3-2-4 Seasonal Variation of Water Level

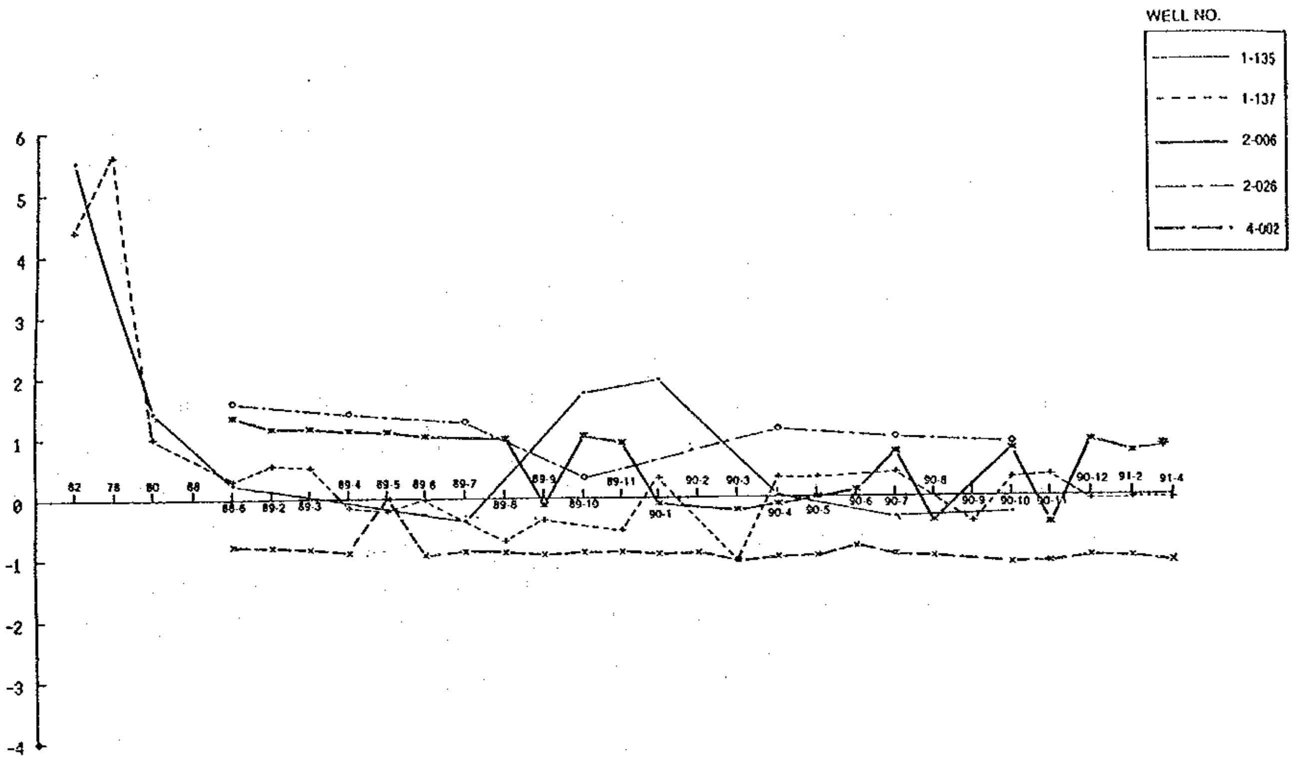
In order to determine the seasonal variation of water level, some monitoring wells were selected in the well field of El-Arish (Table 3-2-1). However, most of the water level records (observed monthly) are assumed to be influenced by noises as shown in Fig. 3-2-4. At present, the seasonal variation of the water level is unknown. However, it is assumed that the regional variation of the water level at well field at El-Arish is insignificant compared to the extent of water level recession caused by the over extraction of groundwater.

Table 3-2-2 (a) **SEASONAL VARIATION OF WATER LEVEL**

	1990												1991	
	1	2	3	4	5	6	7	8	9	10	11	12	2	4
1-048	-0.62			-0.77	-0.57	-1.22	-1.17	-1.49	-1.52	-1.83	-1.37	-0.97	-1.12	-1.26
1-064				-1.18			-2.68			-2.78				
1-075	-2.22			-0.97			-2.32			-2.97				-2.79
1-083	-0.12			-0.15	(9.62)	-0.22	-0.17	-0.37	-0.37	-0.47	-0.40	-0.32	-0.30	-0.25
1-088	-0.91	-0.91			-0.81	-3.66	-1.61		-2.46	-0.96		-0.31	-0.86	-0.90
1-104	-2.82		-2.89	-2.80	-2.72	-2.67	-2.72	-3.12	-3.17	-2.02	-2.02	-2.52	-1.52	-1.42
1-105														
1-107	0.16		0.13	0.13			0.15			0.09				
1-119	0.37			0.47						0.55				-1.60
1-134	0.15			0.85						0.86				
1-135	1.91			0.01			-0.34			-0.29				
1-137	0.31		-1.04	0.32	0.31		0.39		-0.43	0.29	0.34	-0.06	-0.05	-0.06
2-006	-0.11		-0.22	-0.12	0.00	0.10	0.73	-0.40		0.76	-0.45	0.90	0.70	0.81
2-026				1.11			0.98			0.88				
4-002	-0.93	-0.92	-1.04	-0.99	-0.97	-0.83	-0.95	-1.00		-1.10	-1.09	-1.00	-1.02	-1.15
5-002			2.16	1.06	1.86	2.06	2.01		1.88	1.87	1.99	2.21	1.95	1.89
5-005	2.54	2.54	0.05	2.28	2.26	2.27	2.47	2.55	2.16	2.37	2.17	2.56	2.12	2.20
12-024										2.21				
12-032													-0.24	

Table 3-2-2 (b) SEASONAL VARIATION OF WATER LEVEL

Well No.	1962 (10)	1978	1980	1988 (3-5)	1988 (6)	1989 2	1989 3	1989 4	1989 5	1989 6	1989 7	1989 8	1989 9	1989 10	1989 11
1-048	3.20	1.50	0.00			-0.52		-0.76			-1.37			-1.22	-0.82
1-064	-1.40	1.40	0.60		-2.18	-0.63		-1.33			-2.28			-1.03	
1-075	1.80	1.80	0.80			-2.87		-2.53			-2.97			-2.50	
1-083	1.50	0.50	0.70			-0.20	-0.22	-0.25	-0.26	-0.37	-0.67	-0.40	-0.40	-0.45	-0.40
1-088	2.70	2.00	0.30		-2.01		-1.86	-1.35	-1.56	-2.19	-2.11	-2.31	-2.31	-2.31	-0.76
1-104	4.50		1.00		-2.47	-3.07	-3.07	17.88	-3.12	-3.12	-3.57	-3.27	-3.27	-3.29	-3.26
1-105	2.20	1.70	0.50		-0.68			-1.28			-1.92				
1-107	1.90		2.20			0.60								0.15	
1-119	3.10		1.20		-0.53	-0.30		-0.80			-0.70				
1-134	1.10		0.10		0.92	0.85		0.80			0.30			0.51	
1-135	5.50		1.40		0.21						-0.39			1.71	
1-137	4.40	5.60	1.00		0.29	0.53	0.51	-0.16	-0.21	-0.03		-0.71	-0.36		-0.54
2-006					1.33	1.14	1.14	1.10	1.08	1.02		0.98	-0.13	1.01	0.90
2-026					1.57			1.38			1.26			0.33	
4-002					-0.79	-0.80	-0.85	-0.90	0.00	-0.94	-0.88	-0.89	-0.94	-0.89	-0.90
5-002							2.48		2.37	2.38		2.29	2.28	2.28	
5-005					2.56		2.46	2.46	2.45		2.24	2.41	2.37	2.56	2.35
12-024				2.51											
12-032				-0.61											



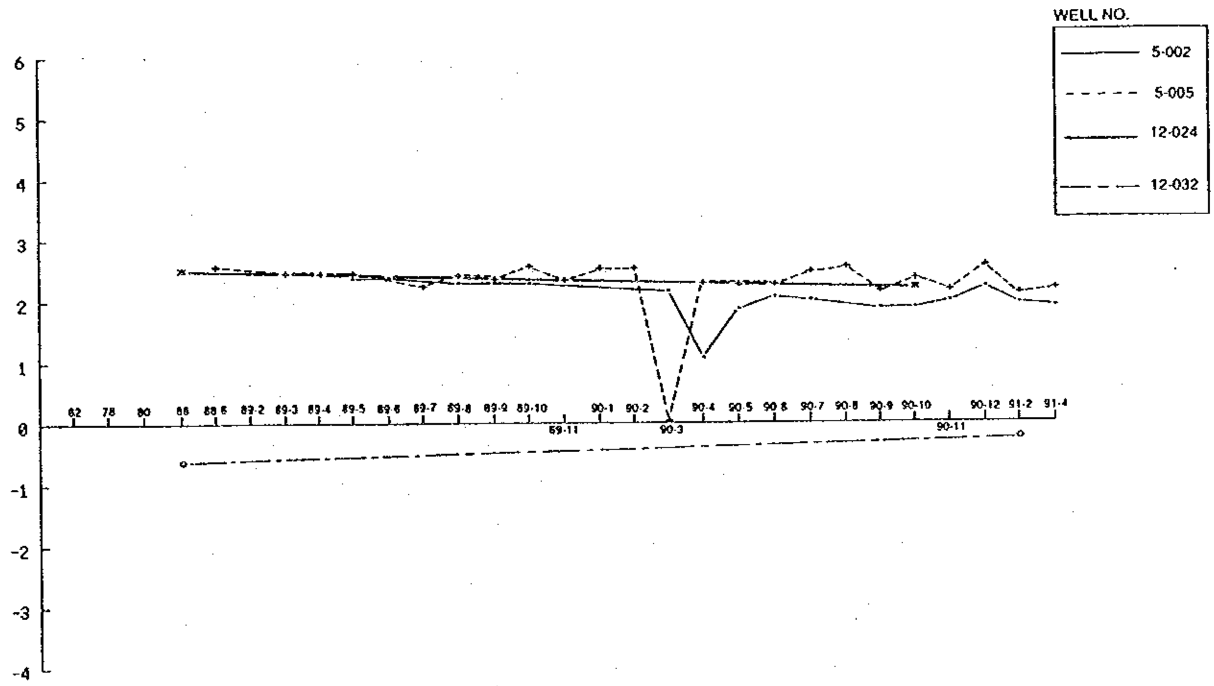


FIG. 3-2-4 SEASONAL VARIATION OF WATER LEVEL

3-2-5 Recession of Water Level

The water level records for the wells in the alluvial plain of the Wadi El-Arish are available for the years 1954, 1962, 1978 and 1981 (GMS).

The 1954 water levels are available at 6 grids. The water level in the sand dunes on the western side of El-Arish was 3 m asl at grids No. 4-3 and 5-2, while it was 2 m asl in grids Nos. 7-2 and 7-3 along the lower part of the Wadi El-Arish. It also indicated 2.2 m asl at grid No. 8-5 and 3.2 m asl at grid No. 9-3 (Fig. 3-2-5).

More data are available for 1962. 15 grids were filled by the water level records. During this period, water levels were recorded at more than 4 m asl at grids Nos. 7-6 and 8-6 in the northern part of the airport. A also, the high water levels were 3.85 m asl at grid No. 9-4, 3 m asl at grid No. 9-5, 2.65 m asl at grid No. 9-4 and 3.35 m asl at grid No. 8-3 at the confluence of the Wadi-Mazaar to the alluvial plain of the Wadi El-Arish (Fig. 3-2-6).

The lowest water level was observed at grid No. 7-4 (-1.4 m asl). The second lowest was at grid No. 7-3 (0.34 m asl) while the adjacent water level was recorded at 2.5 m asl at both of the grids (No. 7-2 and No. 7-5). Distinctively low water level was observed at grid No. 9-2 (1.1 m asl) with a contrast to the surrounding areas. There started already a recession of the water levels : -1.7 m in the grid No. 7-3 and -0.6 m in the grid No. 9-3, in reference to the water levels in 1954.

In 1978, the water levels of wells are available at 12 grids (Fig. 3-2-7). During this period the water levels stood at a narrow range between 1.5 m asl and 1.9 m asl except for grids Nos. 7-6 and 8-6 at 3.0 to 3.8 m asl, respectively, and a particularly high level of 5.6 m asl was found at grid No. 10-4.

The water levels at grids Nos. 7-3 and 7-4 have a recovery compared to 1962 levels. On the other hand, there is a heavy recession in grid No. 8-2 by -3.1 m.

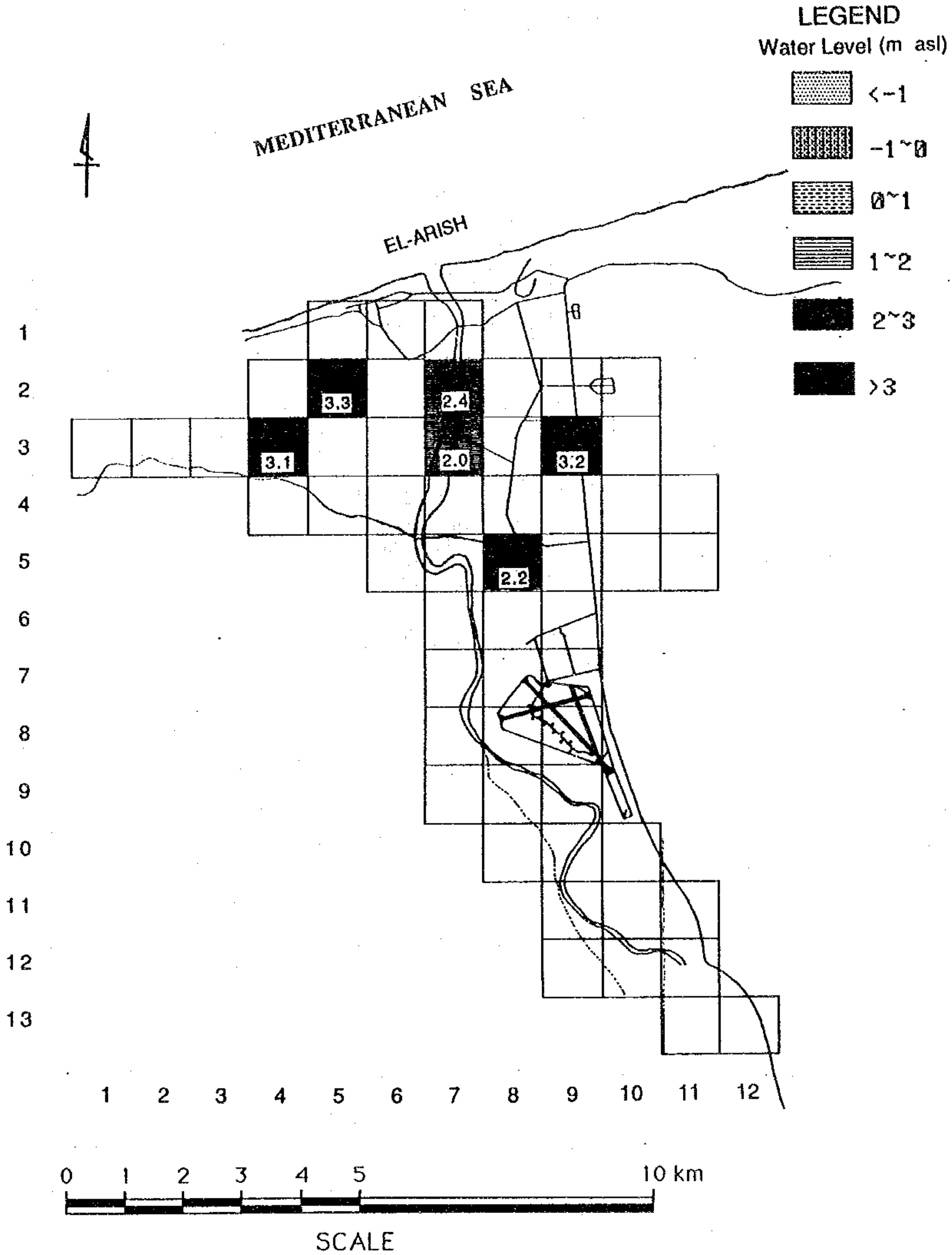


FIG. 3-2-5 AVERAGE WATER LEVEL AT EL - ARISH AREA IN 1954

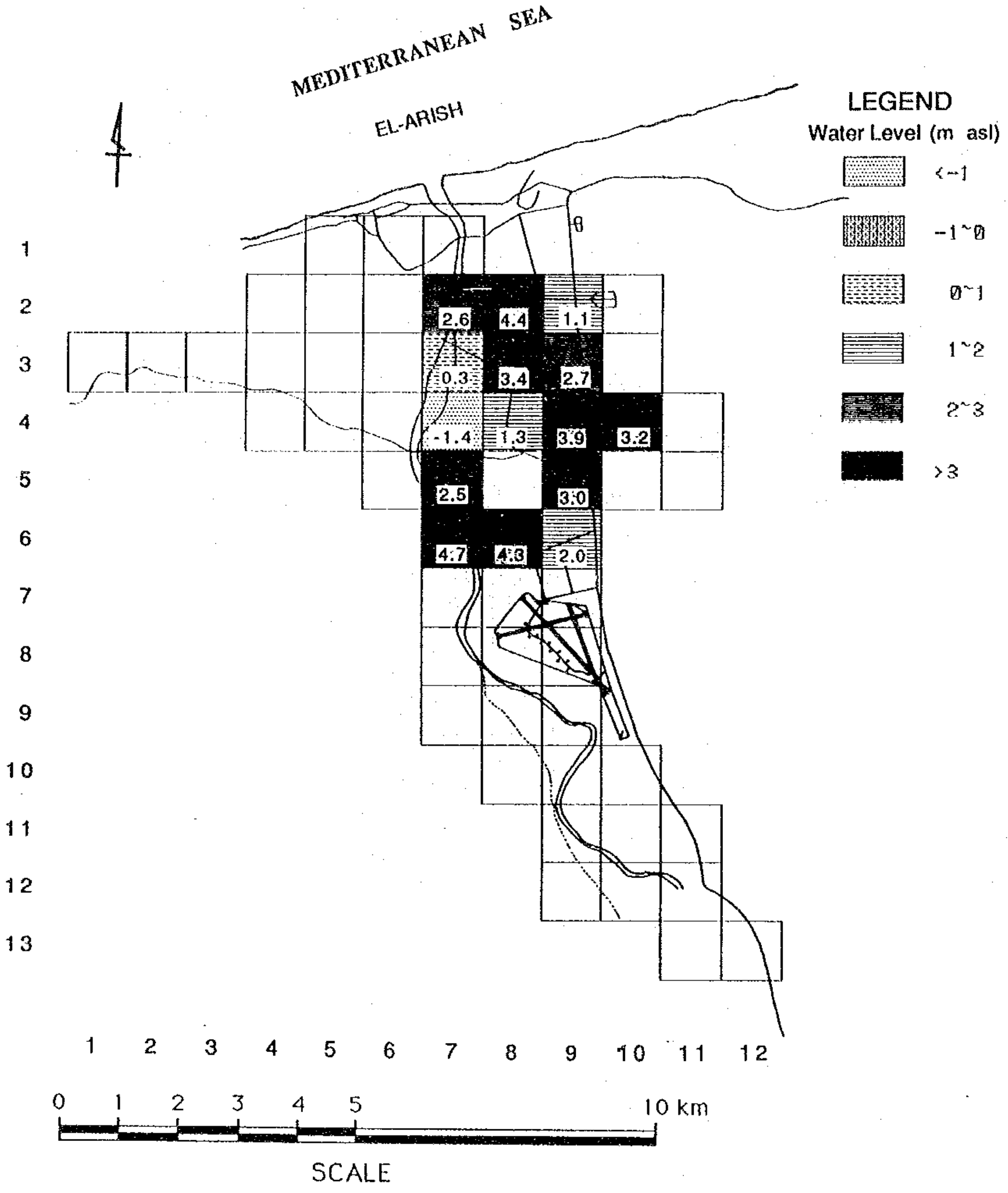


FIG. 3-2-6 AVERAGE WATER LEVEL AT EL - ARISH AREA IN 1962

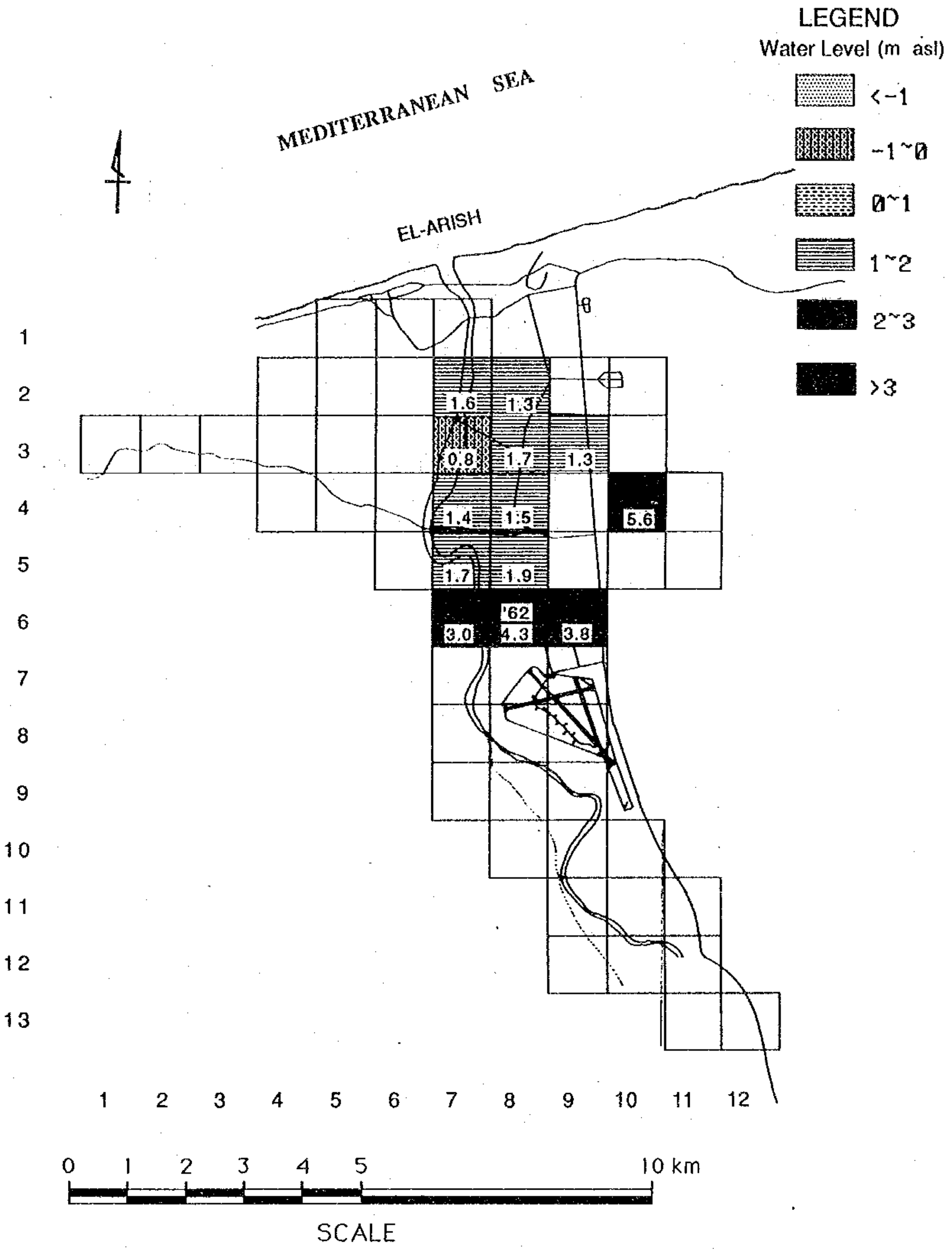


FIG. 3-2-7 AVERAGE WATER LEVEL AT EL - ARISH AREA IN 1978

In 1980, the lowest water level was observed at grid No. 8-3 (0.3 m asl) and the highest was at gird No. 9-6 (1.4 m asl). The water levels in the rest of the grids stay in a range between 0.6 m asl and 1 m asl although the water table seems to hold a very gentle declivity towards northwest (Fig. 3-2-8).

The water level records revealed that the water level of the groundwater in this alluvial plain has been decreasing since the 1950s. The extent of the recession depends on the hydrogeological conditions on the recharge side and the rate of pumping on the discharge side.

The water level records in 1954 fill only five grids. However, the 1962 records cover 15 grids. The total regional pumping rate in 1954 was estimated to be about 1,000 m^3/day and an additional 800 m^3/day was incremented by the end of the 1950s which is an extremely small amount compared to the pumping rate in 1988 (51,000 m^3/day) (Section 8-2-1).

In order to draw a general feature of the recession of water levels in the alluvial plain of Wadi El-Arish the water level distributions in 1962 and 1988 were compared. For this purpose blank grids in 1962 were supplemented by 1954 data (grids Nos. 4-3 and 5-2) (Fig. 3-2-9). Also, blank grids in 1988 were filled by recently available data (Fig. 3-2-1).

Comparing these records, the water level recession is clearly revealed between the years 1962 and 1988 (Fig. 3-2-10). The most significant recession took place in grids Nos. 4-3 and 5-2 in the sand dune in the west of El-Arish town by more than 4 meters.

Since 1962, the water level recession exceeded 3 meters at grids No. 7-5 and 8-5 in the area to the north of the airport. Almost 3 meters of recession took place at grids Nos. 7-2, 7-4, 8-2 and 9-3.

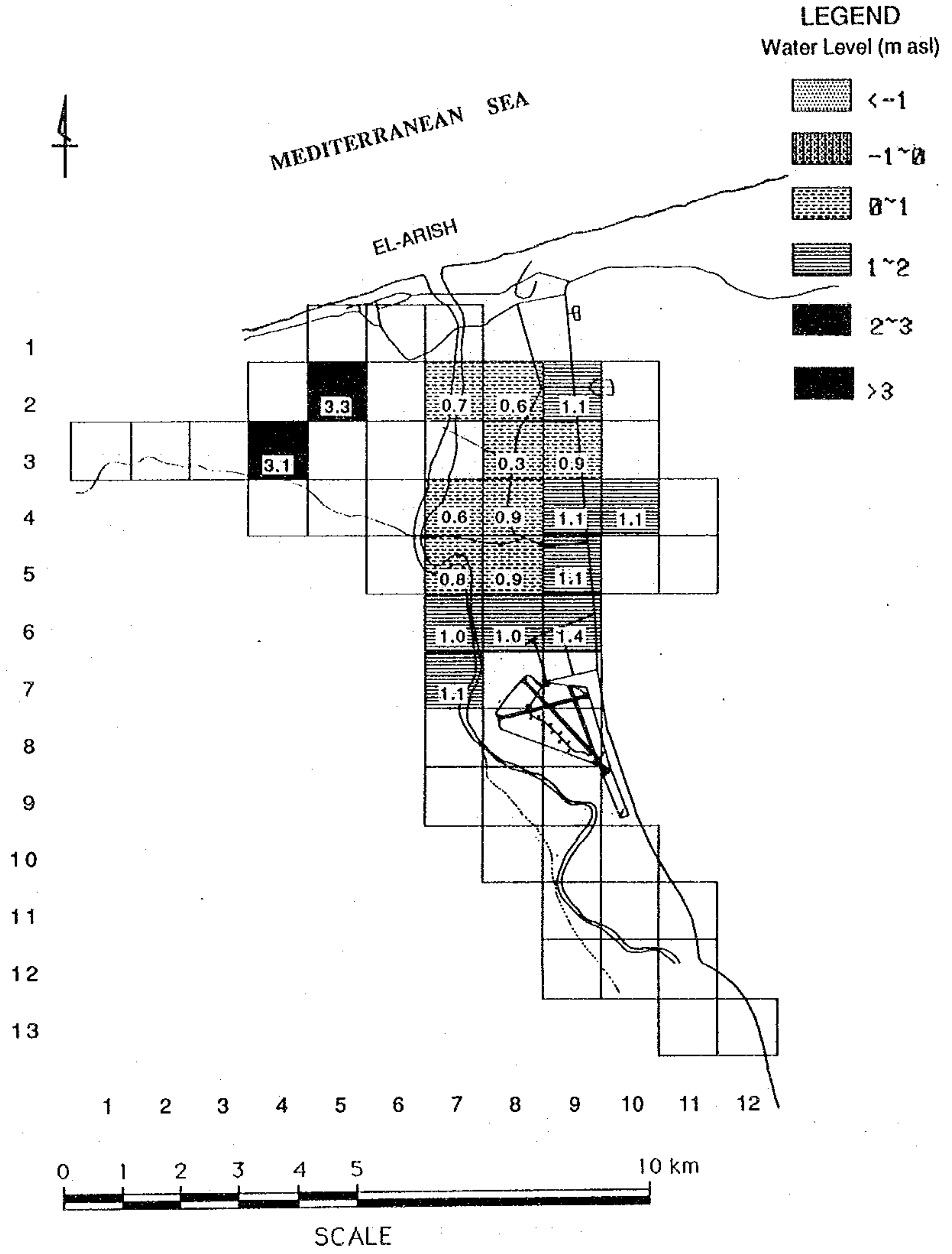


FIG. 3-2-8 AVERAGE WATER LEVEL AT EL - ARISH AREA IN 1980

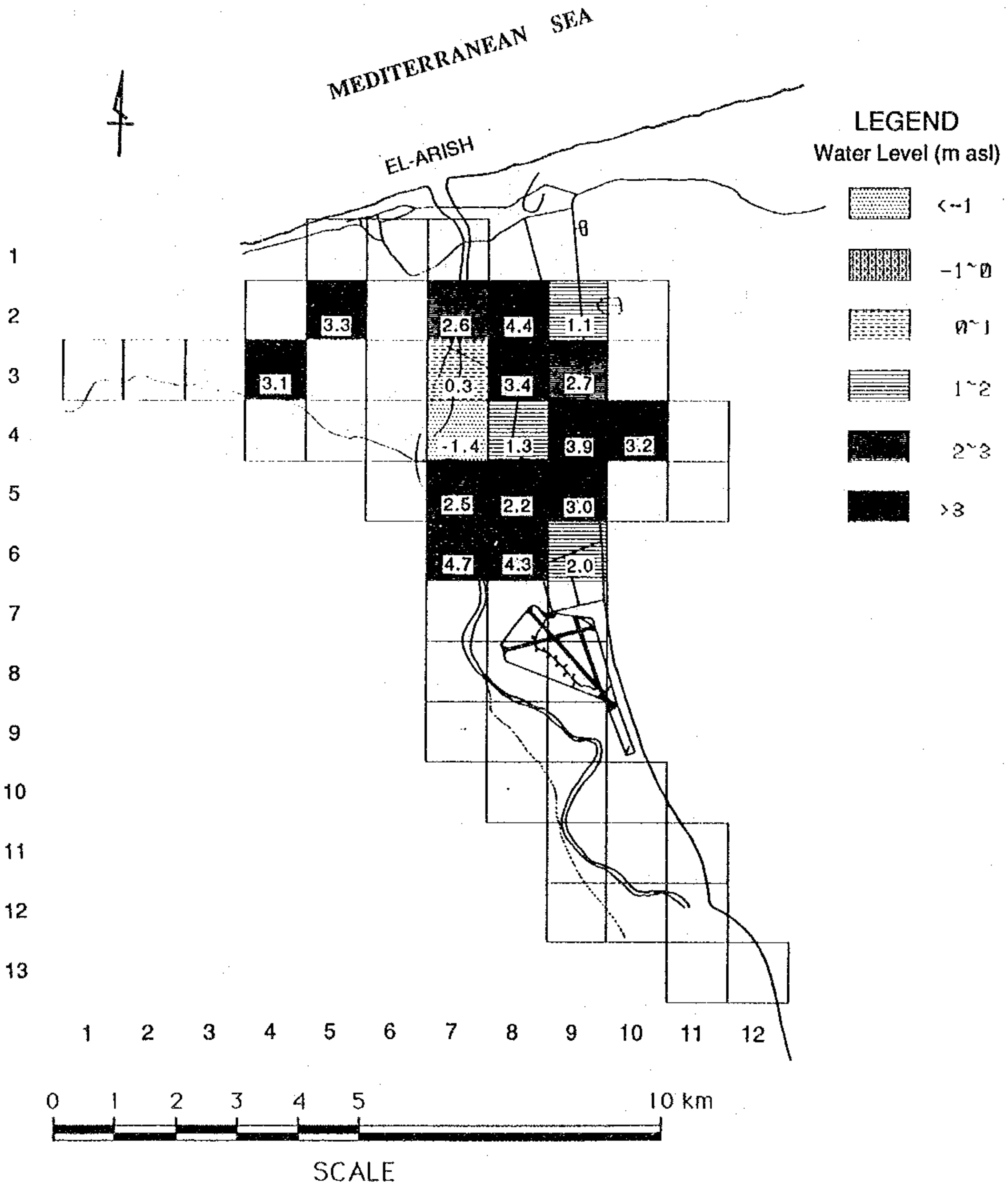


FIG. 3-2-9 SUPPLEMENTED WATER LEVEL AT EL - ARISH AREA IN 1962

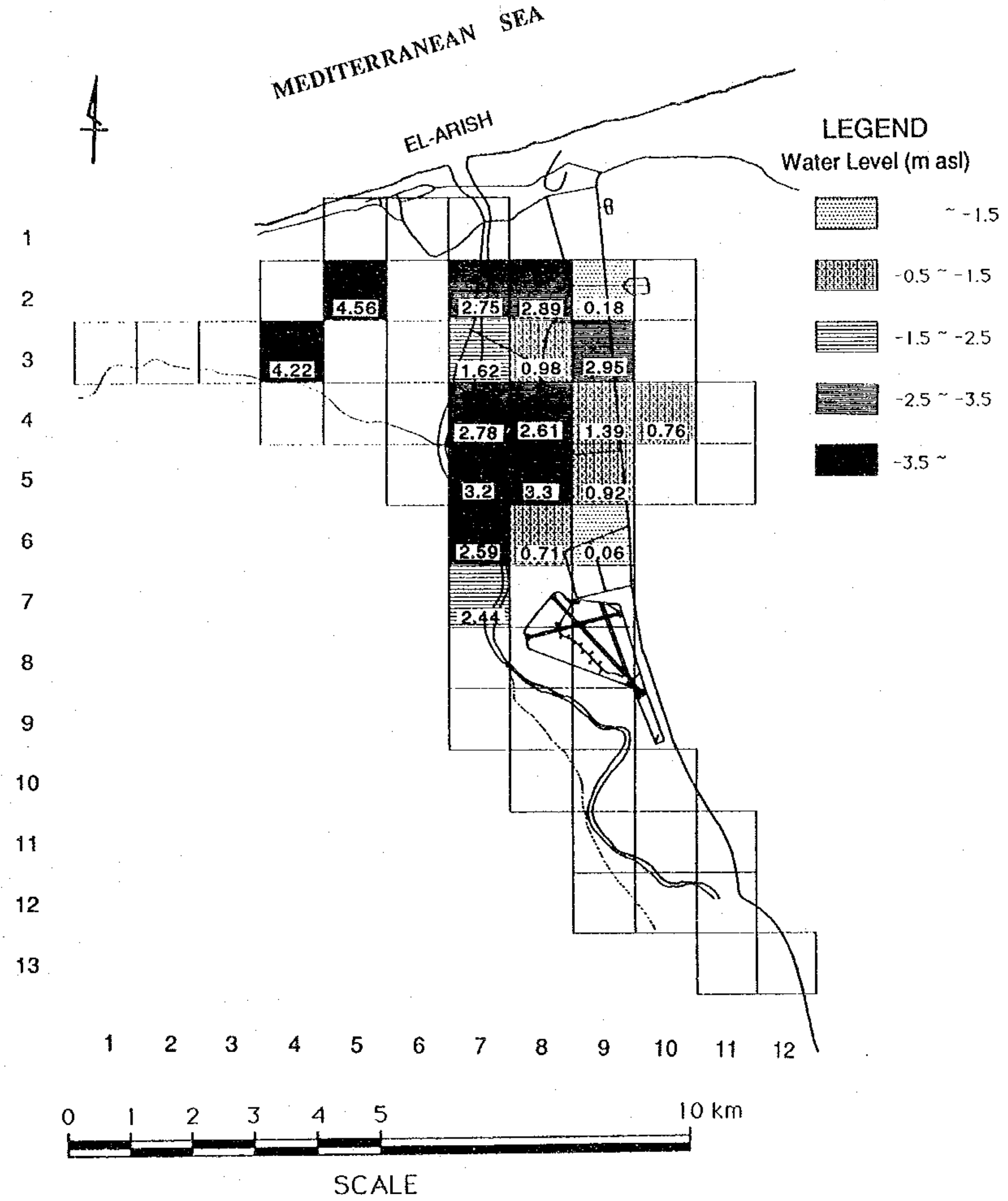


FIG. 3-2-10 RECESSION OF WATER LEVEL AT EL - ARISH '62→'88

3-3 Water Level of Aquifers in Pre-Quaternary

3-3-1 Introduction

Fifty water level data are available from all the wells tapping water from aquifers of the Pre-Quaternary, including the test wells recently drilled by RIWR and the study team. They are summarized below:

Type of Aquifer	Number of Available Data
Tertiary	14
Upper Cretaceous	13
Lower Cretaceous	14
Jurassic	9

The density of the data points in the study area is approximately one datum in each 500 km^2 on an average. However, their distribution is uneven.

In the following part of this section a general feature of the water levels is described by each geological unit to which the aquifer is assigned.

3-3-2 Water Level of Aquifers in Tertiary

There are 14 wells tapping water from the aquifer in the Tertiary of which water levels are defined (Fig. 3-3-1). The geochronological age of aquifer formation was determined at the three wells listed below:

Table 3-3-1 Water Level in Tertiary

Location	Water Level (asl)	Age of Aquifer
No. 45A El-Arish Well No. 10	188 m	Miocene
No. 83 El Mewaleh Well-1	257 m	Eocene
Misr 1	70 m	Miocene

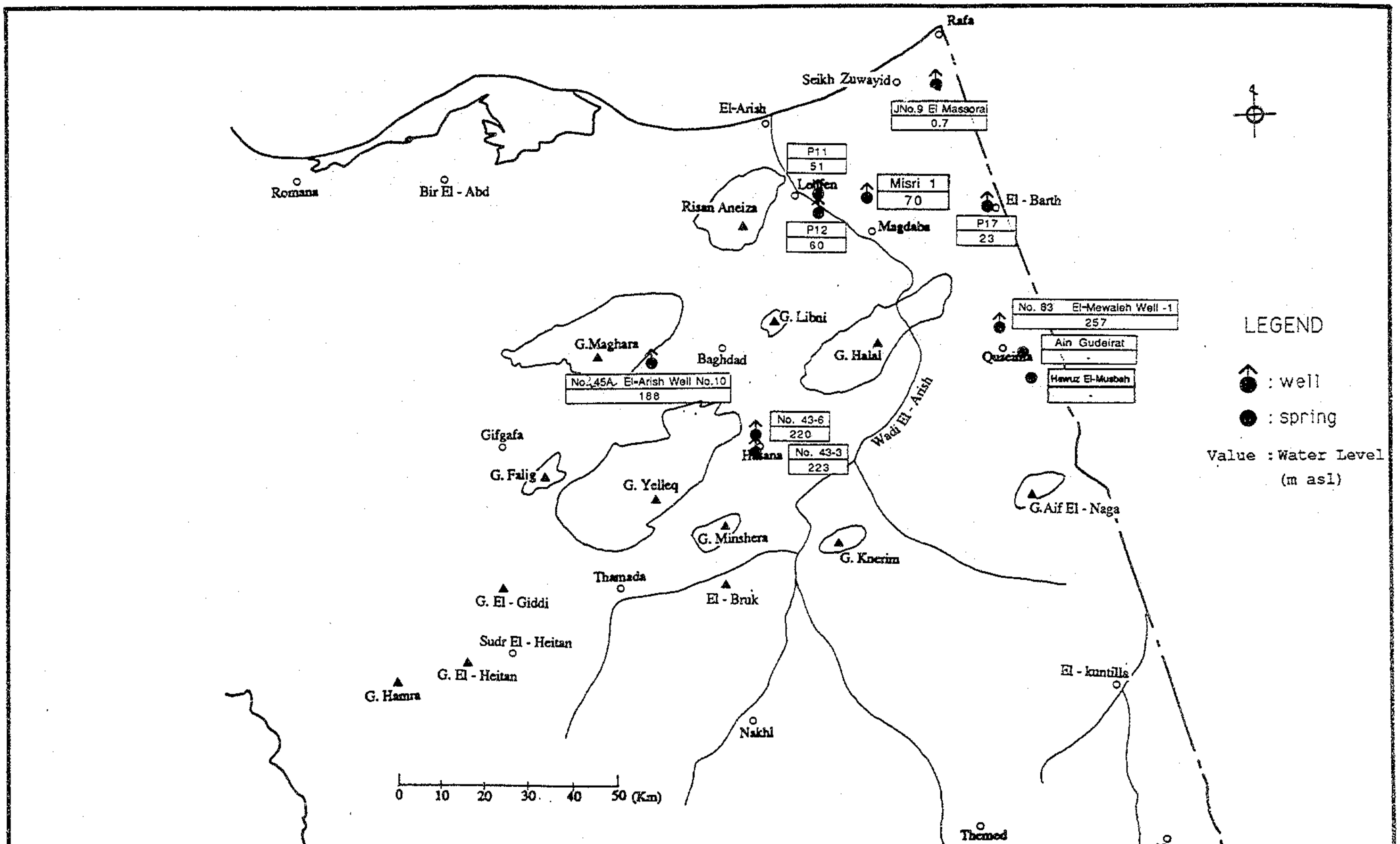


FIG. 3-3-1 WATER LEVEL OF WELLS IN TERTIARY

As shown in Fig. 3-3-1, wells distribute in the following four areas:

1 The area between Magdaba and El Barth,
2 The area in the south of Gebel Maghara,
3 The area around Hasana and
4 The area around Quseima.

Wells indicate the characteristic water level distributions reflecting their own localities:

1) The Area between Magdaba and El-Barth.

This area consists of flat terrain with massive sand dunes on the Tertiary formations in the north and northeast of Gebel Halal. Five wells indicate the water levels of the aquifers in the Tertiary:

Table 3-3-2 Water Level (Magdaba to El-Barth)

Location	Water Level (asl)	Aquifer
P 11	51 m	Eocene
P 12	60	Eocene
Misri-1	70 m	Miocene
P 17	23 m	Eocene

Only at Misri-1, the age and the type of aquifer were confirmed by the composite columns. (Technical Report IV). Determination of these items for the rest of the wells are subject to future confirmation. However, they are cited as supplementaries as the well information of the Tertiary is very scarce.

Aquifers in these area seem to be hydrogeologically independent of each other.

The water level of the well at Magdaba stays at a higher level than those of El-Barth, although Magdaba locates on the lower side of tilting Eocene Strata than El-Barth.

2) The Area in the South of Gebel Maghara

This area is a flat terrain between dome structures of Gebel Maghara and Gebel Yelleq. There is only one well indicating the water level of the aquifer of the Tertiary;

Table 3-3-3 Water Level (South of Gebel Maghara)

Location	Water Level (asl)	Aquifer
No. 45 El-Arish Well No. 10	188 m	Eocene

Referring to the composite column, the lithology of this aquifer is limestone. (Technical Report IV)

3) The Area around Hasana

There are two wells tapping water from aquifers of the Tertiary:

Table 3-3-4 Water Level (Hasana)

Location	Water Level (asl)	Aquifer
No. 43-6	220 m	Miocene
No. 43-3 Turkish Well	223 m	Eocene

These data are cited from SDS. Lithological information was not available. Both water levels stay at similar elevations.

4) The Area around Quseima

There are three wells indicating the water levels in this area:

Table 3-3-5 Water Level (Quseima)

Location of well	Water level (asl)	Aquifer
No. 83 El-Mewaleh	257 m	Eocene limestone
No. 52-23 Ain Gudeirat	spring	Eocene limestone
No. 52-24 Hawuz El-Musbah	spring	Eocene limestone

The composite stratigraphic column of well No. 83 is a standard profile of this study (Technical Report IV). The spring at Ain Gudeirat issues water at about 1,500 m^3/day. The age of the aquifers at No. 5 2-23 and No. 52-24 was confirmed to be the Eocene through field investigation.

3-3-3 Water Level of Aquifers in Upper Cretaceous

The following 13 wells provided the water levels of the aquifers in the Upper Cretaceous:

Table 3-3-6 Water Level in Upper Cretaceous

Location	Water level (asl)	Aquifer
No. 70 Wadi El Meleiz	298 m	Senonian
No. 49 El-Arish Well No. 14	107 m	Senonian
No. 63A Gebel Libni No. 1	58 m	Senonian
No. 63C Libni Well No. 3	58 m	Senonian
No. 50 El-Arish Well No. 15	39 m	Turonian
Sheira Well-2	679 m	Turonian
P1 Gifgara	79 m	Cenomanian
No. 57A El-Arish Well No. 19	169 m	Cenomanian
P4 El-Hasana	63 m	Cenomanian
P16 El-Amro	175 m	Cenomanian
J No. 17 El-Bruk-2	223 m	Cenomanian
Bir Hasana	142 m	undifferentiated

Location of these wells and their water levels are shown in Fig. 3-3-2. The Senonian, the Turonian and the Cenomanian strata are widely distributing in the study area. Although the wells listed above are scattered over a wide area, it is significant that the water levels vary over a wide range, between 40 m and 680 m asl.

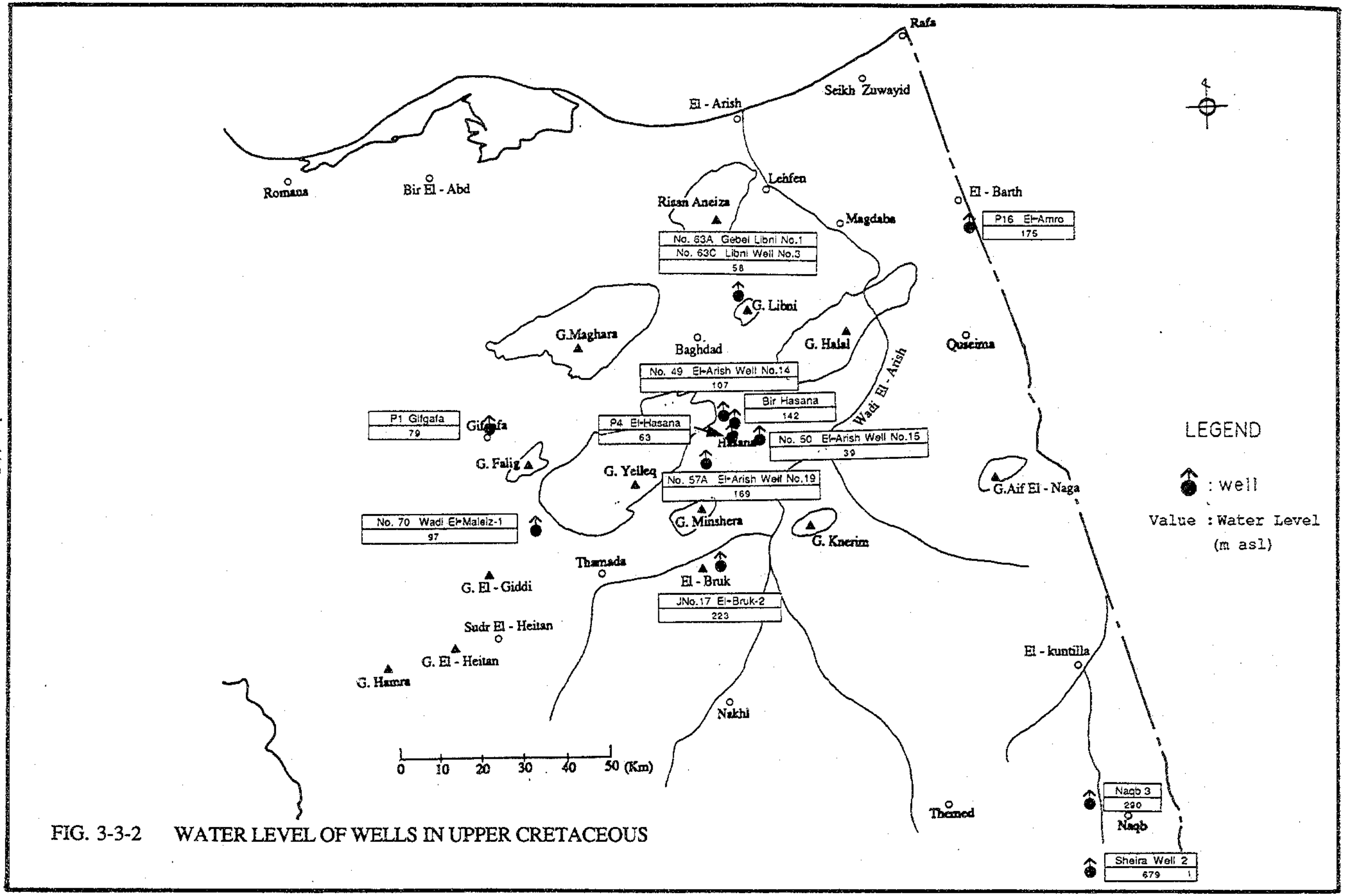


FIG. 3-3-2 WATER LEVEL OF WELLS IN UPPER CRETACEOUS

There are three wells whose aquifer is in the Senonian. The following list is presented in the order of well location from the south to the north;

Table 3-3-7 Water Level in Senonian

Well Number	Water Level
No. 70 Wadi Meleiz	198 m asl
No. 49 Arish Well No. 14	107 m asl
No. 63 A and C Libni	58 m asl

It seems that the water level of the aquifer of the Senonian decreases towards the north.

There are three wells whose aquifer is in the Turonian. The distribution of these wells is limited to the southern corner of the study area. Well Sheira No. 2 is on the southern side of the Ragabet El-Naam fault while well Naqb No. 3 is just on the northern side of the fault. The water level of Sheira No. 2 is at 679 m asl; Naqb No. 3 is at 290 m asl. This difference is most probably caused by the the fault. The water level at Sheira may represent the water level of the aquifer of the Turonian on the southern side of the fault, and that at Naqb on the northern side of the fault. The influence of the fault to the hydrogeology in the Turonian formation is significant.

Since the number and location of the wells tapping water from the aquifers of the Turonian are scarce, further data collection of these aquifers should be necessary in future. General hydrogeological features should be determined for these aquifers.

There are fire wells having screens installed at the level of the aquifer of the Cenomanian. The number is only five, but their distribution covers the entire study area.

The highest water level was observed at well J No. 17 at El-Bruk (223 m asl), but at Hasana, to the north of El-Bruk, the water level decreases to 63 m asl. This may indicate the piezometric potential surface declining toward the north in the central part of the North

Sinai. The water level at well No. P16 of El-Amro shows a rather high level (175 m asl) which may envisage the piezometric potential surface declining towards the west from this point.

Assuming a piezometric potential surface of the aquifer of the Cenomanian, a contour map was drawn (Fig. 3-3-3). In order to confirm the water level distribution of the aquifer of the Cenomanian, further data collection is necessary, especially in the area in the east of Hasana, Quseima and El-Barth.

The water level at well No. P4 of El-Hasana (63 m asl) is much lower than that of the well No. 57A El-Arish No. 19 (169 m asl). This difference within a short distance is probably caused by the local geological structure.

3-3-4 Water Level of Aquifers in the Lower Cretaceous

The following 13 wells indicate the water levels of aquifers in the Lower Cretaceous:

Table 3-3-8 Water Level in Lower Cretaceous

Location	Water Level (asl)	Aquifer
Darag No. 1	263 m	Sandstone
Nakhl-1	269 m	Sandstone
Nakhl-2	260 m	Sandstone
Sheira-1	420 m	Sandstone
Abu Ghazala	101 m	Sandstone
Sadr El-Heitan	205 m	Sandstone
P18 Egyptian Army Hasana	160 m	Sandstone
Talet El-Badan	135 m	Sandstone
El-Halal Israeli; Well	24 m	Sandstone
J No. 12 Minshera	198 m	Sandstone
J NO. 13 Falig	67 m	Sandstone
J No. 16 El-Bruk-1	203 m	Sandstone
J No. 19 Arif El-Naga	159 m	Sandstone

The geologic age of the sandstone is confirmed at all wells except at the El-Halal Israeli Well. The locations of these wells and their water levels are shown in Fig. 3-3-3. The water levels at Darag No. 1, Nakhl-1 and Nakhl-2 were incorrectly cited in previous publications, but were revised as shown above.

The difference between the two water levels at Sheira Well-1 and Nakhl-1 is significant and may be attributed to the fact that the Ragabet El-Naam fault has influence on the local hydrogeological conditions. (David A Jenkins, 1989, and Chapter 5 and 6 of this report)

As shown in Fig. 3-3-3, the water level of the aquifer in the Lower Cretaceous has a very gentle gradient (approximately 1/300) from

Nakhl toward Hasana. The major groundwater body in the area may flow along this gradient.

3-3-5 Water Level of Aquifers in Jurassic

There are nine wells holding water levels in the aquifers of the Jurassic as listed below:

Table 3-3-9 Water Level of Aquifers in Jurassic

Location	Water Level (asl)
No. 5 Coal Mine	305 m
No. 6 Coal Mine	301 m
No. 46 El-Arish Well-11	210 m
No. 47 B El-Arish Well-12	151 m
No. 52A El-Arish Well-17A	147 m
No. 53A El-Arish Well-18	232 m
No. 54A El-Arish Well-4	167 m
No. 55 El-Masajid Well-4	162 m
No. WX2 Coal Mine	157 m

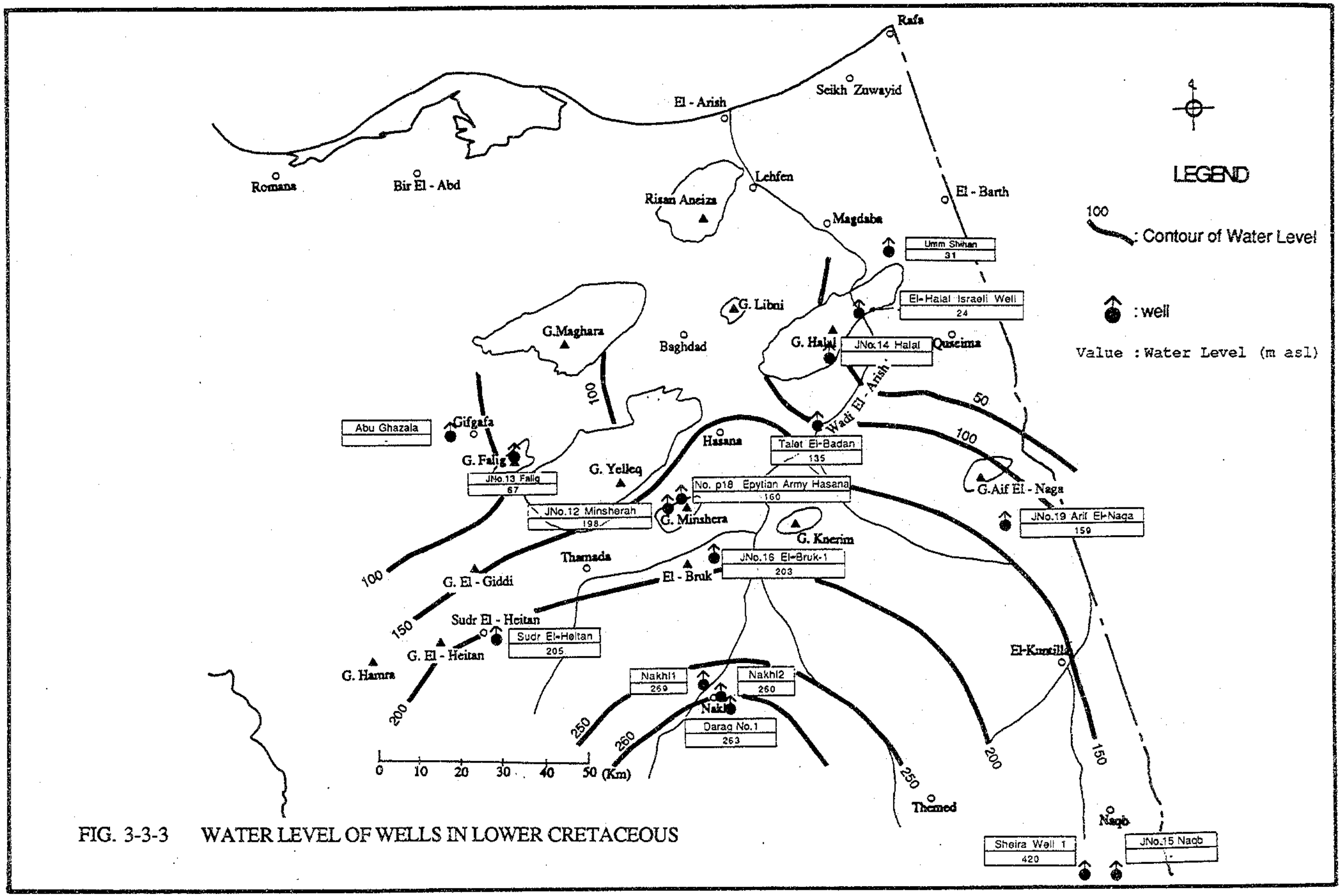


FIG. 3-3-3 WATER LEVEL OF WELLS IN LOWER CRETACEOUS

Locations of these wells and their water levels are shown in Fig. 3-3-4. These wells are classified into four groups according to their distribution:

1) Wells in the northwestern part of Gebel Maghara

These are wells distributing on the northwestern fringe of the dome structure of Gebel Maghara: Nos. 47B, 55, 52A, WX2 and 54A. The water levels of these wells vary within a range between 147 m and 176 m asl.

2) Wells around the coal mine.

These are wells drilled in the area around the coal mine in the central dome of Gebel Maghara (wells Nos. 5 and 6). The water levels of these wells stay at about 300 m asl.

3) Wells in the northeastern end of Gebel Maghara.

These are the wells drilled at the northeastern end of the dome structure of Gebel Maghara (Well No. 53). There is a fault between this area and the area where the wells in group 1) and 2) locate. The water level is recorded at 232 m asl.

4) A well in the west of the coal mine

This is well No. 46 that has a water level of 210 m asl.

Each aquifer in the area classified above is assumed to be independent of each other from a hydrogeological point of view.

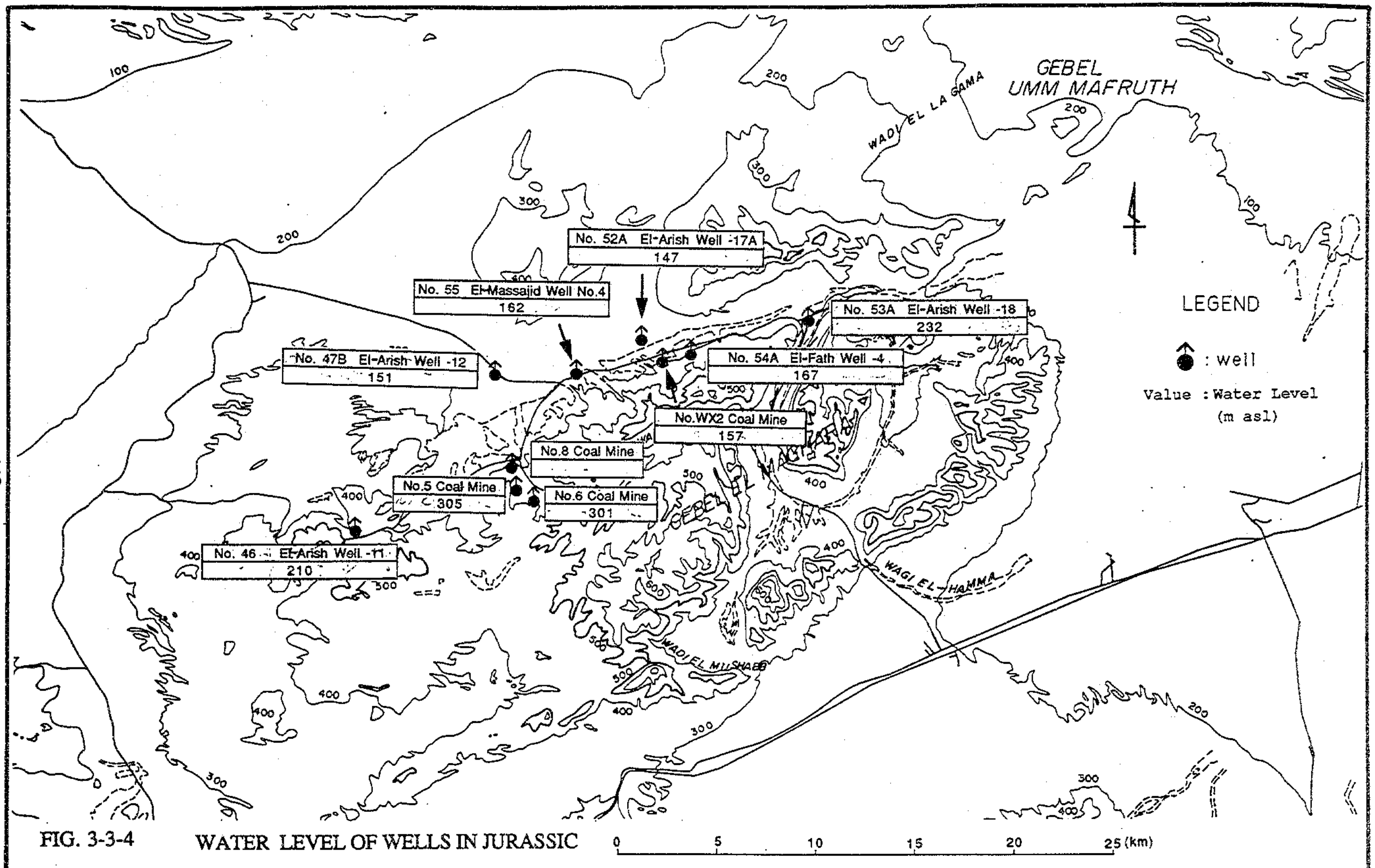


FIG. 3-3-4 WATER LEVEL OF WELLS IN JURASSIC

4. WATER QUALITY

4 WATER QUALITY

4-1 Introduction

The available data of water quality have been compiled by SDS in 1985 for the entire Sinai area and by GMS in 1988 for the coastal plain from El-Arish to Rafah. These are the major data sources together with additional data obtained by the study team through cooperation with RIWR during the study.

Information obtained for the water quality of aquifers of Pre-Quaternary is derived from various sources: oil exploratory wells, test wells and piezometers and some production wells. Accordingly, they are expressed in different manners. Some data consist of concentration of major ions and most of them are expressed as total dissolved solids (TDS). All available data are interpreted to classify the genesis and type of water from each different type of aquifer.

4-2 Water Quality of Aquifers in Quaternary

4-2-1 Introduction

There are only a few data available for the pre 1950s period due to the scarcity of wells. Later on, during the 1980s, a large number of wells were constructed. In 1988, approximately 130 water samples were analyzed by GMS of RIWR.

During the study, 24 water quality data were obtained from test wells drilled by RIWR and the study team. Additional data, approximately 350, were collected from the monitoring wells in El-Arish and Sheikh Zuwayid - Rafah areas and the well survey in Bir El-Abd - Romana.

In general, the high TDS value of the groundwater is a prevailing problem in this area. TDS values of the groundwater vary over a wide range depending on the location. Sometimes remarkable changes happen even over short distances.

To draw a general feature of the TDS distribution, TDS values of available data are plotted on a map and screened by a one square kilometer mesh. All TDS values within each mesh are averaged to represent an average state of TDS values of each mesh.

Since different types of aquifers are assumed to exist, stiff diagrams of major ion composition were constructed to figure out the chemical characteristics of each water sample.

In the first three sections, the present features of the water quality of the major well fields (El-Arish alluvial plain, the coastal plain from Sheikh Zuwayid - Rafah and the coastal sand dunes in Bir El-Abd - Romana area) were described. The last section focussed on the changes in the recorded water quality in El-Arish alluvial plain since 1954.

4-2-2 El-Arish Area

The average TDS value in each mesh in 1988 are shown in Fig. 4-2-1. In general, the values of TDS increase from Lehfan to El-Arish. The highest value appears on the eastern side of El-Arish town while relatively lower values prevail on the western side. The TDS value of wells in the southern part of the airport is the lowest group in this area.

As pointed out previously (Paver and Jordan, 1956, Geofizika Co., 1963, Dames and Moore, 1985, and GWMS, 1988), the TDS value of groundwater in the western area of Wadi El-Arish ranges between 1,500 ppm and 2,500 ppm which is appreciably lower than those in the eastern area of the wadi ranging between 2,200 ppm and 4,500 ppm (Fig. 4-2-1). For example, the TDS values range between 1,500 ppm and 2,300 ppm in the grids Nos. 5-1, 5-3, and 6-4 and exceeds 2,000 ppm at grids Nos. 4-3, 5-2 and 6-3.

Stiff diagrams were constructed to compare the components of major ions of the groundwater (as shown in Portfolio sheet No. 2) which indicate equivalent per million of each ion.

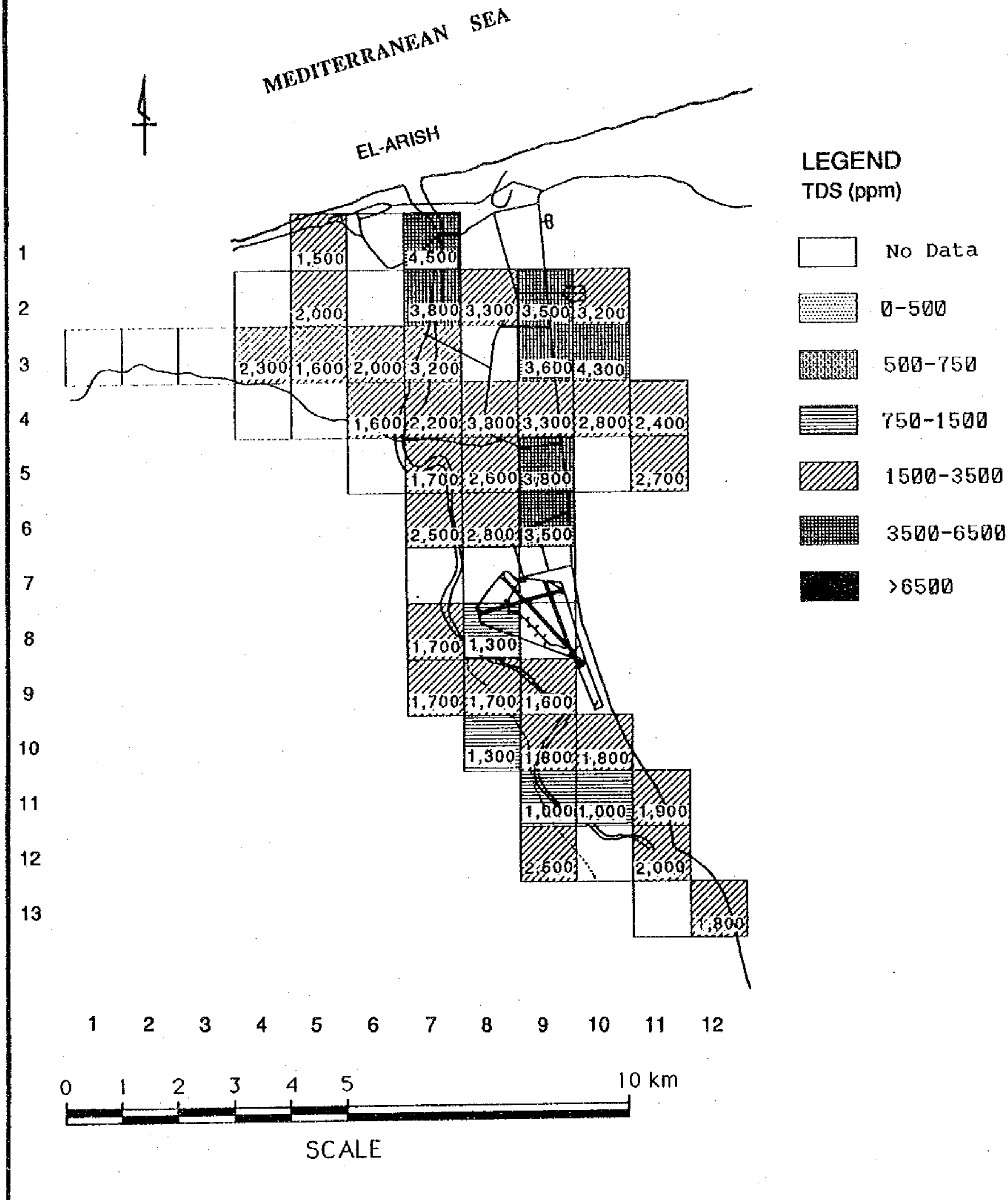


FIG. 4-2-1 TDS DISTRIBUTION AT EL - ARISH AREA IN 1988

The wells in the grids on the western side of El-Arish town are listed in Table 4-2-1.

Table 4-2-1 Well with Relatively Low TDS on the Western side of El-Arish

Grid number	Well number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
4-3	1-9	2,000	0.44	0.97
4-3	1-13	2,600		
5-2	1-26	1,500		
5-2	1-18	2,000		
5-3	1-17	3,000		
5-3	1-19	2,000		
5-3	1-21	900		
5-3	1-22	1,100		
6-3	1-27	1,200	0.71	0.83
6-4	1-29	1,100	0.66	0.68
6-3	1-31	2,800	0.83	0.77
6-4	1-35	2,200	0.76	0.64
6-3	1-38	2,100	0.79	0.85
6-4	1-39	1,400	0.58	0.75
6-3	1-41	2,100		
6-3	1-42	900		
6-3	1-43	2,800	0.72	0.64
6-3	1-45	2,300	0.81	0.79
6-4	1-29	1,700	0.66	0.68
6-4	1-44	1,200		
Average			0.64	0.75

In grid No. 5-1 there is only one well (No. 1-26, with a TDS value of 1,500 ppm). While the TDS of grids No. 4-3, 5-2 and 6-3 exceed 2,000 ppm. Although the TDS in grid No. 5-3 is relatively low (1,600 ppm) this is an average of the TDS of wells in the grid that range between 900 ppm (well No. 1-21) and 3,000 ppm (well No. 1-17).

Grid No. 6-4 indicates a relatively low TDS value of 1,600 ppm. However, 12 wells listed in the above Table 4-2-1 show TDS values of more than 2,000 ppm. The minimum TDS value in the table is 900 ppm.

The high salinity is a prevailing problem in the area and its origin has been a major concern. There are two possibile causes that influence the high salinity of the groundwater: contamination of the sea water and the old deep-born groundwater up coning.

To examine the possibility of sea water intrusion, the ratio of $(Na^{+}+K^{+})/(Ca^{++}+Mg^{++})$ in equilibrium (R_{equ}) is calculated. In general, the alkali metals are more stable than alkaline earth metals and the concentration of alkali metal in the sea water is remarkably high. When the water is influenced by the sea water, R_{equ} becomes very close to 3.96 of the sea water R_{equ}. For the same purpose, Na/Cl ratio in equilibrium was also calculated. Sodium and chlorine are predominating ions in sea water. Both of them are very stable in water. The solubility product of sodium salts are higher than that of other major salt component cations in the natural water, so that when the water is contaminated by the sea water this ratio becomes similar to the ratio of the sea water (1.09).

The R_{equ} and Na/Cl ratio are shown in Table 4-2-1. It is clearly shown that the R_{equ} of all wells is much less than 3.96 and Na/Cl varies between 0.64 and 0.85. It is deduced that a heavy influence of the sea water salinity on the groundwater is unlikely. The concentration of alkali metals in the groundwater is much less than that of the sea water although the Na/Cl in the groundwater is close to that of the sea water ion composition ratio.

As mentioned in Section 6-3, the isotope analysis presented a negative and deterministic basis against the simple seawater intrusion model for the salinization of the groundwater in El-Arish. Fig. 6-3-3 shows a trend between electric conductivity (EC.) and the oxygen isotope ratio, in which any increasing tendencies of oxygen-18 level are observed with the increase of EC. level.
As widely known, seawater is not only the salinity hazard source but is the source of heavy oxygen isotope, i.e., oxygen-18.

The oxygen-18 level of seawater is high at around zero per mille (a standard level), and other natural waters usually hold negative levels to seawater. In other words, other natural waters are usually depleted in heavy oxygen to various extents compared to sea water.

In El-Arish the local sea water was measured at +1.54 permille (Table 6-3-1) in oxygen-18, so an increased oxygen-18 levels were expected for the salinized groundwater as far as sea water intrusion was regarded as the cause of groundwater salinization.

In the figure, the increase in E.C., reaching 10mS/cm (equivalent TDS salinity of ca. 8,000 ppm) does not seem to cause any significant increase in the oxygen-18 content which should result in due course in the case of sea water intrusion. Instead, the oxygen-18 content stays at ca. -4.0 permille level or less without shifting to the +1.54 permille level of the local sea water.

Well No. 1-77 (NSN-13) is one of the extremely salinized wells (E.C., ca. 10 mS/cm) in the locality. Its groundwater holds a low oxygen-18 content of -4.78 permille, which belongs even to the lower side of the isotope level in the locality.

Consequently, they present salinization hazard in El-Arish may be caused by the up-welling of deep-borne and highly mineralized old groundwater in the areas inflicted by over-pumpage.

There would be spatial geochemical conditions to determine the chemical components of the groundwater in the area. It should be noted that the groundwater in the well field on the western side of El-Arish town is assumed to be contaminated by high salinity water although it is very unlikely that there is sea water contamination.

On the other hand, the TDS values of the well field that extends about 13 km from the river mouth of the Wadi El-Arish to the south and ranges from 3 to 4 km, in width varies over a wide range (1,000 ppm to 4,500 ppm). The high values of TDS distribute on the northern area while the low values were observed in the southern area.

The wells with a high TDS value on the eastern side of El-Arish town along the Wadi are listed below:

Table 4-2-2 Well with High TDS on the Eastern Side of El-Arish

Grid Number	Well Number	TDS (ppm)	$\frac{Na^{+}+K}{Ca^{++}+Mg^{++}}$	Na/Cl
7-1	1-56	2,600	0.79	0.97
7-1	1-77	6,500	0.94	0.61
7-2	1-51	3,300	0.97	0.80
7-2	1-70	3,000	0.78	0.85
7-2	1-73	5,400	0.68	0.51
7-2	1-74	4,100	0.71	0.71
7-2	1-76	3,400	0.72	0.60
7-2	1-83	3,500	1.10	0.82
7-3	1-50	3,300		
7-3	1-55	2,500	0.57	0.55
7-3	1-62	3,200		
7-3	1-79	4,200	1.66	0.92
7-3	1-81	2,600		
7-4	1-53	1,900	0.76	0.84
7-4	1-64	2,600	0.67	0.65
7-5	1-47	1,700	0.81	0.89
7-6	1-78	2,200	1.39	0.92
7-6	1-84	2,700	1.13	0.82
Average			0.91	0.76

As shown in Fig. 4-2-1, the highest TDS was observed at the northern end (grid No. 7-1) and decreases toward the south, reaching its lowest value at grid No. 7-5 (1,725 ppm). Then, after it increases to 2,500 ppm at grid No. 7-6 and a relatively low TDS values: 1,700-1,800 ppm, encounter in the further south on the western side of the airport.

There are some wells in grids No. 7-1, 2 and 3 having very high TDS values ranging between 4,000 and 6,500 ppm (wells No. 1-77, 1-73, 1-74 and 1-79). The TDS values of wells in grids No. 7-4 and 7-5 range between 1,700 and 2,600 ppm, a rather moderate magnitude in the area.

R_{equ} ranges between 0.5 and 1.66 which is much less than that of the sea water (3.96). However, there are some relatively high values observed at grids No. 7-2 (well No. 1-83), 7-3 (well No. 1-79) and 7-6 (well No. 1-78 and 1-84). The high values of R_{equ} of some wells in these grids may suggest that there is a greater influence of the high salinity groundwater on the aquifers in this area compared to those in the well field on the western side of El-Arish town.

The range of TDS value (1,700-6,500 ppm) is significant on the eastern side of El-Arish along the lower river course. However, in the well field extending further east from El-Arish town, rather high values of TDS were observed. However, the range of TDS variation is narrow (2,200 -5,100 ppm) (Table 4-2-3).

Table 4-2-3 TDS of Wells in Eastern Part of Alluvial Plain of the Wadi El-Arish

Grid No.	Well Number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
8-2	1-85	3,100	0.92	0.71
8-2	1-104	3,172	0.90	0.79
8-2	1-110	3,700	1.56	0.81
8-3	1-98	3,500	0.99	0.75
8-4	1-88	2,600	0.85	0.76
8-4	1-93	3,600	1.26	0.92
8-4	1-109	4,000	1.09	0.76
8-4	1-97	3,200	0.90	0.71
8-5	1-99	3,300	1.31	0.80
8-5	1-112	2,400	1.93	0.70
8-5	1-114	2,100		
8-6	1-100	2,400	0.71	0.81
8-6	1-107	3,100	1.00	0.64
9-2	1-130	3,400	1.60	0.80
9-2	1-134	3,700	1.57	0.82
9-3	1-122	4,500	1.31	0.75
9-3	1-124	2,300	0.86	0.83
9-3	1-128	3,800	1.52	0.78
9-4	1-123	2,900	1.12	0.63
9-4	1-129	3,800	1.31	0.72
9-5	1-120	3,800	1.08	0.66
9-5	1-127	4,900	1.13	0.64
9-5	1-135	2,900	1.33	0.78
9-6	1-115	3,700	1.65	0.74
9-6	1-125	2,700	1.17	0.71
9-6	1-131	2,700	0.84	0.56
9-6	1-136	5,100	1.46	0.84
10-2	1-139	3,200	1.09	0.73
10-3	1-140	4,300	1.39	0.70
10-4	1-137	2,800	1.22	0.85
10-4	1-141	2,900	1.09	0.85
11-4	4-2	2,200		
11-4	4-3	2,600		
11-5	4-4	2,700		
Average			1.20	0.75

There are 33 wells in 15 grids and 20 of them indicate TDS values of more than 3,000 ppm. More than 60 percent of the wells yield water of more than 3,000 ppm. Among them, five wells exceed 4,000 ppm in TDS.

The highest TDS group was observed at grids No. 9-2, 3, 5 and 6. and No. 10-3. The high salinity wells are Nos. 1-109, 1-122, 1-127, 1-136 and 1-140.

The lowest TDS in this area was observed at grids No. 9-4, 10-4 and 11-4 along the lower stretch of the Wadi Maazar where the TDS values range between 2,500 ppm and 2,800 ppm. The second lowest group of TDSs was found in grids Nos. 8-5 and 8-6.

The ratio of Na/Cl distributes in a similar range (0.62-0.92) to that on the western side of El-Arish town (0.44-0.83). However, the number of wells which indicate a Na/Cl ratio of more than 0.7 is less than 60% of the total number of wells on the western side and along the lower part of the Wadi El-Arish. In the alluvial plain, the same ratio of more than 0.7 occupies more than 80% of wells, although the occurrence of the Na/Cl ratio of more than 8.4 is much less than that of the former.

R_{equ} varies in a range between 0.85 and 1.60 (Table 4-2-3) in the eastern side of El-Arish, while values range between 0.44 and 0.83 in the well field on the western side of El-Arish town. It is assumed that the groundwater in this area is influenced more by the highly saline water than on the western side in a manner that the proportion of sodium content of the groundwater becomes higher than on the western side The salinity in this area is also high.

The TDS values are relatively low in the southern half of the alluvial plain of the Wadi El-Arish (Table 4-2-4);

Table 4-2-4 TDS in Well Field South of Airport

Grid No.	Well Number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
7-8	2-2	1,941	1.09	0.59
8-9	2-9	1,689	0.79	0.67
8-10	2-10	1,335	0.90	0.69
9-10	2-11	1,318	0.93	0.90
9-9	2-13	1,575	0.72	0.75
9-10	2-14	1,878	1.12	0.91
9-10	2-16	2,122	1.59	1.12
9-10	2-18	1,797	0.85	0.75
9-12	2-12	2,500	0.87	0.61
9-11	2-15	966	-	
9-11	2-17	526	-	
10-11	2-20	966	-	
11-12	5-1	1,600	0.85	0.66
11-11	5-2	2,200	1.08	0.66
12-13	5-5	1,800	1.38	0.88
Average			1.01	0.76

The highest TDS value was observed at grid No. 9-12, well No. 2-12, where the TDS was 2,500 ppm, Requ was 0.87 and Na/Cl was 0.61. This water seems to be the same type that is found at the eastern side of El-Arish town along the Wadi El-Arish river channel.

The TDS values in grid No. 9-10 wells Nos. 2-14, 16 and 18 is relatively high and ranges between 1,900 ppm and 2,500 ppm.
R_{equ} distributes in the largest range at these grids (0.93-1.59) compared with the R_{equ} in other wells in this area. The Na/Cl ratio (0.93-1.12) shows the same tendency as that of R_{equ} at these grids. This may suggest that although the TDS values of wells in these grids are relatively low, the ion composition is similar to that in the well field along the lowest part of Wadi El-Arish.

The lowest TDS group is found at grids No. 9-11 and 10-11 where wells No. 2-15, 17 and 20 yield groundwater with TDS less than 1,000 ppm. TDS values in the remaining grids range between 1,600 ppm and

1,900 ppm which is moderate compared with the TDS in the eastern half of the alluvial plain of the lower Wadi El-Arish.

The characteristic aspect of the water quality of the wells in the Wadi El-Arish alluvial plain is that the groundwater is saline with predominating sodium ion, and the R_{equ} is less than that of the sea water although the Na/Cl ratio is close that of the sea water at many wells.

4-2-3 Sheikh Zuwayid - Rafah Area

The distribution of the TDS values of water samples from the existing wells reveals a general feature of salinity conditions in the area. Away from the seashore, TDS value increases towards inland and an obviously low TDS belt was observed along the sand dunes in parallel with the shoreline between Sheikh Zuwayid and Rafah (Fig. 4-2-2).

TDS values in this belt range between 300 ppm and 700 ppm within a narrow strip of sand dunes having a width of approximately 600 m. However, there are some exceptions at Sheikh Zuwayid. Some of the wells in this area have a much higher TDS in grid Nos. 7-9 and 8-9. The wells yielding groundwater with a low TDS value in the area around Sheikh Zuwayid are listed in Table 4-2-5.

Table 4-2-5 Wells Yielding Groundwater with Low TDS on Sand Dune in Sheikh Zuwayid

Grid No.	Well Number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
7-9	12-19	470	0.67	0.93
8-10	12-42	617	1.59	1.49
8-10	12-45	483	1.75	1.89
8-9	12-59	430	0.48	3.05
8-9	12-63	630	1.08	0.91
8-9	12-68	650	0.54	0.88
9-10	12-70	720	1.50	1.49
Average			1.09	1.52

Stiff diagrams were also constructed in the same manner as shown in Portfolio sheet No. 2. The TDS values of these wells range between 430 ppm and 720 ppm which is potable. They are considered as the most precious water source in the study area. Although the salinity of the groundwater is at low level, the R_{equ} of these wells distribute in a range between 0.48 and 1.7, and the Na/Cl ratio indicates an extremely high value (1.49-1.89) at wells Nos. 12-42 and 45, and 12-70. Well No. 12-59 in grid No. 8-9 has the same type of water quality. At the same time, there are wells having rather high TDS values in the same grids as shown above.

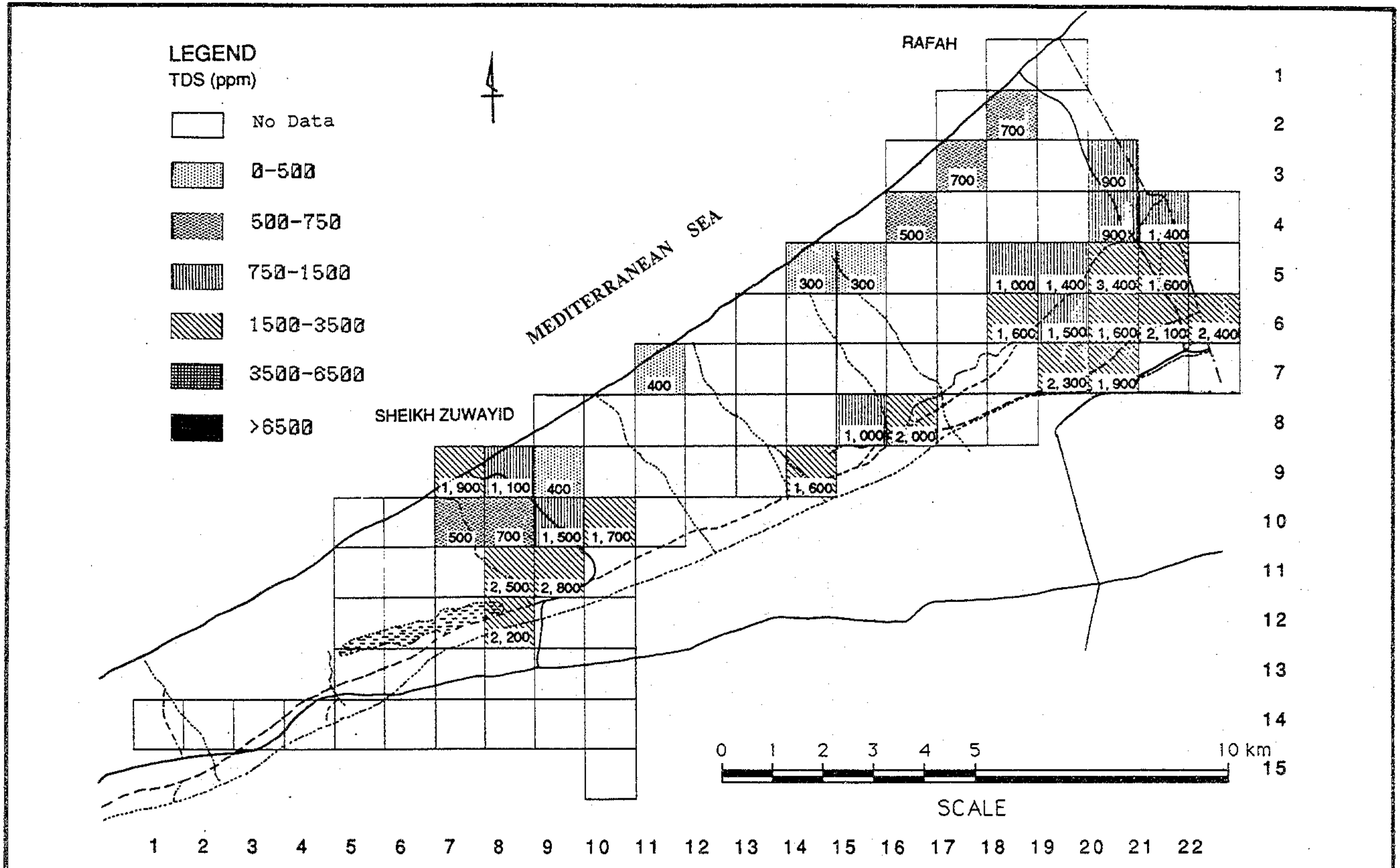


FIG. 4-2-2 TDS DISTRIBUTION AT SHEIKH ZUWAYID - RAFAH AREA IN 1988

Table 4-2-6

Wells yielding Groundwater with High TDS in Sand Dune in Sheikh Zuwayid

Grid No.	Well Number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
8-9	12-31	1,500	1.09	0.66
8-9	12-32	2,700	1.05	0.92
7-8	12-46	1,500	0.84	0.57
7-9	12-57	2,300	1.06	1.13
8-10	12-38	1,100	1.12	0.84
9-10	12-70	2,300	1.50	1.49
Average			0.98	1.52

The TDS values of these wells range between 1,100 and 2,700 ppm which is a relatively moderate salinity in the study area. The R_{equ} stays in a rather narrow range between 0.84 and 1.50. However, the Na/Cl ratio is very high at the wells No. 12-57 and 12-70.

It is assumed that there are two different aquifer systems in the area around Sheikh Zuwayid. One has low TDS values of less than 1,000 ppm and the other has higher TDS values ranging between 1,100 ppm and 3,000 ppm. Sodium predominates in the water of both aquifer systems and the R_{equ} is at the same level.

There are also wells having low TDS values on the sand dunes along the coastline at the eastern end of the study area (see Table 4-2-7).

In a narrow belt along the El-Arish - Rafah road behind the coastal sand dunes, the TDS values distribute in a range between 900 ppm and 1,600 ppm. However, there is an exception to this at the western end of the narrow belt (grids Nos. 8-11, 8-12, 9-11 and 10-10). The TDS values of wells in these grids fall within a range between 1,700 ppm and 3,100 ppm (see Table 4-2-8).

Table 4-2-7 Wells on Sand Dune in Eastern End of Study Area

Grid No.	Well No.	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
11-7	11-2	416	1.00	1.57
11-7	11-4	440	0.68	1.53
11-7	11-10	320	0.63	0.94
14-5	16-3	309	0.94	1.77
15-5	16-6	303	2.19	1.49
16-4	16-13	986	-	-
16-4	16-15	365	0.45	0.80
17-3	16-32	508	1.29	1.72
18-2	16-62	704	2.08	1.33
Average			1.16	1.39

Table 4-2-8 Wells in Narrow Strip Behind Coastal Sand Dune

Grid No.	Well Number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
14-19	17-1	1,665	2.56	1.24
14-19	17-3	1,462	2.57	1.35
15-8	17-6	1,011	2.57	1.53
16-8	17-9	988	2.78	1.63
16-8	17-10	3,023	5.09	1.60
8-11	12-61	2,800	2.68	1.49
8-11	12-66	2,200	3.23	1.28
8-12	12-36	2,200	0.34	0.64
9-11	12-71	3,100	0.71	1.54
9-11	12-74	2,500	5.31	1.25
10-10	12-94	1,700	4.97	1.28
Average			2.98	1.35

There is another notable pattern of TDS distribution in the area in the Southern part of Rafah: The TDS values of the wells falling on the grids No. 19-7, 20-6, 20-7, 21-5, 21-6 and 22-6 indicate a rather high magnitude ranging between 1,400 and 3,400 ppm as listed in Table 4-2-9;

Table 4-2-9 Wells in the Southern Part of Rafah

Grid No.	Well Number	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
19-7	16-76	2,500	3.49	1.31
20-4	16-123	1,100	2.32	1.12
20-6	16-106	1,500	3.11	1.30
20-6	16-121	1,600	3.77	1.44
20-6	16-122	1,300	1.87	0.94
20-7	16-108	1,900	4.15	1.44
20-7	16-114	1,800	6.94	1.50
21-4	16-139	1,400	1.90	0.93
21-4	16-143	1,400	1.57	1.16
21-5	16-136	1,600	3.52	1.10
21-5	16-137	1,500	2.21	0.99
21-5	16-147	1,800	3.42	1.31
22-6	16-167	2,400	10.38	2.03
Average			2.81*	1.25

*Excluding well No. 16-167

Six test wells were drilled during the study (J Nos. 3, 5, 6, 7 and 9) about 10 km inland from the seashore and J No. 10 about 35 km inland. The TDS values of these wells range between 3,500 ppm and 5,600 ppm as shown below:

Table 4-2-10 TDS Distribution along Inland Belt in Sheikh Zuwayid and Rafah Area

Well No.	TDS (ppm)	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl
JNo. 3	5,600	2.42	0.92
JNo. 5	4,300	1.73	0.83
JNo. 6	4,800	2.20	0.88
JNo. 7	5,600	3.71	1.06
JNo. 9	3,500	3.15	1.00
JNo. 10	3,600	1.26	0.90
Average		2.41	0.93

*J No. 9 is assumed to be in the aquifer of the Tertiary.

4-2-4 Bir El-Abd and Romana Area

The most remarkable aspect of the water quality in this area is the high value of TDS in the groundwater ranging from 3,000 ppm to 8,000 ppm, except at Balooza. The TDS value of the groundwater at Balooza is 544 ppm. The groundwater here has an extremely low salt content compared to other places in the area.

Table 4-2-11 Water Quality of Wells in Bir El-Abd - Romana

Well No.	Na/Cl	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	TDS (ppm)
JR5	1.28	1.08	544
JR8	0.48	1.59	4,900
JR263	0.78	1.73	4,100
JR285	0.69	1.24	7,100
JR289	0.74	1.55	7,300
JR56	0.78	1.63	3,000
JR210	0.69	1.46	6,400
JR114	0.83	1.65	3,200
JR122	0.78	1.70	5,100
JR140	0.68	1.35	3,400
JR220	0.99	1.92	4,200
JR130	0.70	2.45	7,800
JR217	0.81	2.01	5,100
JR233	0.64	1.19	1,600
Average	0.78	1.30	4,553

The ionic composition of the groundwater at Balooza is similar to that in the narrow coastal sand dune belt of Rafah.

These wells distribute in the depressions scattered on the sand dunes and there are also many different size of sabkha. The largest sabakh is the Bardawil Sabkha adjacent to this area to the north.

The ionic composition of this highly saline the groundwater is similar to those in the eastern half of the Wadi El-Arish plain near the river mouth. Predominance of Na^{+} and Cl^{-} ions in the groundwater is similar to that in the Sabkha area and the inland area of Rafah. However, the contents of Ca^{++} and Mg^{++} is much higher than those in Rafah and Ca^{++} exceeds Mg^{++} concentration.

4-2-5 Deterioration of Water Quality

One of the typical aspects of the groundwater quality in the aquifers of the Quaternary in the study area is high salinity. Potable water is available only in a limited area in the southern part of the airport in Wadi El-Arish alluvial plain and in the sand dune belt in Rafah.

In the alluvial plain of Wadi El-Arish, the TDS of the groundwater distributes in a range between 1,000 ppm and 6,500 ppm. It has been pointed out by different authors that the deterioration is due to the heavy extraction for irrigation of local farmers.

The necessary data for the interpretation of water quality change are available at the Wadi El-Arish alluvial plain (GMS, 1988).
GMS compiled all available data including some in 1954 and 1962.

The change in the TDS between pre-1963 period and 1987 was compared at 27 wells in the Wadi El-Arish.

Although the available 1954 TDS data are limited in number, a comparison with those for 1962 was made on some grids (Fig. 4-2-3 and 4).

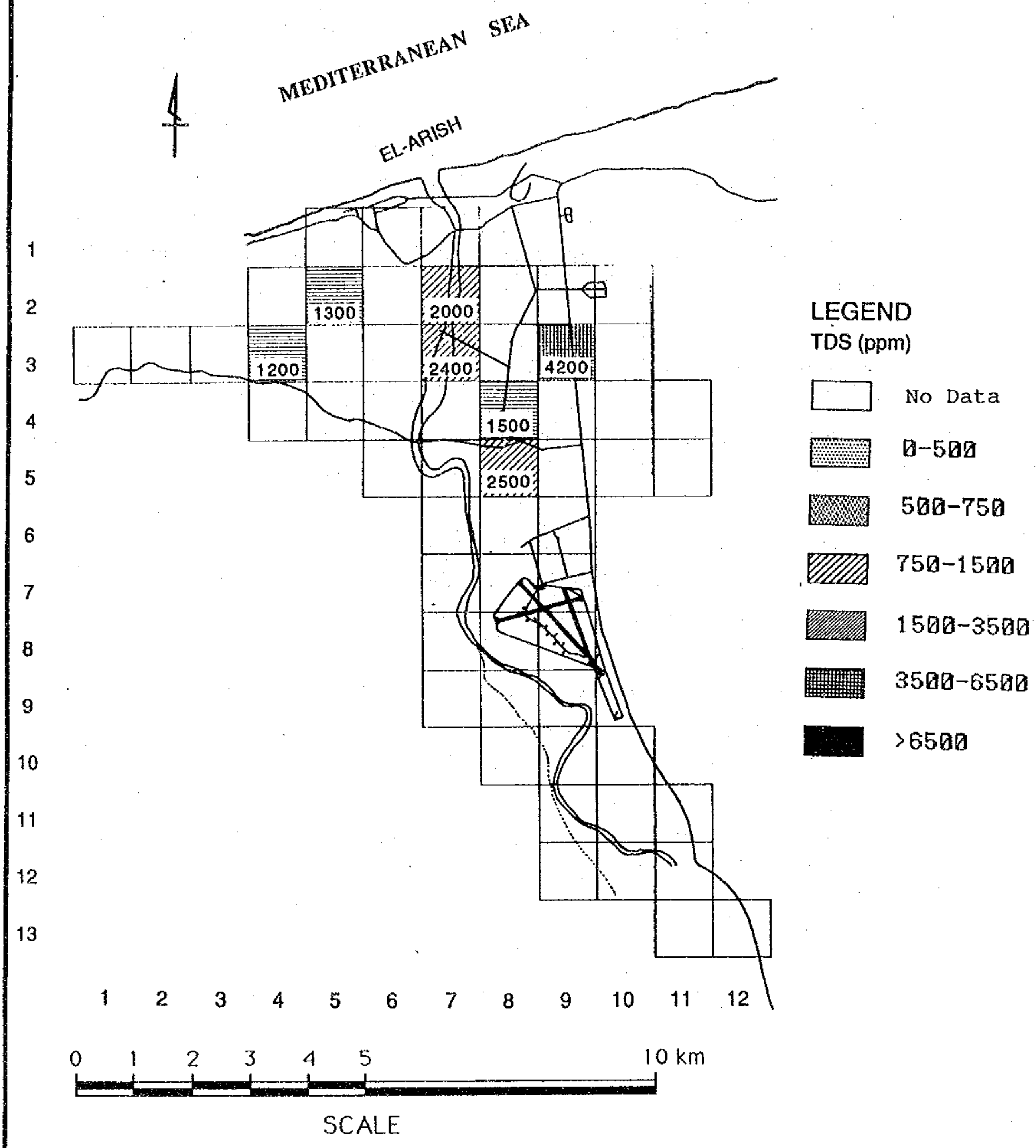


FIG. 4-2-3 TDS DISTRIBUTION AT EL - ARISH AREA IN 1954

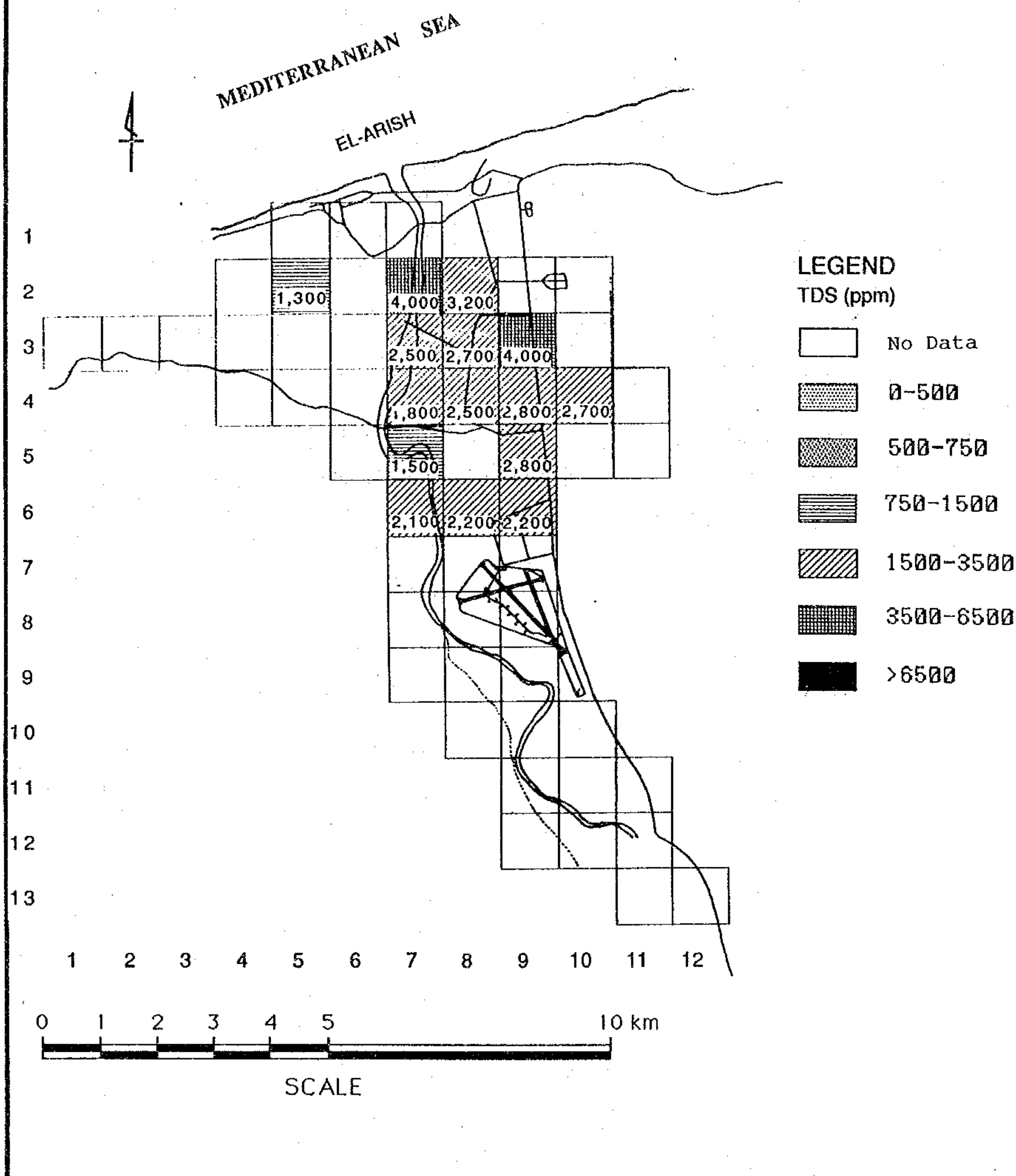


FIG. 4-2-4 TDS DISTRIBUTION AT EL - ARISH AREA IN 1962

Table 4-2-12 TDS Value in 1954 and 1962

Grid No.	Well No.	TDS (ppm)	
		1954	1962
7-3	1-82	3,100	2,500
8-4	1-93	1,500	2,500
9-3	1-133	4,200	4,800

The TDS value in grid No. 1-82 stays on the same order or even decreased in 1962 compared to the 1954 data. However, at grids No. 8-4 and 9-3 the TDS values increased in 1962 from 1954. Although further data for well No. 1-133 are not available, the TDS at well No. 1-82 decreased slightly to 2,200 ppm in 1988 and at well No. 1-93 it increased to 3,600 ppm in 1988.

The same comparison was made between 1962 (Fig. 4-2-5), and 1988 (Fig. 4-2-1): A comparison of the TDS was made over a long time span of more than 20 years together with the present pumping rate by grid (Chapter 8):

Table 4-2-13 Comparison of Water Quality between 1962 and 1988

Grid No.	Well No.	TDS (ppm)		Extraction (m^3/day)
		1962	1988	
4-3	1-9	1,200	2,000	2,000
5-2	1-18	1,300	2,000	105
7-2	1-70	2,000	3,000	624
7-4	1-64	1,700	2,600	3,600
7-6	1-84	2,100	2,700	1,000
8-6	1-107	2,200	3,100	800
9-3	1-128	3,200	3,900	2,550
9-4	1-119	2,300	3,900	880
9-5	1-127	2,700	4,900	1,270
9-6	1-115	2,000	3,700	1,610
9-6	1-125	2,000	2,700	
9-6	1-136	2,800	5,100	

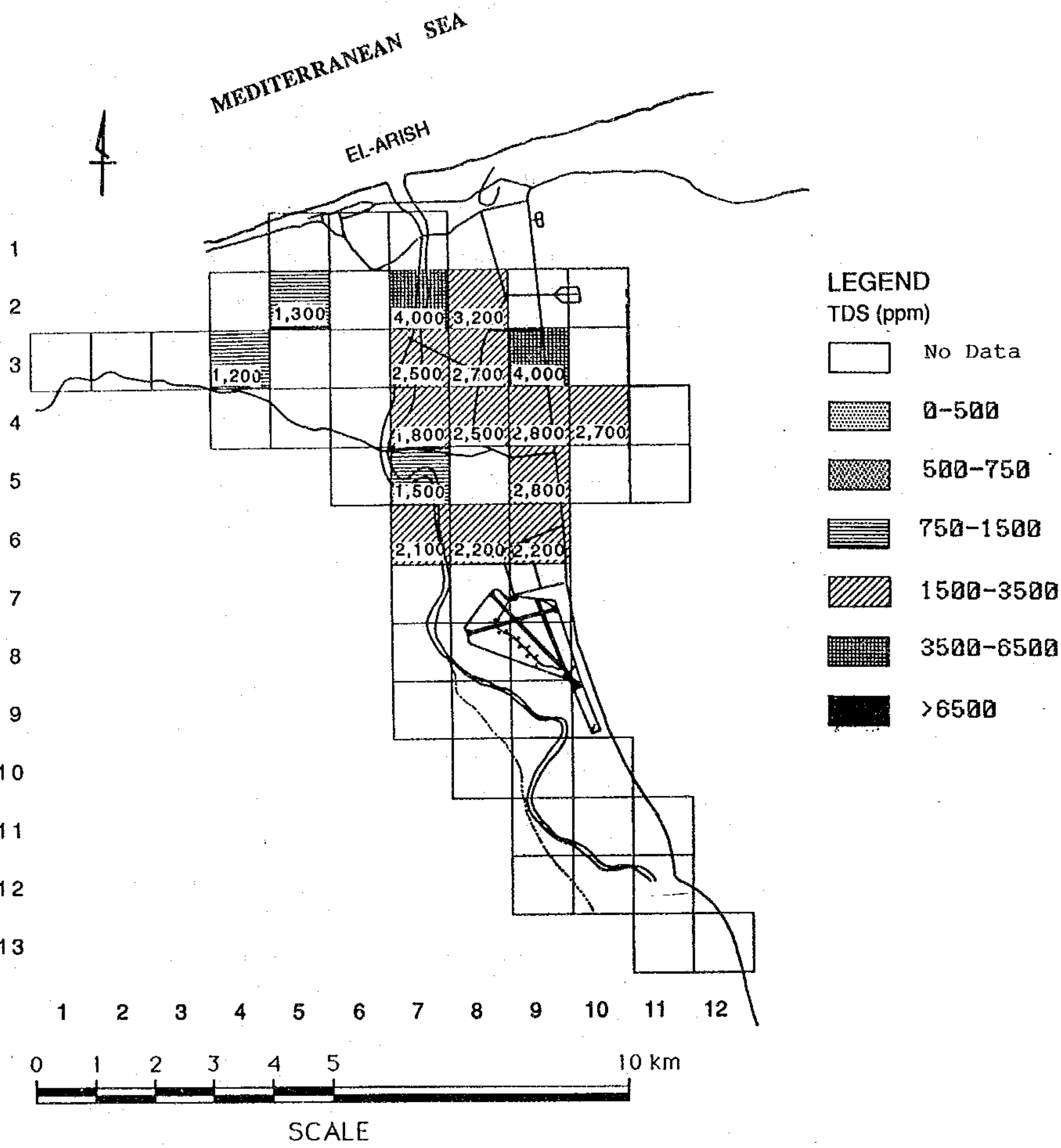


FIG. 4-2-5 SUPPLEMENTED TDS AT EL - ARISH AREA IN 1962

The change in TDS values at these grids over a twenty year period is significant especially at grid No. 4-3, 9-4, 9-5 and 9-6. At these grids the TDS values increased by 50 to 80% in 1988.

Varieties of the TDS change can be pointed out in grids Nos. 4-3, 5-2 and 7-4; The TDS in the order of 1,000 ppm increased to 2,000 to 3,000 ppm, while the TDS in the other grids increased from a level of 2,000 - 3,000 ppm to a level of 3,000 - 5,000 ppm.

A significant increase of TDS took place at thirteen wells out of twenty nine wells of which data were available for this comparison. No significant TDS change was observed in the remaining wells, instead there it was found to decrease in some wells.

Table 4-2-14 Well without Heavy Change in Water Quality

Grid No.	Well No.	TDS (ppm)	
		1962	1988
7-2	1-83	4,000	3,500
7-3	1-82	3,100	2,200
8-2	1-104	3,200	3,200
8-4	1-88	2,700	2,600
8-5	1-112	2,500	2,400
9-4	1-129	3,200	3,800
9-5	1-135	2,900	2,900
10-4	1-137	2,600	2,800
10-4	1-141	2,800	2,900

Although there is a limitation in availability of old data, many wells are developed in the well field in the southern part airport. Recently, it was clearly observed that an increase in the TDS took place at some wells especially in the grids discussed above. However, it is notable that within a small area circumscribed by a 1 km^2 grid, there was a heavy increase in TDS at a well while only a little change was noted at the others. Grid No. 9-4 (well No. 1-119 and 1-129) and Grid No. 9-6 (well No. 1-115, 1-136 and 1-125).

4-2-6 Characteristics of Water Quality of Aquifers in Quaternary

In general, high salinity is a prevailing problem of groundwater in the aquifer of the Quaternary in the study area. It can be pointed out as the characteristics of salinized water quality, that sodium is a predominant cation and magnesium exceeds calcium as shown in the stiff diagram.

As discussed in the previous sections there seems to be different types of groundwater in the aquifers of the Quaternary as summarized in Table 4-2-15;

Table 4-2-15 Characteristic of Water Quality

Location	$\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}$	Na/Cl	Range of TDS (ppm)		
Western side of El-Arish	0.64	0.75	900	-	2,800
Eastern side of El-Arish	0.91	0.76	1,700	-	6,500
Eastern part of El-Arish plain	1.20	0.75	2,100	-	5,100
South of El-Arish	1.01	0.76	970	-	2,500
Sheikh Zuwayid high salinity	0.98	1.52	1,500	-	2,700
Sheikh Zuwayid low salinity	1.09	1.52	470	-	720
Sand dune in Rafah	1.16	1.39	300	-	900
Inland narrow strip behind sand dune	2.98	1.35	1,000	-	3,000
South of Rafah	2.81	1.11	1,100	-	2,400
JICA TEST wells	2.41	0.93	3,600	-	7,800

The salinity in the western side of El-Arish town shows a moderate TDS value (900-2,800 ppm) and the Na/Cl of the minimum value among the rest of the well fields. The $R_{equ}\left(\frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}}\right)$ is also low.

The same nature of the salinity was observed in the eastern side of El-Arish although Na/Cl is slightly higher than that of the former type and the TDS range is much higher (1,700-6,500 ppm) than in the western side.

The salinity of groundwater in the eastern half of the Wadi El-Arish alluvial plain shows the same range of TDS and Na/Cl as those of the eastern side of El-Arish town, but the R_{equ} (1.20) is higher than that of the former type.

In the southern part of the Wadi El-Arish alluvial plain, the type of water quality is assumed to be very similar to that in the eastern side of El-Arish town, although the TDS value in the southern part of El-Arish is much more favorable (970-2,500 ppm) than the in the eastern side.

There are two different groups of wells in the area around Sheikh Zuwayid: wells having a high TDS groundwater and those having a low TDS. The water of these two groups of wells shows a similar magnitude of Na/Cl and R_{equ} although the TDS values are completely different (1,500-2,700 ppm and 470-720 ppm).

The salinity in the sand dunes along the coast line in the eastern end of the study area is assumed to be similar to that in Sheikh Zuwayid. However, the Na/Cl indicates a slightly higher value and the R_{equ} a little lower value than in the Sheikh Zuwayid. TDS values fall on the same range of low TDS groundwater in Sheikh Zuwayid.

The salinity found in the narrow strip behind the coastal sand dune together with the southern area of Rafah, including the further inland area of JICA test-well sites, shows a different type. The R_{equ} is more than 2.0 and the Na/Cl is lower than the water in Sheikh Zuwayid area and the coastal sand dunes. The Na/Cl and R_{equ} seem to decrease towards inland.

In the area from Bir El-Abd to Romana a different type of salinity is recognized. The R_{equ} is similar to that in the western side of El-Arish town, however the Na/Cl is much higher.

Characteristics of water quality in each location have to be determined by a certain spatial condition of hydrogeology. Such is process is absolutely uncertain at present. However, higher magnesium concentration than calcium, and remarkable predominance of sodium and chlorine are typical features of of the groundwater quality found in the aquifers in the Tertiary (Section 4-3-2).

As shown in Table 4-2-14, it is presumable that the groundwater quality in the aquifers in the Quaternary can be influenced by the water quality of the aquifer in the Tertiary. There are only two water samples from the Miocene aquifer : J No. 9 and Misri-1, in the vicinity of these Quaternary aquifers. The TDS of these two samples are 3,450 ppm and 10,450 ppm, respectively. Therefore it is highly possible that the aquifers of the Quaternary have some salinity influence from the groundwater bodies of the Tertiary aquifer depending on their localities.

4-3 Water Quality of Aquifers in Pre-Quaternary

4-3-1 Introduction

Approximately forty water quality data of all types were available for aquifers in Pre-Quaternary. The Major sources of water quality information were the test wells and piezometers drilled by RIWR mainly in the 1980s.

Water sampling and chemical analysis were also carried out wherever it was possible at existing wells during the study, although the number of these samples were limited.

Consequently, test wells drilled by RIWR and the study team are the precious data source.

The density of data points in the study area (over 26,000 km^{2}) is one sample in each 650 km^2. Additionally, its distribution is very uneven (Section 2-2-1).

Under such circumstances, an effort has been made to clarify the genesis and characteristics of water quality of aquifers in each Pre-Quaternary geochronological unit. In the following part of this section the quality of groundwater of four geologic ages are discussed.

4-3-2 Water Quality of Aquifers in Tertiary

Water quality data are available at nine wells sunk into the aquifers of the Tertiary: The composition of major ions are available at four wells, but at the remaining five wells only TDS is provided. (Table 4-3-1);

Table 4-3-1

Water Quality of Aquifers of the Tertiary

Well No.	TDS (ppm)	ANION (epm)					CATION (epm)				
		HCO_3^-	SO_4^{--}	Cl^-	CO_3^{--}	Total	Mg^{++}	Ca^{++}	Na^+	K^+	Total
<MIOCENE>											
Misri-1	10,450	1.69	24.21		0.00	151.9	24.66	22.16			152.53
No. 45A El-Arish-10	5,200	3.71	2.85	60.91	0.00	67.47	0.58	0.55	68.73	0.72	70.58
<EOCENE>											
No. 76A El Amro	5,050	1.00	18.25	59.81	0.00	79.06	0.58	19.36	0.00	0.00	19.94
No. 80A El-Quseima	3,430					0					
Ain Gudeirat	1,440	3.65	4.62	16.02	0.00	24.29	4.39	4.28	13.38	0.12	22.17
43-3 Turkish Well	4,968	3.76	13.34	61.81	0.00	78.91	16.29	52.4	45.68	0.28	114.65
43-5 OLD WELL-2	3,761										
43-6 UNKNOWN NAME	3,000										

The lithology and geologic age of the aquifer were determined either by geological interpretation and/or analysis of well logging at Misri-1, No. 76A, No. 54A and No. 52-23 (Ain Gudeirat).

The TDS values of groundwater range between 1,440 ppm and 5,050 ppm in the aquifers in the Eocene while these values distribute over a wider range between 5,200 ppm and 10,450 ppm in the Miocene. The TDS values are generally high in the aquifers of the Tertiary, and the Miocene aquifers tend to have higher TDS than the Eocene.

Piper diagram and Stiff diagram are given in Fig. 4-3-1. The type of groundwater at spring No. 52-23 Ain Gudeirat is classified as a noncarbonate hardness and NaCl predominating type and that of well No. 43-3 is classified as a noncarbonate alkali and NaCl predominating type.

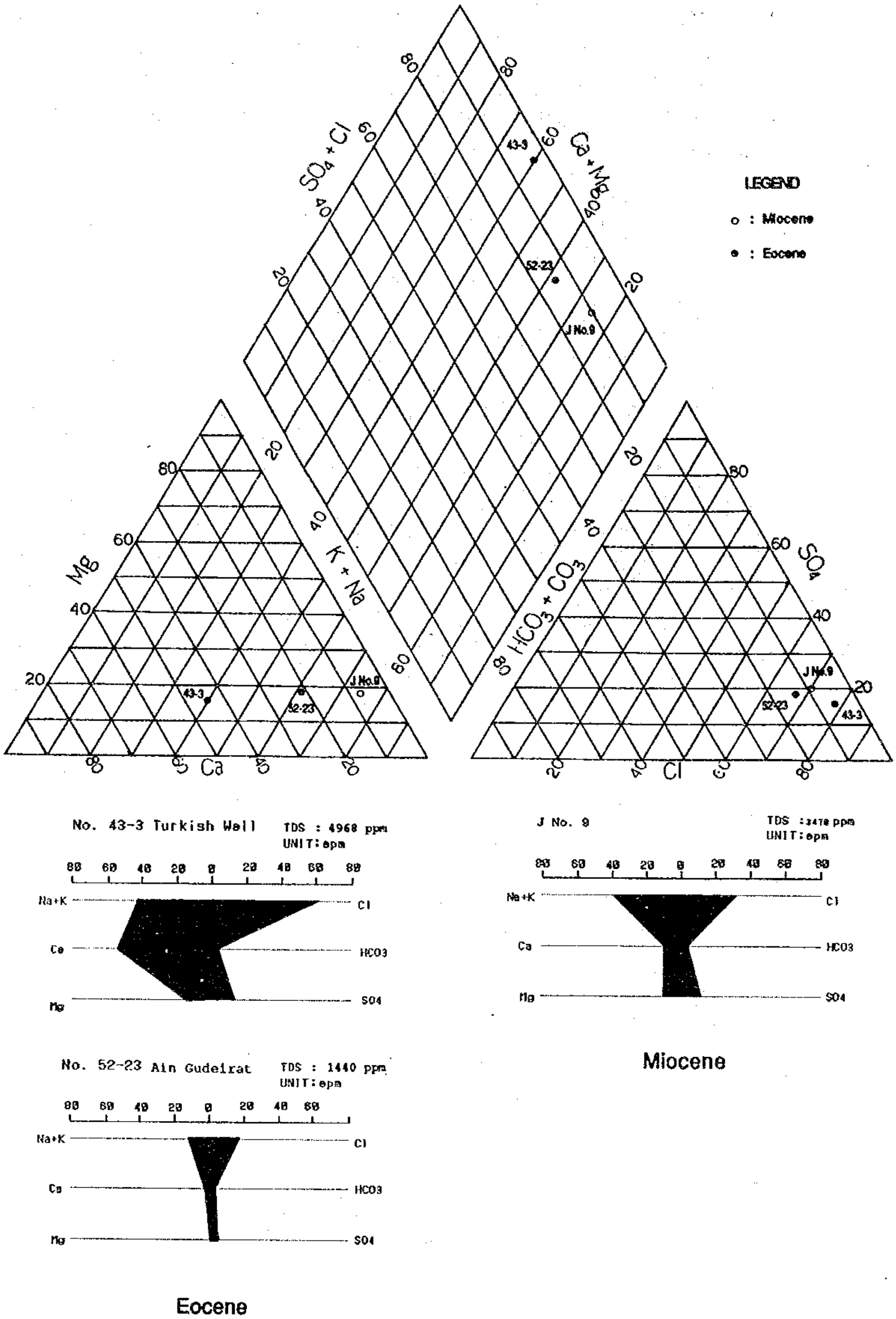


FIG. 4-3-1 PIPER DIAGRAM AND STIFF DIAGRAM OF WATER QUALITY (TERTIARY)

4-3-3 Water Quality of Aquifers in Upper Cretaceous

There are 11 data sources of water quality of aquifers in the Senonian, Turonian and Cenomanian of the Upper Cretacous. All of them provide the major ion composition. The lithology and geologic age of aquifers were determined through the composite columns (Technical Report Vol. IV).

Composition of major ions of the groundwater of these aquifers are summarized in Table 4-3-2 and Fig. 4-3-2.

Table 4-3-2
Water Quality of Upper Cretaceous

Well No.	TDS (ppm)	ANION (epm)				CATION (epm)			
		HCO_3^-	SO_4^{--}	Cl^-	CO_3^{--}	Mg^{++}	Ca^{++}	Na^+	K^+
<SENONIAN>									
No.63A Libni-3	4,500	0.90	15.72	53.60	0.00	3.87	24.00	41.02	0.67
No. 49 EL-Arish 14	2,200								
No. 70 Wadi Meleiz-1	8,480								
<TURONIAN>									
No. 50 El-ArishNo.15	7,000	2.87	33.01	79.10	0.00	20.82	18.36	76.13	0.26
Naqb 3	25,000								
Sheira-2	1,100	1.62	8.54	7.75	0.00	6.81	1.12	9.70	0.36
<CENOMANIAN>									
P1 Gifgara	5,456	7.08	10.28	73.57	0.00	22.05	16.47	46.33	0.88
P4 Hasana	4,120								
No. 57 El-Arish 19A	2,740	1.39	9.13	31.68	0.00	15.88	4.39	30.02	0.21
No. 57 El-Arish 19B	1,800	1.64	3.08	23.41	0.00	0.49	4.19	24.14	0.54
J No. 17	5,628	4.67	1.16	80.43	0.00	8.55	6.49	86.68	0.00

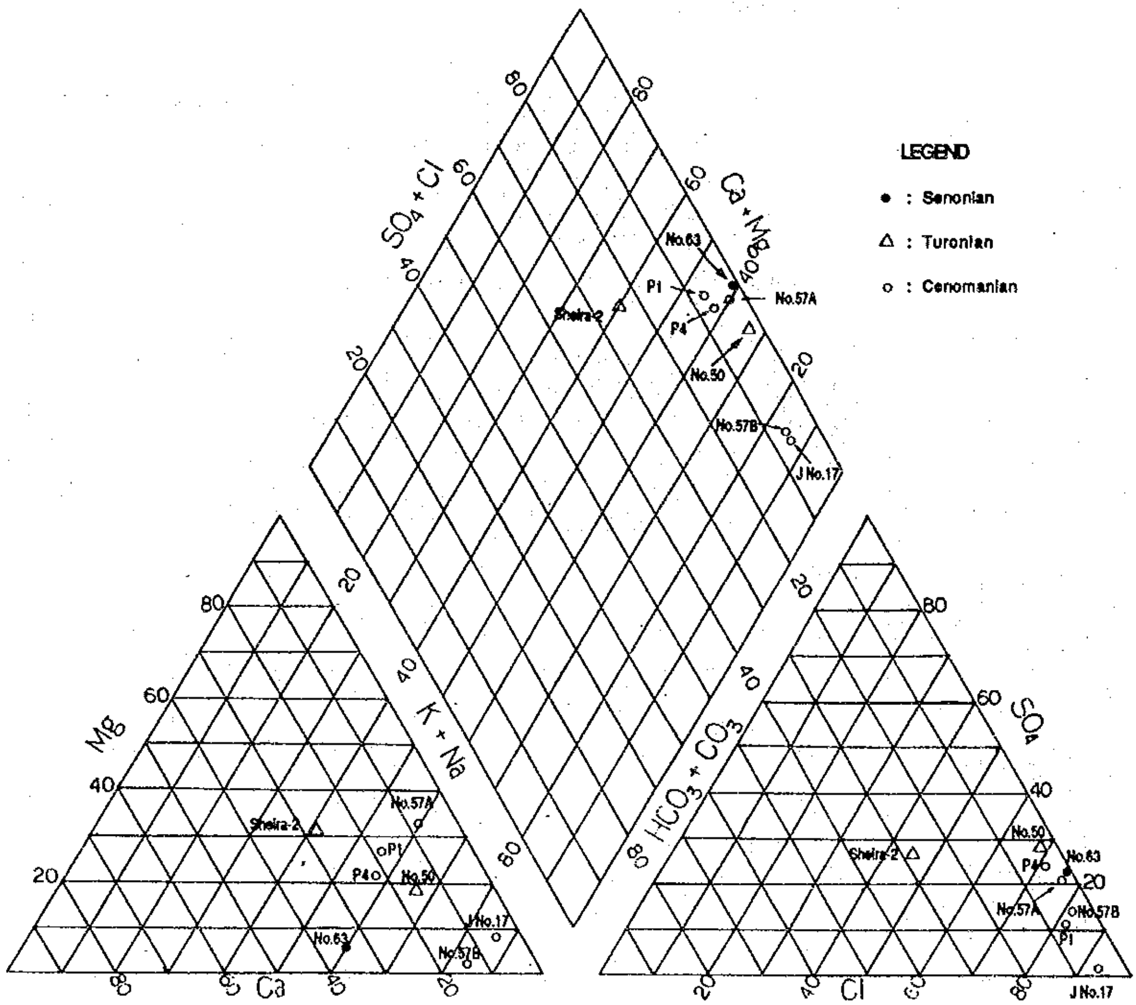


FIG. 4-3-2 (1) PIPER DIAGRAM OF WATER QUALITY (UPPER CRETACEOUS)

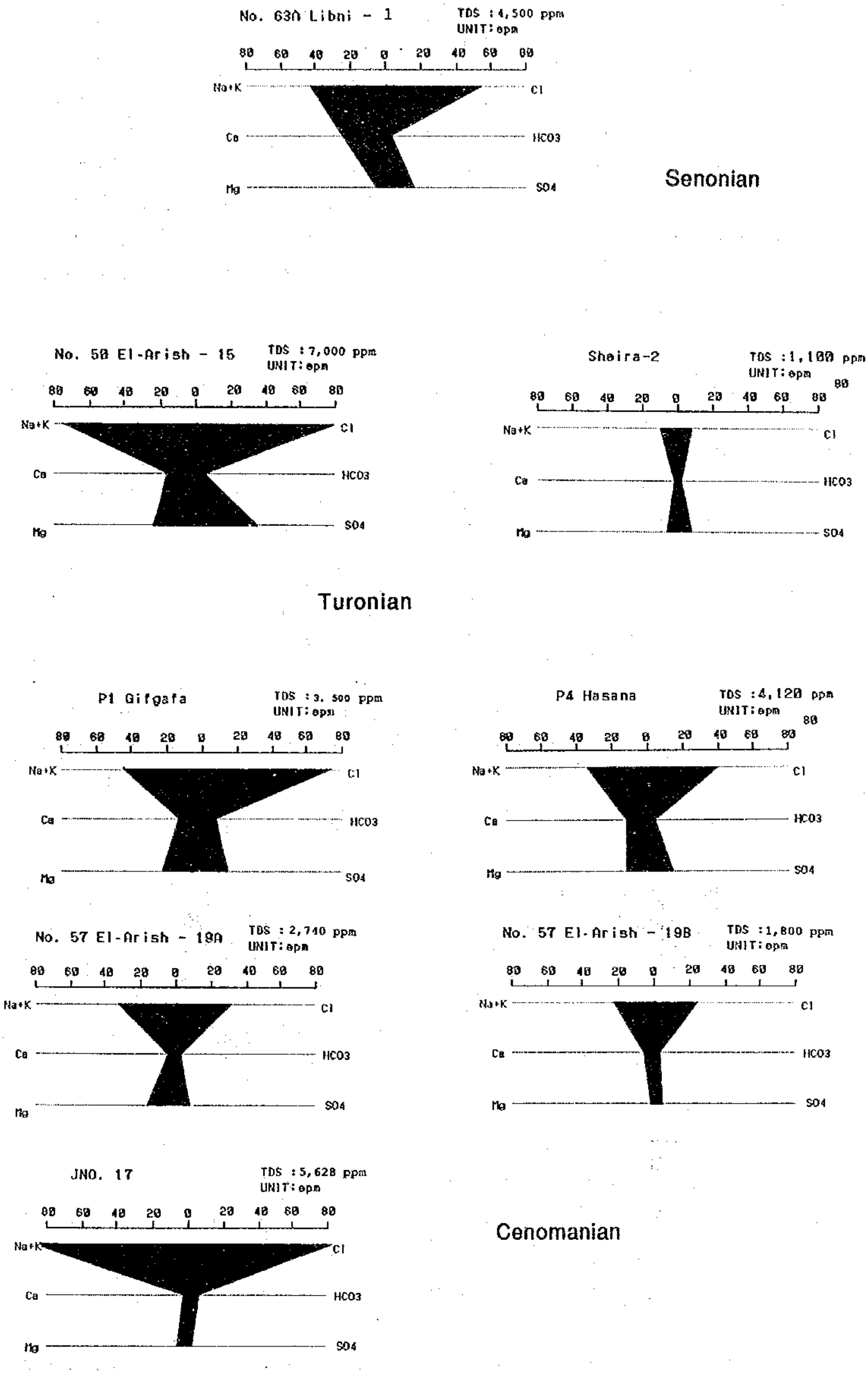


FIG. 4-3-2 (2) STIFF DIAGRAM OF WATER QUALITY (UPPER CRETACEOUS)

There are three wells having screens installed in the aquifer of the Senonian. The one located in the Hasana area (well No. 49 El-Arish-14) indicates a relatively low TDS value (2,200 ppm). However, the other two wells have rather high TDS values (4,500 ppm at well No. 63A Libni-1 and 8,480 ppm at well No. 70 Wadi Meleiz-1). Since the water quality data of the aquifers of the Senonian are scarce and that there is significant differences among them, it is difficult to determine the extent to which the available TDS values represent the nature of the TDS of this type of aquifer.

The chemical characteristics of the groundwater in the aquifers of the Upper Cretaceous is the predominance of sodium ion among cations and the surplus of magnesium over calcium. The ionic composition of the TDS of the groundwater of the Senonian is only available at well No. 63 A at Libni and an identical tendency is confirmed as stated above. The stiff diagram of this water quality assumes a similar type frequently observed among those of the Quaternary (Section 4-2).

There are three wells tapping water from the aquifer of the Turonian. The TDS value of well Sheira-2 located on the southern side of the Ragabet El-Naam Fault indicates 1,100 ppm. The TDS value of well No. 50 El-Arish well No. 15 far north of the fault at Hasana shows 7,000 ppm. As the present availabile data is limited, it might be assumed that the groundwater in this spot rarely has an opportunity to be diluted by the low salinity water due to spatial condition of the geological structure. Just on the northern side of the eastern part of the fault (well No. Naqb-3). TDS is extremely high (25,000 - 30,000 ppm) where the groundwater is isolated or hardly diluted with the low TDS water behind the barrier of the fault.

There are five wells having screens installed at the aquifer of the Senonian. They are located at four places: Gifgafa, Hasana, the southeast Hasana and El-Bruk. The TDS to the southeast of Hasana indicates a relatively low value of 1,800 - 2,740 ppm, while the TDS in the rest of the area range between 4,120 and 5,600 ppm.

Ionic composition of these groundwater is characterized by predominating sodium and chlorine especially in the area at El-

Bruk. At well No. El Bruk No.2, hydrogen sulfide is discernible in the water.

4-3-4 Water Quality of Aquifers in Lower Cretaceous

There are 12 available data for wells tapping the aquifers of the Lower Cretaceous. The ionic composition was available at five wells, but at the remaining 7 wells only TDS values were available as shown in Table 4-3-3.

Table 4-3-3
Water Quality of Lower Cretaceous Aquifers

Well No.	TDS (ppm)	ANION (epm)				CATION (epm)			
		HCO_3^-	SO_4^{--}	Cl^-	CO_3^{--}	Mg^{++}	Ca^{++}	Na^+	K^+
J. No. 12	2,973	0.00	17.68	28.54	0.00	15.21	11.58	23.21	0.00
J No. 18	2,318	4.67	0.81	32.60	0.00	4.27	1.55	34.35	0.00
J No. 19	3,008	6.49	0.81	32.60	0.00	4.27	1.55	34.35	0.00
Sheira-1	1,575	6.00	7.07	11.42	0.00	7.89	6.99	10.37	0.00
Darag No.1	1,490								
Nakhl-1	1,635								
Nakhl-2	1,200								
Sudr El-Heitan	1,246	0.93	8.80	10.69	0.00	4.71	1.97	12.40	0.34
No. P18 Egption Army Hasana	1,500								
Talet El-Badan	5,360								
El-Halal Israeli Well	1,410								
Umm Shihan	3,720								

Composition of major ions of groundwater of these aquifer are summarized in Fig. 4-3-3.

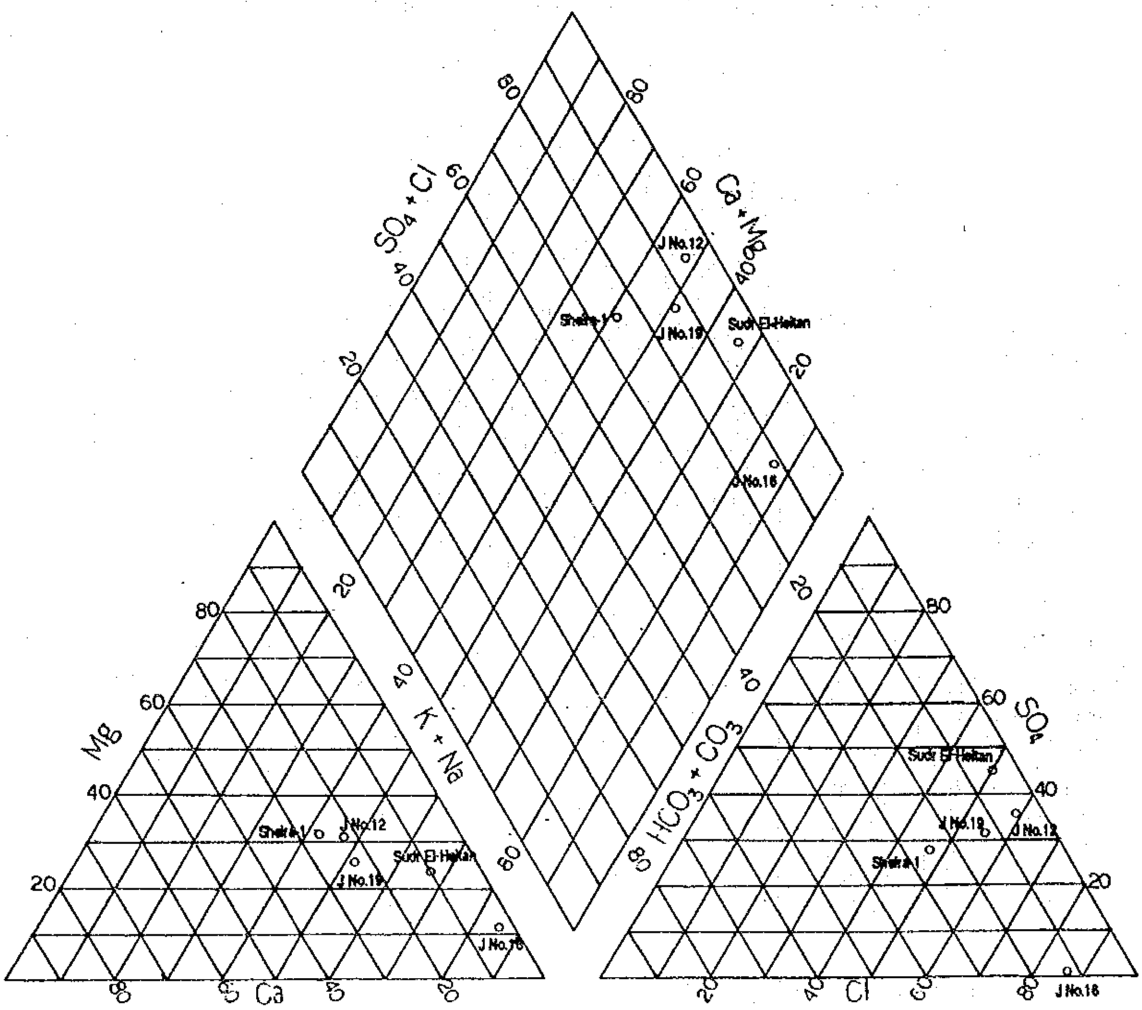


FIG. 4-3-3 (1) PIPER DIAGRAM OF WATER QUALITY (LOWER CRETACEOUS)

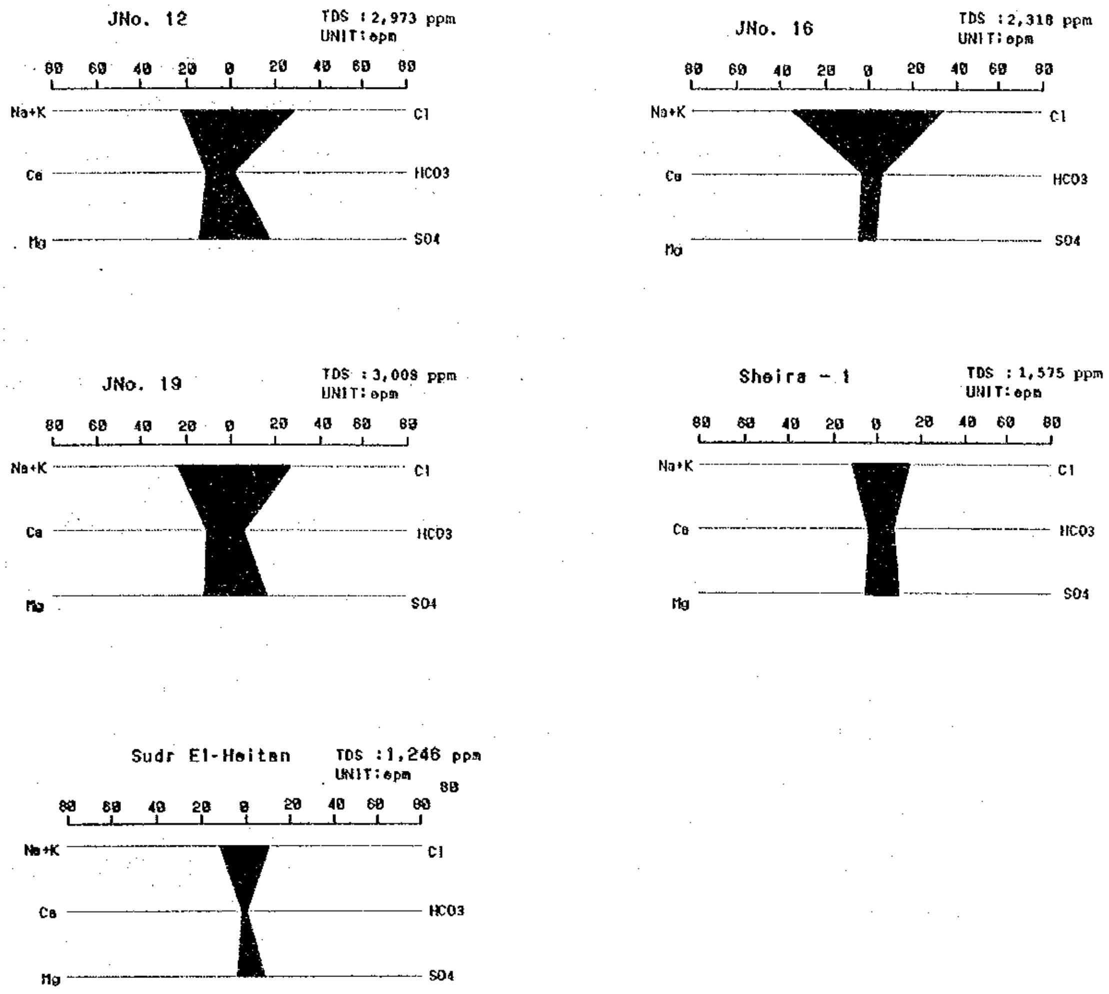


FIG. 4-3-3 (2) STIFF DIAGRAM OF WATER QUALITY (LOWER CRETACEOUS)

The lithology and geologic age of the aquifers were confirmed through the composite columns (Technical Report Vol. IV) at nine wells. The remaining aquifers need a final confirmation of lithology and age. However, they are cited to supplement the data scarcity of the water quality of the Lower Cretaceous.

The TDS values distribute within a range between 1,200 ppm and 3,000 ppm except at well Talet El-Badan. The TDS of this type of aquifers in the area from Nakhl to Gebel Halal through Hasana falls in a range between 1,200 ppm and 2,000 ppm: This group represent the best water quality zone of all aquifers of the Pre-Quaternary.

High TDS value of groundwater at Talet El Badan suggests that water in this area may have contact with water in the aquifer of the Upper Cretaceous. Through the lithostratigraphic column interpretation, this is attributed to the fact that the well site is located in a fault zone where the Lower Cretaceous is thrusted up over the Upper Cretaceous. In addition, the genesis of the water in the aquifers in the Upper Cretaceous tends to indicate a rather high TDS value (Section 4-3-3).

4-3-5 Water Quality of Aquifers in Jurassic

The typical aquifers in the Jurassic are found in the Safa and Massajid formations in the study area. The wells sunk into these formations are found in the area of Gebel Maghara. There are ten water quality data available for this type of aquifers, as shown in Table 4-3-4.

Table 4-3-4

Water Quality of Jurassic Aquifers

Aquifer	Well No.	TDS (ppm)	ANION (epm)				CATION (epm)			
			HCO_3^-	SO_4^{--}	Cl^-	CO_3^{--}	Mg^{++}	Ca^{++}	Na^+	K^+
Upper Jurassic	No. 5 Coal Mine	4,700	5.61	28.23	65.70	0.00	32.01	26.45	40.80	0.00
	No. 6 Coal Mine	8,020	0.88	32.04	85.48	0.00	32.09	37.43	54.81	0.51
	No. 8 Coal Mine	9,600	2.79	33.87	91.97	0.00	42.79	29.44	54.59	0.00
Middle to Lower Jusassic	No. WX2 Coal Mine	2,700	3.28	17.75	20.88	0.00	4.61	10.98	26.10	0.15
	No. 47B EL-Arish-12B'	1,650	0.41	3.65	21.30	0.00	4.44	6.04	14.96	0.51
	N0. 53A EL-Arish-18A	3,810	2.31	25.80	32.55	0.00	12.18	13.62	35.24	0.13
	No. 53B EL-Arish-18B	950	4.43	5.07	5.62	0.00	1.81	2.99	11.09	0.08
	No. 53C EL-Arish-18C	1,519	4.83	3.16	8.52	0.00	1.98	2.77	10.53	0.07
	No. 54A EL-Fath-4A	2,200	1.71	18.25	12.27	0.00	5.10	7.34	20.27	0.23
	No. 55 EL-Masajid-4	2,800	0.41	9.63	33.43	0.00	0.17	16.27	25.10	0.74

The lithology and geologic age of these aquifers were determined through the composite columns (Techinical Report Vol. IV). The TDS values of these aquifers distribute in a range between 2,700 ppm and 9,600 ppm in the Safa formation and between 950 ppm and 3,180 ppm in the Massajid formation.

The wells sunk into the Safa formation distribute along the Wadi El Maghara from the west to the east on the northern side of the dome core, while the wells tapping water from the aquifers of the Masajid formation distribute outside fringe of the dome. The high TDS of some water samples obtained from the Safa formation are attributable to the halitic component in the interbedded sandstone in the coal mine at Gebel Magahra.

The groundwaters in the Jurassic are classified into two types (Fig. 4-3-4). One type is represented by the water in Massajid formation at well No. WX 2 Coal Mine in which the NaCl is predominantly salt and the $MgSO_4$ is scarce. This groundwater is classified as noncarbonate alkali $NaSo4$ and $NaCl$ type. Ionic composition falls on similar position with the sea water in the key diagram. This may imply an influence of the sea water in the past. Another type of water quality is shown by the waters from wells No. 5, 6 and 8 Coal Mine. In this case the TDS is more than that in the previous type and the content of $MgSO_4$ is relatively high which is classified as a noncarbonate hardness type.

Aquifers in the Massajid formation are classified as a noncarbonate alkali type on the key diagram. However, well Nos. 53B and 53C provide relatively low TDS with the predominating Na^+, and Cl^-.

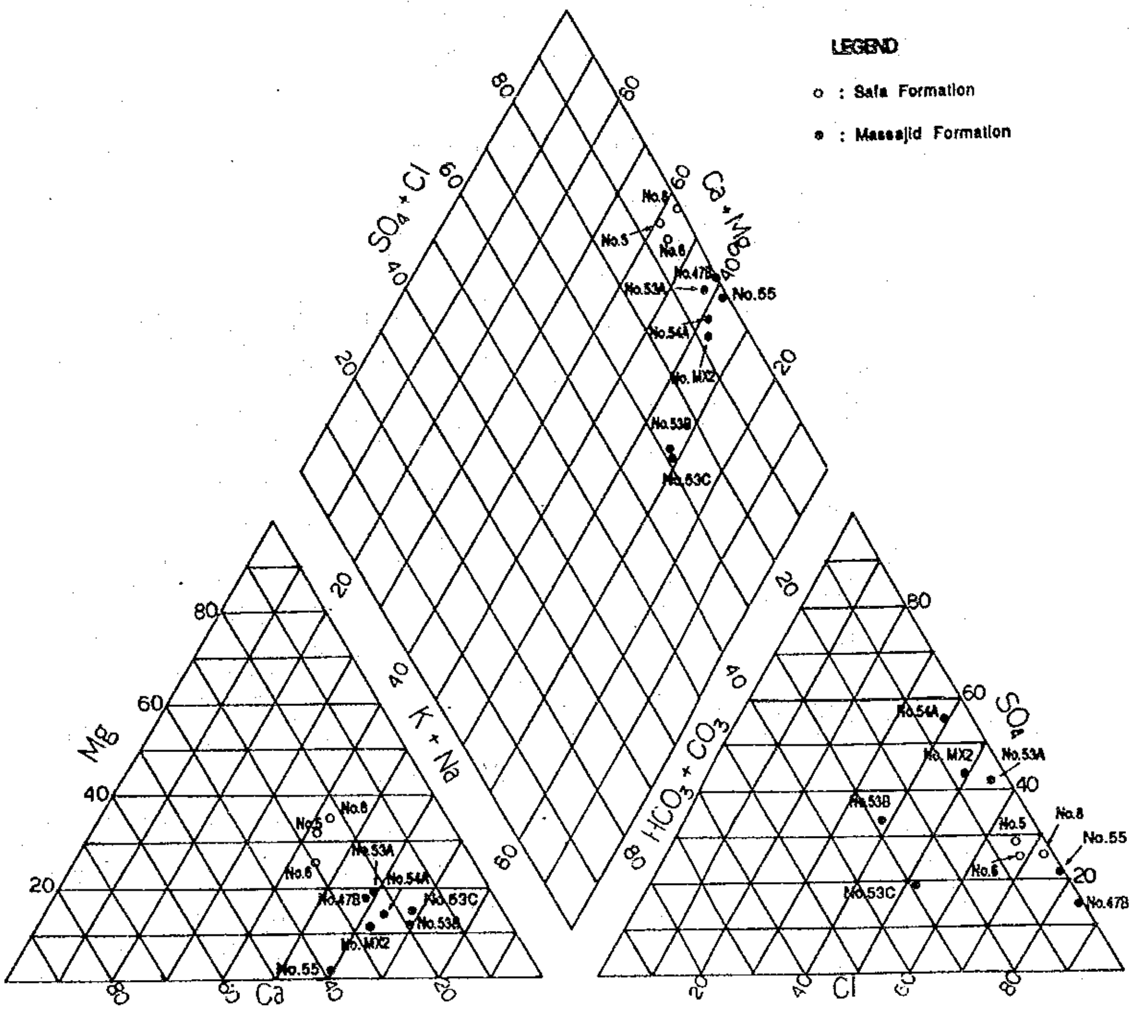


FIG. 4-3-4 (1) PIPER DIAGRAM OF WATER QUALITY (JURASSIC)

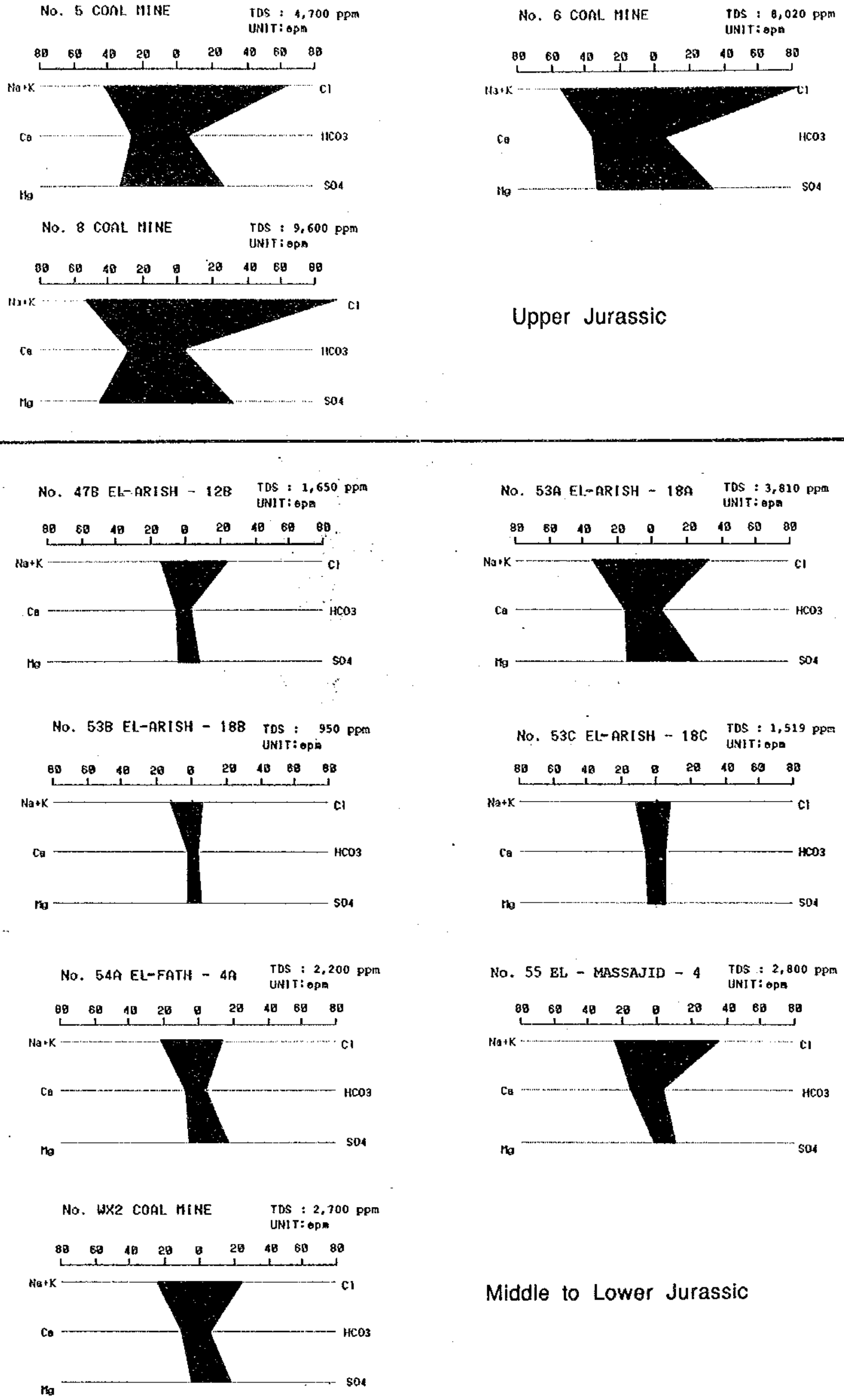


FIG. 4-3-4 (2) STIFF DIAGRAM OF WATER QUALITY (JURASSIC)

5. AQUIFER TEST

5 AQUIFER TEST

5-1 Introduction

To evaluate the capacity of the aquifer, the hydraulic parameters were determined by pump tests at the test wells and at 10 existing wells in the aquifers of the Quaternary. Many pump test results were also obtainable in old RIWR files. In addition, a pump test was undertaken at test well No. Sheira -1 drilled by the RIWR but the static water level was too deep be lifted by the contractor.

A total of 72 pump test results were processed and analyzed as shown in Tables 5-2-1, 2 and 3, and Table 5-3-1.

These pump tests consist of the following groups:

Geologic Age	*Location/Formation*	*Number*
Quaternary	El-Arish	36
	Seikh Zuwayid - Rafah	11
	Bir El-Abd - Romana	11
Tertiary	Miocene	1
Cretaceous	Upper Cretaceous	5
	Lower Cretaceous	7
Total		71

Most of the previous pump tests were the step drawdown tests. However, the constant discharge test was undertaken to determin the approximate safe yield to improve the accuracy of the drawdown measurement.

As most of the aquifer test data in the files of RIWR were step drawdown tests, the first step readings were used for the calculation of hydraulic constants of the aquifer.

Two methods, Theis and Jacob, were applied for the calculation of the transmissivity and the permeability coefficient. However, wherever a significant discrepancy was found, reference was made to the Jacob method since the curve matching process could easily result in error.

5-2 Aquifer Test of Quaternary Aquifer

5-2-1 El-Arish Area

36 pump test data were available. They consisted of 33 data from the RIWR file and 3 data for the new test wells recently drilled by RIWR in the well field of El-Arish (Table 5-2-1).

The Predominating lithology of the aquifers of these wells consists of 4 textural types: calcareous sandstone (kurkar), gravel, gravel/sand and sand.

The permeability coefficients of these aquifers distribute in a range between 2 x 10^{-2} and 5 x 10^{-1} cm/sec which seems to fall in the distribution range of the permeabilities of kurkar. The permeabilities of sand and gravel, however, also distribute in an order of 10^{-2} and 10^{-1}, where the permeabilities in the order of 10^{-1} predominate.

The obtained permeability coefficients for each aquifer are shown in Fig. 5-2-1.

Permeability Coefficient (cm/sec)	10^{1}	10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}
Relative Hydraulic Conductivity	Very high		High		Moderate			Low		Very low	
Kurkar			←——→								
Gravel			←→								
Sand and Gravel			←→								
Sand			◆								

FIG. 5-2-1 PERMEABILITY OF AQUIFER IN EL - ARISH AREA

TABLE. 5-2-1 (1) SUMMARY OF AQUIFER TEST ANALYSIS DATA IN EL-ARISH AREA

(Data used by Distcharge Test, Step No. 1)

No.	Well No.	Discharge Rate (m^3/d)	Pumping Duration (minutes)	Thickness of Aquifer (Screen Length) (m)	Jacob Method		Theis Method		Formation of Aquifer
					Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	
1	98	880.80	120	15	4,030	3.11×10^{-1}	1,031	7.96×10^{-2}	Sand/Sand and Gravel
2	1-48	868.80	120	12	723	6.97×10^{-2}	935	9.02×10^{-2}	Sand and Gravel
3	1-63	907.20	120	15	1,107	8.54×10^{-1}	1,338	1.03×10^{-1}	Calcareous sandstone (Kurkar)
4	1-64	904.80	120	18	662	4.26×10^{-2}	554	3.56×10^{-2}	Calcareous Sandstone (kurkar)
5	1-75	907.20	120	13	1,383	1.23×10^{-1}	1,204	1.07×10^{-1}	Gravel
6	1-78	1,548.00	120	15	1,574	1.21×10^{-1}	725	5.59×10^{-2}	Gravel and Calcareous Sandstone (kurkar)
7	1-83	832.08	120	12	1,903	1.84×10^{-1}	237	2.28×10^{-2}	Calcareous Sandstone (kurkar)
8	1-84	868.80	120	10	418	4.84×10^{-2}	346	$4.0\ \times10^{-2}$	Calcareous Sandstone (kurkar)
9	1-88	1,435.20	120	7	906	1.50×10^{-1}	1,131	1.87×10^{-1}	Gravel with Coarse Sand
10	1-93	1,005.60	120	10	2,629	3.04×10^{-1}	852	$9.9\ \times10^{-2}$	Gravel
11	1-102	868.80	120	15	338	2.61×10^{-2}	407	3.14×10^{-2}	Calcareous Sandstone (Kurkar)
12	1-104	904.80	120	8	2,070	2.99×10^{-1}	1,059	1.53×10^{-1}	Calcareous Sandstone (Kurkar)
13	1-105	1,005.60	120	12	708	6.83×10^{-2}	616	5.94×10^{-2}	Calcareous Sandstone (Kurkar) inter beded with Gravel
14	1-106	972.00	120	15	1,368	1.06×10^{-1}	879	6.79×10^{-2}	Calcareous Sandstone (Kurkar)
15	1-107	1,033.20	120	15	1,719	1.33×10^{-1}	1,645	1.27×10^{-1}	Gravel and Calcareous Sandstone (kurkar)
16	1-109	868.80	120	10	482	5.58×10^{-2}	640	$7.4\ \times10^{-2}$	Gravel
17	1-110	1,320.00	120	15	1,271	9.81×10^{-2}	1,051	8.11×10^{-2}	Sandstone
18	1-116	880.80	120	15	4,030	3.11×10^{-1}	1,752	1.31×10^{-1}	Gravel

TABLE. 5-2-1 (2) SUMMARY OF AQUIFER TEST ANALYSIS DATA IN EL-ARISH AREA

(Data used by Distcharge Test, Step No. 1)

No.	Well No.	Discharge Rate (m^3/d)	Pumping Duration (minutes)	Thickness of Aquifer (Screen Length) (m)	Jacob Method		Theis Method		Formation of Aquifer
					Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	
19	1-119	907.2	120	15	1,509	$1.16x10^{-1}$	722	$5.57x10^{-2}$	Calcareous Sandstone (kurkar)
20	1-123	830.4	120	11	633	$6.66x10^{-2}$	245	$2.58x10^{-2}$	Calcareous sandstone (Kurkar)
21	1-124	1,056.0	120	7	1,056	$1.75x10^{-1}$	672	$1.11x10^{-1}$	Gravel and Sand
22	1-125	1,087.7	120	12	1,244	$1.2\ x10^{-1}$	433	$4.18x10^{-2}$	Coarse Sand with Clay
23	1-127	1,006.1	120	15	1,841	$1.42x10^{-1}$	1,456	$1.12x10^{-1}$	Gravel
24	1-128	907.0	120	12	2,371	$2.29x10^{-1}$	3,439	$3.32x10^{-1}$	Calcareous Sandstone (kurkar)
25	1-134	907.2	120	15	5,534	$4.27x10^{-1}$	1,719	$1.33x10^{-1}$	Gravel and Calcareous Sandstone (kurkar)
26	1-113	928.8	120	17	739	$5.03x10^{-2}$	1,253	$8.53x10^{-2}$	Calcareous Sandstone (kurkar)
27	1-135	1,350.0	120	15	380	$2.93x10^{-2}$	1,034	$7.97x10^{-2}$	Gravel and Sandstone
28	1-137	933.6	120	16	1,220	$8.83x10^{-2}$	2,186	$1.58x10^{-1}$	Gravel and Calcareous Sandstone (kurkar)
29	1-138	904.8	120	10	2,760	$3.19x10^{-1}$	1,441	$1.67x10^{-1}$	Gravel
30	1-141	667.2	120	15	452	$3.49x10^{-2}$	699	$5.39x10^{-2}$	Gravel and Calcareous Sandstone (Kurkar)
31	10B	926.4	120	15	1,304	$1.01x10^{-1}$	802	$6.19x10^{-2}$	Gravel/Sand and Gravel
32	2-26	1,250.0	120	15	1,525	$1.18x10^{-1}$	995	$7.68x10^{-2}$	Sandstone and Linestone
33	2-25	487.0	1,440	8	-	-	374	$5.41x10^{-2}$	Gravel and Calcareous Sandstone (kurkar)
34	AR-7	426.0	1,550	10	-	-	678	$7.85x10^{-2}$	Gravel and Sandy Gravel
35	AR-9	1,382.0	4,320	11	-	-	1,068	$1.12x10^{-1}$	Gravel and Sand
36	AR-11	332.0	4,320	7	-	-	1,017	$1.68x10^{-1}$	Gravel and Sand

Permeability coefficients of the four types of aquifers fall on the values in a similar order, 10^{-1} and 10^{-2} cm/sec. However, the distribution range of permeability coefficients of each type of aquifer is somewhat different as shown in Fig. 5-2-1. It seems that the range of distribution of permeability coefficients of kurkar has a wider range although more data are required to make a final conclusion since the number of the data of kurkar occupies almost 50% of the above data.

Major types of the aquifers in El-Arish area are kurkar or sand and gravel. The transmissivity of kurkar distributes over a wide range (350-2,200 m^2/day) and the high values of transmissivities of more than 2,000 m^2/day were found at wells Nos. 1-104, 1-128 and 1-134 (Fig. 5-2-2).

The transmissivity of the sand and gravel is more than 2,000 m^2/day at wells, Nos. 1-133, 9B and 1-93 (Fig. 5-2-3).

The transmissivity of sand and gravel tends to be slightly higher than that of kurkar. There is a general tendency that the aquifer having a relatively high permeability coefficient also has a relatively high transmissivity.

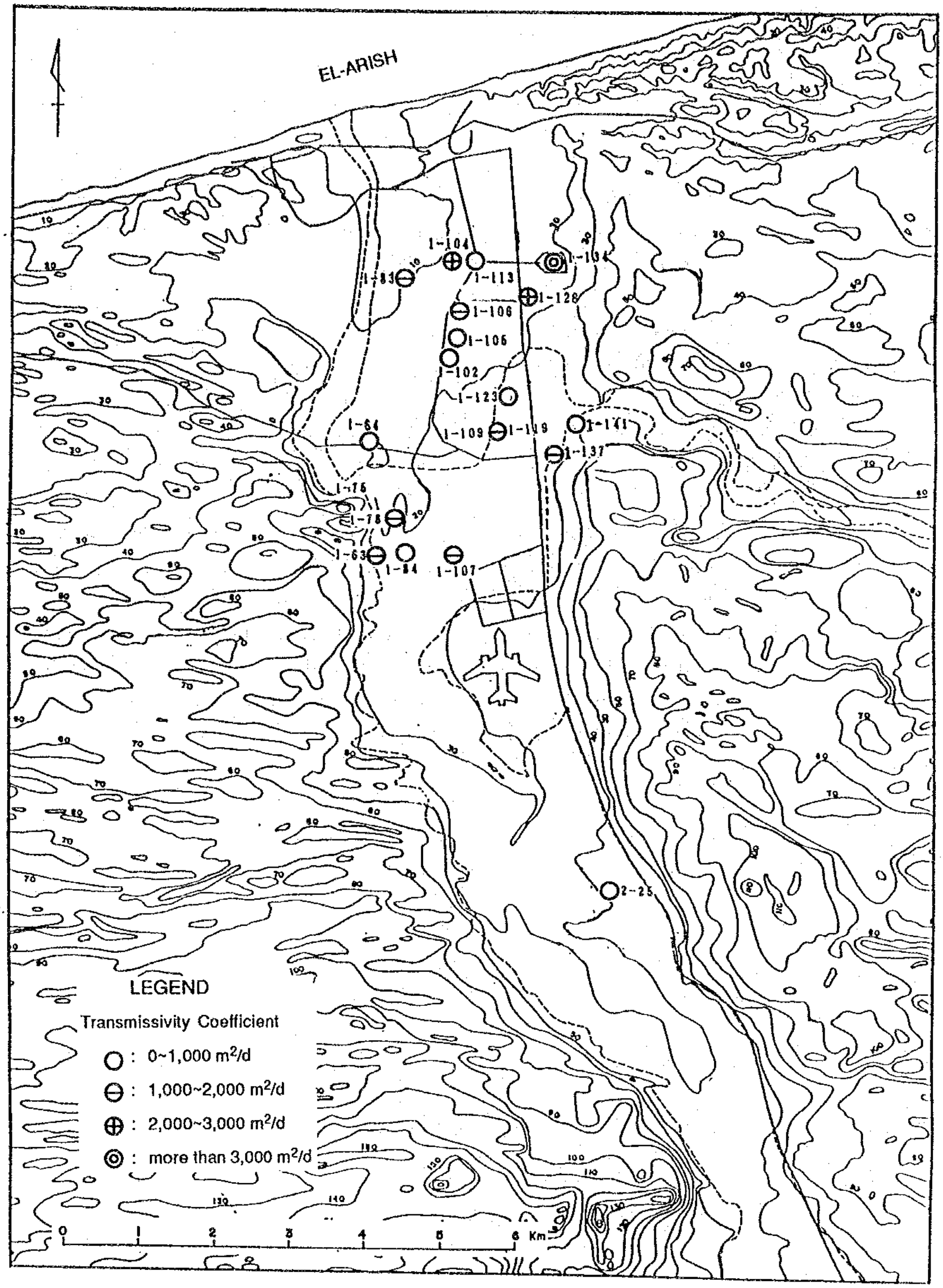


FIG. 5-2-2 DISTRIBUTION OF TRANSMISSIVTY COEFFICIENT IN KURKAR AQUIFER AT EL - ARISH AREA

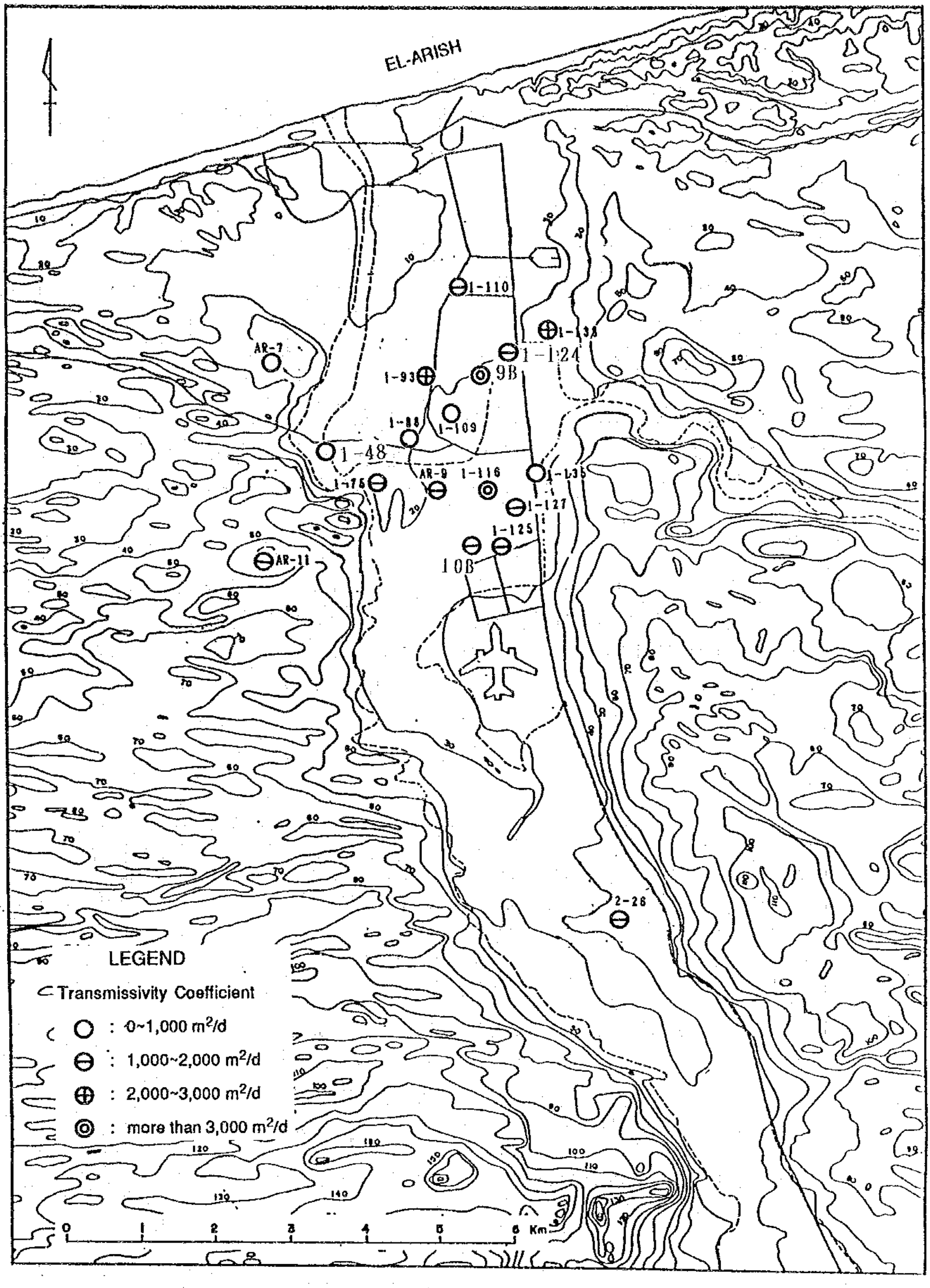


FIG. 5-2-3 DISTRIBUTION OF TRANSMISSIVITY COEFFICIENT IN SAND AND GRAVEL AQUIFER AT EL - ARISH AREA

5-2-2 Sheikh Zuwayid and Rafah Area

Seven aquifer test data were obtained from RIWR's files and four aquifer tests were undertaken at the test wells drilled by the study team. Results of the data analysis are summarized in Table 5-2-2.

Permeability distributes in a range similar to that in El-Arish, i.e, between 10^{-2} and 10^{-2}cm/sec (Fig. 5-2-4). However, the transmissivity shows a smaller range (between 148 and 1,769 m^2/day) than those in El-Arish (Fig. 5-2-5).

There was a tendency for the results of the tests at this area as to be the same as in El-Arish higher permeability accompanied by higher transmissivity. A very high permeability was observed at wells Nos. JNo. 3 and 7.

There are four types of lithology in these aquifers: kurkar, gravel, sand, and sand and gravel. The permeability of these types of aquifers falls on a similar order; however, more data is required to interpret the nature of the permeability of these aquifers.

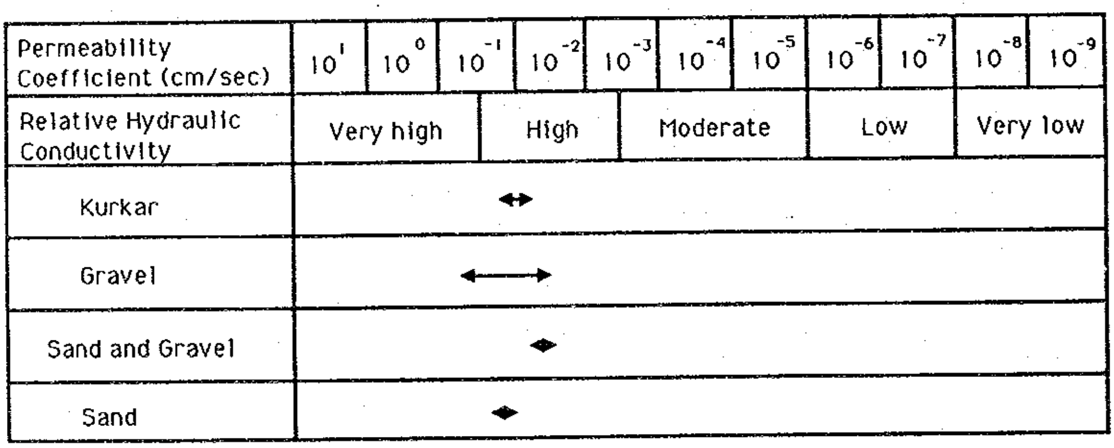


FIG. 5-2-4 PERMEABILITY OF AQUIFER IN SHEIKH ZUWAYID - RAFAH AREA

TABLE. 5-2-2 SUMMARY OF AQUIFER TEST ANALYSIS DATA IN SHEIKH ZUWAYID AREA

No.	Well No.	Discharge Rate (m^3/d)	Pumping Duration (minutes)	Thickness of Aquifer (Screen Length) (m)	Jacob Method		Theis Method		Formation of Aquifer
					Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	
1	16-10	552.0	2,880	4	-	-	419	$1.21x10^{-1}$	Sandy Gravel
2	16-20	451.0	2,880	7	-	-	528	$8.73x10^{-2}$	Calcareous sandstone (Kurkar)
3	16-4	1,886.0	2,880	10	-	-	455	$5.27x10^{-2}$	Clayey Sandstone
4	SR-1	204.0	4,320	4	-	-	148	$4.28x10^{-2}$	Sand
5	SR-4	245.0	4,320	5	-	-	727	$1.68x10^{-1}$	Sand and Calcareous Sandstone
6	SR-6	461.0	4,320	15	-	-	556	$4.29x10^{-2}$	Sand and Calcareous Sandstone
7	SR-7	566.0	4,320	6	-	-	771	$1.50x10^{-1}$	Calcareous sandstone (Kurkar)
8	J-3	338.4	1,440	12	1,417	1.367	1,769	$1.71x10^{-1}$	Calcareous sandstone (Kurkar)
9	J-5	336.0	4,320	12	1,215	$1.17x10^{-1}$	1,229	$1.19x10^{-1}$	Calcareous sandstone (Kurkar)
10	J-6	559.0	4,320	12	468	$9.04x10^{-2}$	947	$9.47x10^{-2}$	Calcareous sandstone (Kurkar)
11	J-7	913.0	4,320	12	1,321	1.274	682	$6.58x10^{-2}$	Calcareous sandstone (Kurkar)

The aquifers in the coastal sand dunes consist of sand and gravel have a transmissivity of less than 1,000 m^2/day. Kurkar at test wells J No. 6 and 7 shows the transmissivity of similar magnitude in the coastal sand dunes. However, the transmissivities of kurkar at test wells J No. 3 and 5 exceed 1,000 m^2/day (See Fig. 5-2-5).

5-2-3 Bir El-Abd and Romana Area

Following the well survey at Bir El-Abd - Romana area, pump tests were carried out at five existing wells.

The type of aquifers in this area is sand. Hydraulic constants obtained are listed in Table 5-2-3. The permeability coefficients of these wells are very high: 10^{-1}-10^{0} cm/sec (Fig. 5-2-5) and the transmissivity is also at high level, ranging between 655 m^2/day and 4,900 m^2/day. Distribution of the transmissivity is shown in Fig. 5-2-6. Very high transmissivities were observed at wells No. 56 and No. 22.

Permeability Coefficient (cm/sec)	10^{1}	10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}
Relative Hydraulic Conductivity	Very high			High		Moderate		Low		Very low	
Sand			↔								

FIG. 5-2-5 PERMEABILITY OF AQUIFER IN BIR EL ABD - ROMANA AREA

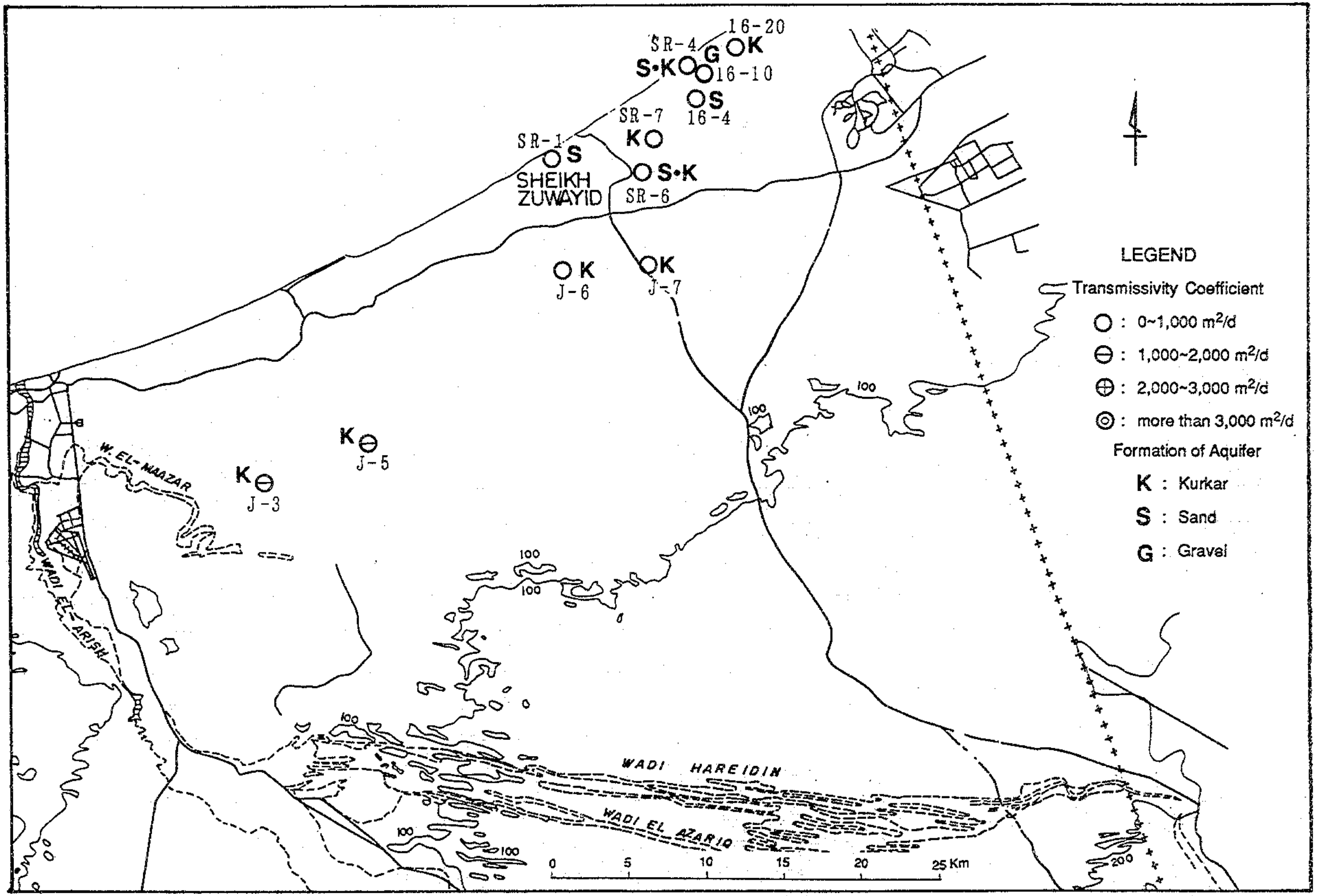


FIG. 5-2-6 DISTRIBUTION OF TRANSMISSIVITY COEFFICIENT IN SHEIKH ZUWAYID - RAFAH AREA

TABLE. 5-2-3 SUMMARY OF AQUIFER TEST ANALYSIS DATA IN BIR EL ABD-ROMANA AREA

No.	Well No.	Discharge Rate (m^3/d)	Pumping Duration (minutes)	Thickness of Aquifer (Screen Length) (m)	Jacob Method		Theis Method		Formation of Aquifer
					Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	
1	No. 56	264	4,320	3	-	-	4,888	1.89	Sand
2	No. 22	373	4,320	5	-	-	2,283	$5.28x10^{-1}$	Sand
3	No. 28	271	4,320	5	-	-	655	$1.52x10^{-1}$	Sand
4	No. 144	312	4,320	4	-	-	1,711	$4.95x10^{-1}$	Sand
5	Masharif	128	120	5	-	-	1,469	$3.39x10^{-1}$	Sand

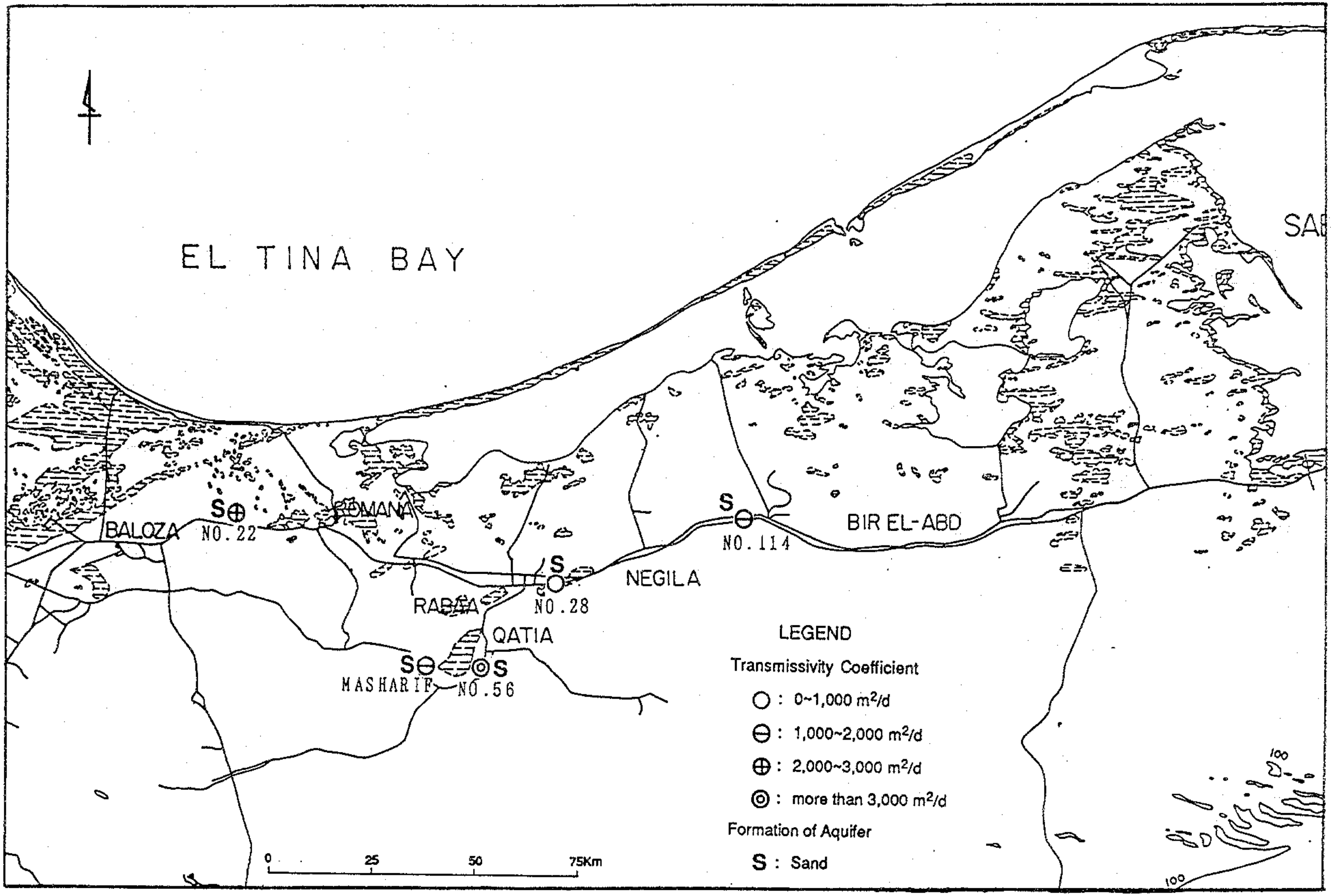


FIG. 5-2-7 DISTRIBUTION OF TRANSMISSIVITY COEFFICIENT IN BIR EL - ABD - ROMANA AREA

5-3 Aquifer Test of Pre-Quaternary Aquifer

5-3-1 Introduction

There were fourteen aquifer tests. Two tests were undertaken by RIWR at Sheira-2 and Sudr El Heitan. Six tests were made by UNICEF at P-1, P-4, Monbateh-2, Nakhl-2, Talet El Baddan and Umm Shihan. The remaining six tests, including one test at the well drilled by RIWR at Sheira, were made by the study team.

The types of tested aquifers are summarized below;

Aquifer	Number of case
Tertiary	1
Upper Cretaceous	5
Lower Cretaceous	8
Total	14

The results of pump test analysis are shown in Table 5-3-1 and the relative hydraulic conductivity is also shown in Fig. 5-3-1. Distribution of the permeability and transmissivity coefficient are plotted in Fig. 5-3-2.

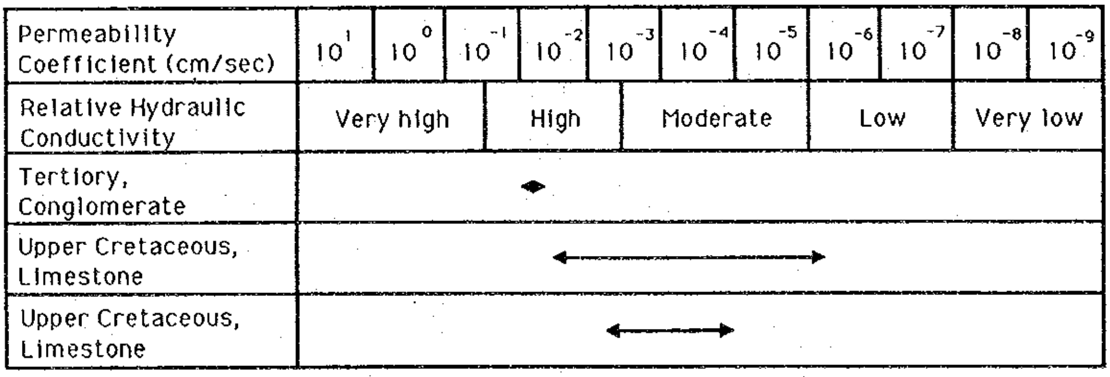


FIG. 5-3-1 PERMEABILITY OF AQUIFER IN PRE-QUATERNARY

TABLE. 5-3-1 SUMMARY OF AQUIFER TEST ANALYSIS DATA IN PRE-QUATERNARY AQUIFER

No.	Well No.	Discharge Rate (m^3/d)	Pumping Duration (minutes)	Thickness of Aquifer (Screen Length) (m)	Jacob Method		Theis Method		Formation of Aquifer
					Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/sec)	
1	J-9	312.0	4,320	6.00	519.00	$1.00x10^{-1}$	451.40	$8.71x10^{-2}$	Tertiary , Conglomerate
2	J-17	504.0	4,320	30.00	658.90	$2.54x10^{-2}$	668.50	$2.58x10^{-2}$	Cenomanian , Dolomitic Limestone
3	P4	1,246.0	1,440	79.62	4,497.00	$6.53x10^{-2}$	-	-	Cenomanian , Limestone
4	P1	960.0	1,440	144.00	18.20	$1.46x10^{-4}$	19.20	$1.54x10^{-4}$	Cenomanian , Limestone
5	Monbateh-2	960.0	2,880	198.00	75.10	$4.39x10^{-4}$	84.00	$4.93x10^{-4}$	Cenomanian , Limestone
6	Sheira-2	95.0	2,880	123.80	0.94	$8.75x10^{-6}$	1.04	$9.69x10^{-6}$	Turonian , Limestone
7	J-12	71.3	55	78.00	54.40	$8.06x10^{-4}$	-	-	Lower Cretaceous , Sandstone
8	J-16	700.8	4,320	90.00	11.90	$1.51x10^{-4}$	14.70	$1.89x10^{-4}$	Lower Cretaceous , Sandstone
9	J-19	480.0	4,320	174.00	399.30	$2.66x10^{-3}$	382.00	$3.01x10^{-3}$	Lower Cretaceous , Sandstone
10	Sheira-1	528.0	4,200	70.00	214.80	$3.55x10^{-3}$	323.20	$5.34x10^{-3}$	Lower Cretaceous , Sandstone
11	Nakhl-2	1,440.0	3,060	20.00	108.00	$6.28x10^{-3}$	60.80	$3.50x10^{-3}$	Lower Cretaceous , Sandstone
12	Talet El Badan	2,001.0	2,420	109.00	302.80	$3.22x10^{-3}$	360.00	$3.78x10^{-3}$	Lower Cretaceous , Sandstone
13	Umm Shihan	960.0	2,880	163.00	117.70	$8.36x10^{-4}$	71.90	$5.10x10^{-4}$	Lower Cretaceous , Limestone

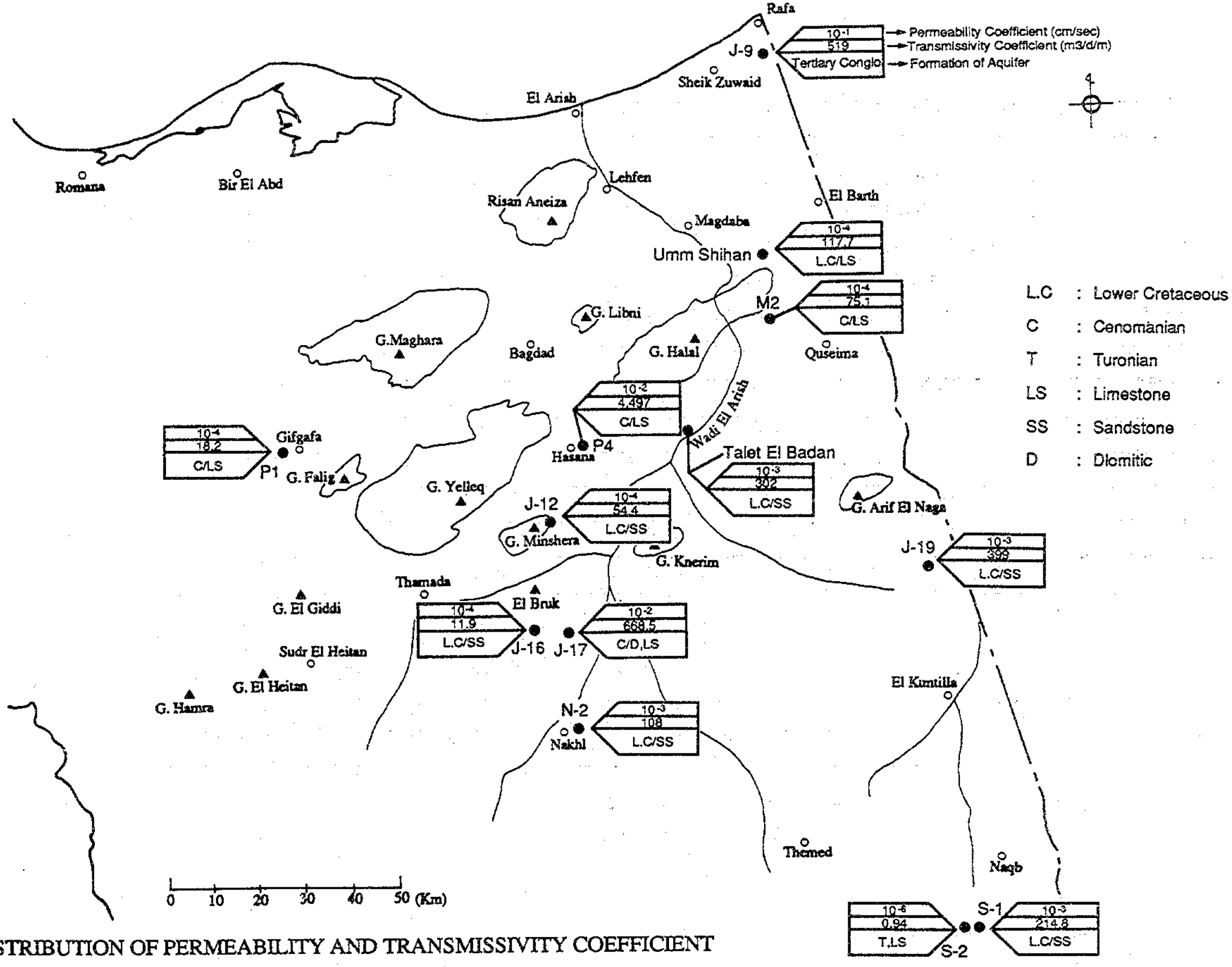


FIG. 5-3-2 DISTRIBUTION OF PERMEABILITY AND TRANSMISSIVITY COEFFICIENT AT PRE - QUATERNARY AQUIFERS

5-3-2 Tertiary

The aquifer test of the Tertiary was available for J No.9. The lithology of this aquifer is conglomerate of the Miocene of which permeability coefficient is estimated at 1 x 10^{-1} cm/sec. The magnitude of this permeability coefficient is very high compared to the figures for other Pre-Quaternary aquifers. However, at this permeability level, the transmissivity of the aquifer (520 m^2/day) is rather small.

5-3-3 Upper Cretaceous

There were five aquifer tests made of the Upper Cretaceous. The lithology of these aquifers is either limestone or dolomitic limestone of the Cenomanian or the Turonian.

The permeability coefficients of these aquifer distribute over a wide range between 10^{-6} and 10^{-2} cm/sec, spanning from the "Low" to "High" relative hydraulic conductivity (Fig. 5-3-1).

The transmissivity is also scattered over wide range. Well No. P-4 has an extremely high transmissivity of 4,500 m^2/day, while the remaining wells have a transmissivity of less than 100 m^2/day. The minimum transmissivity is less than 1 m^2/day at Sheira-2 (Table 5-3-1).

5-3-4 Lower Cretaceous

There were six aquifer tests made of the Lower Cretaceous. The lithology of the aquifers is sandstones except for the limestone aquifer at well Umm Shihan.

The permeabilities of these aquifers fall in a relatively narrow range between 10^{-4} and 10^{-3} m^2/day and the relative hydraulic conductivity is moderate to high (Fig. 5-3-1).

The transmissivities of wells No. J No. 12 and 16 are less than 100 m^2/day. However, the others are range between 100 and 400 m^2/day (Table 5-3-1).

The hydraulic constants of the aquifers of the Lower Cretaceous fall in a narrow range compared to those of the Upper Cretaceous.

The permeability coefficient of the sandstones of the Lower Cretaceous was also estimated through the grain size analysis (Technical Report III). The estimated permeability coefficients based on the percentage of the passing D_{20} are also in a narrow range between 10^{-2} and 10^{-3} cm/sec.

6. DATING OF GROUND WATER

6 DATING OF GROUNDWATER

6-1 Introduction

A large-scale groundwater development scheme in an arid zone tends to rely on the water in aquifers developing in an old geological formation. A great part of the study area receives only 50 to 100 mm of an annual rainfall and a major portion of the persent-day groundwater storage is assumed to have been recharged during a geological time span (A. Issar, A. Bein and A. Micheli, 1981, and A. Issar and R. Ntiv, 1988) without appreciable contribution from the modern precipitation.

In order to interpret genesis and circulation of such type of groundwater, often called palaeo-groundwater, radioisotope dating is a very useful tool. For this reason a noticeable number of radio-isotope datings had been carried out on the groundwater in the study area including Negev desert in Israel (Carmi et. al., 1971, Kaufman, 1971, Ehhalt, 1963, and Münnich and Vogel, 1962). The results had indicated that the datings of the waters from the Pre-Quaternary formations were distributing in a range between 13,000Y. BP and 30,000Y. BP or more.

The stable isotope analysis was also made on the groundwater from Gebel Maghara by JMRDP (JMRDP Progress report No. 6, 1989).

Participating in the above mentioned study trend, the study team undertook the isotopic analysis on the samples from some selected wells.

6-2 Dating Parameters

For the dating of the groundwater, the following parameters were selected:

1. Carbon fourteen: ^{14}C
2. Tritium: ^{3}H
3. Isotopic ratio of ^{18}O and D

6-3 Quaternary Groundwater

Dating samples were collected in the coastal part of the Wadi El-Arish watershed. Sampling locations are presented in Fig. 6-3-1 with the identification code of each sample, except Lehfen, which is shown in Fig. 6-4-1.

Altogether eight samples were collected and seven of them were analyzed as being of tritium. Then, four of the seven were selected for carbon-14 measurement. In addition, stable isotopes (carbon-13, oxygen-18 and deuterium) were analyzed for the supplementary interpretation of the dating results.

Measured values are presented in Table 6-3-1 and 6-3-2. Tritium contents are given in tritium unit (T.U.) and carbon-14 in percentage of modern carbon (pmC). Carbon-13, oxygen-18 and deuterium levels are expressed in permille deviation from the international reference specimens: PDB for carbon-13, and V-SMOW for oxygen-18 and deuterium. Collected groundwater from RIWR monitoring wells are all from the aquifer of kurkar. A schematic geological cross section is shown in Fig. 6-3-2.

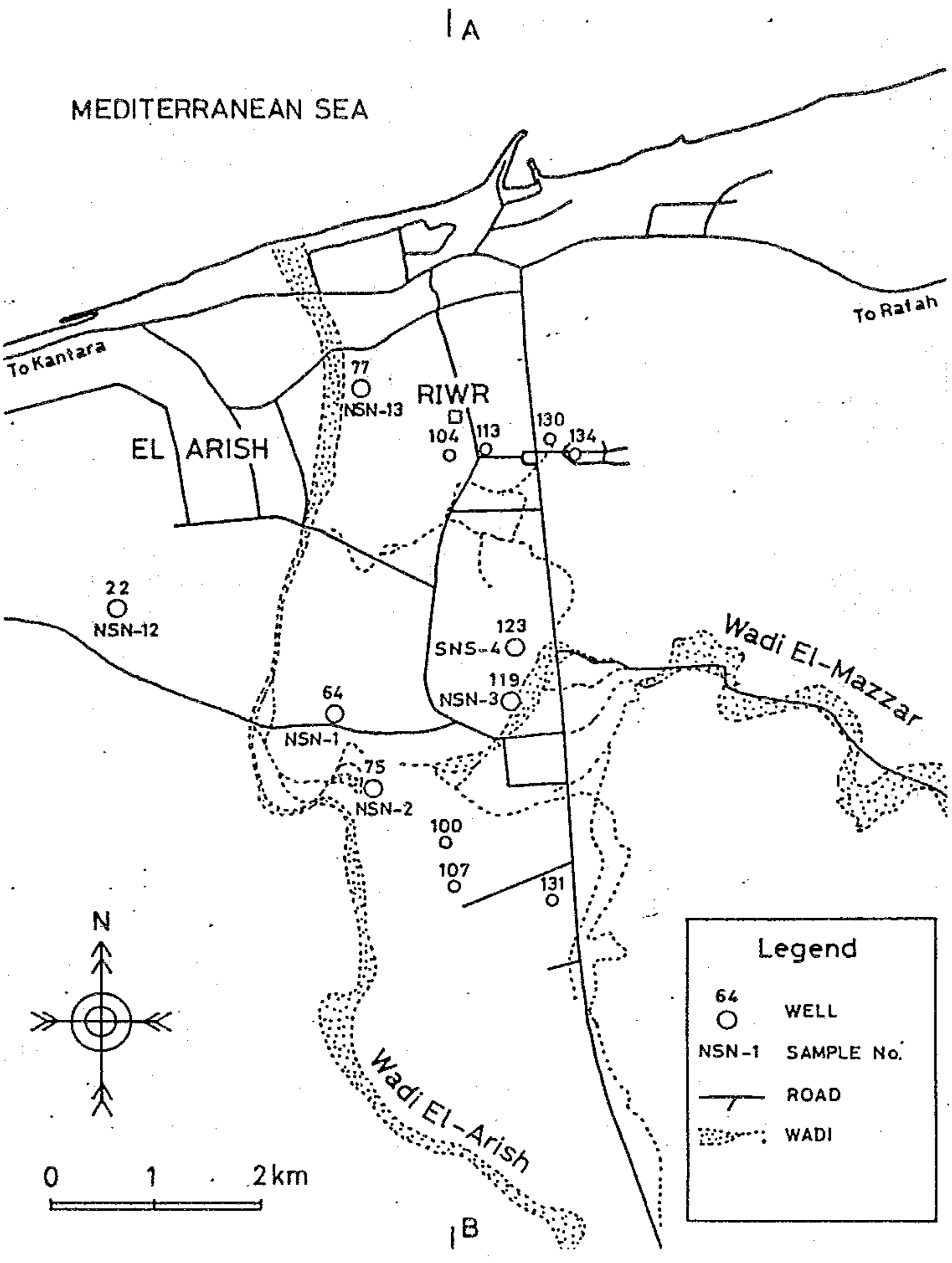


FIG. 6-3-1 SAMPLING LOCATION FOR GROUNDWATER DATING IN THE NORTHERN PART OF WADI EL - ARISH

Table 6-3-1
Isotopic Analyses of Groundwaters in Quaternary Aquifer and Sea Water

Sample I.D. and Sampling date	Tritium (T.U.)	C-14 (pmC)	$\delta^{13}C$ (%)	$\delta^{18}O$ (%)	δD (%)
NSN-1 El-Arish 1-64 80/11/13	< 0.96	34.2 ± 1.0	- 8.6	- 5.15	- 24.3
NSN-2 El-Arish 1-75 89/11/13	2.3 ± 0.3	49.8 ± 0.9	- 10.7	- 4.88	- 24.1
NSN-3 El-Arish 1-119 89/11/14	< 0.94	25.4 ± 0.9	- 9.3	-4.25	- 22.4
NSN-4 El-Arish 1-123 89/11/14	< 0.97	19.1 ± 1.0	- 8.1	- 4.30	- 21.7
NSN-12 El-Arish 1-22 89/12/13	< 0.94	-	-	- 4.10	- 19.2
NSN-13 El-Arish 1-77 89/12/13	< 0.93	-	-	- 4.78	- 26.0
NSN-14 El-Arish Coast, Sea water 89/12/14	-	-	-	+ 1.54	+ 7.1
NSN-15 Lehfen 5-5 90/3/6	< 0.93	-	-	- 5.16	- 28.9

Units
pmC : Percentage of Modern Carbon
T.U. : Tritium Unit, 1 T.U. $\left(\begin{array}{l} = 10^{-18}\ T/H \\ = 3.2\ pCi/liter \end{array} \right)$

The most impressive aspects of these results are the fact that both tritium and carbon-14 show an appreciably low level. Sample NSN-2 shows a high level in tritium, but even this does not reach the recent level of tritium caused by former thermal nuclear tests. This particular water may indicate some mixing of young water which probably is stored in the wadi bed.

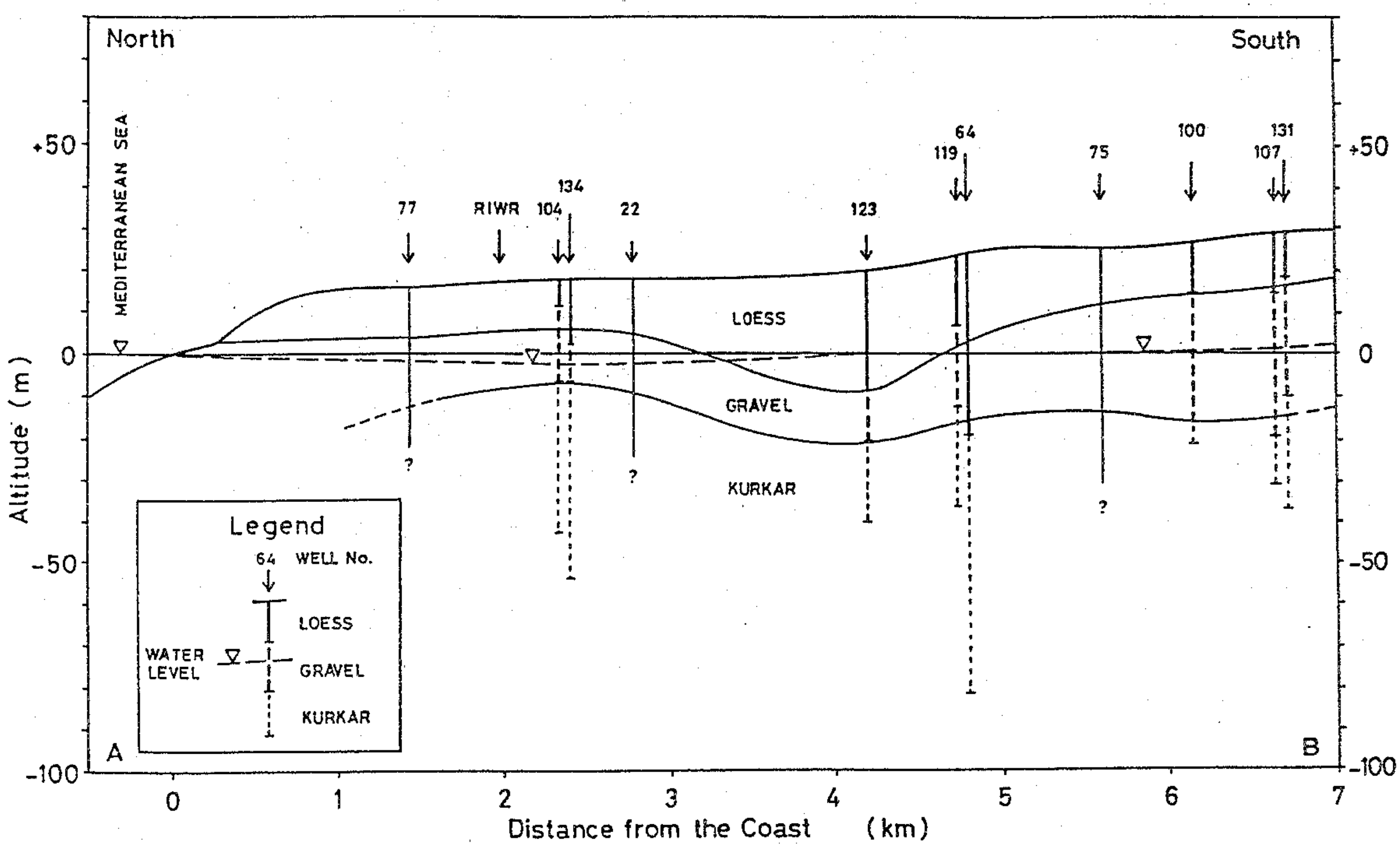


FIG.6-3-2 GEOLOGICAL CROSS - SECTION IN THE COASTAL PART OF WADI EL - ARISH AREA

Table 6-3-2

Carbon-14 Dating of Quaternary Aquifer Groundwaters

Sample I.D. and Sampling date	Apparent C-14 Age (Y. BP)	Corrected Age* (Y. BP)	Laboratory ** Reference No.
NSK-1 El-Arish RIWR#64 8-/11/13	8,610 ± 240	4,390 ± 240	Gak-14802
NSN-2 El-Arish RIWR#75 89/11/13	5,570 ± 140	1,730 ± 140	Gak-14803
NSN-3 El-Arish RIWR#119 89/11/14	11,020 ± 290	6,770 ± 290	Gak-14804
NSN-4 El-Arish RIWR#123 89/11/14	13,240 ± 420	8,620 ± 420	Gak-14805

* Corrected for the carbonate dissolution process.

** Gakushuin University, Tokyo, Japan

Units

T.U. : Tritium Unit, 1 T.U. $\left(\begin{array}{l} = 10^{-18}\ T/H \\ = 3.2\ pCi/liter \end{array} \right)$

Y.BP : years Before Present

Tritium poor waters are presumed to be of deep borne groundwater due to the trend in δ oxygen-18 vs. electric conductivity (E.C.) plot in Fig. 6-3-3, where increase in salinity (i.e., E.C.) does not seem to converge to the higher δ oxygen-18 value of the local sea water, +1.54 (‰).

In water resources evaluation, it should be noticed that the El-Arish region relies much on the aged groundwaters although it is located along one of the most active wadi drainage systems in Northern Sinai.

6-4 Pre-Quaternary Groundwater

Dating samples were collected from four different aquifers at seven sites as shown in Fig. 6-4-1;

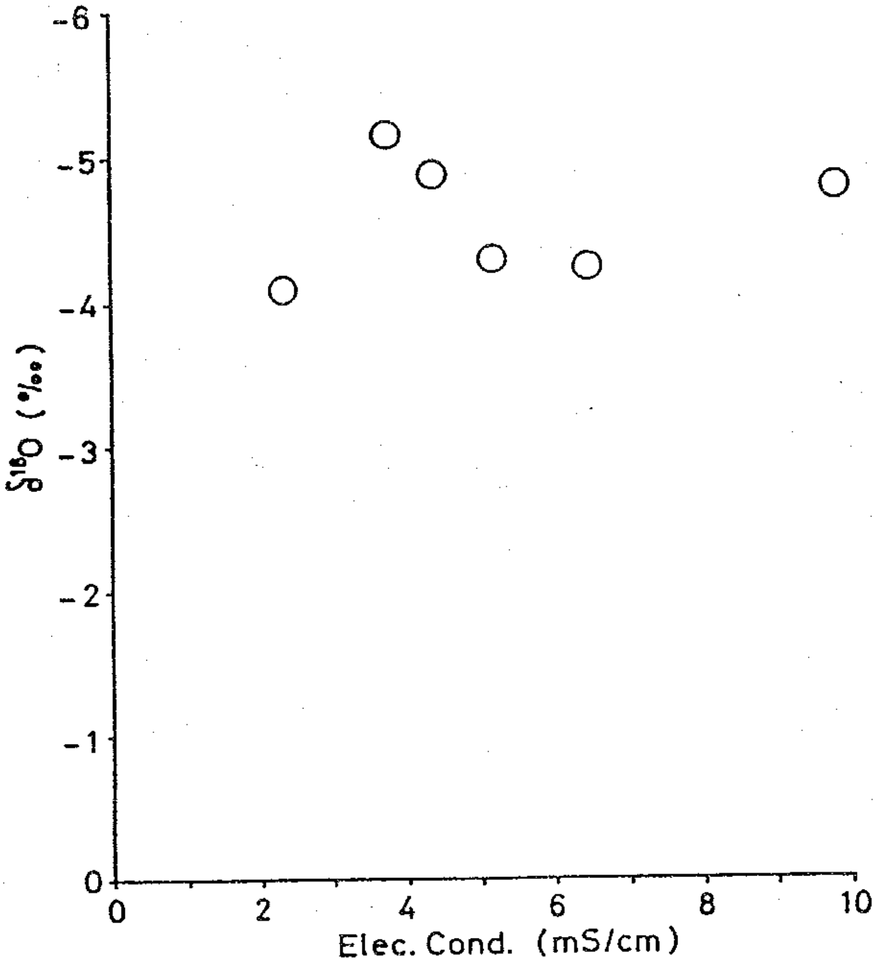


FIG. 6-3-3 $\delta^{18}O$ VS ELECTRIC CONDUCTIVITY FOR THE QUATERNARY AQUIFER

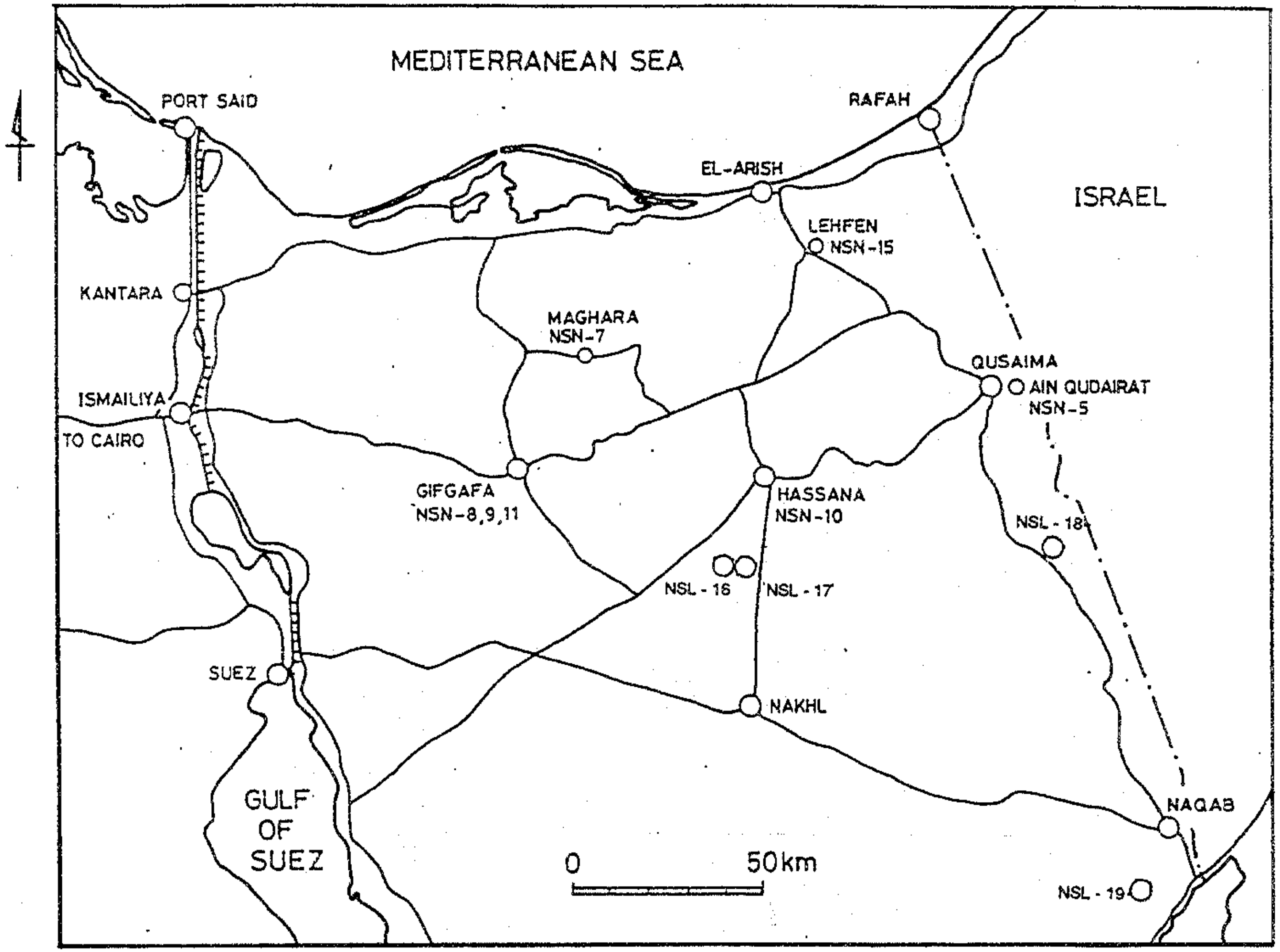


FIG. 6-4-1 LOCATION OF DATING SAMPLES

Table 6-4-1 Pre-Quaternary Groundwater Samples

Well Name	Sample No	Age of Formation
Ain Gudeirat	NSN-5	Eocene
Al-Maghara #12	NSN-7	Jurassic
El-Meleiz-1 Gifgafa	NSN-8	Lower Cretaceous
El-Meleiz-2 Gifgafa	NSN-9	Lower Cretaceous
P4 El-Hasana	NSN-10	Upper Cretaceous
P1 Gifgafa	NSN-11	Upper Cretaceous
J No. 16 El-Bruk-1	NSN-16	Lower Cretaceous
J No. 17 El-Bruk-2	NSN-17	Upper Cretaceous
J No. 19 Arif El-Naga	NSN-18	Lower Cretaceous
Sheira-1	NSN-19	Lower Cretaceous

Except the sample No. NSN-7, the tritium contents of samples are relatively low which suggests that the groundwater of these aquifers were recharged during the time much before thermo-nuclear tests. The high tritium content of No. NSN-7 may have been caused by the mixing of the modern water used by the drilling work (Table 6-4-1).

Table 6-4-2

Isotopic Analyses of Pre-Quaternary Aquifer Groundwaters

Sample I.D. and Sampling date	Tritium (T.U.)	C-14 (pmC)	$\delta^{13}C$ (%)	$\delta^{18}O$ (%)	δD (%)
NSN-5 Ain Gudeirat 89/11/18	< 0.95	9.4 ± 0.6	- 7.4	- 6.14	- 29.1
NSN-7 Al-Maghara#12 89/11/19	6.7 ± 0.5*	1.65 ± 0.37	- 3.5	- 5.39	- 29.7
NSN-8 Al-Maleiz-1 89/11/26	< 0.95	2.09 ± 0.37	- 7.0	-5.33	- 32.5
NSN-9 Al-Maleiz-2 89/11/27	< 0.96	3.32 ± 0.34	- 7.1	- 4.85	- 28.6
NSN-10 Hasana UNICEF 89/12/8	< 0.95	-	-	- 7.45	- 50.7
NSN-11 Gifgafa UNICEF 89/12/10	< 0.98	-	-	- 6.13	- 40.6

* Jebel El-Maghara Rural Development Project
Progress Report No. 6, 1989

Units

Pmc : Percentage of Modern Carbon

T.U. : Tritium Unit 1 T.U. $\left(\begin{array}{l} = 10^{-18}\ T/H \\ = 3.2\ pCi/liter \end{array} \right)$

According to the results of carbon-14 analysis, water from the Ain Gudeirat spring is the youngest of the samples tested. Most of the dated ages fall in a range between 20,000Y. BP and 30,000Y. BP. This range lies within the Würm glacial period (Table 6-4-2).

Table 6-4-3 Water Ages According to ^{14}C Content

Well Name	Age (Y.BP)	Aquifer	Laboratory Ref. No.
Ain Gudeirat	14.100 ± 520	Eocene	Gak-14806
Al Maghara #12	28,620 ± 1,880	Jurassic	Gak-14807
El Meleiz-1	29,960 ± 1,680	Lower Cretaceous	Gak-14808
El Meleiz-2	22,790 ± 870	Lower Cretaceous	Gak-14809
JNo. 16 El-Bruk-1	29,690 ± 1,190	Lower Cretaceous	Gak-15769
JNo. 17 El-Bruk-2	22,620 ± 1,050	Cenomanian	Gak-15949
JNo. 19 Arif El-Naga	>34,780	Lower Cretaceous	Gak-16033
Sheira-1	22,350 ± 2,160	Lower Cretaceous	Gak-16032

Datings of groundwater in the aquifers of the Pre-Quaternary were also made by other authors and summarized by Issar et al, 1981, as shown in Table 6-4-4, for reference.

Table 6-4-4
Water Ages According to ^{14}C Content, Compiled by Issar et al., 1981

No.	Name	Depth	Age(Y.BP.)	Remarks
1	Tamar 3*	76 m	14,900 ± 600	Waters of mixed origin
2	Tamar 3*	400 m	28,500 ± 350	Water of N.S. aquifer
3	Yotvata 2*	50 m	13,200 ± 600	Water of Mixed origin
4	Makhtesh Qatan 3*	763 m	22,000 ± 1,000	Water of N.S. aquifer
5	Nakhel 3**	800 m	19,900 ± 3,000	Water of N.S. aquifer
6	Ayun Musa **	spring	> 30,900	Water mainly of N.S.

* Carmi et al. 1971.

** Kaufman, 1971.

*** Ehhalt, 1963, and Münnich and Vogel, 1962.

N.S. : Nubian Sandstone

The present results of carbon dating show satisfactory consistency with the results by other authors; therefore, most of groundwater in the Pre-Quaternary can be said to have been recharged in the geological past and an influence from the current hydrological phenomena is assumed to be insignificant.

7. OCCURRENCE OF AQUIFER

7 OCCURRENCE OF AQUIFER

7-1 Introduction

Existing well data indicate that there are different types of aquifers in the study area. A large extension of the Quaternary is identified through the study which most probably contain prospecting aquifers in the coastal plain from El-Arish to Sheik Zuwayid. The most promising aquifer is developed in the sandstone of the Lower Cretaceous distributing over most part of the study area. The limestone in the Tertiary and the Lower Cretaceous also contain promising aquifers depending on the locality.

Identified aquifers through interpretarion of existing data in the previous chapters are described of the geological formation and the local conditions of aquifers.

7-2 Quaternary Aquifer

7-2-1 Introduction

The Quaternary formations distribute broadly in the study area. However, in the upstream catchment area of the Wadi El-Arish they are thin deposits and existence of productive aquifers is thought to be unlikely. Therefore, prospecting aquifers are expected along the coastal plain.

There are three well fields in the coastal plain in the study area. One is in the northwestern part of the study area from Bir El Abd to Roamana where shallow wells are intensively utilized for irrigation. Hydrogeological investigation in this area were recently commenced by RIWR so that well survey was undertaken by the study team to locate the longitude and the latitude of these wells together with the elevation of ground level and water level of some selected wells. The other two well fields are the alluvial plain in the lower stretch of the Wadi El-Arish and the coastal plain extending from Seikh Zuwayid to Rafah.

7-2-2 Aquifer in Alluvial Plain of Wadi El-Arish

There are about 170 wells distributing in the alluvial plain of the lower stretch of the Wadi El-Arish. Of these, approximately 40 wells have their lithological profiles (Fig. 2-1-1).

Major aquifers in this well field consist of sand, gravel and kurkar. The base of the Quaternary shows a basin-like shape as shown in Fig. 7-2-1. The gradint of the bottom of the Quaternary is approximately 1/160 from the area of well No. 5-1 towards the area north of the airport. From this point to further north, the bottom of the Quaternary shows a steeper gradient and there are two depressions in the area of wells No. 1-138 and 1-64. The elevation of the bottoms of these depression are -70 m and -80 m asl, respectively. Thickness of the Quaternary deposits in this area is approximately 100 m (Fig. 7-2-2).

Distribution of aquifers along the Wadi El-Arish is shown in Fig. 7-2-3. Kurkar extends approximately 10 km from the river mouth of the Wadi El-Arish towards the south overlain by gravel. The gravel bed extends a little further south from well No. 5-5 and is replaced by the Quaternary deposits consisting of silt, sand and gravel in the south at well J No. 18. At this point there is a gravel bed overlying shale. The age of this bed is assumed to be of Pre-Quaternary. The elevation of the kurkar's top surface is below sea level (Fig. 7-2-3).

Kurkar is one of the major aquifers in the Quaternary in the area. To figure out a general feature of distribution of kurkar this well field was covered by a 1 km^2 mesh. The thickest kurkar was found at grid No. 6-4 which coincides with the location of one of the subsurface depressions of the base of the Quaternary. Kurkar thickness ranges between 25 m and 50 m in the northern part of the plain. Kurakar is either missing or very thin in the southern part of the airport and in the area on the western side of El-Arish (Fig. 7-2-4).

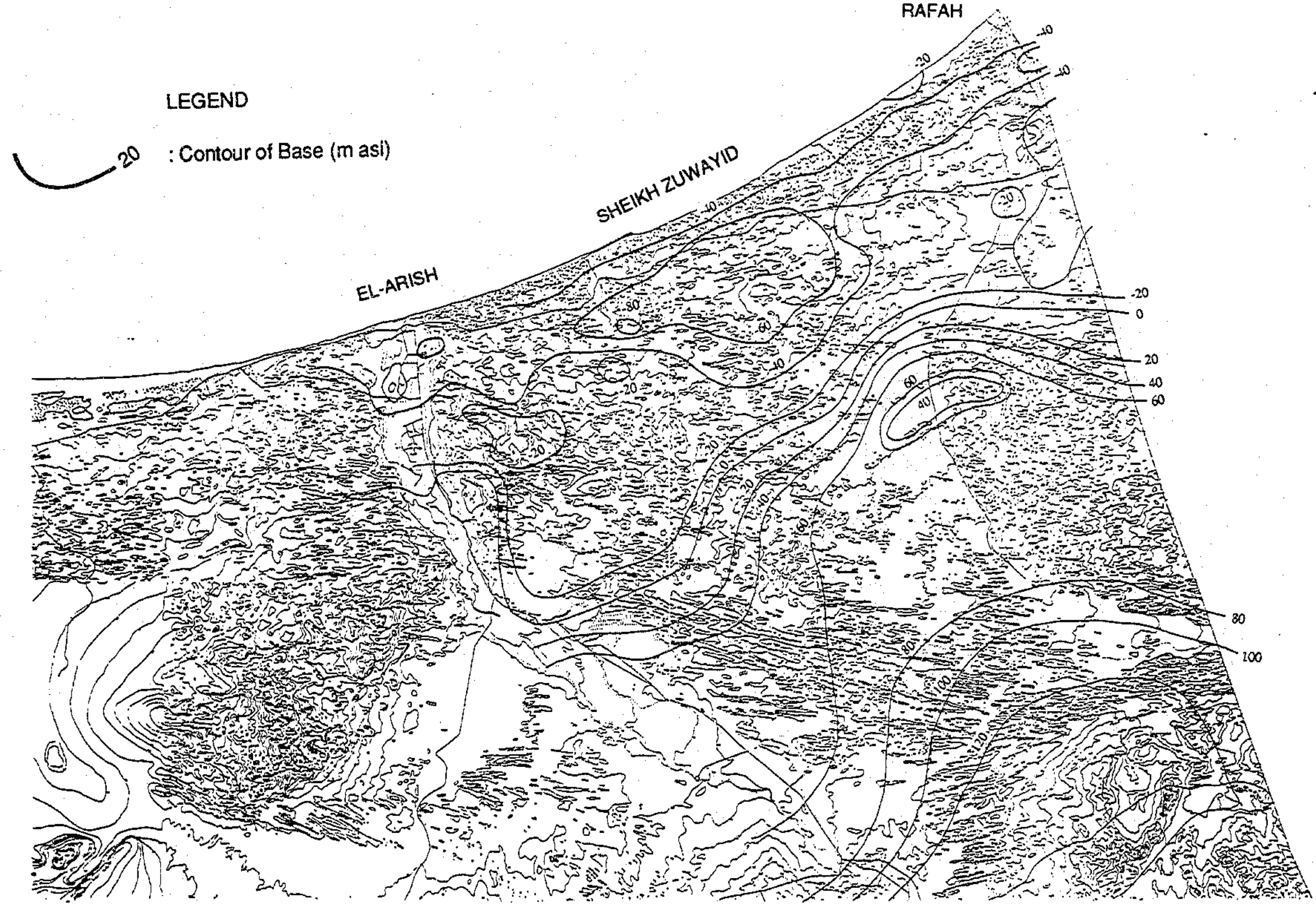


FIG. 7-2-1 BASE OF QUATERNARY

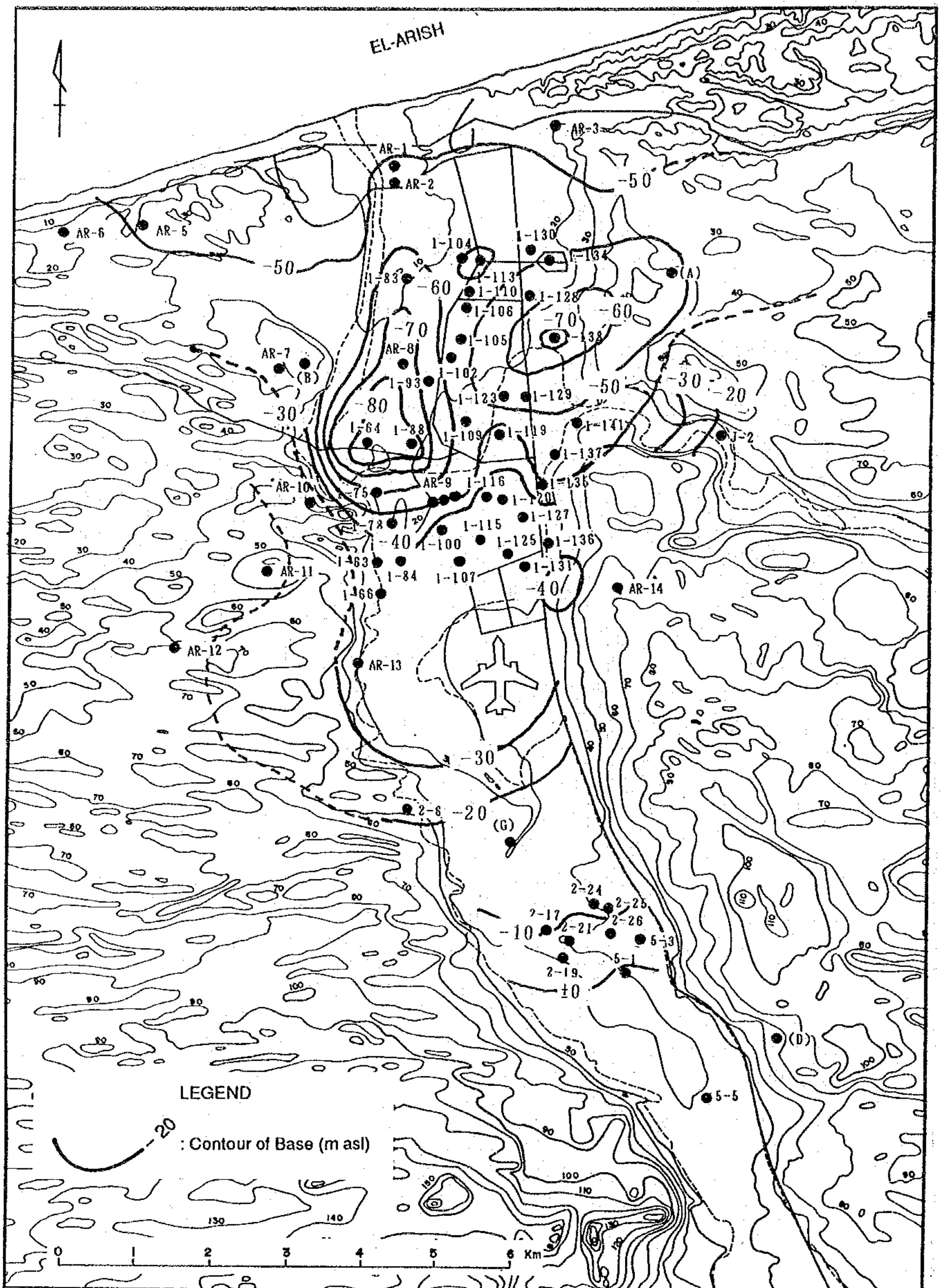


FIG. 7-2-2 BASE OF QUATERNARY IN EL - ALISH AREA

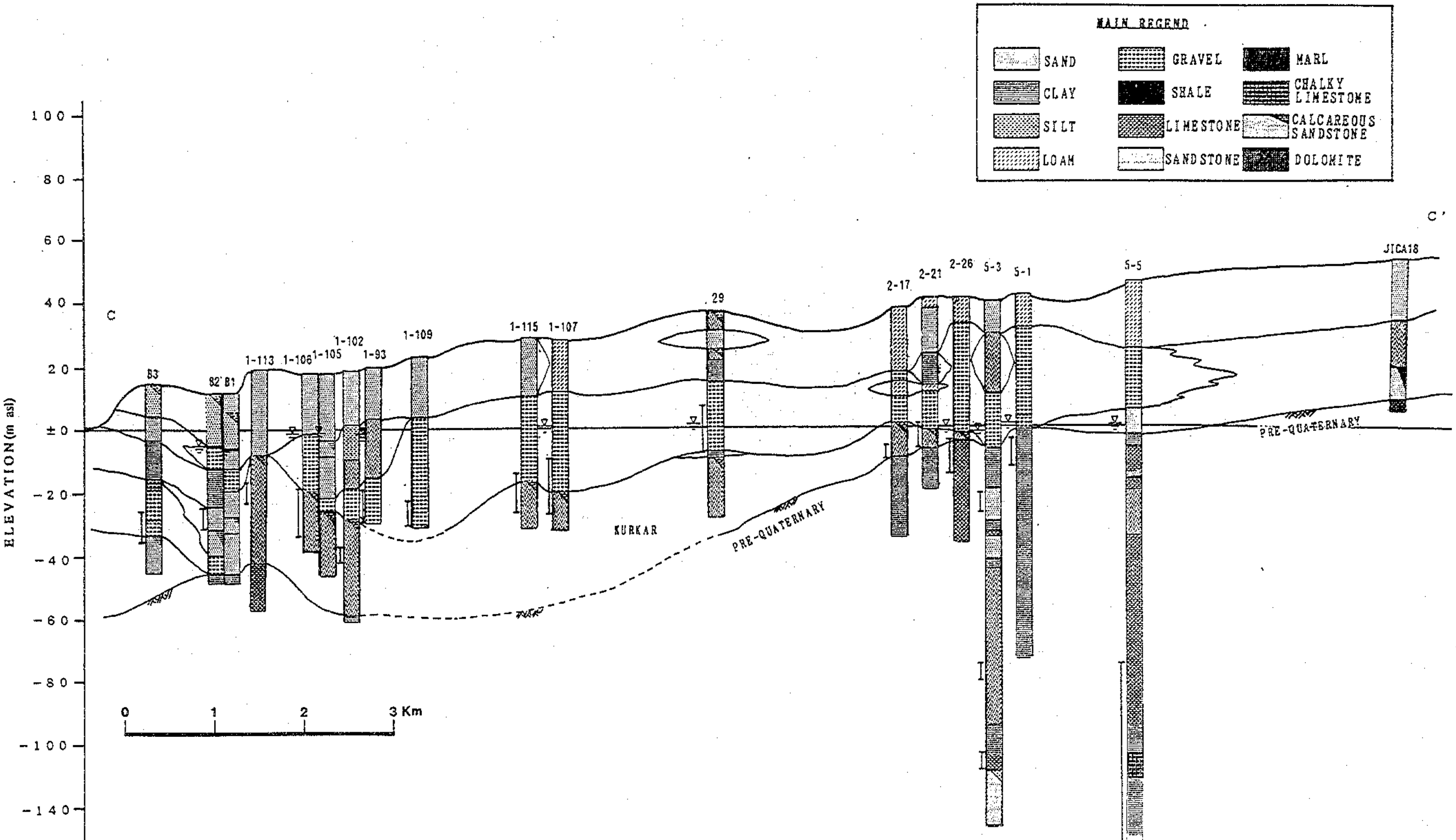


FIG. 7-2-3 GEOLOGICAL SECTION OF NORTHERN PLAIN IN THE SINAI PENINSULA (C-C')