Journal of Engineering
Sciences Assiut University
Faculty of Engineering
Vol. 49, No. 1
January 2021
PP. 064 – 084

CONVEYANCE LOSSES ESTIMATION FOR OPEN CHANNELS IN MIDDLE EGYPT

CASE STUDY: ALMANNA MAIN CANAL, AND ITS DISTRIBUTARIES

Tarek Sayed Abuzeid

Civil Engineering Department, Assiut University, Assiut, Egypt
* *tareksayed1986@aun.edu.eg*

Received 10 January 2021; Revised 02 February 2021; Accepted 03 February 2021

Abstract

Whereas the irrigation water transmission open channel network in Egypt, is one of the largest and longest networks all over the world that dogged in permeable soil (about 33500 km in length). In a country that suffers greatly from an increasing shortage of limited available irrigation water quantities, ignoring the expected huge quantities of irrigation water losses through transport operations is a path of madness, to bridge the accelerated gap between what is required, and what is exist. Irrigation water conveyance losses include seepage, evaporation, and transpiration losses. Such losses are differentiated according to, type of soil, weather condition, and beneficiaries' traditions and behaviors. So, conducting field studies in various agricultural representative regions in Egypt, would be the most effective way for estimating the lost quantities of irrigation water all over the country through seepage, evaporation, and transportation basses. This way, decision-makers can use such acquired quantities for solving the problems of lack or non-arrival of irrigation water to the ends of some canals. In the present paper, the results of a field study carried out on one of the main irrigation canals in Assiut governorate in middle Egypt is introduced, as a case study represents the region of Middle Egypt area. The results of this field study in combination with similar studies conducted in various agricultural regions across Egypt, can provide the decision-makers with the needed documented data, on the basis of which, water resources can be managed at the state level in the way, that maximizes the return from the available limited water, for irrigation and contributes to solve some irrigation problems of the large deficit between the available and required of irrigation water. Almanna canal belongs to Abnoub Irrigation Engineering Administration in Assiut, was chosen to conduct the present field study as a representative open channel having specific properties from different technical points of view, soil type, weather condition, and the length with its off-taking canals. The used data in this research were collected from the field and through the official Ministry of water resources and irrigation authority in Assiut governorate. Results indicate that, the total loss of irrigation water from Almanna canal and its branches (79.90 Km length) reaches about 16.05 million cubic meters per month, which represent 23.90% of the actual discharges that give to the Almanna canal and its branches. The lost water through only seepage reaches about 15.95 million cubic meters per month, representing 99% of all lost irrigation water. While, the rate of increase in the evaporation losses at earthen sections more than the designed sections losses can be neglected. Thus, the lining of Almanna canal and its branches is the most effective solution for saving such a huge amount of water, and directed it to irrigate some newly reclaimed areas, in addition, to solve the problems of non-arrival of the irrigation water to the ends of some irrigation canals. At the same time, improving the environmental situation of the surrounding agricultural community.

Keywords: Seepage losses; irrigation water transportation; Agricultural community's environment.

1. Introduction

Open canals are the common method used to convey water for irrigation in Egypt. Irrigation canals network in Egypt for all levels suffer from water deficit, distorted sections and un-equitable distribution of irrigation water among beneficiaries, however, little or no attention is given to the evaluation of conveyance systems. So, its modernization became omnipresent to overcome the problem of water shortage by the end of canals. The old land which is irrigated by surface irrigation is estimated as 79% of all cropped areas in Egypt. So, it is very important to improve the irrigation system in this area by increasing the irrigation transport efficiency **[1].**

A large portion of the water diverted into irrigation channels is lost in transit, this loss is composed of five parts: (a) leakage, (b) waste, (c) seepage, (d) evaporation, and (e) transpiration, by leakage is meant the water lost through poorly maintained gates and structures. Waste represents the amount which is lost through automatic waste ways or merely discharged into waste ways. Although the waste and leakage may be very high in some instances, these losses are out of the scope of this study. Three basic causes of such water losses will be discussed in this paper which are as: losses due to evaporation, losses due to seepage, and losses due to transpiration (through the weeds and the vegetation on the bank of channels).

1.1. Seepage Loss

Seepage loss is one of the major components of water loss from canals. The reduction or elimination of seepage losses in irrigation canals by means of linings assures better conveyance of the irrigation water and an improved economic situation. Seepage losses from earthen irrigation channels depend on a number of factors and vary from (30 to 50) percent of the discharge available at the head of an irrigation system **[2]**. Canal seepage primarily depends upon the soil permeability, water depth in the canal, length of wetted perimeter, channel geometry, location of groundwater table, velocity of the flowing water, shear stress (force of moving water on bed), slope between surface of water in canal and beneath groundwater surface of an aquifer, constrains on groundwater flow e.g. drains, rivers and streams **[3, 4, 5, and 6]**. Less significant are viscosity of canal water, canal water salinity, sediment load and distribution of size, canal age and plants **[3 and 6]**.

Seepage is measured in the field, through the inflow- outflow, ponding, point measurement, and permeameter measurement method. Also, double ring infiltration test, ADCP (Acoustic Doppler Current Profiler) and electrical resistivity tests are also carried out for seepage estimation **[7]**. Seepage can be reduced up to 30 to 40% with lining but seepage cannot be controlled completely **[6, 8, and 9].** The presence of cracks in the lining greatly reduces its effectiveness **[10]**. Seepage can be reduced by reducing the wetted perimeter and increasing flow velocity **[11]**. Optimization models based on a genetic algorithm reduces water transportation losses in canals. This is carried out by providing a reasonable arrangement of canal water allocation times and discharges **[12]**. The seepage loss was studied at Ismailia canal sections in variable stages using empirical and analytical formulae and found the minimum seepage losses occurred at section which started from Km. (0.00) to Km. (10.05) and the maximum seepage losses occurred at section started from Km (49.00) to Km (67.00) **[13]**. Also, the results showed that the maximum expected seepage losses is 0.645 m^3/sec/km, which represent about 20% from the total discharge. Bakry and Awad **[14]** developed four equations to estimate the seepage in earthen canals using the Inflow-Outflow method. The equations are only valid for earthen canals having discharge ranging from 2 to 20 m^3/sec. Based on the results of the study given by Eshetu and Alamirew **[15],** the average values of seepage loss in the canals were 0.55% per 100 m and 0.84% per 100 m for lined and unlined primary canals respectively. Canal concrete liners normally decrease the seepage losses through the bottoms and sides; prevent weed growth and retard moss accumulation. They also decrease erosion from high velocities, reduce maintenance costs, and increase the capacity of the canal to convey water. However, they do not eliminate seepage loss **[16]**.

1.2. Evaporation Loss

It is the transfer of the water from the liquid to vapor stage. As the canal water is exposed to the atmosphere at the surface, loss due to evaporation is obvious. The evaporation losses are very small as compared to the seepage losses. It is of course true that in most of the cases evaporation loss is not significant. It is may range from 0.25 to 1 % of the total canal discharge **[17]**. Methods commonly used for estimating evaporation loss from canals are given by Liu et al. [18], and McJannet, et al. [19]: the evaporation pan, the water balance method, the heat balance method (also known as the energy balance method), and the aerodynamic method. Evaporation pans have been commonly used to observe open water evaporation such as a large area of open lake **[19]**. Generally, irrigation canals are very narrow and long, and the flow speed of water is relatively high. Thus, it is very difficult to implement the evaporation pans on a running water surface **[20]**. Substantial efforts have been performed to estimate the evaporation loss from agricultural irrigation canals. The evaporation from canals was estimated by using a simple empirical relationship between evaporation rate and water surface area **[21]**, but for simplicity, the author assumed that the evaporation rate of canal water was equal to that of a local water surface without considering the complexity of natural environment conditions. The aerodynamic method based on the double-deck surface air layer model (DSAL) used for estimating evaporation loss from irrigation canals **[22]**. Results showed that cumulative evaporation instances estimated by the DSAL model were equal in order of magnitude to those by the heat balance method. Several former studies (e.g. Burt [23], and Chen and Jia [24]) have attempted to use the water balance method to estimate the evaporation loss from irrigation canals. It is well known that the rate of evaporation from open water depends on the surface wind speed and increases directly with it. The rate of evaporation from a running water surface depended not only on the surface wind speed but also on the flow speed of water **[25]**, and they constructed a formula describing the functional dependence of evaporation rate on wind speed and water flow speed.

1.3. Transpiration Loss

Some amount of water flowing through the canals is lost by the process of transpiration. The plants, grass and weeds or other vegetation that grow on the banks of the canals undergo transpiration thereby resulting in loss water from the canal transpiration losses are very less in comparison to the seepage and evaporation losses in the canal. Aquatic vegetation distort canal design features (increase sedimentation, decrease channel flow, etc.), and reduce water quality. In general, designed capacity of irrigation canals has not accounted for flow resistance caused by aquatic vegetation **[26]**. Aquatic vegetation management in irrigation systems requires the use of a variety of techniques to maintain the water flow critical to agricultural productivity and profitability and to protect and preserve important natural resources **[27]**.

Researches showed that in the near future Egypt will face scarcity of water **[28]**. So the amount of water available should be increased by finding new sources of water other than the Nile, i.e., desalination of seawater, rain harvesting, and reuse of wastewater. At the same time, preserving and decreasing the waste of water from existing water sources will combat the expected water scarcity in Egypt. For example, decreasing seepage, transpiration (through the weeds and the vegetation on the bank of channels), and evaporation that results from irrigation canals will preserve the quantity of surface water in these canals. This is goal of this study, to quantify the seepage, transpiration, and evaporation losses from Almanna canal and its irrigation canal network in Abnoub, Assuit, Egypt, so as to preserve this amount of water that otherwise would have been lost. The utility of the present research is of immense importance at the planning and design stage.

2. Materials and Methods

2.1. Description of the study area

Almanna canal was chosen to conduct the present field study as a representative open channel having specific properties from different technical points of view, soil type, weather condition, and the length with its off-taking canals. Almanna canal belongs to Abnoub Irrigation Engineering Administration in Assiut. It is located between $27^o16'$ and $27^o33'$ north latitude and between $31^o27'$ and $31^o01'$ east Longitude. The area is characterized by arid climate. The elevation of agricultural land is at 48 m above the mean sea water level. The length of the canal is about 32.80 km and its intake located at km 157 at right bank for the Eastern Naga Hammady canal as shown in Fig. (1). Canal cropped area is 13500 feddan. 20 distributary canals are branched from Almanna canal on both sides as shown in Fig. (2). The total length of the branches is about 47.10 km. Winter crops are wheat, clover, bean and summer crops are Y-corn, sorghum, and basil. The meteorological data of the region is shown in Table (1), **[29]**. Table (2) shows the dimensions, characteristics, and discharges of the different sections of Almanna canal. It was firstly constructed between Al-Matmar and Al-Maabda to carry fresh water for irrigation. It has 4 regulators constructed along the total length. The first is a head regulator at km (0.00), the second at km. (10.45), the third at km. (16.45), and the fourth at km. (23.06). The dimensions, characteristics, and discharges of Almanna off-taking canals were shown in the following table (3). Manning equation is used for calculating the earthen (actual) and the designed discharges of canals as given in the tables (2), and (3). Manning equation could be written as:

$$Q = \frac{1}{n} \times S^{0.5} \times A \times R^{2/3} \qquad (1)$$

JES, Assiut University, Faculty of Engineering, Vol.49, No. 1, January 2021, pp. 064 - 084

Where Q: water discharge (m^3/s), S: friction slope it could be taken as water slope as demonstrated in Table (2) and Table (3) (m/km), R: hydraulic radius (m), and A: area of hydraulic section (m^2).

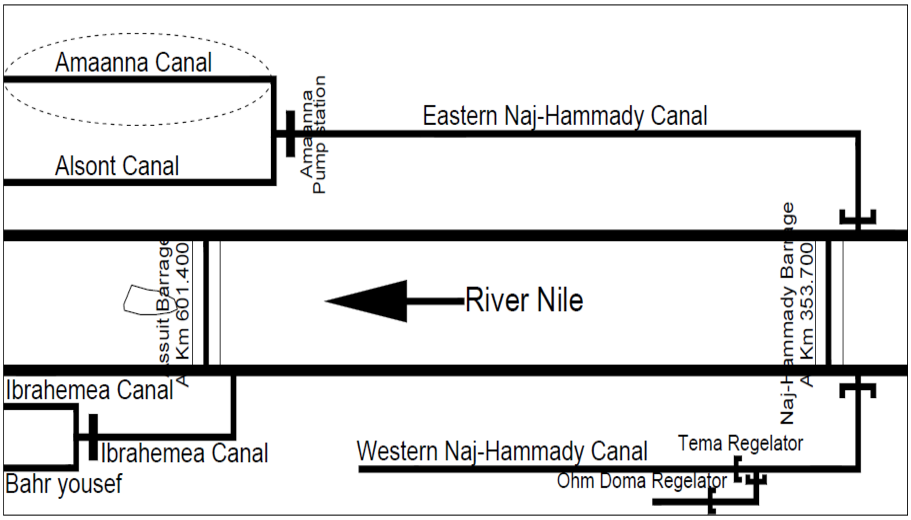

Fig. 1. Description of the study canal network

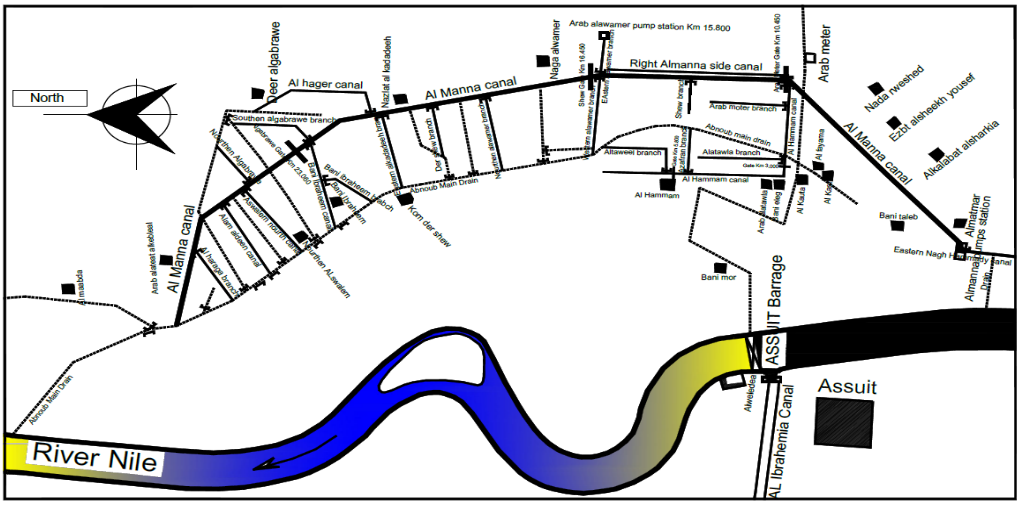

Fig. 2. Layout of Al-Manna canal and its distributaries

Table: 1. Meteorological data of Al-manna canal and its distributaries, **[29]**

Month	Max. Temp. °C	Min. Temp. °C	Avg. Temp. °C	% RH max	Pan Evaporation mm/day	wind speed (km/h)	No. of sunny hours / day
Jan	18	6.50	22.40	60.30	2.80	16.00	8.90
Feb.	22.5	11.20	26.10	52.60	3.20	17.30	9.70
Mar.	25	14.20	30.50	42.90	4.40	19.80	9.90
Apr.	29	17.10	35.10	36.50	6.40	21.30	10.30
May	32	22.00	38.10	35.10	6.60	20.30	11.40
Jun.	36	24.90	40.70	37.40	6.90	21.00	12.30
Jul.	37	25.30	39.10	41.50	7.40	19.50	12.20
Aug.	34.5	24.80	40.30	40.70	8.00	19.80	11.90
Sep.	29	23.80	38.50	46.20	7.00	21.70	10.80
Oct.	29	20.90	33.00	51.30	5.70	19.20	10.00
Nov.	27	13.20	27.00	54.70	5.00	15.20	9.40
Dec.	22.5	9.00	23.20	63.20	3.10	16.80	9.00

Table: 2. Dimensions, characteristics, and discharges of the different sections of Almanna canal (Side Slope 3:2).

No	Sections	Gate	Area (Fedd.)	Length (Km)	Long. Slope (m/Km)	Bed Width (m)	Bed Level	Water level	$Q_{Earthen}$ (m^3/sec)	$Q_{Designed}$ (m^3/sec)
1	(0.00 – 10.45)	Intake regulator-Arab Meter	0.000	10.450	0.00004	10.00	49.00	51.25	12.30	19.34
2	(10.45 – 16.45)	Arab Meter-Shew	7450	6.0000	0.00005	7.50	48.30	51.00	14.33	21.79
3	(16.45 – 23.06)	Shew- Algabrawe	3280	6.6100	0.00005	6.00	48.00	50.40	8.14	14.65
4	(23.06 – 26.40)	Algabrawe - End	2600	3.3400	0.00010	4.00	47.67	49.73	5.52	8.23
5	(26.40 – 32.80)	End	170.0	6.4000	0.00005	3.00	47.25	49.42	4.04	7.55

JES, Assiut University, Faculty of Engineering, Vol.49, No. 1, January 2021, pp. 064 - 084

Table: 3. Dimensions, characteristics, and discharges of Almanna branched or off-taking canals (Side Slope 1:1).

No	Canal	Canal feed	Km	Bank	Area (Fedd.)	Length (Km)	Long. Slope (m/Km)	Bed Width	Bed level	Water level	$Q_{Earthen}$ (m^3/sec)	$Q_{Designed}$ (m^3/sec)
1	R. Almanna s. canal	Almanna	10.50	Right	1000	5.827	0.00010	2.0	49.60	50.80	1.76	2.05
2	Al Hammam	Almanna	10.50	Left	3400	9.000	0.00005	4.0	49.00	50.60	1.07	4.39
2-1	Arab meter branch	Al Hammam	1.000	Left	600	2.000	0.00005	2.0	49.30	50.50	0.34	1.45
2-2	Al Atawla	Al Hammam	3.000	Left	500	2.400	0.00010	1.5	49.20	50.40	0.81	1.65
2-3	Al Zafran	Al Hammam	6.30	Left	400	2.300	0.00005	1.5	49.00	50.29	0.18	1.34
2-3	Al Taweel	Al Hammam	6.940	Left	500	2.400	0.00010	1.5	48.50	50.10	0.64	2.92
3	Shew	Amanna	12.50	Right	450	2.300	0.00010	1.0	49.00	50.20	0.20	1.26
4	Western Al Awamer	Almanna	16.30	Left	200	0.800	0.00005	1.0	48.80	50.28	0.42	1.38
5	Eastern Alawamer	Almanna	16.30	Left	400	0.670	0.00005	1.0	48.75	50.00	0.01	0.04
6	Northen Alawamer	Almanna	17.80	Left	780	1.400	0.00005	1.5	49.00	50.55	0.29	1.93
7	Der Shew	Almanna	19.80	Left	400	1.000	0.00005	1.0	48.55	49.45	0.05	0.50
8	Eastern Al kadadeeh	Almanna	21.80	Left	400	1.000	0.00005	1.0	48.50	49.60	0.12	0.74
9	Al Hager	Almanna	22.80	Right	500	4.200	0.00010	1.5	48.20	49.10	0.20	0.95
10	Bani Ibraheem	Almanna	23.80	Left	800	1.400	0.00005	2.0	48.00	49.65	0.52	1.74
10-1	Bani Ibraheem bran.	B. Ibraheem	0.250	Left	400	1.350	0.00005	1.0	48.00	49.20	0.03	1.45
11	Southern Al Gabrawe	Almanna	23.80	Left	500	2.200	0.00010	1.0	48.00	49.50	0.46	2.01
12	No.n Al Gabrawe	Almanna	25.65	Left	400	1.350	0.00005	1.0	48.00	49.15	0.08	0.81
13	Alswalem	Almanna	26.40	Left	700	1.800	0.00010	1.5	47.70	49.00	0.17	1.93
14	Alam Aldeen	Almanna	27.60	Left	500	1.600	0.00005	1.0	47.49	48.70	0.10	0.90
15	Al Haraga	Almanna	28.35	Left	500	2.100	0.00010	1.0	47.60	48.75	0.12	1.15

2.2. Determination of Seepage loss

In this part, the empirical formula of **Molesworth and Yennidunia** was used for estimating the seepage losses in different earthen sections for all canals of Almanna network. This formula is used in Egypt to estimate seepage loss **[30, 31]**, and is given as follows:

$$S=C\times L\times P\times R^{0.50} \qquad (2)$$

Where S is the conveyance losses for a given canal length (m^3/sec), L is the canal length in km., P is the wetted perimeter in m, R is the hydraulic radius in m, and C is the factor depends on soil types, for clay equal to 0.0015.

For each canal, the maximum seepage losses in different earthen sections every 300m were estimated by using the empirical formula of **Molesworth and Yennidunia.** The calculation of the seepage losses for the different earthen sections of Almanna canal and its branches were summarized as shown in the following Tables (5) and (6) respectively. From these tables, it is clear that the maximum value of Almanna canal seepage losses are in part one from intake regulator to km 10.45. Also, the minimum value of the same losses are in part four from km 23.030 to km 26.400. The maximum seepage losses in Almanna main canal is 0.601m^3/sec/km, which represent about 32.5 % from the total discharge. For the branches of Almanna canals, the maximum and minimum seepage losses are in between 0.0571 m^3/sec/km in Al-Hammam canal and 0.0038 m^3/sec/km in Eastern Al-Kadadeeh canal.

2.3. Determination of Evaporation loss

In this study, evaporation pan method was used to observe the evaporation losses of Almanna canal and its branches by using the meteorological data shown in Table (1). The designed or earthen sections of canals subject to evaporation losses. So, the available meteorological data was used to estimate the rate of increase in the evaporation losses at earthen sections more than the designed sections. For estimating the evaporation losses for the different section of Almanna canal branches in all months of year, the width of water surface in the different sections of canals every 200 or 300 m was measured, the value of the pan evaporation for each month as shown in Table (1) was used. Then, the evaporation losses were calculated by using Eq. (3) **[22]** as follows**:**

$$R= (E\times W\times L)\times Q \qquad (3)$$

Where E is the rate of evaporation (m^3/day), W the width of water surface in the canal (m), and Q the discharge (m^3/day). Since the rate of evaporation changes with time of day, R changes depending on the transportation spell and L length in m.

According to the pan evaporating in the Arab Alawamer meteorological station **[29]**, the minimum and maximum values of evaporation are in January, 2.82 mm/day and July, 8.00 mm/day respectively. Therefore, the seventh and eighth columns of Tables (5) and (6) show the summarized values of the maximum and minimum evaporation losses for the different earthen sections of Almanna canal and its branches respectively. From these tables it is clear that the maximum rate of increase in evaporation losses in earthen sections more than the designed sections are in part one, which started from intake regulator to km 10.45. While, the minimum rate of increase in evaporation losses are in part four, which started from km 23.03 to km 26.40. In Table (6), at Almanna branched canals, the negative values of evaporation losses rate clarify that the designed sections subject to evaporation losses more than the earthen sections because the width of the actual earthen sections are less than the width of designed sections as shown in Fig. (3).

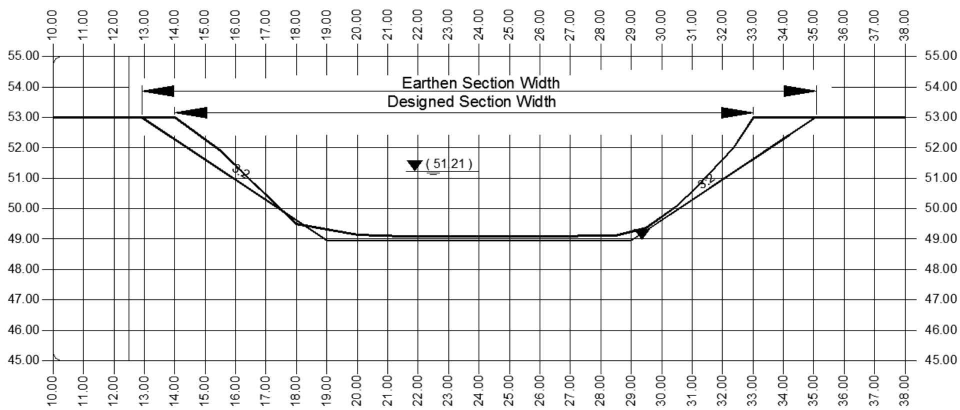

Fig. 3. Negative rate of evaporation losses.

2.4. Determination of Transpiration losses

In the present field study, the transpiration losses for grass and weeds are computed using an approach introduced by El-Enany et al. **[31]** as follows:

$$WC = \left(\frac{ET_O K_a A}{1000}\right) \times \frac{4200}{86400} \quad \text{(4)}$$

Where *WC* is the water consumption needed for the area served by a distributary canal during a month (m^3/sec.), *ETo* is the monthly average evapotranspiration for the area served by a distributary canal (mm/day), *Ka* is monthly average crop coefficient, and *A* is the cultivated area (feddan).

The reference evapotranspiration *ETo* was estimated by using CROPWATER Software for weeds and grass that located inside slopes and bed of canals using available meteorological data at Arab ALawamer local weather station as shown in Table (1), **[29]**. Measuring wheel, Fig. (4), is used for measuring slope lengths, banks widths and distance of grass and weeds at canals network. Fig. (5) shows the reference evapotranspiration for weeds using CROPWATER software. Jensen et al. **[32]** compared 20 methods of computing *ETo* for arid and humid locations. They found that the Penman-Monteith method was the most accurate for either environment. Because of its accuracy, the Penman-Monteith method is recommended when air temperature, relative humidity, wind speed, and solar radiation data are available **[32].**

The average crop coefficient (K_a) must include the basal crop coefficient (K_{Cb}) and the effect of wet soil evaporation (K_w). If water stress is expected, an appropriate stress factor (K_s) can also be selected although this is generally not done **[33, and 34]**. The average crop coefficient (K_a) is defined as:

$$K_a = (K_{cb} \times K_s) + K_w \quad \text{(5)}$$

Where K_{cb} = basal crop coefficients **[34]**; K_S = stress factor to reduce water use for stressed crops (water stress factor) equal to 1 **[30]**; and K_w = factor to account for increase evaporation (wet soil evaporation factor) **[34, and 35]**.

$$K_w = F_w \times (1 - K_{cb}) \times A_f \quad \text{.......................................(6)}$$

Where F_w = the fraction of the soil surface wetted that take 1.0 for basin irrigation, and A_f = the average wet soil evaporation factor, **[19]** as shown in Table (4).

Fig. 4. Measuring Wheel.

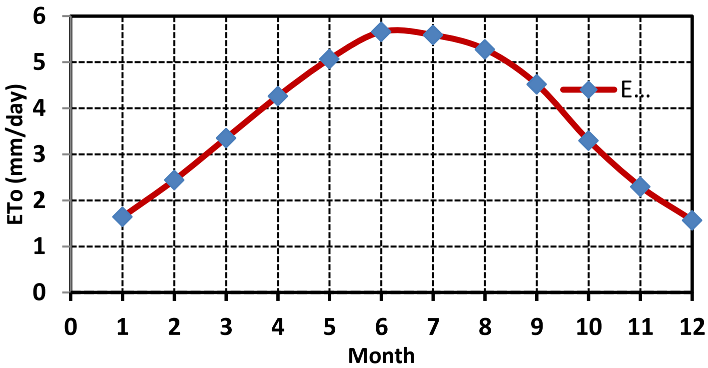

Fig. 5. Reference evapotranspiration (ETo) mm/ day

Table: 4. Values of coefficient K_{cb}, K_s, K_w, and K_a for evapotranspiration.

Crop	K_{cb}	K_s	F_w	A_f	K_w	K_a
Grass	0.25	1	1	0.511	0.38	0.63
	0.63	1	1	0.511	0.19	0.82
	1.20	1	1	0.511	0.00	1.20
	1.20	1	1	0.511	0.00	1.20
	1.20	1	1	0.511	0.00	1.20
	0.86	1	1	0.511	0.07	0.93
	1.00	1	1	0.511	0.00	1.00

The water is lost during on-days. The last three columns of tables (5) and (6) show the area of grass and weeds as measured from Almanna canal and its distributaries by the measuring wheel, the minimum and maximum evapotranspiration losses resulting due to these weeds and grass respectively. From these tables it is clear that minimum and maximum of transpiration losses are in January and July respectively. At Almanna canal, the maximum rate of transpiration losses are in part one from intake regulator to km 10.450 and minimum rate of transpiration losses are in part four from km 23.030 to end at km 26.400. It may be due to the length of the section, as the section length increase, the amount of weeds and grass increases and therefore the transpiration losses increases. At Almanna branched canals, the maximum and minimum transpiration losses due to grass and weeds area in canals are shown in the following Table (6). Figure (6) shows the weeds and grass on the banks and sides of a canal in the study area.

Fig. 6. Grass and weeds in Almanna canal

3. Results and Discussion

The following Tables (7) and (8) show the maximum values of the total losses in Almanna canal and its branches. From these tables it is clear that:

- The seepage losses are the major losses, while the losses due to evaporation is the lowest in Almanna canal.
- The seepage losses represented more than 99% of the total conveyances' losses, which estimated at about 14.36, 1.59 million m^3 per month, which representing 25.18%, 16.47% of the actual discharge in Almanna Canal and its branches, respectively.
- The maximum percentage of the total losses occurred in the first part (Km 0.000 to 10.450) of Almanna canal and its equals 32.55% of the

designed discharge. While the minimum percentage of the total losses occurred in the fourth part (Km 23.030 to 26.400) of Almanna canal equals 4.05% of the designed discharge, this may be due to the length of part, discharge, wetted perimeter, type of soil, and the density of grass and weeds.

- The maximum and minimum amount of total water lost through the whole length of Almanna canal equals 14425185.19 m^3/month and 14385145.54 m^3/month, respectively.
- In branches of Almanna canal, the seepage losses are the major losses, while the rate of increase in the evaporation losses at earthen sections more than the designed sections losses can be neglected.
- In branches of Almanna canal, the maximum percentage of the total water losses occurred in the Right Almanna side canal and Al-Hammam canal and its equals 15.56%, 11.79% of the designed discharge, respectively. While the minimum percentage of the total water losses occurred in the Eastern Al kadadeeh canal and Der-Shew canal and its equals 0.52%, 0.54% of the designed discharge, respectively.
- The maximum and minimum amount of total water lost through all branches of Almanna canal equals 1620316.748 m^3/month and 1600332.604 m^3/month, respectively.

Thus, the lining of Almanna canal and its branches is the most effective solution for saving such a huge amount of water, and directed it to irrigate some newly reclaimed areas, in addition, to solve the problems of non-arrival of the irrigation water to the ends of some irrigation canals. At the same time, the velocity of water in the canal will increase as the surface of the canal will be smooth due to the rugosity coefficient is improved, maintenance cost of the canal can be significantly decreased, and improving the environmental situation of the surrounding agricultural community.

Table: 5. Maximum seepage losses of Almanna canal actual earthen section:

No	Km	Designed Discharge	Actual Discharge	Seepage loss (m^3/s/km)	Total Seepage loss (m^3/day)	Min Rate of Ev. (m^3/day)	Max Rate of Ev.(m^3/day)	Weed area feddan	Min WC (m^3/day)	Max WC (m^3/day)
1	0.000-10.45	1671141.88	1062567.62	0.6010	542630.15	111.00	317.15	37.17	316.92	1047.2465
2	10.45-16.45	1882671.00	1238339.63	0.3066	158962.11	41.77	119.33	20.91	178.27	589.0762
3	16.45-23.06	1265351.41	702872.66	0.2423	138376.86	28.79	82.25	24.39	207.98	654.5291
4	23.03-26.40	710868.17	465260.57	0.0984	28403.40	15.10	43.15	11.62	99.04	327.2645
5	26.40-32.80	652265.34	349443.78	0.1617	89438.34	11.78	33.65	22.07	188.17	654.4837

Table: 6. Maximum seepage losses from actual earthen section of Almanna branched canals

No	Canal	Designed Discharge	Actual Discharge	Seepage loss (m^3/s/km)	Total Seepage loss (m^3/day)	Min Rate of Ev. (m^3/day)	Max Rate of Ev.(m^3/day)	Weed area feddan	Min WC (m^3/day)	Max WC (m^3/day)
1	R.Almanna s. canal	177025.28	151996.79	0.0542	27291.472	17.84	50.61	6.91	58.92	194.68
2	Al Hammam	379180.67	92168.27	0.0571	44399.822	04.34	12.31	10.21	87.05	287.65
2-1	Arab meter branch	125175.78	29300.99	0.0068	1176.7828	-05.48	-01.93	3.8	32.40	107.06
2-2	Al Atawla	142271.26	70081.83	0.0217	4499.6003	10.37	29.41	4.90	41.78	138.05
2-3	Al Zafran	115899.52	15450.98	0.0154	3056.9558	01.78	05.05	6.66	56.78	187.64
2-3	Al Taweel	252027.76	54959.34	0.0231	4789.9882	04.14	11.74	2.48	21.14	69.87
3	Shew	108628.41	17404.20	0.0085	1681.2518	-08.71	-03.07	3.22	27.45	90.72
4	Western Al Awamer	119179.92	36535.36	0.0062	659.7653	02.37	06.72	0.92	07.85	25.92
5	Eastern Alawamer	3737.94	1258.82	0.0047	269.3273	02.03	05.33	0.66	05.63	18.60
6	Northen Alawamer	167118.47	25299.38	0.0104	1261.1675	00.70	01.98	1.09	09.29	30.71
7	Der Shew	42942.39	4377.73	0.0507	221.6157	-00.59	-00.21	1.26	10.74	16.90
8	Eastern Al kadadeeh	64260.14	10049.24	0.0038	325.6952	-00.53	-00.20	1.31	11.17	36.91
9	Al Hager	109951.36	17704.63	0.0174	6298.4147	-00.73	-02.06	4.70	40.07	91.62
10	Bani Ibraheem	150435.59	45160.80	0.0132	1596.7906	05.14	14.59	0.65	05.54	18.31
10-1	Bani Ibraheem branch	125175.78	2555.36	0.0084	983.0117	02.69	07.64	2.12	18.08	59.73
11	Southern Al Gabrawe	173429.19	39705.32	0.0158	3008.8308	04.45	12.61	1.77	15.09	49.87
12	Nor. Al Gabrawe	70373.05	7314.13	0.0051	593.7150	-02.02	-00.71	2.03	17.31	57.19
13	Alswalem	166417.12	15031.11	0.0095	1484.4719	-04.38	-01.55	1.82	15.52	51.28
14	Alam Aldeen	78139.31	8948.50	0.0064	885.1465	-08.58	-03.02	2.09	17.82	58.88
15	Al Haraga	99522.53	10192.58	0.0089	1615.3509	00.48	01.37	4.01	34.19	112.98

JES, Assiut University, Faculty of Engineering, Vol.49, No. 1, January 2021, pp. 064 - 084

Table: 7. Maximum conveyance losses from Almanna canal.

N	Km	Designed Discharge (m^3/day)	Actual Discharge (m^3/day)	Losses (m^3/day)			Total Losses	% of Total Losses
				Evaporation	Transpiration	Seepage		
1	0.0000-10.450	1671141.88	1062567.62	317.15	1047.246	542630.15	**543994.5**	**32.55**
2	10.450-16.450	1882671.00	1238339.63	119.33	589.0762	158962.11	**159670.5**	**8.48**
3	16.45-23.060	1265351.41	702872.66	82.25	654.5291	138376.86	**139113.6**	**10.99**
4	23.030-26.400	710868.17	465260.57	43.15	327.2645	28403.40	**28773.82**	**4.05**
5	26.400-32.800	652265.34	349443.78	33.65	654.4837	89438.34	**90126.48**	**13.82**

Table: 8. Maximum conveyance losses from Almanna branched canals.

N	Km	Designed Discharge(m^3/day)	Actual Discharge (m^3/day)	Losses(m^3/day)			Total Losses)	% of Total Losses
				Evaporation	Transpiration	Seepage		
1	R.Almanna side. c	177025.28	151996.79	50.61	194.6796	27291.472	**27536.76**	**15.56**
2	Al Hammam	379180.67	92168.27	12.31	287.6525	44399.822	**44699.79**	**11.79**
3	Arab meter .b	125175.78	29300.99	-01.93	107.0597	1176.7828	**1283.84**	**1.03**
4	Al Atawla	142271.26	70081.83	29.41	138.0506	4499.6003	**4667.06**	**3.28**
5	Al Zafran	115899.52	15450.98	05.05	187.6362	3056.9558	**3249.64**	**2.80**
6	Al Taweel	252027.76	54959.34	11.74	69.8705	4789.9882	**4871.59**	**1.93**
7	Shew	108628.41	17404.20	-03.07	90.7190	1681.2518	**1771.97**	**1.63**
8	W. Al Awamer	119179.92	36535.36	06.72	25.9197	659.7653	**692.40**	**0.58**
9	E.Alawamer	3737.94	1258.82	05.33	18.5946	269.3273	**293.68**	**7.86**
10	N.Alawamer	167118.47	25299.38	01.98	30.7092	1261.1675	**1293.85**	**0.77**
11	Der Shew	42942.39	4377.73	-00.21	35.4987	221.6157	**257.11**	**0.60**
12	E. Al kadadeeh	64260.14	10049.24	-00.20	36.9074	325.6952	**362.60**	**0.56**
13	Al Hager	109951.36	17704.63	-02.06	132.4159	6298.4147	**6430.83**	**5.85**
14	Bani Ibraheem	150435.59	45160.80	14.59	18.3128	1596.7906	**1622.74**	**1.08**
15	Bani Ibraheem bra.	125175.78	2555.36	07.64	59.7280	983.0117	**1057.33**	**0.84**
16	S. Al Gabrawe	173429.19	39705.32	12.61	49.8673	3008.8308	**3071.31**	**1.77**
17	N. Al Gabrawe	70373.05	7314.13	-00.71	57.1924	593.7150	**650.91**	**0.92**
18	Alswalem	166417.12	15031.11	-01.55	51.2760	1484.4719	**1535.75**	**0.92**
19	Alam Aldeen	78139.31	8948.50	-03.02	58.8828	885.1465	**944.03**	**1.21**
20	Al Haraga	99522.53	10192.58	01.37	112.9761	1615.3509	**1728.33**	**1.74**

4. Conclusions

Conveyances losses of Almanna canal and its branches were estimated by empirical formulas at different sections along the total length of the canals. The main conclusions can be summarized as follows:

(1) The total loss of irrigation water from Almanna canal and its branches reaches about 16.05 million cubic meters per month, which represent 12.08% of the designed discharges, while it represents 23.90% of the actual discharges that give to the Almanna canal and its branches.

(2) The lost water through only seepage reaches about 15.95 million cubic meters per month, representing 99% of all lost irrigation water.

(3) The lost water through the weeds and grass in Almanna canal, is estimated to be about 3272.6 m^3/day, while in the branches of Almanna canal estimated at about 1763.95 m^3/ day.

(4) The rate of increase in the evaporation losses at actual earthen sections which is more than the designed sections losses, might be neglected in Almanna canal and its branches.

(5) According to the high values of conveyances losses in Almanna canal and its distributers, the need for linings has become very urgent to preserve these large quantities of water.

References

[1] Sabry. M., (2019). "Hydraulic Performance Assessment for Improved Irrigation System". M.SC. Thesis, university of Assuit, Egypt.

[2] Abu Gulul, K. A. J., (2004). "Lining of Irrigation Channels". M.Sc. Thesis, College of Engineering, Southampton University, India, 1975.

[3] Alam, M. and Bhutta, M., (2004). "Comparative Evaluation of Canal Seepage Investigation Techniques". Agricultural Water Management, 66(1), 65–76.

[4] International Commission on Irrigation and Drainage (ICID), (1968). "Controlling Seepage Losses from Irrigation Canals". Worldwide survey, New Delhi, India.

[5] Martin, C.A. and Gates, T.K., (2014). "Uncertainty of Canal Seepage Losses Estimated Using Flowing Water Balance with Acoustic Doppler Devices". Journal of Hydrology, 517, 746–761.

[6] Swamee, P.K., Mishra, G.C. and Chahar, B.R., (2000). "Design of Minimum Seepage Loss Canal Sections". Journal of Irrigation and Drainage Engineering, 126(1), 28–32.

[7] Zhang, Q., Chai, J., Xu, Z. and Qin, Y., (2016). "Investigation of Irrigation Canal Seepage Losses through Use of Four Different Methods in Hetao Irrigation District". China. Journal of Hydrologic Engineering, 22(3), 05016035.

[8] Sepaskhah, A. and Salemi, H. (2004). "An Empirical Model for Prediction of

Conveyance Efficiency for Small Earth Canals". Iranian Journal of Sciences and Technology, 28, 623–628.
[9] Wachyan, E. and Rushton, K., (1987). "Water Losses from Irrigation Canals". Journal of Hydrology, 92(3–4), 275–288.
[10] Plusquellec, H., (2019). "Overestimation of Benefits of Canal Irrigation Projects: Decline of Performance over Time Caused By Deterioration of Concrete Canal Lining". Irrigation and Drainage. 68(3), 383–388.https://doi.org/10.1002/ird.2341.
[11] Soothar, R., Mirjat, M., Mangrio, M., Chandio, A. and Leghari, N., (2015). "Estimating Seepage Losses in Different Size of Earthen Watercourses at Farm Level". Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences, 31(1), 81–92.
[12] Yao, W., Ma, X. and Chen, Y., (2019). "Optimization of Canal Water in an Irrigation Network Based on A Genetic Algorithm: A Case Study of The North China Plain Canal System". Irrigation and Drainage 68(2), 629-636.
[13] Mowafy, H.M., (2001). "Seepage Losses in Ismailia Canal". Sixth International Water Technology Conference, IWTC, Alexandria, Egypt, pp.195-211.
[14] Bakry, M.F and Awad, A.A., (1997). "Practical Estimation of Seepage Losses along Earthen Canals in Egypt". Water Resources Management Vol.11, pp.197–206.
[15] Eshetu, B.D. and Alamirew, T., (2018). "Estimation of Seepage Loss in Irrigation Canals of Tendaho Sugar Estate, Ethiopia". Eshetu and Alamirew, Irrigation Drainage Sys Engineering 7:3, Vol.7, No.3, pp.2-5.
[16] Up Irrigation Research Institute, (1984). "Report on Estimation of Seepage Losses from Canals by Radio Isotopes". UPIRI, Reo. TM 54, RR (G15), Roorkee, India.
[17] Sahasrabudhe, S.R., Katariya, s.k., and Sons, (2011). "Irrigation Engineering and Hydraulic Structures". Publisher of Engineering & Compute Books, 3rd edition.
[18] Liu, S.; Wang, W.; Mori, M.; Kobayashi, T., (2016). "Estimating the Evaporation from Irrigation Canals in Northwestern China Using the Double-Deck Surface Air Layer Model". Advanced Meteorology, 1–9.
[19] McJannet, D., Webster, I., Stenson, M., Sherman, B., (2008). "Estimating Open Water Evaporation for the Murray-Darling Basin". CSIRO: Collingwood, Australia, p. 58.
[20] Wang, W., Liu, S., Kobayashi, T., Kitano, M., (2013). "Evaporation from Irrigation Canals in the Middle Reaches of the Heihe River in the Northwest of China—A Preliminary Study". J. Fac. Agric. Kyushu Univ., 58, 371–376.
[21] Wang, Y., (1987). "Calculation of the Evaporation from the Flowing Channels". Groundwater 1, 28–30.
[22] Suhua L., Weizhen W., Makito I., Tetsuo K., (2016). "Estimating the Evaporation from Irrigation Canals in Northwestern China Using the Double-Deck Surface Air Layer Model", Advances in Meteorology, Article ID 3670257, 9 pages, https://doi.org/10.1155/2016/3670257.
[23] Burt, C.M., (1999). "Irrigation Water Balance Fundamentals" In Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balances; Irrigation Training and Research Center: San Luis Obispo, CA,

USA, pp. 1–13.
[24] Chen, J., and Jia, Z., (2007) "Construction and Application of Water Balance Model In the Irrigation Districts of the Midstream Areas of the Heihe River Basin". In The Study of Humanities and Environment in the City of Blackwater City: International Symposium on Human Culture and Environment in the Blackwater City; Shen, W., Shi, J., Eds.; China Renmin University Press: Beijing, China, pp. 150–164.
[25] Kobayashi, T.; Liu, S.; Wang, W., (2013). "Modeling of the Evaporation from A Running Water Surface". Kyushu J. Agric. Meteorol. Ser, 2, 1–14.
[26] Pitlo, R.H. and Dawson, F.H. (1993). "Flow-Resistance of Aquatic Weeds. In: Aquatic Weeds". A.H. Pieterse and K.J. Murphy (Eds.). Oxford Science Pub. pp. 74-84.
[27] Sytsma M. and Parker M., (1999). "Aquatic Vegetation in Irrigation Canals". Center for Lakes and Reservoirs Publications and Presentations. Paper 11. http://pdxscholar.library.pdx.edu/centerforlakes_pub/11
[28] Stanley J.D., and Clemente P.L., (2017). "Increased land subsidence and sea-level rise are submerging Egypt's Nile Delta Coastal Margin". Geol Soc Am 27(5):4–11. https://doi.org/10.1130/gsatg312a.1
[29] Abdelazeez, M.H., (2.015). "Inter Relationship between Modern Irrigation System and Fertilizers Application Methods". ph. D thesis, Assiut university.
[30] Dolatkhah, S., Kazemiazar, F., Deljou, P. and Nourmand, B., (2015). "Simulation of Seepage from Earthen Canals of Moghan Irrigation and Drainage Network Using Seep/w Model". Bulletin of Environment, Pharmacology and Life Sciences, Bull. Env. Pharmacol. Life Sci. Journals. Vol.4 (1), pp.430-435. URL: http: //www.bepls.com.
[31] El-Enany, M. A., El-Alfy, K. S., Sobeih, M. F., Armanious, S. D., and Gergis, E. S., (2004). "Modification of the Improved Irrigation System in the Old Lands in Egypt". Vol.29, No.1.
[32] Jensen, M.E., Burman, R.D. and Allen, R.G. (1990). "Evapotranspiration and Irrigation Water Requirements". Amer. Soc. Civil Eng. Man. and Rep. on Eng. Prac. No. 70, New York, NY.
[33] Hanks, R.J., (1974). "Model for Predicting Plant Yield as Influenced by Water Use". Agronomy Journal, Vol.66, pp.660-665.
[34] Paul K. K., Gylan L. D., and Nelton O. S., (1993). "Part 623 National Engineering Handbook", Chapter 2, "Irrigation Water Requirements" Book, United States Department of Agriculture. Soil Conservation Service.
[35] Allen, G.R., Pereira, L. S., Raes, D. and Smith, M., (1998). "Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements" FAO. Irrigation and drainages paper No 56. Rome, Italy.

تقدير فواقد النقل في القنوات المفتوحة في مصر الوسطى
حالة دراسة: ترعة المعنا الرئيسية وفروعها.

تعتبر شبكة قنوات الري المكشوفة في مصر من أكبر وأطول الشبكات في العالم التي تعانى من تربة منفذة، حيث يصل طولها إلى حوالي ٣٣٥٠٠ كم. وفي بلد يعاني بشكل كبير من النقص المتزايد في الكميات المتاحة من مياه الري، يعتبرتجاهل الكميات الهائلة من مياه الري المتوقع خسارتها خلال عمليات النقل ضرب من الجنون في ظل الحاجة الماسة لسد الفجوة المتسارعة بين ما هو مطلوب وما هو موجود من مياه الري. وحيث أن خسائر نقل مياه الري تشمل ما يفقد بالتسرب والبخر و مايفقد نتيجة ما تستهلكه النباتات والحشائش الموجودة علي جوانب القنوات المائية. تختلف هذه الفواقد حسب نوع التربة والمناخ وسلوكيات المنتفعين. لذلك، فإن إجراء دراسات ميدانية في مختلف المناطق الزراعية في مصر، سيكون الطريقة الأكثر فاعلية لتقدير الكميات المفقودة من مياه الري في جميع أنحاء البلاد من خلال التسرب والبخر في قنوات النقل. وبهذه الطريقة يمكن لصناع القرار استخدام هذه الكميات المكتسبة لحل مشاكل نقص أو عدم وصول مياه الري إلى نهايات بعض الترع .

في هذه الورقة البحثية، تم تقديم نتائج دراسة ميدانية أجريت على إحدى قنوات الري الرئيسية في محافظة أسيوط في وسط مصر كنموذج ممثلاً بالتقريب لمنطقة الدراسة حيث يمكن لنتائج هذه الدراسة الميدانية إلى جانب الدراسات المماثلة التي أجريت في مختلف المناطق الزراعية في جميع أنحاء مصر، أن تزود صانعي القرار بالبيانات الفعلية الموثقة اللازمة التي على أساسها يمكن إدارة الموارد المائية على مستوى الدولة بالطريقة التي تزيد العائد من كميات مياه الري المحدودة المتاحة وتساهم في حل بعض مشاكل الري الملحة التي تعانى منها البلاد. وقد تم اختيار ترعة المعنا التابعة لإدارة هندسة رى أبنوب بأسيوط لإجراء الدراسة الميدانية (حالة دراسة) كقناة مفتوحة لها خصائص محددة، ونوعية تربة، وحالة طقس، وطول وكذلك قنوات متفرعة منها. تم تجميع البيانات المستخدمة في هذا البحث من الموقع (ترعة المعنا وفروعها) ومن خلال وزارة الموارد المائية وادارات الري الرسمية بمحافظة أسيوط. وقد أثبت تحليل البيانات أن إجمالي الفاقد من مياه الري من ترعة المنعا وفروعها يبلغ نحو ١٦,٠٥ مليون متر مكعب شهرياً تمثل حوالي ٢٣,٩٠٪ من كمية المياة الفعلية التي تضخ ترعة المعنا الرئيسية وفروعها. وتصل المياه المفقودة من خلال التسرب فقط إلى حوالي ١٥,٩٥ مليون متر مكعب شهريًا وهو ما يمثل ٩٩٪ من إجمالي مياه الري المفقودة. بينما يمكن إهمال معدل الزيادة في فواقد البخر في الترع قبل التأهيل عنها بعد التأهيل. وبالتالي فإن تبطين ترعة المعنا وفروعها هو الحل الأكثر فاعلية لتوفيرمثل هذه الكمية الهائلة من المياه، وتوجيهها لري بعض المناطق المستصلحة حديثًا، بالإضافة إلى حل مشاكل عدم وصول مياه الري إلى نهايات بعض قنوات الري. في نفس الوقت، تحسين الوضع البيئي للمجتمع الزراعي المحيط.