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Hydrologic Simulation and Groundwater Management of Wadi Al-Lith in Saudi Arabia

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Abstract. The groundwater is the main water source for water consumption over the kingdom of Saudi Arabia. This study illustrates the groundwater status and management in wadi Al-Lith basin, in the Western Province of Saudi Arabia. Using a two-dimensional finite difference groundwater model (GW8) a simulation of the groundwater of the basin is made. The model was developed by the United Nations Organization (Water Resources Branch). Several model tests and calibration were made to verify its ability for simulating the hydrological condition of the area. The aquifer responses to various pumping rates with their elapsed time were illustrated, where the different aquifer hydraulics under conditions of steady and transient conditions were studied. Three scenarios of water supplying for new land expansion and reclamation projects in the study area were performed to find the best planning strategy. Meanwhile, the time dependent exploration curve was estimated and could be used for water usage plans. The final results indicated that the stored groundwater and incoming water could supply Al-Lith City, the nearby villages, and the new expansion projects with enough water for domestic and agriculture demands under certain defined hydrological constraints.

1. Introduction

Numerous of scientists did many of studies concerning of groundwater flow in steady state or unsteady state conditions utilizing analytical or numerical methods; i.e. Dupuit (1863), Thiem (1906), Cooper and Jacob (1946), Walton (1962), Toth (1962), Boulton (1963), Freeze (1971), Prickelt and Lonnquist (1971), and Trescott (1975). The development of some numerical methods such as finite difference and finite element methods with the rapid advancement in the technology of the digital computers made these techniques possible for illustrating and solving the complex groundwater problems. The finite difference method is considered one of the major numerical methods, which is used in the groundwater applications. Tyson and Weber (1964), Prickelt and Lonnquist (1971), Freeze and Cherry (1979), Remson (1971) Trescott *et al.* (1976), and Cooley (1977), have many studies using these numerical techniques in groundwater problems. Meanwhile, the United States Geological Survey (USGS) developed many finite difference models to simulate the groundwater flow. Two dimensional model developed by USGS was used by Pinder and Cooper (1970) for solving two dimensional flow problem of groundwater aquifer. Meanwhile, a three dimensional model was developed by Trescott (1975). The United Nations Department of Technological Co-operation for Development (Water Resources Branch) performed a very useful model for groundwater which applied successfully in different fields of groundwater since 1989. Recently, much effort had been devoted to develop the numerical technique for solving the partial differential equations that governing the water flow in different types of aquifers. Many programs have been published in different literatures, e.g. Pinder *et al.* (1970) , Prickelt *et al.* (1971), and Trescott *et al.*(1976).

2. Groundwater Studies in Kingdom of Saudi Arabia

The location of the study area as shown in Fig. (1) represents around 50 km length of wadi Al-Lith basin with 3080 km^2 catchment area. It lies between 40º14′ and 40º30′ longitude and 20º00 and 21º31′ latitudes.The study area is a part of the western province of Saudi Arabia. This province submitted to several hydrogeological studies performed by some organizations and scientists. In 1984, Ministry of Agriculture and Water in Saudi Arabia (MAW) presented a water atlas for the Kingdom. A hydrological study for the Arabian shield and it's coastal areas of the Red Sea was summarized by Hoztl and Zolt (1982). Dames and Moore (1987) achieved a good report for five wadis in the western provinces of the Kingdom out of which Wadi Al-Lith was one of them. Al-Syari and Zolt (1978) discussed the quartenary deposits in Saudi Arabia. Sogreah (1968) tested the wells in Wadi Al-Lith basin for groundwater evaluation. Othman M.N. (1983) presented a full study of water resources in Saudi Arabia including details study on south Tihama Wadies. Abu Al-Heija (1985), gave the geotechnical properties of Al-Lith Sabkha. Abdul-Razzak (1976) presented a study on the flood prediction in Wadi Al-Lith. Recently, Khayat and Kiwan (2000) performed a study about the hydrogeologic and climatic status of Al-Lith basin in Saudi Arabia, where they estimated the recharging by infiltration to the groundwater aquifer under prevailing rain storm.

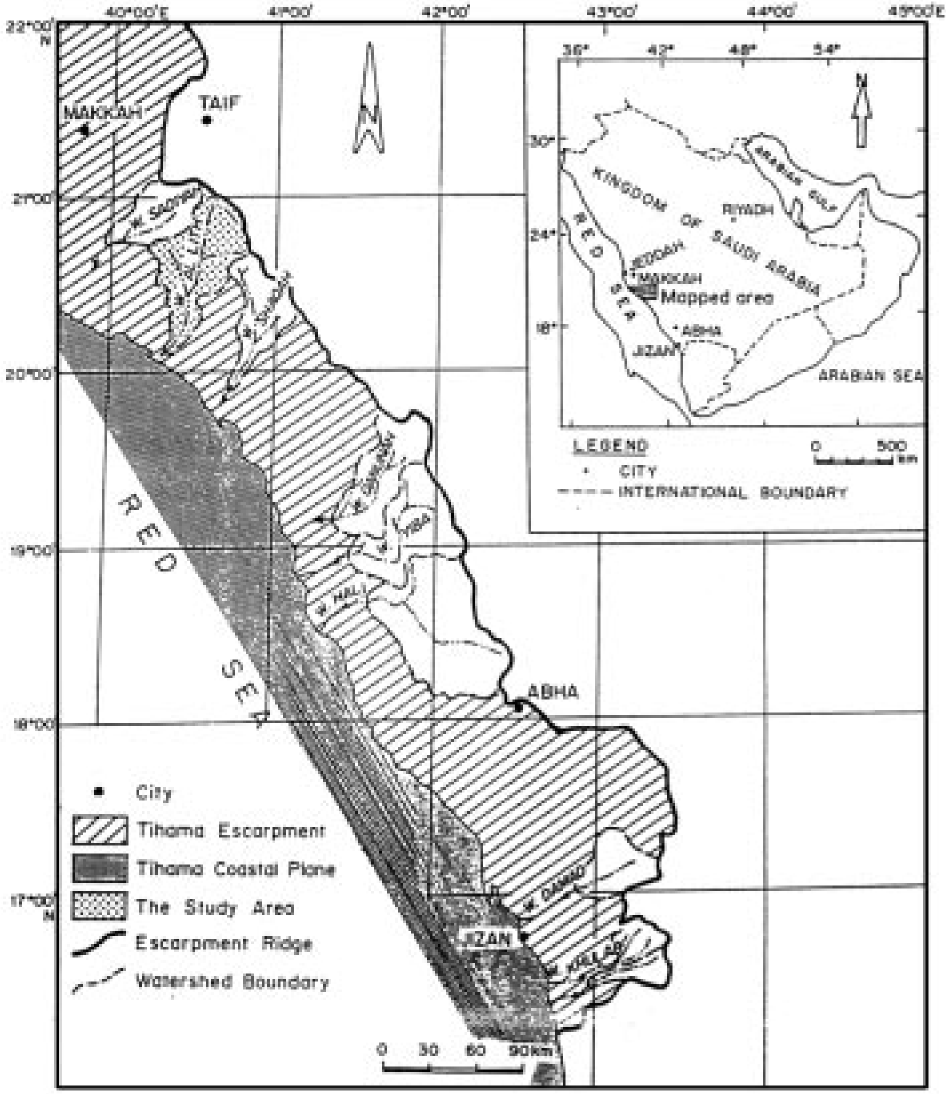

FIG. 1. Location map of Wadi Al-Lith in Saudi Arabia.

3. Model Description

3.1 Governing Equations

The main governing equations of the water flow are the mass conservation and momentum equations. For unconfined aquifer and two-dimensional flow, the main governing equation can be described by the well known flow equation, as follows (Jacob 1969),

$$\frac{\partial h}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial h}{\partial y}(K_y \frac{\partial h}{\partial y}) + R = S_y \frac{\partial h}{\partial t} \tag{1}$$

where, *Kx* and K_y are the hydraulic conductivity in *x* and *y* directions (m/day), respectively, *h* is the piezometric head of aquifer (*m*), *R* is the aquifer sink/ source (recharge/discharge) ($m^3/m^2/d$), and *Sy* is the aquifer specific yield. Meanwhile, the transformation of governing equation in a finite different form had been described in many references, i.e. Jacob(1969), Wang and Anderson (1982), and Trescott *et al.* (1976), where the following equation is one of these descriptions

$$\frac{1}{\Delta x_i}\left[(K_x h)_{i+\frac{1}{2},j} \frac{h^n_{i+1,j} - h^n_{i,j}}{\Delta x_{i+\frac{1}{2}}} - (K_x h)_{i-\frac{1}{2},j} \frac{h^n_{i,j} - h^n_{i=1,j}}{\Delta x_{i-\frac{1}{2}}}\right] + \frac{1}{\Delta y_i}\left[(K_y h)_{i,j+\frac{1}{2}} \frac{h^n_{i,j+1} - h^n_{i,j}}{\Delta y_{i+\frac{1}{2}}} - (K_y h)_{i,j-\frac{1}{2}} \frac{h^n_{i,j} - h^n_{i,j-1}}{\Delta y_{j-\frac{1}{2}}}\right] \tag{2}$$

$$+R^n_{i,j} = S_{i,j} \frac{h^n_{i,j} - h^{n-1}_{i,j}}{\Delta t}$$

Where, $h^n_{i,j}$ and $h^{n-1}_{i,j}$ are the piezometric water heads of node number *i, j,* at time stages *n* and *n*–1, respectively, Δx, Δy are the grid spacing in *X* and *Y* directions, respectively, K_x and K_y are the aquifer hydraulic conductivity in *X* and *Y* directions, respectively, and Δt is the time increment. Equation (2) describes the governing partial differential equation of two dimensional groundwater flow in non-homogeneous isotropic unconfined aquifer in an unsteady conditions. Equation (2) can be rearranged in the form of algebraic equation matrix as stated by Trescott *et al.* (1976), as follows,

$$A_{i,j}(h^n_{i+1,j} - h^n_{i,J}) + B_{i,j}(h^n_{i-1,J} - h^n_{i,j}) + C_{i,j}(h^n_{i,j+1} - h^n_{i,J}) + D_{i,J}(h^n_{i,J-1} - h^n_{i,j})$$
$$= S_{i,j} \frac{(h^n_{i,j} - h^{n-1}_{i,j})}{\Delta t} \tag{3}$$

Where,

$$A = \frac{K_x h_{i+\frac{1}{2},j}}{\Delta x_1^2 + \frac{1}{2}\Delta x_1} \tag{4}$$

$$B = \frac{K_x h_{i-\frac{1}{2},j}}{\Delta x_1^2 - \frac{1}{2}\Delta x_1} \tag{5}$$

$$C = \frac{K_y h_{i,j+\frac{1}{2}}}{\Delta y_1^2 + \frac{1}{2}\Delta y_j} \tag{6}$$

$$D = \frac{K_y h_{i,j-\frac{1}{2}}}{\Delta y_j^2 - \frac{1}{2}\Delta y_j} \tag{7}$$

Equations (3) through (7) are algebraic equations which representing the general governing equations of groundwater flow in non-homogeneous isotropic unconfined aquifer.

3.2 Applied Model

The groundwater model which was developed by the United Nations, Department of Technical Co-operation for Development and Water Resources Branch (GW-8 Model), was applied to simulate the behavior of Wadi Al-Lith aquifer under steady and unsteady conditions. The model was created by super imposing the finite difference grid (equidistant) upon hydrogeological map. The program code was written in Fortran 77 language which could be run on any Fortran compilers. It is based on the differential equation for two dimensional steady and unsteady flow in an unconfined aquifer(as described before), where the numerical solution of the equation was obtained through an iterative, (iterating direction implicit procedure) finite difference approach.

4. Model Application and Calibration

4.1 General Aquifer Data

The records of about 75 observation points including wells, hot springs and base flow were used to estimate the hydrogeological characteristic of the alluvial aquifer. The finite-difference grid upon hydrogeological map of the aquifer Fig.(2) was made in square dimension grid using map scale 1:50,000. Each grid was having 1,000,000 m^2 area. The grid mesh consists of 26 columns and 42 rows.

The groundwater levels data of the aquifer were obtained from regular monitoring of wells, base flow and other irregular distribution and production wells that scattered along the wadi. The date of logging was 13 Jun 1992 – 12 Jan 1993, where the corresponding water levels were considered as the initial water levels for model calibration.

The ground surface elevation identifies the top of the aquifer, where the aquifer is unconfined type. The elevation for each node are determined from a topographic map of scale 1:50,000 and were verified by site investigation. The bottom of aquifer was represented by the bedrock, where their elevations were estimated from longitudinal and cross sections of aquifer which were established by Dames and Moore (1987). Moreover, well inventory, geological map, site visits, were studied to provide this bedrock distribution.

The hydraulic conductivity of the aquifer was in range of 53-160 m/d. This was based on the pumping test which was done by Dames and Moore (1987). However, these values were changed during the running of the program, where the range of 50-130 m/d was selected after running and calibration of the program.

The specific yield of the aquifer varied from up stream to down stream due to physical characteristics of the alluvium. In the up and middle stream, where the grain size was relatively coarse and tends to be well-sorted materials, so the specific yield was relatively high. While in the down stream, the grain size was fine that reflects low specific yield. Generally, after steady state calibration of the model, the specific yield was ranged from 0.18 to 0.35.

4.2 Initial and Boundary Conditions

The measurement of water table depth was applied to find the distributed hydraulic head, which is specified as initial condition. The applied model (GW-8) was used to compute the initial head by using the field measurement of water tables in the wells and excluding all the new stresses or changes in the aquifer condition such as, pumping by wells, evaporation, hot spring recharge, infiltration recharge, and sub-surface in and out flow.

The boundary condition for the study area was categorized into two main types. The first one was Dirichlet condition, or constant water level boundary, which represents the base flow path in the upper part of the area (upstream of

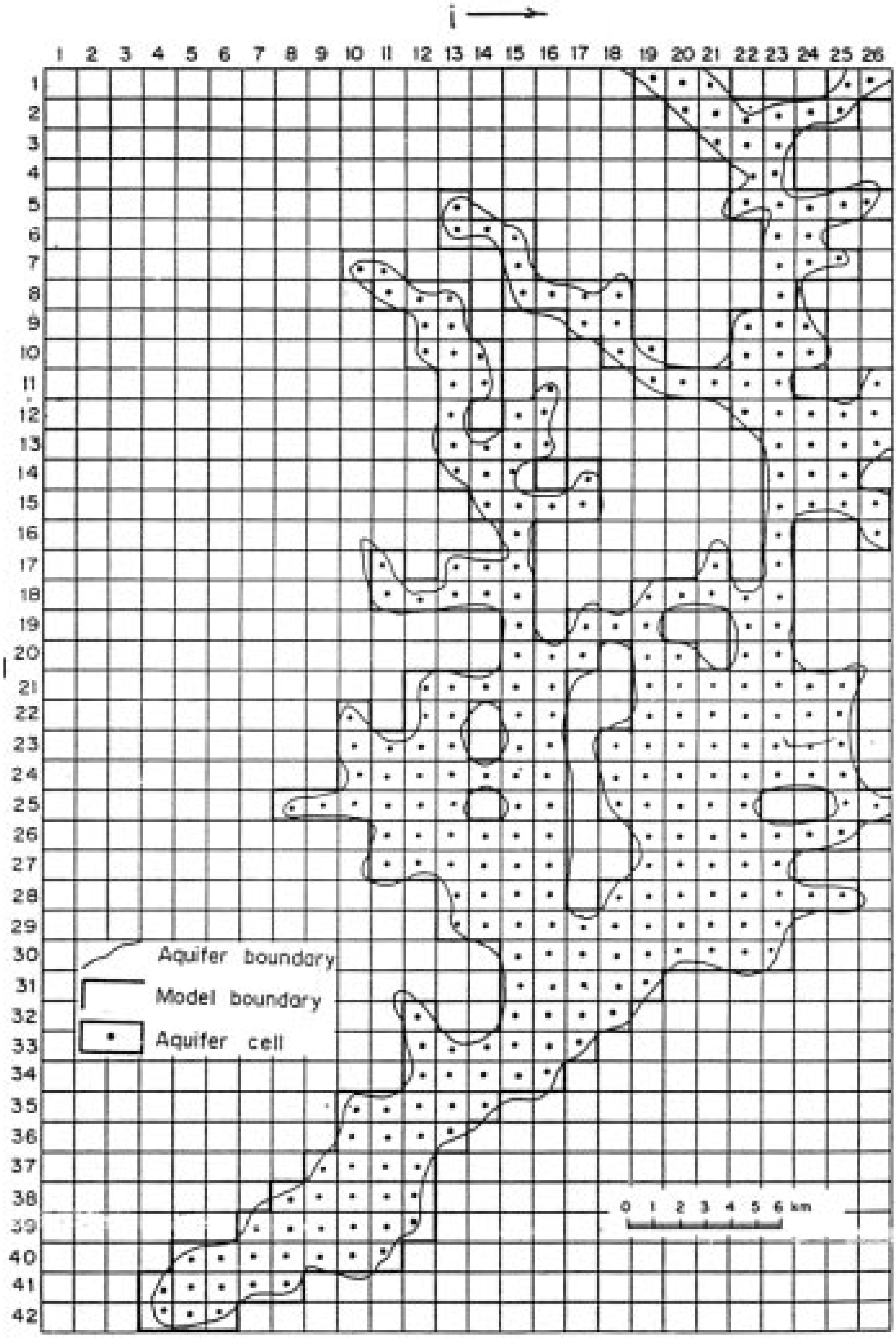

FIG. 2. Finite difference grid of the study area.

the wadi), where 20 years of base flow observation was made. The second type was Neumann condition or dynamic inflow and outflow boundaries, where the total amount of inflow was classified as a sub-surface recharge to the aquifer. The sub-surface flow as outlet discharge from the downstream will be contaminated by seawater while some parts disperse in the fine thick sediment, which characterizes the lower part of the area. The amount of outflow was classified as a sub-surface discharge from the aquifer outlet. The quantity of inflow and outflow were calculated from Darcy's law, where three locations were considered for the inflow calculation and two locations for outflow discharges calculation, respectively. The three location base flow recharges were 150, 56, and 204 m^3/d, while the two locations of outflow discharges were 73 and 61 m^3/d, respectively.

4.3 The Evaporation Parameters

Evaporation is an important component for the water balance process where this process is a dominant process in the region. In term of water balance of the study area, strongly allowances have to be taken for evaporation loss from free water on the ground surface and from certain depth of underground surface subjects mainly on the retained water in soil. The model specifies each cell which is either evaporation or permeable or no-evaporation or impermeable. The input factors which controls evaporation are the following:

i) *Critical depth below land surface:* This depth represents the elevation below land surface which underneath will be no evaporation loss. It is empirically estimated by Schoeller (1959) formula [$D_{cr} = (8^{*}T_{cr}$ +/–15)]. The equation calculates the critical depth D_{cr} (cm) as a function of average mean temperature T_{cr} in Celsius degree (ºC). The calculated critical depth below land surface where water will not evaporate under it, ranged between 273 to 303 cm based on the recorded area temperatures.

ii) *Actual evaporation losses:* The actual evaporation fluxes (E) from water table (m/d) was calculated as a fraction from the maximum evaporation from free water table ($E_{\max}$). The empirical equation developed by Schoeller (1959) [$E = E_{\max} \cdot \exp(-a \cdot z)$], where, z is the depth below land surface (m), and a is a shape factor (fraction). Moreover, in case of water table above the aquifer top, but still under permeable surface condition, the evaporation rate is reduced to some specified fraction. The selected shape factor was 0.15, which comes by try and error and as well as comparing the previous studies of evaporation estimation in the region

4.4 Recharge by Infiltration

Khayat and Kiwan (2000), described four cases of water recharging by infiltration to the aquifer using prevailing rainfall storm events. The first case is valid if the groundwater table was below the surface and above 1 meter depth, where the rechargeable ratio is 40% from the rainfall, equal the ϕ-index of soil (total surface infiltration ratio). The second case would occur if the groundwater table was located at depth 1-2 meter below the land surface, where the rechargeable ratio became 30%. The third case occurs when the groundwater table was located at depth 2-3 meter, where the rechargeable ratio became 4%. The fourth case would be valid if the groundwater table was deeper than 3 meters below the soil surface, then rechargeable ratio would equal to 0.0%.

4.5 Steady State Calibration

The applied model was calibrated for the study area by adjusting different values of hydraulic conductivity in the area network until the model results are reproduced. The historical water levels variations for the period of 1984-1987 was collected and used for model calibration. This period was selected because it has more detailed and continuously measurements of field data in wadi Al-Lith area. At the end of the running process, the simulated heads became close to the historical records.

4.6 Unsteady State Calibration

After executing the initial condition for the illustrated area, the unsteady state calibration was done to draw an appropriate shape of water level changes with time. The procedure was performed by entering and adjusting some input to get matching values between simulated water levels and historical water levels during the period of 1984-87. The input parameters for the unsteady state calibration process in the study area includes changing, and adjusting by trial and error, the specific yield, recharge from hot springs, inflow and outflow, evaporation losses and pumping rates. The specific yield was started by a constant value equal to 0.25 for each node in the model network, but this value have been increased /or decreased in different points of the model in order to achieve more matching values between historical and simulated records. The simulation period for this calibration was selected to be 60 time steps. The length of each step equals to 30 days with irregular pumping rate and evaporation loss. A comparison was made between the two records of historical and simulation as shown in Table (1).

5. Analysis of Results

5.1 Estimation of Discharges and Recharges

i) *Discharge by evaporation:* Depend on climatic variation and groundwater levels, the evaporation loss varies from time to time and from place to place throughout the study area. The loss by evaporation that occurs in the upstream and some part of the middle stream, where the water table is very close to the land surface, takes place in the limit depth of critical zone (0-3 m). Finally the real average water loss by evaporation from the study area was around 24622 m^3/d. This value may increases or decreases depending on the flood activity, which would change the base flow area, as well as, changing the temperature and other factors.

TABLE 1. Measured and simulated water levels in wells.

Well no.	I	J	Water levels difference (m) from 1990 to 1994	Simulated values (m)	Difference between measured and simulated (m)
ID - 2	5	42	1.3	1.5	0.2
ID - 4	8	40	– 0.9	1.1	2
ID - 7	13	36	1.5	0.9	– 0.6
LD - 8	17	32	– 0.7	0.5	1.2
G - 10	15	26	– 2.5	1.9	4.4
G - 34	20	28	– 0.5	0.4	0.9
G - 35	20	27	– 0.9	0.9	1.8
BA - 18	15	19	– 1	– 1.3	– 0.3
G - 16	23	19	0	0	0
LU - 26	23	14	0	0	0
BA - 23	16	12	0.8	1	0.2
LU - 32	23	2	0.4	0.4	0
LU - 33	1	26	0	0	0
TU - 24	18	10	– 1.7	– 1.1	0.6

I : Horizontal node number.
J : Vertical node number.

ii) *Discharge by sub-surface:* The outflow discharge as sub-surface flow occurs in the down stream of the aquifer outlet, utilizing Darcy's law and water level contour maps, the groundwater which leaves the boundary of the modeling zone was 950 m^3/d.

iii) *Discharge by production wells:* Discharge by pumping wells was distributed over the aquifer. Based on the well inventory during site investigations, the average quantity of discharge water from pumping wells reached 2700 m3/d. Most of this water was used for domestic purposes. Table (2) illustrates the average pumping rate from different locations at the study area.

iv) *Aquifer recharge by upstream inflow:* The entering water to the aquifer from upstream boundary is high due to elevation differences and high hydraulic conductivity. Utilizing Darcy's law the calculated average quantity of entering water to the aquifer was 3070 m^3/d.

v) *Aquifer recharge by hot springs:* The produced water from this spring is approximately 670 m^3/d. Around 40% of this quantity may feed the aquifer, where the water table near the spring is very close to the land surface and the soil has ability to infiltrate the water to the saturated zone. Therefore, the total quantity of water, which could recharge the aquifer from hot spring, was estimated as 256 m^3/d.

TABLE 2. Average pumping rate of the available wells.

Well no.	I	J	Average pumping rate (m^3/day)
ID - 4	8	40	120
ID - 5	11	40	70
ID - 6	11	39	65
ID - 7	13	36	110
ID - 8	17	32	120
GU - 9	15	29	250
GU - 10	15	26	90
GU - 11	12	24	250
GU - 12	19	25	320
GU - 13	22	26	220
GU - 14	25	25	30
GU - 15	21	22	195
GU - 18	15	19	90
BA - 23	16	12	50
TU - 24	18	10	70
LU - 26	23	13	130
LU - 29	23	8	140
LU - 30	25	7	140
GU - 34	20	28	150
GU - 35	20	27	100

I : Horizontal node number.
J : Vertical node number.

vi) *Aquifer recharge by rainfall:* The aquifer recharge by the rainfall through infiltration process is spatial and temporal dependent variable. The average estimation of daily recharge water to the aquifer during the rainy season was 677m^3/d. (for 3 months duration per year). This average was extracted from rainfall storm data in 1987.

5.2 Planning and Management Schemes

Different schemes using the simulation process were followed to find various plans of water pumping and usage. The decision variables such as pumping rate, temporal and spatial distribution of pumping may affect the system state variables like water level. For solving the management problem, the prediction response of the system to any suggested policy must be clear to get the new state of the aquifer behavior. The main goal of management of groundwater system at wadi Al-Lith is to exploit an optimum exploitation of the available and incoming water, whether in domestic, agriculture and urban planning demands. This goal can be achieved by selecting one or more of the best suggested policies among different alternative schemes. The best policy should fit to the achievement of the pre-stated objectives and should not violate some imposed constrains to the groundwater system. These constrains must satisfy supplying water at lest for the coming 40 years with good quality.

As main results, the water resources system in the study area regarding to quantity including of three main resources as follows :

1) the total incoming water from subsurface inflow was 1.2×106 m^3/y,
2) the total incoming water from the hot spring was 9.34×104 m^3/y, and
3) the average annual incoming water by rainfall was 6.1×10^6 m^3/y (around three months per year).

The total natural loss was computed as 7033 m^3/d, while the average discharge from available pumping wells for agriculture and domestic use was 2700 m^3/d. As a result of this impression, three scenarios of aquifer yield have been done for exploitation of the incoming available water in the whole water resource system.

5.3 The First Scenario (Deferred Yield)

The idea of deferred perennial yield is to exploit the overall water at saturated zone in the upper three meters because this water has ability to evaporate under effect of mean temperature in the region. In this regard, to achieve this proposed target, two different pumping rates were followed. The first one is the initial rate that is followed to pump high quantity of groundwater from different locations. The pumping rate in this case must exceed the pumping rate of the perennial yield to reduce the water level up to critical depth below land surface under which evaporation loss does not occurs. The calculated losses of groundwater by evaporation were estimated as 24622 m^3/d from the whole-modeled area. In this regard, several cells were selected to pump water equal to that quantity to decrease the water level under critical depth. Therefore, this quantity should be pumped in short period and the extracted water should be used for useful purposes. During this scenario the water level has been lowered to the critical depth, the water level contour map after this scenario was shown in Fig. (3) .

5.4 The Second Scenario (Sustained Yield)

The sustained yield means exploitation the new water that recharges the aquifer from subsurface inflow, hot spring and rainfall. This means the quantity of

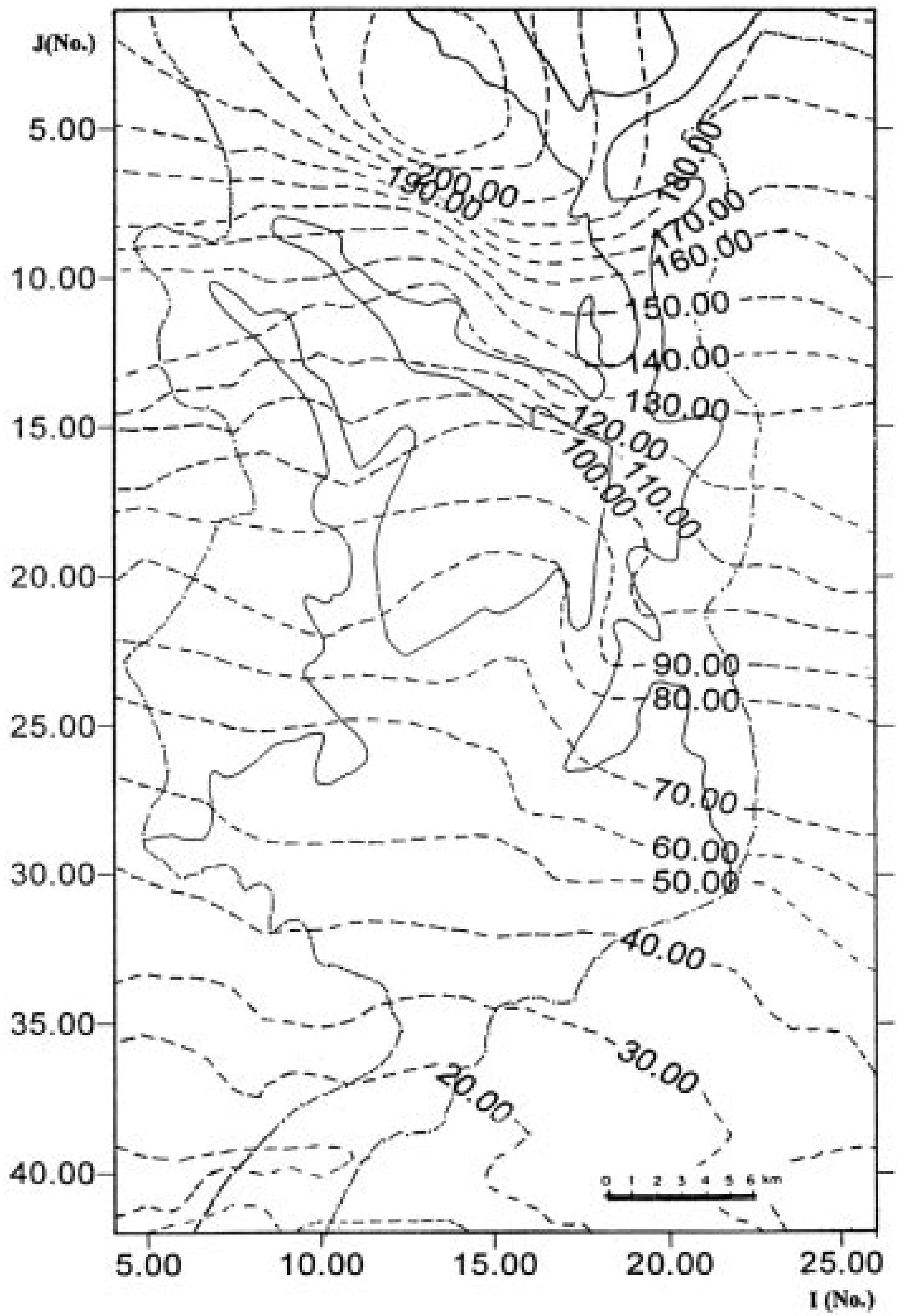

FIG. 3. Water level contour map as simulated by first scenario.

water that equals to the difference between natural recharge and discharge may be withdrawn from the aquifer. This operation implies that the discharging water from pumping wells at that time is an exploitation of all new entering water to the aquifer without undesirable results in groundwater storage. Finally, the storage groundwater in the aquifer will pump at a rate compatible to the perennial yield. To achieve this scenario in the study area, eight locations of production well groups were suggested to drill near the recharge sources. These wells should be located close to the Al-Safra village and at the upstream part, where the hot spring position and subsurface inflow place respectively as well as the location of rechargeable cells where the water level ranged from 0-3 meters. The pumping rate from these wells was 2545 m^3/d which was equivalent to the different between incoming water from the natural resources and outgoing from subsurface outflow. Fig. (4) represents an example of water level contour map after pumping a quantity of water equal to the recharge rate of subsurface inflow, hot spring and recharge water by infiltration through rechargeable cells.

5.5 The Third Scenario (Practical Simulation of Pumping Rate)

For estimating the optimum pumping rate based on real aquifer response with practical withdrawn in particular and different time steps, many sub-scenarios had been done using the method of iteration to see in which direction the water level go down under different pumping rates with time. Meanwhile, different levels of pumping rates were followed to test the sensitivity of pumping rates on the distribution of water levels. Each sub-scenario consists of pumping rate for each cell, percentage of drawdown and number of time steps. Fig. (5) presents the water levels contour maps of real water level distribution in the aquifer after 40 years period under different rates of water pumping. The duration of consumption against rates in this scenario was considered as 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 years, respectively. According to the previous calculations, the following main results obtained from this scenario:

1. Pumping rate which equals to 2.34×10^7 m^3/y (6.5×10^4 m^3/d) against 40 years was selected to be as practical pumping rate, where by this rate around 91% of the aquifer wells will be dried as seen in Fig. (5).

2. The water drawdown in the upstream cells was high and changed rapidly comparing with the drawdown in the downstream due to the high difference in bedrock levels, topography, water slope and hydraulic conductivity values Fig. (6).

3. Water level in the downstream part rise up with progressing of time until 25 years of continuous pumping with the same rate due to accumulation of high quantity of groundwater at that zone as a result of high water velocity due to

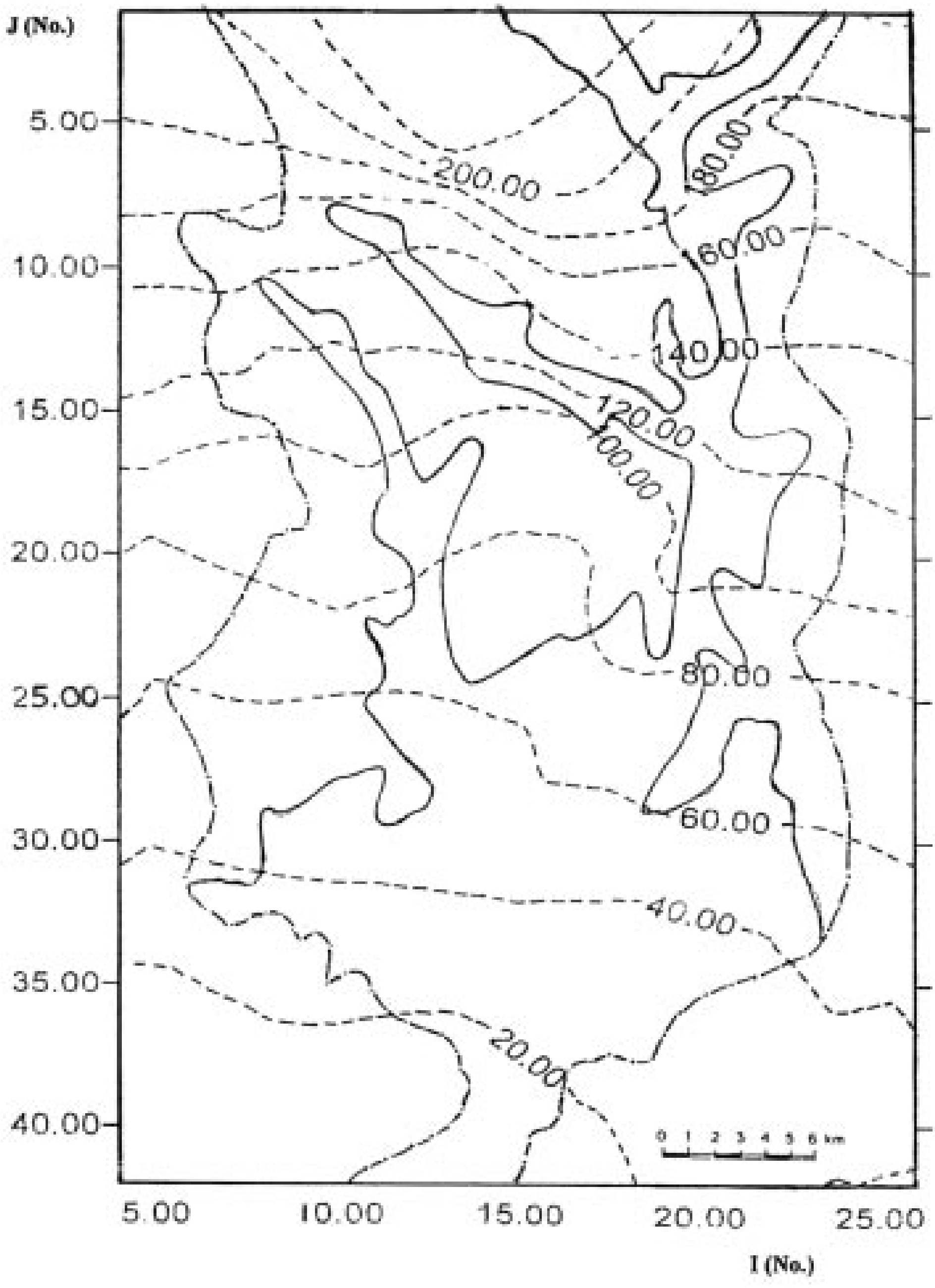

FIG. 4. Water level contour map as simulated by second scenario.

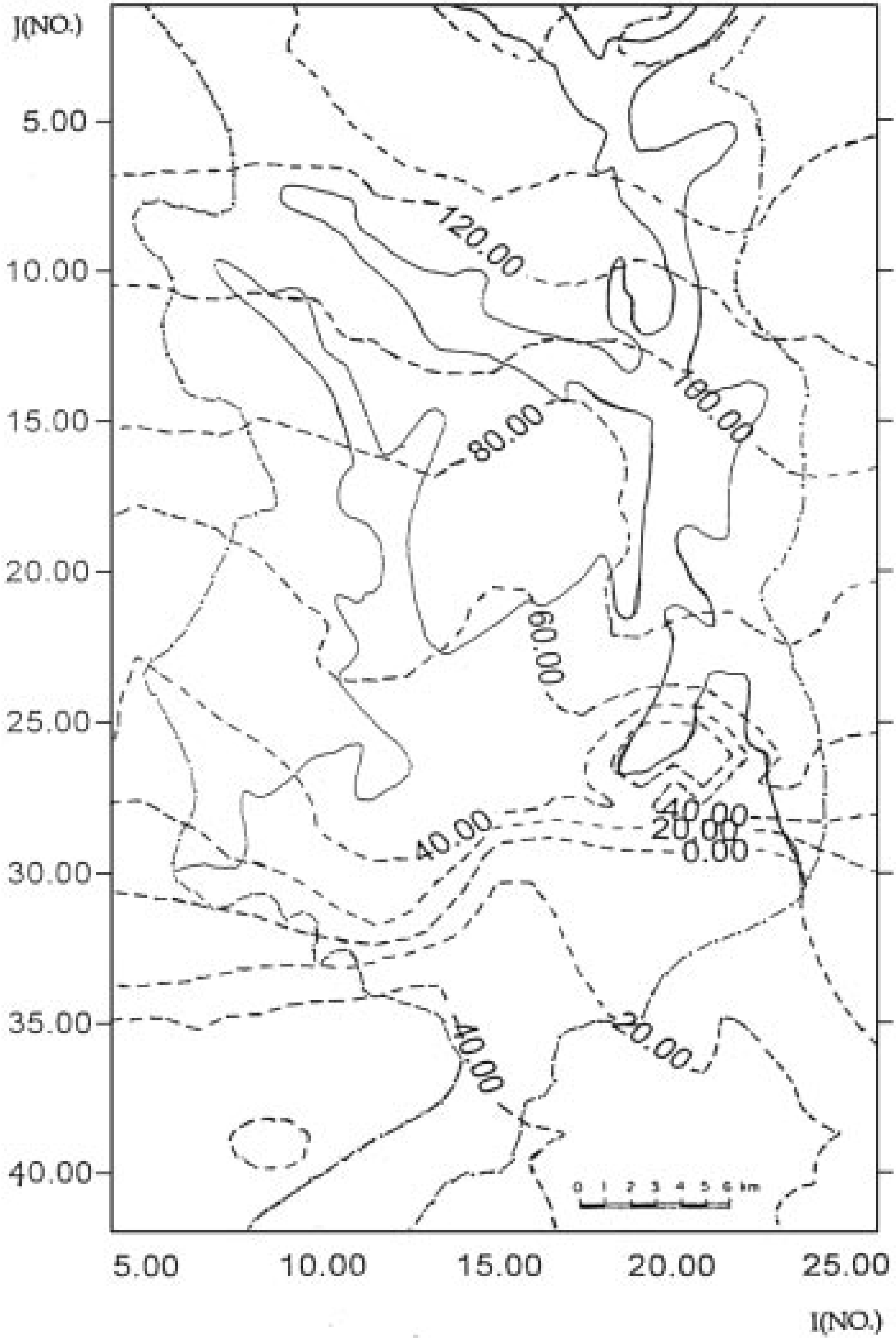

FIG. 5. Water level contour map after 40 years of simulation period.

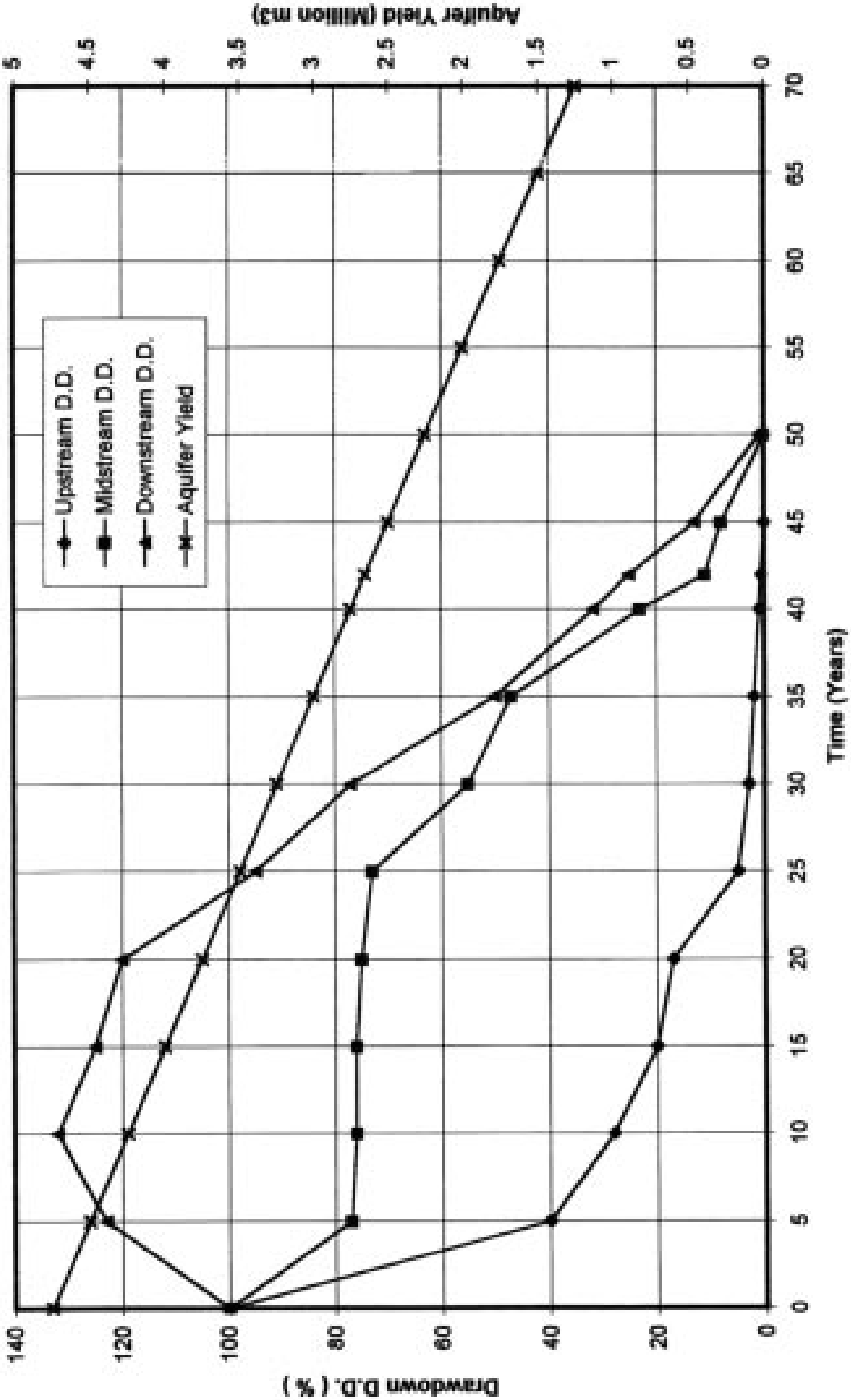

FIG. 6. The aquifer yield and drawdown variations with time.

difference in slope between upstream and downstream. After that period the water starts decreasing. Therefore it is better to increase the pumping rates in that locations.

4. There is no change in drawdown under different rates of pumping in particular time step, because of converging to the equilibrium rate between pumping rate and sub surface movement of water.

6. Conclusions

From the results analysis and discussions, the main conclusions can be summarized as follows:

* The real water head distributions in the aquifer under different values of pumping rates, reflects the sensitivity of pumping rates and well locations on the aquifer response.

* Due to high inclination of aquifer bed toward downstream, a rapid movement of groundwater was developed in the beginning of the simulation, where the maximum quantity of groundwater accumulates in the downstream zone especially the steady state condition was achieved.

* The cells which located at the lateral boundaries of the aquifer in the upstream and middle stream have quick responses to the drawdown rather than the others cells due to high permeability and inclination of bed rocks and shallow thickens of saturated zone.

* Groundwater recharge by infiltration process occurs only in the study area when the water table reaches to 3 meters or less,

* The other recharge sources to the aquifer were from subsurface flow, rainfall and hot spring, while discharge elements were from subsurface loss through outlet of wadi, evaporation and pumping wells,

* The water moves fast from up stream to down stream aquifer during pumping to accumulates in the down stream aquifer,

* The estimated time dependence exploration curve has a good contribution for the different agriculture and urban expansion projects.

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التمثيل الهيدرولوجي وإدارة المياه الجوفية في وادي الليث بالمملكة العربية السعودية

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المستخلص . تعتبر المياه الجوفية المورد الرئيس للاستخدامات المائية على مستوى المملكة العربية السعودية . حيث تناولت هذه الدراسة وضع المياه الجوفية وإدارتها بحوض وادي الليث أحد وديان منطقة تهامة بالمنطقة الغربية بالمملكة العربية السعودية . تم عمل تمثيل للخزان الجوفي بالحوض باستخدام نموذج GW8 ثنائي الأبعاد بطريقة الفروق المحدودة . وهذا النموذج تم تطويره بهيئة الأمم المتحدة (قسم موارد المياه) . تم عمل العديد من الاختبارات والمعايرة للبرنامج للتحقق من قدرة النموذج على تمثيل الوضع المائي للمنطقة . تمت دراسة درجات استجابة الخزان الجوفي وفتراته الزمنية تحت تأثير معدلات سحب (ضخ) للمياه مختلفة ، حيث تم تحديد مختلف الخواص الهيدروليكية للخزان تحت ظروف حالة الثبات والحالة الانتقالية . تم وضع ثلاث خطط للإمداد بالمياه لأغراض التوسعات الجديدة ومشاريع الاستصلاح للوصول إلى أفضل خطة استراتيجية . تم الحصول على منحنى معدلات الضخ المائي–الزمني والذي يمكن الاستعانة به في خطط الاستخدام المائي . أوضحت النتائج النهائية أن مجموع المياه بالخزان الجوفي بالحوض مضافًا إليها معدلات التغذية تكفي لإمداد مدينة الليث والقرى القريبة منها وكذلك مشاريع التوسع العمراني والزراعي الجديدة بالمياه الكافية لأغراض الشرب والزراعة وذلك تحت محددات هيدروليكية معينة .