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Water Management in Al-Kamaliya Irrigation Canal using GIS, CROPWAT and HEC-RAS

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Abstract: The goal of irrigation management is to use water in the most profitable way at sustainable production levels. Irrigation management is important, since, it helps determine future irrigation expectations. This study achieved to develop the management of Al-Kamaliya irrigation project in province of Kerbala in Iraq and improve its operation with the use of GIS, CROPWAT and HEC-RAS applications by developing a better scenario for irrigation and building a database for a good management of the project. The study showed that these programs could be used in building a good management of water irrigation canal.

Key words: GIS, HEC-RAS, irrigation, management, scenario, programs

INTRODUCTION

There are millions hectares of irrigated lands in the world of which most have poor irrigation efficiencies (Shahrokhnia and Javan, 2005). Under limited water resources, an efficient irrigation system must be attained. Irrigation is the artificial exploitation and distribution of water at project level aiming at application of water at field level to agricultural crops in dry areas or in periods of scarce rainfall to assure or improve crop production. The goal of irrigation management is to use water in the most profitable way at sustainable production levels. For production agriculture, this generally means supplementing precipitation with irrigation. In recent days, the management of water resources in Iraq have a great deal because the water sources decrease as the rapid increase in the water demands and the nature of climatic conditions in that region. Therefore, there is a need of water management if the water demand is less than available or the irrigation water requirement is greater than available and shortage of water is taking place. The Geographic Information System (GIS) was used in calculating areas to be irrigated, building database for the information required in irrigation management and analyzing it spatially. The program by FAO (CROPWAT 8.0) was used for estimating the water required for irrigation according to the crop pattern in the irrigated land while (HEC-RAS) for predicting scenarios to improve canal performance and water delivery quantities. Serede *et al*. (2015) conducted hydraulic analysis of irrigation canals using HEC-RAS Model in Mwea Irrigation Scheme, Kenya. The HEC-RAS Model was tested in terms of error estimation and used to determine canal capacity potential. Ghumman *et al.* (2004) evaluated hydraulic performance of an irrigation system in upper Swat canal irrigation system in NWFP Pakistan using the Simulation Model CanalMan. Maatooq and Kadhim (2016) analyzed the actual operation of Al-Ibrahim irrigation canal, South of Iraq and evaluated performance indicators using the program HEC-RAS. The study showed that simulation programs could be used in management of irrigation canals. It could be predict a better scenarios of flow in irrigation canals from simulation process.

Study area: Al-Kamaliya irrigation canal is located on the right side of the Euphrates River in the province of Karbala in Iraq. The project extends between latitudes N32°47’-32°72’ and longitudes E44°01’-44°14’. It is bordered to the North and East by Al-Musayyib town and Al-Hussainiya canal, to the South by Karbala main drain and to the West by desert region and Al-Razaza Lake. The area bounded by the above-mentioned boundaries amounts to about 5588 ha (22352 donums). Al-Kamaliya canal was excavated, since, 1980 and its lining with concrete. It start from Al-Hussainiya canal and it is about 17 km long from end of the branch canal BC1. Al-Kamaliya canal connected with BC1, since, 2010 (Fig. 1 and 2).

Geometric data for the main canal (Al-Kamaliya) and distributaries: The longitudinal sections of the above canals were gathered from the Administrative of Irrigation in Kerbala city in Iraq including the bed level, bank top level, longitudinal bed slope, bed width and water level at different stations of the canals (Table 1 and 2).

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Fig. 1: The location of Al-Kamaliya canal in Kerbala city in Iraq

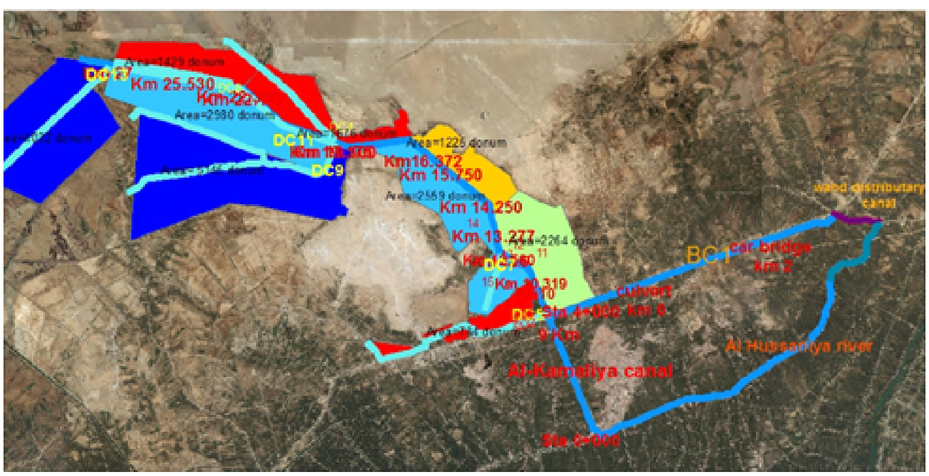


Fig. 2: Location of Al-Kamaliya canal

Table 1: (BC1) branch canal geometric data

Stations	Bed channel elevation (m)	Water surface elevation (m)	Water depth (m)	Bed width (m)	Design discharge (m^3/sec)	Bed longitudinal slope
0	28.7	31	2.3	3	11	0.0001
2	28.45	30.74	2.29	3	-	0.0001
7	27.97	30.15	2.18	3	-	0.0001
9	27.59	29.39	1.8	3	-	0.0001

Data used

Climatic parameters: The main climatic parameters that affect crop water desires include: air temperature, humidity, prevailing wind speed, Sun shine duration, free-water surface evaporation and rainfall. Data from Karbala weather station have been gathered for the main climatic parameters which include mean maximum monthly air temperature, mean minimum monthly air temperature,

Table 2: Al-Kamaliya canal geometric data

Station	Distributary canal	Minimum channel elevation (m)	Bank top level (m)	Bed width (m)	Bed longitudinal slope
4+000	-	28.05	30.55	3	0.0001
4+100	DC5	28.03	30.53	3	0.0001
5+300	Cross regulator 1	27.8	30.30	1	0.0001
6+400	DC7	27.6	30.05	3	0.0001
13+500	DC9	26.500	28.500	2.8	0.0001
13+600	DC11, DC4	26.480	28.700	1	0.0001
13+700	Cross regulator 2	26.46	28.600	2.8	0.0001
16+500	DC8	26	28.100	2.8	0.0001
22+550	DC13	25.3	27.300	2.8	0.0001

Table 3: Summary of climate parameters/Karbala station

Parameters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean. min. temp (°C)	5.3	7.6	11.6	17.4	22.8	26.8	29.1	28.5	24.5	19.3	11.8	6.9
Mean. max. temp (°C)	16.2	19.2	24.2	30.9	37.1	41.8	44.3	44.2	40.3	33.5	23.8	17.8
Humidity (%)	73	61	51	42	34	28	29	31	35	45	62	72
Wind (m/sec)	1.6	2	2.3	2.3	2.4	3	3	2.5	1.8	11.6	1.4	1.5
Sunshine (h)	6.2	7.2	7.9	8.5	9.2	11.2	11.4	11	10.1	8.2	7.1	6.2
Rain (mm)	16.9	14.5	17.1	12.3	3	0	0	0	0	4.4	14	15

mean average monthly air temperature, mean sun shine duration, wind speed, mean monthly evaporation, mean relative humidity and rainfall. A summary of these data are listed in Table 3.

MATERIALS AND METHODS

Estimating the water demand of the crops in Al-Kamaliya irrigation project: The reference Evapotranspiration (ET_o) was calculated by Penman-Monteith method, using decision support Software-CROPWAT 8.0 developed by FAO. The FAO CROPWAT program includes procedures for reference crop evapotranspiration and crop water requirements and allow the modeling of crop water use under various climate, crop and soil conditions (www.fao.org).

The Penman Monteith method of estimating is expressed in equation:

$$ET_o = \frac{0.408(R_n-G)+\gamma\frac{900}{T+273}U_2(e_s-e_a)}{\Delta+\gamma(1+0.34U_2)} \quad (1)$$

Where:

ET_o = Reference Evapotranspiration (mmday^{-1})
R_n = Net Radiation at the crop surface (MJ m^{-2}day^{-1})
G = Soil heat flux density (MJ m^{-2}day^{-1}
T = Mean daily air temperature at 2 m height (°C)
U_2 = Wind speed at 2 m height (msec^{-1})
e_s = Saturation vapour pressure (kPa)
e_a = Actual vapour pressure (kPa)
e_s-e_a = Saturation vapour pressure deficit (kPa)
Δ = Slope vapour pressure curve (kPa°C^{-1})
γ = Psychrometric constant (kPa°C^{-1})

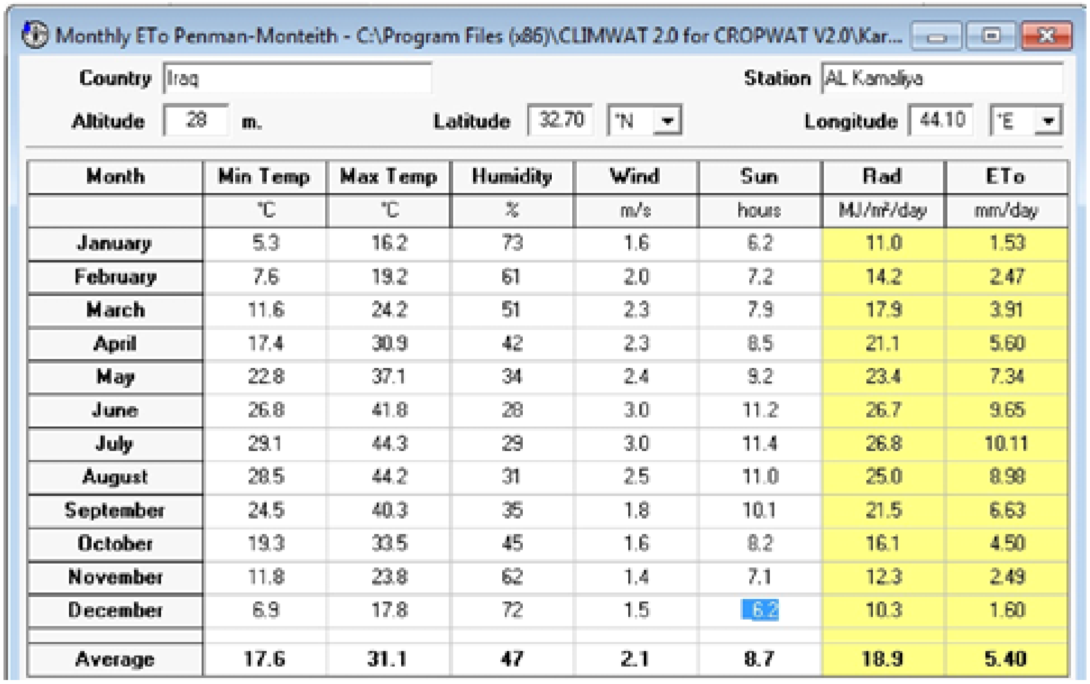
The empirical formula used for effective rainfall in determining the crop water requirement by CROPWAT while the crop coefficients (K_c) used for Al-Hussainiya District in Kerbala:

$$ET_c = k_c * ET_o \quad (2)$$

Figure 3 shows using of climatic data from Table 3 in program CROPWAT and the results of crop water requirements illustrated in Table 4 after multiplying ET_c by crop area.

Flow measurements at Al-Kamaliya main canal and its distributary canals: The flow applied to the canal Al-Kamaliya comes from the branch canal BC1 which take its flow from old and new Al-Hussainiya canal (Fig. 1). The water flow in Al-Kamaliya canal were measured in the Winter season from Dec.-May using the devices (ADCP) and the device (current meter). Table 5 and 6 and Fig. 4 show the difference between the required flow obtained by CROPWAT and available flow measured and estimated. As can be seen from Fig. 4, there was an adequate between the flow provided and required during the year. The flow need to be reduced at Nov-Feb and Aug-Oct while increased at months Mar-Jul in order to save a good amount of water. The estimated flow, Table 6, obtained by the program HEC-RAS based on the previous records of water levels at Al-Hussainiya canal and its effect on the water levels and discharges at the branch canal BC1 and Al-Kamaliya canal (Fig. 5).

GIS application in irrigation management: A georefrenced image of Al-Kamaliya irrigation project was obtained from the website: bing.com by the use of


Monthly ETo Penman-Monteith - C:\Program Files (x86)\CLIMWAT 2.0 for CROPWAT V2.0\Kar...

Country: Iraq   Station: AL Kamaliya

Altitude: 28 m.   Latitude: 32.70 °N   Longitude: 44.10 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/day
January	5.3	16.2	73	1.6	6.2	11.0	1.53
February	7.6	19.2	61	2.0	7.2	14.2	2.47
March	11.6	24.2	51	2.3	7.9	17.9	3.91
April	17.4	30.9	42	2.3	8.5	21.1	5.60
May	22.8	37.1	34	2.4	9.2	23.4	7.34
June	26.8	41.8	28	3.0	11.2	26.7	9.65
July	29.1	44.3	29	3.0	11.4	26.8	10.11
August	28.5	44.2	31	2.5	11.0	25.0	8.98
September	24.5	40.3	35	1.8	10.1	21.5	6.63
October	19.3	33.5	45	1.6	8.2	16.1	4.50
November	11.8	23.8	62	1.4	7.1	12.3	2.49
December	6.9	17.8	72	1.5	6.2	10.3	1.60
Average	17.6	31.1	47	2.1	8.7	18.9	5.40

Fig. 3: Inputting climatic data in CROPWAT

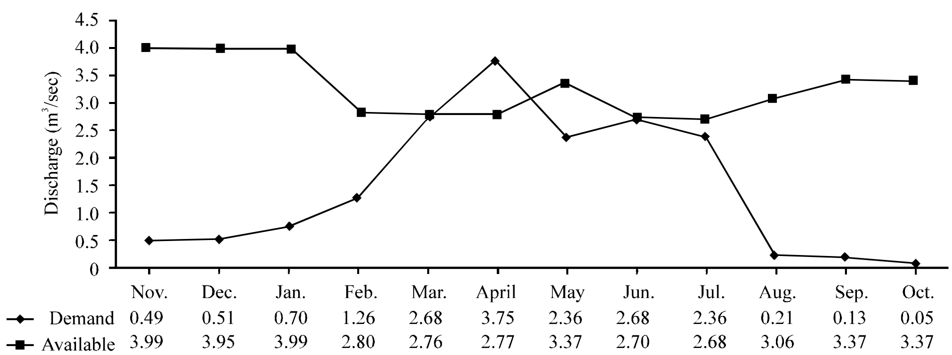


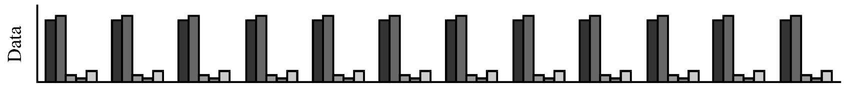
Fig. 4: Over year demand vs. available dischrges

Table 4: Total CWR (m^3/sec) for distributary canal area, using crop coefficient (K_c) for Al-Hussainiya District and empirical effective rainfall method

Dis.Month	DC5	DC7	Right 1	Right 2	DC4	DC9	DC8	DC11	DC13	Sum (m^3/sec)
Nov.	0.0535	0.0529	0.0392	0.0255	0.0059	0.1068	0.0294	0.0617	0.1401	0.5150
Dec.	0.0535	0.0549	0.0412	0.0265	0.0069	0.1117	0.0314	0.0647	0.1499	0.5407
Jan.	0.0726	0.0745	0.0559	0.0363	0.0088	0.1519	0.0421	0.0882	0.2087	0.7390
Feb.	0.1338	0.1343	0.1000	0.0657	0.0157	0.2734	0.0764	0.1588	0.3763	1.3344
Mar.	0.2878	0.2898	0.2349	0.0846	0.0333	0.5904	0.1098	0.3420	0.6516	2.6242
Apr.	0.3861	0.3906	0.3123	0.1287	0.0441	0.7956	0.2214	0.4608	0.9171	3.6567
May	0.2773	0.2790	0.2457	0.0234	0.0315	0.5670	0.1575	0.3285	0.4176	2.3275
Jun.	0.3299	0.3330	0.2934	0.0297	0.0378	0.6777	0.1881	0.3924	0.3771	2.6591
Jul.	0.2773	0.2790	0.2448	0.0270	0.0315	0.5688	0.1584	0.3294	0.4095	2.3257
Aug.	0.0312	0.0300	0.0220	0.0150	0.0030	0.0610	0.0170	0.0360	0.0140	0.2292
Sep.	0.0195	0.0200	0.0140	0.0090	0.0020	0.0400	0.0110	0.0230	0.0090	0.1475
Oct.	0.0078	0.0070	0.0050	0.0030	0.0010	0.0140	0.0040	0.0080	0.0020	0.0518
Sum	1.9450	1.6084	0.4744	0.2215	3.9583	1.0465	2.2935	3.6729	1.9450	17.1508

program SAS planet. ArcCatalogue was used to create the layers for the areas, Al-Kamaliya canal and the drains and adding them to the ArcMap.

ArcMap was used to draw the planted area, Al-Kamaliya canal and the drains and filling the attribute tables of the layers with its properties.



	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18
Bed level	27.59	27.59	27.59	27.59	27.59	27.59	27.59	27.59	27.59	27.59	27.59	27.59
Water level	29.52	29.53	29.51	29.41	29.42	29.40	29.39	29.39	29.39	29.43	29.43	29.43
Water depth	1.93	1.94	1.92	1.82	1.83	1.81	1.80	1.80	1.80	1.84	1.84	1.84
Velocity	0.38	0.38	0.38	0.30	0.30	0.30	0.29	0.30	0.32	0.33	0.35	0.35
Discharge	4.45	4.45	4.45	3.10	3.10	3.10	3.00	3.07	3.28	3.50	3.70	3.70

Fig. 5: Over year flow and water level relationship at Al-Kamaliya canal

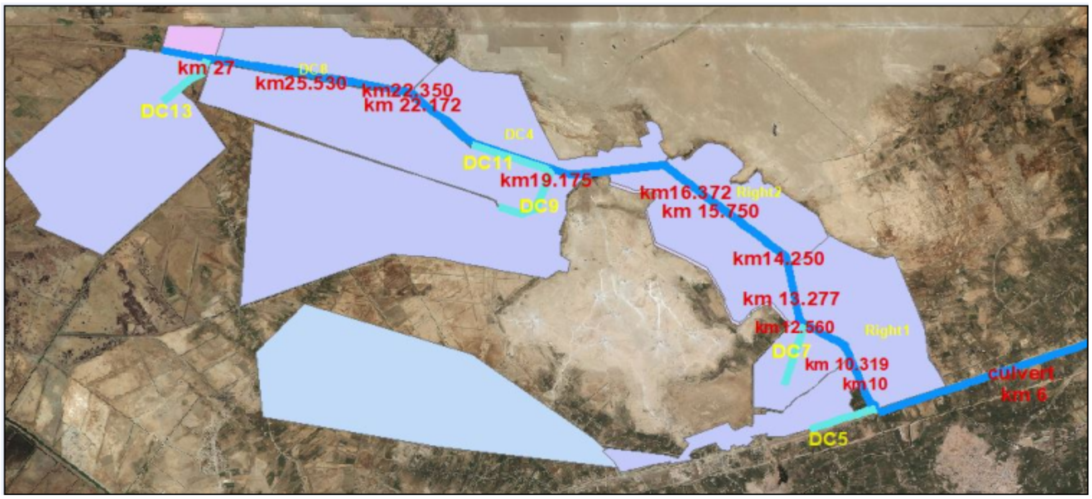


Fig. 6: The locations and distances of distributary canals

Table 5: Al-Kamaliya main canal flow data at upstream (Station 4+000)

Canal	Months	Discharge (m^3/sec)
Kamaliya	Dec.	3.00
Kamaliya	Jan.	3.07
Kamaliya	Feb.	3.28
Kamaliya	Mar.	3.50
Kamaliya	Apr.	3.70
Kamaliya	May	3.70

The areas of the lands around Al-Kamaliya canal were estimated by GIS as shown in Table 7.

Locating the locations and distances of distributary canals branching from Al-Kamaliya main canal (Fig. 6), since, it is not available in the longitudinal section of the canal. Querying the data by interactive selection of layers by ArcMap showing the required water to irrigate the areas around Al-Kamaliya canal (Fig. 7).

Using a simulation program (HEC-RAS): A simulation for the flow to be provided to the distributary canals done by using the software by US Army Crops of Engineering (HEC-RAS) to estimate the value of flow to be increased or decreased in order to obtain the required water level and flow to be provided to these distributary canals (DC9, DC11 and DC13). The simulated flow is at the upstream of the distributary canals, so for, estimating the flow at outlets a conveyance efficiency is assumed equal 94% because the canals are lined with concrete (Table 8).

In order to increase the water flow in far distributary canals DC9, DC11 and DC13. The following scenarios were considered.

Case 1: All outlets and cross regulators are open (normal case).

Case 2: Closing Cross Regulator 2 (CR2) at 0.1 m (to increase flow at DC9, DC11).

Case 3: Closing the outlet DC9, DC11 and DC4 (to increase flow at DC13).

Evaluation of canal performance: The Delivery Performance Ratio (DPR) indicator for the distributary canals is calculated to know if the flow provided is more or lower than required. The DPR is defined as the ratio of actual measured discharge to require or

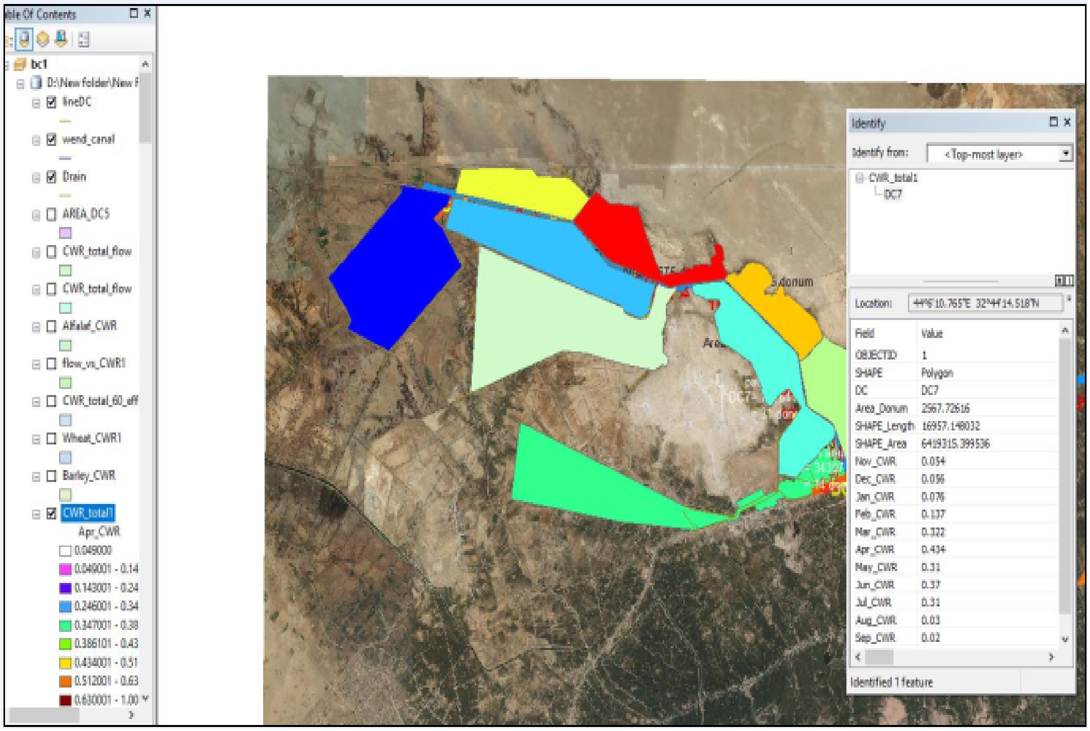


Fig. 7: Querying CWR by GIS

Table 6: Flow data of distributary canals, year (2017-2018)

			Over year discharges (m^3/sec)											
	Design		Estimated (2017)						Measured (2018)					
Outlet No.	discharge (m^3/sec)	Station	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
DC5	3.0	16+900	1.20	1.20	1.20	0.70	0.70	0.71	0.71	0.70	0.71	0.75	0.90	0.90
Right1	0.5	16+300	0.23	0.22	0.24	0.19	0.20	0.20	0.20	0.20	0.20	0.21	0.22	0.22
DC7	3.0	14+600	0.55	0.55	0.55	0.45	0.45	0.45	0.40	0.40	0.40	0.45	0.50	0.50
Right2	0.5	12+500	0.26	0.23	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.20	0.23	0.23
DC9	1.3	7+500	0.45	0.45	0.45	0.32	0.30	0.30	0.29	0.30	0.28	0.35	0.35	0.35
DC4	0.6	7+400	0.35	0.35	0.35	0.27	0.26	0.26	0.25	0.25	0.25	0.30	0.32	0.32
DC11	1.3	7+400	0.35	0.35	0.40	0.27	0.25	0.26	0.25	0.25	0.25	0.30	0.30	0.30
DC8	0.6	4+500	0.30	0.30	0.30	0.20	0.20	0.20	0.18	0.20	0.20	0.30	0.25	0.25
DC13	1.3	0+00	0.30	0.30	0.30	0.20	0.20	0.20	0.20	0.20	0.18	0.20	0.30	0.30
Sum	-	-	2.7	2.68	3.06	3.37	3.37	3.99	3.95	3.99	2.80	2.76	2.77	3.37

Table 7: Area of the lands around Al-kamaliya canal by GIS

Land	Area (donum)
DC5	5479
DC7	2559
Right 1	2264
Right 2	1225
DC4	1576
DC9	5145
DC8	1687
DC11	2980
DC13	4062
Sum	26975

intended discharge in a certain point through the system which has been used by Clemmens and Replogle (1989), Molden and Gates (1990), Bos *et al.* (1993), Murray-Rust and Snellen (1993). The equation for DPR is:

$$DPR = \frac{\text{Actual delivered flow of water}}{\text{Required or intended flow of water}} \quad (3)$$

The delivery performance classifies as excessive if DPR is >1.15, moderate flow if DPR within the 0.9-1.15 and inadequate flow if DPR <0.9. The actual flow obtained from measured and simulated scenarios (Table 8-11) while the required flow obtained from CROPWAT (Table 3).

Table 8: Over year discharges (m^3/sec) with conveyance efficiency 94%

Outlet No.	Design discharge (m^3/sec)	Station	Over year discharge (m^3/sec) conveyance efficiency (0.94) Jan.	Feb.	Mar.	April	May	Jun.	Jul.	Aug.	Sep.	Oct.
DC5	3.0	16+900	0.6580	0.6674	0.7050	0.8460	0.8460	1.1280	1.1280	1.1280	0.6580	0.658
Right 1	0.5	16+300	0.1880	0.1880	0.1974	0.2068	0.2068	0.2162	0.2068	0.2256	0.1786	0.188
DC7	3.0	14+600	0.3760	1.3760	0.4230	0.4700	0.4700	0.5170	0.5170	0.5170	0.4230	0.423
Right 2	0.5	12+500	0.1880	0.1974	0.1880	0.2162	0.2162	0.2444	0.2162	0.1880	0.1880	0.188
DC9	3.0	7+500	0.2820	0.2632	0.3290	0.3290	0.3290	0.4230	0.4230	0.4230	0.3290	0.329
DC4	0.7	7+400	0.2350	0.2350	0.2820	0.3008	0.3008	0.3290	0.3290	0.3290	0.2820	0.282
DC11	3.0	7+400	0.2350	0.2350	0.2820	0.2820	0.2820	0.3290	0.3290	0.3760	0.3760	0.282
DC8	0.7	4+500	0.1880	0.1880	0.2820	0.2350	0.2350	0.2820	0.2820	0.2820	0.1880	0.188
DC13	3.0	0+500	0.1880	0.1692	0.1880	0.2820	0.2820	0.2820	0.2820	0.2820	0.1880	0.188

Table 9: Delivery performance ratio for simulated scenario case 1

			Case 1 DPR											
			2017							2018				
Outlet No.	Design discharge (m^3/sec)	Station	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
DC5	3	16+900	3.4	4.1	36.2	33.8	84.6	12.5	12.5	9.1	5.0	2.5	2.2	3.1
Right 1	0.5	16+300	0.7	0.9	10.5	12.9	38.0	4.8	4.6	3.4	1.9	0.9	0.7	0.9
DC7	3	14+600	1.6	1.9	17.3	21.0	60.0	7.9	6.9	5.1	2.8	1.4	1.2	1.7
Right 2	0.5	12+500	8.1	8.1	12.7	21.1	63.3	7.5	7.2	5.2	3.0	2.2	1.7	9.4
DC9	1.3	7+500	0.6	0.7	6.9	5.5	16.4	2.2	2.1	1.6	1.0	0.6	0.4	0.6
DC4	0.6	7+400	8.7	0.0	110.0	125.0	240.0	40.7	34.8	27.3	15.3	8.4	6.8	9.5
DC11	1.3	7+400	0.8	1.0	10.6	9.1	27.5	3.4	3.4	2.4	1.5	0.8	0.6	0.9
DC8	0.6	4+500	1.5	1.8	16.5	17.3	47.5	6.5	5.4	4.5	2.5	2.6	1.1	1.5
DC13	1.3	0+000	0.7	0.7	20.0	21.1	95.0	1.4	1.3	0.9	0.5	0.3	0.3	0.7

Table 10: Delivery performance ratio for simulated scenario case 2

			Case 2 DPR											
			2017							2018				
Outlet No.	Design discharge (m^3/sec)	Station	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
DC5	3	16+900	3.637	4.327	38.462	35.897	89.744	13.084	13.084	9.642	5.306	2.606	2.331	3.246
Right 1	0.5	16+300	1.022	1.225	13.636	14.286	40.000	5.102	4.854	3.578	2.000	0.894	0.704	0.895
DC7	3	14+600	1.652	1.971	18.333	20.000	57.143	7.561	7.286	5.369	2.978	1.553	1.280	1.792
Right 2	0.5	12+500	10.101	11.111	20.000	22.222	66.667	7.843	7.547	5.510	3.196	2.600	1.787	9.829
DC9	1.3	7+500	1.328	1.582	14.754	12.500	35.714	4.682	4.476	1.975	2.377	1.186	0.880	1.235
DC4	0.6	7+400	10.582	10.740	133.333	150.000	300.000	50.847	43.478	56.818	19.108	12.012	9.070	12.698
DC11	1.3	7+400	1.310	1.821	16.667	17.391	50.000	6.483	6.182	4.535	2.519	1.754	0.868	1.218
DC8	0.6	4+500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DC13	1.3	0+000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 11: Delivery performance ratio for simulated scenario case 3

			Case 3 DPR											
			2017							2018				
Outlet No.	Design discharge (m^3/sec)	Station	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
DC5	3	16+900	3.6	4.3	38.5	35.9	89.7	13.1	13.1	9.6	5.2	2.5	1.9	3.2
Right 1	0.5	16+300	1.0	1.2	13.6	14.3	40.0	5.1	4.9	3.6	2.0	0.9	0.6	0.9
DC7	3	14+600	1.7	2.0	18.3	20.0	57.1	7.6	7.3	5.4	3.0	1.4	1.0	1.4
Right 2	0.5	12+500	10.1	11.1	20.0	22.2	66.7	7.8	7.5	5.5	3.0	2.4	1.7	9.8
DC9	1.3	7+500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DC4	0.6	7+400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DC11	1.3	7+400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DC8	0.6	4+500	3.2	3.8	35.3	45.5	100.0	13.6	12.7	9.5	5.2	3.6	2.3	3.2
DC13	1.3	0+000	1.9	1.7	50.0	66.7	250.0	3.6	3.3	2.4	1.3	0.8	0.5	1.3

RESULTS AND DISCUSSION

From Fig. 3, the flow provided at beginning of Winter and end of Summer seasons is greater than required and need to be reduced .The required flow to irrigate the crops in Al-Kamaliya District varies around the months of the year. It is found that at months from (January-February) the provided flow is more than required, especially, at area of DC4, DC8, DC5 and Right 2. The flow provided at warmer months from (March-July) is lower than required at area of DC9, DC11, DC13 (Table 9). From the DPR for the simulated scenario (Case 1) of the flow in the distributary canals it is shown that the flow need to be increased in the distributary canals (DC11, DC9 and

DC13) for the months (March-July). The scenario (Case 2) Table 10 could provide adequate water to distributary canals (DC9, DC11) and excessive water to DC4 in months (March-July) (Case 3) scenario show that the flow increased to be adequate in month May and unadequate at months (March-April) and excessive in all other months (Table 11).

CONCLUSION

More water could be saved by providing right amount of water at specified season. From the resulted DPR of flow values from scenarios suggested, it is shown that the flow values increased highly in DC4 and moderately in DC9 or DC11 when (closing CR2), so, it is recommended to close DC4 partially or open CR2 at 0.2 m in order to increase the water flow at DC11. At scenario (closing DC9, DC11 and DC4), the value at DC8 increase more than required while at DC13 remained low, so, it is recommended to close the DC8 partially to increase the flow reach to DC13.

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