IMPACTS OF THE IRRIGATION IMPROVEMENT PROJECT, EGYPT
Part 2 of 3: Technical information

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1. ABBREVIATIONS USED

IAS	Irrigation Advisory Service, IIS
AAP	Egyptian-Dutch Advisory Panel Project on Water Management and Drainage, NWRC
APRP	Agricultural Policy Reform Program, MPWWR and MALR
DRI	Drainage Research Institute, NWRC
EPADP	Egyptian Public Authority for Drainage Projects, MPWWR
EPIC	Environmental Policy and Institutional Strengthening Indefinite Quantity Contract, APRP
EWUP	Egyptian Water Use Management Project
ICID	International Commission on Irrigation and Draiage
IIS	Irrigation Improvement Sector, MPWWR
IIP	Irrigation Improvement Project, IIS
MALR	Ministry of Agriculture and Land Reclamation
MPWWR	Ministry of Public Works and Water Resources
NWRC	National Water Research Center, MPWWR
RDI	Reform, Design and Implementation Unit, APRD
RIGW	Research Institute for Ground Water, NWRC
USAID	United States Agency for International Development
WDMRI	Water Distribution ad Management Research Institute, NWRC
M&E	Monitoring and Evaluation
O&M	Operation and Maintenance
WUA	Water Users Association

2. GENERAL DATA ON IRRIGATION AND DRAINAGE IN EGYPT

2.1. Water and salt balances

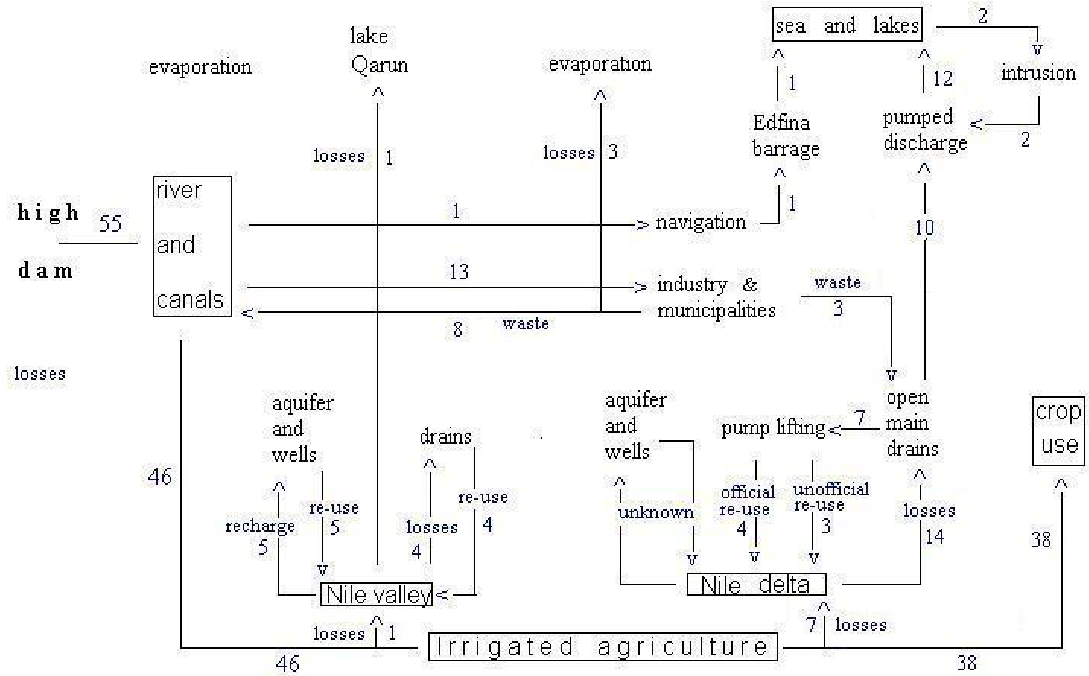
2.1.1. Irrigation

Apart from natural groundwater supplies in oases and the limited rainfall along the Mediterranean coast, agriculture in Egypt is entirely dependent on surface irrigation with waters from the river Nile.

The construction of the High Dam at Aswan in Upper Egypt close to the border with Sudan, completed around 1968, had a great impact on the irrigation and drainage situation in Egypt. On the one hand it increased the availability of irrigation water to some 46 billion m^3 per year. On the other hand, the intensified irrigation has led to a rise of water tables, drainage problems, and an increased salt import into the agricultural lands.

The availability of irrigation water (fig. 1) is determined as follows:
1 - The High Dam releases annually about 55 billion m^3 per year;
2 - Un-beneficial evaporation losses from Egypt’s extensive river and irrigation canal system are about 3 billion m^3 per year;
3 - Industrial water use is around 8 billion m^3 per year, of which some 1 billion m^3 per year evaporates, 1 billion m^3 per year is pumped into the sea, and some 6 billion m^3 per year returns to the surface water and can be re-used for irrigation;
4 - Municipal water use is more or less 5 billion m^3 per year, of which some 2 billion m^3 per year evaporates, and some 2 billion m^3 per year returns to the surface waters and can be re-used for irrigation;
5 - Escape losses from the Edfina barrage at the downstream end of the Rosetta branch of the river Nile into the sea, in relation to shipping requirements and the closure period of the irrigation for maintenance, are presently close to 1 billion m^3 per year;
6 - The availability of irrigation water results from the balance of the above quantities: 46 billion m^3 per year.

The data used are essentially derived from Dr. Bayoumi et al., RDI, 1997, but some rounding off has occurred.



Quantities in billion m3/year

Figure 1. Average annual water balance of the river Nile downstream of the High Dam

In some reports, the availability of irrigation water is estimated to be higher, as the annual use of groundwater pumped by wells from the aquifer in the Nile Delta, and the re-use of drainage water is added. However, both the RIGW and the DRI institutes have confirmed that annual groundwater recharge (replenishment) exclusively stems from the deep percolation of water from the Nile river, the irrigation canal systems, and the irrigation applications on the agricultural lands. Hence, groundwater and drainage water are not an independent source of water and their use is merely a recirculation (recapturing) of a part of the losses of the irrigation water. The re-use of water losses to the groundwater results merely in a decrease of the total losses and an increase of the water use efficiency. Whether the recapturing is done by well or drainage systems makes essentially no difference when it concerns the water balance.

The water streams for different categories of water use cannot be separated as they are intermingled continuously in Egypt's river and canal systems. The same holds for the re-use as the water losses from the various categories may en up in the same drainage systems. So it may very well happen that one drop of water has passed through a municipal, industrial and agricultural stage.

The intermingling complicates the assessment and allocation of water resources.

2.1.1. Salinity and drainage

The salt concentration of the water in lake Nasser at the High Dam is about 0.25 kg salt/m^3. The salt import into Egypt's water use systems thus amounts to about 14 million tons per year (55 billion m^3 water/year x 0.25 kg salt/ m^3 water) or roughly 1.6 ton/feddan/year over 8.7 million feddan of irrigated land, i.e. 4.0 ton/ha/year.

To combat the problems of water logging and salinity, Egypt's drainage systems have been gradually intensified. After partial use of the drainage water for supplementary irrigation downstream, some 12 billion m^3 of drainage water is discharged annually through pumping stations into the sea and coastal lakes. Of this water some 2 billion m^3 is estimated to originate from sea water intrusion through the underground, while an unknown amount, say also 2 billion m^3 stems from municipal and industrial waste water, so that the discharge of drained irrigation water is about 12-2-2=8 billion m^3/year.
In the Fayoum area, about 1 billion m^3 of drainage water is discharged annually into lake Qarun.

Excluding the drained salty water intrusion from the sea through the underground, the salt concentration of water evacuated into the sea and lakes is, on average, 2.7 kg salt/m^3. The salt export from the Delta thus amounts to some 10 x 2.7 = 27 million ton/year.

The above data, derived from DRI yearbook 1995/1996, excluding the salt export from Fayoum, lead to the conclusion that much more sat is exported than imported: on average the agricultural land desalinizes.

2.1.2 Overall irrigation efficiency and re-use

Relating the amount of drainage water from agricultural lands discharged into the sea and lakes (8 billion m^3/year in the Northern Delta and 1 m^3/year Fayoum) to the total amount of water available for irrigation (47 billion m^3/year) one arrives at an overall irrigation efficiency of about 81%

According to international standards he above efficiency is very high. The reason for this is the continuous re-use of the drainage losses of irrigation water.

In the Nile valley, the drainage water (perhaps some 4 billion m^3/year) returns by gravity or by pump lifting to the river and it is re-used downstream. The re-used water is not considered a loss.

The pumping from groundwater through wells is estimated at roughly 5 billion m^3/year. This water is used for irrigation. Thus the deep percolation from the irrigated lands to the underground are recovered, and the percolation is not considered a loss.

Also there is a considerable un-official re-use through private pumps for application directly to the crop land, but the quantity is unknown. Yet, DRI estimates it at about the same quantity as the official re-use, while RDI sets it at 2.8 billion m^3/year. Let us tentatively say that the amount is 3 billion m^3/year.

Of the 8 billion m^3/year drainage water from the irrigated agricultural lands and the 2 billion m^3/year municipal and industrial waste water, together 10 billion m^3/year that is presently discharged into the sea and lakes (excluding the drainage of groundwater intrusion along the sea), some 4 billion m^3/year are planned to be re-used for irrigation in the new lands of the El Salam canal in the Eastern Delta, Kalabsho in the Middle Delta, and Umun Drain Project in the Eastern Delta (DRI yearbook 1995/1996). Further, the IPP envisages an additional re-use by installing extra pumping stations. The quantity of this re-use is unknown, but for the time being it may be set at 1 billion m^3/year. All this would reduce the discharge into the sea and lakes to some 5 billion m^3/year. To that one must add the yet unknown amount of discharge that will come in the future from the new irrigation developments.

Most of the planned additional re-use will be abstracted from the open drains carrying the relatively best quality drainage water. Hence the additional re-use consists of water that is a mixture of agricultural drainage water and municipal/industrial waste water.

The salt export from the Delta will be unaffected by the proposed additional re-use, excepting the re-use in the IIP areas. However, as the present total export of salts from the agricultural lands is greater than the import, the IIP re-use appears harmless from point of view of the overall salt balance.

Still excluding the evacuation of intrusion water, the salt export into the sea and coastal lakes after effectuation of the additional re-use plans will be minimum 5 x 2.7 = 13.5 million ton/year. The export will in reality be somewhat more as the salt concentration of the exported water may slightly increase as a result of the additional re-use in IIP areas. Also, a small part of the additional re-use will again be drained to the sea at a still higher salt concentration and contribute to the export. Further, the export figure still excludes the export from the Sinai area and the export to lake Qarun.

All in all, the conservatively estimated salt export of 13.5 million ton/year almost equals the import, which was calculated before at 14 million ton/year. Hence the overall alt balance will still look healthy.

In the overall salt balance, no provision has been made for the salt balance in the individual command areas of the irrigation canals. In some command areas, the salt balance may become critical after execution of the additional re-use programs. Therefore it can be recommended that evacuation of drainage water to the sea and lakes should not be less than, and the incremental re-use more than 5 billion m^3/year.

2.1.3. Crop water demands

The overall net quantity of irrigation water, equaling inflow (47 billion m^3/year) minus outflow (some 9 billion m^3/year) is roughly 38 billion m^3/year.

The irrigated area presently amounts to some 7.8 million feddan (RDI, 1997), consisting of 6.2 million feddan “old land” and 1.6 million feddan new reclamation area.

Relating he net quantity of irrigation water to the irrigated area, one arrives at an annual average crop consumptive use of 4900 m^3 per feddan or 1200 mm.

Farooq Shahin (1995) estimated the crop water use in he Manaifa canal area, in the Northern Middle Delta (around Kafr El Sheikh), where the water availability is less than average, at 4500 m^3/year per feddan.

The Staff Appraisal Report (SAR) sets the irrigation deficit in the Mahmoudia Canal Comand at 750 million m^3/year over 0.246 million feddan, i.e. 3000 m^3/year per feddan)., the deficit in the Manaifa Command would be 133 million m^3/year over 0.042

million feddan, i.e. 3000 m^3/year per feddan, and in the El Wasat Command at 125 million m^3/year over 0.075 million feddan, i.e. 1500 m^3/year per feddan.

Even though the above deficits seem improbably high, they explain clearly why the areas depend heavily on re-use of drained irrigation water from elsewhere.

During the present mission it could not be ascertained whether the crop water use of about 38 billion m^3/year corresponds to the optimal crop water use, i.e. the use that would yield maximum crop production, or whether it is sub-optimal so that a certain yield depression would occur from water deficit. In the latter case, there would certainly be competition for water.

The crop requiring a particular high irrigation supply is paddy rice. The high requirement is not only due to continuous ponding of water on the fields during the growing season, but also to the regular refreshing of the ponded water by surface drainage and irrigation replenishment as practiced by the farmers. On top, the subsurface drainage systems tend to discharge an excessive amount of water from the rice fields. Seasonal irrigation requirements of rice of over 7000 m^3/year per feddan have been reported, which is almost 150% of the average annual availability.

The remedy against excessive subsurface drainage, the “modified/controlled drainage system (fig. 2), has not yet been implemented at a large scale. This is partly due to the difficulty of maintaining crop consolidation in the “sub-collector areas” under the present liberalization trends in Egyptian agriculture.

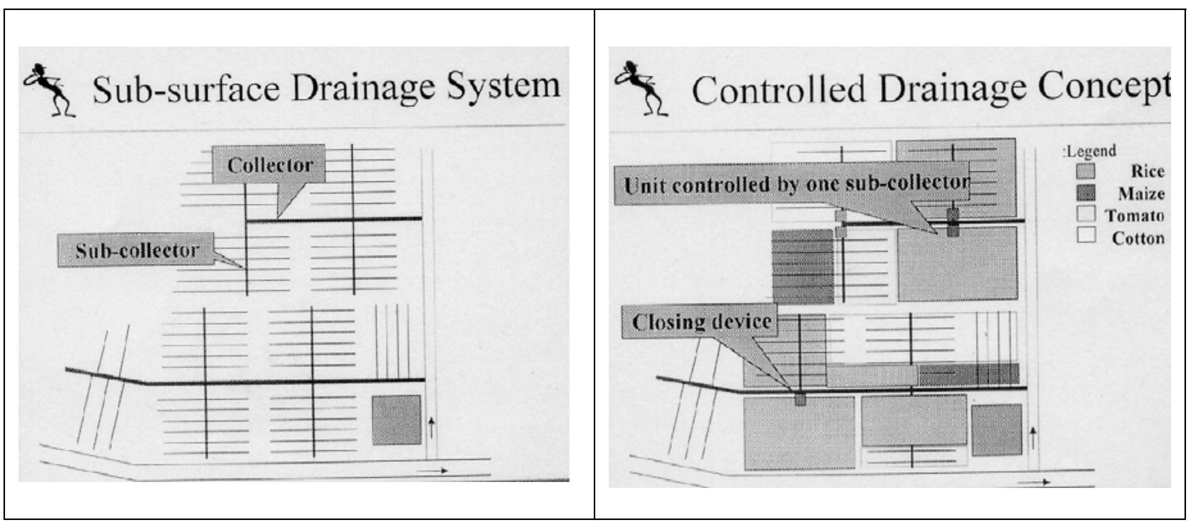


Figure 2. A drainage system with piped collector (left) and the modified (controlled) system for rice cropping (right).

Recently, the area under rice crops has been expanding rapidly, the market process of rice have increased sharply, and export promotion of rice is being undertaken. All this has given rise to an increasing water demand at farm level.

When the potential water savings through IIP need to be assessed, more accurate information on the optimal crop water use, given present copping patterns and estimating future cropping patterns, would be necessary.

2.1.4. Future irrigation water use

The government of Egypt is intending to divert canal water for new irrigation developments: some 3 billion m3/year for the Toshka (South Valley) project in upper Egypt, and about 1 billion m3/year for the Salam canal project in Sinai.

The water diverted to the Salam canal project is to be mixed with drainage water diverted from the North-Eastern delta.

Due to the re-allocation of Nile waters to the new irrigation developments (" horizontal expansion"), the availability to the presently irrigated lands will be reduced to about 90% of the original supply, and the existing net availability of irrigation water would drop from 4900 to 4400 billion m3/year per feddan.

To mitigate the decrease, water savings would have to be realized through improvement of irrigation efficiencies and reduction of irrigation water losse within the presently irrigated lands.

2.2. Distribution of irrigation water

2.2.1 Primary systems

The irrigation water is diverted from the Nile by barrages (fig. 3), and from there through a system of main canals. This is the primary irrigation system, and it works continuously except during the 3 weeks closure period needed for canal maintenance. With the water supply through the main canals it is in principle possible to irrigate the total command area with 2 crops per year.

The quantity of flow (discharge) in the main irrigation canal systems is essentially regulated by head-control structures, generally equipped with lifting gates. Between the main regulators one finds cross-regulators at the boundaries between the irrigation directories.

The target discharge in the main canals is determined by the irrigation sector of MPWWR on the basis of estimated cropping patterns and corresponding expected consumptive of the crops per irrigation directorate.

The Central Directorate of Water Distribution allocates the water to the Irrigation directories, and the latter distributes it to the Irrigation Districts. The district areas are on the average 50.000 feddan.

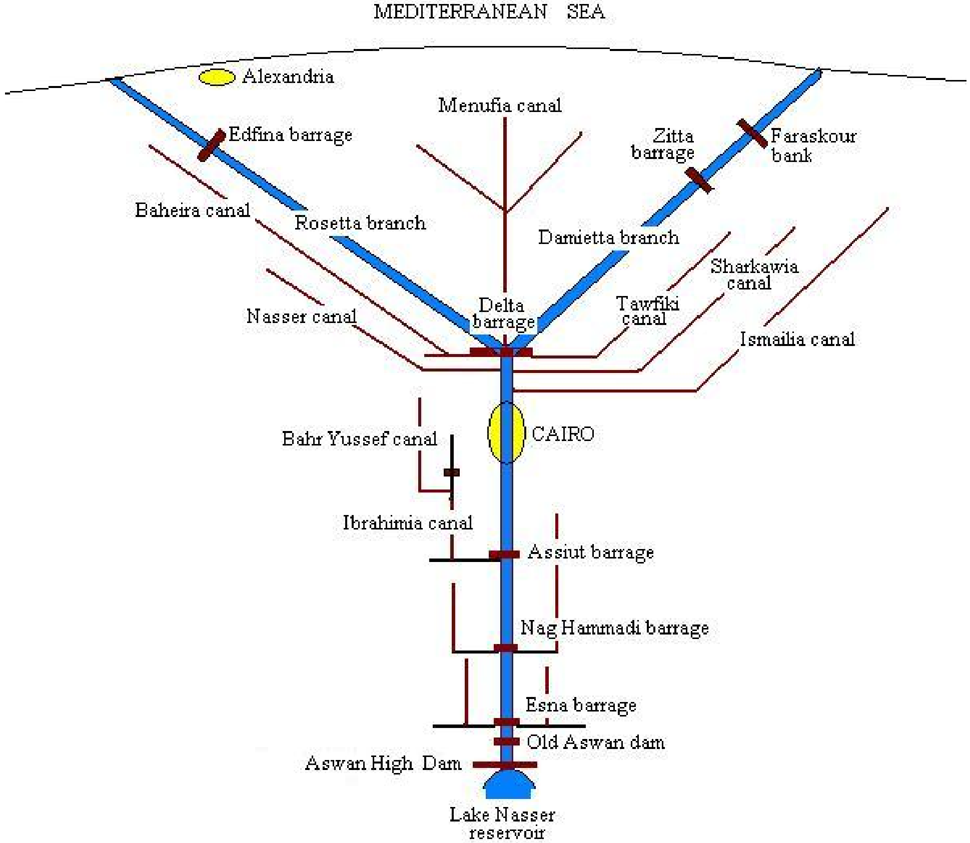


Figure 3. Sketch of the primary irrigation systems.

The method to achieve the target discharge is based on rating curves of the structures (i.e. the known relation between discharge and upstream water level at the gate) or on rating curves of the downstream channel (i.e. the known relation between discharge and the water level in the downstream channel. The latter curves are checked by periodic current metering.

2.2.2. Secondary systems

From the main system, the irrigation water is admitted to the secondary systems, consisting of branch canals (or distributaries or delivery canals) by means of lifting gates operated under supervision of district engineers. The gates are opened so as to maintain the target downstream water levels. Here, however, the discharges are not routinely controlled.

Often the final ramifications of the main canal system from which the branch canals derive their water are called feeder canals.

The off-take point of the branch canals from the feeder canals is the last instance where the discharge can be regulated. It is the meeting point of water users and water suppliers.

Of old, the branch canals are set to work under rotations according to “on” and “off’ periods. The rotational periods are typically 1:2 (e.g. 5 days on and 10 days off) or 1:1 (e.g. 4 days on and 4 days off). The 1:2 rotation prevails in the winter season whereas the 1:1 rotation prevails in summer, especially in view of the demands for rice crops. However, other rotation sequences are also used.

The area served by branch canals is variable in the order of 1000 to 10.000 feddan.

2.2.3. Tertiary systems

The water in the branch canals is distributed over the tertiary canals (meska’s). In the last two decades, the method of off-take from the branch canals underwent drastic changes, and IIP is now aiming, again, at innovations. Below, an overview will be given of the tertiary systems in the past and at present.

Tertiary systems in the past

In the past, the water levels in the *meska*’s were 0.5 m or more below the soil surface. From here the water is lifted by the irrigators into the quarternary canals (*marwa*’s), and from there it is spread over the crop land.. However, water can also be lifted directly from the branch canals.

The area served by a *meska* is variable and usually in the range of 50 to 100 feddan. A *marwa* serves an area of 10 to 20 feddan.

The lifting of water from the *meska* into the *marwa* was carried out mainly by animal driven wheels (*sakia*’s), which were licensed by the irrigation districts. The *sakia* was a fixed installation whose sump was connected to a can or *meska* by an intake pipe of a specified diameter. The farmer’s capacity to abstract water from this delivery system was thus restricted in terms of number and location of lifting points and of the discharge. In particular the need to share the use with several other famers in the same *sakia* “ring”, and the limited discharge of the *sakia* combined with the restriction of the rotation system, meant that farmers were considerably retrained in terms of when, how long, and with how much water they could irrigate.

The output (discharge) of a *sakia* is directly related to the water level in the sakia sump and thus in the parent *meska* or canal. This limited the ability to draw down the water level in the meska and canal since, when the water level becomes low, the output of the *sakia* would be considerably reduced. In effect, the particular characteristics of the *sakia* introduced a degree of self-compensation in the operation of the system, which helped to assure a modest withdrawal of water.

Some further restrictions were also applied at the *meska* off-take from the branch canal. The off-take takes the form of a pipe whose diameter was originally related to the area served on the basis of a defined hydraulic head loss at the design discharge.

Tertiary systems at present

Over the last 20 or 30 years *sakia*'s have been progressively replaced by mobile diesel driven pumps. Unlike the *sakia*, which was almost always collectively owned by the member of the *sakia* ring, most motor pumps are privately owned by individual farmers, but a significant number of farmers do not own pumps but rent them form others. In some cases engine-driven *sakia*'s were installed.

Many of the pumps have a discharge capacity of around 60 l/s whereas the sakia's could lift only around 15 l/s.

The widespread introduction of the motor pumps has largely removed the various constraints imposed by the *sakia*-based system. The larger discharge provided by the pumps means that farmers can complete their irrigation in a shorter time.

In some cases two or more pumps may operate simultaneously at a former sakia site. In addition, many farmers whose fields are adjacent to canals or meska's have established additional lifting points. Even where lifting takes place at former sakia-sites the pump suction is often placed directly in the canal or *meska* rather than in the old *sakia* sump, because the *sakia* inlet pipe would not be big enough to supply the pump discharge. Also, the original *meska* off-takes were sometimes replaced by pipes with a larger diameter. Many of these changes are, strictly speaking illegal.

In summary, the tertiary system has gradually evolved from one which operated at a rigid set of controls down to the head of the *marwa*, to one in which there is little operational control within the branch canal and many farmers now enjoy a considerable degree of autonomy and flexibility, though still subject to the constraints of the canal rotation system.

However, this un-planned evolution, combined with changes in the cropping patterns, such as the increased rice areas, has led to problems of water distribution. In particular, there is an increased inequity of water availability between head and tail areas along the branch canals. The ability of head farmers to abstract water preferentially at the start of the rotational "on" periods means that, at times of peak demand, tail farmers receive initially little or no water, restricting their irrigation in time, if not in quantity. As an insurance against the uncertainty of the rotation system, head farmers may also carry out a top-up irrigation at the end of the "on" period, again reducing the availability of water at the tail end.

The reduction of equity in the water distribution over the *meska*'s along a branch canal owing to the introduction of the pump sets, forced the farmers who initially did not wish to acquire a pump set to join the ranks of pump owners. Hence, the replacement of the *sakia*'s by mobile pumps was not always done voluntarily but rather out of a competitive necessity, which increased the speed of the partly auto-propelled evolution.

The quite sudden wave of pump applications at a time that relatively cheap pumps appeared on the market, suggests that the farmers must have been perceiving a certain shortage of water, and it would seem highly relevant to investigate if the perception is based on realistic experience that the actual crop consumptive use of water under the prevailing water distribution system is less than the optimal consumptive use at which the maximum crop production is obtained. In other words, the standard supply of water might not have been sufficient to secure the highest possible crop yields.

2.3. Efficiency and equity of water distribution

The variations in the distribution of the irrigation water of the Mansuriya canal (near Gizeh, Cairo) over the branch canals in terms of m^3/feddan is illustrated in Table 1, derived from EWUP, 1984.

Table Water distribution over branch canals
in the period of March to August (summer)

Name of canal	water supply m^3/fed
Kafret Nasser (KN)	4600
Beni Magdul Branch	4000
El Mansuriya	3500
El Hammami upstream (EH-1)	2700
El Hammami downstream (EH-2)	1400
Shimi Branch (ShBr)	1200

The 5-monthly (summer) supply of more than 4500 m^3/feddan to the KN canal is high, certainly compared to the average availability of 4900 m^3/feddan in 12 months as calculated in chap. 2.1. The summer supplies of less than 1500 m^3/feddan to the EH(2) and ShBr canals are low.

Presumably the variation is mainly attributable to the operational difference at the control gates. It appears that the target discharges in the main and feeder canals are not strictly translated into corresponding target discharges in the branch canals.
Hence the district engineers, and possibly the branch canal gate keepers who have the dau to day control) appear to be able to exercise some flexibility and discretion in the water table control. The gate openings, and sometimes the rotation schedules, are adjustable to some extent with the aim to minimize complaints from the farmers. Possibly the growing of rice with its higher water requirement may have been of influence.

Although no extensive information like in table 1 is available for the whole of Egypt, the original restrictions imposed on the *sakia* system and the massive adoption of the mobile pumps suggest that there is a definite scarcity of irrigation water. The scarcity may be due to one or more of the following factors:

1 - the crop water requirements are higher than perceived by the supplier;
2 - the cropping pattern may include more high water demanding crops than foreseen by the supplier;
3 - the irrigation requirements perceived by the farmers are higher than the crop water requirements;
4 - the field irrigation efficiency is lower than estimated by the supplier;
5 - the timing of the supplies and the farmers’ irrigation needs deviate to a certain extent from each other, which mat result in spillage of canal water into the drains.

3. CONCEPTS AND RATIONALE OF IIP

To be completed

4. IIP PROGRESS

To be completed

5. LITRATURE CONSULTED

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