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EFFICIENCY OF GROUND WATER RESOURCES IN NORTHEAST SINAI PENINSULA, EGYPT

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كفاءة موارد المياه الجوفية
شمال شرق شبه جزيرة سيناء بمصر

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يشمل البحث الحالي منطقة الشيخ زويد ـ رفح التي تقع شمال شرق شبه جزيرة سيناء على حدود مصر الشمالية الشرقية وتغطي حوالي ١٠٠ كيلومتر مربع ، وقد تم عمل خريطتين لمعاملات المياه الجوفية بمقياس رسم ١ : ٢٥٠٠٠ في عامي ١٩٨٢ و ١٩٨٨ لدراسة الكفاءة الكمية للخزان الجوفي أثناء العامين المذكورين ، ثم خريطة محصلة لمعاملات المياه الجوفية لدراسة التغير الذي طرأ على الخزان الجوفي نتيجة للسياسة المائية خلال تلك الفترة .

تم كذلك تجميع خريطة تشمل الكفاءة الكمية والنوعية للخزان الجوفي حتى عام ١٩٨٨ وأمكن على أساسها تصنيف الأراضي المنزرعة بالمنطقة حسب مدى صلاحية مياه الري الجوفية وأولويتها للاستغلال الأمثل مع وضع توصيات للمناطق التي تحتمل التوسع الزراعي والمناطق التي يلزم إعادة النظر في الاستغلال الحالي بها

Key Words: Ground water hydrology, northeast Sinai

ABSTRACT

The present study deals with actual quantitative and qualitative evaluation of the groundwater resources in El Sheikh Zuwayid-Rafah area, the northeast coast of Sinai Peninsula. The quantitative analysis is achieved by using groundwater contour maps in 1982 and 1988m while the qualitative evaluation is done using an isosalinity contour map in 1988. A resulting modulus contour map (1982-1988) is drawn to show the variations in the groundwater flow condition. An efficiency groundwater map is compiled from the modulus contour map alongwith the isosalinity contour map. Accordingly, the studied area is classified to different zones arranged according to their priority of groundwater utilization.

INTRODUCTION

El Sheikh Zuwayid-Rafah area occupies the northeastern coastal borders of Sinai. It covers and area of about 100 km^2 between Latitudes 30° 13' & 31° 19' N and Longitudes 34° 04' & 34° 14' N (Fig. 1).

The main water-bearing formations belong to the Quaternary and are differentiated into aeolian sand, alluvium and calcareous sandstone (Kurkar) aquifers (Salem, 1963). The aeolian sand aquifer exists along the shore line under water table condition, where the depth to water ranges from less than one meter to about 5 m. The alluvium and the calcareous sandstone aquifers cover a vast area representing the main water-bearing formation and underlain by the Miocene shale which form hydraulically connected semiconfined condition (El Ghazawi, 1991). The depth to water varies between 14 m and 60 m. The maximum recorded thickness of the alluvium deposits is 60 m, while the calcareous sandstone deposits reach to about 50 m thickness. The thickness of the underlying Miocene shale is more than 400 m which forms the impervious layer for the whole water-bearing formation.

MATERIAL AND TECHNIQUE

The modulus contour map of a groundwater basin can be used to evaluate the hydrologic condition and water efficiency of a basin and hence it may show character of the water balance (Rofail, 1967).

The modulus of groundwater flow may be defined as the groundwater flow (either recharge or discharge) per km^2 of the groundwater flow (either recharge or discharge) per km^2

contour map can be calculated, for any period, from the water table maps. This can be done by dividing each contour line of the given water table map to (n) numbers of equal parts each of width (b) meters (Sewidan and Rofail, 1972). Discharge could then be estimated using Darcy's law. The total discharge for the total length of the contour line would then be:

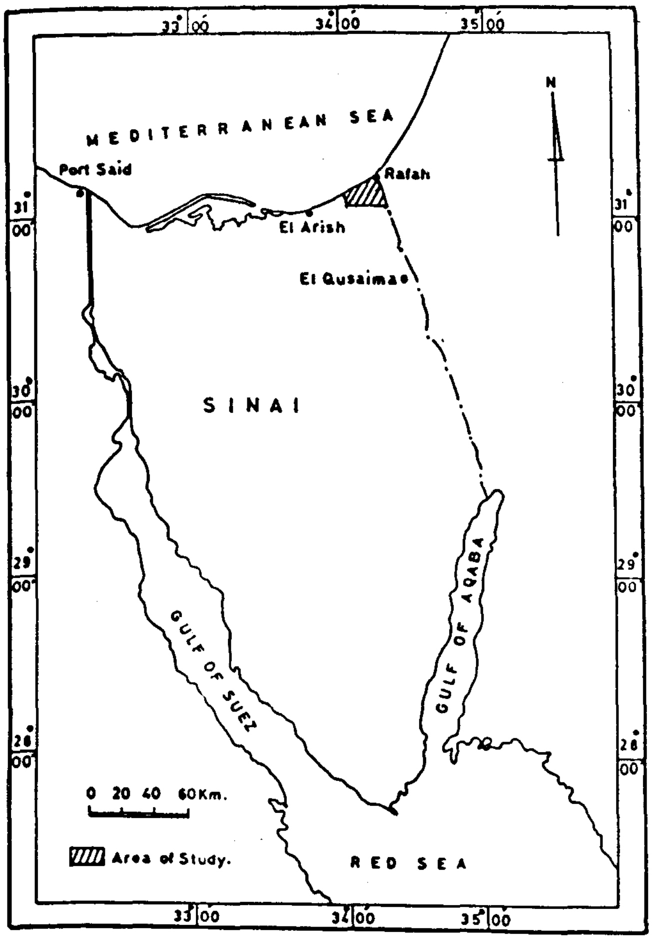

Fig. 1: Location Map of El Sheikh Zuwaid-Rafah Area

$$Q = b \sum_{i=1}^{n} T_i \; I_i \quad \text{.......... (1)}$$

where:

Q; the total discharge for the contour line (lit/sec).
T_i; coefficient of transmissivity at the i-sector (lit/sec/m).
I_i; hydraulic gradient at the i-sector (m/m).

For the coastal boundary of the aquifer subjected to salt water intrusion, the following equation developed by Columbus (1965) can be used:

$$h^2x = \frac{2 X q \delta}{K} + \frac{0.549\ q^2}{K^2} \quad \text{.......... (2)}$$

where:

hx; elevation of groundwater level (m) of a paint at distance X (m) from the sea.
q ; groundwater discharge per unit width (lit/sec/m).
K ; hydraulic conductivity (lit/sec/m²) of the water-bearing formation near the discharge coastal front.
δ ; (ds - df)/ds.
ds ; density of salt water (gm/cm³).
df ; density of fresh water (gm/cm³).

The total discharge for the contour line (Q) would then be:

$$Q = q L \quad \text{.......... (3)}$$

where: L is the length of the northern contour line.

The value of the modulus groundwater flow can be calculated as the difference between the discharge values at any two successive contour lines divided by the surface area between them, and its unit is lit/sec/km². The value of the modulus in this case is considered to be the mean values of the water gain or loss per unit area. The modulus coefficient Mm-n between two contours m and n is expressed as follows:

$$Mm\text{-}n = \frac{Qm - Q n}{Am\text{-}n} \quad \text{.......... (4)}$$

where:

Qm; the natural discharge at contour m (lit/sec).
Qn ; the natural discharge at contour n (lit/sec).
Am-n ; the surface area between contours m & n (km²).

RESULTS AND DISCUSSION

Applying the previous technique to construct the modulus contour maps for the study area, necessitates the presence of the following:

- Water table contour maps to detect the value and direction of groundwater flow.

- Data of pumping test analyses for a group of wells to get the transmissivity (T).

To develop the groundwater efficiency map, the aforementioned modulus contour map is compiled with:

- An isosalinity contour map for the purpose of water quality.

Two water table contour maps (Scale 1:2500) in 1982 and 1988 are taken after El Ghazawi (1991). To get the transmissivity values, pumping test analysis is carried out for 24 wells distributed in the study area using step-drawdown test method (Kruseman and de Ridder, 1970). The data used for such analysis is taken after the report of the REGWA (1983). The isosalinity contour map (Fig. 5) is drawn using the salinity measurements of the water points by the Research Institute for Water Resources (1988).

The two modulus contour maps (Figs. 2 and 3) show that the study area is characterised by successive positive and negative modulus zones. The minor changes noticed in the modulus contour values are due to the small storage capacity of the aquifer and poor groundwater flow as a result of low values of transmissivity (average 217 m² / day) as well as the groundwater gradient. The two modulus zones are:

Table 1
Evaluation of groundwater condition in El Sheikh Zuwayid-Rafah area

Symbol	Modulus value	Salinity content (gm/lit)		Water level (m)		Depth to water (m)		Hydrological condition of the aquifer
		from	to	from	to	from	to	
A1.1	negative	>	0.5	1.5	2.5	4.85	20.33	High efficiency, very low salinity, moderate areal extent and shallow water level. It has the first priority for groundwater development.
A1.2	negative	0.5	1.0	1.5	3.4	0.60	30.52	High efficiency, low salinity, large areal extent and shallow water level. It has second priority for development.
A1.3	negative	1.0	1.5	1.0	2.5	1.60	22.00	As A1.2 but has higher salinity and limited areal extent.
A1.4	negative	1.5	2.0					
A1.5	negative	2.0	2.5					
B1.1	positive	>	0.5	-1.0	2.5	0.67	9.87	Medium efficiency, very low salinity and occupies the northern and eastern portions of the study area. It contains most of the native wells. Recommended for limited and controlled development especially in the northwest to avoid more salt water intrusion.
B1.2	positive	0.5	1.0	-1.0	1.5	0.24	22.00	Medium efficiency, low salinity. It occupies a moderate area in the northwestern side and contains a considerable amount of native wells. Not recommended for further development.
B1.3	positive	1.0	1.5	-1.0	1.2	6.60	18.60	Medium efficiency, high salinity and occupies the coastal zone of the western portion. Wells in this zone should be limited and properly spaced.
B1.4	positive	1.5	2.0	-1.0	1.5	1.66	11.00	
B1.5	positive	2.0	2.5	-1.0	0.5	0.96	4.64	
B1.6	positive	<	2.5	-1.0	-0.5	1.20	3.00	
B2.3	positve	1.3	1.5	1.5	2.3	1.50	2.50	Low efficiency, high salinity and contains a limited number of wells and limited areal extent.
B2.4	positive	1.5	2.0	1.5	2.5	1.35	1.41	
B2.5	positive	2.0	2.5	1.5	2.0	0.60	4.20	Very low efficiency, very high salinity and shallow water level. Occupies a limited area near Sabkhet El Sheikh Zuwayid. The wells should be properly spaced. Not recommended for further development.
B2.6	positive	<	2.5	1.5	2.0	0.91	3.53	

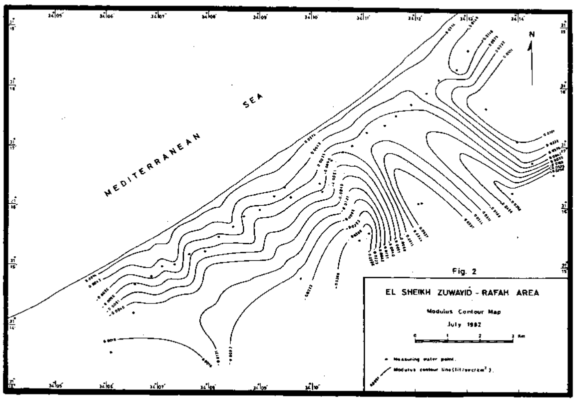

Fig. 2

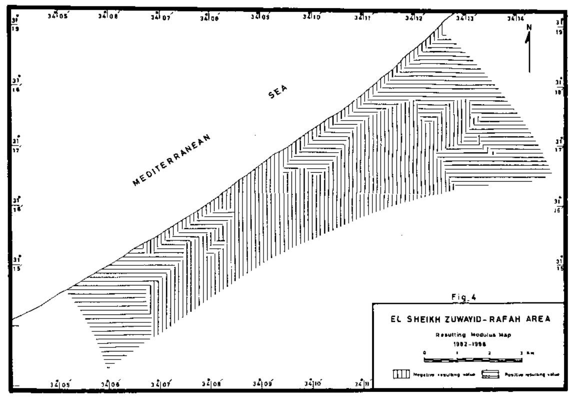

Fig. 4

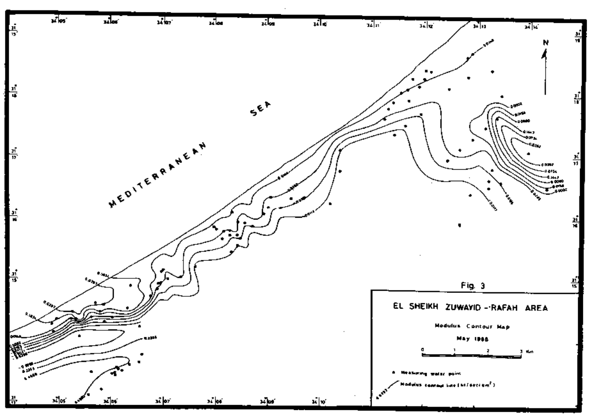

Fig. 3

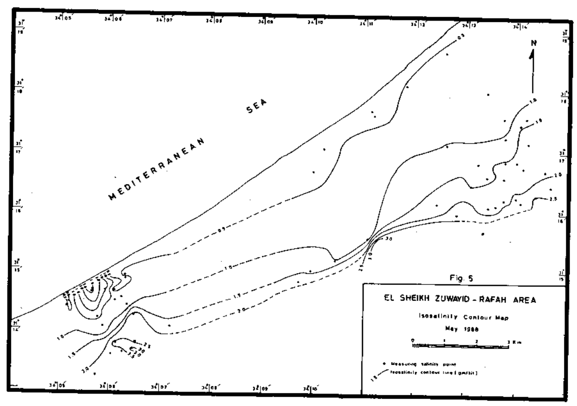

Fig. 5

Negative modulus value zone: This means that the amount of subsurface recharge along the upstream contour is less than the amount of subsurface discharge along the preceding downstream contour. This is due to additional vertical recharge for the aquifer in the area between this two contours by surface infiltration or by downward leakage from upper aquifers. This zone usually has high efficiency and considerable water replenishment.

Positive modulus coefficient zone: In this zone, the amount of subsurface recharge along the upstream contours is more than the amount of subsurface discharge along the preceding downstream contour. This zone has medium efficiency and medium water replenishment.

The resulting groundwater modulus map (Fig. 4) is drawn as the difference between the superimposed contour values of the two modulus contour maps in 1982 and 1988 to detect the changes in the groundwater efficiency during the studied period. The resulting modulus map shows that the area is divided into positive and negative zones. The negative zone indicates a better efficiency and that the hydrological condition had been emeliorated from 1982 to 1988, while the positive zone indicates deterioration in the groundwater resources in the same period.

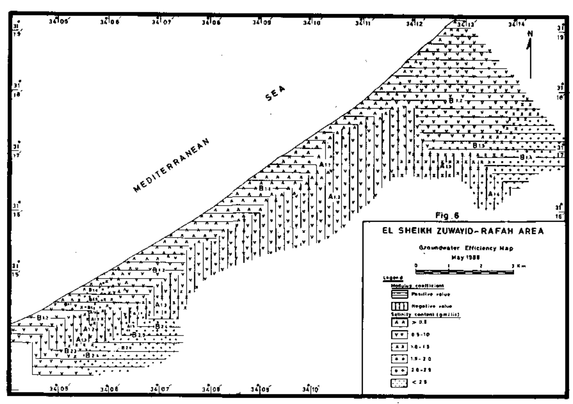

Fig. 6

Groundwater Efficiency Map:

The groundwater efficiency map (Fig. 6) is compiled from the modulus contour map in 1988 (Fig. 3) alongwith the isosalinity contour map for the same period (Fig. 5). The classification of the studied area is performed quantitatively according to the modulus values and qualitatively according to the salinity of the groundwater. The classification classes are: (Axy) for negative modulus zone and (Bxy) for positive modulus zone. The symbol (x) takes the numbers 1 and 2 and stands for the repitition of the zone in the studied area. The symbol (y) stands for the amount of salinity content and takes the values 1, 2, 3, 4, 5 and 6 as follows:

y = 1 for salinity content less than 0.5 gm/lit.
y = 2 for salinity content between 0.5 and 1.0 gm/lit.
y = 3 for salinity content between 1.0 and 1.5 gm/lit.
y = 4 for salinity content between 1.5 and 2.0 gm/lit.
y = 5 for salinity content between 2.0 and 2.5 gm/lit.
y = 6 for salinity content more than 2.5 gm/lit.

The following Table (1) shows the classification of the studied area into zones arranged according to their priority of groundwater utilization (see Fig. 6):

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