# NILE VALLEY REGIONAL PROGRAM
# PHASE II

## Resource Management Series

### Volume 8

# INVENTORY STUDIES

## New Lands of Egypt

## Water Management


Editors

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Volume 8

# Resource Management in the New Lands of Egypt: Water Management

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# Foreword

Limited soil and water resources and threatened sustainability of agricultural production call for an effective resource management strategy and farming systems approach in agricultural research. Implementing a long-term research program where more emphasis would be on systems-oriented rather than commodity-oriented agricultural research would represent such a strategy. Therefore, the Resource Management Component of the Nile Valley Regional Program (NVRP) of the International Center for Agricultural Research in the Dry Areas (ICARDA) was developed. The Component, which started in 1994 in one of the Nile Valley countries, Egypt, and is expected to be extended to the others, aims at achieving sustainable production at a high level, based upon the need to protect the resource base (land and water) through good management. This would be achieved through basic intensive technical research (long-term on-station trials) and on-farm extensive monitoring of resources in farmers' fields and farmers' decision making logic.

Preparatory studies were carried out prior to conducting the trials and monitoring activities. The objectives of these studies were to define and characterize the major farming systems of the main agroecological environments; to identify and prioritize—with respect to the natural resources—the constraints to optimum utilization and the threats to sustainable production; and to provide an outline for the strategy, design and implementation of the long-term research activities.

The preparatory studies involved three procedures for information collection: **Inventory Studies**, in which existing information and details of the ongoing research and development, related to soil and water management, agronomy and cropping systems, and socioeconomics were collected; **Rapid Rural Appraisals**, which included qualitative sampling of farmers and extension views concerning current limitations, constraints, dangers, and opportunities in the utilization of soil, water, and inputs; and **Multidisciplinary Surveys**, which employed short-focused questionnaires to fill some important information gaps. In general, information collected in the preparatory studies dealt with resource description, resource utilization and management, productivity, and threats to sustainability. This knowledge was used in planning the long-term research activities at selected locations by identifying high-priority researchable resource management problems, in the context of realistic cropping sequences and farm level economics.

The outcome of these studies is hence presented in what is called the **Resource Management Series**. The series includes a total of 18 volumes on Inventory Studies, Rapid Rural Appraisals, and Multidisciplinary Surveys in the Old Irrigated Lands, New Lands, and Rainfed Areas. In the Inventory Studies, five volumes on the research and development activities and findings in each of the Old and New Lands were compiled. These volumes were on Agronomy, Soil Fertility and Management, Water Management, Socioeconomic Studies, and a Synthesis of all the latter. The Inventory Studies of the Rainfed Areas included two volumes, one on the Northwest Coast and the other on North Sinai.

These studies were conducted in Egypt with the involvement of the Agricultural Research Center (ARC), Desert Research Center (DRC), National Water Research Center (NWRC), National Research Center (NRC), Ain Shams University and ICARDA within the NVRP with financial support from the European Commission. Appreciation is expressed to all those who contributed to these important reviews and studies.

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## Weights and Measures

1 feddan (fed) = 0.42 hectare = 1.037 acres
1 hectare (ha) = 2.38 feddans

## Acronyms

ARC = Agricultural Research Center
CWR = Crop Water Requirement
EU = European Union
ET = Evapotranspiration
ETo = Reference Evapotranspiration
ICARDA = International Center for Agricultural Research in the Dry Areas
Kc = Crop coefficient
LMP = Land Master Plan
MPWWR = Ministry of Public Works and Water Resources
PET = Potential Evapotranspiration
RIGW = Research Institute for Ground Water
SWERI = Soil, Water and Environment Research Institute
WUE = Water-Use Efficiency

# Executive Summary

The report on water management in the New Lands of Egypt includes six sections, which are summarized below.

## Introduction

The introduction focuses on the need for land reclamation in Egypt, highlighting the following facts:

- The per capita area was 0.13 fed in 1993.
- In its final report, the national Land Master Plan (LMP) estimated that about 2.88 million fed (1.21 million ha) could be reclaimed and irrigated with Nile water, and about 0.57 million fed (0.24 million ha) could be reclaimed and irrigated with groundwater. Approximately 60% of potential reclamation is in the Delta, and 30% in the Valley.
- Large amounts of agricultural land are lost to urbanization every year. Various organizations have attempted to quantify this loss. The most reliable estimate, by the National Policy of Urbanization, is approximately 30,000 fed (12,600 ha) per year.
- Land reclamation projects between 1960 and 1992 have only modestly increased the total agricultural land base.

Maintaining sustainable agriculture in the New Lands under the stress of a reduced water supply and the non-availability of additional reclamation areas is of prime importance.

## Historical Background

Land reclamation in Egypt started at the beginning of the nineteenth century. The Egyptian government has learned the following regarding the management of newly reclaimed areas:

- Newly reclaimed areas managed as government state farms have not been profitable.
- The terms "old" New Lands (areas reclaimed before 1971, about 912,000 fed [383,194 ha] mostly in the West Delta), and "new" New Lands (areas reclaimed after 1971, about 747,700 fed [313,865 ha]) were introduced.
- The cost of reclaiming the 912,000 fed of "old" New Lands was approximately LE 485 million. Since 1952, over 3.0 billion LE has been spent on land reclamation. The actual market value of the total area reclaimed since 1952 (about 1,660,000 fed [697,478 ha]) is about LE 25 billion.
- Production in the "old" New Lands has reached about 89% in the heavy clay areas, 85% on calcareous soils, and 54% on sandy soil. The majority of the "new" New Lands have not yet reached high production levels.

## Water Resources

Regarding irrigation in the New Lands, 2,374,600 fed (997,731 ha) will be based on surface water (Nile and drainage water) and 217,400 fed (91,344 ha) on groundwater.

- The area reclaimed between 1987 and 1992 was 715,000 fed (300,420 ha), with a water requirement estimated to be 4.2 bcm/year.
- The area reclaimable after 1992 is about 1,265,500 fed (531.722 ha), with an annual water requirement of about 7.6 bcm.
- According to the Water Master Plan, the available water resources for the New Lands are:
    - About 10.2 bcm of Nile and drainage water, to be used for about 1.7 million fed (0.714 million ha).
    - An additional 2.3 bcm per year could be safely withdrawn from the groundwater reservoirs, bringing the total withdrawal up to 4.9 bcm/year. This will be used for about 300,000 fed (126,050 ha).
    - About 1.1 bcm of treated domestic sewage water will be used in the reclamation of about 200,000 fed (84,033 ha).
    - The implementation of the Irrigation Improvement Project, covering an area of 2 million fed (0.84 million ha) will save about 1.0 bcm/year.
    - Storage projects for water released at Aswan during the closure period will reduce direct spills to the sea by about 2.6 bcm/year.
- The yearly water requirement and source of water are given in Table 5.
- The characteristics of the aquifers in the Nile Delta and Valley are discussed, along with the groundwater development plan.
- Groundwater pumping rates for different purposes in the Delta and the Valley are presented in Table 7. The geographical distribution of pumping rates within each region is presented in Table 8.

### Irrigation Methods and Management

Since most of the New Lands are classified as sandy and calcareous soils, efficient irrigation methods are essential. The selection of a suitable irrigation method plays an important role in the planning and the future success of an irrigation project. In all newly reclaimed areas the modern irrigation system should be used, and flood irrigation should be prohibited by law. A survey of the irrigation systems expected to be used in the New Lands between 1990 and 2000 is given in Table 9.

The different irrigation methods used in the "old" and "new" New Lands are explained. Three methods are generally used: gravity, sprinkler, and micro (localized irrigation). The advantages and disadvantages of each method are discussed.

### Crop Water Requirements

Optimum water management can be achieved by providing crops with enough water to prevent stress that may cause yield reduction. Proper management is governed by the prevailing climatic conditions, crop, and soil moisture.

- Various empirical approaches have been proposed to estimate potential evapotranspiration (PET). The Blaney and Criddle formula is still widely used in Egypt.

- Potential ET and actual ET are distinguished. In general, the seasonal ET for a typical crop (actual ET) does not equal the potential ET, even if the moisture regime is wet. The average seasonal actual ET for a well-watered crop is likely to range between 0.6 and 0.9 of seasonal potential ET.
- The average reference evapotranspiration (ETo) for three years (1976, 1977, and 1988) is presented in Table 11. The seasonal consumptive use of different crops and their crop coefficient (Kc) values are given in Table 12.
- The monthly water requirement for different crops grown in West Nubaria and North Tahrir (sandy and calcareous soils) is presented in Tables 13–16.
- The available climatic data in newly reclaimed areas (North Tahrir, West Nubaria, and Maryut) for 1976–1978 are presented in Annexes 1–6.
- The water use efficiency for different crops in newly reclaimed areas in relation to the irrigation system is summarized in Table 18.

The actual crop water use for different crops in the New Lands is summarized below.

### *Cereal Crops*

**Wheat.** Under sprinkler irrigation the water requirement for wheat in El Bustan (sandy soil) varies from 2,200 to 2,400 $m^3$/fed. In sandy soils as many as 24 irrigations may be needed between mid November and the end of April. In calcareous soils the water consumption by wheat was 1,650.6 $m^3$/fed.

**Barley.** Water consumption in some experiments ranged between 1533.8 and 816.5 $m^3$/fed depending on the water suction in the soil.

### *Legumes*

**Faba bean.** Seasonal consumption was 1,079.4 and 1,327.7 $m^3$/fed for sprinkler and flooding irrigation, respectively. In calcareous soil, water consumption was estimated at 1335.6 $m^3$/fed.

**Lentil.** For varieties Giza 9, Giza 47, and NEL 231, water consumption was 50.56, 41.0, and 35.4 cm, respectively. The number of irrigations was 23, 17, and 12, respectively.

## Irrigation and Drainage Problems

The basics of reclamation projects in Egypt are explained, from the use of available resources—i.e. water, land, financial, and human—to project implementation.

The major problems for irrigation systems in the New Lands are related to:

- Topography and related problems.
- Tail end problems.
- Inadequacy of the water supply.
- Inefficiency of the conveyance system.
- Changing to modern systems.
- Soil management problems.

# Water Management in the New Lands

## Introduction

Due to the rapid increase in population, Egypt now has the lowest land per capita of any country in Africa. Since the beginning of the century, despite an increasing cultivated area, land per capita has steadily declined.

| Year | Population (million) | Cultivated area (million fed) | Area per capita (fed) |
|---|---|---|---|
| 1907 | 11.2 | 5.40 | 0.48 |
| 1927 | 14.2 | 5.55 | 0.38 |
| 1947 | 19.0 | 5.76 | 0.30 |
| 1967 | 30.1 | 5.90 | 0.19 |
| 1987 | 53.0 | 7.19 | 0.14 |
| 1993 | 58.0 | 7.49 | 0.13 |

Thanks to the construction of the High Aswan Dam in the 1960s, it has been possible both to intensify cultivation in the Old Lands and to expand agricultural activities in the New Lands by reclaiming the desert.

Until the beginning of the 1960s, progress in land reclamation was very modest. During the 1960s land reclamation projects increased rapidly. In the 1970s there was a noticeable slowdown. Finally, a sharp increase took place at the beginning of the 1980s, which continues to date.

| Year | | Cumulative reclaimed area (× 1000 fed) |
|---|---|---|
| before 1960 | | 78.8 |
| 1970 | | 891.0 |
| 1980 | | 924.0 |
| 1982 | First Five-Year Plan | 1132.0 |
| 1987 | | 1527.0 |
| 1992 | Second Five-Year Plan | 2277.0 |

The most detailed survey of land resources in Egypt was conducted in 1987 through the national Land Master Plan (LMP). The main conclusions of the LMP were twofold:

- An area of 2.88 million fed (1.21 million ha) could be reclaimed using Nile water.
- An area of 0.57 million fed (0.24 million ha) could be reclaimed using groundwater in the Sinai and the New Valley.

The total area was divided into five categories, depending on one or more land-use and management options. These options took into account cropping pattern, irrigation system and farm type. The distribution of the potential reclamation area is given in Table 1, from which it is clear that most of the priority areas lie in the fringes of the Nile Valley and Delta (almost 60% in the Delta and 30% along the Valley).

**Table 2. Definition of land-management categories.**

| Land category | Soil type | Tenacity | Main location | Most suitable farming system | | |
|---|---|---|---|---|---|---|
| | | | | Crop | Irrigation and drainage | Farm type |
| I | Clay, low permeability, saline | Flat | Coastal areas, Western Desert depressions | Rice, fodder | Basin; drainage difficult | Small holders, family farms. |
| II | Clay to sandy loam, permeable, calcareous | Flat | Nubaria New Valley | Cereals, legumes, fodder, vegetables, grapes | Gated pipe, sprinkler; drainage easy | Small holders, family farms |
| III | Sandy loam to sandy, low available moisture | Flat to gently undulating | Desert | Legumes, oil crops, fodder, vegetables, fruit trees | Sprinkler and drip; drainage easy | Family, commercial, and estate farms |
| IV | Sandy loam to sandy, low available moisture | Undulating | Desert | As in III | As in III; drainage easy; requires good water management | Commercial and estate farms |
| V | Coarse sand, very low moisture retention | Flat to rolling | Desert | As in III but limited number | Sprinkler and drip; drainage easy | Estate farms |

Most of the above estimates are based on informal observations. Given a total cultivable area of 7.5 million fed (3.13 million ha) and assuming a net irrigated agricultural area of 6.7 million fed (2.8 million ha) the best guess for agricultural land lost to urbanization is about 30,000 fed (12,600 ha) per year. This estimate is consistent with the Land Master Plan, which originally estimated 45,000 fed (18,900 ha) per year, but later modified because of the intervention of the state, and the imposition of harsh penalties for cutting earth for brick manufacturing and for the expansion of housing on agricultural land. Assuming this estimate of loss of land is reasonably accurate, it follows that the land reclamation projects have increased the total agricultural land base, but only very modestly.

This report tries to illustrate the effect of proper water management on agricultural sustainability under prevailing conditions. Water management is not the only aspect to be studied in this respect, others are socioeconomics, crop production, and soil.

### Historical Background

In the arid country of Egypt, land reclamation has been practiced for thousands of years. For most of this time, reclamation centered around the Nile Valley and Delta, since land in these areas could be reclaimed with minimal technology and investment. At the beginning of the nineteenth century, the cultivated area was estimated at 2 million fed (0.84 million ha), out of which only 250,000 fed (105,000 ha) could be cultivated in summer.

By the beginning of the twentieth century, due to the construction of the Delta Barrages in the 1830s, the cultivated area had doubled to about 5 million fed (2.1 million ha). Since the independence of Egypt in the 1950s, rapid population increases have contributed to a shortage of arable land, i.e., land that can be economically cultivated. The social objective of settling landless people was considered more important than the economic objective of increasing agricultural production. Despite this priority, progress in resettlement was slow, with only 80,000 fed (33,613 ha) reclaimed before 1960, of which 30,000 fed (12,605 ha) were handed over to small landless farmers.

From 1960 to 1971 a total of 912,000 fed (383,193 ha) were reclaimed, mostly in the West Delta. The area reclaimed during this period is now called the "old" New Lands. Even though the net agricultural area is generally assumed to be about 85% of the gross area, only about 75% is considered to be productive (i.e., about 685,000 fed [287,815 ha]). This is because some of these areas are no longer cultivated for various reasons, among which are serious waterlogging, salinity, and lack of irrigation water. Another 900,000 fed (378,151 ha) is currently under rehabilitation.

Much of the land reclaimed during the 1960s was designated as state farms, since the prevailing view was that only such large farms would allow extensive mechanization and could benefit from economics of scale. This represented a policy change towards increasing agricultural production and generating a marketable agricultural surplus. Due to the poor physical performance and management of the public sector, the return of these reclaimed lands was far from being economic.

During most of the 1970s, governmental policies were focused on military issues. Accordingly, land reclamation was neglected. However, productivity in the reclaimed area continued to increase. In 1978, land reclamation projects were resumed, and in the next decade, a total of 747,700 fed (314,159 ha) was reclaimed. These lands are called the "new" New Lands. The land reclaimed from 1960 to 1992 is summarized in Table 3.

**Table 1. Reclaimable land in Egypt (area in 1000 fed).**

| Region | Land category | | | | | | Priority |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | Total | areas |
| **With Nile water** | | | | | | | |
| East Delta | 268.5 | - | 135.1 | 43.5 | 351.1 | 798.2 | 612 |
| West Delta | 41.5 | 171.2 | 49.1 | 65.0 | 358.1 | 684.9 | 264 |
| Central Delta | 59.0 | - | - | - | - | 59.0 | 59 |
| Middle Egypt | - | - | 31.5 | 6.2 | 186.2 | 223.9 | 184 |
| Upper Egypt | - | 3.6 | 160.1 | 342.5 | 275.4 | 781.6 | 195 |
| Aswan High Dam Lake shores | - | 9.0 | - | - | 41.0 | 50.0 | 0 |
| Sinai | 102.5 | - | - | 111.6 | 69.5 | 283.6 | 212 |
| Total | 471.5 | 183.8 | 375.8 | 568.8 | 1281.3 | 2881.2 | 1526 |
| **With groundwater** | | | | | | | |
| New Valley | 1.5 | 62.5 | 14.2 | - | 484.5 | 562.7 | |
| Sinai | - | - | 2.0 | 5.2 | - | 7.2 | |
| Total | 1.5 | 62.5 | 16.2 | 5.2 | 484.5 | 569.9 | 82 |
| **Total** | 473.0 | 246.3 | 392.0 | 574.0 | 1766.8 | 3451.1 | 1608 |

The classification of land into five categories was based on a modified US Bureau of Reclamation system. A summary of these categories is given in Table 2, from which the following can be concluded:

- Coarse to gravelly sand (category V) accounts for more than half of the area that can be reclaimed.
- Categories III, IV, and V, which contain coarse sandy soils and sandy loam, account for nearly 80% of the potentially reclaimable area.

| Organization | Year | Annual loss (1000 fed) |
|---|---|---|
| Ministry of Agriculture | 1965–1975 | 10–15 |
| Ministry of Planning | 1965–1975 | 20 |
| El Gabaly | 1975 | 5 |
| El Tobgy | 1976 | 40 |
| Zagazig University | 1980 | 75 |
| National Policy of Urbanization | 1982 | 30 |
| Strategy of Agricultural Development | 1982 | 4 |
| Land Master Plan | 1985 | 30 |

The area of agricultural land which is lost every year to urbanization and land degradation is a matter of controversy. Estimates given by a number of organizations and individuals are presented below.

**Table 3. Land reclaimed (1000 fed) 1959/60–1991/92.**

| Year | East Delta | Middle Delta | West Delta | Middle Egypt | Upper Egypt | Other | Total |
|---|---|---|---|---|---|---|---|
| 1960 | 23.6 | 2.5 | 42.9 | 6.7 | - | 3.1 | 78.8 |
| 1960/61 | 1.5 | 2.0 | 5.7 | - | - | 19.0 | 28.2 |
| 1961/62 | 10.7 | 17.7 | 25.2 | 3.1 | 9.6 | 23.1 | 89.4 |
| 1962/63 | 13.2 | 23.6 | 42.9 | 4.9 | 13.6 | 24.0 | 122.2 |
| 1963/64 | 8.0 | 33.7 | 53.9 | 5.5 | 23.8 | 34.5 | 159.4 |
| 1964/65 | 8.5 | 27.0 | 58.9 | 12.0 | 16.7 | 12.9 | 136.0 |
| 1965/66 | - | 4.0 | 65.5 | 22.0 | 11.1 | 17.0 | 119.6 |
| 1966/67 | - | 4.0 | 27.5 | 21.5 | 2.1 | 2.0 | 57.1 |
| 1967/68 | - | 2.0 | 32.0 | - | - | - | 34.0 |
| 1968/69 | 7.0 | 19.0 | 19.1 | - | - | - | 45.1 |
| 1969/70 | 5.0 | 7.0 | 6.0 | - | 3.0 | - | 21.0 |
| 1970/71 | 13.0 | 8.0 | - | - | - | - | 21.0 |
| 1978/79 | 1.0 | - | 14.9 | 0.8 | 0.5 | 4.7 | 21.9 |
| 1979/80 | 8.3 | 8.1 | 4.6 | - | 0.8 | 2.5 | 24.3 |
| 1980/81 | 3.7 | 7.0 | 2.5 | - | 1.0 | 2.1 | 16.3 |
| 1981/82 | 57.3 | 1.0 | 32.5 | 0.3 | 4.6 | 4.2 | 99.9 |
| 1982/83 | - | 3.4 | 27.9 | 1.5 | - | 10.9 | 43.7 |
| 1983/84 | 13.0 | 4.4 | 18.9 | 5.1 | - | 5.2 | 45.6 |
| 1984/85 | 14.7 | 2.5 | 22.4 | 6.6 | - | 4.4 | 50.6 |
| 1985/86 | 11.5 | 2.3 | 26.4 | 15.7 | - | 0.5 | 56.4 |
| 1986/87 | 3.5 | 11.5 | 36.2 | 13.0 | - | 1.7 | 65.9 |
| 1987/88 | 20.0 | 2.3 | 96.2 | 18.2 | - | 16.9 | 153.6 |
| 1988/89 | - | - | - | - | - | - | 170.0 |
| Up to 1988/89 | | | | | | | 1,661.0 |
| 1987/88–1991/92 | 175.0 | 5.0 | 214.4 | 41.5 | 94.5 | 219.6 | 750.0 |

Reclamation between 1970/71 and 1978/79 is excluded due to lack of activity.

In the 1980s a policy was instituted to allow allocation of "new" New Lands to investors with adequate capital to develop their own farms and to economically disadvantaged groups such as landless farmers, unemployed graduates and government officers. The ratio of allocation between the two groups was more or less 50:50.

The cost of reclaiming 912,000 fed (383,193 ha), completed before 1975, was LE 485 million. Since the 1952 revolution, more than LE 3.0 billion has been spent on land reclamation. This amount is the nominal value; the actual market value of the area reclaimed since 1952 (about 1,660,000 fed [697,478 ha]) is about LE 25 billion.

Table 4 summarizes the increase in agricultural land between 1963 and 1989 in each governorate, from which it is clear that most reclaimed land lies within the governorates that border the desert (Nile Valley and Delta fringes). In interior governorates, such as Gharbia and Menoufia, no reclamation took place. For governorates close to the Mediterranean, such as Kafr El Sheikh, reclamation was carried out on saline heavy clays overlying a shallow saline water table.

Tables 3 and 4 contradict the estimate of the area lost to super- and infrastructure development. In Table 3, the total area reclaimed up to the year 1988/89 is given as 1,659,900 fed (697,436 ha). Table 4 gives the difference in cultivated area between 1963 and 1989 as 1,471,160 fed (618,134 ha). The difference between the two figures should be equal to the area of land lost to super- and infrastructure development, i.e. 1,659,900 – 1,471,160 = 188,740 fed (79,303 ha). If this area is divided by the number of years between 1963 and 1989 (26 years), the average area loss per year is calculated at 7,260 fed/year. This number is far below the various estimates.

**Table 4. Cultivated areas in Egypt, 1963 and 1989.**

| Governorate | Cultivated area (fed) | | |
|---|---|---|---|
| | 1963 | 1989 | Difference |
| **Lower Egypt** | | | |
| Alexandria | 24,448 | 141,278 | 116,830 |
| Beheira | 745,156 | 1244,810 | 499,654 |
| Kafr El Sheikh | 447,714 | 575,089 | 127,375 |
| Gharbia | 425,724 | 397,714 | -28,010 |
| Menoufia | 330,133 | 321,967 | -17,146 |
| Kalioubia | 202,190 | 213,278 | 11,088 |
| Damietta | 101,568 | 132,791 | 31,223 |
| Dakahlia | 659,125 | 687,614 | 28,489 |
| Sharkia | 608,595 | 790,105 | 181,510 |
| Port Said | 132 | 6,995 | 6,863 |
| Ismailia | 51,045 | 155,954 | 104,909 |
| Suez | 9,325 | 8,828 | -497 |
| **Total** | **3,605,155** | **4,676,423** | **1,071,268** |
| **Middle and Upper Egypt** | | | |
| Cairo | | | |
| Giza | 19,257 | 11,252 | -8,005 |
| Fayoum | 181,235 | 232,807 | 51,572 |
| Beni Sueif | 328,067 | 351,901 | 23,834 |
| Minia | 273,529 | 275,300 | 1,771 |
| Assiut | 465,045 | 507,589 | 42,544 |
| Sohag | 330,135 | 325,807 | -4,329 |
| Qena | 333,245 | 317,867 | -15,278 |
| Aswan | 369,993 | 374,783 | 4,790 |
| | 114,745 | 153,758 | 49,013 |
| **Total** | **2,415,251** | **2,551,16** | **135,912** |
| **Total Nile Valley** | **6,020,406** | **7,218,606** | **198,200** |
| **Desert governorates** | | | |
| Matrouh | - | 34,346 | - |
| New Valley | - | 29,930 | - |
| North Sinai | - | 106,882 | - |
| South Sinai | - | 1,419 | - |
| Red Sea | - | 383 | - |
| **Total** | **7,491,566** | **272,960** | |

### *Areas of ultimate production*

Reclamation of lands both from desert and/or heavy saline clays is a long process that requires step by step planning, design, and implementation. Post implementation is even more important because of the effect of cultivating barren lands not previously planted.

- Phase I: This is the engineering part of reclamation, which ends with the installation and construction of the super- and infrastructures.
- Phase II: Land is put under cultivation through irrigation, drainage, and different agricultural processes.

From the Egyptian experience in land reclamation it is clear that heavy clay soils and calcareous soils mature earlier than sandy soils. The following table confirms this conclusion in the "old" New Lands.

| Soil texture | Reclaimed area | | Area which has reached maximum production | |
|---|---|---|---|---|
| | 1000 fed | Percentage | 1000 fed | Percentage |
| Heavy clay soil | 270 | 30 | 240 | 89 |
| Calcareous soil | 200 | 22 | 170 | 85 |
| Sandy soil | 442 | 48 | 240 | 54 |
| Total | 912 | 100 | 650 | |

From the above table we see that 89% of heavy clay areas and 85% of calcareous soils have reached maximum production, as opposed to 54% of sandy soils. This is because the majority of clay soil reclamation, and some calcareous soil reclamation, is based on improving drainage and reducing salinity levels. In sandy soils, however, the top layer is generally poor in many elements, permeability is very high, and the intake rate is high. In addition, increased salinity and the presence of toxic substances are common. Curing this situation takes effort, money, and time.

Most of the "new" New Lands reclaimed after 1978 have therefore not reached maximum production.

## Water Resources in Newly Reclaimed Lands

As indicated below, the total area of land reclaimed before 1992, using surface and groundwater, is estimated at 2,591,100 fed (1,089,075 ha) distributed as follows:

| Reclamation based on surface water | |
|---|---|
| **Region** | **Area (fed)** |
| East Delta | 687,700 |
| West Delta | 570,000 |
| Middle Delta | 59,000 |
| Middle Egypt | 172,000 |
| Upper Egypt | 710,000 |
| Sinai | 175,000 |
| **Total** | **2,373,700** |
| **Reclamation based on groundwater** | |
| **Region** | **Area (fed)** |
| New Valley | 152,000 |
| Sinai | 14,000 |
| East Delta | 32,400 |
| Northwest Coast | 19,000 |
| **Total** | **217,400** |

The area expected to be reclaimed during the Five-Year Plan (1987–1992) using surface water was estimated at 715,000 fed (300,420 ha). The annual water requirement for this area was estimated at 4.2 bcm, with an evapotranspiration requirement of 2.8 bcm. The remaining reclaimable area to be irrigated with surface water after 1992 was estimated at about 1,265,500 fed (531,722 ha). The annual water requirement for this area was estimated at about 7.6 bcm, with an evapotranspiration requirement of 5.1 bcm.

The Water Master Plan summarized the available water resources for newly reclaimed areas as follows: net available water for horizontal expansion using Nile water is estimated as 10.2 bcm, to be used to reclaim about 1.7 million fed (0.714 million ha).

Further exploitation of groundwater in the Nile Valley and Delta is possible, since studies show that an additional 2.3 bcm/year could be safely withdrawn from the groundwater reservoirs. This additional quantity would bring the total withdrawal up to 4.9 bcm/year. About 300,000 fed (126,050 ha) could be reclaimed based on these resources.

Treated domestic sewage of about 1.1 bcm could be used in the reclamation of about 200,000 fed (84,033 ha). This would bring the total reclaimable lands to about 2.2 million fed (0.92 million ha). In addition to the above-mentioned resources, the implementation of the Irrigation Improvement Project, which will cover an area of 2.0 million fed (840,330 ha) will save about 1.0 bcm/year by improving field application efficiency. Storing water released at Aswan during winter closure would reduce the amount of direct spillage to the sea by about 2.6 bcm/year. About 3.0 bcm of land drainage water (as projected in 1992) over the currently used drainage water (estimated at 3.0 bcm) will be used for new reclamation projects and horizontal expansion.

## Anticipated Water Demand for Newly Reclaimed Lands

### *Reclamation based on surface water*

The Horizontal Expansion Authority of the Ministry of Public Works and Water Resources (MPWWR) estimates that the expected reclaimed areas during the current Five-Year Plan (1992-1997) is about 733,100 fed (308,025 ha). The total water required for this area is estimated at 4.22 bcm, which will be made available by mixing Nile water (2.51 bcm) and land drainage water (1.71 bcm). The study estimates the expected reclaimed area to the year 2000 at 971,900 fed (408,361 ha), which will require about 5.26 bcm of Nile water and about 3.57 bcm of land drainage water.

Table 5 shows the reclaimed area (using surface water) during the current Five-Year Plan and up to the year 2000. It is clear that drainage water is considered a major resource in land reclamation projects for the next Five-Year Plan. The mixing ratio between irrigation and drainage water is 1:1. Table 5 shows that the area expected to be reclaimed by the year 2000 is about 1,705,900 fed (716,764 ha), which will require about 8.83 bcm/year. This quantity will be made available by mixing 3.57 bcm/year of drainage water with 5.26 bcm/year of Nile water to bring the mixture to a reasonable salinity level (less than 1000 ppm).

**Table 5. Water requirement and resources (1993/94–2000).**

| Year | Area (1000 fed) | Water requirement (million $m^3$/year) | Source | |
|---|---|---|---|---|
| | | | Nile | Drains |
| During the current Five-Year Plan | | | | |
| 1993/94 | 73.2 | 425.3 | 318.0 | 107.3 |
| 1994/95 | 261.9 | 1538.9 | 928.1 | 610.8 |
| 1995/96 | 541.9 | 3127.3 | 1914.3 | 1213.0 |
| 1996/97 | 733.1 | 4221.9 | 2511.0 | 1710.9 |
| Future plan (up to the year 2000) | | | | |
| 1997/98 | 1203.1 | 6606.9 | 4076.8 | 2530.1 |
| 1998/99 | 1510.1 | 8002.6 | 4775.2 | 3227.4 |
| 1999/2000 | 1705.9 | 8831.4 | 5261.1 | 3570.3 |

### *Reclamation based on groundwater*

The main aquifers in Egypt are described as follows: the alluvial aquifer, which is the main water-bearing formation in the Nile Valley and Delta, consists of quaternary and late tertiary sand and gravel beds. The aquifer thickness decreases from 300 m at Sohag to a few meters at Cairo; then increases northwards to about 1,000 m near the Mediterranean coast. The main source of replenishment is seepage from surface water systems. The total amount of fresh groundwater stored in the Nile Valley and South Delta amounts to 500 bcm (storage capacity of Lake Nasser is about 162 bcm). The annual replenishment is about 8 bcm, out of which about 3 bcm/year flows back to the Nile. The groundwater quality in this aquifer is generally suitable for irrigation. The Nubian Sandstone aquifer system is a part of the regional hydro-geological system with extensions into Libya, Sudan and Saudi Arabia. It is considered the main aquifer in the Western Desert of Egypt. The Maghara aquifer is another granular aquifer system with regional extension, and dominates the northwestern portion of the Delta. The water quality is saline (brackish water). Local and low-production aquifers are found along the coastal zones and in the fissured carbonate and crystalline rock. Characteristics of the various aquifers are given in Table 6.

**Table 6. Characteristics of the main aquifer systems in Egypt.**

| Aquifer complex | Locality | Depth of top aquifer (m) | Saturated thickness (m) | Depth to water table (m) | Hydraulic conductivity (m/day) | Salinity (ppm) |
|---|---|---|---|---|---|---|
| Granular rock | | | | | | |
| Nile Valley and Delta aquifer | Nile Valley | 0–20 | 10–200 | 0–5 | 50–70 | < 1500 |
| | Nile Delta (south) | 0–20 | 100–500 | 0–5 | 50–100 | < 1500 |
| | Nile Delta (north) | 20–100 | 500–1000 | 0–2 | < 50 | > 5000 |
| Coastal aquifers | Mediterranean coastal aquifers | 0 | <5 | 0–15 | 15–25 | 1000–6000 |
| | El Oaa plain | 50–100 | 60–00 | 50–70 | 5–10 | 600–2500 |
| | El-Arish aquifer | 15–30 | 40–50 | 0–30 | 5–20 | 1500–6000 |
| Nubian sandstone | **Western Desert** | | | | | |
| | Kharga | 200 | 500–700 | 0–30 | 2–4 | < 1000 |
| | Dakhla | 200 | 500–1000 | 0–20 | 6–7 | < 1000 |
| | Bahariya | 150–300 | 1000–1500 | 0–20 | 5–10 | < 1000 |
| | Farafra | 200–500 | 1500–2000 | flowing | 2–5 | < 1000 |
| | East Oweinat | 10–20 | 100–300 | 20–30 | 10–20 | < 1000 |
| | **Nile Basin** | | | | | |
| | Qena area | 100–250 | 500 | flowing | 1–2 | 2000–5000 |
| | Takita area | 100–500 | 200–400 | flowing | 1–3 | 1500–2000 |
| Maghara aquifer | **Eastern Desert** | | | | | |
| | East Mattaha | 0.30 | >200 | flowing | – | 3000–4000 |
| | **Sinai** | | | | | |
| | Nakhl | 1000 | 2000 | 200 | – | 1500–2000 |
| | Ayoun Musa | 100–500 | 1500 | flowing | – | 1000–4000 |
| | Natrun/Qattara | 0–200 | 500–200 | 100 | – | 1000–1200 |
| Fissured rock | | | | | | |
| Carbonates | Wadi Araba | 0–100 | 500 | flowing | – | 1000–1200 |
| Hard rocks | South Sinai | 0–50 | — | 0–5 | – | 1000–1200 |

Source: RLGW/IWACO (1900).

### *Groundwater development plan*

The information used in the development of water plans includes:

- The rate and distribution of present extraction.
- The present quality of groundwater.
- Land use and source of irrigation.
- Aquifer characteristics and boundary conditions.
- Type and rate of recharge.
- Depth to groundwater and aquifer productivity.
- Drainage conditions.

With this information it is possible to determine the additional amount of water that can be pumped, the total pumping head, and the expected changes in groundwater quality.

Thus, priorities are set according to economic return. The Research Institute for Ground Water (RIGW) identified the regional geographic distribution and magnitude of future pumpage (Ministry of Public Works and Water Resources 1992, 1993). Table 7 shows the current and planned groundwater extraction according to activity. Table 8 shows the geographic distribution of current and planned extraction. From these two tables, it can be concluded that 5 bcm/year can be extracted from groundwater reservoirs. This quantity may be increased to 8.6 bcm/year in the future.

**Table 7. Current and planned groundwater pumping rates.**

| Location | Purpose | Pumping rate (million m³/year) | | |
|---|---|---|---|---|
| | | 1990 | Available | Total |
| 1. Delta | Land reclamation | 690 | 635 | 1325 |
| | Conjunctive use in irrigation | 660 | 460 | 1120 |
| | Domestic and Industry | 325 | – | 325 |
| 2. Valley | Land reclamation | 20 | 190 | 210 |
| | Conjunctive use in irrigation | 815 | 1225 | 2040 |
| | Vertical drainage | - | 340 | 340 |
| | Domestic and industry | 120 | - | 120 |
| 3. Desert and Sinai | | 576 | 2530 | 3106 |
| **Total** | | **3,206** | **5,380** | **8,586** |

The volume of pumped water for vertical drainage is added to the water consumptive use because they are both used locally.

**Table 8. Geographical distribution of pumping rates.**

| Location | Pumping rate (million m³/year) | | |
|---|---|---|---|
| | 1990 | Available | Total |
| **Delta** | | | |
| a- Alluvial formations | 985 | 460 | 1445 |
| b- East Delta fringes | 490 | 380 | 870 |
| c- West Delta fringes | 200 | 255 | 455 |
| **Nile Valley** | | | |
| a- Alluvial formations | 935 | 1225 | 2160 |
| b- Fringes | 20 | 195 | 215 |
| Total Valley and Delta | 2630 | 2515 | 5145 |
| **Western Desert** | | | |
| a-Kharga | 120 | 0 | 120 |
| b-Dakhla | 250 | 230 | 480 |
| c-Farafra | 60 | 300 | 360 |
| d-Bahariya | 30 | 180 | 210 |
| e-Siwa | 30 | 100 | 130 |
| f-Oweinat | 0 | 1500 | 1500 |
| **Coastal Zones** | | | |
| a-Mediterranean | 1 | 0 | 1 |
| b-Red Sea | 5 | 0 | 5 |
| Total deserts | 496 | 2310 | 2806 |
| **Sinai Peninsula** | **80** | **220** | **300** |
| **Total** | **3206** | **5045** | **8251** |

## Irrigation Methods and Management in Newly Reclaimed Areas

The fact that most of the newly reclaimed lands in Egypt have a coarse texture and calcareous nature necessitates the use of efficient irrigation methods, i.e. sprinkler and micro-irrigation (localized) systems. The selection of a suitable irrigation method plays an important role in the planning and success of an irrigation project. The objective of obtaining a high application efficiency and a uniform distribution of water in the root zone at low cost must be constantly considered.

In Egypt, about one million fed (420,000 ha) are irrigated by sprinkler and localized irrigation systems. There are about 15,000 greenhouses operated by the public and private sectors. Drip and spray irrigation is used widely to irrigate these greenhouses. The continued development of these irrigation systems has faced many constraints in the last few years. However, in all newly reclaimed areas modern irrigation systems should be used; flood irrigation methods are prohibited by law.

An additional one million feddan will be irrigated by modern irrigation methods by the year 2000 (Table 9).

**Table 9. Areas under modern irrigation systems in Egypt.**

| Method and system | Area (1000 fed) | | |
|---|---|---|---|
| | 1990 | 2000 | Total |
| **Sprinkler irrigation** | 750 | 700 | 1450 |
| 1- Portable hand-moved system | 300 | 200 | 500 |
| 2- Permanent and solid-set | 300 | 425 | 725 |
| 3- *Side-roll system* | | | |
| 4- Traveler gun system | 150 | 75 | 225 |
| 5- Center-pivot system | | | |
| **Micro-irrigation (localized)** | 250 | 300 | 550 |
| Fruit trees | 175 | 225 | 400 |
| Vegetables | 75 | 75 | 150 |
| **Total** | **1,000** | **1,000** | **2,000** |

A typical farm irrigation system consists of:

- An off-take to divert irrigation water from the main system.
- A network of field ditches to convey and distribute water to individual field plots. In the New Lands, these ditches are replaced by pressurized pipes to suit the irrigation method.
- A lifting device to raise water from below the supply canal to the *marwa* in order to command the field by gravity.
- The lifting device is replaced by a pressure-booster unit to maintain suitable pressure in the network for the application (irrigation) device.
- The irrigation system is surface in most Old Lands, and sprinkler and drip in most New Lands.

### Gravity Irrigation

Gravity irrigation covers all the methods in which water is distributed by means of open conduit flow with no pressure. These methods include: corrugation, furrow, borders of various types, basin, and flooding. Modern design methods for gravity systems have, however, led to much greater accuracy and efficiency of water application than was previously achieved. Good irrigation by gravity methods is still, in many cases, far less expensive than by pressure methods. However, although the engineering design procedures are relatively simple in gravity irrigation, the requirements of skill and experience with irrigation on the part of the farmer are much greater. The opposite is true of pressure systems.

### Furrow Irrigation

Furrow irrigation is generally used under the following conditions:

- For row crops, tree crops, vineyards, and especially tall crops.
- On regular topography and level to moderate slopes.
- Where the water supply has low pressure and a small discharge rate.
- On medium to heavy soils.

#### *Advantages*

The advantages of furrow irrigation are:

- Low investment in equipment.
- Low pumping cost.
- Low operating cost.
- Full use of irregularly shaped fields.
- Complete irrigation of fields margins without wetting the adjoining fields.
- Suitability for crops sensitive to sprinkler irrigation because of leaf diseases.
- Suitability for crops sensitive to flood irrigation because of root diseases.
- Does not interfere with crop spraying.
- Not affected by wind conditions; can be used at all hours of the day and night.
- Low evaporation losses.

#### *Disadvantages*

The disadvantages of furrow irrigation are:

- Can cause soil salinity problems in strip areas between furrows.
- Irrigation efficiency is lower than sprinkler and micro-irrigation.
- Water distribution uniformity is not high.
- Furrows must be renewed every year, and sometimes after each cultivation.
- May cause soil erosion if slopes are too great.

- Requires more land leveling than sprinkler irrigation or micro-irrigation.
- Not suitable for light, sandy soils because the length of the furrows is limited.
- Not suitable for the application of very small amounts of irrigation water.

### *Slope and discharge*

Slopes generally vary from 0.2 ("light" soils) to 1–2% ("heavy" soils). Usually, however, the range is 0.2–0.6%. Unless the land is relatively flat, the direction of the contour lines is normally followed. In principle, the steeper the slope the shorter the furrow.

### *Spacing*

For efficient irrigation, furrows should be parallel, with uniform slope and regular spacing. The optimal spacing of furrows depends on the type of soil and the crop as well as the tillage machinery used. Spacing normally ranges from 0.6 to 1.5 meters, larger spacing is used with the "heavier" soils where the lateral movement of water is more pronounced.

### *Length*

Furrow length depends on the type of soil, land slope, and irrigation discharge, other factors being constant. Longer furrows can be used in "heavier" soils, since these have low infiltration rates. Assuming uniform soils along furrows the following lengths normally apply:

**Light soils:** 120 m.

**Medium soils:** 120–250 m.

**Heavy soils:** 250–400 m and up.

Table 10 presents maximum furrow length as a function of soil slope, and depth of water application.

**Table 10. Suggested maximum furrow lengths.**

| Slope (%) | Depth of water application (mm) | | | | | |
|---|---|---|---|---|---|---|
| | Clay | | Loam | | Sand | |
| | 75 | 150 | 50 | 100 | 50 | 75 |
| 0.2 | 370 | 470 | 220 | 370 | 120 | 190 |
| 0.5 | 400 | 500 | 280 | 370 | 120 | 190 |
| 1.0† | 280 | 400 | 250 | 300 | 90 | 150 |

† For a 1% slope, furrow lengths are decreased because of increased erosion risk if high discharges are used.

## Sprinkler Irrigation

Sprinkler irrigation is the application of water in the form of a spray somewhat resembling rainfall. Sprinkling is man's simulation of natural rainfall. This irrigation method is also known as overhead irrigation.

Sprinkler irrigation systems can be divided into two categories. In periodic move and fixed systems, the sprinklers remain at a fixed position while irrigating, whereas in continuous move systems, the sprinklers operate while moving in either a circular or a straight path. With carefully designed periodic move and fixed systems, water can be applied uniformly at a rate based on the intake rate of the soil, thereby preventing run-off and consequent damage to land and crops.

### Advantages

Some of the most important advantages of the sprinkler method are:

- Small, continuous streams of water can be used effectively.
- Run-off and erosion can be eliminated.
- Soils with intermixed textures and profiles can be properly irrigated.
- Shallow soils which cannot be graded without detrimental results can be irrigated without grading.
- Steep and rolling topography can be easily irrigated.
- Light, frequent irrigation can be efficiently applied.
- Labor is utilized for a short period daily in each field as a result of mechanization and automation.
- Fixed systems can eliminate field labor during the season.
- Unskilled labor can be used since decisions are made by the manager rather than by the irrigator.
- Weather extremes can be modified by increasing humidity, cooling crops, and alleviating freezing by use of special design.
- Salts are leached from the soil.
- High application efficiency can be achieved by a properly designed and operated system.

### Disadvantages

The disadvantages of sprinkler irrigation systems are:

- High initial costs that must be depreciated.
- Large flows intermittently delivered are not economical without a reservoir, and even minor fluctuations in application rate cause difficulties.
- Windy and excessively dry locations result in appreciably lower efficiency.
- Field shape, other than rectangular, is not convenient, especially for mechanized sprinkler systems.
- Saline water may cause problems because salt may damage the leaves of some crops.
- Systems must be designed by a competent specialist with full consideration for efficient irrigation, the economics of pipe size and operation, and the convenience of labor.
- High concentrations of bicarbonates in irrigation water may affect the quality of fruit when used with overhead sprinklers.

## Micro-irrigation

Micro-irrigation is the frequent, slow application of water to the root zone of the plant. Water is applied by surface and subsurface trickle, bubbler, spray, mechanical move, and pulse systems. Water is applied as discrete or continuous drops, a tiny stream, or a miniature spray through emitters or applicators placed along a water delivery line near the plant.

### *Advantages*

- Increased beneficial use of available water.
- Enhanced plant growth and yield.
- Reduced salinity hazard to plant.
- Improved fertilizer and other chemical application.
- Limited weed growth.
- Decreased energy requirements.
- Improved cultural practices.

### *Disadvantages*

- High maintenance.
- Salt accumulation near plants.
- Restricted plant root development.
- Potential for clogging.
- Susceptible to insect and rodent damage (in relation to soft tubing).
- High installation cost.

# Crop Water Requirements in the New Lands

The main objective of proper water management is to provide plants and crops with sufficient amounts of water to prevent stress that may cause yield reduction. The timing and amount of applied water is governed by prevailing climatic conditions, crop, soil moisture holding capacity, and root development as determined by the type of crop and stage of growth.

## Consumptive Use

Crop consumptive use is the most important factor in computing irrigation water requirements. Therefore, numerous methods have been developed for this purpose. The subject of consumptive use for crops planted in Egypt has been of some controversy in the past, even though a considerable number of studies has been undertaken on the subject. A review of several selected studies and reports has been conducted to determine the most suitable figures for the major crops planted in Egypt.

Consumptive use, often called evapotranspiration (ET), is the amount of water used by vegetative growth plus that evaporated from adjacent soil. Only a small fraction of water absorbed by plants is used in photosynthesis, while as much as 99% escapes as vapor from plant canopies in the process of transpiration. The process of ET obviously depends on both the external weather, including radiation, humidity, temperature, and wind, and the internal state of the field itself. Theoretically, if the field is maintained wet, the ET should depend only on the weather. The potential evapotranspiration (PET) characterizes the climatic condition in terms of its evaporative power, i.e., it represents the externally imposed evaporative demand. Various empirical approaches have been proposed for the estimation of PET. The simplest method, by Thornthwaite (1948), is based on air temperature. The formulation of Blaney and Criddle (1950) is still widely used. Their method requires data on air temperature and day length. Penman (1948) put forward a formulation, which was later modified by Van Bavel (1960). Many evaporation measuring devices, such as the evaporation pans, have been proposed to estimate PET.

The actual crop ET rate is seldom equal to PET as measured from a well-watered turf or as calculated from any empirical formula. Stand density, canopy characteristics, stage of growth, degree of surface cover, and moisture regime all affect the actual ET. In general, the seasonal total ET for a typical crop will not equal the total PET even if the moisture regime is wet. For instance, early in the season, during the germination and seedling phase, the rate of transpiration is generally small, and the direct evaporation rate from the bare soil surface is also lower than PET. Later, as the crop approaches full cover, the transpiration rate increases and approximates the calculated values of PET. Finally, in the fruiting and drying stage, the actual ET again falls below the PET.

The average seasonal ET from a well-watered crop is likely to range between 0.6 and 0.9 of the average seasonal PET. For most crops, keeping a moist irrigation regime results in maximum production per unit area. Therefore, the maximum ET for major crops in a region can serve as the basis for planning an irrigation regime, and often represents the crop water requirement (CWR). In fact, knowing PET, it is possible to account for the effect of specific crop characteristics on CWR using the following empirical crop coefficient (Kc) formula:

$$CWR = Kc \times PET$$

In general, Kc values vary among crops because of differences in reflectivity, crop height, roughness, canopy resistance to transpiration, and degree of ground cover. In order to determine an appropriate Kc value the different stages of growth must be considered. Kc is calculated from research data and plotted against time or stage of growth. Kc values typically increase from a low value at seedling emergence to a maximum value in full ground cover stage, then declines as the crop matures and dries out.

Average reference evapotranspiration (ETo) for various New Lands is shown in Table 11. The seasonal consumptive use of different crops and Kc values are given in Table 12.

**Table 11. Daily and monthly average ETo (mm).**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North D | 2.3 | 3.1 | 4.1 | 5.6 | 7 | 7.7 | 7.8 | 6.7 | 5.6 | 4.0 | 2.9 | 2.1 |
| Tahrir M | 71 | 87 | 127 | 168 | 217 | 242 | 208 | 208 | 108 | 124 | 87 | 65 |
| West D | 2.8 | 3.8 | 5.1 | 7.0 | 8.4 | 9.8 | 9.7 | 9.0 | 6.9 | 4.6 | 3.3 | 2.6 |
| Nubaria M | 87 | 106 | 158 | 210 | 260 | 294 | 301 | 279 | 207 | 143 | 99 | 81 |
| Coastal area D | 2.52 | 3.21 | 4.29 | 5.11 | 6.1 | 6.73 | 7.10 | 6.61 | 5.82 | 4.26 | 2.81 | 2.1 |
| East Delta D | 2.82 | 4.08 | 5.59 | 6.94 | 8.62 | 8.62 | 9.37 | 7.18 | 6.03 | 4.44 | 2.65 | 2.0 |
| Ismailia D | 1.92 | 2.75 | 4.13 | 5.40 | 5.40 | 7.86 | 7.66 | 6.90 | 5.63 | 4.01 | 2.36 | 1.73 |

D = day; M = month.

**Table 12. Seasonal consumptive use for different crops.**

| Crop | Growth period (days) | Kc | Consumptive use (mm) | | |
|---|---|---|---|---|---|
| | | | West Nubaria | North Tahrir | Ismailia |
| **Cereal crops** | | | | | |
| Barley | 180 | 0.62 | 417 | 433 | 344 |
| Wheat | 180 | 0.62 | 417 | 499 | 433 |
| Corn | 120 | 0.73 | 517 | 497 | - |
| **Legumes** | | | | | |
| Faba bean | 120 | 0.65 | 193 | 271 | 304 |
| Lentil | 180 | 0.63 | 319 | 453 | 410 |
| Soybean | 135 | 0.67 | 541 | 550 | 410 |
| **Fodder** | | | | | |
| Berseem | 225 | 0.95 | 621 | 549 | 562 |
| Corn (fodder) | 75 | 0.73 | 517 | 497 | - |
| Alfalfa | 365 | 0.95 | 1,452 | 1,108 | - |

The available climatic data for the New Lands for 1976–1978 are given in Annexes 1-5. These data include the following:

- Maximum, minimum and average air temperature (°C).
- Maximum, minimum, and average soil temperature (°C).
- Maximum, minimum, and average relative humidity (%).
- Class A pan evaporation (mm/day).
- Sunshine (hours/day).
- Average monthly rainfall (mm/month).
- Wind speed (m/sec).

Water requirements for crops in North Tahrir and West Nubaria are given in Tables 13–16. Irrigation requirements for field crops in the New Lands are given in Table 17.

**Table 13. Winter and perennial crop water requirements (mm) for North Tahrir.**

| Crop | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barley | 75 | 95 | 140 | 171 | 116 | | | | | | 24 | 45 | 666 |
| Berseem | 75 | 91 | 133 | 176 | 114 | | | | | 105 | 82 | 68 | 844 |
| Cabbage | 71 | 86 | 57 | | | | | | | 33 | 56 | 62 | 365 |
| Carrot | 75 | 90 | 55 | | | | | | | 33 | 63 | 65 | 381 |
| Cauliflower | 71 | 86 | 57 | | | | | | | 33 | 56 | 62 | 365 |
| Flax | 73 | 91 | 130 | 87 | | | | | | | 48 | 48 | 477 |
| Horse bean: dry | 74 | 21 | | | | | | | | 37 | 86 | 71 | 271 |
| green | 34 | | | | | | | | | 37 | 68 | 71 | 210 |
| Lentil: dry | 78 | 89 | 69 | | | | | | | 69 | 76 | 72 | 455 |
| Onion | 52 | 93 | 123 | 151 | | | | | | | | 16 | 435 |
| Pea: dry | 77 | 56 | | | | | | | | 37 | 62 | 70 | 302 |
| green | 77 | | | | | | | | | 37 | 62 | 70 | 246 |
| Potato | 20 | 58 | 136 | 163 | | | | | | | | | 377 |
| Squash | 77 | 37 | | | | | | | | | 52 | 60 | 266 |
| Spinach | 70 | 33 | | | | | | | | 33 | 54 | 56 | 246 |
| Sugar beet | | | | | | | | | | 37 | 67 | 61 | 165 |
| Tomato | 78 | 92 | 97 | | | | | | | 37 | 61 | 68 | 433 |
| | 43 | 76 | 140 | 150 | | | | | | | | | 409 |
| | 65 | | | | | | | | | 69 | 75 | 72 | 281 |
| Wheat | 75 | 95 | 140 | 171 | 116 | | | | | | 24 | 45 | 666 |
| Alfalfa | 67 | 82 | 121 | 160 | 206 | 219 | 230 | 198 | 160 | 117 | 83 | 62 | 1705 |
| Almond/pear/plum | -- | -- | 108 | 160 | 228 | 266 | 278 | 239 | 185 | 111 | 47 | -- | 1649 |
| Citrus | 64 | 78 | 108 | 143 | 184 | 196 | 206 | 177 | 143 | 106 | 47 | 55 | 1534 |
| Date | 64 | 78 | 114 | 151 | 195 | 208 | 218 | 187 | 151 | 111 | 78 | 59 | 1614 |
| Grape | -- | -- | 32 | 76 | 130 | 162 | 169 | 135 | 95 | 55 | 30 | -- | 881 |
| Olive | 43 | 52 | 76 | 101 | 130 | 139 | 145 | 125 | 101 | 75 | 52 | 39 | 1078 |

**Table 14. Summer crop water requirements (mm) for North Tahrir.**

| Crop | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cowpea: dry | | | | 102 | 202 | 254 | 165 | | | | | | 723 |
| fodder | | | | 50 | 158 | 125 | | | | | | | 373 |
| | | | | | 65 | 169 | 131 | | | | | | 365 |
| | | | | | | 69 | 177 | 122 | | | | | 358 |
| Cucumber | | | | 104 | 180 | 208 | 97 | | | | | | 589 |
| Eggplant | | | | 108 | 195 | 231 | 237 | 88 | | | | | 897 |
| Maize: grain | | | | | 60 | 171 | 264 | 214 | 57 | | | | 766 |
| fodder | | | 35 | 124 | 237 | | | | | | | | 396 |
| | | | | 46 | 161 | 252 | | | | | | | 459 |
| | | | | | 60 | 171 | 264 | | | | | | 459 |
| | | | | | | 64 | 179 | 227 | | | | | 470 |
| | | | | | | | 67 | 154 | 183 | | | | 404 |
| Peanut | | | | 50 | 132 | 173 | 230 | 208 | 136 | | | | 929 |
| Pepper | | | | 94 | 187 | 254 | 240 | | | | | | 777 |
| Potato | | | | | | | | 106 | 150 | 135 | 33 | | 424 |
| Sorghum: fodder | | | | 46 | 161 | 252 | | | | | | | 459 |
| | | | | | 60 | 171 | 264 | | | | | | 495 |
| | | | | | | 46 | 179 | 227 | | | | | 470 |
| Soybean | | | | | | 67 | 154 | 183 | | | | | 404 |
| Sunflower | | | | | 115 | 213 | 254 | 210 | 53 | | | | 845 |
| Squash | | | | 46 | 158 | 252 | 254 | 63 | | | | | 775 |
| Sweet corn | | | | 101 | 167 | 208 | 189 | 78 | | | | | 743 |
| Tomato | | | | | 40 | 155 | 259 | 225 | | | | | 679 |
| Watermelon | | | | | | 129 | 208 | 229 | 150 | | | | 716 |
| Sweet melon | | | | 94 | 169 | 219 | 206 | -- | | | | | 688 |

**Table 15. Winter and perennial crop water requirements (mm) for West Nubaria.**

| Crop | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barley | 91 | 117 | 174 | 214 | 130 | | | | | | 27 | 56 | 809 |
| Berseem | 91 | 111 | 166 | 221 | 137 | | | | | 122 | 104 | 58 | 1,037 |
| Cabbage | 87 | 106 | 71 | | | | | | | 39 | 63 | 77 | 443 |
| Carrot | 91 | 110 | 68 | | | | | | | 40 | 71 | 81 | 461 |
| Cauliflower | 37 | 106 | 71 | | | | | | | 39 | 63 | 77 | 443 |
| Flax | 90 | 11 | 161 | 109 | | | | | | | 55 | 60 | 586 |
| Horse bean: dry | 91 | 25 | | | | | | | | 43 | 77 | 88 | 324 |
| green | 42 | | | | | | | | | 43 | 77 | 88 | 250 |
| Lentil: dry | 96 | 109 | 58 | | | | | | | 80 | 86 | 89 | 545 |
| Onion | 63 | 114 | 153 | 89 | | | | | | | | 20 | 539 |
| Pea: dry | 95 | 69 | | | | | | | | 43 | 70 | 87 | 364 |
| green | 94 | | | | | | | | | 43 | 70 | 87 | 294 |
| Potato | 24 | 71 | 169 | 204 | | | | | | | | | 468 |
| | 95 | 45 | | | | | | | | | 59 | 75 | 274 |
| Squash | 77 | 40 | | | | | | | | 40 | 61 | 70 | 288 |
| Spinach | | | | | | | | | | 43 | 76 | 76 | 195 |
| Sugar beet | 96 | 112 | 120 | | | | | | | 43 | 69 | 85 | 525 |
| Tomato | 53 | 93 | 174 | 187 | | | | | | | | | 507 |
| Alfalfa | 91 | 117 | 174 | 214 | 130 | | | | | | 27 | 65 | 809 |
| Almond/pear | 83 | 101 | 150 | 200 | 247 | 279 | 286 | 265 | 197 | 136 | 94 | 77 | 2,115 |
| Plum | -- | -- | 134 | 200 | 273 | 338 | 346 | 321 | 228 | 129 | 84 | -- | 2,053 |
| Citrus | 78 | 95 | 134 | 179 | 221 | 250 | 256 | 237 | 176 | 122 | 84 | 69 | 1,901 |
| Date | 78 | 95 | 142 | 189 | 234 | 265 | 271 | 251 | 186 | 129 | 89 | 73 | 2,002 |
| Grape | -- | -- | 40 | 95 | 156 | 206 | 211 | 181 | 114 | 64 | 25 | -- | 1,102 |
| Olive | 47 | 64 | 95 | 126 | 156 | 176 | 181 | 167 | 124 | 86 | 59 | 49 | 1,330 |

**Table 16. Summer crop water requirements (mm) for West Nubaria.**

| Crop | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cowpea: dry | | | | 129 | 242 | 323 | 205 | | | | | | 889 |
| fodder | | | | 63 | 190 | 159 | | | | | | | 412 |
| | | | | | 78 | 216 | 163 | | | | | | 457 |
| | | | | | | 88 | 220 | 151 | | | | | 459 |
| Cucumber | | | | 130 | 216 | 265 | 121 | | | | | | 732 |
| Eggplants | | | 48 | 134 | 234 | 294 | 295 | 119 | | | | | 1,124 |
| Maize: grain | | | | | 72 | 218 | 328 | 287 | 71 | | | | 976 |
| fodder | | | 44 | 155 | 283 | | | | | | | | 482 |
| | | | | 58 | 192 | 320 | | | | | | | 570 |
| | | | | | 72 | 218 | 328 | | | | | | 618 |
| | | | | | | 81 | 223 | 304 | | | | | 608 |
| | | | | | | | 83 | 206 | 226 | | | | 515 |
| Peanut | | | | 63 | 159 | 221 | 286 | 279 | 168 | | | | 1,176 |
| Pepper | | | | 118 | 224 | 323 | 301 | | | | | | 966 |
| Potato | | | | | | | | 142 | 184 | 156 | 42 | | 524 |
| Sorghum: fodder | | | | 58 | 192 | 320 | | | | | | | 570 |
| | | | | | 72 | 218 | 328 | | | | | | 618 |
| | | | | | | 81 | 223 | 304 | | | | | 608 |
| Soybean | | | | | | | 83 | 206 | 226 | | | | 515 |
| Sunflower | | | | | 138 | 271 | 316 | 282 | 65 | | | | 1,072 |
| Squash | | | | 58 | 190 | 321 | 316 | 85 | | | | | 970 |
| Sweet corn | | | | 126 | 200 | 265 | 262 | 105 | | | | | 958 |
| Tomato | | | | | 48 | 197 | 322 | 301 | | | | | 868 |
| Watermelon | | | | | | 165 | 259 | 307 | 184 | | | | 915 |
| Sweet melon | | | | 118 | 203 | 279 | 256 | -- | -- | | | | 856 |

**Table 17. Irrigation water requirement for field crops in the New Lands ($m^3$/fed).**

| Crop | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alfalfa | 326 | 532 | 782 | 935 | 1,176 | 1,349 | 1,355 | 1,265 | 759 | 759 | 423 | 319 | 9,980 |
| Cotton | -- | -- | 74 | 271 | 525 | 1,024 | 906 | 724 | 348 | -- | -- | -- | 3,870 |
| Maize | -- | -- | -- | 132 | 377 | 826 | 978 | 3,923 | -- | -- | -- | -- | 2,704 |
| Soybean | -- | -- | 90 | 334 | 796 | 885 | 685 | 132 | -- | -- | -- | -- | 2,920 |
| Sunflower | -- | -- | -- | 220 | 570 | 919 | 868 | 154 | -- | -- | -- | -- | 2,730 |
| Groundnut | -- | -- | -- | -- | 397 | 813 | 1067 | 951 | 334 | -- | -- | -- | 3,562 |
| Onion | -- | 74 | 243 | 505 | 681 | 432 | -- | -- | -- | -- | -- | -- | 1,935 |
| Clover beet | 206 | 426 | 576 | 768 | 893 | 286 | -- | -- | -- | 65 | 123 | 106 | 3,448 |
| Flax | -- | -- | -- | -- | 223 | 534 | 779 | 115 | 961 | 666 | -- | -- | 4,309 |
| Sesame | -- | -- | -- | 48 | 376 | 1,020 | 1,173 | 501 | -- | -- | -- | -- | 3,118 |
| Barley | 134 | 330 | 522 | 434 | -- | -- | -- | -- | -- | -- | -- | 65 | 1,483 |
| Wheat | 130 | 475 | 638 | 773 | -- | -- | -- | -- | -- | -- | 98 | 89 | 2,153 |
| Sorghum | -- | -- | -- | -- | 180 | 533 | 1,131 | 962 | 217 | -- | -- | -- | 3,023 |

At Ismailia (sandy soil), El Sebsy (1993) found that seasonal ET for wheat ranged from 435.79 to 444.99 mm. Periodical ET increased during the last 6 days of crop establishment and during the first 4 days of the early vegetative growth period. The maximum ET was during the 10 days of crop formation, and the lowest value was during the week of crop ripening.

The water consumed by wheat on calcareous soil at Fayoum was 39.3 and 40.0 cm in 1991/92 and 1992/93, respectively (Yousef and Eid 1994).

Using a sprinkler irrigation system at El Bustan (sandy soil), Emara (1992) compared the effect of conventional (C) and evaporation pan (E) methods on wheat yield and water-use efficiency. Seasonal ET values were 534 and 585 mm for the E and C methods, respectively. The results show that scheduling sprinkler irrigation with evaporation pan enables efficient and adequate irrigation with savings in energy, water, and fertilizers in sandy soils.

## Actual Crop Water Use and Water-use Efficiency

### *Cereal crops*

#### *Wheat*

Eid *et al.* (1987) found that water evapotranspiration of wheat was 417 mm, with 0.62 seasonal Kc at Nubaria. Wheat was planted on 15 November and harvested on 1 June. But actual ET for the area was 296.8 mm (Irrigation Department 1988).

Sprinkler irrigation (Ministry of Agriculture 1989) at Nubaria showed that the water requirement for wheat varies between 2200 and 2400 $m^3$/fed during the growing season. Since the overall efficiency of the sprinkler system is 70%, that means the gross amount of water applied to the field should be increased by 30%. In areas with sandy soil, the number of irrigations can reach 24 between mid-November and the end of April. The following table shows the number of irrigations, intervals, time of application, and amount of water applied during different stages of growth.

| Stages of growth | Period | No. of irrigations | Interval (days) | Irrigation time (hours) | Amount ($m^3$/fed) |
|---|---|---|---|---|---|
| Sowing and seedling | 15–20/11 | 1 | - | 4.0 | 180 |
| Vegetative growth (3 leaves) | Dec | 2 | 15 | 2.5 | 225 |
| Tillering | Jan | 2 | 15 | 3.0 | 270 |
| Heading | Feb | 6 | 5 | 3.0 | 810 |
| Seed formation (milk) | Mar | 7 | 4 | 3.0 | 945 |
| Ripening (dough) | Apr | 6 | 5 | 3.0 | 810 |

#### *Barley*

At Nubaria, irrigation frequencies of 2, 4, 6, 8, and 10 bar water suction in addition to rainfall dependent, resulted in water consumptive use of 36.52, 29.88, 27.45, 26.08, and 19.44 cm, respectively (Irrigation Department 1988).

### *Legumes*

#### *Faba bean*

According to Kaoud *et al.* (1988), water consumptive-use values were 257 and 316 mm/season for sprinkler and flood irrigation systems, respectively.

Four on–off cycles of surge flow irrigation were suggested: (i) continuous flow; (ii) a 10 minute cycle; (iii) a 15 minute cycle; and (iv) a 20 minute cycle. At Abis (clay soil), Osman

(1991) obtained water consumptive use values of 26.35, 23.3, 22.9, and 22.74 cm for the above treatments, respectively.

Abbas *et al.* (1994) on the calcareous soil of Nubaria obtained 31.8 cm water consumptive use for faba bean.

In the extreme desert of southwest Egypt, Schneider (1991) reported that the General Petroleum Company had in 1984 started to utilize 21,000 fed (8,823 ha) in the area for agricultural purposes by using intensive irrigation. He investigated *Alhagi manifera*. *Phragmites oustralis* and *Tamarif nilotica* grown in an oasis, and *Medicago sativa* and *Vicia faba*, grown at an agricultural station, for their water consumption. Mature stands of *V. faba* in March showed a water consumption of 9.0 mm/day. Estimates of total water used showed a mean range of 600–700 mm per growth cycle.

### *Lentil*

On sandy soil at Ismailia, El Rayes (1990) found that lentil varieties (Giza 9, Giza 47, and NEL 231) had higher seed yields at 60% soil moisture depletion than at either 40 or 80% available soil moisture depletion. These soil moisture levels resulted in consumed water at 50.6, 41.0, and 35.4 cm depths and numbers of irrigation of 23, 17, and 12 for 40, 60, and 80% available soil moisture depletion, respectively.

### *Chickpea*

A field study was conducted at the Nubaseed company farm by Kaloush *et al.* (1987) to determine the response of 13 chickpea cultivars to different water stress levels. The variable levels of water stress were provided by a decreasing gradient of water through a line-source sprinkler system. The water applied decreased linearly with increasing distance from the line. Seed yield, biological yield (straw + seed), and harvest index were determined. Seed yield of the 13 varieties was affected by the amount of water applied. Seed yield increased significantly, from 1,302 to 2,126 kg/ha, as water was increased from 4.8 to 13.2 cm. There was a non-significant increase of mean seed yield from 2,126 to 2,416 kg/ha with increased water from 13.2 to 19.8 cm. Statistical analysis of the results showed no significant differences among cultivars in seed yield but significant differences in harvest index. Crop water-use efficiency is summarized in Table 18.

**Table 18. Water-use efficiency (WUE) for field crops in the New Lands.**

| Crop | Irrigation system | Yield (t/fed) | Irrigation requirements ($m^3$/fed) | WUE (kg/$m^3$) |
|---|---|---|---|---|
| Alfalfa | Sprinkler (fixed) | – | 9980 | - |
| Berseem | Sprinkler (fixed) | – | 4355 | – |
| Cotton | Drip | – | 3872 | – |
| Maize | Drip-sprinkler | 2.03 | 4100 | 0.50 |
| Soybean | Sprinkler | 1.51 | 4502 | 0.34 |
| Sunflower | Drip-sprinkler | 0.50 | 4074 | 0.12 |
| Groundnut | Drip-sprinkler | 0.85 | 6314 | 0.13 |
| Onion | Sprinkler | – | 2264 | – |
| Fodder beet | Sprinkler | - | - – | – |
| Flax | Sprinkler | – | – | – |
| Barely | Sprinkler | – | 1500 | – |
| Wheat | Sprinkler | 1.2 | 2153 | 0.56 |
| Sorghum | Sprinkler | – | 2394 | – |
| Sugar beet | Sprinkler | 16.4 | 2205 | 7.4 |
| Sesame | Sprinkler | 0.46 | 3100 | 0.15 |

Other results of irrigation trials show the following:

- Water-use efficiency for barley was 40.39, 51.81, 51.87, 52.82, 12.35 kg/cm in some irrigation treatments in Nubaria.
- The effect of irrigation system on the water-use efficiency for faba bean showed that:
    - Sprinkler irrigation resulted in 4.67 kg/mm.
    - Furrow irrigation resulted in 3 kg/mm.
    - Surge flow improved WUE more than continuous flow.

## Irrigation and Drainage Problems in the New Lands

Newly reclaimed lands in Egypt differ from the Old Lands in that the farmers are engaged in economic cultivation through national plans which are based on sound scientific studies and ideas. Development of the Old Lands resulted from thousands of years of experience passed on from one generation to the other. Development of land reclamation projects in Egypt, begun intensively in the 1950s, was based on the following steps:

### Planning of available resources

#### *Water resources*

This includes fresh Nile water, rainfall, groundwater, land drainage, treated sewage, and treated industrial wastewater.

#### *Land resources*

Various soil surveys have been carried out to assess the suitability of land for cultivation. The most important survey was completed in the 1960s after the construction of the High Aswan Dam. This was followed by a number of smaller surveys. This effort was crowned in the 1980s by the establishment of the Land Master Plan which introduced criteria for suitability of land for reclamation and established Land Management Categories in five divisions, taking into consideration soil physical characteristics, irrigation method, need for drainage, suitable crops, expected return, agricultural management, type and size of farm, and management procedure (Table 1).

#### *Financial resources*

Land reclamation projects are very costly due to various expenses incurred before the land becomes mature and reaches maximum economic production. Finance of land reclamation projects is therefore in most cases beyond the capability of the government and individuals. The management of local and foreign funds forms an important part of planning in this field.

#### *Human resources*

This includes the build up of well-trained staff in different fields starting from machine operators to top management in engineering, soil, water, agronomy, economics, and sociology. Training also covers different levels from local training based on the experience gained from the implementation of projects to the importation of up-to-date know-how.

#### *Implementation*

Land reclamation projects are a mixture of many activities, including irrigation, drainage, roads, housing, potable water supply, sewage collection and disposal, electricity supply, etc. Coordination between all these activities is a must. For example, if the civil and mechanical work on a pumping station is completed before the electric current not connected, it will be impossible to operate the station and deliver irrigation water.

Land reclamation projects include six stages of implementation:

**Engineering**: Construction of central and service villages, infrastructure (roads, potable water supply, electricity, telephones, etc.).

**Cultivation:** This starts with the improvement of soil properties through leaching, management, control of the groundwater table, adding agricultural gypsum to alkaline soils, adding organic matter to sandy soils, etc. This process is followed by the raising of appropriate crops, which further improves the properties of the soil.

**Economic farming**: This starts when land has reached the production stage. Farming is carried out by public sector companies (which are currently being privatized), investors, cooperative societies and/or disadvantaged members of the community (i.e., university graduates, retired employees, landless farming laborers, etc.).

**Land settlement**: This occurs along with the integrated development of New Lands by owners and users.

**Development**: During this stage the occupiers of the New Lands are helped to overcome the problems they may face, including: acquiring material, marketing farm products, transfer of research results, finding credit services, introducing new seed and fertilizer, etc.

**Assisting agencies**: These are local, central and international organizations concerned with helping new settlers improve their standard of living. Examples of these organizations are: The General Cooperative Society for Reclaimed Lands, the Central Fund for Livestock, World Food Program, etc.

## Irrigation Problems in the New Lands

### *Topography and related problems*

Unlike the Old Lands, the New Lands are characterized by abrupt changes in topography: irregularities in land level and/or steep slopes. This necessitates the lifting of water, land leveling, and the use of modern irrigation systems.

When large-scale water lifting is practiced, as it is in most of the reclamation projects, large pumping stations, generally arranged in a cascade, are used to lift water from low levels to irrigate elevated lands. Because of the complexity of the stations, there are many systems whose failure could cause damage to crops, especially if such failures take place during peak periods.

Land leveling used to be carried out at the early stages of land reclamation projects. When it was realized that the cost of land leveling was close to the cost of installing modern irrigation systems, land leveling was no longer practiced. However, one of the most serious problems of steep slopes and irregular land surfaces is surface run-off, which allows water to run quickly over the surface without sufficient opportunity to infiltrate the soil, and then pond in depressions, causing waterlogging.

### *Tail-end problems*

Land reclamation projects are generally located at the tail ends of irrigation canals which feed the Old Lands. The only exception is the Nubaria Canal, which serves only New Lands projects, although these projects are partially "old" New Lands and partially "new" New Lands.

Generally, land reclamation projects suffer from tail end problems caused by the users at the head of the system taking more than their fair share.

### *Inadequacy of supply*

As concerns the supply of irrigation water, land reclamation projects are treated as if they were projects inside the Nile Valley and Delta. Crop water requirements on the fringes of the Nile Valley and the Delta are different from the interior, since they are affected by the surrounding desert climate, in which temperatures might be higher, reflectivity different, and humidity lower.

### *Inefficiency of conveyance systems*

In most of the reclamation projects in Egypt, canals are concrete-lined in order to reduce seepage. Lining of canals usually takes place ahead of pumping water into the system. Poor curing and severe weather conditions can cause cracks in the lining and leakage on a large scale. Poor quality control of the lining material and on the lining of expansion and construction joints means the concrete does not prevent seepage from the bed and side slopes.

### *Change from modern to surface irrigation*

The rules of the Ministry of Public Works and Water Resources do not allow for the irrigation of New Lands by traditional methods (surface irrigation). However, in most cases settlers realize that the operation, maintenance, and management of modern systems are expensive, and they convert from these systems to surface irrigation.

This process causes inadequacy of supply, inequity of distribution, and increases losses due to the sandy nature of the soil, the steep slope, and the irregular terrain.

### *Soil management*

Unlike the Old Lands, soils in the New Lands are not mature; they need different treatments to reach maximum production levels. This can be done through the addition of animal manure, chemical fertilizers, agricultural gypsum, etc. In some cases the physical properties of the soil need to be improved. For example, the infiltration or intake rate and the permeability may be improved by adding clay to sandy soil. Soil nutrients may be increased by plowing green manure into the soil, which also improves permeability.

### *Night irrigation*

Night irrigation is not practiced in the Old Lands because of severe climatic conditions, especially in winter, but the situation in the New Lands is even worse. In addition to severe weather conditions, night irrigation in the New Lands is not practiced due to the remoteness of these areas.

### *Irrigation and drainage master plan in the New Lands*

Because of the rapid preparation and implementation of land reclamation projects (more than 2 million fed [0.84 million ha] in less than 50 years), the master plan for irrigation and drainage systems needs to be reviewed, analyzed, and improved. This is particularly important in view of the fact that most of these projects depend on the recycling of water through the reuse of drainage water at appreciable quantities.

This master planning is expected to take into consideration other sources of water, i.e., groundwater and rainfall. Special reference should be given to reclaimed areas close to the seashore where the possibility of obtaining moisture through the fall of dew and rain is considered as an important part of supply, especially during the winter season.

### *Winter closure*

Winter closure has some negative effects on the irrigation system in the Old Lands. In the New Lands, this negative effect is much worse. The reason for this is twofold: i) the soil in the New Lands is mostly sandy, and has a low water-holding capacity, becoming dry soon, and ii) reclamation projects lie at the tail end of the irrigation system. When water is opened at the head of the system following the closure, it only reaches the tail end after all the head users are fully satisfied. This makes the duration of the closure period in the New Lands at least 10–15 days longer than in the Old Lands, which causes severe damage to sensitive crops and to crops grown in extremely coarse-textured soils.

### Drainage Problems in the New Lands

Because of the high elevation of most of the newly reclaimed areas, drainage was originally considered of minimum importance. However, the rapid rise of the groundwater table in some locations has resulted in both official and non-official awareness of the importance of drainage in the New Lands. Drainage problems in the New Lands can be summarized as follows:

- At the beginning of the reclamation program, surface-irrigated areas were designed with open drainage systems which ended with widely-spaced field drains (100 m in some cases). Farmers tended to fill these drains in order to increase their cultivated land. Gradual increase in the groundwater table caused severe waterlogging in some locations (e.g., Mechanized Farm in the West Nubaria Project).
- In areas in which modern methods were changed to surface methods, drainage systems were essential to crops, with surplus water resulting in on-farm and operational losses. The absence of drainage systems caused the groundwater table to rise, resulting in waterlogging and salinity build-up.
- Because of the high elevation of the New Lands and the low elevation of the neighboring Old Lands, and due to the change of irrigation systems in the New Lands, severe waterlogging and inundation has been observed in the Radisia, Wadi Abbadi, Tahta, West Samalut, and West Fashn projects. These projects are located in Aswan, Sohag, Minia, and Beni Sueif Governorates. The reason for this phenomenon was seepage from the elevated New Lands to the low-lying Old Lands, which confirmed the need to stick to the modern irrigation system in the New Lands.
- Drainage systems are not only needed to control the groundwater table, but for salinity control as well. If this is true for the Old Lands, it is particularly true in the New Lands, where most soils are saline and include soluble salts that need to be leached during the reclamation process. Leached salts should not be allowed to percolate downwards to contaminate the groundwater aquifer. They should be allowed to leave the soil system and be flushed from the system.
- Drainage of tail end areas is of particular importance in case of unexpected storms, when many farmers refrain from irrigating, and water in the main and secondary canals is diverted to the nearest drain. Over-topping of drains under these circumstances is possible, and might cause inundation of low-lying lands. Forecast and early warning systems could be implemented as preventive measures.

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**Annex 1. Measured climatological data for North Tahrir Station.**

| Month | Year | Air temperature (°C) | | | Soil temperature (°C) | | | Humidity (%) | | | Class A | Sunshine | Rainfall | Wind |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. | Mean | (mm/day) | (hours/day) | (mm/mo) | (m/s) |
| January | 1976 | 8.0 | 17.1 | 12.6 | 11.7 | 13.02 | 12.4 | | | 66.0 | 1.4 | 6.0 | 9.5 | 1.9 |
| | 1977 | 8.6 | 18.5 | 13.6 | 12.5 | 14.1 | 13.3 | 88.7 | 87.6 | 72.8 | 1.8 | 5.4 | 34.0 | 1.5 |
| | 1978 | 7.6 | 17.7 | 12.7 | 11.3 | 12.5 | 11.9 | 55.9 | 87.6 | 72.5 | 2.0 | 6.1 | 30.0 | 1.9 |
| February | 1976 | 8.2 | 16.8 | 12.5 | 11.8 | 13.2 | 12.5 | | | 65.0 | 2.4 | 5.4 | 10.5 | 1.9 |
| | 1977 | 8.9 | 21.6 | 15.3 | 13.6 | 15.1 | 14.4 | 50.0 | 90.3 | 69.1 | 3.1 | 7.6 | 10.5 | 1.6 |
| | 1978 | 8.5 | 21.4 | 15.0 | 13.6 | 15.3 | 14.5 | 43.6 | 87.7 | 65.7 | 3.2 | 7.6 | 0.8 | 1.9 |
| March | 1976 | 9.4 | 20.5 | 15.0 | 14.3 | 16.0 | 15.2 | | | 65.0 | 4.3 | 6.6 | 16.5 | 2.3 |
| | 1977 | 9.8 | 20.2 | 15.0 | 14.3 | 16.0 | 15.2 | 55.3 | 91.1 | 72.6 | 6.1 | 7.6 | 46.9 | 1.9 |
| | 1978 | 9.9 | 22.3 | 16.1 | 16.0 | 17.7 | 16.9 | 45.1 | 86.3 | 67.3 | 4.1 | 7.5 | 3.5 | 2.0 |
| April | 1976 | 12.6 | 24.7 | 18.7 | 17.4 | 19.2 | 18.3 | | | 60.0 | 5.8 | 7.4 | 3.5 | 2.2 |
| | 1977 | 13.4 | 24.8 | 19.1 | 18.5 | 20.3 | 19.4 | 41.7 | 79.4 | 59.6 | 5.6 | 8.3 | 0.5 | 2.1 |
| | 1978 | 11.7 | 26.3 | 19.0 | 18.7 | 20.6 | 19.7 | 42.7 | 85.5 | 65.2 | 5.6 | 8.8 | 0.3 | 2.0 |
| May | 1976 | 15.9 | 28.7 | 22.3 | 20.6 | 22.5 | 21.6 | | | 60.0 | 6.7 | 8.6 | 4.5 | 2.3 |
| | 1977 | 16.0 | 29.8 | 22.9 | 20.9 | 23.0 | 22.0 | 41.1 | 85.1 | 61.5 | 6.6 | 9.1 | 1.0 | 1.8 |
| | 1978 | 15.0 | 31.0 | 23.0 | 22.7 | 24.8 | 23.7 | 38.9 | 85.1 | 62.9 | 7.3 | 9.8 | 0.2 | 2.0 |
| June | 1976 | 17.0 | 29.0 | 23.0 | 22.0 | 24.0 | 23.0 | | | 65.0 | 7.3 | 10.6 | 0 | 1.9 |
| | 1977 | 18.5 | 31.2 | 24.8 | 24.0 | 25.9 | 25.0 | 47.5 | 86.6 | 67.4 | 8.9 | 10.1 | 0.5 | 1.9 |
| | 1978 | 18.3 | 30.5 | 24.4 | 24.0 | 27.0 | 25.5 | 49.4 | 83.2 | 65.9 | 5.9 | 10.4 | 0 | 1.8 |
| July | 1976 | 19.6 | 30.4 | 25.0 | 24.8 | 26.8 | 25.9 | | | 67.0 | 7.6 | 10.7 | 0 | 1.7 |
| | 1977 | 21.1 | 31.5 | 26.3 | 26.1 | 28.0 | 27.1 | 51.8 | 86.9 | 69.4 | 7.3 | 10.5 | 0.5 | 1.7 |
| | 1978 | 20.3 | 31.8 | 26.0 | 26.3 | 28.2 | 27.2 | 48.4 | 84.8 | 68.4 | 6.9 | 10.6 | 0.8 | 1.7 |
| August | 1976 | 19.4 | 29.2 | 24.3 | 24.5 | 26.4 | 25.5 | | | 71.0 | 7.0 | 10.4 | 0 | 1.8 |
| | 1977 | 20.0 | 32.1 | 26.1 | 26.6 | 28.5 | 27.5 | 49.1 | 88.2 | 68.8 | 6.5 | 10.2 | 0.7 | 1.5 |
| | 1978 | 18.8 | 30.2 | 24.5 | 25.3 | 26.9 | 26.1 | 55.8 | 82.5 | 70.4 | 6.8 | 10.2 | 0.4 | 1.6 |
| September | 1976 | 17.0 | 29.1 | 23.0 | 23.6 | 25.1 | 24.3 | | | 67.0 | 5.6 | 9.1 | 0 | 1.5 |
| | 1977 | 17.1 | 30.7 | 24.1 | 24.8 | 26.5 | 25.7 | 51.0 | 89.7 | 69.3 | 5.9 | 9.0 | 0.5 | 1.5 |
| | 1978 | 16.5 | 30.0 | 23.3 | 23.4 | 25.1 | 24.3 | 53.6 | 92.0 | 73.0 | 6.0 | 9.0 | 5.7 | 1.4 |
| October | 1976 | 16.0 | 28.5 | 22.2 | 21.1 | 22.6 | 21.9 | | | 68.0 | 4.2 | 7.8 | 2.5 | 1.6 |
| | 1977 | 14.4 | 26.1 | 20.3 | 21.9 | 23.4 | 22.7 | 53.6 | 86.5 | 70.4 | 3.7 | 7.7 | 6.9 | 1.4 |
| November | 1976 | 11.9 | 22.6 | 17.2 | | | | | | 63.5 | | 5.2 | 0 | 1.5 |
| | 1977 | 12.8 | 24.4 | 18.6 | | | | | 87.6 | 71.0 | 3.3 | 6.1 | 22.0 | 1.5 |
| | 1978 | 11.3 | 25.1 | 18.2 | 17.4 | 18.9 | 48.1 | 48.1 | 89.0 | 68.6 | 2.6 | 6.8 | 0.5 | 1.2 |
| December | 1976 | 9.7 | 18.3 | 13.6 | 13.6 | 14.5 | | | | 71.0 | 2.0 | 4.7 | 49.5 | 1.4 |
| | 1977 | 9.3 | 20.2 | | | | | | 85.4 | 71.0 | 2.0 | 6.1 | 4.0 | 1.4 |
| | 1978 | 9.3 | 19.3 | 13.5 | 13.5 | 14.4 | 56.4 | 56.4 | 86.9 | 72.3 | 2.6 | 5.9 | 5.5 | 1.8 |

**Annex 2. Mean monthly climatological data for North Tahrir Station, 1976–1978.**

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean air temp. (°C) | 13.0 | 14.3 | 15.4 | 18.9 | 22.7 | 24.1 | 25.8 | 25.0 | 23.5 | 21.2 | 18.4 | 14.6 |
| Mean humidity (%) | 70 | 67 | 68 | 62 | 61 | 66 | 68 | 70 | 70 | 69 | 70 | 72 |
| Class A (mm/day) | 1.7 | 2.9 | 4.8 | 5.7 | 6.9 | 7.4 | 7.3 | 6.8 | 5.8 | 4.0 | 30 | 2.3 |
| Sunshine (hrs/day) | 5.8 | 6.9 | 7.2 | 2.8 | 9.2 | 10.4 | 10.6 | 10.3 | 9.0 | 7.8 | 65 | 6.0 |
| Rainfall (mm/month) | 24.5 | 7.3 | 22.3 | 1.4 | 1.9 | 0.2 | 0.4 | 0.4 | 2.1 | 4.7 | 11.3 | 4.8 |
| Wind (m/sec) | 1.8 | 1.8 | 2.1 | 2.1 | 2.0 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.4 | 1.6 |

**Annex 3. Measured climatological data for the Nubaseed Station (West Nubaria).**

| Month | Year | Air temperature (°C) | | | Soil temperature (°C) | | | Humidity (%) | | | Class A | Sunshine | Rainfall | Wind |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. | Mean | (mm/day) | (hours/day) | (mm/mo) | (m/s) |
| January | 1976 | 7.5 | 17.8 | 12.7 | 12.9 | 15.7 | 14.3 | | | 57.0 | 0.94 | 7.3 | 0 | 2.7 |
| | 1977 | 8.2 | 18.0 | 13.1 | | | | 49.1 | 91.2 | 71.3 | 3.7 | 5.8 | 7.8 | 2.6 |
| | 1978 | 8.8 | 18.2 | 13.5 | 12.0 | 16.4 | 14.2 | 51.0 | 76.4 | 63.6 | 2.3 | 6.1 | 14.5 | 3.1 |
| February | 1976 | 8.1 | 17.4 | 12.8 | 13.8 | 15.7 | 14.8 | | | 70.7 | 3.2 | 5.5 | 5.5 | 3.1 |
| | 1977 | 9.1 | 20.7 | 14.9 | | | | 35.6 | 87.4 | 62.2 | 3.6 | 7.8 | 9.5 | 3.0 |
| | 1978 | 9.6 | 21.9 | 15.7 | 14.6 | 21.0 | 17.8 | 36.6 | 77.5 | 55.3 | 3.0 | 7.9 | 0 | 3.0 |
| March | 1976 | 10.3 | 21.6 | 15.9 | 17.2 | 19.7 | 18.5 | | | 59.7 | 5.3 | 7.2 | 3.5 | 3.6 |
| | 1977 | 10.1 | 20.4 | 15.3 | | | | 41.6 | 85.4 | 66.1 | 4.5 | 8.2 | 24.5 | 3.3 |
| | 1978 | 10.4 | 23.1 | 16.8 | 17.7 | 22.8 | 20.3 | 37.0 | 80.0 | 54.8 | 5.7 | 6.3 | 1.0 | 3.3 |
| April | 1976 | 14.1 | 26.5 | 20.3 | 21.7 | 24.1 | 22.9 | | | 55.5 | 7.6 | 8.1 | 1.5 | 3.5 |
| | 1977 | 13.7 | 25.3 | 19.5 | | | | 35.6 | 79.8 | 56.7 | 6.2 | 8.2 | 0 | 3.6 |
| | 1978 | 13.1 | 27.5 | 20.3 | 21.2 | 25.7 | 23.5 | 29.9 | 77.5 | 49.5 | 7.5 | 8.4 | 0 | 3.1 |
| May | 1976 | 17.0 | 30.5 | 23.8 | 23.8 | 26.7 | 25.2 | | | 56.6 | 8.2 | 8.9 | 8.5 | 3.5 |
| | 1977 | 16.5 | 31.0 | 23.8 | | | | 33.0 | 80.7 | 56.0 | 8.9 | 9.2 | 4.0 | 3.2 |
| | 1978 | 16.2 | 31.9 | 24.1 | 24.9 | 29.9 | 27.4 | 27.6 | 72.5 | 46.4 | 9.7 | 9.7 | 0 | 3.3 |
| June | 1976 | 18.3 | 31.1 | 24.7 | 24.9 | 28.6 | 26.7 | | | 56.9 | 8.6 | 11.1 | 0 | 3.2 |
| | 1977 | 19.2 | 34.5 | 26.9 | | | | 32.1 | 80.1 | 53.5 | 9.2 | 10.5 | 1.0 | 3.2 |
| | 1978 | 18.6 | 31.5 | 25.1 | 27.6 | 37.3 | 30.0 | 31.3 | 72.6 | 48.2 | | 11.3 | 0 | 3.1 |
| July | 1976 | 20.3 | 32.2 | 26.3 | 26.2 | 29.8 | 28.0 | | | 56.8 | 8.6 | 11.3 | 0 | 3.0 |
| | 1977 | 20.1 | 33.9 | 27.0 | | | | 35.2 | 83.4 | 56.6 | | 10.4 | 0 | 3.2 |
| | 1978 | 20.7 | 32.9 | 26.8 | 29.5 | 33.7 | 31.6 | 31.3 | 69.6 | 46.8 | | 11.2 | 0 | 3.1 |
| August | 1976 | 19.2 | 30.2 | 24.7 | 27.9 | 30.7 | 29.3 | | | 69.3 | 8.1 | 10.8 | 0 | 3.3 |
| | 1977 | 18.9 | 33.4 | 26.1 | 29.0 | 35.4 | 32.2 | 37.7 | 85.4 | 60.4 | | 10.5 | 0 | 2.8 |
| | 1978 | 19.0 | 31.3 | 25.2 | 28.5 | 32.7 | 30.6 | 37.0 | 73.5 | 53.6 | | 11.2 | 0 | 2.8 |
| September | 1976 | 18.3 | 30.0 | 24.3 | 26.4 | 29.4 | 27.9 | | | 66.3 | 6.3 | 9.4 | 0 | 2.8 |
| | 1977 | 18.8 | 31.6 | 25.2 | 28.0 | 33.2 | 30.6 | 42.4 | 82.5 | 61.1 | | 9.6 | 0 | 2.5 |
| | 1978 | 17.5 | 31.2 | 24.4 | 25.8 | 31.1 | 28.5 | 34.9 | 73.9 | 56.5 | | 9.8 | 0 | 2.3 |
| October | 1976 | 16.9 | 28.5 | 22.6 | 25.0 | 27.3 | 26.1 | | | 66.8 | 6.1 | 7.5 | 0 | 2.9 |
| | 1977 | 15.4 | 26.9 | 21.1 | 23.8 | 28.4 | 26.1 | 43.0 | 80.0 | 62.1 | | 6.7 | 0 | 2.5 |
| November | 1976 | 13.2 | 23.9 | 18.5 | 22.5 | 24.6 | 23.6 | | | 70.2 | 4.4 | 6.1 | 10.5 | 3.0 |
| | 1977 | 12.5 | 25.4 | 18.9 | 19.8 | 23.7 | 21.8 | 42.1 | 83.5 | 61.7 | 3.7 | 7.3 | 0 | 2.1 |
| December | 1976 | 80.8 | 20.6 | 14.5 | | | | | | 73.0 | 2.9 | 6.5 | 1.0 | 2.5 |
| | 1977 | 9.4 | 18.5 | 14.0 | | | | 48.2 | 78.8 | 64.3 | | 7.3 | 34.5 | 3.0 |

**Annex 4. Mean monthly climatological data for West Nubaria Station.**

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean air temp. (°C) | 13.1 | 14.5 | 16.0 | 20.0 | 23.9 | 25.6 | 26.7 | 25.3 | 24.6 | 21.9 | 18.7 | 14.3 |
| Mean humidity (%) | 64 | 63 | 60 | 54 | 53 | 53 | 53 | 61 | 61 | 64 | 66 | 70 |
| Class A (mm/day) | 2.3 | 3.3 | 5.2 | 7.1 | 8.9 | 8.9 | -- | -- | -- | -- | 4.1 | -- |
| Sunshine (hrs/day) | 6.4 | 7.1 | 7.2 | 8.2 | 9.3 | 11.0 | 11.0 | 10.8 | 9.6 | 7.1 | 6.7 | 6.9 |
| Rainfall (mm/month) | 7.4 | 5.0 | 9.7 | 0.5 | 4.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 5.3 | 17.8 |
| Wind (m/sec) | 2.8 | 3.0 | 3.4 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.5 | 2.7 | 2.6 | 2.8 |

**Annex 5. Measured climatological data for Maryut Station.**

| Month | Year | Air temperature (°C) | | | Soil temperature (°C) | | | Humidity (%) | | | Class A (mm/day) | Sunshine (hours/day) | Rainfall (mm/month) | Wind (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. | Mean | | | | |
| January | 1978 | | | | | | | | | | | | | |
| February | 1978 | 8.1 | 20.2 | 14.2 | 7.7 | 8.3 | 8.0 | 37.5 | 81.0 | 62.1 | 5.0 | 7.8 | 1.5 | 2.8 |
| March | 1978 | 9.9 | 21.3 | 15.6 | 9.6 | 10.1 | 9.9 | 47.6 | 77.2 | 63.0 | 4.9 | 7.8 | 9.3 | 3.4 |
| April | 1978 | 11.3 | 24.9 | 18.1 | 12.0 | 12.6 | 12.3 | 43.2 | 79.1 | 63.2 | 7.3 | 6.5* | 0.5 | 2.9 |
| May | 1978 | 14.1 | 28.7 | 21.4 | 15.8 | 15.8 | 15.8 | 45.0 | 83.3 | 65.8 | 9.2 | 9.6 | 0.5 | 3.1 |
| June | 1978 | 17.3 | 28.5 | 22.9 | 17.7 | 18.3 | 18.0 | 49.8 | 83.1 | 67.3 | 10.9 | 6.4* | 1.0 | 3.0 |
| July | 1978 | 20.0 | 29.9 | 25.0 | 19.9 | 20.3 | 20.1 | 55.1 | 83.6 | 61.0 | 11.1 | 9.2 | 1.5 | 2.8 |
| August | 1978 | 18.7 | 28.3 | 23.5 | 19.1 | 19.3 | 19.2 | 58.9 | 83.7 | 73.1 | 11.0 | 11.2 | 1.0 | 3.0 |
| September | 1978 | 15.9 | 28.1 | 22.0 | 17.3 | 17.3 | 17.6 | 60.4 | 88.6 | 75.6 | 9.7 | 8.7 | 0.5 | 2.5 |
| October | 1978 | | | | | | | | | | | | | |
| November | 1978 | | | | | | | | | | | | | |
| December | 1978 | | | | | | | | | | | | | |