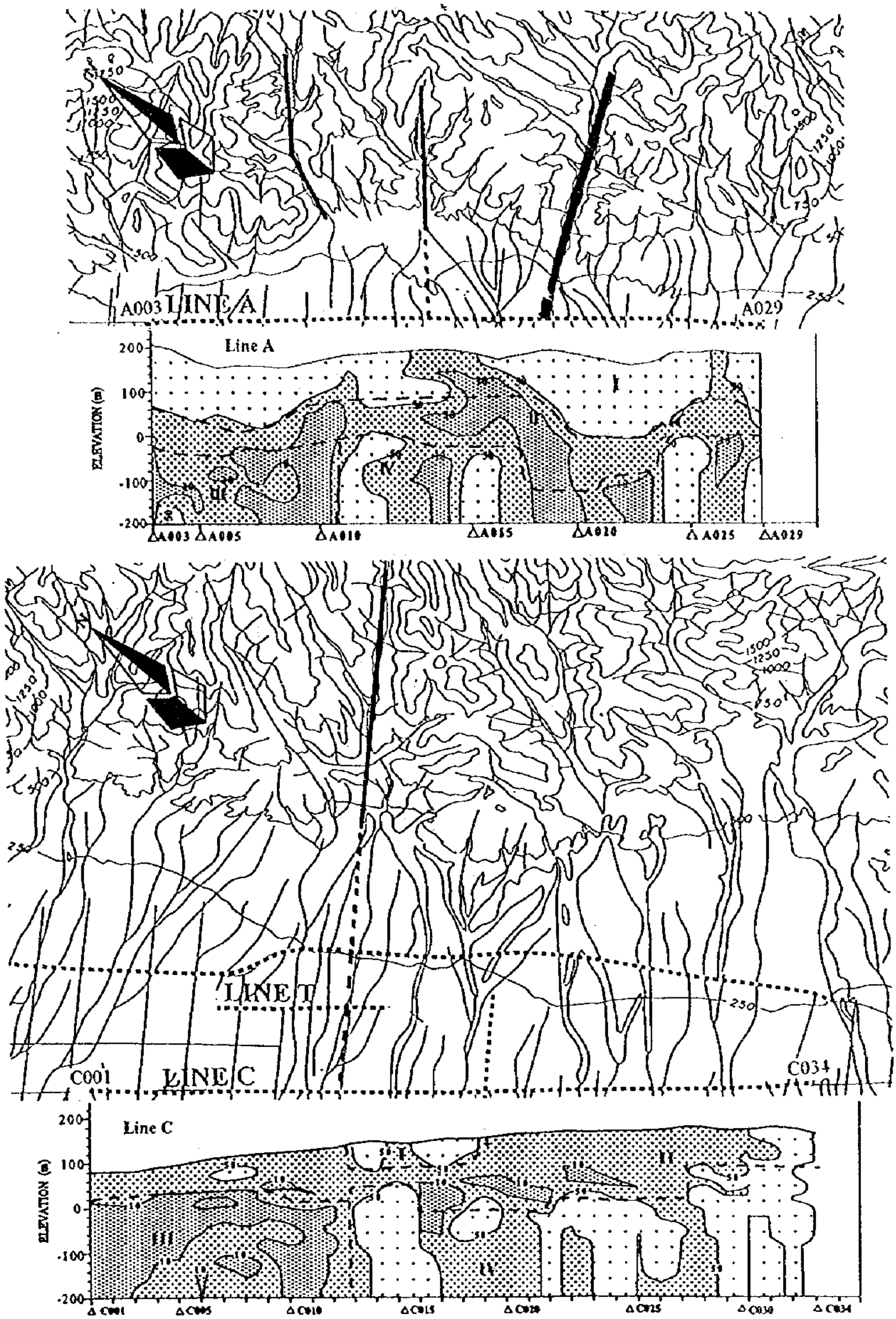

Fig. 3.3-4 (1) Geoelectric Profile in El Qaa Plain (Line A and C)

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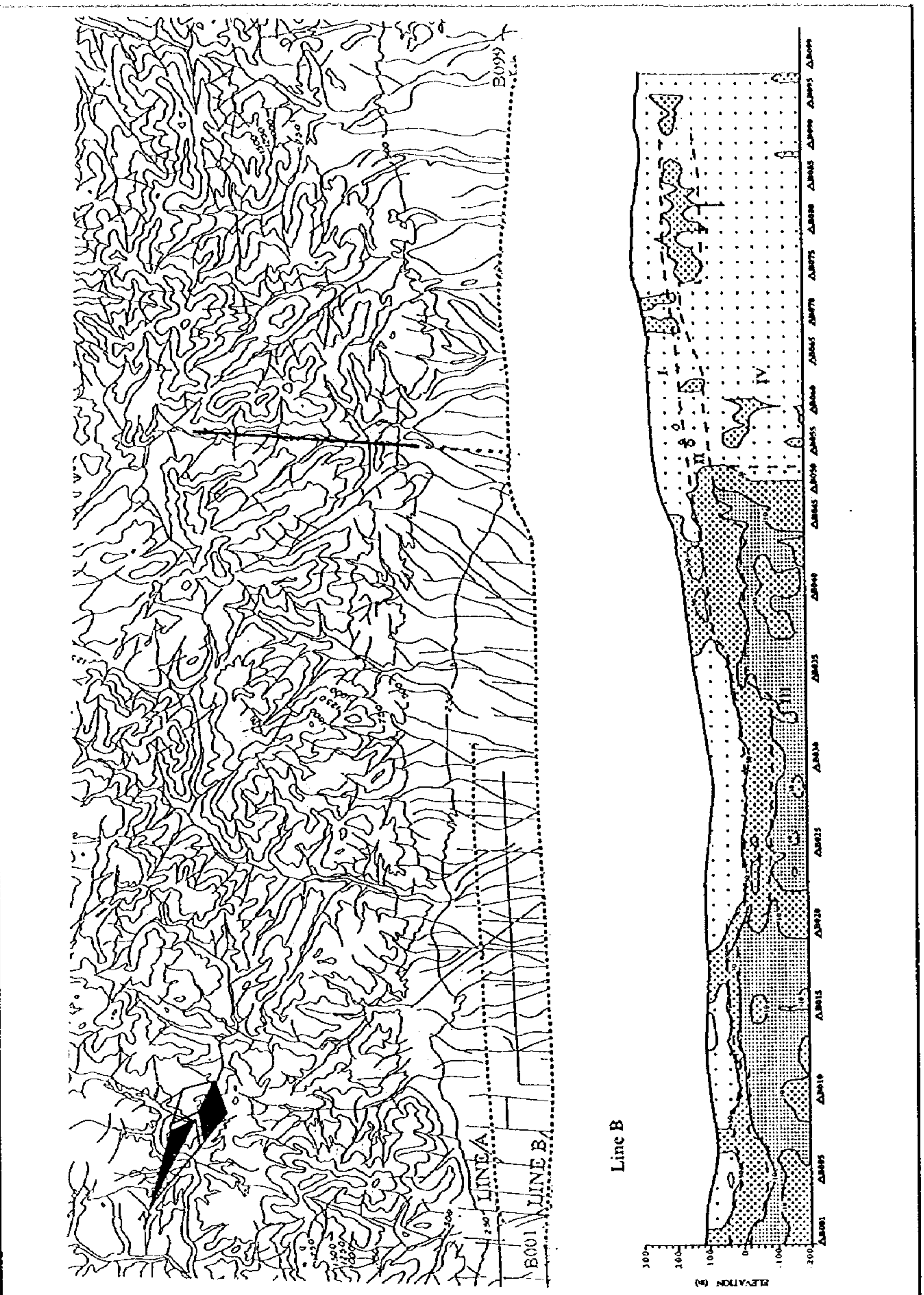

Fig. 3.3-4 (2) Geoelectric Profile in El Qaa Plain (Line B)

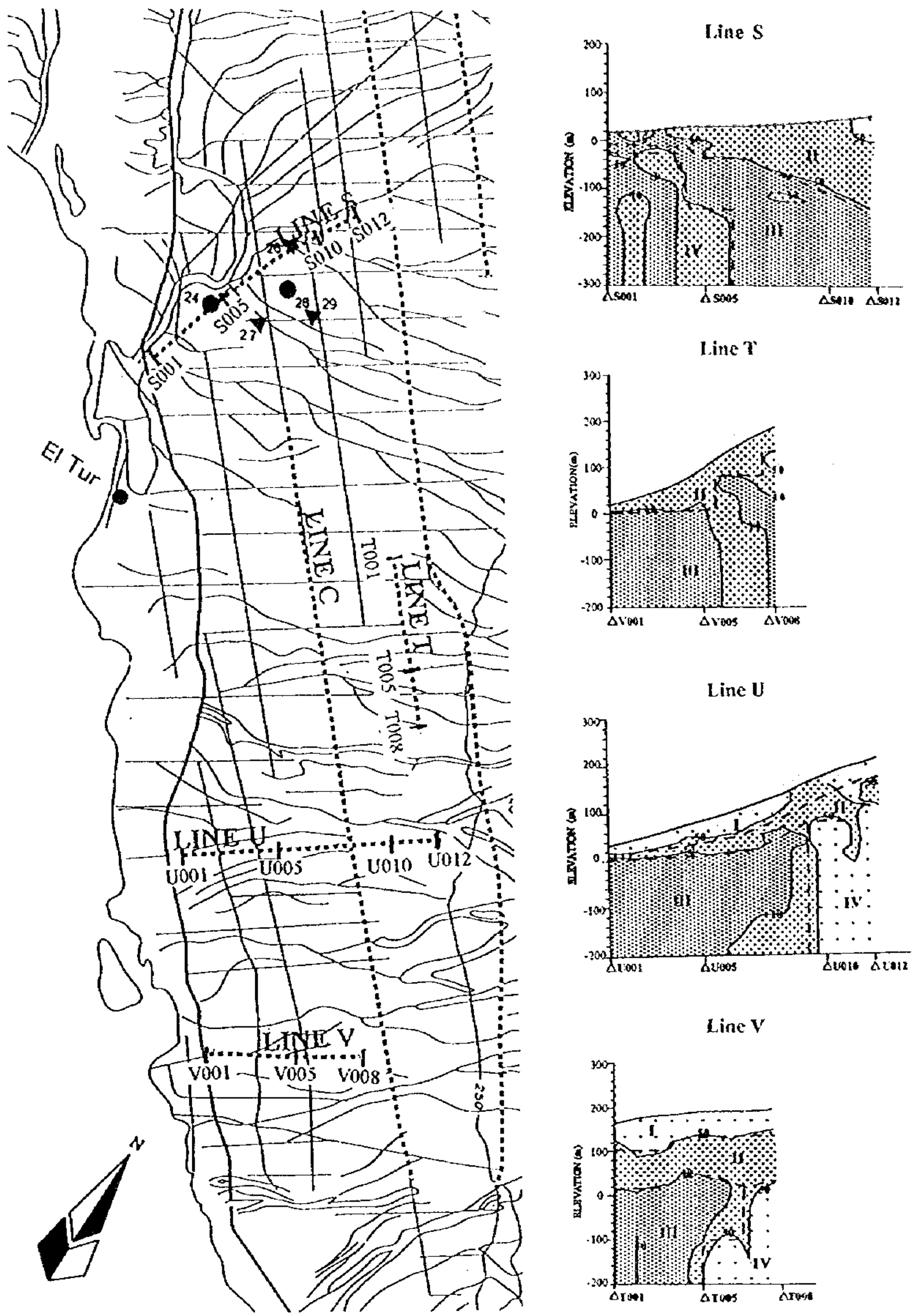

Fig. 3.3-4 (3) Geoelectric Profile in El Qaa Plain (Line S, T, U and V)

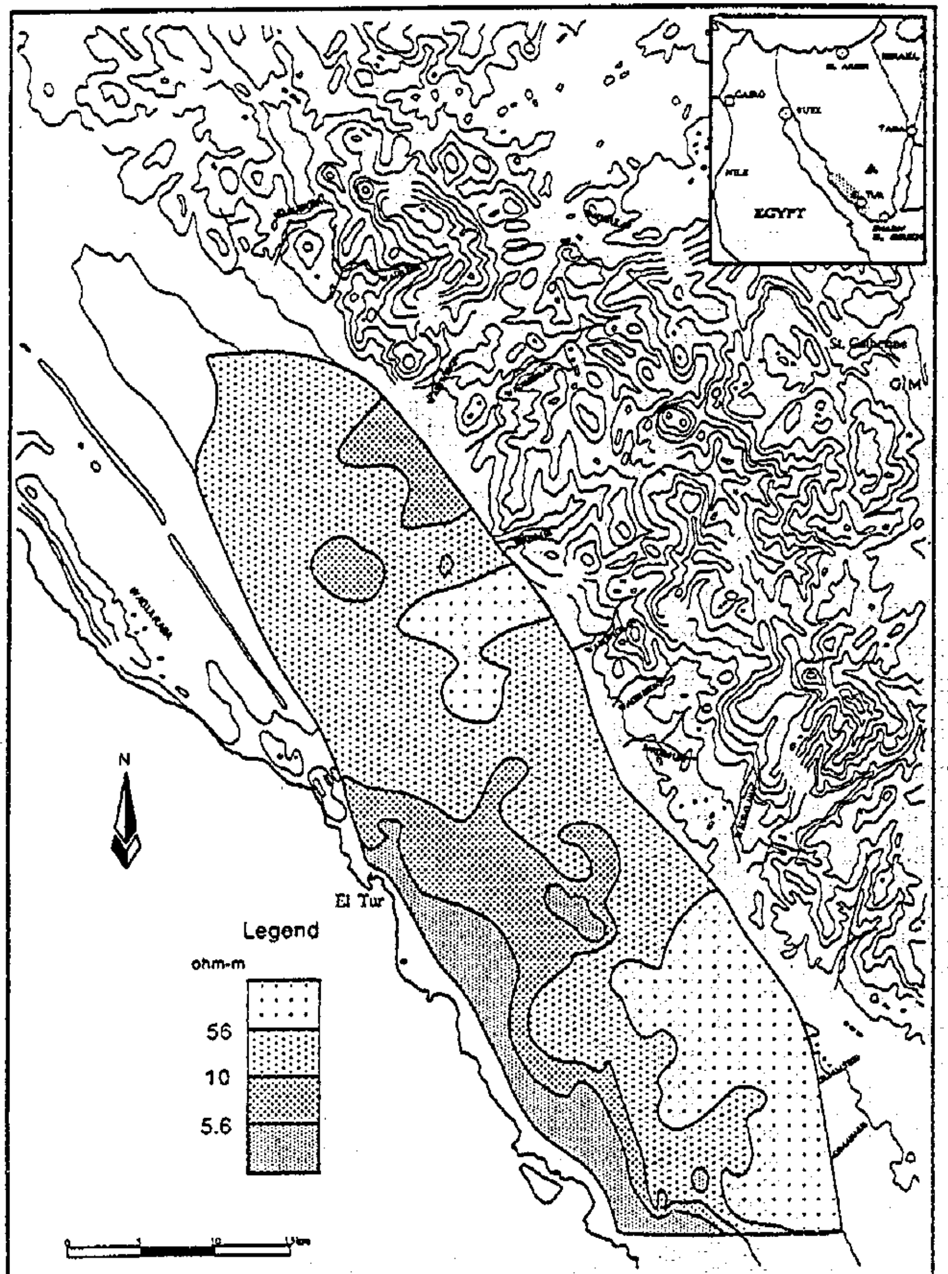

Fig. 3.3-4 (4) Horizontal Resistivity Profile in El Qaa Plain (0 m A.S.L)

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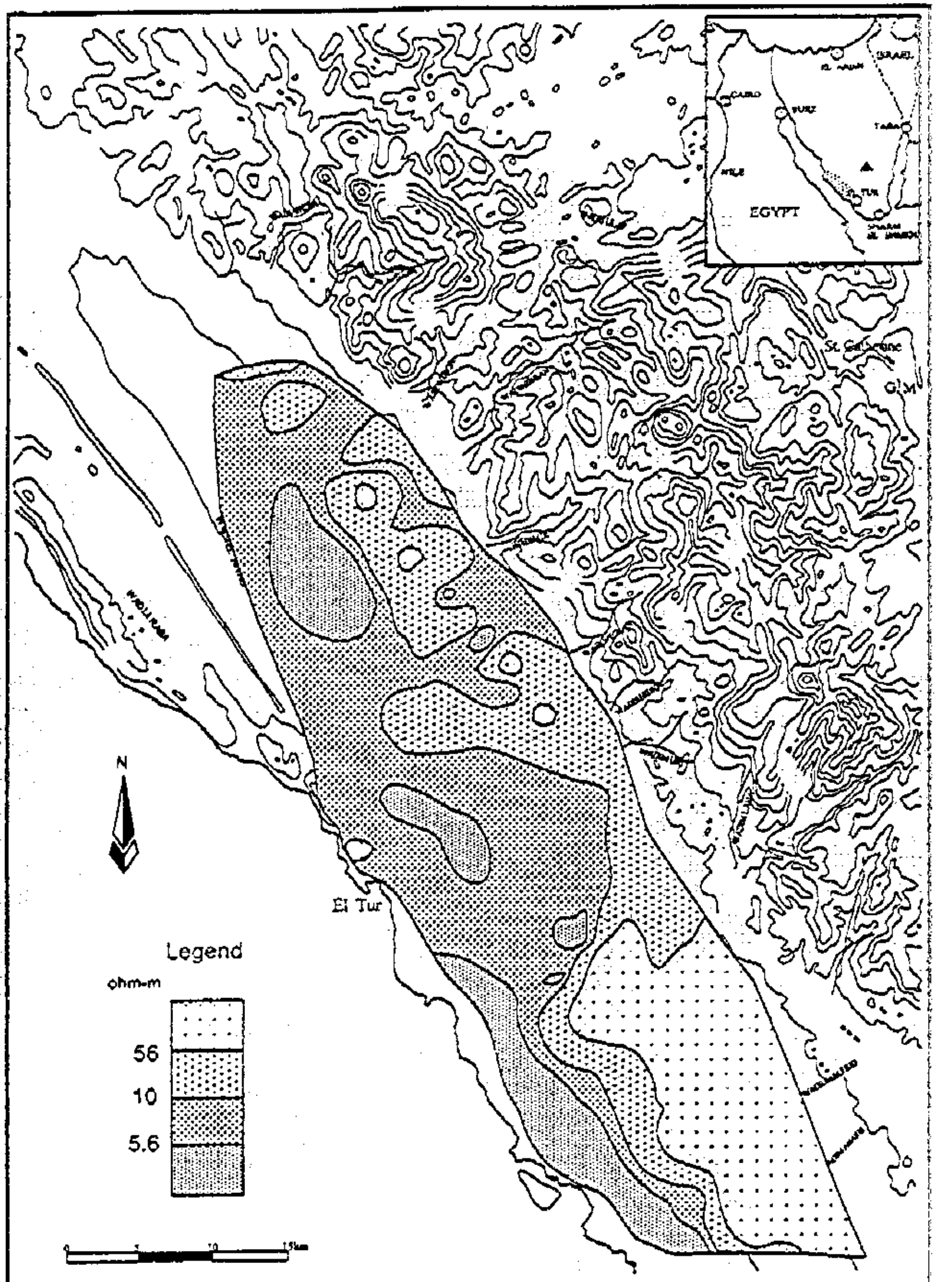

Fig. 3.3-4 (5) Horizontal Resistivity Profile in El Qaa Plain (-100 m A.S.L)

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SOUTH SINAI GROUNDWATER RESOURCES STUDY

LOG OF WELL JICA J-7

Date of Completed :
Drilling Depth : 250m
Lat : N28,08,29
Long : E35,52,18
Water Level :

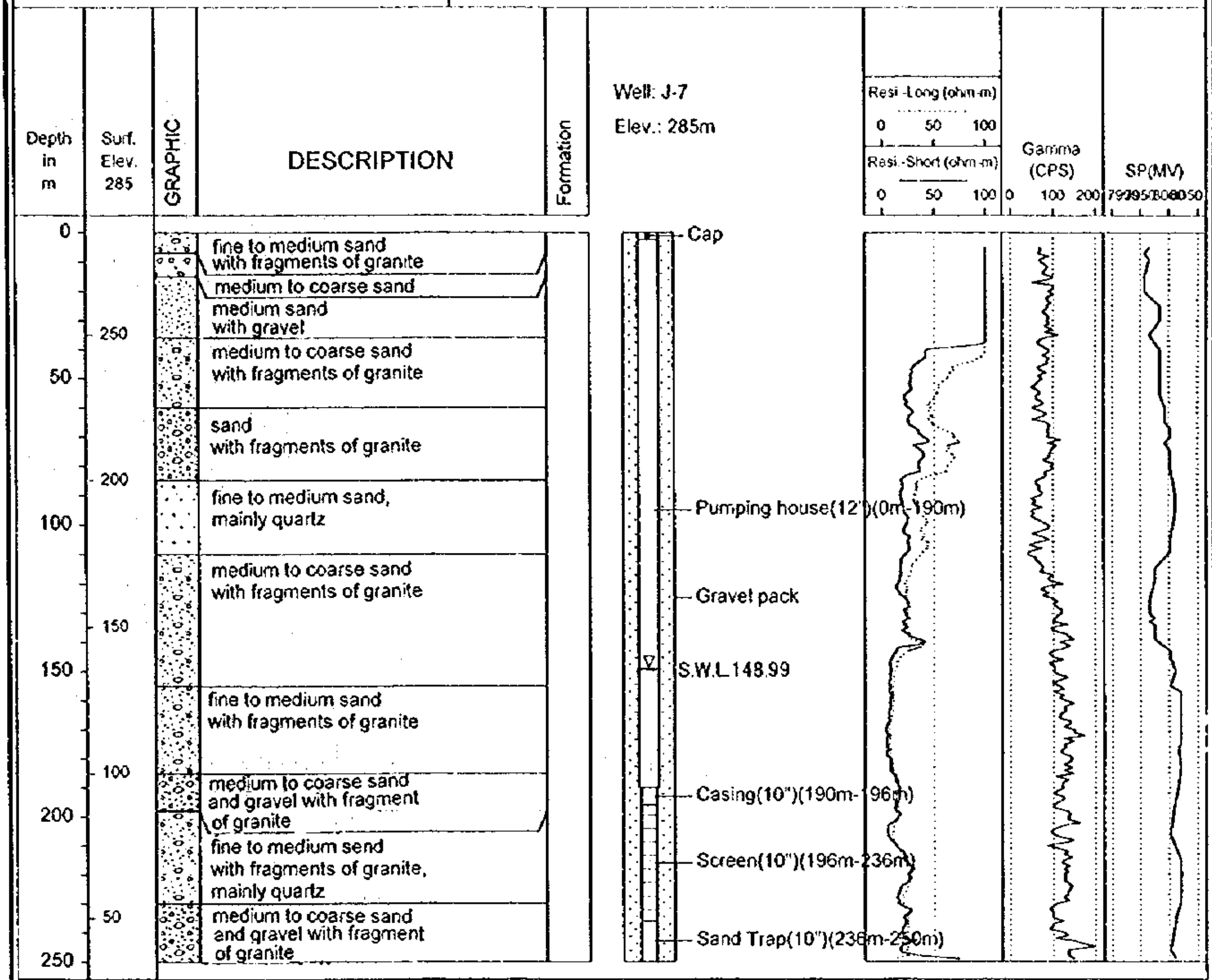

Fig. 3.3-5 Drilling Log of Test Well (J-7)

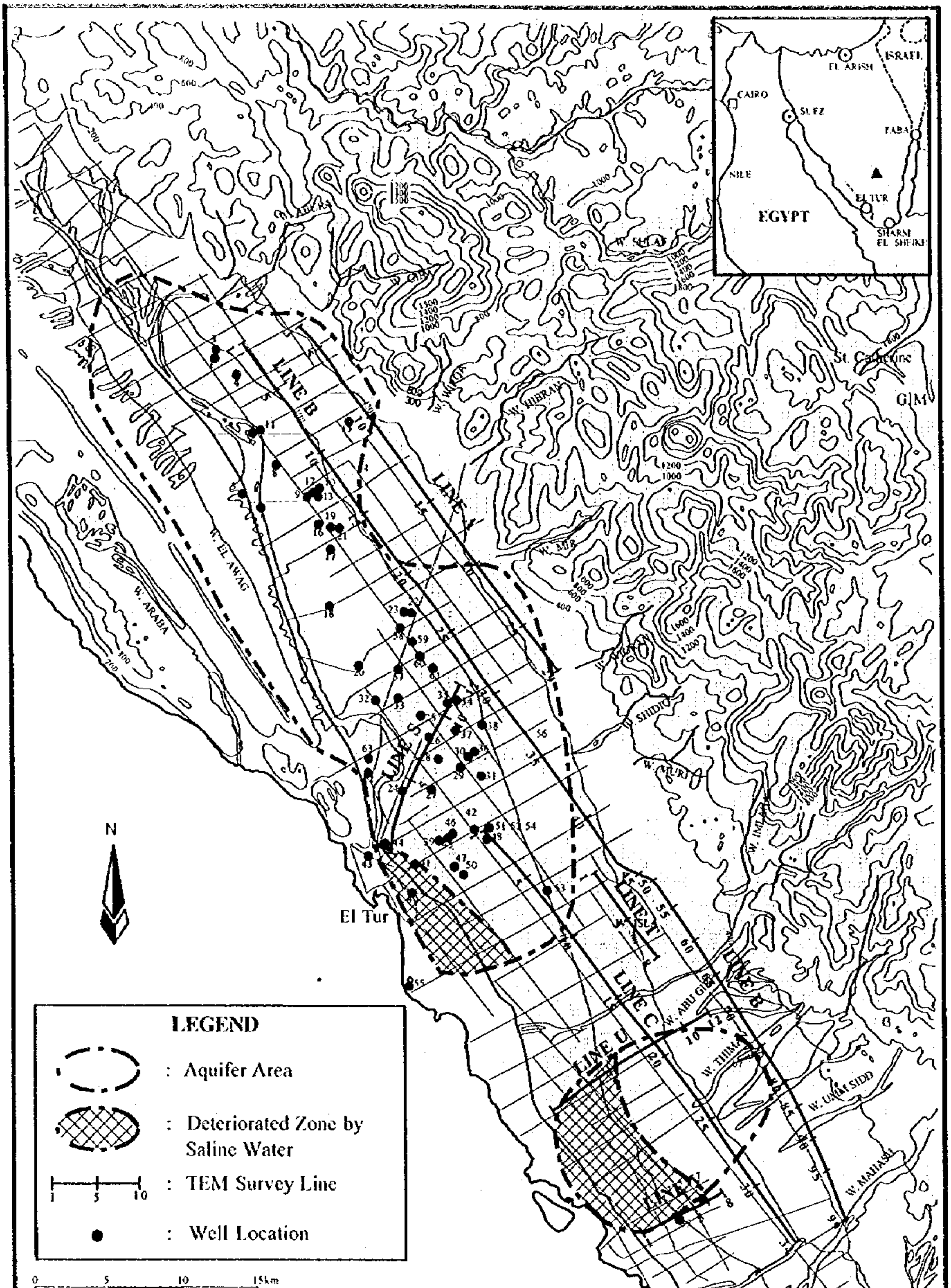

Fig. 3.3-6 Aquifer Area in El Qaa Plain

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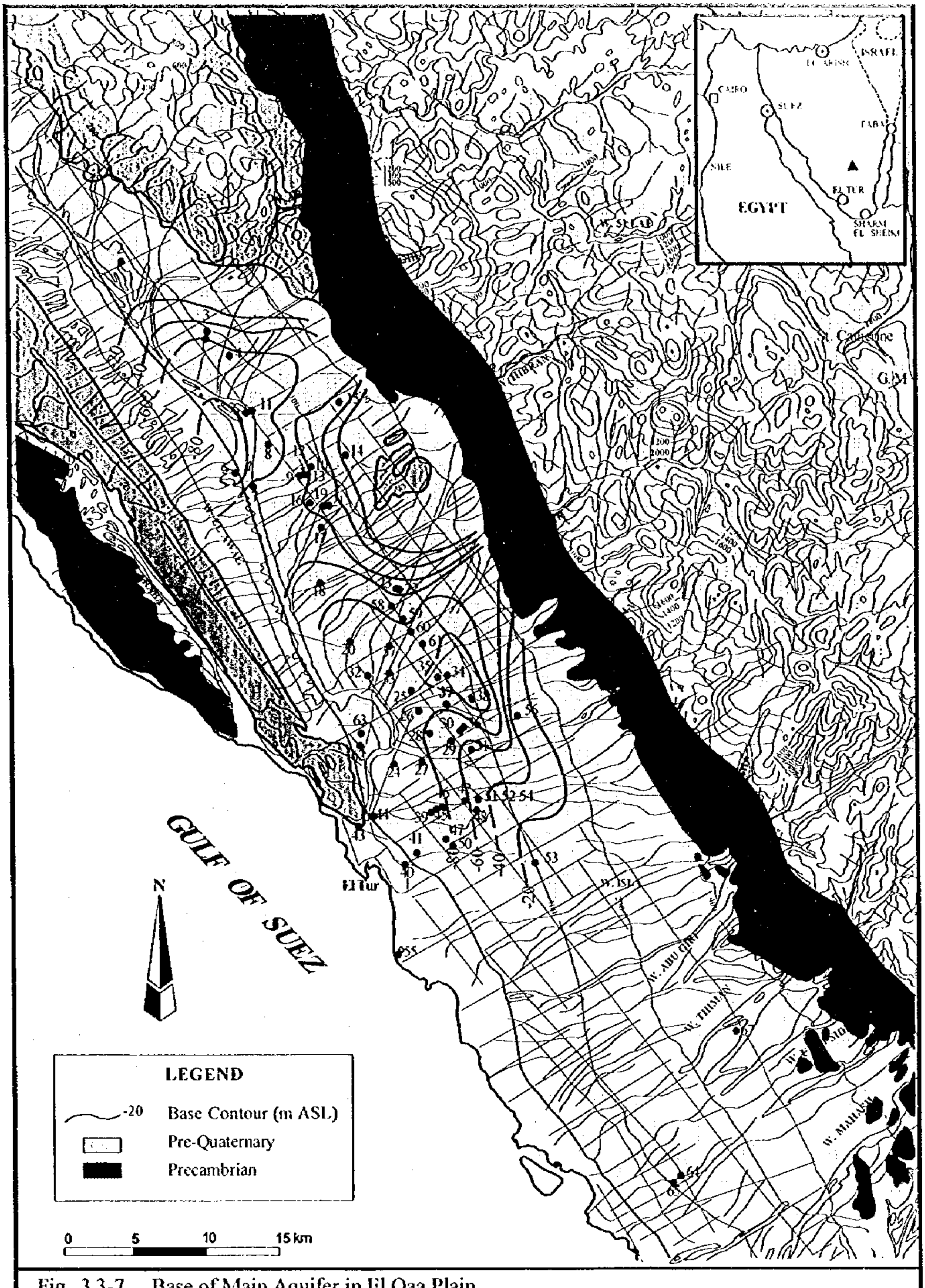

Fig. 3.3-7 Base of Main Aquifer in El Qaa Plain

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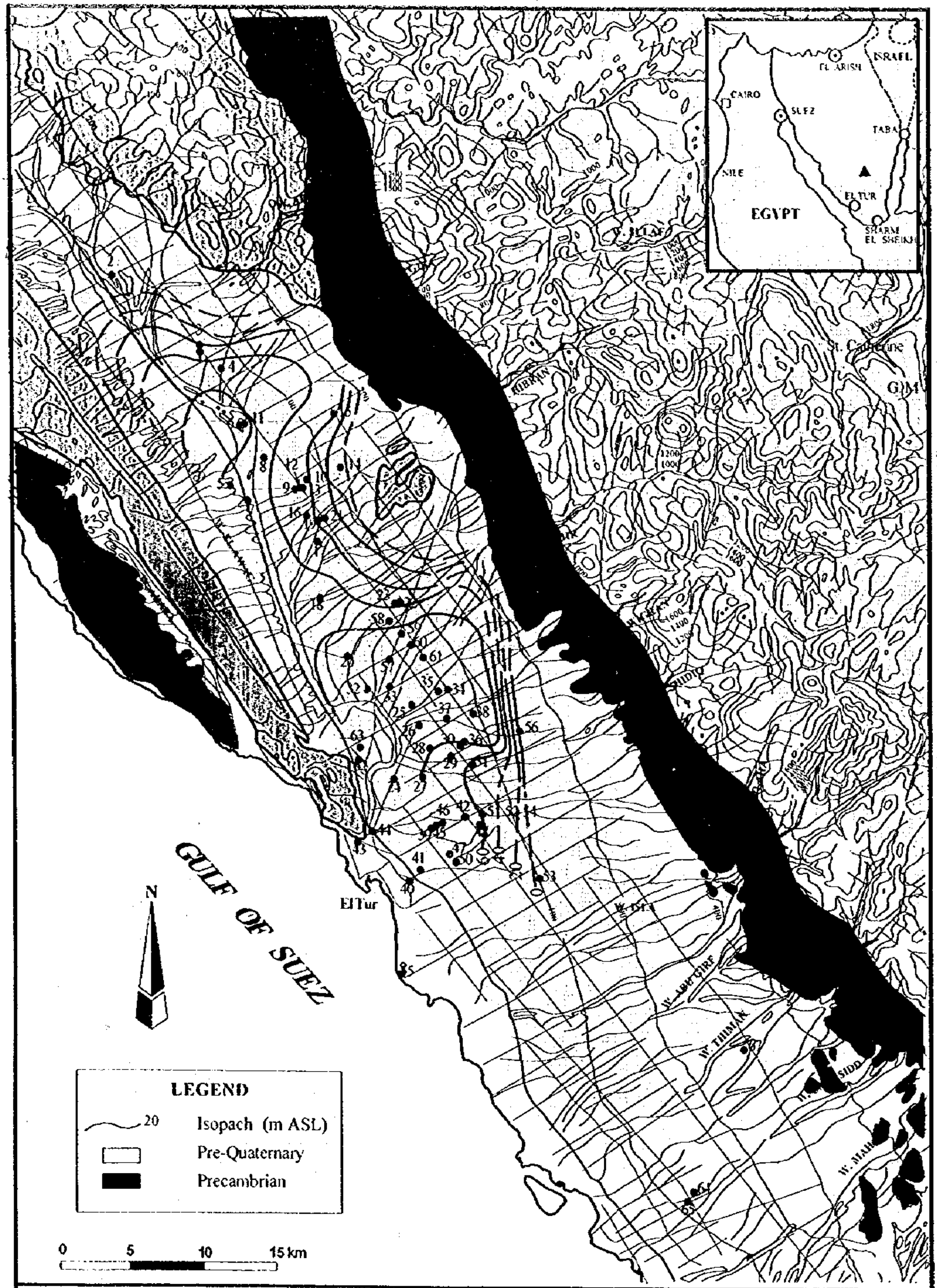

Fig. 3.3-8 Isopach Map of Main Aquifer in El Qaa Plain

SOUTH SINAI GROUNDWATER RESOURCES STUDY IN THE ARAB REPUBLIC OF EGYPT | JICA

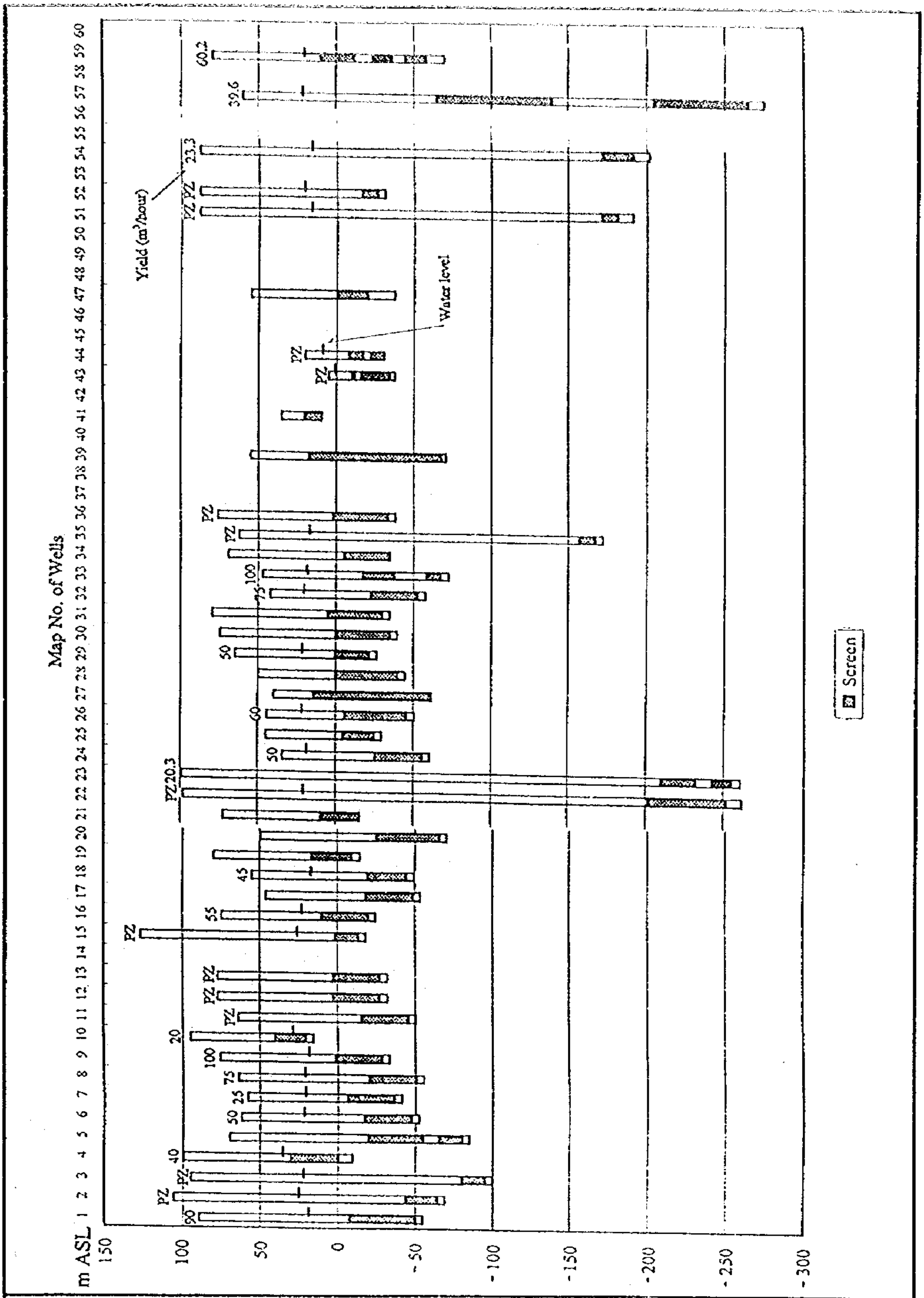

Fig. 3.3-9 Static Water Level and Range of Screen in El Qaa Plain

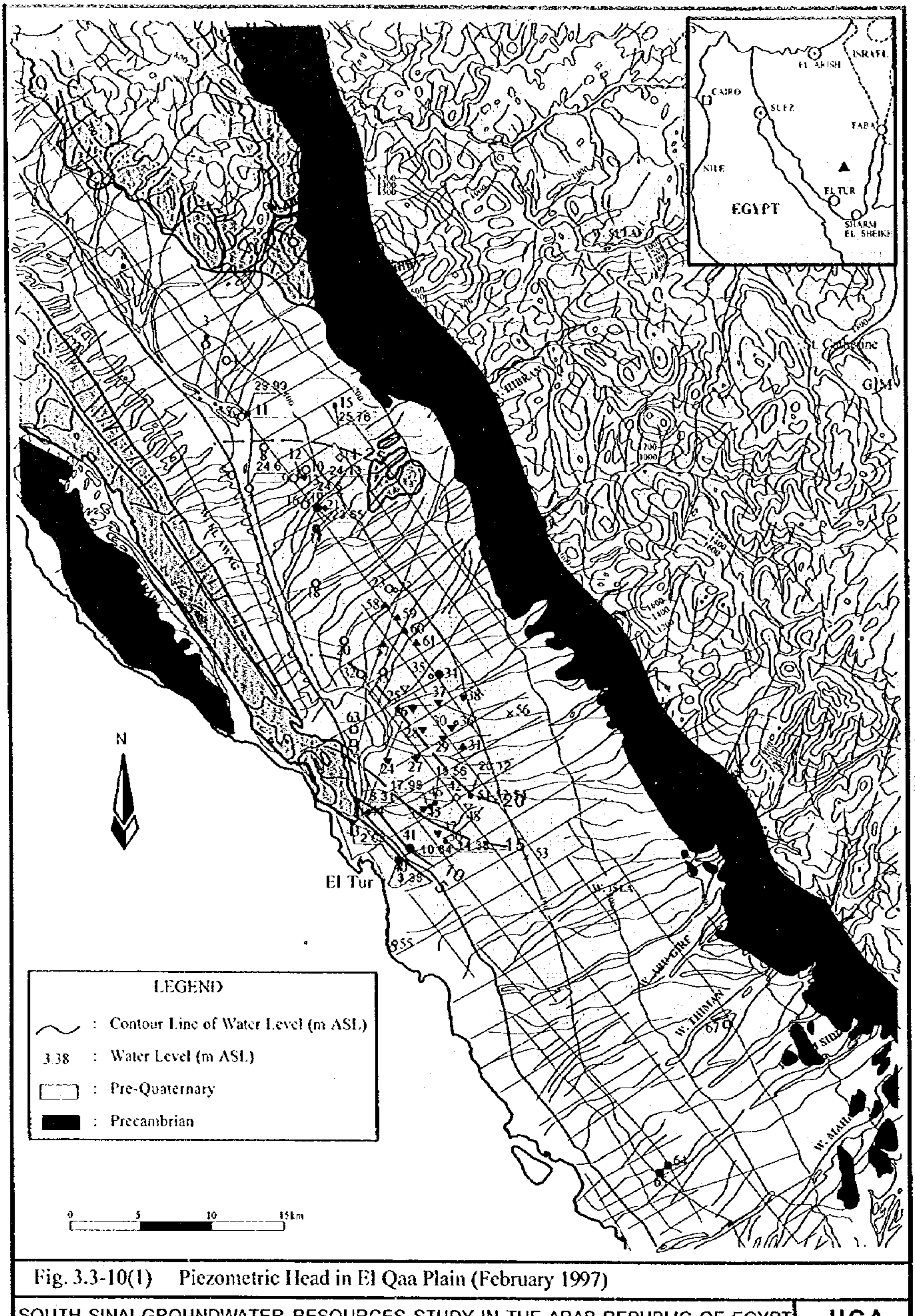

Fig. 3.3-10(1) Piezometric Head in El Qaa Plain (February 1997)

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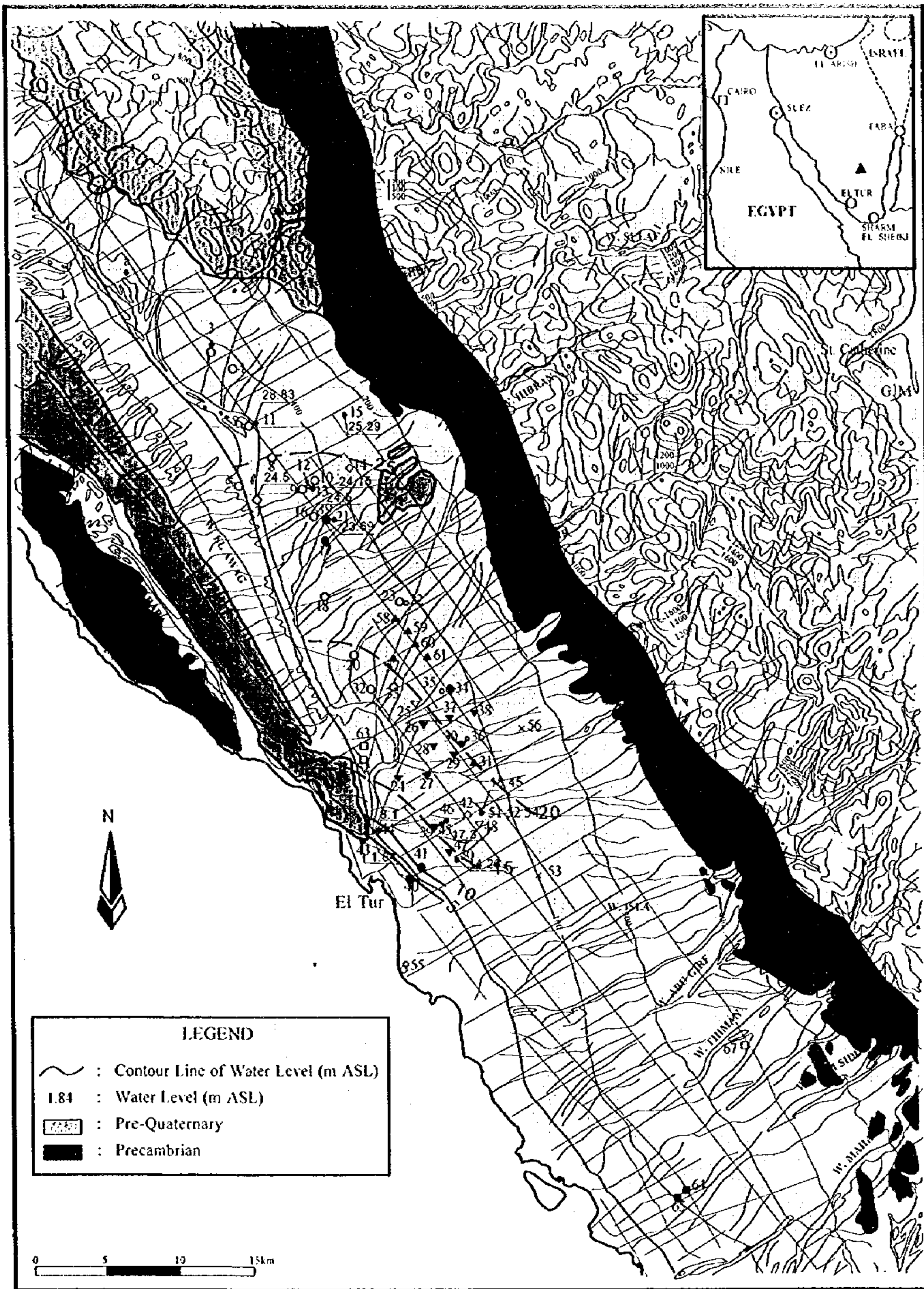

Fig. 3.3-10(2) Piezometric Head in El Qaa Plain (September 1997)

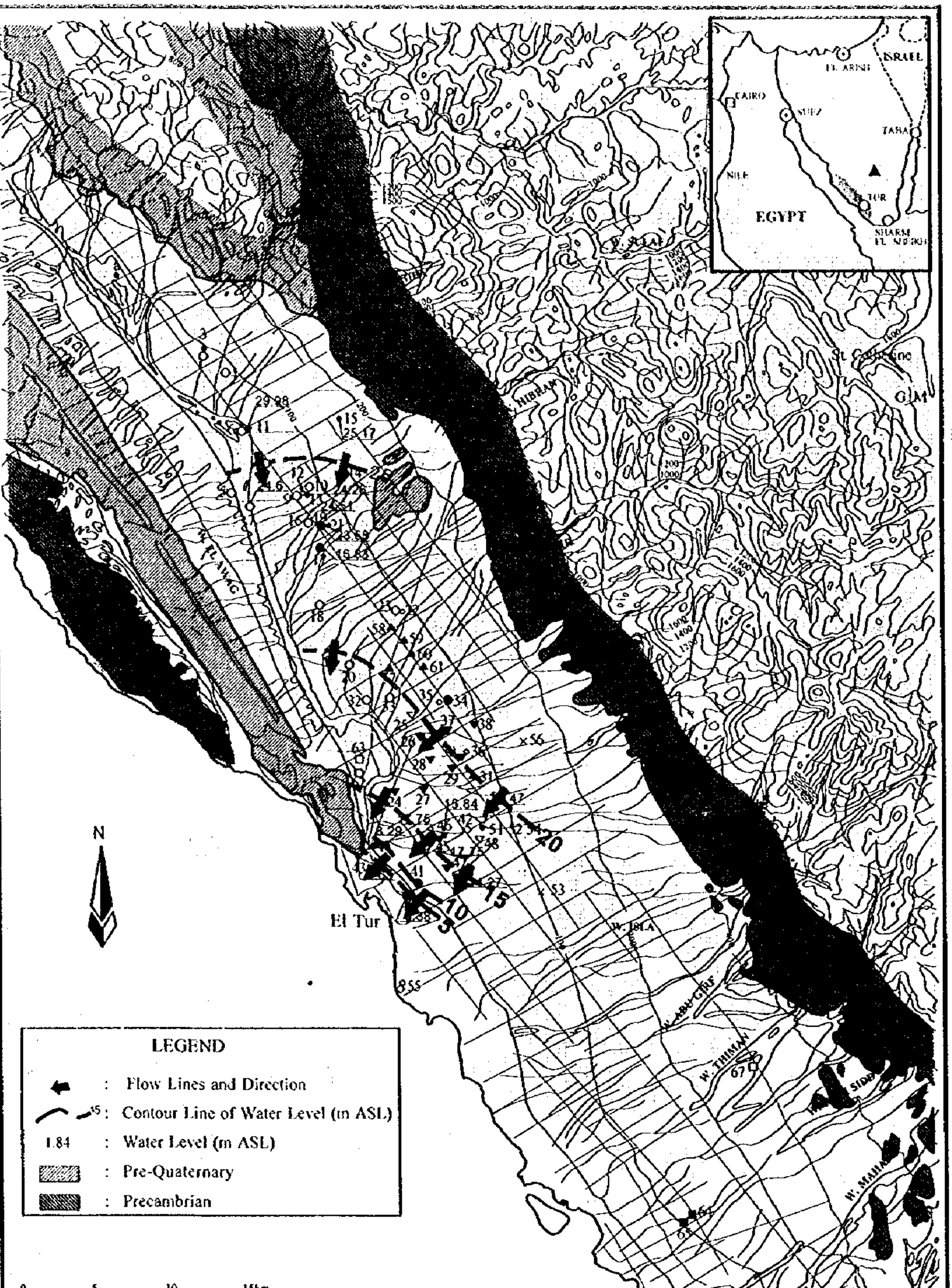

Fig. 3.3-11 Groundwater Flow in El Qaa Plain

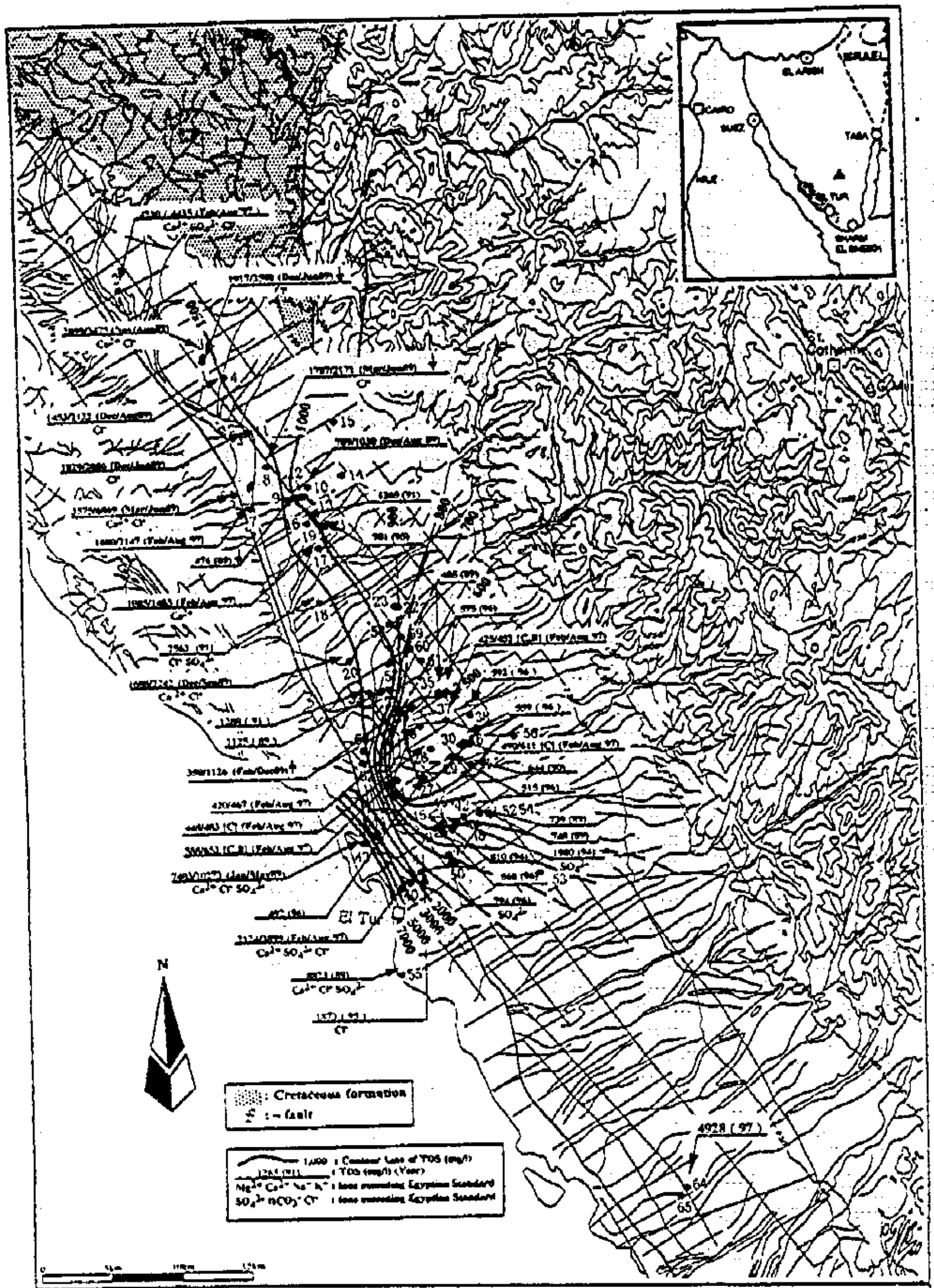

Fig. 3.3-12 (1) Groundwater Quality in Winter (El Qaa Plain)

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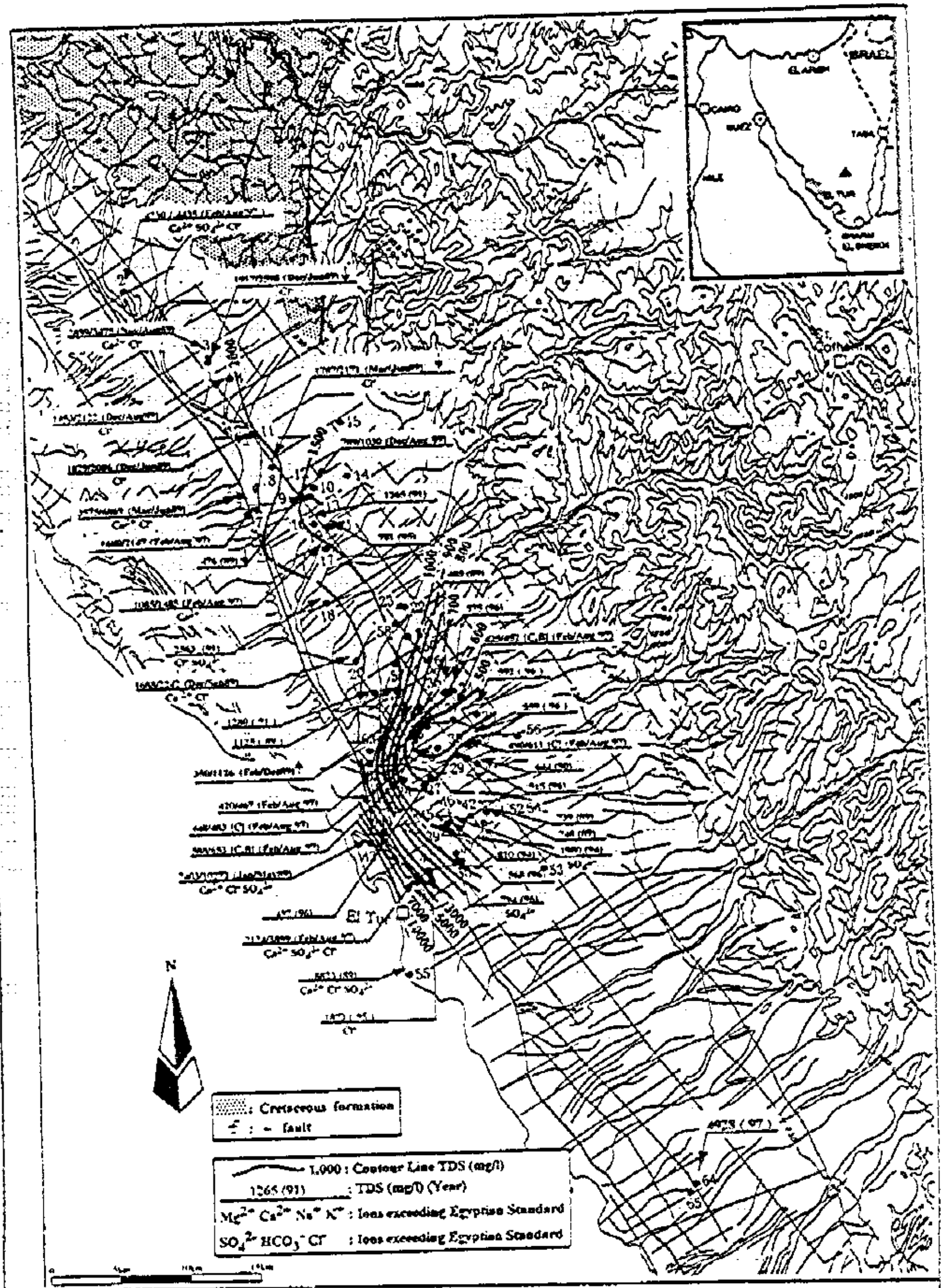

Fig. 3.3-12 (2) Groundwater Quality in Summer (El Qaa Plain)

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3.3.2 Coastal Plain

Main coastal plains are formed in Ras Sudr and Nuweiba. Their locations are shown in Fig. 3.3-1. In both areas, groundwater has been extracted for domestic and irrigation use.

1) Ras Sudr Coastal Plain

Ras Sudr Coastal Plain was formed by the Wadi Sudr facing to the Gulf of Suez. Agricultural farms are wide spread on the coastal plain. This area is also one of the oil fields in Sinai. In addition, new development of tourism is going on, spreading the area to the north and south.

Groundwater is extracted by 35 dug wells for private sector. Their inventory and locations are shown in Table 3.2-6 and Fig. 3.2-6, respectively. The well field distributes in front of the outlet of the Wadi Sudr. The shape of the well field is like an oval elongated in N-S direction.

Static water level in this area is generally less than 4 mASL as shown in Fig. 3.3-13. The contour line of water level (mASL) is also drawn in the figure. It reveals that groundwater gently flows from east to west with slight gradient, while depth to water level gradually increases to east.

TDS is shown in Fig. 3.3-14 and it is in a range between 2,450 and 7,624 mg/l. All the TDS values are over the Drinking Water Standard. In addition, Cl^-, SO_4^{2-} and Ca^{2+} contents are over the standard in most wells.

Contour line of the static water level and TDS show that groundwater flows into the coastal plain from the Wadi Sudr (Refer, Fig. 3.3-13 and 3.3-14, respectively).

Only one (1) well's data is available for water type as shown below.

Sr. No	Code No.	Name	Aquifer	Winter (Feb. 1997)		Summer (Aug. 1997)	
				Water Type	TDS	Water Type	TDS
14	25BC-009	A. K. Khamis	Quaternary	$MgSO_4$	4360	NaCl	4565

Water type is $MgSO_4$ in winter and changes to NaCl in summer.

2) Nuweiba Coastal Plain

As shown in Fig. 3.3-1, Nuweiba Coastal Plain is formed in the outlets of the Wadi Watir (Fan I), small wadi (Fan II), Wadi Sadha El Samra (W. Black Samra) (Fan IIIa) and Wadi Samra El Beda (W. White Samra) (Fan IIIb) facing to the Gulf of Aqaba. The plain is composed of three (3) Fan Deposits derived from each wadi. There are Nuweiba City and agricultural farms in the plain. Nuweiba City is one of the most important tourism sites in South Sinai. Number of hotel for tourism is increasing.

Groundwater is extracted by 30 wells, consisting of 25 dug wells and five (5) cased wells. Their inventory and location are shown in Table 3.2-10 and Fig. 3.2-10, respectively. Cased well are constructed in the fanhead, while dug wells are located at the foots of the Fans. Relation between topography and well location is shown in Fig. 3.3-15.

Static water level (Refer to Fig.3.3-16), water quality (TDS, refer to Figure 3.3-17) and groundwater extraction rate are classified into following four (4) groups depending on the locations.

Well Group	SWL (mBGL)	TDS (mg/l)	Extraction (m^3/day/well)
Cased Well (Fantop of Fan I)	28.5 - 40.15	1783 - 9470	2500*
Dug Well (Northern fanfoot of Fan I)	6.68 - 14.4	1639 - 3961	20 - 80
Dug Well (Southern fanfoot of Fan I)	7.4 - 11.95	2741 - 8823	10 - 80
Dug Well (Fanfoot of fan IIIa)	2.5 - 10.24	2788 - 11790	1 - 20

* : total extraction of cased wells

In all the wells, TDS is more than the Drinking Water Standard. Further, Cl^-, SO_4^{2-} and Ca^{2+} contents are over the standard in most wells.

Total extraction rate from groundwater is approximately 3,200 m^3/day.

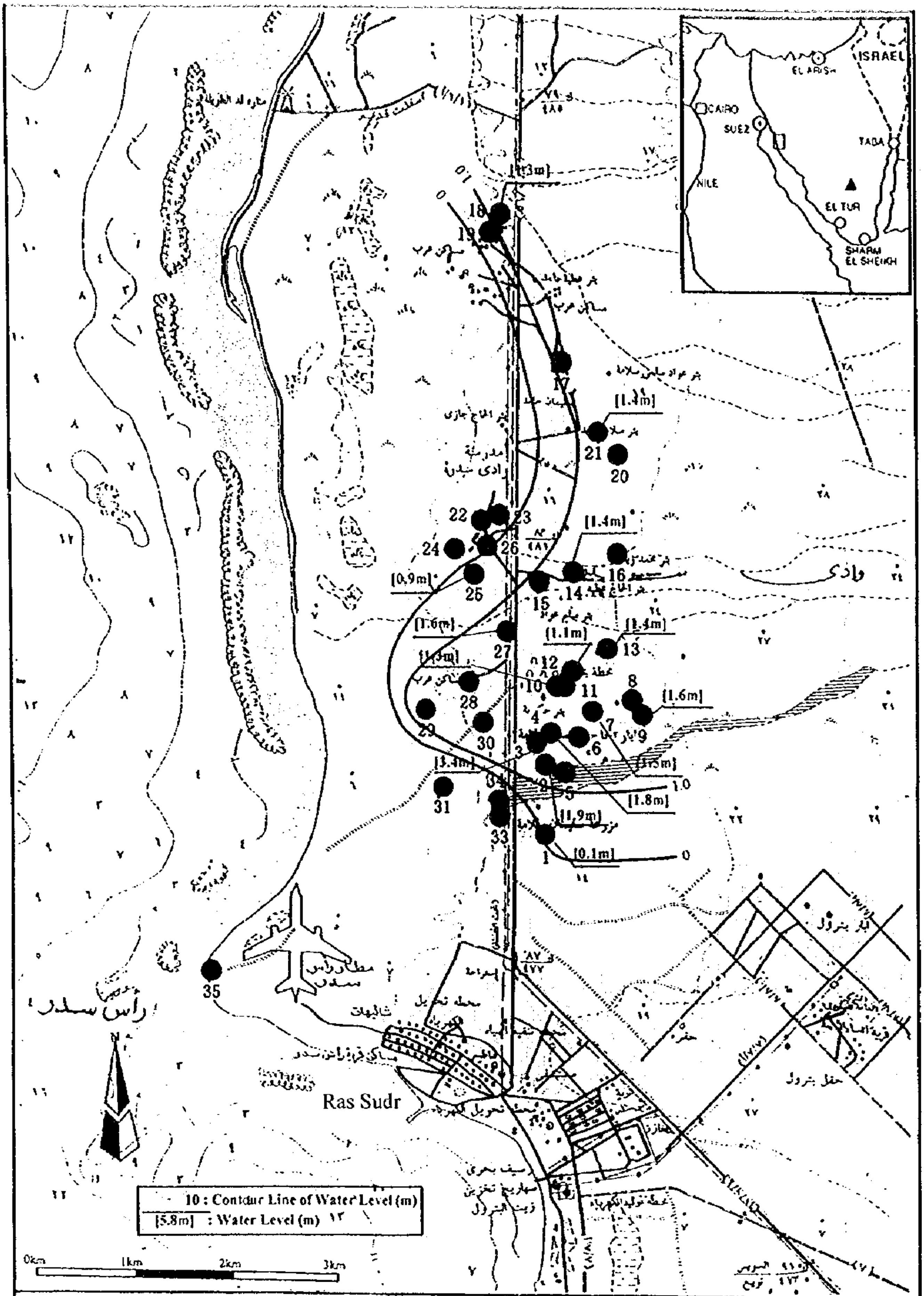

Fig. 3.3-13 Static Water Level in Ras Sudr Coastal Plain (unit : m A.S.L)

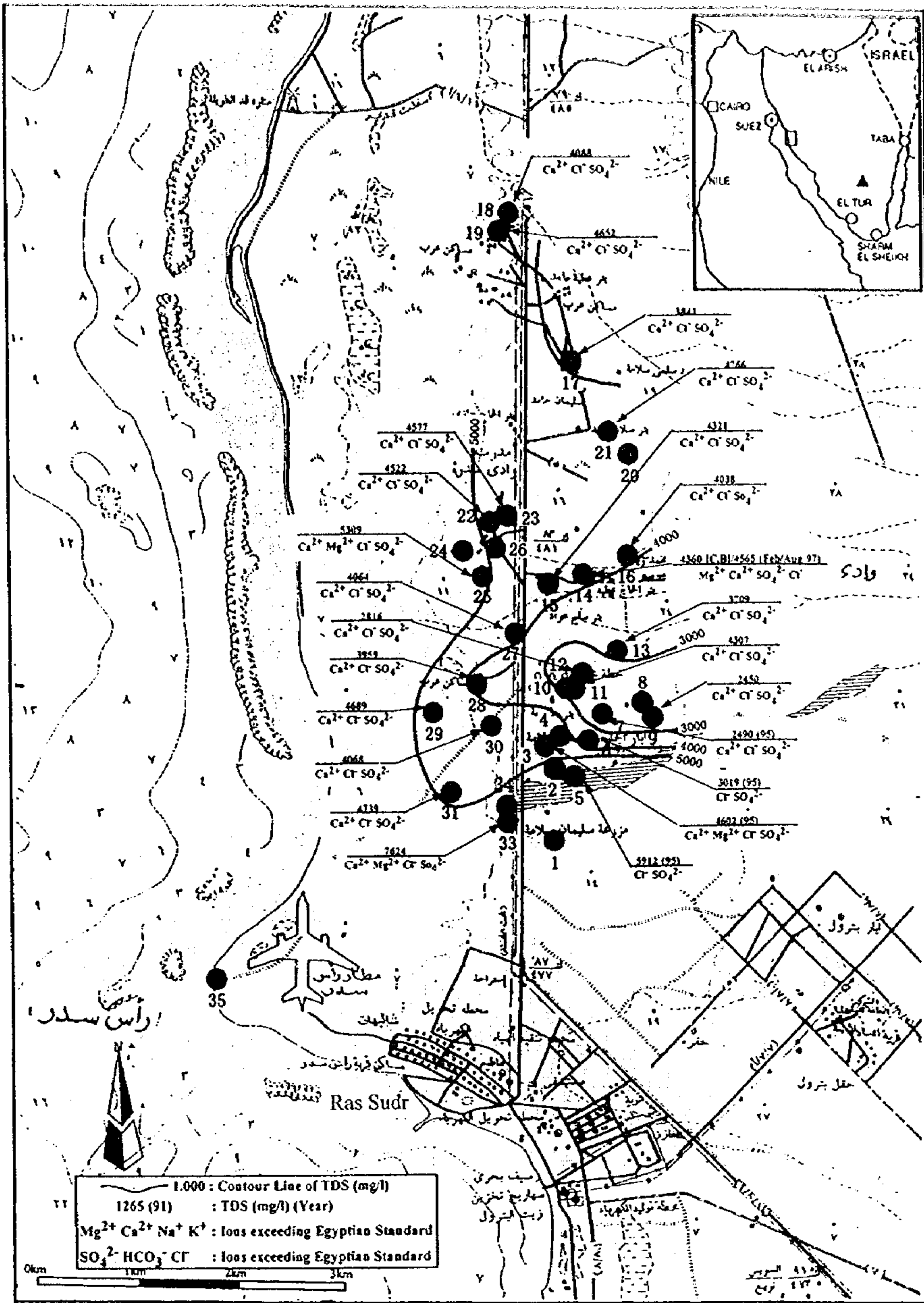

Fig. 3.3-14 Groundwater Quality in Ras Sudr Coastal Plain

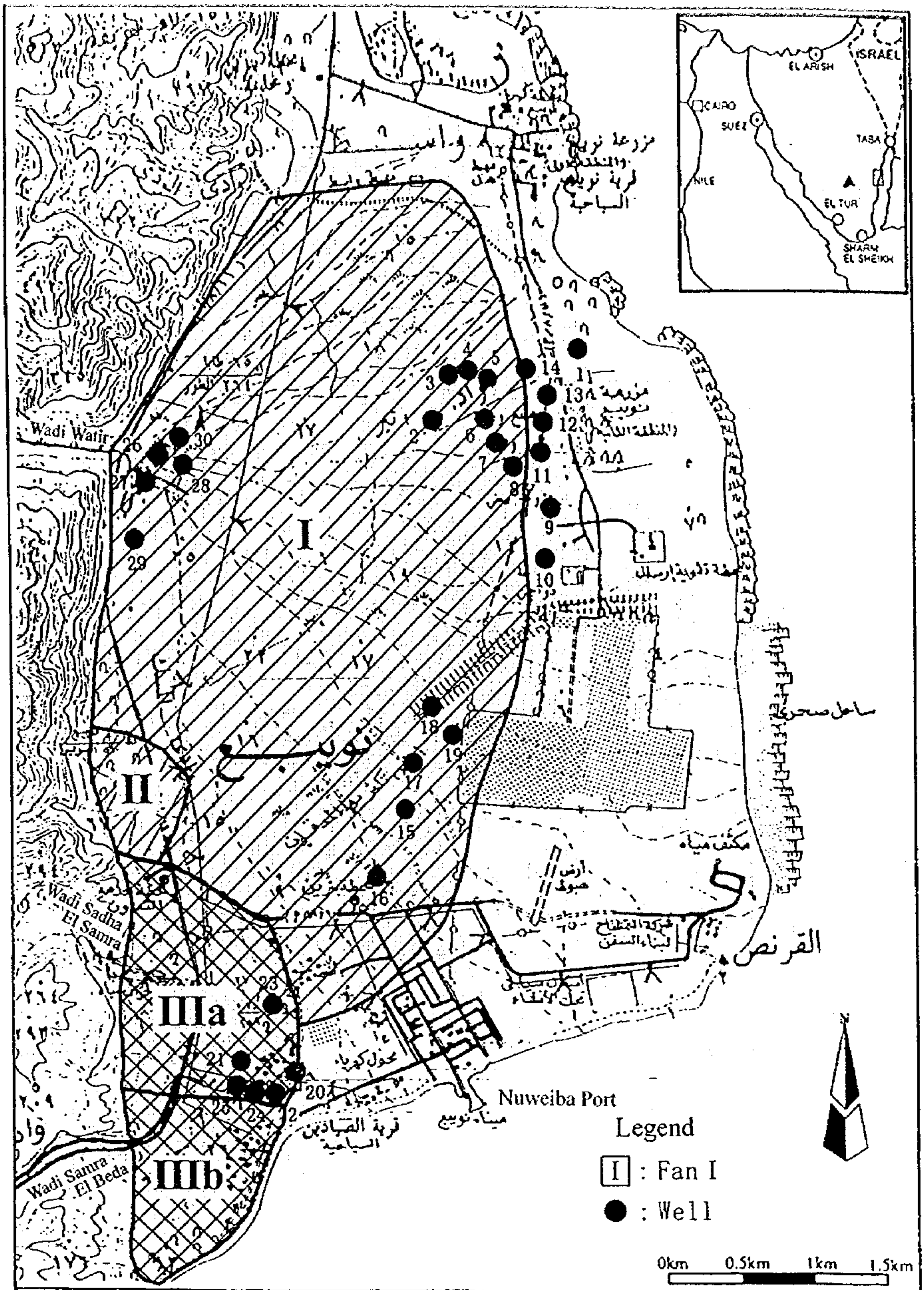

Fig. 3.3-15 Topography and Well Location in Nuweiba Coastal Plain

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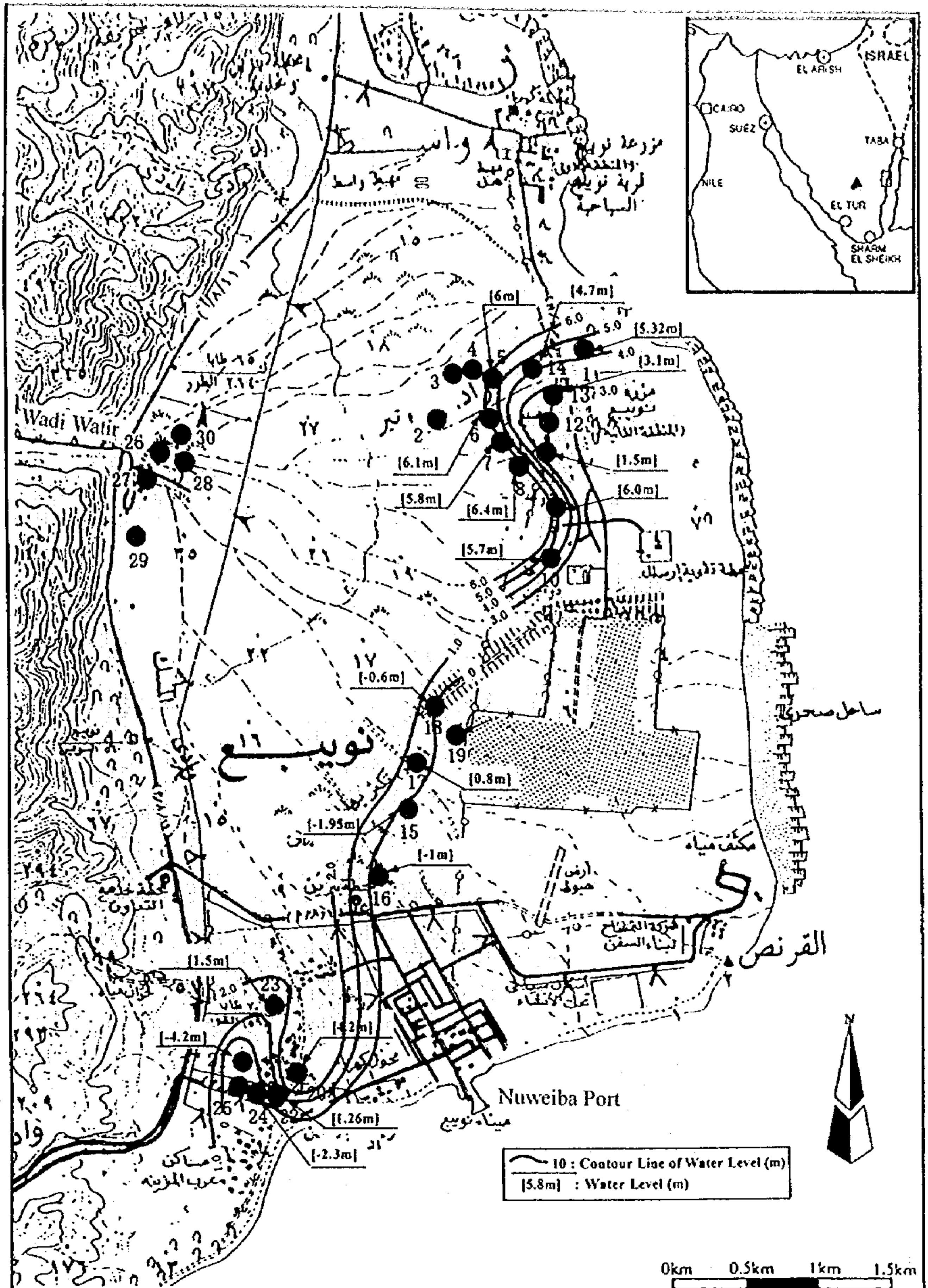

Fig. 3.3-16 Static Water Level in Nuweiba Coastal Plain (unit : m A.S.L)

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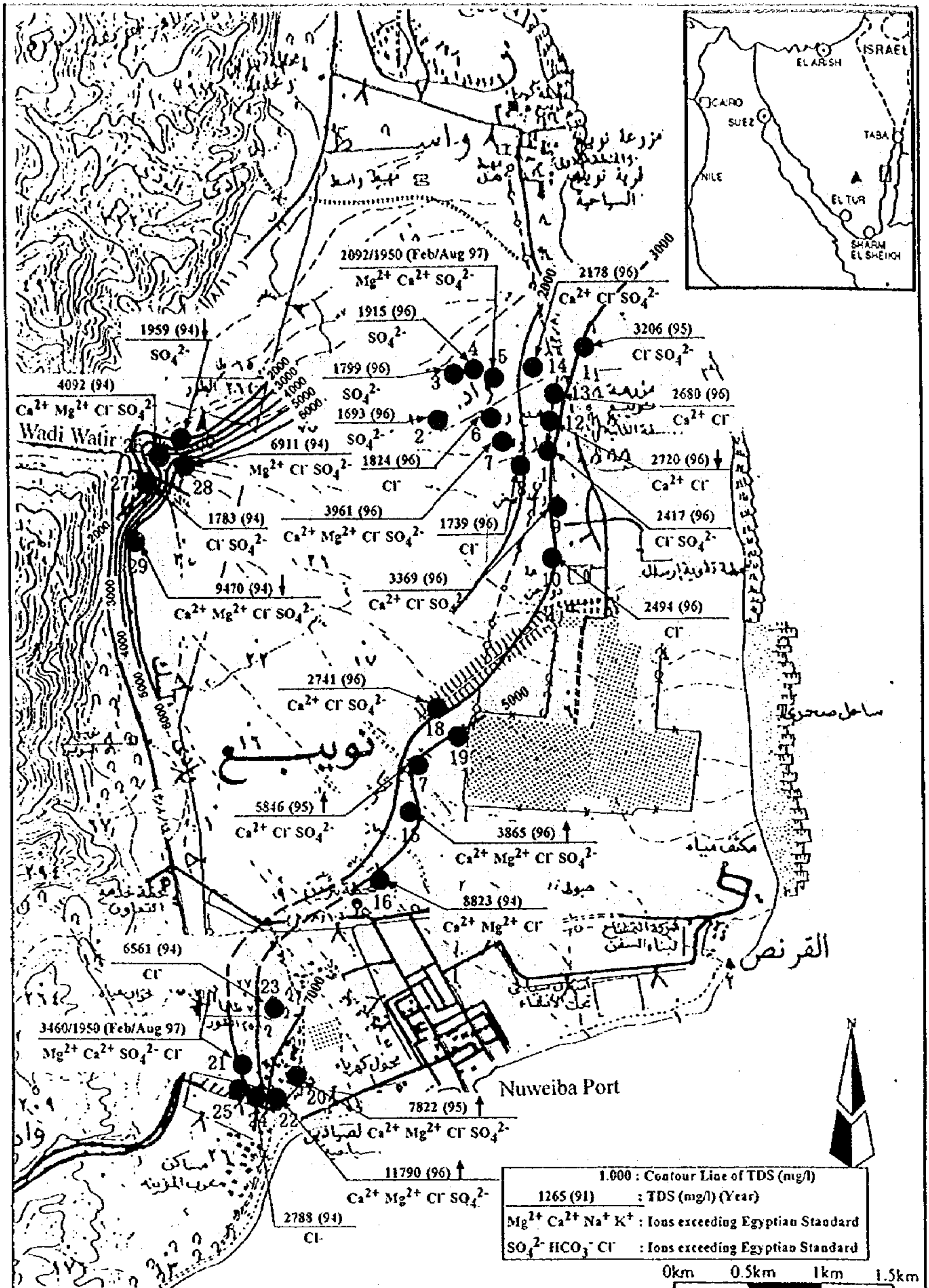

Fig. 3.3-17 Groundwater Quality in Nuweiba Coastal Plain

3.3.3 Wadi Area

Groundwater in many wadis has been used by Bedouin people. These wadis are,

<Western side of South Sinai>

Wadi Feiran and St. Catherine (Wadi Sheikh), Wadis Garf and Babaa, Wadi Gharandal

<Eastern side of South Sinai>

Taba area, Wadi Watir, Wadi Zalaga, Wadis Zaghara and Nasb, Wadis Saal and Safra, Wadi Dahab, Wadi Kid

<Central Sinai>

Upstream of Wadi El Arish

The Quaternary Wadi Deposits are distributed as shown in Fig. 3.3-1 and are the main aquifer in the area. Groundwater is exploited by dug wells. Water use is for domestic and irrigation. Inventories and locations of dug wells are shown in previous clause as Table 3.2-2 to 3.2-16 and Fig. 3.2-2 to 3.2-16.

The Wadi Deposits consist of sand and gravel. Most of the Wadi Deposits are underlain and surrounded by the Precambrian Basement rocks except the Wadis El Garf, Babaa, Gharandal, the upstream of the Wadi El Arish and Wadi Watir. Basement of the Wadi Deposits in each wadis is summarized as follows.

Basement	Wadi area
Eocene and Upper Cretaceous Limestone	Upper stream of the Wadi El Arish Wadi Gharandal
Lower Cretaceous to Paleozoic Sandstone	Wadi El Garf, Wadi Babaa
Precambrian Basement Rocks	Wadi Feiran, St. Catherine, Taba area, Wadi Watir, Wadi Zalaga, Wadi Saal, Wadi Safra, Wadi Zaghara, Wadi Nasb, Wadi Dahab, Wadi Kid

In order to supplement the geophysical survey results by WRRI and to confirm the thickness of the Wadi Deposits, the TEM survey was carried out in six (6) wadis. Location of the TEM survey points is shown in Fig. 3.3-18. Thickness of aquifer in each wadis is estimated based on the field survey, existing survey results and the TEM survey results. The TEM survey results are presented as Fig. 3.3-19 (1) to 3.3-19 (3).

Location	Resistivity Profile	No. of Survey Point	Thickness of Wadi Deposits (m)
Wadi Feiran		44	
-Tarfa	D	(7)	70 - 170
-Oasis Feiran	E,F	(16)	15 - 100
-Mokattab	G	(11)	50 - 120
-Downstream to El Qaa Plain	H	(10)	
Wadi El Garf and Babaa	-	-	
Wadi Gharandal	I,J	20	10 - 50
Upstream of Wadi El Arish	-	-	
Taba area	-	-	20 - 80
Wadi Watir		12	
-Wadi Khareiza	N	(4)	20 - 60
-Wadi El Hathy	O	(4)	80 - 100
-Sheikh Attia	P	(4)	20 - 60
Wadi Zalaga		9	
-Ain Umm Ahmed	Q	(4)	80 - 100
-El Sawana	R	(5)	60 - 110
Wadi Saal	-	-	About 10
Wadi Zaghara	K,L	10	20 - 160
Wadi Dahab	M	20	80 - 240
Wadi Kid	-	-	About 70
Total	15 Profiles	115	

The Wadi Deposits are 10 to 240 m in thickness. The maximum thickness is less than 100 m in the Wad Gharandal, the Taba area, the Wadi Khareiza, Sheikh Attia in the Wadi Watir, the Wadi Saal and the Wadi Kid. It is more than 100 m in other wadis. In the Wadi Dahab, the maximum thickness reaches 240 m.

Static water level and water quality (TDS) in each area is as shown below.

Area	SWL (mBGL)		TDS (mg/l)	
	range	average	range	average
Wadi Feiran				
-Tarfa	10.87 – 41.91	15.96	257 - 796	573
-Oasis Feiran	11.70 – 26.00	15.36	384 - 707	574
St. Catherine				
-(shallow well)	2.40 – 14.40	7.67	160 - 676	430
-(deep well)	29.70- 48.80	38.14	337 - 575	456
Wadi El Garf	7.52 – 14.90	11.89	788 - 3117	2032
Wadi Babaa	5.88 – 11.41	8.52	1549 - 1805	1685
Wadi Gharandal	13.00 – 31.49	20.45	834 - 2944	1625
Upstream of Wadi El Arish	4.97 – 11.15	8.06	3150 - 3250	3200
Taba area	24.50 – 32.43	28.47	2131 - 2800	7579
Wadi Watir				
-Sheikh Attia	4.30 – 14.30	9.43	640 - 1802	1021
-Wadi El Hathy	12.75 – 43.89	21.32	1100 - 1969	1535
Wadi Zalaga	2.82 – 10.20	5.81	1241 - 2234	1735
Wadi Saal	2.60 – 10.12	6.86	138 - 3782	1341
Wadi Zaghara	2.00 – 11.67	5.01	609 - 900	725
Wadi Dahab	28.00 – 35.00	32.38	2500 - 3000	2750
Wadi Kid				
-upstream	3.60 – 7.16	5.38	337	-
-downstream	50.29	-	-	-

Most wells are dug wells in the Wadi area, therefore, static water level is within 16 mBGL.

TDS is relatively low in the Wadi Feiran area including St. Catherine, the Wadi Zaghara and the upstream of the Wadi Kid where it is less than 1000 mg/l. These areas are distributed in the Precambrian Basement Rocks area. High TDS values appear in the area where sedimentary rocks are distributed.

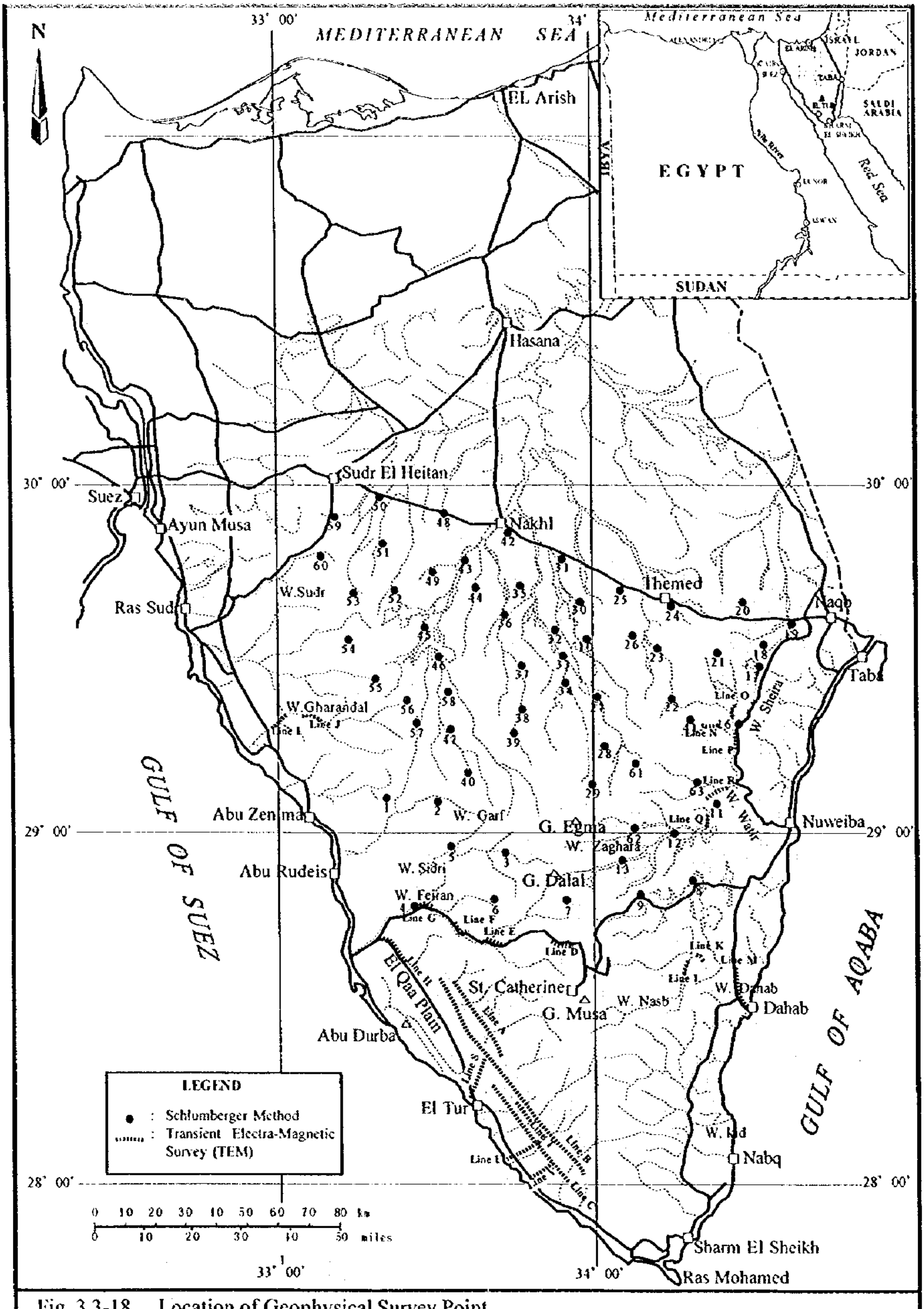

Fig. 3.3-18 Location of Geophysical Survey Point

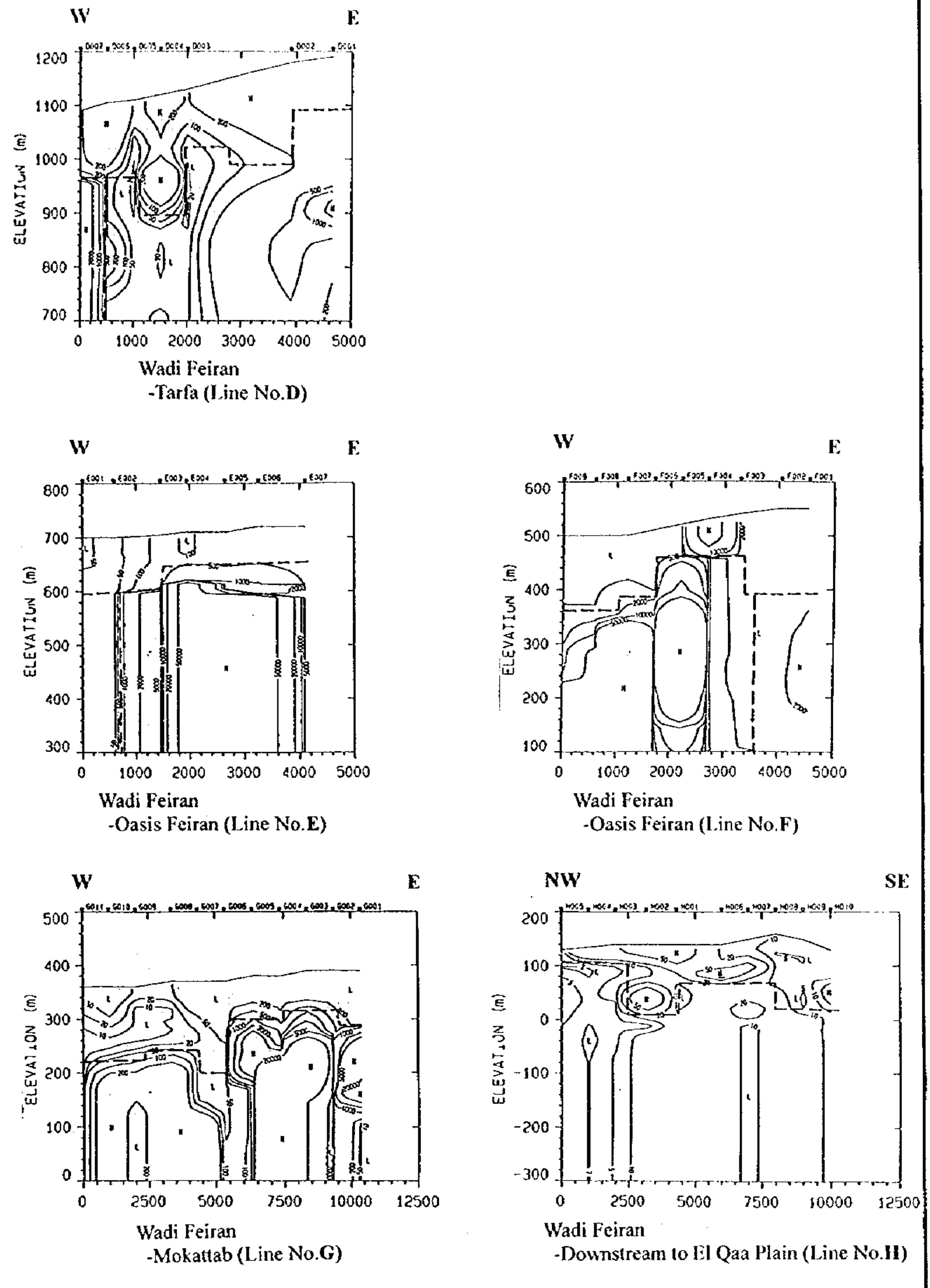

Fig. 3.3-19 (1) Resistivity Profile in Wadi Area (1/3)

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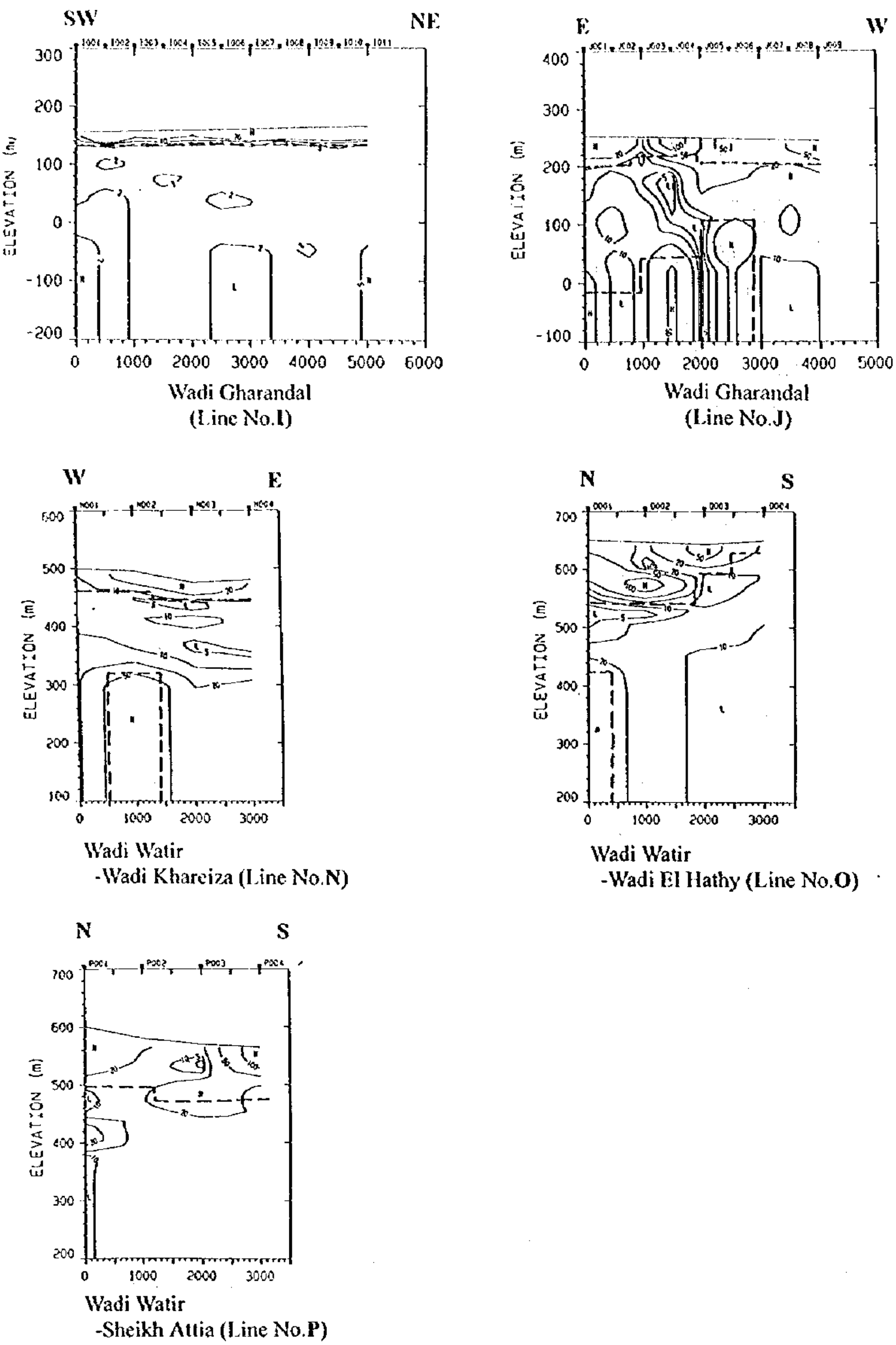
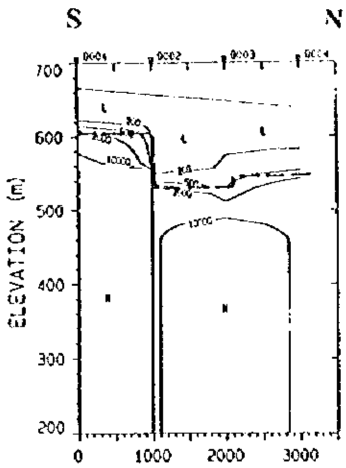
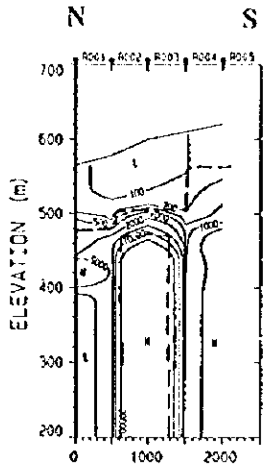


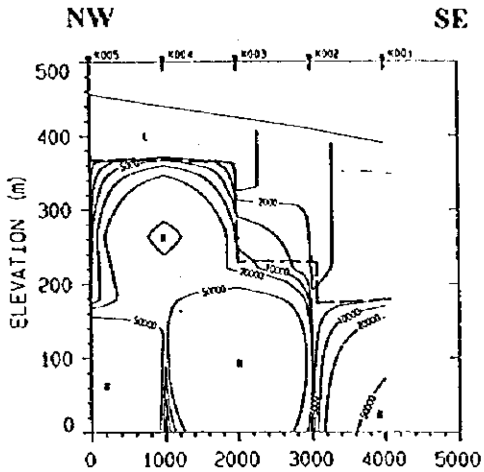
Fig. 3.3-19 (2) Resistivity Profile in Wadi Area (2/3)



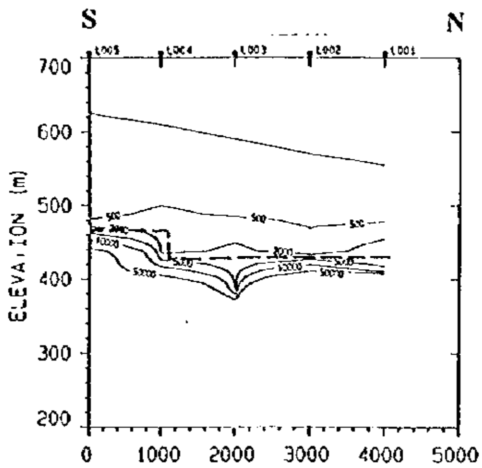
Wadi Zalaga
-Ain Umm Ahmed (Line No.Q)



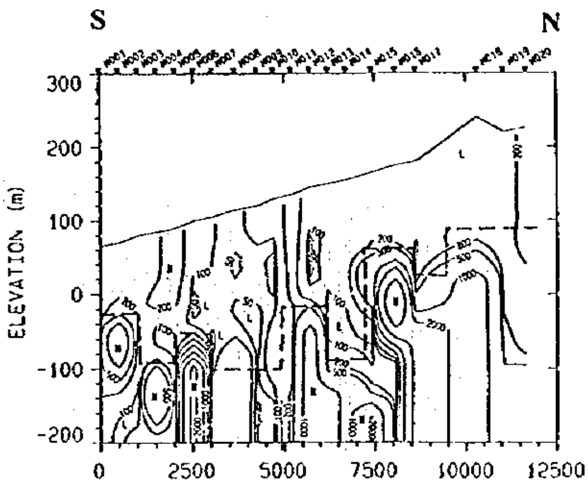
Wadi Zalaga
-El Sawana (Line No.R)



Wadi Zaghara
(Line No.K)



Wadi Zaghara
(Line No.L)



Wadi Dahab
(Line No.M)

Fig. 3.3-19 (3) Resistivity Profile in Wadi Area (3/3)

3.4 Upper Cretaceous Aquifer

3.4.1 General Features

The Upper Cretaceous Formations are mainly predominant in the central plateau area (Egma and El Tih Plateaux) overlying the Lower Cretaceous Formation and are overlain by the Tertiary Formations. The Formations are also distributed in the Wadi Gharandal and the Wadi Feiran.

Upper Cretaceous Sedimentary Rocks are divided into four (4) geological units by age.

Age	Formation	Main Facies
Senonian	Sudr Formation	chalk
	Matallah Formation	marl
Turonian	Wata Formation	limestone, dolomitic limestone
Cenomanian	Galalah Formation	limestone

Among them, limestone in the Turonian is called as "fissured limestone" and it has been considered as the main aquifer in the Upper Cretaceous. Groundwater in the Turonian Limestone is extracted in the Wadi Sheira, the Wadi Gharandal and the Wadi Sudr.

Furthermore, many dug wells are tapping groundwater from the Sudr Formation at El Malha area.

3.4.2 Well Inventory for Upper Cretaceous Aquifer

A total of 26 groundwater points was confirmed. They consist of three (3) cased wells, 16 dug wells, five (5) springs and two (2) hot springs.

Inventory of wells reached to the Upper Cretaceous is shown in Table 3.2-17 and their locations are shown in Fig. 3.2-17, together with other wells that reached the Pre-Quaternary. Wells, which have information on the Upper Cretaceous Aquifer, are shown in Fig. 3.4-1.

In addition, six (6) JICA Test Wells penetrated the Upper Cretaceous Aquifer. They are listed in Table 3.2-1 (17).

3.4.3 Supplementary Geological Survey

Data on the Upper Cretaceous Aquifer was scarce in South Sinai, especially in the El Tih and Egma Plateau area. In order to study the Pre-Quaternary Aquifers, test wells were drilled at the six (6) locations. All the wells reached the Upper Cretaceous Aquifers. Locations of those wells are presented in Fig. 3.4-1. Lithology and test results are presented in Fig. 3.4-2.

Aquifer Test by airlifting was carried out in the section of the Upper Cretaceous to examine the hydrogeological condition of the Upper Cretaceous Aquifers. The results are shown below.

Well	Tested Section (mBGL)	Aquifer	SWL (mBGL)	SWL (mASL)	Q_{max} (m^3/hour)	TDS (mg/l)
J-1	402-500	Turonian	71.08	449	5.5	2,790
J-2	620-650	Turonian	dry			
J-3	382-420	Turonian	-3.8*	548	40.0	2,170
J-4	380-450	Coniacian -Turonian	dry			
J-5		Cenomanian -Albian	dry			
J-6	220-260	Turonian	115.08	595	11.0	2,670

*: automatically flown out.

3.4.4 Configuration of Aquifer

The Upper Cretaceous Formations crop out in the total area of Egma Plateau. Figure of the Upper Cretaceous was obtained by the JICA Test Well Drilling as mentioned above.

Thickness and top of the Upper Cretaceous are presented in Fig. 3.4-3. Thickness of each age of the Upper Cretaceous is summarized as follows.

Age		J-1	J-2	J-3	J-4	J-5	J-6	Sheira-1	Average
Senonian	Maastrichtian	170	140	60	268	0	40	129	223
	Campanian	110	120	169		0	140		
	Santonian-Coniacian	55	56	72		0	30		
Turonian		175	151	194	380	80	80	208	181
Cenomanian		370	280	276	430	230	320	207	302
Total UC*		880	747	771	1078	310	610	544	706

UC: Upper Cretaceous (unit : m)

In South Sinai, the Upper Cretaceous aquifer appears in Senonian and Turonian. The Senonian is from 40 to 170 m in thickness. It decreases toward the south and increases to the north.

The Turonian, main aquifer in the Upper Cretaceous in South Sinai, is between 80 and 380 m in thickness, averaging 181 m.

3.4.5 Groundwater Level

The Upper Cretaceous Aquifers are classified into confined one and unconfined one. The former is represented by the Turonian aquifer and the latter is the Senonian aquifer cropping out in El Malha.

Groundwater level of the Upper Cretaceous is shown in table below and in Fig. 3.4-4.

Well	Elevation (mASL)	SWL (mBGL)	SWL (mASL)
J-1	520	71.08	449
J-3	544	-3.80	548
J-6	710	115.08	595
El Malha 2	640	14.50	625
Gharandal 2	290	120.70	169
Dug wells in Malha		3.2 – 11.4	

Artesian flow of groundwater was observed at J-3 during the aquifer test. Groundwater automatically flowed out from the top of the casing without airlifting. It was the first time in the whole Sinai that this phenomenon was confirmed.

No confined layer overlies the Senonian Aquifer, therefore, the aquifer is considered as the unconfined one. On the one hand, the Turonian Aquifer is considered as the confined one because head of groundwater is much higher than depth of aquifers in those wells that were penetrated into the Turonian Aquifer.

Gradient of piezometric head in the Upper Cretaceous aquifer is 1.7/1000 between J-6 and J-3, and 4.8/1000 between J-3 and J-1. It is considered that this change of gradient is due to the influence of dolerite dykes intruded into the Upper Cretaceous. Influence of the dolerite dykes to the groundwater is discussed more detail in the section 3.5 Lower Cretaceous Aquifer.

3.4.6 Groundwater Quality

Groundwater quality of the Upper Cretaceous Aquifers is shown in the Table 3.2-17. Distribution of TDS is shown in Fig. 3.4-4 together with water level.

TDS values of upper Cretaceous aquifer vary from 1,572 to 12,930 mg/l and they are unsatisfying the Drinking Water Standard. However, TDS is relatively low in El Malha and south of Nakhl.

Ion contents of Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} are in excess of the drinking water standard.

Water type of the Upper Cretaceous Aquifers is shown in Fig. 3.4-5. Most groundwater is the NaCl type. No seasonal variation was confirmed except El Malha. Groundwater in El Malha is the $MgSO_4$ type in winter and NaCl type in summer. It seems that this variation is due to the recharge by rainwater in the winter season.

3.4.7 Hydrogeological Characteristics of Aquifer

In the Egma and El Tih Plateau, noteworthy geological structures are recognized from the hydrogeological point of view. These structures are faults and dykes. 26 groundwater points were confirmed in the Upper Cretaceous Aquifers. Except dug wells in El Malha, other groundwater points are located near faults as shown in Fig. 3.4-6.

It is considered that groundwater in the Upper Cretaceous is mainly stored in fractures formed by faults. This is suggested by the fact that groundwater was not confirmed in the Upper Cretaceous Formations of J-2 and J-4, that were allocated far from faults.

Another remarkable issue is the change in gradient of piezometric head as mentioned in 3.4.5. This is caused by fault and dolerite dykes which run in E-W direction between J-3 and J-1.

Groundwater level in El Malha area decreases in dry season and quickly recovers after rainfall. This fact suggests that groundwater in the area is recharged by present surface water through fissures and fractures developed in the chalky limestone.

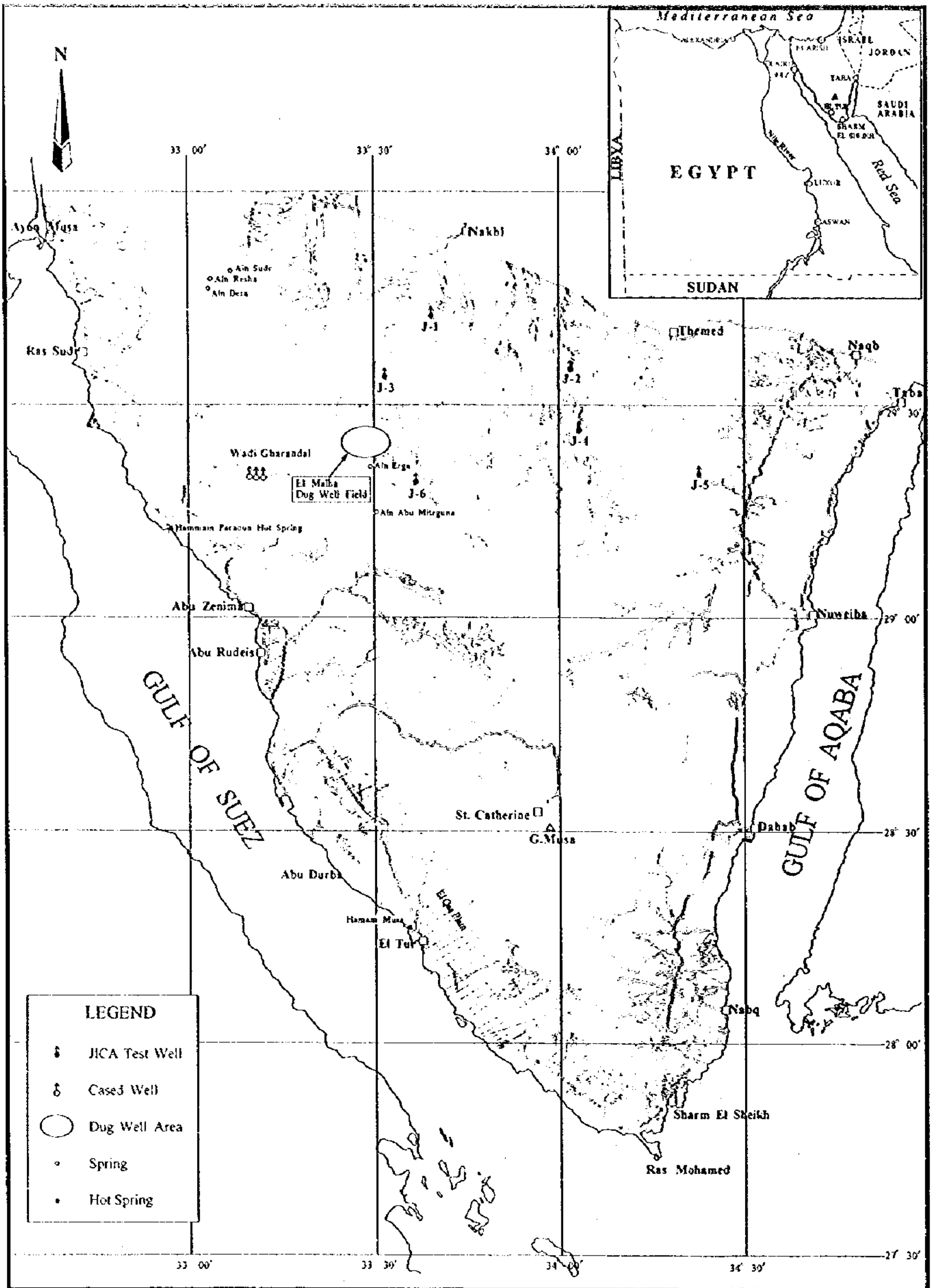


Fig. 3.4-1 Well Location of Upper Cretaceous

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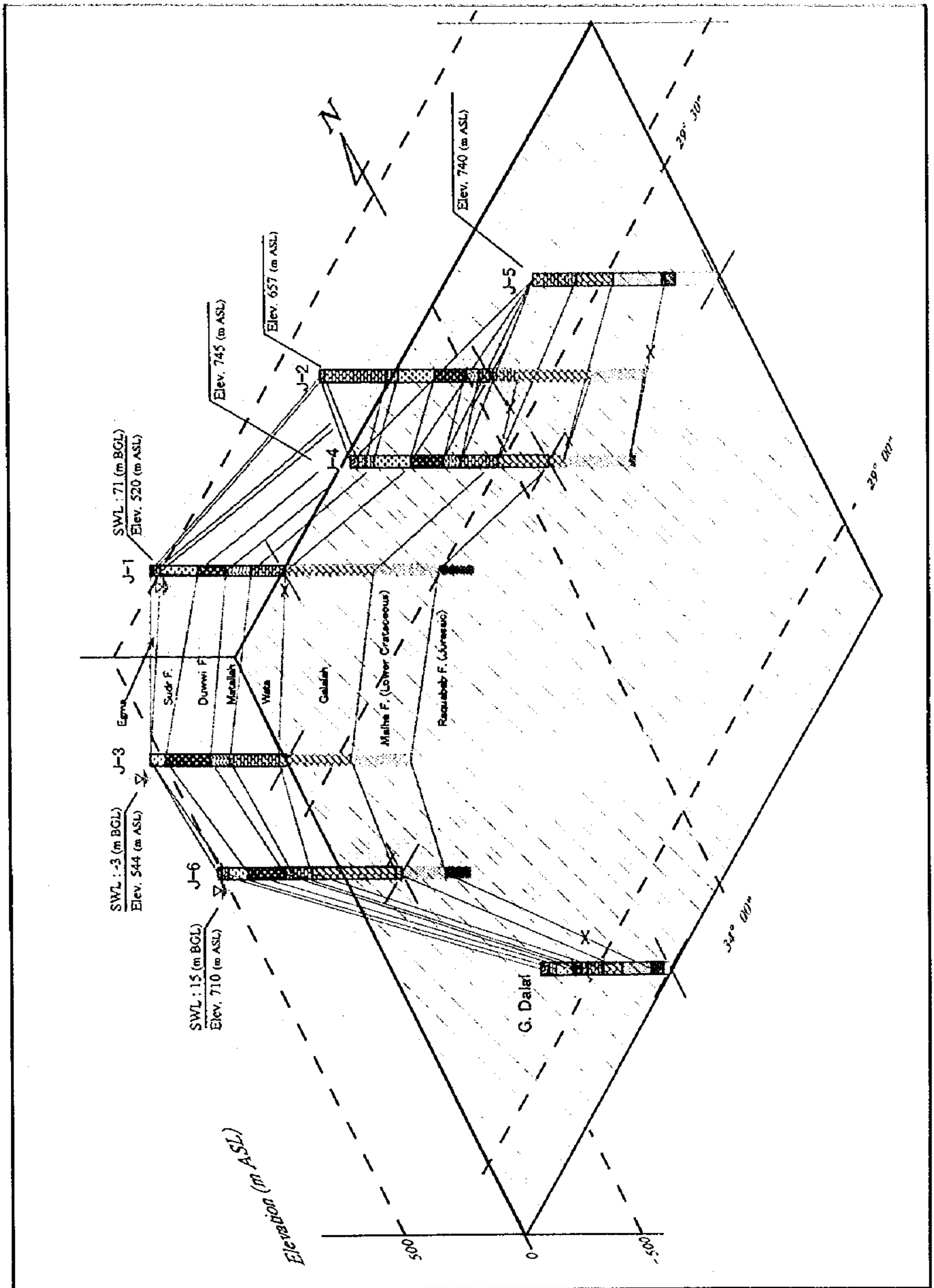

Fig.3.4-2 Correlation of Geological Column and Water Level (JICA Wells)

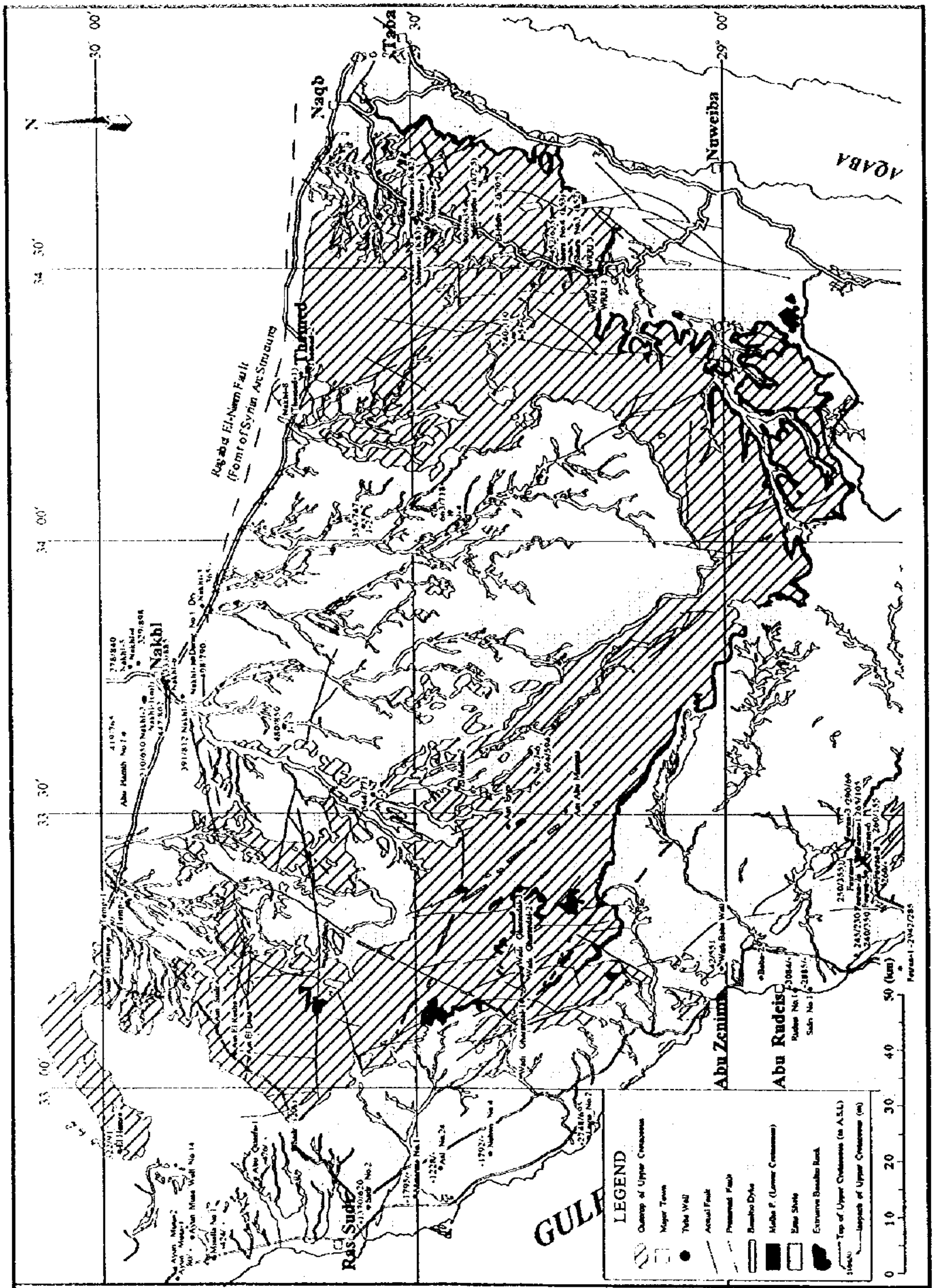

Fig. 3.4-3 Thickness and Top of Upper Cretaceous

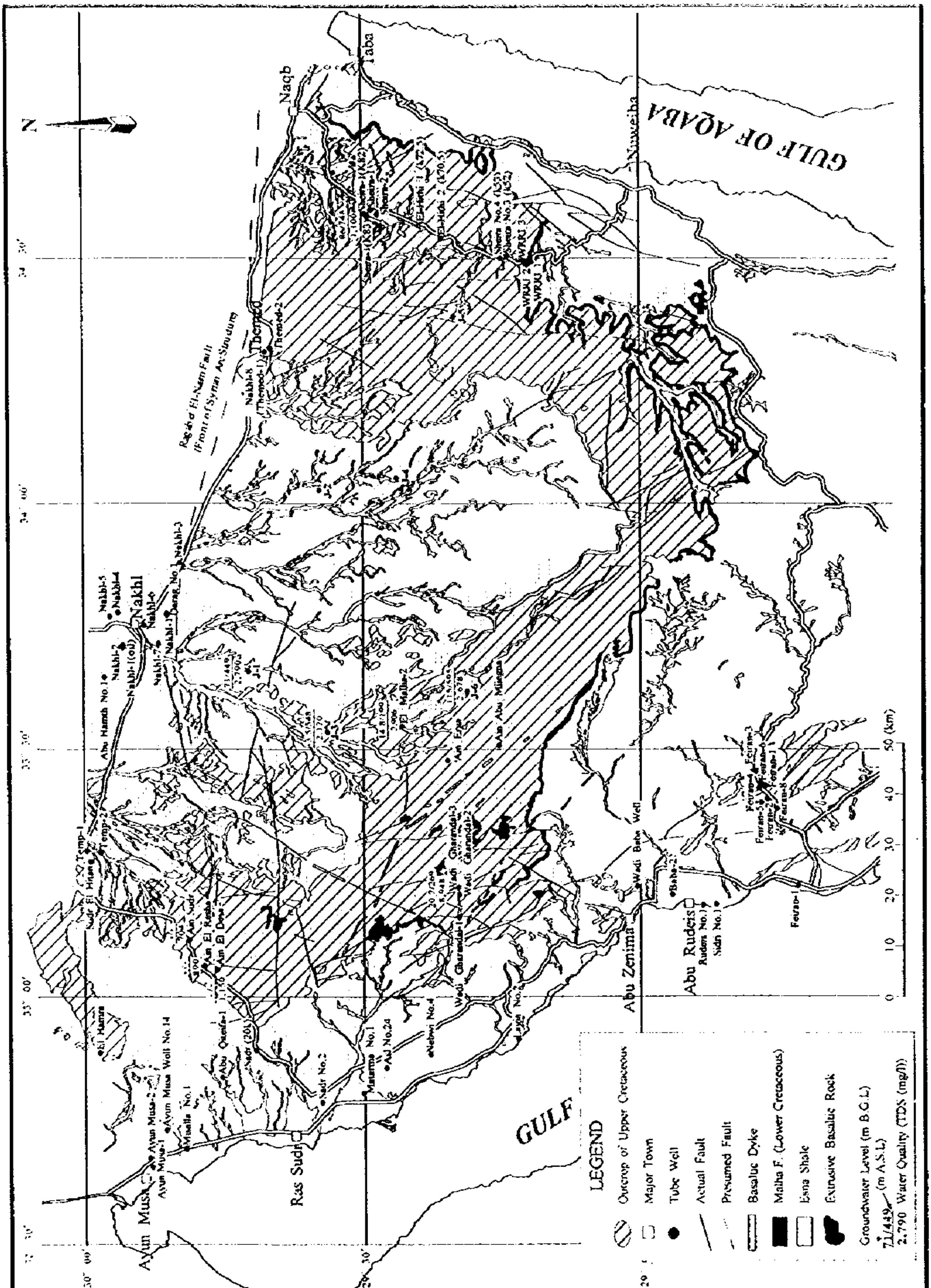

Fig. 3.4-4 Groundwater Level and Quality of Upper Cretaceous

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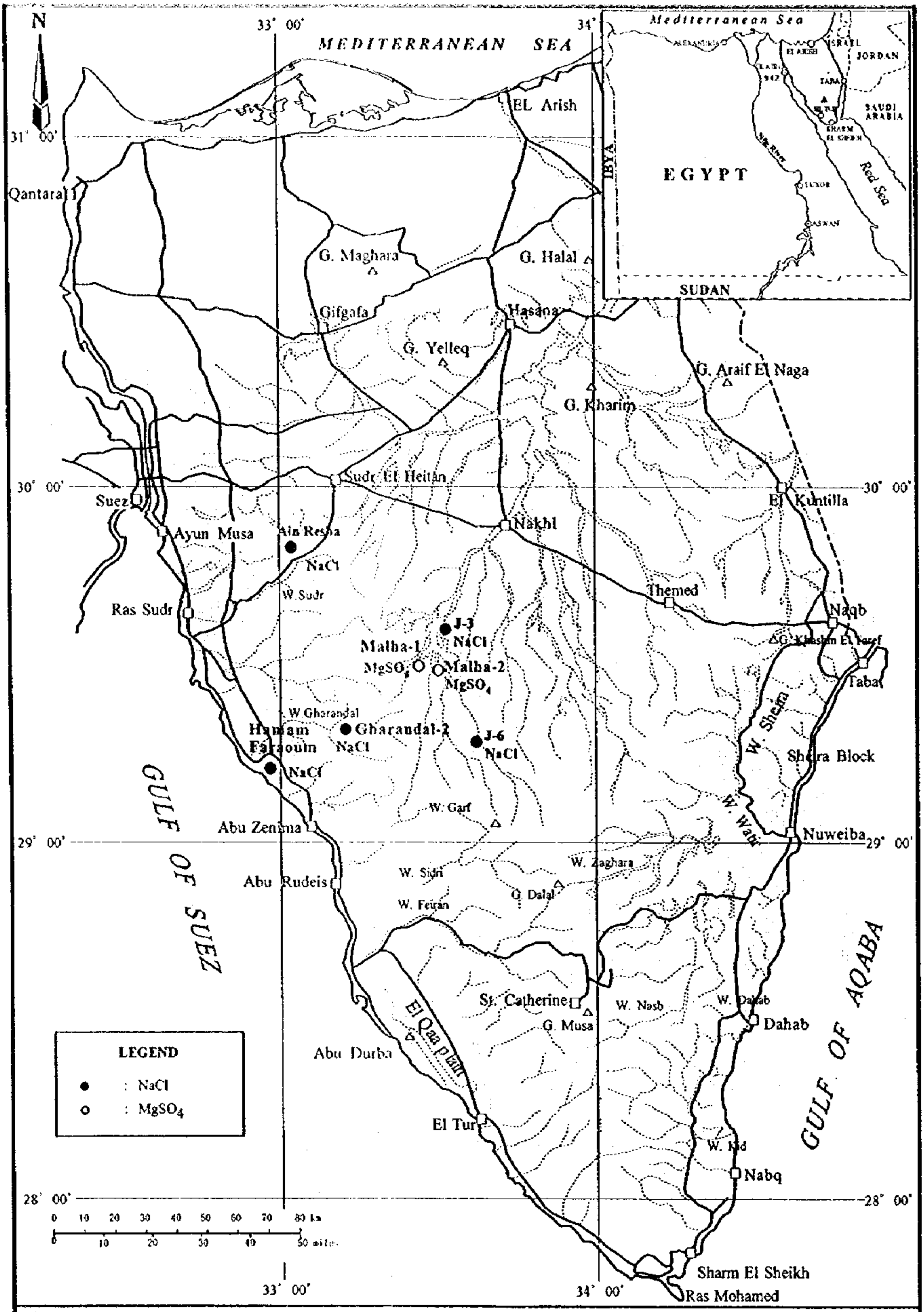

Fig. 3.4-5 Water Type of Upper Cretaceous Aquifer

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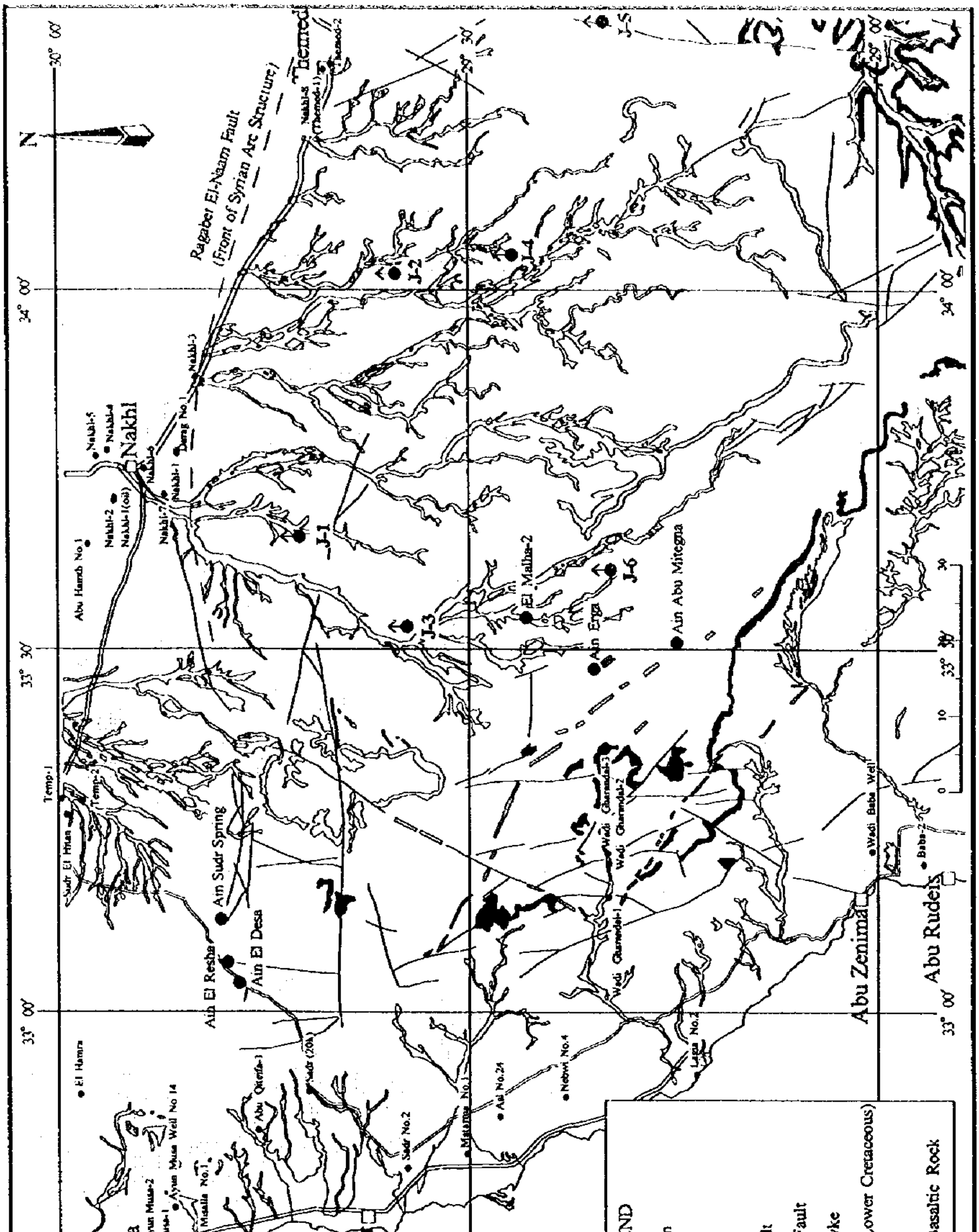

Fig. 3.4-6 Hydrogeological Situation of Groundwater Points (Upper Cretaceous)