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Numerical modeling of Umm-Gudair well field, Kuwait

F. M. AL-RUWAIH

Geology Department, Kuwait University, P.O. Box 5969, Safat, 13060, Kuwait

ABSTRACT

The study area, Umm-Gudair field, is located in the southwest of Kuwait near the Kuwait-Saudi Arabia border. It occupies an area of 450 Km^2. The Umm-Gudair field includes 41 production wells screened in the Kuwait Group and the Dammam Formation (dual-completion well). The field production started on October, 1986 with 54,550 m^3/day increased to the present production of 113,650 m^3/day. In countries located in arid and semi-arid regions such as Kuwait, groundwater is a major water supply source. The groundwater modeling aims to duplicate the hydrogeological conditions with a view to predict the consequences of proposed activity in the aquifer. Detailed studies of groundwater potentiometric heads are essential for the development of the effective and long-term water pumping policies and water management, especially in Kuwait where the groundwater is pumped out at a high rate. Numerical techniques define the contribution of each aquifer to the total groundwater production and predict the future performance of the field. Model studies show that, in the Umm-Gudair field, most of the groundwater is produced from the Dammam Formation. Moreover, the calculated drawdown value is 16.50 m at the present production rate of 113,650 m^3/day, and the projected future drawdown is 26.40 m when the production increases to 181,840 m^3/day for the Dammam Formation, for the period 1993–2012. The drawdown values of the Kuwait Group aquifer are 5.81 m and 8.96 m for the present and future production rates of 113,650 m^3/day and 181,840 m^3/day respectively, for the period 1993–2012.

INTRODUCTION

Kuwait is situated at the northwestern part of the Arabian Gulf and lies between latitudes 28° 30′ and 30° 08′ north and between longitudes 45° 30′ and 48° 30′ east. The study area, Umm-Gudair field, is located in the southwest of Kuwait near the Kuwait-Saudi Arabia border as shown in Fig. 1. Kuwait is a desert country with very hot and dry climate and limited rainfall, with an average of 100 mm/year as indicated from the records of annual precipitation during the period 1958–1994 shown in Fig. 2 (Anonymous. Meteorological Department, Climatological Division, Ministry of Communications, Kuwait). The natural groundwater resources are limited and are mainly brackish water. Groundwater replenishment from rainfall is negligible. Hence, the country depends on the desalination plants for drinking water and brackish groundwater for irrigation purposes. Groundwater production is equivalent to the mining out of the aquifers. Therefore, the estimation of the groundwater quantity for future production is important, as the demand for water is

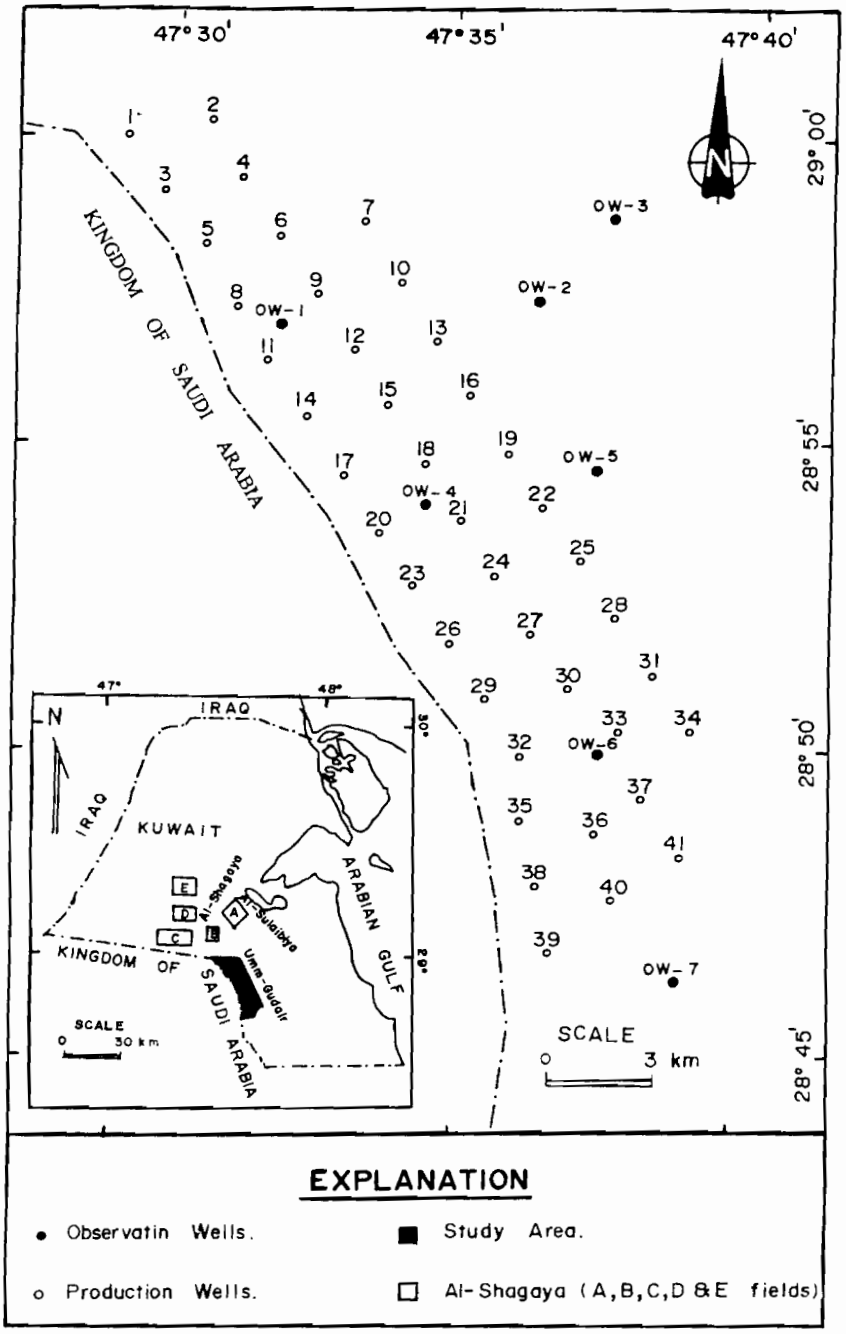

Fig. 1. Location map of the Umm-Gudair field showing distribution of the production and observation wells.

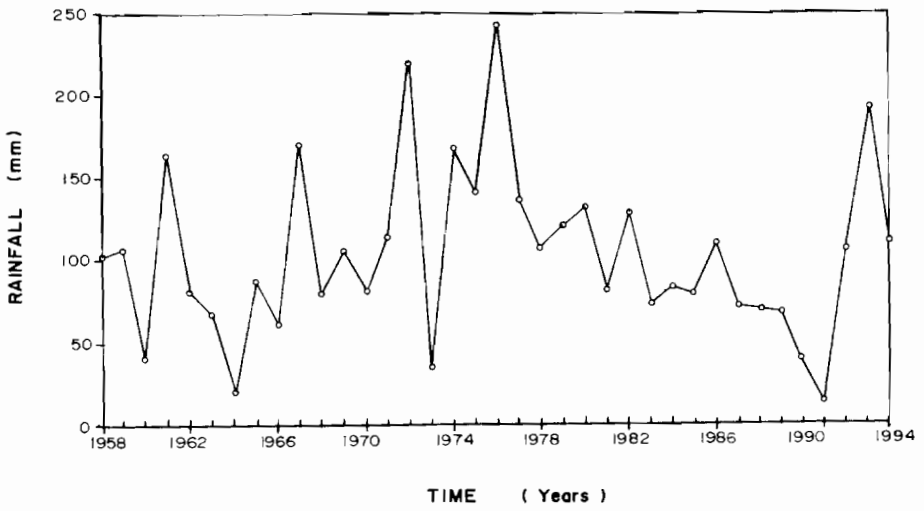

Fig. 2. Distribution of the annual total rainfall for 36 years records (1958–1994). Anonymous. Meteorological Department, Climatological Division, Ministry of Communication, Kuwait.

continuously increasing in response to the growing population, developing industry, gardening and farming activities. The present work is intended to predict future performance of aquifers in the Umm-Gudair field. This modeling study paves the way for more comprehensive and elaborate aquifer performance simulation studies to aid water management in Kuwait.

PREVIOUS WORK

Al-Rashed (1993) carried out hydrogeological research on the dual-completion wells of the fields C and E of Al-Shagaya area. The effect of these fields and the surrounding fields of A, B, C of Al-Shagaya area and Al-Sulaibiya on Umm-Gudair field was studied. It is found that the decline in the simulated heads of the Kuwait Group in the Umm-Gudair field was 9.14 for the periods 1993–1998 and 1998–2003, where the production rate was assumed to range from 18,184 to 25,185 m^3/day. Also, the simulated head of the Dammam Formation aquifer was found to decline 3.05 m for the period 1993–1998 and 1998–2003, where the production rate increased from 11,365 to 26,367 m^3/day. Mukhopadhyay *et al.* (1994) stated that at the present production rate, the groundwater resources of Kuwait are being mined. Moreover, the Kuwait Group and Dammam Formation may be dewatered at some locations. The two previous studies did not include the Umm-Gudair field, as the field production started on October 1986. Therefore, the present study is carried out where a more recent field production rate, hydrogeological data, and water level records are available. In addition, the recent data 1991–1995 has been utilized in fine tuning of model calibration and prediction.

Aquifers of the study area

There are two main aquifers in Kuwait, the Kuwait Group and the Dammam Formation, as shown in Fig. 3 (Owen and Nasr 1958). The Kuwait Group is composed

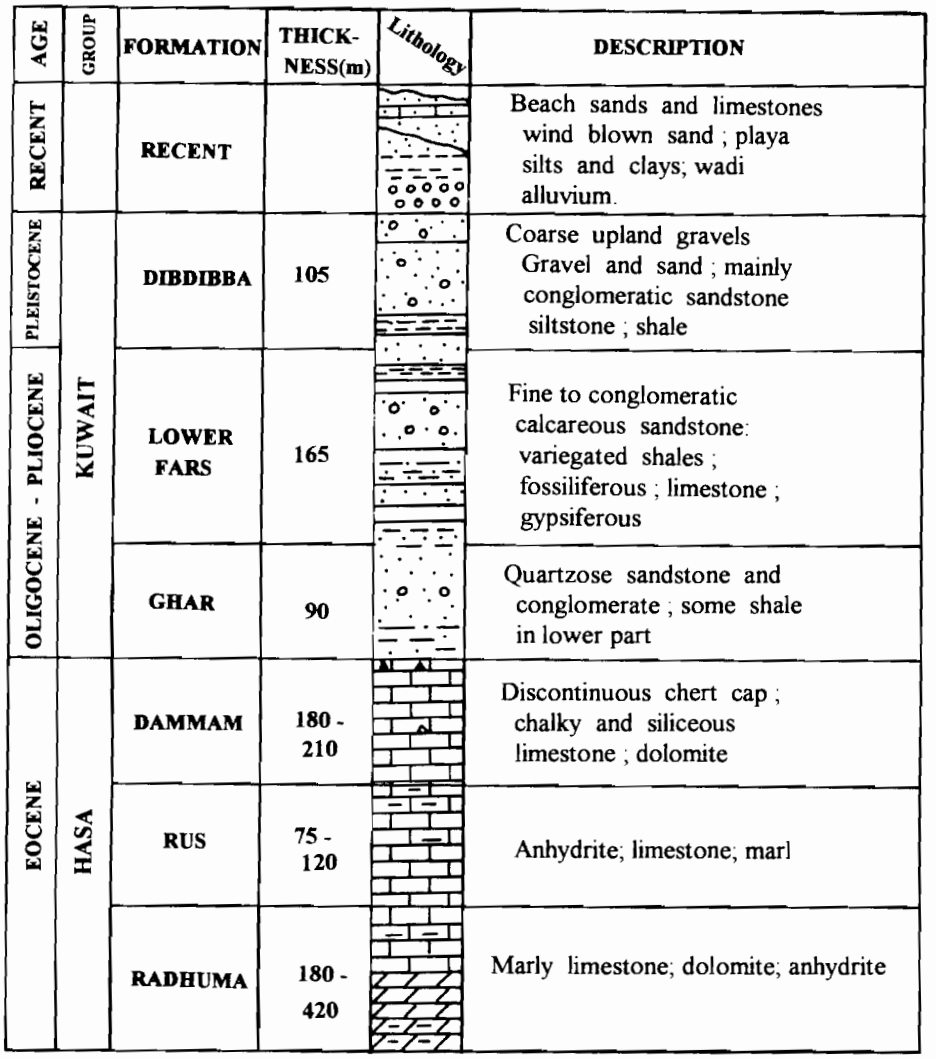

Fig. 3. Cenozoic stratigraphic column of Kuwait showing the stratigraphic position and lithology of the Kuwait Group and the Dammam Formation aquifers (after Owen & Nasr 1958).

of sand, gravel with some clay and silt. The Kuwait Group is subdivided from top to bottom into Dibdibba, Lower Fars and Ghar Formations. The Kuwait Group is of Oligocene to Quaternary age with 360 m thickness. The thickness increases towards the north. The Dammam Formation is a Middle Eocene dolomitic limestone with 180–210 m thickness. The Dammam Formation is highly fractured and contains vuggy and moldic porosity. The unconformable contact between the Dammam Formation and the overlying Kuwait Group is marked by the presence of a siliceous cherty zone and a basal clay layer, which acts as an aquitard and separates the two aquifers. The area 1 distribution of the top of the Dammam

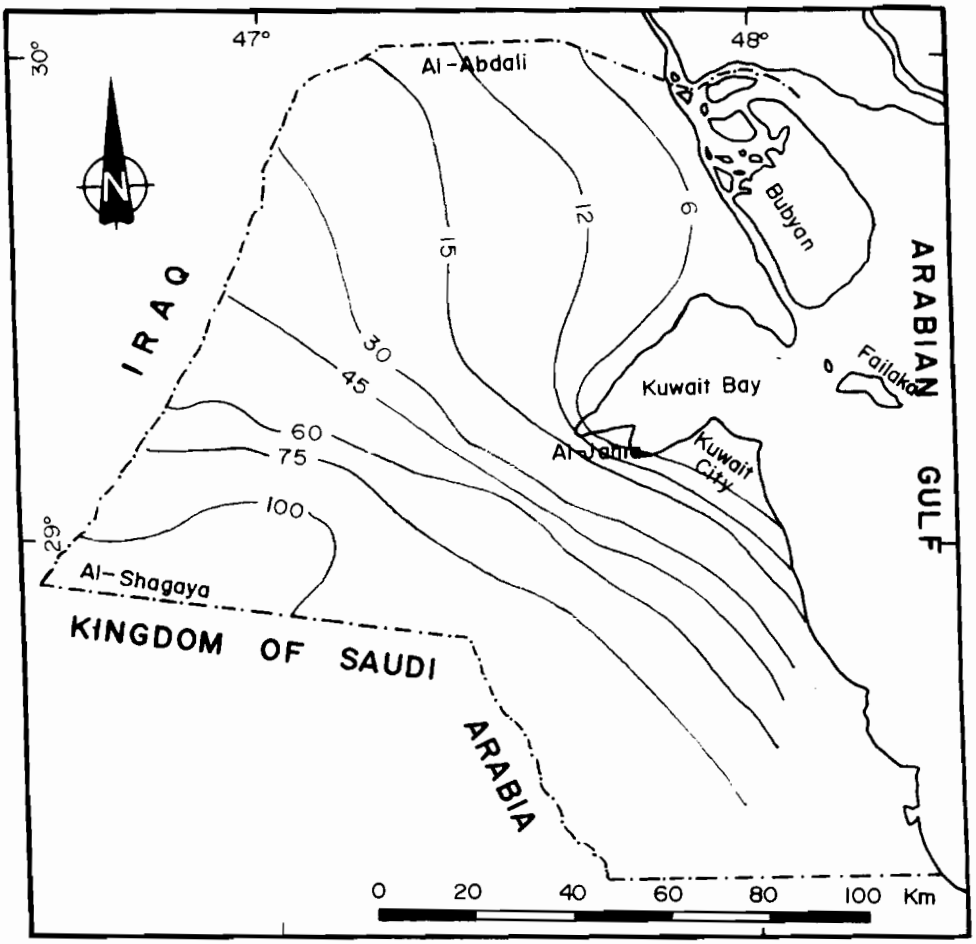

Fig. 4. Piezometric contour map (in meters) for the Kuwait Group aquifer in 1976 (after Al-Hajji 1976).

Formation (Mean Sea Level, M.S.L.) indicates that the elevation of the formation is decreasing towards the northwest direction (Pasek 1986).

The Kuwait Group aquifer is semi-confined, with an average transmissivity value of 208.74 m^2/day and an average effective permeability value of 2.16×10^{-8} cm^2. The average piezometric level of the Kuwait Group aquifer is 96.77 m from (M.S.L.). The estimated storage coefficient of well No. 18 is 3.17×10^{-4}. The Dammam Formation aquifer is acting as a semi-confined to confined aquifer, and its average transmissivity and effective permeability values are 581.5 m^2/day and 2.8×10^{-8} cm^2 respectively, and increase towards the north. The average transmissivity and effective permeability of the Dammam Formation aquifer are higher than those of the Kuwait Group aquifer, due to the karstification effect in the Dammam Formation. The estimated values of the storage coefficient of the Dammam Formation aquifer range between 5.28×10^{-4} and 6.7×10^{-4}, with an average value of 5.8×10^{-4}.

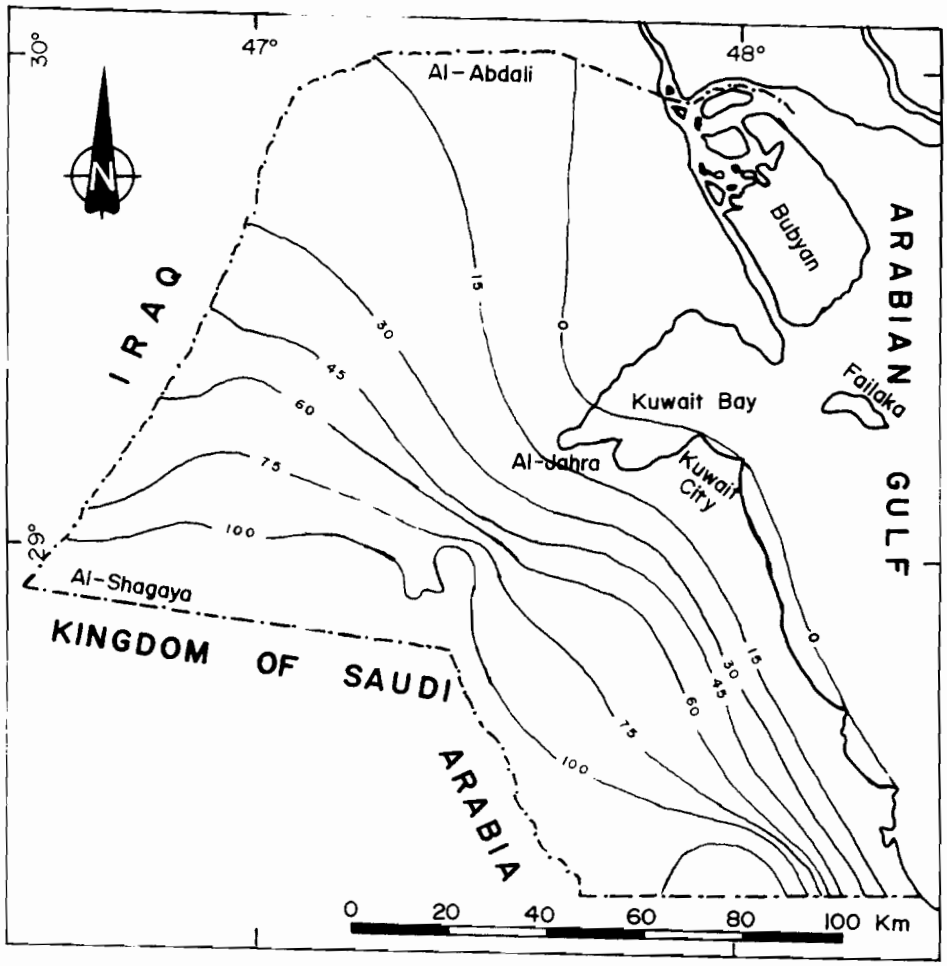

Fig. 5. Piezometric contour map (in meters) for the Dammam Formation aquifer in 1972 (after Al-Rashed 1993).

The average piezometric level of the Dammam Formation aquifer is 82.69 m from (M.S.L.), which is lower than the piezometric level of the Kuwait Group aquifer. This indicates the possibility of a downward leakage from the Kuwait Group aquifer to the Dammam Formation aquifer (Abu-Hijleh 1988). The production from the nearby fields and the Umm-Gudair field has caused a lowering of the Dammam Formation potentiometric level which leads water to leak from the overlying Kuwait Group sediments into the Dammam Formation. The pumping test data analysed by Walton method (Kruseman & De Ridder 1970) reveal that the leakage coefficient (r/L) of the Kuwait Group aquifer is 0.02, and the calculated leakage factor (L) is 10,667.48 m. The large value of (L) indicates a low leakage rate through the aquitard, the basal clay and the chert layer. The calculated hydraulic resistance of an aquitard to vertical flow is 5.5×10^5 days.

Transmissivity and storativity of the aquifers were determined on the basis of analysed pumping test data by analytical methods. The values were cross checked by simulating pumping test data using the finite-difference model of the study area using MODFLOW (Version 3.0). The model results confirmed the previously estimated values of aquifer transmissivity and storativity by Abu Hijleh (1988).

The plot of the piezometric levels of the Kuwait Group and the Dammam Formation aquifers show a regional east-northeast hydraulic gradient from Saudi Arabia to the Arabian Gulf as shown in Fig. 4 (after Al-Hajji 1976) and Fig. 5 (after Al-Rashed 1993). The hydraulic gradient is 1.5×10^{-3} which yields a groundwater flow of 10,450 m^3/day to the Umm-Gudair field through the Dammam Formation. For the Kuwait Group, the hydraulic gradient is 1.7×10^{-3} and the groundwater flow across the Umm-Gudair field is 4550 m^3/day. The present groundwater production of the field is 113,650 m^3/day which is much larger than the total regional groundwater flow. The annual production of the Umm-Gudair field is plotted against the average piezometric level of the Kuwait Group and the Dammam Formation aquifers recorded in the observation wells during the period 1984–1995 as shown in Fig. 6. The missing production data during August 1990–April 1992 are due to the halt in the field production due to the Iraqi invasion. It is noticed that the piezometric levels of the two aquifers show a close correspondence to the groundwater abstraction and show a seasonal fluctuation.

Groundwater quality

Groundwater in aquifers of the Kuwait Group and the Dammam Formation is generally brackish to saline. The water salinity is around 4000 mg/l in the southwestern part of the country, and gradually increases towards the eastern and northeastern part of the country and with depth, reaches a level of 150,000 mg/l and more near the coastal regions.

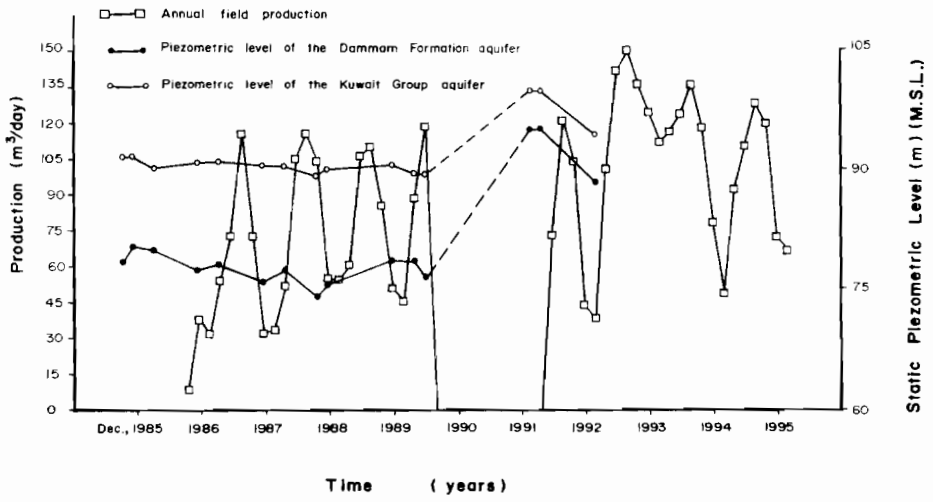

Fig. 6. Plot of the average piezometric level of the Kuwait Group and the Dammam Formation aquifers and the annual field production during 1984–1995.

The extracted water quality of the Umm-Gudair field is the result of mixing of the water of the two aquifers (Kuwait Group and Dammam Formation). It is important to determine the groundwater quality and water types, because this brackish groundwater is mainly used for irrigation of private and public farms and gardens, as well as blending by a ratio of 10–90 with desalinated water to produce a potable water for Kuwait City.

Groundwater samples of the Kuwait Group and the Dammam Formation aquifers were separately collected while conducting the pumping test, and have been analyzed for basic cations and anions. Moreover, water samples have been collected from the production dual-completion wells to study the chemistry of the mixed water from the two aquifers.

The chemical analyses reveal that the salinity of the Kuwait Group ranges from 3500 mg/l in the southwest to about 5000 mg/l northeast of the Umm-Gudair field. The predominance order of anions is $Cl^- > SO_4^{2-} > HCO_3^-$ and that of cations is $Na^+ > Ca^{2+} > Mg^{2+}$ (Al-Yaqubi 1987).

Groundwater is characterized by calcium-sodium cation facies and chloride-sulfate anion facies, according to Back (1966). In addition the aquifer is mainly occupied by NaCl and $CaCl_2$ water types, according to Collins (1975). The water salinity of the carbonate Dammam Formation aquifer is about 2800 mg/l in the northwest and increases slightly to the east and southeast, where it reaches 4000 mg/l. The sequence of the anions is $SO_4^{2-} > Cl^- > HCO_3^-$ and that of cations is $Na^+ > Ca^{2+} > Mg^{2+}$. The aquifer water exhibits calcium-sodium and chloride-sulfate anion facies. In the Dammam Formation the $CaCl_2$, Na_2SO_4 and $CaSO_4$ water types were identified. Chemical analyses carried out for the samples of dual-completion wells showed that the average total dissolved solids of the mixed water is 3396 mg/l and the groundwater is mainly a NaCl water type in which the $Cl^- > (Na^+ + K^+)$ (Al-Ruwaih 1995).

NUMERICAL MODELING OF UMM-GUDAIR FIELD

The computer simulation study is conducted in the Umm-Gudair field and extended to regional scales. The field scale study is necessary for calibration and prediction of the aquifer performance using the numerical techniques. The regional study is intended to show the impact of the groundwater production in the Umm-Gudair field on regional potentiometric configuration.

For the local study a 30 × 30 square grid system with each grid equal to 1 km^2 covering only the Umm-Gudair field area was utilized. For the regional study an 80 × 80 square grid system with each grid equivalent to 1 km^2 covering part of Kuwait and extending eastward to the sea was used. The model comprises two distinct aquifers: the Kuwait Group is modeled as a semi-confined to confined aquifer and the Dammam Formation as a confined to semi-confined aquifer. The piezometric levels of the Kuwait Group and the Dammam Formation aquifers are assumed to be horizontal at the start of simulation runs. The local and regional modeling of the Kuwait Group and Dammam Formation aquifers were conducted in a transient mode. Although the production rates vary seasonally, a constant rate was used during simulation runs because only the overall production impact for a prolonged period of time is needed, rather than the aquifer response to a short term stress. Recharge from surface infiltration is practically non-existent in the Umm-

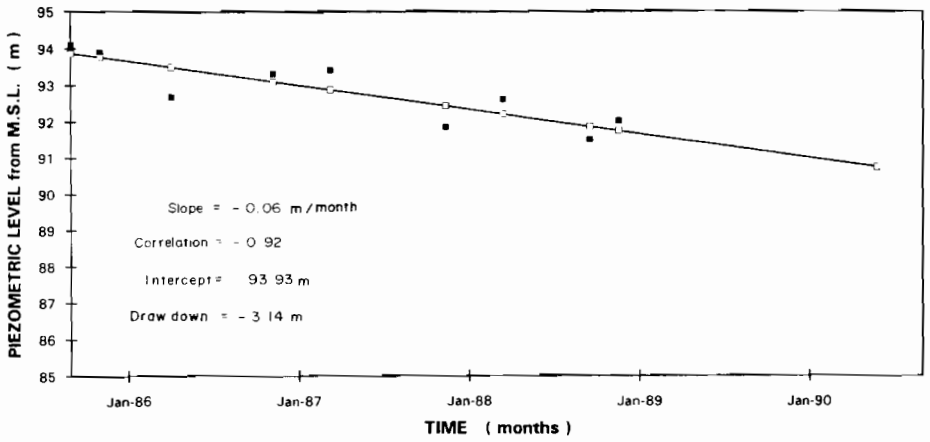

Fig. 7. Drawdown in the piezometric level of the Kuwait Group aquifer during the production period from 1986 to 1990.

Gudair field and is neglected in the present model study. Cross flow from the Kuwait Group to the Dammam Formation aquifer was also neglected because the vertical permeability of the intervening aquitard is very low.

Boundary conditions

There are no natural boundaries for the aquifers in the Umm-Gudair field. In fact, the only natural boundary is the shore-line which lies about 100,000 m to the east. For the regional model, the shore-line of the Arabian Gulf was defined as a constant head boundary for both the aquifers. A constant head defined as a constant head boundary for both the aquifers. A constant head boundary was also defined at about the same distance from the Umm-Gudair field to the west and southwest. The initial regional hydraulic gradient was obtained by setting the piezometric level at the sea level along the shore-line to the east. West of the field, the piezometric level was fixed to ensure the present regional hydraulic gradient. The model was operated until a steady-state simulation was reached and the regional hydraulic gradient was approximately equal to the configuration before starting water production at Umm-Gudair field. Constant head boundary conditions were adopted for the Umm-Gudair field models. Boundaries were fixed at a large distance from the field at the initial piezometric level. The piezometric surface was approximated as horizontal for the local model as the regional hydraulic gradient is negligible at that scale. The piezometric level was set to the average at the observation wells at the start of the production in 1986 during the calibration runs. The level was set to the average level in 1992 for the prediction runs.

Procedure

The MODFLOW (Version 3.0), (McDonald & Harbaugh 1988, Prudic 1989) is used for modeling. Details and theory of finite-difference modeling can be found in

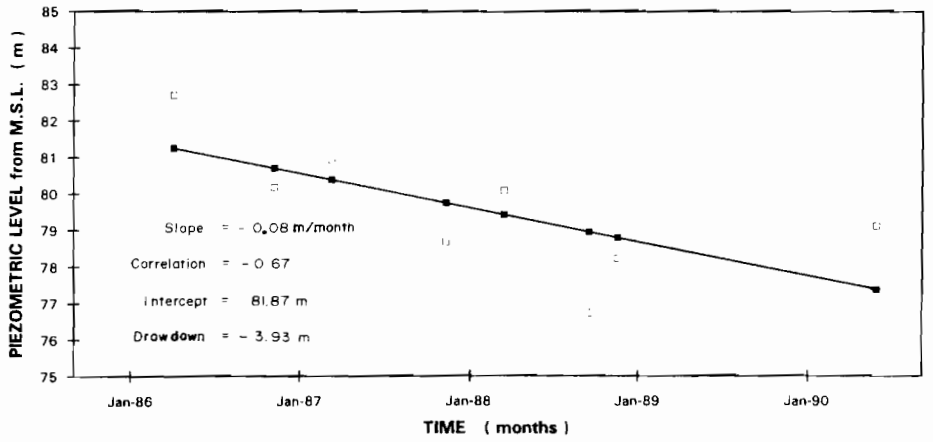

Fig. 8. Drawdown in the piezometric level of the Dammam Formation aquifer during the production period from 1986 to 1990.

several sources including Anderson & Woessner (1991) and Prudic (1989). The performance of the Kuwait Group and the Dammam Formation aquifers was simulated separately as follow: (1) calibration of the aquifer parameters using historical data, and (2) modeling of future aquifer performance for the present and projected

Table 1. Model input parameters and calibration results from numerical simulation of water production from the dual-completion wells over the production period from 1986 to 1990.

Model Input Data	Kuwait Group	Dammam Formation
Premode	Transient	Transient
Time unit	days	days
No. of time units	1337	1337
Grid:		
No. of cells in X & Y	80 × 80	80 × 80
Cell size (m)	1000	1000
No. of layer	1	1
Top layer	115.21	−4.88
Bottom layer	−4.88	−172.81
Layer type	Confined/semi-confined	Confined/semi-confined
Boundary array	Active cell H = 1	Active cell H = 1
Properties:		
Specific yield	0.02	0.02
Specific storage (m^{-1})	1×10^{-3}	5×10^{-4}
Hydraulic conductivity (m/day)	2.45	6.12
Transmissivity (m^2/day)	293.73	1026.93
Initial piezometric head (m)	91.07	87.99
Package:		
Production of aquifer/well (m^3/day)	136.38	1236.51
% Production	10% of 56,370 m^3/day	90% of 56,370 m^3/day
Drawdown during simulated period (m):		
Observed field	−3.14	−3.93
Model result	−3.12	−3.87

Table 2. Model parameters and calibration results from numerical simulation of water production from dual-completion wells over the production period from 1992 to 1993.

Model Input Data	Kuwait Group	Dammam Formation
Premode	Transient	Transient
Time unit	days	days
No. of time units	304	304
Grid:		
No. of cells in X & Y	80 × 80	80 × 80
Cell size (m)	1000	1000
No. of layer	1	1
Top layer (m)	115.21	−4.88
Bottom layer (m)	−4.88	−172.81
Layer type	Confined/semi-confined	Confined/semi-confined
Boundary array	Active cell H = 1	Active cell H = 1
Properties:		
Specific yield	0.02	0.02
Specific storage (m^{-1})	1×10^{-3}	5×10^{-4}
Hydraulic conductivity (m/day)	2.45	6.12
Transmissivity (m^2/day)	293.73	1026.93
Initial piezometric head (m)	91.07	87.99
Package:		
	113.65	1750.21
Production of aquifer/well (m^3/day)	6% of 76,827.4 m^3/day	94% of 76,827.4 m^3/day
% Production		
Drawdown during simulated		
period (m):	−1.05	−2.25
Observed field	−1.17	−2.25
Model result		

levels of groundwater production. Accordingly, the drawdowns of the Kuwait Group and the Dammam Formation aquifers were estimated using the linear regression, utilizing the average monthly records of the piezometric levels of seven observation wells as shown in Figs. 7 and 8. It is obvious that the fluctuation of the piezometric levels is attributed to the seasonal changes in groundwater production rate. The calculated drawdown of the Kuwait Group and the Dammam Formation aquifers during the period 1986 to 1990 is −3.14 m and −3.93 m respectively. Furthermore, these drawdowns have been used in model calibration.

The production and the piezometric level data from January 1986 to January 1990 were utilized for the calibration of: (i) aquifer transmissivity and storativity; and (ii) percentage of water production from the two aquifers. An estimate of the percentage of production from the Kuwait Group and the Dammam Formation aquifers is necessary because the production wells are screened in the two aquifers.

Therefore, the percentage of the groundwater production from each aquifer is estimated by trial and error method. The model input field data and the results of estimation by numerical techniques are shown in Table 1. The production rates from the Kuwait Group and the Dammam Formation aquifers were changed until the predicted drawdown matched observed drawdown. The trials suggest that about 10% of the field production comes from the Kuwait Group and 90% from the Dammam Formation aquifer.

Table 3. Model parameters and drawdown predictions by numerical simulation of water production from the Kuwait Group and the Dammam Formation aquifers at a rate of 181,840 m^3/day from 1993 to 2012.

Model Input Data	Kuwait Group	Dammam Formation
Premode	Transient	Transient
Time unit	days	days
No. of time units	7269	7269
Grid:		
No. of cells in X & Y	80 × 80	80 × 80
Cell size (m)	1000	1000
No. of layer	1	1
Top layer (m)	115.21	−4.88
Bottom layer (m)	−4.88	−172.81
Layer type	Confined/semi-confined	Confined/semi-confined
Boundary array	Active cell H = 1	Active cell H = 1
Properties:		
Specific yield	0.02	0.02
Specific storage (m^{-1})	1×10^{-3}	5×10^{-4}
Hydraulic conductivity (m/day)	2.45	6.12
Transmissivity (m^2/day)	293.73	1026.93
Initial piezometric head (m)	86.88	81.82
Package:		
A: Production of aquifer/well (m^3/day)	166.32	2604.86
% Production	6% of 113,650 m^3/day	94% of 113,650 m^3/day
Model drawdown (m)	−5.81	−16.50
B: Production of aquifer/well (m^3/day)	266.10	4168.68
Observed	6% of 181,840 m^3/day	94% of 181,840 m^3/day
Model drawdown (m)	−8.96	−26.40

The aquifer parameters and the percentage of aquifer productions were recalibrated using the recovery period during the Iraqi invasion and the new production during 1992 to 1993. The results were found to be in close agreement with the previous estimates of the aquifer parameters except for the present field production and the percentage production of each aquifer. The drawdown values from the 1992 to 1993 period suggested a greater percentage of water could be produced from the Dammam Formation aquifer with the increased rate of production. The recalibrated parameters and results are summarized in Table 2.

Prediction of aquifer performance

The aquifer performance was simulated for the period 1993 to 2012 for the Kuwait Group and the Dammam Formation. The model input data and the results of the prediction runs are summarized in Table 3. It is obvious that, the production rate of the Umm-Gudair field is much greater than the regional groundwater flow. Hence both aquifers are being mined out causing an over increasing drawdown. A total drawdown ranging from 16.50 m to 26.40 m for the Dammam Formation, and 5.81 m to 8.96 m for the Kuwait Group aquifer has been predicted, corresponding to the production rates of 113,650 m^3/day and 181,840 m^3/day respectively, for the period 1993-2012. The regional piezometric levels of the Kuwait Group and the Dammam

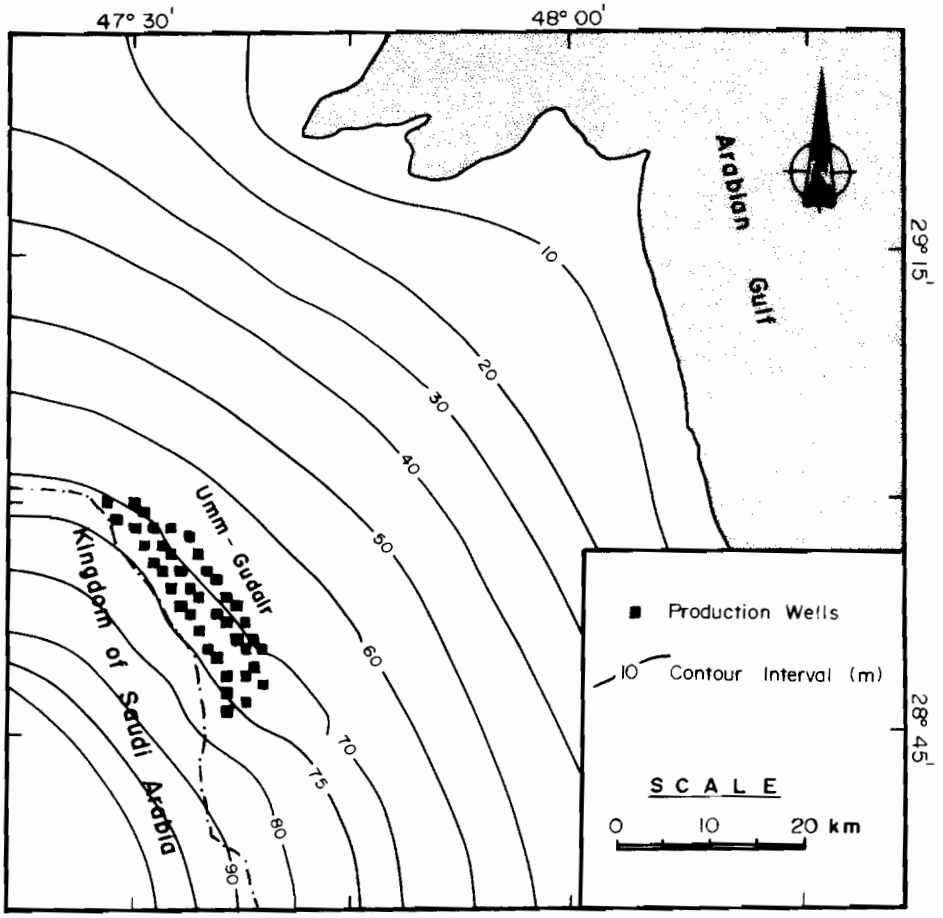

Fig. 9. Contour map showing the predicted regional configuration of the Kuwait Group piezometric level in the year 2012 after 10 years of production in the Umm-Gudair field at a rate of 181,840 m^3/day. The map does not show the effect of water production in other water fields in Kuwait. It is intended to show only the extent of the drawdown caused by production in the Umm-Gudair field.

Formation aquifers are presented in Figs. 9 and 10 for the 181,840 m^3/day production rate. The future regional distribution of the piezometric level on these maps do not indicate what will happen all across Kuwait. The maps are intended only to show the scale of drawdown that will be caused by water production in the Umm-Gudair field.

The predicted time-drawdown curves of the Kuwait Group and the Dammam Formation aquifers are shown in Figs. 11 and 12 for 113,650 m^3/day and 181,840 m^3/day production rates respectively. The piezometric levels tend to stabilize with time for the prescribed production rates. The pseudo-steady state piezometric level remains about 60.95 m above the top of the Dammam Formation aquifer. The groundwater level nearly stabilizes at about 83.82 m above the base and about 30.48 m below the top of the Kuwait Group. The actual drawdown in the Umm-Gudair

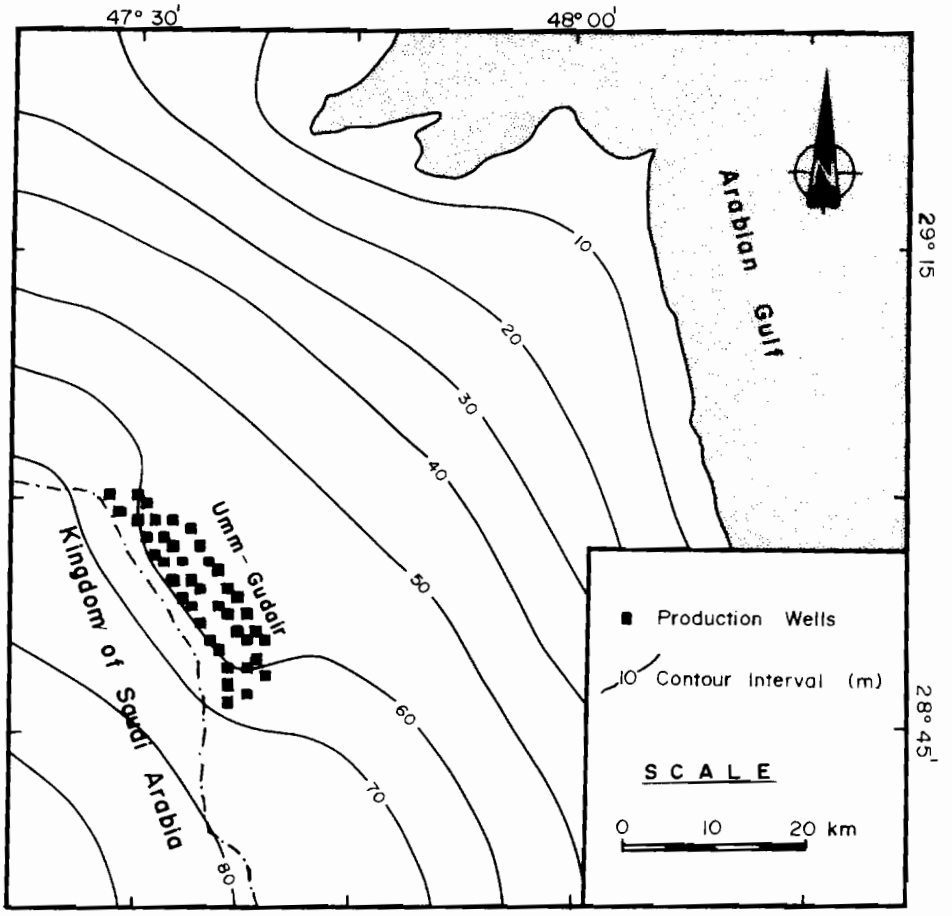

Fig. 10. Contour map showing the predicted regional configuration of the Dammam Formation piezometric level in the year 2012 after 10 years of production in the Umm-Gudair field at a rate of 181,840 m^3/day. The map does not show the effect of water production in other water fields in Kuwait. It is intended to show only the extent of drawdown caused by production in the Umm-Gudair field.

field may be slightly more than the predicted values owing to the effect of production in nearby fields such as the A1-Shagaya field.

CONCLUSIONS

The model calibration and prediction of the aquifer performances of the Umm-Gudair field using numerical techniques indicated that the groundwater production rates are much higher than the regional groundwater flow. Most of the groundwater of the dual-completion wells is pumped from the Dammam Formation. The drawdown values are 16.50 m and 26.40 m for the Dammam Formation, and 5.81 m and 8.96 m for the Kuwait Group aquifer when the field production is increased from 113,650 m^3/day to 181,840 m^3/day during the period 1993–2012. The piezometric level of the Dammam Formation aquifer remains nearly 45.72 m above the top of

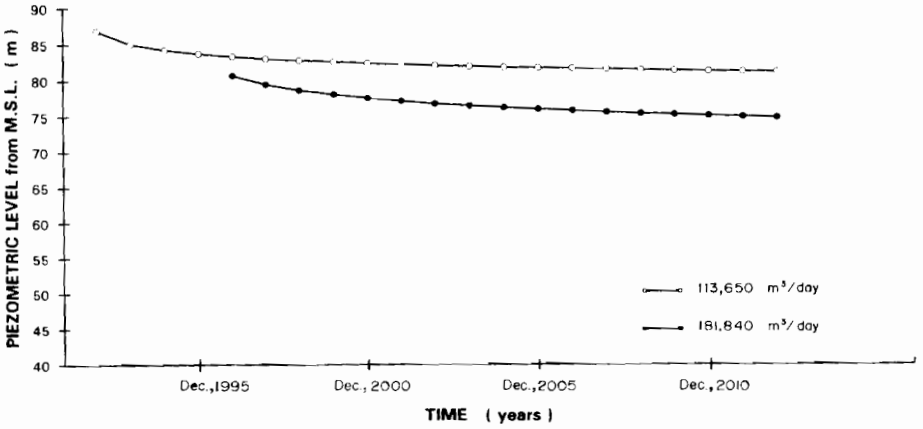

Fig. 11. Predicted time-drawdown curves of the Kuwait Group aquifer at a production rate of 113,650 and 181,840 m^3/day respectively during the period 1993–2012.

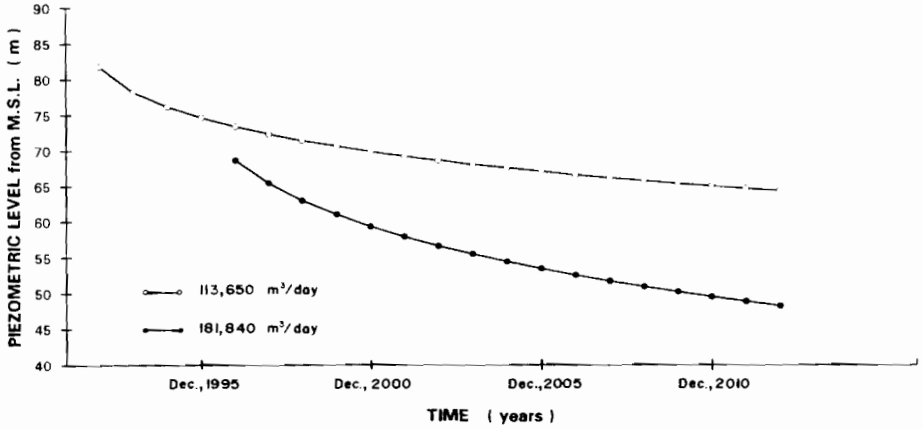

Fig. 12. Predicted time-drawdown curves of the Dammam Formation aquifer at a production rate of 113,650 m^3/day and 181,840 m^3/day respectively during the period 1993–2012.

the formation even after a continuous production rate of 181,840 m^3/day from 1993 to 2012.

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REFERENCES

Abu-Hijleh, A.S. 1988. Hydrogeological and hydrochemical study of Umm-Gudair groundwater area. Southeast Kuwait. M.Sc. Thesis. Kuwait University.

Al-Hajji, Y.Y. 1976. A quantitative hydrogeological study of Field—A, south of Kuwait. M.Sc. thesis. Ohio University.

Al-Rashed, M.F. 1993. Hydrogeology of Shagaya Fields C and E, Southeast Kuwait. Ph.D. Dissertation. University College of London.

Al-Ruwaih, F.M. 1995. Assessment and Management of a Desert Basin in Kuwait. Water International **2:** 213–224.

Al-Yaqubi, A.A. 1987. Hydrochemistry of Umm-Gudair Groundwater field. Ministry of Electricity and Water. Kuwait. Unpublished report.

Anderson, M.P. & Woessner, W.W. 1991. Applied Groundwater Modeling. Simulation of Flow and Advective Transport. Academic Press, New York.

Back, W. 1966. Hydrochemical facies and ground water flow patterns in north part of the Atlantic coastal plain. U.S. Geological Survey Professional paper 498A.

Collins, A.G. 1975. Geochemistry of oil fields waters. Elsevier Scientific Publication Co. Amsterdam. Pp. 258–262.

Kruseman, G.P. & De Ridder, N.A. 1970. Analysis and evaluation of pumping test data. International Institute for Land Reclamation and Improvement. Bull. 11. Wageningen. pp. 1–200.

McDonald, M.C. & Harbaugh, A.W. 1988. MODFLOW, a modular three dimensional finite-difference groundwater flow. U.S. Geological Survey. Open-file report. pp. 83–875.

Mukhopadhyay, A., Al-Sulaimi, J. & Barrat, J.M. 1994. Numerical modelling of ground-water resource management options in Kuwait. Groundwater **32 (6):** 917–928.

Owen, R.M.S. & Nasr, S.N. 1958. Stratigraphy of Kuwait-Basra area, in Habit of oil: American Association of Petroleum Geological Bulletin **42:** 1252–1278.

Pasek, J. 1986. A lithological and stratigraphical study of the Eocene and Post-Eocene deposits in Umm-Gudair area in Kuwait. Ministry of Electricity & Water. Kuwait. Unpublished report.

Prudic, D.E. 1989. Documentation of a computer program to simulate stream-aquifer relation using a modular finite-difference groundwater flow model. U.S. Geological Survey. Open-file Report. pp. 88–729.

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نمذجة عددية لحقل أم قدير بالكويت

فوزية محمد الرويح
قسم الجيولوجيا - جامعة الكويت ص.ب. 5969 الصفاة 13060 – الكويت.

خلاصة

دلت نتائج دراسة النموذج الرياضي ودراسة التنبؤ بأداء الخزان المائي لحقل أم قدير بالكويت على أن معدل إنتاج المياه الجوفية من حقل أم قدير أعلى من معدل جريان المياه الجوفية في الخزان المائي. كما دلت على أن معظم إنتاج المياه من الآبار ثنائية الاكتمال ينتج من تكوين الدمام. وقد اتضح أن قيمة الهبوط فى مستوى المياه الجوفية يتوقع أن تبلغ 16.5 متر و 26.2 متر لتكوين الدمام و 5.8 متر و 8.85 متر لمجموعة الكويت وذلك بزيادة معدل انتاج الحقل من 113650 مترا مكعبا في اليوم إلى 181480 مترا مكعبا في اليوم خلال الفترة 1993 – 2012 . كما بينت الدراسة أن مستوى المياه الجوفية يظل تقريبا 45.72 متر فوق سطح تكوين الدمام، وذلك على الرغم من استمرار انتاج المياه الجوفية بمعدل 181840 مترا مكعبا في اليوم من عام 1993 – 2012 م.