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ASSESSMENT OF THE DRAINAGE WATER REUSE IN THE IRRIGATION IMPROVEMENT AREAS, KAFR EL SHEIKH GOVERNORATE OF EGYPT

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ABSTRACT

During the period between March 1998 to July 1999, a study has been carried out to investigate the possibility to reuse the drainage water within the Irrigation Improvement Project (IIP) areas at El-Wasat and El-Manaifa in Kafr El Sheikh Governorate (DRI, 2000). A monitoring program on branch drains and irrigation canals was established and routinely implemented for the water quantity and quality. The program comprised five locations at El-Manaifa area and three at El-Wasat area. A simulation desk study was also conducted to predict the impacts of the reuse of drainage water within the IIP areas on the soil salinity and crop production. The study succeeded in answering where and, if possible, how much drainage water can be reused. The water supply-demand at each proposed mixing location was identified to calculate the water deficit spatially and temporally. The compensation of drainage water was determined using the salinity parameter as a guiding factor. According to FAO guidelines for drainage water reuse for agricultural uses, the TDS, Cl and Na concentrations in the drainage water could have slight to moderate salinity and toxicity problems. At any rate, the concentration of common metals in drainage and irrigation water does not reach the value that could cause problems to soil and plant. The bacteria count level for most of the sites comply with quality criteria to irrigate the restricted crops according to WHO guidelines (1989).

The SIWARE model was used for the simulation study using the data for year 1998. The relative evapotranspiration rate was used as an indicator of crop yield. The simulated strategies were concentrated on the increase of the irrigation water salinity in steps after implementing the mixing plans. The effects of an increase of irrigation water salinity have been examined for El-Wasat and El-Manaifa areas. SIWARE model simulations have shown that:

- Evapotranspiration and the crop yield are impeded by salts as indicated by the average simulated soil salinity;
- The maximum reduction in relative evapotranspiration is not higher than 12.5%;
- The maximum increase of the soil salinity is 139% (3800 ppm) whereas the maximum increase of irrigation water salinity is 316% (1040 ppm).

It is recommended to implement such a strategy, while starting the Irrigation Improvement Programme (IIP) for El-Wasat and El-Manaifa areas. Meanwhile, the national plan for the treatment of domestic wastewater should have a priority. This intervention of wastewater treatment would allow for the cultivation of different types of unrestricted crops. In all cases, an economical analysis would determine the optimum alternative.

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1. INTRODUCTION

Preliminary studies indicated that there is a water supply shortage for both IIP project areas of El-Wasat (75,000 feddan) and El-Manaifa (47,000 feddan) in Kafr El-Sheikh Governorate. It is proposed to substitute shortage in fresh water supply from the available drainage water within the project areas, which could be mixed with canal fresh water at proper locations. The mixture should be within pre-determined quality limits that takes into consideration the long-term effect on the soils and crops in both areas.

The study aimed at monitoring and defining the available drainage water resources and its quality in both project areas. The negative impacts on agriculture due to drainage water reuse have to be kept minimum.

As the available quantities and qualities of the drainage water are subject to changes in the future, an integrated reuse plan that includes the recommended mixing locations were identified. The use of simulation model helped in predicting these future changes.

The study objectives were as follows:

- Identifying the appropriate mixing locations to substitute the shortage in fresh water supply. The mixed water should meet the sustainability requirements of the agricultural production in the project area.
- Estimating the monthly abstraction from the drains and lifting head at each mixing location.

To achieve the goal of the study, the following activities have been carried out:

- Identifying sources of water supply to the study areas.
- Determining water demands for each of the study areas which include irrigation, municipal and industrial water.
- Designing and setting-up of a monitoring network locations.
- Field monitoring and data analysis.
- Simulation study.

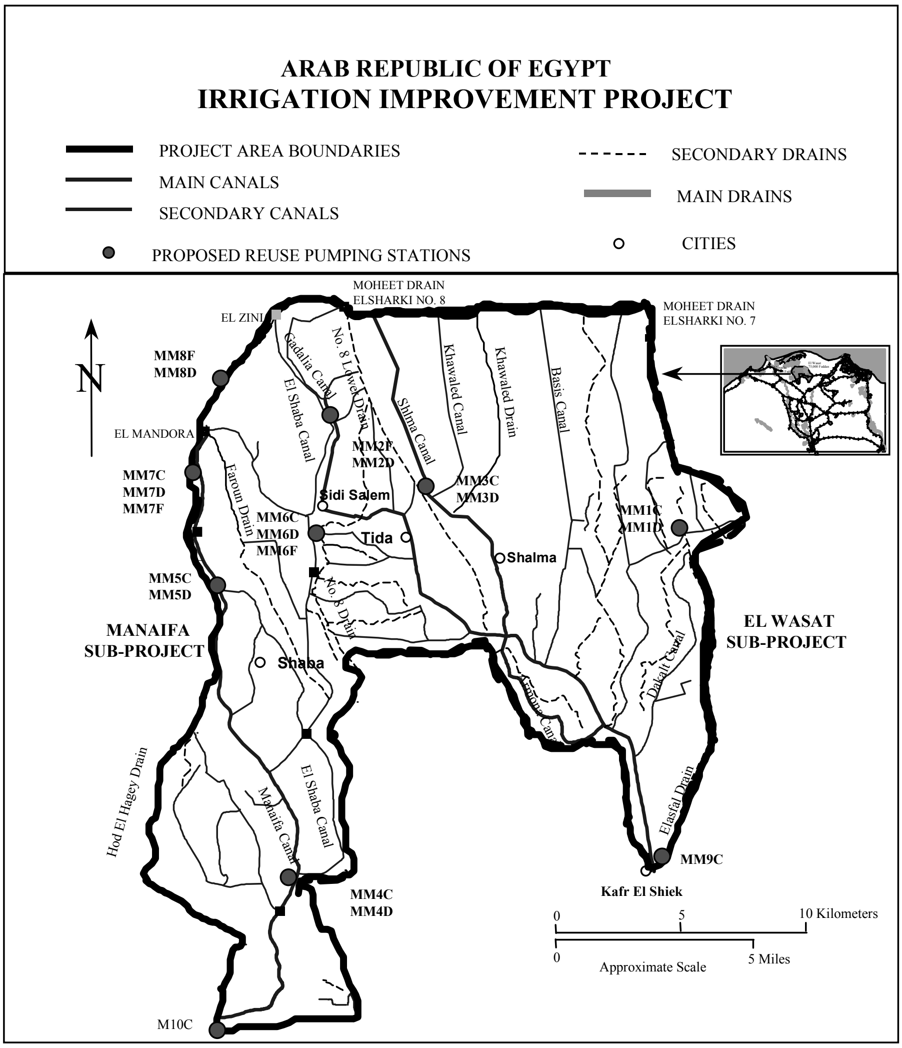
2. WATER QUANTITY AND QUALITY MONITORING

2.1 Proposed Mixing Locations

The suitability of a mixing location to blend fresh and drainage water is usually assessed according to the following criteria:

- Minimum distance between the drain and canal where mixing is to take place,
- Smallest possible lifting head for the pump station to be constructed to lift drainage water to the canal,
- Quantity and quality of the drainage water are enough and suitable to satisfy the shortage in canal water. After mixing, the canal water quality should be within the permissible standards to protect soils, crop yield and the environment,
- Mixing location should be downstream of the current and future drinking water intakes,
- Mixing location should also be upstream the outfall of point source pollution such as wastewater treatment plant or factory outlets,

According to these criteria and in co-ordination with local IIP staff at Kafr El-Sheikh, locations in El-Wasat and El-Manaifa areas were proposed as mixing sites, Figure



(1).

2.2 Monitoring Program

Actual field monitoring started early July, 1998 at the proposed mixing locations to assess the drainage and irrigation water quantity and quality and to determine the suitability of these locations for final selection of mixing sites and ratios. The correlation between the water level and flow discharge was obtained. Q-H relationship is considered acceptable when the correlation coefficient (R) is $>= 0.50$ to give a chance for more installed instruments to continuously measure the flow. Based on the findings of these measurements, significant Q-H relations were achieved at some measurement points.

The final monitoring locations proposed for mixing and water quantity measurement methods in El-Wasat and El-Manaifa areas are shown in Table (1). Where appropriate, Q-H relationships are also presented in the table. The land levelling is also determined, following the survey analysis, to obtain the lifting head for each location.

Table (1) Final monitoring locations proposed for mixing and water quantity measurement methods in El-Wasat and Manaifa Areas.

Name of the Canal or Drain	Site Code	Area served (fed.)	Lifting head	No of Measurements	R	Relationship
El-Wasat Area						
El Melaha Canal	MM1C	5800	3 m	6	0.93	Q = -2.9723Hm + 8.2901**
Lower Drain No. 7	MM1D			11	0.79	Q = -7.3416Hm + 38.473**
Shalma	MM3C	1100	4 m	6	0.83	Q = -8.0306Hm + 33.227**
Lower Drain No. 8	MM3D			11	0.88	Q = -0.4585Hm + 3.9143
Gad Allah	MM2F	5200	3 m	7	0.63	Q = -0.3365Hm + 2.4282*
Nashert Drain	MM2D			10	0.60	Q = -11.302Hm + 51.281**
Meet Yazied (El-Wasat regulator)	MM9C			4		Q = 27.493Hm - 64.208**
El-Manaifa Area						
El-Manaifa	MM4C	17000	6 m	11	0.46	
Upper Drain No. 9	MM4D			11	0.91	Q = -4.0718Hm + 21.387**
Abto	MM5C	1500	4 m	6	0.72	Q = -1.581Hm + 5.2897**
Drain No. 9	MM5D			9	0.19	
El Shiekh Ibrahim	MM6C	10500	3 m	11	0.22	
El Shiekh Ibrahim Feeder	MM6F			4	0.98	Q = -3.406Hm + 11.535**
Baher Nashert Drain	MM6D			9	0.92	Q = -19.695Hm + 47.097**
El-Mostagada Company	MM7C	250	3 m	9	0.30	
El-Mostagada Company Feeder	MM7F			4	0.99	Q = -1.2171Hm + 1.0743*
Drain No. 9	MM7D			6	0.40	
El-Gammalia	MM8F	450	3 m	6	0.45	
Drain No. 9	MM8D			8	0.80	Q = -0.8547Hm + 9.1717
El-Manaifa Intake	M10C			6		Q = -0.8547Hm + 9.1717

R: Correlation Coefficient
* Significant relationship
** Highly significant relationship
Hm: Water surface depth from the reference point in m
Q: Water Quantity in m^3

2.3 Monitored Parameters, Measurement Methods and Frequency

The ultimate goal of the proposed monitoring network is to obtain knowledge about the accurate values of the quantity and quality of irrigation and drainage water at the proposed locations in the study area.

The data processing has started with field sheets and laboratory measurements and ended with the analysis tabulation that include all relevant details of chemical and hydrological data at each proposed mixing location presented on monthly basis. A number of steps were made to check the consistency of raw and processed data. In addition, graphs showing some important indicators were drawn.

Table (2) presents the monitored parameters, measurement methods and frequency. For the sites with significant Q-H relationship, water quantities were estimated from water level data. For the other sites velocity measurements with the current meters were taken. Water salinity measurements were carried out during the process of measuring water quantity. Additionally, water samples were collected for laboratory analysis to determine the water quality parameters, which are:

- Chemical analysis to determine main ions, TDS, SAR and Adj SAR.
- Boron, nitrogen, and phosphorus
- BOD, COD, turbidity, grease, oil, total suspended solids and total volatile solids
- Bacteria
- Heavy metals (Cu, Fe, Zn, Pb)

Table (2) Monitored parameters, measurement methods and frequencies

Parameter	Measurement Method	Frequency
Water Quantity	Q-H (Water Level Recorder)	Hourly (daily average)
	Q-H (Staff Gauge)	Twice a day (daily average)
	Velocity (Current Meter)	Every other week
Water Salinity	Portable EC meter	Every other week
Chemical Parameters	Sampling and in Situ	Every other week
Biological Parameters and Heavy Metals	Sampling	Monthly

The samples were analysed at the DRI laboratory according to the established and well-known Standard Operating Procedures.

2.4 Assessment of the Water Quality Parameters

The following can be generally noticed from the in-situ measurements and laboratory analysis over the study period.

Seasonal variation in the water quality is observed. It is noticed that the highest concentrations of the variable parameters occurred in winter and the lowest occurred mainly in summer. This is usually happened because all the head regulators of the irrigation canals are closed in alternative duration in winter for maintenance. Therefore the pollutants concentration increased in the wintertime. On the other hand, water discharge increases in the summer time due to high water requirement of the summer crops. These amounts of water increase the dilution rate of the pollutants.

Summary of water quality variables is included in Table (3).

3. SIMULATION STUDY

The SIWARE (**S**imulation of **I**rrigation **W**ater management in the **A**rab **R**epublic of **E**gypt) is a well-known model that was developed under the cooperation between the governments of Egypt and the Netherlands. The model has been successfully applied in Egypt as well as in Argentina, Pakistan and India after some modifications (Abdel-Gawad, S.T. et al., 1991), (Sijtsma, B.R. et al., 1995).

3.1 Model Application in Wasat and Manaifa Areas

SIWARE is a regional scale model that cannot be run exclusively for El-Wasat and El-Manaifa areas in isolation of the rest of the Middle Delta region. Therefore, those two study areas were represented by a number of calculation units within model application over the Middle Delta region, using the parameters obtained from the calibration and validation of a previous study.

The Middle Delta is about 1.576 million feddans of cultivated land, and the supplied Nile irrigation water is about 10.797 BCM/year. Year 1998 was selected to prepare the simulation-input data.

Table (3) Summary of the main water quality parameters at El-Wasat & El-Manaifa areas (1998 / 1999)

Location	Site Code	BOD mg/l			COD mg/l			NH4 mg/l			DO mg/l		
		stand ≤ 10			stand ≤ 15			Stand ≤ 45			stand ≥ 5		
El- Wasat area													
		Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
El- Melaha Canal	MM1C	19.80	114.50	57.53	30.00	173.00	83.29	0.39	0.67	0.52	5.16	7.30	6.19
Lower Drain No.7	MM1D	31.60	159.00	77.87	43.40	268.00	113.32	0.53	1.05	0.77	929.09	1621.00	1339.13
Shalma Canal	MM3C	16.00	97.20	46.20	49.61	113.00	74.24	0.51	0.97	0.72	5.22	8.20	6.56
Lower Drain No.8	MM3D	24.30	119.40	65.81	67.00	246.00	125.04	0.65	1.44	0.95	3.25	6.90	5.23
Gad Allah canal	MM2F	27.30	100.00	84.63	42.00	158.00	129.59	0.37	0.99	1.07	2.00	5.13	3.87
Nashart Drain	MM2D	43.80	159.00	91.05	70.00	249.00	155.91	0.69	1.61	0.91	1.27	4.72	3.01
El- Manaifa Area													
El-Manaifa Canal	MM4C	13.80	178.80	75.79	24.80	248.00	111.74	0.30	0.95	0.68	4.6	9.12	6.27
Upper Drain No.9	MM4D	36.30	203.60	104.10	71.80	368.00	159.74	0.60	3.73	1.56	1.98	5.7	3.28
Abto canal	MM5C	16.80	148.10	71.01	37.00	237.00	110.38	0.33	0.81	1.10	5.15	7.73	6.29
Drain No.9	MM5D	46.80	193.00	106.04	81.00	275.00	159.09	0.56	1.37	0.71	2.28	5.10	3.33
El-Shiekh Ibrahim canal	MM6C	24.00	134.00	84.98	53.00	264.67	134.00	0.24	0.98	0.87	2.84	7.10	5.35
Nashart Drain	MM6D	56.00	217.00	103.83	90.60	432.45	148.93	0.55	1.54	0.84	1.80	5.63	3.45
El Mostagada canal	MM7C	46.00	101.40	63.35	45.60	183.20	98.29	0.28	0.96	0.60	3.13	5.30	4.01
Drain No.9	MM7D	86.60	140.40	95.18	101.10	232.00	145.49	0.58	1.56	1.33	1.92	4.60	3.28
El-Gammalia canal	MM8F	25.80	93.90	50.41	34.00	157.70	91.30	0.22	0.98	0.66	2.60	5.71	3.77
Drain No.9	MM8D	32.80	149.10	71.53	53.00	218.00	119.79	0.41	1.91	1.03	2.11	5.20	3.12

The Middle Delta region is characterized by arid climatic conditions. Low average annual rainfall varies from 180 mm/year along the Mediterranean to 25 mm/year at Cairo. High average daytime temperatures vary from 20 to 40 ^oC. Evaporation rates are accordingly high and reach values of 3,500 mm/year.

The study region was subdivided into 116 calculation units. The size of the calculation units varied from a 3,500 feddans, up to a 38,000 feddans. The areas of interest in this study; namely El-Wasat and El-Manaifa area were represented by six and three calculation units, respectively. Figure (2) shows the boundaries of the calculation units of the study region of the Middle Delta as input to SIWARE, including the calculation units that comprise El-Wasat and El-Manaifa areas. The values of parameters for the initial condition input to the model were prepared using the model itself. The model was run for that region for a number of years, and the output of each year was used to prepare the initial conditions of the next year.

To account for the reuse of drainage water to supplement the shortage in irrigation water, a number of model simulations were made using more saline irrigation water in the reuse areas. This is expected to represent the actual situation of mixing saline drainage water with fresh irrigation water in the reuse areas.

3.2 Input Data Processing

3.2.1 Crop pattern

As mentioned above, crop pattern within each calculation unit is simplified to average representative areas for each crop. This is done by summing all the areas cultivated with the same crop within the calculation unit. Moreover, only 11 crops have been considered in the model input. Minor crops that occupy small areas were added to the most similar one of the considered 11-crops. Crop pattern within each field agricultural district (called ‘Markaz’) was used to prepare the crop pattern for the corresponding ‘calculation unit’ in the model input. Table (4) shows the percentage of each area occupied by a major crop to the total cultivated area in the Middle Delta during the year 1998.

Table (4) Cropping pattern and its relative area occupied by crops in the Middle Nile Delta (1998)

Crop Name	Area (feddan)	Percentage (%)
Long Berseem	5,354,60	17.42
Wheat	541,340	17.61
Winter Vegetables	32,859	1.07
Rice	454,120	14.77
Cotton	309,690	10.07
Maize	541,166	17.60
Summer vegetables	85,374	2.78
Perennials (trees)	101,314	3.30
Sugar beet	466,89.2	3.02
Short berseem	312,166	10.15
Nili vegetables	40,075	1.30
Winter fallow	37,116	1.21
Summer fallow	67,865	2.21

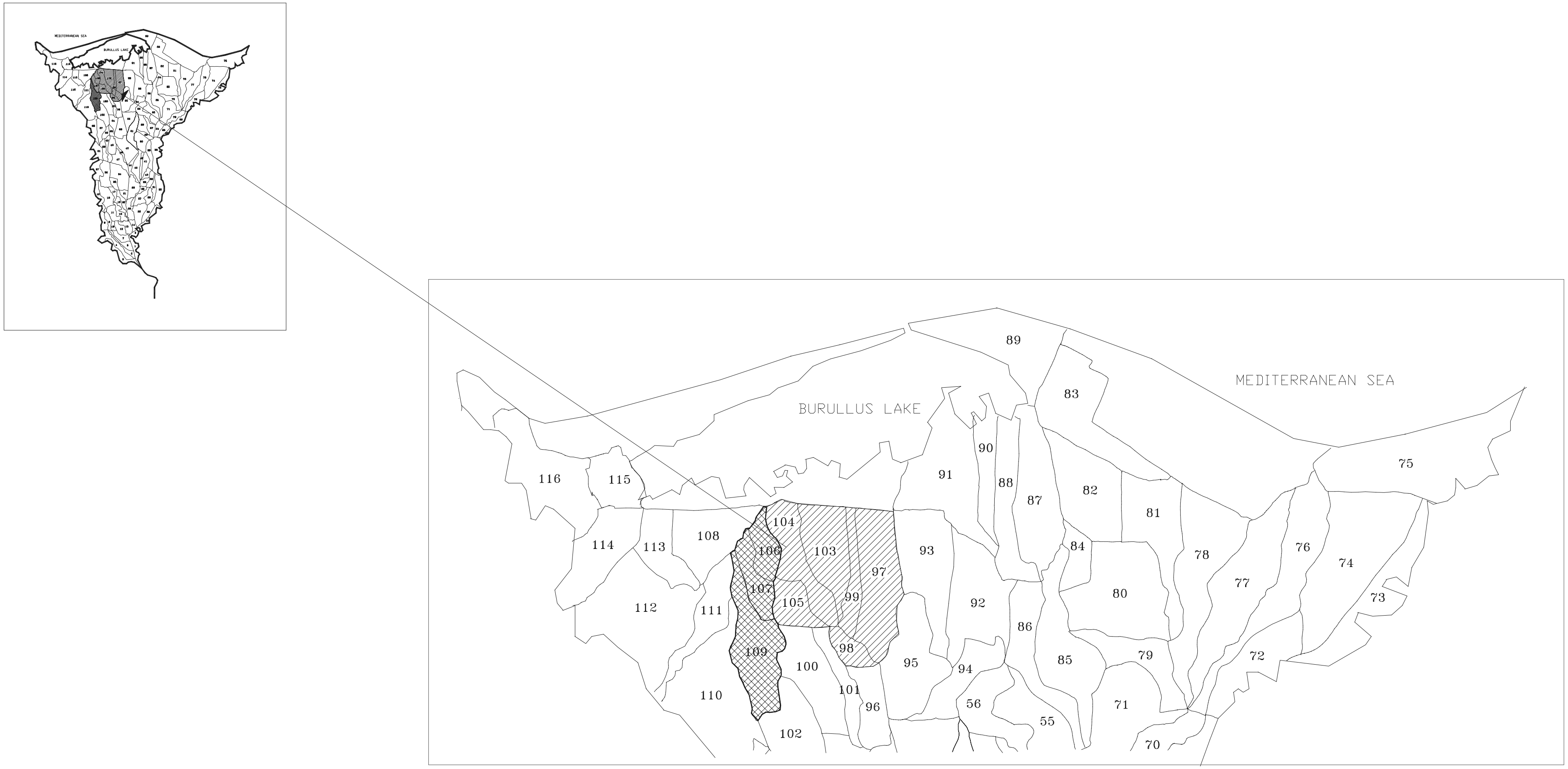


Figure (2) The boundaries of the study area as defined in the SIWARE model schematization

3.2.2 Crop water requirement

Crop water requirement is affected by the crop growth stage as a funct ion of time, and by the climatic conditions. Conveyance and operational losses of irrigation water depend on crop type, and they are included in the crop water requirement. Crop water requirement per unit area as a function of time has been calculated and tabulated for three zones in Egypt: Upper Egypt, Middle Egypt and Lower Egypt. These tables were prepared using field experiments and past experience. The entire Nile Delta, including the study areas of the Middle Delta, is located in the Lower Egypt zone. It is important to note that the actual water quantities supplied to the fields by the farmers may differ from the tabulated crop water requirement. The MWRI water requirement tables were used in preparing the crop pattern input to the model, as well as in calculating the crop water requirement.

3.3 Results of the simulation scenarios

One of the main objectives for the analysis of the tested strategies is to determine the impacts of reusable drainage water for irrigation on the crop yield and soil salinity. The simulated strategies were concentrated on the increase of the irrigation water salinity after implementing the mixing plans. The salinity of irrigation water was increased in steps started from average value ~ 290 till ~1040 ppm for both areas. In addition, the analysis of the required mixing amounts of drainage water to compensate the shortage of fresh water, after monitoring the irrigation and drainage water, within the study area has shown the salinity level up to ~1000 ppm. Figure (3) shows the relation between the increase of irrigation water salinity and corresponding changes of the soil salinity and relative evapotranspiration for El-Manaifa area.

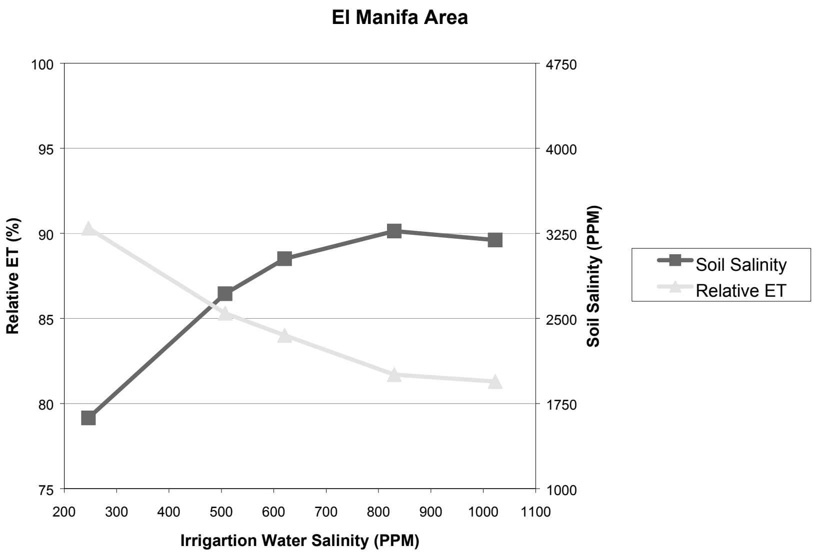


Figure (3) Impacts of irrigation water salinity increase on the soil salinity and relative evapotranspiration for El-Manifa area

The percent of increase of the irrigation water salinity and its effects on the percentage of decrease of the soil salinity and the relative evapotranspiration are summarised in table (5) for both areas.

Table (5) The percentage of soil salinity increase and relative E_t reduction due to the increase of irrigation water salinity within the study area.

	Percent of increase and decrease							
	El Wasat				El Manaifa			
Irrigation Water Salinity	87%	118%	174%	224%	106 %	152 %	237 %	316 %
Relative Et	-7%	-10%	-12%	-12.5%	-5 .5 %	-7%	-9%	-10%
Soil Salinity	102%	124%	139%	131%	68%	87%	102 %	97%

4. WATER DEFICIT

The amounts of discharged irrigation water at the inlets of the study areas are summarised in table (6). The total amount of irrigation water to El-Wasat and El-Manaifa areas are 632 and 322 million cubic meters/year respectively. The salinity level is around 0.40 mS/cm for El-Wasat area and 0.39 mS/cm for El-Manaifa area. The increase of the salinity level could be described by the reuse of the drainage water practices upstream of the study areas. Based on the quantity of the irrigation water delivered to the areas and the cultivated area served, it can be concluded that the water duties are around 8000 and 7200 m^3/fed for El-Wasat and El-Manaifa areas respectively.

Table (6) Water delivery, El-Wasat and El-Manaifa areas (in million cubic meters)

Month	El Wasat (million m^3)	EC (mS/cm)	El Manaifa (million m^3)	EC (mS/cm)
Jul-98	69.10	0.40	37.12	
Aug-98	68.59	0.37	35.29	
Sep-98	51.53	0.38	29.69	0.34
Oct-98	49.02	0.39	20.99	0.36
Nov-98	48.89	0.39	22.58	0.33
Dec-98	32.03	0.41	19.59	0.42
Jan-99	36.60	0.40	19.20	0.45
Feb-99	38.79	0.40	18.83	0.39
Mar-99	47.67	0.48	26.57	0.38
Apr-99	50.74	0.41	27.04	0.41
May-99	67.88	0.43	30.34	0.43
June-99	71.33	0.41	34.53	0.40

Table (7) summarises the deficit amounts and the calculated salinity levels after blending the required amounts of drainage water to replenish the shortage amounts of irrigation water. The data used through this analysis is the calculated crop water duty for each proposed mixing location and the measured quantity of the irrigation and drainage water. The table covered a period between July 1998 to June 1999.

The following are some remarks of the operation of the monitored mixing locations:

- Some of the irrigation locations do not receive fresh water all the time. Due to lack of fresh water, these canals are supplied with drainage water directly because of the scattered feeders along the reach for each canal.

Table (7) Water deficit during the monitoring period at each mixing location and the calculated salinity after mixing with drainage water

El-Wasat area

Month	MM1C MM1D		MM2C MM2D		MM3C MM3D	
	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM
Jul. 98			0.17	1715		
Aug. 98			0.26	1497		
Sep. 98			0.65	819		
Oct. 98			0.68	908		
Nov. 98			0.57	832		
Dec. 98			1.00	819		
Jan. 99	2.43	568	1.51	908		
Feb. 99	5.60	882	1.59	1030		
Mar. 99	4.83	1175	1.46	1056	2.06	568
Apr. 99	0.93	635	0.64	940		
May 99			0.17	1049		
Jun. 99	0.54	599	0.33	921		
	14.33		9.03		2.06	

El-Manaifa area

Month	MM6C MM6D		MM4C MM4D		MM5C MM5D		MM7C MM7D		MM8C MM8D	
	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM	Q_F m^3/month $x10^6$	$EC_{MIX.}$ PPM
Jul. 98							0.04	1715	0.07	1670
Aug. 98							0.06	1728	0.11	1728
Sep. 98	3.77	275	6.83	950			0.15	1100	0.27	1113
Oct. 98	3.13	649	1.03	341			0.15	1331	0.28	1331
Nov. 98	0.91	385					0.13	832	0.23	832
Dec. 98	5.80	692	1.90	324			0.23	806	0.41	812
Jan. 99	10.70	974	14.27	794			0.34	902	0.62	915
Feb. 99	8.99	691	18.80	866			0.36	1331	0.65	1024
Mar. 99	9.21	812	17.20	783	0.07	305	0.33	1094	0.60	1203
Apr. 99	3.19	926	5.02	607			0.15	1548	0.26	1606
May 99							0.04	1568	0.07	1561
Jun. 99			1.93	605			0.08	1158	0.24	928
	45.71		66.98		0.07		2.05		3.81	

Q_c Fresh water canal discharge.
EC_{ic} Salinity of fresh canal irrigation water .
SL_c Salt load in fresh canal water .
Q_d Discharge of drain.
EC_d Salinity of drainage water .
SL_d Salt load in drainage water .
Q_R Required discharge of area served (calculated)
Q_F Water Quantity Deficit
$EC_{MIX.}$ Salinity of mixing water

- Several feeders are already existing within the boundaries of the areas and deliver drainage water to satisfy the shortage of irrigation water. The irrigation districts operate these feeders officially. However, these feeders are not operated continually since they depend on the level of the water at the drains.
- El-Wasat regulator and El-Manaifa intake represent the water delivered to both areas. These locations are monitored for the check and balance purposes.

5. Conclusions and Recommendations

The previous analysis and discussion leads to the following main conclusions:

- All crops grown in the area suffer from the increase of the irrigation water salinity, although they already did so under the reference conditions;
- Evapotranspiration and the crop yield are also impeded by salts as indicated by the average simulated soil salinity;
- The maximum reduction in relative evapotranspiration is not higher than 12.5%;
- The maximum increase of the soil salinity is 139% whereas the maximum increase of irrigation water salinity is 316%.
- At any rate, the concentration of common metals in drainage and irrigation water does not reach the value that could cause problems to soil and plant.
- The BOD and COD concentrations in the monitored irrigation and drainage canals do not comply with the national standards.

The following are recommended based on the water quality assessment:

1. A detailed study should be implemented to identify the sources of pollution to the areas and to define the appropriate pollution control measures.
2. There is a need to design and implement an environmental management plan to insure safe drainage water reuse after operation of the proposed mixing locations.

6. REFERENCES

Abdel Gawad, S.T., Abdel Khalik, M.A., Boels, D., El Quosy, D.E., Roest, C.W.J., Rijtema, P.E., and M.F.R., Smit, 1991, Analysis of water management in the Eastern Nile Delta, Final Report, Reuse of Drainage Water Project, Report 30, DRI and WSC, Cairo, Egypt

DRI, 2000, Assessment of the drainage water reuse in El-wasat & El-Manaifa areas, Kafr El-Sheikh Governorate, Final Report, Irrigation Improvement Project, March 2000, Cairo, Egypt.

Sijtsma, B.R.; Boales D., VisserT.N.M, Roest C.W.J., Smit M.F.R., “Siware User’s Manual”, 1995, Wageningen, Netherlands.