OPTIMUM MANAGEMENT OF AQUATIC WEALTH FOR AL-HILLAH KIFL REGION USING A MATHEMATICAL SIMULATION TECHNIQUE OF GROUNGWATER MOTION REJIME +

الادارة المثلى للثروة المائية لاقليم الحلة-كفل باستخدام تقنية التمثيل الرياضي لنظام حركة المياه الجوفية

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Abstract:

An optimization management study based on a mathematical simulation technique for Al Hillah Kifl Region with an area of 771.8 km^2 is developed. The area located between longitudes of (44° 15′- 44° 27′) and latitudes of (32° 15′ – 32° 42°) with average wind speed, sun shine, temperature, evaporation, humidity, and rainfall are 1.73m/s, 8.79hrs, 23.61c^0 , 190.21mm, 50.23%, and 8.61mm respectively occurred in the region. A complex geologic formation of Quaternary Deposits and Upper Miocene encountered there; flood plain deposits of Euphrates River and depression fill deposits which in general, consist of fine sandy silt and siltclay layers.

Sixteen existing wells are used for the hydrogeologic properties estimation of the unconfined aquifer. The maximum TDS of 136.7ppm is less than the maximum allowable limits of the Iraqi Standard and world Health Organization (WHO). It is found the maximum allowable groundwater exploitation (safe yield) of the unconfined aquifer is 250m^3/day/node which produces 5m drawdown at the centers of the production wells which represents a critical depletion depth; the steady state condition is obtained after 784999days of continuous pumping, moreover it is found that the maximum water demand and available surface irrigation water of 21000 m^3/day/node and 20850 m^3/day/node for Cotton Crop is occurred July.

المستخلص

تم تطوير دراسة الادارة المثلى والتي تستند على تقنية التمثيل الرياضي لاقليم الحلة- كفل بمساحة مقدارها ٧٧١,٨كم٢. تقع هذه المساحة بين خطي طول (′27 °44 -′15 °44) وخطي عرض (°42 °32 – ′15 °32) وبمعدل سرعة رياح وسطوع وحرارة وتبخر ورطوبة وامطار هي ١,٧١م/ثا ، ٨,٧٩ساعة،٢٣,٦١ درجة مئوية، ١٩٠,٢١ ملم ، ٥٠,٢٣%، ٨,٦١ ملم على التوالي تحدث في هذا الاقليم . تصادف في المنطقة تراكيب جيولوجية معقدة تتكون من المرحلة الجيولوجية الرابعة والعصر المايوسيني الاعلى مع ترسبات المسطحات الفيضانية لنهر الفرات و ترسبات المنخفضات والتي تتكون من طبقات الغرين الرملي والطين الغريني.

تم استخدام ١٦ بئر موجودة في المنطقة لحساب الخواص الهيدروليكية. ان اقصى قيمة للاملاح الذائبة الكلية هي136.7 جزء بالمليون اقل من القيمة القصوى المسموح بها بموجب المواصفة العراقية ومنظمة الصحة العالمية (WHO) . لقد وجد ان أقصى قيمة للاستهلاك المائي المسموح به للمكمن المفتوح هي٢٥٠ م٣/يوم/للوحدة والتي تسبب هبوطا مقداره ٥م لمستوى المياه الجوفية في مراكز آبار الضخ والتي تمثل الهبوط الحرج عند حالة الضخ

+ Received on 18/2/2009 ,Accepted on 3/1/2010 .

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الثابت و تحصل بعد ٧٨٤٩٩٩ يوم، علاوة على ذالك لقد وجد ان أقصى قيمة للاحتياجات المائية و أقصى استهلاك مائي متوفر لمياه الري هي21000 م٣\يوم\وحدة و ٢٠٨٥٢م٣\يوم\وحدة على التوالي لمحصول القطن تحدث في تموز.

Introduction:

[1] accomplished a wide study at the region, it was compromised a climatic, hydrologic, and even hydrochemical data collection. [2] described the soil type of Euphrates Shoulders near the study area and the most important soil types at Babil province which are found to be a silty and clayey loam with deep cracks. [3] studied the Iraqi Sedimentary Plain which includes the land plains along Al Hillah River to depths exceed ten meters. He indicated that the hydraulic conductivity is increased as the depth increases. [4] studied the hydro and geochemical properties of Euphrates River and the sediments of its branches. His study is aimed to assess the degree of pollution due to human activity and nature effects. He concluded that rivers water characterized by nil pollutants with intermediate salinity and high turbidity during humid and flood season. The geo-hydro chemical study and sedimentation of the region was undertaken by [5]. He indicated that the solutions are alkaline with low to high salinity, moreover the dominant major chemical elements are chloride and sulphur. [6] assigned that a high salinity at the area may be attributed to the rise of groundwater levels. Many foreign companies such; Arcif and Scapanous worked at the region for the years from (1980-1990) for the purposes of soil salinity reclamation and rehabilitating of irrigation and drainage system. Recently, their irrigation and drainage network enhanced the quality of the soil and the productivity of the agricultural fields.

[7], [8], [9], [10], [11] , and [12] are the firsts among others who shared in the numerical modeling technique development; some of them formulate programs to solve a set of linear equations which are resulted from the solution of a partial differential equation, whereas [13] and others simulate a groundwater scheme for a specified areas. In this simulation technique, a *FORTRAN POWER STATION* program is used in the formulation of the case study.

Case Study and Social Problems:

In recent decades, the population of Al Hillah- Kifl Region suffers many problems due to discrepancy of surface water resources especially for those areas of higher levels. Rainfall is available with inadequate quantities to satisfy the necessary water requirements for the common types of plant crops and so on for groundwater source.

The visit to the area, one concludes that many large parts of it left uncultivated. In last few decades, an artificial network of irrigation canals has been constructed to solve partially the problem, but it is practically unsolved for other parts.

Purposes of the Research:

The purposes of this study can be summarized in the following targets:-

1- Defining the important role and features of the main existing hydraulic boundaries
2- The hydrogeologic interaction of surface and subsurface water resources through a mathematical modeling process.
3- Assessment of regional plant crops and water demand (WD) estimation.
4- Studying of Optimum management through different environmental scenarios and searching for the available optimum solution and possible options.

Geographic Definition & Topography:

The region under consideration as shown in Fig.(1) is located between longitudes (44˚ 15′ 41″ & 44˚ 24′ 26″) and altitudes (32˚ 36′ 24″ & 32˚ 20′ 50″) with an approximate area of (771.8km$^{2)}$. It looks like a fusiform shape surrounded by Al Hillah River from the east and Euphrates from the west. The region starts with Al Hindyia Barrage at the north and is ended at Al Kifl City at the south. Al Hillah-Kifl Street represents the southern-east boundary of the interested area. Al Hillah Kifl Main Drain flows from the north toward the south taking a zigzag way inside the area. Fig.(1) shows the main geographic infrastructures and the location of the area under interest.

In general, the area seems to be flat with gradual lowering of ground surface levels toward the south. The highest levels occurred at the north which is equal 31m.a.s.l, whereas the lowest levels occurred at the south near Al Kifl City which is found to be 24m.a.s.l. The levels shown in Fig. (1) are obtained depending on field measurements in many sites within the area and certified by the geographic map of Iraq.

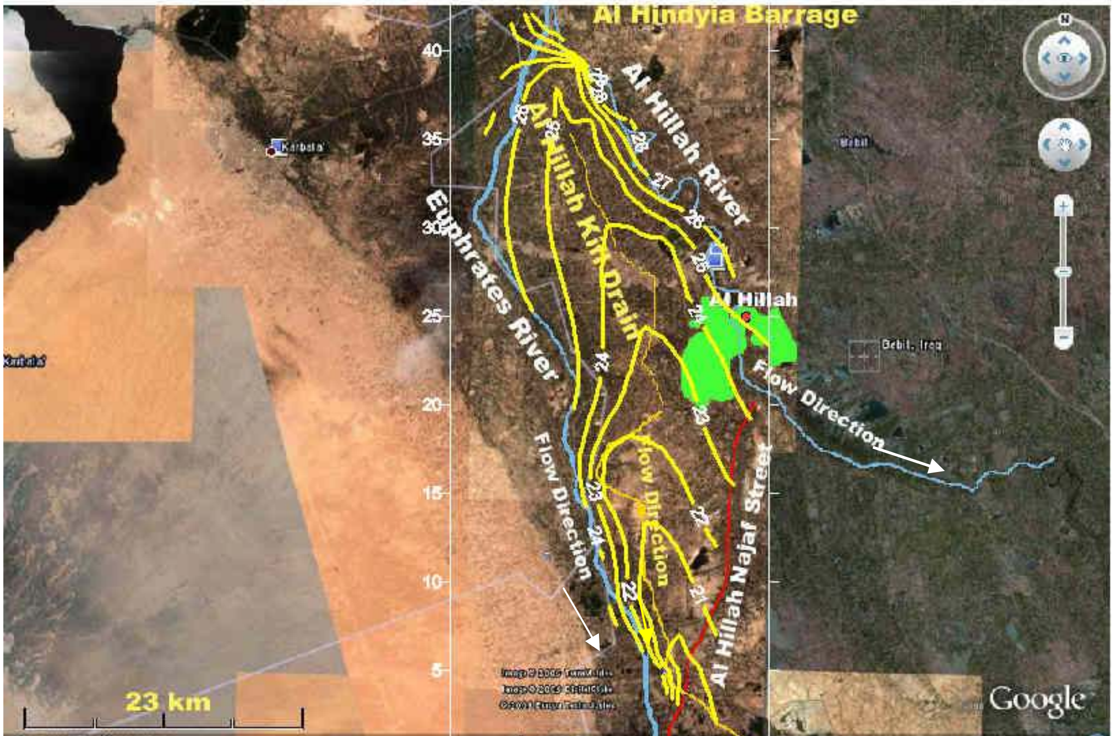


Fig.(1) Geographic Map of Al Hillah Kifl Region (Areal photographic view, Based on Google Earth 2009)

Meteorological Elements:

Meteorological data of the region under interest were collected and summarized (Iraqi Meteorological Organization, 2007). The Major climatic elements are tabulated in Table (1). In general, the records indicate that the region is characterized with maximization of average monthly evaporation, temperature; wind speed, sunshine and minimization of rainfall, and humidity are occurred in summer months and vice versa in winter.

Table (1) Average Monthly Meteorological Elements (1981-2006), Meteorological Organization of Iraq, 2007

Months	Wind speed, m/s	Sun Shine, hrs	Temp., C°	Evaporation, mm	Humidity, %	Rainfall, mm
Oct.	1.04	8.55	25.91	161.32	48.86	3.73
Nov.	1.04	7.10	17.71	61.46	63.33	14.1
Dec.	1.10	6.10	12.71	52.46	74.15	18.8
Jan.	1.20	6.20	10.76	52.32	74.05	20.7
Feb.	1.70	7.40	13.04	74.90	63.45	13.4
Mar.	2.10	8.00	17.38	134.46	55.70	15.2
Apr.	1.87	8.80	23.4	186.79	48.19	15.3
May.	1.99	9.94	29.00	293.5	37.77	2.05
Jun.	2.50	10.0	32.74	339.61	32.27	0.02
Jul.	2.80	11.90	34.70	358.06	31.95	0.00
Aug.	2.03	11.40	34.65	321.60	34.36	0.00
Sep.	1.41	10.1	31.33	246.07	38.71	0.04
Average	1.73	8.79	23.61	190.21	50.23	8.61

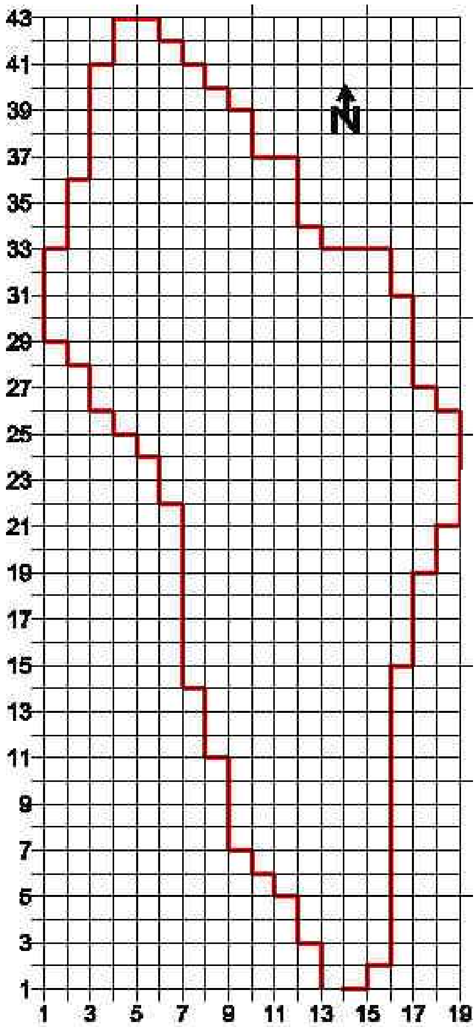
Simulation Technique and Mathematical Modeling:

This process is usually started with preparation and assessment of necessary information such as natural and artificial recharges estimation, mesh design of the considered area domain, stratification of sub layers and hydrogeologic properties (aquifer properties).

For more information about mathematical modeling, [12] and [13] report a brief study of simulation techniques; calibration, verification and limitations. Several programs have been written for aquifer simulation by a mathematical model, using a finite difference approach. The program of [9] has been modified and used for its flexibility and modification. The derivation of finite difference equation is based on the mass conservation principle and Darcy's Law. A detailed derivation of the finite differences equations and convergence test for errors study are found in [9].

I) Discretization of the Domain

The first step in modeling job is to discretize the system by superimposing a mesh of finite difference grid over a geographicl map of the area. The size and the number of nodes to be chosen depend on the requested accuracy. The total dimensions of the grids are defined by NC (the number of columns), and NR (the number of rows) of the model. (NC = 19) and (NR = 43) are the selected number of columns and rows respectively. The total number of grids inside the modeled area equals 454. Such discretization of the domain gives a scale equals (1node space =1314m). Fig. (2) shows the discretization of the domain.



(NR)

Fig. (2)Discretization of

(NC)

II) Hydrogeologic Properties & Stratigraphy

Sixteen existing wells have been found and used for local measurements at the site as shown in Fig.(3). The essential hydrologic and hydrochemical data have been listed in Tables (2 & 3) respectively.

Table (2) Hydrologic Characteristics of the Existing Wells

WELL No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Depth, m	**8**	**9**	**8**	**6**	**8**	**8**	**12**	**6**	**12**	**10**	**8**	**12**	**9**	**12**	**10**	**12**
Elevation, (masl)	**28**	**38**	**30**	**25**	**27**	**28**	**27**	**25**	**24**	**24**	**28**	**25**	**25**	**27**	**24**	**29**
Static W.L. (masl)	**25.7**	**26.7**	**27**	**24**	**25.5**	**26.1**	**24**	**24**	**21.5**	**22.5**	**24.5**	**23.5**	**22.5**	**25.6**	**22.1**	**27**

Measured by the Author, 2007

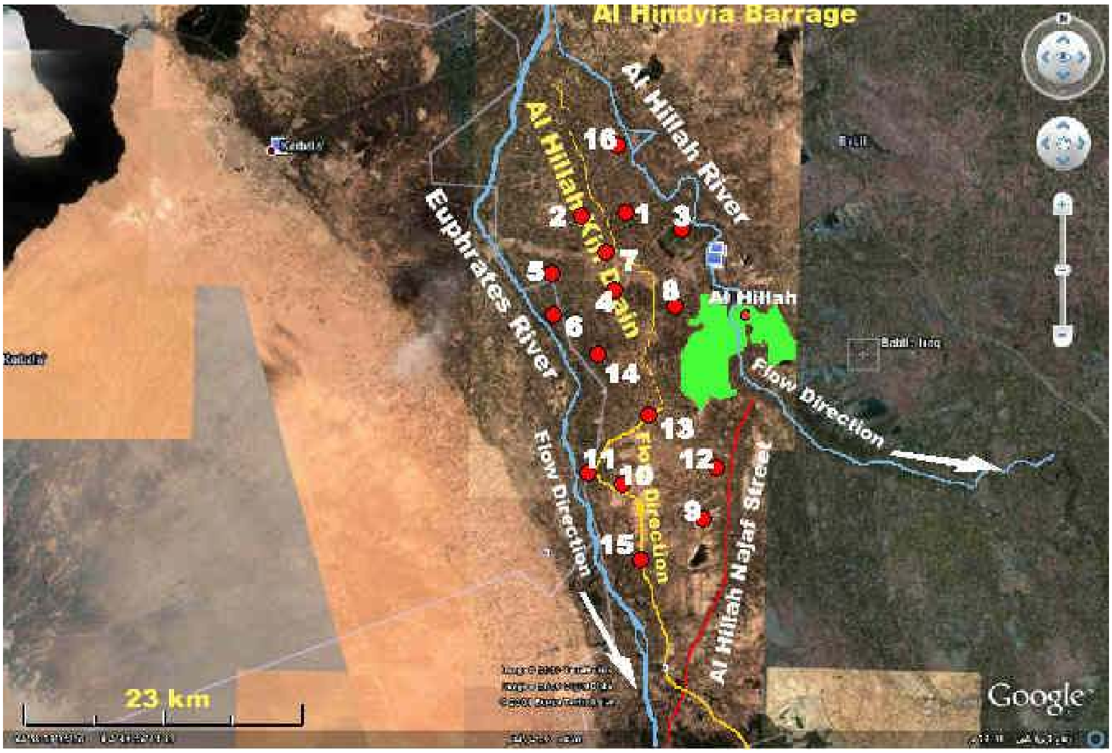


Fig.(3) Existing Wells Location

Table (3) Hydrochemical Test Analysis of Wells water, (ppm)

Well No.	KCL	NaCl	$MgCl_2$	Na_2So_4	$MgSo_4$	$CaSo_4$	$Ca(Hco_3)$	$Mg(Hco_3)$	$NaHco_3$	TDS
1	1.45	13.30	0.00	19.3	51.74	7.86	6.26	0.00	0.00	99.5
2	0.14	41.9	0.00	26.80	44.64	0.00	3.00	9.45	0.00	125.9
3	1.17	12.9	0.00	26.80	44.64	0.00	12.84	1.11	0.00	99.5
4	2.02	42.3	0.00	7.30	31.00	2.27	14.11	0.00	0.00	99.0
5	1.42	42.82	0.00	31.02	12.18	0.00	8.62	4.52	0.00	100.6
6	1.21	15.00	25.69	0.00	41.4	0.00	9.52	7.21	0.00	100.0
7	1.25	42.16	0.00	41.97	0.00	0.00	3.03	10.68	0.89	100.0
	1.60	23.1	0.00	31.04	21.56	0.00	15.5	10.46	0.00	103.3
9	1.42	35.68	0.00	21.82	14.18	0.00	7.90	21.05	0.00	102.0
10	1.96	84.94	0.00	21.51	15.00	13.32	0.00	0.00	0.00	136.7
11	1.59	39.41	0.00	8.02	31.78	0.00	9.44	9.78	0.00	100.0
12	1.59	24.32	0.00	8.38	33.30	30.54	0.00	0.00	0.00	98.1
13	1.59	37.53	0.00	21.47	16.26	0.00	1.67	21.57	0.00	100.0
14	0.26	42.42	0.00	38.98	4.44	0.00	7.74	0.00	6.26	100.1
15	1.4	64.66	0.00	18.04	17.77	12.99	0.00	0.00	0.00	114.8
16	1.48	22.92	0.00	3.35	54.65	19.95	0.00	0.00	0.00	102.3

Tested by the Author, 2007

The maximum TDS (Total dissolved salts) of 136.7ppm is encountered in the well No.10 of Table (3). This quantity is less than the maximum allowable limit of Iragi Standard world Health Organization (WHO, 2003) which is equaled 1000ppm for human been purposes and too much less than the maximum limit for animals agricultural purposes, [15].

The study area consists of quaternary deposits and upper Miocene. The area is characterized with flood plain deposits of Euphrates River and depression fill deposits which in general consists of fine sand silt and siltclay layers [1]. Secondary gypsum has a wide spread at the region; it constitutes (4.92%) of the total deposits. [14] presents that the area under study is located at Mesopotamian Zone between Zakaros Mountain Series Syncline and the Stable Arabian Plateau. He described the tectonics of the sedimentary plain and presented that the area represents a syncline which is tectonically activated and passed with a subsidence stage and local minor uplifts. The presence of marshes and swamps at the area is evidence to the tectonic movements.

Hydrogeologic Properties Determination of the Unconfined Aquifer:

The hydraulic properties of the unconfined aquifer are estimated depending on the pumping test analysis of sixteenth existing wells. The wells No.7, 10, and 12 are chosen randomly to explain the method of how the hydraulic properties have been estimated. Their lithology are shown in Fig.(4). The methodology of estimation based on [15] and representation of a transmissivity of the unconfined aquifer of wells No. 7, 10, 12 are shown in Figs.(5 ,6 ,and 7) respectively. Unfortunately, the specific yield couldn't be obtained since no observation wells are existed [15], and [16]. The values of hydraulic conductivity of the existing wells are obtained accordingly and represented in Fig.(8)

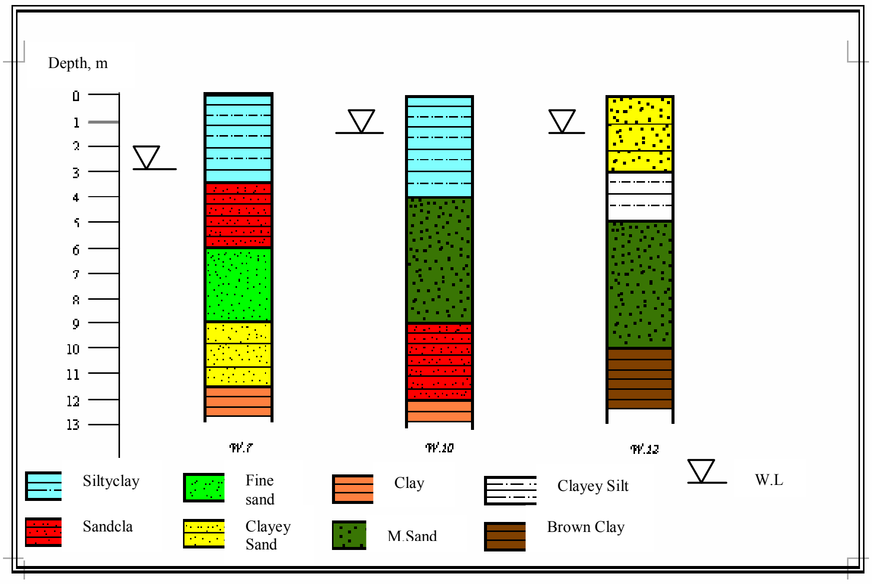


Fig.(4) Lithilogy of Wells No. 7,10, and 12

The specific yield of the unconfined aquifer is assumed to be 0.2 [15] and adjusted through the model calibration

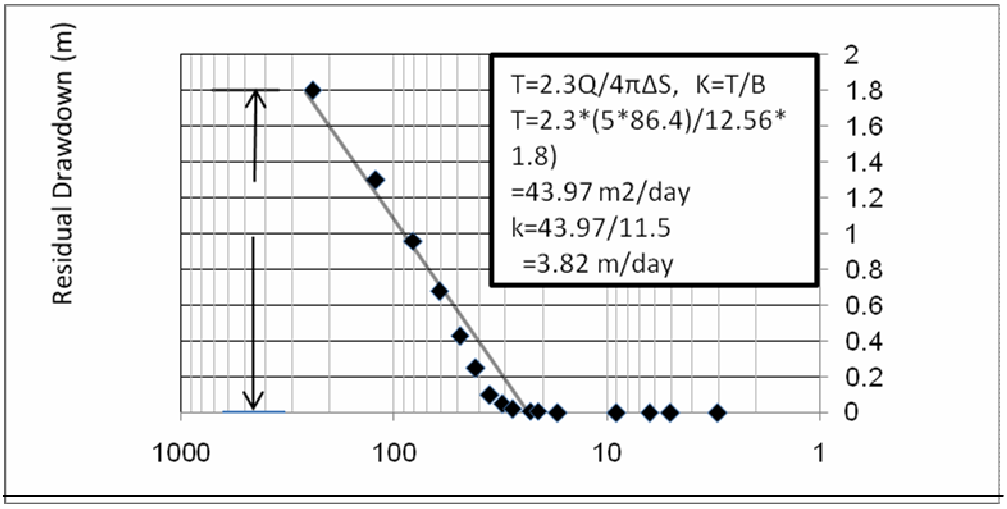


Fig.(5) Hydraulic Conductivity Analysis of Well No.7

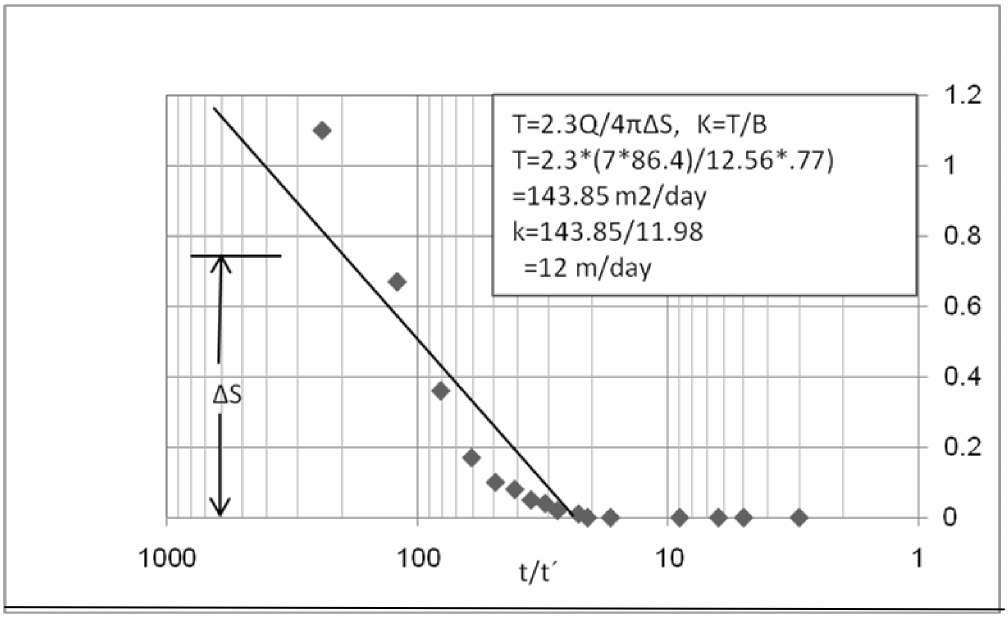


Fig.(6) Hydraulic Conductivity Analysis of Well No.10

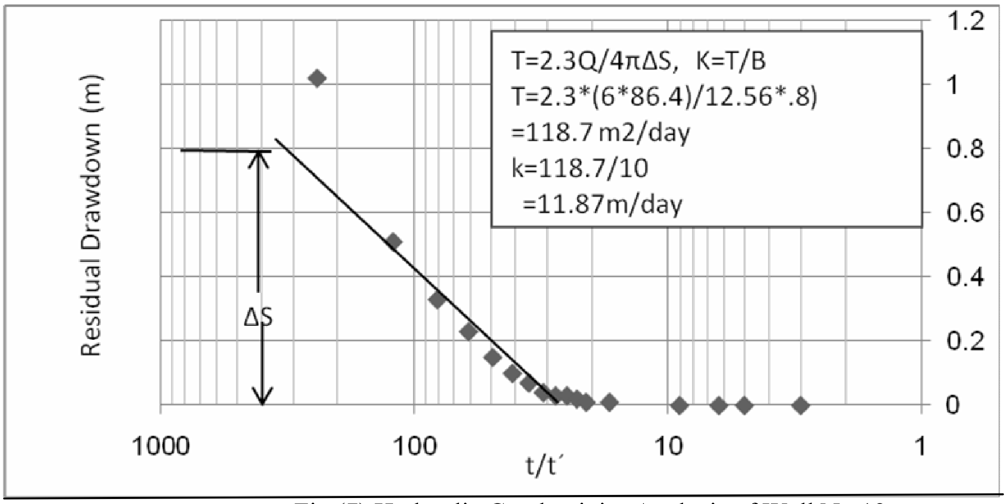


Fig.(7) Hydraulic Conductivity Analysis of Well No.12

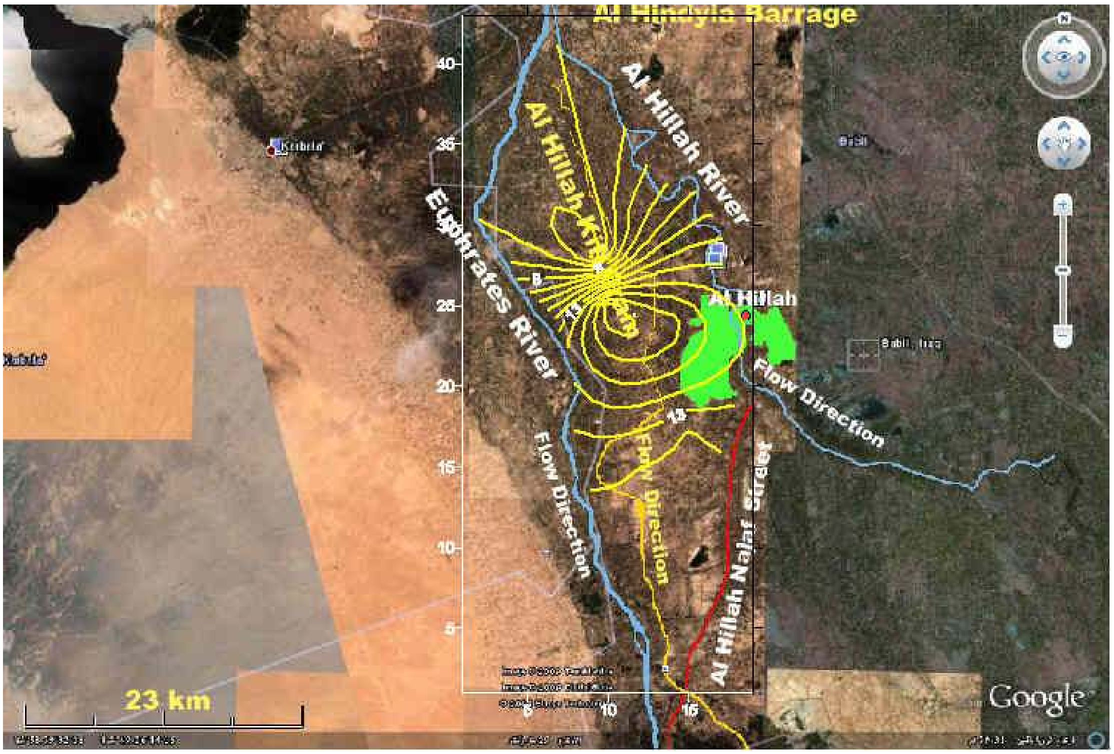


Fig.(8) Hydraulic Conductivity Distribution, m/day

III) Natural Recharge (Deep Infiltration) Estimation

In general recharge values are fallen in the range of 2% for clayey soils to 20% for very coarse gravelly soils of the total rainfall as indicated by [17]. According to [17] and since the soil is a clayey, then Table (1) gives:

Natural Recharge $= 0.02 * \frac{8.61mm/month}{1000mm/m*30day/month} * (1314\text{m/Node})^2 = 10\text{m}^3\text{/day/node}$

Total Deep Infiltration = (454 nodes)* 10m^3/day/node =4540 m^3/day

Specifically, the natural recharge is specified for each node in the input data file and necessary adjustment for recharge is made during the model calibration.

Since the modeled area has a unique exit which is represented by the outlet of Al Hillah Kifl Drain of discharge equals 6.12 m^3/s [Al Hillah Directorate of Agriculture, 2007], the natural recharge can simply be estimated using the continuity equation [18].

Inflow = Outflow + ΔStorage ……………………………………………….(1)

$Q_{Lateral}$ + Deep Infiltration + Runoff = $Q_{outflow}$, [assuming Δs=0]

The hydrologic components of the considered area are shown in Fig. (9)

$Q_{outflow} = 6.12*3600*24 = 528768\text{m}^3\text{/day}$

Lateral flow is absolutely induced by Euphrates and Al Hillah Rivers, therefore

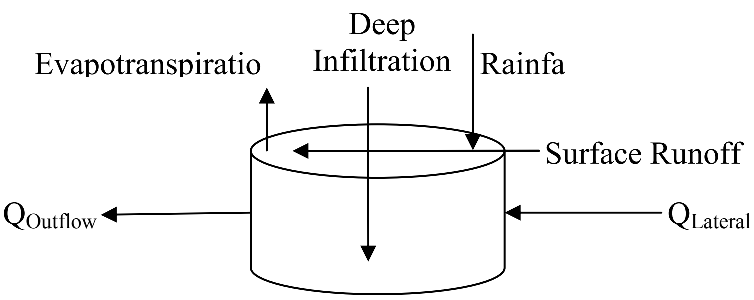


Fig.(9) Hydrologic Components

$Q_{Lateral} = Q_{Euphrates\ River} + Q_{Hillah\ River}$

The contour maps of the natural groundwater levels (Fig.(10)) and the hydraulic conductivity (Fig.(8)) are superimposed to estimate the lateral inflow along the boundaries of the two rivers using Darcy's Law [15].

$Q_{Hillah\ River} = 15928m^3/day$, $Q_{Euphrates\ River} = 36429m^3/day$, therefore

$Q_{Lateral} = 52357m^3/day$. Now, from Equ.(1)

$52357 + 4540 + Runoff = 528768$

$Runoff = 471871\ m^3/day = 1039m^3/day/node$

The sources of runoff water at the area are mainly the overflow of irrigation water toward the drain due to farmers' carelessness and the water exceeding deep infiltration during rainfall storms

IV) Simulation of Groundwater Flow Regime

a) Model Calibration

[13] presents the input data files preparations for the modeling process. After the input data files have correctly prepared, the model is exactly run for 88040days to obtain the steady state. The simulation groundwater levels of the study area resulted from the model and the natural groundwater levels are represented graphically in Fig.(10). The figure shows a good match between the simulated and natural W.L.

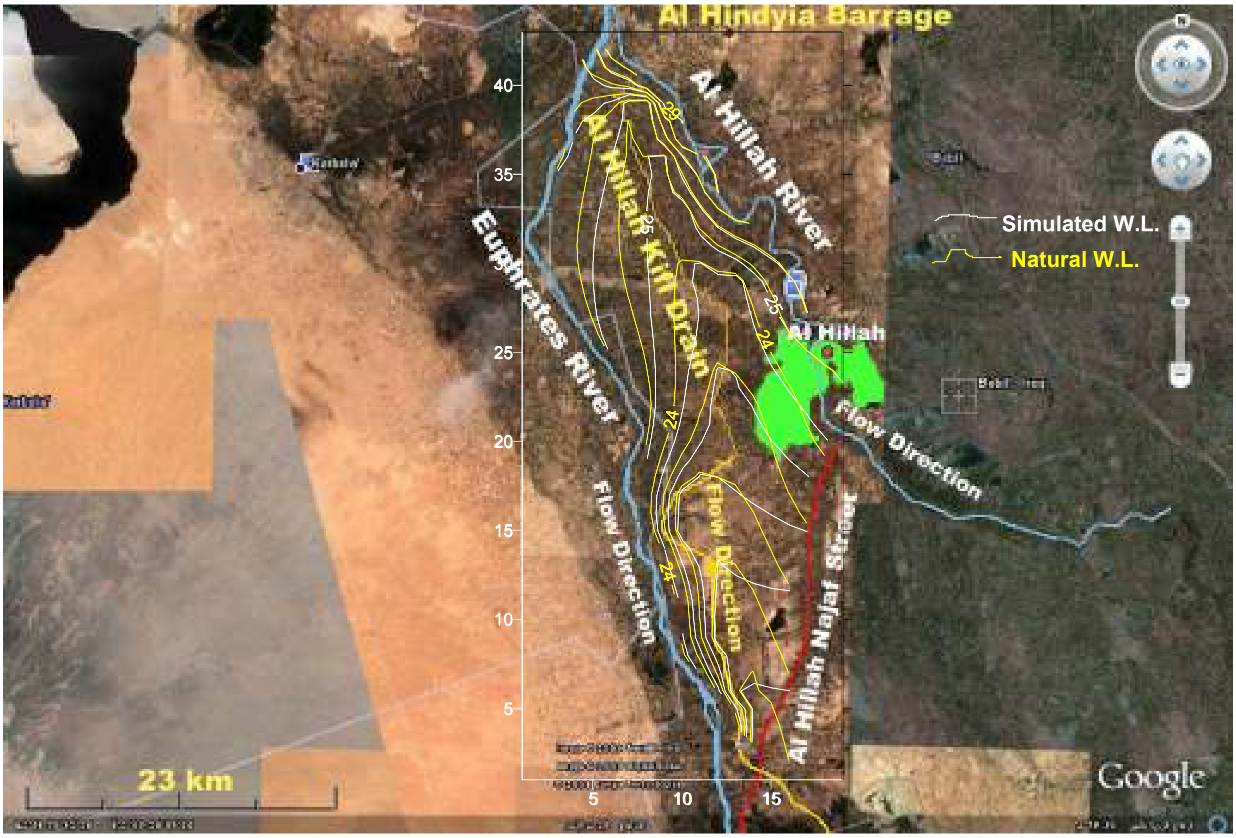


Fig.(10) Matching of Simulated & Natural Ground W.L.

b) Optimum Management and Applications

One of the difficulties in studying the management of the area is the variation in water resources; they are: - 1- Rainfall. 2- Groundwater Extraction. 3- Surface Water, in addition to water demand estimation.

1- Assessment of Water Resources

i) Rainfall assessment

By using of Table (1), the rainfall allocation for each node can be calculated as:

$$Q = \frac{8.61mm}{1000} * (1000)^2 * \frac{1}{30} = 287m^3/day/\,km^2$$
$$=287m^3/day/\,km^2 * (1314/1000)^2 = 495.533m^3/day/\,node$$

ii) Groundwater Extraction, Safe Yield & Drawdown Issue

The major goal of modeling process is the estimation of aquifer safe yield, this may be accomplished by using the model to deplete a production well at the area meanwhile a maximum productivity is estimated. The correct situation for the process requires estimating the amount of productivity without allowing groundwater system to be depleted. [19] defined that *Sustainable Yield* as the amount of groundwater giving to existing groundwater withdrawals that can be withdrawn from an aquifer based on continual pumping at rated pump capacity and without causing a progressive decline of the water level at least 7.5m below the static water level within an existing water well that is completed in consolidated geologic formation. [12] indicated a drawdown of 30% of the average thickness of the unconfined aquifer may be suitable to be used as an allowable limit. This percentage allows maximum drawdown of about 5m at the center of the production well within the modeled area. The model is run for 784999days (2150.6 years) to reach a steady state condition for two production wells penetrate the full zone depth of the unconfined aquifer with a safe yield of 250 m^3/day (2.89liter/s). The western and eastern wells cause a maximum drawdown of 5m and 6m respectively. Fig.(12) shows the locations of the selected production wells and the resulted drawdown.

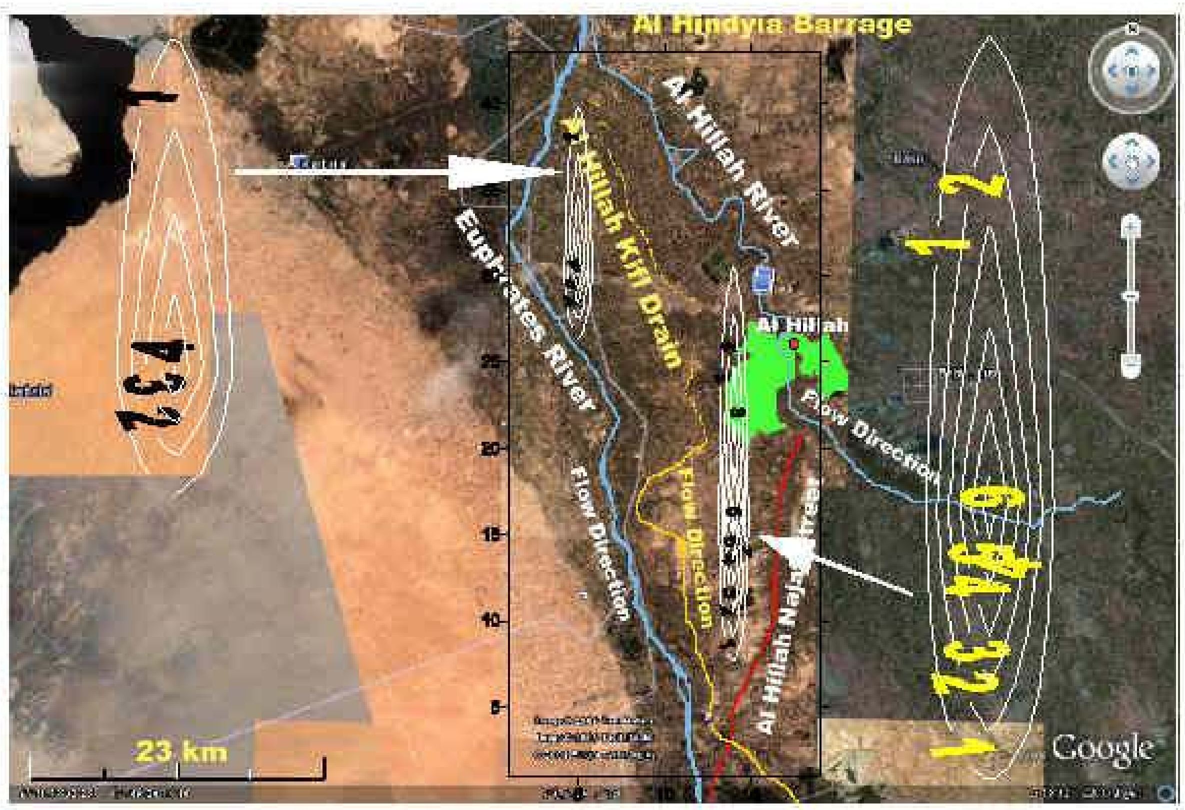


Fig. (12) Drawdown Contour Map Due to the Current Pumping of the Two Wells for a continuous pumping rate of 250m^3/day

Comment: The deformation of the cones of depression is attributed to a good groundwater feeding in east-west direction (lateral flow), in reversing of weak lateral flow in north-south direction.

ii) Surface Water

Since the area is located between the famous two rivers, therefore the water duty with a required quantity is available. The basic theory of this study is to minimize the surface water consuming to minimum amounts.

2- Water Demand Estimation

The estimation of water demand depends mainly on two important factors. The first is the weather condition which includes temperature, number of hourly sun shine, humidity, wind speed, elevation above sea level, longitude, laltitude …etc. The second factor is plant type, which represents plant requirement for water and that reflects the plant coefficient

The amount of the evapotranspiration is outlined by Blaney- Criddle Technique [20] which reflects the effects of all these parameters as follows:

$$E_o = k' \ f \qquad \text{……………(2)}$$

In which,

$$f = p\,(0.46\ {}^{\circ}c + 8.14) \qquad \text{……………..(3)}$$

$$k' = 0.0311\ {}^{\circ}c + 0.24 \qquad \text{……………..(4)}$$

and

$$U = K_c\ E_o \qquad \text{……………..(5)}$$

Where: E_o : potential evapotranspiration, mm/month

P : yearly percentage of monthly day light

C : average monthly temperature, $^{\circ}c$

K_c : crop coefficient

U : monthly crop consumptive use, mm/month

Crops coefficients & potential evapotranspiration for different crops which are common in the region are listed in Table (4).

Table (4) Crops Coefficients & Evapotranspiration

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Evapotra, mm	168	82	52	41	55	101	154	236	279	312	284	223
Wheat	0.00	0.40	0.80	1.20	1.20	1.00	0.50	0.00	0.00	0.00	0.00	0.00
Barely	0.00	0.58	0.77	1.01	1.14	1.12	0.82	0.00	0.00	0.00	0.00	0.00
Cotton	0.00	0.00	0.00	0.00	0.00	0.60	1.00	1.10	1.20	1.20	1.20	1.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.58	0.68	0.84	1.02	0.49	0.00	0.00
Corn	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.80
Vegetable	0.70	0.50	0.50	0.50	0.60	0.80	0.80	0.80	0.90	1.00	0.90	0.70
Orchard	0.70	0.50	0.50	0.50	0.60	0.80	0.80	0.80	0.90	1.00	0.90	0.70

After lateef 1999

The water demand for each plant crop is estimated according to Blaney- Criddle Technique and listed in Table (5) and represented graphically in Fig. (11)

Table (5) Consumptive Use, m^3/day/node

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wheat	0	1887	2317	2740	4070	5625	4431	0	0	0	0	0
Barely	0	2737	2230	2306	3866	6300	7267	0	0	0	0	0
Cotton	0	0	0	0	0	3375	8863	14458	19268	20852	18981	12834
Sunflower	0	0	0	0	0	3262	6027	11041	16378	8514	0	0
Corn	4678	943	0	0	0	0	0	0	0	17377	15817	10267
Vegetable	6550	2359	1448	1141	2035	4500	7090	10515	14451	17377	14236	8984
	Orchar	2359	1448	1141	2035	4500	7090	10515	14451	17377	14236	8984

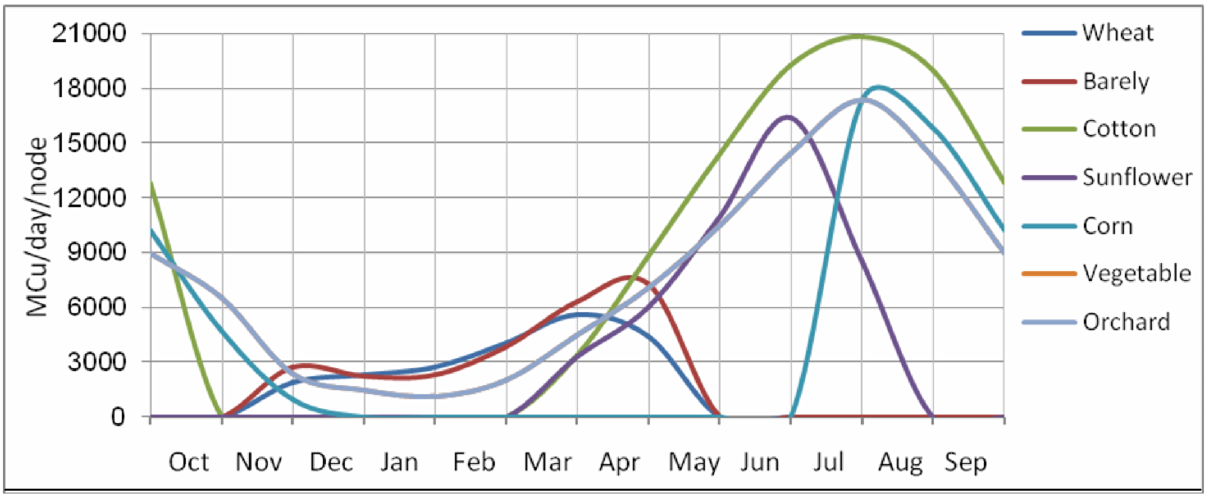


Fig.(11) Water Demand for Different Plant Crops

3-Optimum Aquatic Policy

The optimum policy in this scenario requires the following assumptions:-

a- Full exploitation of seasonal rainfall.

b- Full exploitation of the safe yield.

c- Minimization of surface water consuming.

The water demand (WD) for each plant crop should be satisfied using the available water resources provided that the preceding assumptions are fulfilled. This scenario requires the covering of each nodal area (1314m^2) with the needed WD for each plant crop. This can be done by subtracting the daily rainfall and the safe yield from the total WD of each plant crop. For instance, for Wheat crop, minimum surface water Row(3) = Row(4) -Row(1) - Row(2) of Table (6).

Table (6) Available Water Resources for each Plant Crop, m^3/day/node

	Source	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wheat	Safe yield (1)	-	250	250	250	250	250	250	-	-	-	-	-
	Rainfall (2)	207	811	1147	1153	826	846	880	114	1	0	0	2
	Surface Water (3)	-	826	920	1337	2994	4529	3301	-	-	-	-	-
	Total WD(4)	0	1887	2317	2740	4070	5625	4431	0	0	0	0	0
Barely	Safe yield	-	250	250	250	250	250	250	-	-	-	-	-
	Rainfall	207	811	1147	1153	826	846	880	114	1	0	0	2
	Surface water	-	1676	833	903	2790	5204	6137	-	-	-	-	-
	Total WD	0	2737	2230	2306	3866	6300	7267	0	0	0	0	0
Cotton	Safe yield	-	-	-	-	-	250	250	250	250	250	250	250
	Rainfall	207	811	1147	1153	826	846	880	114	1	0	0	2
	Surface water	-	-	-	-	-	2279	7733	14094	19017	20602	18731	12584
	Total WD	0	0	0	0	0	3375	8863	14458	19268	20852	18981	12834
Sun-flower	Safe yield	-	-	-	-	-	250	250	250	250	250	-	-
	Rainfall	207	811	1147	1153	826	846	880	114	1	0	0	2
	Surface water	-	-	-	-	-	2166	4897	10677	16127	8264	-	-
	Total WD	0	0	0	0	0	3262	6027	11041	16378	8514	0	0
Corn	Safe yield	250	250								250	250	250
	Rainfall	207	811	1147	1153	826	846	880	114	1	0	0	2
	Surface water	4221		-	-	-	-	-	-	-	17227	15567	10017
	Total WD	4678	943	0	0	0	0	0	0	0	17377	15817	10267
Veget-able	Safe yield	250	250	250	250	250	250	250	250	250	250	250	250
	Rainfall	207	811	1147	1153	826	846	880	114	1	0	0	2
	Surface water	6093	1298	45	-	959	3404	5960	10151	14200	17127	13986	8732
	Total WD	6550	2359	1448	1141	2035	4500	7090	10515	14451	17377	14236	8984

Comment: A full use of rainfall is considered in the calculation of table (6) and ignoring the small allocation of deep percolation 2% of the total rainfall.

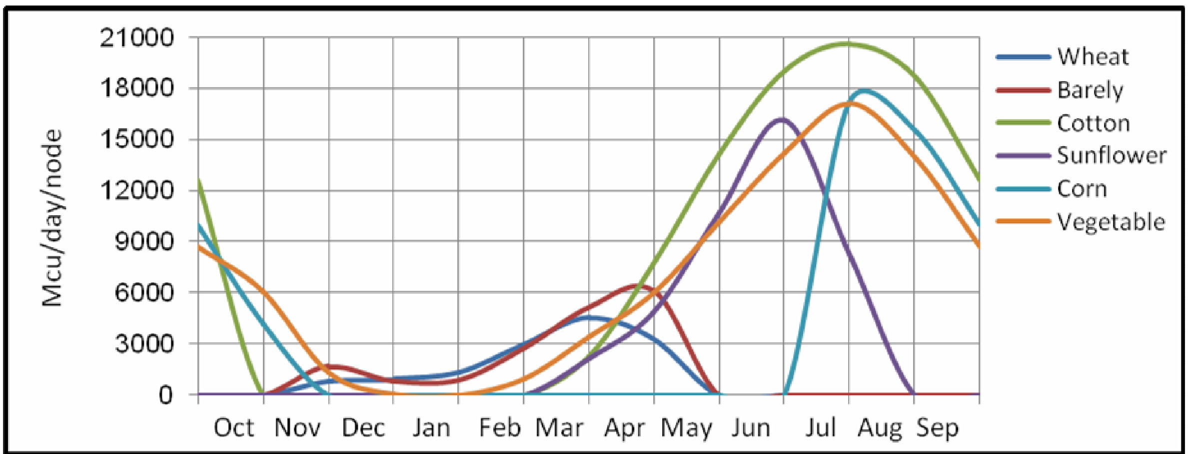


Fig. (12) Surface water Requirements, m^3/day/node

Comment: For a specified agricultural field and for any plant crop, the farmer requires firstly full consuming of the available rainfall and groundwater source(safe yield) of no more that $250m^3$/day/node and secondly exploits the surface water according to table (6).

Conclusions:

The following conclusions may be summarized from the current study:-

1- The region is bounded by Euphrates and Al Hillah Rivers which are playing an important role in supplying surface and subsurface water and Al Hillah Kifl Drain which is draining the subsurface layer by $6.12m^3/s$.
2- The existing hydraulic boundaries formulate the natural groundwater levels.
3- The region characterized with different permanent and seasonal plant crops with maximum WD variation occurred on summer.
4- The current optimum management reduces the consuming of surface water by exploitation of the unconfined aquifer safe yield ($250m^3$/day/node) and rainfall resources.

Recommendations:

The following points are recommended:-

1- Al Hillah Kifl Drain Play an important role in rebalancing the environmental hydrologic system, therefore it should be kept in good condition a protection agency.
2- An extension statistical study for the region is recommended.
3- An extension study for soil salinity and reclamation from one side and groundwater propriety for human been use overall the region lands.

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