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GROUNDWATER ASSESSMENT OF MIOCENE AQUIFER IN THE COASTAL PLAIN BETWEEN ABU RAMAD AND HALAYEB, SOUTHEASTERN PORTION, EASTERN DESERT, RED SEA.

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This paper aims to focus the light on the groundwater conditions of Miocene aquifer in the coastal plain between Abu Ramad and Halayeb, southeastern portion of Eastern Desert, Red Sea. Six water points are tapping this aquifer. The depth to water varies from 11 m (Bir Abu Ramad) to 20.89 m (Bir Halayeb 3) from the ground surface. The main sources of recharge are the rain water and surface runoff on the area under investigation during the present time as well as during the ancient wet periods. In a trial to elucidate and calculate the hydraulic parameters of the study aquifer, five pumping tests were performed on the study wells. The transmissivity of the shallow zone ranges between 1.9 m^2/day (Bir Yobeeb) and 4.3 m^2/day (Bir Emblacit), while it varies from 21.6 m^2/day (Bir Halayeb 2) to 27 m^2/day (Bir Halayeb 3) for deep zone. The low values of hydraulic parameters are due to the absence of condensed fractures, small thickness of water bearing formation, as well as the low rate of recharge. These properties have a direct impact on the groundwater movement (more or less stagnant). Therefore, this phenomenon gives the chance for leaching and dissolution of terrestrial salts. Finally, it reflects a saline water type. Three multi- step tests were carried out on the drilled wells (Halayeb 1, Halayeb 2 & Halayeb 3). The obtained results of these tests displayed low efficiency of the drilled wells (Well efficiency ranges between 45.42 % and 59.26 %). This means that these wells are not completely developed beside the unsuitability of gravel packs. Water harvesting and conservation should be implemented to trap runoff floods in cisterns for different purposes.

Keywords: Groundwater, hydraulic parameters, well efficiency, Halayeb basin.

It is obvious that the groundwater management in arid or semi- arid regions plays an important role in the development processes of these regions. Three great basins facing Red Sea coast to the east distinguish EL Shalateen – Halayeb region. These basins are; 1- Barnis basin, 2- El Shalateen basin, 3- Halayeb basin.

This study emphasis on Halayeb basin in which the investigated area lies within it. Halayeb basin occupies an area of about 2500 km^2 It is dissected by Wadi Kansesrob (240 Km^2), Wadi Audaib (180 km^2), Wadi Sermaty (155 Km^2), Wadi EL Shalal (112 Km^2) and Wadi Ikowan (115 km^2) (Fig. 1). In addition, the Miocene rocks formed limited areas at Wadis Sarara, Abu Ramad, Emblacit and El Yobeeb.

PHYSICAL ASPECTS

The Eastern Desert occupies a portion of the arid belt zone of Egypt. The investigated area is characterized by hot summer with temperature reaching 38 ^{0}C and warm winter with temperature reaching 23 ^{0}C. The rainfall is scarce over most of the area and occurs occasionally as storms. The average rainfall rate is less than 20 mm / year and increases southward Hassan *et al*, 1996).

Geomorphologically, the studied area can be classified into the following geomorphic units

1- Coastal plain: it extends westward of the Red Sea shoreline for a distance ranging from 5 – 25 km. Sand sheets, alluvial and deltaic deposits cover the plain.

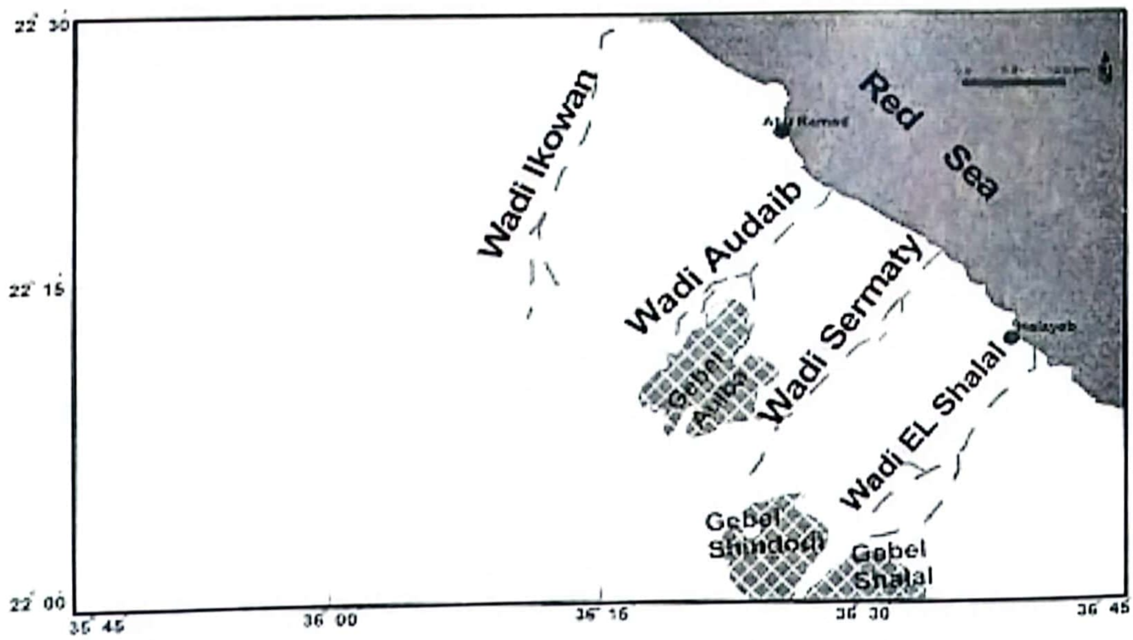


Fig. (1) Distribution of main hydrographic basins within the study area.

Along the shoreline, the plain is characterized by the presence of sabkha patches. It is partly covered by bushes, scrubs and acacia.

2- Mountainous area: it borders the coastal plain and is covered by the mountains oriented in a northwest – southeast direction parallel to the Red Sea shore line. It is dissected by a group of Wadis and its morphology is controlled by the tectonic elements mainly faulting.

Geologically, the studied area is covered by isolated patches of Miocene sediments located to the west of Abu Ramad and Halayeb area which consists mainly of alternating limestone and marl of Gebel EL Rusas Formation. In addition, Quaternary sediments comprising wadi fill and alluvial deposits cover vast areas. The basement rocks cover most of the area to the south and west, where they constitute the mountainous range, (EL Gamal, 1991; Elewa 2000 and Abdel Latif 2001) (Fig. 2).

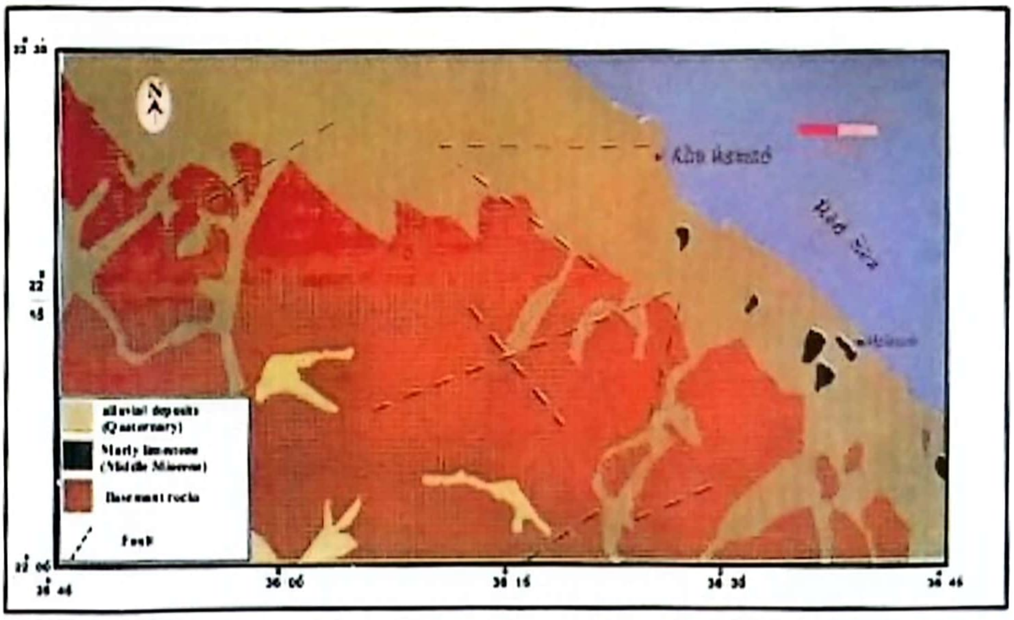


Fig. (2). Geological map of Abu Ramad – Halayeb area (GSE, 1996).

GROUNDWATER OCCURRENCE

The groundwater in this region is exploited from six water points, three of them are belonging to the shallow zone, aquifer namely: Bir Emblacit, Bir Abu Ramad – 2 and Bir Yobeeb, while the others reflect the deep aquifer zone (Figure 3 and Table 1). The depth to water varies from 11m (Bir Abu Ramad – 2) to 20.89 m (Halayeb well No. 3) from the ground surface. The aquifer is recharged from local rainfall and water quality of

Miocene aquifer belongs to saline water type. Its poor quality could be attributed to marine formation and salt-water intrusion.

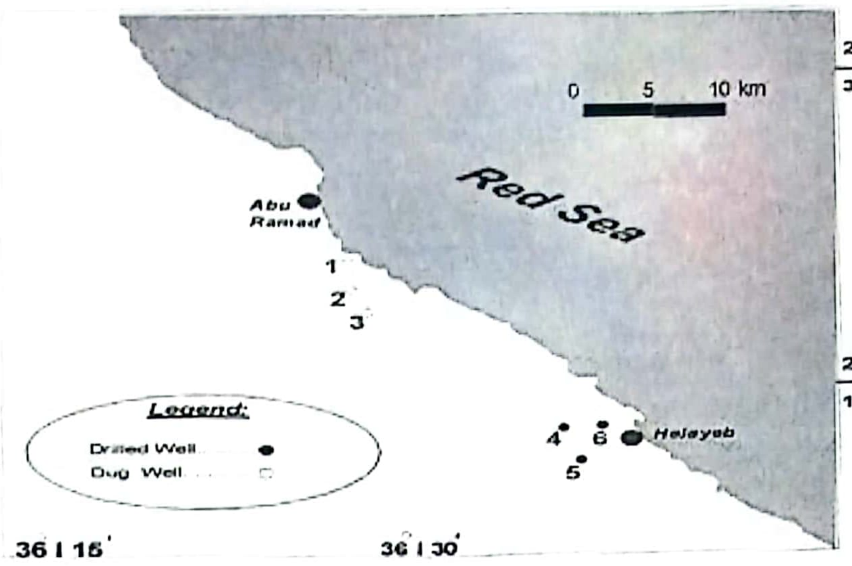


Fig. (3). Distribution of water points within the studied area.

Table (1). Hydrogeological data of water points tapping the Miocene aquifer.

Well no	Local name	Basin	Well type	Water bearing formation	Depth to water (m)	TDS (ppm)
1	Bir Emblacit	Wadi EL Yoheeb	Dug Well	Marly Limestone	17.56	12058
2	Bir Abu Ramad – 2	"	"	"	11.00	14398
3	Bir Yoheeb	"	"	"	15.98	11032
4	Halayeb well No.1	Halayeb Basin	Drilled well	"	18.05	21000
5	Halayeb well No.2	"	"	"	20.27	20300
6	Halayeb well No.3	"	"	"	20.89	21374

HYDRAULIC PARAMETERS

An approach was conducted during the fieldwork to evaluate and calculate the hydraulic parameters of Miocene aquifer. In order to achieve this target, six pumping tests were carried out on all the investigated water points. Jacob (1964), Papadopulos and Cooper (1967) and Papadopulos *et al.*

(1973) methods were applied in the analysis of the pumping test data. These methods include the following equations to solve directly for transmissivity (T) and storability(S).

$T = 2.3\ Q / 4\pi\Delta s$

$S = 2.25\ Tt_o$ Jacob (1964)

$T = Q/ 4\pi\ sw * F(Uw,\beta)$

$S\ 4Tt / (rw)^2 * U(w)$ Papadopulos and Cooper (1967)

$T = (rc)\ 2 / t * I$

$S = (rc)^2 / (rs)^2 * \alpha$ Papadopulos *et al.* (1973)

Where,

T : the transmissivity (m^2/day)

S : the Storativity (dimensionless)

Q : the rate of discharge (m^3/ h)

Δs : the slope of the straight line per log cycle (m)

r : the distance between the productive well and the observative well (m).

t_o : the interception of the straight line with abscissa where s = 0.0. (min).

F (Uw,β) : the well function.

rs : the radius of open hole (m).

rc : the radius of casing in interval over which water level fluctuates. (m)

The results of these tests are tabulated in table 2 and shown in figures 4, 5 and 6.

Table (2). The hydraulic parameters of the studied aquifer.

Well No.	Well name	Hydraulic parameters	Papadopulos (1967)	Papadopulos *et al.* (1975)	Jacob (1964)
1	Bir Emblacit	Transmissivity (m^2/day) Storativity (dimensionless)	4.3 $2.9*10^{-6}$		
2	Bir Abu Ramad-2	Transmissivity (m^2/day) Storativity (dimensionless)		2.6 $4.28*10^{-4}$	
3	Bir Yobeeb	Transmissivity (m^2/day) Storativity (dimensionless)			
4	Halayeb 1	Transmissivity (m^2/day)			22.56
5	Halayeb 2	Transmissivity (m^2/day)			21.6
6	Halayeb 3	Transmissivity (m^2/day)			27.0

It is clear, that the Miocene aquifer reveals very low capability of transmitting and store water. The low values of hydraulic parameters could be attributed to the hard nature of limestone rocks (absence of water paths, joints, fractures, small thickness of water bearing formation and low rate of recharge). This condition reveals slow movement for groundwater (more or less practically stagnant water), which give the chance for leaching and dissolution of salts. So, it reflects saline water type.

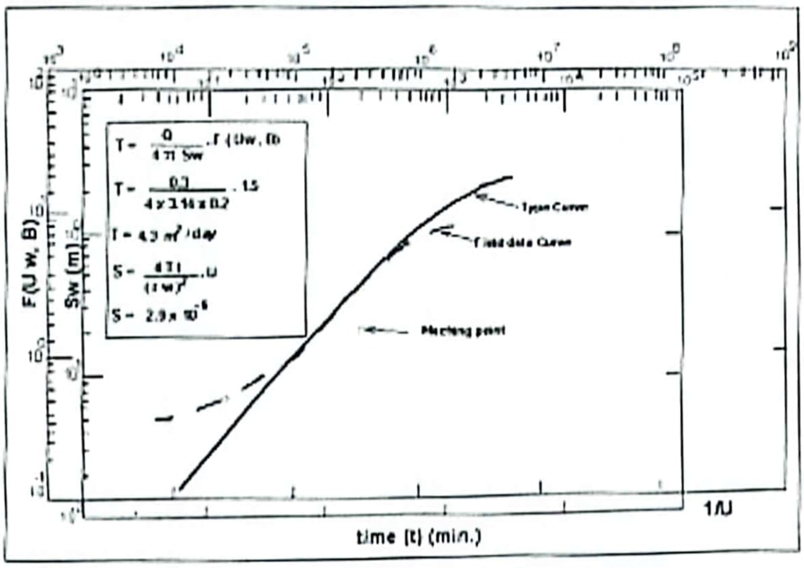


Fig. (4). Analysis of pumping test data of Emblacite well.

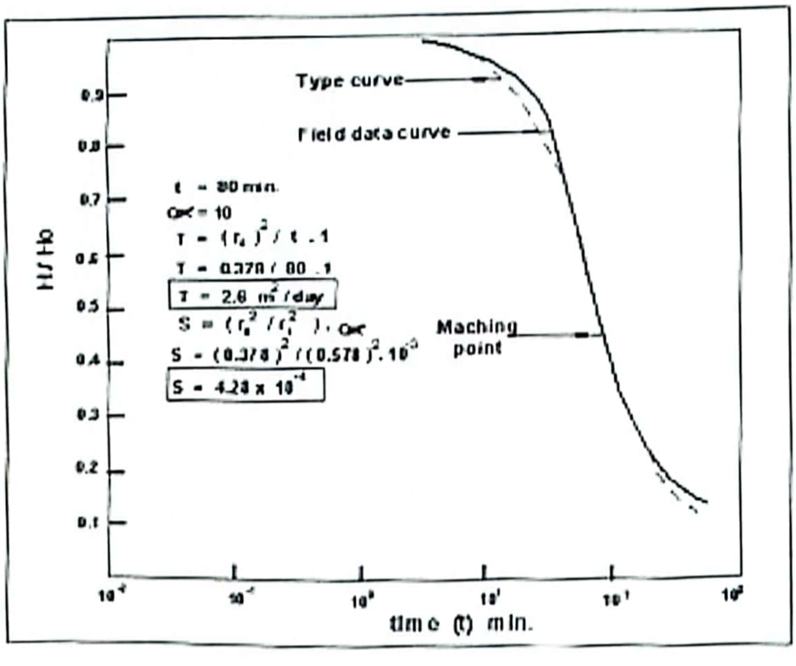


Fig. (5). Analysis of pumping test data of Abu Ramad-2 dug well.

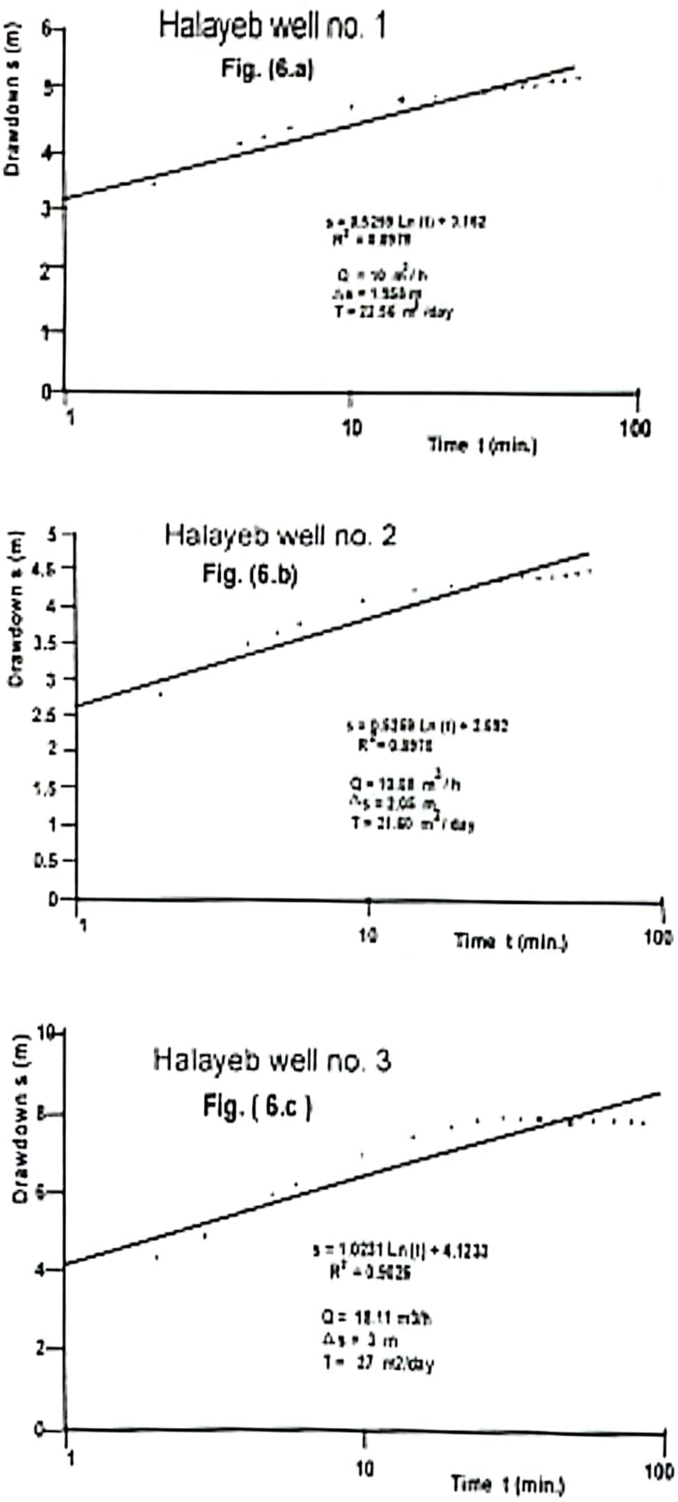


Fig. (6). Analysis of pumping test data of Halayeb wells (1, 2 and 3).

WELL CHARACTERISTICS

Due to focus a new light on the well characteristics of the drilled wells, three multi–step tests were performed on wells Nos, 4, 5 and 6. This attempt was made in this study to calculate and evaluate formation loss (head loss resulting from laminar flow in the formation) and well loss (head loss resulting from turbulent flow in the zone close to the well screen, through the well screen and well casing. The data of these tests were analyzed by the application of empirical formula (Walton, 1962) and the well losses were calculated based on equations given by Jacob (1964) as follows:

$$sw = BQ + CQ^2$$

Where,

sw : the well drawdown (m)

C : the well loss coefficient (min^2 / m^5)

B : the formation loss coefficient (h/m^2)

Q : the discharge rate (m^3/h)

By dividing the drawdown by the discharge of the well, the above equation changes as; $sw / Q = B + CQ$

Where, sw/Q is the specific drawdown of the well (h/m^2). By plotting the specific drawdown versus discharge for several steps, the well loss and formation loss coefficients were determined from the slope and the intercept of the straight line plots respectively.

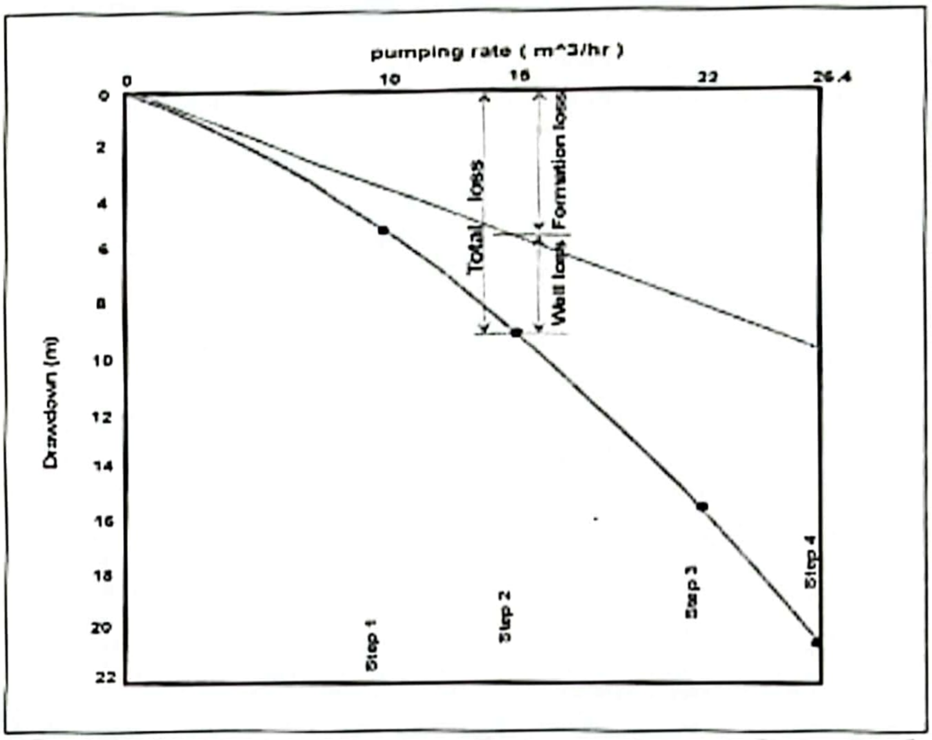
The values of well loss and formation loss are given in table 3 and shown in figures 7, 8 and 9. The obtained values indicate that the average formation loss is 50.39 %, while the average well loss is 45.42%. On the other hand, the well efficiency varies from 45.42% to 59.26%. The relatively low values of well efficiency means that the wells are not completely developed in addition to the unsuitability of gravel packs. These remarks should be taken into consideration in the design of new wells to minimize the well loss as possible.

Table (3). The obtained values of multi- step tests.

Well name	Steps	Discharge Q (m^3/h)	Drawdown s (m)	Specific drawdown s/Q (h/m^2)	Well loss (CQ^2) (m)	Formation loss (BQ) (m)	Total drawdown ($BQ+CQ^2$) (m)
Halayeb 1	1	10	5.09	0.509	1.6(31.4%)	3.5(68.6%)	5.1
	2	15	8.98	0.599	3.6(40.68%)	5.25(59.32%)	8.85
	3	22	15.42	0.70	7.7(50.14%)	7.7(49.86%)	15.41
Halayeb 2	1	10.08	4.52	0.448	2.03(44.62%)	2.52(55.38%)	4.55
	2	15.5	8.41	0.543	4.81(55.35%)	3.88(44.65%)	8.69
	3	22	15.21	0.691	9.68(63.77%)	5.5(36.23%)	15.18
Halayeb 3	1	11.8	7.88	0.668	3.48(45.04%)	4.25(54.96%)	7.73
	2	17.20	13.45	0.782	7.40(54.43%)	6.19(45.57%)	13.59
	3	22.6	21.88	0.968	12.77(61.0%)	8.14(38.92%)	20.91

Halayeb well no. (1)

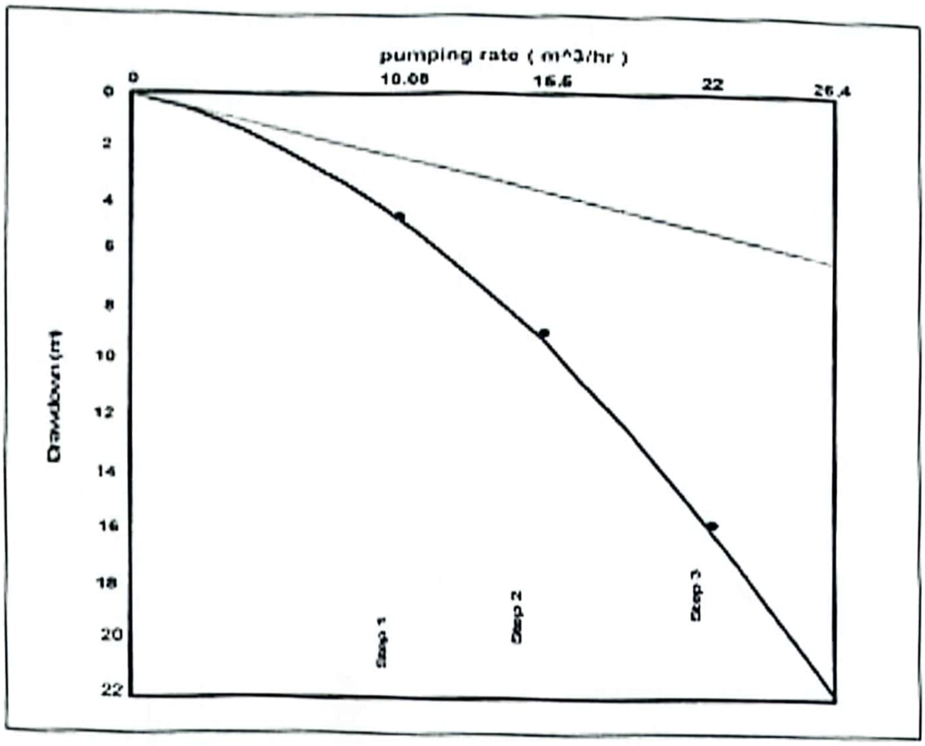
B = 0.360900	C = 0.015500	Equation power = 2	Efficiency = 61.35 %



Drawdown	5.09	8.98	15.42	20.33
Pumping rate	10	15	22	26.4
Aquifer loss	3.61	5.41	7.94	9.53
Well loss	1.55	3.49	7.50	10.8
Efficiency %	70.9	60.3	51.5	46.9

Fig (7). Analysis of step drawdown test of Halayeb well no.1.

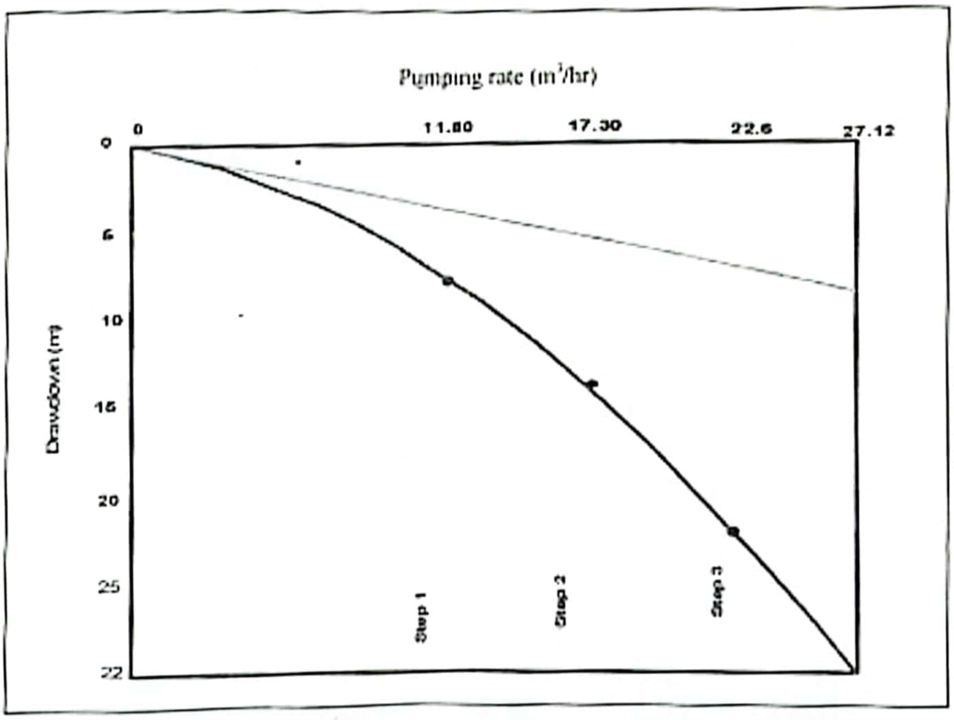
Halayeb well no. (2)			
= 0.22320	C = 0.02119	Equation power = 2	Efficiency = 41.80 %



Drawdown	4.62	8.41	15.21	20.66
Pumping rate	10.08	16.5	22	26.4
Aquifer loss	2.25	3.46	4.91	5.89
Well loss	2.15	5.09	10.25	14.77
Efficiency %	49.8	41.1	32.3	26.5

Fig. (8). Analysis of step drawdown test of Halayeb well no. 2.

Halayeb well no. (3)			
B = 0.2987	C = 0.029350	Equation power = 2	Efficiency = 40.32 %



Drawdown	7.88	13.46	21.88	29.68
Pumping rate	11.80	17.20	22.6	27.12
Aquifer loss	3.62	5.14	6.75	8.10
Well loss	4.09	8.68	14.99	21.58
Efficiency %	44.70	36.20	30.90	27.30

Fig. (9). Analysis of step drawdown test of Halayeb well no. 3.

HYDROCHEMICAL COEFFICIENT

From the hydrochemical point of view, the following ratios (Na^+/r Cl^-, r SO_4^{--}/ r Cl and r Ca^{++}/ r Mg^{++}), were found to be helpful in detecting hydrochemical processes affecting water quality such as leaching, mixing and ion exchange. Table (4) includes a comparison between the hydrochemical ratios for the analyzed selected water points, sea water and rain waters.

Table (4). Hydrochemical ratios of selected water points, sea water and rain water.

Well Name	TDS (ppm)	Water Type	rNa^+/rCl^-	rSO_4^{--}/rCl^-	rCa^{++}/rMg^{++}
Bir Emblacit	12058	Na – cl	0.77	0.15	2.16
Bir Abu Ramad –2	14398	"	0.73	0.18	1.25
Bir Halayeb 3	21374	"	0.59	0.10	2.71
Rain water	675	"	0.64	0.85	7.20
Red sea water	46136	"	0.81	0.10	0.13

rNa^+ / rCl^- :

This ratio in the investigated groundwater samples (Bir Emblacit & Bir Abu Ramad – 2) is comparable to the value of seawater. This mainly attributed to the impact of marine deposits. While, the value of this ratio of (Bir Halayeb 3) is closed to rain water, which reflects the source of recharge, is precipitation with leaching of terrestrial salts.

$r SO^{--}_4 / rCl^-$:

This ratio is useful as a guide for sulphate mineral dissolution. From the values of $r SO^{--}_4 / r Cl^-$ recorded in table (4), it is clear that the groundwater samples show dissolution of terrestrial sulphate salts such as gypsum.

$r Ca^{++} / Mg^{++}$:

This ratio usually indicates seawater contamination with $r Ca^{++} / rMg^{++}$ equals 0.20 or surface water mixing where, $r Ca^{++} / r Mg^{++}$ equals 1.07. The high values of this ratio in the investigated water samples reveal the leaching influence of some terrestrial salts rich in calcium.

CONCLUSIONS AND RECOMMENDATIONS

1- Due to the high water salinity of the studied water points, water harvesting and conservation should be implemented to trap runoff flood in cisterns for drinking and crops.
2- Drilling a system of piezometeric wells for monitoring the salt- water intrusion along the coastal plain.
3- The intersection between fractures and faults are best locations for groundwater drilling, especially in the vicinity of this area, but with the using of the suitable safe yield to prevent the recession of water - table.
4- The development of new plant species adapted to dry land and resistant to high water salinity for improving the sustainability of the eco – system in the area, and reducing risks of soil degradation by erosion.

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تقدير خزان الميوسين بالمنطقة الساحلية بين أبو رماد وحلايب - جنوب شرق الصحراء الشرقية البحر الأحمر

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يهدف البحث إلى إلقاء بعض الضوء على خصائص الخزان الجوفي الساحلي بمنطقة أبو رماد حلايب والذي يتبع خزان الميوسين وذلك من خلال إجراء عدد من تجارب الضخ المرحلى وكذلك الضخ لفترات طويلة على آبار منطقة الدراسة مع وضع التوصيات الضرورية للاستفادة من مياه هذه الآبار في تنمية المنطقة. وقد أوضحت الخصائص الهيدروليكية للخزان الجوفى بأنها تتصف بقيم هيدروليكية منخفضة مما ينعكس على حركة المياه وإتجاهاتها بالإضافة إلى أن تجارب الضخ المرحلى أظهرت كفاءة منخفضة لإنتاجية الآبار والتى تراوحت بين ٤٥% إلى ٥٩% وذلك نتيجة لعدم وضع التصميم الجيد للآبار وعدم ملائمة الغلاف الزلطى للمواصفات السليمة المطلوبة وأوصت النتائج إلى أهمية تطبيق الطرق العلميه فى كيفيه حصاد مياة الأمطار من السيول للإستفادة منها فى أغراض التنمية المختلفة.