3. Field Investigation

3.1 Interpretation of Aerial Photographs

The analysis of aerial photographs (scale 1/30,000) showed the lineaments described in the following paragraphs (refer to Fig. I-3.1.1). The characteristics of units such as texture, pattern and density of drainage system, and resistance are summarized in Table I-3.1.1

(1) Many lineaments are observed in the escarpment and the foot hills through the Study area. There are a few lineaments in the highlands.

(2) Lineaments are observed in three directions: North - South (NS), North - East (NE) and North-West (NW). Some of these lineaments correspond to the geological boundaries and faults that divide the geological units. Some of the North-East and North-West lineaments are observed clearly and/or continuously.

(3) Generally, there are more lineaments in the Zerqa and Kurnub Group than in the Ajlun Group and also North-South lineaments are more frequent in the Zerqa and Kurnub Group than in the Ajlun Group.

(4) In the North-East area of the Dead Sea, two lineaments at N50° E and N68° W are observed very clearly. The lineament at N50° E is one of the major tectonic lines which extend along Dead Sea-Wadi Araba-Red Sea in a general North-South direction. This lineament changes direction to North-East in this area and extends to Wadi Quseib, but becomes illegible in the escarpments.

This lineament forms a geological boundary; the Main formation of the Zerqa Group is distributed on the East side of the lineament and the Neogene formation is on the West side. The lineament at N68° W is also one of the major faults and forms the geological boundary between the Zerqa Group and the Kurnub Group at its eastern end.

ES SALT

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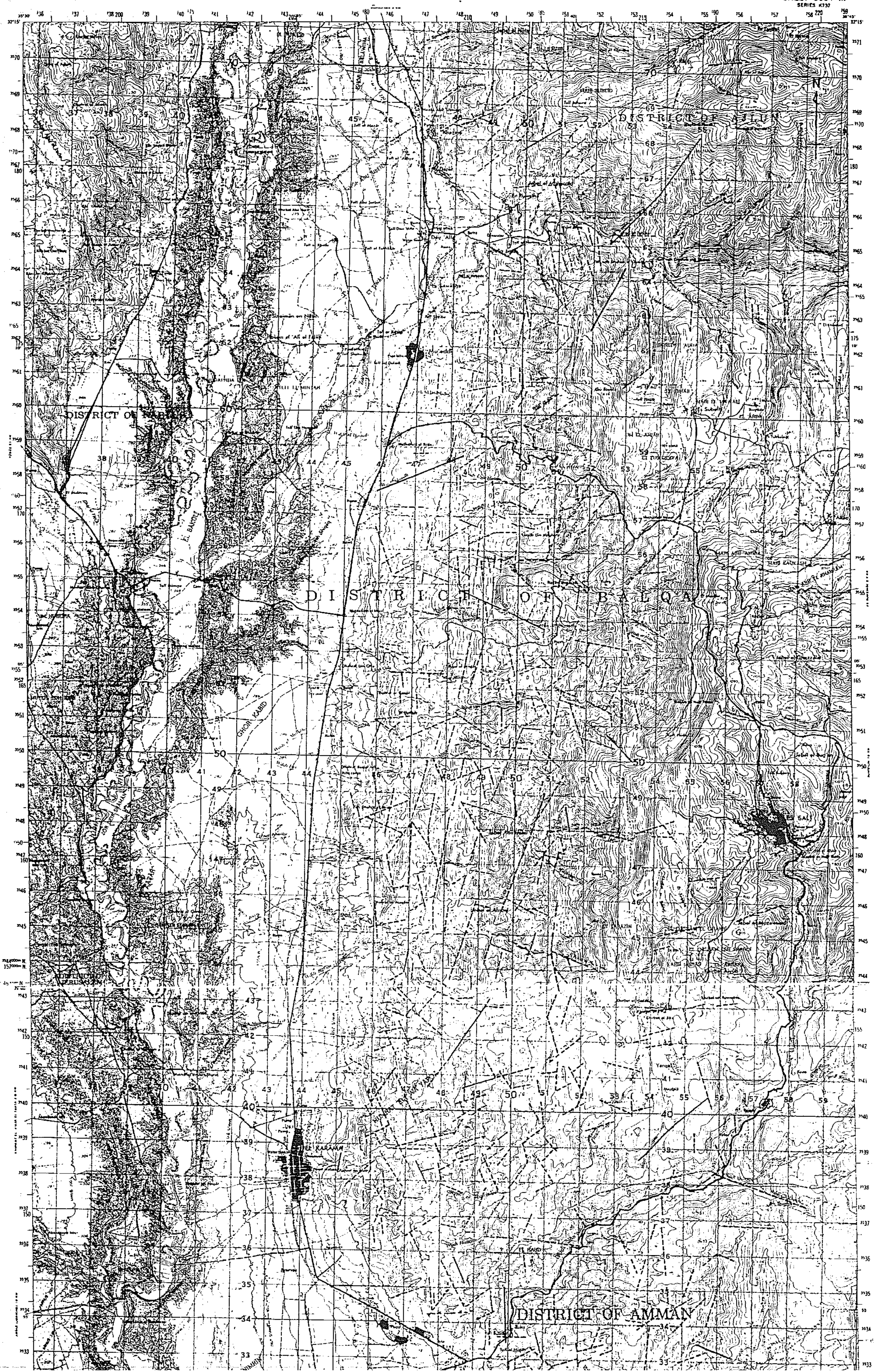


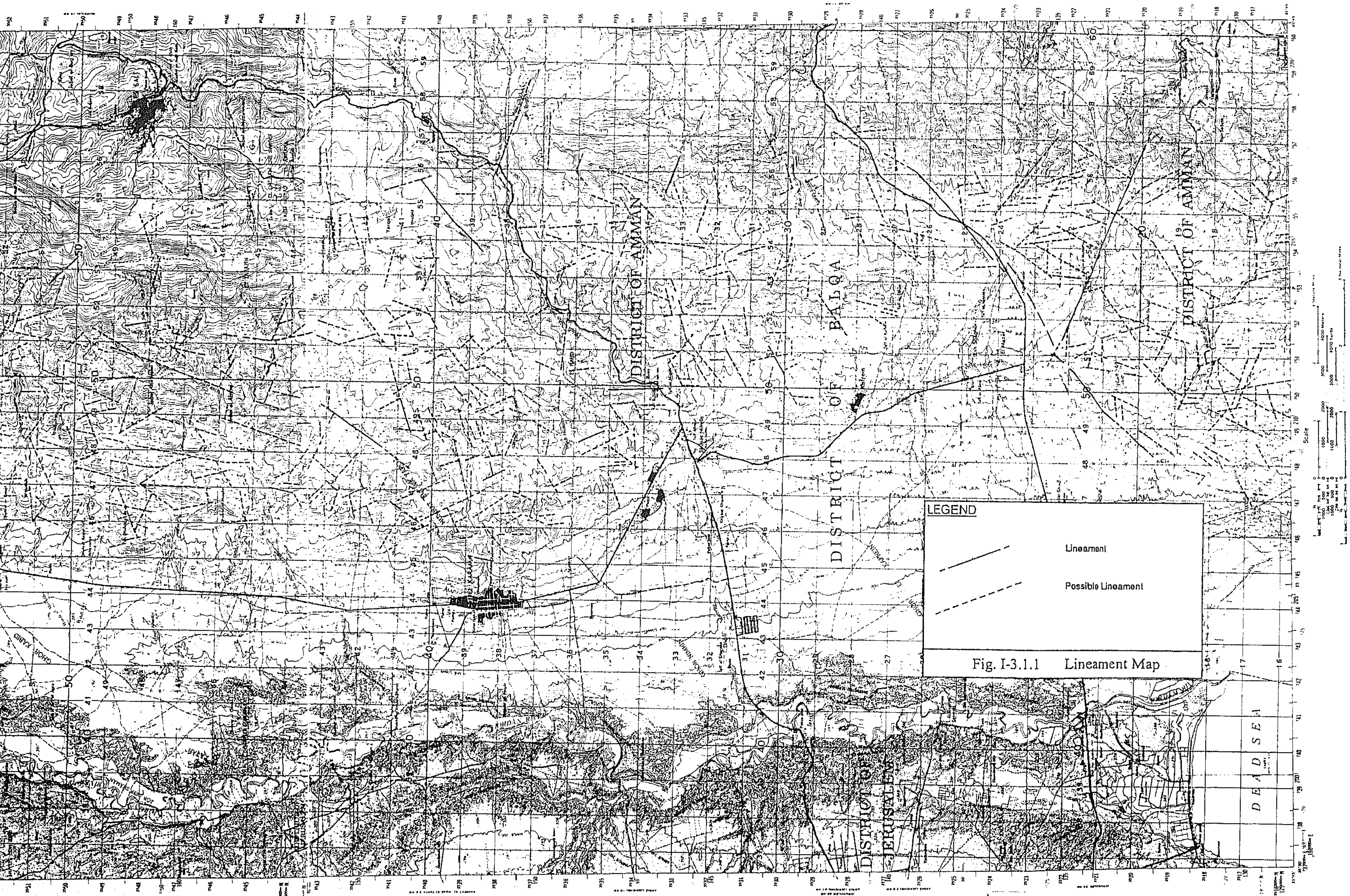


Fig. I-3.1.1 Lineament Map

Table I-3.1.1 Photo-geological Interpretation Chart

Characteristics / Units	Tone	Texture	Drainage			Rock properties				Cover			Lithology	Formation or Group
			Pattern	Density	Cross section of valley or gully	Resistance	Bedding	Attitude	Jointing	Surficial material	Vegetation	Cultivation or other human influence		
J	light gray –light	even,smoth	pinnate dendritic	very high	Shallow sharp V–form	very low	well bedded	horizontal	none	thin	dense aligned	intense	marl	Lisan
B	light–medium gray	smooth	dendritic	low	shallow gentle V–form	low	well bedded	gentle	low density	thin	sparse	rare	limestone	B1–2
A'	medium–dark gray	smooth–relatively smooth	dendritic	low–medium	shallow gentle V–form	low	well bedded	gentle	low density	thin	sparse–moderate Patchy	rare–frequent	limestone, marl	A4–7
A	medium gray	relatively smooth	dendritic	medium	shallow gentle V–form	low	well bedded	gentle	medium density	very thin – thin	sparse–moderate Patchy	rare–comon	limestone, marl	A1–3
K	medium gray	relatively rough	dendritic	high	deep sharp V–form	moderate	well bedded	gentle	medium density	very thin	sparse	rare	sandstone with marl	Kurnub
Z1	medium gray	relatively smooth	subparallel subdendritic	high	deep sharp V–form	moderate	well bedded	gentle	medium density	very thin	sparse	rare	limestone, marl	Azab
Z2	medium–dark gray	relatively smooth	subdendritic	medium	shallow gentle V–form	moderate	well bedded	gentle	medium density	very thin	sparse	rare	sandstone, limestone	Main

(5) In the North - East area of Kafrein, an East - North - East (ENE) lineament is observed clearly in the Ajlun Group. There are fewer lineaments in this area than in the other areas, and lineaments are more frequent in the Kurnub Group and the A1~3 formation of the Ajlun Group than in the A4~7 formation of the Ajlun Group and the B1~2 formation of the Belqa Group.

(6) In the East area of Karama, three NE lineaments are observed clearly in the Ajlun Group. NW and NE lineaments are frequent in this area and the difference in the number of lineaments in the geological units is not recognized.

(7) In the East area of Wadi Bassat el faras-Muddi, two lineaments in ENE and WNW directions are observed clearly in the Azab formation of the Zerqa Group. Lineaments in NS, NE and NW directions exist and long lineaments in the NS direction are common in this area.

The Azab formation of the Zerqa Group and the Kurnub Group are mainly distributed in this area and the difference in the number of lineaments between the two Groups is not recognized. There are few lineaments in the Ajlun Group in the Highlands .

(8) In the East area of Deir Alla (the area around the Zarqa River), four NE lineaments and one NS lineament are observed clearly.

In these lineaments, one of the NE lineaments is in the Ajlun Group and the others are in the Zerqa and the Kurnub Group.

The NS lineaments are frequently observed in the South side of the Zarqa River and the NE lineaments are frequently observed in the North side.

Lineaments are generally recognized more frequently in the Zerqa and Kurnub Group than in the Ajlun Group in this area.

3.2 Geophysical Exploration

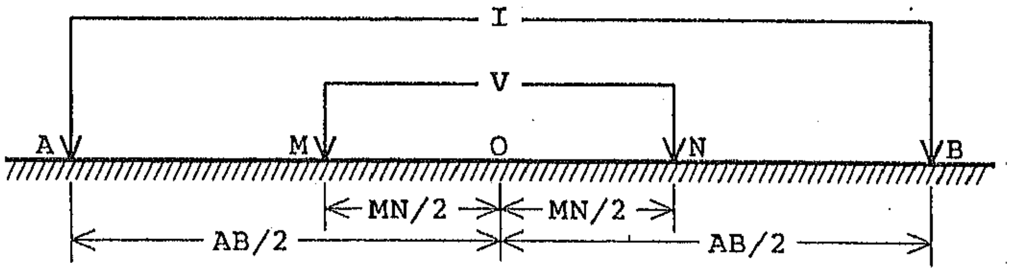
The geophysical exploration considering of an electric sounding and electromagnetic survey, was carried out in the East of the Jordan Valley. The Schlumberger sounding method was used in order to investigate underground resistivity distributions as electrical soundings. After the electrical soundings, the VLF-EM method, an electromagnetic method, was adopted in order to detect faults and fracture zones which are vertical conductors.

The locations and directions of electric sounding and electromagnetic survey are shown in Fig. I-3.2.1.

3.2.1 Electrical Sounding

(1) Methodology

The electrical sounding system by Schlumberger array is shownin the following illustration:



Schlumberger array

where, I is an electric current (milli-amperes) between electrodes A and B,

V is a potential (milli-volts) received between electrodes M and N,

O is the location of the electrical sounding,

and AB/2 is the depth of investigation.

An apparent resistivity at each electrode array is calculated using the following formula:

$$Ra = K * \frac{V}{I}, \qquad K = 3.14 * \frac{(AB/2)^2 - (MN/2)^2}{MN}$$

where Ra is an apparent resistivity in ohm-m.

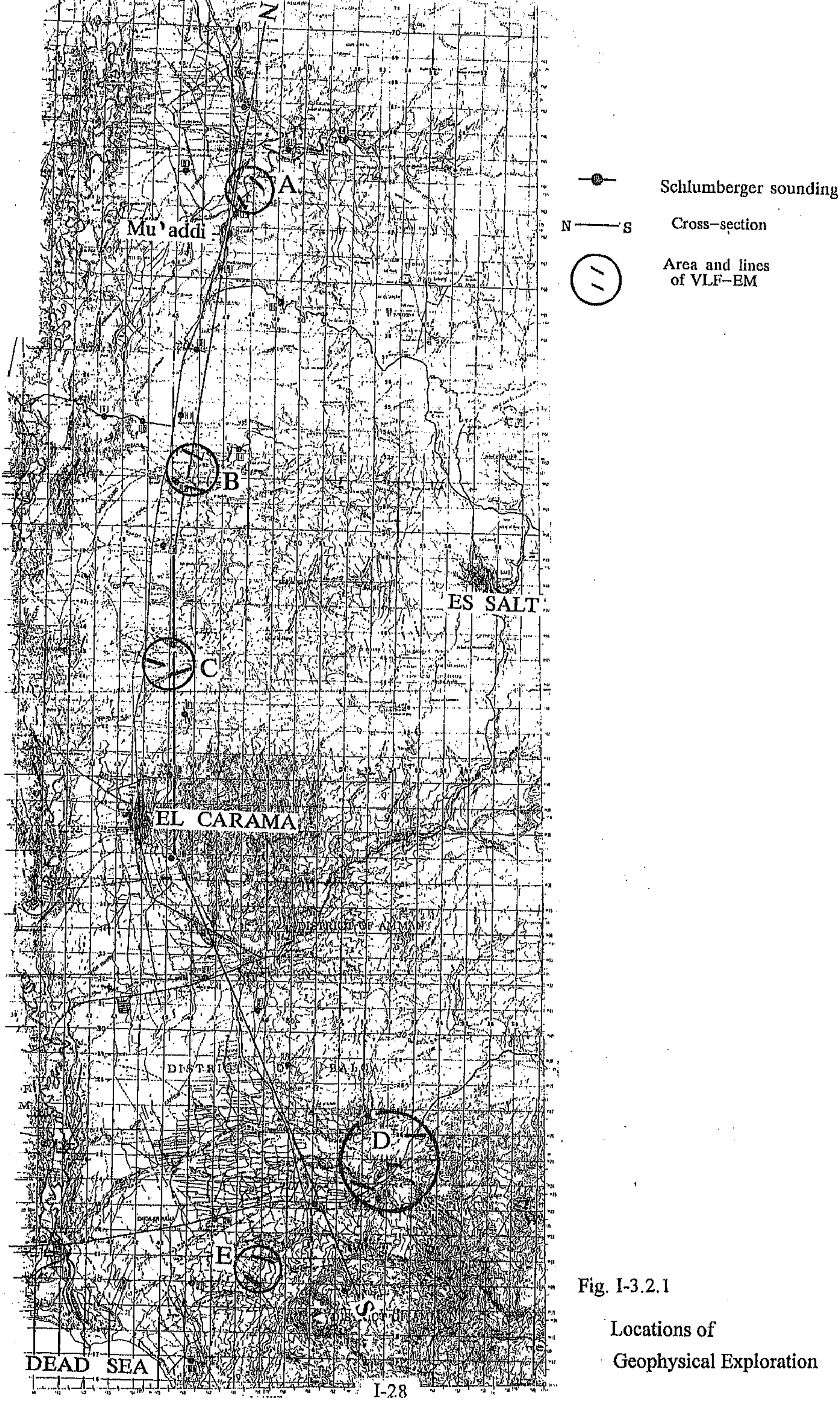


Fig. I-3.2.1

Locations of Geophysical Exploration

The specification of the Schlumberger sounding and expansion of electrode spacings are as follows:

"Instrument": BRGM SYSCAL-R2 system made in France

"Depth of investigation": maximum 300 metres

"Number of profiles": 30 profiles (as shown in Fig.3.2.2)

"Expansion of current electrode spacing": 6 to 300 metres

Electrode spacing

No.	AB/2(m)	MN/2(m)	
1	6	2	–
2	10	2	–
3	15	2	–
4	20	2	–
5	30	2	–
6	40	2	–
7	55	2	15
8	75	2	15
9	100	2	15
10	130	–	15
11	170	–	15
12	225	–	15
13	300	–	15

By linking the apparent resistivity values at each array spacing, a VES (vertical electric sounding) curve is obtained. Then, assuming horizontal layers, a resistivity structure can be estimated by fitting the results to the VES curve using the 1-dimensional modelling inversion method.

(2) Results of the Electrical Sounding

The results of the analysis are shown in Fig.3.2.2. Fig.3.2.2 forms horizontal resistivity distributions at each profile.

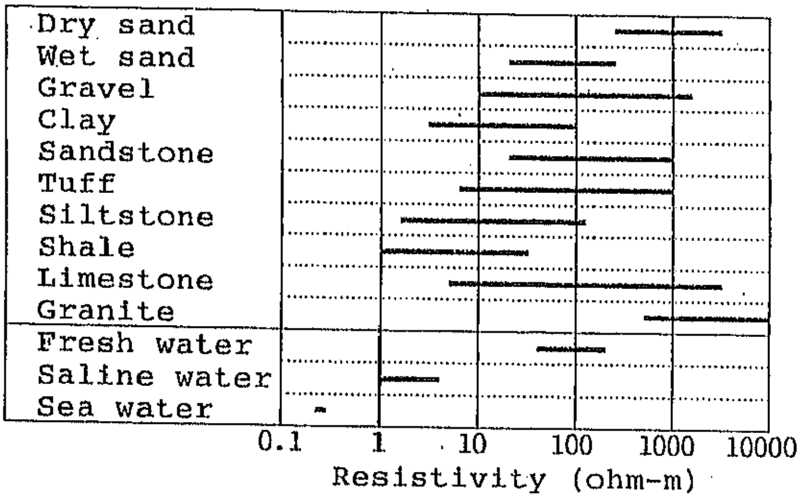
The resistivity distributions in Fig.3.2.2 are divided into 4 groups as follows:

1) High-resistivity : above 200 ohm-m
2) Intermediate-resistivity : 20 to 200 ohm-m
3) Low-resistivity : 5 to 20 ohm-m
4) Very low-resistivity : below 5 ohm-m

The features of the resistivity structures were found to be as follows:

1) Almost of the structures belong to the low resistivity group (5 to 200 ohm-m.)
2) The resistivities show various distributions, particularly in the shallow zone.
3) A high-resistivity dome appears in the deep zone at profile-11 to profile-16.
4) A very low-resistivity structure exists the in deep zone of profile-18 and 19.
5) There are vertical discontinuities in the resistivity between profile-16 and profile-18, and between profile-19 and profile-24.

Generally, the resistivities of main rock and water samples are given in following table;



Resistivities of rock and water samples

Comparison with the resultant resistivity structures and geological information, showed the following characteristics in the surveyed area;

i) A variation in resistivity will depend not only on the difference of geology but also the existence of fresh rock, fracture zones and saline water.

ii) It would seem that high-resistivity zones can be compared with fresh rocks such as Pre-Tertiary limestone. The above-mentioned high-resistivity dome is a typical example.

iii) It is considered that very low-resistivities reflect fracture zones including saline water. Limestone is observed in this area, because it does not necessarily follow that limestone leas a high-resistivity.

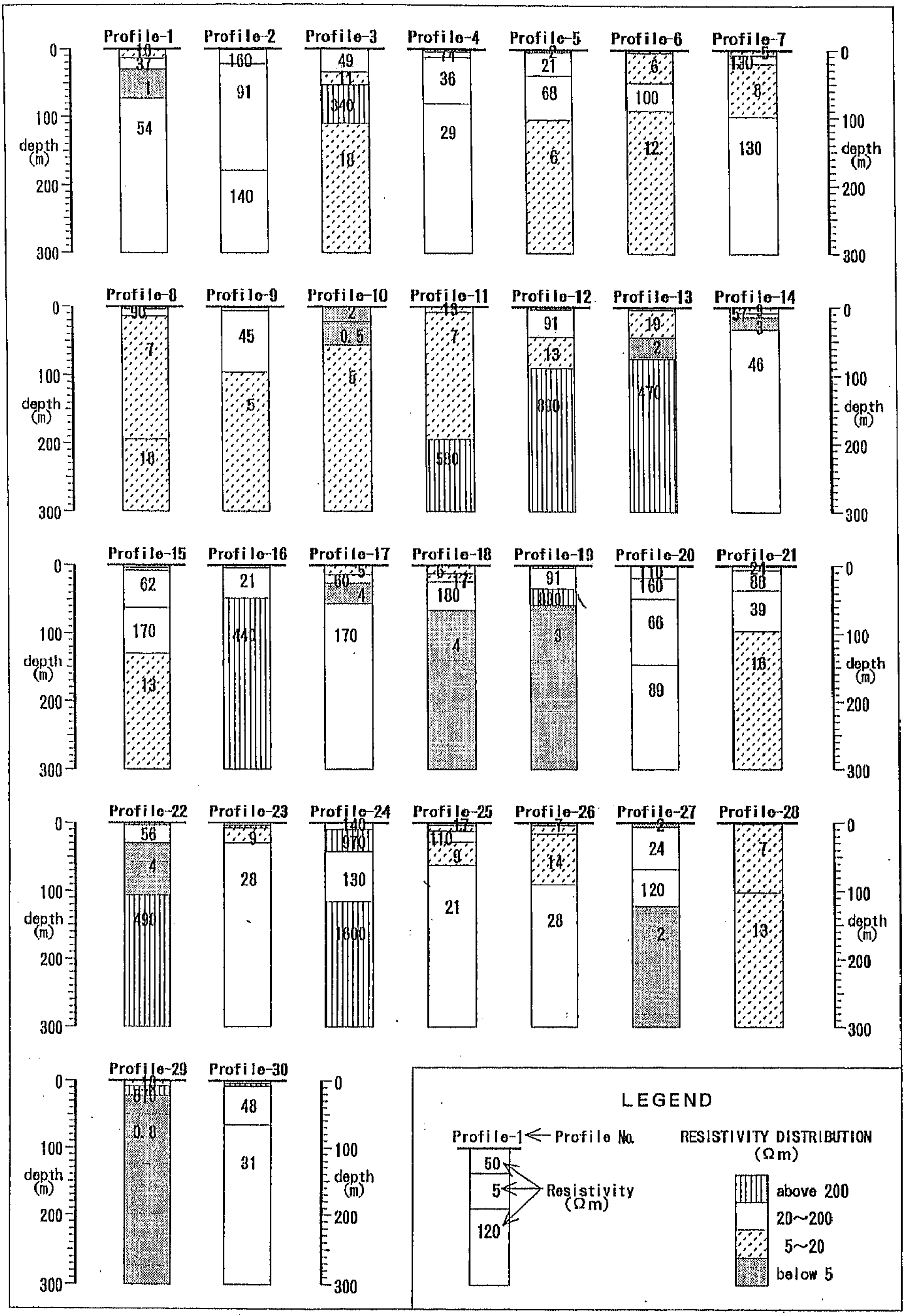


Fig. I-3.2.2 The Results of Schlumberger Sounding Inversion

iv) The aforementioned vertical resistivity discontinuities might be associated with fault action in the deep zone.

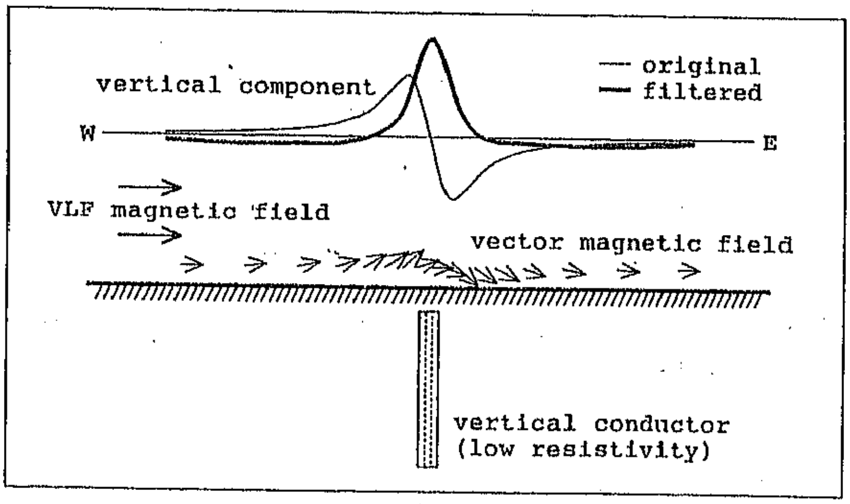
The electrical sounding results have been plotted on the hydrogeological profiles in order to estimate the lithological continuity (see Supporting Report).

3.2.2 Electromagnetic Survey

(1) Methodology

The VLF-EM (very low frequency electro-magnetic) method is an electromagnetic method using VLF band waves. Originally, the VLF method was developed forlocating submarines. The low-frequency field used is sent out from a military radio transmitter. Normally, the frequency is between 15 and 30 kHz. The VLF-EM method is well suited for water prospecting in fracture zones.

VLF-EM anomaly indications are shown in the following vertical cross-section:



VLF-EM anomaly indications

At a vertical conductor such as a fracture zone, the primary VLF magnetic field makes an electric current in the conductive body. Then the secondary magnetic field caused by the induction current appears in a vertical direction, and the VLF anomaly indication can be measured on the ground-surface as a vertical component of the vector magnetic field.

(2) Results of the Electromagnetic Survey

The VLF-EM results are shown in Supporting Report.

The results are summarized in the following table:

VLF-EM fault indications on surveyed lines

Line name	Clear indication	Non-clear indication
A-1	Station 34	Station 21
A-2	Station 92	Station 34
B-1		Station 49
B-2		Station 11,56,138
C-1		Station 16
C-2	Station 41,44	Station 38,76
D-1		Station 70,86
D-2		Station 45,55,62,83,92
D-3		Station 36,61
E-1	Station 66	Station 32,43
E-2		Station 15,34

Based on the results of the electromagnetic survey, the locations of the test well drilling sites were determined as described in Section 3.3.1.

3.3 Test Well Drilling

3.3.1 Test Well Drilling Plan

(1) Purpose of Drilling

The purpose of the test well drilling was to establish the followings:

(i.) Potentiometer of the Zerqa Aquifer

(ii.) Hydraulic Properties

(iii.) Influence of the Development of the Zerqa Aquifer on the Other Aquifers

(iv.) Groundwater Quality Change

(v.) Thickness of the Zerqa Aquifer

(2) Site Selection and Number of Test Wells

For (i) and (ii) above, the test well locations were scattered as widely as possible over the Study area in order to grasp the basic hydrogeological data of the Zerqa aquifer with the limited amount of drilling available to the Study.

For (iii), two test wells were drilled in an area where both Zerqa aquifer and Kurnub sandstone aquifer are distributed. One well tapped into the Kurnub sandstone aquifer and another well tapped into the Zerqa aquifer sealing the Kurnub sandstone aquifer. The influence was measured in the upper aquifer during the pumping test in the lower aquifer. The distance between them was thirty (30) meters.

For (iv.), one test well was drilled in the Southern part of the Study area where the basement of the Zerqa aquifer (Ram Sandstone) is supposed to underlie at a shallower depth.

Six test wells were planned as follows:

The locations of the test wells are shown in Fig. I-3.3.1. For the determination of the drilling points, the results of the electromagnetic survey were taken into consideration as shown in Figs. I-3.3.2 to I-3.3.6. The drilling points were finally decided through the field inspections.

Scheduled Test Wells

Well No	Scheduled Depth (m)	Assumed Geology	Purpose
1	300m	Zerqa G.	- Potentiometry - Hydraulic Properties - Quality change.
2	300m	Zerqa G.	- Potentiometry - Hydraulic Properties - Quality change.
3	200m	Kurnub Ss =200m	- Potentiometry - Hydraulic Properties - Quality change. - Influence to upper aquifer
4	300m	Kurnub Ss = 200m Zerqa G.= 100m	- Potentiometry of K and Z - Hydraulic Properties - Quality change. - Influence to upper aquifer
5	300m	Zerqa G.	- Potentiometry - Hydraulic Properties - Quality change
6	300m	Zerqa G. = 200m Ram Ss. = 100m	- Thickness of Zerqa F. - Potentiometry - Hydraulic properties - Quality change.
Total	1,700 m		

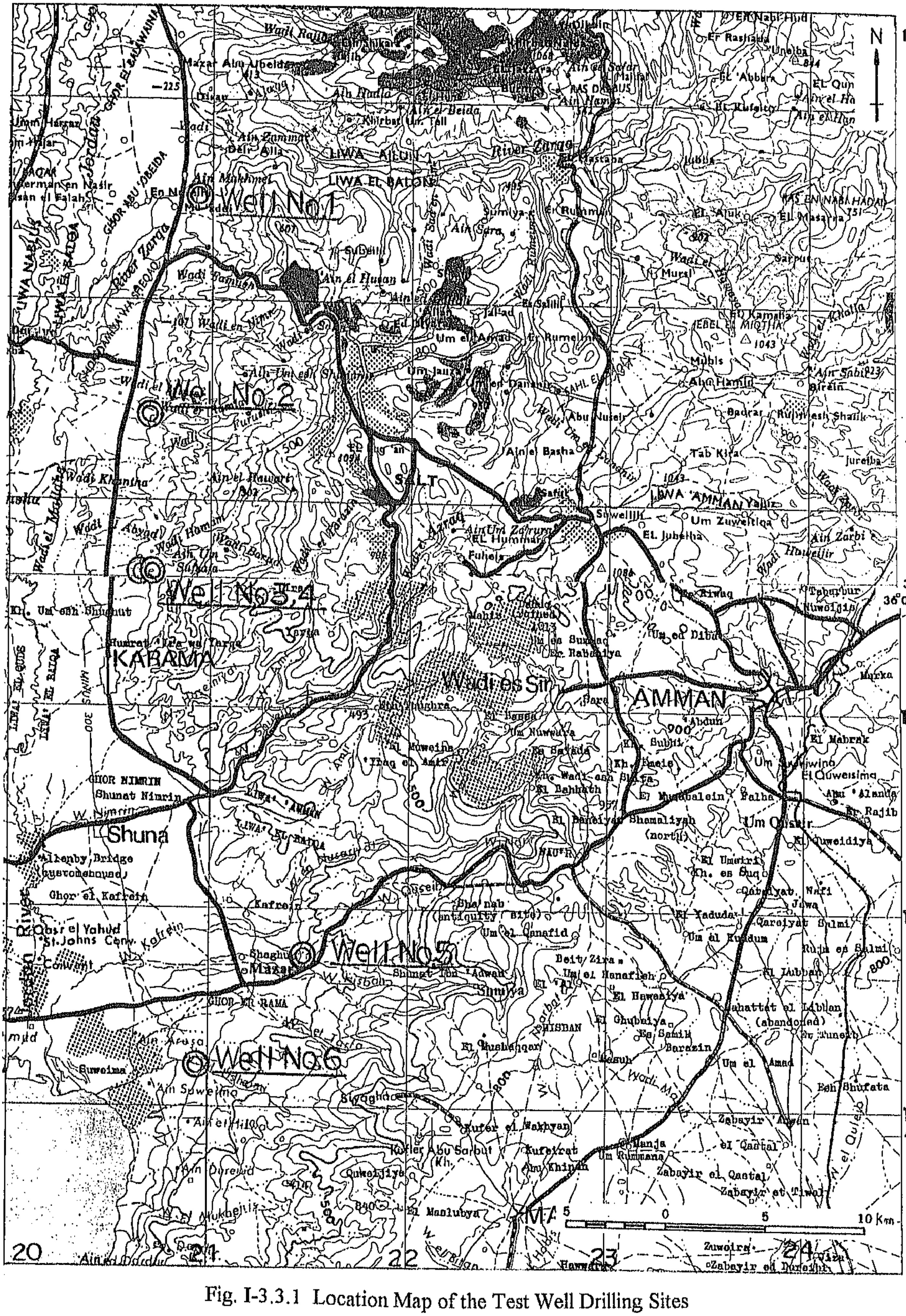


Fig. I-3.3.1 Location Map of the Test Well Drilling Sites

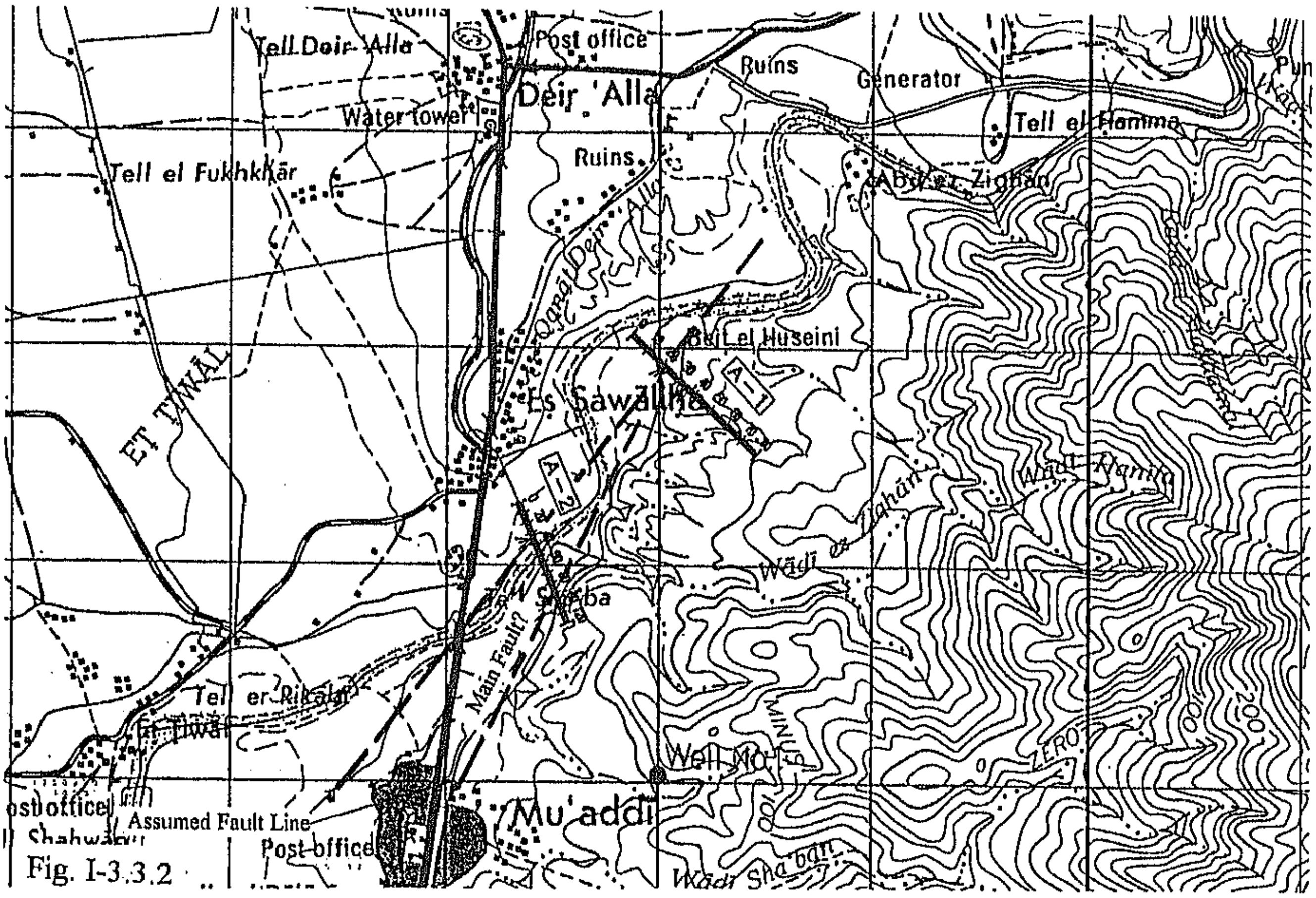


Fig. I-3.3.2

Electromagnetic Survey Results and Well Drilling Point at Muaddi, Well No. 1

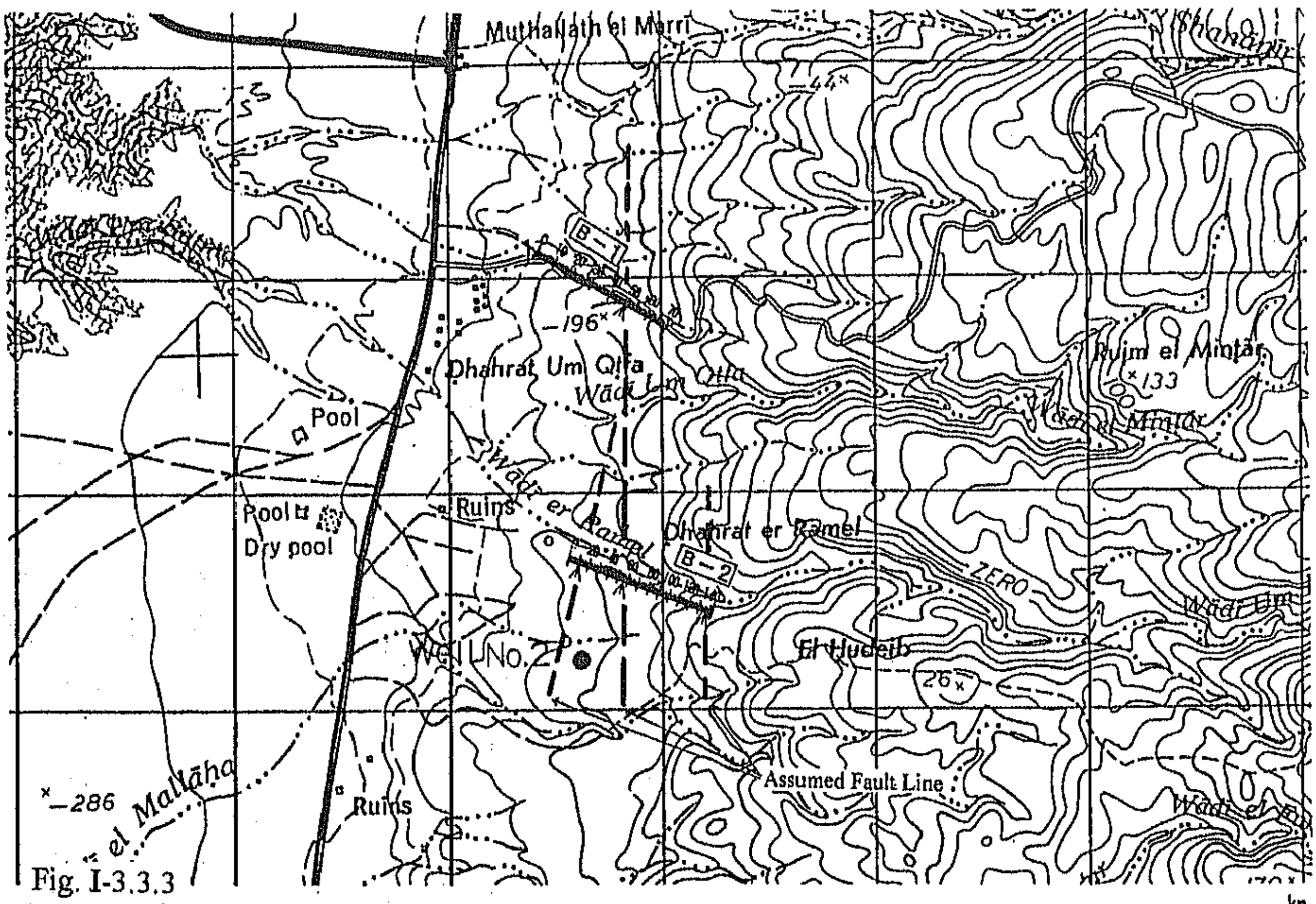


Fig. I-3.3.3

Electromagnetic Survey Results and Well Drilling Point at Wadi er Ramel, Well No. 2

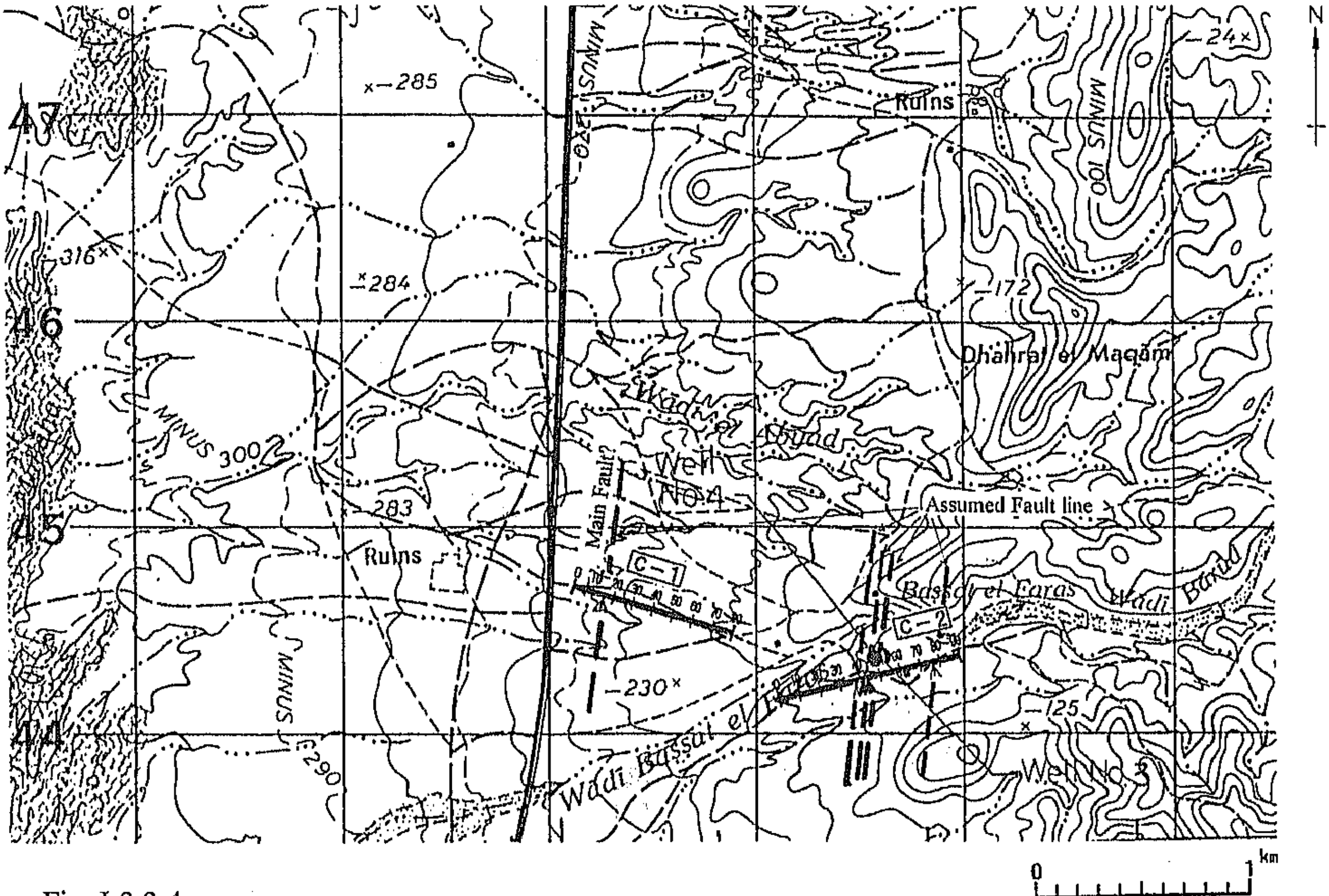


Fig. I-3.3.4
Electromagnetic Survey Results and Well Drilling Points at Wadi Bassat el Faras, Well No. 3 and

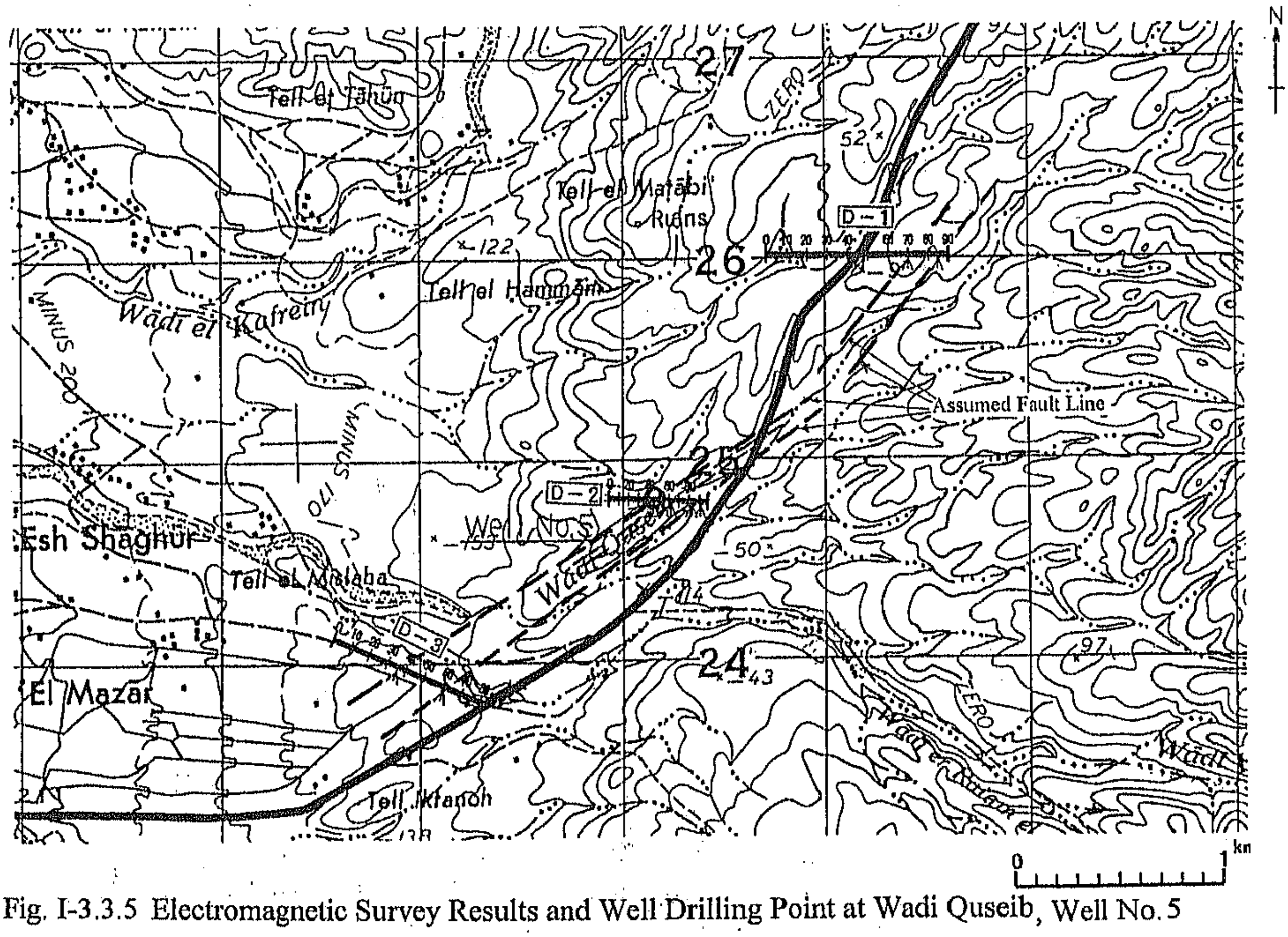


Fig. I-3.3.5 Electromagnetic Survey Results and Well Drilling Point at Wadi Quseib, Well No.5

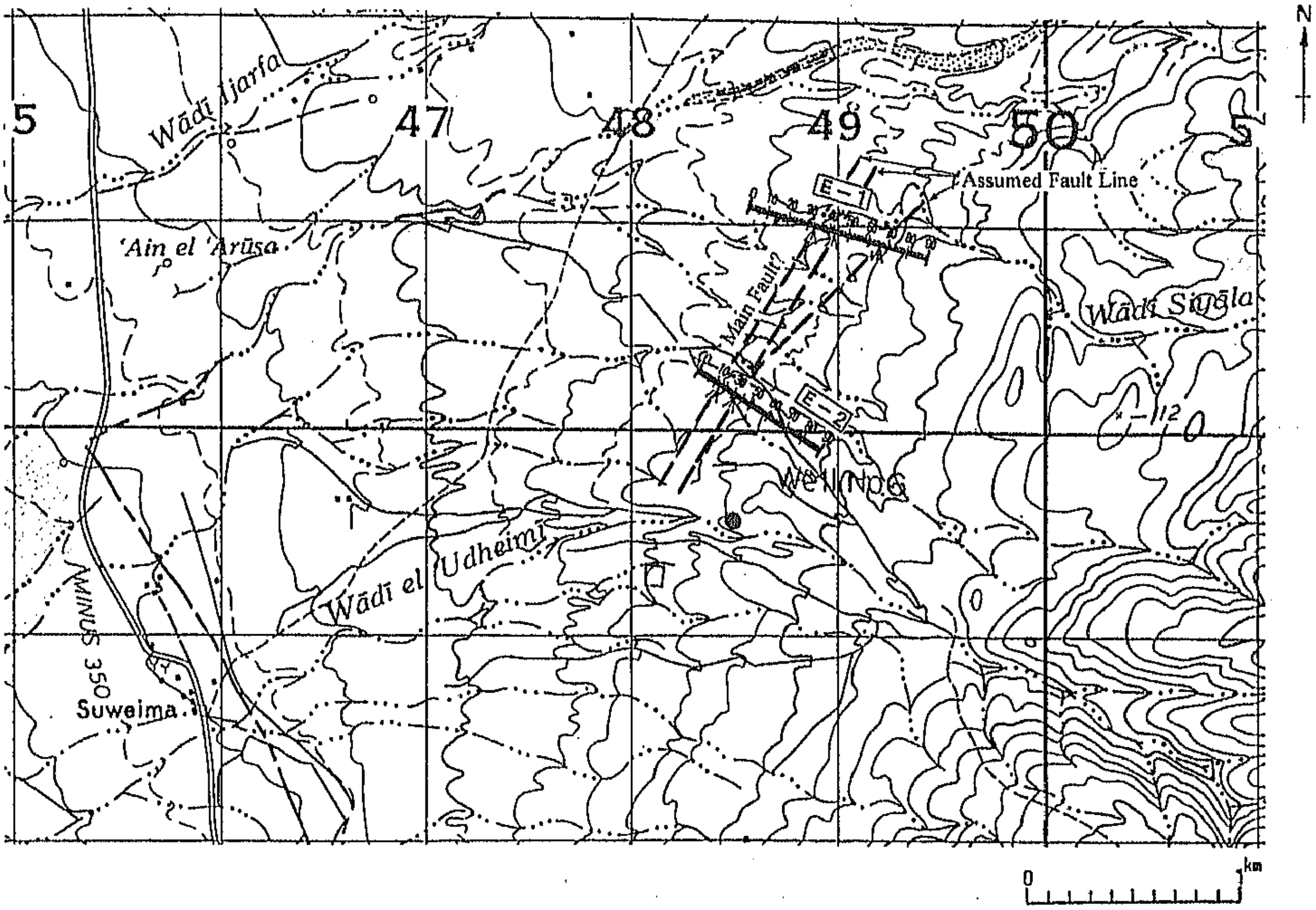


Fig. I-3.3.6 Electromagnetic survey Results and Well Drilling Point at Suweima, Well No. 6

3.3.2 Results of Test Well Drilling

There are five exploration boreholes, numbers 1, 2, 4, 5 and 6, and one observation borehole, number 3, with a combined total depth of 1,802m. The drill rigs used for drilling operations are operating on the normal rotary drilling method, using a water base bentonite mud as drilling fluid. The drilling work has been commenced on August 29th 1994 and completed on February 10th 1994. The casing program of the completed wells is shown in Fig. I-3.3.7. Drilling progress on the sites is described in Supporting Report.

(1) Lithological Description

The borehole lithology logs of each borehole are shown in Fig. I-3.3.8. The follwoing is a brief summary of the lithologic and stratigraphic analysis of each borehole:

1) Well No. 1

Well No. 1 entered the Azab Formation (Z2) of the Zerqa Group at a depth of 12.0m and penetrated it at 227.0m. Below 227.0m, the Main Formation (Z1) of the Zerqa Group was drilled.

The total depth was 383.0m.

The Azab Formation (Z2) consisted of dolomitic limestone between 12.0m and 144.0m, calcareous sandstone between 144.0m and 175.0m, dolomitic limestone below 175.0m.

The Main Formation (Z1) consisted of calcareous sandstone, sandstone interbedded with black shale.

2) Well No. 2

Well No. 2 entered the Kurnub Sandstone (K) at a depth of 19.0m and penetrated it at 50.0m, the Azab Formation (Z2) of the Zerqa Group was drilled. The total depth was 300.0m.

The Kurnub Sandstone was gray to dark gray, friable sandstone.

The Azab Formation (Z2) consisted of sandstone, dolomitic limestone between 50.0m and 116.0m, and friable sandstone, dolomitic limestone, shale below 116.0m.

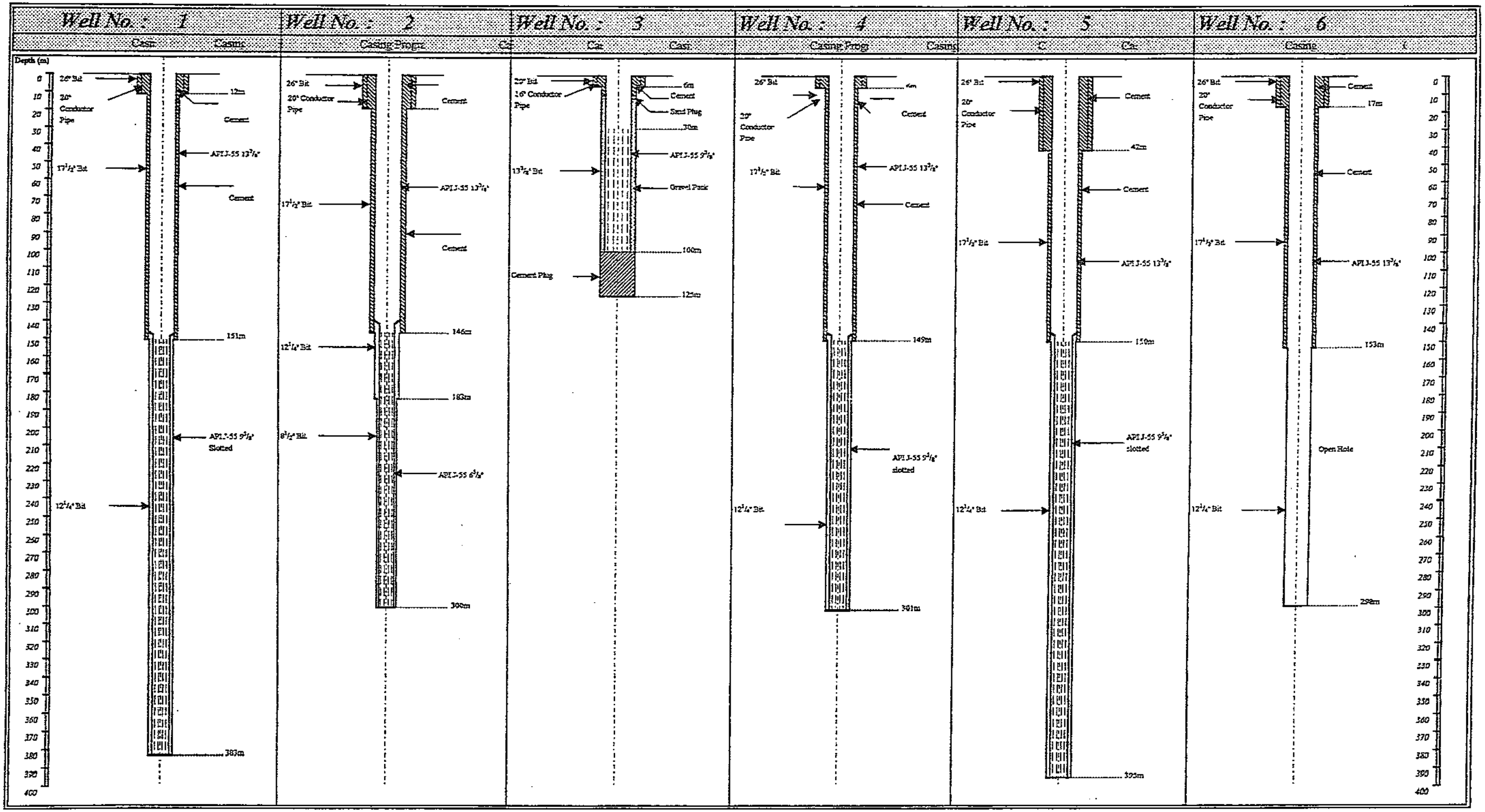


Fig. I-3.3.7 Casing Program of the Test Wells

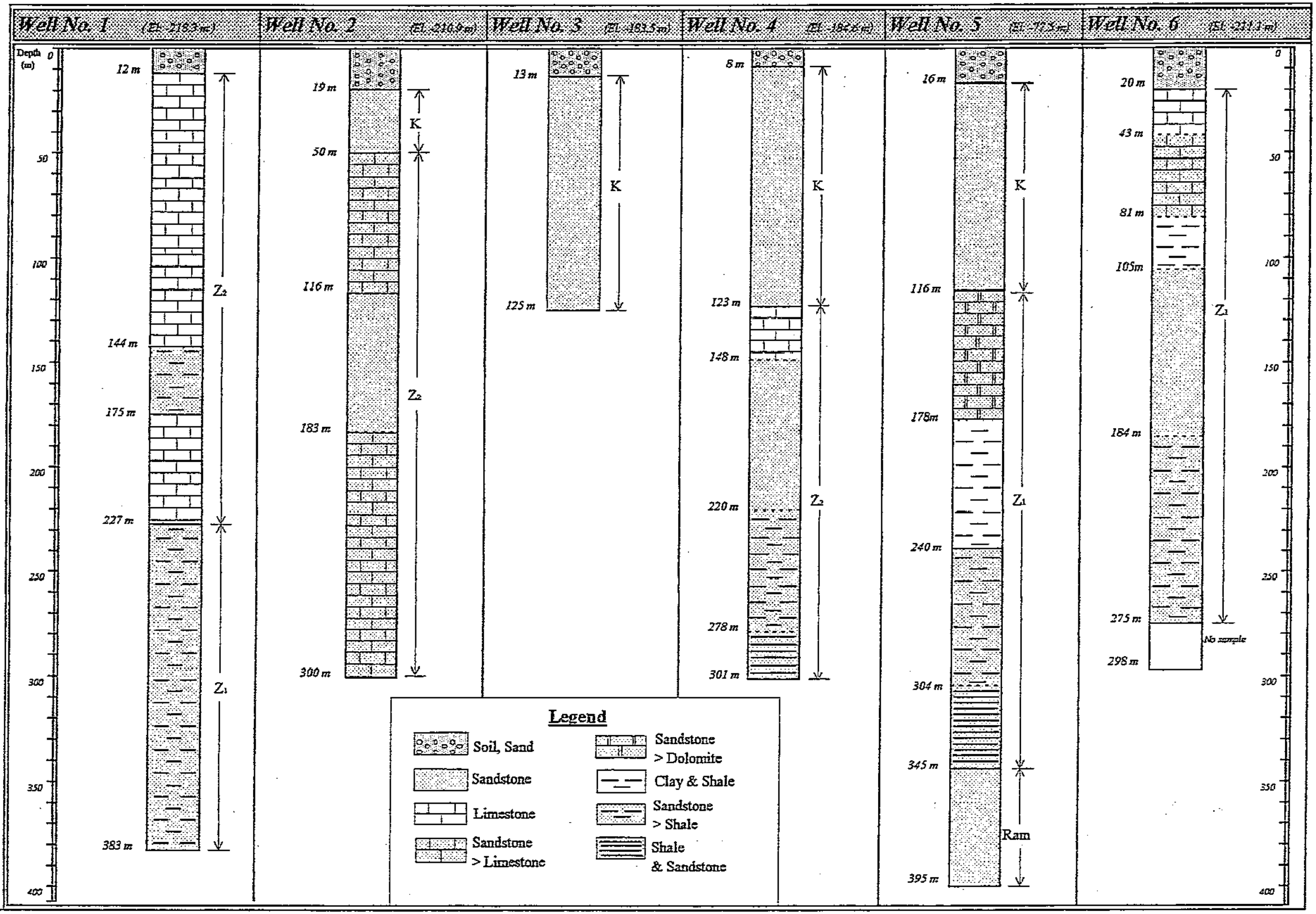


Fig. I-3.3.8 Lithological Logs of the Test Wells

3) Well No. 3

Well No. 3 entered the Kurnub Sandstone (K) at a depth of 13.0 m. Below 13.0 m, a sequence of sandstone of the Kurnub Sandstone was drilled. The color was gray to dark gray. The sandstone was friable to weakly cemented. Total depth was 125.0 m, but the bottom 25 meters were plugged with cement between 100 m and 125 m depth.

4) Well No. 4

Well No. 4 entered the Kurnub Sandstone (K) at a depth of 8.0 m and penetrated it at 123 m. Below 123 m, the Azab Formation (Z2) of the Zerqa Group was drilled. The total depth was 301.0 m.

The Kurnub Sandstone consisted of a sequence of predominantly gray to dark gray, well cemented sandstone.

The Azab Formation (Z2) consisted of dolomitic limestone, marl between 123.0 m and 148.0 m, and friable sandstone below 148.0 m. Below 220.0 m, this sandstone contained some interbedded shale, which became abundant towards the bottom of the well.

5) Well No. 5

Well No. 5 entered the Kurnub Sandstone (K) at a depth of 16.0m and penetrated it at 116.0m. The Main Formation (Z1) of the Zerqa Group from 116.0m to 345.0m and the Ram Sandstone below 345.0m were drilled. The total depth was 395.0m.

The Kurnuyb Sandstone was yellow to gray, friable sandstone.

The Main Formation (Z1) consisted of sandstone, dolomite, shale between 116.0m and 178.0m, clay, shale between 178.0m and 240.0m, and sandstone, shale below 240.0m.

The Ram Sandstone was whwite, friable sandstone with black shale.

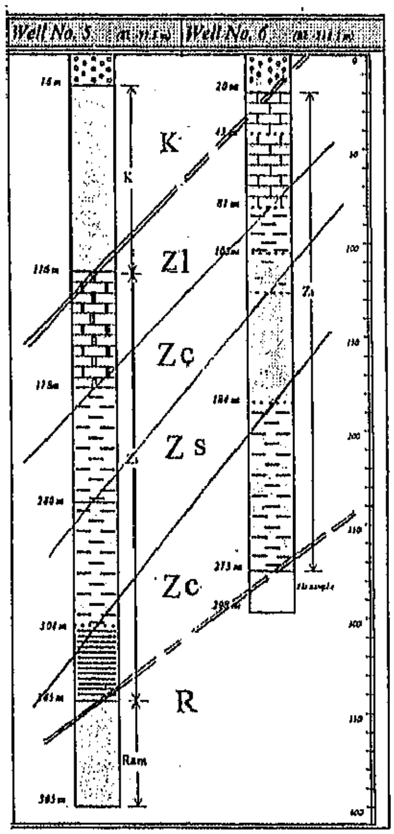
The identification report on the Ram Sandstone samples is attached in Supporting Report.

6) Well No. 6

Well No. 6 entered the Main Formation (Z1) of the Zerqa Group at a depth of 20.0m and this formation was drilled to 275.0m.

From 275.0m to the bottom of the well, lithologic samples were not taken because of the blind drilling. The total depth was 395.0m.

However, lithological correlation between Well No. 5 and No. 6 suggests that the bottom of the well might be upper part of Ram Sandstone as shown in Fig. I-3.3.9.



K: Kurnub Sandstone

Z1: Limestone prominent layer of Zerqa Group

Zc: Shale and Claystone prominent layer of Zerqa Group

Zs: Sandstone prominent layer of Zerqa Group

R: Ram Sandstone

Fig. I-3.3.9 Lithological Correlation between Well No. 5 and No. 6

(2) Pumping Test Results

1) Well No. 1

a. Step Draw-down Test

A step draw-down test of five steps was carried out for ten hours using a submergible pump. From the results of the test, the specific capacity of Well No. 1 was evaluated as between 86m^2/day and 137 m^2/day and the optimum discharge rate was evaluated as more than 40.5*l*/sec. because a yield point could not be found in the draw-down discharge curve (See Supporting Report).

b. Constant Discharge Test and Recovery Test

A constant discharge test was carried out for fifty four (54) hours using the submergible pump. The average discharge rate was 30.8*l*/sec and it was kept constant. The Maximum draw-down was 28.20 m. After completion of the constant discharge test, the recovery of the ground water tablewas measured for one day.

The transmissibility and storage coefficient of the Upper Zerqa Group aquifer (Azab Formation Z2) were calculated as follows:

Test/Method	Transmissibility (T) (m^2/day)	Storage Coefficient (S)
i. Constant discharge		
a. Walton method	69.7	-
b. Yacob method	157.0	0.01
ii. Recovery	62.5	-

2) Well No. 2

a. Step Draw-down Test

A step draw-down test of five steps was carried out for ten hours. From the results of the test, the specific capacity of Well No. 2 was calculated as 54.5 m^2/day and the optimum discharge rate was calculated as 38.6l/sec.

b. Constant Discharge Test and Recovery Test

A constant discharge test was carried out for ninety six (96) hours. The average discharge rate was 28.9l/sec. On completion of the constant discharge test, the recovery of the piezometric pressure was measured for twenty three (23) hours.

Transmissibility and storage coefficient of the Upper Zerqa Group aquifer (Azab Formation, Z_2) were calculated as follows:

Test/Method	Transmissibility (T) (m^2/day)	Storage Coefficient (S)
i. Constant discharge		
a. Walton method	141.7	0.001
b. Yacob method	120.1	0.004
ii. Recovery	91.3	-

3) Well No. 3

a. Step Draw-down Test

A step draw-down test of five steps was carried out over a one day period. From the results of the test, the optimum discharge yield for well No. 3 was evaluated as Q = 1,290 m^3/day.

b. Constant Discharge Test and Recovery Test

A constant discharge test for well No. 3 was carried out for 96 hours. During the entire period of the test, the discharge rate (Q = 17.5l/sec) remained constant. The recovery of the groundwater table was measured for eighty three (83) hours after completion of the constant discharge test.

Transmissibility and storage coefficient of the Kurnub Sandstone aquifer were calculated as follows:

Test/Method	Transmissibility (T) (m^2/day)	Storage Coefficient (S)
i. Constant discharge		
a. Walton method	120.0	0.002
b. Yacob method	110.0	0.002
ii. Recovery	110.4	-

4) Well No. 4

a. Step Draw-down Test

A step draw-down test was done for Well No. 4 on five stages at different discharge rates. From the results of the test, the optimum discharge rate was evaluated as 30l/sec and the specific capacity was calculated to be 620m^2/day.

b. Constant Discharge Test

The constant discharge test results of well No. 4 were calculated based on the Walton Method which was developed for the pumping test analysis of leaky aquifers. Using this method, not only the normal hydraulic properties (transmissibility, storage coefficient) can be calculated but also the leakance factor of an aquitard can be inferred. A detailed examination of the leakance factor of the aquitard and transmissibility of the Zerqa Group Aquifer has been carried out based on the combination pumping test results and is discussed in section 5). The results of the Walton Method calculation used for the determination of the initial condition of the detailed examination mentioned above are as follows:

Test/Method	Transmissibility of the Zerqa G. Aquifer (T) (m^2/day)	Leakance Factor of the Aquitard (/day)
Constant discharge Walton method	26	3.8×10^{-4}/day

5) Well No. 5

Small amount of flowing (around 1~2 lit/sec) was observed during the drilling in the Zerqa Group aquifier. After the penetration of the Zerqa Group aquifer, huge amount of flowing (more than 100 lit/sec) started from the Ram Sandstone aquifer at the depth of 353m. Therefore, it is suggested that the hydraulic properties obtained by pumping test in the Well No. 5 are almost represented as those of the Ram Sandstone aquifer.

The pumping test analysis results are shown below:

a. Step Draw-down Test

A step draw-down test of five steps was carried out for sixty hours. From the results of the test, the specific capacity of Well No. 2 was calculated as 42 m^2/day to 907m^2/day and the optimum discharge rate was calculated as 56.0 l/sec.

b. Constrant Discharge Test and Recovery Test

A constant discharge test was carried out for ninety six (96) hours. The average discharge rate was 74.5 l/sec. On completion of the constant discharge test, the recovery of the piezometric pressure was measured for twenty four (24) hours. Results of the pumping test analysis are shown below:

Test/Method	Transmissibility (T) (m^2/day)	Storage Coefficient (S)
i. Constant discharge		
a. Walton method	204.8	$4x10^{-3}$
b. Yacob method	261.7	$6x10^{-4}$
ii. Recovery	261.0	-

6) Well No. 6

During the drilling of Well No. 6, it is also observed that huge amount of flowing (200 to 300 lit/sec) started at the depth of 275m. Small amount of flowing (1 to 2 lit/sec) was observed between 111m and 274m in depth.

Although the samples could not be taken under 275m, it is inferred that Ram Sandstone underlies beneath 275m in Well No. 6 according to the geological correlation with Well No. 5. Accordingly, it is also supposed that the hydraulic properties in Well No. 6 are almost represented as those of the Ram Sandstone aquifer.

The calcularated hydraulic properties are shown below:

a. Step Draw-down Test

A step draw-down test of four steps was carried out for twenty hours. From the results of the test, the specific capacity of Well No. 6 was calculated as 262 m^2/day to 3,762 m^2/day and the optimum discharge rate was calculated as 36.0 l/sec.

b. Constrant Discharge Test and Recovery Test

A constant discharge test was carried out for ninety six (96) hours. The average discharge rate was 35.0 l/sec. On completion of the constant discharge test, the recovery of the piezometric pressure was measured for twenty (20) hours. Results of the pumping test.

Test/Method	Transmissibility (T) (m^2/day)	Storage Coefficient (S)
i. Constant discharge		
a. Walton method	120.3	-
b. Yacob method	369.0	$1x10^{-6}$
ii. Recovery	198.0	-

7) Pumping Test of Combination Wells (Well No. 3 and No. 4)

The pumping test of combination wells was conducted to obtain the leakance factor of Marly Layer which is aquitard binding the Zerqa Group aquifer and the Kurnub Sandstone aquifer. Well No. 3 and No. 4 are employed for this pumping test.

Detailed pumping test procedure and analysis are discussed in Supporting Report. Following two hydraulic properties were obtained by the test.

- Leakance factor of arly Layer (Aquitard) --------- $0.7x10^{-4}$/day
- Transmissbility of the Zerqa Group Aquifer ----- 100 m^2/day

8) Long Term Disicharge Test

Long term discharging tests were carried out using the flowing wells in order to see the draw-down of piezometric pressure and water quality change during the continuous discharging.

Draw-down curves and EC measuring results are shown in Supporting Report. The results of the long term discharging tests are summarized in Table I-3.3.1.

Table I-3.3.1 Results of the Long Term Discharging Test

Well No.	Aquifer[1)]	Constant Discharging Rate (lit/sec)	Test Period (days)	Final Draw-down (m)	Final[2)] Condition
No. 2	Z	17.5	54	29	S
No. 4	Z	42.0	84	33	S
No. 5	R	13.0	43	38	US
No. 6	R	22.0	11	12	US

1) Z: Zerqa Group aquifer
R: Ram Sandstone aquifer
2) S: Steady status
US: Unsteady status

As shown in Supporting Report, the grandwater take at the Kurnub Sandstone aquifer in Well No. 3 rose by maximum 51.5 cm after the discharging from Well No. 4. The groundwater table in Well No. 3 started decreasing after 43 days from start of discharging and did not reach its initial level. The reasons of this phenomeena are discussed in Section 2 of Supporting Report.

It is inferred from Table I-3.3.1 that the final draw-down of wells tapped into the Zerqa Group aquifer is around 30 m at the discharging rate of 35 lit/sec (3,000 m^3/day).

During the long term discharging test, notable change of electric conductivity (EC) could not found at every test wells (see Supporting Report).

3.4 Flow Measurement

3.4.1 Introduction

Flow measurements were carried out in order to provide data from which the inflow from the Zarqa Group to the rivers and wadis in the Study area could be calculated. Measurements were taken on the River Zarqa and the other wadis in the Study area which arise within or flow through the Zarqa Group and in which there is a continuous baseflow. One set of measurements was made at the end of the dry season during September and October 1994 and a second set was made in the wet season in January 1995. The dry season flows represent the baseflows in the river and wadis and have been carried forward for use in the water balance analysis (See Section 5). The wet season measurements have been used as a check.

Measurements were taken at the following points:-

(a) River Zarqa: (i) immediately downstream of the Talal al Dhahab out-take
(ii) immediately upstream of the Abu Zeigan out-take at a site prepared by WAJ for their flow measurements.
(iii) at Damieh

(b) Wadi Mallaha

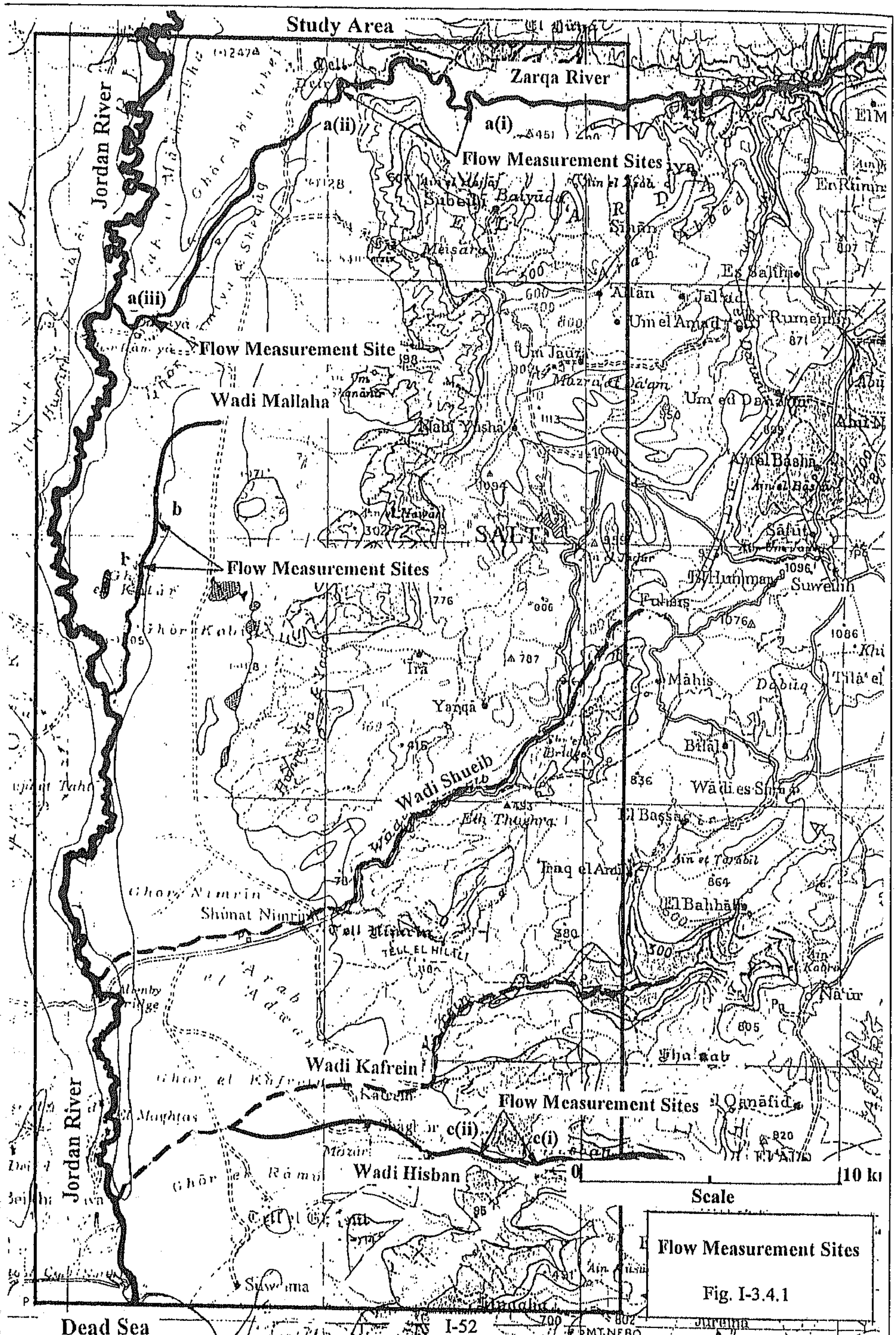
(c) Wadi Hisban, (i) upstream and (ii) downstream.

The locations are shown in Fig. I-3.4.1.

3.4.2 Description of Measurements

Measurement of the larger flows was carried out using a standard size cup-type meter. Flows measured with this meter were calculated from measured meter revolutions using a rating table supplied with the instrument. The meter was spin tested at the commencement and completion of measurements.

Measurements of smaller flows were taken with a miniature propeller flow meter. The meter provided a direct velocity read-out. Calibration was provided by the manufacturer.



Flow Measurement Sites

Fig. I-3.4.1

In each case, a reasonably straight, smooth-flowing section of the river or wadi was selected for the measurement site. The stream at the measurement site was prepared prior to measurement by removing large stones from the bed and vegetation from the banks in order to ensure that flow conditions were as steady as possible. A series of velocity and depth measurements was taken at suitable intervals across the stream.

a) River Zarqa

Measurements a(i) and a(ii) were taken with the cup-type meter.

Flow measurements at location a(iii) were taken in the dry season using the miniature propeller meter and in the wet season using the cup-type meter.

Discharges from King Talal dam at the time of the measurements were also noted.

b) Wadi Mallaha

The measurements on the Wadi Mallaha were taken with the miniature propeller flow meter. An additional measurement was taken in the wet season at a location 1km upstream of the Karameh Dam site. Construction work for the dam precluded taking measurements at the dam site.

c) Wadi Hisban

Two sets of dry season measurements were taken in Wadi Hisban. The first set of measurements was made using a thin plate weir for the upstream measurement and the miniature flow meter for the downstream measurement. At the time the second set of measurements was taken, the out-take from the wadi upstream of the upstream site had been closed, causing the flow in the wadi to increase. The miniature flow meter was therefore used for both measurements.

The weir measurement was made by inserting a rectangular notch weir into the wadi channel and sealing it to prevent leaks around the base and sides. The weir was constructed of steel plate with a 150 mm wide notch. When flow over the weir had stabilized, a pool was formed upstream of the weir which provided tranquil flow conditions. The depth of flow over the weir was then measured and the flow calculated from the rating table supplied with the weir.

The wet season measurements were made with the miniature flow meter.

3.4.3 Results

The flow at each measurement site has been calculated from the field measurements using spreadsheets, copies of which are included in the Supporting Report. The calculated flows are given in Tables I-3.4.1 and 3.4.2.

The inflow from the Zarqa Group to Wadi Hisban and to the River Zarqa between Talal Dhahab and Abu Zeigan is the difference between the upstream and downstream flow measurements.

The inflow from the Zarqa Group to the River Zarqa downstream of Abu Zeigan is the measured flow at Damieh minus the flow at Abu Zeigan, which was zero at the time the measurements were taken.

The Wadi Mallaha arises within the Zarqa Group. The inflow is therefore the flow at the downstream end of the wadi, at the dam site.

3.4.4 Discussion

The flows measured in the River Zarqa in the wet season were less than those measured in the dry season because the outflow from the King Talal Reservoir is reduced in the wet season and increased in the dry season as shown in Tables 3.4.1 and 3.4.2 above and described in Section 2.

The difference between the measured upstream and downstream flows was again less in the wet season than the dry season because, at the time of the wet season flow measurements, it was observed that the riparian farmers were pumping water for their irrigation systems directly from the river between the upstream and downstream measurement points. No pumping was taking place during the dry season measurements, when water resources in the Jordan Valley are more limited and curtailment of this type of unofficial abstraction is more rigorous.

The water in the River Zarqa between Abu Zeigan and Damieh is not used for irrigation. The measured wet season flow is greater than the measured dry season flow, as expected under natural conditions.

Table I-3.4.1 Results of Flow Measurements - September/October 1994

Wadi/River	Date measured	Upstream Flow (liters/sec)	Downstream Flow (liters/sec)	Difference (liters/sec)
Zarqa	22 Sept 94	600	1,450	850
Zarqa	24 Sept 94	600	1,326	726
Zarqa	11 Oct 94	960	1,670	710
Zarqa (Damieh)	24 Sept 94		445	
Mallaha (JICA)	21 Sept 94		34	
Mallaha (Gibb)	Sept 92		132	
Hisban	21 Sept 94	0.5	29	28.5
Hisban	25 Sept 94	10	49	39

Discharges from King Talal Dam (cu.m/second):- 22 Sept 94: 3.6
24 Sept 94: 3.6
11 Oct 94: 4.5

Table I-3.4.2 Results of Flow Measurements - January 1995

Wadi/River	Date measured	Upstream Flow (liters/sec)	Downstream Flow (liters/sec)	Difference (liters/sec)
Zarqa	7 Jan 95	620	1,220	600
Zarqa	10 Jan 95	65	500	435
Zarqa (Damieh)	8 Jan 95		620	
Zarqa (Damieh)	11 Jan 95		525	
Mallaha	8 Jan 95	25		
Mallaha	9 Jan 95	21	170	
Mallaha	11 Jan 95		67	
Hisban	5 Jan 95	73	201	128
Hisban	9 Jan 95	65	146	81

Discharges from King Talal Dam (cu.m/second):- 7 Jan 95: 2 - 3
10 Jan 95: zero.

Wadi Mallaha has been the subject of an extensive study for the proposed Karameh Dam (See Reference 13 and Section 2.2). The study includes flow measurements on the Wadi Mallaha at the proposed dam site and on the tributary wadis entering the reservoir basin. An average of six measurements per month was taken on each wadi throughout the period November 1991 to October 1992. The baseflow at the dam site given in Reference 13 represents the flow from the whole Wadi Mallaha catchment and has therefore been used in the water balance calculation.

The JICA Study upstream flow measurement site is near to one of the upstream measurement sites in Reference 13. The dry season flow measured in the present study agrees closely with that recorded in Reference 13 at this location.

At the time of the wet season flow measurements, construction of the dam was already under way. As part of the construction works, the Wadi Mallaha and its tributaries had been dammed and most of the flow had been diverted. The flow in the Wadi Mallaha was therefore considerably reduced and the measurements taken were not, therefore, representative of natural conditions.

The measured flows in the Wadi Hisban, like those at Damieh, show the expected seasonal variation. The measured downstream flows are within the ranges recorded by WAJ in both September and January - see Section 2.3 (3).

3.4.5 Conclusion

The flows carried forward for use in the water balance analysis (see Section 5) are as follows:-

The difference between the measured upstream and downstream dry season flows in Wadi Hisban and the River Zarqa between Talal Dhahab;

The measured dry season flow at Damieh in the River Zarqa downstream of Abu Zeigan;

The base flow at the dam site given in Reference 13 in Wadi Mallaha.

4. Water Quality Analyses

Water quality analyses were conducted with respect to the waters from (1) the existing wells, springs and wadis, (2) the test wells drilled by JICA Study Team in the Study area. The objectives were to investigate the characteristics and seasonal variations of water quality in the Study area and to understand the water quality in the brackish groundwater aquifer.

4.1 Water Quality Analyses for the Existing Wells, Springs and Wadis

4.1.1 Water Quality Analyses at the End of the Wet Season

(1) Water sampling sites

The 35 sites from which water samples were collected at the end of the wet season are as follows:

a) Existing wells (8 points): Abu Zeigan No.1, Deir Alla No.2, Basset el Faras No.1, Kaffrein No.2, Kaffrein No.4, Kaffrein No.6, Kaffrein No.7 and Hisban No.2
b) Springs (17 points): Ain Ezzaqqoom, El Balawi, Hafayer, Es Sahn, Basset el Faras, Ain Wadi el Muhtariqa, Musa South, el Anis, Suweima, Hajjar, Bir el Azraq, Ain Wadi Abiad, Khuneizir, Hisban, el Fara, Spring for men and Spring for women
c) Wadis and canal (10 points): Wadi Kufrinia (upstream and downstream), Wadi Shueib (upstream and downstream), Wadi Kaffrein (upstream and downstream), Wadi Hisban (upstream and downstream), Wadi el Mallaha (downstream) and King Abdullah Canal (upstream and downstream of Deir Alla)

The locations of these sites are shown in the Supporting Report.

(2) Water quality analyses items

Temperature, pH, EC, TDS, Turbidity, SDI (silt density index, for 8 groundwater samples), Na, K, Ca, Mg, Fe, Mn, NH_4, Al, Total hardness, Cl, SO_4, HCO_3, CO_3, NO_3, NO_2, SiO_2, COD, H_2S, Total bacteria, Total coliform, Pb, Se, As, Cr, CN, Cd, Hg, Sb, Ag, Cu, Zn, Ni and F

The water quality data are shown in the Supporting Report.

4.1.2 Water Quality Analyses at the End of the Dry Season

(1) Water sampling sites

Most of the sites for water sampling at the end of the dry season were the same as those at the end of the wet season, except a small modification due to the need for hydrogeological study. 32 samples were collected from the following sites:

a) Existing wells (8 points): Abu Zeigan No.1, Deir Alla No.2, Basset el Faras No.1, Kaffrein No.2, Kaffrein No.4, Kaffrein No.6, Kaffrein No.7 and Hisban No.2
b) Springs (17 points): El Balawi, Hafayer, Es Sahn, Basset el Faras, Ain Wadi el Muhtariqa, Musa South, el Anis, Suweima, Hajjar, Bir el Azraq, Ain Wadi Abiad, Khuneizir, Hisban, el Fara, Spring for men, Spring for women and Spring in er Ramel
c) Wadis (6 points): Wadi Kaffrein (upstream and downstream), Wadi Hisban (upstream and downstream), Wadi el Mallaha (downstream) and Wadi Zarqa (downstream)
d) The pool of Ghor el Kabid (1 point)

The locations of these sites are shown in the Supporting Report.

(2) Water quality analyses items

Temperature, pH, EC, TDS, Turbidity, SDI (silt density index, for 10 groundwater samples), Na, K, Ca, Mg, Fe, Mn, NH_4, Al, Total hardness, Cl, SO_4, HCO_3, NO_3, SiO_2, COD, H_2S, Total coliform and F

The water quality data are shown in the Supporting Report.

4.1.3 Comparison of Water Quality Analyses Results in Wet and Dry Seasons

For all the existing wells, springs and wadis, little difference was seen from the water quality analyses results in the wet and dry seasons. The salinity of the water stayed at the same level through the hot summer time from April to September, and the concentrations of the main component ions did not vary at all for most of the sites.

These facts can be seen more clearly from a comparison of the tri-linear diagrams of water quality in the two seasons for the existing wells (Fig. I-4.1.1) and springs (Fig. I-4.1.2). The positions of the points in the diamond diagram and the two triangle diagrams show the composition of the main cations (Na+K, Ca and Mg) and anions (Cl, HCO_3 and SO_4+NO_3) as their equivalent percentages. No appreciable difference is found between the winter and summer samples from the same site.

From these diagrams, the way that ion composition varies with salinity is clear either for wells or for springs. For lower salinity water, Ca and HCO_3 percentages are higher among cations and anions, respectively. As salinity increases, Ca and HCO_3 percentages decrease, and Na and Cl percentages increase.

Among the 7 existing wells, the hydrogeological evidence suggests that Hisban No. 2, Abu Zeigan No. 1 and Kafrein No. 7 belong to the Zerqa Aquife. Their water quality is similar as shown on the diagrams. Na (including K) is the main cation with a percentage of 60-70%, and Cl is the main anion with a percentage of 55-70% in the water.

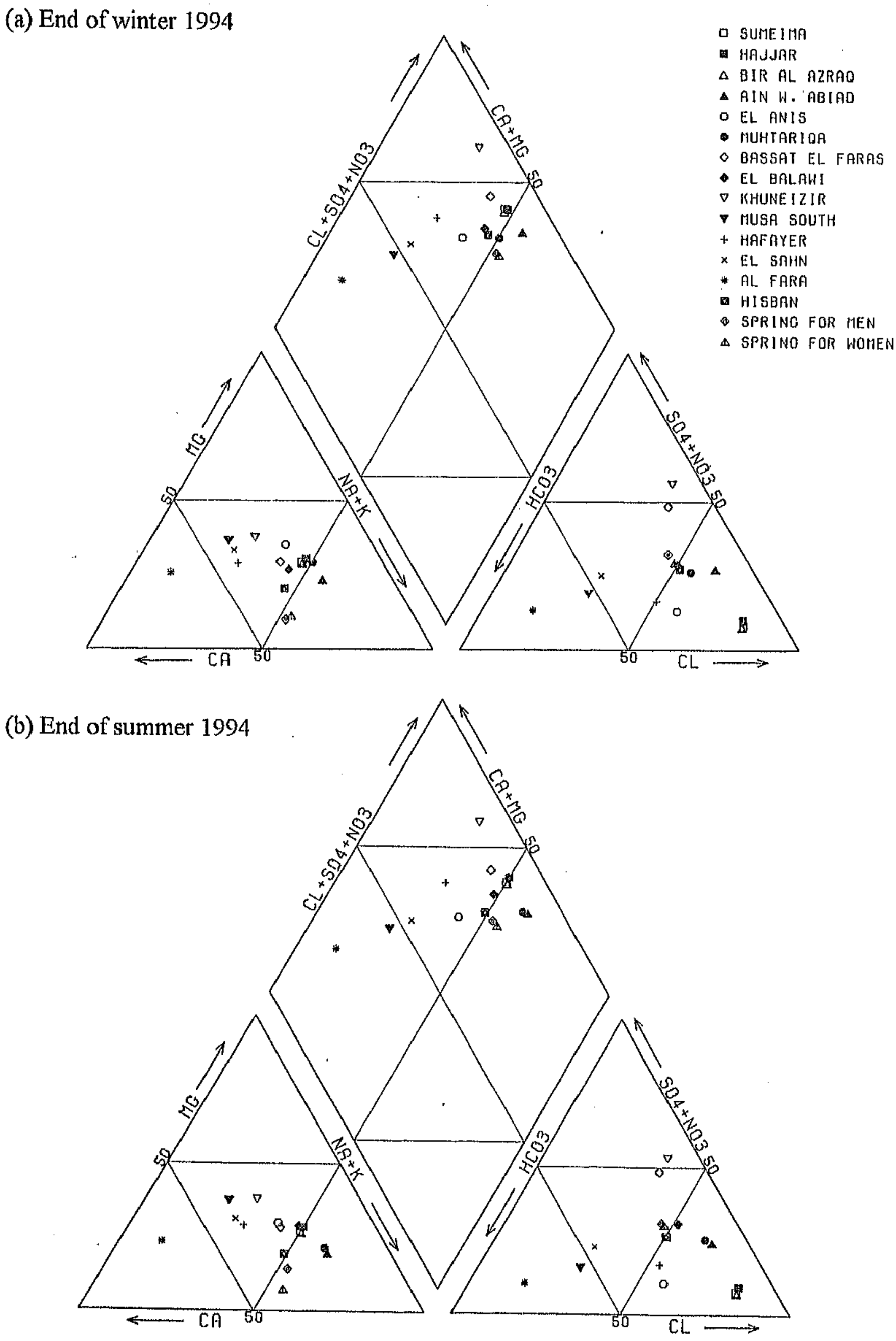
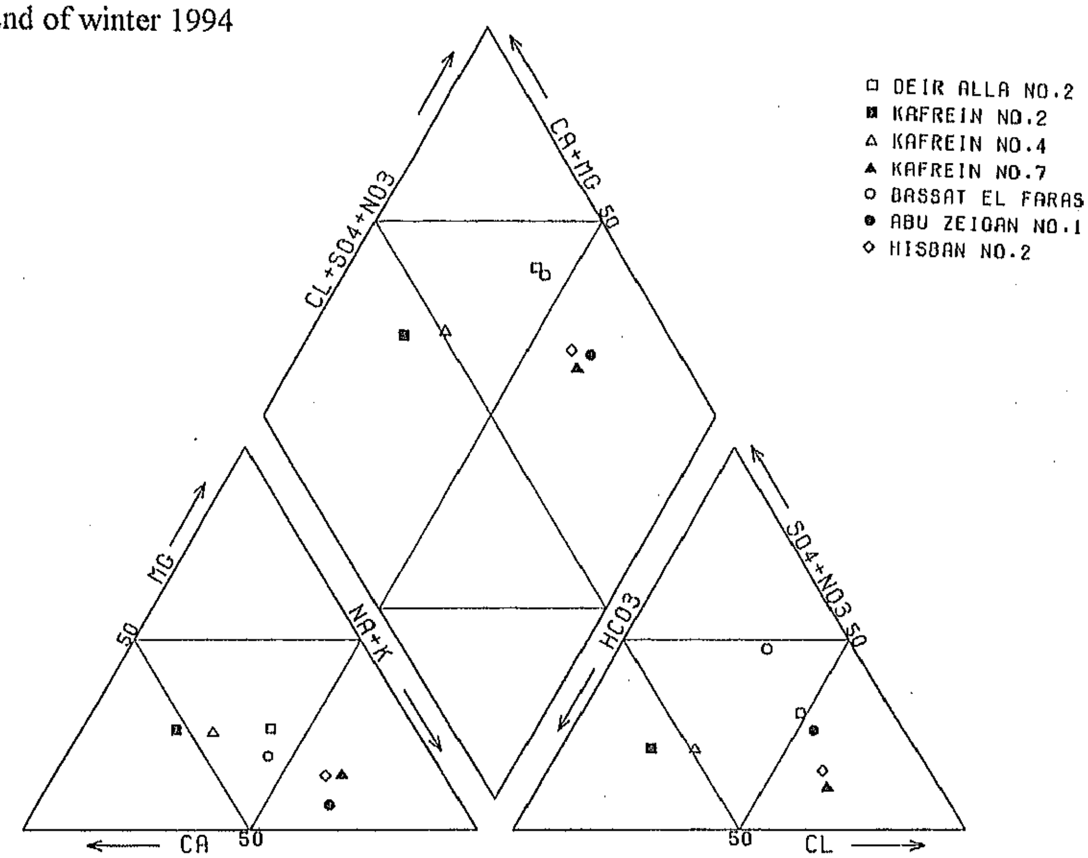


Fig. I-4.1.1 Tri-Linear Diagram of Water Quality Of Springs

(a) End of winter 1994



(b) End of summer 1994

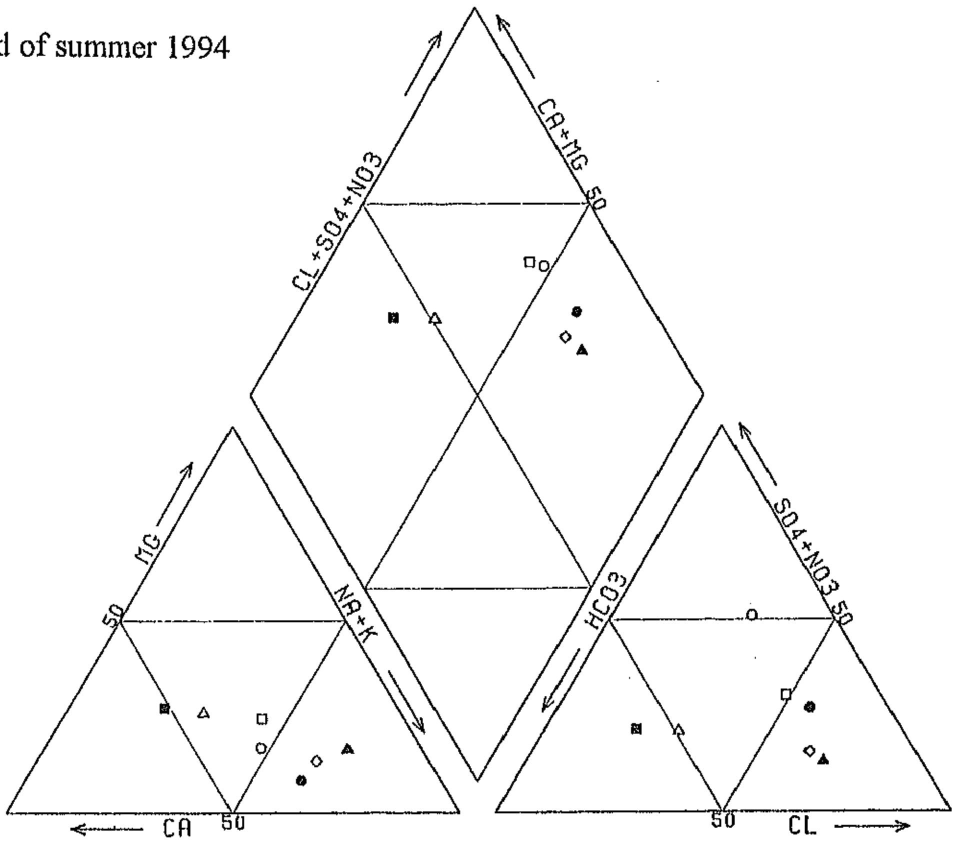


Fig. I-4-1.2 Tri-Linear Diagram of Water Quality Of Existing Wells

4.2 Water Quality Analyses for Test Wells

4.2.1 Work Plan and Progress

(1) Water sampling schedule

Water quality analyses for the 6 test wells are following the progress of drilling work and pumping tests. It is scheduled that monthly water sampling from each test well starts at the time when the well is completed and continues to the end of long term pumping and observation. One sample is collected from each well for groundwater dating.

(2) Water quality analyses items

i) General analyses items (24 items)

Temperature, pH, EC, TDS, Turbidity, SDI, Na, K, Ca, Mg, Fe, Mn, NH_4, Al, Cl, SO_4, HCO_3, NO_3, SiO_2, COD, H_2S, Total bacteria, Total coliform and F

Analyses of these items are required for all the monthly collected samples.

ii) Heavy metals and toxic substances (13 items)

Pb, Se, As, Cr, CN, Cd, Hg, Sb, Ag, Cu, Zn, Ni and Ba

Analyses of these items are only required for one sample from each well.

(3) Progress in water sampling and water quality analyses

Following the progress of drilling work, water sampling and water quality analyses for Test Wells No. 2, No.3, and No.4 began at the beginning of December, 1994, and that for Test Wells No. 1, No. 5 and No.6 at the beginning of January, 1995. The work is continuing to the end of March, 1995.

Samples for groundwater dating were collected from all the wells and analyses are being conducted in the laboratory.

4.2.2 Water Quality Analyses Results

(1) General results

The data of water quality analyses during the long term pumping and observation from December 1994 to March 1995 are shown in the Supporting Report. Generally speaking, there have been no abvious change in the water quality of each well in this period. The mean values of water quality items for the 6 wells are shown in Table I-4.2.1. The characteristics of water quality in each well can be generalized as follows.

i) Test Well No. 1

TDS of the water is about 7,000 mg/L with a temperature of 30 °C. From the concentrations of the main ions in the sample, NaCl is estimated to be about 3,000 mg/L which is 40% of the total salts in the water. Ca+Mg amounts to 40~47 meq/L and is equivalent to a hardness of 2,000~2,350 mg/L as $CaCO_3$. The concentrations of anions in the water show the relationship [Cl]>[SO_4]>[HCO_3] both in equivalent and in weight. As for the other substances which would foul a membrane, SiO_2 is about 20 mg/L and Fe is about 10 mg/L.

The values of SDI and turbidity show that pre-treatment will be required if a membrane process is used for desalination.

The concentrations of heavy metals and toxic substances are very low in the water.

ii) Test Well No. 2

Generally speaking, water from this well is very brackish (TDS > 10,000 mg/L). The concentrations of the main cations and anions are in the orders of [Na]>[Ca]>[Mg] and [Cl]>[SO_4]> [HCO_3]. NaCl is more than 6000 mg/L and the total hardness is higher than 3000 mg/L.

The quality of this water may not be suitable for brackish water desalination.

iii) Test Well No. 3

Test Well No. 3 is an observation well at the same location as Test Well No. 4. The water from this well should belong to the upper Kurnob aquifer which is a fresh water aquifer in most of the study area. However, from the analysis results, it is seen that the water quality of this well has been heavily influenced by the lower Zerqa aquifer.

Table I-4.2.1 Water Quality Analyses Results of Test Wells

Test Well		No.1	No.2	No.3	No.4	No.5	No.6
Parameter	Unit						
Temp.	°C	30.35	30.97	26.10	31.37	34.67	30.26
pH		6.53	6.50	6.53	6.57	6.86	6.77
EC	μS/cm	8,220	14,588	7,960	12,545	8,037	7,748
TDS	mg/L	6,976	11,033	6,551	9,792	5,530	5,422
Turbidity	NTU	564.30	90.22	335.00	274.50	210.40	225.50
SDI		5.73	4.91	5.57	5.48	4.07	5.34
Ca	meq/L	33.69	37.59	32.78	42.81	19.71	21.67
Mg	meq/L	11.05	23.83	13.15	13.57	12.65	12.60
Na	meq/L	50.20	108.04	50.93	95.98	55.03	52.69
K	meq/L	4.23	6.42	3.00	5.54	4.33	4.65
Cl	meq/L	49.80	114.44	45.65	81.20	59.69	55.78
SO_4	meq/L	33.51	37.42	35.56	44.81	11.72	14.07
HCO_3	meq/L	14.98	24.89	17.19	24.55	19.49	18.96
NO_3	mg/L	7.75	2.90	7.44	4.13	1.67	1.50
Fe	mg/L	14.35	2.37	24.70	14.61	0.56	1.92
Mn	mg/L	0.54	0.21	0.66	0.39	0.20	0.51
NH_4	mg/L	0.39	0.40	0.44	0.48	0.29	0.19
Al	mg/L	0	0	0	0	0	0
SiO_2	mg/L	18.85	16.27	12.84	18.94	14.31	17.13
COD	mg/L	37.00	92.83	71.00	48.00	43.83	37.80
H_2S	mg/L	0.42	0.28	0.51	0.38	0.21	0.34
THBC	CFU/mL	1,000	4,220	5,000	3,520	2,500	2,660
TCC	MPN/100mL	0	5	0	0	5	5
Pb	mg/L	0.1	<0.01	0.26	<0.01	0.15	0.12
Se	mg/L	< 0.001	<0.001	< 0.001	<0.001	< 0.001	<0.001
As	mg/L	< 0.001	<0.001	< 0.001	<0.001	0.0064	<0.001
Cr	mg/L	0.02	0.01	< 0.01	<0.01	0.01	0.03
CN	mg/L	< 0.02	0.02	< 0.02	<0.02	< 0.02	<0.02
Cd	mg/L	-	0.03	0.02	0.03	0.03	0.02
Hg	mg/L	< 0.001	<0.001	< 0.001	<0.001	< 0.001	<0.001
Ag	mg/L	0.02	<0.01	0.02	<0.01	< 0.01	0.01
Cu	mg/L	0.02	0.03	0.02	0.03	0.03	0.02
Zn	mg/L	0.04	0.05	0.25	0.04	0.02	0.03
Ni	mg/L	0.03	<0.01	0.06	<0.01	0.04	0.05
F	mg/L	2.06	2.28	2.7	2.4	0.47	0.58

iv) Test Well No. 4

The water quality of Test Well No. 4 is similar to that of Test Well No. 2 in salinity and the concentrations of the main ions.

v) Test Well No. 5

The water from Test Well No. 5 has a TDS about 5200 mg/L. The estimated NaCl concentration is about 3,400 mg/L which is 65% of the total salts in the water. From the Ca and Mg concentrations, the total hardness is calculated as 1,750 mg/L as $CaCO_3$. Unlike Test Wells No.1, No.2 and No.4, the concentrations of the main cations have a relation of [Cl]>[HCO_3]>[SO_4].

SDI of the water is lower than the other wells. Fe and SiO_2 are also at low concentration levels.

Heavy metals and toxic substances in the water are of very low concentrations.

vi) Test Well No. 6

The water quality of Test Well No. 6 is similar to Test Well No. 5.

(2) Tri-linear water quality diagrams

Fig. I-4.2.1 shows the tri-linear water quality diagrams for Test Wells No.1 – No.6. Generally speaking, the patterns of water quality shown on the diagrams are similar to each other, because the water is from the same Zerqa aquifer in Jordan Valley. Further, the characteristics of water quality mentioned in (1) can be seen more clearly by a detailed comparison of the data for these wells shown on the diagram, i.e., the water quality similarity of No.2 with No.4 and that of No.5 with No.6, and so on.

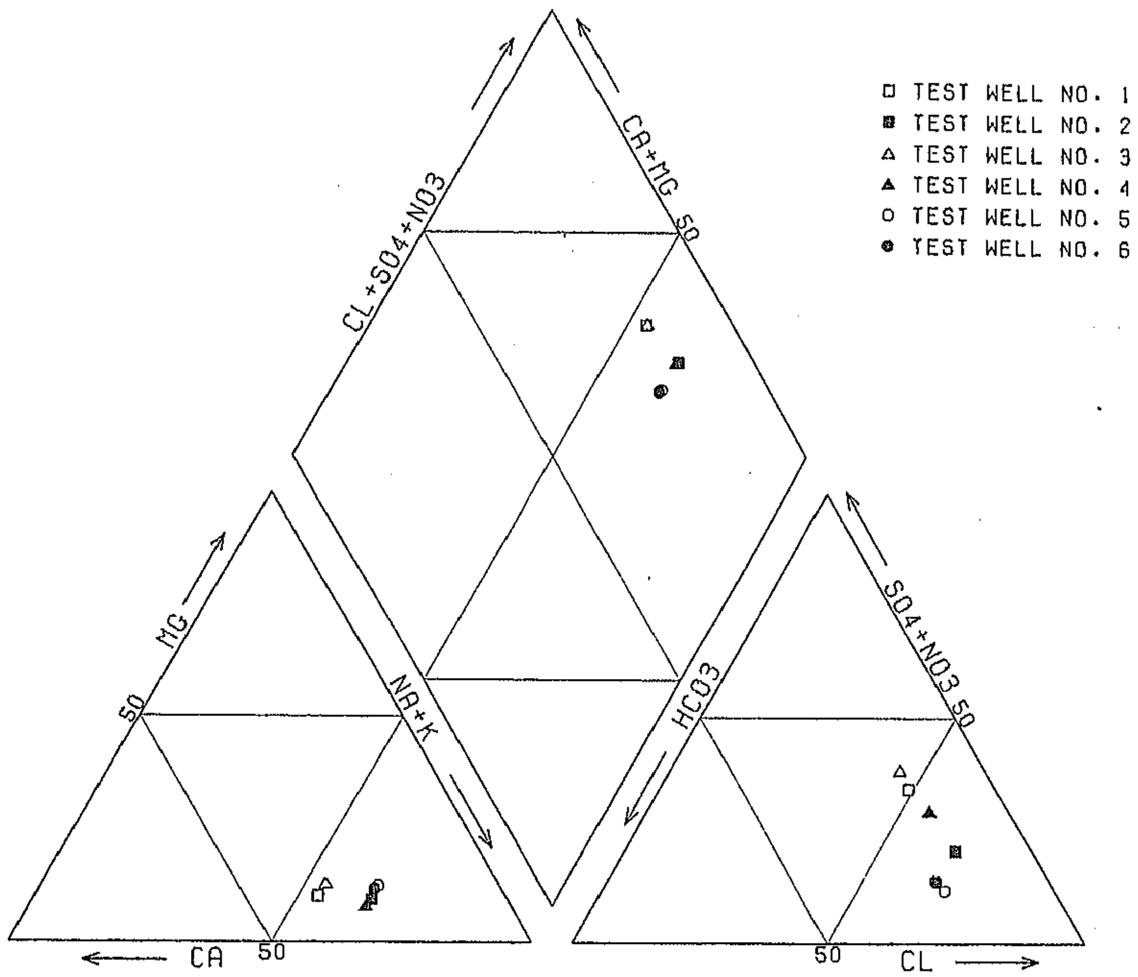


Fig. I-4.2.1 Tri-Linear Diagram of Water Quality of Test Wells

5. Water Balance Analysis

Calculations have been based on the flow measurements described in Section 3.4 and additional data which have been collected from JVA and WAJ. Data has been abstracted from the references listed at the end of Section 2. Information received in meetings and discussions with JVA is summarised in Section 2.3 (5).

The purpose of the calculations is to calculate the inflow from groundwater into the Jordan River and hence establish the Western boundary condition for the groundwater simulation model of the Study area.

The Study area divides naturally into four areas from North to South as follows:

Area A - the catchment of the Zarqa river;

Area B - the catchment of the Wadi Mallaha;

Area C extends from the Wadi Mallaha to the Wadi Hisban;

Area D is the small strip between the Wadi Hisban and the Dead Sea.

The areas are shown in Fig. I-5.1.1.

The irrigated areas in the Jordan Valley are described in Reference 12.

In general, the water balance is given by:

$$Q = G + E + S$$

In which, Q = groundwater entering the aquifer (from outside the Study area)

G = groundwater discharge to rivers and wadis

E = evaporation

S = groundwater discharge through springs

In order to estimate the groundwater inflow into the Jordan River, use has been made of the flow measurements carried out by JVA in August 1980 (Reference 16). Measurements were taken at Abu Sus (190 North)and Damieh Bridge (168 North). This reach is 22 km long, of which the Southern 11 km is within Area A and the remainder is outside the Study area. In addition to the flow measurements, JVA made a visual flow estimate at King Hussein Bridge (at the Southern end of the Jordan River). Based on these measurements, the inflow to the Jordan River between Abu Sus and Damieh Bridge has been calculated to be 800 liters/second, equivalent to 25.2 MCM/year.

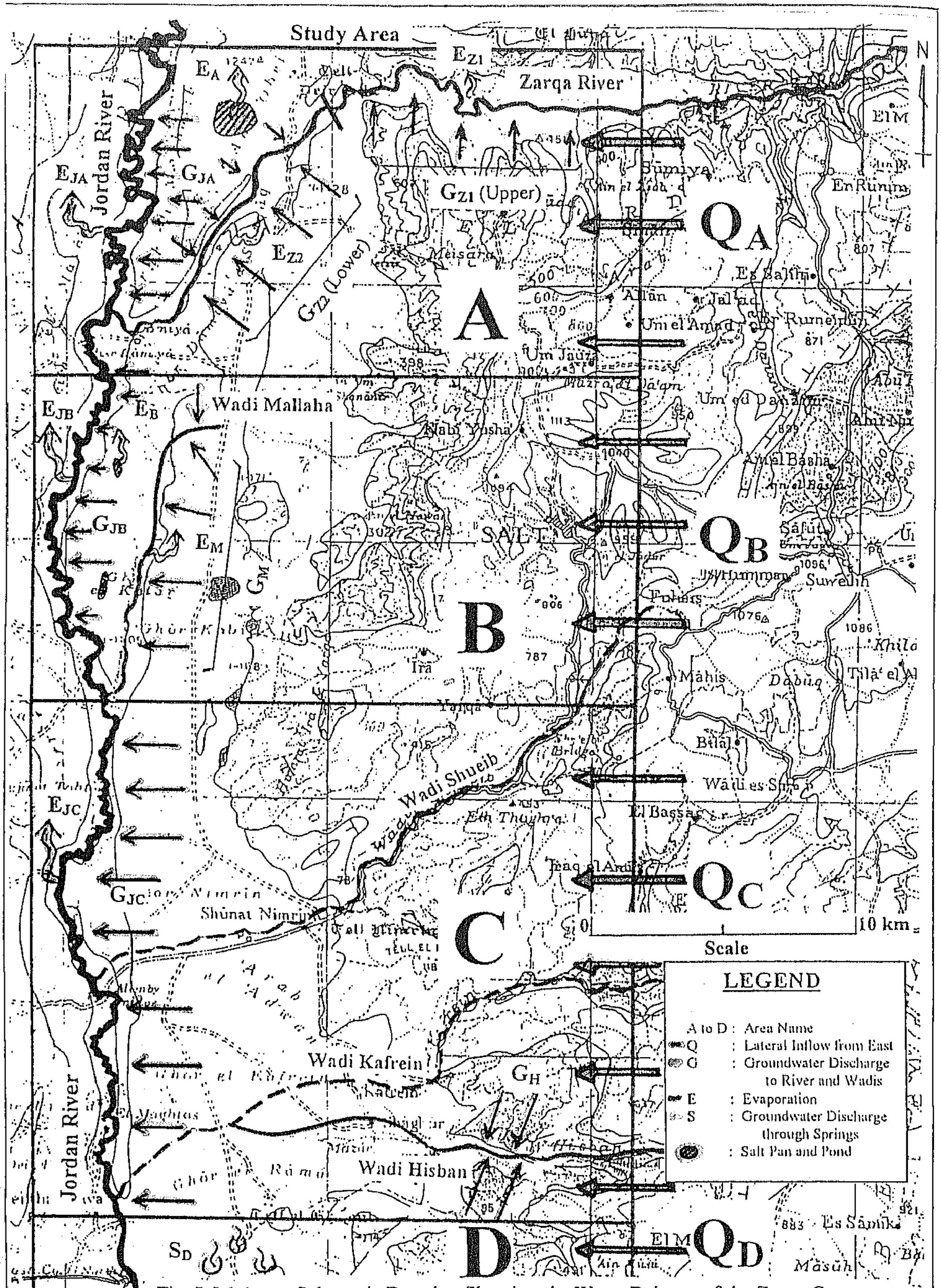
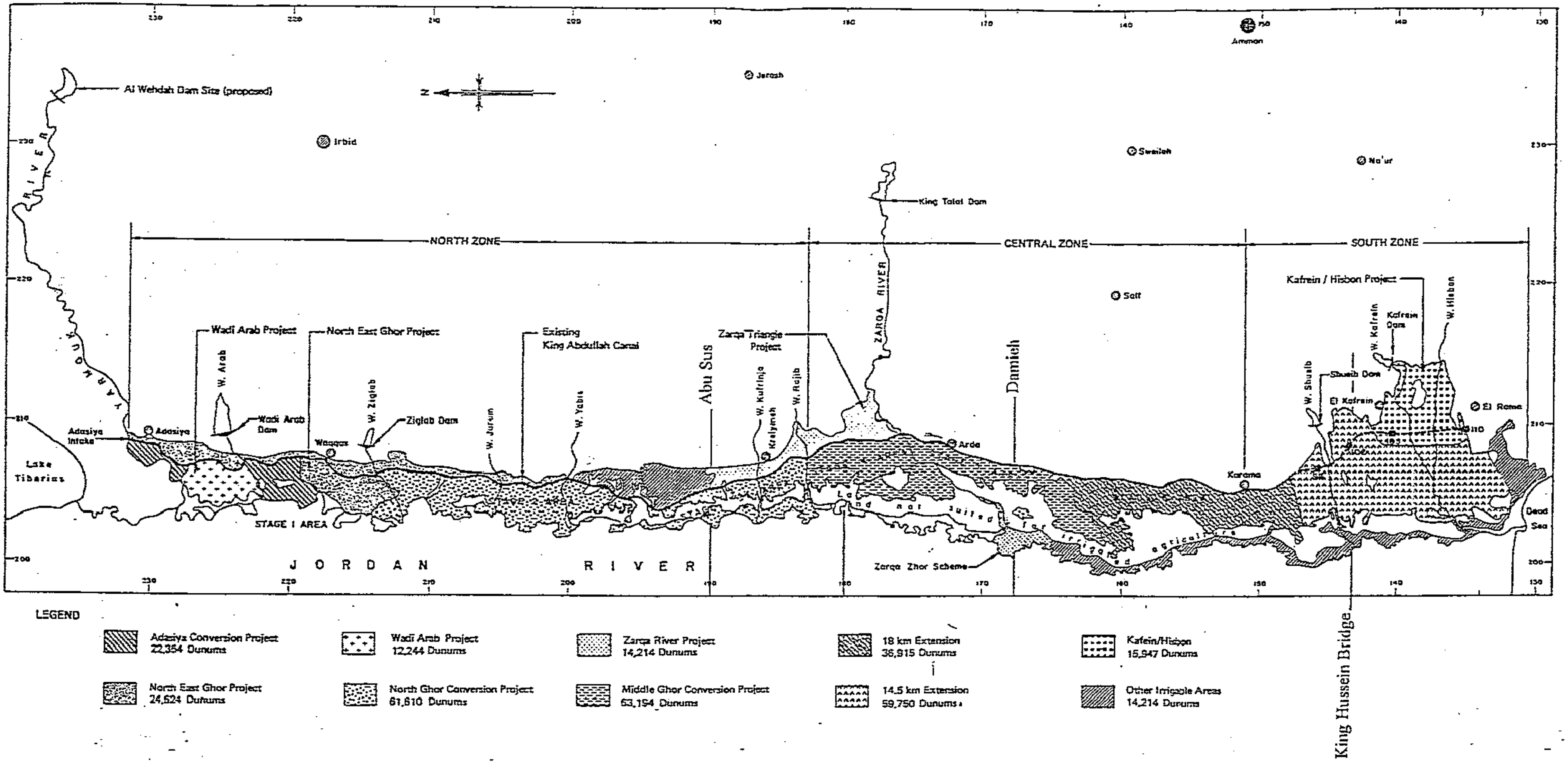


Fig. I-5.1.1 Schematic Drawing Showing the Water Balance of the Zerqa Group Groundwater



Irrigated Areas in the Jordan Valley

Copied from Harza (1989) -
Storage Facilities in the Jordan Valley (Vol II)

Fig. I-5.1.2

The inflow to the Jordan River comprises groundwater inflow from the East Bank and the following components:

base flows in rivers and wadis;

irrigation return flow;

infiltration from irrigation;

evaporation;

leakage from the King Abdullah Canal;

flow from the West Bank.

Additional data collected during the Study have been used to quantify the components of this inflow. Each of these components has been subtracted from the total inflow. The remaining flow has been assumed to be groundwater inflow from the East Bank. The Zerqa Group is widely exposed on the East Bank of the Jordan River between the two measurement points and has therefore been assumed to be the source of the groundwater inflow except Area C.

The irrigation return flow and infiltration flows for this initial calculation have been based on the irrigated areas in 1980. These were obtained from Reference 14.

Based on the foregoing, a groundwater inflow rate to the East Bank of the Jordan River from the Zerqa Group of 0.29 MCM/km/year has been calculated (see Section 4 of Supporting Report).

It has been assumed that the calculated groundwater inflow rate from the Zerqa Group to the East Bank of the Jordan River is the same at the present time as in 1980 and this rate has been used to evaluate the groundwater inflow from the Zerqa Group to the East Bank of the Jordan River in Areas A and B of the Study area.

Hydrological data for Area C is limited and a calculation of the groundwater inflow to the East Bank of the Jordan River from the Zerqa Group in Area C using this method does not give a realistic result. The groundwater inflow to the East Bank of the Jordan River from the Zerqa Group in Area C has therefore been evaluated from Hydrogeological data and the Groundwater Simulation Model (See Sections 6 and 7).

Groundwater inflow to the East Bank of the Jordan River in Area D has been assumed to be negligible because the configuration of the interface between Dead Sea water and the groundwater forms a barrier to groundwater flow. All the groundwater inflow from the Zerqa Group in Area D, therefore, discharges as springs near the coast line of the Dead Sea.

For each area, estimates have been made of all the inflow components. These include groundwater inflow to the Jordan River, inflows to the Zarqa River and Wadi Mallaha, inflows from springs and evaporation losses. The calculations are set out in Section 7.4 and illustrated in Fig. I-7.4.7

The total groundwater inflow from the Zerqa Group within the Study area was estimated to be approximately 120 MCM/year as shown in Table I-5.1.1 below.

Table I-5.1.1 - Groundwater Inflow from the Zerqa Group within the Study Area

	Area A	Area B	Area C*	Area D	Total
Groundwater Inflow from the Zerqa Group (MCM/year)	40.8	8.4	70	2.6	121.8

* Inferred from groundwater simulation.