The Egyptian International Journal of Engineering Sciences and Technology

ISSN:1687-1006

Vol. 22 (January 2017) 50–57

http://www.eijest.zu.edu.eg

Assessment for Drainage Water Supplements to the Irrigation Network at Kalabsho and Zian Area, SOBEK-Application

Ahmed M. Nada

Researcher, Hydraulics Research Institute, National Water Research Centre, Egypt

ARTICLE INFO

Article history:
Received: 11 July 2016
Received in revised form: 9 October, and 4 December 2016
Accepted: 13 December 2016
Available online: 19 December 2016

Keywords:
Drainage
Irrigation
Network
Sobek

ABSTRACT

The fresh water resources in Egypt are very limited and almost constant. The agriculture reuse of drainage water is well developed. The amount of it is expected to reach 8.8 BCM annually by the year 2017. The objective of the study is to assess the drainage water to find supplements to the irrigation network at Kalabsho and Zian Area west of Dakhlia governorate. Drains No.1 and 2 and their branches at Kalabsho and Zian area are studied here including water quality criteria, extensive field measurements, constrains and fast interventions, modelling setting and testing of different scenarios. The comparison between measured field data, calculated data and the analyzed results indicated that the SOBEK model has a strong adaptability and can be applied in case of modelling double direction flow which could be used to simulate the reuse of drainage water. This is very common in Egypt as the canals could be fed from the head with fresh water and at the tail with drainage water. A new scheme of water supply management was processed to get advantage of available drainage water.

1. Introduction

The annual per capita share of the available fresh water resources in Egypt has dropped from 2189 m^3 in 1966 to 611 m^3 in 2016. It is expected to go below 540 m^3 in 2025 [1]. The agricultural sector is the highest fresh water consumer, utilizing about 86% of the available supplies of Egypt allocation that reaches 55.5 BCM annually.
One of the main irrigation problems in Egypt is the water supply shortage at the end of the irrigation network especially at the tail of the canals. The Ministry of Water Resources and Irrigation (MWRI) depends mainly in its national plan on reusing the drainage water to feedback some canals which have shortage of water supply (water from main drains is pumped into main canals).
Drainage water being reused is expected to increase up to 8.8 BCM annually by the year 2017 [1]. The three national projects of reusing drainage water in Egypt are El-Salam Canal, Omoum Drain and Drains No. 1 and 2.

2. The Study Area

Drains No.1 and 2 and their branches are studied here to convey the available drainage water to be reused and compensate the shortage of water supply from the Nile Canal. The study area layout is shown at Figure 1.

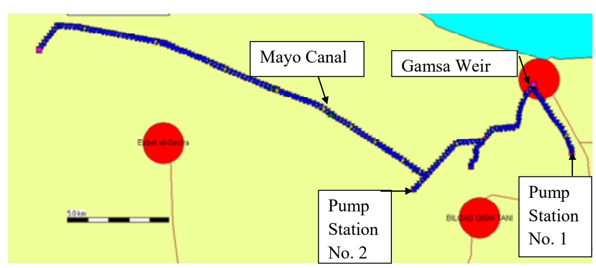

Fig. 1. General layout at the study area at Dakhlia governorate the far north of the middle Nile delta region

* Corresponding author: Tel. +2-01222642428
E-mail address: ahmedmostafanada@hotmail.com.

Drains No. 1 and 2 are located at the far north of the Middle Nile Delta region. The collective discharge of the two pumping stations is about 1 Milliard m^3 /year [2].
The maximum capacity for Pump Station No. 1 is 52 m^3/s and the maximum capacity for Pump Station No. 2 is 26 m^3/s. It is planned to pump part of the delivered water by those drains to Kalabsho and Zian areas. The available drainage water is reused to supply Mayo, Benny and Om Dongol Canals. Figure 2 shows the existing irrigation network in the study area.
Mayo Canal has a total length of about 17.0 km and it is supplied with drainage water from Drain No. 2. The extension of this canal is called Nile Branch Canal which is supplied from the Nile canal with fresh water [3].
The excess drainage water from Pump Stations No. 1 and 2 is discharged to the Mediterranean Sea through Gamasa Weir. Table 1 presents the studied irrigation network including main canals length and served area in feddans as well.

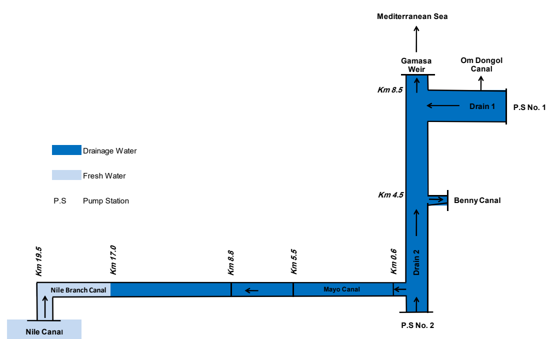

Fig. 2. A schematic diagram of the existing irrigation network in the study area at the far north of the middle Nile delta region

Table 1 Studied irrigation network including main canals lengths and served area

Main Canals at Irrigation Network	Length (Km)	Served Area (Feddan)
Drain No.1	4.0	
Drain No.2	8.5	
Mayo Canal	17.0	35000
Nile Branch Canal	4.2	26000
Benny Canal	1.5	13000
Om Dongol	Intake	15000

Always the peak demand of water in Egypt takes place in summer. During this period, the water supply from the Nile Canal is less than the demand for the served area, which is a difficult issue that should be resolved.

The objective of this study is to to find an assessment for drainage water supplements to the irrigation network at Kalabsho and Zian Area. Figure 3 shows the new scheme of water supply management to Mayo and Nile Branch Canal. The new scheme delvers the fresh water to Km 17.0 from Mayo Canal directly not from Nile Branch Canal.

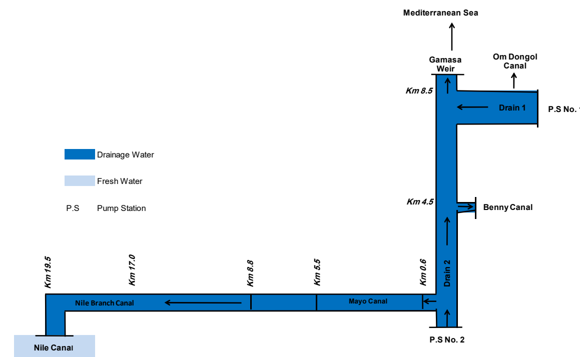

Fig. 3. A schematic diagram of the new scheme of water supply management to Mayo and Nile Branch Canal

3. Methodology

To reinstate the irrigation network for the new purpose and achieve the study objectives, a software SOBEK 1-D hydrodynamics numerical model is used to simulate the studied irrigation network area and double direction flow. The water quality criteria and extensive field data measurements for the existing water supply balance were carried out in coordination with MWRI sectors for fast intervention. The steps are as the follow:
1-Review: reports, maps, thesis,
2- Field measurements: surveying, discharges, water quality measurements
3- Analysis
4- Interventions
5- Modelling: set up, calibration and scenarios
6- Comparison of different scenarios
7- Conclusion and recommendation

While Item 1 presented at the study area characteristics section, item 2, 3and 4 presented at the methodology section, item 5 presented at model setup section, item 6 and 7 presented at the summary and conclusion section.
Table 2 presents the drainage water quality criteria for irrigation purposes in the Nile Delta, Egypt [4]. Drains No. 1 and 2 had an average salinity value of 1000 ppm. A unit of water quality reported to IS measures the salinity every month. Consequently, the available water can be used in irrigation directly. No Drinking water plants feeds from Mayo Canal.

Table 2 Restrictions of drainage water quality criteria to be used for irrigation purposes in the Nile Delta, Egypt [4]

Salinity of Drainage Water (ppm)	**Restriction of Irrigation Use**
< 1000	Used directly for irrigation
1000 – 2300	Mixed with canal water at ratio 1:1
2300 – 4600	Mixed with canal water at ratio 1:2 or 1:3
> 4600	Not used for irrigation

Extensive field measurements were completed in February 2012 {for 20 km of Mayo Canal and 8.5 km of Drain}. They were carried out to collect the data required for the numerical model. The data consists of bathymetric survey and flow measurements. The bathymetric survey covered the studied area. Table 1 shows the surveyed lengths of canals and its served areas. Cross sections were surveyed every 100 m. The bathymetric data resulted in the contour map with 0.5 m contour interval. The details are referred at [5].

The flow measurements were carried out at nine cross-sections covering the surveyed reach using calibrated current meters. The locations and magnitude of the measured flow cross sections and the corresponding water levels are shown in Figures 4 and 5. The measured discharges and corresponding water levels were used in the calibration phase of the numerical model.

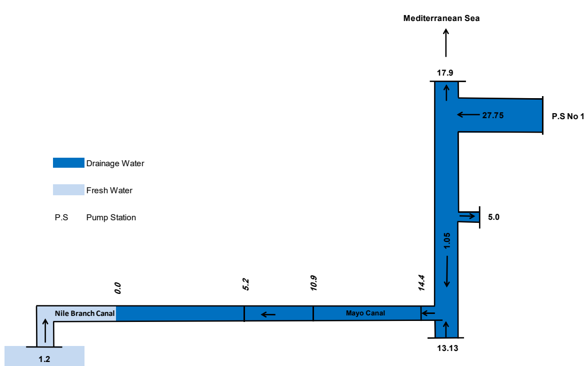

Fig. 4. A schematic diagram of the location of the measured (actual) flow cross sections and its magnitude (m^3/s)

High precision leveling processes were used to determine the water surface profile using an accurate and calibrated level meter device. An example of water surface level measurements along Drain No. 2 is shown in Figure 6.

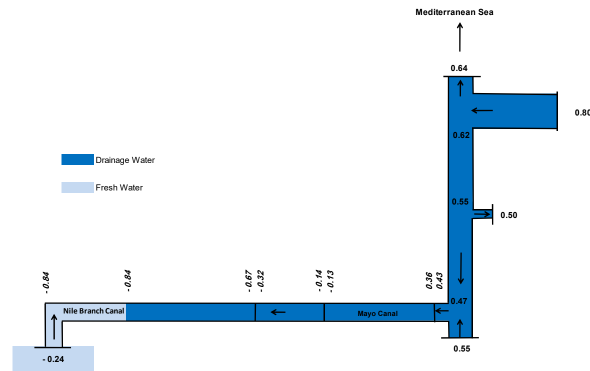

Fig. 5 A schematic diagram of the Locations and values (m) + msl of the Measured Water Levels

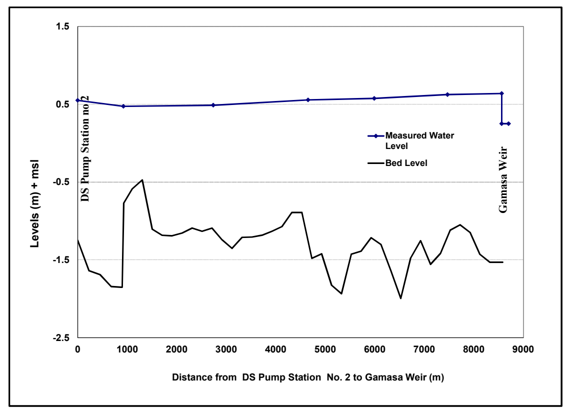

Fig. 6 Water level measurements along Drain No. 2

The Irrigation Sector, MWRI put the criteria that the maximum permissible water level for Drain No. 2 is (0.90) m. This is because of the following two constrains:

- Low area upstream of Gamasa weir, about 300 feddans is very low land and embankment level is about (1.00) m which causes high ground water table issues and flooding, Fig. 7.
- The design delivery water level is only (0.70) m for Pump Station No. 2, so the low level of the structure of the delivery basin is about (1.00) m, Fig. 8.

Another constrain at Mayo Canal is the embankments failure because of the existing loose sand nature behind the seas as sea water level is higher than Mayo Canal and wrong method of excavation or dredging process during maintenance [6]. Figure 9 shows the embankments failure along Mayo Canal.

From bathymetric survey, the surveyed cross sections of Mayo Canal were compared to the design cross sections, Figure 10. Sediment quantities at the existing bed of more than 0.75 m at the first 12 km of Mayo Canal can be observed although there is some widening in the studied area that has been developed due to dredging.

Fig. 7. Low level area of about 300 feddans upstream of gamasa weir, and embankment level is about (1.00) m

Fig. 8. The delivery basin of pump station No. 2

Fig. 9. The embankments failure along Mayo Canal

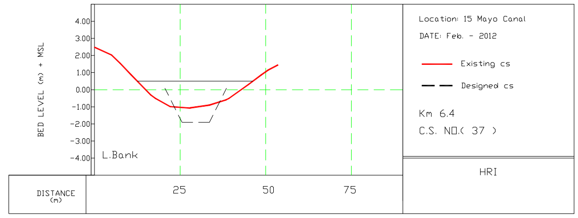

Fig. 10. A comparison between the existing (the surveyed) and the design cross sections of Mayo Canal

Intervention No. 1

Intervention No. 1 suggests that the Irrigation Sector should raise the embankments level and construct revetments with impermeable layer to protect the low leveled area of 300 feddans upstream of Gamasa weir against high ground water table and flooding problems.

Intervention No. 2

Intervention No. 2 is to to figure out some engineering solutions for the low leveled delivery basin of pump station No. 2.

It was found that the design suction level is (-3.00) m, design delivery level is (0.70) m, and the static head is 3.7 m. From the obtained data for summer 2011, it was found that the existing suction level is (-1.90) m, delivery level is (0.90) m, and static head is 2.8 m. It is concluded that there is a theoretical chance to raise the water level at delivery basin to be (1.80) m (existing suction level is (-1.90) m + design static head is (3.7) m). This means that the delivery level could reach 1.80 m.

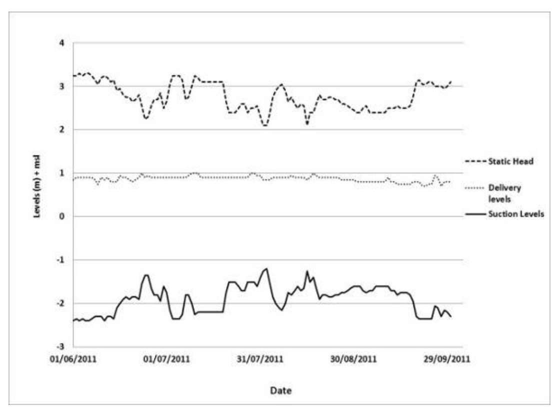

Fig. 11. The measured hydraulic data in summer 2011 for pump station No. 2

Figure 11 shows the obtained hydraulic data for summer 2011 for Pump Station No. 2. Intervention 2 suggested that the Mechanical and Electrical

Department should modify the structure of pump station No. 2 to comply with the new requirements of irrigation system to have water level of (1.50) m immediately by casting new concrete layer above the existing one as proposed in Figure 12 for protection against flooding, raising the embankments and develop the pumps for the new suction and delivery water levels in the future.

Fig. 12. Proposed solution for pump station No. 2 for protection against flooding

4. Model Setup

The One dimensional open channel SOBEK model is a dynamic numerical software package, capable of solving equations that describe unsteady flow. It is applied here to simulate the irrigation canals network [7]. The hydrodynamic behavior of these systems is well described by a set of basic equations. The flow in one dimension is characterized by two equations: the continuity equation and the momentum equation [8].

4.1 Continuity Equation

$$\frac{\partial A_t}{\partial t} + \frac{\partial Q}{\partial x} = q_{lat} \qquad (1)$$

in which

A_t = Total cross-section area (m^2)

q_{lat} = Lateral discharge per unit width (m^2/s)

Q = Flow Discharge (m^3/s)

4.2 Momentum Equation

$$\underbrace{\frac{\partial Q}{\partial t}}_{1} + \underbrace{\frac{\partial}{\partial x}\left(\alpha B \frac{Q^2}{A_f}\right)}_{2} + \underbrace{g A_f \frac{\partial h}{\partial x}}_{3} + \underbrace{\frac{g Q|Q|}{C^2 R A_f}}_{4} - \underbrace{W_f \frac{\tau_{Wi}}{\rho_W}}_{5} = 0 \qquad (2)$$

in which

1 = The inertia term,

2 = The convection term,

3 = The water level gradient,

4 = The bed friction term,

5 = The wind friction term and

Q = discharge,	(m^3/s)
t = time,	(s)
x = distance,	m
αB = Boussinesq constant,	(-)
A_f = cross-section flow area,	(m^2)
g = gravity acceleration,	(m/s^2)
h = water level	(m)
C = Chézy coefficient,	(m$^{0.5}$/s)
R = hydraulic radius,	(m)
W_f = flow width,	(m)
τ_{wi} = wind shear stress	(N/m^2)
ρ_w = water density,	(kg/m^3)

A finite difference number method, the “Delft Scheme” is applied to solve the equations. The third term in the momentum equation is the surface water level gradient. This force tries to achieve a flat-water surface under the influence of the gravitational acceleration. The bed friction is the friction between the flowing water and the channel bed. As such, it exerts a force on the flowing water always in a direction that is opposite to the water flow. In water courses, bed friction force with the water level gradient force caused by earth gravity have the greatest effect on the water movements usually determines the flow conditions: the other forces are far less important [8]. After reviewing the basic two equations, the continuity and momentum equations and the affecting forces, it is clear that bed friction force with the water level gradient force caused by earth gravity have the greatest effect on the water movements. This means that the model should be calibrated according to water level as the follow.

5. Model Calibration

Model calibration was performed using the measured water levels, cross section, flow discharges and control structures. Figure 13 shows a comparison between measured and calculated water levels from the model along Drain No. 2. Good agreement between them was obtained. Five Scenarios were modeled and tested. It was assumed that the Pump Stations No. 1 and 2 will be operated with maximum capacity and reaching to the steady state conditions for all scenarios. The difference between measured and calculated water levels is within 2.5 cm.

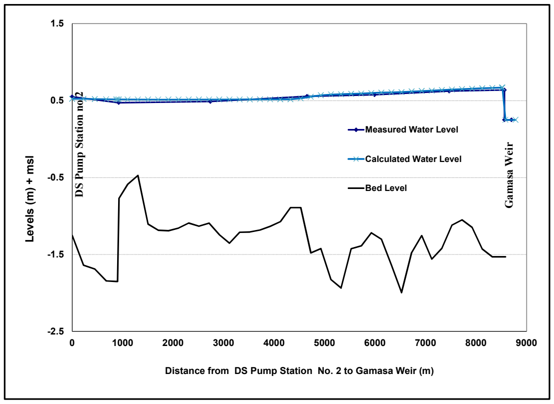

Fig. 13. A comparisons between measured and calculated water levels based on the model results along Drain No. 2.

6. Model Scenarios and Analysis

6.1 The first scenario (existing situation)

The first scenario represents the peak summer period case and maximum water supply requirements. Figures 14 and 15 show the scheme of the flow discharge distribution and corresponding water levels respectively.

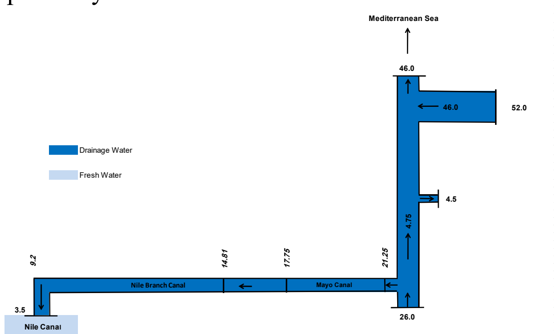

Fig. 14. A schematic diagram of the scheme of the flow discharge distribution with its magnitude (m^3/s) for scenario 1

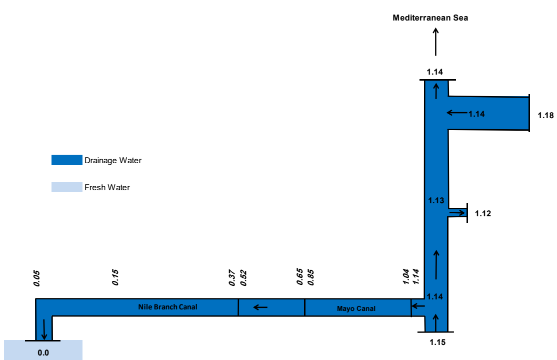

Fig. 15. A schematic diagram of corresponding water levels with its magnitude (m)+ msl to the flow discharges for scenario 1

It is noted that the water level needed is (1.14) m at Drain No. 2, which necessitates the implementation of Interventions 1 and 2.

6.2 The second scenario (excavation of mayo canal to the design bed level)

The second scenario represents the peak summer period and maximum water supply requirements and excavation of Mayo Canal to reach the design bed level.

Figures 16 and 17 show the scheme of the flow discharge distribution and corresponding water levels respectively for scenario 2.

It is noted that the water level needed is (1.02) m at drain 2, which necessitates the implementation of interventions 1 and 2 in addition to the difficulty of excavation of Mayo Canal to the design bed level which needs a protection of embankments.

The effect of excavation is not as severe as the cross section widening compensates the bed raising.

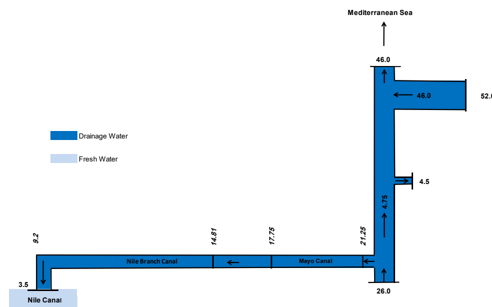

Fig. 16. A schematic diagram of the scheme of the flow discharge distribution with its magnitude (m^3/s) for scenario 2

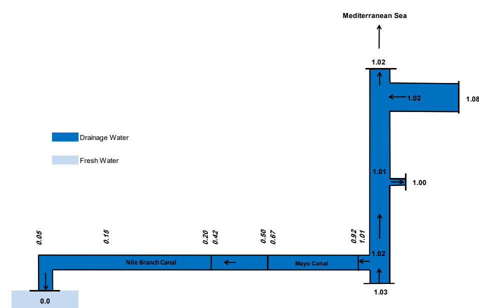

Fig. 17. A schematic diagram of corresponding water levels with its magnitude (m)+ msl to the flow discharges for scenario 2

6.3 The third scenario (constructing a new pump station at the entrance of mayo canal)

Figures 18 and 19 show the scheme of the flow discharge distribution and the corresponding water levels respectively for this scenario No. 3. It is noted that the water level needed is (0.90) m at Drain No.2, the difficulty of this scenario is the high initial cost of building new pump station at the Mayo Canal entrance in addition to the running cost of operation and maintenance.

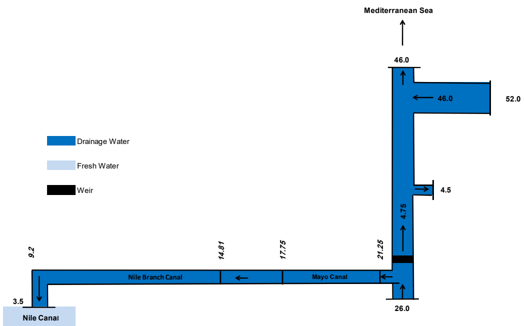

Fig. 18. A schematic diagram of the scheme of the flow discharge distribution with its magnitude (m^3/s) for scenario 3

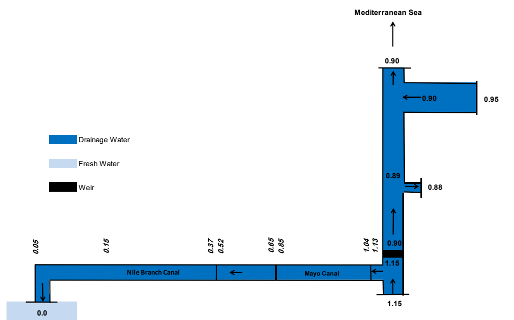

Fig. 19. A schematic diagram of the corresponding water levels with its magnitude (m)+ msl to the flow discharges for scenario 3

6.4 The fourth scenario (constructing a new submerged weir at drain no. 2 downstream of the entrance of mayo canal)

Figures 20 and 21 show the scheme of the flow discharge distribution and corresponding water levels respectively for this scenario.

The dimensions of the weir are (0.7) m crest level with a crest width of 10 m. It is noted that the water level needed is (0.90) m at Drain No.2 downstream of the new weir and (1.15) m upstream of the new weir. Here, intervention 2 only is needed to be implemented.

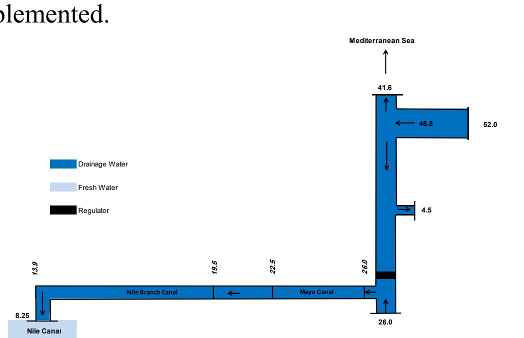

Fig. 20. A schematic diagram of the scheme of the flow discharge distribution with its magnitude (m^3/s) for scenario 4

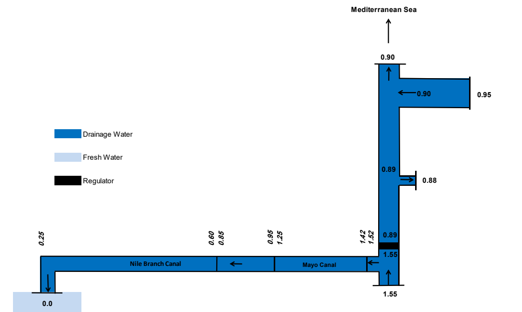

Fig. 21. A schematic diagram of corresponding water levels with its magnitude (m)+ msl to the flow discharges for scenario 4

6.5 The fifth scenario (constructing a new regulator at drain no 2 downstream of the entrance of mayo canal)

Figures 22 and 23 show the scheme of the flow discharge distribution and corresponding water levels respectively for this scenario.

It is noted that the water level needed is (0.90) m at Drain No. 2 downstream of the new proposed regulator and (1.55) m upstream of the new regulator. It is recommended here to implement intervention 2 only.

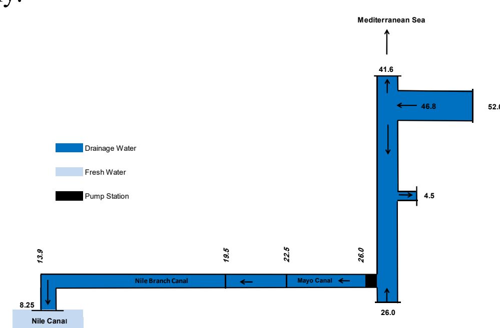

Fig. 22. A schematic diagram of the scheme of the flow discharge distribution with its magnitude (m^3/s) for scenario 5

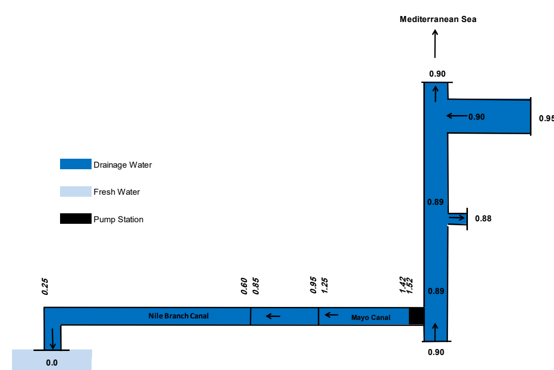

Fig. 23. A schematic diagram of corresponding water levels with its magnitude (m)+ msl to the flow discharges for scenario 5

7. Summary and Conclusion

Table 3 presents a summary of the five tested scenarios results and comments, it is concluded that constructing a new submerged weir at Drain No. 2 downstream of Mayo Canal entrance can be used for short term to satisfy existing irrigation requirements. While for long term and future irrigation expansion, constructing a new regulator at Drain No. 2 downstream of the Mayo Canal entrance will be more effective.

Table 3 Summary of the Tested Scenarios Results and Comments

No	Scenarios **Description**	**Water Level Downstream Pump Station No 2 (m)**	**Water Level Upstream of Gamasa Weir (m)**	**Comments**
1	Existing Situation	(1.14)	(1.14)	Ground water table cause some issues
2	Excavation of Mayo Canal to the Design Bed Level	(1.02)	(1.02)	Difficulty of excavation
3	Constructing a New Pump Station at Mayo Canal Entrance	(0.90)	(0.90)	Initial and operational high costs
4	Constructing a New Submerged Weir at Drain No. 2 Downstream of Mayo Canal Entrance	(1.15)	(0.90)	It can be used as short term solution for existing irrigation requirements
5	Constructing a New Regulator at Drain No. 2 Downstream of Mayo Canal Entrance	(1.55)	(0.90)	It can be used as long term solution of future irrigation expansion(the scenario proof that the system is capable to carry more water)

Possibility of complementing irrigation networks at Mayo Canal with drainage water from Drain No.1 and 2 was assessed in this paper. Drains No. 1 and 2 and their branches were surveyed, modeled and analyzed to find out a new scheme to match supply and demand in the studied area.

To reinstate the irrigation network for the new requirements, a study was conducted including water quality criteria, extensive field measurements, coordination with MWRI Sectors for fast interventions, modeling and testing of different scenarios.

Five scenarios were tested as shown in Table 3, it is concluded that constructing a new submerged weir at Drain No. 2 downstream of Mayo Canal entrance can be used for the nearly summer peak period to satisfy the existing irrigation requirements. While for future irrigation expansion, constructing a new regulator at Drain No. 2 downstream of Mayo Canal entrance will be necessary.

Acknowledgment

Gratitude is due to my colleagues at the HRI for providing the hydrographic, bathymetric survey data and the available data related to the study area.

References

[1] NWRP, (2005), "National Water Resources Plan: Water for Future, 2017" Planning Sector, Ministry of Water Resources and Irrigation, Egypt.

[2] Mostafa, H., F. El -Gamal and A. Shalby, (2004), "Reuse of Low Quality Water in Egypt",Non-conventional water use: WASAMED project. Bari : CIHEAM / EU DG Research,. p. 93-103, 2005. http://om.ciheam.org/article.php?IDPDF=800754

[3] Channel Maintenance Research Institute, (2008), "Hydraulic Efficiency Improvement Study for Mayo Canal, Gamasa", Report No 312/2008, December 2008, Egypt.

[4] Abu Zeid, M. A., (1997), "Egypt Water Policy for the 21st Century", In: IX th World Water Congress of IWRA special session on water management under scarcity conditions, the Egyptian experience. pp 1-7, IWRA, September 1997, Montreal, Canada.

[5] Hydraulics Research Institute, (2012), "Hydraulic Study for Supplying Mayo Canal with Reuse Drainage Water at Kalabsho and Zian, Gamasa", Report No 78/2012, April 2012, Egypt.

[6] Channel Maintenance Research Institute, (2002), "Technical Study for the Failure Problems of Banks of Kalabsho and Zian Drains, Gamasa", Report No 18/2002, November 2002, Egypt.

[7] Delft Hydraulics, (2015), "Sobek Software Manual", Delft Hydraulics, Delft, the Netherlands.

[8] Abbott, M. B., (1979), "Computational Hydraulics; Elements of the Theory of Free Surface Flows", Pitman Publishing, Ltd., London, United Kingdom.

Abbreviations

BCM	Billion cubic meters
HRI	Hydraulics Research Institute
MWRI	Ministry of Water Resources and Irrigation
NWRP	National Water Resources Plan
ppm	Part Per Million
msl	Mean Sea Level