MODIFICATION OF THE IMPROVED IRRIGATION SYSTEM IN THE OLD LANDS IN EGYPT

تعديل نظام الرى المطور فى الأراضى القديمة فى مصر

By

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خلاصة:

من الأغراض الأساسية لمشروع تطوير الرى هو زيادة كفاءة توزيع مياه الرى فى الأراضي القديمة فى وادى النيل والدلتا ولكن تقييم المراحل الأولى لهذا المشروع أظهرت أن هذا المشروع فى حاجة إلى تعديلات ولذلك فالهدف من هذا البحث هو إقتراح لتعديل فى مشروع تطوير الرى لكى يتم توصيل إمداد كافى من المياة فى الوقت المناسب للرى مع تحقيق عدالة فى توزيع مياة الرى على طول زمام ترعة التوزيع. وفكرة هذا البحث تقوم على أساس إستبدال المساقى الترابية بمساقى خرسانية مرفوعة ، ويتم إمدادها بالمياة بالرفع بنظام المناوبات وذلك خلال ساعات معينة فى كل يوم من أيام العمالة، ويتم تشغيل المساقى تحت إشراف وزارة الموارد المائية والرى، ويتم إمداد الحقول بالمياة بالراحة من خلال فتحات الرى التى تأخذ المياة من المساقى. تم عمل برنامج كمبيوتر على أساس هذا التعديل المقترح لتصميم وتشغيل المساقى وفتحات الرى فى زمام الترعة التوزيعية، كما تم تطبيق ذلك البرنامج على ترعة " دقلت " بمحافظة كفر الشيخ ثم تحليل النتائج حيث وجد أن التعديل المقترح فى هذا البحث يحقق زيادة كفاءة إستخدام مياة الرى ويوفر حوالى ١% من زمام الترعة التوزيعية يمكن إضافتها لمساحة الأرض الزراعية كما يقلل كثيرا من الآثار الضارة للرى على البيئة المحيطة.

ABSTRACT

The main objective of the Irrigation Improvement Project (IIP) is to increase the efficiency of the irrigation delivery system in old lands of the Nile valley and the Delta. But, evaluation the improved irrigation system showed that there is a need for modification of the improved irrigation system. So, the suggested approach in this research is a modification for the improved irrigation system, utilizing the advantages of both the traditional rotational and the improved irrigation distribution systems. The main objective of the modification is to operate the distributary canals by conveying an adequate and dependable supply of water in equitable and efficient manner. According to the suggested approach, earthen meskas are replaced by elevated concrete ones, which are rotationally operated under control of Ministry of Water Resources and Irrigation. The water is lifted to meskas only at specified hours each day of the on-period according to actual water requirement and the preferable working hours of farmers. Gravity flow is introduced through the outlets along the meskas to irrigate the lands. Computer program was developed to facilitate utilizing the suggested approach for the operation of the distribution system. The suggested approach was applied for Dakalt command area, (Kafr El-Sheikh Governorate), which represents the improved irrigation system. The analysis of the results showed that adequate and dependable water distribution system was achieved in equitable and efficient manner to the water users. Also, the suggested approach saved about 1% of the land, which could be cultivated, and reduced the harmful side effects of the irrigation on the environment. The developed computer program could be utilized to select the optimum

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cropping pattern of the areas served by distributary canals according to the available water supply.

INTRODUCTION

Fast growing of population all over the world necessitates increasing agricultural products, which requires reclamation and cultivation of new lands. Consequently, additional quantities of water are needed. In order to meet this need, many countries have started large- scale irrigation projects involving reclamation of arid and semi-arid areas for cultivation [7]. The Egyptian water budget is limited according to the international agreement in 1959, so increasing irrigation water use efficiency can save some quantities of water. The traditional rotational system has some disadvantages such as; severe shortage of water, especially at the tail reaches; low conveyance efficiency; high operational cost; and excessive water loss to drains [1,2,5, and 13]. Tremendous efforts should be implemented towards effective management for irrigation system [6].

The Ministry of Water Resources and Irrigation has begun the Irrigation Improvement Project, IIP, to improve the irrigation water system [1,2,5, 12, and 13]. Continuous flow in distributary canals and their branches is the major measure, which is introduced by IIP. Other measures are introduced such as; down- stream control devices; high level marrwas (concrete lined or low pressure pipe line); lifting points; Water User Association (WUA); and Irrigation Advisory Services (IAS). Continuous flow means water runs in the distributary canal, their branches and earthen meskas on a continuous basis. Demand irrigation is available and water users have their own opinion to irrigate when they prefer through lifting points along the distributary canal, its branches and earthen meskas.

Since the target of Irrigation Improvement Project is to cover the whole area of the cultivated old land, evaluation of the project in the first stages and any modifications and/or alterations will have significant impact on the project in the coming stages. Also, the problems of first stages have to be solved carefully in the coming stages [5 and 14]. The performance of any irrigation system depends on the structural and management characteristics [1,5, and 9]. Zaki, et al. examined the limitation and advantages of irrigation improvement in Beni Ibeid command area, which is located in El-Minia Governorate [13]. Also, El-Kholy, et al. investigated the improvements in on-farm management in Herz & Numania command area, which is located in El-Minia Governorate [2]. While, El-Hasawy [14] mentioned the problems in the irrigation system improvement in Belqatr command area, which is located in Al-Behaira Governorate.

The evaluation of the improved irrigation system, in Al-Qahwagy command area that located in Kafr El-Sheikh Governorate, showed that the improved system has some problems related to management characteristies [1 and 5]. Also, it is indicated that there is still need for modification for efficient management. The increasing demands for irrigation water will coincide with raising concern about the environmental effects of the irrigation [3]. The objective of this research is to introduce suggested approach for increasing the management efficiency of the improved system. Also, it is required to reduce the negative impacts of the irrigation system on the environment.

THE SUGGESTED APPROACH CONCEPT

The suggested approach for modification the improved irrigation system is a tool to increase its operational efficiency, utilizing the advantages of the improvement and the traditional rotational system. The modification is introduced for the improved irrigation system covering both hardware and software as well. The hardware modification includes; earthen meskas and earthen direct irrigation offtakes are replaced by elevated concrete ones; and outlets pass water from meskas and direct irrigation offtakes through valved or gated pipes, under the roads, to the earthen marrwas. The meskas and direct irrigation offtakes bed level is approximately at the level of the cultivated land. The software modification includes; continuos flow is introduced in the distributary canals and their branches; and rotational flow is introduced in elevated meskas and direct irrigation offtakes.

The distributary canal reaches its maximum discharge during the beginning hours of irrigation, but it is decreased by the time until the end time of irrigation hours. Water is lifted to meskas and direct irrigation offtakes through one lifting point at the intake of meska and direct irrigation offtake, only at certain hours each day of on-period, under the supervision and control of Ministry of Water Resources and Irrigation. These certain hours represent the irrigation hours, which are the preferable hours for irrigation by water users. Gravity flow is introduced through the outlets along the meskas to earthen marrwas. There is a rotation schedule between the outlets of each meska and direet irrigation offftake during the on-period to irrigate the crops according to the water requirements. Farmer involvement (Water Users Associations and Water Advisory Services) is necessary for efficient operation schedule on meskas and direct irrigation offtakes and their maintenance.

The objectives of the suggested approach are; to enhance the operation of distributary canals and their branches to convey an adequate and dependable supply of water in equitable and efficient manner to water users served by the system; to increase the irrigation efficiency; to decrease the negative impacts of irrigation system on the environment; and to decrease the conflict between operaters of the system and water users, also between the head and tail-end water users on distributary canal, their branches and meskas. Increasing the irrigation efficiency is achieved by increasing conveyance efficiency in concrete meskas (preventing seepage and weed growth) and on-Farm application efficiency. While, decreasing negative impacts of irrigation delivery system on the environment is carried out by preventing weed growth in concrete meskas, consequently decreasing water born diseases, also preventing seepage leads to decrease in water table. The expected outputs of the suggested approach are; design of elevated meskas, direct irrigation offtakes, and the outlets along the meskas; and operation of the distributary canal, meskas, direct irrigation offtakes and outlets.

OUTPUTS OF THE SUGGESTED APPROACH

Design of Meskas and Outlets

According to the suggested approach concepts, the water is lifted to meskas in rotation and at specific hours during on-days, and the water is conveyed from meskas to earthen marrwas through oulets by gravity. The area served by a meska is cultivated by the same ratio of cultivated crops in the area served by distributary canal. Design calculations of meskas and outlets are as follows:

$$WC = \sum_{i=1}^{Nc} (ET_{o(avg)} \times K_{ci(avg)} \times A_{ci} / 1000) \times 4200/86400 \qquad (1)$$

In which

WC water consumptive needed for the area served by a distributary canal during a month (m^3/sec),

Nc number of cultivated crops in the area served by a distributary canal according to cropping pattern,

$ET_{o(avg)}$ monthly average evapotranspiration for the area served by a distributary canal (mm/day),

$K_{ci(avg)}$ monthly average crop coefficient, and

A_{ci} area cultivated by a crop i (fed.).

$$Q_d = [WC \times \frac{24}{T_e - T_s} \times (1 + LR)/(I_{ed})] \tag{2}$$

$$Q_d \leq Q_{des} \tag{3}$$

In which

Q_d discharge of a distributary canal during hours of irrigation (m^3/sec),
T_e assumed day hours at which irrigation ends,
T_s assumed day hours at which irrigation starts,
LR leaching requirement, which is a ratio of water consumptive use (%),
I_{ed} irrigation efficiency for distributary canal, where conveyance and on-farm efficiencies are included, and
Q_{des} design discharge of the distributary canal (m^3/sec).

$$WC_{avg} = (WC/AT) \tag{4}$$

In which

WC_{avg} average water consumptive use per feddan (m^3/ fed./sec), and
AT total area served by a distributary canal (fed.).

$$WR_m = WC_{avg} \times \frac{N_1}{N_2} \times \left[\frac{24}{(T_e - T_s)}\right](1 + LR)/I_{em} \tag{5}$$

In which

WR_m discharge of a meska during hours of irrigation (m^3/ fed/sec),
N_1 rotation length (days),
N_2 number of on days (days), and
I_{em} irrigation efficiency for meskas (meska covneynace and on-farm effciencies are included) (%).

WC, Q_d, WC_{avg} and WRm are calculated for each month during a year.

$$Q_{md} = WR_{mm} \times A_m \tag{6}$$

In which

Q_{md} design discharge of a meska (m^3/sec.),
WR_{mm} maximum value of WR_m during a year (m^3/fed./sec.), and
A_m area served by a meska (fed).

By applying Manning equation for a rectangular cross section, the meska dimensions are calculated as follows:

$$b = X\,d \tag{7}$$

$$d = \left[\frac{Q_{md} * n_m (X+2)^{2/3}}{X^{5/3} * S^{1/2}}\right]^{3/8} \tag{8}$$

In which

b bottom width of a meska (m),
d water depth in meska (m),
X ratio between b and d,
n_m roughness coefficient of a meska, and
S bed slope of a meska.

Taking free board equal to 0.25 m, yields:

$$d_1 = d + 0.25m \tag{9}$$

where d_1 is the depth of a meska (m).

Similarly, the design discharge, Q_{dd}, for direct irrigation offtake is calculated using equation (6) according to the area served, A_d, by each direct irrigation offtake. The dimensions of direct irrigation offtakes are calculated using equations (7 to 9). The suggested approach can handle a multi crop system. The design calculations for an outlet are as follows:

$$WD_c = \sum_{i=1}^{Nc} \left[ET_{o(avg)} \times K_{ci(avg)} \times NP \times (1 + LR) \times 4200\right] / (I_{ef} \times 1000) \tag{10}$$

$$q_c = \sum_{i=1}^{N_c} \left[\frac{WD_c}{\frac{NP}{N_1} \times N_{irr} \times T_{irr} \times 3600} \right] \tag{11}$$

In which

WD_c water duty per feddan for a crop during a month (m^3/fed.),
$ET_{o(avg)}$ monthly average evapotranspiration for the area (mm/day),
$K_{ci(avg)}$ monthly average crop coefficient,
NP number of planting days for a crop during a month (day),
LR leaching requirement, which is a ratio of water consumptive use (%).
I_{ef} on-farm efficiency (%),
q_c required discharge for one irrigation per feddan during an on-period (m^3/sec.),
N_c number of cultivated crops in the area served by a distributary canal,
N_1 length of a rotation (day),
N_{irr} number of irrigations during an on-period, which depends on the crop, and
T_{irr} assumed time for one irrigation per feddan (hour).

The values of WD_c and q_c are calculated every month for each crop through the year.

$$q_{otd} = q_{cm} \cdot A_{irr} \tag{12}$$

In which

q_{otd} design discharge of an outlet (m^3/sec),
q_{cm} maximum value of q_c (m^3/sec), and
A_{irr} maximum area irrigated at the same time from the outlet (fed).

The diameter of an outlet pipe is calculated from the following equation:

$$q_{otd} = \sqrt{\frac{2gH}{1.5 + \frac{4FL}{D}}} \times \frac{\Pi D^2}{4} \tag{13}$$

In which

g gravitational acceleration (m/sec^2),
H head loss through the outlet pipe, which equals to 0.25m (according to Depui assumption),
F roughness coefficient for the inner surface of the outlet pipe,
L outlet pipe length, which is the road width (m), and

D inner diameter of the outlet pipe (m).

The area served by an outlet is calculated as follows:

$$T_P = (T_e - T_s) \quad (14)$$

$$A_{ot} = \frac{T_m}{T_{irr}} \quad (15)$$

In which

T_P irrigation hours each day during the on-period, which are calculated for each month of the year (hour),

T_e assumed time at which irrigation ends (hour),

T_s assumed time at which irrigation starts (hour),

A_{ot} area served by an outlet (fed), and

T_m maximum value of Tp (hour).

The number of outlets along a meska, N_{otm}, is calculated as follows:

$$N_{otm} = \frac{A_m}{A_{ot}} \quad (16)$$

Similarly, the number of outlets along a direct irrigation offtake , N_{otd} is calculated using equation (16).

Operation Procedure

Operation of Distributary canal

During irrigation hours, maximum discharge of the distributary canal is delivered to be lifted into meskas and direct irrigation offtakes. It is considered that on-meskas and on-direct irrigation offtakes are operated at the same hours. The maximum discharge $Qreq_{drd}$ of the canal reach is calculated as follows:

$$Qreq_{drd} = \left[\sum_{i=1}^{Non-m} (Q_{md})_i + \sum_{i=1}^{Non-dir} (Q_{dd})_i \right] \quad (17)$$

$$Qreq_{drd} \leq Qdes_r \quad (18)$$

In which

$Qreq_{drd}$ discharge of a distributary canal reach during hours of irrigation (m^3/sec),

N_{on-m} number of on-meskas along a reach,

N_{on-dir} number of on-direct irrigation offtakes along a reach,

Q_{md} design discharge of a meska (m^3/sec),

Q_{dd} design discharge of direct irrigation offtake (m^3/sec), and

$Qdes_r$ design discharge of a reach (m^3/sec).

Operation of Meskas

The lifted discharges to a meska and direct irrigation offtakes are the design discharge, Q_{md} and Q_{dd}, respectively. Actual water requirement for the area served by a meska depends on the actual cultivated crops, which is calculated during each on-period as follows:

$$qcon_m = \sum_{i=1}^{N_{cm}} [ET_{oa} \times K_{cia} \times A_{ci}/1000] \times 4200/86400 \quad (19)$$

In which

$qcon_m$ water consumptive use for the area served by a meska (m3/sec),
N_{cm} number of cultivated crops in the area served by a meska,
ETоa actual evapotranspiration during an on-period (mm/day),
Kcia actual crop coefficient for a crop i, and
A_{ci} cultivated area by a crop i (fed.).

$$qreq_m = qcon_m (1 + LR)/I_{em} \quad (20)$$

In which

$qreq_m$ water requirement for the area served by a meska in case of continuous flow (m3/sec),
LR leaching requirement, which is a ratio of water consumptive use (%), and
I_{em} irrigation efficiency of a meska (conveyance efficiency and on-farm efficiency are included) (%).

According to the concept of applying rotational flow on meskas:

$$qreq_{mr} = qreq_m \cdot (N_1/N_2) \quad (21)$$

In which

$qreq_{mr}$ water requirement for the area served by a meska during an on-period (m^3/sec.),
N_1 length of a rotation (day), and
N_2 number of on-days during a rotation (day).

According to water requirement, $qreq_{mr}$, and design discharge of a meska, Q_{md}, the number of operating hours, N_{opm}, for each meska is calculated from the following equation:

$$N_{opm} = \frac{qreq_{mr} \times 24}{Q_{md}} \quad (22)$$

Each meska has a number of operating hours, which depends on the actual water requirement for its area served and its design discharge. Similarly, the number of operating hours of direct irrigation offtake, N_{opd}, is calculated using equations (19 to 22). Storage in meskas and surplus from tail ends are not accepted by the suggested approach. So, the supply pattern on meskas must match the delivered pattern by outlets as follows:

$$N_{on\text{-}otm} = \frac{Q_{md}}{q_{otd}} \quad (23)$$

In which

$N_{on\text{-}otm}$ number of on-outlets of a meska during irrigation hours,
Q_{md} design discharge of a meska (m^3/sec), and
q_{otd} design discharge of an outlet (m^3/sec).

Similarly, the number of on-outlets of direct irrigation offtake, $N_{on\text{-}otd}$, is calculated from equation (23).

Operation of Outlets

During hours of irrigation, the discharge of on-outlets is the design discharge q_{otd}. The number of operating hours for each outlet depends on the cultivated crops in the area served by an outlet. The actual time of irrigation for each crop is calculated as follows:

$$T_{irra} = \sum_{i=1}^{Nc}\left(\frac{ET_{oa} \times K_{cia} \times NP \times 4200)}{q_{otd} \times (NP/N_1) \times N_{irr} \times 3600 \times 1000}\right)(1 + LR)/I_{ef} \quad (24)$$

In which

T_{irra} actual time for one irrigation per feddan cultivated by certain crop (hour),
N_c number of cultivated crops in the area served by a distributary canal,
ET_{oa} actual evapotranspiration (mm/day),
K_{cia} actual crop coefficient,
NP number of planting days during a month (day),
LR leaching requirement, which is a ratio of water consumptive use (%),
I_{ef} on-farm efficiency (%),
q_{otd} design discharge of an outlet (m^3/sec),
N_1 rotation length (day), and
N_{irr} number of irrigations during an on-period,

COMPUTER PROGRAM

The suggested approach was formulated to a computer program, which could be used as an easy tool to design and operate the distributary canal system. The computer program facilities are:

- distributary canal consists of up to four reaches,
- up to two branches offtake from each reach,
- up to thirty meskas and direct irrigation offtakes are arranged on a branch, and also on the main stem of a reach,
- two-turn and three-turn rotations are considered,
- up to seven crops could be cultivated each season,
- the irrigation hours are selected approximately according the water users preference, and
- outlet pipes could be made of steel, PVC, or concrete.

The flow chart of the Computer Program is shown in Fig. (A.1).

APPLICATION OF THE SUGGESTED APPROACH

Dakalt canal and its command area, which is located in Kafr El-Sheikh Governorate, was chosen to test the suggested approach. Dakalt canal, which was recently included in the Irrigation Improvement Projeet (IIP), takes water from Mit-Yazid canal at km 41.0 on the right bank. Dakalt canal has overall length of 11.4 km, and its command area is about 5458 feddans. There are three Avis gates along the canal at km 1.150, km 5.150, and km 8.400, respectively. The canal length is divided into three reaches, where their lengths are 2.865 km, 2.710 km, and 5.825 km, respectively. There are fourteen meskas on the right bank and nine meskas on the left bank, Maps (B.1 and B.2). Also, there are thirty one direct irrigation offtakes on the right and the left banks. The direct irrigation offtakes serve about 1558 feddans of Dakalt command area.

The description of Dakalt canal and its command area is shown in Maps (B.1 and B.2) and Table (C.1). For other details of Dakalt canal and its eommand area, see [5]. The suggested approach application was carried out in each month of the cultivation seasons in the year. Maps (B.1 and B.2) show the locations of lifting points according to the IIP and the suggested approach, respectively. The cultivated crops of each meska and direct irrigation offtake area in July are shown in Table (C.2), while the cropping pattern in the other months are tabulated in [5]. Some of the results of the suggested approach application on Dakalt canal are presented in this research, meanwhile, the other results are listed in [5].

Design of Meskas and Outlets

Leaching requirement, LR, was calculated using the following equation [10]:

$$LR = \frac{Eci\ (mmhos/cm)}{Ecd\ (mmhos/cm)} \quad (25)$$

In which; Eci is the quality of irrigation water, and Ecd is the quality of drainage water.

Eci and Ecd were assumed 0.4 mmhos/cm and 8.0 mmhos/cm, respectively [4]. So, LR is equal to 5%. On-farm efficiency, I_{ef}, irrigation efficincy in meskas, I_{em}, and irrigation of distributary canal, I_{ed} were calculated according to the following:

- On-farm conveyance efficiency in marrwas was assumed 90%,
- On-farm application efficiency in case of high discharge of outlets was assumed 82%.

Consequently, on-farm efficiency, I_{ef}, is 74%.

Conveyance loss in elevated concrete meskas is only due to evaporation from free water surface, which is about 0.6 cm/day, [15]. Because of the reduction of cross sections of elevated concrete meskas and lifting water to meskas at specific hours during the on-periods, the loss from meskas becomes very small, which was assumed 1% [15]. Consequently, the irrigation efficiency of meskas, I_{em}, is about 73%. The loss in distributary canal was assumed 3% due to seepage and evaporation [4]. Consequently, the irrigation efficiency in distributary canal system, I_{ed}, is about 71%.

The average values of monthly average evapotranspiration, $ETo_{(avg)}$, and crop coefficient, $K_{ci(avg)}$, were assumed as in [8]. Based on the main crops cultivated in Dakalt canal area, two types of rotations were considered in the application. The first one was two-turn rotation, which was applied in summer season. The rotation length, N_1, was 10 days and on-period, N_2, was 5 days. While, the second one was three-turn rotation, which was applied in winter season. The rotation length, N_1, was taken 12 days and on-period, N_2, was 4 days.

The water consumptive use needed for the area served by Dakalt canal, WC (m^3/sec), the discharge of Dakalt canal during irrigation hours, Q_d (m^3/sec), the average water consumptive use for Dakalt canal area, WC_{avg} (m^3/fed/sec) and the discharge of a meska during hours of irrigation, WR_m (m^3/fed/sec), were all calculated monthly using equations (1 to 5), Table (C.3). The maximum value of WR_m was 0.0016, Table (C.3). The time at which irrigation starts and ends, T_s and T_e, respectively were assumed 6 a.m. and 6 p.m. in summer season, and 8 a.m, and 4 p.m. in winter season. As shown in Table (C.3), the results of calculation gave that, T_s and T_e were 5 a.m. and 9 p.m., respectively in summer season, and are 8 a.m. and 4 p.m., respectively in winter season.

The design discharges for meskas and direct irrigation offtakes, Q_{md}, and Q_{dd}, respectively, were calculated using equation (6). The roughness coefficient, n_m, was assumed 0.016 for concrete pipe, the bed slop, S, was assumed 15 cm/km, and the ratio, X, between the bottom width of a meska, b, and water depth in meska, d, was assumed 1.5. The monthly number of planting days, NP, for each crop was taken according to [8]. The design dimension for meskas and direct irrigation offtakes were calculated using equations (7 to 9), Table (C.4). The design discharge and dimensions for outlets were calculated using equations (10 to 16), Table (C.5).

Operation Procedure

Operation of Dakalt Canal

Tables (C.6 and C.7) show the operation of Dakalt canal for two- turn and three- turn rotations, respectively.

Operation of Meskas

According to the cultivated crops and the rotation type, water requirements for the area served by a meska or by a direct irrigation offtake were calculated using equations (19 to 21). The number of operating hours for each meska, N_{opm}, and direct irrigation offtake, N_{opd} were calculated using equation (22). The operation of meskas and direct irrigation offtakes is shown in Table (C.8).

Operation of Outlets

The number of on-outlets on each meska, N_{on-om}, or on each direct irrigation offtakee, N_{on-od}, was calculated using equation (24), Table (C.5). The number of operating hours of outlet to irrigate one feddan cultivated by certain crop, T_{irra} , was calculated using equation (24), Table (C.9).

ECONOMICAL COMPARATIVE STUDY

According to the IIP, elevated concrete marrwas take from the earthen meskas by one lifting point, Map (B.1). But, earthen meskas need regular maintenance, which costs about 30 L.E./feddan/year. After maintenance, the earthen meskas became wider due to over excavation. The initial cost of elevated marrwas in IIP is about 2500 L.E./feddan. The suggested approach introduces elevated concrete meskas instead of the excavated earthen meskas. According to the design of meskas and the direct irrigation offtakes using the suggested approach, the average cross section was 0.9 x 0.85 m, Table (C.4), and the average thickness of bottom and sides was assumed 0.175 m.

The calculation of initial cost of the suggested approach per feddan was as follows:

- The total length of meskas and direct irrigation offtakes = 48.36 km, Table (C.1),
- The average length of direct irrigation offtake = 100 m,
- Reinforced concrete cost = (48.36 x 1000 x 2.95x 0.175 x 500)/5458 = 2287 L.E.,
- Plain concrete cost = (48.36 x 1000 x 1.25 x 0.2 x 200)/5458 = 443 L.E.,
- Filling cost = (45.26 x 1000 x 2.3 x 1.7 x 30)/5458 = 970 L.E.,

Consequently, the initial cost per feddan = 3700 L.E.

Comparing the required area for cross sections of the elevated concrete meskas and direct irrigation offtakes with that of the measured cross sections of earthen ones [5], it is found that the suggested approach saved about 1% of the area served by Dakalt canal, Table (C.10). The saved area per feddan, which could be cultivated, has price of 700 L.E. and annual return of 35 to 40 L.E./year. Table (C.11) presents the results of the economical comparative study per feddan between the Irrigation Improvement Project and the suggested approach.

ENVIRONMENTAL IMPACTS

Elevated lining meskas, which represent about 80% of the length of distribution system, restrict snail and mosquito breeding [11]. So, the harmful effect of schistosomiasis, malaria, and some others diseases will be eliminated using the suggested approach. Continuous flow system in earthen meskas in IIP, which has no drying period, encourages weed growth. While, lined elevated meskas will prevent weed growth. Continuous flow system in earthen meskas in IIP increases seepage losses. Meanwhile, lined elevated meskas will prevent seepage, consequently, the suggested approach will decrease the water table.

CONCLUSIONS

The main gained benefits from the suggested approach are as follows:

- Adequate and dependable water delivery is achieved in equitable and efficient manner to users,
- Reducing irrigation labor requirements, costs and time,
- Increasing conveyance efficiency in meskas by preventing seepage and weed growth. The losses will be only due to evaporation from free water surface, which is also reduced by reducing meskas cross sections.
- Increasing on farm efficiency. where high flow rates decrease leakage from the farm land and marrwas,
- Irrigation efficiency in the distributary canal could be increased up to 71%,
- Saving about 1% of the area served by the distributary canal, which could be cultivated,
- Achieving an optimum cropping pattern, which could be selected with operation schedule using the developed computer program, according to the available water and water requirements of crops,
- Increasing cooperation between water users themselves and operators, and finally
- Decreasing water born diseases, especially Malaria and Schistomasis.

It is recommended that the suggested approach in this research has to be applied in other different locations considering different conditions. It is hoped that the results of this research will be helpful for field engineers to fulfill efficient management of irrigation distribution system.

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NOTATION

AT total area served by a distributary canal (fed.),
A_{ci} cultivated area by a crop i (fed.),
A_d area served by a direct irrigation offtake (fed.),
A_{irr} maximum area irrigated at the same time from the outlet (fed),
A_{ol} area served by an outlet (fed),
A_m area served by a meska (fed),
b design bottom width of meska (m),
b_{actual} actual bottom width of meska (m),
D inner diameter of outlet pipe (m).
d design water depth in meska (m),
d_{actual} actual water depth in meska (m),
d_1 depth of a meska (m),
Eci the quality of irrigation water (mmhos/cm),
Ecd the quality of drainage water (mmhos/cm),
ET_{oa} actual evapotranspiration during an on-period (mm/day),
$ET_{o(avg)}$ monthly average evapotranspiration for the area served by a distributary canal (mm/day),
F roughness coefficient for the inner pipe surfaee,
g gravity acceleration (m/sec^2),
H head loss (m),
IAS Irrigation Advisory Services,
IIP Irrigation Improvement Project,
I_{cd} irrigation efficiency for distributary canal (conveyance and on-farm efficiencies are included) (%),
I_{ef} on-farm efficiency (%),
I_{cm} irrigation efficiency for meskas (meska covneynace and on-farm effciencies are included) (%),
K_{cia} actual crop coefficient for a crop i,
$K_{ci(avg)}$ monthly average crop coefficient,
L outlet pipe length (m), which is the road width,
LR leaching requirement, which is a ratio of water consumptive use (%),
Nc number of cultivated crops in the area served by a distributary canal according to the cropping pattern,
NP number of planting days for a crop during a month (day),

N_{cm}	number of cultivated crops in the area served by a meska,
N_{irr}	number of irrigations during an on-period, which depends on the crop,
N_m	number of meskas and direct irrigation offtakes along the distributary canal,
N_{on-dir}	number of on-direct irrigation offtakes along a reach,
N_{on-m}	number of on-meskas along a reach,
N_{on-otd}	number of on-outlets of a direct irrigation offtake during irrigation hours,
N_{on-otm}	number of on-outlets of a meska during irrigation hours,
N_{opd}	number of operating hours for direct irrigation offtake during on-period,
N_{opm}	number of operating hours for each meska during on-period,
N_{otd}	number of outlets along a direct irrigation offtake,
N_{otm}	number of outlets along a meska,
N_1	rotation length (day),
N_2	number of on days (day),
n_m	roughness coefficient of a meska,
$Qdes_r$	design discharge of a reach (m^3/sec),
$Qreq_{drd}$	discharge of a distributary canal reach during hours of irrigation (m^3/sec),
Q_d	discharge of the distributary canal during hours of irrigation (m^3/sec),
Q_{dd}	design discharge of direct irrigation offtake (m^3/sec),
Q_{des}	design discharge of the distributary canal (m^3/sec),
Q_{md}	design discharge of a meska (m^3/sec),
$qcon_m$	water consumptive use for the area served by a meska (m^3/sec),
$qreq_m$	water requirement for the area served by a meska in case of continuous flow (m^3/sec),
$qreq_{mr}$	water requirement for the area served by a meska during an on-period (m^3/sec),
q_c	required discharge for one irrigation per feddan during an on-period (m^3/sec),
q_{cm}	maximum value of q_c (m^3/sec),
q_{otd}	design discharge of an outlet (m^3/sec),
S	bed slope of a meska,
T_e	assumed time at which irrigation ends (hour),
T_{irr}	assumed time for one irrigation per feddan (hour),
T_{irra}	actual time for one irrigation per feddan cultivated by certain crop (hour),
T_p	irrigation hours each day during on-period (hour),
T_m	maximum value of Tp (hour),
T_s	assumed time at which irrigation starts (hour),
WC	water consumptive use needed for the area served by a distributary canal during month (m3/sec),
WC_{avg}	average water consumptive use per feddan (m^3/ fed./sec),
WD_c	water duty per feddan for a crop during a month (m^3/fed.),
WR_m	discharge of a meska during hours of irrigation (m^3/ fed/sec),
WR_{mm}	maximum value of WR_m during a year (m^3/fed./sec),
WUA	Water User Association, and
X	ratio between meska width and water depth in meska.

APPENDIX A: Flow chart of the computer program

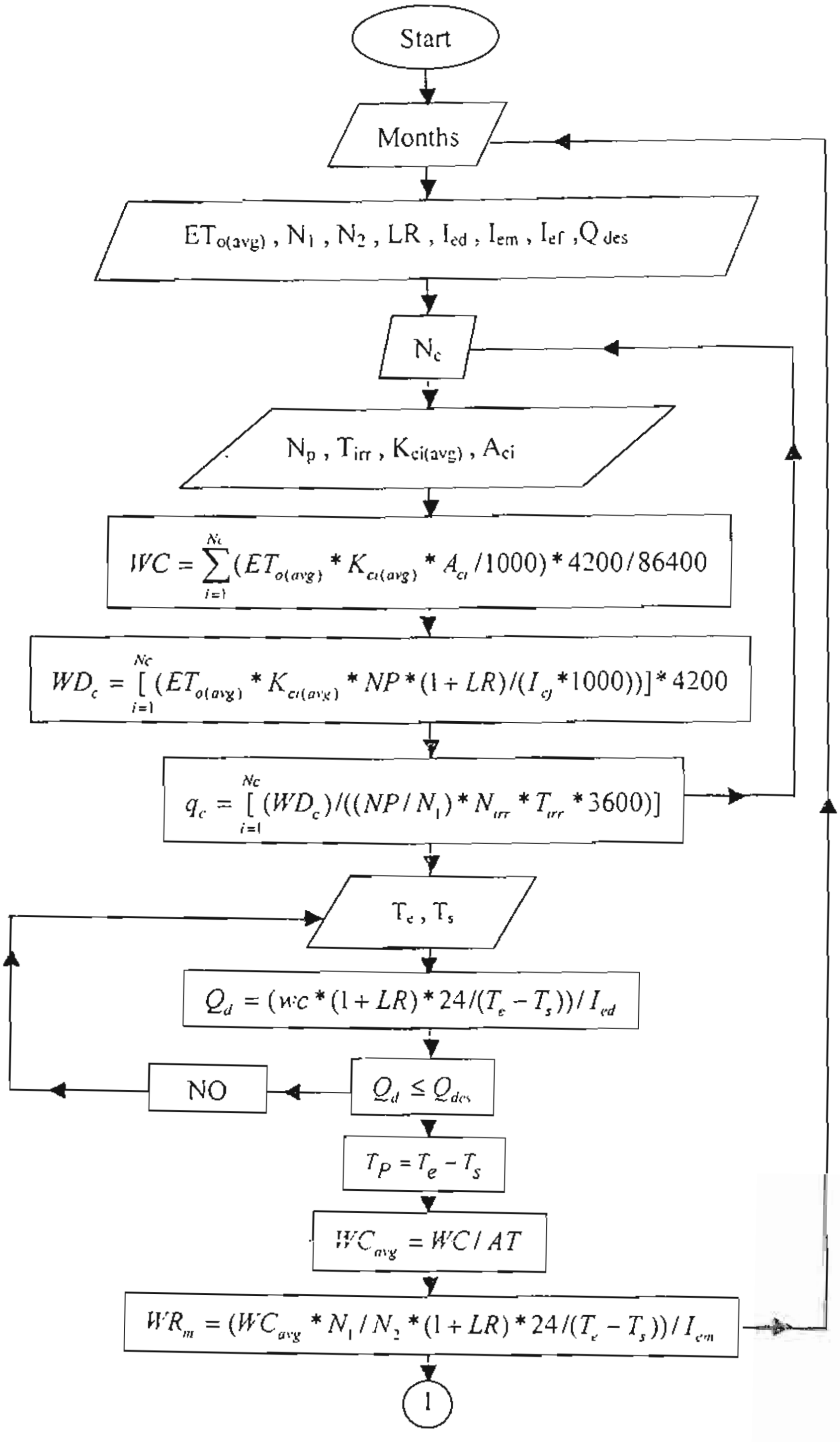


Fig. (A.1) Flow chart of the computer program

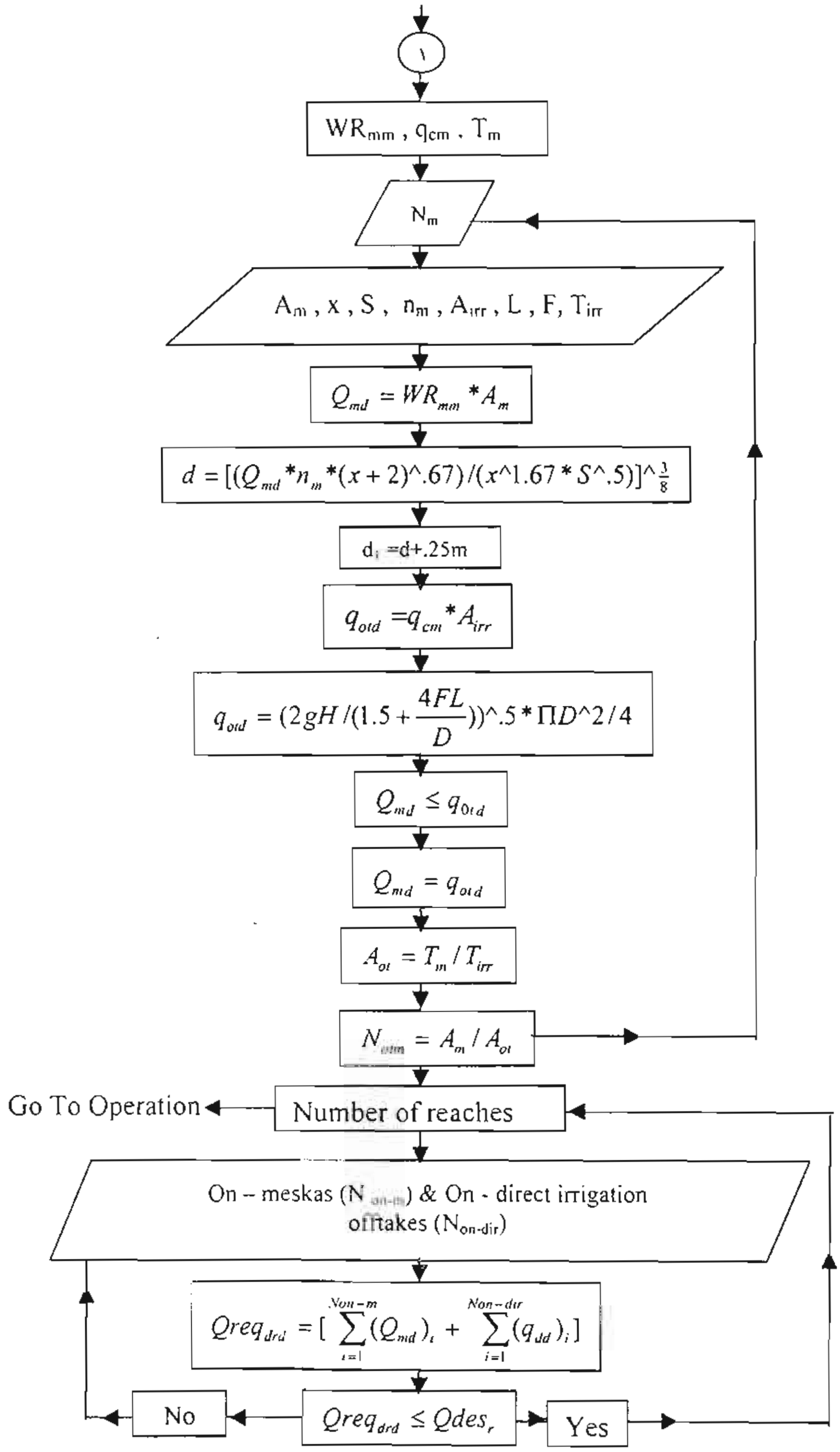


Fig. (A.1) (Continued) Flow chart of the computer program

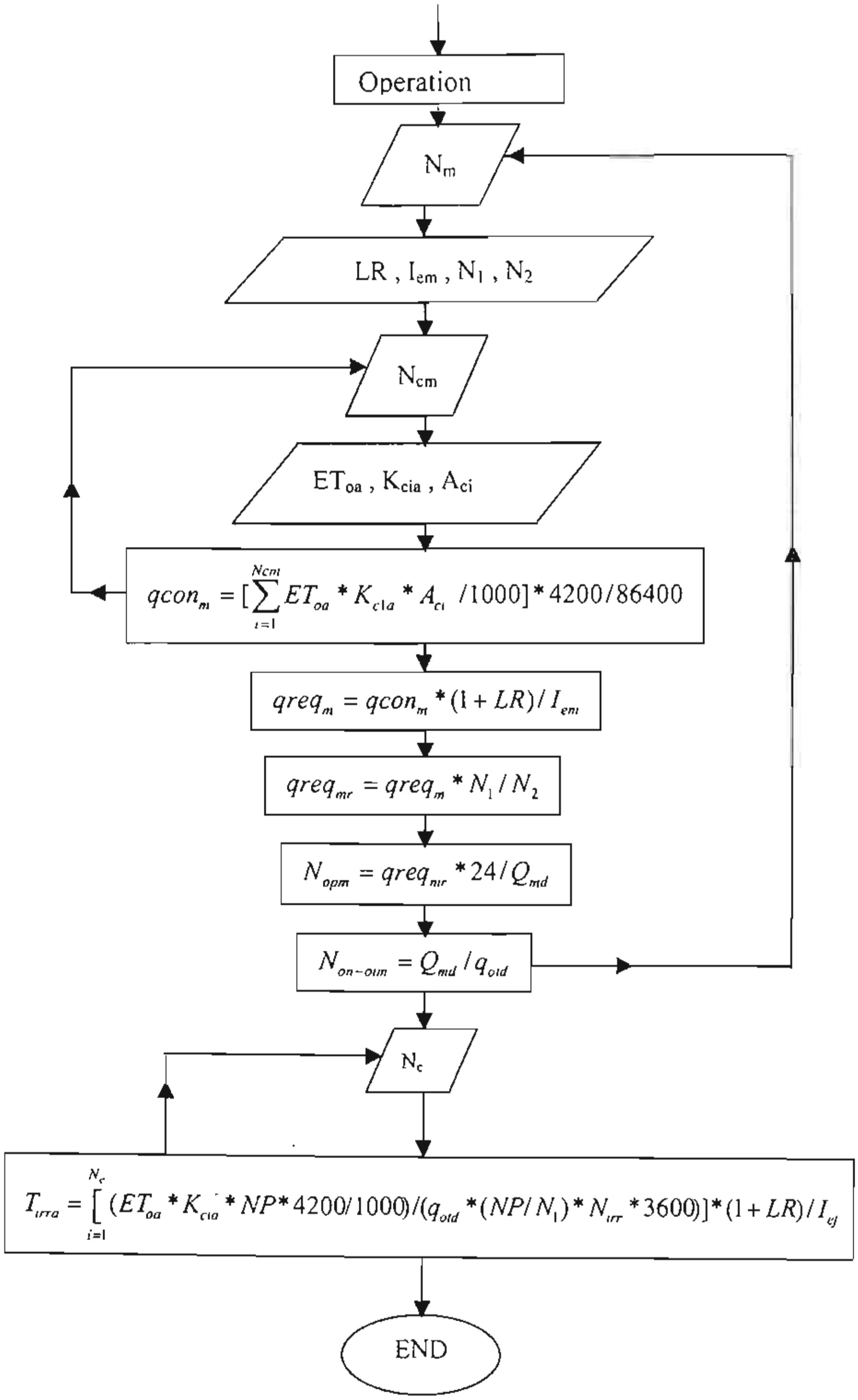
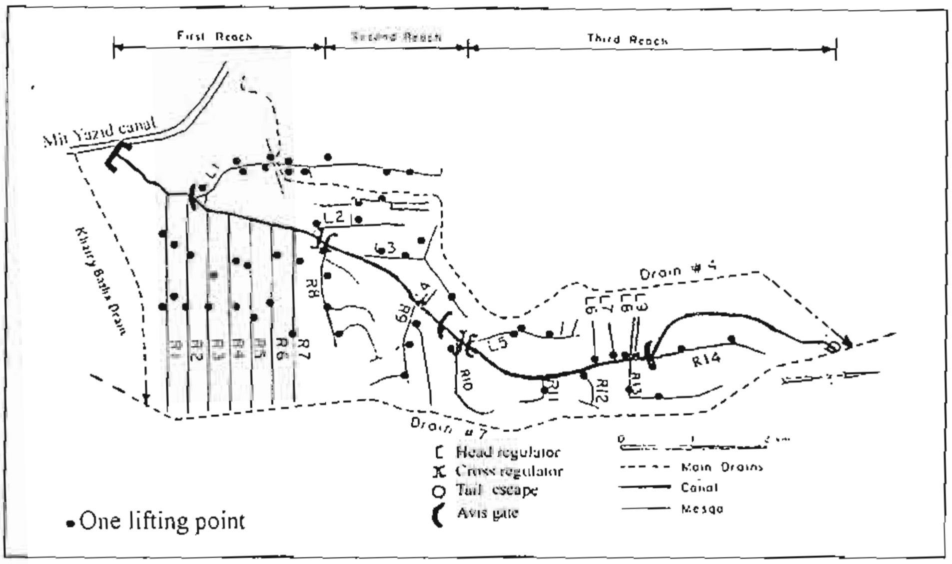
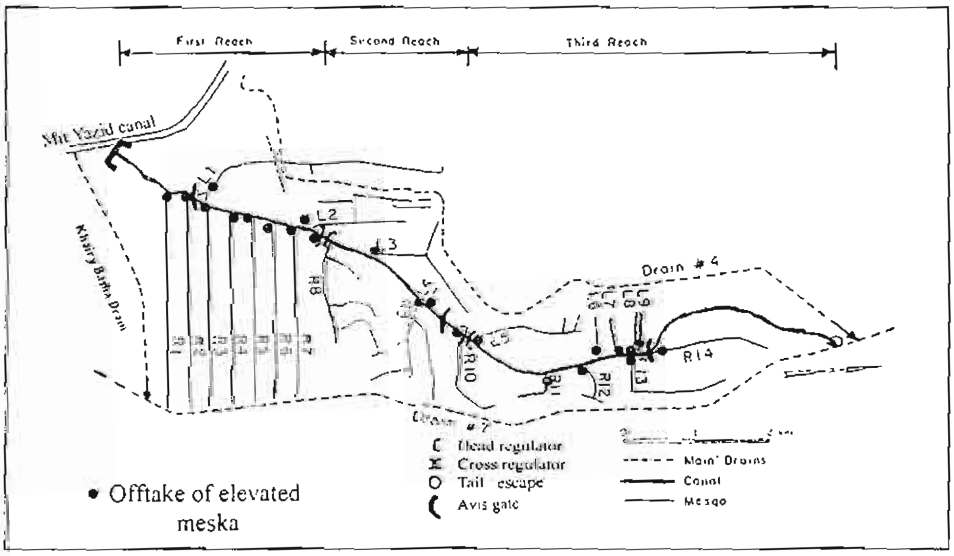


Fig. (A.1) (Continued) Flow chart of the computer program

APPENDIX B: Offtakes of lined marrawas (After IIP) and lined meskas (Suggested approach)



Map (B.1) Offtakes of the lined marrwas along Dakalt canal (after IIP)



Map (B.2) Offtakes of the elevated lined meskas along Dakalt canal according to the suggested approach

APPENDIX C: Application of the suggested approach on Dakalt canal

Table (C.1) Description of Dakalt canal system

Distribution canal reaches	Meskas & direct irrigation offtakes						
	Name	Location (km)	Side	Length (km)	$A_m\&A_d$ (right) (fed)	$A_m\&A_d$ (leftt) (fed)	Total $A_m\&A_d$ (fed)
Reach # 1	El-Gheit El-Bahary	1.450	Left	6.800	220	288	508.0
	Edrega Bahary	1.800	Right	1.900	0	177	177.0
	Ghogar	2.100	Right	2.700	0	169	169.0
	El-Tamaneen	2.410	Right	2.840	0	165	165.0
	Sarhan	2.660	Right	2.780	0	253	253.0
	El-Khalif	2.850	Right	4.600	0	504	504.0
	Al-Wezariya	2.850	Left	4.360	106	198	304 0
	R1D1	1.190	Right		8	0	8.0
	R1D2	1.850	Left		0	58	58.0
	R1D3	2.100	Right		11.3	0	11.3
	R1D4	2.415	Right		11.7	0	11.7
	R1D5	2.760	Left		73	0	73.0
Reach # 2	El-Fara' El-Alee	4.200	Left	3.142	118	305	423.0
	El-Tayiara	4.800	Right	3.180	43	137	180.0
	El-Sba'tasher	4.950	Left	0.210	0	40	40.0
	Helal	5.570	Right	1.500	50	92	142.0
	R2D1	3.730	Left		33.6	32.9	66.5
	R2D2	4.185	Right		91.5	0	91.5
	R2D3	4.350	Left		0	9.6	9.6
	R2D4	4.353	Left		0	4.9	4.9
	R2D5	4.685	Left		0	7.3	7.3
	R2D6	5.160	Left		0	33.3	33.3
	R2D7	5.400	Right		0	34.6	34.6
Reach # 3	El-Manshiya	5.754	Left	2.439	111	135	246.0
	El-Shahaiyna	6.950	Right	0.854	9	32	41.0
	El-Gabbana	7.400	Right	0.995	49	49	98.0
	Hema	7.675	Left	0.586	23	46	69.0
	El-Gamiya	7.840	Left	0.710	72	0	72.0
	Hamad	8.150	Right	2.210	131	88	219.0
	El-Desouky	8.175	Left	1.027	17.3	9.7	27.0
	Shams El-Din	8.195	Left	0.800	37.7	20.3	58.0
	Om-Sen	8.450	Right	1.710	123	82	205.0
	R3D1	5.920	Left		0	10	10.0
	R3D2	6.275	Right		0	65	65.0
	R3D3	6.395	Left		0	35	35.0
	R3D4	6.400	Right		60	0	60.0
	R3D5	6.950	Right		0	76	76.0
	R3D6	7.380	Right		0	60	60.0
	R3D7	7.596	Left		30	30	60.0
	R3D8	8.240	Right		56	28	84.0
	R3D9	8.525	Left		0	10	10.0
	R3D10	8.880	Right		78	17	95.0
	R3D11	9.025	Left		0	48	48.0
	R3D12	9.400	Left		37	37	74.0
	R3D13	9.750	Left		38	38	76.0
	R3D14	10.077	Right		42	43	85.0
	R3D15	10.150	Left		31	32	63.0
	R3D16	10.480	Left		31	32	63.0
	R3D17	10.650	Right		62	0	62.0
	R3D18	10.705	Left		38	38	76.0
	R3D19	11.175	Left		46	0	46.0

Table (C.2) Actual cropping pattern of Dakalt canal in July

Distribution canal reaches	Meskas &direct irrigation offtakes	Cultivated area by each crop (fed)				
		Rice	S.Beets	Cotton	Maize	W.Melon
Reach # 1	El-Gheit El-Bahary	266.0	0.0	124	50.0	68.0
	Edrega Bahary	0.0	0.0	93	84.0	0.0
	Ghogar	73.0	0.0	60	36.0	0.0
	El-Tamaneen	46.0	0.0	57	62.0	0.0
	Sarhan	102.0	0.0	68	53.0	30.0
	El-Khalif	318.0	0.0	100	35.0	51.0
	Al-Wezariya	208.0	0.0	44	9.0	43.0
	R1D1	4.0	0.0	2	1.0	1.0
	R1D2	30.0	0.0	14	6.0	8.0
	R1D3	6.0	0.0	3	1.0	1.3
	R1D4	6.0	0.0	3	1.0	1.7
	R1D5	38.0	0.0	19	8.0	8.0
Reach # 2	El-Fara' El-Alee	223.0	0.0	92.0	43.0	65.0
	El-Tayiara	90.0	0.0	20.0	33.0	37.0
	El-Sba'tasher	20.0	0.0	7.0	8.0	5.0
	Helal	70.0	0.0	46.0	16.0	10.0
	R2D1	34.0	0.0	16.0	4.0	12.5
	R2D2	48.0	0.0	24.0	9.0	10.5
	R2D3	5.0	0.0	2.5	1.0	1.1
	R2D4	2.0	0.0	1.5	0.7	0.7
	R2D5	3.0	0.0	1.5	1.5	1.3
	R2D6	15.0	0.0	8.0	3.3	7.0
	R2D7	16.0	0.0	8.3	3.3	7.0
Reach # 3	El-Manshiya	147.0	0.0	51.0	22.0	26.0
	El-Shahaiyna	24.0	0.0	0.0	8.0	9.0
	El-Gabbana	41.0	0.0	18.0	20.0	19.0
	Hema	6.0	0.0	50.0	6.0	7.0
	El-Gamiya	38.0	0.0	16.0	14.0	4.0
	Hamad	125.0	0.0	51.0	35.0	8.0
	El-Desouky	14.0	0.0	5.0	4.0	4.0
	Shams El-Din	31.0	0.0	15.0	10.0	2.0
	Om-Sen	101.0	0.0	62.0	15.0	27.0
	R3D1	4.0	0.0	3.0	2.0	1.0
	R3D2	33.0	0.0	16.0	7.0	9.0
	R3D3	16.0	0.0	8.0	5.0	6.0
	R3D4	28.0	0.0	14.0	8.0	10.0
	R3D5	39.0	0.0	19.0	8.0	10.0
	R3D6	30.0	0.0	15.0	8.0	7.0
	R3D7	30.0	0.0	15.0	6.0	9.0
	R3D8	42.0	0.0	21.0	9.0	12.0
	R3D9	4.0	0.0	2.0	3.0	1.0
	R3D10	47.0	0.0	24.0	10.0	14.0
	R3D11	24.0	0.0	12.0	5.0	7.0
	R3D12	36.0	0.0	19.0	8.0	11.0
	R3D13	37.0	0.0	19.0	8.0	12.0
	R3D14	43.0	0.0	22.0	9.0	11.0
	R3D15	31.0	0.0	15.0	7.0	10.0
	R3D16	31.0	0.0	15.0	6.0	11.0
	R3D17	30.0	0.0	15.0	8.0	9.0
	R3D18	37.0	0.0	19.0	8.0	12.0
	R3D19	23.0	0.0	12.0	5.0	6.0

Table (C.3) Maximum required discharge during hours of irrigation (m^3/fed/sec) for the area served by Dakalt canal

Month	$Et_{o(avg)}$ (mm/day)	Crop	$K_{c i(avg)}$	A_{ci} (fed)	N_2 (day)	N_1 (day)	initial T_c (day-hour)	T_s (day-hour)	WC (m^3/sec)	Final T_c (day-hour)	T_P (hour)	Q_d (m^3/sec)	WC_{avg} (m^3/fed/sec)	WR_m (m^3/fed/sec)	WR_{mm} (m^3/fed/sec)
January	2.04	Clover	0.83	2838	4	12	16	8	0.434	16	8	1.927	7.96E-05	0.0010	0.0016
		Wheat	0.69	1345											
		S.Beets	0.86	1275											
February	2.57	Clover	0.89	2838	4	12	16	8	0.598	16	8	2.653	0.00011	0.0014	
		Wheat	0.78	1345											
		S.Beets	0.95	1275											
July	6.5	Rice	1.52	2726	5	10	18	5	2.052	21	16	4.552	0.000376	0.0016	
		Cotton	0.88	1368											
		Maize	0.99	781											
		W.Melon	0.64	583											
August	5.97	Rice	1.87	2726	5	10	18	5	1.973	21	16	4.376	0.000361	0.0016	
		Cotton	0.50	1368											
		Maize	0.89	781											
		W.Melon	0.55	583											
September	5.09	Rice	2.22	2630	5	10	18	6	1.655	19	13	4.519	0.000303	0.0016	
		Cotton	0.33	976											
		Maize	0.53	555											
		W.Melon	0.20	8											
		S.Beets	0.18	1289											
October	3.81	Rice	1.78	521	6	12	16	8	0.214	16	8	0.951	3.93E-05	0.0003	
		Cotton	0.00	758											
		Maize	0.00	66											
		Clover	0.00	2838											
		S.Beets	0.18	1275											
November	2.63	Clover	0.57	2838	4	12	16	8	0.376	16	8	1.667	6.89E-05	0.0009	
		Wheat	0.49	1345											
		S.Beets	0.52	1275											
December	1.86	Clover	0.86	2838	4	12	16	8	0.393	16	8	1.742	7.193E-05	0.0009	
		Wheat	0.75	1345											
		S.Beets	0.70	1275											

Table (C.4) Design of meskas and direct irrigation offtakes

n_m = 0.016 Free board = 0.25 m X = b / d = 1.5 S = 0.00015

Distribution canal reaches	Meska & direct irrigation offtakes	Q_{md} & Q_{dd} (m^3/sec)	d (m)	b (m)	b_{actual} (m)	d_{actual} (m)	d_t (m)
Reach # 1	El-Gheit El-Bahary	0.824	1.09	1.637	1.65	1.08	1.35
	Edrega Bahary	0.287	0.73	1.102	1.15	0.69	0.95
	Ghogar	0.274	0.72	1.083	1.10	0.70	1.00
	El-Tamaneen	0.268	0.72	1.07	1.10	0.70	0.95
	Sarhan	0.410	0.84	1.26	1.30	0.81	1.10
	El-Khalif	0.818	1.09	1.63	1.65	1.07	1.35
	Al-Wezariya	0.493	0.90	1.35	1.40	0.86	1.15
	R1D1	0.051	0.38	0.58	0.60	0.36	0.65
	R1D2	0.094	0.48	0.73	0.75	0.46	0.75
	R1D3	0.051	0.38	0.58	0.60	0.36	0.65
	R1D4	0.051	0.38	0.58	0.60	0.36	0.65
	R1D5	0.118	0.53	0.79	0.80	0.52	0.80
Reach # 2	El-Fara' El-Alee	0.686	1.02	1.53	1.55	1.00	1.25
	El-Tayiara	0.292	0.74	1.11	1.15	0.71	1.00
	El-Sba'tasher	0.065	0.42	0.63	0.65	0.40	0.70
	Helal	0.230	0.68	1.02	1.05	0.65	0.90
	R2D1	0.108	0.51	0.76	0.80	0.48	0.75
	R2D2	0.148	0.57	0.86	0.90	0.54	0.80
	R2D3	0.051	0.38	0.58	0.60	0.36	0.65
	R2D4	0.051	0.38	0.58	0.60	0.36	0.65
	R2D5	0.051	0.38	0.58	0.60	0.36	0.65
	R2D6	0.051	0.38	0.58	0.60	0.36	0.65
	R2D7	0.051	0.38	0.58	0.60	0.36	0.65
Reach # 3	El-Manshiya	0.399	0.83	1.25	1.25	0.82	1.10
	El-Shahaiyna	0.067	0.42	0.64	0.65	0.41	0.70
	El-Gabbana	0.159	0.59	0.88	0.90	0.57	0.85
	Hema	0.112	0.52	0.77	0.80	0.50	0.75
	El-Gamiya	0.117	0.52	0.79	0.80	0.51	0.80
	Hamad	0.355	0.80	1.19	1.20	0.79	1.05
	El-Desouky	0.051	0.38	0.58	0.60	0.36	0.65
	Shams El-Din	0.094	0.48	0.73	0.75	0.46	0.75
	Om-Sen	0.333	0.78	1.16	1.20	0.75	1.00
	R3D1	0.051	0.38	0.58	0.60	0.36	0.65
	R3D2	0.105	0.50	0.76	0.80	0.47	0.75
	R3D3	0.051	0.38	0.58	0.60	0.36	0.65
	R3D4	0.097	0.49	0.73	0.75	0.47	0.75
	R3D5	0.123	0.54	0.80	0.85	0.50	0.75
	R3D6	0.097	0.49	0.73	0.75	0.47	0.75
	R3D7	0.097	0.49	0.73	0.75	0.47	0.75
	R3D8	0.136	0.56	0.83	0.85	0.54	0.80
	R3D9	0.051	0.38	0.58	0.60	0.36	0.65
	R3D10	0.154	0.58	0.87	0.90	0.56	0.85
	R3D11	0.078	0.45	0.68	0.70	0.43	0.70
	R3D12	0.120	0.53	0.79	0.80	0.52	0.80
	R3D13	0.123	0.54	0.80	0.85	0.50	0.75
	R3D14	0.138	0.56	0.84	0.85	0.55	0.80
	R3D15	0.102	0.50	0.75	0.75	0.49	0.75
	R3D16	0.102	0.50	0.75	0.75	0.49	0.75
	R3D17	0.101	0.50	0.74	0.75	0.49	0.75
	R3D18	0.123	0.54	0.80	0.85	0.50	0.75
	R3D19	0.075	0.44	0.67	0.70	0.41	0.70

Table (C.5) Design of outlets on meskas and direct irrigation offtakes

A_{irr} =1 fed. F = 0.0075 H = 0.25 m Concrete pipe of diameter = 0.225 m
T_m = 16 hour A_{ot} = 6 fed. q_{otd} = 0.051 m^3/sec

Distribution canal reaches	Meskas & direct irrigation offtakes	right road width (m)	Left road width (m)	N_{otm}&N_{otd} (right)	N_{otm}&N_{otd} (left)	N_{otm}&N_{otd} (total)	N_{un-otm} & N_{un-otd}
Reach # 1	El-Gheit El-Bahary	10	10	37	48	85	17
	Edrega Bahary	10	4	0	30	30	6
	Ghogar	10	3	0	29	29	6
	El-Tamaneen	14	4	0	28	28	6
	Sarhan	9	4	0	43	43	9
	El-Khalif	20	3	0	84	84	16
	Al-Wezariya	7	3	18	33	51	10
	R1D1	0	0	2	0	2	1
	R1D2	0	0	0	10	10	2
	R1D3	0	0	2	0	2	1
	R1D4	0	0	2	0	2	1
	R1D5	0	0	13	0	13	3
Reach # 2	El-Fara' El-Alee	7	3	20	51	71	14
	El-Tayiara	7	3	8	23	31	6
	El-Sba'tasher	6	8	0	7	7	2
	Helal	6	4	9	16	25	5
	R2D1	0	0	6	6	12	3
	R2D2	0	0	16	0	16	3
	R2D3	0	0	0	2	2	1
	R2D4	0	0	0	1	1	1
	R2D5	0	0	0	2	2	1
	R2D6	0	0	0	6	6	1
	R2D7	0	0	0	6	6	1
Reach # 3	El-Manshiya	8	6	19	23	42	8
	El-Shahaiyna	6	4	2	6	8	2
	El-Gabbana	10	10	9	9	18	4
	Hema	10	10	4	8	12	3
	El-Gamiya	10	10	12	0	12	3
	Hamad	8	6	22	15	37	7
	El-Desouky	10	10	3	2	5	1
	Shams El-Din	10	10	7	4	11	2
	Om-Sen	6	3	21	14	35	7
	R3D1	0	0	0	2	2	1
	R3D2	0	0	0	11	11	3
	R3D3	0	0	0	6	6	1
	R3D4	0	0	10	0	10	2
	R3D5	0	0	0	13	13	3
	R3D6	0	0	0	10	10	2
	R3D7	0	0	5	5	10	2
	R3D8	0	0	10	5	15	3
	R3D9	0	0	0	2	2	1
	R3D10	0	0	13	3	16	4
	R3D11	0	0	0	8	8	2
	R3D12	0	0	7	7	14	3
	R3D13	0	0	7	7	14	3
	R3D14	0	0	7	8	15	3
	R3D15	0	0	6	6	12	2
	R3D16	0	0	6	6	12	2
	R3D17	0	0	11	0	11	2
	R3D18	0	0	7	7	14	3
	R3D19	0	0	8	0	8	2

Table (C.6) Operation of two-turn rotation of Dakalt canal

N_1 = 10 days N_2 = 5 days

Reach #	Q_{desr} m^3 / sec	Rotations	
		On-meskas & direct irrigation offtakes	$Qreq_{drd}$ (m^3/s)
1	1.9	Sarhan, El-Gheit El-Bahary, Al-Wezariya, R1D5	1.864
		Edrega Bahary, Ghogar, El-Tamaneen, El-Khalif, R1D1, R1D2, R1D3, R1D4	1.791
2	0.88	Helal, El-Tayiara, R2D2, R2D1, R2D3, R2D7	0.85
		El-Fara' El-Alee, El-Sba'tasher, R2D4, R2D5, R2D6	0.825
3	1.86	R3D8, El-Manshiya, Hamad, Om-Sen, El-Gabbana, R3D10, R3D14, R3D19	1.749
		Hema, El-Gamiya, El-Desouky, El-Shahaiyna Shams El-Din, R3D1, R3D2, R3D3, R3D4, R3D5, R3D6, R3D7, R3D9, R3D11, R3D12, R3D13, R3D15, R3D16, R3D17, R3D18	1.792

Table (C.7) Operation of three-turn rotation of Dakalt canal

N_1 = 12 days N_4 = 5 days

Reach #	Q_{desr} m^3 / sec	Rotations	
		On-meskas & direct irrigation offtakes	$Qreq_{drd}$ (m^3/s)
1	1.9	El-Gheit El-Bahary, Edrega Bahary, R1D5	1.229
		Ghogar, El-Tamaneen, Sarhan, , R1D1, R1D2, R1D3, R1D4	1.199
		El-Khalif, Al-Wezariya	1.311
2	0.88	El-Fara' El-Alee	0.686
		El-Tayiara, El-Sba'tasher, Helal	0.587
		R2D1,R2D2, R2D3,R2D4, R2D5, R2D6	0.511
3	1.86	El-Manshiya, El-Shahaiyna, El-Gabbana,Hema, El-Gamiya Hamad	1.209
		El-Desouky, Shams El-Din, Om-Sen,R3D1, R3D2, R3D4, R3D5, R3D6, R3D7, R3D8	1.184
		R3D3,R3D9,R3d10, R3D11, R3D12, R3D13, R3D14,R3D15, R3D16, R3D17, R3D18,R3D19	1.183

Table (C.8) Operation of meskas and direct irrigation offtakes in July (two turn rotation)

Distribution canal reaches	Meskas & direct irrigation offtakes	$qcon_m$ (m^3 / sec)	$qreq_m$ (m^3 / sec)	$Qreq_{mr}$ (m^3 / sec)	Q_{md} & Q_{dd} (m^3 / sec)	N_{opm} & N_{opd} (hour)
Reach # 1	El-Gheit El-Bahary	0.1916	0.276	0.551	0.824	17
	Edrega Bahary	0.0521	0.075	0.150	0.287	13
	Ghogar	0.0630	0.091	0.181	0.274	16
	El-Tamaneen	0.0573	0.082	0.165	0.268	15
	Sarhan	0.0905	0.130	0.260	0.410	16
	El-Khalif	0.2018	0.290	0.581	0.818	18
	Al-Wezariya	0.1236	0.178	0.356	0.493	18
	R1D1	0.0030	0.004	0.009	0.051	5
	R1D2	0.0218	0.031	0.063	0.094	16
	R1D3	0.0043	0.006	0.012	0.051	6
	R1D4	0.0044	0.006	0.013	0.051	6
	R1D5	0.0277	0.040	0.080	0.118	17
Reach # 2	El-Fara' El-Alee	0.1593	0.229	0.458	0.686	17
	El-Tayiara	0.0666	0.096	0.192	0.292	16
	El-Sba'tasher	0.0151	0.022	0.043	0.065	17
	Helal	0.0534	0.077	0.154	0.230	17
	R2D1	0.0246	0.035	0.071	0.108	16
	R2D2	0.0347	0.050	0.100	0.148	17
	R2D3	0.0036	0.005	0.010	0.051	5
	R2D4	0.0017	0.003	0.005	0.051	3
	R2D5	0.0026	0.004	0.007	0.051	4
	R2D6	0.0119	0.017	0.034	0.051	17
	R2D7	0.0124	0.018	0.036	0.051	17
Reach # 3	El-Manshiya	0.0969	0.139	0.279	0.399	17
	El-Shahaiyna	0.0158	0.023	0.046	0.067	17
	El-Gabbana	0.0348	0.050	0.100	0.159	16
	Hema	0.0201	0.029	0.058	0.112	13
	El-Gamiya	0.0279	0.040	0.080	0.117	17
	Hamad	0.0868	0.125	0.250	0.355	17
	El-Desouky	0.0102	0.015	0.029	0.051	14
	Shams El-Din	0.0226	0.032	0.065	0.094	17
	Om-Sen	0.0759	0.109	0.218	0.333	16
	R3D1	0.0036	0.005	0.010	0.051	5
	R3D2	0.0243	0.035	0.070	0.105	16
	R3D3	0.0127	0.018	0.036	0.051	18
	R3D4	0.0219	0.031	0.063	0.097	16
	R3D5	0.0285	0.041	0.082	0.123	16
	R3D6	0.0225	0.032	0.065	0.097	16
	R3D7	0.0223	0.032	0.064	0.097	16
	R3D8	0.0313	0.045	0.090	0.136	16
	R3D9	0.0036	0.005	0.010	0.051	5
	R3D10	0.0352	0.051	0.101	0.154	16
	R3D11	0.0178	0.026	0.051	0.078	16
	R3D12	0.0273	0.039	0.079	0.120	16
	R3D13	0.0280	0.040	0.080	0.123	16
	R3D14	0.0318	0.046	0.092	0.138	16
	R3D15	0.0233	0.033	0.067	0.102	16
	R3D16	0.0232	0.033	0.067	0.102	16
	R3D17	0.0229	0.033	0.066	0.101	16
	R3D18	0.0280	0.040	0.080	0.123	16
	R3D19	0.0172	0.025	0.049	0.075	16

Table (C.9) Required time for one irrigation per one feddan of certain crop in July and December

Month	Crop	Nirr	Kcia (Average)	Tirra (hour)
July	Rice	2	1.520	2
	Cotton	1	0.880	2
	Maize	1	0.990	3
	W.Melon	1	0.640	2
December	Clover	1	0.860	1
	Wheat	1	0.750	1
	S.Beets	1	0.700	1

Table (C.10) Saved area due to lined meskas

Meska	Length (Km)	Area served (fed)	Top width of earthen meska	Bottom width of lined meska	Saved area (%)	Average saved area (%)
Edrega Bahary	1.9	177	7	1.15	1	1
Ghogar	2.7	169	6	1.1	2	
El-Tamaneen	2.84	165	6	1.1	2	
Sarhan	2.78	253	8	1.3	2	
El-Khalif	4.6	504	6	1.65	1	
Al-Wezariya	4.36	304	3	1.4	1	
El-Fara El-Alee	3.142	423	7	1.55	1	
El-Tayiara	3.18	180	4	1.15	1	
Helal	1.5	142	5	1.05	1	
El-Manshiya	2.439	246	8	1.25	2	
Hamad	2.21	219	3.5	1.2	1	
Om-Sen	1.7	205	4	1.2	1	

Table (C.11) Economical comparative study per feddan between the Improved Irrigation Project (IIP) and the suggested approach

Annual maintenance cost (L.E./fed/year)		Initial cost (L.E./ fed)		Return of saved area (1% feddan)			
				Annual return (L.E./year)		Price of area served (L.E.)	
IIP	Suggested approach	IIP	Suggested approach	IIP	Suggested approach	IIP	Suggested approach
30	-	2500	3700	-	35-40	-	700