 Desert Inst. Bull., Egypt, 50, No. 1,pp. 175-207 (2000)

Divalent Ion Chemistry as an Indicator of Groundwater Flow Type Through the Carbonate Aquifer in EL-Arish - Rafah Area.

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The main object of this work is to study the chemistry of groundwater hardness in the carbonate aquifer in EL Arish – Rafah area and its relationship with the groundwater flow type.

Generally, the water chemistry including the salinity, hardness (total, temporary and permanent) and the controlling factors affecting them (leaching, dissolution, CO_2, water pH, temperature and ion exchange processes) were studied in details.

The study revealed that the total hardness of the continental kurkar groundwater is generally less than that of marine kurkar groundwater. The groundwater hardness in the continental kurkar aquifer is more temporary than that of permanent hardness and vice versa in case of the marine kurkar aquifer.

The effect of leaching, dissolution, longer residence time in continental and old marine sediments, CO_2, alkaline pH (7-9), water temperature and cation exchange leads to an increase of total hardness compared to the marine facies groundwater types more than that of the continental facies. Also, the permanent hardness of marine facies groundwater types exceeds permanent hardness of the continental facies and the reverse is true in case of temporary hardness.

The variation coefficient of hardness has been used to detect the mode of water circulation within the carbonate aquifer. The high temporal variation coefficient of groundwater hardness of continental kurkar aquifer at EL – Sheikh Zewied – Rafah coast and marine kurkar at the southern parts, indicates fast flowing system. On the other hand, the low temporal variation coefficient of groundwater hardness of continental kurkar aquifer at South Rafah inland and marine kurkar of west EL - Kharouba indicates slow flowing system. These results are also confirmed by determination of the velocity groundwater movement from the hydraulic parameters of both continental and marine kurkar aquifers. Another trial was performed by using the variation in total hardness relative to salinity (TH / TDS). The obtained data follow the same pattern obtained by variation in total hardness.

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Key words: Hydrogeochemistry, Carbonate aquifers, Arish – Rafah, Divalent ion chemistry, flow type, Variation coefficient, Total hardness, Temporary hardness, Permanent hardness, Leaching and dissolution process, Cation exchange.

The carbonate (kurkar) aquifer can be distinguished into two main facies; continental and marine aquifers (Taha, 1968, EL Said,1994, and ACSAD, 1998).

The chemistry of groundwater in porous carbonate aquifer and the variation in some hydrochemical properties with time are related to the nature of the carbonate aquifer and to the type of groundwater circulation. Several indices are used for the identification of water that is involved in exchange processes, among them the alkali number and the cation exchange index (Schoeller, 1962, Atwa, 1979, Matthess, 1982 and EL Said, 1994).

The variation in the hardness have been used to detect whether the carbonate system is of diffused (slow) flow or of the conduit type (fast) flow, (Shuster and White, 1971, Ternan, 1972, and Sadik and Karam , 1986). They used the coefficient for variation of hardness rather than its values to describe the characteristics of carbonate groundwater. Furthermore, the variation in the water salinity value is used to assist in detecting the relative residence time of the circulating water (Jacobson and Langmuir, 1970).

In the current work, the distribution of two carbonate aquifers, total salinity, total hardness and the general trend of groundwater flow, were studied. The frequency distribution of total salinity, and total, temporary, permanent hardness, factors controlling them in both continental, marine carbonate aquifers and their groundwaters were evaluated. The hypothetical salts combination of both continental and marine facies groundwater types is used as an indicator for leaching and dissolution, as well as, the cation exchange processes. Alkali number and cation exchange index were applied on both continental and marine groundwater facies types. Also, the variation coefficients of hardness (V) have been used to detect the mode of water circulation within the carbonate system (diffused or fast- flowing system). Another trial was performed using the variation in total hardness as related to groundwater salinity. These are confirmed by the determination of velocity of groundwater movement as calculated using hydraulic parameter of the carbonate aquifers.

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Materials and Methods

1) Measurement of the depth to water (during March 1995) was conducted for about 40 wells representing the two mean aquifers (continental and marine kurkar aquifers) within the study area.
2) Water levels were estimated through determination of ground elevation at each water point using precise Altimeter.
3) Aquifer thickness was determined through lithological study of ditch samples collected from about 40wells.
4) Chemical analysis of (Ca + Mg) carbonate for the aquifer rock samples(40 sample) were determined.
5) The cation exchange capacity(C.E.C. me/100g)of the two sediment facies was determined by using $Na\text{-}NH_4$ acetate, Richards (1954).
6) Water samples (117 sample) were collected during 1996 from the available water wells in the studied area to study the hydrochemistry of groundwater hardness. Another 52 water samples were periodically collected during 1995 – 1999, to study variation in hardness to detect the mode of water circulation inside the carbonate system Fig. (1). The analysis of the collected samples was carried out according to the methods adopted by the U.S. Geological Survey Rainwater and Thatcher (1960), Tables (1-3).
7) The P_{CO2} values of the groundwater in both aquifers were computed by WATEQF program, Plummer *et al.* (1984), Tables (1-3).

Results and Discussion

1-Water bearing formations (aquifer system):

EL Arish – Rafah area is located at 50 Km East of EL Arish city and is extended to the Eastern Egyptian border. It is bound by longitudes 33^0 55' and 34^0 15' E and latitudes 31^0 05' and 31^0 20' N. It occupies about 1000 km^2 and is geographically bound by the Mediterranean Sea to the North and the tableland to the South (EL Gora, Gabal EL Dalfa – EL Amr belt). The distribution of the two types of aquifers within the study area, as well as, their hydrogeological conditions are largely affected by a number of faults that dissect the area either parallel to the shore line (*e.g.* F_3, F_4 and F_5) or normal to the shore line (*e. g.* F_2 and F_6), Fig.(1).

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Table (1) Chemical analysis of the marine facies groundwater (mg/l) oriented according to the alkali number up to 100 and positive value of cation exchange index.

Aquifer type	Well No.	T C°	pH	TDS	TH	Tempor	Perm	PCO_2 $x10^{-3}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}	Hypothetical salt combinations
													Fresh				
CONTINENTAL	29*	25	7.4	989	385	99	287	4.3	69	52	220	3	4	112	225	360	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	114	24	8.0	585	348	57	291	0.7	48	56	70	7	5	70	200	165	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	149	25	8.1	474	205	121	84	1.1	33	30	100	2	4	140	22	213	iv $NaCl, MgCl_2, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	180	25	8.0	643	244	160	85	1.7	39	36	160	2	12	165	60	253	iv $NaCl, MgCl_2, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	208	25	8.4	1196	217	166	52	0.6	17	45	380	3	25	152	50	601	iv $NaCl, MgCl_2, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	234	25	8.0	682	390	74	316	0.8	59	59	110	3	0	91	100	306	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
													Brackish				
KURKAR	30	24	7.6	3132	1027	99	929	2.4	198	130	740	6	4	112	750	1249	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	46	24	8.1	1659	487	122	367	1	78.0	71	440	2	12	128	300	692	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	74	25	8.2	1967	721	40	681	0.3	137	92	410	4	12	41	520	771	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	183	24	7.9	1628	485	119	367	1.5	123	43	440	3	8	128	70	878	vi $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
													Brackish				
MARINE	131	25	7.9	3491	751	126	625	1.6	129	101	1000	9	4	146	600	1573	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	160	24	7.9	2952	470	54	416	0.7	89	61	920	8	0	66	350	1493	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	204	24	7.3	3477	779	115	665	5.7	127	113	1050	9	16	107	300	1809	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	236	24	7.3	3459	756	115	642	5.7	107	119	1050	5	16	107	300	1809	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	237	26	8.5	4705	536	420	116	1.9	98	71	1600	9	54	402	150	2523	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	315	24	7.9	3570	544	158	386	2	139	48	1120	6	10	172	350	1822	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	316	25	8	3693	618	106	512	1	149	60	1180	7	7	116	290	1943	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	317	25	7.8	4227	916	95	821	1.5	198	102	1200	8	7	103	740	1870	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	63	26	8.0	4457	560	111	449	1.1	88	83	1500	10	5	124	200	2503	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
													Saline				
KURKAR	1	24	7.2	6020	1784	92	1693	5.3	295	255	1600	17	8	95	1000	2798	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	2	24	7.4	5858	1807	85	1723	3.1	343	231	1450	16	4	95	1125	2642	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	3	24	7.7	6228	1816	66	1750	1.3	303	258	1700	9	4	73	700	3219	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	286	24	7.5	5695	1841	131	1681	3.7	323	252	1500	9	17	124	200	3338	vi $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	287	24	7.5	6258	1992	54	1938	1.6	313	295	1550	10	4	59	600	3458	vi $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	288	28	7.6	6668	2648	72	2576	1.6	475	356	1550	10	4	81	300	3934	vi $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	289	27	7.5	5752	1993	69	1924	2	323	288	1500	10	2	81	250	3338	vi $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	290	27	7.6	5772	2119	57	2062	1.3	303	331	1450	10	2	66	425	3219	vi $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	291	27	7.8	4668	1614	78	1536	1.2	232	252	1150	9	4	88	375	2623	v $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$

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Cont. table (1)

Aquifer type	Well No.	T C°	PH	TDS	TH	Tempor	Perm	PCO_2 $X10^{-3}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	SO_4^{-}	Cl^{-}	Hypothetical salt combinations
MARINE KURKAR	292	25	7.3	5646	1665	72	1593	3.4	273	239	1500	11	4	81	600	2980	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	293	27	7.2	5153	1362	84	1278	5.2	232	190	1300	10	0	102	1175	2195	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	294	24	7.3	5506	1451	95	1356	4.5	267	191	1450	16	2	112	1000	2522	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	295	24	8.0	5231	1332	42	1290	0.4	233	179	1450	18	4	43	900	2402	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	296	24	7.5	4702	903	35	868	1.1	190	104	1450	19	0	43	275	2642	VI $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	297	25	7.2	4961	1464	77	1387	4.6	267	197	1300	19	4	86	370	2762	VI $NaCl, MgCl_2, CaCl_2, CaSO_4, Ca(HCO_3)_2$
	298	24	7.3	5114	1213	106	1108	5.1	210	168	1437	19	0	129	1000	2217	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	299	25	7.6	5814	1463	54	1409	1.3	212	227	1600	12	0	66	750	2980	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	314	25	7.8	7601	1587	136	1451	1.9	248	235	2300	11	13	139	1250	3475	V $NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$

Table (2) Chemical analysis of the continental facies groundwater (mg/l) oriented according to the alkali numb:r from 100 to 120 and negative value of cation exchange index.

Aquifer type	Well No.	T C°	PH	TDS	TH	Tempor	Perm	PCO_2 $X10^{-3}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	SO_4^{-}	Cl^{-}	Hypothetical salt combinations
CONTINENTAL KURKAR												Fresh					
	61	26	8.3	340	112	104	8	0.6	31	8	80	4	4	119	46	106	I $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	75	25	8.6	315	127	40	87	0.1	21	18	64	2	12	25	100	85	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	112	25	8.2	790	121	121	0	0.8	17	18	250	4	4	139	90	337	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	161	25	8.1	1157	226	76	150	0.9	32	36	340	21	16	93	180	485	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
												Brackish					
	49	25	8.7	1718	429	88	342	0.2	66	64	460	3	8	91	380	691	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	65	25	8.1	1805	429	122	307	1	59	69	480	2	8	132	430	692	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	175	25	8.2	2079	406	159	248	1	49	69	600	5	21	152	450	810	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	177	25	8.2	1477	322	166	157	1.1	41	53	460	2	24	152	155	665	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	181	24	7.8	2314	390	151	239	3.9	51	64	740	3	20	141	300	1064	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	186	25	8.3	1431	282	211	72	18.7	40	47	420	4	37	181	200	592	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	187	26	7.9	1733	361	156	206	2.1	59	52	540	3	16	157	200	785	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	190	25	8.3	1742	302	69	233	0.4	42	48	520	4	0	84	320	766	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	210	25	8.2	2210	306	190	117	1.2	34	54	700	6	17	198	340	961	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	230	25	8.2	1520	254	156	99	1	33	41	480	4	16	157	175	692	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$

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TABLE (3). Chemical analysis of the continental facies groundwater (mg/l) oriented according to the alkali number above 120 and negative value of cation exchange index.

exchange

Aquifer type	Well No.	T C°	PH	TDS	TH	Tempor	Perm	PCO_2 x10^{-3}	Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-	Hypothetical salt combinations
	Fresh																
Continental	16	25	8.5	347	112	107	5	0.4	23	13	88	2	16	99	78	85	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	19	24	8.2	427	127	115	13	0.8	25	15	112	2	20	99	100	101	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	29'	24	7.6	767	141	141	0	6.1	29	20	230	19	8	245	75	264	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	34	25	7.8	1129	309	92	218	1.6	42	50	290	5	8	95	275	312	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	42	24	8.9	337	91	91	0	0.2	20	12	96	2	0	148	22	112	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	59	26	8.7	341	133	78	56	0.2	29	14	80	4	16	62	100	85	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	67	25	7.8	1129	309	92	218	1.6	42	50	290	5	8	95	275	312	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	87	25	8.4	402	109	109	0	0.9	19	11	115	5	33	177	50	80	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	89	25	8.5	497	76	56	21	0.2	23	5	72	2	8	51	50	85	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	96	25	8.2	814	248	84	164	0.5	44	34	180	4	4	95	310	192	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	99	25	8.3	1211	180	169	11	0.9	28	23	380	3	83	38	180	475	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	107	25	8.9	208	102	102	0	0.2	23	9	42	2	4	139	20	38	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	117	24	8.2	966	123	123	0	1.3	16	19	320	2	16	198	175	319	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	119	25	8.2	495	112	112	0	1.5	19	14	145	3	21	202	40	133	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	127	24	8.3	435	125	125	0	0.8	28	13	120	4	12	156	30	150	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	132	25	8.2	449	117	117	0	1.5	25	16	145	4	21	210	40	133	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	133	25	8.7	1273	115	115	0	0.4	19	22	440	4	21	215	175	485	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	140	25	8.6	333	85	85	0	0.4	13	15	95	1	4	135	50	87	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	146	25	8.4	499	114	114	0	0.8	23	16	145	11	17	177	65	144	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	155	25	8.3	749	169	169	0	0.9	21	20	230	2	4	198	80	293	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	159	24	8.0	1215	306	111	195	1.2	70	32	210	7	17	101	380	349	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	163	25	8.5	491	93	93	0	0.6	14	14	160	1	4	206	22	173	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	164	25	8.3	505	100	100	0	1	20	18	160	1	16	185	25	173	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	168	28	7.7	1317	128	128	0	6.1	13	21	460	3	33	253	200	461	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
Kurkar	200	25	8.3	968	171	85	87	0.5	29	11	290	3	0	103	225	346	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	211	25	8.3	934	50	50	0	1	5	13	340	3	41	131	100	364	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	212	27	8.4	696	304	211	94	0.9	16	64	145	3	37	181	200	141	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	214	27	9.0	1402	131	131	0	0.2	9	23	480	3	50	126	275	500	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	215	25	8.8	985	65	65	0	0.5	6	18	360	4	41	253	80	349	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	219	28	8.2	611	88	88	0	2.2	11	17	210	2	37	290	50	138	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	220	24	8.3	247	77	77	0	0.6	14	9	68	2	8	119	17	69	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	221	25	8.3	234	112	98	15	0.6	27	11	48	2	4	111	17	69	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	222	25	8.4	468	170	165	5	0.7	43	13	120	2	4	194	94	128	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$

Cont. table (3)

CONTINENTAL	226	27	8.4	463	234	125	110	0.6	57	23	80	2	12	128	130	96	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	227	25	8.7	369	122	112	11	0.2	29	12	92	2	8	119	70	96	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	228	25	8.4	560	180	85	96	0.4	41	19	140	2	0	103	115	192	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	229	25	8.3	914	239	188	51	1	21	45	270	2	32	165	115	346	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	231	28	8.7	841	94	94	0	0.4	16	15	280	2	20	173	115	306	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	232	24	8.3	1148	133	133	0	0.9	16	26	380	2	20	161	225	399	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	233	25	8.4	748	40	40	0	0.9	12	9	270	1	12	231	115	213	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	235	25	7.8	1196	283	183	100	3.8	12	62	360	4	24	214	175	452	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	239	25	8.2	329	183	183	0	1.4	32	22	60	4	8	215	25	73	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	247	25	8.4	501	105	105	0	0.6	14	21	148	5	11	154	78	148	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	251	27	8.4	561	109	109	0	0.7	18	19	166	8	9	176	98	155	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	252	24	8.3	767	204	150	54	0.8	30	31	190	19	11	161	220	186	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	275	24	7.8	1017	262	113	150	2	38	41	270	5	4	129	357	237	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	312	25	8.2	282	113	104	11	0.8	28	10	60	3	0	126	40	78	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	Brackish																
KURKAR	36	25	7.7	1911	323	133	190	2.8	42	53	560	8	8	146	630	537	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	40	25	7.6	1436	438	99	340	2.7	67	66	360	2	4	112	470	408	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	41	24	7.7	1624	395	116	279	2.5	59	60	420	8	6	129	630	377	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	70	25	8.5	1776	215	192	23	0.6	31	33	560	3	20	194	540	492	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	97	25	7.9	3244	462	166	296	2.1	55	[illegible]	1040	7	50	101	750	1213	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	124	27	7.7	2663	352	207	145	4.5	29	68	820	5	58	135	750	861	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	139	31	7.9	2277	421	200	221	2.9	47	74	720	5	21	282	400	910	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	178	26	8.5	1999	251	173	79	0.6	19	58	620	9	25	160	460	737	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	182	25	8.0	1969	351	122	230	1.3	27	69	640	3	16	115	225	930	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	193	25	10	1724	14	14	0	0.01	4	10	650	3	101	16	350	616	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	202	25	8.2	1814	155	155	0	1.9	19	25	640	4	37	282	210	737	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	209	25	8.8	2087	138	138	0	0.3	21	40	720	4	46	173	430	740	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	216	25	8.1	3263	391	211	180	1.7	49	65	1050	7	37	181	800	1164	II $NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$
	217	25	8.2	2001	183	183	0	2.6	19	50	680	5	54	375	400	606	I $NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$
	223	25	8.1	4551	634	186	448	1.4	127	77	1350	6	12	202	1575	1303	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	274	25	7.8	1284	448	120	328	2	51	78	290	6	4	137	450	336	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$
	Saline																
	21	25	8.0	5995	1217	128	1089	1.3	185	183	1750	6	16	148	1625	2154	III $NaCl, Na_2SO_4, MgSO_4, CaSO_4, Ca(HCO_3)_2$

TDS= Total dissolved salts, TH =Total hardness, Tempor. = Temporary hardness, Perm. = Permanent hardness and PCO_2 = The carbon dioxide partial pressure (bars), T C° = Water temperature in the field.

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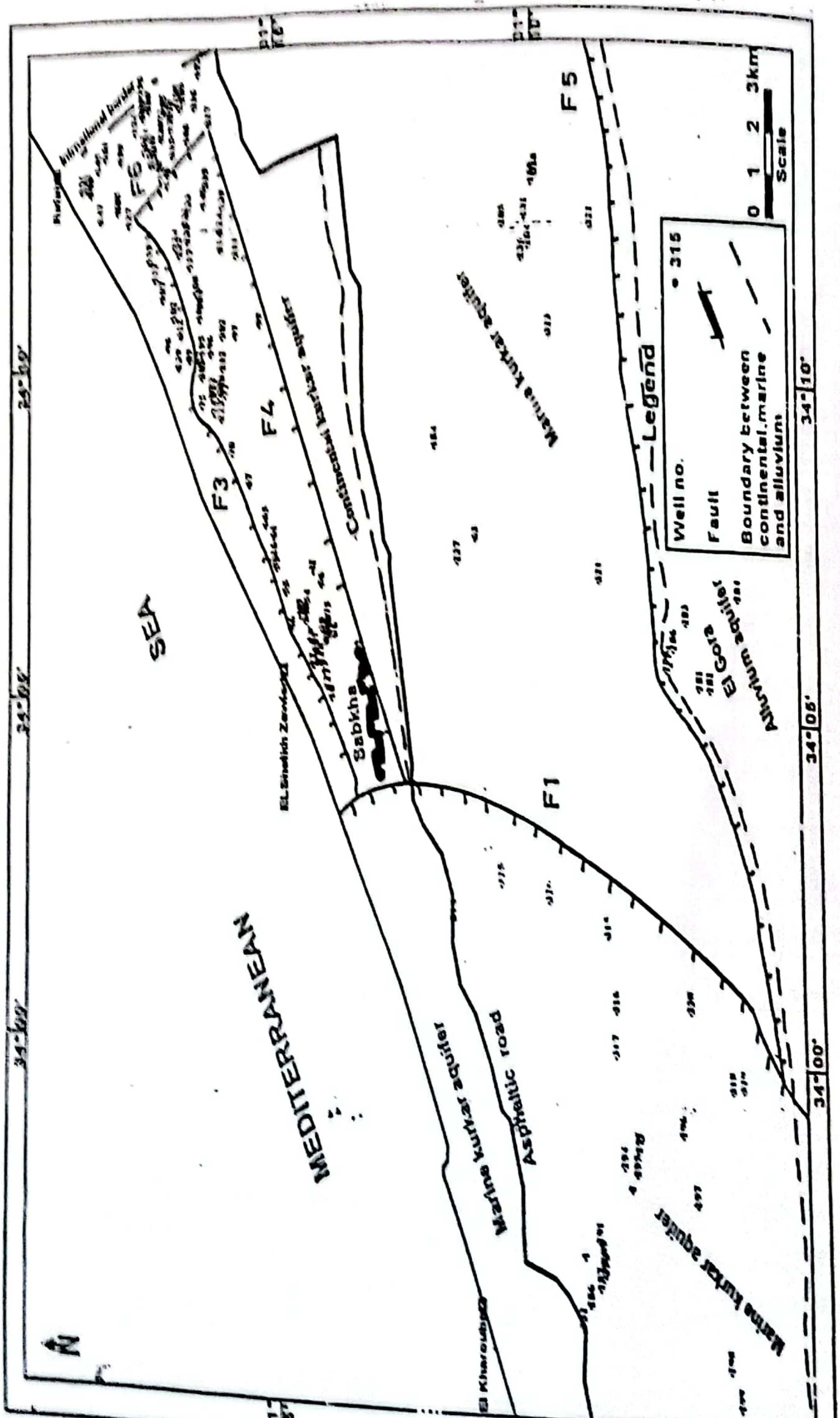

Fig.-(1):The areal distribution of the aquifers and wells in the studied area.

The carbonate aquifer (calcareous sandstone) represents the main exploited aquifer in EL Arish - Rafah area. This aquifer exhibits a high potentiality where the present groundwater extraction rate is estimated as much as 100,000 m^3 / day. The carbonate aquifer (kurkar) can be distinguished into two main facies namely:

A- *The upper kurkar (continental kurkar)* having a thickness of about (10 – 45 m) and is particularly developed in EL Arish – Rafah coastal plain except at the West of EL Sheikh Zewied and El Kharouba areas, (Fig.1). It is formed of coarse to medium quartz grains coated with Ca and Mg carbonates (55 – 92 %), together with few shell fragments and intercalations of loamy materials. The continental kurkar aquifer is underlain either by the marine kurkar aquifer or by the Miocene carbonate rocks, and overlain by clay layer or alluvium or sand dunes aquifer.

B- *The lower kurkar (marine kurkar),* having a thickness of about (10–30 m) and characterizes the subsurface of EL Arish – Rafah coastal plain. This kurkar is also recorded in the Southern part of the studied area, (Fig.1), which is overlain either by a clay bed or alluvium deposits. It is composed of shell – rich calcareous sandstone (4 – 82 %) as well as quartz grains with intercalations of loamy materials.

The depth to water from ground surface being (3 – 40 m) in the continental kurkar aquifer and (24 – 80m) in the marine one. The groundwater in the kurkar is confined or semi confined to unconfined according to locality. The general trend of the groundwater flow is from South to North, (Fig.2). The deviations from the general trend of water flow are either due to hydrogeologic features (as buried channels) or intensive well exploitation. The water table contour lines show that the zero line is missed allover the area of study which means that a real sea water intrusion did not take place until March 1995. In the marine Kurkar (South), the hydraulic gradient of the water table is gentle where it amounts to 0.0067 and 0.0003, while at the southern and northern parts of continental kurkar, the hydraulic gradients of water tables is steep where it amounts to 0.0015 and 0.0004, respectively. This supports the assumption that the main recharge comes from the direct rainfall and subsurface flow from South to North and through the old wadis.

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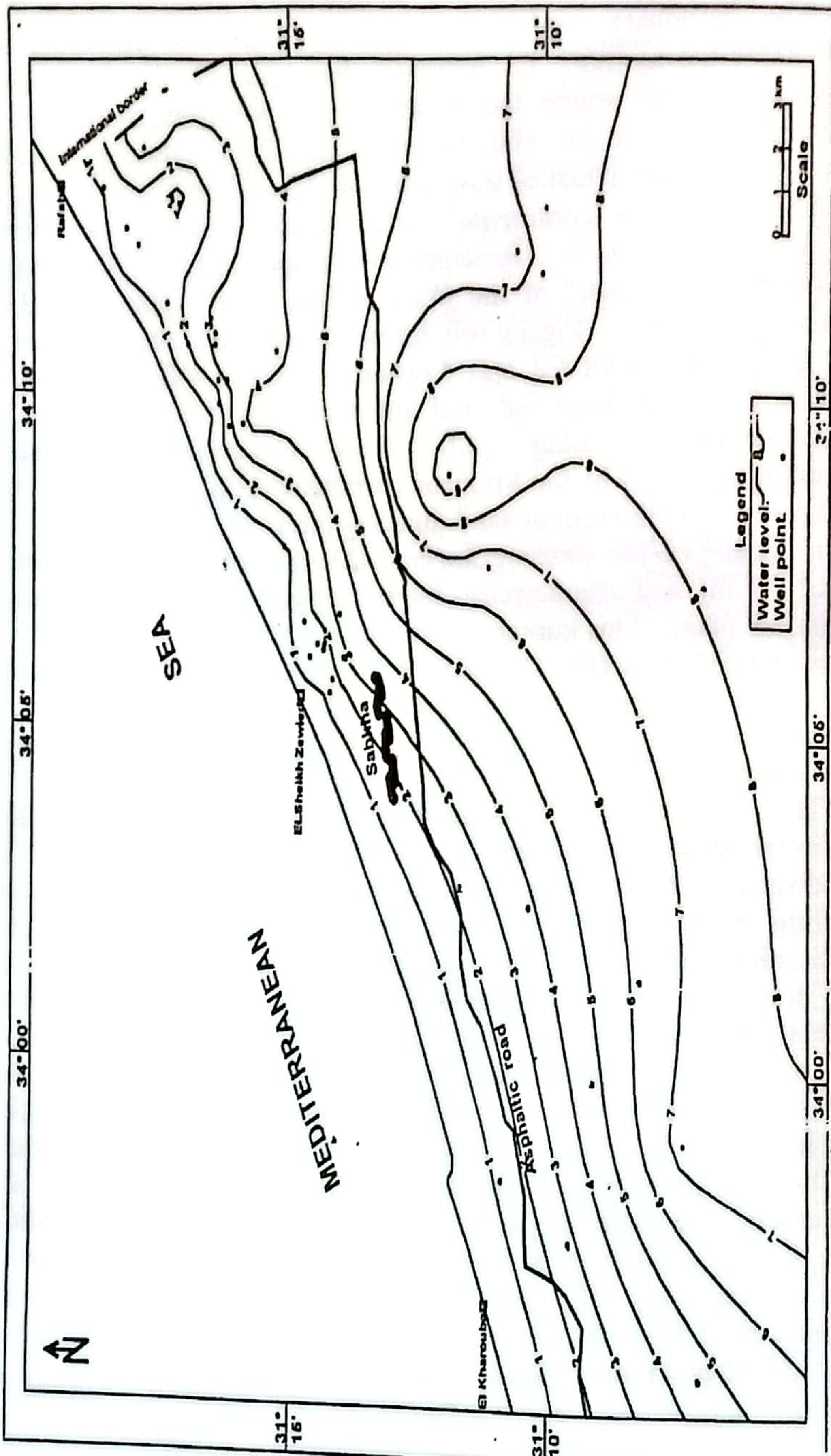

Fig. (2): Water table map of both continental and marine Kurkar aquifers in El Arish - Rafah area and its Southern parts (March, 1995)

2- Hydrochemistry of water:

1-Total Salinity: Correlation between the total dissolved solids (TDS) and the corresponding values of the ionic strength (U) of the investigated groundwater within the study area revealed that three categories could be recognized:

A-Fresh water category, having TDS values less than 1500 mg/l and U less than 0.03.

B-Brackish water category, having TDS values between 1500 and 5000 mg/l and U 0.03 – 0.1.

C- Saline water category, having TDS values more than 5000 mg/l and U more than 0.1.

The frequency distribution of water salinity of the continental and marine kurkar aquifers is presented in Table (4).

TABLE 4. The frequency distribution of ionic strength (U) of groundwater in continental and marine kurkar aquifers in the studied area.

Kurkar aquifer Type	No. of water Samples	Distribution %		
		Fresh water < 0.03 U	Brackish water 0.03 – 0.1U	Saline water > 0.1U
Continental	89	64	35	1
Marine	27	---	37	63

From this table, it is clear that in the continental kurkar aquifer, the fresh water dominates, followed by brackish water, while saline water is nearly absent.

The dominance of fresh water at the coastal area is caused by the relatively high amount of rainfall (200 - 300 mm / yr.) which has direct contribution to the groundwater recharge in addition to the continental nature of this aquifer (mean water salinity, 1231 mg / l).

With regard to the marine kurkar aquifer, the fresh water is almost absent while saline water dominates and brackish water is less pronounced. This pattern is attributed to the subsurface flow (from south to north) with the possible leakage of saline waters from the Eocene rocks that dominate the catchment area together with the marine environment of this aquifer (mean water salinity, 5076 mg / l).

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Based on July 1996 samples, the iso – salinity distribution in the continental and marine kurkar aquifers of the studied area is shown in Figure (3). The trend is the same as the regional flow direction of groundwater in the area between West EL- Kharouba (marine kurkar aquifer) and West EL – Sheikh Zewied at fault plain F_1 (marine kurkar aquifer). On the other hand, the iso – salinity distribution follows an opposite trend to the regional flow direction of groundwater in the area between fault plain F_5 and the coastal plain from EL – Sheikh Zewied to Rafah, due to the direct effect of the local rainfall on the coastal plain (continental kurkar aquifer). From the iso – salinity map, the following could be concluded:

a) A general increase of water salinity from South (3000mg/l) to North (7500mg/l) in the area between West EL-Kharouba (marine Kurkar aquifer) and West EL – Sheikh Zewied at fault plain F_1 (marine kurkar aquifer). On the other hand, water salinity decrease from South (6000mg/l) to North (< 500mg/l) in the area between fault plain F_5 (marine kurkar aquifer) and the coastal plain from EL – Sheikh Zewied to Rafah (continental kurkar aquifer).This can be explained on the basis of the integrated recharge of subsurface flow that contain relatively high salinity water from alluvium aquifer in the southern parts at fault F_5 towards the marine kurkar and also towards the coastal area (continental kurkar aquifer), as well as the effect of the local rainfall on the coastal plain.

b) The low salinity water (< 1500 mg / l) at the coastal area is expected as a result of the relatively high rate of direct precipitation in the coastal area (200 -300 mm / yr.) which feeds the continental kurkar aquifer with a considerable amount of fresh water. This is stimulated by the high rate of infiltration in sand dunes dominating this area.

c) The occurrence of brackish water in the continental kurkar aquifer could be attributed to the possible leakage of saline water from the deep marine kurkar aquifer, as well as, intensive groundwater withdrawal at South of EL - Sheikh Zewied – Rafah and South Rafah city. Similarly, the occurrence of brackish water in the shallow marine kurkar aquifer at South, near the fault plainF_5, is due to the possible leakage of saline water from the Southern alluvium aquifer. Such explanation is based on the data obtained from different wells tapping the marine kurkar aquifer which have brackish and highly saline waters (3000 – 6000 mg / l).

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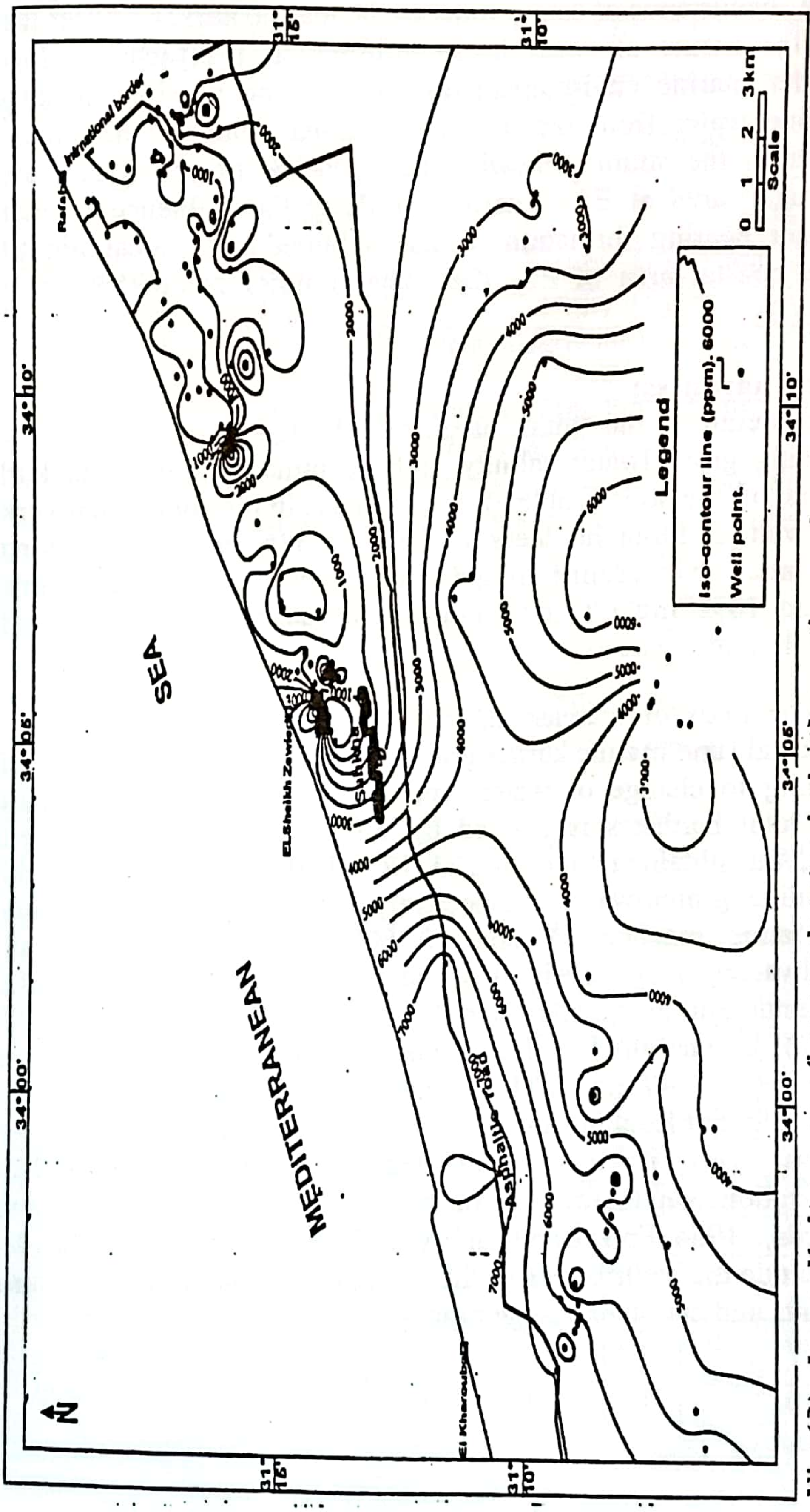

Fig.(3): Iso-salinity map of groundwater in both continental and marine Kurkar aquifers in El Arish-Rafah area and its southern parts (1996)

d) The occurrence of saline water in the marine kurkar aquifer is due to the nature of water bearing formation itself which is formed under marine environment, as well as, the possible leakage of saline water from the Eocene rocks that dominate the catchment area in the south. Likewise, the presence of saline water in the coastal area at EL- Kharouba reflects the influence of marine water bearing formation which is diluted by the local rainfall on the coastal area of EL- Kharouba (salinity from 7500 to 3000 mg/l).

2) Total hardness:

Generally, the total hardness(TH) tends to increase with increasing groundwater salinity in the continental and marine kurkar aquifers of the area (Table 5) .For instance, in the continental kurkar, mean values of total hardness reached 164, 386 and 1217 mg / l in the fresh, brackish and saline groundwaters, respectively, while became at 659 and 1692 mg / l in the brackish and saline groundwaters of the marine kurkar, respectively.

The rates of increase in the total hardness with salinity of the continental and marine kurkar groundwaters are about 3.2 to 2.4 folds according to change of water type from fresh to brackish to saline. When total hardness is divided by water salinity in the continental kurkar, the obtained ratios are 23, 19 and 20 % in the fresh, brackish and saline groundwaters, respectively, while in the marine kurkar these ratios reached 17 and 30 % in the brackish and saline groundwaters, respectively. It is evident that the mean hardness of the continental kurkar groundwater (mean TH = 253 mg / l, TH / TDS = 21.2 %) is generally less than that of the marine kurkar groundwaters (mean TH = 1347 mg / l, TH /TDS = 27 %). This is mainly attributed to the effect of leaching and dissolution of salts leading to increase of hardness with particular importance to the effect of NaCl concentration on increasing solubility of Ca^{2+} and Mg^{2+} in water (Richards, 1954, Freeze and Cherry, 1979 and Hem, 1989). This does not exclude the contribution of the CO_2, pH, sea water in older marine sediments and cation exchange process.

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TABLE 5. Mean total hardness (mg/l) and total hardness /total salinity in groundwater samples of the study area.

Kurkar aquifer Type	Groundwater type								
	Fresh			Brackish			Saline		
	TDS	TH	TH/ TDS %	TDS	TH	TH/ TDS %	TDS	TH	TH/TDS %
Continental	698	164	23	2038	382	19	5995	1217	20
Marine	---	---	---	3848	659	17	5687	1692	30

TDS = Mean values of water salinity, TH= Mean values of total hardness

The distribution of the total hardness of the kurkar aquifer in the studied area is shown in Fig. (4), which reveals that:

1) The distribution of total hardness shows a considerable increase from South (<600 mg/l) to North (>1800mg/l) in the area between West EL-Kharouba (marine kurkar aquifer) and West EL – Sheikh Zewied at fault plain F_1(marine kurkar aquifer) while decreases from South(>1200mg/l) to North (<200mg/l) in the area between fault plain F_5(marine kurkar aquifer) and the coastal plain from EL – Sheikh Zewied to Rafah (continental kurkar aquifer).This behavior could be explained on basis of the same reasons already mentioned.
2) The distribution of total hardness shows a considerable decrease from West (marine kurkar,>1800mg/l) to East (continental kurkar,<200mg/l).
3) The total hardness distribution follows, more or less, the same trend of total salinity.

TABLE 6. The frequency distribution of temporary and permanent hardness in groundwater of both continental and marine kurkar aquifers.

Kurkar aquifer Type	State of hardness	Fresh Groundwater			Brackish Groundwater			Saline groundwater		
		No.of w.s*.	% of Fresh	% of total	No.of w.s*.	% of Brachish	% of total	No .of w.s*.	% of Saline	% of total
Continental	Temporary	27	47	30	4	13	5	---	---	---
	Temporary >permanent	18	32	20	8	26	9	---	---	---
	Permanent >Temporary	12	12	14	19	61	21	1	100	1
Marine	Permanent >Temporary	---	---	---	10	100	37	17	100	63

* w.s. = water samples

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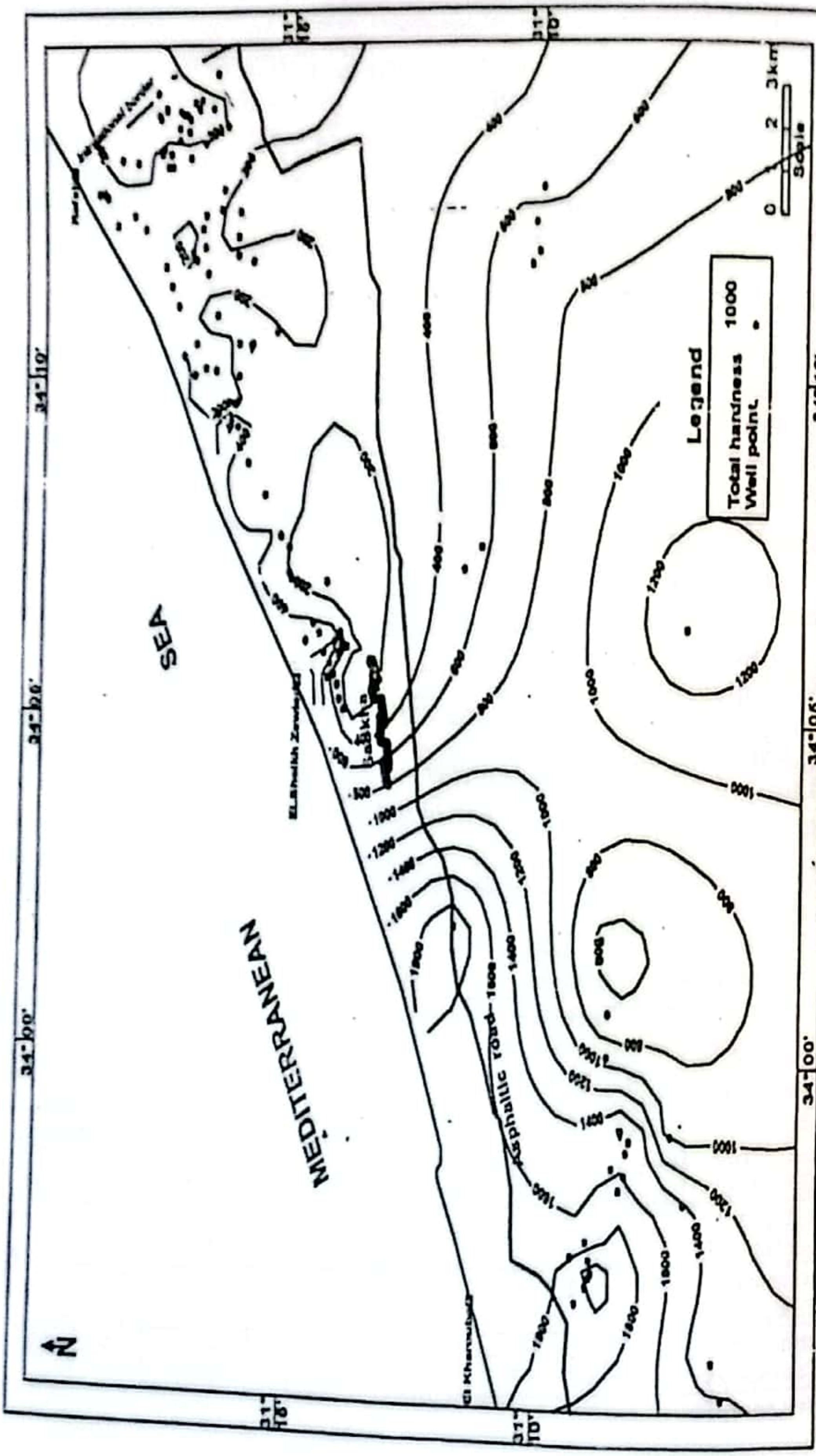

Fig. (4): Iso-total hardness map of groundwater in both continental and marine Kurkar aquifers in El Arish-Rafah area and its Southern parts (1996)

From the data in Table (6) one finds the following:

In case of the continental kurkar:

- Where total hardness is mainly temporary, the hardness in the fresh and brackish aquifer represents 47and 13%, while being 30 and 5% out of all the water samples collected.
- Where temporary hardness exceeds the permanent one, the hardness in the fresh and brackish aquifer represents 32 and 26%, while being 20 and 9% of the total water samples, respectively.
- Where permanent hardness exceeds the temporary one, the hardness in the fresh, brackish and saline aquifer is 21, 61 and 100% , while being 14, 21 and 1% of the total water samples, respectively.

In case of the marine kurkar:

- Where permanent hardness exceeds temporary one, the hardness in the brackish and saline aquifer represents 100 and 100%, while being 37 and 63% of the total water samples, respectively.

The relationships between temporary hardness and theP_{CO_2} values for groundwaters in both continental and marine kurkar aquifers, (Tables1-3), are shown to be higher than the P_{CO_2} of the earth' s atmosphere(0.32×10^{-3}bar).This indicates that the groundwater in these aquifers became charged with CO_2 during infiltration through the soil zones .The computed P_{CO_2} values in the groundwater of the continental and marine kurkar aquifers (0.1 - 5.7 and 0.3 - 4.6 $\times10^{-3}$ bars) suggest an open (P_{CO_2} is less than 0.32×10^{-3}bar) and closed system (P_{CO_2} is more than 0.32×10^{-3} bar), indicating an equilibrium and disequilibrium conditions with the atmospheric CO_2 in the former and latter systems, respectively. This is in agreement with the hydrogeological conditions of the continental and marine aquifers where the hydraulic condition of the groundwater varies from unconfined (open system) to confined (closed system) according to localities. It is therefore believed that the recharging conditions of the confined carbonate aquifers are more related to the P_{CO_2} than to the type of water circulation inside that aquifers and vice versa in the unconfined carbonate aquifers.

The pH of water in both aquifers is normally between 7 and 9,indicating that the dissolved inorganic carbon exists almost entirely as HCO^-_3, Freeze and Cherry (1979). The concentrations of HCO^-_3 (temporary hardness) are widely variable, being much higher in the continental (mean temporary hardness=124mg/l) than to the marine kurkar aquifer (mean temporary hardness=102mg/l). Since the water temperatures of both aquifers are unique (mean water temperature = 25°C), it is expected that P_{CO_2} and water pH play the major role in HCO_3^- dissolution.

The solution equilibrium reaction of Ca^{2+} and Mg^{2+} carbonates which contributes to temporary hardness is influenced by H_2CO_3 (CO_2 and H_2O) in percolating rain water, water pH and temperature. This is generally reflected on the temporary hardness in the continental and marine kurkar aquifers, *i.e.* temporary hardness is more dominant in the continental kurkar aquifer. In the marine sediments, beside the temporary hardness, because of the longer residence time and influence of older salty marine waters, sulfates and chlorides of calcium and magnesium are increased in groundwater, *i.e.* permanent hardness is more dominant in the marine kurkar aquifer.

In conclusion, 64% of the analyzed water samples show temporary hardness rather than permanent hardness in the continental kurkar. This is attributed to the leaching and dissolution of the terrestrial salts of continental kurkar matrix (Ca + Mg) CO_3 beside the contribution of CO_2, water pH, and cation exchange process which play an important role in the chemistry of groundwaters hardness to give either temporary hardness salts $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$ or permanent hardness salts $MgSO_4$, $CaSO_4$,$MgCl_2$ and $CaCl_2$, (Tables1-3) . An opposite trend is seemingly displayed in the marine kurkar where, 100%of the investigated water samples show permanent hardness rather than temporary hardness. This is attributed to the leaching and dissolution of the marine salts of marine kurkar matrix (Ca + Mg) CO_3 beside the contribution of longer residence time in the marine sediments, CO_2, water pH and cation exchange process which play an important role in the chemistry of groundwaters hardness to give either permanent hardness salts $MgSO_4$, $CaSO_4$; $MgCl_2$ and $CaCl_2$ or temporary hardness salts Mg $(HCO_3)_2$ and $Ca(HCO_3)_2$, (Tables1-3) .

From the hydrogeochemical study on both aquifers, (Tables1-3), it is clear that, few groundwater samples (12% of the total samples) of the continental kurkar and all groundwaters of the marine kurkar aquifer reflect marine facies (marine salt assemblages IV, V and VI, rNa / rCl<1), while most groundwaters of the continental kurkar have continental facies (terrestrial assemblages I, II and III, rNa/Cl> 1).

The marine facies of some groundwaters in the continental kurkar are most probably due to either upward leakage from deep

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horizons (subsurface marine kurkar) through the faults plains or the recharge from marine facies groundwater of sand aquifer that hydraulically connects with the kurkar aquifer.

Considering salinity of both continental and marine facies groundwater types, generally it is observed that in the mean total and permanent hardness tends to increase with increasing the groundwaters salinity and the mean temporary hardness tends to decrease with increasing salinity of groundwaters, (Table 7).

TABLE 7. Average and relative values of total, temporary and permanent hardness compared to the water salinity in the continental and marine facies groundwater types.

Water Type	Groundwater salinity								
	TDS mg/l	TH mg/l	TH/ TDS%	Tempor. mg/l	Tempor. /TH%	Tempor. /TDS%	Perm. mg/l	Perm. /TH%	Perm. /TDS%
	FRESH								
Continental facies	690	148	21	111	75	16	37	25	5
Marine fac.es	762	298	39	113	38	15	186	62	24
	BRACKISH								
Continental facies	2030	339	17	147	43	7	192	57	10
Marine facies	3309	665	20	131	20	4	534	80	16
	SALINE								
Continental facies	5995	1217	20	128	11	2	1089	89	18
Marine facies	5687	1692	30	77	5	2	1613	95	28

It is evident that the groundwater types, affected by leaching and dissolution of terrestrial salts, are possibly accompanied by cation exchange processes (related to clay minerals assemblage, dominated by montmorillonite, palygorskite, hydrous mica and kaolinite as well as amorphous inorganic materials, cation exchange capacity ranges from 20 to 167 me./100g clay in both aquifers) that lead to an increase or a decrease in the temporary(equations 1 and 2) and permanent hardness(equations 3) as follows:

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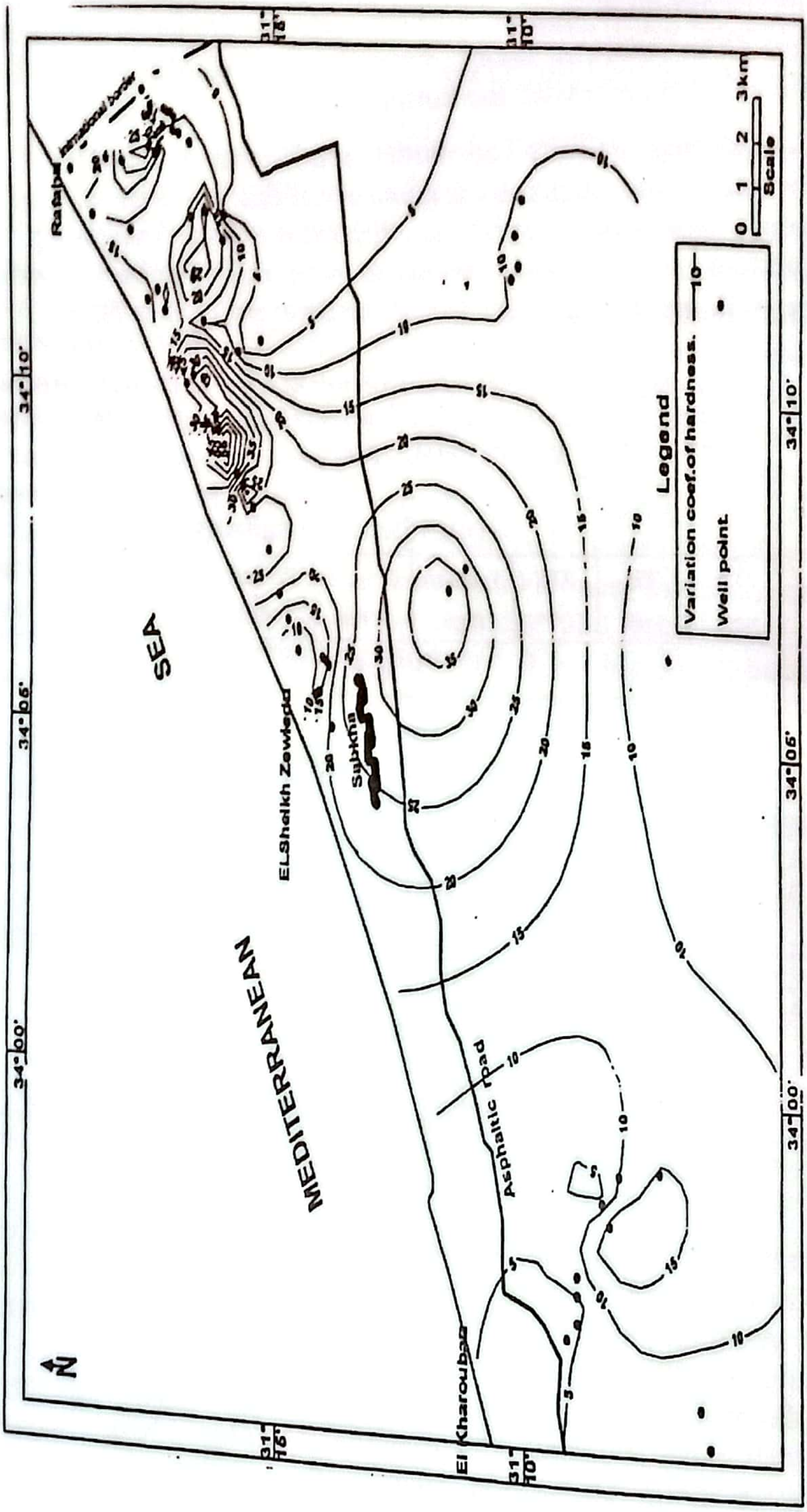

Fig.(5): Variation coefficient of total hardness in groundwater for both continental and marine Kurkar aquifers in El-Arish-Rafah area and its Southern parts

$$1)\ \underset{\text{in solution}}{Ca\,(Mg)\,(HCO_3)_2} + \underset{\text{colloid}}{2\,Na^+} \overset{\text{cation exchange}}{\rightleftarrows} \underset{\text{in solution}}{2NaHCO_3} + \underset{\text{colloid}}{Ca^{2+}\,(Mg^{2+})}$$

$$2)\ \underset{\text{in solution}}{Ca\,(HCO_3)_2} + \underset{\text{colloid}}{Mg^{+2}} \overset{\text{cation exchange}}{\rightleftarrows} \underset{\text{in solution}}{Mg\,(HCO_3)_2} + \underset{\text{colloid}}{Ca^{2+}}$$

$$3)\ \underset{\text{in solution}}{Ca\,(Mg)\,SO_4} + \underset{\text{colloid}}{2\,Na^+} \overset{\text{cation exchange}}{\leftrightarrows} \underset{\text{in solution}}{Na_2SO_4} + \underset{\text{colloid}}{Ca^{2+}\,(Mg^{2+})}$$

On the other hand, the groundwater types affected by leaching and dissolution of marine salts are possibly accompanied by cation exchange processes that lead to an increase or a decrease of the permanent hardness (equation 1) as follows:

$$\underset{\text{in solution}}{2Na^+} + \underset{\text{colloid}}{Ca(Mg)Cl_2} \overset{\text{cation exchange}}{\rightleftarrows} \underset{\text{in solution}}{Ca(Mg)\,Cl_2} + \underset{\text{colloid}}{2Na^+}$$

The presence of $NaHCO_3$, $Mg\,(HCO_3)_2$, Na_2SO_4, $MgCl_2$ and $CaCl_2$ gives a good evidence of cation exchange in the studied groundwaters, (Tables 1-3).

Several indices are used for the identification of water that have undergone cation exchange processes (Schoeller, 1935, Schoeller, 1962, Atwa, 1979, Matthess, 1982 and EL Said,1994). The alkali number is expressed as 100 (Na+K) / Cl (me / l). An increase or decrease of the alkali number is mainly attributed to cation exchange which takes place under three conditions as follows:

I) Up to alkali number 100, alkalis (in solution) replace Ca and Mg in their halogens (on the surface of clay minerals in aquifer matrix).

II) From 100-120, alkaline earths Ca and Mg in their sulphates and part of their carbonates(in solution) replace alkalis(on the surface of clay minerals in aquifer matrix).

III) Above 120, alkaline earths Ca and Mg in their carbonates (in solution) replace alkalis (on the surface of clay minerals in aquifer matrix).

From Table (8), it is clear that the alkali number of all groundwater samples in the marine kurkar aquifer and 12 % of the continental kurkar groundwater aquifer range from 56 to 100. These groundwater types are characterized by the assemblages of salt combination VI, V and IV which reflect the effect of leaching and dissolution of marine salts with some contribution of cation exchange

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phenomenon, forming the following hypothetical salt combinations in such groundwaters, (Table 1).

IV- $NaCl$, $MgCl_2$, $MgSO_4$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$.

V - $NaCl$, $MgCl_2$, $MgSO_4$, $CaSO_4$, $Ca(HCO_3)_2$.

VI - $NaCl$, $MgCl_2$, $CaCl_2$, $CaSO_4$, $Ca(HCO_3)_2$.

In this case, the high concentration of alkalis (Na^+ and K^+) in solution replaces Ca^{2+} and Mg^{2+} in their halogens (on the surface of clay minerals in aquifer matrix).

As a result of cation exchange processes, Na^+ concentration decreases, this is accompanied by an increase of Ca^{2+} and Mg^{2+}. concentrations in solution, leading to an increase in salts causing permanent hardness ($MgCl_2$, $CaCl_2$, $MgSO_4$, and $CaSO_4$) rather than those causing temporary hardness {Ca and $Mg(HCO_3)_2$ } which is in equilibrium with P_{CO2}. Nevertheless, an opposite trend (temporary hardness > permanent hardness) is observed in case of some marine facies groundwater types of the continental kurkar which exhibits an assemblage of marine hypothetical salts.

Few groundwater samples (16%) of the continental kurkar aquifer have an alkali number that ranges from 100 to 120. These groundwater types are related to the salt combination assemblages of II & III which reflect the effect of leaching and dissolution of terrestrial salt (terrestrial facies groundwaters) with some contribution of cation exchange processes, forming hypothetical salt combinations, (Table 2), as follows:

II: $NaCl$, Na_2SO_4, $MgSO_4$, $Mg(HCO_3)_2$,$Ca(HCO_3)_2$.(63%,temporary > permanent)

III: $NaCl$, Na_2SO_4, $MgSO_4$, $CaSO_4$, $Ca(HCO_3)_2$. (37%,permanent>temporary)

In this case, the alkaline earths Ca^{2+} and Mg^{2+} in their sulfates and part of their carbonates in solution replace the alkalis (Na^+ and K^+) on the surface of clay minerals in the aquifer matrix.

As a result of cation exchange processes, the increase of Na^+ concentration and decrease in Ca^{2+} and Mg^{2+} concentrations in solution, lead to a decrease in salts causing temporary and permanent hardness.

On the other hand, about 72% of groundwater types of the continental kurkar display an alkali number above 120. These groundwater types have the assemblages of salt combinations I, II and III which reflect the effect of leaching and dissolution of terrestrial salts (terrestrial facies groundwaters) with some

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contribution of cation exchange processes, forming hypothetical salt combinations, (Table 3), as follows:

I: $NaCl$, Na_2SO_4, $Na(HCO_3)$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$. (48%)

II: $NaCl$, Na_2SO_4, $MgSO_4$, $Mg(HCO_2)_2$, $Ca(HCO_3)_2$. (33%)

III: $NaCl$, Na_2SO_4, $MgSO_4$, $CaSO_4$, $Ca(HCO_3)_2$ (19%)

In this case, the alkaline earths Ca^{2+} and Mg^{2+} in their carbonates (in solution) replace alkalis Na^+ and K^+ (on the surface of clay minerals in aquifer matrix).

As a result of cation exchange processes, the increase of Na^+ concentration and decrease in Ca^{2+} and Mg^{2+} concentrations in solution, lead to a decrease in salts causing temporary hardness only, $Ca(HCO_3)_2$ $Mg(HCO_3)_2$.

In brief, one can conclude that in most cases, cation exchange phenomenon in the continental kurkar aquifer is expected to decrease the temporary and permanent hardness, while in the marine kurkar aquifer cation exchange processes are expected to increase the permanent hardness.

For further elucidation of the data, the cation exchange index is employed where:

$$\text{cation exchange index} = \frac{rCl - r(Na + K)}{rCl}$$

This ratio has either negative or positive values. The negative value means that, the alkaline earths (Ca^{2+} and Mg^{2+}) in water replace the alkalis (Na^+ and K^+) on the surface of clay minerals in aquifer and vice versa in case of positive value.

All groundwater types of the marine kurkar aquifer and few groundwater types (12%) of the continental kurkar aquifer have positive values of cation exchange index, while most groundwater types (88%) of the continental kurkar have negative values regardless of water salinity (Table 8).

Combination of alkali number, cation exchange index and hypothetical salts data revealed that, all groundwaters of the marine and some groundwater types of the continental kurkar (marine facies groundwater) have an alkali number up to 100, positive values of cation exchange index and marine salts (IV, V, VI). Also, long residence time in the older marine sediments, cation exchange processes and concentration process through dissolution or evaporation lead to considerable increase in permanent hardness more than that of temporary hardness which is equilibrium with P_{CO_2}. On

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the contrary, most groundwaters of the continental kurkar (continental facies groundwaters) are characterized by an alkali number above 100, negative value of cation exchange Index and terrestrial salts (I, II, and III). Also, CO_2 and pH of the medium, cation exchange processes, leaching and dissolution of terrestrial salts lead to a slight increase in temporary more than permanent hardness.

In conclusion, the effect of CO_2, pH, longer residence time in the older marine sediments, leaching and dissolution processes accompanied by cation exchange process leads to increased total hardness in the marine facies groundwaters (mean TH / TDS = 27 %), more than that of the continental facies groundwaters (mean TH / TDS = 19 %). Moreover, the permanent hardness of the marine facies groundwaters (mean Perm. / TH = 91 %) exceeds that of the continental facies groundwater types (mean Perm. / TH = 46 %). On the other hand, the temporary hardness of the continental facies groundwater types (mean Temp. / TH = 54 %) exceeds that of the marine facies groundwaters (mean Perm. / TH = 9 %) (Table 8).

TABLE 8. Mean total hardness, TH / TDS, temporary and permanent hardness, Temporary /TH, permanent/TH, alkali number and cation exchange index in both continental and marine facies groundwaters.

Water type	TDS mg/l	TH mg/l	TH/ TDS%	Temp. mg/l	Temp. / TH%	Temp./ TDS%	Perm mg/l	Perm. /TH%	Perm./ TDS%	Alkali No.	Cation exchange Index	Salt asseblages
Continental Facies	1217	232	19	124	54	10	104	46	9	Above100	-ve	I, II, III
Marine Facies	4053	1105	27	102	9	2.5	1003	91	24.5	Up to 100	+ve	IV,V,VI

According to Shuster and White (1971) and Sadik and Karam (1986) the temporal variation in the total hardness as a concept in the chemistry of groundwater in porous carbonate aquifer have been used to detect whether the carbonate system is of diffused type (slow flow) or of the conduit type (fast flow) . In this respect, Shuster and White (1971) and Ternan (1972) found that the high temporal variations in total hardness are usually associated with fast – flowing water(conduit carbonate type), while low temporal variations reflect a rather diffuse flow system. They used the coefficient of variation of total hardness rather than the absolute values of total hardness to describe the characteristics of a carbonate aquifer. This coefficient is defined as;

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$$V = \left(\frac{\sigma}{\bar{x}} \right) \times 100$$

Where σ is the standard deviation of the total hardness values and $\bar{x}$ is their mean.

Values (V) less than 5% are considered as indicative of the diffused flow type, and hence a long contact residence time. High values are associated with fast-flowing water. However, exceptionally high coefficient of more than 10% were also reported by Shuster and White (1971)as diffused flow. The same authors described the coefficient of variation as the most important parameter while Ternan, (1972) relied completely on it for describing the mode of recharge of carbonate aquifers.

In the present work, the data obtained (Fig.5), revealed that, the variation coefficients of groundwater hardness (V) of the marine kurkar aquifer, (Permanent hardness > temporary hardness) in the southern parts range between 5 – 42% which indicate fast – flowing system. Some exceptional cases in the western part of EL-Kharouba area and South Rafah inland are recorded where the variation coefficients of groundwater hardness of the marine kurkar is less than 5%, indicating slow – flowing system. With respect to the variation coefficients of groundwater hardness (V) of the continental kurkar (temporary hardness > permanent hardness) at EL Sheikh Zewied – Rafah coast range between 5 – 65.7 % indicating fast -flowing system.

On the other hand, the variation coefficients of groundwater hardness at South Rafah inland are less than 5% which is considered within the diffusion flow system. As mentioned before, the general trend of groundwater flow is from South to North (Fig.2).

The change from diffused to fast flow system in both continental and marine kurkar aquifers depend on the variations of hydraulic conductivity and hydraulic gradient. Furthermore, the fault plain plays an important role in groundwater flow in the studied area as it may act as a source of recharge from the deep - seated aquifer as well as the buried channels.

These results are confirmed by the determination of velocity of groundwater movement as follows:

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$$V = K \frac{dh}{dl}$$

where **V** = the velocity of groundwater movement.

K = the mean hydraulic conductivity which is 16.9 m/day in the marine kurkar aquifer at (South) and 5.1 m/day in the continental kurkar at (North), (EL Tablawi,1997).

$\frac{dh}{dl}$ = the hydraulic gradient which is 0.0015 in the continental kurkar at the coastal plain (North), between the shoreline and fault (F_3) plain;0.00042 in the continental kurkar at South Rafah, between the fault plain (F_3) and (F_4) and; 0.00067 in the marine kurkar (South),between the fault plain (F_4) and (F_5),0.0003 in the marine kurkar at South Rafah, between the fault plain (F_4) and (F_5).

From the above equation it is obvious that the velocity of groundwater movement is (2.79 and 4.1m/yr. , fast flow system) in the continental kurkar at the coastal plain between the shoreline and fault (F_3) and marine kurkar between the faults plain (F_4) and (F_5), while being far below such velocity (0.74 – 1.85m/yr. , diffused flow system) in the continental kurkar at South Rafah between the faults plain (F_3) and (F_4) and marine kurkar at South Rafah between the faults plain (F_4) and (F_5). The results of the velocity obtained from this equation stand in agreement with the variation coefficient of the total hardness (V) in the continental and marine kurkar aquifers. This may suggest that geochemical prediction through variation in the total hardness could be used as a guide for determination of relative velocity of water movement (fast or diffused flow system) in the carbonate aquifer.

Another trial was performed by using the variation in total hardness relative to their salinity (TH /TDS). The obtained data, (Fig.6), follow nearly the same pattern obtained by variation in total hardness (TH).

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Conclusion

The carbonate aquifer (kurkar) represents the main exploited aquifer in EL Arish – Rafah area. This aquifer can be distinguished into two main facies namely; continental and marine kurkar aquifers. The depth to water being 3 to 40 m in the continental kurkar and 24 to 80 m in the marine kurkar aquifer. The general trend of groundwater flow is from South to North. The zero line is missed allover the area of the study meaning that sea water intrusion did not take place until March 1995.

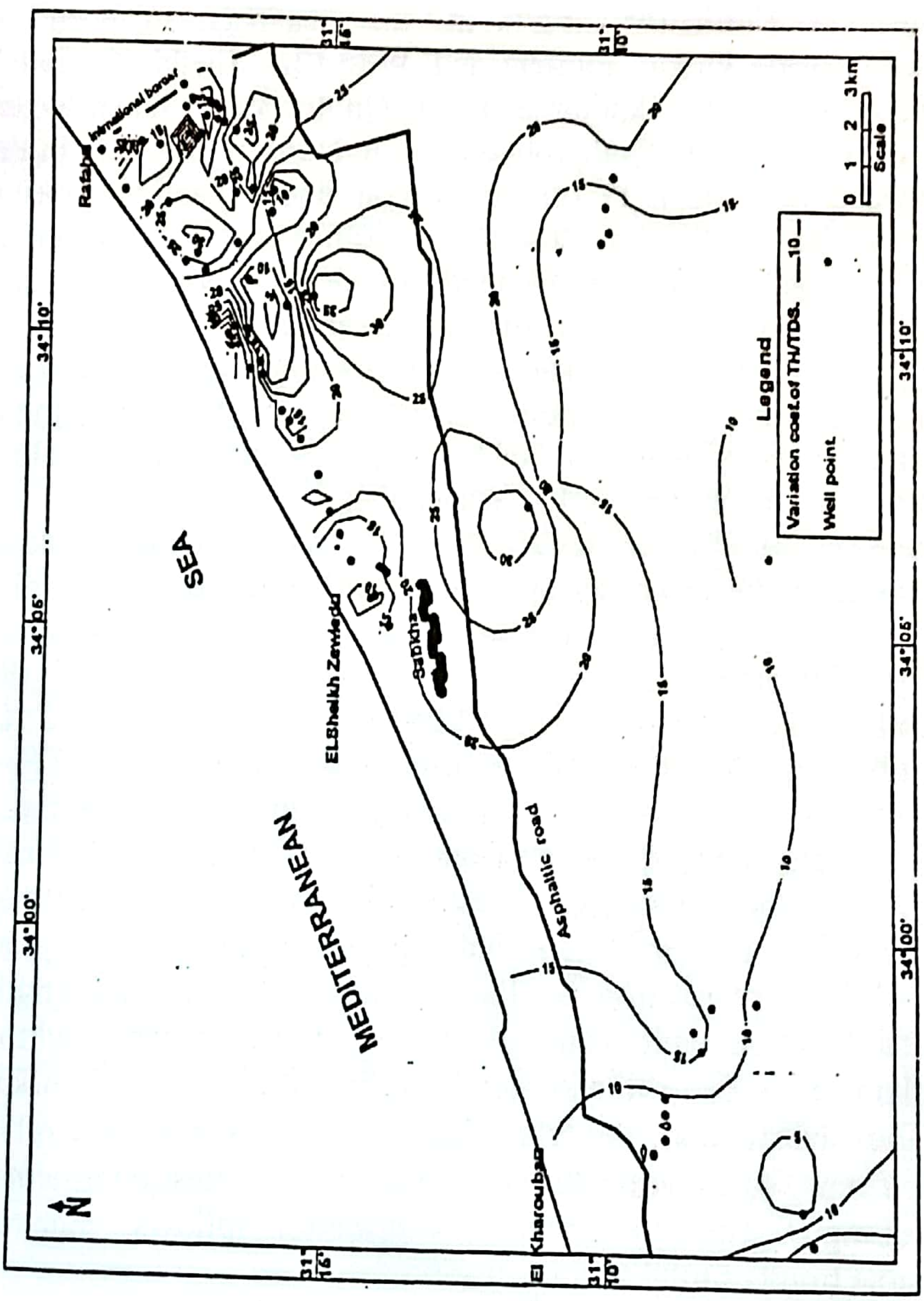

Fig.(6): Variation coefficient of TH/TDS in groundwater for both continenta and marine Kurkar aquifers in El-Arish-Rafah area and its Southern parts

The main target of this work is to elucidate the chemistry of groundwater hardness and the hydrochemical factors controlling them in EL Arish- Rafah area and its Southern extremities`.

Also, the variations in total hardness have been used to detect the mode of water circulation within the carbonate system.

In the continental kurkar, the fresh water dominates 64%, followed by brackish water while saline water is nearly absent. With regard to marine kurkar aquifer, the fresh water is almost absent, while saline water dominates 63% and brackish water is less pronounced. Water salinity generally increases from South (3000mg/l) to North (7500mg/l) in the area between West El-Kharouba (marine kurkar aquifer) and West EL – Sheikh Zewied at fault plain F_1 (marine kurkar aquifer). On the other hand, water salinity decrease from South (6000mg/l) to North (<500mg/l) in the area between fault plain F_5 (marine kurkar aquifer) and the coastal plain from EL – Sheikh Zewied to Rafah (continental kurkar aquifer).The total hardness (TH) tends to increase with increasing salinity in the continental and marine kurkar aquifers. A mean total hardness in the continental kurkar, reaches 164, 386 and 1217 mg/l for fresh, brackish and saline waters, respectively, in the same time it reaches the mean of 659 and 1692 mg/l in the brackish and saline groundwaters of the marine kurkar, respectively.

The ratio TH/TDS reaches 23, 19 and 20 % in the fresh, brackish and saline groundwaters of the continental kurkar, respectively, while in the marine kurkar this ratio reaches 17 and 30 % in the brackish and saline groundwaters, respectively. The mean hardness of the continental kurkar groundwater (TH = 253 mg/l, TH / TDS = 21.2 %) is generally less than that of the marine kurkar groundwaters (TH = 1347 mg/l, TH / TDS = 27 %). The distribution of total hardness shows a considerable increase from South (<600mg/l) to North (>1800mg/l) in the area between West EL-Kharouba (marine Kurkar aquifer) and West El – Sheikh Zewied at fault plain F_1 (marine kurkar aquifer) while decreases from South(>1200mg/l) to North (<200mg/l) in the area between fault plain F_5(marine kurkar aquifer) and the coastal plain from EL – Sheikh Zewied to Rafah (continental kurkar aquifer).The distribution of total hardness shows a considerable decrease from West(marine kurkar,>1800mg/l) to East(continental kurkar,<200mg/l). The total hardness distribution follows, more or less, the same trend of total salinity.

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٥- الفارق العمرى بين الزوج والزوجة:

تراوح الفرق العمرى بين الزوج والزوجة بين (١ - ٢٥ سنة)، ويلاحظ ارتفاع نسبة المبحوثات فى الفرق العمرى من (١ - ٨ سنوات) حيث بلغت نسبتهن حوالى ٦٦,٧% من إجمالى عدد المبحوثات بالعينة، بينما بلغت نسبة المبحوثات فى الفرق العمرى (٩ - ١٦ سنة) حوالى ٢٩,٥% من إجمالى عدد المبحوثات بالعينة، فى حين بلغت نسبة المبحوثات فى الفرق العمرى (١٧ - ٢٥ سنة) حوالى ٣,٨% من إجمالى عدد المبحوثات بالعينة.

٦- حجم الأسرة:

تراوح حجم الأسرة بين (٣- ١٢ فرداً) وبلغت نسبة المبحوثات ذات الأسر الصغيرة (أقل من ٦ أفراد) حوالى ٣٣,٤% من إجمالى عدد المبحوثات بالعينة، فى حين بلغت نسبة المبحوثات ذات الأسر المتوسطة الحجم من (٦ - ٩أفراد) حوالى ٥٧,٦% من إجمالى عدد المبحوثات بالعينة، بينما بلغت نسبة المبحوثات ذات الأسر الكبيرة الحجم (أكثر من ٩ أفراد) حوالى ٩% من إجمالى عدد المبحوثات بالعينة.

٧- نوع الأسرة:

أظهرت النتائج ارتفاع عدد المبحوثات من الأسر النووية حيث بلغ عددهن ١٢٦ مبحوثة يمثلن حوالى ٦٠% من إجمالى عدد المبحوثات بالعينة، بينما بلغ عدد المبحوثات من الأسر الممتدة ٨٤ مبحوثة يمثلن حوالى ٤٠% من إجمالى عدد المبحوثات بالعينة.

٨- وجود مصدر دخل مستقل للزوجة:

تبين من النتائج أن حوالى ٤٧,١% من إجمالى عدد المبحوثات بالعينة ليس لديهن دخل مستقل فى حين أن باقى المبحوثات بالعينة والبالغ نسبتهن حوالى ٥٢,٩% لديهن دخل مستقل.

٩- حجم الحيازة المزرعية للأسرة:

تراوح حجم الحيازات الزراعية لأسر المبحوثات من (١-١٢ فدان) وبلغت نسبة المبحوثات اللاتى تحوز أسرهن أرض ذات حيازة صغيرة (١-٤ فدان) حوالى ١٩% من إجمالى عدد المبحوثات بالعينة، بينما بلغت نسبة المبحوثات اللاتى تحوز أسرهن أرض ذات حيازة متوسطة (٥ - ٨ فدان) حوالى ٥٥,٣% من إجمالى عدد المبحوثات بالعينة، فى حين بلغت نسبة المبحوثات اللاتى تحوز أسرهن أرض ذات حيازة كبيرة (٩ - ١٢ فدان) ٢٥,٧% من إجمالى عدد المبحوثات بالعينة.

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١٠- مشاركة الزوجة فى العمل المزرعى:

من النتائج اتضح أن نسبة المبحوثات المشاركات فى العمل الزراعى بلغت حوالى ٨٥,٢% من إجمالى عدد المبحوثات بالعينة، بينما بلغت نسبة غير المشاركات فى العمل الزراعى حوالى ١٤,٨% من إجمالى عدد المبحوثات بالعينة.

١١- حالة المسكن الصحية والبيئية:

تم تحديد حالة المسكن الصحية والبيئية من خلال تسعة بنود(مواد البناء - السقف - الطلاء الداخلى - نوعية الأرض - الإضاءات الصناعية - مكان زريبة المواشى - مياه الشرب - التهوية - نوع الصرف) وقد أعطى كل بند من البنود السابقة متدرج من الدرجات وفقاً لأفضلها صحياً وحماية للبيئة ومجموع هذه الدرجات يعبر عن حالة المسكن الصحية والبيئية وتراوح المدى الفعلى لهذا المؤشر بين (١٨ - ٢٦) درجة وقد أظهرت النتائج أن نسبة المبحوثات اللاتى يعشن فى مسكن غير صحى بلغت حوالى ٢٩,٥% من إجمالى عدد المبحوثات بالعينة، بينما بلغت نسبة اللاتى يعشن فى مسكن متوسط صحياً حوالى ٤١,٤% من إجمالى عدد المبحوثات بالعينة، فى حين بلغت نسبة اللاتى يعشن فى مسكن صحى حوالى ٢٩,١% من إجمالى عدد المبحوثات بالعينة.

١٢- الانفتاح الحضارى والثقافى:

تم تحديد مقدار انفتاح الزوجة حضاريا وثقافيا من خلال سبعة بنود هى (زيارة القرى المجاورة - زيارة المركز أوعاصمة المحافظة - زيارة المحافظات الأخرى - السفر للخارج - الاستماع للإذاعة - مشاهدة التليفزيون - قراءة الصحف) وقد أعطى كل بند من البنود السابقة درجات متدرجة من دائما - أحياناً - نادراً - لا ٤، ٣، ٢، ١ ومجموع هذه الدرجات يعبر عن الانفتاح الحضارى والثقافى وتراوح المدى الفعلى بين (١٠ - ٢٨) درجة، وقد أوضحت النتائج أن نسبة المبحوثات ذات المستوى الانفتاحى المنخفض بلغت حوالى ١٥,٧% من إجمالى عدد المبحوثات بالعينة، بينما نسبة المبحوثات ذات المستوى الانفتاحى المتوسط بلغت حوالى ٤٢,٤% من إجمالى عدد المبحوثات بالعينة، فى حين أن نسبة المبحوثات ذات المستوى الانفتاحى المرتفع بلغت حوالى ٤١,٩% من إجمالى عدد المبحوثات بالعينة.

١٣- التردد على مراكز الخدمات:

تم تحديد مقدار التردد على مراكز الخدمات الموجودة بالقرية حيث تراوح المدى الفعلى بين (٦-٢٠) درجة وقد أظهرت النتائج أن نسبة المبحوثات ذات التردد المنخفض بلغت حوالى ٦٣,٨% من إجمالى عدد

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المبحوثات ذات التردد المنخفض بلغت حوالى ٦٣,٨% من إجمالى عدد المبحوثات بالعينة، فى حين أن نسبة المبحوثات ذات التردد المتوسط بلغت حوالى ٢٤,٨% من إجمالى عدد المبحوثات بالعينة، فى حين أن نسبة المبحوثات ذات التردد المرتفع بلغت حوالى ١١,٤% من إجمالى عدد المبحوثات بالعينة.

ثالثا- علاقة دور المرأة فى اتخاذ القرارات كمتغير تابع ببعض خصائصها الاقتصادية والشخصية كمتغيرات مستقلة:

- يتوقع الفرض البحثى الأول وجود علاقة بين دور المرأة فى اتخاذ القرارات الأسرية وبين كل متغير من المتغيرات المستقلة المدروسة. ولاختبار تلك العلاقة تم حساب قيمة مربع كاى ومقارنتها بالقيم الجدولية . طبقا للنتائج الواردة بالجدول رقم (٦) يتضح أن هناك علاقة معنوية عند مستوى ٠,٠١ بين دور المرأة فى اتخاذ القرارات الأسرية وبين الفرق العمرى بين الزوج والزوجة وأن هناك علاقة معنوية عند مستوى ٠,٠٥ بين دور المرأة فى اتخاذ القرارات الأسرية وبين الحالة التعليمية، نوع الأسرة، وجود دخل مستقل للزوجة. وبناءا على ذلك فإنه يمكن قبول الفرض بالنسبة للمتغيرات الحالة التعليمية، الفرق العمرى بين الزوج والزوجة، نوع الأسرة، وجود دخل مستقل للزوجة، بينما لم يمكن قبول هذا الفرض بالنسبة لباقى متغيرات الدراسة.
- يتوقع الفرض البحثى الثانى وجود علاقة بين دور المرأة فى اتخاذ القرارات الزراعية وبين كل متغير من المتغيرات المستقلة المدروسة ولاختبار تلك العلاقة تم حساب قيمة مربع كاى ومقارنتها بالقيم الجدولية طبقا للنتائج الواردة بالجدول رقم (٦) يتضح النتائج أن هنالك علاقة معنوية عند مستوى ٠,٠١ بين دور المرأة فى اتخاذ القرارات الزراعية وبين الحالة التعليمية، الحالة الزواجية، نوع الأسرة، حالة المسكن الصحية والبيئية، الانفتاح الحضارى والثقافى، التردد على مراكز الخدمات. وأن هناك علاقة معنوية عند مستوى ٠,٠٥ بين دور المرأة فى اتخاذ القرارات الزراعية وبين العمر، مشاركة الزوجة فى العمل المزرعى. وبناءا على ذلك فإنه يمكن قبول الفرض بالنسبة لمتغيرات العمر، الحالة التعليمية، الحالة الزواجية، نوع الأسرة، مشاركة الزوجة فى العمل المزرعى، حالة المسكن الصحية والبيئية، الانفتاح الحضارى والثقافى، التردد على مراكز الخدمات، بينما لم يمكن قبول الفرض بالنسبة لباقى متغيرات الدراسة.

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- يتوقع الفرض البحثى الثالث وجود علاقة بين دور المرأة فى اتخاذ القرارات المتعلقة بأنشطة تربية المواشى (البقر والجاموس) وبين كل متغير من المتغيرات المستقلة المدروسة. ولاختبار تلك العلاقة تم حساب قيمة مربع كاى ومقارنتها بالقيم الجدولية طبقا للنتائج الواردة بالجدول رقم (٦) يتضح النتائج أن هناك علاقة معنوية عند مستوى ٠,٠٥ بين دور المرأة فى اتخاذ القرارات المتعلقة بأنشطة تربية المواشى (البقر والجاموس) وبين وجود دخل مستقل للزوجة، حالة المسكن الصحية والبيئية. وبناءاً على ذلك فإنه يمكن قبول الفرض بالنسبة لمتغيرات وجود دخل مستقل للزوجة، حالة المسكن الصحية والبيئية، بينما لم يمكن قبول هذا الفرض بالنسبة لباقى متغيرات الدراسة.
- يتوقع الفرض الرابع وجود علاقة بين دور المرأة فى اتخاذ القرارات المتعلقة بأنشطة تربية الدواجن وبين كل متغير من المتغيرات المستقلة المدروسة ولاختبار تلك العلاقة تم حساب قيمة مربع كاى ومقارنتها بالقيم الجدولية طبقاً للنتائج الواردة بالجدول رقم (٦) يتضح النتائج أن هناك علاقة معنوية عند مستوى ٠,٠٥ بين دور المرأة فى اتخاذ القرارات المتعلقة بأنشطة تربية الدواجن وبين حجم الأسرة، نوع الأسرة، حالة المسكن الصحية والبيئية. وبناءاً على ذلك فإنه يمكن قبول الفرض بالنسبة لمتغيرات حجم الأسرة،ونوع الأسرة، حالة المسكن الصحية والبيئية، بينما لم يمكن قبول الفرض بالنسبة لباقى متغيرات الدراسة.

وفى ضوء نتائج الدراسة يمكن التوصية بما يأتى:

- الاهتمام بمحو أمية المرأة من خلال فصول محو أمية تتناسب مواعيدها مع مواعيد المرأة فى تلك المناطق وأن يتخللها بعض البرامج لتوعية المرأة بأهمية دورها فى الأسرة وفى الأنشطة المزرعية وذلك لتصبح قادرة على اتخاذ القرارات الرشيدة .
- توجيه برامج خاصة للإرشاد الاجتماعى لتثقيف المرأة وتحسين معلوماتها عن كيفية تربية الأولاد وتوجيههم، وتنظيم الأسرة، وتنظيم الدخل ووضع ميزانية، حيث تعتبر المرأة شخصية إدارية هامة على مستوى أسرتها ومجتمعها.
- الاهتمام بتوجيه الإرشاد الزراعى عن طريق المرشدات الزراعيات أو الرائدات الريفيات لتبين للمرأة أهمية دورها فى

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النواحى الزراعية وتربية المواشى (البقر والجاموس) والدواجن ومدى إسهامها فى اتخاذ القرارات المناسبة لتلك المجالات .

- العمل على اكتشاف القيادات الريفيات وجعلهن قنوات اتصال بين السيدات والأجهزة المختلفة لنشر الثقافة فى المــــرأة وتعريفــــها بأهمية دورها فى اتخاذ القرارات الأسرية والمزرعية.
- الاهتمام بمراكز الخدمات ودورها فى توعيــــة المــــرأة بأهميــــة دورها فى اتخاذ القرارات الأسرية والمزرعية وذلك من خـــلال الندوات التى تهدف إلى زيادة دور المرأة وحسن اختيارها لإتخاذ القرارات .
- العمل على نشر المشاريع التنموية التى تعمل على زيادة دخـــل المرأة وبالتالى تزيد دورها فى اتخاذ القرارات السليمة .
- يجب توجيه الإرشاد الاجتماعى لتوعية المرأة بأهمية الاهتمــــام بمسكنها من الناحية الصحية والبيئية .

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جـــــــدول (١) توزيع المبحوثات وفقاً لبعض خصائصهن الشخصية.

خصائص المبحوثات	عدد	%
١- العمر		
من ١٧ - ٣٤ (الشباب)	٨٦	٤١
من ٣٥ - ٥٢ (متوسط العمر)	٩٣	٤٤,٢
من ٥٣ - ٧٠ (متقدمى العمر)	٣١	١٤,٨
المجموع	٢١٠	١٠٠
٢- الحالة التعليمية.		
أمى	٧٧	٣٦,٧
يقرأ ويكتب	٥٨	٢٧,٦
حاصلة على الابتدائية	٣٣	١٥,٧
حاصلة على الإعدادية	٢٣	١١
حاصلة على الثانوية أو ما يعادلها	١٩	٩
المجموع	٢١٠	١٠٠
٣- الحالة الزواجية		
متزوجة	١٩٠	٩٠,٥
مطلقة	٤	١,٩
أرملة	١٦	٧,٦
المجموع	٢١٠	١٠٠
٤- مدة الزواج		
من ١ - ١٨	١١٢	٥٣,٤
من ١٩ - ٣٦	٧٤	٣٥,٢
من ٣٧ - ٥٥	٢٤	١١,٤
المجموع	٢١٠	١٠٠
٥- الفرق العمرى بين الزوج والزوجة		
من ١ - ٨	١٤٠	٦٦,٧
من ٩ - ١٦	٦٢	٢٩,٥
من ١٧ - ٢٥	٨	٣,٨
المجموع	٢١٠	١٠٠
٦- حجم الأسرة		
أقل من ٦ (صغيرة الحجم)	٧٠	٣٣,٤
من ٦ - ٩ (متوسطة الحجم)	١٢١	٥٧,٦
أكثر من ٩ (كبيرة الحجم)	١٩	٩
المجموع	٢١٠	١٠٠
٧- نوع الأسرة		
أسرة نووية	١٢٦	٦٠
أسرة ممتدة	٨٤	٤٠
المجموع	٢١٠	١٠٠

خصائص المبحوثات	عدد	%
٨- وجود مصدر دخل مستقل للزوجة		
مبحوثات ليس لهن دخل	٩٩	٤٧,١
مبحوثات لهن دخل	١١١	٥٢,٩
المجموع	٢١٠	١٠٠
٩- حجم الحيازة المزرعية للأسرة		
من ١-٤ (حيازة صغيرة)	٤٠	١٩
من ٥ - ٨ (حيازة متوسطة)	١١٦	٥٥,٣
من ٩ - ١٢ (حيازة كبيرة)	٥٤	٢٥,٧
المجموع	٢١٠	١٠٠
١٠- مشاركة الزوجة فى العمل المزرعى		
مبحوثات لا تشاركن	٣١	١٤,٨
مبحوثات تشاركن	١٧٩	٨٥,٢
المجموع	٢١٠	١٠٠
١١- حالة المسكن الصحية والبيئية		
من ١٨ - ٢٠ (غير صحى)	٦٢	٢٩,٥
من ٢١ - ٢٣ (متوسط صحيا)	٨٧	٤١,٤
من ٢٤ - ٢٦ (صحى)	٦١	٢٩,١
المجموع	٢١٠	١٠٠
١٢- الانفتاح الحضارى والثقافى		
من ١٠ - ١٥ (انفتاح منخفض)	٣٣	١٥,٧
من ١٦ - ٢١ (انفتاح متوسط)	٨٩	٤٢,٤
من ٢٢ - ٢٨ (انفتاح مرتفع)	٨٨	٤١,٩
المجموع	٢١٠	١٠٠
١٣- التردد على مراكز الخدمات		
من ٦ - ١٠ (تردد منخفض)	١٣٤	٦٣,٨
من ١١ - ١٥ (تردد متوسط)	٥٢	٢٤,٨
من ١٦ - ٢٠ (تردد مرتفع)	٢٤	١١,٤
المجموع	٢١٠	١٠٠

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جـــدول (٢) المبحوثات تبعاً لدورهن فى اتخاذ القرارات الأسرية.

فئات اتخاذ القرار	العدد	%
من ١٤ – ٢٥ (منخفض)	٧	٣,٣
من ٢٦ – ٣٧ (متوسط)	٣٦	١٧,٢
من ٣٨ – ٤٨ (مرتفع)	١٦٧	٧٩,٥
المجموع	٢١٠	١٠٠

جـــدول (٣) المبحوثات تبعا لدورهن فـــى اتخـــاذ القـــرارات المزرعيـــة المتعلقة بأنشطة الإنتاج النباتى.

فئات اتخاذ القرار	العدد	%
من ٨ – ١٥ (منخفض)	٤٦	٢١,٩
من ١٦ – ٢٣ (متوسط)	١٠٠	٤٧,٦
من ٢٤ – ٣٢ (مرتفع)	٦٤	٣٠,٥
المجموع	٢١٠	١٠٠

جـــدول (٤) المبحوثات تبعا لدورهن فى اتخاذ القرارات المزرعية المتعلقة بأنشطة تربية المواشى (البقر وجاموس).

فئات اتخاذ القرار	العدد	%
من ١١ – ٢١ (منخفض)	٢٠	٩,٥
من ٢٢ – ٣٢ (متوسط)	٥٦	٢٦,٧
من ٣٣ – ٤٤ (مرتفع)	١٣٤	٦٣,٨
المجموع	٢١٠	١٠٠

جـــدول (٥) المبحوثات تبعا لدورهن فـــى اتخـــاذ القـــرارات المزرعيـــة المتعلقة بأنشطة تربية الدواجن.

فئات اتخاذ القرار	العدد	%
من ١٢ – ٢٣ (منخفض)	١٠	٤,٨
من ٢٤ – ٣٥ (متوسط)	١٦	٧,٦
من ٣٦ – ٤٨ (مرتفع)	١٨٤	٨٧,٦
المجموع	٢١٠	١٠٠

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جدول رقم (٦) العلاقة بين المتغيرات المستقلة وبين اتخاذ القرارات.

اتخاذ القرارات / المتغيرات المستقلة	قيمة مربع كاى			
	القرارات الأسرية	القرارات الزراعية	القرارات المتعلقة بأنشطة تربية المواشى	العلاقات المتعلقة بأنشطة تربية الطيور
١- العمر	٥,٢٢٤٠	٩,٩٠٣٤*	٣,٤٤٩٢	٣,٤٩٠١
٢- الحالة التعليمية	١٩,٩٧١١*	٤٤,١٢٢٩**	١٤,٠٨٣٢	٨,٥٥٨٦
٣- الحالة الزواجية	٣,٤٠٤٥	١٧,٧٤٠٤**	٤,٧٥٤٠	٣,١١٣٧
٤- مدة الزواج	٤,٠٠٤١	٨,٨٢٤٦	٣,٣٨٧٦	٣,٨٩١٨
٥- الفرق العمرى بين الزوج والزوجة	١٤,٢٣٦٥**	٤,٦٧٨٩	٨,٩٥٩٠	١,٥٤٣٢
٦- حجم الأسرة	٦,٦٣٨٤	٦,٣٩٢٦	٤,٣٢٨٩	٩.٤٩٨٣*
٧- نوع الأسرة	٨,٩١٣٥*	١٩,١٨٢٥**	٤,١٩٣٨	٦,٢٢٠٦*
٨- وجود دخل مستقل للزوجة	٦,٠١٤٩*	٤,٠٨٦٤	٦,٧٩٣٣*	٥,١٢٢٢
٩- حجم الحيازة المزرعية للأسرة	٤,٦٢٩١	٠,٠٧٠٤٢	٢,٧٧٢١	١,١١٩١٤
١٠- مشاركة الزوجة فى العمل المزرعى	٥,٥٧٩٣	٨,٦٦٠١*	١,٣٢١١٧	١,٨٧٣٦
١١- حالة المسكن الصحية والبيئية	٤,٧٦٢١٥	٢١,٩٣٧٢**	١١,٢٥٥٩*	١٣,٢٦٩٥*
١٢- الانفتاح الحضارى والثقافى	٤,٥٨٩٣	٢٥,٥٣٤٦**	٤,٧٩٦٥	٢,١٥٨٣
١٣- التردد على مراكز الخدمات	٨,٨٧١٨	٢١,٧٢٩١**	٦,٨٠٨٦	٧,٣٥١٢

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* معنوى على ٠,٠٥

** معنوى على ٠,٠١

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Received 17/6/2000
Accepted 12/8/2000

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Women's Role in Decision Making within Family and Farm in some Desert Areas (Salah EL Din and Omar Makram Villages in South Sector of EL-Tahrir)

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Woman participation in decision-making has its impact on the developmental plans. The study aimed at defining women's role in the decision-making process within the family, farm activities, raising cattle and poultry as well as defining the relevant factors. Data was collected by a questionnaire filled out in personal interviews with 210 ladies chosen at random from both Salah EL Din and Omar Makram villages in South sector of ELtahrir.

The questionnaire in its items included three ranks each: low medium and high. The response to each rank was calculated as percentage of the total sample size. The data have been analyzed using percentages and Chi Square Test. Study Results can be summarized as follows:

1- Highly ranked women participation in family decision-making scored 79.5% of the total sample . Highly ranked women participation in farm activities decision-making scored 30.5% of the total sample. Highly ranked women participation in raising cattle decision-making scored 63.8% of the total sample. And highly ranked women participation in raising poultry decision-making scored 87.6% of the total sample.

2- There was a significant relation between women's role in the family decision-making process as independent variables and the difference in age between husband and his wife at significant relation with 0.1% while at 0.5% level with each of educational status, family type, and the wife is financially independent.

3- There was a significant relation between women's role in the farm activities decision-making process as independent variables and the difference in educational status, marital status, family type, house environmental health status, cultural and civilized exposure, frequency of attending at service centers at significant relation with

0.1%, while at 0.5% level with each age, and woman participation in the work farm.

4- There was a significant relation between women's role in the raising cattle decision-making process as independent variables and the difference in the wife is financially independent, and house environmental health-status at significant relation with 0.5%.

5- There was a significant relation between women's role in the raising poultry decision-making process as independent variables and the difference in family size, family type, house environmental health-status, at significant relation with 0.5%.

The study recommends increasing the role of women in the decision-making process in family and farm activities.

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