Assessment of the Feasibility of Applying the Rotation System in the Improved Aareas in Egypt

Gamal Elsaeed, Talat El-Gamal, Neveen Abd El-Maged and Magda Ahmed

Abstract*— *The Nile is almost the only water source in Egypt and the limitation of the river resource with the rapid increase of the demand on water set Egypt to face up an expected water scarcity. The attempts of the south countries for more utilization of the Nile water intensify the problem. Given that the chance to increase Nile water resources is very limited and the requirements are rapidly increasing, the only feasible way to confront the expected irrigation crises is to increase the irrigation efficiency and water productivity. Irrigation improvement project (IIP) is one of the most attempts in Egypt to implement more effective on-farm irrigation technologies for modifying traditional irrigation system and saving water by improving the existing delivery system in the Nile delta of Egypt with a total area of about 1.05 million ha by 2017. The improved irrigation system was designed on applying the continuous flow and applying internal rotation (Motarfa) between Mesqas. Practically the continuous flow system was not applied truly in any improved canals. This study aims to investigate the feasibility of applying the rotation system in the improved branch canals in Egypt. Dakalt canal was chosen as study area as an example for the improved canals. The results showed that applying the rotation system in Dakalt canal was not only applicable, but it could decrease water crises at the tail end regions with lower water supply. Based on the results, it is recommended to apply the rotation system in the improved regions (IIP1 region) especially in the paddy areas.

Keywords*— *Improved Irrigation, Continuous Flow, Rotation Water Distribution System

I. INTRODUCTION

Water scarcity is a growing global problem challenging sustainable development and placing a constraint on producing enough food to meet increasing food requirements [1]. Egypt is one of the countries facing great challenges, due to its aridity and fixed share of limited Nile water. Because of population growth, the per capita share of water renewable resources has dropped dramatically to about 700 m^3/capita which, by international standards is considered the water poverty limit [2]. The value may even decrease to 500 m^3/capita in 2025 [3]. Poor management has been cited as the most frequent problem of irrigation leading to less than optimal use of limited water resources. Critically important for Egypt, as well as in many countries of the world is the need to produce more food with even less water going to agriculture, as cities industries take an increasing share, and with the recognized need to leave enough water for the environment. Egypt with its long running experience provides valuable lessons in this area. Improving efficiency of irrigation has long been an important water management goal in order to reduce wastage and save water. Irrigation improvement project is one of the most important attempts in Egypt to implement more effective on-farm irrigation technologies for modifying irrigation system and saving water. The general objective of IIP is to improve the irrigation water management and to make equity water distribution between the farmers and increase the crop productivity hence increase the farmer’s income.

A. The operation irrigation systems in Egypt:

The oldest irrigation system in Egypt was the basin irrigation system, by the end of 19 century, and with the beginning of the perennial irrigation, the rotation system was introduced to replace old basin irrigation system. The new system was built gradually with the building of the new barrages ended by the construction the High Dam that end the basin irrigation in the last part of Upper Egypt. The irrigation rotation system was developed in Egypt to facilitate the equitable distribution of limited and varied amount of water [4]. The "on/off" sequence of the rotation system is designed to provide the distributary canals with the sufficient amount of water while allowing the continuous flow in the main canals. Operation of the system has traditionally been based on rotational water deliveries to individual branch canals. The main canals flow continuously, with each irrigation general directorate receiving a seasonally varied supply determined centrally by the Irrigation Sector in accordance with the expected cropping pattern. Releases from High Aswan Dam are made according to the predicted water requirements and taking into account the considerable travel time from Aswan to the delta. It is important to note that in managing water deliveries under the rotation system, operating staff are able to vary not only the flow rate, but also the flow duration, by adding or subtracting days from the on-period. This ability to use time as an operating variable makes it possible to compensate for any surpluses or deficits arising from the imprecision of the flow regulation, and in particular to deal with “emergency” shortages on individual canals. [5] Stated that the most significant advantage of the rotation system is that during the "off" periods the canal can serve as drains that allow the removal of some subsurface soil salts. Also the rotation schedules require low investment in canals and involve the least water agency management and operation output.

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[6] the main rotational used in Egypt is 2-turn rotations, which are divided into 4 days “on" and 4 days "off" (for rice crop), or 7 days "on" and 7 days "off" (for cotton crop) and 3-turn rotations, which are divided into 4 days "on" and 8 days "off" (general crops/summer), 5 days "on" and 10 days "off" (general crops/winter), or 7 days "on" and 14 days "off" (general crops/winter).

II. STUDY AREA AND METHODOLOGY

The command area namely Dakalt canal of IIP project in the Nile Delta is chosen and the same area before improved irrigation. Dakalt allocated on the right-hand side of Meet Yazid canal (Km 41.070). It is about 11.4 km long and serves about 2344 ha. The physical status represents the situation of the middle and north part of the Nile Delta and it is fed from Meet Yazed main canal in Kafr El-Sheikh directorate. It is served by two drains; No 7 drain on the right hand side and El-Raghama drain in the left hand side and it has 19 sub- branches. The map of the study area is shown in Fig. (1).

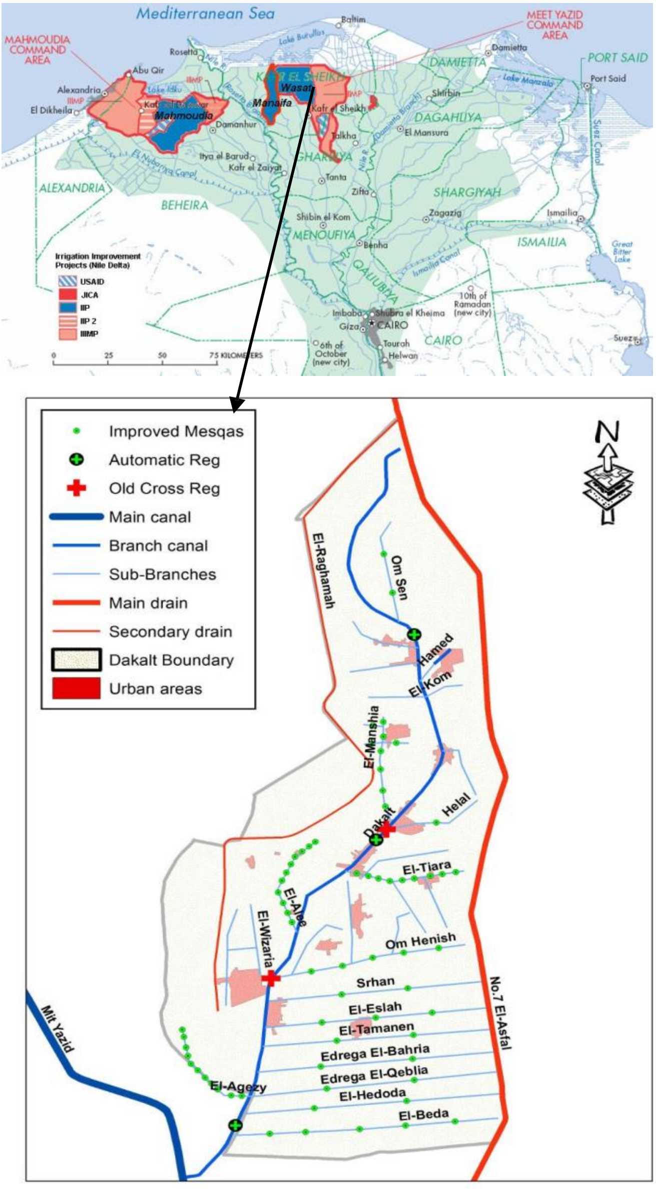

Fig. (1): Dakalt command area with Mesqas and all sub-branches.

Simulation Program:
River Analysis System (HER-RAS) was developed by the Hydraulic Engineering Center (U.S Army Cops of Engineering). The program performs one dimensional steady and unsteady flow calculations. Unsteady flow calculation in HEC-RAS is capable of simulating one-dimensional unsteady flow through a full network of open channels.

Data entry:

Geometry data:
Defining the geometry include drawing the network, defining the cross sections, junction and structures as shown in Fig. (2).

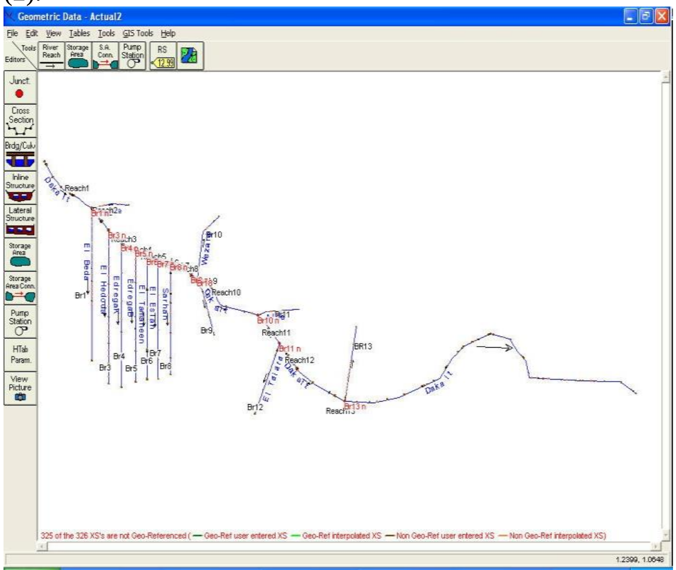

Fig. (2): Schematic drawing of Dakalt Canal and sub-branches in HEC-RAS program

Boundary conditions and lateral inflow:
In the current study, boundary conditions included upstream boundary at the upstream end and downstream boundary conditions at the downstream end. The consumptions in the canal were defined as lateral inflow boundary condition.

Initial condition:
The default way to define the initial condition in HEC-RAS program is to define the initial discharge at the beginning of each reach. The program uses the steady flow calculations to calculate the initial condition (water levels and velocities at different points of the canal).

Calibrating the Model:
Before using the model to evaluate the operation strategies and the suitability of applying the rotation system in the improved areas, the model should be calibrated to assess the sufficiency/suitability of surveyed cross sections and structures and to define different parameters and coefficients, such as the roughness coefficients for different reaches of the canal. Calibration the model was made by comparing the calculated values with the observed values. This includes water levels and discharges at different locations of the investigated canal.

Results from the model:
For the measured discharges downstream the head regulator, the calculated values were considerably lower than the measured values as shown in Fig. (3). The difference was about 0.2 ~ 0.3m^3/sec.

Regarding water levels downstream the head regulator; the measured values had the same trend of the observed values but with a difference about 0.2 m.

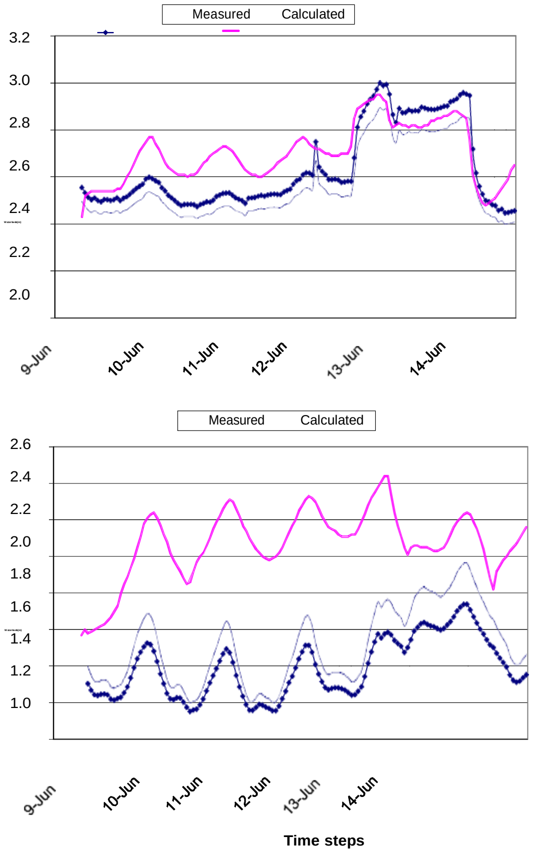

Fig. (3): Measured and calculated water levels downstream Dakalt head regulator and at Km 5.18

III. RESULTS AND DISCUSSION

Practically, the rotation system is already applied in many canals in the improved areas (IIIMP1 regions). Some improved canals were returned to the rotation system after being opened continuously for some time, such as Bahr El-Nour canal in Middle Delta, and other continued with the rotation system after the improvement, such as El-Karion canal in West Delta. The irrigation directorates began returning to the rotation at most of other improved canals including the case study (Dakalt canal). This chapter is searching for the theoretical bases that makes the application of the rotation system possible in the improved areas by simulating the flow in an improved canal.

The Feasibility of Applying the Rotation System in the Improved Areas:

The ability to operate the improved Mesqas with the rotation returns mainly to the margin of safety in the designing of the improved Mesqas, especially in the first phase of the improvement project (IIP1). The improved Mesqas were designed in IIP1, under the assumption that 100% of the served area is rice, and with average abstraction rate (1.15 l/fed/sec ~ 99.0 m^3/fed/day), which is a relatively high value. Monitoring showed that even the Mesqas that have 100% rice were not under critical conditions. Fig. (4) presents an example for the operation hours in an improved Mesqa in Dakalt canal.

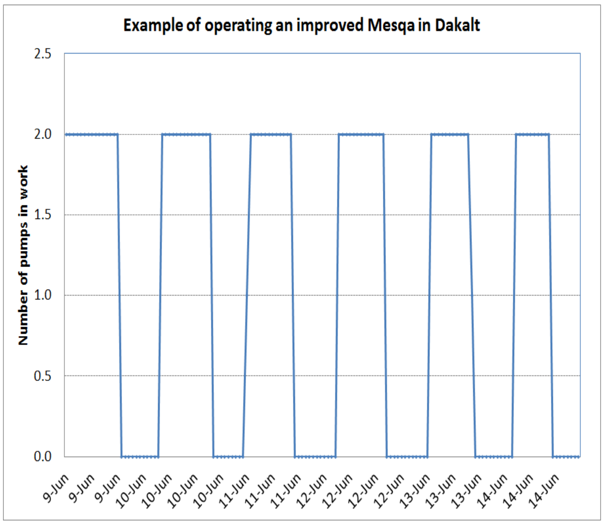

Fig. (4): Operation hours at the first lifting point in El-Beda sub-branch

Moreover, it should be considered that the improved Mesqas were designed for the abstraction during high consumption values. There was a big difference between water requirements during this period and the rest of the year as shown in Fig. (5). This means that operating the improved pumps during the rest of the year will have no problem under the rotation system.

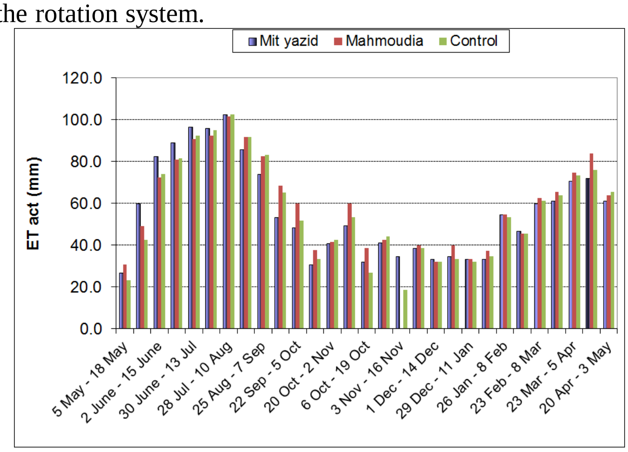

Fig. (5): ET_{act} values for different canals in the improved areas

Fig. (6) present the actual water requirement of Dakalt canal. From Fig. (6), the actual water requirements were lower than the design requirements by 38% and this makes the operation of the rotation system is feasible in the IIMP1 regions.

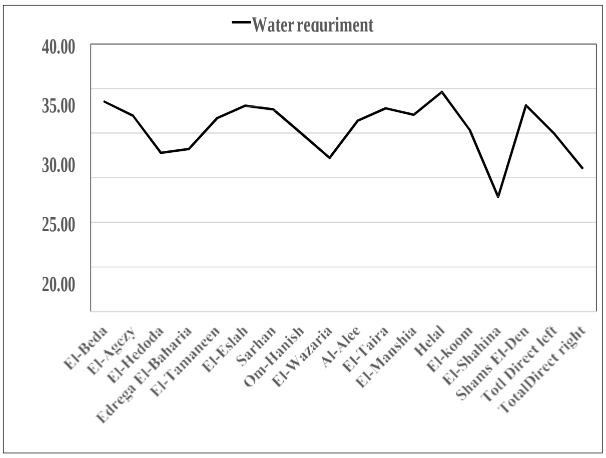

Fig 6: Actual water requirements of Dakalt canal

The sufficiency of water supply during "on" period:

Working with rotation system means that the operation of the improved Mesqas will be concentrated during "on" days, which should be enough to satisfy water requirements. The monitoring results showed that the improved canals were running with the capacity that is less than the design capacity, and this gives chance to apply the rotation system. Fig. (7) presents maximum and minimum design water levels at different sections of Dakalt canal, which bound the night storage volume between them. For instance, maximum design water levels downstream first automatic downstream control regulator (ADSCG) was 2.6, which should be controlled by the automatic regulator. Minimum water level, to satisfy the requirements, is 2.15 m.

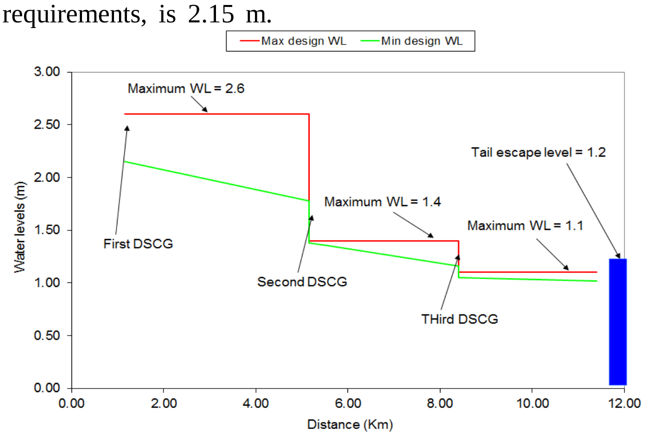

Fig. (7): Maximum and minimum design water levels in Dakalt canal

From Fig. (8 and 9), water levels downstream first automatic gate were below minimum design water level between 40% & 50% of the time during summer seasons. During winter seasons, water levels were below minimum design water level between 65% & 82% of the time (WMRI 2008). This means that actual abstraction rate is below the design, and it means that working with the design levels could offer higher storage that might be enough to satisfy the abstraction during day hours. Moreover, the current situations give chance to work with higher water levels in the urgent events, such as the transplanting of the rice. The automatic gates were malfunction, just after the installation due to the encroachments of the farmers. Last years, the irrigation directorates began to remove them completely as presented in Fig. (10) and from Fig. (8), bank levels is higher than maximum design level.

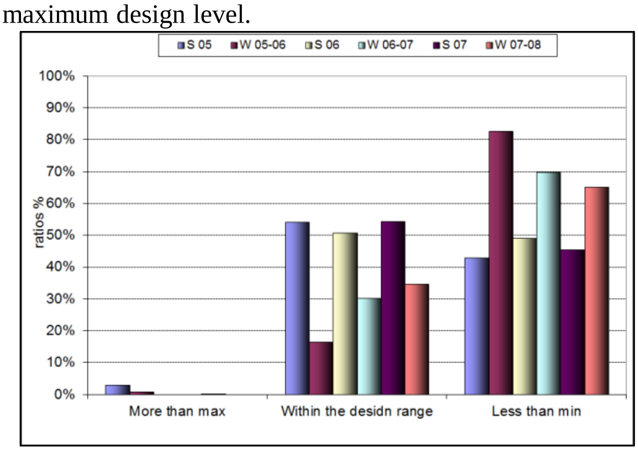

Fig. (8): The ratio between design and actual water levels downstream first cross regulator of Dakalt canal (WMRI 2008)

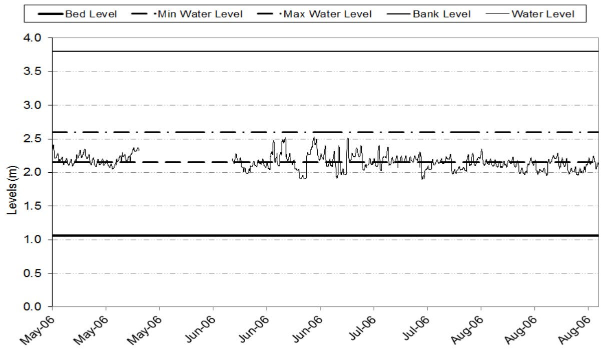

Fig. (9): the water levels values downstream first cross regulator of Dakalt canal during summer 2006

Fig. (10): The situation of the automatic gates in Dakalt canal during 2006 & 2015

Simulating the Flow, Based on Rotation System in an Improved Canal:

The main difference between simulating the flow under the rotation and the continuous flow systems is the concentration of the abstraction rates in the first system during "on" period. The schedule of operating the improved pumps will be developed during "on" period, and the abstraction rates will be estimated based on that. Then the operation of the canal will be adjusted to satisfy the requirements without having water shortage events and with minimum access flow to the drain.

Run the model and analyzing the outputs

The model was run for four days or 96 hours at the first half of June as shown in Figs from (9) to (12). The results had no floods or water shortage events were existed, but there was some excess water to the drain.

The calculated discharges downstream the head regulator are presented in the next Fig. As expected, the change in water supply was analogues to the change in gate openings. Higher water supply values were found during day hours, and lower values were found during the rest of the day. Average water supply during the four days was 69.0 m^3/fed/day. Considering it is a rotation system with 4 days "on" and 4 days "off", average daily water supply was less than 35.0 m^3/fed/day.

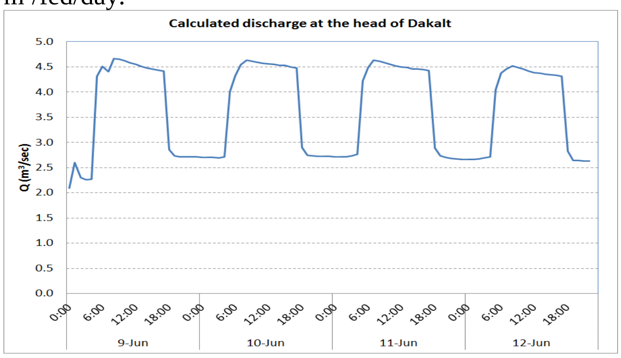

Fig. (11): Calculated discharges at the head of Dakalt canal

Calculated water levels reveled other characteristics of the effect of applying the rotation system. First, the night storage was still effect as could be observed from Fig. (12), which presents water levels at 6:00 AM and 4:00 PM of the second day through the main stream of Dakalt canal.

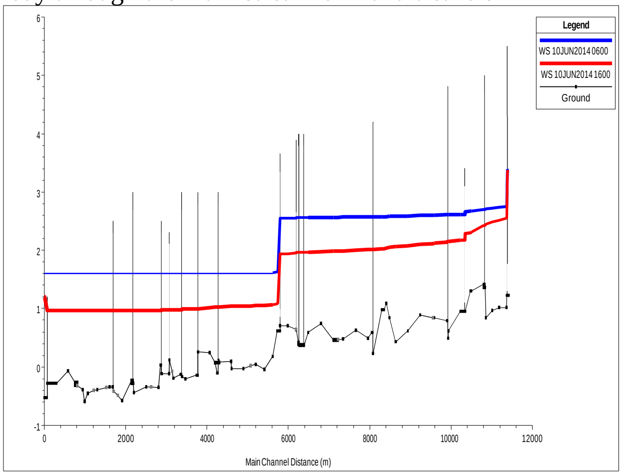

Fig. 12: Water levels in Dakalt canal

water supply) was 95720 m^3. The available storage was calculated between maximum water levels that were recorded in the program and the minimum available water depth in the canal and the branches, with which the improved Mesqas could work probably. It was assumed that this minimum water depth is 0.5 m, which should be satisfied at any section. The available storage based on this assumption was 117200 m^3. This means that the canal will work probably during the "on" period without water shortage. This was obvious from the run of the model, as any water shortage should stop the model from running.

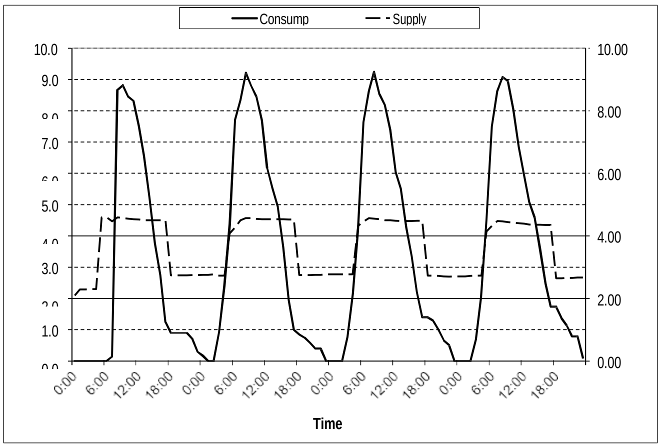

Fig. 13: The total water consumption and supply of Dakalt canal

CONCLUSION AND RECOMMENDATION

The results from the simulation model showed that the application of the rotation system is applicable for the investigated canal (Dakalt canal). Some points have to be highlighted:

The first point is the sufficiency of night storage in the canal to face the increase of water abstraction during day hours without having any dry sections in the canal. The relation between water supply and total abstraction from the canal during the simulation period is presented in Fig. (13). From the figure, the maximum required storage volume (maximum difference between abstraction and

The real observation indicates that water levels at the tail end of the canal were normally lower than the calculated values and the flow during day hours was normally lower than calculated during this period, which has highest abstraction rates. This is normally on the expense of some water shortage events at the tail end or at some branches. The difference between real observation and simulation results were related to the sensitivity of the model to very low water levels. Such situation decreases the stability of the model and affected the accuracy. Therefore, considerably high discharges are assumed at the head and higher water levels are existed at the tail end of the canal. Real observation refers to the existence of some water shortage events at the tail ends of the canal or its branches at day hours during the simulation period, which is the highest consumption period. Normally, this is faced by the farmers at these tail end regions by irrigating during night hours.

The results of the simulation showed that the required from the operation was lower than the storage capacity of the canal by 33% and this makes applying the rotation system in the improved areas is feasible.

From the previous results it is recommended to apply the rotation system in Dakalt improved canal

For future studies, it is recommended to investigate the feasibility of applying the rotation system in the improved canal under the new phases (IIP2 & IIIMP). The design criteria in these phases were changed from the first phase (IIP1), where Dakalt canal belong, and the consumption rate decreased from 1.14 l/fed/sec to 0.84 l/fed/sec. It is also recommended to extend the study to the entire irrigation network to investigate the effect of applying the rotation system at the entire improved areas.

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