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Simulation and Assessment of Groundwater for Domestic and Irrigation Uses

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Abstract

The alluvial fan of Mandali located between latitude 30˚45'00" N longitude 45˚30'00" E in east of Diyala Governorate, Iraq. Thirty-five wells were identified in the study area with average depth of 84 m and estimated area of 21550 ha. A three-dimensional conceptual model was prepared by using GMS program. From wells cross sections, four geological layers have been identified. The hydraulic conductivity of these layers was calculated for steady state condition, where the water levels for nine wells distributed over the study area were observed at same time. Afterward, PEST facility in the GMS was used to estimate the aquifer hydraulic characteristics. Other characteristics such as storage coefficient and specific yield have been determined from one year field observations that were collected by General Authority of Groundwater, Diyala Governorate. Also, the observations were used for calibration of unsteady state model. Then wells were hypothetically redistributed and increased to 103 wells, assuming a distance of 1500 m between the wells, a well productivity rate of were 7 l/s, annual rainfall rate was used for recharging. Three different wells operating times were suggested and these 6, 12, and 18 hr/day with total discharge of 150, 300, 450 m^3/day and maximum drawdown of 7, 11, and 20 m respectively. For water quality assessment, the collected groundwater samples were analysed at the laboratory. Results showed that the TDS in all wells was ranged from 1000-3000 mg/l but TDS in well number 18 was exceeded 3000 mg/l which indicate that the groundwater in this well is not recommended to be used for irrigation. According to Iraqi standard for drink (IQS 2009), it can be used for drinking if saline treatment units were provided.

Keywords: Groundwater; Mandali Basin; Hydro-chemical Properties.

1. Introduction

Water being one of the necessities for life, the human through history has striven to locate and develop it. Over 90% of freshwater available at any time on the earth lies under the land surface [1]. Groundwater reverse surface water, is available in some quantity almost everywhere that man can settle in, is more stable in periods of drought, and has many other advantages over surface water. Groundwater can be used for drinking, irrigation, industries and municipalities.

The lack of surface water due to climatic change and construction of dams on the water sources in the riparian countries increases the importance of groundwater as an alternative source. Therefore, it is requiring knowledge and study on groundwater at the above areas in order to control and organize usage, as well as to define the quality and indicate the suitability for domestic, irrigation and industrial purposes [2]. Lately, software has been developed as hydraulics modelling to simulate groundwater flow, which gives ~~a~~ better idea on ~~of~~ the nature of groundwater usage [3].

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The Mandali city located between latitude 30˚45'00" N and longitude 45˚30'00" E, at the eastern of Diyala Governorate, near the Iranian border as shown in Figure 1, the city suffered from a lack of surface water sources. The population and agriculture in this city have been influenced by surface water deficit and started using groundwater as an alternative source. Many wells have been driller randomly in these areas, also the use of groundwater is not ideal, so it is necessary to study the characteristics of groundwater in this city and created conceptual model by using GMS software [4].

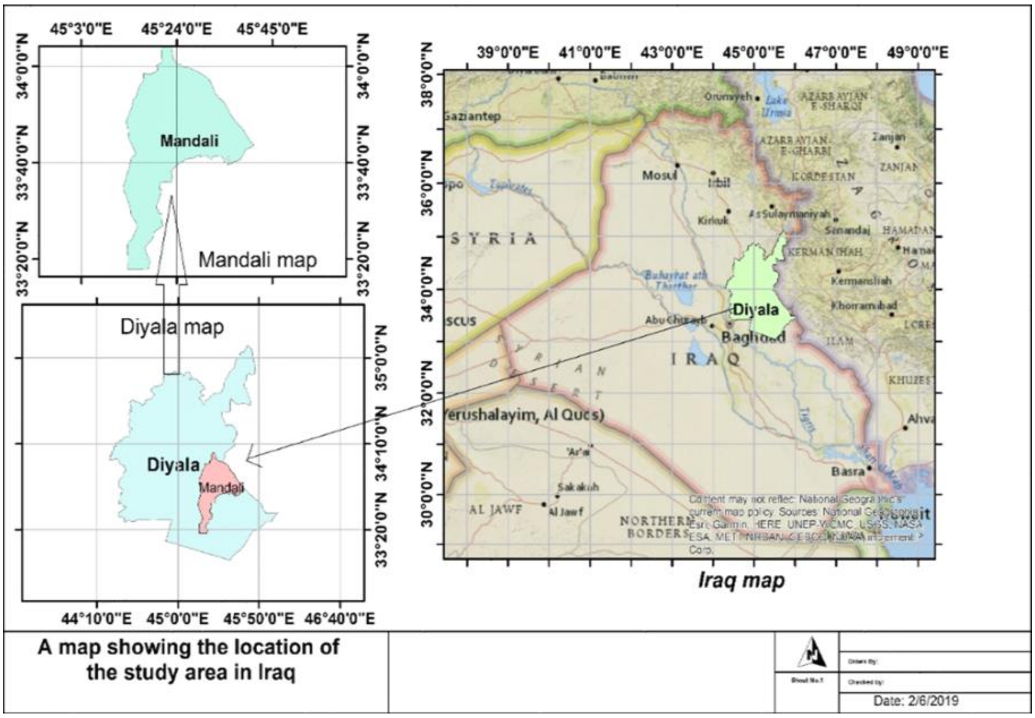

Figure 1. Exact location of the study area (Mandali City)

The area of the study is determined by the border of the alluvial fan, which includes both the center cities of Mandali and Qazaniyah as showing in Figure 2.

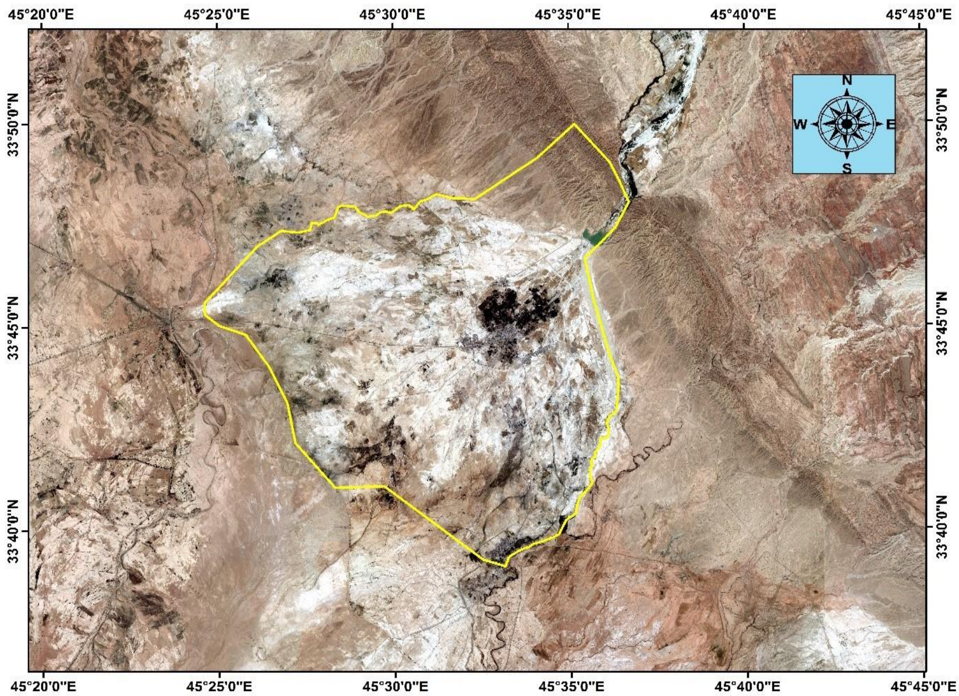

Figure 2. Mandali alluvial fan

The objectives of the present research are to constructed a conceptual model for the Mandali alluvial fan, then determine the hydraulic properties of aquifers of the study area by using (GIS & GMS) software [5]. Then define the best distribution of wells. However, it also includes qualitative evaluation for the groundwater for various uses such as domestic, irrigation and others.

2. Research Methodology

The research methodology consists of collecting data for 31 wells drilled at the study area, represented by the location of wells, their depths, and groundwater levels, and the physical and chemical characteristics of groundwater and these were presented using GIS program including the alluvial fan boundaries borrowed from the satellite maps. The data was exported as shapefile in the GMS program. From wells cross sections the longitudinal section of the soil can be create then building MODFLOW, the surface of MODFLOW was editing with (DIM) map for study area. The conductivity of soil layers was determined at the steady state and the storage coefficient and Specific Yield would be determined at the unsteady state by using PEST package. The following steps demonstrate the process of creating a conceptual model step by step:

- Insert the wells data as tables in Excel program, this tables includes the coordinates of the wells and all the geometry data for wells. then import this data in GIS program
- Import the geological maps of the study area then make a georeferenced for this map and match them with the satellite map in GIS software.
- Determination and drawing the border of the study area.
- From available report of wells using cross section to prepare tables as text file including the layers of soil and thickness.
- Open a new project in the GMS program with a definition of the coordinate system and units.
- Import all tables, map and shapefiles that was created in previous steps in GMS program.
- Created borehole data from table in step 4 then create cross-sections between boreholes.
- From digital elevation map (DEM) for study area can be created surface grid (TIN).
- Edit surface of cross-section by snapping with surface net (TIN).
- Generating solid data from cross-section for study area (generating aquifer).
- Create conceptual model then from it can be generating boundary layer, sink and source layer, recharge layer, and observation layer.
- From GIS data can be define the layers in conceptual model.
- The establishment of a three-dimensional grid covering all solid formation of the study area, the distance between line in X and Y axis are 100 m and create five layers in Z axis.
- Create MODFLOW model then active steady state in zone of model type and estimate parameter in PEST package.
- It is necessary to inactivate the cells outside the model domain in three-dimensional grid.
- Interpolating the data in solid model and conceptual model with MODFLOW model, then enter the initial estimated value for hydraulic conductivity of soil layers with determine range (min & max).
- Define starting head from record of water table to observation wells was taken at same time.
- Run the MODFLOW model and after several cycles the hydraulic conductivity value will be stabilized and the simulated water table for the observation wells are close to the recorded values.
- The hydraulic conductivity values of the aquifers are then stabilized and the model converted from the steady state to the transient state with the inclusion of all the required data.
- Repeat step 18 to obtain the storage coefficient, and specific yield values for aquifers.
- Finally, the results are compared with the recorded values of observation well, then the model is ready for simulation.

Figure 3 illustrates the flowchart of the simulation model.

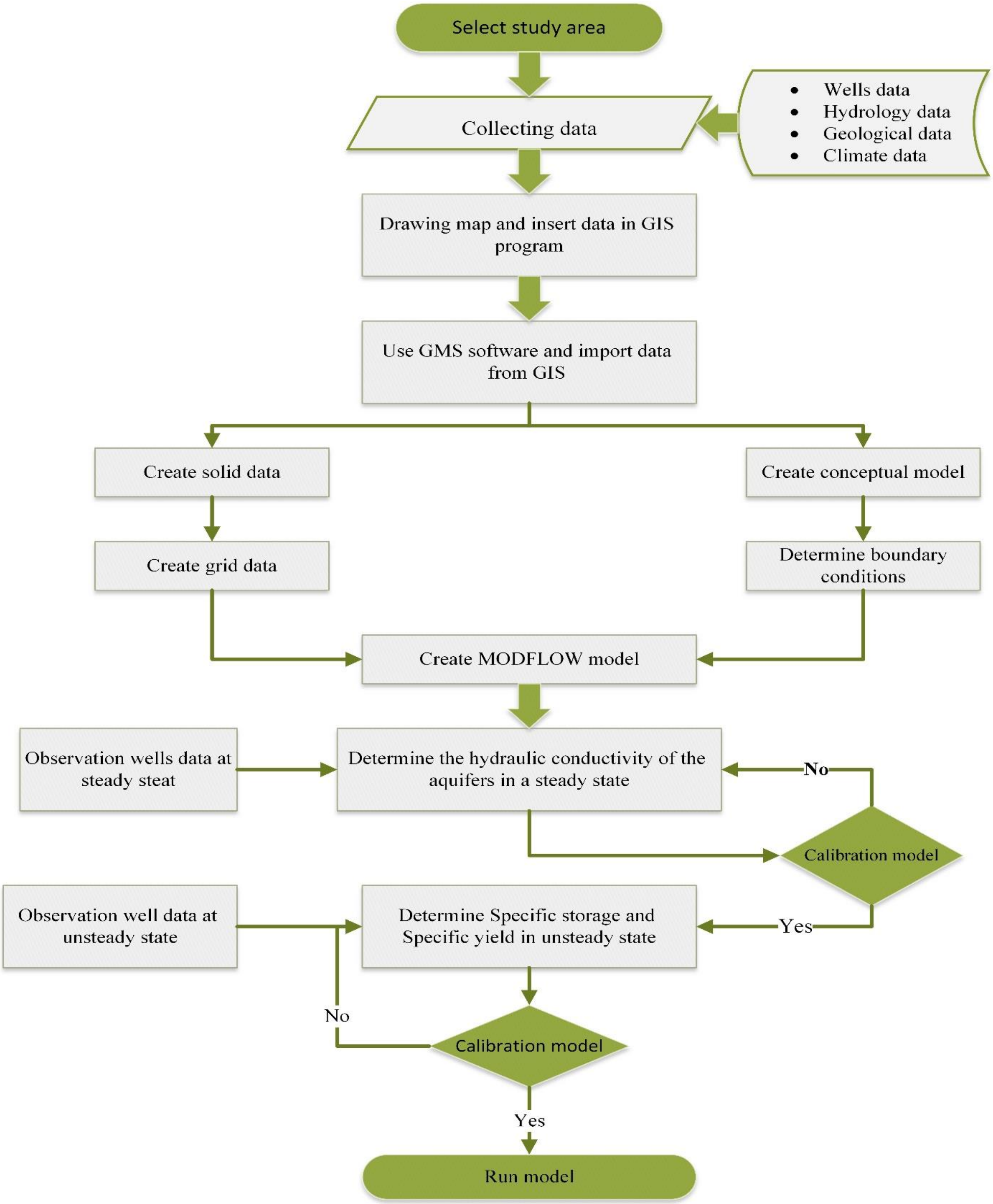

Figure 3. Flowchart of the simulation model

3. Data of the Study Area

The following data were gathered and used as inputs for the simulation model.

3.1. Geological Information for the Study Area

The geological formations in the study area are Muqdadiyha (Lower Bakhtiari). It consists of sandstone, silt and Claystone beds. This type of formation is for confined aquifer. It is a visible on the surface in the high northeastern of alluvial fan and extend into the lower layers of the study area [6, 7]. Above the Muqdadiyha layer, the alluvial fan was form and it considered one of the modern formations resulting from the flow of water in the flood seasons of Wadi Harran. The fan was composed of several layers formed from coarse materials such as gravel and sand deposits in high discharges of the flood in the lower layers, and then the fine sediments above that layer to form a higher layer with low permeability in the low discharge as shown in Figure 4 below.

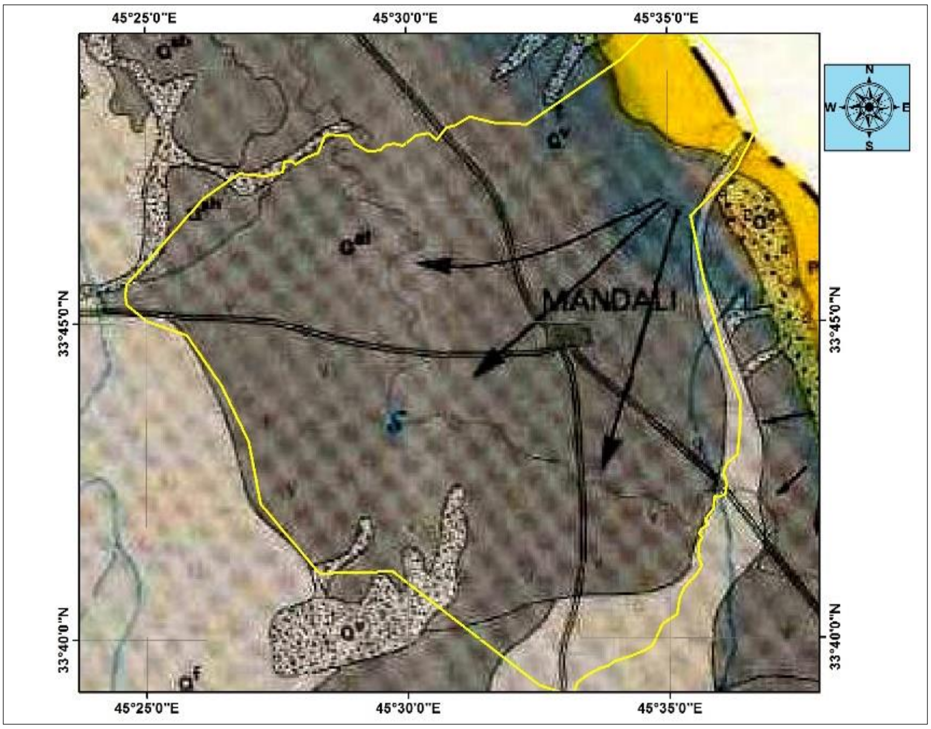

Figure 4. Geological map of study area

3.2. Climatological Information for the Study Area

Rain is one of the most important sources of recharge for groundwater in dry areas where there are no water bodies or other sources of surface water. The climate of the study area is generally hot and dry in summer, cold and rainy in winter, the rainfall is between 100-300 mm per year, as shown in the Table 1

Table 1. Average of rainfall in Mandali City

Year	Rainfall (mm)												Total
	Month												
	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
2010	41	36	26	36	42	0	0	0	0	0	6	26	213
2011	82	0	0	0	13	0	0	0	0	34	1	1	131
2012	3	35	36	4	0	0	0	0	0	0	146	43	267
2013	30	24	0	0	30	0	0	0	0	0	69	28	181
2014	20	31	4	4	0	0	0	0	0	10	14	6	89
2015	3	24	0	0	0	0	0	0	0	141	68	25	261
2016	18	34	95	95	0	0	0	0	0	0	0	23	265
2017	24	14	19	19	0	0	0	0	0	14	10	0	100
2018	2	157	0	21	10	0	0	0	0	0	0	0	190

3.3. Topography of the Study Area

The study area is located between a mountainous area on the eastern side near the Iraqi-Iranian border and Al-Naft valley to the west. The level of the region is sloping from the northeast to the southwest, the average elevation of the ground surface ranges from 300 meter above the sea level at the east to 50 meter above the sea level at the west as shown in Figure5.

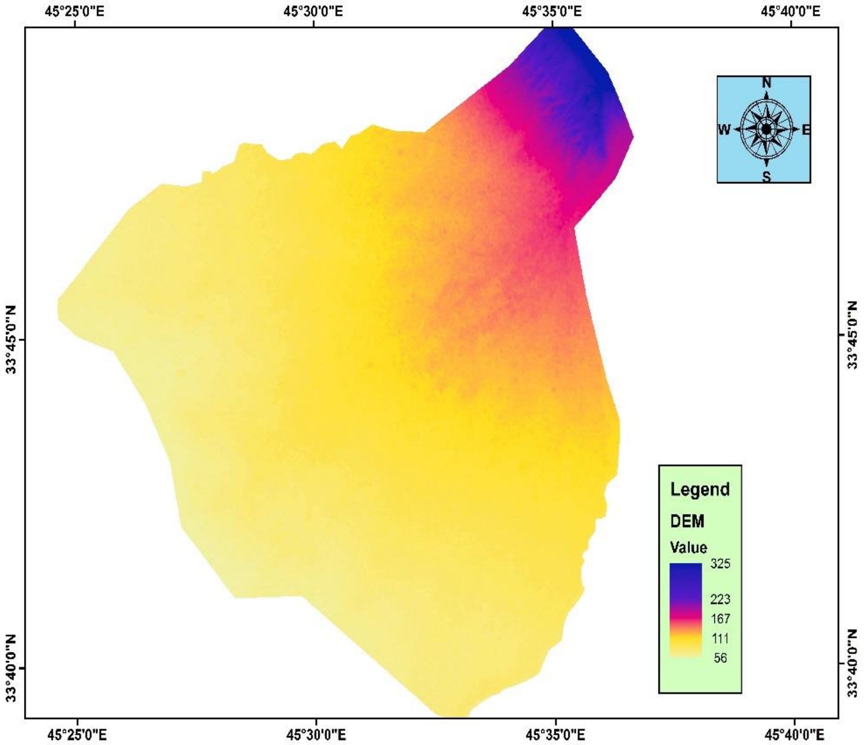

Figure 5. Topographic map of Mandali alluvial fan

3.4. Wells Data

The data of the wells can be dividing divided into two parts: firstly, the geometric data, including the coordinates, depth, water level, diameter and cross section of the wells shown Table 2. Secondly, groundwater quality data of the wells as shown in Table 3. The first part of data was used for studying the hydraulic properties of the aquifers and established a conceptual model using the GMS software and redistribution of wells in the study area. While the second part was used for assessing the water quality.

Table 2. Geometry data of wells

Name	X-CORDNET	Y-CORDNATE	Elevation	depth m	water level m	Q L/sec	dia.mm
W1	45.52441667	33.76694444	112	84	84	7	200
W2	45.49888889	33.73416667	97	72	82	5	200
W3	45.57222222	33.80805556	180	150	141	7	225
W4	45.56575	33.72383333	113	84	113	7	200
W5	45.56772222	33.73986111	123	84	96	7	200
W6	45.53761111	33.74305556	115	84	87	7	200
W7	45.55602778	33.75047222	130	84	98	7	200
W8	45.55416667	33.74644444	125	84	92	7	200
W9	45.57366667	33.76958333	154	90	154	6	200
W10	45.54988889	33.76916667	141.5	84	104.5	6	200
W11	45.55416667	33.75194444	138	90	103	7	200
W12	45.56630556	33.75944444	142.5	90	107.5	7	200
W13	45.55722222	33.76361111	134.3	90	98.3	7	200
W14	45.54944444	33.74972222	126.2	90	91.2	7	200
W15	45.56647222	33.7535	130	90	98	7	200
W16	45.57541667	33.73822222	132	90	97	6	200
W17	45.53638889	33.75333333	121.9	78	94.9	8	200
W18	45.49944444	33.73666667	94	78	67	6.5	200
W19	45.50222222	33.74861111	98	78	83	7	200

W20	45.48055556	33.69111111	62	42	62	6.5	200
W21	45.53527778	33.74138889	120	82	95	7	200
W22	45.47555556	33.74777778	71	38	71	6	200
W23	45.59	33.72722222	110	84	84	7	250
W24	45.58027778	33.725	111	81	86	7	200
W25	45.51888889	33.76472222	108	82	88	7	200
W26	45.49	33.71583333	75	84	50	7	200
W27	45.52666667	33.72083333	102	78	76	7	200
W28	45.5675	33.78222222	146	114	113	8	200
W29	45.56527778	33.68777778	89.5	78	89.5	7	200
W30	45.51333333	33.745	110	78	94	7	250
W31	45.53416667	33.76583333	113	78	90	7	250

Note; X, Y Coordinates in decimal degree, Q =Productivity of wells, and dia. = diameter of wells.

Table 3. Physical data of wells

Name	EC	TDS	PH	Ca	Mg	Na	K	Cl	Hco3	So4	No3
W1	1560	1190	7.2	88	67	78	7	185	66	288	1.9
W2	2020	–	–	–	–	–	–	–	–	–	–
W3	676	–	–	–	–	–	–	–	–	–	–
W4	1503	1149	7.31	95	42	203	4.1	190	168	390	0
W5	1965	1690	7.4	174	193	209	5	480	273	392	4
W6	1744	1265	7.14	86	43	192	2	390	96	270	1.4
W7	2380	1998	7.2	180	115	225	12	568	166	520	1.2
W8	2240	1490	7.15	168	75	191	5.2	335	240	471	0.4
W9	–	–	–	–	–	–	–	–	–	–	–
W10	1533	–	–	–	–	–	–	–	–	–	–
W11	1866	1692	7.12	150	93	180	8	427	155	413	2
W12	1518	1299	7.11	93	40	207	4.5	191	92	481	4.1
W13	1538	1400	7.21	102	140	258	9	358	79	451	1.5
W14	1775	1200	7.3	121	74	305	13	440	91	551	1.1
W15	1780	1300	7.25	128	89	137	11	249	61	556	4
W16	1606	1100	7.12	89	68	79	5	170	48	361	3
W17	1820	1500	7.81	38	21	248	6.1	160	194	307	4
W18	2860	3871	7.12	330	156	540	116	720	508	1294	5
W19	1647	1410	7.22	30	20	240	5	150	190	150	3.9
W20	1890	1327	7.21	128	89	139	9	249	61	583	5.1
W21	1597	1048	7.2	63	36	180	2.5	230	52	312	0.1
W22	1878	1327	7.21	128	89	139	9	249	61	583	6
W23	1277	1050	6.61	83	33	133	2	165	109	277	10
W24	1430	1300	7.67	128	87	132	15	242	67	552	7
W25	1223	983	7.32	80	52	130	3.4	256	61	52	2
W26	2410	1691	7.16	160	50	245	1.8	300	207	519	2.3
W27	1920	1358	7.22	130	82	95	2	155	63	580	2.5
W28	1503	1036	7.35	80	30	174	2	262	85	284	3.1
W29	1675	1110	7.6	92	67	110	5	200	97	378	2
W30	1811	1500	7.81	30	20	240	5	82	190	300	4
W31	1455	1290	7.91	129	88	138	10	248	60	248	5

4. Groundwater Flow Modelling

From the Darcy equation, the flow of the aquifers can be calculated by using finite difference method in GMS program

$$\frac{\partial}{\partial x}(K_x h\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y h\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z h\frac{\partial h}{\partial z})-w=Sy\frac{\partial h}{\partial t} \tag{1}$$

Where: Kxx, Kyy, Kzz are hydraulic conductivities in three directions (m^3/day), h: Groundwater pressure (m), w: volumetric flow rates per unit time (m^3/day). *SY*: specific yield of the porous media, and t: time (day).

The cross section of the wells used to create boreholes, then can be drawn longitudinal sections and soil layers (solid data), shown in Figure 6.

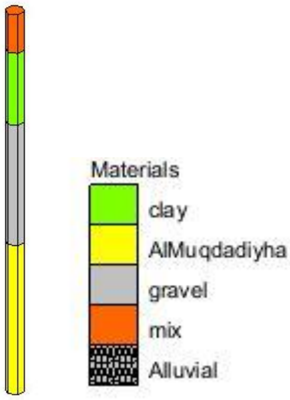

Figure 6. Cross section of Borehole

From the geological map and the data available on the study area, several configurations of the soil layers were defined. The formation of Muqdadiyha is the oldest form, non-permeable layer as mentioned earlier. The layer of gravel mixed formed, above it with some material like sand and clay and above the layer of gravel formed a layer of clay with a little of gravel and sand too. Above these layers formed a mixture of sand, gravel, salts and clay at surface of earth as shown in Figure 7.

In the next step the establishment of a three-dimensional grid required covering all the solid shape. The interval distance between two lines is 100m in X-axis, and Y-axis. The vertical interval was 50 m for each layer in the grid (Z-axis) [8]. The number of layers in grid is five layers started from zero level to 350m above sea level.

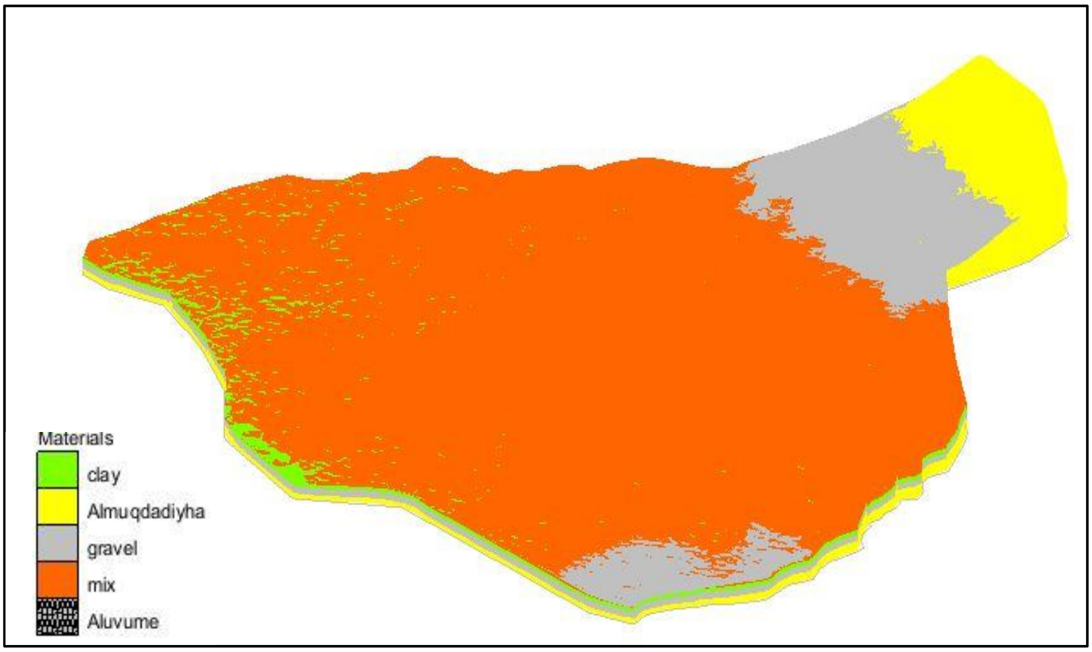

Figure 7. Soil layers at the study area

From GIS data, the layers of the conceptual model can be created by including boundary conditions, sources and sinks data, recharge zone and observation wells data. Then grid is constructed, and the data was initializing to be used with MODFLOW, before the conceptual model was converted to a grid-based numerical model. For giving stratigraphy for MODFLOW, models, which consider the main objective of using solid models, a grid-independent of the layer elevations were define, which used for directly, re-create the MODFLOW grid geometry after the grid resolution changed. As well as solid models of stratigraphy can be easily, create by the use of GMS "horizons approach" [9].

5. Defining Layers of the Conceptual Model

Boundaries layers: It is very important to define the boundary conditions of the study area, for creating a model that simulates the reality, and since the study area is local, most of the borders are of the type of constant head except the northeast it is a non-permeable border of the water. The region does not have rivers or drainage effect on the level groundwater, shown in Figure 8.

Sources and Sinks layer: That layer will be including all sources of recharge and discharges of groundwater in study area. Since the area is devoid of surface water resources, all the inhabitants of this city depend on the groundwater. The specifications of wells of study area were mention in Table 3, except the operating (pumping) data, which will be estimate for each situation separately.

Recharge layer: This layer represents the amount of net rainfall that feeds the groundwater, as usually rainwater goes in the form of surface runoff or evaporation. It was calculated as a daily average of the year at steady state condition by taking the annual rainfall rate (250) mm divided by the number of days of the year multiplying by deep percolation percentage which ranges from (5-20) % of the amount of rainfall [10].

Recharge = (250/ (365×1000))×15%=0.0001 m/day

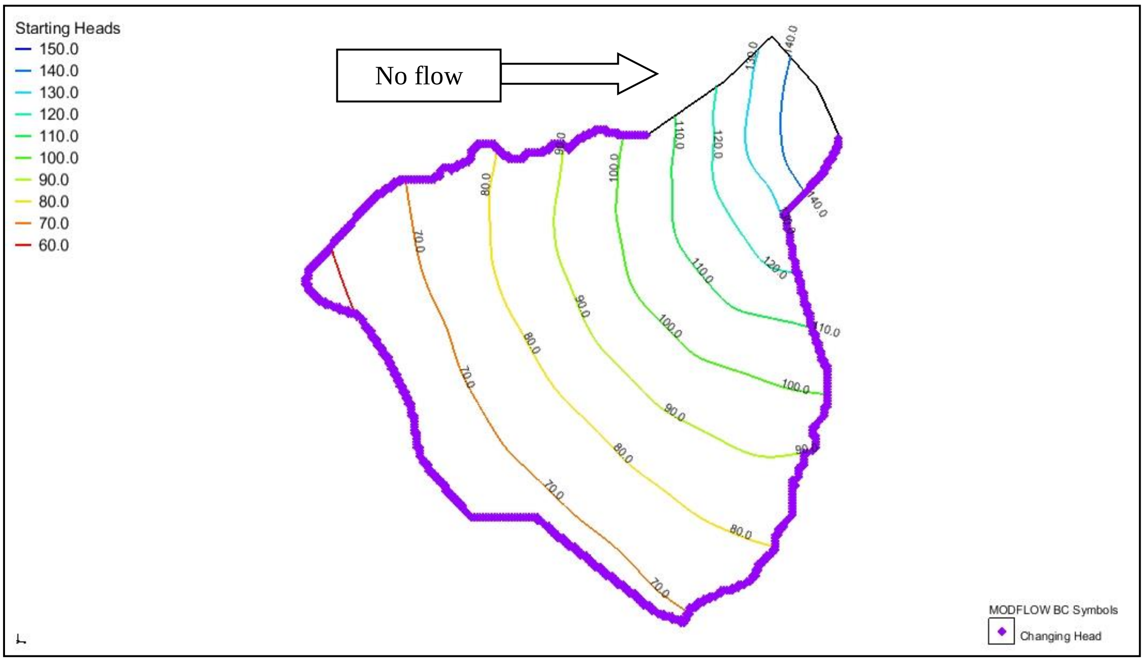

Figure 8. Boundary condition and starting head

Wells observation layer: This layer includes the data of observation wells during the research period, where the groundwater levels were measure for nine wells at a specific date and used for the purpose of calibrating the conceptual model and determining the properties of the soil hydraulic (hydraulic conductivity of layers).

After completing all above data, the next steps are creation MODFLOW model from solid data then interpolated MODFLOW with all layer in conceptual model, the readings of the observation wells, were recorded after stopping pumping to obtain the best static water level for the purpose of increasing accuracy during the calibration process of the model.

6. Estimating Properties of Layers and Running MODFLOW

Before starting run of MODFLOW, soil specifications should be introduced as default values according to soil layer type, then by giving minimum and maximum value for conductivity of aquifer at steady state accordant to range of hydraulic conductivity values for geological materials (After Todd, 1980), assuming the storage coefficient and specific yield equal to zero at steady state. The starting head must be defined for each layer of MODFLOW model see Figure 7. Then, from the PEST package provided by the program, the conductivity of layers values can be estimated and calibration of model at same time.

Now MODFLOW model can be running, and after several cycles the values of the hydraulic conductivity can be estimate, the error ratio in the initial values will be reduce until it reaches the optimal values, the program will be stopping, and then these values used to define the soil properties in the study area as showing in table 4. For check calibration are showing in Table 5 and Figure 9.

Table 4. Hydraulic conductivity of soil layers (k)

I D	Name	horizontal k m/day	Vert. anisotropy (kh/kv)
1	clay	3	4
2	Muqdadiyha	0.05	1
3	gravel	12	10
4	mix	9	5
5	Alluvial	12	9

Table 5. Observation wells data and different value between field data and computed data

Name	Obs. Head m	Obs. Head interval	Obs. Head conf. (%)	Obs. Head std. dev.	Computed head	Residual head
W30	88.76	0.5	95	0.51021	88.92538	-0.16538
W10	109	0.5	95	0.51021	109.3191	-0.3191
W35	122	0.5	95	0.51021	122.3665	-0.3665
W31	101.64	0.5	95	0.51021	101.8517	-0.2117
W34	81	0.5	95	0.51021	81.12373	-0.12373
W33	72	0.5	95	0.51021	71.73165	0.26835
W32	70.6	0.5	95	0.51021	70.41917	0.18083
W4	96	0.5	95	0.51021	96.19826	-0.19826
W21	95.66	0.5	95	0.51021	95.81802	-0.15802

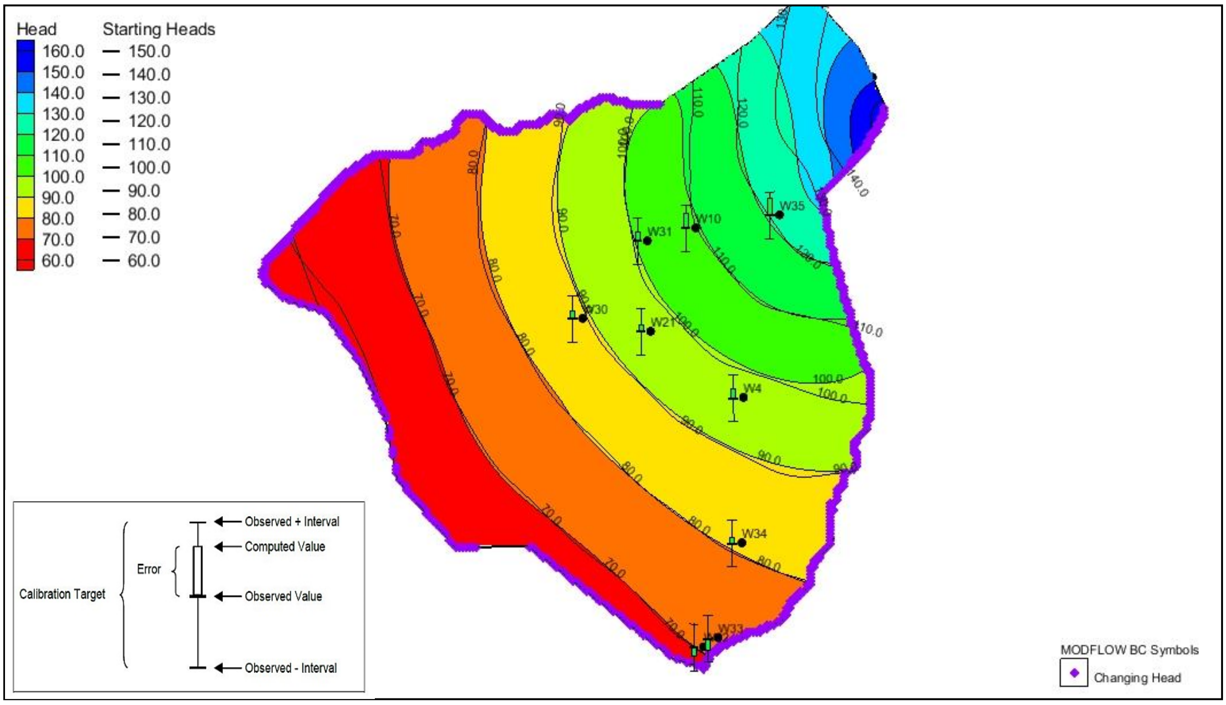

Figure 9. Computed heads in study area at steady state

The error was represented by the colored bar. When the color bar is green that's means bar lies entirely within the target, but when the error is less than 200%, means that the bar is outside the target, so the bar is draw in yellow. As well as when the error is greater than 200%, the bar will be drawing in red. In this case, the color bar is green. The red triangle represents the dry cells and the blue triangle represents the flooded cells.

From the results obtained by the MODFLOW model, the hydraulic conductivity of Layer two (clay layer) was found to be of low value (3m/day). That layer represents a perched aquifer in the local area. The water flows in the horizontal and vertical direction above the clay layer, at the end of the alluvial fan the clay layer will be close to the ground surface, that leading to flow of water above the surface. From field observations, the groundwater flows at the fan's border in form of springs. The gravel layer below the clay layer it is a semi-confined layer and it is the main storage layer of groundwater in Mandali alluvial fan.

7. Determine the Storage Coefficient and Specific Yield at Unsteady State

After determination of the hydraulic conductivity values of the soil layers, the values of storage coefficient and specific yield can calculate in the same way, as the conductivity was calculated, with the need for data for one of the observation wells at lies. The management of transient information from a different source would be create a transient simulation, including pumping wells data, Table 8, recharge data shown in Figure 10, and water table of observation wells showing in Table 6. The first step in an unsteady state it is to convert the MODFLOW model from a steady to transient form, then import the transient data like rainfall, pumping periods, flow rates of wells in study area and stress period shown in Tables 7 and 8.

Table 6. Observation transient wells data

Date	Obs. Trans. Head m	Date	Obs. Trans. Head m
6/1/2013	120	1/1/2014	119.78
7/1/2013	119.7	2/1/2014	121
9/1/2013	118	3/1/2014	121
10/1/2013	118	4/1/2014	120.5
11/1/2013	119	5/1/2014	120.2
12/1/2013	119.4	6/1/2014	119

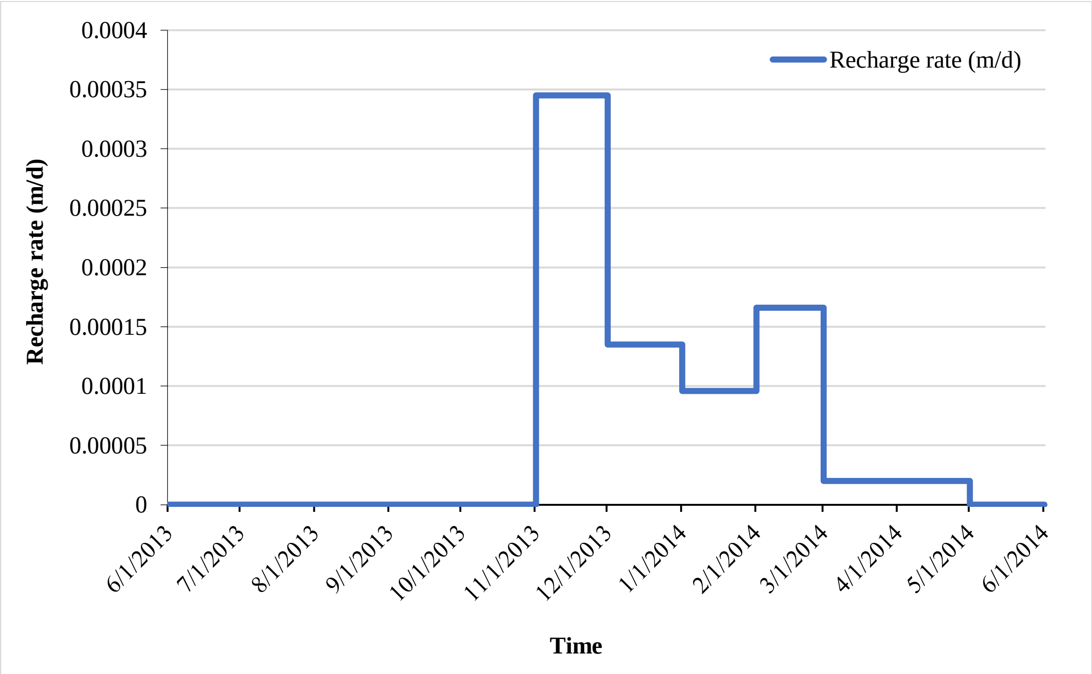

Figure 10. The recharge transient data

Table 7. Stress period data

Start Date	Length	Num. Time Steps	Multiplier
6/1/2013 0:00	0	1	1
6/1/2013 0:00	30	10	1
7/1/2013 0:00	31	10	1
8/1/2013 0:00	31	10	1
9/1/2013 0:00	30	10	1
10/1/2013 0:00	31	10	1
11/1/2013 0:00	30	10	1
12/1/2013 0:00	31	10	1
1/1/2014 0:00	31	10	1
2/1/2014 0:00	28	10	1
3/1/2014 0:00	31	10	1
4/1/2014 0:00	30	10	1
5/1/2014 0:00	31	10	1
6/1/2014 0:00	End		

Table 8. Pumping data for all wells

Time	Flow rate (m^3/day)
6/1/2013 0:00	-600
9/1/2013 0:00	-600
9/1/2013 0:00	-400
12/1/2013 0:00	-400
12/1/2013 0:00	-300
3/1/2014 0:00	-300
3/1/2014 0:00	-400
6/1/2014 0:00	-400
6/1/2014 0:00	-600

Note: The negative sign indicates that discharge wells

After determining the values of the storage coefficients and the specific yields, and the calibration the model was done, the results of the unsteady state of the simulation model can be compared with observation records, as shown in Table 9.

Table 9. Properties of Aquifer

ID	Name	horizontal k m/day	Vert. anisotropy (kh/kv)	storage coefficient	specific yield	porosity
1	clay	3	4	0.00001	0.025	0.5
2	Muqdadiyha	0.05	3	1.00E-06	0.005	0.01
3	gravel	12	10	0.0001	0.25	0.3
4	mix	9	5	0.0001	0.15	0.25
5	Alluvial	12	9	0.0001	0.15	0.25

Figure 11 shows the differences between water table in observation well measured in the field and level of water obtained by the conceptual model and the difference is within the permissible limits.

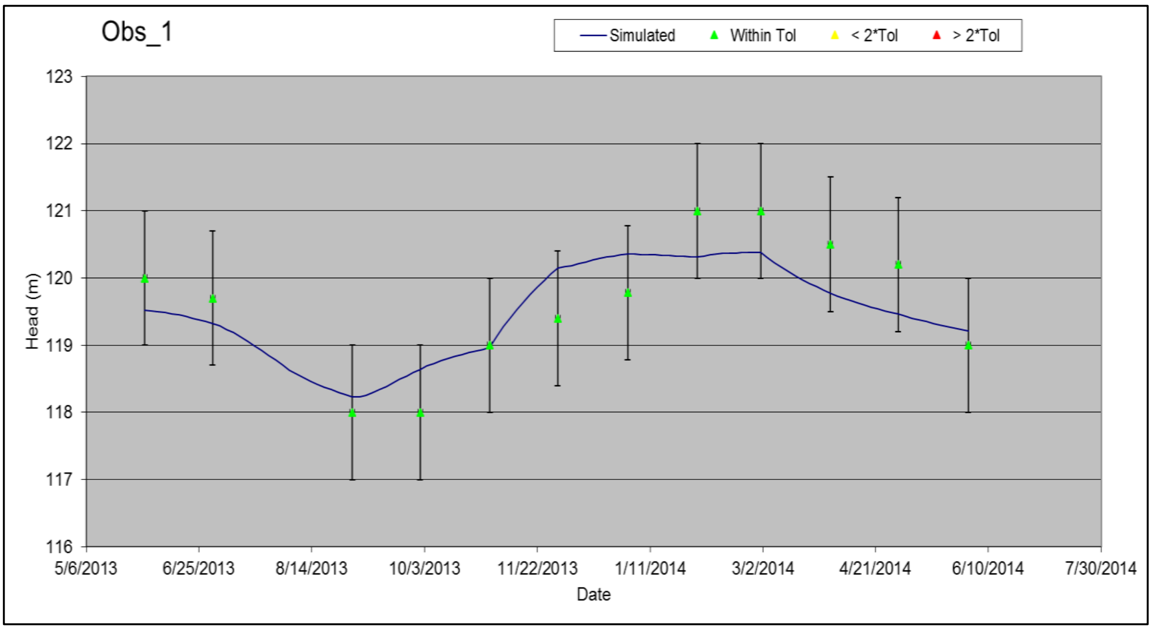

Figure 11. Water table in observation wells

8. Run-time Scenarios and Distribution of Wells

After running the MODFLOW model in a normal state as shown in Figure 12, red triangles in the high regions are representing dry cells while blue triangles at the low end of the alluvial fan are representing the flooded cell. In fact, dry cells are only found in the top layer of the highlands, and submerged areas are the natural springs of water. These springs were formed because of a high hydraulic gradient of water, and because of the second layer (clay layer) which has low hydraulic conductivity, and then the flow above this layer will be in two directions, horizontal flow and vertical flow. The third layer (gravel layer) is the main storage for groundwater in the study area.

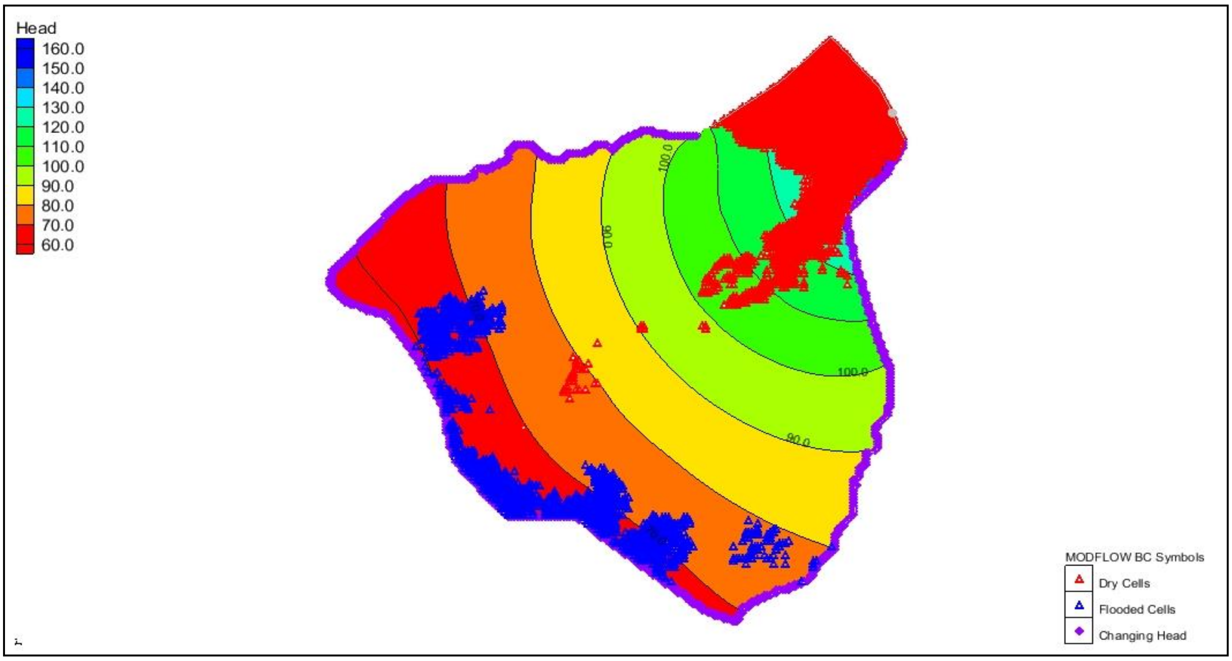

Figure 12. Drawdown in water table after 6 hrs.

After determining the hydraulic specifications of the soil layers in the study area, the wells were hypothetically increased and different spacing between these wells were tested. To determine the optimum distribution with acceptable drawdown of water table, 103 wells with spacing of, 1500 m, are used in this scenario. Assuming the productivity of the well was 7 liters per second, or about 600 cubic meters per day. Three daily operating times were proposed and these are 6, 12 and 18 hours, with annual rainfall rate of (0.0001 m/day), the discharges from wells for the three scenarios were 150, 300, and 450 m^3/day respectively. The proposed operation of these wells was for one year only.

- Scenario 1: The operation time was 6 hours with discharge 150 m^3/day, Figure 13 shows that the drop in the water table was between 1m and 7m, and the maximum drawdown was in the middle of the study area.
- Scenario 2: The operation time was 12 hours with discharge of 300m^3/day, Figure 14 shows that the drop in the water level was between 1m and 11.5 m, and the maximum drawdown of water table was in the middle of the study area too.
- Scenario 3: The operation time was 18 hours with discharge of 450m^3/day, Figure 15 shows that the drop in the water level was between 2.5m and 20m, and the maximum drawdown of water table was in the middle of the study area too.

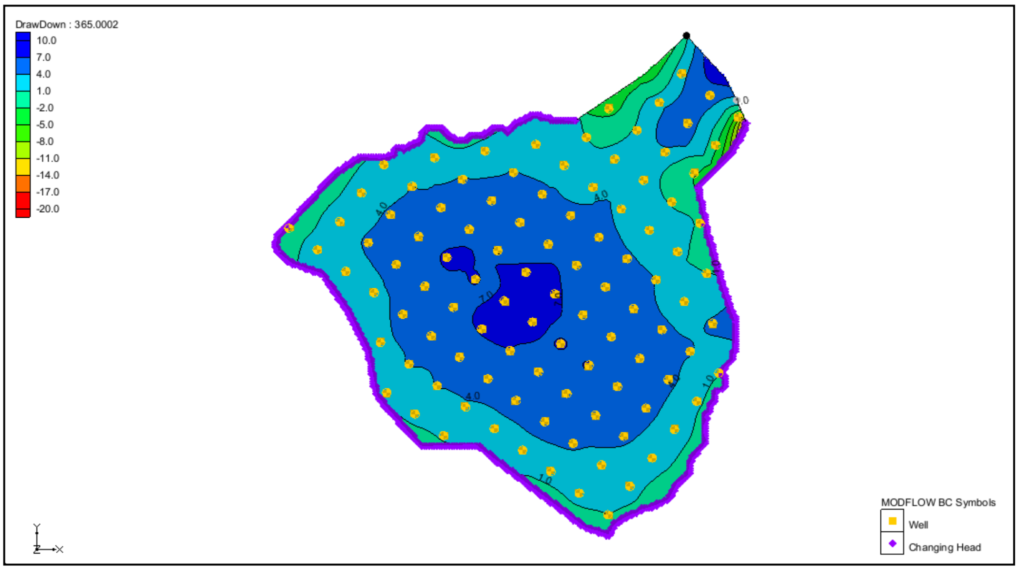

Figure 13. Drawdown in water table after 6 hrs.

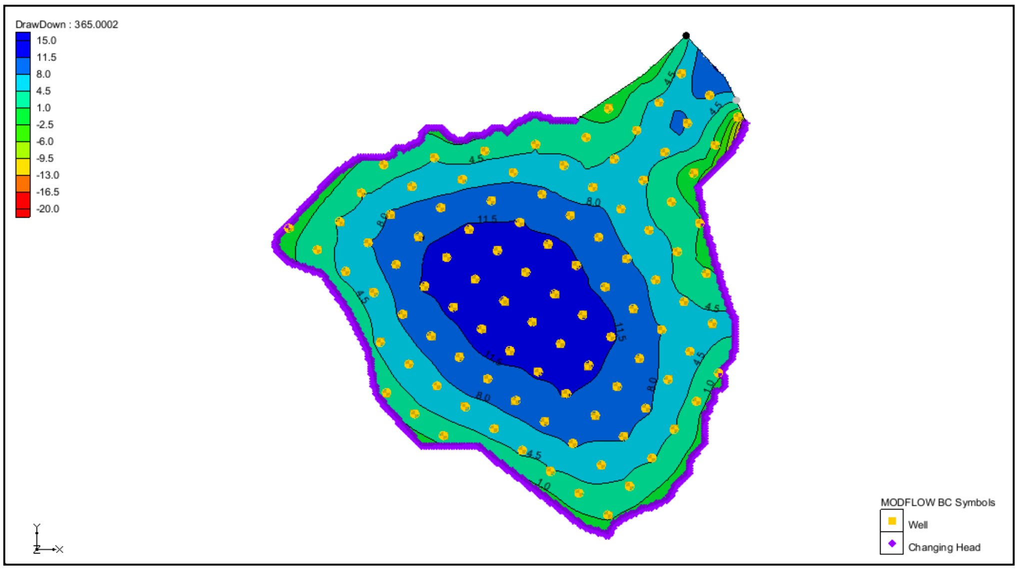

Figure 14. Drawdown in water table after 12 hrs.

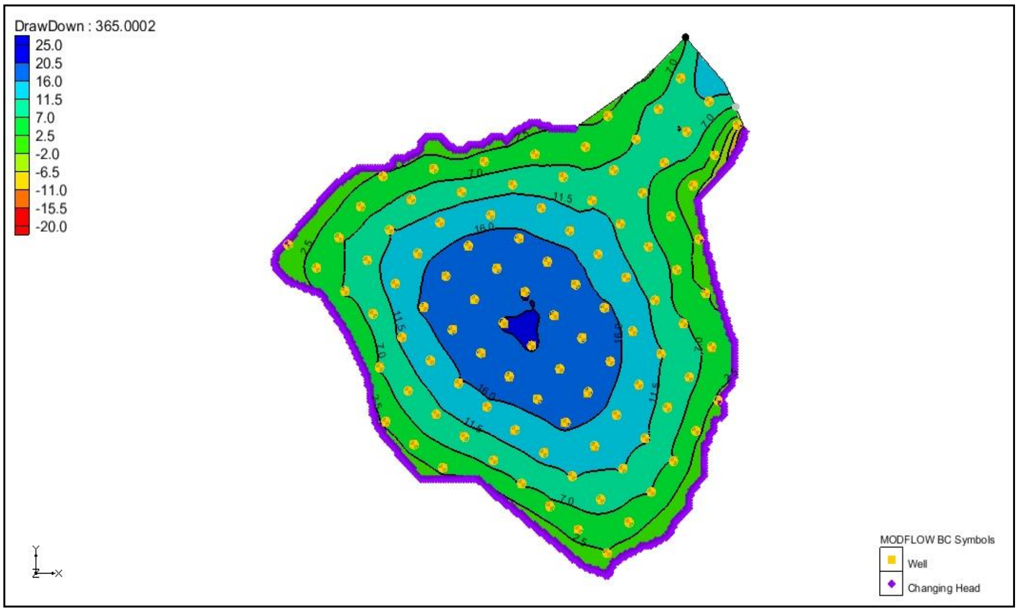

Figure 15. Drawdown in water table after 18 hrs.

9. Assessment of Groundwater Quality

It is essential to study the physical and chemical characteristics of groundwater in the study area before recommend it for drinking or irrigation usage. It was well known that in the movement of groundwater it may pass through regions where impurities will be dissolved and deteriorating its quality [11, 12]. There are many classifications to assess water quality, but the simplest of these classifications is depending on the value of total dissolved solids (TDS) on the basis of as shown in Table 10. According to this classification, the groundwater of the wells in the study area in Table 3 is slightly saline water except for well (W18) [13, 14]. It is a moderately saline water show Figure 16.

Table 10. Water classification based on dissolved solids [15]

Water class	T.D.S (mg/l)
Fresh	<1000
Slightly saline	1000-3000
Moderately saline	3000-10000
Very saline	10000-35000
Briny	>35000

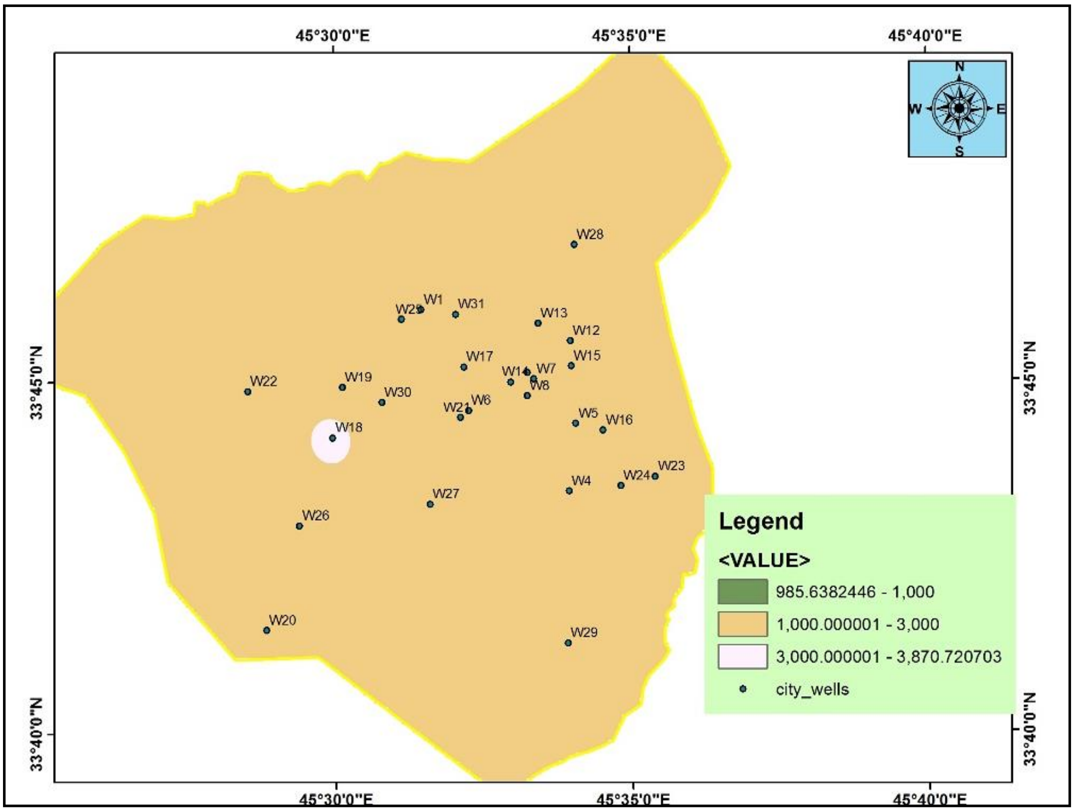

Figure 16. Value of T.D.S in the study area

10. Conclusions

In this research, Groundwater Modeling System (GMS) software was used to build three-dimensional conceptual model and management of groundwater usage in the Alluvial fan of Mandali aquifer after the determining the hydraulic conductivity, storage coefficient and specific yield. Three scenarios with different daily operation time (6, 12 and 18) were tested for feasible wells distribution based on minimum drawdown. The wells is hypothetically increased to 103 over the study area with spacing of 1500 m. From GMS software simulation results for the study area, the following conclusions can be drawn:

- For daily operation of 6 and 12 hours, the maximum drawdowns were found to be 7m, and 11.5 m, respectively.
- For daily operation of 18 hours, the maximum drawdown was 20 m, so this operation scenario will be recommended for operating the proposed number of wells and meet the demand in the study area.

- For all wells excluding well number 18, the range of TDS was from 1000 to 3000 mg/l. However, for well number 18, the TDS was found more than 3000 mg/l which indicate that the groundwater in this well is not recommended to be used for irrigation but according to Iraqi stander for drink (IQS 2009) it can be used for drinking after advanced treatment.

11. Conflicts of Interest

The authors declare no conflict of interest.

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