Journal of Zankoy Sulaimani- Part A (JZS-A), 2013, 15 (1)

گۆڤاری زانكۆی سلێمانی- بەشی A

Numerical Groundwater Flow Modeling for The Intwrgranular Aquifer in Sarsian Sub-Basin, Dokan Lake, Iraqi Kurdistan Region

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Abstract:

Sarsian sub-basin is located in the northeastern part of Iraq and to the northwest of Sulaimani governorate, north of Dokan dam between Northing (3987401–4006440) and Easting (498677–506055), covering an area of 99 km^2. It is located within the Dokan reservoir catchment area. It extends on the left bank of the reservoir along the distance of 19 Km. The main aquifers in the studied area are integranular Quaternary aquifer and karstic to karstic fissured aquifer of Qamchuqa and part of Sarmord. Based on the analysis of the available water points, it was found that the general groundwater movement is from northeast to southwest, with two different directions; one unconfined and the other confined aquifer. Based on the well tests performed on 14 wells that penetrate the Quaternary aquifer, it was found that the hydraulic conductivity to be with median value of 3.445 m/d, transmissivity with median value of 382.95 m^2/day and specific yield with median value of 0.1. Groundwater flow simulation was performed for the north part of Sarsian Sub-basin in both steady and transient states. The steady-state simulation is based on lower groundwater level (October 2009). A qualitative analysis of the map indicates that the simulated and the observed piezometric contours display the same pattern. The hydraulic gradients obtained from the simulated piezometry are similar to those of the observed piezometry in the whole study area. The model was run for four future scenarios of groundwater level. The first scenario of Dokan lake stage was simulated, and three stress periods of transient simulated with different volume of extraction per day. From the results, it is obvious that Dokan Lake stage has significant influence on the head fluctuations in the area.

Introduction

Sarsian area is located in the northeastern part of Iraq, exactly 80 km to the northwest of the city of Sulaimani Fig. (1). Due to its high groundwater resources potential for irrigation of medium and large scale projects, an increased demand for farm production on one hand and a stagnancy, or even decrease in farm production on the other, the 50 recently drilled water wells for the purpose of irrigating the 5000 hectare of land located on the foot of Asos Mountain have been used for the main portion of this study.

The studied area extends between Easting (498677–506055) and Northing (3987401– 4006440). It is bounded from west and southwest by Dokan Reservoir and from north and northeast by Asos Mountain. Sarsian area as an elongate plain extends on the left bank of the reservoir for a distance of 19 km. It is part of Dokan reservoir catchment, covering an area of 99 km^2.

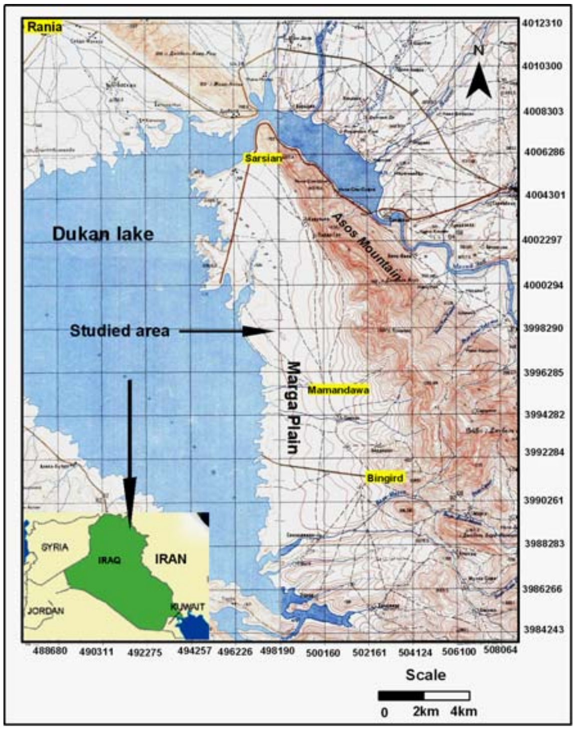

Fig. (1) Location map of the studied area

GEOLOGY

According to the tecto–structural setting and physiographical classification of Jassim and Goff (2006), the area of study lies within the unstable platform, high folded zone, Sulaimaniya – Zakho subzone, and in the Qamchuqa–Rania subzone according to Buday and Jassim (1987).

The anticlines in the area mostly built by late Cretaceous–Paleogene sequences, Southwestern parts of the unit are somewhat less expressive, built mostly by late Cretaceous–Paleogene sequences, the synclines are always filled by Paleogene sediments. The anticlines become higher, the synclines narrower towards the northeast. There, overturned anticlines occur too and reverse faults are more widespread. The main structures in the area are is Asos anticline.

The Sarsian area is located within the so called Rania plain being a vast morphological depression. Generally, the area is inclined to Dokan Reservoir, which delimits the area from the west. In the northern part of the area, a series of coarse clastic deposits occurs containing mainly conglomerates and gravels, which are clearly observed on the banks of Dokan Reservoir. In the lower part, it contains also layers of sands and sandstones. In the southern part of the area, alluvial deposits occur, forming the younger part of the Plio–Pleistocene. The maximum thickness of the alluvial deposits is estimated as 150 -200 m.

Sarmord Formation comprises 455 m of homogeneous brown and bluish marls, with beds of argillaceous limestones. The total thickness of Sarmord Formation in Rania section (Hanjera Village) is about 403 m. In Sarsain area, Sarmord Formation is overlain by alluvial deposit, as in Fig**.** (2), and appears in Bardashani Saroo. Even though the Jurassic rocks are not cropping out in the study area, but they comprise the more extensive out crops of the west of the study area. (Al-Manmi, 2008).

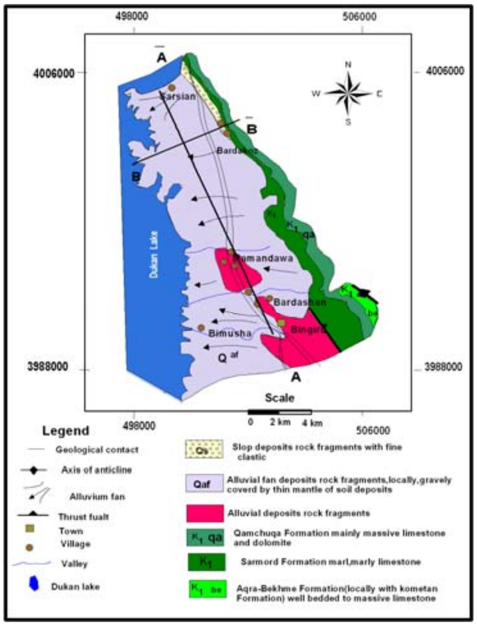

Fig (2) Geological map of the studied area modified by Sissakian

HYDROGEOLOGY

The Quaternary deposits which cover the majority of the study area are composed of alluvial fans, polysengenetic valley fillings and river terraces. It forms medium to highly productive Intergranular aquifer. The most favorable hydrogeological conditions are connected with the Plio –Pleistocene formation. In the northern part of the area the series of layer of sand, conglomerates and gravels is saturated with water below the depth of 25–70 m (depending on the season) forming an aquifer of unconfined character. Fluctuation of water table is influenced by the draining activity of Dokan Reservoir.

In the middle southern part of the area the alluvial deposits contain numerous coarse–grained layers forming an aquifer of confined or / and semi-confined character of static water level at 10-30 m below ground surface. This aquifer is characterized by much differentiated hydrogeological conditions caused by lithological alternation as well as by various permeability of coarse–grained layers resulting from the content of the loamy fraction, Fig.3. The majority of drilled wells benefit from the water of this aquifer which is exploited for different purposes like domestic, livestock and agriculture.

There are 50 water wells which are drilled at the northern part of the area for the purpose of irrigation. Most of the aquifers penetrated by these wells are unconfined; The estimated thickness of this unit is more than 140 m and varies from site to another. The existing drilled wells deriving water from the Plio–Pleistocene Formation (Quaternary) have yield of 3-16 l/s.

Flow net map was constructed from the collected data in (October 2009), Fig. (4), for Quaternary aquifer, which shows that the groundwater level in the northeast and southeastern side area is high while the low groundwater level occurs in the middle and south-southwest side of the area (near Dokan Lake). This means that groundwater moves from northeast to southwest toward the Dokan Lake, so it flows in the same direction as regional groundwater flow.

Flow net map of the Quaternary aquifer for the studied area showed two zones of flow net, the space between contour line in the north area is wide in comparison to the middle and southern part of the area which is much stepper and the water table elevation for the north zone is lower than the southeastern zone, accordingly two types of aquifers supposed to exist.

Pumping tests and hydraulic properties of the Quaternary aquifer

Physical properties from single well test could be found especially when observation wells are absent (Kruseman and de Ridder, 1994; Dellur, 1999; Schaaf, 2004).This method was used by many Iraqi and international researchers like Chnaray, (2003), and Schaaf, (2004).

The single well pumping test data are available for 50 wells drilled within the Quaternary (intergranular) aquifer in the studied area that are obtained from Sulaimani groundwater directory. These data were introduced to (AQTESOLV 4. 1, and Aquifer$_{win32}$ version 3.0 software to calculate hydraulic properties of the aquifer.

The result of transmissivity, hydraulic conductivity and Storage coefficient values is tabulated in tables (1) , (2) and (3). As it is clear from these tables, a very large variation could be seen in the transmissivity values for the intergranular aquifer. This is the result of regional and local hydrogeological conditions, variations of lithofacies, saturated thickness, and heterogeneity, though the effect of technical performance during drilling and testing cannot be neglected. In practical terms, the hydraulic losses and resistance of screen (intake) zones are sometimes very high as a result of improper well construction. Thus; presence of non-removed clayed components in the screen and gravel pack section and sometimes the intensive pumping rate can simulate clogging and significantly hinder well performance.

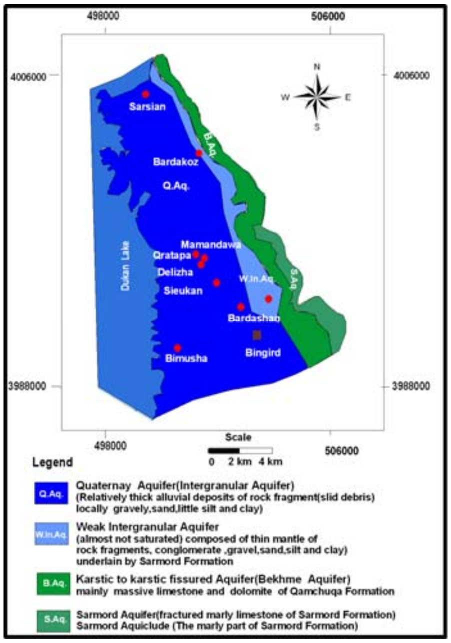

Fig. (3) Hydrostratigraphic map of the studied area

Construction model of Sarsian Quaternary aquifer

Northern part of Sarsian area (Quaternary aquifer) was selected for modeling, processing MODFLOW Pro (PMWIN) software was used for modeling, PMWIN Pro is a three-dimensional finite-difference groundwater flow model (Chiang and Kinzelbach, 2001; Chiang, 2005).

Conceptual model

The hydrogeologic system of the area is a single layer aquifer system. It is an unconfined aquifer, the Quaternary aquifer is approximately more than 140 m thick, recharge is distributed throughout the model domain based on lithological facies of the Quaternary aquifer, and the modeled area covers 56 km^2.

Spatial discretization

The domain of the study area is discretized with regular square cells of 200 m length. The cells are distributed in 100 rows and 66 columns in the E–W and N–S directions. The grid contains a total of 1290 active cells and the total model surface area is 51.6 km2.

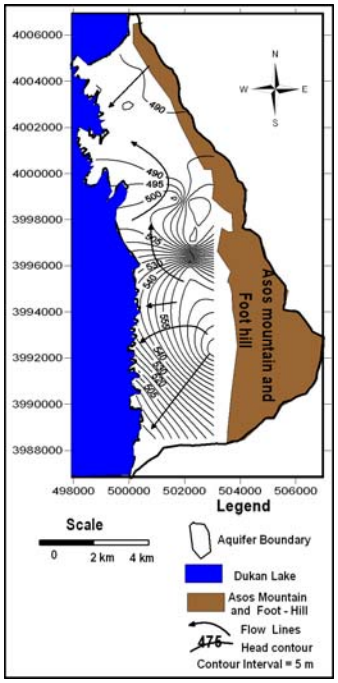

Fig. (4) Flow net of the intergranular aquifer in studied area.

Boundaries

Three types of boundary conditions are used in Sarsian groundwater flow model, specified head positive values (+1) in the I bound array define an active cells when expressing the domain inside. A (0) value defines inactive cells (no flow) taken place within the cells, I bound defines any outer flow boundary cells which are represented at the northeast and at the groundwater divided line in the southern part of the study area (direction of groundwater flow), while specific head conditions represented Dokan Lake were imposed along the west borders of the model are represented as a constant head (-1), Fig.(5).

Initial hydraulic head

In groundwater modeling, hydraulic heads vary as a function of time, they require to define the initial conditions for simulation achievement.

The initial conditions are the hydraulic heads distribution within time equals to zero; i.e. h= *f* (x, y. t = 0). Reflection of system state before the simulation starting is through initial conditions that are considered at the whole nodal cells either, internal or external, the water-level data for 22 wells were collected for the October of 2009 and 1 year monitored wells (5, 24, 33, and 41).

Parameter values-hydraulic conductivity

The hydraulic conductivity, transmissivity, and specific yield for the Quaternary aquifer were determined from previous aquifer test analyses from well tests of 17 wells. These values were used as initial parameter values for the model. The values were altered later through trial and error during calibration. Initial estimation of recharge was calculated using the precipitation data from the Dokan meteorological station located close to the studied area. The method of water balance was used for estimating recharge from precipitation data. The calculated values were used to provide initial values to the recharge zone.

Aquifer material properties

The top elevation and the bottom of the layer were also provided; the values for the top and bottom of the aquifer were derived from data sheet of the lithological column of 50 wells obtained from

Sulaimani Groundwater Directorate. Transmissivity is one of the input readings required in the model; the distribution of aquifer transmissivity was also prepared and the values were loaded to the model. Flow packages representing recharge (L/T) with positive values and wells (L^3/T) with negative values will be introduced to the transient model. Recharge is defined by assigning the data to each vertical column of cells.

Table (1): Transmissivity, specific yield and hydraulic conductivity values of some selected wells in Sarsian area (Northern part) aquifer

Well No.	Q (m^3/day)	s (m)	T. Depth (m)	Depth to SWL (m)	b (m)	Sc(Q/s) (m^2/day)	T (m^2/day)	Sy (b/1000)	K (m/day)
1	1055.8	1.05	140	34.2	105.8	1005.5	2434.5	0.105	23
5	1055.8	1.3	140	33.5	106.5	812.1	438.4	0.106	4.116
13	1123.2	1.5	149	32.8	116.2	748.8	567.5	0.116	4.88
16	1123.2	1.1	135	32	103	1021.1	477.7	0.103	4.64
22	1123.2	0.5	160	30.55	129.45	2246.4	2331.2	0.129	18.01
24	1055.8	0.7	160	36.8	123.2	1508.3	359.2	0.123	2.92
25	1149.1	2.1	140	38.2	101.8	547.2	177.9	0.101	1.75
27	1149.1	1.7	140	37.9	102.1	675.9	101.4	0.102	1
33	1149.1	0.65	140	37.6	102.4	1767.8	406.7	0.102	3.97
41	1010.9	4.25	130	70	60	237.8	128.27	0.06	2.14
43	1042	1.3	140	48.85	91.15	463.1	3539	0.091	38.8
47	689.5	18.8	150	35	115	36.67	16.1	0.115	0.14
48	678.2	14.1	130	53.4	76.6	48.1	20.7	0.076	0.27
50	311	9	130	53.85	76.15	34.5	48.44	0.076	0.63
Min							16.1	0.06	0.14
Max							3539	0.129	38.8
Median							382.95	0.1	3.445

Table (2): Hydrogeological data and hydraulic parameters of some selected wells in Sarsian area (middle southern) aquifer (confined or semi- confined aquifer)

Well No.	Q (m^3/day)	s (m)	T. Depth (m)	Depth to SWL (m)	b (m)	Sc(Q/s) (m^2/day)	T (m^2/day)	S	K (m/day)
Qaratapa	633.3	52	152.5	8	144.5	12.17	5.44	4.56 * 10^{-6}	3.7 * 10^{-2}
Bardashan Saroo	751.68	47.2	200	over flow	200	15.9	4.61	1 * 10^{-5}	2 *10^{-2}

The input parameters are assumed to be constant during a given stress period, negative values indicate pumping wells; MODFLOW assumes that a well penetrates the full thickness of the cell (Chiang, 2005). To calculate the heads in each cell in finite difference grid PROCESSING MODFLOW (PMWIN PRO) prepares one finite difference equation for each cell, expressing the relationship between the head at a node and the heads at each of the eight adjacent nodes at the end of time step. Strongly Implicit procedure (SIP) package is used to solve the system of finite difference equation.

Table (3): Results of pumping test analyses of northern part aquifer (Unconfined Alluvium Aquifer)

Wells No.	Q. l/sec	Depth (m)	b satur. thickness	SWL (m)	DWL (m)	Pump. Time (min)	Draw Downs (m)	Time of Recovery (min)
1	12.22	140	105.8	34.2	35.25	600	1.05	2.5
5	12.22	140	106.5	33.5	34.8	600	1.3	2.5
13	13	149	116.2	32.8	34.3	600	1.5	2.5
16	13	135	103	32	33.1	600	1.1	3
22	13	160	129.4	30.55	31.05	600	0.5	3
25	13.3	140	101.8	38.2	40.3	600	2.1	4.5
27	13.3	140	102.1	37.9	39.60	600	1.7	6
33	13.3	140	102.4	37.6	38.25	600	0.65	3
41	11.7	130	60	70	74.25	600	4.25	6
43	12.06	140	91.1	48.85	50.15	600	2.25	4
47	7.98	150	115	35	53.8	600	18.8	50
48	7.85	130	76.6	53.4	67.5	600	14.1	30
50	3.6	130	76.1	53.85	62.85	600	9	70

Water budget

A summary of water budget is all inflows and outflows to a region, inputs of water to the Quaternary aquifer include direct recharge from water surplus, subsurface flow from the surrounding carbonate aquifers, the outputs include pumping for irrigation and residential use, discharge through flow cell assigned to represent pumping well. Recharge was distributed throughout the study area to account for the recharge value reported in the water budget.

RESULTS AND DISCUSSION

Groundwater flow simulation

Simulation is performed in both steady and transient states. The steady-state simulation is based on lower groundwater level (October 2009). The aim of this simulation is to calibrate the model by adjusting the spatial distribution of the hydraulic conductivity and recharge.

The transient simulation, based on the calibration obtained in steady-state simulation, aims at simulating the evolution vs. time of the groundwater flow of the aquifer. The piezometric maps of the lower groundwater level (October 2009) were complied. It is assumed that the period corresponds to the steady-state condition of the water table.

A Calibration of the numerical model during the period of lower groundwater level

The groundwater levels were only monitored from October 2009– October 2010. The water levels measured in October 2009 were used as a basis to represent the observed groundwater levels. Additionally, this period also correspond to the beginning of the groundwater level monitoring. Model calibration was done by a trial-and error process during which initial estimates of model parameters were adjusted until a satisfactory match between observed and simulated groundwater level was achieved, in a first step, the model was calibrated by changing both the hydraulic conductivity and the recharge during lower groundwater level period in October 2009, however, produced acceptable matches between the observed and the calculated (simulated) groundwater levels, fig.5 (Dokan Lake level 482.5 m a. s. l).

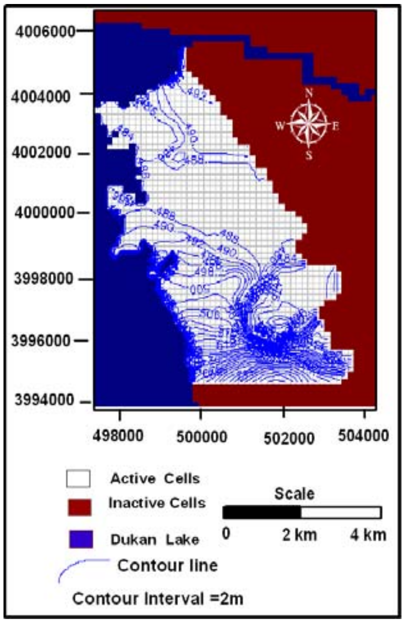

Fig.(5) calibrating the steady state model during lower groundwater level period (October) Dokan lake reservoir level 482.5 m a. s. l.

A qualitative analysis of the map indicates that the simulated and the observed piezometric contours display the same pattern. The hydraulic gradients obtained from the simulated piezometry are similar to those of the observed piezometry in the whole study area.

The steady-state model calibration was carried out to minimize the difference between the simulated and observed groundwater level of the 20 bores distributed over the study area. Table (4) shows a reasonably good match between the simulated and observed heads in most of the boreholes of the study area.

Table (4): Correlation between observed head and calculated head (m.a.s.l.) during lower groundwater level period in October 2009.

Name of well code	Observed head m.a.s.l	Calculated head m.a.s.l
1	484.5	484.7
5	487.6	487.59
6	484.5	484.9
10	485.5	486
13	492.44	491
16	487.3	487.7
20	492.4	492.11
22	489.9	490.8
24	491.3	491.2
25	488	487.8
27	486.2	487.6
30	486	487
32	491.6	490
33	489.6	488
39	484	484
41	471.86	474.8
42	485.8	485
43	484	485
46	473	473.2
49	488.8	487

Table (5): The slight variation between simulated and observed heads with 10 hours pumping for some selected wells

Name of well code	Observed head m.a.s.l	Calculated head m.a.s.l	Ratio of observed drawdown
1	483.41	483.7	1.09
5	486.3	486.3	1.3
6	483.5	484.1	1
10	484.8	485.3	0.7
13	491.	489.6	1.5
16	486.3	486.9	1
20	491.6	491.3	0.8
22	489.4	490.3	0.5
24	490.7	490.4	0.7
33	489.	487.4	0.65
41	467.86	472.5	4

Verification

A model is verified "if its accuracy and predictive capability have been proven to lie within acceptable limits of error by tests independent of the calibration data" (Anderson and Woessner, 1992, Todd, 2005). A typical verification is performed for an additional field data set in either steady state or transient simulation.

It is worthy to mention here that the verification of the model was done for April, i.e. after six months of the model construction, when Dokan reservoir level was at elevation of 494 m a.s.l. as shown in Fig. (6) and the table below:

Table (6): The verification data of the observed and calculated heads when Dokan Reservoir was at 494m elevation.

Name of well code	Observed head m.a.s.l	Calculated head m.a.s.l	Node k,j,i
5	494.77	494.4	1,15,11
24	495.2	495.08	1,23,24
33	494.9	494.88	1,27,25
41	495.05	595.2	1,46.34

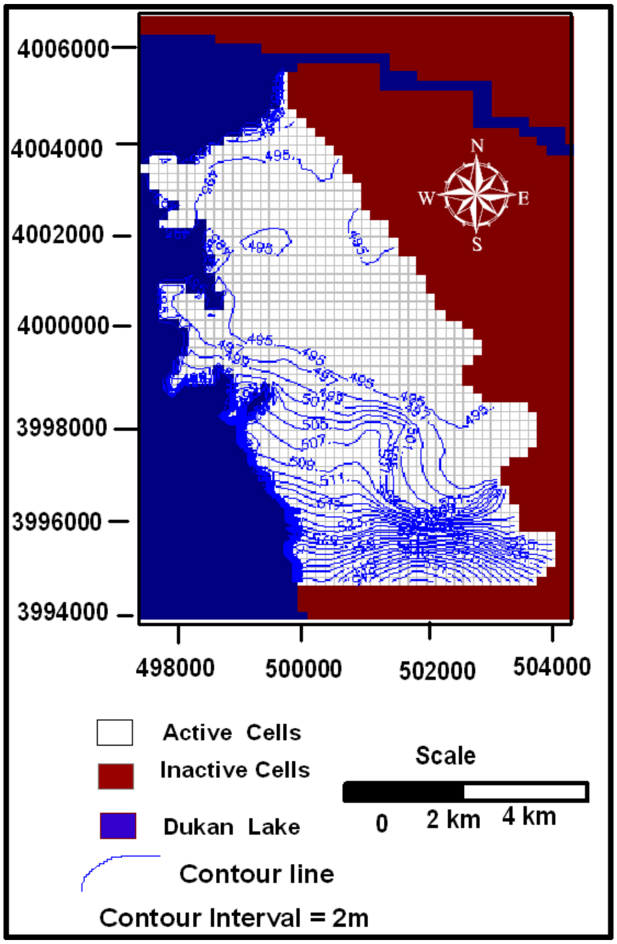

Fig. (6) Verification model after six months (construction in October)

Water budget procedure

A water budget provides an indication of the overall acceptability of the solution, the difference between total inflow and total outflow should equal the total change in storage. In the model program the volumes of water entering and leaving the model during the time step are calculated as the product of flow rate and time step length.

PMWIN pro calculates water budget for each sub region in each time step, the percent of discrepancy is calculated. In this step (steady state simulation) the percent discrepancy was 0.02 % this means that the model equation has been correctly solved, this agrees with what is mentioned in the literature requiring that the mass balance for any time step in a model should have less than a 1% discrepancy (Harbaugh, 2005).

Predictive simulation

A model may be used to predict future groundwater flow conditions, such simulation estimates the hydraulic response of an aquifer, and it also can predict the pumping rate needed to monitor the hydraulic heads.

A pumping (groundwater management) strategy is a set of spatially and possibly temporary distributed rates of extracting water from aquifers. The 50 drilled wells that disturbed in the northern part are not exploited yet.

Sensitivity analysis

A sensitivity analysis was used to examine the response of the numerical model calibrated to steady state conditions to changes in model parameters including horizontal hydraulic conductivity, recharge, and pumpage, which were increased and decreased for the sensitivity analysis. In steady state the model was most sensitive to recharge and relatively less sensitive to horizontal hydraulic conductivity. Sensitivity analysis of transient flow model is accomplished by specific yield parameters. Finally, the model was used to simulate the response of aquifer to different scenarios.

Simulation scenarios

The model was run for six future scenarios of groundwater level. Three scenarios of Dokan Lake stage were simulated, and three stress periods of transient were simulated with different volumes of extraction per day. The lake stage data were obtained from the Dokan Dam Directorate.

A Simulation without pumping

The time for one year simulation without sinks (wells) is divided into 2 period lengths, one for wet period represented by 150 days while the other one for dry period represented by 210 days. Twelve stress periods, each stress period represents a month, while the period length of each stress period is divided into days, so the total time step is equal to 12 months, while the total simulation time is equal to 365 days. The model output as a monthly flow map depends on the variation groundwater recharge.

1. The model run was specified to simulate a period of steady-state conditions with no pumpage followed by a transient state as the minimum stage of the lake which is at 482.5 m a.s.l., see Fig. (7).
2. The second was during the period of higher groundwater level in a month (June 2010) when the stage of the Dokan Lake is set at 494 m a.s.l., see Fig. (8).
3. The third was set as the maximum stage of the lake which is at 511 m a.s.l., see Fig. (9).

Simulation with pumping

A scenario is applied for simulation when the 50 wells are pumping at the same time with a constant uniform discharge during irrigation period.

The transient period is simulated with three stress periods: A) pumpage to 1000 m^3 /day, B) pumpage to 2000 m^3 /day, C) pumpage to 3000 m^3 /day, Figs (10,11,12), and Table (7).

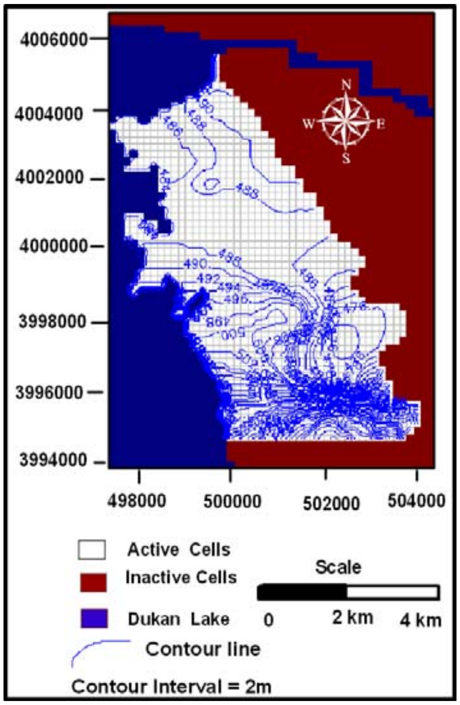

Fig. (7) Model run is specified to simulate a period of steady-state conditions with no pumpage followed by a transient state as the minimum stage of the lake which is at 482.5 m a. s.l.

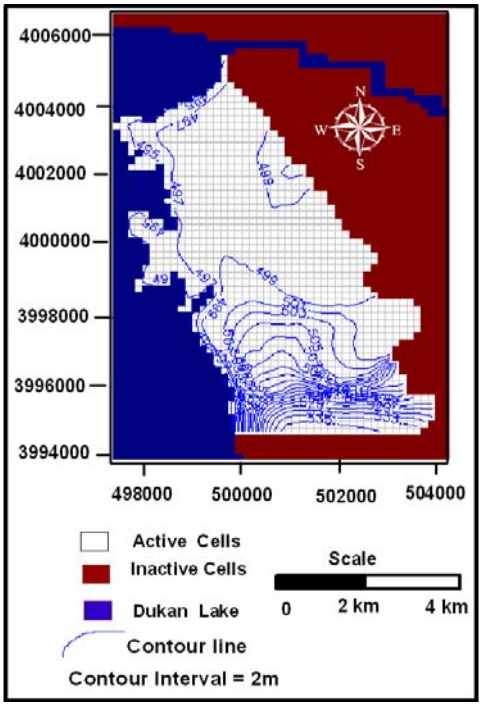

Fig. (8) The second was during the period of higher groundwater level in a month (June 2010) when the stage of the Dokan Lake is set at 494 m a. s. l.

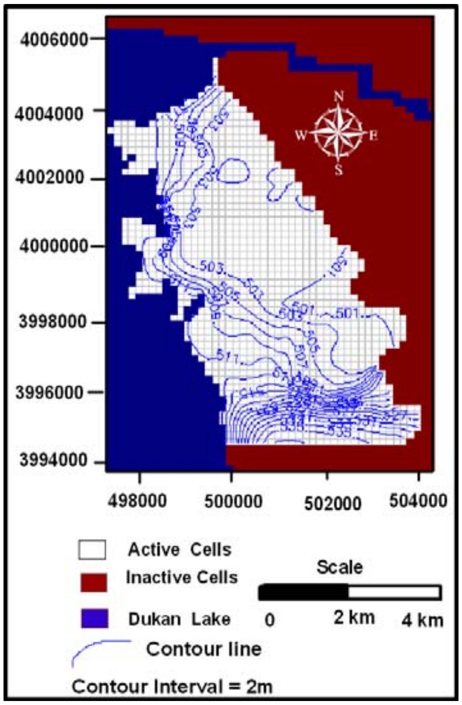

Fig. (9) Calculated hydraulic heads at June simulation (Dokan Lake stage at 511 m a. s. l.)

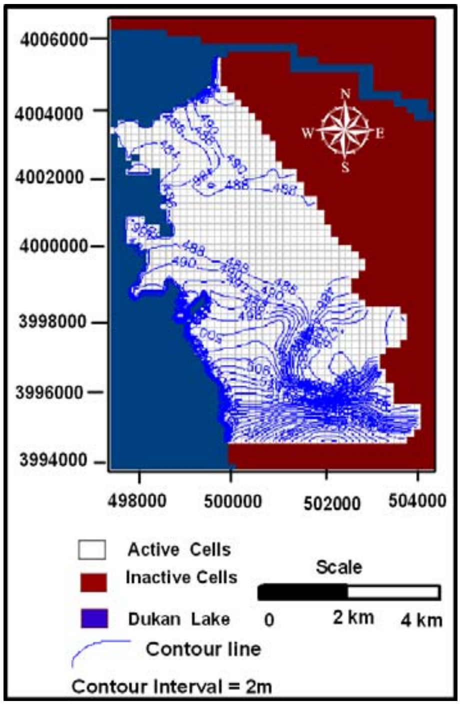

Fig.10 Results of water level changes in response of hypothetical scenario abstraction A) pumpage to 1000 m^3 /day,

Table (7) Results of water level change in response of hypothetical scenario abstraction

Well	Node	Pre Scenario	Scenario A	Change	Scenario B	Change	Scenario C	Change
No.	k,j,i	W.L	W.L	W.L	W.L	W.L	W.L	W.L
1	1,20,7	484.4	483.4	1	482.45	1.95	481.48	2.92
2	1,19,9	484.96	483.4	1.56	481.85	3.11	480.26	4.7
3	1,17,10	486.4	485.64	0.76	483.84	2.56	484	2.4
4	1,16,11	487.5	486.7	0.8	485.9	1.6	485.1	2.4
5	1,15,11	487.57	486.7	0.87	486	1.57	485.2	2.37
6	1,22,10	484.758	483.2	1.5575	481.6	3.1575	479.97	4.7875
7	1,21,12	485.25	484	1.25	482.75	2.5	481.48	3.77
8	1,19,13	486.81	484.77	2.04	482.7	4.11	480.6	6.21
9	1,17,14	490.06	489.6	0.46	489.2	0.86	488.7	1.36
10	1,23,13	486.17	484.65	1.52	483.1	3.07	481.5	4.67
11	1,21,13	485.4	485	0.4	484.6	0.8	484.18	1.22
12	1,20,14	486.33	484.8	1.53	483.2	3.13	481.7	4.63
13	1,25,15	490.86	489	1.86	487.27	3.59	485.46	5.4
14	1,24,15	490.16	489.18	0.98	488.2	1.96	487.29	2.87
15	1,21,16	488.09	487.58	0.51	487	1.09	486.48	1.61
16	1,27,15	488.1	486.97	1.13	485.82	2.28	484.65	3.45
17	1,24,17	489.94	489.3	0.64	488.7	1.24	488.18	1.76
18	1,16,16	491.5	489.7	1.8	487.9	3.6	486.1	5.4
19	1,16,15	490.93	489.87	1.06	488.8	2.13	487.7	3.23
20	1,14,16	492.1	491.38	0.72	490.6	1.5	489.87	2.23
21	1,15,18	492.17	490.6	1.57	489.1	3.07	487.5	4.67
22	1,17,18	491.857	490.26	1.597	488.65	3.207	487	4.857
23	1,21,21	491.33	490.16	1.17	488.96	2.37	487.7	3.63
24	1,23,24	491.226	490.19	1.036	489.9	1.326	487.98	3.246
25	1,32,26	487.55	486.56	0.99	485.56	1.99	484.5	3.05
26	1,35,26	487.54	485.5	2.04	485.45	2.09	484.39	3.15
27	1,36,28	487.234	486.13	1.104	485	2.234	483.86	3.374
28	1,38,27	487.364	486.25	1.114	485	2.364	483.79	3.574
29	1,39,26	487.734	486.6	1.134	485.35	2.384	484.1	3.634
30	1,40,28	487.342	486.08	1.262	484.69	2.652	483.33	4.012
31	1,38,29	486.9	486.5	0.4	486.25	0.65	485.9	1
32	1,39,31	486.25	484.9	1.35	483.83	2.42	482.5	3.75
33	1,27,25	488.39	487.68	0.71	486.9	1.49	486.2	2.19
34	1,42,32	484.607	484.17	0.437	483.7	0.907	483.29	1.317
35	1,43,29	487.96	486	1.96	484.1	3.86	482.18	5.78
36	1,46,28	491.14	488.2	2.94	485.3	5.84	482.3	8.84
37	1,45,33	480.14	478.28	1.86	476.1	4.04	473.8	6.34
38	1,49,32	479.36	475.68	3.68	475.5	3.86	475.3	4.06
39	1,48,28	483.92	481.8	2.12	480.1	3.82	478.4	5.52
40	1,47,31	477.733	476.9	0.833	475.56	2.173	474.1	3.633
41	1,46,34	478.736	475.7	3.036	472.55	6.186	469.3	9.436
42	1,50,31	474.9	472.8	2.1	469.3	5.6	466.4	8.5
43	1,46,29	485.26	482.88	2.38	480.2	5.06	477.7	7.56
44	1,50,32	474.5	472.2	2.3	468.75	5.75	465.7	8.8
45	1,51,32	472.26	469.47	2.79	466.6	5.66	463.6	8.66
46	1,51,35	473.5	471.34	2.16	469.2	4.3	467.08	6.42
47	1,55,33	481.54	478.6	2.94	479.8	1.74	479.69	1.85
48	1,54,33	479.37	477.1	2.27	474.7	4.67	473.2	6.17
49	1,55,31	483.87	479.9	3.97	479.7	4.17	479.6	4.27
50	1,54,34	482.4	480.05	2.35	477.67	4.73	475.2	7.2

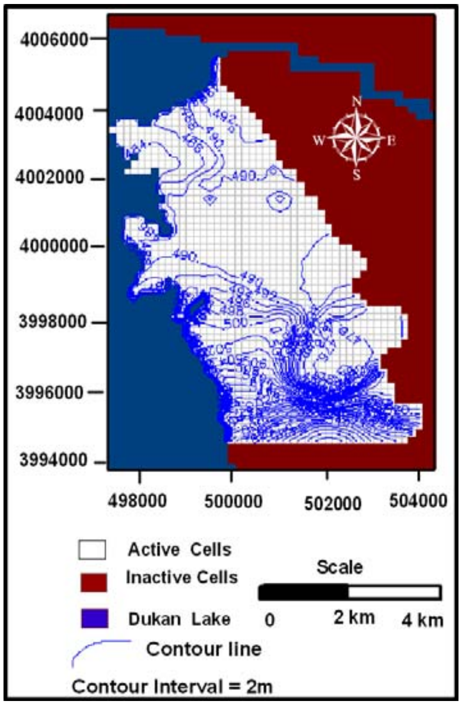

Fig.11 Results of water level changes in response of hypothetical scenario abstraction B) pumpage to 2000 m^3 /day

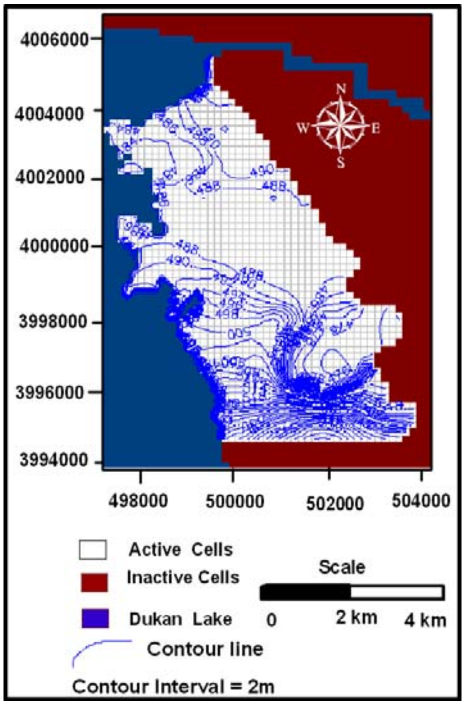

Fig. 12 Results of water level changes in response of hypothetical scenario abstraction C/ pumpage to 3000 m^3 /day.

Conclusion

1- The shape of simulated and the observed piezometric contours displays the same pattern and the same flow direction.
2- The calibration of the steady state of the model showed that recharge is more effective and sensitive than hydraulic conductivities.
3- For the transient calibration model, it was found that the maximum drawdown with pumping for the period of 10 hours was 0.5m and 4 m.
4- Using MODFLOW, a groundwater flow model is constructed and three different scenarios are introduced to predict the influence of 1day pumping for the 50 wells at the same time during the maximum demand days of the year and in three stress periods. A) pumpage to 1000 m^3 /day B) pumpage to 2000 m^3 /day , C) pumpage to 3000 m^3 /day. It was concluded that the drawdown of water table ranges between 0.4-3.97m, 0.65-6.18m, and 1-9.43m respectively.
5- The results showed that there is a significance effect of Dokan Lake level on the groundwater head elevation near the lake.

Reference

Al Manmi, D. A., (2008): Water resources management in Rania area, Sulaimaniyah NE-Iraq. Unpublished ph.D. thesis, University of Baghdad, 225p.

Anderson, M.P. and Woessner, W.W., (1992): Applied groundwater modeling: Simulation of flow and advective transport. Academic press, San Diego.381p.

Buday, T. and Jassim, S.Z. (1987): The Regional geology of Iraq .Vol. II: Tectonism, Magmatism, and Metamorphism. 352 P.

Chiang, W.H., and Kinzelbach, W. (2003): Modflow a computer program for groundwater flow and pollution.

Chiang, W.H. (2005): 3D–Groundwater modeling with PMWIN, A simulation system for modeling groundwater flow and transport processes 2nd edition, Springer Berlin Heidelberg, 414 p.

Chnaray M.A.H.(2003): Hydrogeology and hydrochemistry of Kapran basin, Erbil, N– of Iraq, Unpublished PhD. Thesis, College of Science, University of Baghdad, Iraq.172p.

Dellur, J. W, (1999): The hand book of groundwater engineering Purdue University, West Lafayette, Indian, 940 P.

Harbaugh, Arlen W., (2005): Modflow-2005, the U.S. geological survey modular ground-water model the ground-water flow process, techniques and methods 6-A16.U S. geological survey, 206 p.

Jassim, S. Z., and Goff. J. C (eds.), (2006): Geology of Iraq. Dolin , Prague and Moravian Museum .Brno 341P.

Kruseman, G . P. and de Ridder, N.A., (1994): Analysis and evaluation of pumping test data. International institute for land reclamation and imporovement, Wageningen, the Netherlands, 377 P.

Schaaf, S.V., (2004): A single well pumping and recovery test to measure in Situ Acrotelm Transmissivity in Raised Bogs. Journal of hydrology, Vol 290: pp. 152-160.

Todd, D.K. (2005): Groundwater hydrology *(3rd edition)*. John Wiley and Sons, New York, USA, 650 P.