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IMPACT OF COVERING IRRIGATION CANALS ON EVAPORATION RATES IN ARID AREAS

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Water is the essence of life; thus preserving enough quantities and good quality of water will elevate the standards of living and health of communities. Egyptian government approved Toshka New Valley project to help deal with the rapidly growing population of the country. The project entails building a series of canals; the main is Sheikh Zayed canal - to irrigate portions of the Western Desert of Egypt. It is expected that the recovered land will become home to three million residents by 2020 and cultivate about 550000 feddans. Toshka is a very arid area with high air temperatures; thus very high evaporation rate; about 3 billion m^3 /year. Researches showed that in the near future Egypt will face scarcity of water. So saving water from Sheikh Zayed canal by reducing evaporation will provide additional source of water to the area. This research aim is to estimate evaporation rate from the canal and its main branches. Variable configurations and spacing of covering canals were chosen to reduce evaporation and at same time allow for re-aeration and other water quality parameters to meet their standards. It was found that full coverage calculated evaporation amount is about 9 million m^3/year which could drip irrigate 35000 feddans of wheat per year which is about 7% of the total area of the land intended to be cultivated in Toshka project.

Keywords: Waterways, Numerical, Modeling, Desert, Water, Sufficiency, Lakes.

1 INTRODUCTION

Water and Energy are the most two vital parameters that would decide on the health and prosperity of a community. If those two parameters could be provided in adequate quantities and managed in an efficient way, then communities are going to flourish. The aim of this research is to reduce water evaporation from irrigation canals, especially in arid areas.

In Egypt, research showed that in the near future we will face scarcity of water. So the amount of water available should be increased by finding new sources of water other than the Nile, at the same time preserving and lessen the waste of water from existing water sources, and hence lessen evaporation from irrigation canals will enhance this idea of water preserving.

The New Valley project or Toshka project -location is shown in Figure 1- is taken as a case study because this area is very arid and it is facing the problem of very high evaporation rate - about 2.5 billion m^3 per year.

In 1997, the Egyptian government approved the Toshka project to help deal with the rapidly growing population of the country. The project entails building a series of canals and a pumping station to carry water from Lake Nasser to irrigate portions of the Western Desert of Egypt. It is expected that the recovered land will become home to over three million residents by 2020. The New Valley will increase Egypt's arable land area by *ten* percent.

Figure 1. Egypt map showing Toshka area, Sheikh Zayed canal and Lake Nasser.

Toshka Project consists of a system of canals carrying water from Lake Nasser to irrigate the sandy wastes of the Western Desert of Egypt, which is part of Sahara Desert. The canal inlet starts from a site lying eight km to the north of Toshka Bay (Khor) on Lake Nasser. The canal is meant to continue westwards until it reaches Darb el-Arbe'ien route, then northwards along Darb el-Arbe'ien to Baris Oasis, covering a distance of about 310 km. The Mubarak Pumping Station in Toshka was inaugurated in March 2005 with a discharge of 300m^3/sec. It pumps water from Lake Nasser to be transported by way of a canal through the valley, with the idea of transforming about 550,000 feddans of desert into agricultural land.

There is a very high evaporation rate in Toshka. As for the Toshka lakes that extend on a water surface area of about 1500 Km^2; they lost about 12.69 billion m^3 between years 2002 and 2006 and one of the five lakes completely dried out (this is an indication of how high the evaporation in this area is). This means that for each of those *four* years the estimated loss due to evaporation is about *three* billion m^3/year (El Bastawesy *et al.* 2007).

The actual project is meant to relocate millions of Egyptians from overcrowded cities to the New Valley area. So, this vast amount of people needs to be provided with a sufficient amount of water for drinking and irrigation.

This research is a part of a larger funded research project studying the effect of covering irrigation canals with solar panels.

2 METHODOLOGY

Different coverage scenarios are being studied. As previously mentioned, this is a part of a larger study on covering irrigation canal with solar panels meaning different spacing and hence different covered area strips are assumed and for each case of coverage the evaporation is calculated. The calculations are made for only one km length (960 m exactly) reach of the main Sheikh Zayed canal (total length is 50 km). The coverage pattern could then be repeated for the whole 50 km.

Kindly note that in this research paper covering the canal is taken as a pure action in itself; whereas the material and structure system of the covering will be decided as a step of the larger funded research that was mentioned before.

3 EQUATIONS

The evaporation calculation method for this research is the Penman-Monteith equation, Eq. (1) (Monteith 1965):

$$E = \frac{1}{\lambda} * (\frac{\Delta w*(Rn-G)+\gamma*f(u)*(ew-ea)}{\Delta w+\gamma} \quad (1)$$

Where E is the open water evaporation (mm/day), λ is the latent heat of vaporization (MJ/kg), Δ_w is the slope of the temperature saturation water vapor curve (kPa/ºC), R_n is the net radiation (MJ m-2day-1), G is the change in heat storage in the water body (MJ/m^2/day), f(u) is the wind function (MJ/m^2/day/kPa), e_w is the saturated vapor pressure at water temperature (kPa), e_a is the vapor pressure at air temperature (kPa) and γ is the psychometric constant (kPa/ºC).

4 CALIBRATION

Calibration was done to the Penman-Monteith equation for Lake Nasser real reading of evaporation which is 6.35 mm/day (Elba *et al.* 2014), as shown in figure 2. All parameters of the equation are entered as those of Aswan weather station (where is very close to Lake Nasser).

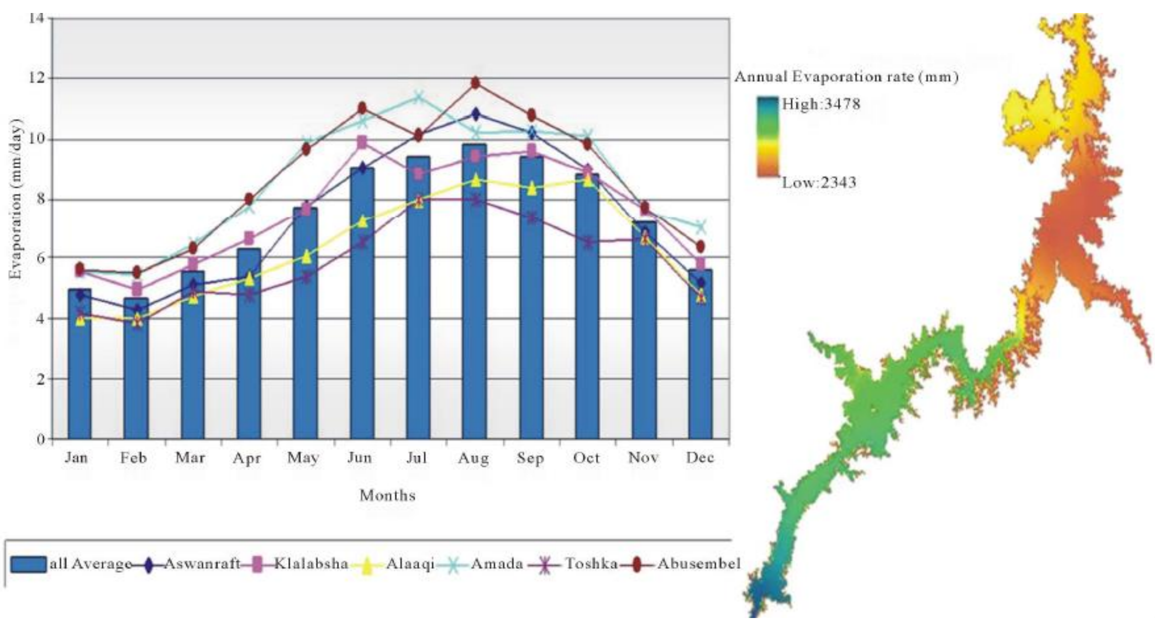

Figure 2. Mean monthly evaporation rate along Lake Nasser (Aswan), including Toshka in mm/day, 2014.

The calibration results are summarized in Table 1, the % error is value is acceptable. The small error could have originated from not very accurate real life readings either of the reference value or of the metrological data such as; water temperature, air temperature, etc. that were used in the Penman-Monteith equation to calculate the evaporation.

Table 1. The percentage error of the calculated average evaporation rate of Lake Nasser.

Calculation method	Avg. annual Evap. (mm/day)	Ref. value (mm/day)	Error %
Penman-Monteith	6.22	6.35	2

5 RESULTS

5.1 Case Study: New Valley Project, Toshka

The case study is taken to be the New Valley project in Toshka in Upper Egypt governorate. This is because this is a very arid area with high evaporation rates as mentioned before. The Sheikh Zayed canal, which will be irrigating the project is about 300 km long containing all structures (culverts, entrance structures…etc). The canal consists of a main part with the dimensions shown in Table 2. There are two sub-branches coming out of this main canal but those are not accounted for in this study.

Table 2. The main Sheikh Zayed canal dimensions.

Parameter	With freeboard	Without freeboard (wetted area)
Length	50 km	50 km
Top width	58 m	54 m
Bottom width	30 m	30 m
Depth	7 m	6 m
Side Slopes	2:1	2:1

5.2 Simulation Results

Table 3. The evaporation rates and volumes for the main canal for different covering spacing.

Spacing length (m)	uncovered area (m^2)	covered area (m^2)	Avg. Evap. rate (mm/day)	Annual Evap. rate (mm/yr)	Evaporation Volume (m3/yr)
960	51840	0	8.77	3202.68	166026.9
48.84	50112	1728	8.78	3205.02	160610.1
22.97	48384	3456	8.79	3207.45	155189.2
14.64	46656	5184	8.79	3209.97	149764.2
10.53	44928	6912	8.8	3212.58	144334.9
8.08	43200	8640	8.81	3215.31	138901.2
4.83	38880	12960	8.83	3222.64	125296.2
3.22	34560	17280	8.85	3230.87	111658.8
2.25	30240	21600	8.88	3240.24	97984.8
1.61	25920	25920	8.91	3251.11	84268.8
1.15	21600	30240	8.94	3264.05	70503.4
0.8	17280	34560	8.99	3279.99	56678.2
0.53	12960	38880	9.04	3300.74	42777.6
0.32	8640	43200	9.12	3330.34	28774.2
0.15	4320	47520	9.27	3381.98	14610.2
0	0	51840	0	0	0

Table 4. Percentage of covered area vs. percentage annual evaporation volume for one km length of Sheikh Zayed main canal for different covering spacing.

Spacing length (m)	% Area Covered	% Annual Evaporation Volume
960	0	100
48.84	3.33	96.74
22.97	6.67	93.47
14.64	10.00	90.20
10.53	13.33	86.93
8.08	16.67	83.66
4.83	25.00	75.47
3.22	33.33	67.25
2.25	41.67	59.02
1.61	50.00	50.76
1.15	58.33	42.47
0.8	66.67	34.14
0.53	75.00	25.77
0.32	83.33	17.33
0.15	91.67	8.80
0	100	0

Mathematical modeling was done to simulate the evaporation rates and volume that would be generated from the canal with varying the coverage area of the canal. An Excel spreadsheet was created to make the simulation. Sample evaporation calculation for *one* kilometer length of the main canal of Sheikh Zayed, the calculations summary is shown in Tables 3, 4 and Figure 3.

It is worth to mention that the calculated total evaporation for the whole uncovered 50 km main reach of the canal is about 9 million cubic meters per year, as shown in table 5.

Table 5. Total annual evaporation volume of the total length of the main canal.

Total Length of the main canal	50	km
Surface Area	2.7	km^2
Total evaporation Volume	8.65E+06	m3/year

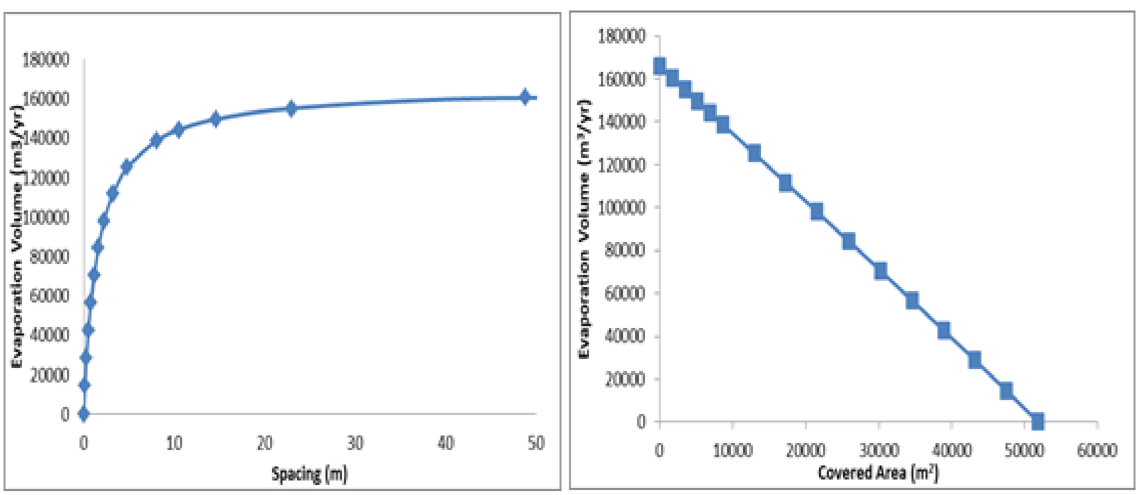

Figure 3. The total evaporation volume vs. different spacing and covered area for the 1 km reach of the main canal.

Because the New Valley project is a project concerned mainly with cultivation and because one of the main crops Egypt cultivates is wheat, the feddans of wheat that could be irrigated with the evaporation amount of water yielded if the total main canal is totally covered are calculated.

Here drip irrigation for the wheat is assumed; this is so because Toshka is a desert area so water is scarce there. As the water requirements for wheat under drip irrigation are 247 cubic meters per cultivation season, once a year (Gamal et al. 2016). The 33,700 feddan of wheat (see Table 6) are equivalent to about 6.5% of the whole 550,000 feddan that are planned to be cultivated in the New Valley project in Toshka.

Table 6. The cultivated area of wheat using the evaporated water of main reach of Sheikh Zayed canal.

Total Evaporation volume (totally uncovered)	8.65E+06	m3/year
# of acre cultivated of wheat	3.50E+04	acre/year
# of feddans cultivated of wheat	3.37E+04	Feddan/year

6 CONCLUSIONS

To summarize, the aim of this research is to study the effect of covering irrigation canals on evaporation rates. The Sheikh Zayed canal in Toshka at Upper Egypt governorate is taken as a case study because Toshka is a very arid area with very high evaporation rates. Also, a new agricultural project is established in this area that would cultivate more than 550,000 feddans that will need lots of water. So, finding ways to preserve water will be of great importance to this project and to all of Egypt as well.

From the evaporation calculation it was found that covering more area of the canal will lessen the evaporation volume. Many possibilities of covering are studied as fully covering will negatively affect the water –as being studied in coming stages of this funded research-.

It was also found that the evaporation volume, which the main canal yields is about 9 million m^3/year which could provide the needed water to cultivate 6.5% of the 550000 feddans by wheat.

To conclude, the evaporation has to be greatly taken into consideration when proceeding with the New Valley project to be able to preserve water that could be otherwise lost.

Acknowledgments

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