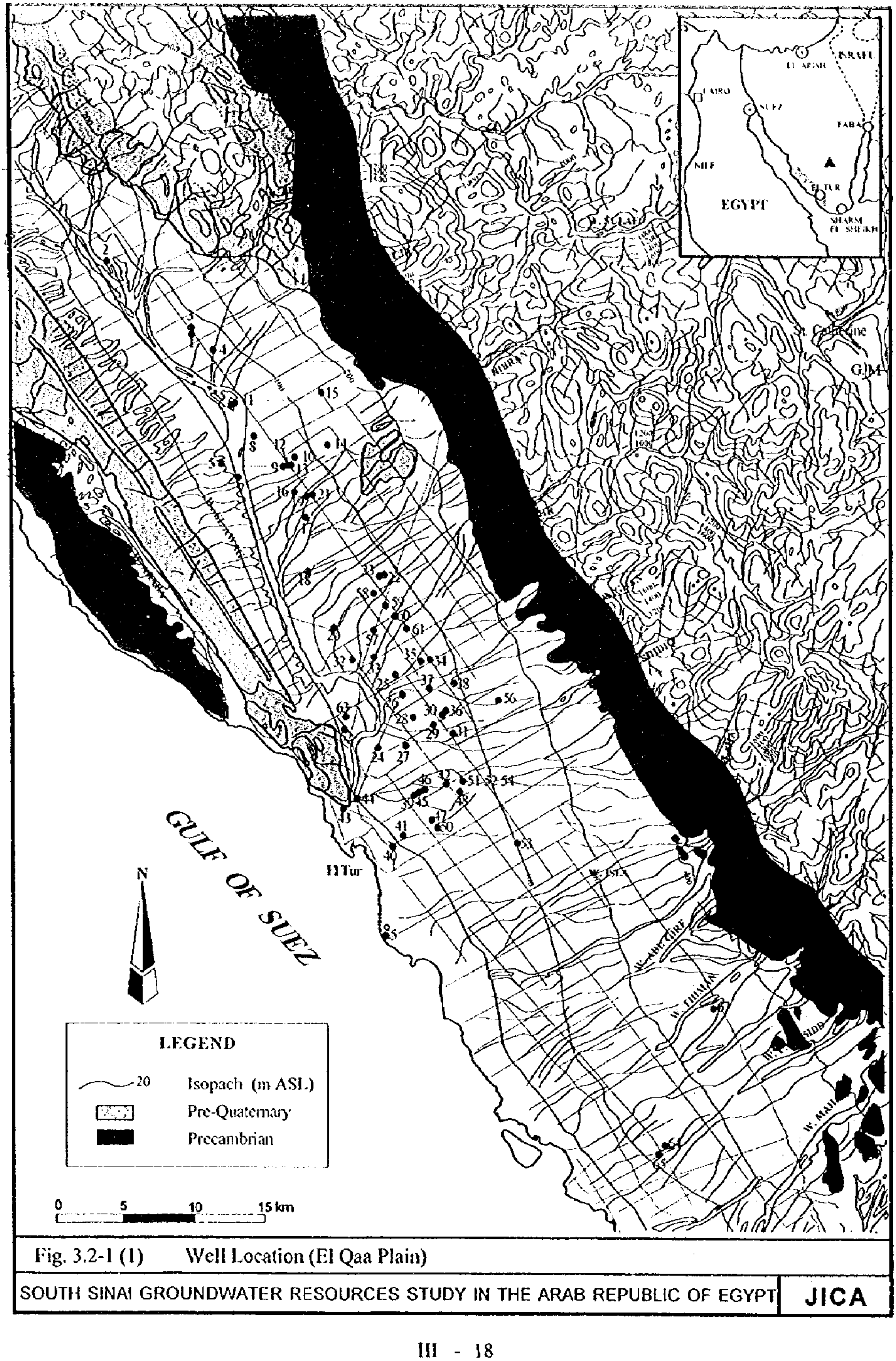

Fig. 3.2-1 (1) Well Location (El Qaa Plain)

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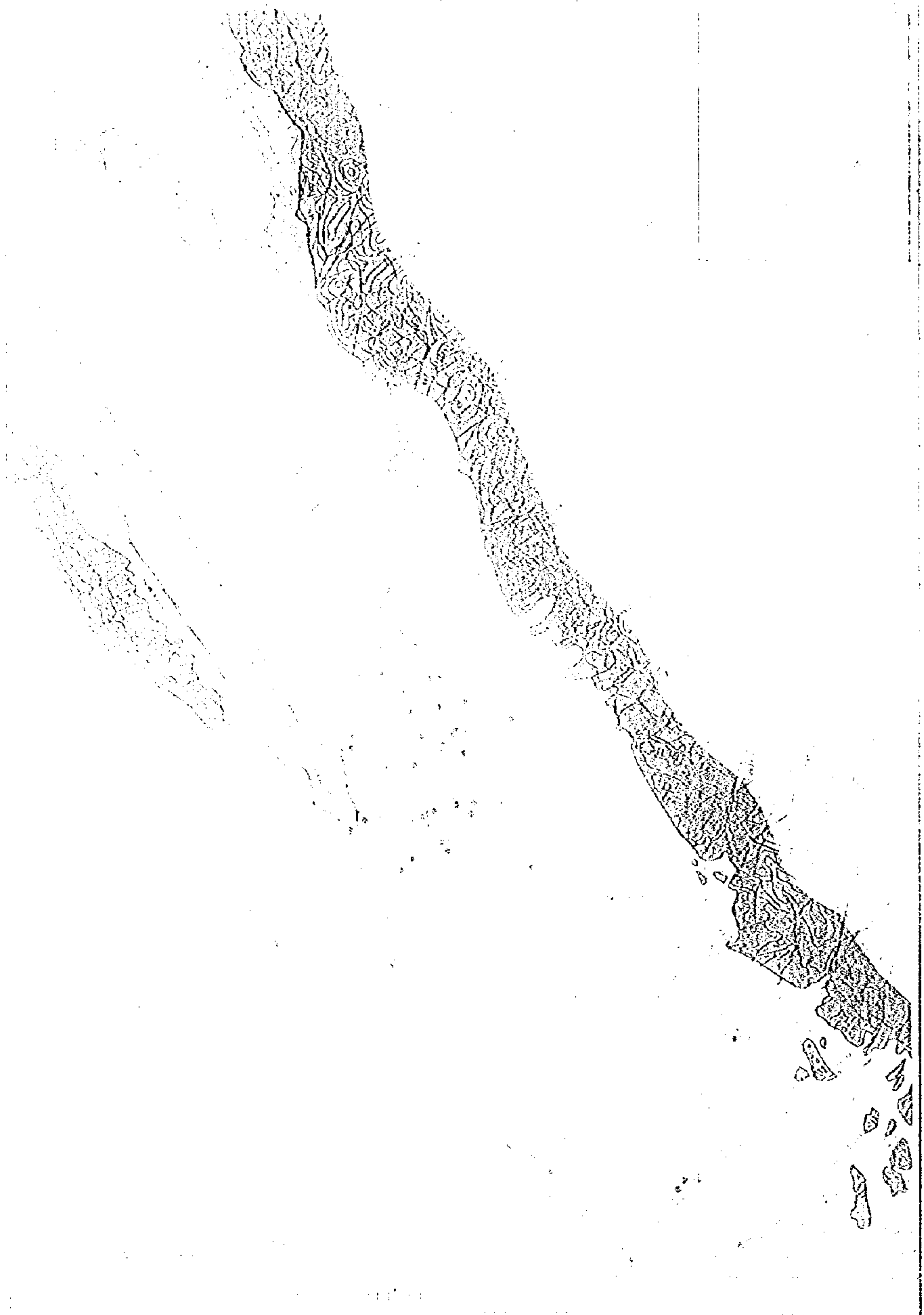

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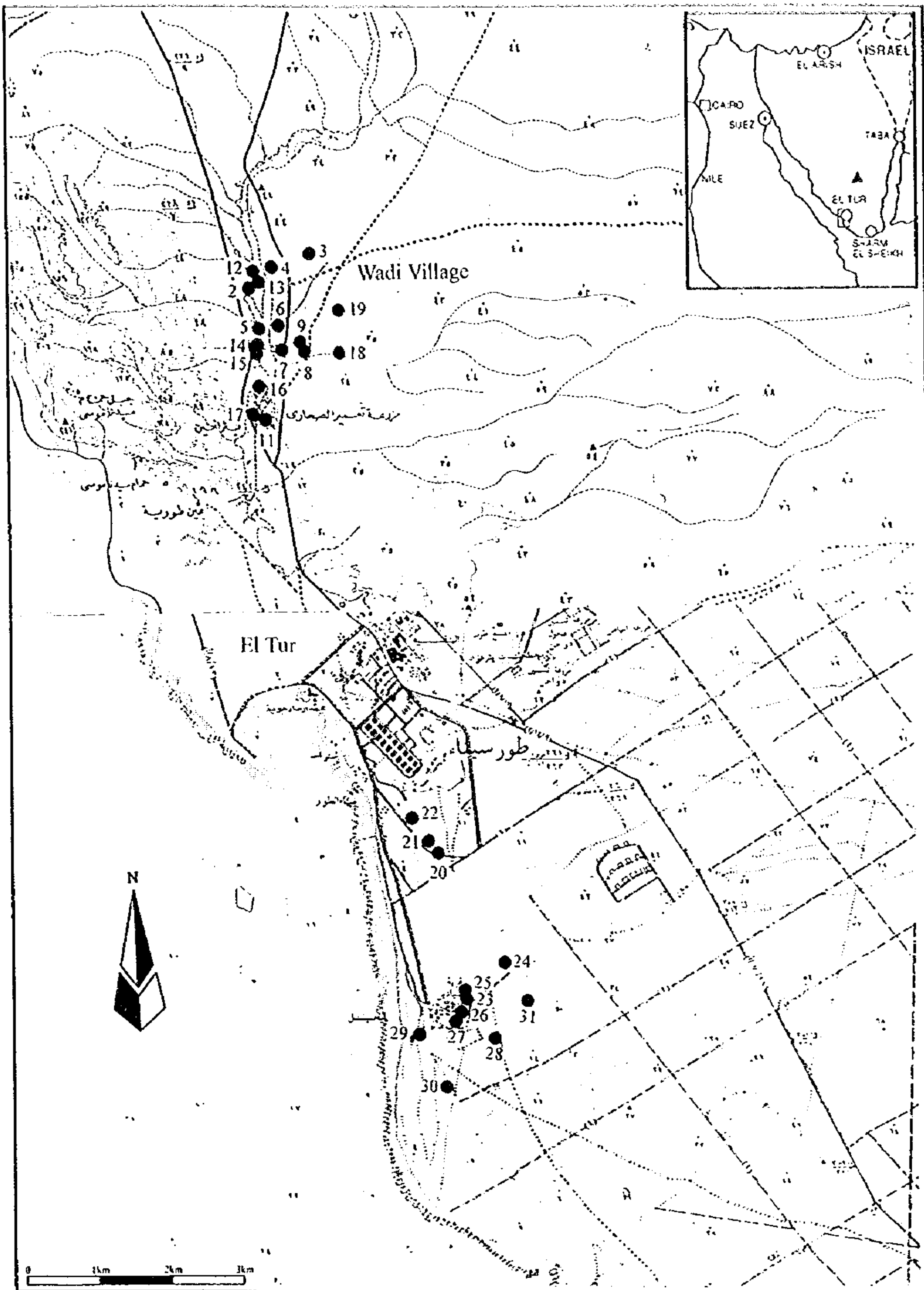

Fig. 3.2-1 (2) Well Location (Dug Well : El Tur)

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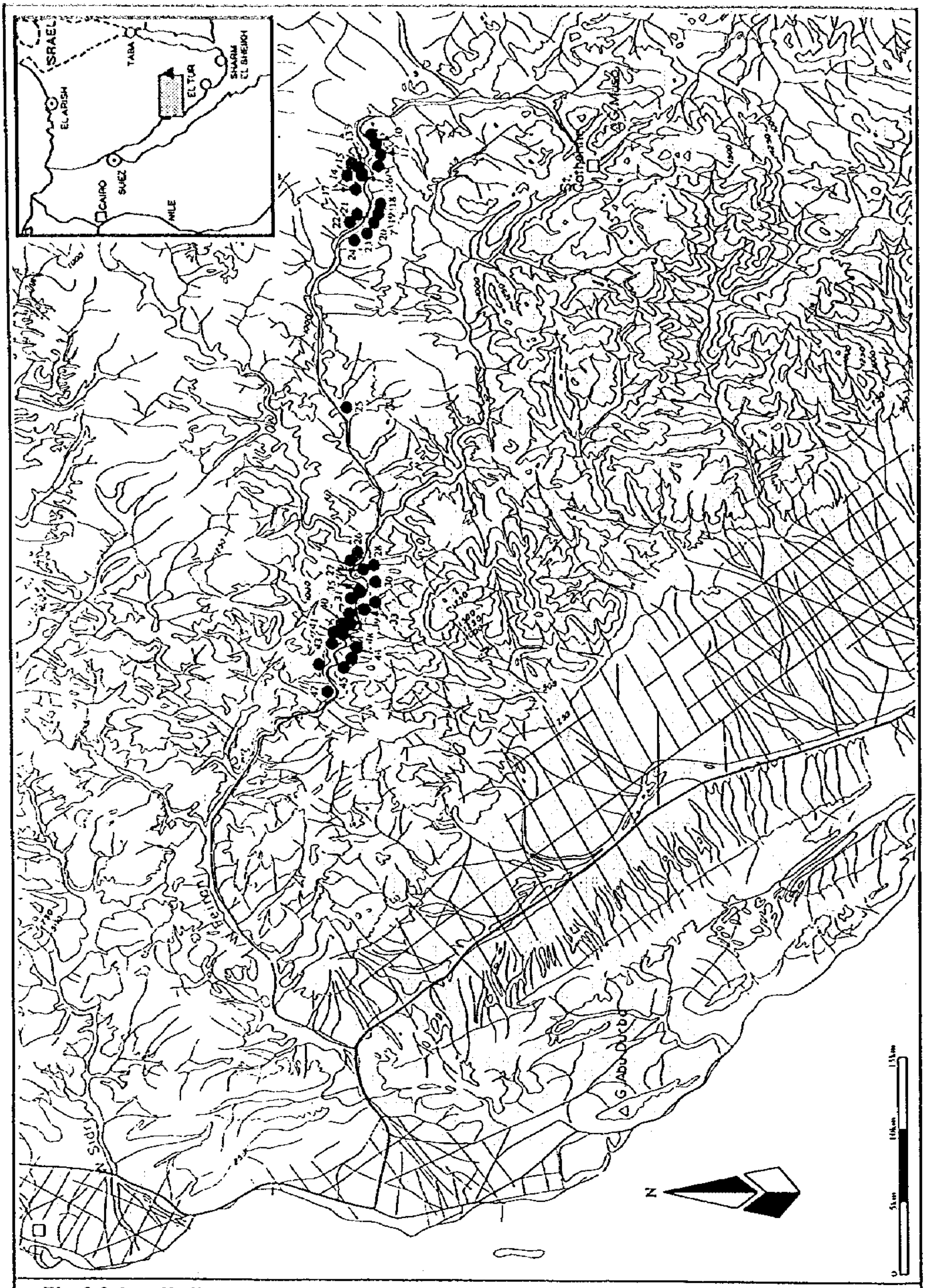

Fig. 3.2-2 Well Location (Wadi Feran and El Tarfa)

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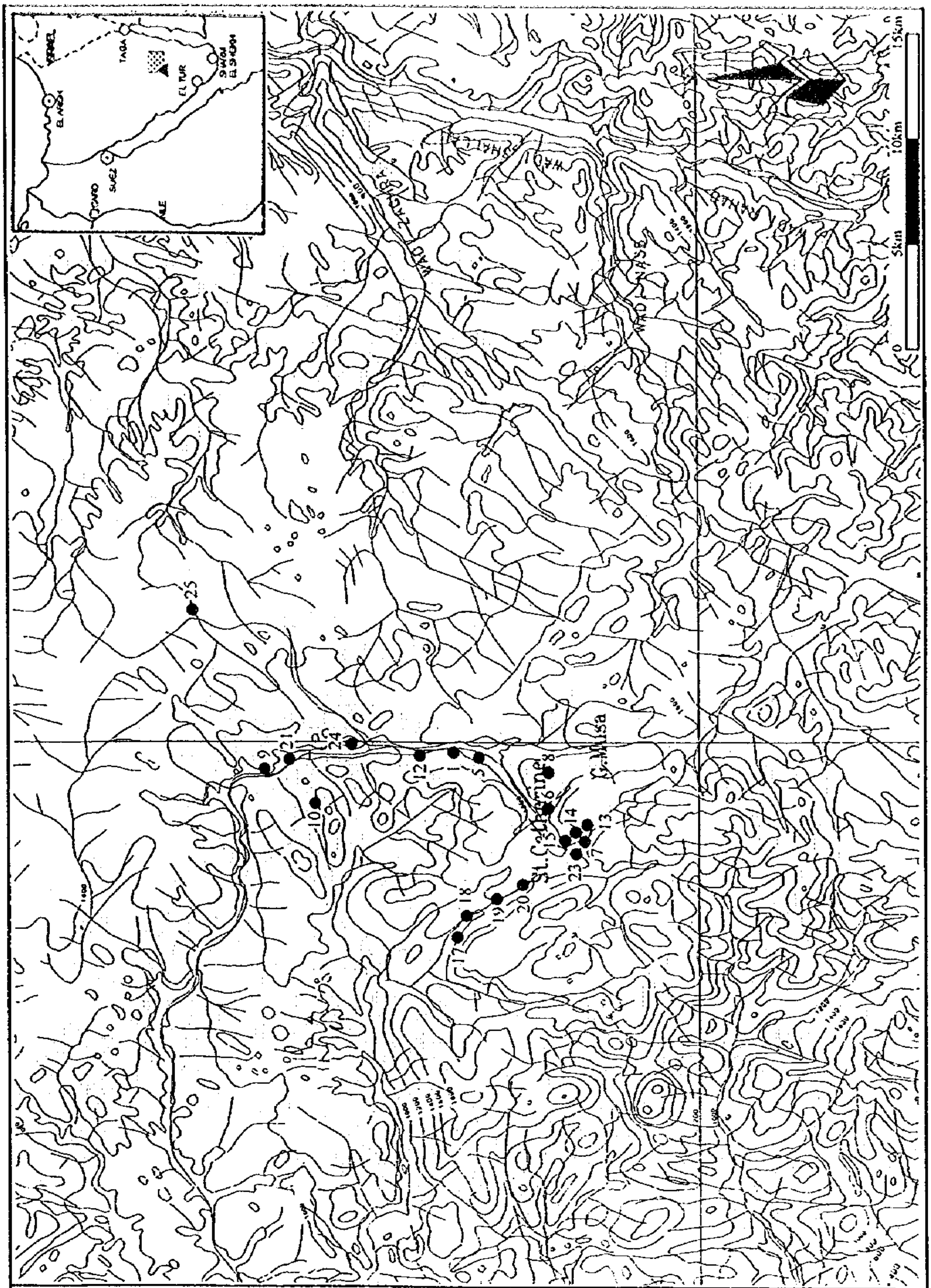

Fig. 3.2-3 Well Location (St. Catherine)

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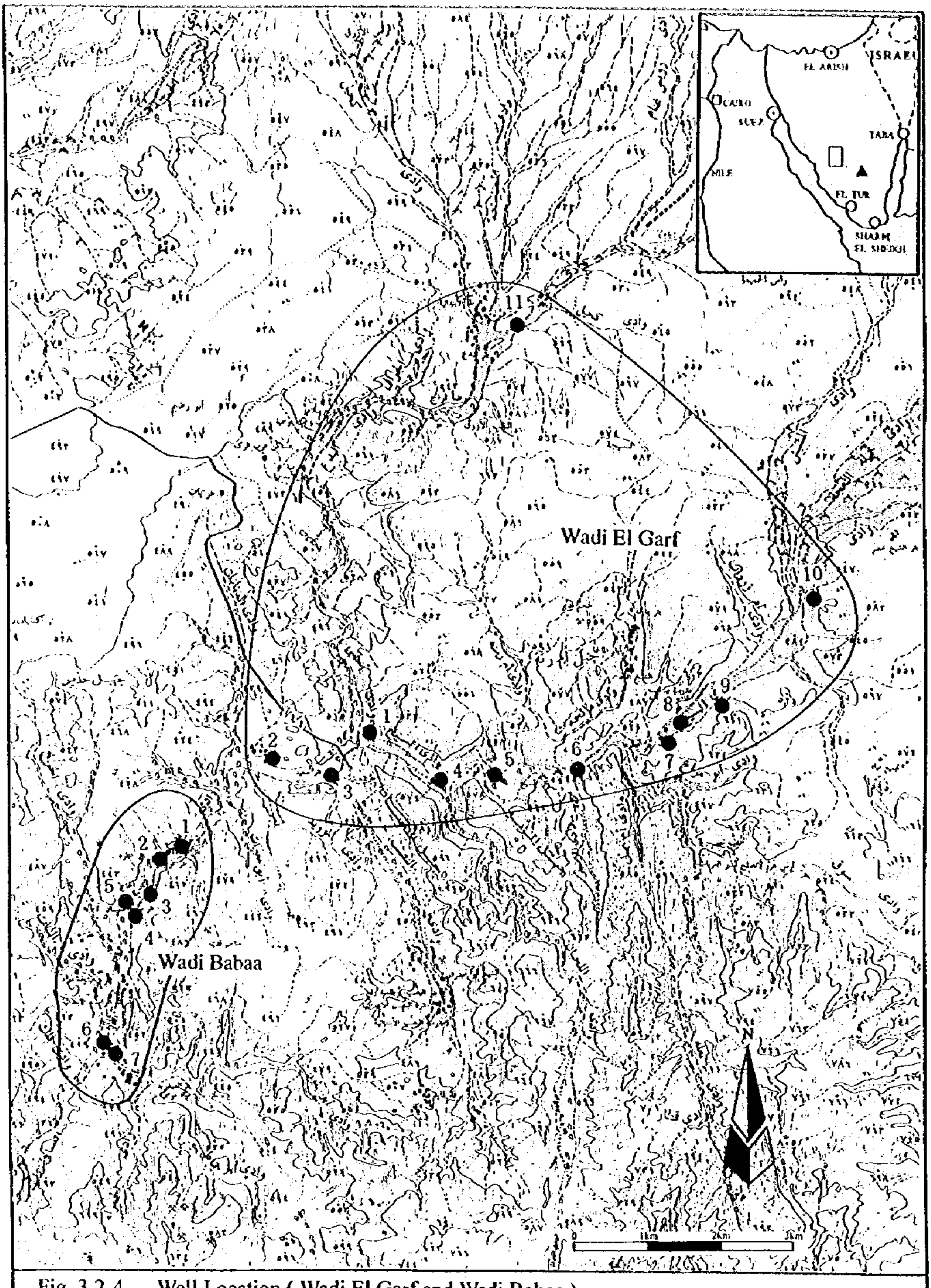

Fig. 3.2-4 Well Location (Wadi El Garf and Wadi Babaa)

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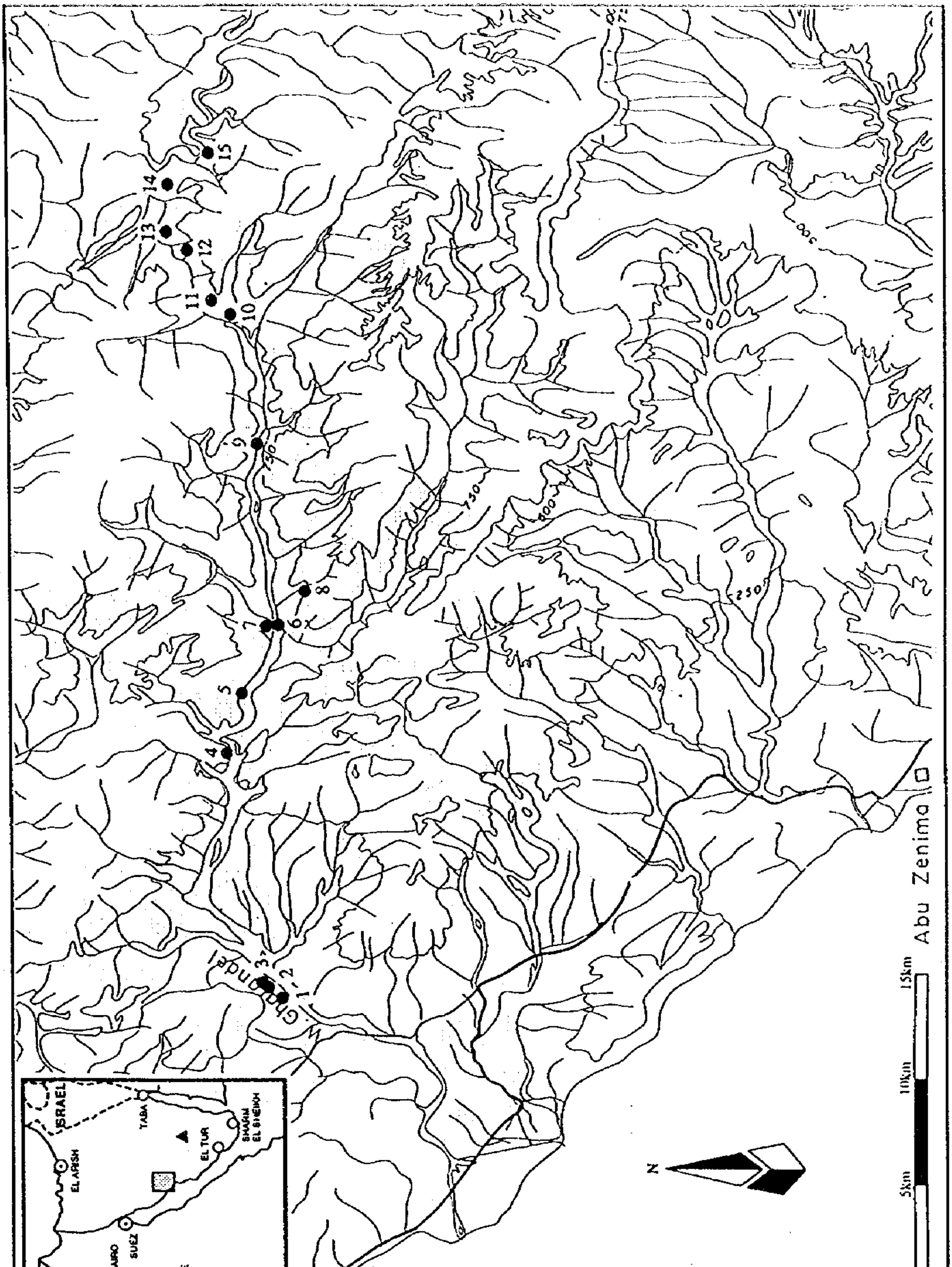

Fig. 3.2-5 Well Location (Wadi Gharandal)

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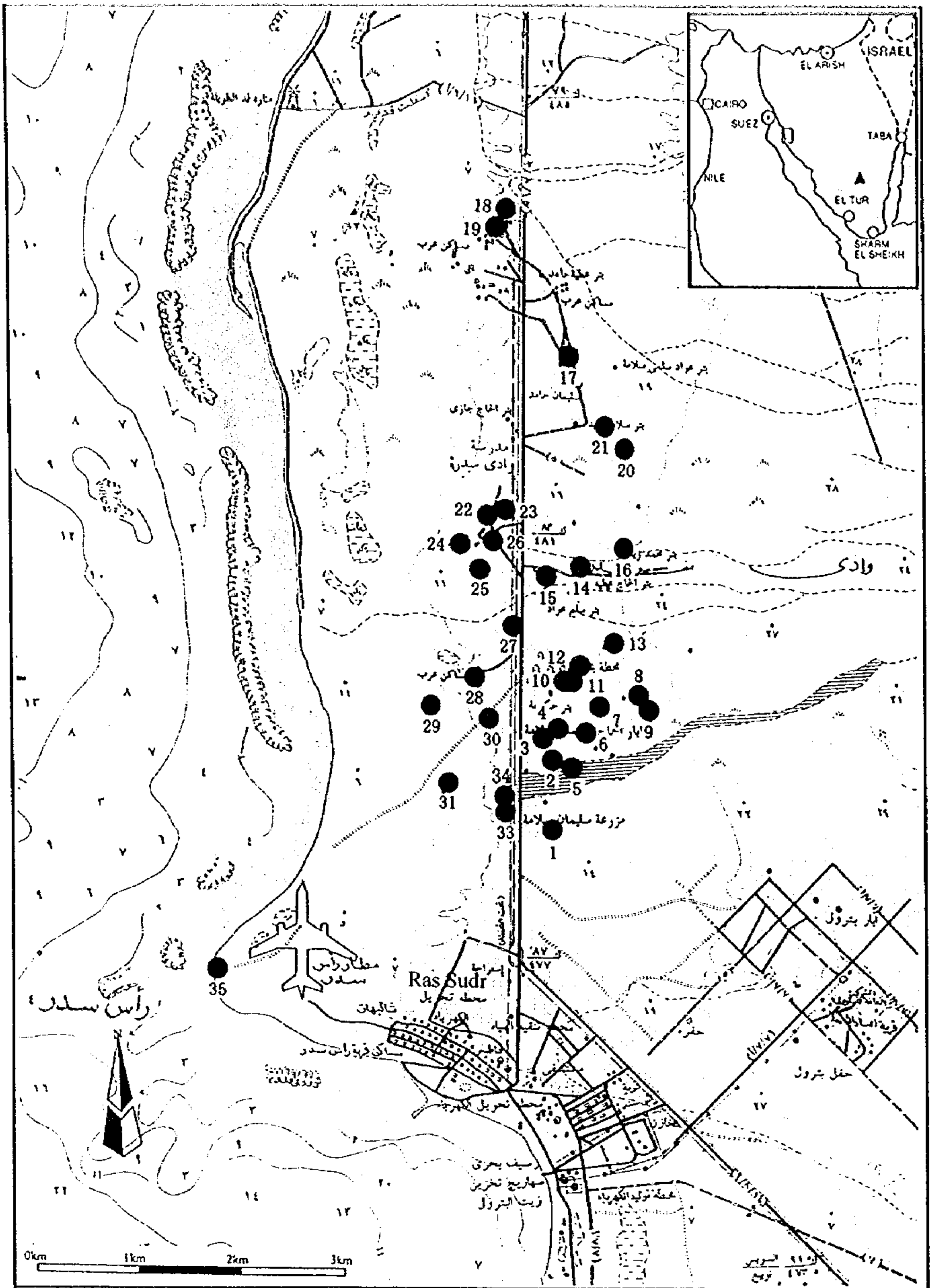

Fig. 3.2-6 Well Location (Ras Sudr Coastal Plain)

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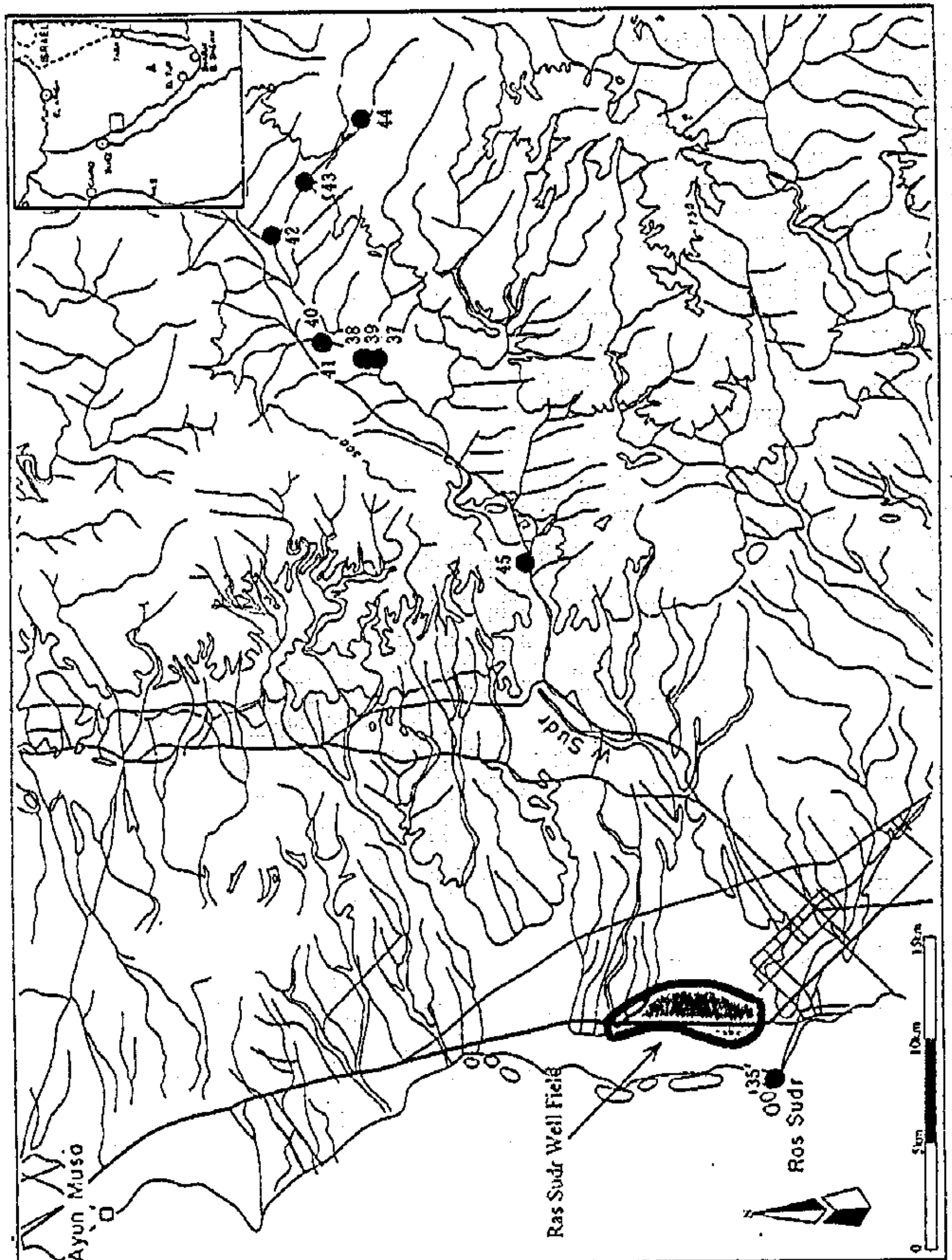

Fig. 3.2-7 (1) Well Location (Wadi Sudr 1/3)

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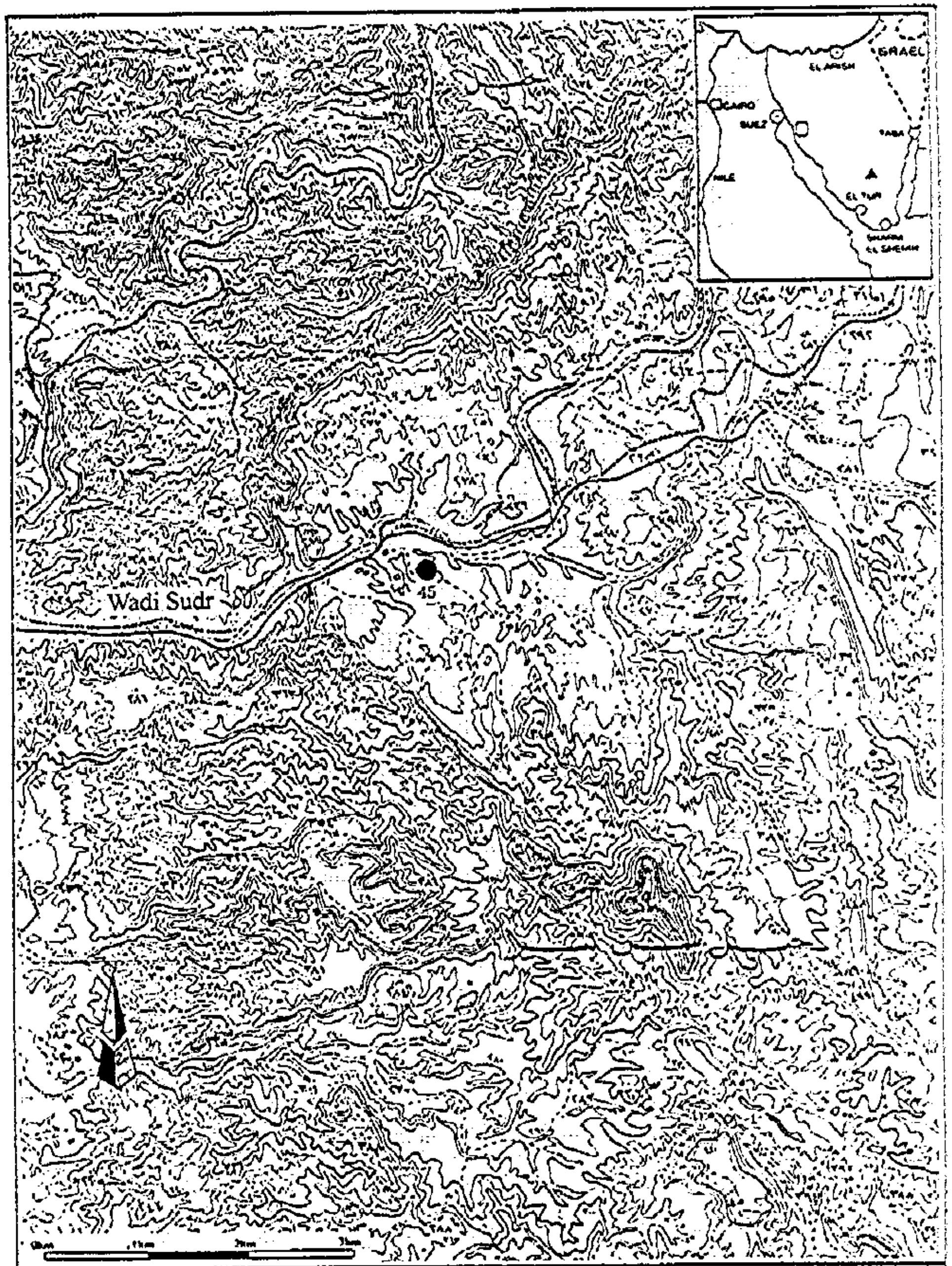

Fig. 3.2-7 (2) Well Location (Wadi Sudr 2/3)

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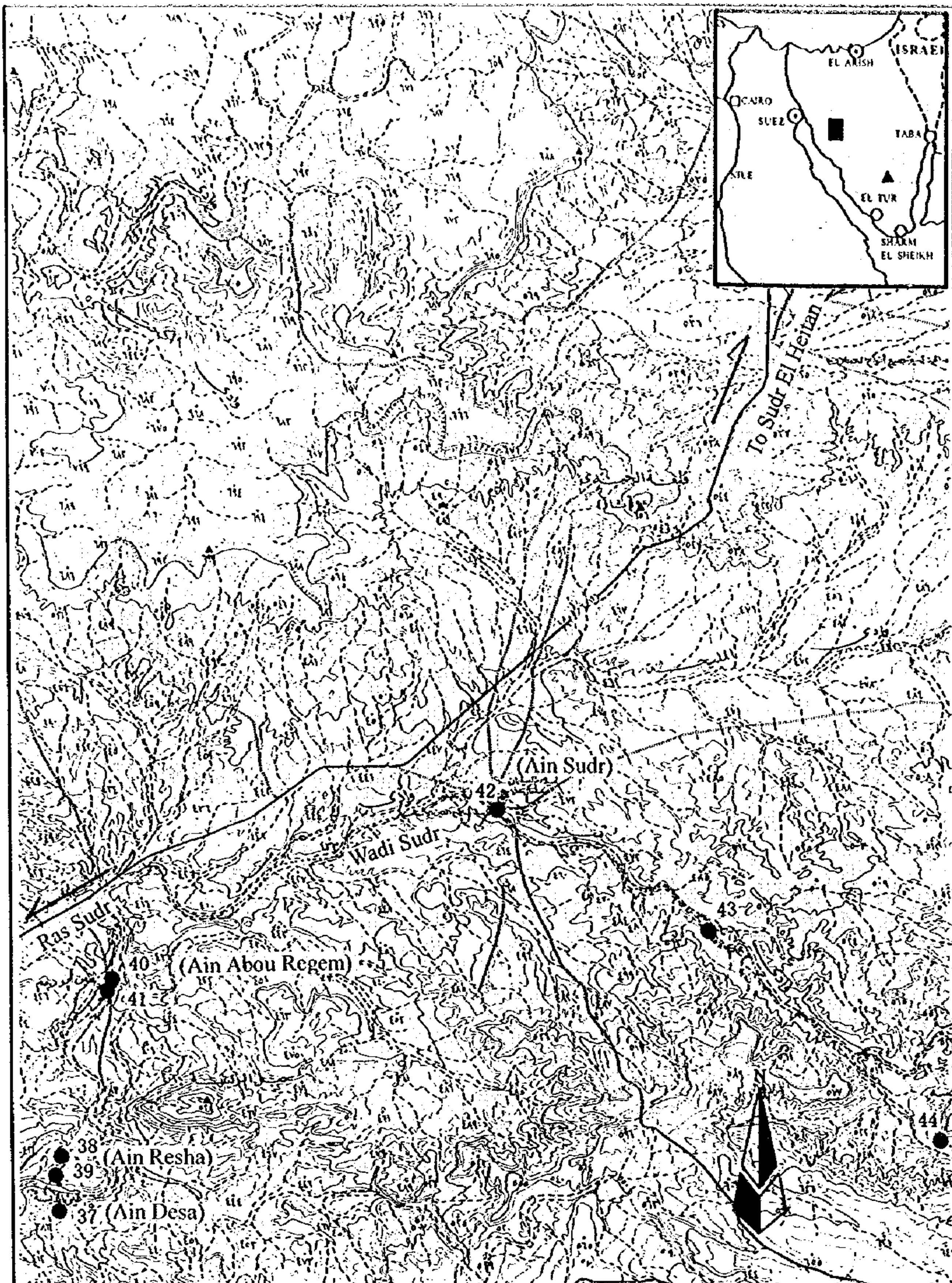

Fig. 3.2-7 (3) Well Location (Wadi Sudr 3/3)

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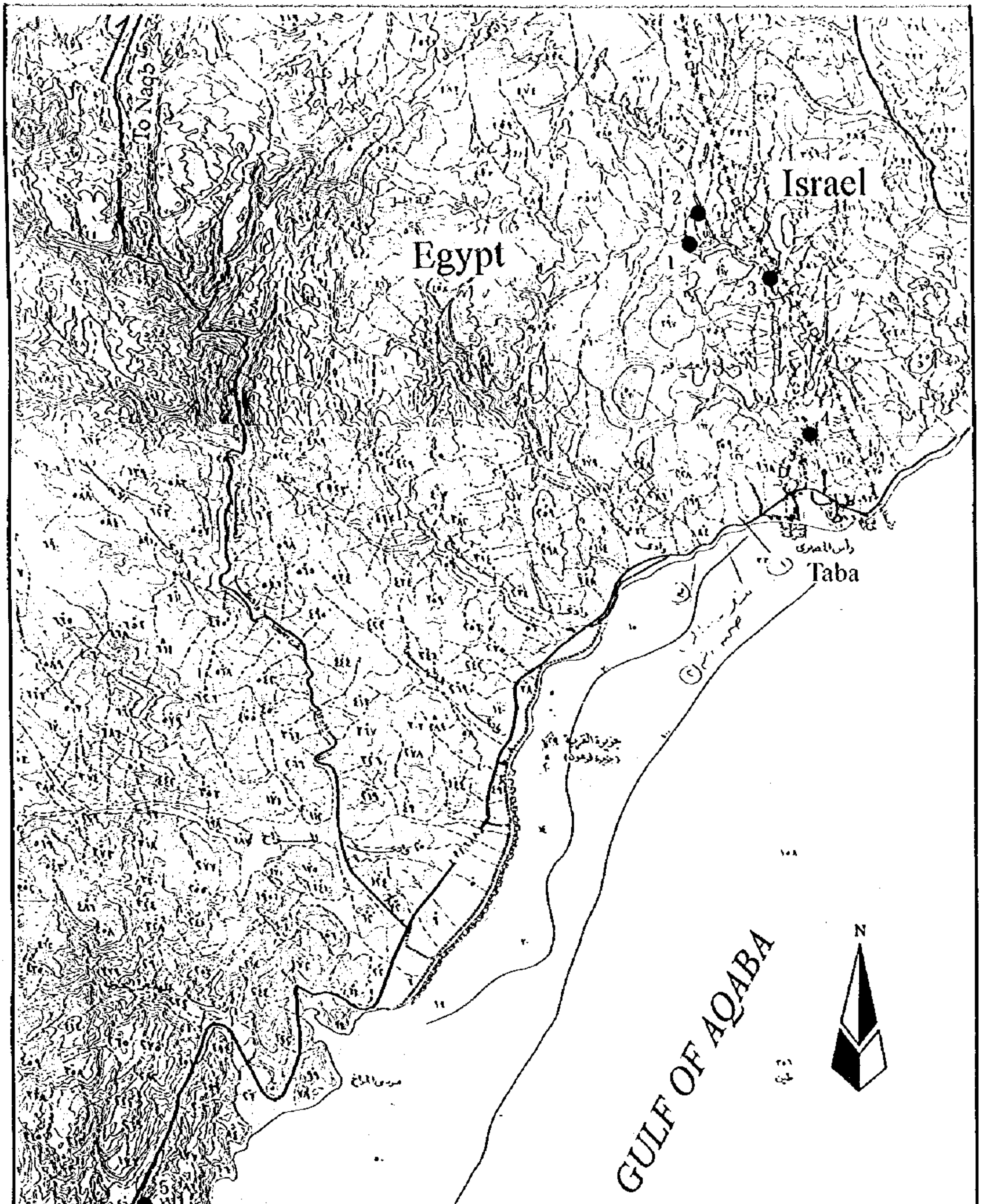

Fig. 3.2-8 Well Location (Taba Area)

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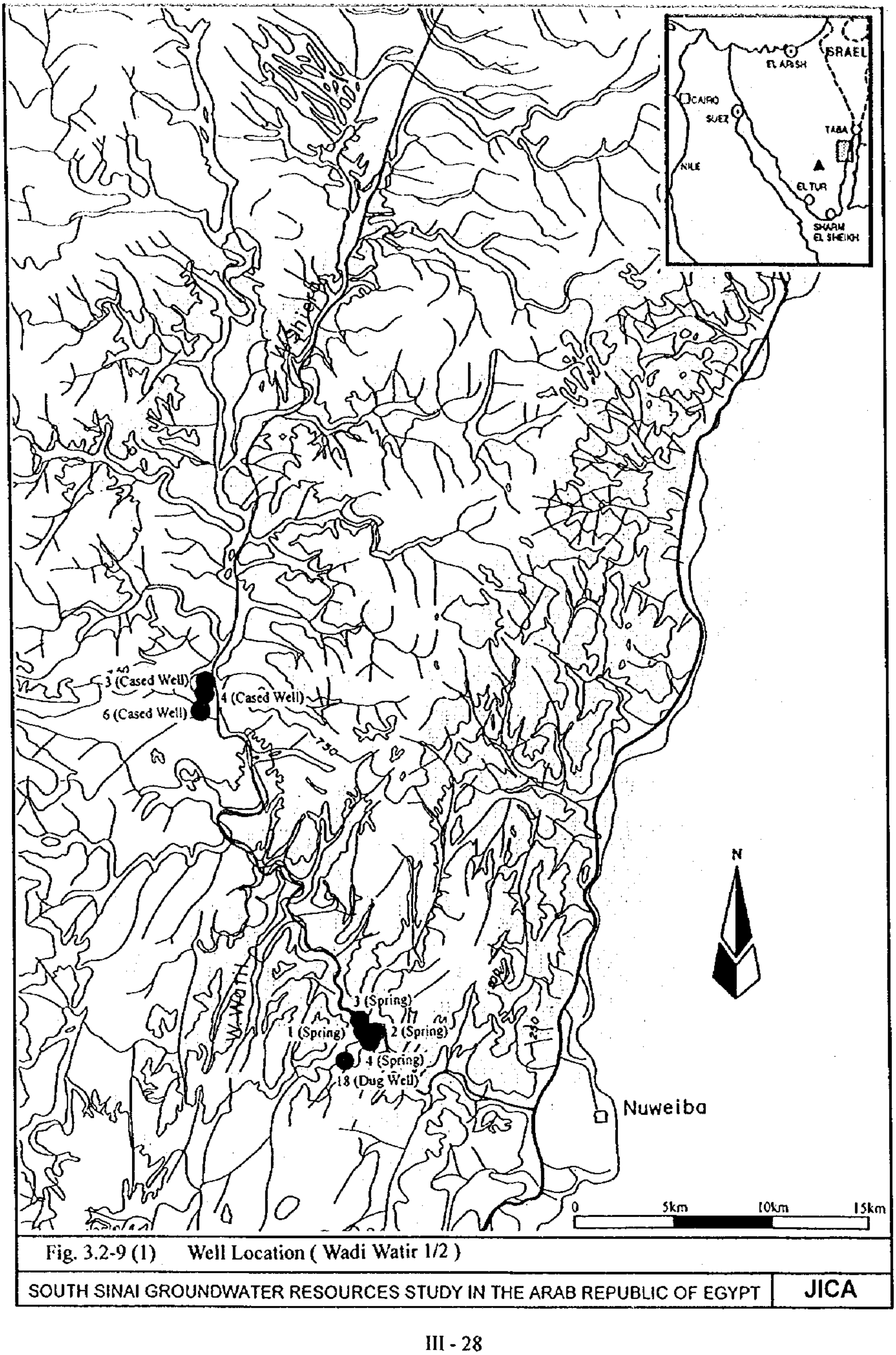

Fig. 3.2-9 (1) Well Location (Wadi Watir 1/2)

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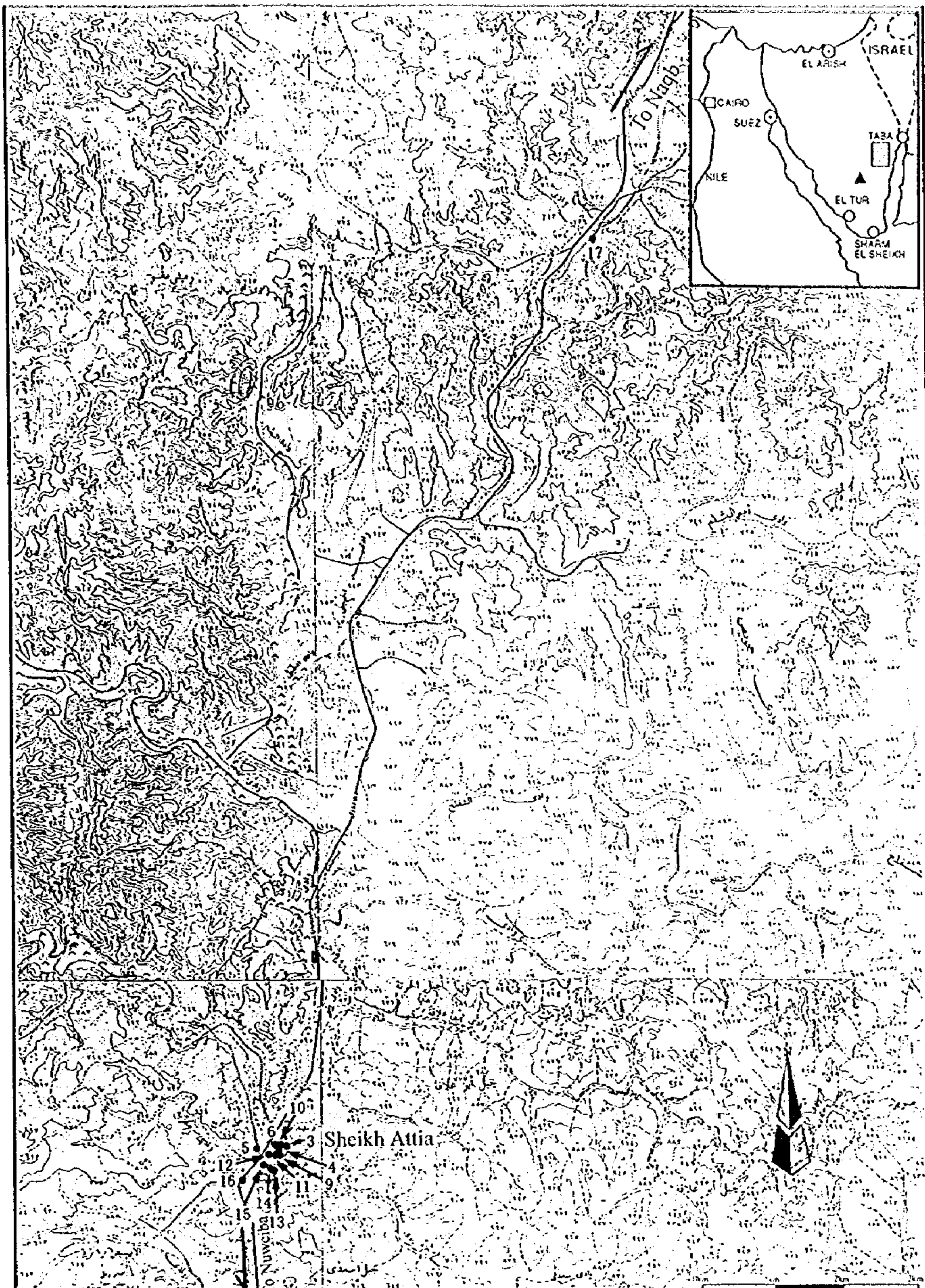

Fig. 3.2-9 (2) Well Location (Wadi Watir 2/2 Sheikh Attia Area)	
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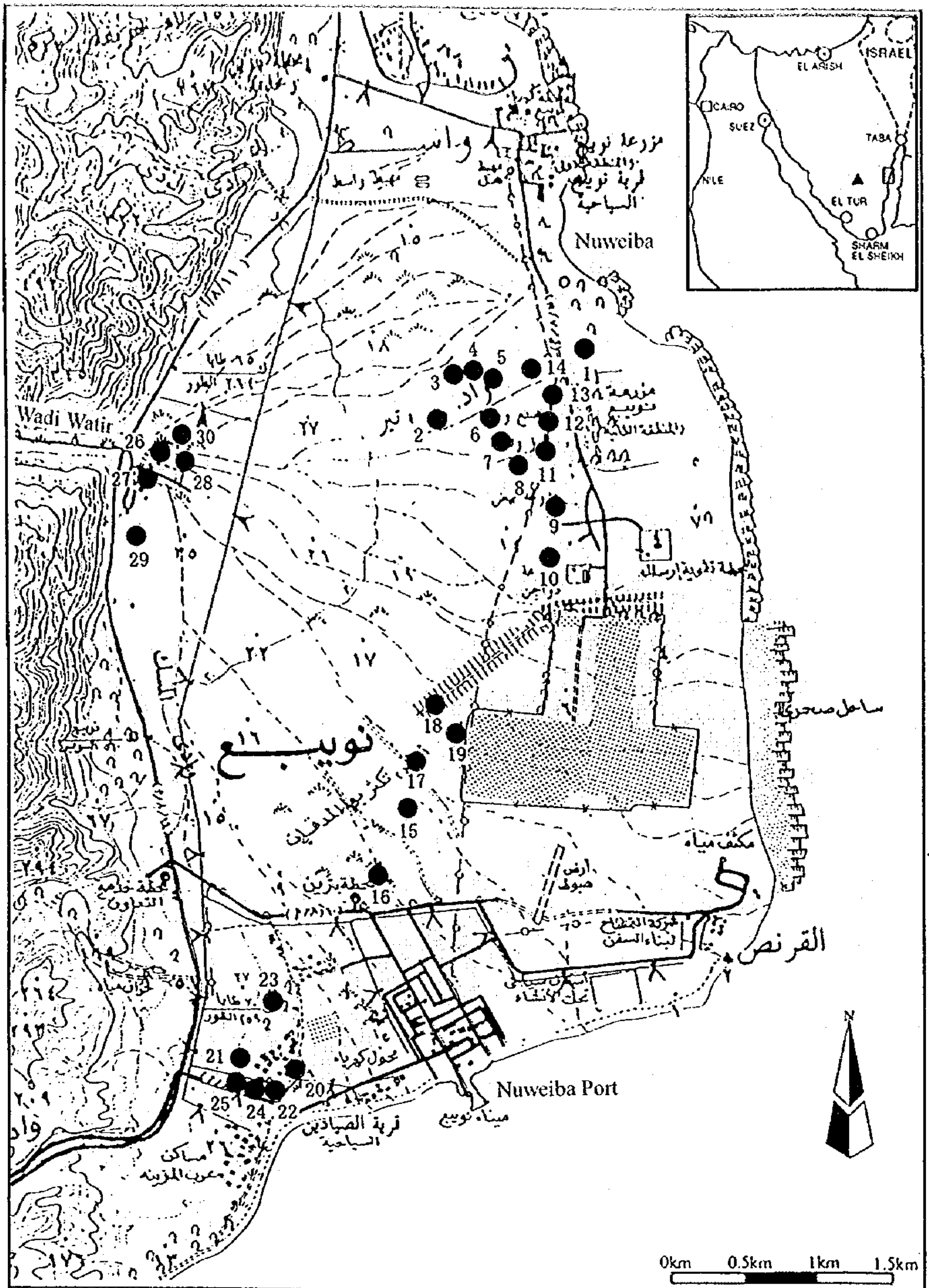

Fig. 3.2-10 Well Location (Nuweiba Coastal Plain)

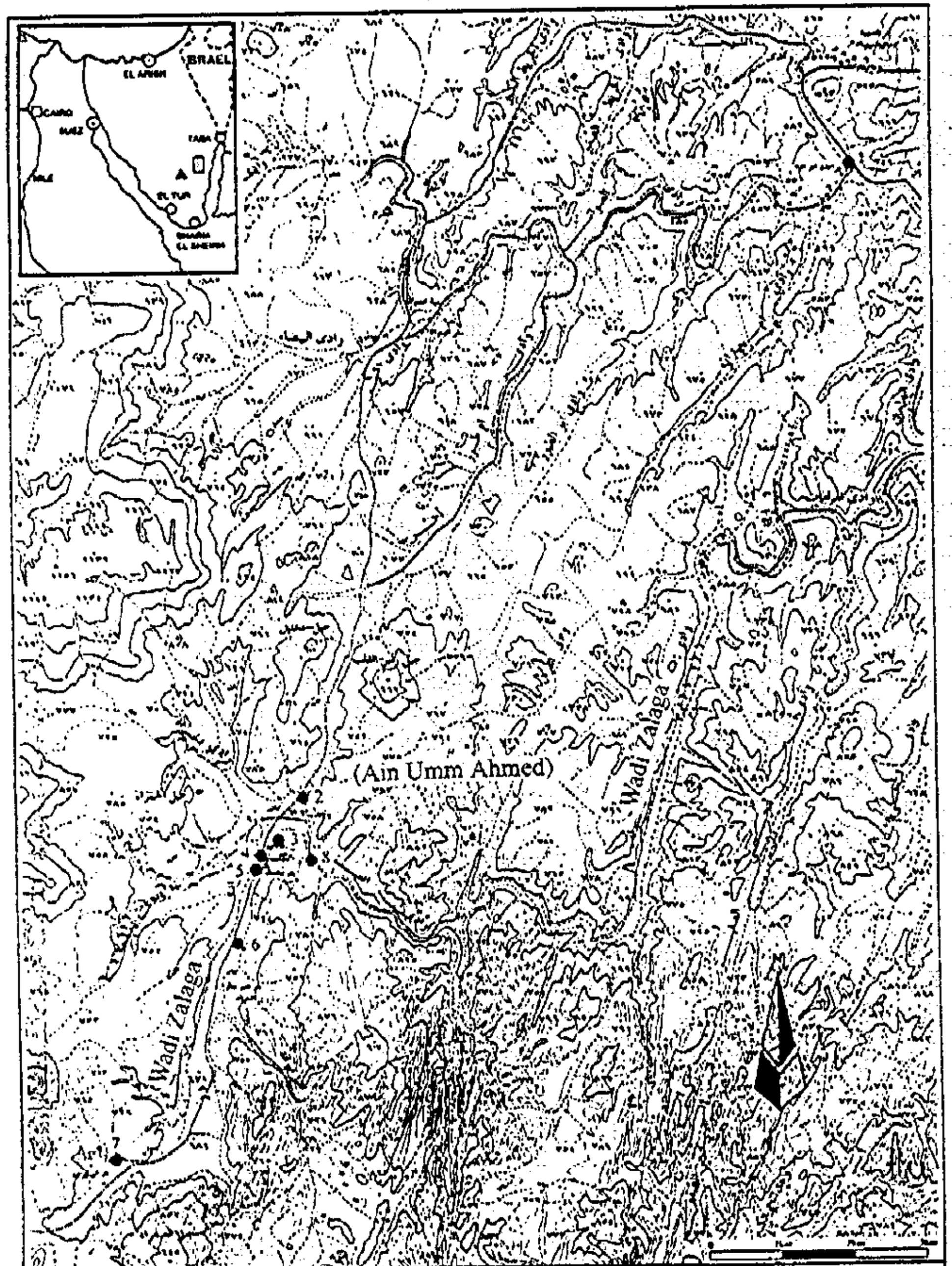

Fig. 3.2-11 (1) Well Location (Wadi Zalaga 1/2)

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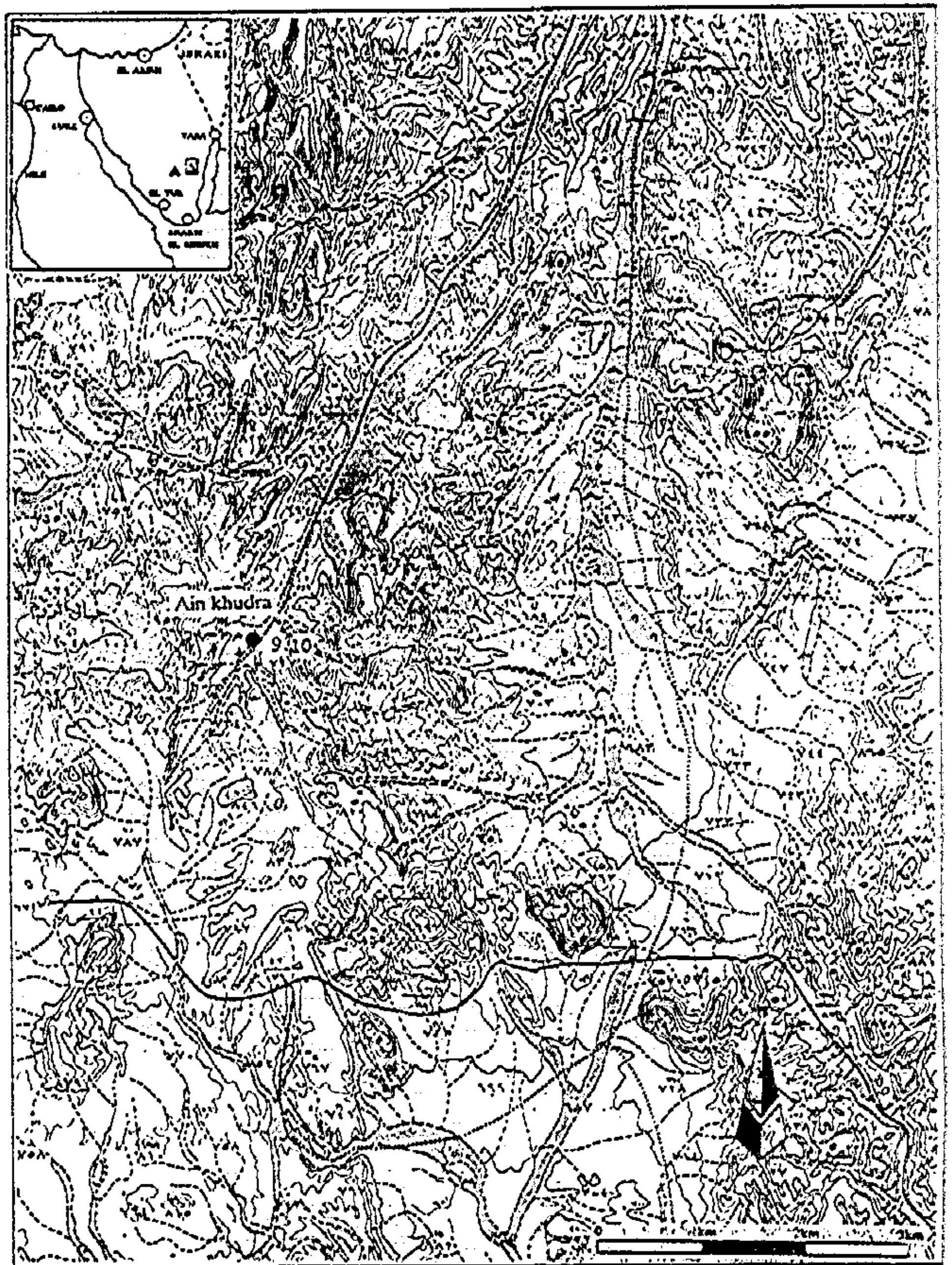

Fig. 3.2-11 (2) Well Location (Wadi Zalaga 2/2 Ain Khudra)

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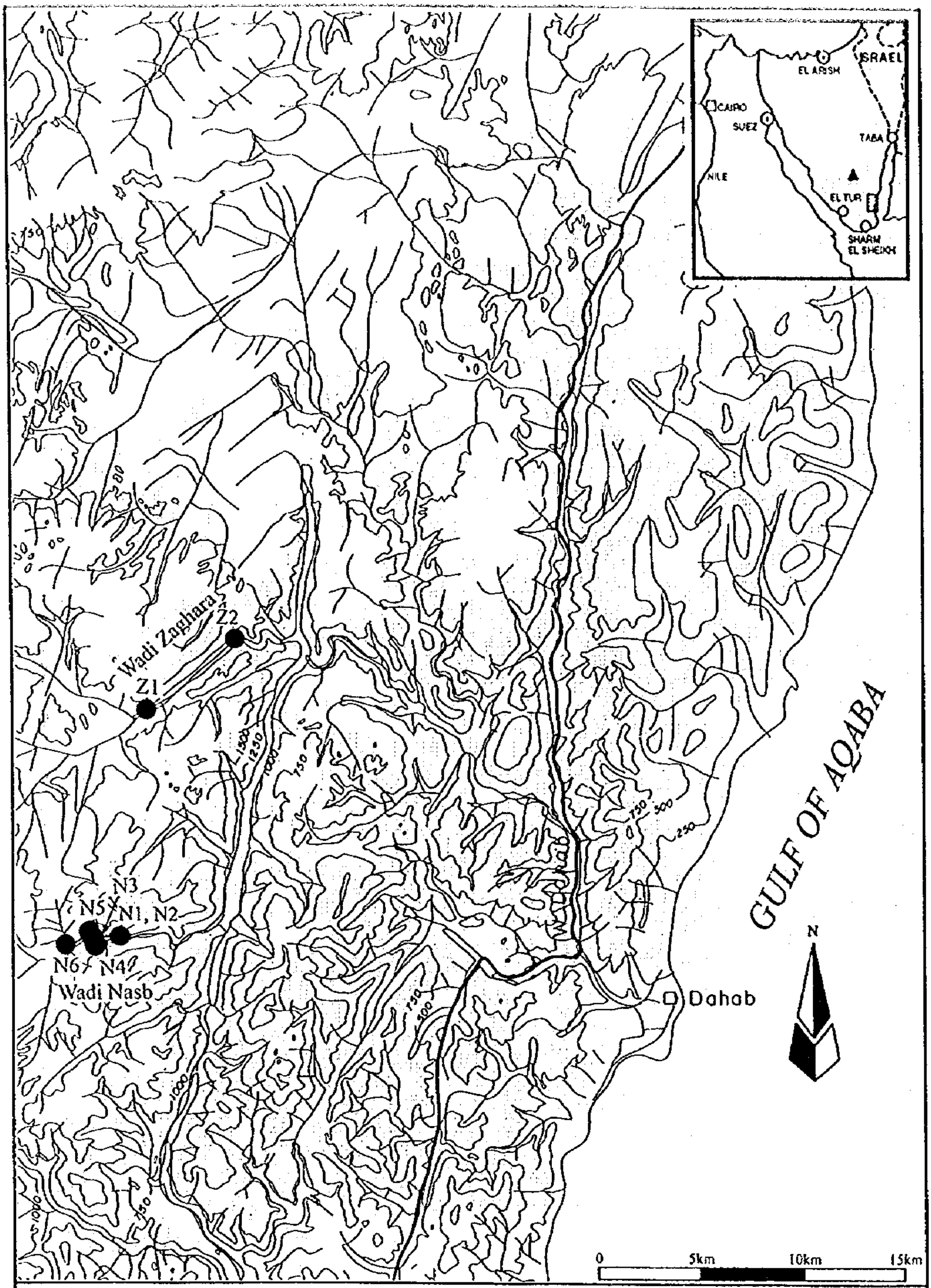

Fig. 3.2-12 Well Location (Wadi Zaghara and Wadi Nasb)

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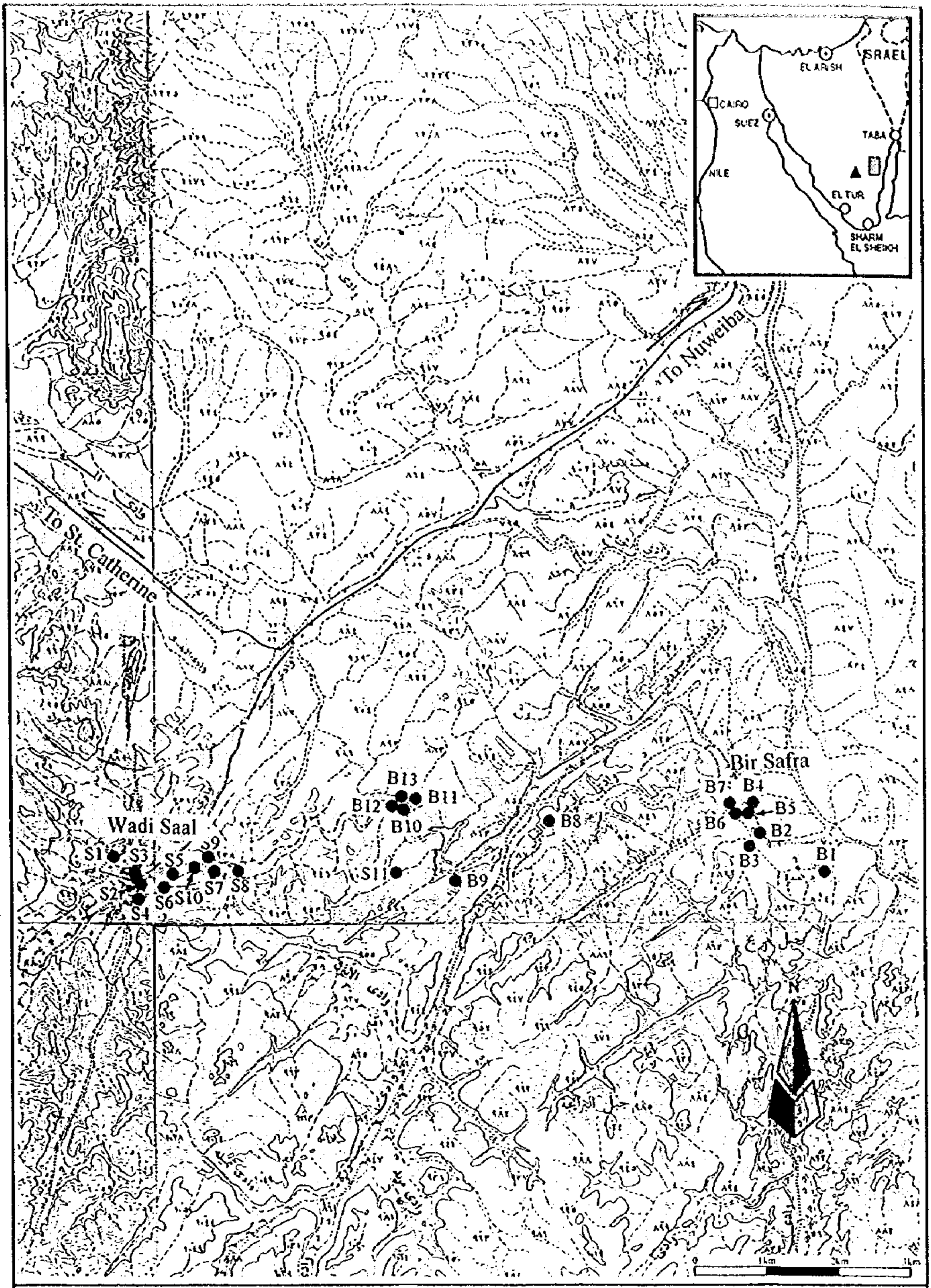

Fig. 3.2-13 Well Location (Wadi Saal)

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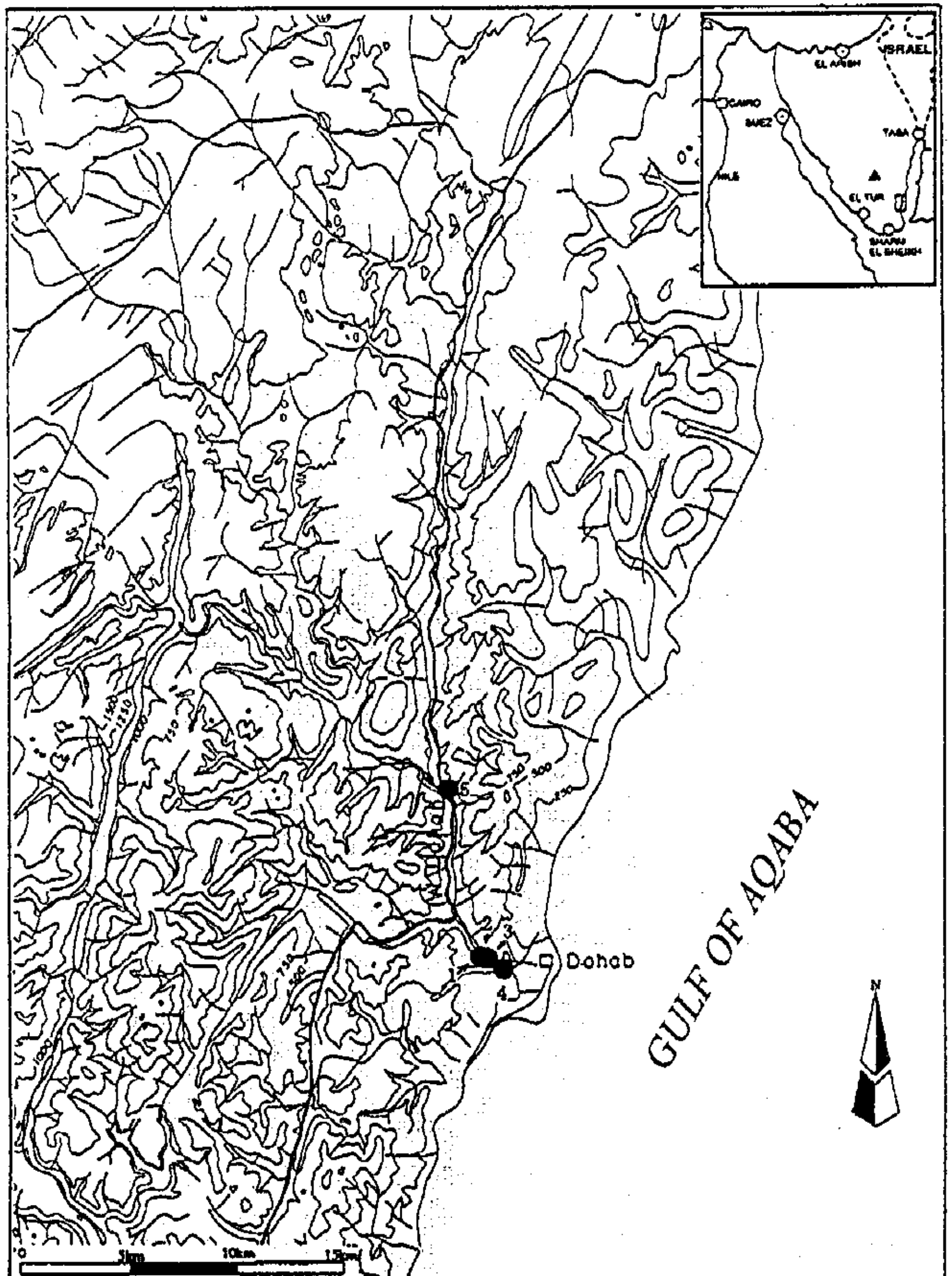

Fig. 3.2-14 Well Location (Wadi Dahab)

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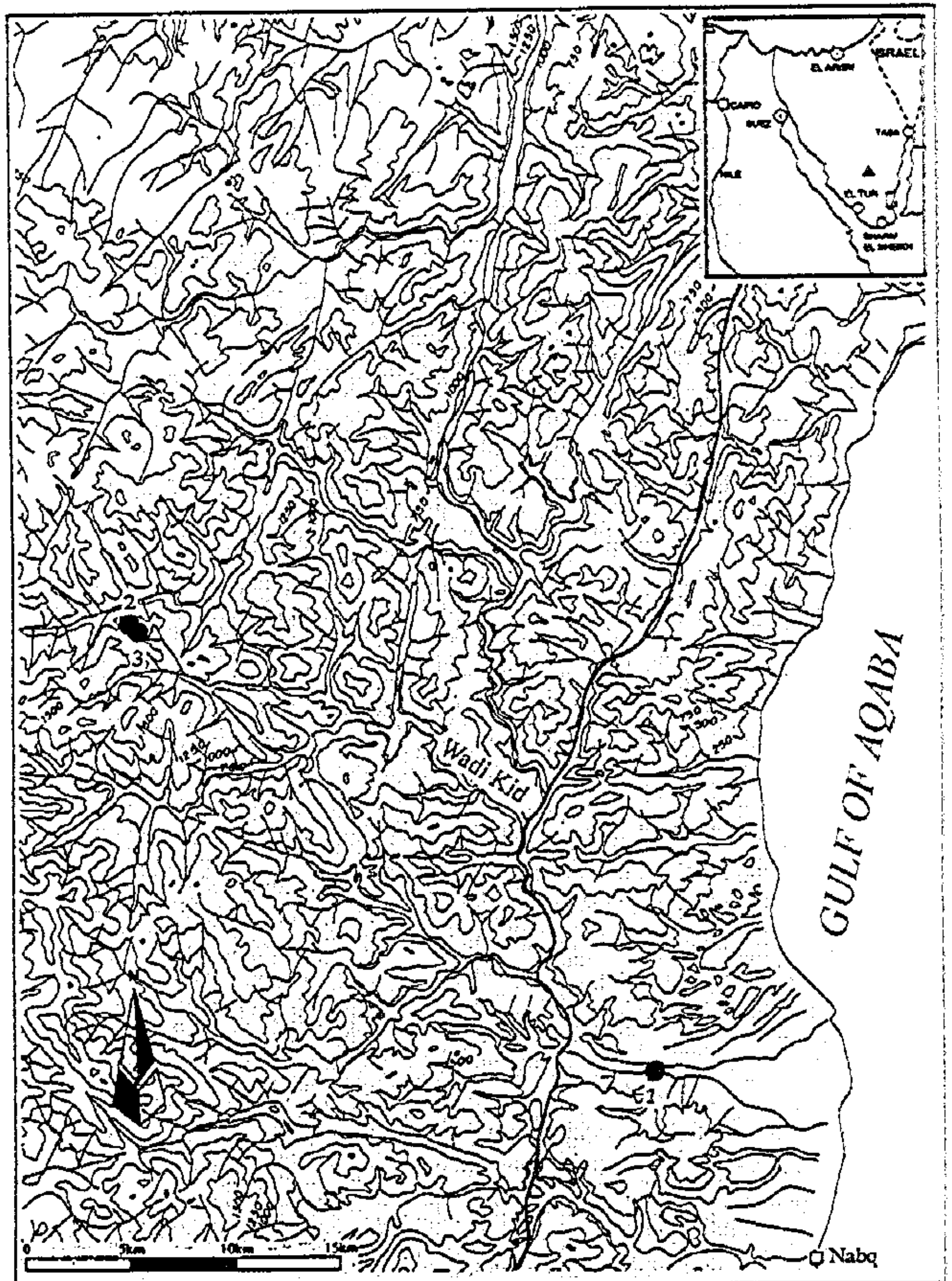

Fig. 3.2-15 Well Location (Wadi Kid)

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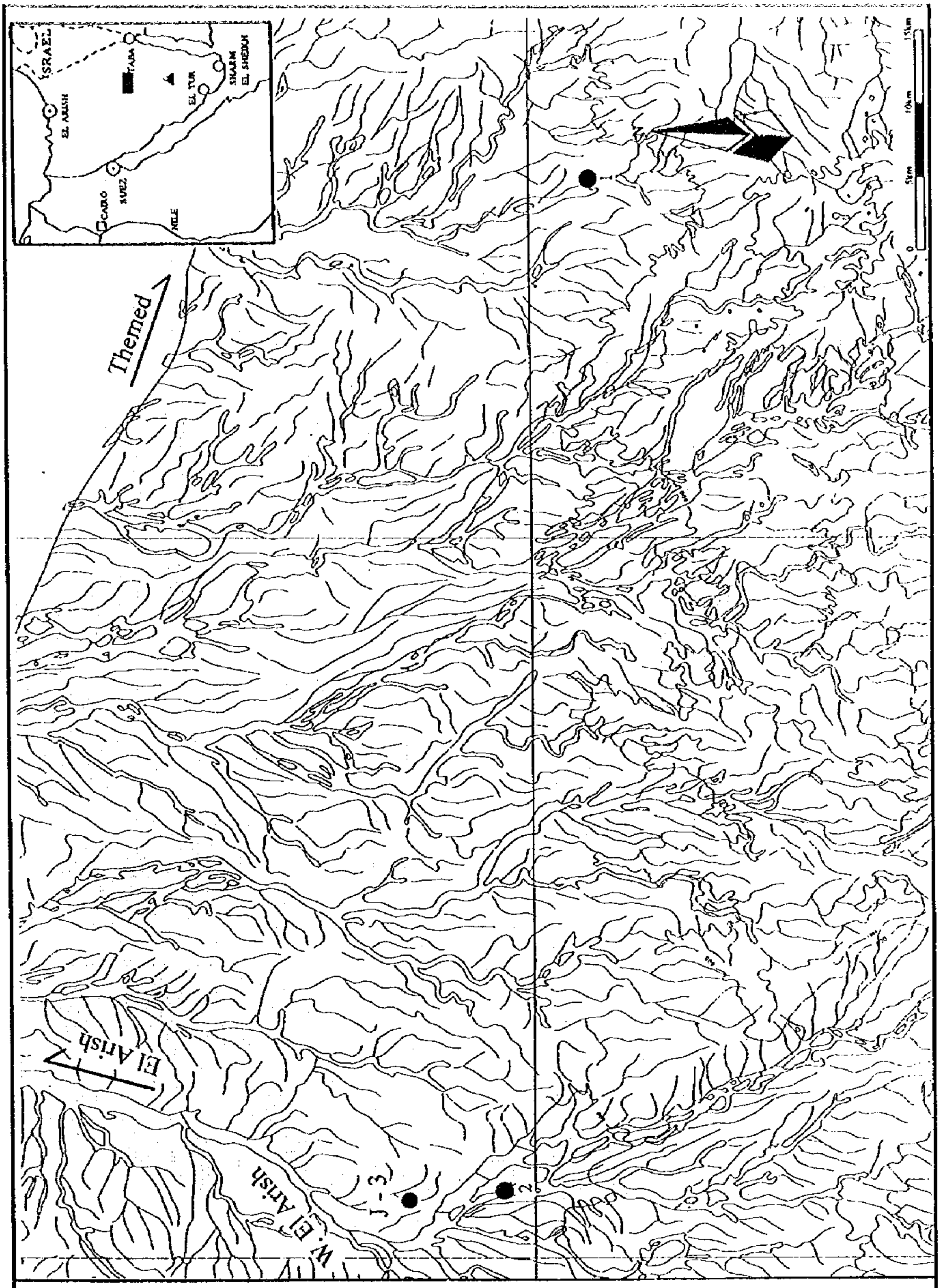

Fig. 3.2-16 Well Location (Wadi El Arish)

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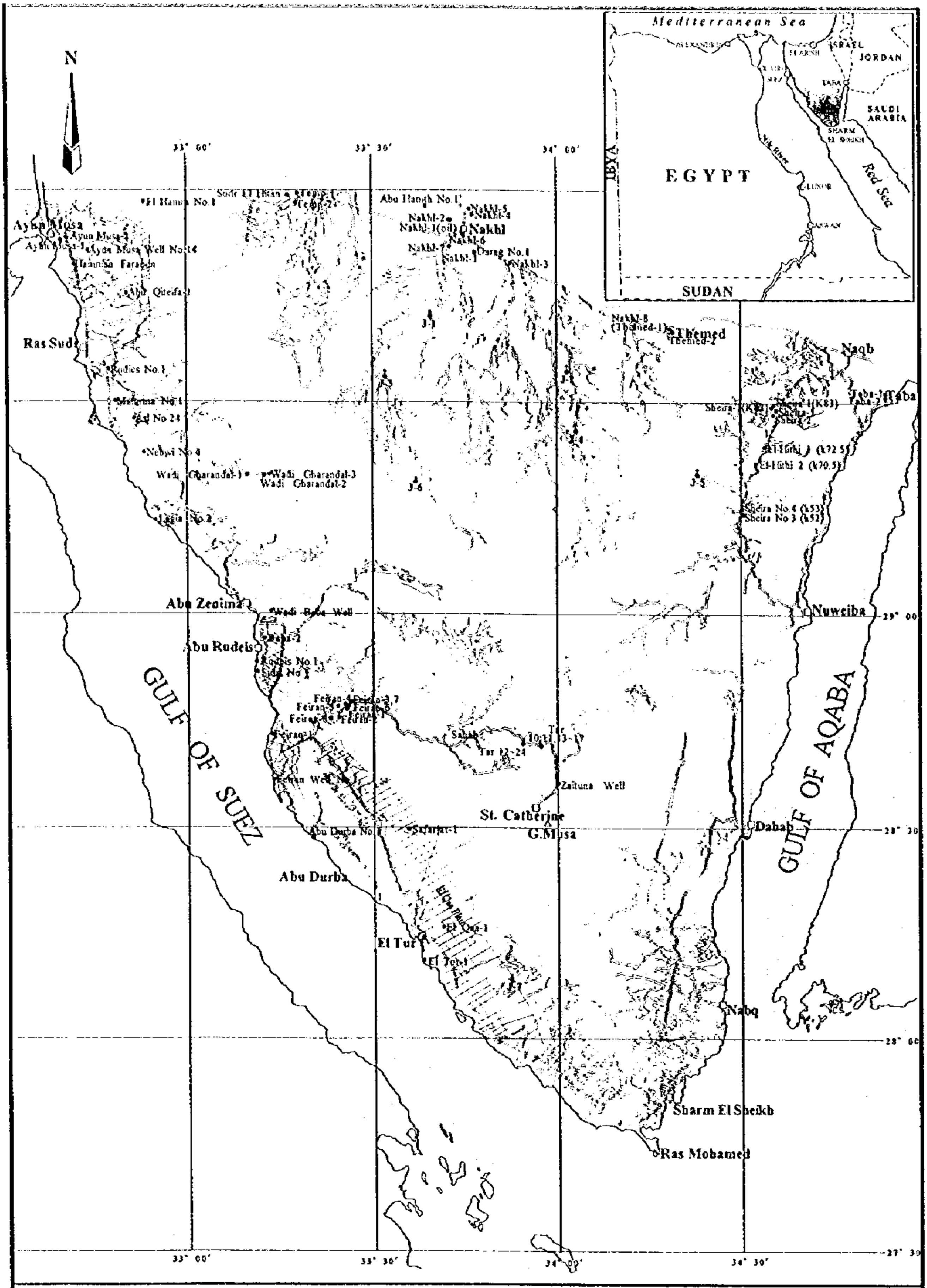

Fig. 3.2-17 Well Location (Pre-Quaternary Aquifer)

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3.3 Quaternary Aquifer

Distribution of the Quaternary Deposits in South Sinai are divided into three (3) categories by their sedimentary environment, El Qaa Plain, Coastal Plain and Wadi Area. The Quaternary Aquifers occur in those Quaternary Deposits. They are considered as local aquifers except El Qaa Plain and are used by Bedouin people

Distribution of the Quaternary Aquifers is shown in Fig. 3.3-1.

3.3.1 El Qaa Plain

1) General Features of the Basin

The El Qaa Plain is the most representative Quaternary sedimentary basin in South Sinai. The plain is located in the southwestern part of the area and covers an area of 1,930 km^2. The plain is bounded in the east by the uplifted Precambrian Basement Rocks, in the northern half of the west part by Gebel Hamam Saidna Musa and in the southern half by the Suez Bay. Main wadis flowing into the basin are W. Gibah, W. Hibran, W. Mir, W. Isla and W. Thiman. The total area of hydrological basin reaches 3,900 km^2.

El Qaa Plain is ranked as the high priority development area in South Sinai. The groundwater in the Quaternary aquifers are considerably exploited to meet the water demand of domestic water use in El Tur and Sharm El Sheikh, and irrigation use in the plain.

More than 60 wells, consisting of test wells, productive wells and piezometers, have been drilled in the plain, however, most of wells are now not in use or abandoned except WRRI's and TAAMIR's wells because most of agriculture farms were abandoned due to inadequate management of well facilities.

Well Inventory and Well Location are presented as Table 3.2-1 to 3.2-17 and Fig. 3.2-1 to 3.2-17 in the previous clause 3.2.

2) Hydrogeology of El Qaa Plain

Thick Quaternary Deposits cover the El Qaa Plain overlying the older formations such as the Tertiay, Mesozoic, Paleozoic and Precambrian. The Quaternary Deposits are called as the El Tur Group and consist of mainly sand and gravel with clay. Thickness of the deposits reaches 1000 m or more. The El Qaa Plain is divided into two (2) areas by a inferred fault which runs through the Wadi Isla.

Geological data is rich in the northern of the El Qaa Plain, while it is scarce in the south. A geological cross section in N-S direction is shown in Fig. 3.3-2. Geological description of each formation is presented in the table below.

<Hydrogeological description of formations in El Qaa Plain>

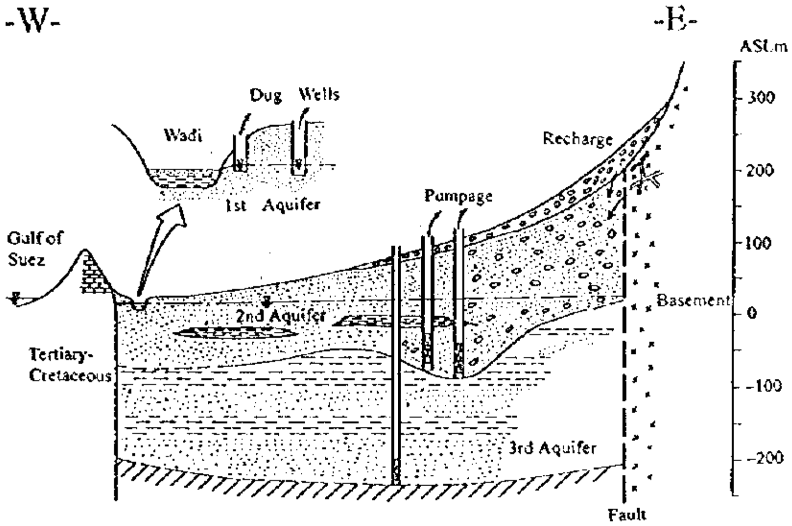
Period	Formation	Thickness (m)	Description
Quaternary Holocene	Sabkha Deposits		Distributed in the limited area at northwest of El Tur. Unexploitable aquifer.
	Wadi Deposits		Distributed in some wadi valleys. Mainly sand with small gravel. No aquifer in general but the area around El Tur.
Pleistocene	Gravel Deposits		Distributed in the whole El Qaa Plain. Composed of three parts; Upper, Middle, Lower.
		>100 in the central area	Upper; Coarse gravel with sand. An aquifer occurs at the shallow in the limited area around El Tur. Generally high electric resistivity value (>100 ohm-m) indicates no water.
		About 100	Middle; Coarse to medium sand and gravel, with interbeded clay. 2^{nd} aquifer occurs. Most of production wells extract groundwater from the aquifer. No distribution in southern El Qaa Plain, where basement likely occurs at the shallow depth. Showing medium electric resistivity value (10<50 ohm-m).
		>1000 depending on the location	Lower; Sand and gravel with clay and silt. 3^{rd} aquifer occurs. Less productivity than 2^{nd} aquifer. Showing low electric resistivity value (<10 ohm-m) in general. Probably low quality of water.
	Terrace Deposits		Mainly distributed on the northwestern border of El Qaa plain in contact with Gebel Quabiliyat.
Tertiary --- Paleozoic			Distributed in the mountainous region on the north and northwest side of El Qaa Plain. Remnant occurs in Gebel Safariat. Mainly limestone. No wells except oil exploration wells reached the formations in the plain.
Precambrian			Metamorphic rocks and igneous rocks. Distributed in the mountainous region on the eastern side of El Qaa Plain and in the southern area of the plain in places. Results of geophysical prospecting detected the basement rocks at shallow depth in the south of El Qaa Plain.

(1) Northern Area

In the northern area, the Quaternary Deposits are divided into following three (3) units.

Unit	Thickness	Lithology
Upper layer	100 m in maximum	gravel with sand
Middle layer	about 100m	sand and gravel with clay
Lower layer	(unknown)	sand and gravel with silt and clay

Three (3) aquifers are known in the El Qaa Plain, the first, the second and the third. Their schematic section in the E-W direction is shown below.



<Schematic Section of El Qaa Plain>

The first aquifer occurs in the limited area along the downstream of the Wadi El Awag near El Tur and Wadi Village.

The second aquifer occurs in the middle layer mentioned above and consists of coarse to medium sand and gravel. It is the most prospective aquifer in the El Qaa Plain. Most of wells were constructed reaching the second aquifer.

The third aquifer occurs in the lower layer and consists of sand and gravel. Several wells reached to this aquifer.

(2) Southern Area

The Quaternary Deposits in the southern area become almost one (1) unit and is composed mainly of sand and gravel.

No fresh groundwater was found in the southern part of the El Qaa Plain in the past. Three (3) test wells were drilled by WRRI, however, the results were dry or saline. Only saline groundwater has been extracted by a petroleum company, PETROBEL, by two (2) wells located about 5 km inland from the coast.

On the other hand, fresh groundwater has been extracted by Bedouin people in the Wadi Isla and the Wadi Thiman that flow into the southern part of the El Qaa Plain.

The TEM survey and Test Well Drilling by the Study Team confirmed the existence of fresh groundwater aquifer in the southern part of the El Qaa Plain as mentioned following clause.

2) Geological Survey

The Transient-Electromagnetic (TEM) survey was conducted in the Study for the Quaternary Deposits to supplement the existing geological data. In addition, one (1) test well was drilled in the south of the El Qaa Plain to confirm the existence of an aquifer which was detected by the TEM survey.

(1) Transient-Electromagnetic (TEM) Survey

The TEM survey was performed for 202 stations set on seven (7) survey lines. Spacing of survey station was 1 km in general, while 0.5 km of spacing was applied in the southern half of the survey line B to detect possibilities of existence of fresh groundwater aquifers. Location of the survey lines and stations are shown in Fig. 3.3-3.

Resistivity profiles along the seven (7) survey lines and two (2) horizontal profiles were drawn based on the observed apparent resistivity curve at each station. They are shown in Fig. 3.3-4 (1) to (5).

Geology of the survey area is classified into four (4) layers in terms of apparent resistivity. The thickness, resistivity and estimated lithology of each layer are summarized below.

Layer	Thickness (m)	Resistivity (ohm-m)	Lithology
1st Layer	about 10	more than 50	sand and gravel
2nd Layer	about 80	10 - 20	sand and gravel
3rd Layer	more than 1000	10 or less	sand with silt and clay
4th Layer	-	more than 50	basement rocks

Among four (4) layers, the 3rd layer is lack in the south of the area, while the 4th layer is not recognized in the north of the area.

The 2nd layer is considered as the most prospective aquifer in the area.

Remarkable discontinuous resistivity structure is recognized, which divides El Qaa Plain into two parts, the north and the south. The boundary between both areas is considered as an inferred fault located on the extension of the valley of the Wadi Isla. The basement rocks occur in a comparative shallow depth in the southern side of the inferred fault, while it is very deep (more than 1000 m) in the northern side. This situation is shown in geoelectric profile of Line B (Fig. 3.3-4 (2)).

It has been considered that there is no fresh groundwater aquifer in the south of the El Qaa Plain. However, the TEM survey revealed the existence of a layer of which resistivity is same as that of the 2nd layer as shown in Fig. 3.3-4 (1) and (2). It was confirmed by test well drilling that a fresh groundwater aquifer also distributes in the south of the El Qaa Plain. The result is mentioned in the next clause.

Fig. 3.3-4 (4) and 3.3-4 (5) are horizontal resistivity profiles at depths of 0 mASL (sea level) and –100 mASL, respectively.

At the sea level (Fig. 3.3-4 (4)), the 2nd layer is widespread in the northern part of the El Qaa Plain. Low resistivity zone, the 3rd layer distributes near El Tur. On the other hand, the area of the 2nd layer becomes small at 100 m below the sea level (Fig. 3.3-4 (5)) and the low resistivity zone (the 3rd layer) occupies more than half of the northern part of the plain.

Extremely low resistivity zone (less than 5.6 ohm-m) distributes along the coast in the south from El Tur. It suggests the existing of the sea water intrusion to the aquifers.

(2) Test Well Drilling

One (1) test well, J-7, was drilled in the southern part of the El Qaa Plain to confirm the TEM survey result, existence of groundwater aquifer. The test well location (J-7) is shown in Fig. 3.3-3 together with the TEM survey lines.

The test well was drilled in the Quaternary Deposits up to the depth of 250m, however, it did not reach the basement rocks. Lithology is sand and gravel. Screen was installed in the section between 196 m and 236 m. Static water level was confirmed at 148.99 mBGL. The geological column and other logs of the well are shown in Fig. 3.3-5.

The result of the pumping test is summarized in the next table.

Maximum Discharge (m^3/h)	Drawdown (m)	Transmissibility T:(m^2/min)	Storage S	Permeability k (cm/sec)	TDS (mg/l)
6.0	85.01	6.81×10^{-4}	-	1.14×10^{-3}	458

3) Aquifer

(1) Configuration of Aquifer

Location and size of the aquifers of the El Qaa Plain were estimated based on the TEM survey results and the result of test well along with the existing data.

The aquifers in the El Qaa Plain extend in two (2) areas from the northern part of the plain toward the east of El Tur and mountain foot area about 22 km east from El Tur. The former is the main aquifer in the area and the latter is newly confirmed aquifer. Their locations are shown in Fig. 3.3-6.

The base (bottom) of the main aquifer and its isopach map were prepared as Fig. 3.3-7 and 3.3-8, respectively.

i) Northern Part

Two (2) aquifers are recognized in the area, the first aquifer and the second aquifer. The first aquifer occupies a limited area in the Wadi Awag near El Tur and Wadi Village. The second aquifer is the main aquifer and is widespread in the El Qaa Plain.

The main aquifer (the second aquifer) is distributed in the wide area between about 10 km from the entrance of Highway to the north-east end of the plain. and near El Tur. It is about 60 km in length with about 10 km of width. Therefore, the main aquifer occupies about 678 km^2. The bottom of the main aquifer varies in a range from -20 mASL to deeper than -100 mASL. The deepest place is found at about 15 km NNE from El Tur. Another deep bottom place is located in about 13 km east from Gebel Safariat, where it is -80 mASL.

The static water level and the range of screen installed in each well are shown in Fig.3.3.9. Range of screen concentrates in a horizon between about 20 mASL and -70 mASL. This fact reveals that most of wells are exploiting groundwater in the second aquifer.

ii) Southern Part

The aquifer was detected by the TEM survey and confirmed by the Test Well Drilling. The distribution area is near the outlet of the Wadi Thiman as shown in Fig. 3.3-6.

The bottom of the aquifer in the southern part has not been confirmed because the test well did not reach there. Judging from the drilling result, it is lower than 80 mASL.

The area of the fresh groundwater aquifer is estimated at approximately 79 km^2.

(2) Hydrogeological Characteristics of Aquifer

The prospective aquifers are mainly composed of sand and gravel. Based on the existing data and the Test Well drilling, hydrogeological factors of aquifers are summarized as follows.

	Yield (m^3/h)	Specific Capacity (l/s/m)	Transmissivity (m^2/day)	Hydraulic Conductivity (m/day)
Second aquifer (northern part)	20 - 115 (average 56.7)	0.33 - 6.11 (average 2.64)	106 - 2150 (average 768)	4.6 – 71.6 (average 23.9)
Second aquifer (southern part)	48.6 --101.5 (average 67.2)	0.53 -9.23 (average 4.36	81 - 2639 (average 989)	2.7 – 71.5 (average 25.5)
Third aquifer	20.3 – 52.0 (average 34.6)	0.08 – 1.07 (average 0.54)	9 – 52.3 (average 85)	0.28 – 5.23 (average 2.0)
J-7 (Southern part of the El Qaa Plain)	6.0	0.07	0.98	1.64

4) Groundwater Level and Quality

(1) Existing Groundwater Extraction

At present, 14 wells are exploiting groundwater from the second aquifer. Seven wells of them are for domestic water supply to El Tur and two (2) of them are for domestic water supply to Sharm El Sheikh. And the remaining five (5) wells are for irrigation in the plain. Further, 29 dug wells are used for private farms and some of them are supplying water to Sharm El Sheikh.

Although no flow meter is working at the wells, extraction amount from the main aquifer is estimated as following table.

Year	Number of wells		Average groundwater extraction (m^3/day)		
	Irrigation	Domestic	Irrigation	Domestic	Total
1971	2	3	500	1,700	2,200
1984	14	6	5,350	3,200	8,550
1987	14	9	6,540	6,500	13,040
1990	14	9	2,310	7,960	10,270
1992	10	8	830	7,790	8,820

In addition, dug wells yield an amount of 2,000 m^3/day of groundwater.

Total extraction in the El Qaa Plain in 1997 is itemized as below.

(unit: m^3/day)

Domestic water for El Tur	Domestic water for Sharm El Sheikh	Irrigation	Dug wells	Total (m^3/day)
6,000	1,000	451	2,000	9,415

Furthermore, some amount of groundwater is led to a facility near the Highway from the Wadi Isla and transport to Sharm El Sheikh by lorries. Its amount is estimated at 50 to 60 m^3/day. Annual total extraction reaches 3.44 x 10^6 m^3/year.

(2) Groundwater Level

Static water level in the El Qaa Plain has been periodically observed by WRRI. The results are shown in the following table.

Change of average water level from 1989 to 1997 (mASL)

Well No. (Code & Name)	1989	1990	1991	1992	1994	1995	1996	1997
43; 48CB-001	1.93	1.81	2.09	1.88	1.93	1.93	1.75	
RIWR 1		-0.12	0.28	-0.21	0.05	0.00	-0.18	
44; 48CB-002	8.65	8.70	8.54	8.44	8.47	8.51	8.36	8.20
RIWR 2		0.05	-0.16	-0.10	0.03	0.04	-0.15	-0.16
50; 48CC-003	15.05	14.51	14.41	14.38	14.34	14.32	14.36	14.27
T-7		-0.54	-0.10	-0.03	-0.04	-0.02	0.04	-0.09
52; 48CC-005	19.03	19.01	18.97	18.84	18.66	18.66	19.41	18.46
RIWR 1B		-0.02	-0.04	-0.13	-0.18	0.00	0.75	-0.95

Upper raw: Average water level in the year.
Lower raw: Difference from the previous year.

The above table shows long-term change of groundwater level between 1989 and 1997. Judging from the table, groundwater level tends to decrease gradually. Annual average decrease is 6.3 cm/year since 1989.

Based on the observation result of groundwater level, two (2) contour maps of water level were prepared. One is in February 1997 (Fig. 3.3-10 (1)) and another is in September 1997 (Fig. 3.3-10 (2)). No difference was confirmed between the both results.

Static water level is 25 mASL in the central area of the El Qaa Plain (near Gebel Safariat) and 5 mASL near El Tur. Gradient of water level is 0.6/1000.

Based on the analysis of water level, groundwater flow is considered as shown in Fig. 3.3-11. Two (2) apparent groundwater flows are recognized. One is from the north of the plain or the upstream of Wadi Amag. toward the south and another is from the Wadi Hibran and Wadi Mir originated in the Precambrian Basement Rocks.

Both streams merge at the north of Wadi Village and flow down toward El Tur.

Dug wells are concentrated in two (2) areas, Wadi Village and the south of El Tur. Groundwater level is in a range from 5.2 to 13.9 mASL in Wadi Village and from 1.1 to 13.6 mASL in the south of El Tur. Those dug wells are tapping groundwater from the first aquifer, however, water level of those dug wells are concordant with that of the second aquifer. Therefore, the first aquifer is considered as a part of the second aquifer.

(3) Groundwater Quality

Water samples were collected from 38 wells in February (winter season) and August (summer season) in 1997.

Two (2) maps were prepared for distribution of TDS: One is for winter season (Fig. 3.3-12 (1)) and another for summer season (Fig. 3.3-12 (2)).

Generally, TDS increases from the northeastern side of the plain to the southwestern side. Range of TDS varies from 425 to 7403 mg/l in winter and from 452 to 10,273 mg/l in summer. TDS decreases in winter and increases in summer.

A low TDS area (less than 500 mg/l) is distributed in an area about 15 km NNE from El Tur. The area in winter is wider than it in summer. The area involves the well field for water supply to El Tur.

Judging from the distribution and seasonal variation of TDS, groundwater in low TDS is recharged from the wadis through in the Precambrian Basement Rocks such as the Wadi Hibran and Wadi Mir. On the other hand, groundwater in high TDS is supplied from the Mesozoic Sedimentary Rocks distributed in the northern side of the El Qaa Plain. No contribution of the Abu Durba area (mountain range in the western side of the plain) is recognized to the recharge of groundwater in the plain.

Compared with the Drinking Water Standard in Egypt, most of TDS is within the standard except of the coastal area in El Tur. In such area, some wells show high contents of Ca^{2+}, Cl^- and SO_4^{2+}, and TDS more than the standard.

Groundwater in the plain is classified into five (5) types as the table shown below.

Sr. No	Code No.	Name	Aquifer	Winter (Feb. 1997)		Summer (Aug. 1997)	
				Water Type	TDS	Water Type	TDS
26	48BB-004	QAA15	Quaternary	$CaCl_2$	420	$CaCl_2$	467
30	48BB-008	QAA21	Quaternary	$CaCl_2$	490	NaCl	611
37	48-BB016	QAA29	Quaternary	$CaCl_2$	425	$CaCl_2$	452
S-2*	47EC-001	W. Hibran	Quaternary	$CaCl_2$	900	$CaCl_2$	1424
S-3*	47EC-002	W. Mir	Quaternary	$MgSO_4$	685	$CaSO_4$	533
S-4*	48CE-002	W. Thiman	Quaternary	$MgSO_4$	834	dry	
5	48CE-001	W. Isra	Quaternary	$MgSO_4$	765	NaCl	796
17	48AB-003	QAA8	Quaternary	Na_2SO_4	1085	NaCl	1485
13	48AB-019	El Hag Sobahe	Quaternary	Na_2SO_4	1250	$CaSO_4$	1643
2	37DE-001	PZ-8	Quaternary	NaCl	4230	NaCl	4435
7	37EE-001	QAA10	Quaternary	NaCl	1680	NaCl	2147
24	48BB-006	QAA12	Quaternary	NaCl	588	NaCl	653
40	48CB-005	Abu Kalam	Quaternary	NaCl	2124	NaCl	3899
26	48CB-012	M Abu Salem	Quaternary	NaCl	3280	NaCl	2320
1	-	Hammam Musa	Quaternary	NaCl	9378	NaCl	7572
28	48BB-007	QAA23	Quaternary	$NaHCO_3$	448	$NaHCO_3$	483

Note: * shows the serial No. of spring.

$MgSO_4$ type appears in the Wadi Mir, Thiman and Isla in winter season. This water type changes to $CaSO_4$ or NaCl type in summer. $CaCl_2$ type is dominant in winter in the existing well field. NaCl type is widely distributed in the area where TDS is more than 1,500 mg/l.

(4) Groundwater Storage

i) Estimation of Groundwater Storage

The second aquifer (the main aquifer) is composed of sand and gravel with silt and clay. Then, the effective porosity is estimated as 0.15. The saturated volume of the aquifer is approximately 83.6 x 10^9 m^3. Therefore, total groundwater storage is estimated at 12.5 x 10^9 m^3 in the northern part of the El Qaa Plain.

ii) Estimation of Groundwater Recharge

The change of groundwater storage, dQ, is given by following formula.

$$dQ = A \cdot dh \cdot Sy$$

where, A is the area in which change of water level is observed,
h is the change in water level,
Sy is the specific yield or effective porosity of the aquifer.

From September 1994 to May 1996, the change of water level was as shown below.

(unit: cm)

Sep. 94	Dec. 94	Mar. 95	Jun. 95	Sep. 95	Dec. 95	Mar. 96	May.96
	+0.22	-0.05	+0.08	+0.06	-0.08	-0.05	+0.96

Total increase of groundwater storage during the above mentioned period is calculated as 36.6 x 10^6 m^3. In addition, annual extraction of groundwater is estimated as 3.4 x 10^6 m^3.

Therefore, total recharge amount is estimated as 40.0 x 10^6 m^3/year.

On the other hand, observed rainfall in St. Catherine was as shown below.

(unit: mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1994	12.7	0.0	5.9	0.0	0.0					16.9	12.5	0.1
1995	0.2	2.9	5.8	3.5	0.0					0.0	0.0	9.2

The catchment area of the Wadi Awag is 1934 km^2. Then, total amount of precipitation is calculated as 80 x 10^6 m^3.

Therefore, it is assumed that the second aquifer received approximately 50 % of total volume of precipitation in the period.

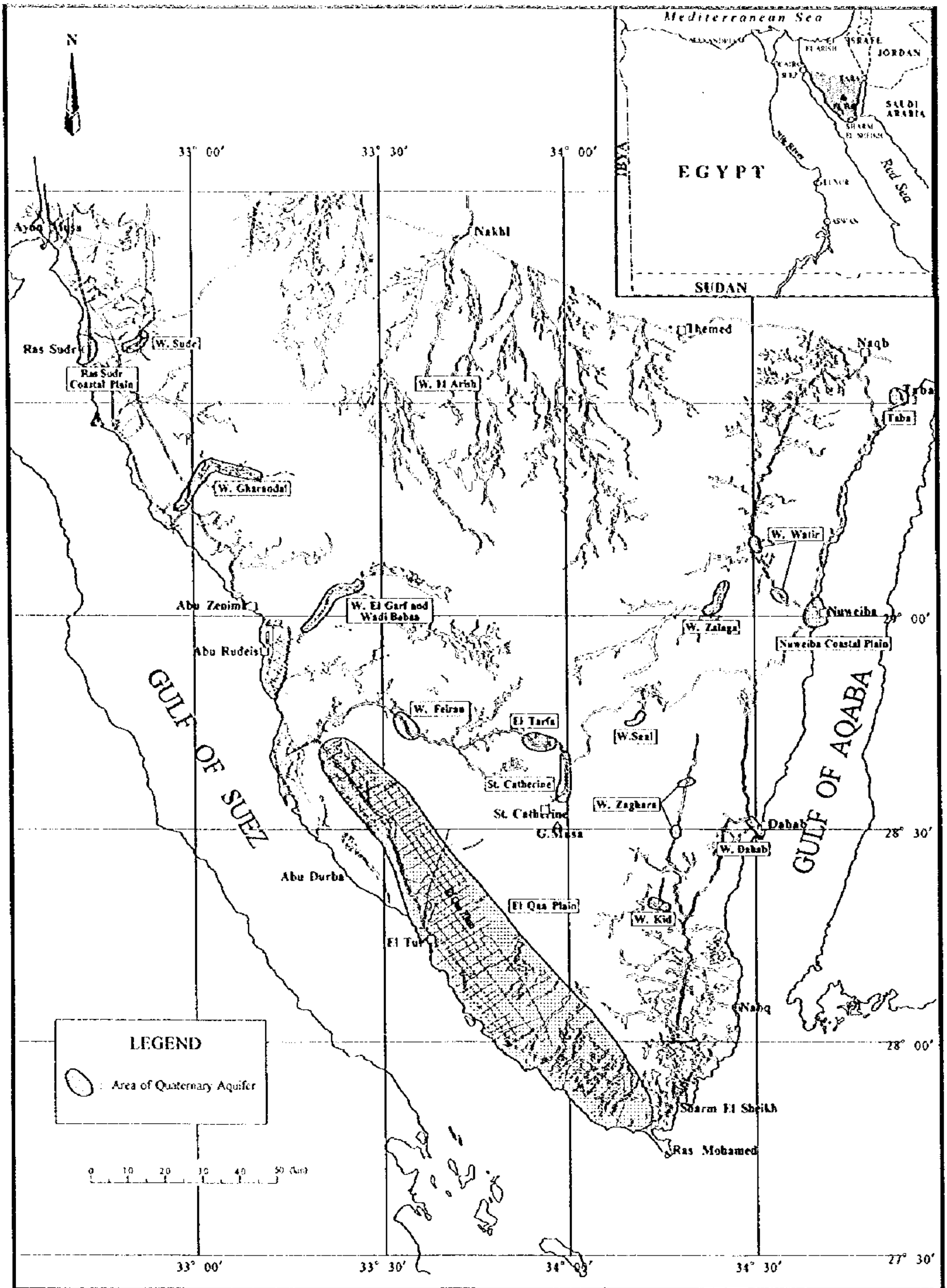


Fig. 3.3-1 Distribution of Quaternary Aquifers in South Sinai

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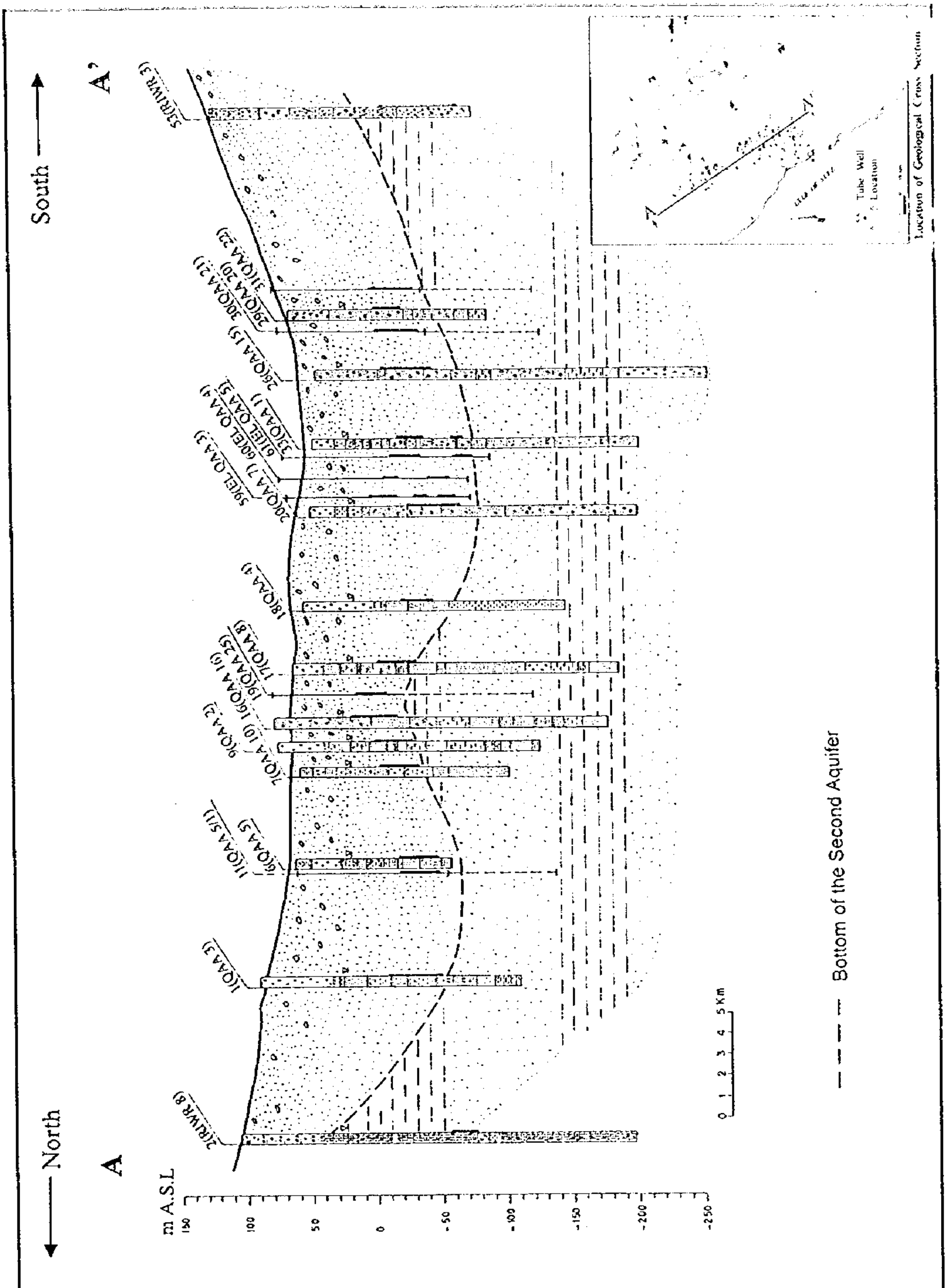

Fig. 3.3-2 Geological Cross Section in North of El Qaa Plain

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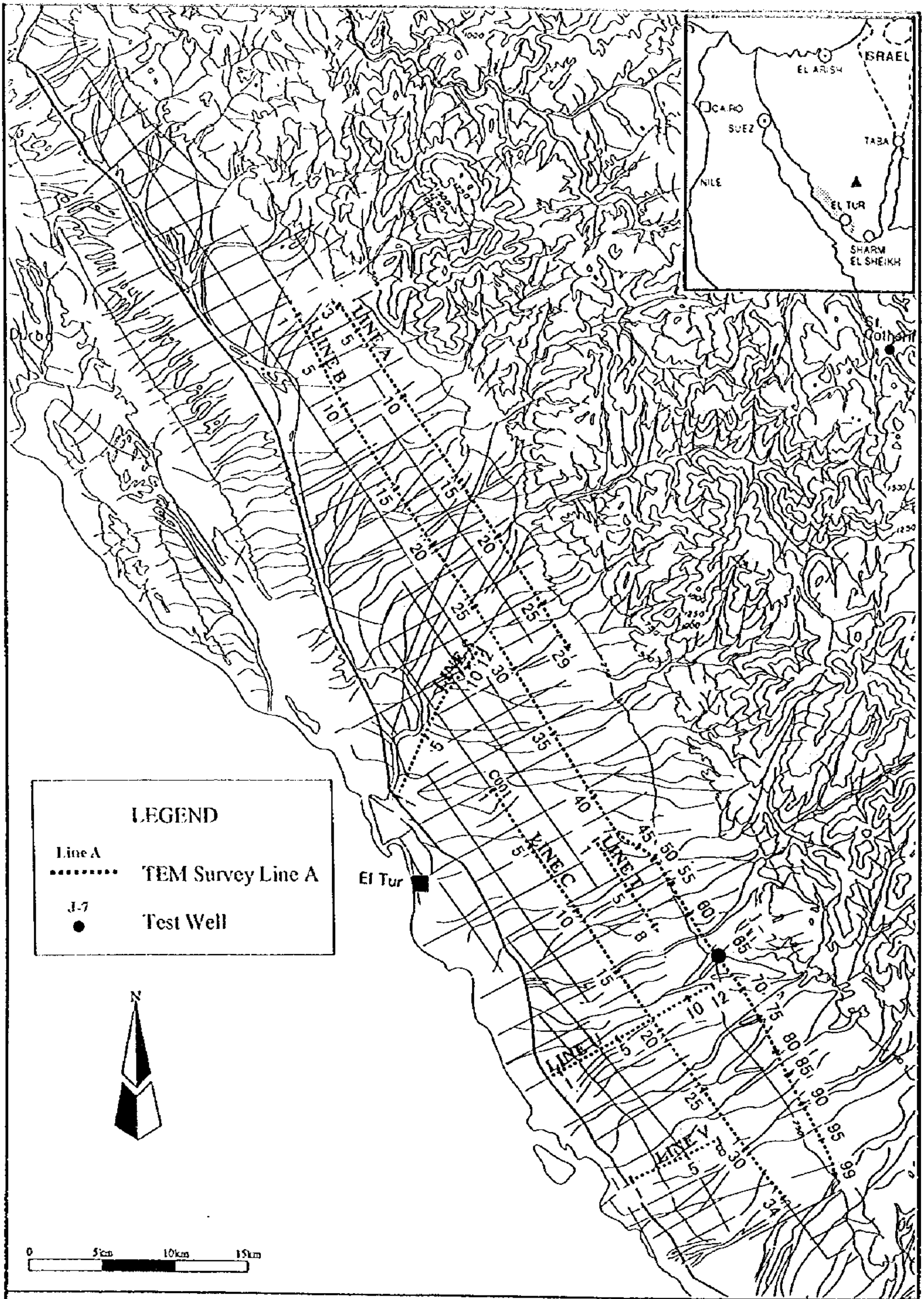

Fig. 3.3-3 TEM Survey Line and Station (El Qaa Plain)