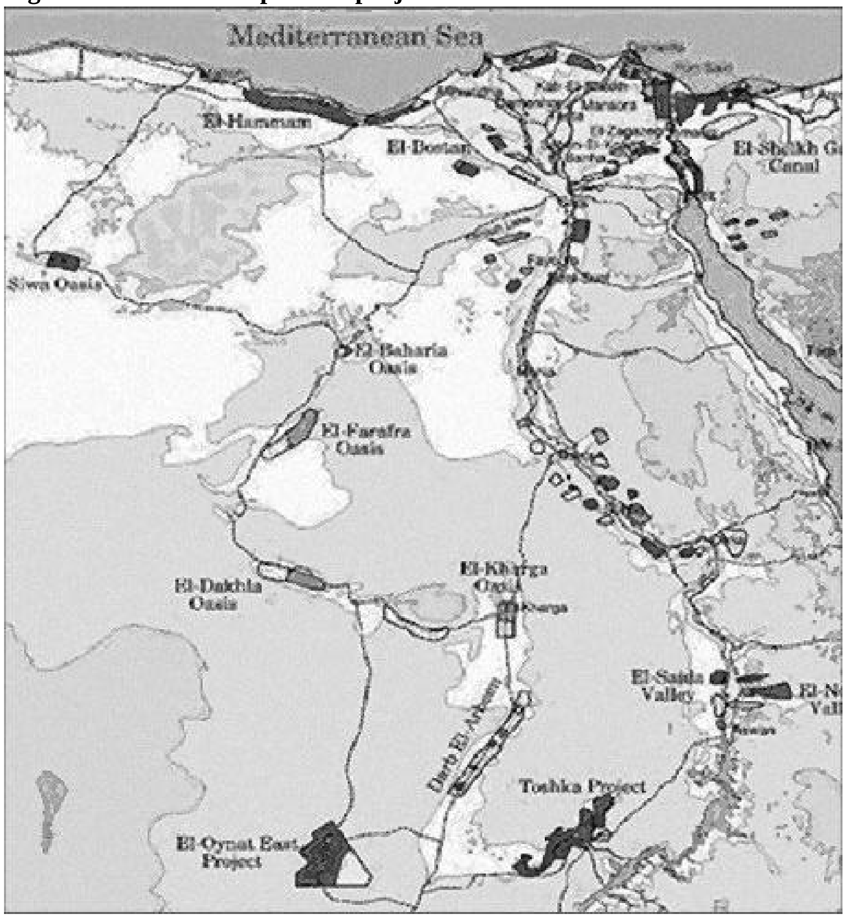
The 1970s were marked by the "open door policy," a political transition phase between the socialist and the market-oriented economy. Reclamation activities were put on hold in the 1970s, due partly to political changes and partly to a critical overview on the poor performance of the land reclaimed in the 1960s. Reclamation activities were started again by 1978 with a target of 578 000 feddans (242,000 ha), most of which was planned for the West Delta to be fed by Nasr Canal fed by the Nile River. The area, sometimes referred to the "new lands," had new technical features such as the introduction of water saving irrigation techniques like sprinklers and, later, drip irrigation. Options for land acquisition reflected the new political and economic orientation. Of the total reclaimed land, 40 percent was composed of plots not exceeding 5 feddans (2.1 ha) each to be allocated to disadvantaged groups. Most of this group of settlers were unemployed university graduates. This somewhat extraordinary policy was meant to reduce the fall-out from the government's decision to abandon its early socialist commitment to providing every graduate with a public sector job. Land allocated to settlers was developed up to field level, including access to distribution channels, land leveling wherever applicable, and micro-irrigation technology. The remaining 60 percent of the land was auctioned to private investors in parcels ranging from 50,000 feddans to 200 feddans (21,000 to 84 ha) (IFAD 1990). The land was sold with access to main irrigation canals and drain. The investor was responsible for providing irrigation and drainage infrastructure within the farm boundaries and was expected to hire private services to finish developing the land.

Funding for the development of the main irrigation and drain network came from a revolving fund established with the proceeds of the land auction. With this approach, the government signaled its disengagement from its earlier full support policy for land reclamation. However, responsibility for planning, designing, and building the main irrigation infrastructure remained with GARPAD, the main authority in charge of the land reclamation work.

The Mega Projects of the 1990s

The beginning of the 1990s marked the full commitment of the government to a market-led economy and the implementation of the structural adjustment policy. Measures were introduced to encourage land reclamation led and run by the private sector and financed by large national and international investors. Seeking to create jobs for an ever-growing population of unemployed youth and to relieve population congestion in the Nile Valley, the Egyptian government has embarked on large-scale horizontal expansion projects to expand inhabited land from the current 5 percent to 25 percent. A comprehensive scheme was put into motion, based on increasing the cultivable land area from the current 8.2 million feddans (3.44 million ha) to 11.4 million feddans (4.8 million ha) by 2017. In a distinct change of policy, the major objective of the mega projects is to develop an agriculture-for-export scheme, create job opportunities, and divert investment pools outside the Old Valley into new regions. Three Mega projects have been launched (figure 4).

Figure 4 Horizontal expansion projects



Source: Hesham Kandil 2002.

The South Valley Development project aims at reclaiming an area of around 1 million feddans in the New Valley Governorate in three regions: around the Toshka depression, in East Oweinat and in the New Valley Governorate oases. Toshka and East Oweinat are considered the most important phases of the project. Together, they encompass more than 750,000 feddans (315,000 ha) of the total targeted area. Total investment to develop the region is estimated at LE 300 billion (US$88 billion) over the coming 20 years until 2017. The government will finance up to between 20 percent and 25 percent for construction of the main canals, pumping station, and basic physical infrastructure. The rest will be financed by local and foreign private direct investment. Land is being auctioned to national and foreign investors without any limit on size. A small portion is being kept for graduates and small farmers under the same conditions as applied before. In Oweinat, the government intends to invest US$1 billion for the preparation of an initial 168,000 feddans (70,500 ha). The land will be made available for private investment. The third Mega project is the North Sinai Agricultural Development project. Here the construction of El Salaam Canal (called El Sheikh Gaber in the downstream section) will irrigate approximately 620,000 feddans (260,000 ha) of new land in the northeastern Nile Delta and northern Sinai Peninsula, using a mix of drainage and fresh water.

GARPAD has been assigned responsibility for the study and preparation of these new reclamation projects—carrying out the soil survey and economic feasibility studies. The organization is expected to move from a service organization to an economic organization that oversees the development of the basic infrastructure in the new land and managing sales to investors. MWRI has been assigned responsibility for planning, design, and construction of the main water distribution system fed by Nile water. The role of EPADP in planning, design, construction, or monitoring drainage in these areas is not defined in general, but decisions have been made on a project basis, as shown in table 3.

In an area where the availability of groundwater is promising such as Oweinat, a depression at the southwest corner of Egypt on the border of Sudan and Lybia, GARPAD prepared a land use master plan. This included agricultural, industrial, and residential zoning. Design and construction of the irrigation structure will be undertaken by the investors; the Groundwater Sector of MWRI will license development and operation of the wells. Drainage of the land has not been investigated during the preparation of the master land use plan. Investors are expected to handle local drainage requirements.

Both the development of Toshka and the North Sinai Agricultural Development project (El Salaam Canal) will be supported by water from the Nile. MWRI has been given responsibility for planning, design, and construction of the irrigation distribution network and basic access roads.

In short, MWRI is responsible for planning and construction of the irrigation distribution network and basic access roads to develop the areas where Nile water is the primary source as in Toshka and El Salaam. Responsibility for land reclamation remains fully with GARPAD in the groundwater-based source of irrigation such as Oweinat. While responsibility over the surface water and groundwater systems seems to be divided in the newly planned areas, the creation of a groundwater sector within MWRI is slowly bringing changes. GARPAD works in close cooperation with the groundwater sector to define the allowed level of groundwater exploitation for specific projects. Responsibilities for monitoring groundwater exploitation and maintenance of the boreholes owned by the state in the New Valley, Siwa, and Sinai have been transferred to the Groundwater Sector of MRWI.

Impact of Drainage Development

There have globally been few systematic studies that have quantified the impact of drainage. One notable exception is the work by Freedman et al. (2002) on the Mardan SCARP drainage system in Pakistan.

Agricultural Impact

In Egypt, however, a large-scale monitoring and evaluation project was started in 1994 as part of the National Drainage Program. One or two years before the installation of drainage, representative sample areas were selected. The sample areas usually measured 400 ha and consisted of five to eight drainage collectors, with associated lateral drains. Countrywide, 15 sample areas were selected within the area to be provided with a horizontal pipe drainage system under NDP-1 in the Nile Delta as well as the Valley. The sample areas were to cover recently reclaimed, extremely saline areas as well as slightly saline and nonsaline areas that had been cultivated since ancient times. Most sample areas had been provided with open drains long ago. In each area, about 20 observation wells were installed, each serving some 20 ha. Monitoring of the observation wells was carried out two to three times per growing season. Time series were prepared two years before and four years after the installation of the horizontal subsurface drains.

Three parameters were measured: the groundwater table depth related to the number of days after irrigation; the salinity (EC) of the groundwater; and the soil salinity (ECe). Data collection and processing was done by EDAP regional and central monitoring units in cooperation with local district engineers. Soil samples were analyzed at EPADP regional soil and water laboratories established under the project.

A major finding of the study was that drainage development in Egypt results in significant productivity gains (Ali, van Leeuwen, and Koopmans 2001). The data indicate significant increases in productivity for the main agricultural commodities. This finding is worth including in the ongoing water productivity debate. This is often narrowed down to the pursuit of "more crop per drop," looking at higher irrigation efficiency or water-efficient varieties and crop husbandry. However, "more crop per drop" misses the important productivity gains that can be made at the level of water resources systems rather than water flows as such.

According to the study, gross production values (GPV) typically improved by between US$500 and US$550/ha.[3] The annual net farm income of the traditional farm increased by US$375/ha in the non-saline areas and by about US$200/ha in the saline areas. Even in rehabilitation areas, there was an average incremental increase of US$180/ha in farm income. The overall cost of installing drainage (including remodeling open drains, planning, design, and supervision) is estimated at US$750/ha and US$550/ha for rehabilitation. Maintenance costs are about US$10/ha/yr. Assuming that two thirds of the incremental income can be attributed to drainage (a conservative estimate), this would mean that the payback period of drainage is short—no more than three to four years.

Farmers contribute to the cost of drainage by repaying the cost of installing the field drains and material cost in interest-free installments over a period of 20 years. Not surprisingly, willingness to pay is generally not problematic.

Other Impacts. In addition to the narrowly defined productivity effect, the development of drainage had other positive impacts—in farming and outside of farming. These have not been quantified but were assessed in focus group discussions as part of the study.

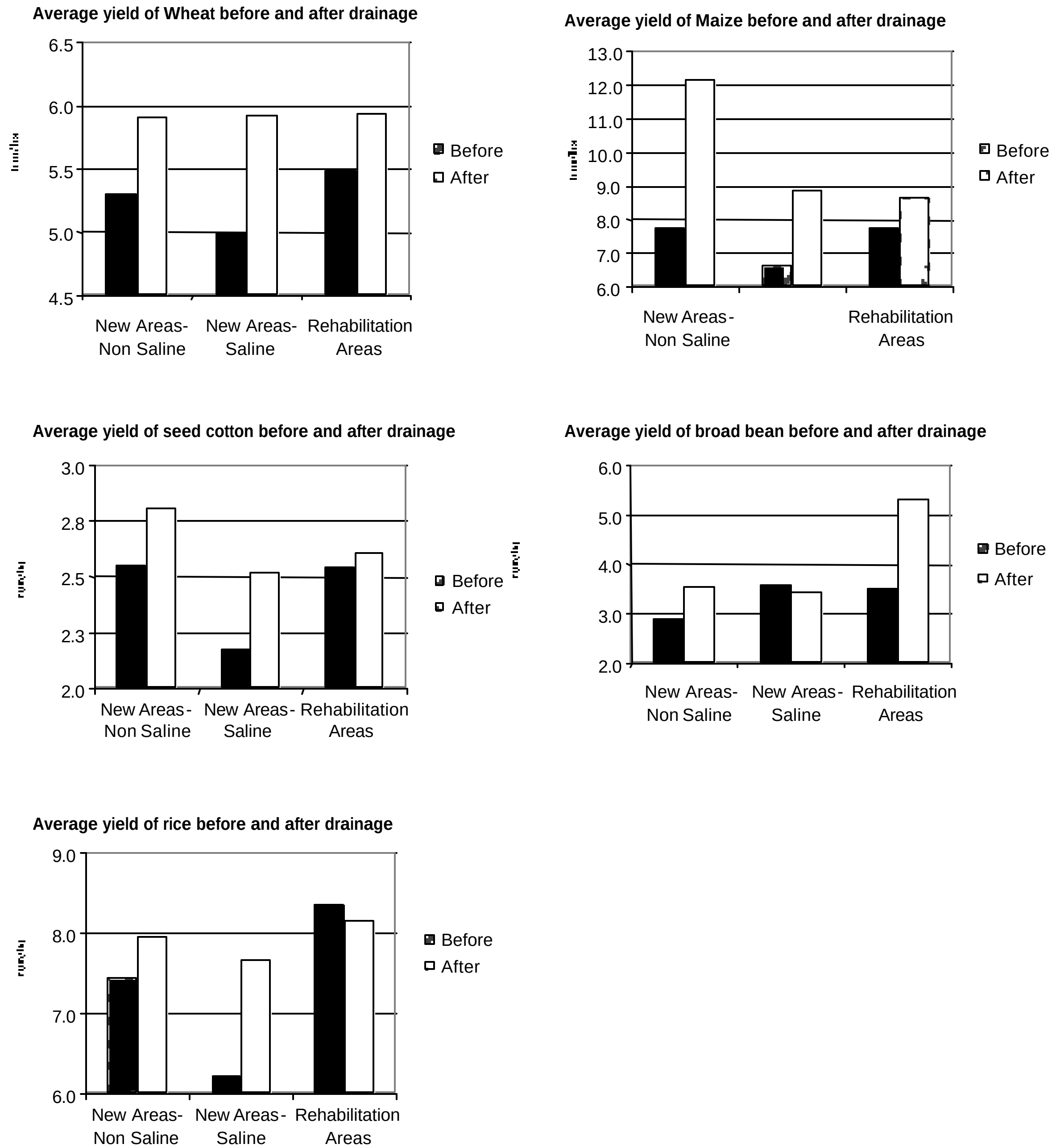
Agricultural Benefits. Important agriculture benefits include improved workability of the soil and lower incidence of fungal diseases. Beyond agriculture, drainage has reduced dampness—which has meant less damage to houses and monuments and lower incidence of cattle diseases. Other agricultural benefits include: widened range of crops through improved trafficability and workability of the topsoil; lower incidence of fungal diseases and better seed emergence rates; leaching of salts even in heavy clays; and increases in land prices.

Nonagricultural Benefits. Nonagricultural benefits include: reduction in water-borne diseases, improvement in sanitation and domestic water supply, and protection of built-up areas. In addition to positive effects on human health, drainage can improve animal health by reducing the number of water-related animal diseases.

3 Calculated on the basis of the yields recorded and the farm-gate prices for primary and secondary products in successive years

Drainage considerably reduces damage to property and improves living conditions in those areas. Well known in Egypt is the effect of high groundwater tables on archaeological monuments. Drainage of agricultural land helps to reduce this damage, especially where monuments are surrounded by farmland.

Figure 5 Impact of drainage on yields



Source: Arcadis Euroconsult 2001b.

3. Institutional Development in Drainage

More than in other countries, the public sector has played a dominant role in drainage development in Egypt. It took over from private investors in the early part of the twentieth century and helped to reach almost national coverage in the course of that century. Only recently the tide is changing, and larger roles are being sought again for private parties and local organizations.

Drainage as a Public Responsibility

Following the cotton crisis of 1909, the development and maintenance of drainage works in Egypt turned into a public responsibility. In Egypt, the history of drainage is different from the early history of drainage in the Netherlands, for instance, or much of contemporary history in Indonesia. Whereas in the Netherlands and Indonesia drainage was a means to "reclaim" agricultural land—by private investors or pioneer groups—in Egypt the state has taken the lead in developing, operating, and maintaining drainage systems to safeguard agricultural productivity. The scale of the system required, the possibility of economies of scale, and the risk of conflicting interests justified a strong public sector role. The instances of farmer-initiated drainage in Egypt are small in nature and sporadic. In the old lands in Egypt, the public sector literally delivered drainage at the doorstep.

The same state-centered approach was followed in the horizontal expansion or land reclamation projects, which were started in the socialist era after the 1952 revolution. Following the development of new irrigation canals, the state developed public infrastructure and on-farm works. It established turn-key state farms and provided disadvantaged groups with leveled fields, with irrigation at farm gate, and with housing. Independent military-style organizations were established to lead land reclamation and settlement in this period. Since then, land and water in old and new lands have been managed under different institutional arrangements, but in both cases strong public-sector implementation authorities played major roles.

Institutional Arrangements in the Old Lands

The Ministry of Public Works accepted the development of drainage systems as a prime responsibility as early as the beginning of the twentieth century. In 1949, Law 35 was promulgated, spelling out the terms for the implementation of a countrywide subsurface drainage system. The state would undertake the implementation of subdrainage for all the cultivated land, and farmers would cover the cost. Public bonds were issued to prefinance the project. The ideology of the socialist era that came into vogue after the revolution facilitated in many ways the implementation of the national subsurface drainage project. There was a strong emphasis on centrally planned and executed agricultural development projects. The decision to continue with the implementation of a horizontal pipe drainage system was reinforced by the decision to build the Aswan High Dam with Russian assistance. The feasibility study for the horizontal pipe drainage program was completed in 1964 with the assistance of FAO/UNDP (NEDECO/ILACO 1966). In the same year, Presidential Decree 301/64 redefined government mandates and limited the responsibilities of the Ministry of Public Work to planning, design, construction, operation, and maintenance of the irrigation and drainage systems. The Ministry of Public Works became the Ministry of Irrigation.

Negotiations with the World Bank were initiated in 1968–69. They were concluded with the approval of a loan to finance a first 10-year Nile Delta Drainage project over an area of 400,000 ha. Subsequently, a number of key institutional measures were taken by the Ministry of Irrigation to enable timely implementation of the project. The Nile Delta Authority of Tile Drainage Projects (NDDA) was established in 1969 for the execution of the project. Next, the first Upper Egypt Drainage project followed, and the Egyptian General Authority for Drainage (EGAD) was established in 1971 to execute the construction of horizontal tile drains in 125,000 ha in Upper Egypt. In 1973, the two authorities were merged into the Egyptian Public Authority for Drainage Projects (EPADP) to consolidate under one authority the ministry's activities for the implementation of the national subsurface drainage program (Nijland 2001).

EPADP was given full autonomy over project execution. The steady progress in the execution of the Egyptian national drainage project (section 2) is strongly related to the institutions put in place. Within this period, EPADP did well in developing unambiguous right-of-way, crop-compensation, and cost-recovery procedures. Standard design criteria and implementation procedures with public and private contractors as well as individual farmers were worked out. The drainage technology choice became imbedded in a package of work processes and departmental capabilities—similar to the vertical drainage projects under the SCARP program in Pakistan. The relatively uniform and straightforward drainage situation in Egypt (in contrast to, for instance, conditions in Indonesia or Bangladesh) made this scaling up possible.

Box 5 The Egyptian Public Authority for Drainage Projects

The Egyptian Public Authority for Drainage Projects (EPADP) is an autonomous organization under the Ministry of Water Resources and Irrigation (appendix C), created under law by Presidential Decree No. 158 for 1973, to undertake design, implementation, operation, maintenance, and development of drainage systems at the national level. EPADP carries out the following main activities:

- Field investigations for predesign of drainage systems
- Planning and design of both field and main system drainage networks
- Supervision and implementation of the drainage networks, comprising field systems, collectors, open drainage, and pump stations
- Monitoring and evaluation of constructed drainage systems.

In 1992, EPADP was put in charge of design, planning, and implementation of rehabilitation and maintenance of the national drainage systems of open and subsurface drains. The public work was carried out by hired public sector companies until 1992. Emergency centers were established to enable the regional sectors to execute directly emergency repairs of open main drains. Today, the regional sectors execute an estimated 20 percent of the yearly open drain maintenance. Maintenance of the subsurface pipe drains is carried out entirely by EPADP maintenance centers and subcenters.

EPADP employs a permanent staff of about 4,000 at Cairo Headquarters and directorates. Casual laborers number about 3,000, working particularly in the field of drainage maintenance.

Source: This study.

Until the late 1970s, EPADP transferred completed infrastructure to the Irrigation Department for operation and maintenance. As maintenance and rehabilitation of the subsurface drains became more important and the Irrigation Department lacked the expertise to do it, EPADP was asked to take this on in addition to its construction portfolio. In 1978, the first EPADP Department for Maintenance was established. Over the years, this department was upgraded and its task expanded to part of the surface drainage network as well. In 1992, EPADP took over from the Irrigation Department the responsibility for maintaining the entire public open drain network in the old lands. Thus, it was in charge of design, planning, and implementation of rehabilitation and maintenance of the national drainage systems. Also in 1992, emergency centers were established to enable the regional sectors to repair open main drains promptly in emergencies. The availability of equipment and know-how within the organization, coupled with the disappointing performance of hired contractors, led EPADP increasingly to step directly into the maintenance of open drains. Today, the regional sectors of EPADP execute an estimated 20 percent of the yearly open drain maintenance in-house and contract out the remainder. The maintenance of subsurface drains rests entirely with EPADP. At field level EPADP has 30 field directorates and 168 drainage centers. They undertake the cleaning and flushing of subsurface drains in-house and execute or supervise the cleaning and desilting of open main drains.

While implementing the drainage program, EPADP had access to a research facility, the Drainage Research Institute. This made it possible to build up a strong core of in-house competence. The institute's work is complemented by the Soil Water and Environment Research Institute (box 6).

Box 6 The drainage research institutes

The Drainage Resource Institute

The Drainage Resource Institute (DRI) was established in 1975 under the Ministry of Irrigation to carry out applied drainage research to support the drainage program. In the first 15 years, its research focused strongly on drainage technology. Subsequently, drainage management and reuse figured more prominently. In addition to the research studies, DRI monitors drainage water quality and quantity in the Nile Delta and Fayoum, and publishes a yearbook.

DRI has four principal departments: Covered Drainage, Open Drainage, Special Studies, and an analytical laboratory. These departments are supported by the secretary general (finance, personnel, mechanical department, administration, and human resource development) and a Technical Office (public relations, management information services, special research). The organization has 72 professional staff members and 150 support and administrative employees. DRI is part of the National Water Resource Centre (NWRC) It has close ties with the rest of the NWRC institutes, and the ministry, especially the Irrigation Sector, the Planning Sector, and the Egyptian Public Authority for Drainage Projects.

The Soil and Water Research Institute

The Soil and Water Research Institute (SWERI) was established in 1971 as an independent institute of the Agricultural Research Center under the Ministry of Agriculture and Land Reclamation. SWERI's mission is to conduct basic and applied research, survey and classify available soil and water resources, improve productivity of old and newly reclaimed soil, and protect soil and water resources. The institute employs more than 260 researchers. Scientists are responsible for basic and applied research projects and land surveys aimed at the conservation and improvement of Egypt's soil and water resources. One department is for field drainage.

The components of SWERI's research program are: surveying and classifying available soil and water resources; monitoring productivity of old and newly reclaimed soil; protecting soil and water resources; optimizing fertilizer use; making recommendations for crop production improvement; and monitoring soil and water pollution and impact on the environment.

To support the implementation of the drainage program in the old lands, a large-scale human resources development program was started in the 1970s with the Dutch-supported Drainage Executive

Management project (DEMP). The core of the program was practical, skill-based training of technicians and engineers (Nijland 2000). EPADP decided to consolidate the in-service training into a permanent Drainage Training Center (DTC) in the late 1980s. The in-house training program helped to standardize working procedures. Besides training EPADP staff, DTC provides training for private and public contractors to reinforce their capacity to execute EPADP plans. Initially, the extra cost was covered by DEMP. Today the training conditions and related cost are included in the tender documents and are ultimately covered by the contractors.

DTC offers 43 training courses in applied civil and mechanical engineering as well as agricultural engineering. With the new challenges facing EPADP in the area rehabilitation, water quality control, environment law enforcement, quality control in the planning and supervision of maintenance work, and transfer of maintenance to farmer organizations, new courses and new approaches are needed. The training facilities have developed into an important asset to EPADP. Training should not be viewed only as an internal core function, but as a source of support for diversification of EPADP services into training and consulting services for the public and private sectors in Egypt as well as in the African and Arab regions.

EPAPD's remarkable physical progress over the years (section 2) is strongly related to its command and control system. EPADP was given full executive autonomy and developed the procedures necessary to exercise it. As things look now, the construction of the open drains on the old lands will be completed by 2007. According to plan, by 2012 the last new horizontal pipe drain will be installed. With this, the core functions of EPAPD in design and construction will come to an end. Increasingly, EPAPD is engaged in maintenance and rehabilitation. More than 50 percent of EPAPD personnel are currently deployed in this area. With construction activities phasing out, in several respects EPADP is an organization at the crossroads. The new policies of the MWRI to transfer drainage system maintenance to local organizations such as water boards and private contractors requires a new definition of EPADP's mandate (NSCE 2001a). At the same time, there is a move to closer integration of functions and to integrated water resources management, the latter adopted as part of the new National Water Resources Plan. This may require a more regulatory role for the MWRI. The question is what EPADP's role will be in this new setting: will it transform itself from a project-based organization in the old lands into a nationwide drainage services organization? What shape will it then take?

Institutional Arrangements in the New Lands

Institutional development in the new lands followed a different track from the old lands. Until the 1950s, land reclamation was driven by private initiative in the shape of large farm estates (section 2). The role of the state was limited to land allocation and construction of irrigation and drainage infrastructure. The agrarian reform of the mid-1950s, however, dismantled all large farms. The maximum area that an individual farmer could own and cultivate was 50 feddans (20 ha). This left all the initiative with the state. Land reclamation started on a large scale, and the state took a comprehensive approach to new land development.

Independent authorities were established, the Desert Development Organization for the New Valley and the Land Reclamation Organization for areas along the Nile Valley, relying on military engineers, Russian technical assistance, and a generous state budget to develop the land and manage agricultural production from seed to the market. The 1960s were marked by ideological fights over the exploitation model—state farms or smallholders. With the advent of Sadat and the open door policy in the early 1970s, however, the failings of the state-controlled land reclamation approach were publicly recognized, and a number of radical institutional changes took place. The General Authority for Reclamation Projects and Agricultural Development was established in 1975, merging the different land reclamation organizations. In 1977, a presidential decree assigned responsibility for land reclamation to a special Ministry of Development of New Communities and Land Reclamation. In 1987, however, GARPAD was moved to the Ministry of Agriculture.

The role of GARPAD is to coordinate the development of the new lands. In developing the new areas, GARPAD has had autonomy to select its own sources of expertise, private or public, for the planning, design, and construction of irrigation, drainage and basic infrastructure. Drainage development has generally taken a back seat in most of the new land development. Where a drainage component was included, it concerned surface drains. Upon completion of the works, the different components were supposed to be transferred by GARPAD to other departments—with MWRI to take care of irrigation and drainage infrastructure. As described, this transfer process is often delayed. In the entire scheme of things, there has also been no systematic role for EPADP in the new lands. This has meant that drainage problems were, at best, corrected only after some difficulty. The case of Nubariya illustrated in section 2 is an example.

Changes under the Market Economy

Within the last decade, the state has moved from a centrally planned system to a market economy. A number of measures have been set in motion to improve the management of the public budget and stimulate economic growth such as reduction of the government's direct involvement in the operation and maintenance of some public services; reduction of government subsidies to public services; deregulation of the agricultural sector; promotion of direct private sector participation in the development and operation of public services, and the creation of incentives and favorable policies to attract foreign direct investment.

These measures are profoundly changing the way water and land resources are managed, raising some critical questions. Which responsibilities can the state transfer to the private sector—yet at the same time maintain the integrity of a national water and land resources management policy? Has the Egyptian private sector sufficiently recovered from the socialist period to take on these new responsibilities? Is it attractive enough? What are the transaction costs involved in changing from a centralized structure, strongly focused on new construction and development, to a more pluriform set-up with a broader focus on resources management and a larger role for users therein? How can agricultural productivity be maintained in this changing context?

Institutional Changes in the Old Lands

With the completion of the construction of the open and horizontal pipe drains in the old lands, the center of gravity in drainage in the old lands is shifting to maintenance and rehabilitation of the old horizontal pipe drains, particularly those constructed before PVC pipes became the standard. What will the role of EPADP be in all this in long run? Ten years from now its role will clearly be quantitatively different. Table 4 summarizes the expected changes over the next two decades.

Table 4 Expected changes in EPADP functions 2000–17

Function	*2001–2002*	*2003–2007*	*2008–2012*	*2013–2017*
Design				
New subsurface drain	■	■	■	
New open drain	■			
Open drain remodeling	■	■		
Subsurface drain rehabilitation	■	■	■	■
Drainage extension	■	■		
Planning and follow up				
New subsurface drain	■	■	■	
New open drain	■			
Open drain remodeling	■	■		
Subsurface drain rehabilitation	■	■	■	■
Drain water quality control	■	■	■	■
Subsurface drain performance	■	■	■	■
Open drain performance	■	■	■	■
Drainage extension	■	■		
Construction				
Manufacture of pipes				
New subsurface drain	■	■	■	
New open drain	■			
Open drain remodeling	■	■		
Subsurface drain rehabilitation	■	■	■	■
Drainage extension	■	■		
Maintenance				
Subsurface drain	■	■	■	
Open drain		■	■	
Drainage extension	■	■		
Rehabilitation				
Subsurface drain	■	■	■	■
Open drain	■	■		
Drainage extension	■	■		
New activities				
Monitoring water quality	■	■	■	■
Consulting services			■	■
Training services			■	■

Source: NSCE 2001.

The ministry's intended policy is to integrate operation and maintenance of irrigation and drainage services. This has already been translated into the policy intention of moving the operation and maintenance of the main open drains out of EPADP and back to the Irrigation Sector. Maintenance of the horizontal pipe drains is still done by EPADP in-house. Privatization is discussed, but alternative options for maintaining the horizontal pipe drains are not yet fully identified. The investment and skills required necessitate a certain scale of operation. This may make horizontal subsurface drains less amenable to in-house maintenance by water boards. The alternative to maintenance seems to be hiring specialized contractors, yet the relatively low demand may make it difficult to transform this activity immediately into a privately run, profitable operation.

So far, the emphasis has been on the management of infrastructure, but the management of water is becoming increasingly important. An increase in reuse of drainage water has been targeted in the national water policy, Egypt and the Twenty-first Century" (section 4). The aim is to add to current resuse 4.5 BcM (billion m^3) of environmentally safe drainage water for reinjection into the irrigation system. This is more easily said than done, as even now there are serious concerns about the quality of the water reused. Clearly, water quality management deserves a larger role in drainage. The creation of an environmental unit within the headquarters of EPADP to enforce water quality standards and reinforce the capacity of EPADP to monitor water quality within territory covered by the National Drainage Project II is a cautious move in that direction. Within a long-term perspective, managing drainage water quality should be decentralized to a lower level. The district drainage engineer under EPADP is already vested, by Law 12/1984, with the legal power to grant licenses for discharge into drainage waterways and to enforce penalties for infringements. The issue in this regard is not the law but its enforcement. The other question is how best to shape water resources management at this decentralized level where integrated arrangements are needed.

Institutional Changes in the New Lands

The various land reclamation projects, the so-called new lands, developed in stages since the 1960s are also affected by the gradual introduction of the market economy—although in many of these new lands the temporary project arrangements of the early years still continue.

Old New Lands. The old new lands are a cultivated area of about 2.5 million feddans (1 million ha) west and east of the Nile Delta, along the northwest coast and in the New Valley, reclaimed in 1952–2000 by GARPAD. Most of the land has been distributed to landless farmers, state farm employees, and university graduates. Over time, land tenure in the new lands has come to resemble that of the old lands. Two drainage centers, Nubariya and Nasr, have been established in the old new lands. Since 1996, the Nubariya center has been operating as a technical service provider to GARPAD and not as a maintenance center. Administrative procedures to turn it into a full-fledged maintenance center have almost been completed. There is a case for deploying the same institutional arrangements in operation and maintenance of drainage facilities with EPADP in these old new lands, but the transfer of responsibilities in this regard is at an impasse somewhere between GARPAD and MWRI. Much remains to be done in planning, design, and construction of drainage system in most of these old new lands—let alone the integrated management of water resources.

The land reclamation projects in the oases of the Western Desert (New Valley and Siwa) were transferred by GARPAD to the MWRI following the creation of the Groundwater Sector. Since then, regional offices have been established in both locations. In cooperation with DRI, the Groundwater Sector has started to explore the steps required to address the drainage problems related to the closed basin structure of these areas and reduce formation of large drainage lakes.

Mega Projects. Unlike the earlier horizontal expansion projects (the old new lands), the mega projects of the 1990s have been planned and devebped under a free-market, small-government philosophy.

GARPAD undertook the planning and arranged for the necessary studies and surveys. MWRI was assigned responsibility for planning, design, and construction of the main water distribution system fed by Nile water in the Toshka and El Salam areas. Much was expected of private sector initiative. In Oweinat, for instance, a groundwater-supplied depression on the border of Sudan and Libya, plots are being sold to investors who can develop them and sell smaller plots if they wish to do so. The investors will undertake design and construction of the irrigation structure. The groundwater sector will provide its technical approval for the development and operation of the wells. Drainage of the land was not investigated during the preparation of the master land use plan. Investors are expected to handle local drainage requirements. Similarly in Toshka, land is auctioned to investors without an upper size limit. A small portion is kept for smallholders, with a minimum size of 8 ha per plot. The mega projects of Toshka, Salaam, and Oweinat renew the nineteenth-century tradition of close cooperation with the state by national and foreign investors to develop export-based agricultural production. Table 5 outlines the roles and responsibilities in the Mega projects.

Table 5 Roles and responsibilities in horizontal expansion, the Mega projects

Land reclamation stages	*Salaam*	*GW Oweinat*	*Toshka*
Planning land reclamation			
Identify suitable areas (level, soil)	GARPAD	GARPAD	GARPAD
Decision water availability	MWRI	MWRI	MWRI
Infrastructure development			
Design main irrigation distribution	NSDA	Private	HE
Design on farm irrigation distribution system	Private	Private	Private
Design main open drain infrastructure	NSDA	GARPAD	HE
Design secondary open drain	Private	Private	Private
Design tile drain if needed	Private	Private	Private
Supervision construction	NSDA	GARPAD	HE
Drainage research	Private/DRI	Private	Private/DRI
Operation and maintenance			
Main water distribution network	NSDA	Private	HE
On-farm irrigation network	Private	Private	Private
Main open drain network	NSDA	Private	HE
Secondary open drain	Private	Private	Private
Tile drain	Private	Private	Private
On farm drainage system	private	Private	Private

GW ground water source; MALR Ministry of Agriculture and Land Reclamation; GARPAD–MALR General Authority for Rehabilitation Project for Agricultural Development; MWRI Ministry of Water Resources and Irrigation; NSDA–MWRI North Sinai Development Authority; HE–MWRI; Horizontal Expansion Department; EPADP–MWRI Egyptian Public Authority for Drainage Projects; DRI–MWRI Drainage Research Institute.

Source: This study.

Only in the North Sinai Development Project (El-Salaam Canal) has the development of a drainage system been included in plans. In the other areas, it is left to private investors to take the initiative. Unlike other countries with a long drainage tradition (such as the Netherlands or the United States), there is no private sector in Egypt that can serve the need for drainage development—for design, installation, and supervision. In the shadow of a dominant public sector, which did most of the work in-house, private sector service providers never fully developed. In principle, the Drainage Research Institute and the Soil

Water Environment Research Institute have the flexibility to provide consulting services at cost to private individuals and firms. However, these institutes are centrally located and have limited outreach in the areas under development. They can fulfill some of the needs of the private sector—particularly in advisory services—provided that they develop a service- and market-oriented approach. Private construction companies can provide services—several of them were trained by EPADP—but it is a matter of scale and competition.

There is a case for "opening" up EPADP, as much of the capacity to design and develop drainage systems rests within this public agency. Particularly in horizontal pipe systems all expertise remains with EPADP. At present, private investors are sometimes left with little choice but to try to make an informal deal with EPADP staff. EPADP does not have a formal mechanism to provide consultancy services to the private sector. But in the context of privatization and management transfer (discussed below), it may make sense to provide incentives to EPADP staff and others to develop this capacity.

Farmer Participation in Drainage

Farmer participation in water management is at a relatively early stage in Egypt, with several experiments going on, but policy or legislation have not yet been formalized. The centralized water management, dictated by the structure of the singular water source of the system and the blanket approach to drainage, gave little room for user participation in the past. The present move toward a participatory water management policy has been spurred by the mounting burden of responsibilities on the administration and the need to satisfy increasing demands with limited resources. Since the early 1990s, an elaborate policy debate has been going on over the privatization of water services, particularly on enlarging user organizations' responsibilities in the management of water infrastructure in the old lands. One of the most effective forums in this regard has been the Advisory Panel on Water Management and Drainage—which started as a platform for reviewing and strengthening the drainage program (box 7). Water policy development in Egypt has been further influenced by the benchmarking process, which tied budgetary support from the U.S. government to the achievement of agreed policy milestones. The establishment of water boards and the preparation of a revised Law 12 (on the role of water users in water management) have figured as milestones in recent years.

Box 7 Advisory Panel on Water Management and Drainage

The Advisory Panel is an informal annual peer-level discussion between water policymakers in Egypt and the Netherlands—preceded by workshops and studies. Six Egyptian and five Dutch members sit on the panel. The last few years it has been chaired by the Minister of Water Resources and Irrigation

Throughout the years, the panel has worked to: achieve better and cheaper subsurface drainage installations; upgrade design procedures; develop operation, maintenance, and rehabilitation criteria for drainage systems; study soil and water management; establish water quality monitoring programs, support a reuse strategy; and sponsor public consultation programs. In the panel's early years, its activities focused on the large-scale drainage development program, but the agenda has widened to encompass water management in general. The panel's focus has shifted from a technological orientation to a policy orientation.

Source: This study.

Up to this stage, all participatory water management initiatives have been initiated through the MWRI, supported by donor funding and encouragement. Farmer involvement has been reactive, mostly welcoming and cooperative. Several types of farmer organization have been tested, addressing both irrigation and drainage, usually separately, and addressing different levels of responsibility—from consultation to transfer of responsibilities. The overriding lesson so far is that moving from central government–controlled to decentralized, user-involved water management is more a process than a formula.

In addressing the process, one prerequisite identified was legal stature for the farmer organizations, permitting official delegation of such responsibilities as distributing water and collecting charges. Other prerequisites identified have been an enabling environment for the farmer organizations to assume their roles and capacity building and financial powers for the farmer organizations. Although these are cornerstones of that process, they have not been forthcoming and are still being pursued.

The collector-user association (for drainage only) and the water board are the two forms of farmer organizations that have addressed issues of drainage. The association, the earlier effort, has not met with much success mainly due to a lack of activities for them. The collector-user association model is not now regarded as an option for participatory water management as far as drainage is concerned.

In the last five years, the spotlight in participatory water management has been redirected to the water board. Though still experimental, for the potential that these organizations have shown, they are thought to stand a better chance in representing farmers and possibly other local water users. The move to water boards from collector-user associations is a move to local water management at secondary canal command area with potential to extend to even larger command areas, for example, districts *[markaz]*. It is also a move toward organizations with a diverse mandate that better serves integrated water management. Experience with spontaneous farmer involvement in drainage, with collector-user associations, and with water boards is briefly discussed below.

Self-Organized Farmer Involvement in Drainage

Formal farmer engagement in drainage management in Egypt is an individual responsibility. Farmers are responsible for maintaining specific parts of the system, in particular those in their fields. The responsibility is currently defined in Law 12/1984. Farmers are responsible for open field drains and tertiary drains. The law also defines their responsibility for the *merwa* (on-field waterways) and the *mesqas* (the corresponding irrigation waterways).

The main open drains are owned, operated, and managed by MWRI and are public property. The interface is at the level of secondary drains. These are designed, built, and monitored by the MWRI; but maintenance is often done by farmers or, where they exist, by agricultural cooperatives[4] on behalf of the

4 Agricultural cooperatives are joint organizations between farmers and the Ministry of Agriculture. There are agricultural credit coops, land improvement coops, and land reclamation coops. Land improvement coops are managed by farmer-elected bodies and supported technically and financially by the Ministry of Agriculture. These organizations, before the agricultural liberalization measures, were pillars of any farmer production and sales processes. They provided everything at fixed prices. With market competition, their role has diminished. Maintenance of the mesqas and private drains still remains with the agricultural cooperatives

farmers. In the latter case, the costs are ultimately borne by the farmers and usually combined with other costs the farmers incur with the cooperative and are charged against farmers' earnings from crop sales to the cooperative. With a few exceptions, however, farmers did not organize themselves in any institutional way to carry out those responsibilities. In the absence of formalized drainage systems, in some places the national drainage program has not yet reached, farmers developed open field drains. Some farmers even devised indigenous methods to overcome the drawbacks of open field drains and made makeshift subsurface drains (box 8).

Box 8 Farmer initiatives for horizontal pipe drainage

Farmers in a number of places have identified the importance of subsurface drainage and tried to overcome land loss to field and secondary drains by developing indigenous subsurface drainage systems. They have used clay pipes (oven hardened), surrounded them by cotton straw to provide a bed for infiltration, and buried them in their fields. The pipes have been designed to overlap each other, extend to the fields' ends, and discharge the collected drainwater into the nearest waterway. The pipes are manufactured in Damanhour, Beheira, where the clay has the right porosity.

Other simpler ways of draining the land are to dig out a field drain, fill it with cotton straw, and cover it up. Although this structure has to be renewed yearly, it allows farmers to use land that would otherwise be used as an open field drain.

Source: This study.

Collector-User Associations

Collector-user associations were set up at the initiative of EPADP on a voluntary basis as a drainage copy of the established water user associations (WUAs). A special extension wing under EPADP, the Drainage Advisory Services (DAS), promoted them. The CUAs are an example of what is called "institutional xeroxing," using models nurtured in the irrigation sector directly in the field of drainage. WUAs, are farmer organizations set up on the tertiary (mesqa) level to organize management of that level of the irrigation waterway hierarchy on a single point lifting basis (box 9). The CUAs were organized around drainage collectors. Farmer involvement, even on a minimal, preventive maintenance level, was thought to contribute to the effective and efficient operation of the subsurface system (NSCE 2001a). The CUAs were established after the subsurface drainage system was in place in order to "turn over" the system to them. All in all, some 2,172 CUAs were formed. No legal or institutional framework was developed to support their activities.

Box 9 Water user associations

Water user associations (WUAs) were set up as part of the irrigation improvement package through the Irrigation Improvement project (IIP). IIP introduced single point lifting on the mesqa (tertiary level) irrigation canals. Single pumps replaced individual farmer pumps, mesqa were raised or changed to pipes, secondary canals received continuous flow, and water user associations were established to own, operate, and maintain the pumps. To ensure sustainability of the WUAs, irrigation legislation was amended to regulate their establishment, thereby providing them with legal identity, and to specify their responsibilities. Law 213/1994 activated this amendment.

The basic functions of the WUAs are:

- To participate in planning, designing, and implementing mesqa systems.
- To operate and maintain WUA pumps and regularly undertake mesqa maintenance.
- To improve mesqa water delivery and return flows.
- To enhance water use management through improved irrigation scheduling and other irrigation practices.
- To develop a functional linkage with irrigation directorates through branch canal federations, training programs, seminars, and workshops.
- To procure and manage finances for the maintenance of mesqas.
- To develop the roles and responsibilities of mesqa and branch canal WUAs in the resolution of complex water disputes.
- To develop relations and, when necessary, closely coordinate with organizations that provide essential services such as banks, public/private laser and leveling firms, local village councils, and agricultural extension units.
- To maintain relations with local political and religious leaders.
- To ensure good communication between WUA members and field staff and all organizations concerned with irrigation and agricultural improvement.

Source: Van Leeuwen 2001b.

With this handicap, lack of legal framework to recognize CUAs, these voluntary organizations failed to assume the significant responsibilities that would lead to a sustainable existence. CUAs were not able to:

- Receive ownership rights (on behalf of the farmers) to the appropriate section of the subsurface drainage system. The system was, therefore, not turned over in a meaningful sense to the farmers, although this could have been done as partial compensation of the farmers' payments to the investment cost.

- Enforce preventive maintenance or correct infringements as there was no official authorization to buttress their existence.

- Collect fees from its members to carry out any form of maintenance or collection of the cost-recovery payments. The cost contributions (to the capital investments) were made through the tax collection mechanism, alienating the farmers from the system. Many farmers interviewed did not know how much they paid.

Further, on assuming O&M responsibilities CUAs were being marginalized. The maintenance of subsurface systems required the use of sophisticated equipment, which prompted EPADP to step onto the scene. While the maintenance of open field drains is carried out and paid for by the farmers (for this is their private property), EPADP decided to undertake as well as finance the maintenance of subsurface drainage networks at farm level. No local private maintenance services sector that could serve farmer organizations has come into existence. Other roles in management of the system or involvement in design, implementation, or maintenance faded into the background. The CUAs were formed to facilitate the implementation plans and reduce damage to the system once installed—preventive maintenance. In the absence of a strong policy drive, defined by legal, financial, and institutional arrangements, the view of farmer participation remained limited to this micro-level involvement. The CUAs served to introduce the drainage program and avoid farmer opposition to field implementation of subsurface drainage due to insufficient knowledge or understanding. Farmers also frequently damaged manholes, and manhole covers were stolen to access the drains for water at times of irrigation water shortage. These practices caused increased maintenance costs and failure of parts of the system. CUAs had a limited remit and were to reduce these incidents and thus facilitate implementation schedules and reduce costs from damage to the new systems.

These constraints worked against CUAs' becoming a viable option for farmer organizations in the participatory water management process. The CUAs were mostly organizations on paper except for a few that commanded rights of existence, based on local CUA leaders' strong commitment and volunteerism. Although Law 74/1971 states that landholders have to repay the costs of subsurface drainage, no farmer entitlement to the asset was worked out. Horizontal pipe drains replaced field and tertiary drains, which farmers were responsible for operating and maintaining under Law 12/1984. EPADP now stepped in and took up duties in managing the drainage system up to tertiary level. In the final analysis, the CUAs did not survive, because they were out of the framework, had little effective support, and had too little to do: preventive maintenance on subsurface systems did not justify the effort of sustaining an organization.

Box 10 Drainage conflicts after deregulation

During the period of a regulated economy, uniform cropping patterns were prescribed. Under deregulation, conflicts increased—for instance, between paddy farmers and cotton farmers. A rice grower would block the outlet of the drain collector to maintain the water level in his field, but the blocked drainage would ruin his neighbor's cotton crop. This has made drainage management far more complex, as interests in water table management now differ.

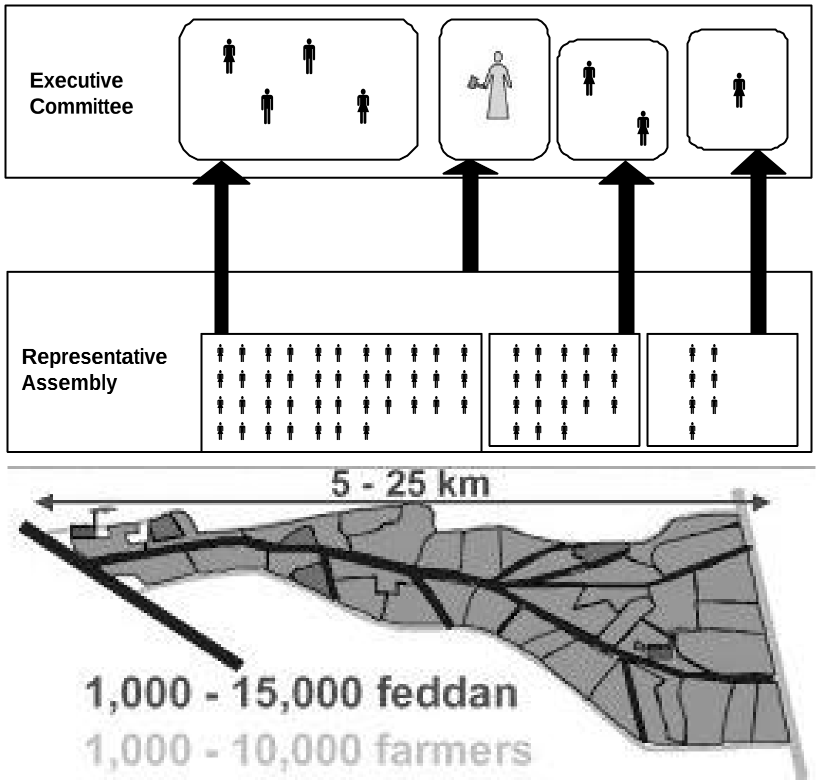
Source: Verstappen 2001.

Another effort in improving local management in drainage at the level of drainage collectors was more technical than organizational in nature. It concerned the introduction of *controlled drainage* in rice cultivation in two pilot areas managed by DRI. The idea behind controlled drainage was to introduce demand management in drainage and give landowners the means of determining groundwater levels that suited their farming priorities.

Toward this end, gates were installed on the collector that could be closed to raise water levels, especially for rice cultivation (appendix B). This would also reduce damage and vandalism, as it would avoid the current practice of dumping bags and other obstacles in the manhole. The controlled drainage experiment was a less than resounding success. A main problem was how to coordinate the different priorities of farmers, growing different crops, in the absence of a strong local organization (box 10). Before crop liberalization (starting in 1986), cotton, wheat, and rice were usually grown in large blocks arranged at village level by the cooperatives, thereby making farm operations more efficient. Economically, controlled drainage makes much sense. An increase of 27 percent in construction costs (equivalent to

$50/ha), because the system has more collectors, is offset by annual savings in pumping costs for rice farmers, amounting to $50/ha (Abdel Gawad 2002). The bottleneck appears to be in the unfulfilled organizational challenge. Controlled drainage would at a minimum go hand-in-hand with an empowered CUA, able to play a role in coordinating crop choices, yet at this stage these do not exist (Verstappen 2001).

Figure 6 Water board representation



Source: Reconstructed from Bron 2002.

Water Boards

Since 1995, another institutional model important to farmer-managed drainage has been explored. Water boards have been established at the level of secondary canal command areas—typically serving between 500 ha and 750 ha. At this level, they can, in principle, combine both irrigation and drainage services—because irrigation and drainage commands partly overlap and because the volume of activities is sufficient to justify a specialized organization.

The water boards are being piloted in some 50 command areas around the country, under different names and by different projects.[5] So far, they have been engaged in coordinating water allocation plans,

5 Branch Canal Water User Association (federation of WUAs on a secondary canal) under the IIP and water boards under the Fayoum Water Management project and Water Boards project

performing system maintenance, discussing system improvements, and resolving conflicts. They have an elected board, which represents the constituency—in terms of geographical spread of the command area, the different water sectors (farm, residential, commercial, and industrial)—and men and women (see figure 6).

An evaluation of some of the earliest water boards indicated that they were able to distribute water more fairly and increase the area under cultivation by 10 percent in the winter season (Verstappen, van der Sluis, and Yacoub 1997).

The water boards operate under ministerial decrees that have given them official status with pseudo-legal capabilities. They have been able to assume local legitimacy, providing useful coordination and facilitating communication and service between their command area and the district engineers in various MWRI departments (Irrigation, Drainage, Irrigation Improvement, and Irrigation Advisory Services).

Yet the current legal regime does not yet provide for formal management transfer. Water boards cannot yet take charge of operation and maintenance of the local water system, collect fees, or enforce regulations in this regard. Their limited legal space has dampened interest in some of the pilot water boards, according to reports from the Fayoum, where pilot water boards were established first, but they have now run out of things to do. Another concern is that water boards may fade away, once ties with externally funded projects are severed. Examples of such short-lived efforts have been recorded in Sharkeya and Gharbeya.

Important changes in the legislation are, however, in the making. A series of proposed revisions in Law 12/1984 (box 11) establish water boards as formal partners to the MWRI in water management and provide for management transfer and collection of dues. The preparation of these legal revisions is a protracted process that started in 1998. The minister of Water Resources and Irrigation has approved the changes in the law and has sent them to the cabinet. It has to be approved by Parliament to be passed into law. Executive bylaws then have then to be issued, which will detail procedural, organizational, institutional, and financial steps for implementation and enforcement of the law. It is evident that transfer of public assets to a new organization will require it to have a multisectoral legal status. The authority to sanction such organizations depends not only on the MWRI, but equally on recognition by local governments and by the financial, tax, and other authorities. In particular, the bylaws must be evaluated for compatibility with, for example, local administration laws, election laws, financial laws, and taxation laws.

Box 11 Proposed changes in Law 12

The most important articles in the changed Law 12 for decentralization and privatization are:

Article 33. Water user associations are required and accepted at mesqa level. The water boards must have a physical boundary at a higher level. This can be branch canal, a main canal, or district level. This is not specified in the law. Water boards deal with public water functions, can be jointly financed, and can engage in O&M, construction, and rehabilitation.

Article 34. This article authorizes the minister to transfer a command area for full O&M to private companies, water boards, or other private organizations. These companies can collect fees from their constituency.

Source: Bron 2002.

The next challenge is then to scale up the water boards program. To facilitate this, Institutional Reform Units (IRU) have recently been established under the minister's Technical Office in the MWRI—and in EPADP.

A point of discussion at this stage is the level at which water boards should operate. The proposed changes in Law 12 create the opportunity for water boards to operate at district/markaz level. Most districts cover 10,000 ha to 15,000 ha. The argument for water boards at this level is that the portfolio and scale of activities would make for more viable units than the secondary canal level, which is small in Egypt (compared, for instance, to Pakistan or India). Water boards at district level could more effectively integrate irrigation and drainage functions and take up locally integrated water resources management (section 4). District water boards would introduce user-controlled institutions at what is now the lowest administrative and budgetary unit within the Ministry of Water Resources and Irrigation.

If water boards are to go farther—either at secondary canal level or at district level—there are also important questions to be answered on the scaling-up process. The 50 water boards now in place have support from various projects. If water boards were to develop more widely, the capacity to support this shift would also need to be developed. This raises the important question of whether management transfer will be on a voluntary basis or by program. Similarly, the role and composition of the Ministry of Water Resources and Irrigation at different levels would have to be adjusted. In fact, high staff levels and financial shortfalls were drivers behind the move to participatory water management. The function of the different levels and sectors within the MWRI would have to be rethought. Similarly, regulatory mechanisms would have to be revised, as relations between relatively autonomous water boards in water management are significantly different from relations between units belonging to the same government organization.

Drainage Financing

In line with Egypt's centralized tradition in drainage, drainage projects are being financed by the Egyptian government and by international funding. Over the years, more than an estimated US$3 billion has been spent on subsurface drains, remodeling and deepening open drains, and constructing and rehabilitating drainage pump stations.

Law 74/1971 and Law 12/1984, article 34, determined that landholders had to repay the capital costs of subsurface drainage. Repayment of the capital costs is done in 20 interest-free annual installments after a grace period of three years following construction (Barakat 2001). Assuming annual inflation of 5 percent, landowners pay less than 60 percent of the costs. Box 12 presents a break down of capital costs. The drainage program in Egypt is one of the rare examples where landowners have made a significant financial contribution to capital investments.

Box 12 Cost recovery in horizontal pipe drainage

Farmers pay:

- Contract value of the installation of the subsurface drainage system (contract between contractor and the Egyptian Public Authority for Drainage Projects)
- Materials supplied by EPADP
- Materials supplied by contractor
- Fee for EPADP supervision
- Fee for establishing EPADP maintenance center
- Crop compensation payments to impacted farmers

Not accounted for in the present payments by the farmers are:

- Payments from public funds
- Construction of open drains and structures
- Construction of pumping stations
- Operation and maintenance of pumping stations
- Maintenance of open drains and structures
- Depreciation of machines (trenchers)—EPADP now provides the machines
- Insurance.

Source: This study.

Capital cost charges are collected as part of the land tax, an arrangement that makes for low additional transaction costs and effective enforcement. Its relatively anonymous nature also defies some of the current logic of creating a larger sense of responsibility for the system through payment for its services. Some landowners are not even aware that they are paying for the drainage system. Collection efficiency is high in Egypt, more than 90 percent. In contrast, water charge collection in many developing countries is problematic—usually the lower the charges, the more abysmal is the collection rate (Bosworth, et al. 2002).

Although farmers pay for part of the capital costs of subsurface drainage works, they do not pay the costs of operating the drainage systems. The issue of charging for the operation and maintenance of irrigation and drainage systems is fraught with political sensitivity in Egypt that has up to now precluded the introduction of significant charges (Abu Zeid 2001). Even when introduced, assessment and collection costs may exceed returns from low charges. Though at present landowners do not pay directly for drainage or irrigation services, it has been argued that the land-tax is supposed to pay for these costs. Transferring part of the land-tax proceeds to water boards is one option that has been contemplated—particularly if water management is decentralized to autonomous water boards (APP 2002).This would not entirely resolve the issue, as the annual land tax, amounting to between LE15 and LE20/feddan ($10.50 toUS$14/hectare), is also meant to pay for other infrastructure services. The total budget of the MWRI for maintenance is on average LE28/feddan (US$20/ha). A water board in the future might absorb LE18/feddan (US$12.50/ha) (Bron 2002). The overview in table 6, suggests that most of the expenditures are required for maintenance of irrigation infrastructure. For the entire drainage system, the maintenance costs are LE7.3/feddan (US$5/ha), 25 percent of the total.

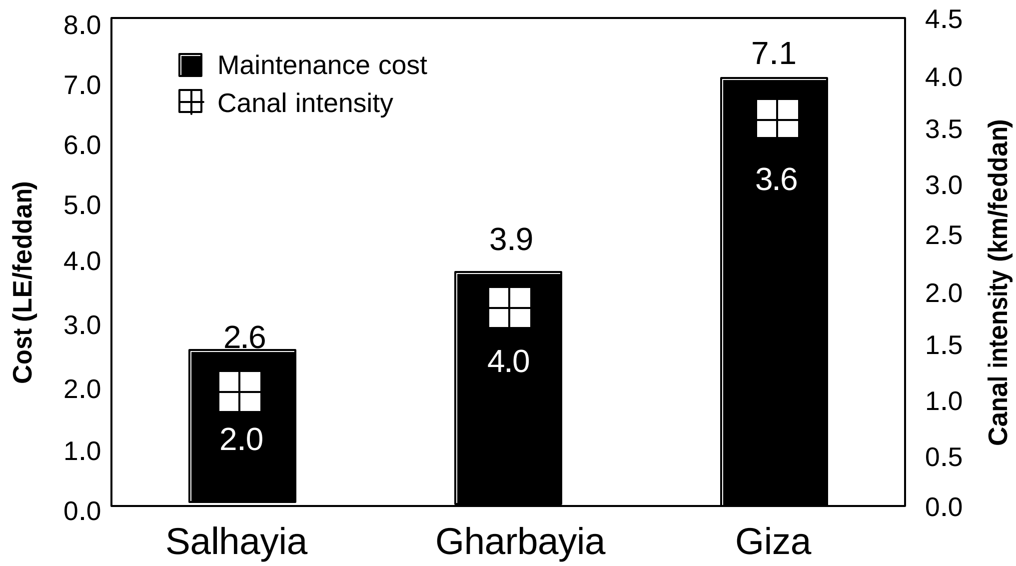
Table 6 Maintenance budget, MWRI

Budget	*Budget (million LE)*	*Area under O&M (feddan)*	*Expenditure/ area (LE/feddan)*	*Potential for transfer to water boards (percent)*
Maintenance canals and structures	144.7	8.2	17.6	50
Maintenance roads and bridges	7.8	8.2	1.0	10
Other	7.8	8.2	1.0	10
Subtotal	160.3	8.2	19.5	—
Maintenance open drains	35.2	8.2	4.3	30
Maintenance subsurface drains	14.1	4.8	2.9	90
Other	1.9	8.2	0.2	10
Subtotal	51.2	8.2	7.3	—
General main system maintenance costs.	4.3	8.2	0.5	10
Other	12.2	8.2	1.5	10
Subtotal	16.5	8.2	2.0	—
Total	228	8.2	27.8	50

Source: Bron 2002.

National figures hide wide local variations in O&M costs. From the Manual Channel Maintenance Project—Phase II actual maintenance expenditures for open drains were collected for three different parts of Egypt: Giza (Upper Egypt), Salhayia (New Lands) and Gharbayia (Delta). The measured maintenance costs and related to the density of drains are shown in figure 7. These figures compare to the LE4.3/feddan 4 (US$3/ha) from the budgeted amounts, but show the considerable variability, strongly related to the density of drains.

Figure 7 Maintenance cost per area served



Source: Manual Channel Maintenance Project—Phase II.

4. Drainage, Environment, and Integrated Water Resources Management

Water resources management in Egypt was long concerned mainly with quantitative water management and salinity control to sustain the productivity of irrigated agriculture in a small area with a fast-growing population. The drainage program has always been closely linked to the irrigation program—universal coverage in the old lands and a more delayed implementation in the new lands.[6]

Integrated Water Resources Management

Integrated water resources management can be defined as "a process which promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems" (GWP 2000). By this definition, drainage has played an important role on the economic and social welfare side. The evaluation of the drainage program in the old lands, (section 2) suggests that

6 In Egypt, as in other countries, drainage often started out as a remedy for inadequate irrigation. The dream of planning irrigation and drainage systems simultaneously did not happen in Egypt—nor has it happened elsewhere. The question is whether this is not easily explained by political feasibility and technical expedience: planning the drainage system, when the problem is obvious and its location in space is visible, is easier than trying to forecast where drainage infrastructure is most needed.

drainage provided the basis for significant increases in agricultural productivity. Drainage also helped to improve the human living environment through lowered incidence of waterborne diseases, improved sanitation, and reduced damage to property.

As the intensity of water uses is constantly increasing in Egypt, the interlinkage and interdependency between the different uses is growing exponentially. Drainage plays a crucial role in these interlinkages in Egypt, particularly through reuse policy and practice, which raises important issues on water quality throughout the system. Drainage is also a key to integrated water resources management in Egypt because of the effects of drainage effluents on aquatic ecology, particularly in the northern estuaries. This section explores whether concerns about water quality and ecology should not get a more central place in drainage management and water resources management in general.

Drainage Water Reuse

In the 1970s, a policy was formulated for reusing drainage water for irrigation. Because irrigation water was scarce, reuse of drainage water became an essential element in water management starting in the late 1980s after a series of studies by the Drainage Research Institute and others. This reuse was made possible by the extensive network of open drains and subsurface drains that was being developed. Of all the countries in arid regions, Egypt has gone farthest in reusing drainage water. In Upper Egypt, drainage water is reused by gravity flow.[7] In Lower Egypt, reuse is by lifting water to the irrigation canals. In implementing the reuse policy, 25 centralized mixing stations were built on the main drains in the Nile Delta, managed by the MWRI Mechanical and Electrical Department (MED). Upper limits were set on the salinity of the water that can be used for mixing. The official reuse of drainage water was 2.9 BcM/yr in 1984–85. It increased to 4.4 BcM/yr in 1996–97, the latest published figure. The Water Policy Reform Program of 1999 projected further increases in reuse to 8.4 BcM/yr by 2017. This water will be required to meet demand for new horizontal expansion projects, including those now coming on stream, as well the increased water demand from the domestic and industrial sectors. The national policy seeks a 20 percent increase the volume of water available by 1997–2017. Of this, a fifth would have to come from increased reuse.

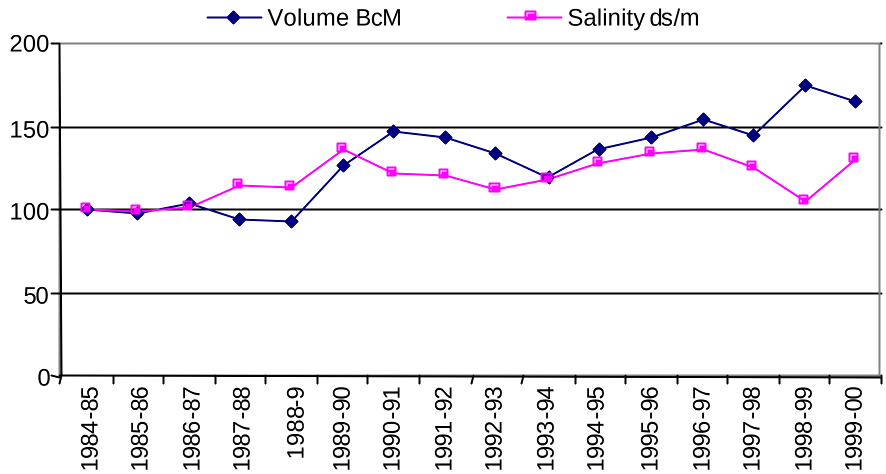
In addition to the “official” reuse, there is unofficial reuse by farmers. This happens mainly in the northern part of the Delta, the tail-end area, which has serious water shortages during rice transplanting. Farmers put mobile pumps in small drains or in the manholes, usually with little attention to water quality (salinity or pollution). This informal reuse of drainage water is estimated at between 3 BcM and 4 BcM—almost as much as the official reuse (Bazaraa 2002).

With more reuse, the salinity of the water increases. Figure 8 illustrates this indexed trend. In 1984–85 average salinity of the water reused was 1.35 dS/m. In 1996–97, it was 1.84 dS/m. Salinity dipped for two

7 Some have argued that several of the new horizontal expansion projects such as Toshka, by virtue of their remote location, do little to add to the recoverable return flows, as seepage is lost to a sink. By comparison, no water is lost to the system in horizontal expansion projects along the fringes of the old lands, particularly in Upper Egypt, where water lost maybe reused several times before it reaches the Mediterranean.

years, as a result of a larger outflow at the Aswan High Dam as the Nile went through a cycle of relatively wet years. As more and more drainage water is reused, its quality becomes increasingly important. The salinity load from the drains can be reduced with existing technology but at high cost (box 13).

Figure 8 Indexed trends in drainage water reuse 1984–2000



Source: NWRP 2000b.

Box 13 Drainage spacing, costs, and salinity

An example of designing for multifunctionality are the considerations on drainage spacing. A reduction in drain spacing will reduce salinity. If 50-m drainage spacing is used instead of 100-m spacing, the layer that will be leached, in a deep unconfined flow regime, is reduced to 50 percent, which results in a reduction of salt load of the effluent. Yet it also results in an increase in investment costs, though not necessarily proportional, as diameters of the drains will be smaller. Whether such solutions are economically justified depends on the values attached to the effects of an additional salt load transported to the downstream areas.

Source: Croon 2001.

Probably more serious than the increase in the salinity are the rising levels of organic and inorganic pollutants in the drains. Water quality monitoring in Egypt is done by several agencies. The Drainage Research Institute monitors the drainwater quality. From samples taken at 130 locations, the institute measures a large number of parameters—from organic contamination to chemical composition to salinity and other physical properties.

Results of this monitoring indicate that hardly any drain meets the general standards for water quality, much less the stringent norms of Law 48/1982 on Protection of the Nile. These norms are based on the disposal of effluent in canals used as sources of domestic water. From the summary of drainage water status in table 7, it is obvious that contamination is serious, particularly from coliform bacteria and heavy metals (Bazaraa 2002):

- In most places, the coliform bacteria count far exceeds the standard defined in Law 48/1982.

- Almost every drain far exceeds the norms for biological oxygen demand (BOD) and chemical oxygen demand (COD).
- Of the nutrients related to the use of agrochemicals, ammonia levels are especially worrisome.
- Cadmium is the most serious heavy metal pollutant.
- Pesticide residues and heavy metals may also be accumulating in the drain sediment, but this issue has been little investigated in recent years (NWRP 2000b). Earlier research established that the concentration of pesticides in waterways was far below the guidelines set by the World Health Organization (Abdel-Dayem and Abdel-Ghani 1992).

This contamination originates in the urban and industrial centers through which the drains pass. Notorious sources of pollution are Helwan and Shoubra El Khaima near Cairo as well as the Alexandria metropolitan area. Some drains are particularly problematic. A prime example is the Bahr El-Baqr drainage system (Assiouti 1994). Bahr El-Baqr receives untreated and semi-treated wastewater from Cairo. Along most of its 170 km length, the drain system is completely anaerobic with high levels of BOD, ammonia, and heavy metals. The drain discharges into Lake Manzala, where water quality and fish production have been severely affected (see next section). Other particularly heavily polluted drains are the Gharbia Drain in the Middle Delta, the Umoum and Abu Keer Drain in the Western Delta, and the Elmoheet Drain in the Eastern Delta (Bazaraa 2002). The extensive drainage network now in place is used as a sewer for treated and untreated municipal wastewater and industrial effluents. Tanta, Shoubra El-Keema, Sharkia, and several minor towns are major sources of pollution. Water supply networks have been expanded in new urban and industrial areas, without sufficient parallel construction of new sewerage and treatment systems. Both urban and peri-urban areas are guilty of numerous illegal, often heavily polluted, discharges into open drains. In rural areas, untreated domestic wastes from vacuum-trucks (e.g., contents of septic tanks) discharged into drains are a main problem.[8] In 1992–2000, more than US$3 billion was spent to construct wastewater treatment facilities. To add another 2 million m^3/day of treatment capacity by 2007 will require an investment of US$2 billion (Bazaraa 2002).

Table 7 Drainage water quality status

Parameter	***Unit***	***DRI measurements***	***Law 48/1982 standard***	***Excess concentration (percent)***
Coliform bacteria count	MPN/100ml	Average 100,000	5,000	85
Suspended solids	TSS mg/l	Average 218	15 (for fisheries)	99
Heavy metals	Mg/l			
Cadmium		0.012–0.016	0.01	65 (most critical)
Copper		0.027–0.080	0.004 (fisheries/Canada limit)	99

[8] A problem closely related to the disposal of effluent in the drains (and irrigation channels) is the clogging with solid waste. This is particularly common when uncovered open drains pass through towns and villages, and the surface drains are not covered. The clogging is sometimes aggravated by the disposal of rice chaff. Chaff used to be burned, but this practice caused air pollution in Cairo and is no longer allowed.

Zinc		0.027–0.067	0.03 (fisheries/Canada limit)	42
Nutrients	Mg/l			
Nitrate		1.91	10	3
Ammonia		2.72	0.5	89
For fisheries		2.72	1	53
Phosphate		0.57	1	16
BOD		98	10	99
COD	Mg/l	174	15	100
DO		3.7	>5	<69
Total dissolved solids	Ppm	1,000–2,000	500	100

MPN Most probable number; TSS total suspended solids; BOD biological oxygen demand; COD chemical oxygen demand; DO dissolved oxygen; Ppm parts per million.
Source: DRI 2001.

Box 14 Closure of the El -Mahsama pumping station

The El-Mahsama Pumping Station was built to pump drainage water from the El-Mahsama Drain into the Ismailia Canal. Because the canal supplies five governorates with drinking water, people were quite concerned over the degradation of water quality after mixing. Following pressure from the local governments, the mixing station was closed in 1994 and has not been in operation since.

Source: Bazaraa 2002.

With reuse, all kinds of pollutants are diffused throughout the entire water network. Reuse of drainage water is no longer limited to irrigation and drainage only but involves wastewater disposal, drinking water supply, and aquatic ecology as well. A number of mixing stations were closed, mainly because the drinking water supply from the irrigation canals was jeopardized by the inflow of low-quality drainage water. Of the 25 mixing stations in the delta, five stopped operations and two were interrupted for extended periods. The closed mixing stations represent a capacity of 1.56 BcM/yr, about a third of total capacity. The largest mixing station no longer in operation is on the Umoum Drain in the West Delta, where water supplies are polluted not so much by agricultural production water as by untreated municipal and industrial wastewater from the Abu Hommos and Shereshtra area (box 14).

To improve water quality and safeguard drainage water reuse policy and practice, some suggestions have been made for policy direction, all involving a more integrated approach to water management and drainage than practiced so far:

- First is the continuation of heavy investments in water treatment facilities. Instead of giving priority to distributing investments according to political or geographical allocation, priority should be given to investments in water treatment that improve regional water quality and facilitate the use of surfacewater as a source of drinking water (Bazaraa 2002). Related to this, the use of semi-treated wastewater to irrigate urban parks or specially designated agricultural areas (as is happening in some new towns) has also been advocated. Concerns have been expressed, however, about the impact of drainage water reuse on the quality of shallow groundwater. So far, little systematic monitoring has gone into this field. The topic is becoming increasingly relevant, as substantial use is being made of groundwater wells for irrigation and for municipal and industrial demand.

- A second solution is to reduce the inflow of agrochemicals and other pollutants into the water system. Subsidies on agrochemicals are being scaled down in the expectation is that this will lower pollution loads. More gains are also possible through training on integrated pest management, particularly for crops such as cotton that are heavily dependent on pesticides. As part of the National Water Resources Plan, it was also suggested that a program of public disclosure on industrial and municipal effluents should be initiated, along the lines of the PROPER program in Indonesia.

Other proposals relate to water management solutions. One suggestion has been the designation of certain drains as national sewers and preventing pollutants from escaping from them. In fact, this is already happening with the closure of pumping stations. This suggestion still leaves unanswered such questions as what to do at the end of the drain. A closely related proposal is to reconsider the current reuse policy (Bazaraa 2002). The current policy is based on mixing water from the main drains with water in main irrigation canals. This policy would allow large volumes of drainage water to be captured with a limited number of large mixing stations. The long distance that water travels through the drains helps the degradation of at least some toxicants.

The centralized approach also has some drawbacks, however. One is that the long distances increase the opportunities for pollution from various point and nonpoint sources and spreads pollutants over the entire water network. Moreover, having a limited number of large mixing stations reduces flexibility in adding or abandoning mixing points. As an alternative, intermediate reuse has been proposed. In intermediate reuse, drainage water and fresh irrigation supplies are mixed at a lower level, where a drainage catchment coincides with a number of secondary canals. Intermediate reuse, among other advantages, would allow poor-quality water to be isolated so that the better quality water, lower in salinity and contamination could be used. Nonetheless, careful integrated management of both fresh water and drainage water would still be required. Decentralized mixing would also avoid the exportation of salinity and contamination from one drainage catchment to another. Measuring water quality at the exit may give an impetus to tackling some of the sources of contamination locally, for instance, by improving local treatment. In addition, because the mixing facilities required for intermediate reuse are less complicated, they are more amenable to local management by a water board or an integrated district (section 3). In this way, intermediate reuse would support the subsidiarity principle of water management at the lowest appropriate level. Intermediate reuse offers the added advantage that, in the areas where it is practiced, water levels in drains would be lowered, improving drainage. However, areas where water quality does not favor intermediate reuse would suffer. Finally, intermediate reuse adds flexibility throughout the water system, since closing or opening small new facilities will be decided locally.

There is a case for strengthening integrated water resources management at a lower level and not just to decentralize functions in operation and maintenance. Decentralization would require water management plans to be prepared at local level—governorate or district—reconciling the available resources and their quality with demand from the different sectors. In this way, local priorities would be identified for water treatment, enforcement of emission standards, development of new water resources, and reuse.

It is also important to revisit the water quality standards formulated in Law 48/1982. The standards in these laws are considered very strict. The salinity limits for water to be blended with irrigation water where fresh water is used for irrigation are, for instance, 500 mg/l. The standard for ambient drainage water is 650 parts per million (ppm) FAO guidelines for irrigation water quality and the findings of the

Drainage Water Irrigation project (DWIP 1997) suggest that water with a much higher salinity (2000 ppm) can be used with proper management and more investment in domestic water treatment. The strict norms create what may be called “inverse moral hazard.” No one can enforce these norms effectively, yet no one dares to compromise and negotiate on a middle way.

In the meantime, no drain in Egypt meets the water quality standards. Moreover, different areas have different water uses. Water quality standards where canal water is used for drinking water should be different from areas where this practice is not in place. Where there is a risk of shallow groundwater contamination by reuse, another set of standards should apply. The usefulness of a single set of national standards should be revisited.

Strengthening the capacity to develop local water management strategies would also require a considerable amount of training and retraining. For instance, although the Drainage Research Institute takes water quality samples, there is little follow up. While monitoring could continue to be done centrally, local capacity to use this information should be expanded so that water quality could be monitored locally. A number of initiatives underway address water quality concerns (box 15).

In addition to decentralized mixing, local water management would also require the irrigation system to be capable of adjusting the volume of water flows. If more drainage water is used, less irrigation water would be needed. Also, wherever saline drainage water is plentiful, more fresh water should be supplied to keep a balance. The present irrigation infrastructure is not, however, fully capable of such flexible adjustments.

Box 15 Water quality initiatives

The Egyptian Environmental Affairs Ministry is responsible for environmental security in general, while fresh water management is the responsibility of the Ministry for Water Resources and Irrigation. Recently a water quality unit was established within the MWRI to work closely with other relevant departments. A prime output will have to be the development of a system for water quality management, including the integration of monitoring with enforcement. The Interministerial Committee on Law 48/1982 has discussed the need to classify the different water functions and water uses of Egypt’s various water bodies. This would allow a more relaxed approach to water quality norms, as the priority would be improvement of water quality rather than enforcement of the standards. This seems a more practical approach than the rigidity currently surrounding the norms.

Source: This study.

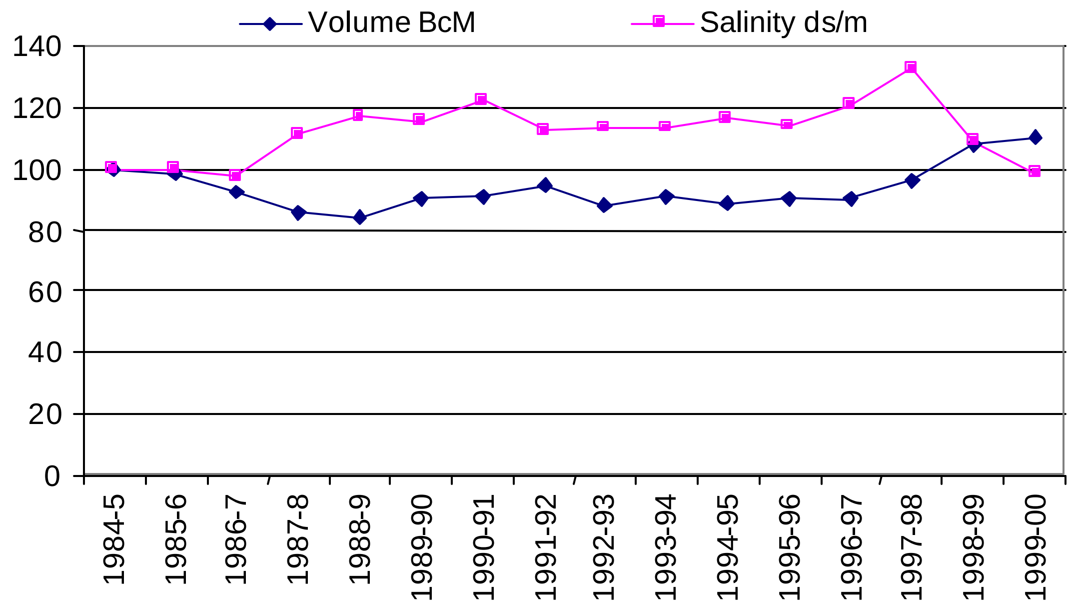
The Northern Lakes

The low quality of the drainage water has had substantial impacts on the aquatic conditions of the northern lakes and on Lake Qarun in the Fayoum.

The four northern lakes—Maryut, Edku, Burulus, and Manzala—provide 52 percent of the fish production in Egypt, and Lake Burulus is also a Ramsar Convention site. In addition to their environmental value, the lakes provide employment to 53,000 fishermen and generate a gross annual income equivalent to US$100 million (Bazaraa 2002).

With increased reuse of drainage water, the drainage effluent at these points has become more concentrated. The average quality of the salinity outflow to the sea gradually increased from 3.72 ds/m in 1984 to 4.92 ds/m in 1997. It dropped in subsequent years, but this was related to the unusually large volumes of water discharged from the Aswan High Dam. This was due to floods in the upper catchments, causing flows exceeding the reservoir capacity. In the Nile Delta, this extra discharge increased tail flows in the irrigation canals, reducing salinity while it lasted (figure 9). While the outflows remain more or less constant, the more intense circulation of water results in higher salinity except in the last few years due to the high Nile flow.

Figure 9 Indexed trends in drainage outflows to the sea, 1984–2000



Source: NWRP 2000b.

The policy of intensifying reuse may be expected to accelerate this trend—increasing salinity levels but also pollution parameters in these lakes. The Water Policy Reform Program foresees an increase in reuse and a simultaneous reduction in the outflow to the northern lakes from 12.5 BcM to 8.5 BcM. A minimum drainage water outflow to the lakes of 8.5 BcM was estimated as part of this policy document to provide sufficient flushing of at least once a year. This would keep salinity levels below 4,000 ppm and discharge sufficient salt loads from the delta to keep the salt balance in check.

Lake Edku. Photo: Flower 2001.

The increased salinity that comes with more intense reuse is likely to have an impact on the aquatic ecology of the lakes, particularly in a cycle of dry years, when salinity of the outflows would exceed normal levels. Yet discussion of the impact of salinity on the coastal lakes needs to be put in a larger timeframe. The changes in the aquatic ecology of Lakes Edku, Manzala, and Burulus over the last century were studied under the Cassarina project (Flower 2001). Macrofossil samples taken from lakebed deposits suggest that the lakes once had a balance between brackish and freshwater conditions. After the closure of the Aswan High Dam, the resulting year-round freshwater supplies reduced salinity, and the coastal lakes became fresher and more eutrophic.

This eutrophication was accelerated by the increased use of agricultural fertilizer. It resulted in infestation of water hyacinth, duckweed, and homworth—especially in Lake Edku and Lake Manzala, which are least connected to the Mediterranean. Eutrophication reduced fish quality and creates anoxic conditions in the winter, when biomass sinks to the lake bottom. In other words, eutrophication rather than changes in salinity appears to have the greater effect on the aquatic ecology of the lakes. Of more immediate concern, the concentration of persistent pesticides, toxic trace elements, and heavy metals of urban and industrial origin, carried by the drains, promises serious long-term consequences for the condition of the lakes (table 8).

Table 8 Comparison of water quality data in Lakes Manzala and Maryut with standards (mg/l)

Water body	***Hg***	***Cd***	***Pb***	***Cu***	***Zn***	***Source***
Lake Manzala South, 1996	n.d.	0.0010	0.0170	0.0217	0.0114	National Water Resources Plan (NWRP) 1999
Lake Manzala South, 1997	0.0001	0.0009	0.0032	0.0222	0.0475	NWRP 1999
Lake Manzala		0.0044	0.0270	0.0027	0.0290	Hussein 1995
Lake Maryut		0.0002		0.0106	0.0183	Saad 1985
Lake Maryut		0.0010	0.0011	0.0026	0.0151	NWRP, 1999
Standards						
Egyptian drinking water	0.005	0.005	0.05	2.00	5.00	
FAO irrigation water		<0.01	<5.0	<0.2	<2.0	
Egyptian ambient water	0.001	0.010	0.05	1.00	1.00	
Safe for fish	0.050	0.004	0.03	0.10	0.05	

n.d. no data; FAO Food and Agriculture Organization.

The Bahr El-Baqr drainage system is an example of urban pollution (Assiouti 1994). All sewage and industrial wastewater from the eastern zone of greater Cairo ends up in the Belbeis Drain, which ultimately discharges into the Bahr El-Baqr Drain. The drainwater is heavily contaminated with BOD, ammonia, and heavy metals. The drain ultimately discharges into Lake Manzala.

Although heavy metal concentrations in fish do not lead to fishkills, they are dangerous as they accumulate in the edible parts of the fish. The same holds true for various residues of persistent pesticides. As part of the National Water Resources Plan (2000a), studies found high concentrations of organochlorine pesticide residues and PCBs in fish meat. All reported average concentrations were far above maximum allowable concentration standards. For some compounds (DT-isomers, PCBs) this was true for 100 percent of the fish sampled (NWRP 2000a). One source suggests that fish caught from Lake Maryut near Alexandria is no longer fit for human consumption (Abdel-Shafy and Aly 2002).

There are similar concerns about the impact of the El Salaam Canal on Bardawil Lake (appendix D). Like Lake Burullus, Bardawil is a wetland, registered under the Ramsar Convention. The El Salaam Canal depends largely on drainage water reuse. It takes water from the Damietta Nile branch and picks up drainage water from three drains on its way to the Suez Canal. It crosses the Suez Canal just north of Qantara and brings irrigation water (from there on, it is named the El Sheikh Gaber Canal) to the North Sinai Agricultural Development project (NSADP) aiming ultimately at 400,000 feddans (168,000 ha) on the east side of the Suez Canal. The project has both development and strategic value. NSADP, which will introduce large- scale irrigation along the southern border of the Bardawil Lagoon along the coast of the Mediterranean, may cause desalinization of the lagoon because of the relatively fresh drainage water flows, while at the same time bringing pollution from fertilizers, pesticides, and urban development. Options for safe disposal of project drainage flows around the Bardawil Lagoon Nature Reserve to the Mediterranean Sea are summarized in box 16 (APP 2001).

Box 16 Bardawil Lagoon drainage system

The construction of an east-west running main open drainage system has been recommended to control groundwater levels in the extensive and flat topographic lows between the sand dune ridges north of the El Sheikh Gaber Canal. The system will be about 55 km long. Its discharge will be conveyed around Bardawil Lagoon to the Mediterranean Sea northwest of Romana. Several low-lift pumping stations with drainage water storage reservoirs and lined drainage channel reaches are necessary, as most of the system is located in deep sandy soils with elevations from zero to a few meters above the Mediterranean Sea level. Branch and secondary drains will extend southward from the main drainage system to control the rising groundwater levels in the smaller valley bottoms between the increasingly higher sand dune ridges just north and south of the El Sheikh Gaber Canal.

Source: APP 2001.

Addressing Drainage Water Quality and Aquatic Ecology

To manage water quality in Egypt, several components of a framework are in place—both in general and related to the drains. In this respect, more work has been done in the country than in most other countries with extensive irrigation and drainage systems, including some of the countries in the comparative study. Yet, as a report of the NWRP (2000a: 35) establishes, “the main and foremost problem in Egypt is the absence of an integrated coordinated approach that is policy driven and takes into account agreed priorities.” The management of aquatic ecology, moreover, is not part of the equation so far.

Two laws set the framework for water quality management, Law 48/1982 on Protection of the Nile and Law 4/1994 on Protection of the Environment. Law 48 includes effluent standards and a licensing procedure for industries. In recent years, some progress has been made in controlling illegal discharges of industrial effluents and wastewater. In some cases, suitable treatment facilities have been provided, but many uncontrolled and illegal situations persist, especially in older, publicly owned facilities.

Water quality monitoring in Egypt is done by several agencies. The Drainage Research Institute (part of the National Water Resources Research Institute) is part of the MWRI and monitors the water quality in drains. Part of the monitoring is on a project basis and is supported by the NAWQAM project and under NDP-II. The follow up to the monitoring efforts and the linkage to enforcement is not always clear and straightforward, which leaves water quality monitoring as data collection effort only.

As mentioned above, the merits of Law 48 at it now stands are being widely discussed. Apart from the wisdom of having uniform standards and norms so strict that they are difficult to enforce, there are other points of criticism:

- The law emphasizes standards for the disposal of waste and pays less attention to standards for the receiving water.
- The law seems geared more to pollution control than to water management. The standards relate to the concentrations of pollutants rather than the total load of wastewater discharge.
- The discharge of domestic wastewater—with or without treatment—into freshwater bodies is flatly outlawed. This removes any incentive to treat domestic wastewater treatments.
- Penalties are low and do not encourage industries to install treatment facilities.

Beyond changing the current legislation, there seems to be a need for a more integrated approach to water management in Egypt, including drainage. More localized management is needed to balance priorities and increase local enforcement and management capabilities. For some time, integration of the various water services has been discussed. One driver for integration has been the scale argument of gaining efficiency by extending routine maintenance activities. EPADP has argued for combining irrigation and drainage operations (Abdel-Dayem 2000 in Nijland 2000: 313).[9] It would also help to coordinate the management of water levels in open drains and fine-tune the operations of the pumping stations in this respect. As discussed in section 3, three different sections of the MWRI manage the local water management infrastructure. The Irrigation Department is responsible for canal operation and maintenance. EPADP, through its drainage centers, undertakes drain maintenance, and the Mechanical and Electrical Department operates the pumping (and mixing) stations.

Besides improving operation and maintenance, closer integration of the different departments would provide a better basis for integrated water resources management—serving water quality management as well as coordinated operation of drainwater levels. At field level, the boundaries of the different local

[9] The Irrigation Improvement project has recently proposed again combining EPADP and the Irrigation Improvement Sector for the upcoming Integrated Irrigation Improvement project.

units differ. A move toward integration at the level of water districts has been discussed for some time. Two districts were singled out as pilots, but activities have yet to take off.

Finally, efforts to reduce pollution at the source should be intensified. Substantial investments and institutional improvements are required in the area of wastewater collection and treatment. Without these, agricultural drains are turning into uncontrolled sewers, spreading contaminants and pollutants throughout the water system.

5. Conclusion and Synthesis

The theme of this case study is how to maintain the productivity of the water resources system in a situation of increased demand and environmental pressure on the resource. Egypt is an arid country with finite water resources that are already extensively used. Population growth is still so high that even long-term projections place Egypt in the group countries where fast population growth will continue for some time to come. This implies that both the agricultural and industrial economy will have to grow just to stay even, to maintain current welfare levels. Mega-city growth and the urbanization and industrialization of the countryside, already far along in the Nile Delta, will continue in Egypt. The upshot of this is increased pressure on good quality water resources and a trend in which water uses will become more and more interdependent.

Drainage has helped maintain and increase agricultural productivity in Egypt and prevent land salinization. The modern history of drainage goes back to the early part of the twentieth century, when a failed cotton crop mobilized a strong response from the government to overcome waterlogging and salinization. Since then, drainage development has become a public responsibility. Economies of scale and the integrated nature of the water system in Egypt, the socialist model of the 1950s and 1960s, and the prevalence of smallholder agriculture have triggered this development. In the late 1960s, Egypt embarked on the "national subsurface drainage project," covering almost the "old lands" (the Nile Valley and Delta and Fayoum) with surface drains and horizontal pipe drains. The impact in terms of agricultural production has been significant. Monitoring as part of the National Drainage Program established that annual net farm income increased by US$375/ha in nonsaline areas and US$200/ha in saline areas. The large impact of drainage development on agricultural productivity is not easily captured in the currently popular "more crop per drop" philosophy, which narrowly stresses maximizing returns from irrigation water. But it does show the importance of looking at water resources systems rather than at water productivity per se. In contrast to the old lands, in the new lands drainage development has been less systematic.

Institutions

To implement the drainage program, the Egyptian Public Authority for Drainage Projects (EPADP) was established in 1973 within the Ministry for Irrigation (now MWRI)—an example of a strong, centralized body, not atypical for that period. EPADP was given full autonomy to develop the drainage system in the old lands. A uniform approach was chosen—full coverage and standardized designs and procedures. There was considerable internal knowledge development, strongly focused on the technology chosen and reinforced through collaboration and personnel exchanges with the Drainage Research Institute (DRI) and the establishment of a Drainage Training Center.

Design, construction, supervision, and maintenance (of horizontal pipe drains) were done in-house. This allowed EPAPD to develop into an effective deliverer—with an impressive throughput of new drainage systems and rehabilitation of the earlier systems. The downside is that outside EPAPD relatively little capacity developed—still felt as a constraint in the current drive toward private investment in the new lands and user management of drainage systems in the old lands.

The blanket approach to drainage development and the technology chosen in Egypt allowed steady progress but left little space for farmer involvement in drainage. Local conflicts have arisen between farmers growing different crops—with rice farmers preferring high water tables and the others preferring adequate drainage for dry food crops. EPADP, with the help of its Drainage Advisory Services, took the initiative in establishing more than 1,000 collector-user associations modeled on the water user associations in irrigation. The CUAs were never given legal status to support their activities, but they played a role in communication on project implementation—facilitating data collection, providing inputs to the design and discussing the timing of operations. In system maintenance, the CUAs played no role, as this is done by specialized equipment operated by EPADP. The nature of the horizontal pipe drainage systems put some outer limits on this process, but in the final analysis CUAs did not work because they had too little to do in scheme of things.

Box 17 Tradeoffs: participation and implementation

Egypt's Ministry of Water Resources and Irrigation has been using a blanket approach to drainage. The Egyptian Public Authority for Drainage Projects as the implementing agency, together with the Drainage Research Institute as research organization, and the Advisory Panel as the adviser, have been installing drainage systems all over the old lands successfully with a top-down approach. During field discussions, various users and department officials suggested that the same successful blanket approach should be used for the integrated water management program in the Integrated Irrigation Improvement project.

Source: This study.

This raises important points on the subsidiarity principle. This principle—one of the four Dublin Principles—states that water should be managed at the lowest appropriate administrative level, but the CUAs appear to have been too small and limited in nature in this respect. Apart from subsidiarity in water management, the organizations playing roles in water management also need a minimum critical mass of activities to sustain their operations. This point is particularly relevant in light of the move toward participatory water management in Egypt through water boards. Water boards are being piloted in 50 secondary canal commands with typical operating areas of around 750 ha. At this level, water boards can integrate services in both irrigation and drainage—although the boundaries of irrigation and drainage commands do not overlap. The water boards, as they exists now, have performed a number of useful functions in coordination and local improvements, but in the absence of a legal status they are not yet in charge of canal operation and maintenance. A legal amendment is before the Parliament, which would make it possible to transfer what are now public functions to water boards, either at secondary canal or district level. The amendment would also enable the water boards to collect charges. The discussion on district level water boards is particularly important—the argument is that, from an organizational point of view, this may be the most viable level for user management. In addition, at this level there is scope to improve local water management with a broader remit than the operation of canals and drainage systems.

If there is one appropriate level for integrated water resources management in Egypt (and there is probably no such thing as a single appropriate level), the district level seems to offer more scope than secondary canal or drainage commands. The discussion—it should be remembered—is still in a very early stage. No integrated water resources management district is in place, nor does a water board operate at this level. Important questions also remain about the role of the MWRI, the regulation of water functions, financing mechanisms, and more that have not even been asked.

A special feature of the drainage program in Egypt has been the cost-recovery policy. Through a surcharge to the land tax, landowners have repaid a large part of the capital costs of the horizontal pipe drainage systems. Cost recovery was on soft terms and effectively amounted to between 50 percent and 60 percent of the real costs. As the charges were clubbed together with the land tax, transaction costs were low, and collection rates have been high—unusually high for water charges in developing countries. This history defeats some of the conventional wisdom in the debate about global "water as an economic good." In this debate, the point has been made that paying for water services would give water users a larger stake and would change their water consumption behavior. The argument is essentially economic and psychological rather than financial in approach to water financing. Yet in case of cost recovery of the investments in horizontal pipe drainage, collection rates were high, allowing part of the investment to be recouped, although reportedly some landowners were not aware of the nature of the surcharge to the land tax. Direct cost recovery for operation and maintenance in irrigation and drainage in Egypt has not been introduced and is politically sensitive. The introduction of simple, modest, direct, crop-based water charges is favored, for instance, in Abu-Zeid (2001). Others argue that the current land tax is meant to finance public services such as the maintenance of irrigation and drainage infrastructure and that no direct water charge system is needed. That argument does not tally with the decentralization of functions to autonomous water boards and water user associations, which has been in the cards for some time. These user-driven organizations would need to self-finance their operations and would have to be able to charge users for the cost of their services.

The blanket approach followed by EPADP also raises another question: what next? The horizontal drainage program is expected to be completed by 2012. The discussion is whether the Authority for Drainage Projects should be dismantled with it (as happened, for instance, with the Public Authority for Ysselmeer Polder in the Netherlands) or whether there is an afterlife. Some part of the implementation core business of EPADP will continue to be needed beyond 2012. Drainage still has to be developed in the new lands, and earlier subsurface systems still have to be rehabilitated, especially where cement pipes were used. Yet there is no doubt about the need for a sincere reorientation. Increasingly, drainage *services* will be provided to private drainage users—investors or water boards—in new development, selective rehabilitation, design, or maintenance. How the sector should look needs rethinking, as EPADP now has a virtual monopoly on drainage expertise but is exclusively geared to work in a public sector environment. If EPADP has a continued role, it is likely to be more service oriented and demand driven and probably more modest and integrated with other water sectors, too. Other public sector organizations in Egypt such as the construction companies have gone through similar transformations. In a future drainage market, EPADP will likely not be the only operator but will compete with others, maybe even with its own offshoots.

Integrated Water Resources Management

This study has shown that agricultural drainage has substantial impact on rural-agricultural livelihoods and on environment, positive and negative. Table 9 provides an overview of changes, impacts, and the values for different stakeholders. Drainage has a far more crucial place in integrated water resources management than generally professed by drainage professionals or advocates of integrated water resources management. With growing pressure on water resources and the completion of an extensive network of canals, drains, and mixing stations, the complexity and interlinkages in Egypt's water system have also increased. This puts drainage now in the context of integrated water resources management rather than in sustaining agricultural productivity only, its decades-long focus.

Current reuse practice and future policy have meant that drainage water is spread over a large area. They have also meant that the outflow, especially to the northern lakes, is changing, becoming less in volume but carrying a more concentrated pollutant load. Despite their already impaired ecological value, these lakes sustain a large population of fishermen and serve a substantial part of the domestic market for fish.

Water quality in the drains is hence becoming more and more critical. The major issue at stake is not so much the increased salinity levels, but the pollution of drainage water with toxic substances, particularly bacteria, heavy metals (cadmium, lead), ammonia, and pesticide residues. These pollutants come from untreated or semi-treated wastewater discharged into drains in urban and industrial areas as well as from agricultural production water. These effluents have turned several large drains into sewers with anaerobic water all along their course. Where irrigation canals also serve as the source of domestic water, the discharge of contaminated drainage water in the irrigation system has been particularly problematic. A number of mixing stations were taken out of operation. A main part of the water policy in Egypt is to meet water scarcity by doubling official reuse, and "unofficial" private reuse at tail-ends of canals is already substantial, managing the quality of drainage water is emerging as an important issue.

A number of remedies have been suggested—continue substantial investment in water treatment under improved, location-specific priorities; reduce the use of agrochemicals through reduced subsidy and increased awareness; tighten enforcement of water quality legislation with the help of public disclosure. Other solutions are in the realm of water resources management—designating special drains as sewers and moving from a centralized drainage water reuse system to intermediate reuse.

What appears important in this constellation is to also reinforce local water resources management—looking at the local water supply and sector-specific demand and preparing local strategies to optimize the management of water volume and quality. Already under discussion is integrating irrigation and drainage services more closely at district and governorate level—combining operation and maintenance activities. This may have to go a step farther—improving local water management. The development of the water boards should also fit into this picture. Water quality has emerged as an important issue in water management in Egypt and needs to move from monitoring to active management at various levels, national and local—reinforced by closer integration and strengthened capacities of the different water sectors.

Table 9 Effects of drainage on livelihoods and environment in Egypt

Change	***Affected landscape***	***Impact***	***Values (stakeholders italicized)***
Lowering of soil water table combined with resulting reduction in soil salinity	Agricultural land	Better soil properties lead to higher productivity (production function)	Food self-sufficiency of *country*, higher *farmer* income
Improved soil structure	Agricultural land	Improved accessibility for mechanized equipment (carrier function)	Modernization of agriculture, leading to higher *farmer* income
Lowering of soil water table (off-site)	Built area	Reduced damage to buildings; healthier living environment (carrier function)	Property value for *house owners*; reduced disease; improved conditions for human settlement (*urban development*?)
Disappearance of open field drains	Agricultural land	Reduction in breeding grounds for disease-transmitting snails and mosquitoes (regulation function)	Better health for humans and domestic animals—*social and economic* benefits
Increased scope for reuse of drainage water	Agricultural land	Increased irrigation supplies and reliability	Food self-sufficiency of *country*, higher *farmer* income.
Transport of drainage water (saline/polluted) elsewhere—accelerated by reuse	Open drains	Public water supply affected by pollution and salinity	Health problem or less reliable supplies for *individuals who depend on canal supplies*
	Open drains	Agricultural water supply affected by salinity and pollution	Effects on *farmers'* crop yields
	Open drains	Facility for disposal of liquid and solid waste from urban and industrial facilities	*Multiple values* (in a circular process, since water is being reused—see above)
	Ecosystems receiving drainage water (coastal wetlands, Nile River, Mediterranean)	Threat to production functions related to biodiversity (mainly fish)	*Fisheries communities* marginalized; health hazard for *fish consumers*
		Polluted waters threat to landscape quality (signification function)	*Tourism industry*, leisure opportunities for *urban inhabitants*
		Threat to natural water purification processes due to overload of pollutants	Costs for wastewater *treatment facilities* to compensate loss of natural treatment capacity
	Coastal wetlands	Threat to biological diversity	Ecological value for *future generations* and for *areas elsewhere* (migratory birds and fish)

Source: This study.

Appendix A Field Visit Schedule

Note—this is the combined schedule of meetings for consultants from Arcadis Euroconsult and North South Consultancy Exchange.

Date	*Organization*	*Contact person*	*Position*
Aug 6-02	Institutional and Technical Support Program (INTESP) and Egyptian Public Authority for Drainage Projects (EPADP)	Hans van Leeuwen	Team Leader, INTESP
Aug 6-02	EPADP	Eng. Nabil Fawzy Nashed	Chairman of Egyptian Public Authority for Drainage Projects
Aug 7-02	World Bank	Ayat Soliman	Natural Resources Specialist
Aug 8-02	Water Boards project	Jan Bron	Team Leader
Aug 8-02	Water Boards project	Eng. Yehia Adbel Aziz	Project Director
Aug 10-02	EPADP - Nubaria	Safaa	Drainage District Engineer, Nubaria
Aug 10-02	Water Board, El Rash Elagharbeya Canal	Abd Elwahab Elhadad, Abd Eljawad	Chairman, Head of Drainage Committee
Aug 11-02	Ministry for Water Resources and Irrigation (MWRI)Irrigation Improvement project (IIP)	Adel Hashem	Director of Irrigation Improvement Sector/Project Director
Aug 11-02	MWRI	Dr. Tareq Mohie Eldin Sadek	Project Director, National Water Resources Plan
Aug 12-02	World Bank	Ayat Soliman	Natural Resources Specialist
Aug 26-02	Directorate Agriculture	Fawzi El Sobary	Under Secretary
	Kafr El Sheikh	Eng. Fawzi Ibrahim	Under Secretary
	Shoruk	El Said El Bahwari	Head, Development Department
Aug 27-02	Minia Irrigation Directorate	Eng. Toulba Ahmed Toulba	Head, Central Department of Irrigation and Water Resources, Minia
	Minia Governorate	Samir Abu Elleil	Secretary General
	Shoruk	Malak 6Abu el Kheir	Under Secretary, Agriculture
	Shoruk	Omar Ibrahim Abu El Leil	
	Shoruk	Eng. Mahmoud Tawfiq Abbas	
Sep 14-02	EPADP	Abd Elmoneim Hamza	Director; Chairman Technical Office; Head, Institutional Reform Unit
Sep 16-02	MWRI	Hussein Elwan	Undersecretary, Irrigation Sector
Sep 17-02	MWRI, Mechanical Electric Department.	Makram Ibrahim	Director, Mechanical and Electric Department, Middle Delta
Sep 17-02	MWRI, Horizontal Expansion Department	Laban Tamouz	Deputy, Horizontal Expansion Department, Middle Delta
Sep 17-02	Land Reclamation Cooperative, Sidi Salem	Fahmy Hassanein Elnaggar	Chairman
Sep 17-02	MWRI, Kafr elsheikh	Mohamed Zakaria	Irrigation District Engineer, Sidi Salem

Sep 17-02	Water Board, Elfadly Canal	Fathy Eltarawy	Chairman, Water Board Committee
Sep 21-02	MWRI, Institutional Reform Unit	Hisham Kandeel	Director, Technology and Information, Office of Minister
Sep 21-02	MWRI	Hussein Elatfy	Undersecretary, Technical Office, Office of Minister
Sep 21-02	MARL UN-WFP Assessment. project	Suzan M.Kamel	Executive Director
Sep 21-02	General Authority for Reclamation Projects and Agricultural Development (GARPAD)	Abd Elrahman Abd Elmeguid Ali	First Undersecretary, Deputy Chairman,
Sep 21-02	Ministry of Agriculture	Ahmed Fouad Abou Hadab	Agronomist, Land Reclamation-Minister Consultant
Sep 21-02	EPADP	Nabil Fawzy Nashed	Chairman
Sep 21-02	Advisory Panel Project on Water Management& Drainage	Dr. Samia Elguindi	
	NWRP Project	Nader Aly El-Masry M.Sc.	Deputy Team Leader
	Advisory Panel Project on Water Management& Drainage	Magdy A. Salah El Deen	Assistant Director, Central Office
	Kreditanstal fur Wiederaufbau (KfW)	Jan Blum/Waleed A. Reheem	Director,German Development Cooperation KFW
	Embassy of the Netherlands	Ron Havinga/Peter Flik/Tareq Mourad	
	Social Fund For Development	Tareq Mohamed Hussein	Assistant, Esmaillia Office
	GADPLAST Modern Co.	Tareq Abdel Latif Gad	Director
	Borg El Arab	Gamal El Din Marey	General Director

Appendix B Drainage Technology

Much development has taken place in the drainage technology used in Egypt, fueled largely by the decision to implement large-scale, well-financed drainage projects since the early 1970s. Close association and interaction with the international drainage community (Holland, Canada, and Germany) catalyzed this development. Countries just getting into this type of drainage can draw on lessons learned when building up their own drainage knowledge and industry.

Planning and Design

A pilot project for drainage of agricultural lands, implemented in the early 1960s, established design criteria and studied the feasibility of mechanized pipe laying (FAO-UNDP 1966). The design criteria for the Nile Delta and Valley (the "old lands") have been well established. A steady-state criterion of one mm/day with a design water table midway between drains of 0.4 m above drain level. In the northern parts of the delta with very heavy soils and upward seepage, the criterion is 1.2 mm/day. With the planned increase in reuse of drainage water with higher salinities, drainage criteria may have to be adjusted (leaching requirements will be higher) to accommodate those higher salinities, if possible.

For drainage in the reclaimed lands, new design criteria and technology are being developed since these "new lands" are different from the old lands in a number of ways. The soils are sandy, vs. clay in the old lands; hard layers may occur at 2 m to 4 m below field level (e.g., in Nubariya); some locations have a tendency toward alkalinization (rarely a problem in the old lands); and the topography is undulating (dune landscape) with level differences from 2 m to 4 m over short distances, vs. flat surfaces in the old lands. This requires research and new approaches to designs for the new lands (INTESP November 2000).

The sandy soil influences the choice of irrigation system. Basin irrigation is inefficient (larger drainage volumes), so sprinklers and drip irrigation were introduced. Drainage is costly. Reducing the design drainage discharge with improved water management practices will thus reduce the discharge and thus costs. Other possible design changes include adjusting the drainage layout and starting to drain the low spots by connecting them in the reclaimed areas, where possible with a deep subsurface drain pipe.

Design Layout

The horizontal pipe drainage system is a composite system consisting of a network of laterals and collector drains (figure B1):

- The laterals are corrugated PVC pipes, laid at a minimum slope of 0.1 m/100 m and having a 72 mm inside diameter. In the past, 50 cm clay pipes and later concrete 50cm pipes were used. The laterals, on average 200 m long with an average spacing of 50m, discharge into collectors (figure B1).

- The collectors are plain concrete pipes with inside diameters of 150 mm to 400 mm set at varying slopes, which evacuate the drainage water into the main and branch open drains. The average length of the collectors is 1,500 m with a spacing of 400 m. (The concrete pipes are being replaced in new and rehabilitation projects with corrugated PE or PVC pipes).

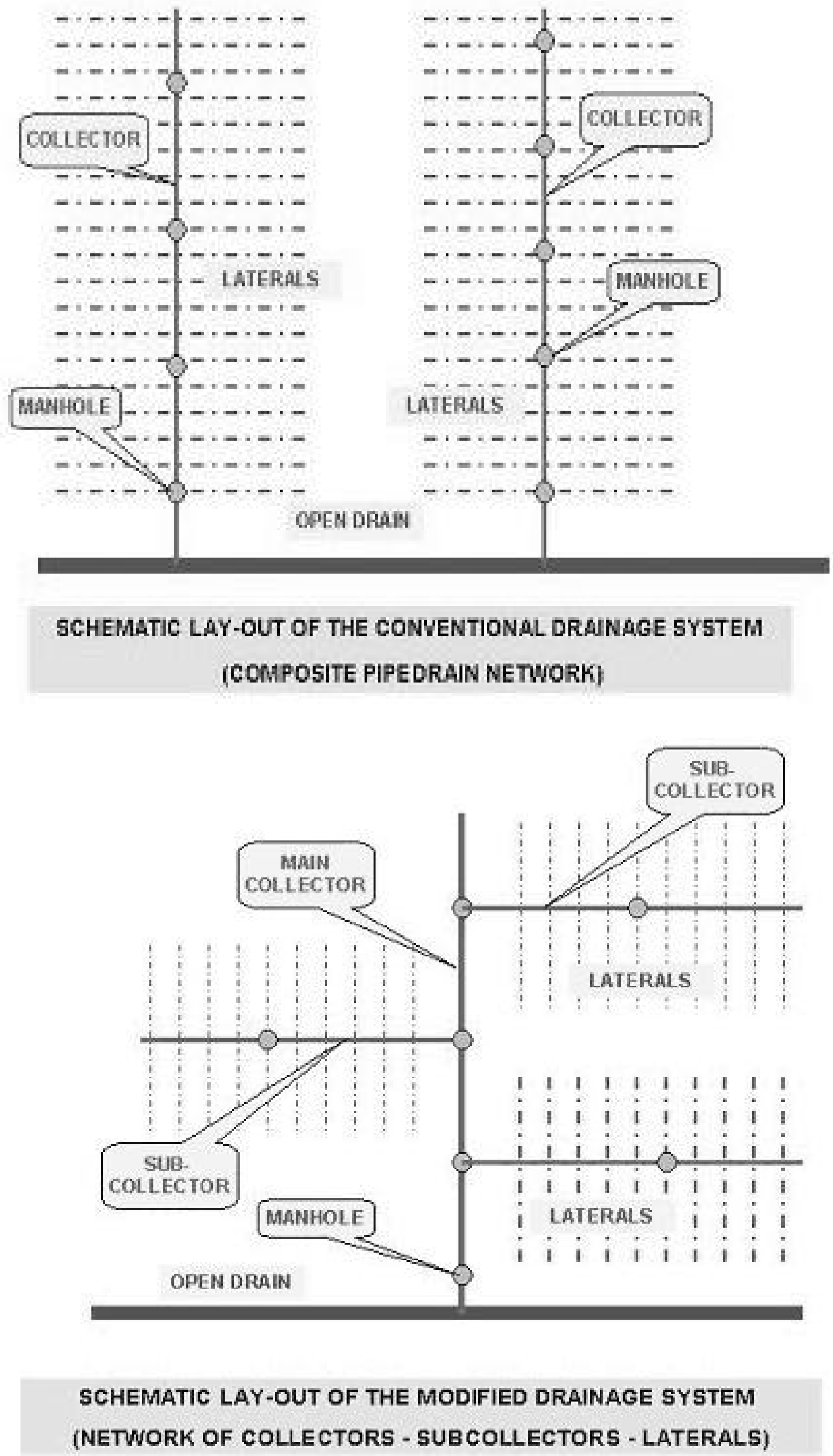
Controlled Drainage

Manholes are placed at regular intervals (180 m) in the collector, always where a lateral connects with the collector. In certain cropping systems (i.e. rice), it would be advantageous to control drainage flow (and thereby groundwater tables). Dry foot crops, however, do not want drainage flows blocked. The drainage system described does not allow parts of the area served by a collector to be closed off easily. Only a part can be blocked by closing a collector in a manhole with a moving mechanical device,[1] a fixed overflow,

[1] Alternatively a "stoplock" can be used. This is a small gate in the collector (or lateral) that can be pulled up and down directly from the land surface. This system was used in South Korea in the 1980s. Made out of plastic, it was susceptible to vandalism.

or a plug, which then retains water in the upstream part. Using a constructed mechanism will prevent farmers from creating their own blockage. A modified drainage system was therefore developed (figure B1) using subcollectors that allow smaller parts of the drainage area served by the collector to be blocked off.

Figure B1 Horizontal pipe drainage systems (composite and modified)



Source: Adapted from Amer and de Ridder 1989.

Pipes

Lateral pipes were first made of 10-cm diameter clay pipes (30-cm long), replaced in 1963 by concrete pipes (10-cm and 50-cm long), and in 1979 by plastic PVC pipes (ID 72 mm) were introduced and took over. PE lateral pipes (ID 75 mm) were later introduced. Laying the plastic corrugated pipe (rolls) improved both speed of installation and quality control.

Concrete collector pipes 75 cm to 100 cm in length and 150-mm to 600-mm internal diameter were used until 1998. PE/PVC collectors were introduced in 1985. In 1998, the Egyptian Public Authority for Drainage Projects (EPADP) decided to use only PE/PVC collector pipes, which facilitates installation and quality control. An additional advantage is that they more suitable for installation in the unstable soils (sandy with upward seepage) in the reclaimed areas and on the fringes of the old lands.

With the shift from concrete to plastic pipes, the connecting pieces between laterals and collectors also changed.

Manholes

Manholes were originally cast in situ; later, prefabricated elements were used. Plastic manholes are also being experimented with (much lighter in weight and quicker installation but expensive).

Some questions about manhole design are being discussed. Should they open from the top? Should they close with a lid (access) or should the manhole be made shorter and the lid put below surface? Open manholes mean possible misuse (garbage and blockage), but buried manholes mean no visual inspection is possible. The verdict is still out.

Drain Envelopes

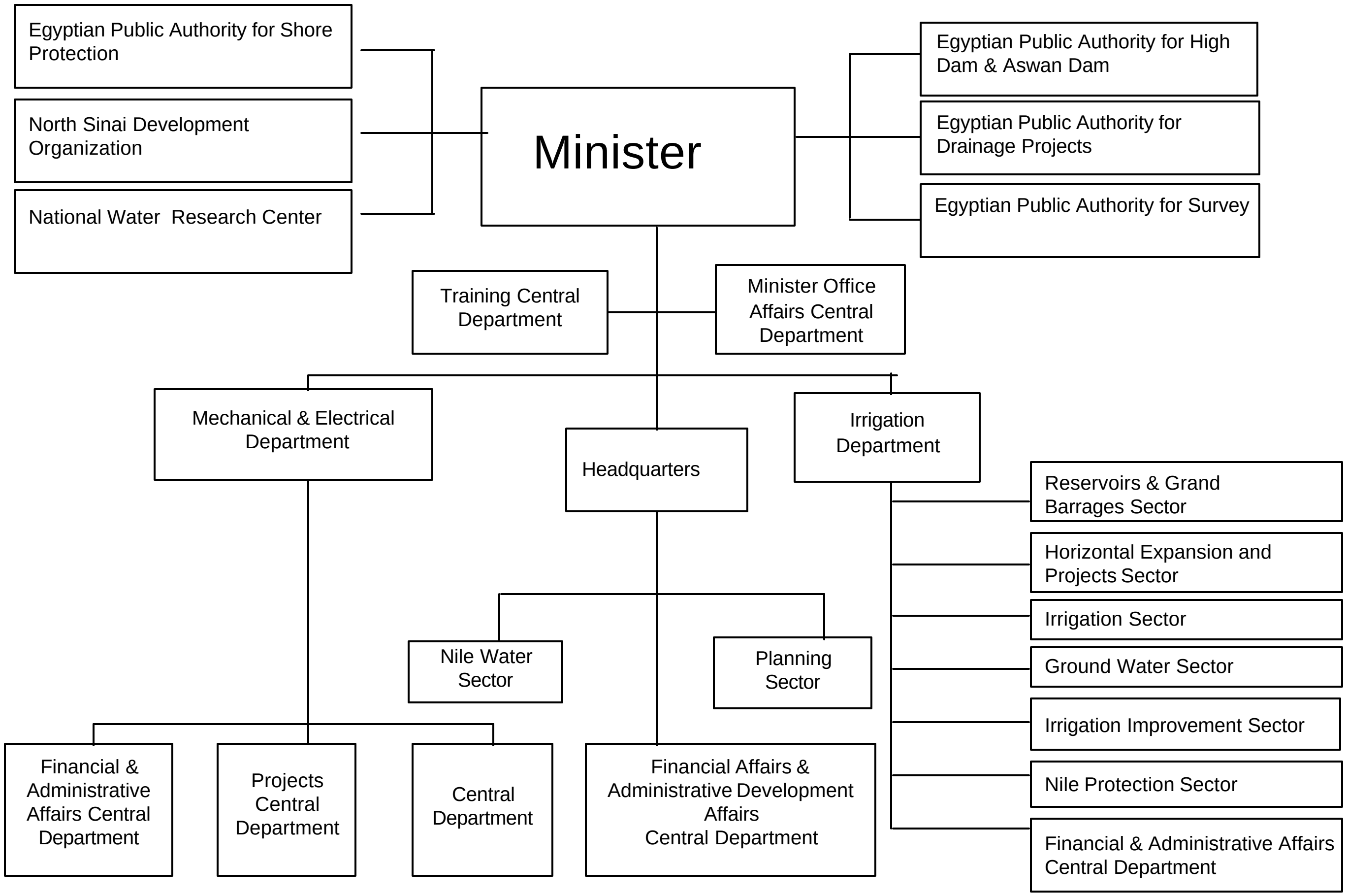
Graded gravel has been widely used to protect the laterals against the intrusion of soil particles that can clog pipes laid in soils with a clay content of less than 30 percent. Because gravel is costly to apply, there has been a shift to using prewrapped synthetic envelopes for the laterals. In 2000, it was decided to use only synthetic envelopes, where needed.

Drainage Machinery

Mechanized installation started in the 1960s with three imported lateral laying machines. Large-scale use started in the 1970s, and many more drainage machines have since been imported. These were of the trencher type with a digging chain to dig a trench in which the pipe was laid in one operation and subsequently backfilled. A modification was made because of the sticky clay soil and water tanks were installed on the machine. Since 1976, collector-laying machines (deeper installation depths and bigger pipes) were introduced. The trenching type of installation causes considerable crop damage. At the end of the 1990s, trenchless installation was introduced for lateral laying with a V-plough type and may well continue to be used.

Grade control of the laid pipes was greatly improved with the introduction of laser-guided grade control equipment in 1990.

Appendix C Structure Ministry of Water Resources and Irrigation



Source: Recreated from http://www.mwri.gov.eg/.

Appendix D Ramsar Wetlands in Egypt

Site: Lake Bardawil	Designation date: 09/09/1988	
Coordinates: 31°05'N 033°05'E	Elevation: 0 m	Area: 59,500 ha

Location. The site is located about 3 km north of the town of Mistag, 35 km from El Arish, on the north coast of the Sinai peninsula, in northeastern Egypt.

Importance. Lake Bardawil is the least polluted wetland in Egypt and one of the least polluted in the entire Mediterranean region. The site is an important wintering and staging area for many waterbirds. Annually it harbors more than 1 percent of the relevant populations of the bird species *Phalacrocorax carbo*, *Phoenicopterus ruber roseus*, *Sterna albifrons* and *Charadrius alexandrinus*.

Biological/ecological notes. The dune slopes support the plants *Thymelaea hirsuta*, *Artemisia monosperma*, and *Retama raetam*. The dune slacks harbor *Juncus subulatus*, *Nitraria tridentata*, *Lycium arabicum*, *Phragmites australis*, and *Cynodon dactylon*. The lagoon is a spawning area for fish and supports commercially important populations of *Sparus aurata*, *Mugil cephalus*, *Dicentrarchus labrax*, *Argyrosomus regium*, *Solea solea*, and *Epinephelus aeneus*. The site is also an important wintering and staging area for birds, including *Podiceps cristatus*, *Casmerodius albus*, *Circus cyaneus*, *Calidris alpina* and *Larus genei*.

Hydrological/physical notes. The lagoon is 95 km long and 25 km wide. It is separated from the Mediterranean Sea along most of its length by a long, narrow sand bar. However, some natural and artificial channels connect the lagoons with the sea. Within the lagoon are a number of islands and peninsulas, particularly in the east. Extensive mudflats are frequently exposed, particularly in the eastern section.

Human uses. The site and its surroundings are considered government property, although the Bedouins claim traditional landownership. At the site, fishing, salt production, grazing, and tourism take place. Towns are scattered in the surrounding area, and on the northwestern side of the lake there is the North Sinai Development project, a large-scale land reclamation project. Tourism is spreading along the coastline, and there is scattered rainfed agriculture and grazing.

Conservation measures. A wetland evaluation technique will be applied to Lake Bardawil, using relevant information collected on the uses and resources of the area. Information will be gathered about fishing, tourism and hunting, biological resources such as birds, mammals, fish, aquatic plants, hydraulic and hydrologic data (water levels and flows), and ecosystem components data. Wetland monitoring will be included in the management programs for Lake Bardawil. Protection laws and their enforcement require strengthening, although since 1990 the environmental officers of El Arish have successfully enforced a ban on bird catching (mainly trapping of *Coturnix coturnix*) within the protected area. Fishing is regulated (there is a closed season). Most of the industrial, domestic, and agricultural runoff waters draining from the eastern section flow into Lake Bardawil. A comprehensive Environmental Impact Assessment was carried out by the Dutch consultancy firm Euroconsult. Lake Bardawil was included on the Montreux Record of priority sites for conservation action in 1990.

Adverse factors. An extensive salt production system, constructed in the eastern part of the site, is causing considerable ecological changes. Constantly shifting sandbars have caused frequent closure of channels connecting the lagoons with the sea, posing the risk of desiccation. It is the responsibility of the government to keep the channels open by artificial means, but this is infrequently implemented. The inflow of contaminants will adversely affect Lake Bardawil. The inflow of freshwater will change the lake from a saline to brackish lagoon, as well as lead to the deterioration of water quality. Pressure to establish tourism developments along the lakeshores is increasing. The North Sinai Development project could affect Lake Bardawil. The project includes plans to divert water from

Site: Lake Bardawil	Designation date: 09/09/1988	
Coordinates: 31°05'N 033°05'E	Elevation: 0 m	Area: 59,500 ha

the Nile River through a tunnel under the Suez canal to irrigate land converted for agriculture south of Lake Bardawil. This could result in up to 300,000 people settling in the area. There is also illegal overfishing, overhunting, and overgrazing.

Site management. Egyptian Environmental Affairs Agency, General Authority for Fisheries Resource Development, and Governor of North Sinai, all at Governate Building, El Arish, North Sinai, Egypt.

Site: Lake Burullus		Designation date: 09/09/1988
Coordinates: 31°30'N 030°50'E	**Elevation: 0 m**	**Area: 46,200 ha**

Location. The site is located about 27 km north of the city of Disuq, on the north coast of Kafr El Sheikh, northeast Egypt.

Importance. The lake is the second largest and the least polluted in the Egyptian Nile Delta. Large numbers of waterbirds visit the site for wintering and staging. Annually the lake harbors over 1 percent of the relevant populations of the waterbirds *Anas penelope*, *A. clypeata*, *Aythya nyroca*, *Recurvirostra avosetta*, *Porphyrio porphyrio*, *Glareola pratincola*, *Charadrius alexandrinus*, *Tringa totanus*, *Larus minuta*, *L. ridibundus*, *Sterna albifrons,* and *Chlidonias hybridus.* The site is an important spawning and nursery area for fish.

Wetland types. Lake Burullus is a fresh to brackish coastal lagoon, connected to several drainage channels.

Biological/Ecological notes: The extensive Phragmites beds in the southern and eastern parts of the lake, covering about 20,000 ha, provide an important breeding habitat for Ixobrychus minutus and Porphyrio porphyrio. The site is an important wintering and staging area for birds, including *Ardea cinerea, Casmerodius albus, Egretta garzetta, Ardeola ralloides, Ixobrychus minutus, Anas crecca, Aythya ferina, A. nyroca, Circus aeruginosus, Fulica atra, Vanellus spinosus, Tringa stagnatilis, Calidris minuta,* and *Larus cachinnans.*

Hydrological/physical notes. The site is a shallow fresh to saline lagoon, about 65 km in length, varying in width from 6 km to 16 km, and containing about 50 islands and islets. Water depth ranges between 0.5 m and 1.6 m, the eastern part being the shallowest. The lagoon is separated from the Mediterranean along most of its length by a long sand bar, but is connected in the east with the open sea by a narrow channel (about 50 m wide) near the village of El Burge. As a result, there is a strong salinity gradient from east to west, with the western part of the lagoon containing relatively freshwater.

Human uses. Most of the land within the site belongs to the government, although there are likely claims of traditional landownership. Some of the land is privately owned. The surrounding area consists of a mixture of government and privately owned land. The lagoon is used for fishing. The surface of Lake Burullus has decreased by about 20 percent in the last century as a result of landfill and conversion activities, with new reclamation projects currently being developed along the southern shore. Plans to construct a major road over the northern coastal bar have been proposed. This includes a 3-km long bridge and excavation of a second channel linking the lagoon with the sea. Between the towns of Baltim and El Burge, 5 km of coastal protection barriers have been erected. There is a proposal for diverting floodwater from the Nile River into Lake Burullus, which would be developed as a water storage reservoir. There is little or no tourism to the lake, although large-scale tourism (leisure and ecotourism) development has been proposed for both the domestic and international markets. There is no conservation education program. Research is being conducted, and the quality of the water is being monitored. There is a field station at Burg Al Arab.

Conservation measures. Lake Burullus was designated a Protected Area in 1998. A management plan is being developed. Wetland monitoring will be included in the management programs for Lake Burullus. There are proposals for protecting a number of the islands for nature conservation. Fishing is regulated, but there is no closed season. The active coastal sand dunes frequently block the channel connecting the lagoon with the sea, but the channel is kept open artificially through dredging. The lake was included on the Montreux Record of priority sites for conservation action in 1990. A Management Guidance Procedure mission (now called Ramsar Advisory Mission) was carried out in 1991. The report of this mission recommended that the government of Egypt submit an application to the Ramsar Wetland Conservation Fund (now Small Grants Fund) to facilitate the initiation of a number of urgently required surveys and management actions. The reclamation of the lake is prohibited, which is an important action to maintain the lake's ecosystems.

Adverse factors. In an attempt to control the expansion of the Phragmites beds, local fishermen have domestic

Site: Lake Burullus		Designation date: 09/09/1988
Coordinates: 31°30'N 030°50'E	Elevation: 0 m	Area: 46,200 ha

buffaloes grazing on the more accessible areas, although this has been largely unsuccessful as a management measure. The reduction of rice growing in the delta will entail less freshwater inflow into the lake, which could lead to a corresponding increase in salinity. Substantial volumes of water laden with fertilizer and pesticide runoff enter the lagoon's southern side through a number of drainage channels. This has led to rapid eutrophication and pollution. Water quality problems have combined with increasing levels of commercial fishing activity, resulting in major declines in fish production. Ambitious development projects, claims for agricultural land and fish farms, and the construction of the coastal highway along the Mediterranean coast of Egypt can have an adverse impact on the site. The building of the coastal highway will open up the area for agriculture and tourism development, which might increase freshwater inflow into the lake and cause pollution unless mitigation measures are taken to treat the drainage water. The potential impacts will be studied as part of a monitoring program.

Site management. General Authority for Fisheries Resource Development, Lake Burullus Branch, Burg El Asrab, Kafr El Sheikh Government; Lake Burullus Protected Area, Kafr El Sheikh; Governor of Kafr El Sheikh, Governate Building, Kafr El Sheikh, Egypt.

Source: Ramsar Wetlands Database.

Glossary of Terms

Land drainage. "[T]he removal of excess surface and subsurfacewater from the land to enhance crop growth, including the removal of soluble salts from the soil" (source: ICID : International Commission on Irrigation and Drainage, New Delhi 1979).

Subsurface drainage (syn. SSD) The removal of water from the soil profile

Horizontal drainage. Open ditches or pipe drains (also referred to as tile drains in Egypt or closed drainage). Buried pipes (i.e., technical drainage artifacts) located below the land surface.

Vertical drainage. By tubewells

Surface drainage. Water flowing on the surface (surface runoff).

Lateral. A tile drain or field drain.

Collector. Main subsurface pipe drain into which laterals discharge

Mesqa. Private irrigation ditches, serving an area from 10 to 300 feddan

Marwa. Small irrigation ditches, taking off from the mesqa

Farmers. Landholders, landowners

1 Feddan = 0.420 ha

1 ha = 2.380 feddan

BcM = Billion $m^3 = 10^9$

LE = Egyptian pound

1 US$= LE 3.39

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IRC International Water and Sanitation Centre: www.irc.nl

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