JOURNAL OF ENVIRONMENTAL HYDROLOGY

Open Access Online Journal of the International Association for Environmental Hydrology

VOLUME 27 2019

INTEGRATED SOLUTION FOR THE WATERLOGGING PROBLEM: A STUDY ON EL- MINYA, EGYPT

Marwa M. Aly | Faculty of Engineering, Matareya, Helwan University, Egypt
Mohamed S. M. Zayed | Civil Enginering Dpt., Faculty of Engineering, Matareya, Helwan University, Egypt

The waterlogging in the low lands is caused by the seepage coming from the cultivation of the neighboring cultivated new high lands. This seepage is due to the unlined surface water canals and the use of flooding irrigation system in both the old and the new cultivated lands. In addition, the existence of clay lenses with shallow depth in the soil zone of the old cultivated lands creates a perched condition leading to a rapid rise in soil water table. The aim of this paper is to embrace an integrated approach to minimize the waterlogging problem in the low lying lands for better crop production.

El-Edwah region in El Minya governorate, is one of the most areas suffering from waterlogging problem. Visual MODFLOW was used to simulate the groundwater system in the Quaternary aquifer trying to mitigate the problem. The model was calibrated for both steady and transient states; three mitigation measures scenarios were applied to solve the waterlogging problem. The three scenarios are; the installation of pumping wells around the waterlogged area, the execution of subsurface drains and the construction of cutoff wall barrier . The results of these scenarios were compared from the groundwater drawdown and the implementation cost point of views. The most efficient scenario was the pumping wells with high drawdown values and low cost, the cut off wall scenario hasn't any significant observed draw down regardless the cost, and the scenario of subsurface drains has the highest cost. It's highly recommended to apply the pumping wells as a temporary solution as fast as possible to mitigate waterlogging problem in the suffering areas. For permanent solution for the waterlogging, subsurface drains should be used even though its high cost.

INTRODUCTION

The waterlogging problem has become a severe problem throughout the world. Waterlogging is the condition where the upper boundary of saturated zone i.e. the piezometric surface rises up and reaches into the root zone. The depth of the root zone generally depends on the crop pattern. Usually the depth of the root zone is determined at the level above which 90% of the roots occur. If the piezometric surface exceeds the depth of the root zone, it will influence root development and crop production as it will reduce the aeration zone required for crops growth, Houk et al. 2006 .

In Bangladesh, the Teknaf area was subjected to waterlogging due to rain fed flooding. Anisha. N.F et al., 2014 investigated the problem and provided recommendations to minimize its adverse effects. Kaiser M. Fet al., 2013 utilized the waterlogging problem and the management of the drainage deficiency along Wadi EL Tumilate basin in north Eastern Nile Delta of Egypt by integrating GIS and remote sensing data with ground water modelling. Ahmed A. Abd El Monem et al, 2016 use of numerical modeling to predict the impacts of desert development schemes and water resources management schemes on groundwater in west El Minya Governorate. El Bastawesy et al., 2013 recommended that; the geomorphology of closed drainage basins has to be considered when planning for a new cultivation in dry land catchments e.g. the Farafra and Baharia Oases to better control waterlogging hazards. The dry drainage concept can be implemented as the drainage and seepage water can be conveyed through the inactive alluvial channels into certain abandoned playas for evaporation. El Kashouty, 2012 studied the above mentioned problem, where groundwater levels at observation wells were measured to generate groundwater levels profile with respect to ground surface elevation in order to determine groundwater depth below ground surface to determine waterlogged areas. It was concluded that, in the northern part of the study area; from Edwah to Matai village, the groundwater levels are above ground surface elevation which reflects the existence of waterlogging problem.

The previous studies show that there are several reasons for the waterlogging problem such as the drainage deficiency and the soil type that allows the ground water table to rise. In this study the seepage due to the difference in elevations between the cultivated lands is considered.

One of the most benefits from the construction of High Aswan Dam HAD is safeguarding water resources in Egypt for agriculture and other purposes, that encourages the horizontal expansion of the cultivated lands. Before HAD construction, the cultivated area in the Nile valley was about 2 million Feddan, after HAD construction this figure increased by around 750,000 Feddans Attia, 1989 . During the last decades more than 1.6 million Feddan of new lands have been reclaimed and cultivated.

Most of the new reclaimed areas are situated in the elevated desert lands, adjacent to the Nile valley. Consequently several parts of old cultivated lands in the Nile valley are subjected to waterlogging problem due to subsurface drainage system in these high elevated lands towards the west and the east. The existence of subsurface faults acting as conduits for water drainage increase groundwater levels in the Quaternary aquifer.

The aim of this research is to study groundwater system in El-Edwah region which is located North of El-Minya governorate and suffer from the waterlogging problem due to the seepage caused by the difference in the cultivated land elevations. The MODFLOW model was applied to detect the most waterlogged areas in EL-Edwah region. Also, it was used to simulate the groundwater aquifer to define the most efficient mitigation measures from groundwater drawdown and the implementation cost point of views.

MATERIALS AND METHODS

The DEM-derived hydrological parameters are integrated with the groundwater modelling in order to determine the relation of waterlogging patterns to the drainage networks, geomorphology and soil properties of the catchments. This is to determine the most suitable remedial action, which should be uniquely compatible with the inherited hydrogeological setting and characteristics of each catchment. In the following sections the location, climate, geomorphology, hydrogeology and hydrology of the study area is well explained.

Study Area

El-Edwah region is located in El-Minya governorate, Egypt, between latitudes 28º 35 30' to 28º 46'37"N and longitudes 30º 38' 53" to 30º 57' 4"E .It extends from El-Edwah to Maghagha city and is bounded by the Nile River from the east and western Desert fringes from the east as shown in Figure 1.The climate is arid to semi-arid, hot climate, dry, rainless in summer and mild to rare in winter. The minimum and maximum temperatures vary from 4.6º C in January to 20.5º C in July and from 20.4º C in January to 37.1º C in June, respectively, while the average temperature ranges from 10º C in January to 27ºC in June . The cropping pattern for the project area includes different crops like Clover, Grape, Groundnuts, Maize, Potatoes, Sesame, Sorghum, Soybean, Sugar beet, Sugar cane, Vegetables and Wheat, El Deeb et. al, 2015.

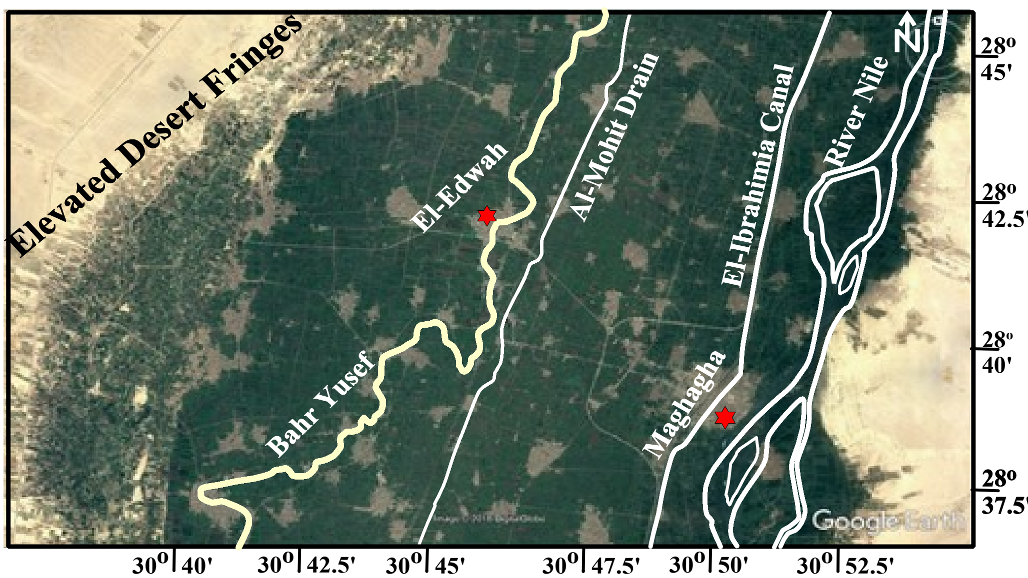

Figure 1. Location of the Study Area

Geomorphology of the study area

The study area located to the west of the Nile River flood plain, it passes through high eastern and western calcareous plateaus with general slope from South to North of 0.1m/Km Korany et al., 2006 . Nile River covers the eastern portion of its valley making the cultivated areas in the west wider than in the east, Shabana, 2010. The Digital Elevation Model DEM file with resolution 90m x 90m was utilized, the ground level in the low lands gradually vary from 20m to 60 m above mean sea level amsl , while the new high reclaimed lands located at the western side vary from 60m to 140m amsl, as shown in Figure 2

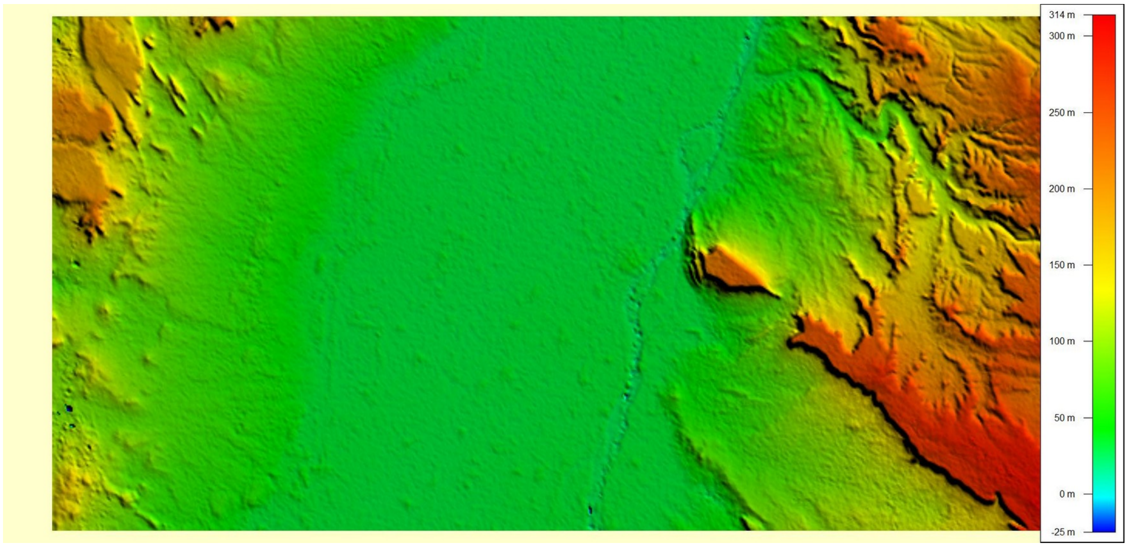

Figure 2. The Digital Elevation Model of the Study Area

Hydrogeology of the study area

Generally, the surface and subsurface geologic characteristics have vital importance for detecting the hydrogeological configuration in terms of aquifer characteristics, water potentiality and water movement. The geology of the study area shows that the surface and subsurface are occupied with sedimentary rocks belonging to Tertiary - Quaternary deposits. The surface stratigraphic sequence from top to base is built up from Holocene silt and clay forming the cultivated flood plain where the high sand/ clay ratio content of the soil cover of these deposits, especially in the southern area decreases the drainage efficiency and consequently causes a waterlogging problem. Pleistocene sands and gravels forming a narrow strip extending between the flood plain and the valley slopes and the Eocene limestone which is encountered in the subsurface, they form the rocky plateau bounding the valley westwards as shown in Figure 3, Said, 1981

The subsurface Tertiary stratigraphic sequence in the study area was recorded by Tamer et al. 1974 . The Eocene deposits 385 m include Middle and Upper Eocene deposits. The Pliocene deposits include Kom El Shelul Formation and undifferentiated clay, sand and conglomerates. The subsurface Quaternary succession reached about 214m, it is subdivided into Plio-Pleistocene of Old Nilotic deposits with total thickness of 150m, Pleistocene of Old lacustrine deposits and Young Nilotic sediments 5m and 44m, respectively and Holocene section with 15m. The Quaternary deposits are underlain by the impermeable Pliocene clays and/or the Eocene carbonate Tamer et al, 1974 as shown in Figure 3 and Figure 4.

The water resources in the study area are represented in the River Nile, Ibrahimia Canal and Bahr Youssef canal as well as El-Moheet Drain forming the surface water systems, while the Groundwater system falls into two broad categories; aquifers having primary porosity including the Quaternary and the Oligocene-Pleistocene aquifers and consolidated fractured aquifer including the Eocene fractured limestone aquifer. Quaternary aquifer is the main aquifer in the study area. It has a wide areal extension especially in the northern side of the study area. The aquifer is formed of relatively thick formation of the Quaternary deposits that range from 100 m to 130 m, RIGW/IWACO, 1989 and is composed of sands, gravels and alluvial sediments of sand and gravel intercalated with clay lenses. The aquifer is

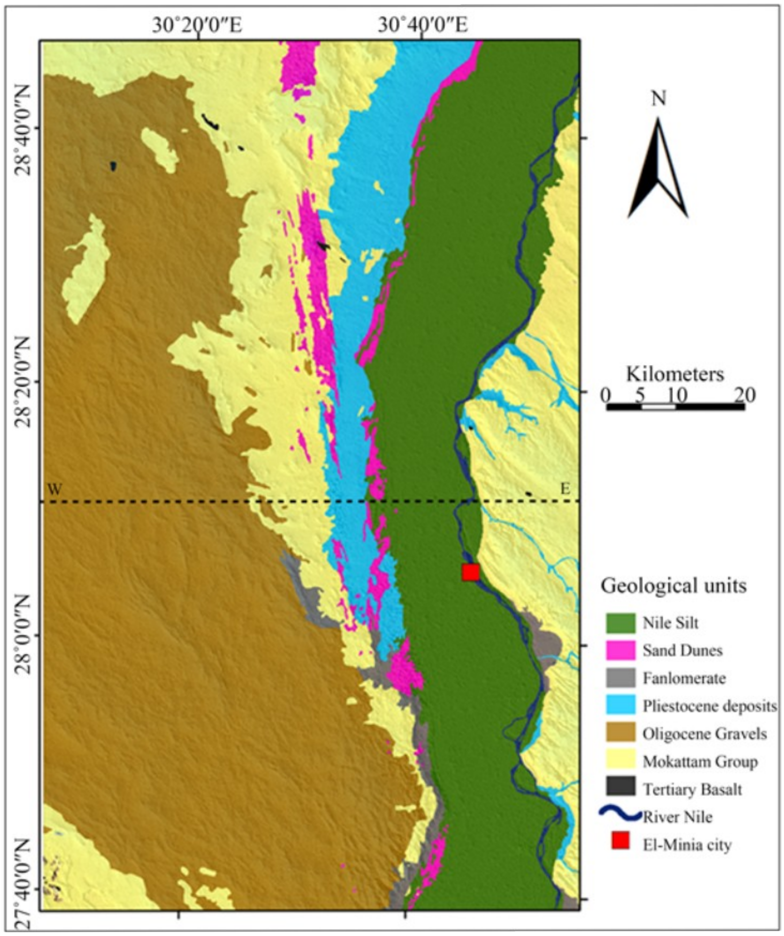

Figure 3. Geological Map of the Study Area

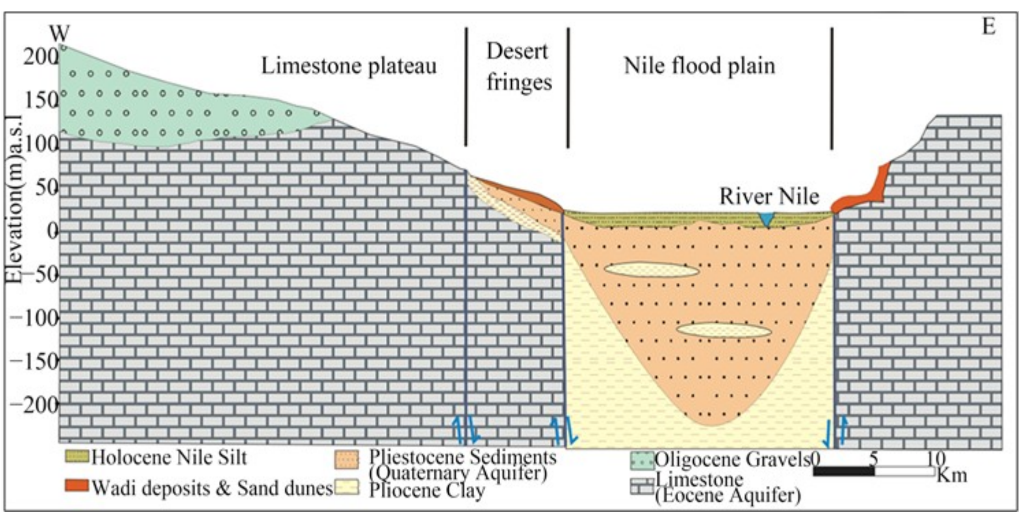

Figure 4. Hydrogeological cross-section in E-W direction showing the groundwater aquifer

overlaid by a layer of Holocene Nile silt and sandy clays extending into semi-permeable and impermeable layer. This top layer receives excess water after irrigation of new cultivated lands and seepage from wetted perimeter of irrigation canals and conduits. The thickness of the top Holocene silt and sandy clay layer vary between zero at desert fringes to16 meters near the River Nile with an average depth of 9-10m as shown in Figure4.There are hydraulic connections between Quaternary aquifer and the underlying aquifer either by upward or downward flows through the open faults and fractures, taking into consideration that the Eocene rocks are fractured Korany,1984 .The aquifer has high potentiality for storing and transmitting groundwater from the recharge areas to nearby areas.It discharges naturally towards River Nile effluent stream condition ,drains and adjacent aquifer systems as it can be detected from the groundwater movement in Figure 5, Gad 2004

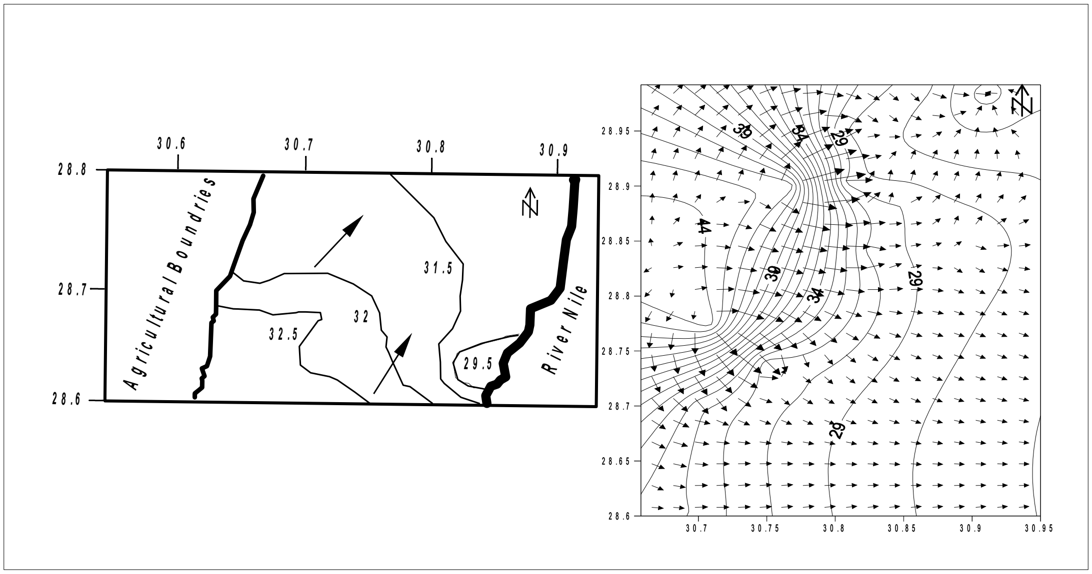

Figure 5. Piezometric surface contour map and groundwater movement at March 2003 (right map, Gad 2004) and 2012 (El Kashouty et al., 2012 left map).

Water Table Fluctuation Maps - Resultant map

The resultant water table map was developed from the observed groundwater levels at years 2003 and 2012 Gad, 2004 and El Kashouty et al., 2012 , respectively to determine the vulnerability of the aquifer in the study area to the occurrence of waterlogging. From Figure 6, it can be noticed that; the maximum and minimum observed groundwater fluctuations records are +2.0m near Nile River and -7.5m near cultivated boundaries with total groundwater fluctuation of 9.5m.The minor change in groundwater levels is close to Bahr Youssef canal. The area characterized by zero contour line means that there is no change in the groundwater levels, the area characterized by positive contour lines means that there is an increase in the groundwater levels and exceedance of the probability of waterlogging occurrence. On the other side, the area characterized by negative contour lines means that there is a decrease in groundwater levels and there is no threatening from waterlogging occurrence.

The change in water table means the change in the stored volume of groundwater. If the effective porosity of the subsurface soil is known, the change in groundwater storage over a given period can be expressed as:

$$\Delta S = \mu \, \Delta h \quad (1)$$

where, ΔS is the change in storage of groundwater over a given period and per unit of horizontal surface area m , μ is the effective porosity of the soil dimensionless and Δh is the change in water table elevation over the given period m.

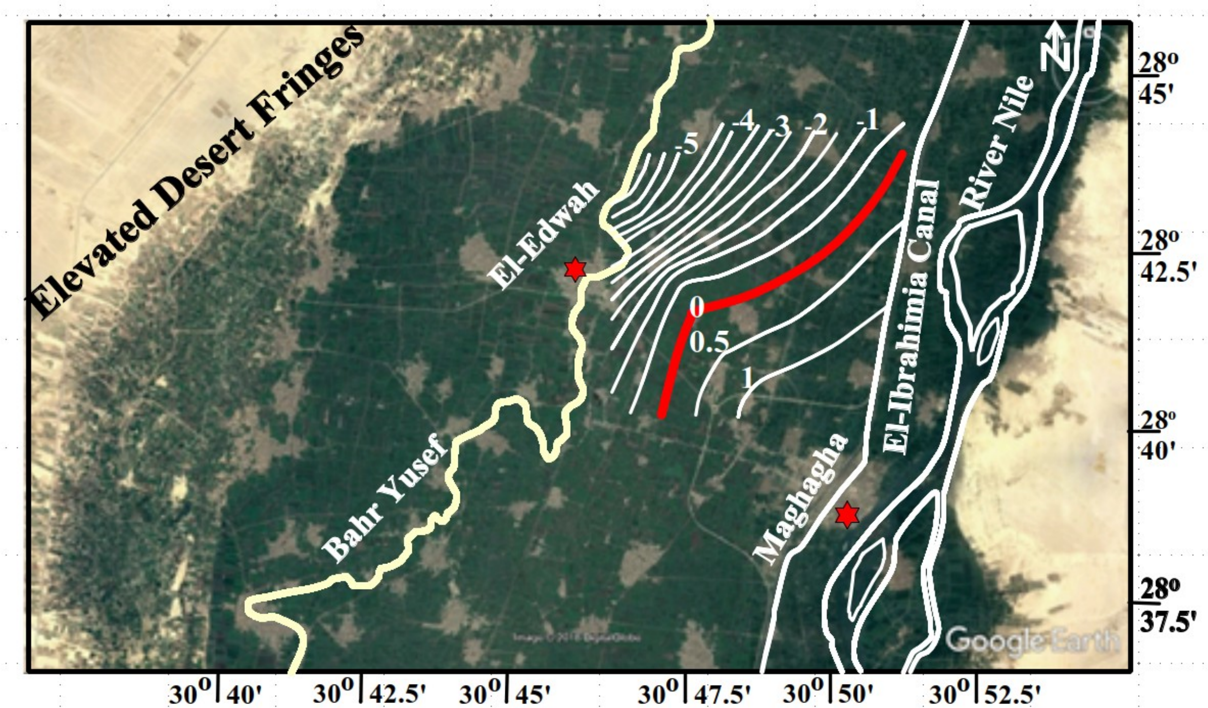

Figure 6. Resultant map showing annual fluctuations of groundwater level 2003-2012

The resultant water table map was developed from the observed groundwater levels at years 2003 and 2012 Gad, 2004 and El Kashouty et al., 2012, respectively to determine the vulnerability of the aquifer in the study area to the occurrence of waterlogging. From Figure 6, it can be noticed that; the maximum and minimum observed groundwater fluctuations records are +2.0m near Nile River and -7.5m near cultivated boundaries with total groundwater fluctuation of 9.5m.The minor change in groundwater levels is close to Bahr Youssef canal. The area characterized by zero contour line means that there is no change in the groundwater levels, the area characterized by positive contour lines means that there is an increase in the groundwater levels and exceedance of the probability of waterlogging occurrence. On the other side, the area characterized by negative contour lines means that there is a decrease in groundwater levels and there is no threatening from waterlogging occurrence.

Visual MODFLOW Model Set Up

MODFLOW was applied to calibrate the physical parameters to define the flow mechanism, and the initial conditions for flow were evaluated accordingly. The model describes the groundwater flow of constant density under non-equilibrium conditions in a heterogeneous and anisotropic medium according to the following equation Bear, 1979 and Bear & Verruijt 1987 :

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t} \tag{2}$$

where K_{xx}, K_{yy}, K_{zz} are values of hydraulic conductivity along the x, y and z coordinate axes LT^{-1}; h is the piezometric head L; W is a volumetric flux per unit volume and represents sources and/or sinks of water T^{-1}; S_s is the specific storage of the porous material L^{-1} and t is time T.

The Quaternary aquifer hydraulic parameters such as hydraulic conductivity, specific yield, specific storage, transmissivity and storativity which were taken from previous studies Korany, et al. 2006, Gad, 2007, Ibrahim, 2007, El Kashouty, et al. 2012, and Dawoud, et al. 2013 are presented in Table 1.

Table 1. Aquifer characteristics after different authors

Hydraulic parameter	upper Holocene deposits	Quaternary aquifer
K_x, K_y	0.07 - 0.2 m/day	100 - 200 m/day
K_z	0.007 - 0.02 m/day	10 - 20 m/day
Specific yield S_y	0.04	0.15
Specific storage S_s	0.00011 1/m	0.001 1/m
Porosity	0.3	0.4

Conceptual model of the studied aquifer

Generally, success of a numerical model depends upon the approximation of the conceptual model to the reality. Conceptual model must include all the sources and sinks, different hydrogeological units with their areal extent and thickness and the boundaries of the problem domain. The model is composed of two layers; Quaternary aquifer layer with 75m thickness overlaid by the Holocene layer with 17m thickness Tamer et al., 1974. The two layers are hydraulically connected and vertically homogeneous so it is considered as a single layer.

The sources of water to the conceptual model are the infiltration from rainfall with an estimated value of 23.5 mm/year, Ismail et al, 2015 and the seepage from the irrigation process and it is taken into consideration through western boundary condition. The sinks are the evapotranspiration which estimated to be 1077.12 mm/year, Ahmed, 2009; and the discharge from pumping wells located in the study area for irrigation purpose with an average extraction rate of 600 m^3/day Gad 2004 as shown in Figure 7.

Based on the resultant map shown in Figure 6, the model domain of the water logged area reaches about 5240 Feddans in El-Edwah region. It is divided into 100 columns and 100 rows with cell area of 40*50 m^2 as shown in Figure 7.

The hydraulic boundaries specified in the modeled area are; Nile River in the eastern side as a constant head boundary and the zero contour line extracted from the resultant map in the western side as a general head boundary Figure 7.

Model Calibration

Due to the limited availability of groundwater level measurements, the steady state calibration was run based on the observed groundwater levels at year 2003 Figure 5 and the data of seven observation wells distributed in the model domain Gad, 2004 .

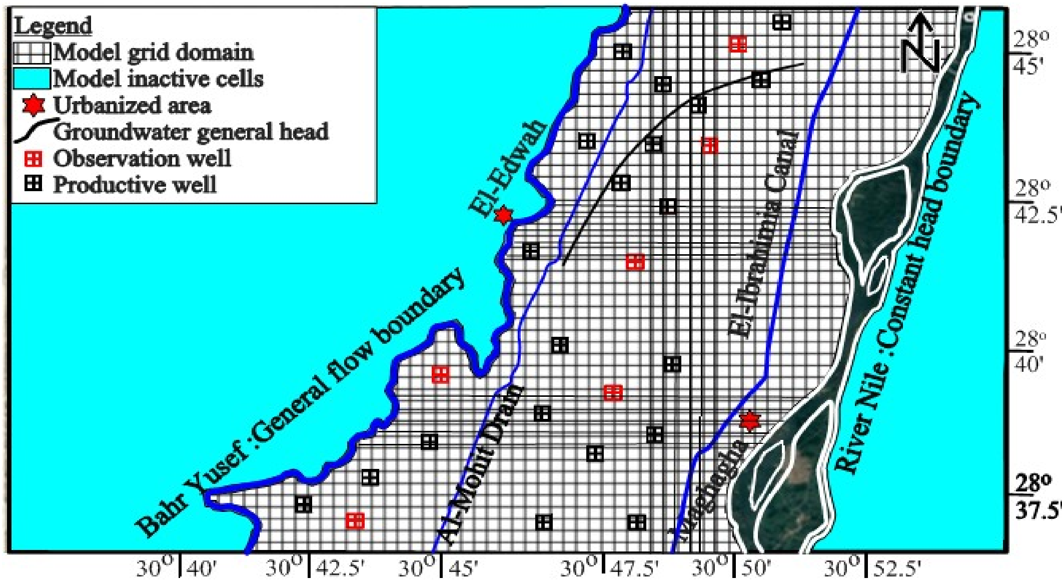

Figure 7. Model domain and boundary conditions of the study area

In steady state calibration, the dominant factor is the hydraulic conductivity, where the adjustment of its value was done until the calculated heads from the model match the measured head values as represented in Table 2.

In transient calibration, the model allows to run in the period from year 2003 to year 2012. Storage coefficient was the dominant factor in the calibration process. Its values were adjusted by trial and error till reaching a good agreement between observed and calculated groundwater level, as presented in Table 3.

Table 2. The final difference between measured and calculated heads at steady state calibration

Observation well no.	Coordinates		Heads		Difference m
	X	Y	Measured	Calculated	
Ob1	3173366	285071.2	29.00	29.15	+0.15
Ob2	3174150	280628.9	30.00	30.12	+0.12
Ob3	3180863	289042.9	29.00	29.04	+0.04
Ob4	3178860	273463.8	36.00	36.19	+0.19
Ob5	3174920	272295.2	34.00	33.94	-0.06
Ob6	3169054	284662.6	29.00	29.28	+0.28
Ob7	3169388	280236.2	30.00	30.16	+0.16

Table 3. The final difference between measured and calculated heads at transient calibration

Observation well no.	Heads		Difference m
	Measured	Calculated	
Ob1	30	30.09	+0.09
Ob2	31.00	30.88	-0.12
Ob3	31.50	31.46	-0.04
Ob4	32.00	32.04	+0.04
Ob5	32.00	32.13	+0.13

The water depth contour map was extracted from mathematical model to determine the regions suffering from waterlogging as shown in Figure 8.

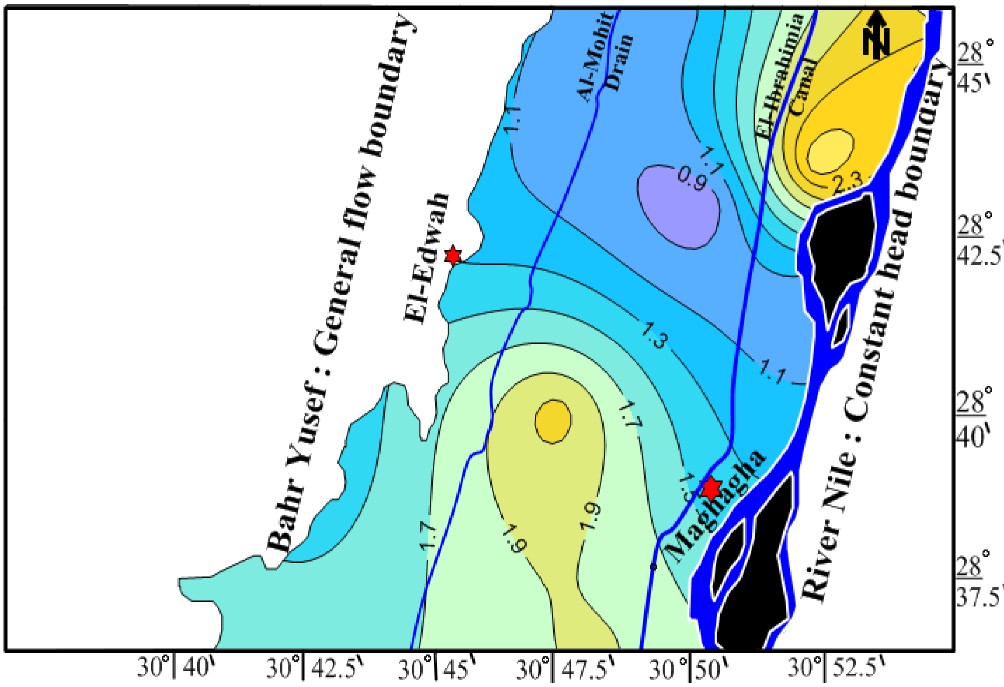

Figure 8. Depth to Water contour map extracted from the model in m

Mitigation Measures Scenarios

Mitigation measures scenarios of waterlogging problem used in previous works relating to the study area are based on surface/subsurface drainage, pumping wells and biological farms. They assume the homogeneity of the Quaternary aquifer. In this research, heterogeneity of Quaternary aquifer is considered.

The suggested mitigation measures scenarios invoked by the model are; the installation of pumping wells around the waterlogged area, the execution of subsurface drains, and the construction of cutoff wall barrier. The efficiency of each scenario in decreasing groundwater levels was tested through four proposed observation wells as shown in Figure 9.

The first scenario distributes nineteen pumping wells around the waterlogged area in order to lower groundwater levels below ground surface. It is assumed that the discharge rate from each well is 150 m^3/hr, 24-working hours per day and The pumping wells are penetrating the Holocene layer to the Quaternary aquifer and the pumped water will be drained into nearest water body in the area, as shown in Figure 10.

The second scenario consists of two subsurface drains perpendicular to groundwater flow in order to lower groundwater levels in the modeled area. The location of these drains were chosen in the unurbanized area. After many trials for adjusting drain levels, the selected drains were 9-10 m below ground surface in the Holocene aquifer with assumed conductance of 90000m^2/day, as shown in Figure 11.

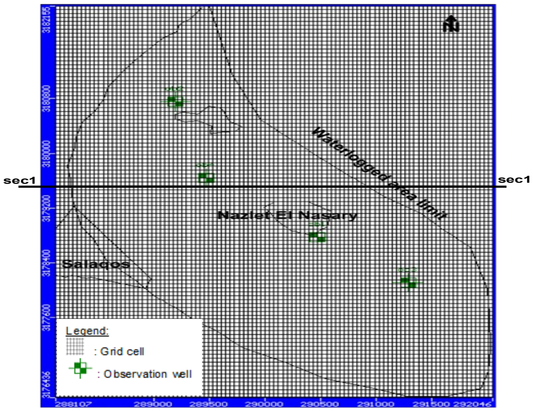

Figure 9. Model domain & proposed Observation wells extracted from MODFLOW

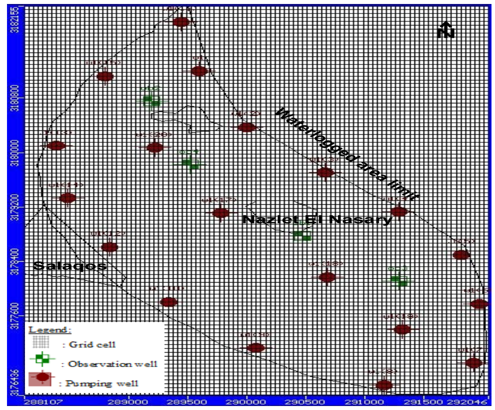

Figure 10. Pumping wells distributed aroundwater logged area for the 1st. scenario

To determine the amount of water discharged into the subsurface drain, zone budget analysis has been run. This zone budget analysis shows that the amount of water discharged into the subsurface drains after 300 day is equal to 56431m^3/day it is recommended to drain towards the nearest surface water body .

The diameter of the drainage pipe was taken 0.60 m and is determined using Manning Equation as follow

$$Q = 1/n * S^{0.5} * R^{2/3} * A \tag{3}$$

Where,Q is the discharge passing through the pipe, n is Manning's coefficient, S is the longitudinal slope, A is the cross section area of the drainage pipe and R is the hydraulic radius = Area of pipe/ Perimeter of pipe.

<u>The third scenario</u> consists of a cutoff wall barrier perpendicular to groundwater flow direction in order to change the direction of groundwater flow. The suggested cutoff wall, assumed to have a thickness of 0.3m until it reaches the end of the Holocene aquifer layer with average depth 20m, as shown in Figure 12.

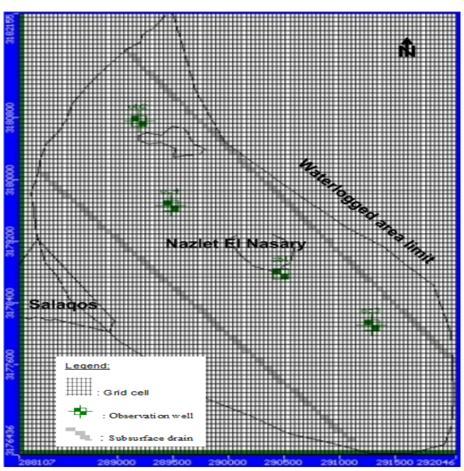

Figure 11. Assumed subsurface drains, in the modeled area for the 2nd scenario.

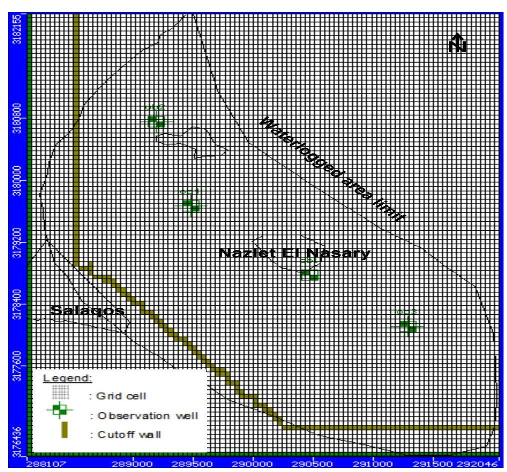

Figure 12. Assumed cutoff wall in the modeled area for the 3rd scenario.

RESULTS AND DISCUSSION

The results of the three scenarios after a period of 300 days are shown in Figure 13, where in the first scenario, , the decline of the groundwater levels in the modeled area is varying between 1.22m and 1.80m at Ob4 and Ob2, respectively. The drawdown values seem to be acceptable taking into consideration the safe aeration root zone for cultivated lands. While for the second scenario the drawdown values reach a least value of 0.78 m at Ob2 and a highest value of 1.37m at Ob3. The drawdown results also satisfy the safe aeration root zone. From Figure 14, it can be seen that the drawdown values resulting from the first scenario are relatively higher than the resulting drawdown of the second scenario. This may be attributed to the relatively high hydraulic conductivity in the Quaternary aquifer which consists mainly of sand and gravel in this area. On the other hand, the proposed subsurface drains are embedded in the Holocene layer which consists of silt and clay with low hydraulic conductivity that affects the groundwater flow towards the drains.

Running the third mitigation scenario on the water logged area achieved minor drawdown values when compared to the previous scenarios. The results of the last scenario proved that the waterlogging phenomena in the study is not only from the horizontal movement of shallow groundwater drained from the new reclaimed lands, but also from the vertical infiltration of irrigation water of these new reclaimed lands deeply to the Quaternary aquifer and then, the rise to the ground surface of the old cultivated lands Brikowski and Faid 2006. The cutoff wall which is the concept of this scenario penetrated only the Holocene layer. The drawdown was achieved only at Ob1 with value of 0.25m, while in the three observation points; the water levels are still above the ground surface. This may be referred to the fact that, the embedded cut wall depth which is not enough to affect groundwater direction. The rising of groundwater level in this scenario is due to existence of the barrier with very low hydraulic conductivity which acts as an obstacle in the way of the subsurface water. From the above explanation there is no effect of this scenario on decreasing groundwater levels.

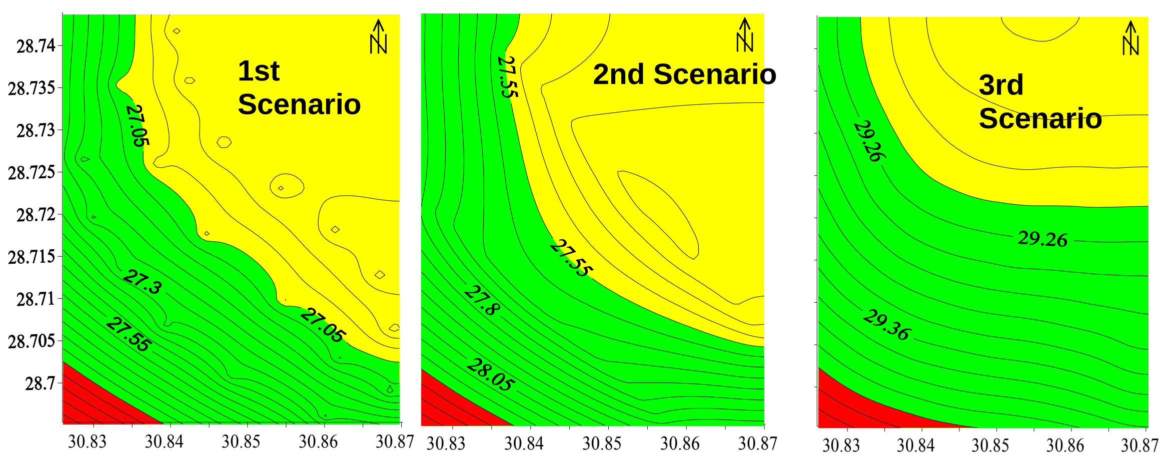

Figure 13. Groundwater levels for water logged area after 300 days for different scenarios.

Cost Estimation of the Proposed Scenarios

The estimated cost for the different measures of each scenario is calculated , as follow:

In the 1st scenario, the cost per pumping well is 153990 L.E, and as the pumping system consists of 19 wells, then the total estimated cost is $2.92x10^6$ L.E. as presented in Tables 4 and 5. Cost of the

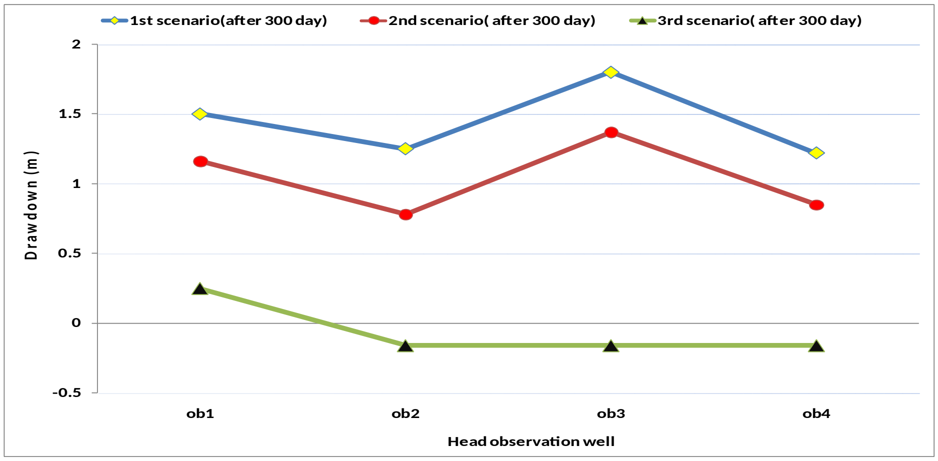

Figure 14. Drawdown in observation wells for each scenario.

pumping well has been increased by 3 times due to dollar price rising against the Egyptian pound . http://omrasad.blogspot.com.eg/2015/06/blog-post_27.html .

In the 2nd scenario, the cost for sub-surface drains execution is about 5.3 x10^6 L.E. as presented in Table 6. https://www.facebook.com/permalink.php?id=283005178506164&story_fbid=323204214486260 .

In the 3rd scenario the construction cost of the cutoff wall barrier concrete pile wall is about 2.88x10^6 L.E. As presented in Table 7. http://engmuslim1.blogspot.com.eg/2014/12/2015.html

Table 4. Cost of items related to each well

Item	Unit Price L.E	Unit	Total Price L.E
Cost of excavation/m	130	30 m	3900
Cost of steel pipes of execution	140	30 m	4200
Well face	1000	--	1000
Delivery pipes	150	28 m	4200
Electric cable	95	29 m	4180
Submersible pump	26000	1	26000
Fees for one well	2500	1	2500

Table 5. Cost of items related to all wells

Item	**Unit Price L.E**	**Unit**	**Total Price L.E**
Electric generator	95000	1	95000
Electric unit	5000	1	5000
Water for ease of execution	500	1	500

Table 6. Cost of items related to subsurface drains execution

Items	Unit Price L.E
Total length of drains m	8800
Cross section area of drain m^2	97.2
Volume of excavation m^3	855360
Cost of 1m of excavation L.E/m^3	6
Total cost of Excavation	5132160
Cost of pipe L.E/m according to price of EGIC company	20
Total cost of pipe	176000
Total cost of drains	5308160

Table 7. Cost of items related to cutoff wall execution

Items	**Unit Price L.E**
Cost of 1m long of the cutoff wall L.E /1m long	385.5
Length of the proposed cutoff wall m	7480
Total cost of cutoff wall execution L.E	2883540

Comparisons between the cost of each proposed scenario and the cost of one meter drawdown for each proposed scenario are shown in Figures 15 and 16.

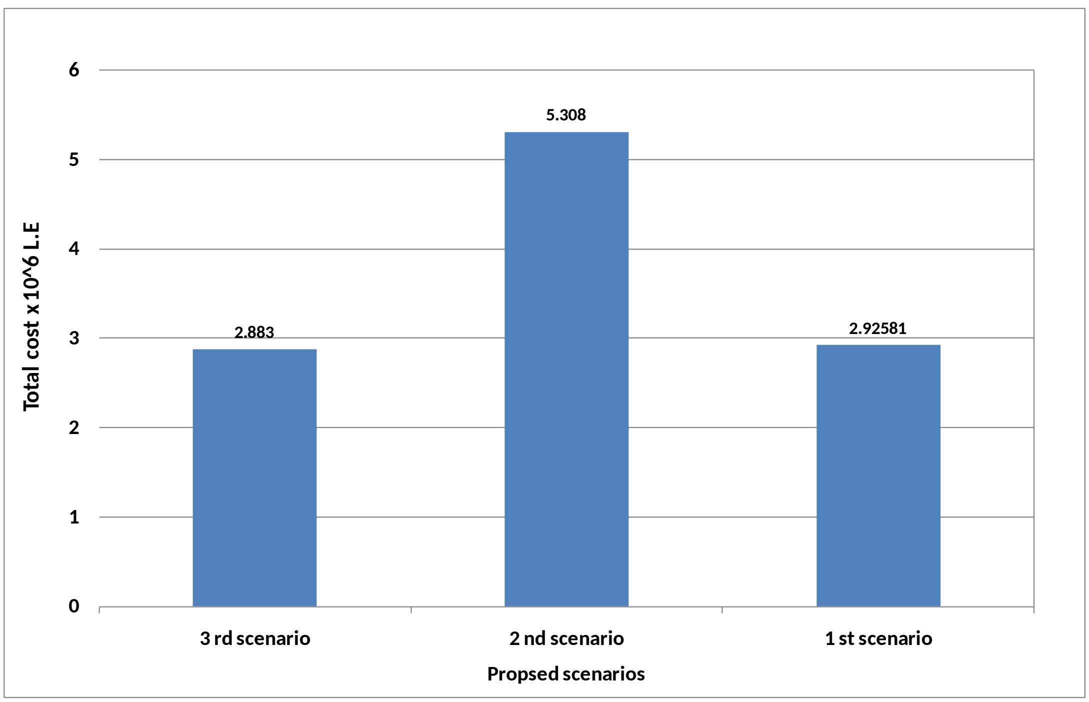

Figure 15. Comparison between the cost of each proposed scenario

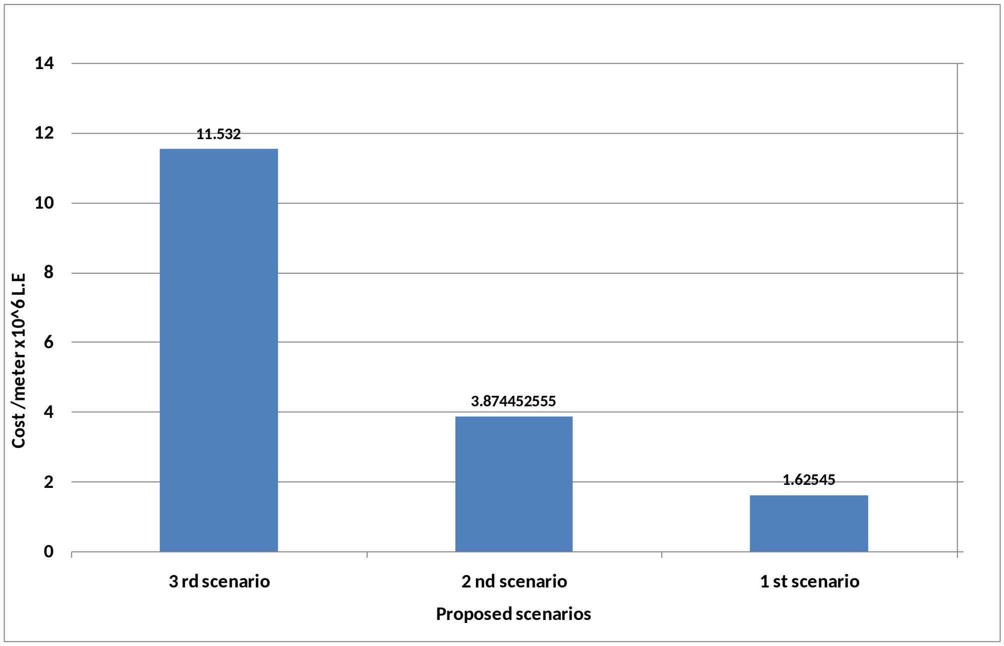

Figure 16. Comparison between the cost of one meter drawdown for each proposed scenario

From the results of the model and the estimated cost of each scenario, it can be concluded that: -

The first scenario, Pumping wells, is the most effective and economical solution for waterlogging problem in the study area.

- It is worth to mention that the cost of the pipes network required to drain the pumped water to the nearest surface water body in the first scenario is not calculated as well as the maintenance cost of subsurface drains in the second scenario assuming that it is almost the same. The reason for groundwater table rise in the old cultivated lands is not only the lateral seepage from the new cultivated lands but also upward flux from Quaternary aquifer to the top surface layer as a result of infiltration of new cultivated lands irrigation water.
- Even though the pumping well scenario is preferred, using subsurface drainage pipelines is a common practice in Egypt. Based on this fact, the suggested solution to the waterlogging problem in El-Edwah region can be two fold. A temporary solution by using the pumping well system as a temporary and fast solution for the drawdown process to get rid of the excess water and a permanent solution could be to install subsurface pipelines to collect any excess water and eliminate the waterlogging problem.
- This integrated solution for the waterlogging problem by combining the pumping wells and the subsurface drainage pipelines can be generalized considering the suitable design for the pumping wells and the subsurface pipelines for each area suffering from the waterlogging problem.
- Cut-off walls are inefficient in dealing with the waterlogging problem as the flow flux is in both the horizontal and vertical directions at the same time.

- To protect the old cultivated lands located in the Nile Valley from deterioration as a result of groundwater table rise, it is recommended to: -
- Transform the irrigation by flooding at any cultivated lands to drip or sprinkle irrigation.
- The installation of surface or sub surface drains around the new cultivated land to collect the excess water before it reaches to the old cultivated lands.
- Applying the pumping wells solution as fast as possible to mitigate waterlogging problem in the study area is a must.

ACKNOWLEDGMENT

This paper was reviewed first by Dr Ahmed Medhat Abd El-Hamid, Researcher, National Water Research Center, Ministry of Water Resources and Irrigation, then by Professor Dr Mohamed Mohamed Abd Ellatif, Hydraulic Research Institute, National Water Research Center, Ministry of Water Resources and Irrigation, and finally by Dr Tahany Youssf Professor of Water Resources Management, Helwan University.

REFERENCES

Ahmed, A. Ayman, 2009. Using lithologicalmodeling techniques for aquifer characterization and groundwater flow modeling of the Sohag area, Egypt, Hydrogeology Journal, 17, 1189–1201.DOI 10.1007/s10040-009-0461-z.

Ahmed, A. Abdel Moneim, José, P. F., Elsayed M. Abu El Ella, Ahmed M. Masoud, 2016. Groundwater Management at West El-Minia Desert Area, Egypt Using Numerical Modeling, Scientific Research, volume 4, number 7, July 2016.

Anisha, N. F., Hossain, S., 2014. A case study on waterlogging problems in an urban area of Bangladesh and Probable analytical solution. International Conference on Advance in Civil Engineering 2014.Chittagong, Bangladesh. December 26-28.

Attia, F., 1989. Drainage problems in the Nile valley resulting from land reclamation , Irrigation and Drainage System, 3, 153-167.

Bastawesy, M. E., Ramadan, Ali R., Faid, A., and Osta, M. E., 2013. Assessment of waterlogging in agricultural megaprojects in the closed drainage basins of the Western Desert of Egypt. Hydrology and Earth System Sciences, 17 4 , 1493-1501.

Bear, J., 1979 .Hydraulics of Groundwater. McGraw-Hill, New York.

Bear, J., &Verruijt, A. 1987. Modeling Groundwater Flow and Pollution. D. Reidel Publishing Company, Dordrecht, Holland. 414 pp.

Brikowski, T.H., and Faid, A., 2006. Pathline-calibrated groundwater flow models of Nile Valley aquifers, Esna, upper Egypt, Journal of Hydrology, Vol. 324, 195–209.

Dawoud, M. A., Ismail, S. Sh., ,2013. Saturated and unsaturated River Nile/groundwater aquifer interaction systems in the Nile Valley, Egypt. Arab J Geoscience 6, 2119–2130.

El Kashouty, M., El Sayed, E., Elewa, A. M., and Morsi, M., 2012. Environmental impact of anthropogenic activity on surface and groundwater systems in the western part of the River Nile, between EL-Edwa - Der Mawas area, El Minia Governorate, Upper Egypt. Journal of American Science, 8 5 : 150-161.

Fetter, C. W., 2001. Applied Hydrogeology. 4th edition, Pearson Education International, New Jersey.

Gad, M. I. M..,2004. A Trial for Mitigation of Water Logging Problem in New Reclaimed Areas in the Desert Fringes of Beni Suef and El-Minya Governorate, Egypt , Mansoura Engineering Journal, Mansoura University, 29 2 , pages 33-52.

Harbaugh, A. W., Banta E. R., Hill M. C., and McDonald M. G., 2000. MODFLOW 2000, the USGS Modular ground-water model – User guide to modularization concepts and the ground water flow process . USGS Open file report, 00-92Said, R. 1981 . The Geological Evaluation of the River Nile. Springer Verlage, p. 138.

Houk Eric, et al., 2006 . The agricultural impacts of irrigation induced waterlogging and soil salinity in the Arkansas Basin . Agricultural Water Management 85, 175–183.

Ibrahim, S. M. M., 2007 Hydrological evaluation of the tertiary-Quaternary aquifer system west of Malawi, upper Egypt; case study . Egyptian Journal of Geology, V. 57, p.1-30.

Ismail, E., Zaki R., Kamel, Ali, 2015. Hydro chemistry and evaluation of groundwater suitability for irrigation and drinking purposes in West El-Minya district, north upper EGYPT . 18thInternational Water Technology Conference, IWTC18.

Kaiser ,M. F. K., Rayes A., Geriesh , B, 2013. GIS Data Integration to manage waterlogging problem on the eastern Nile delta of Egypt. Geology Department, Suez Canal University, Egypt, International Journal of Geosciences, June

Korany, E., Sakr, S., Darwish, M., Morsy, S., 2006. Hydrogeological modeling for the assessment of continuous rise of groundwater levels in the Quaternary aquifer, Nile Valley, Egypt, case study . Inter. Conf. Geol. Arab World GAW8 , Cairo Univ., 703-711.

Korany, E., 1984 Statistical approach in the assessment of the geohydrology profiles . 9thIntern. Cong. Statis. Comp Science, Social and Demogr. Research, Cairo, Ain Shams University Press, 161-176.

Zayed, M.S.M., 2017. Groundwater resource management for sustainable development, case study Quaternary aquifer at desert fringes of west Menia, Egypt, M.Sc. Thesis, Faculty of Engineering, Matareya, Helwan university.

RIGWA/IWACO., 1989 Groundwater development for irrigation and drainage in the Nile Valley: groundwater development West El Fashn, evaluation of measures to control waterlogging . Technical Report 70, 124-88-04 Internal report .

Shabana, A. R., 2010. Hydrogeological studies on the area West Deir Mouas-Mallawi, El Minya governorate-Egypt . Egypt Journal of Geology 54, 61-78.

Sadek, M., 2001. Isotopic criteria for upward leakage in the alluvial aquifer in north El Minya district, Egypt . Ann. Geol. Surv. Egypt, XXIV, 585-596.

Said, R., 1981. Geological Evaluation of the Nile Springer Verlag, New York.

Tamer,, M. A., El Shazly, M. and Shata, A., 1974. Geology of El-Fayum, Beni Suef Regions : Bull. Desert Inst. Egypt, Vol. 25, No. 1, 2, pp.27-47.

ADDRESS FOR CORRESPONDENCE
Marwa M. Aly
Assistant Professor
Faculty of Engineering
Matareya, Helwan University
Egypt
Email: marwaaly3@gmail.com