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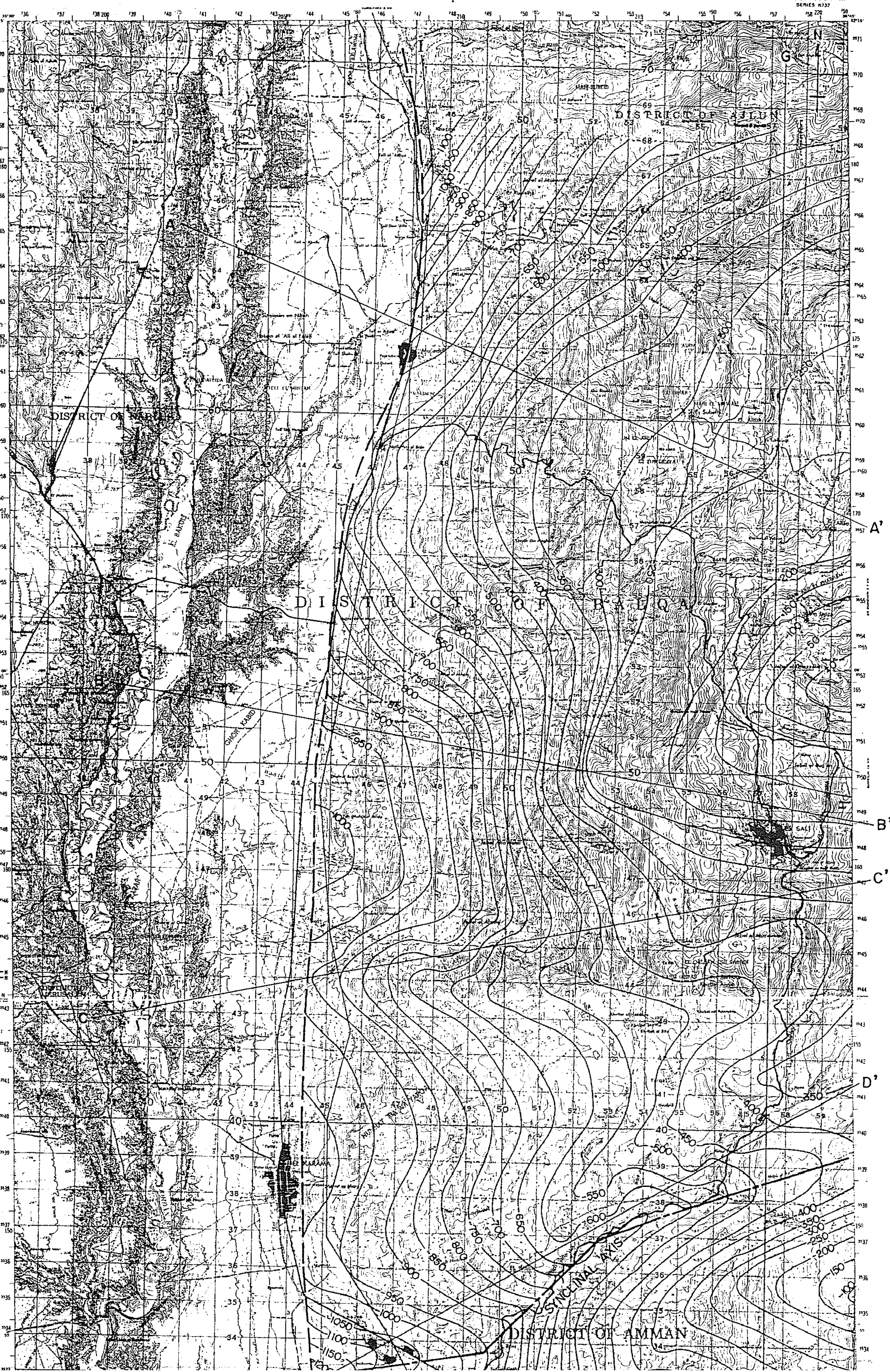


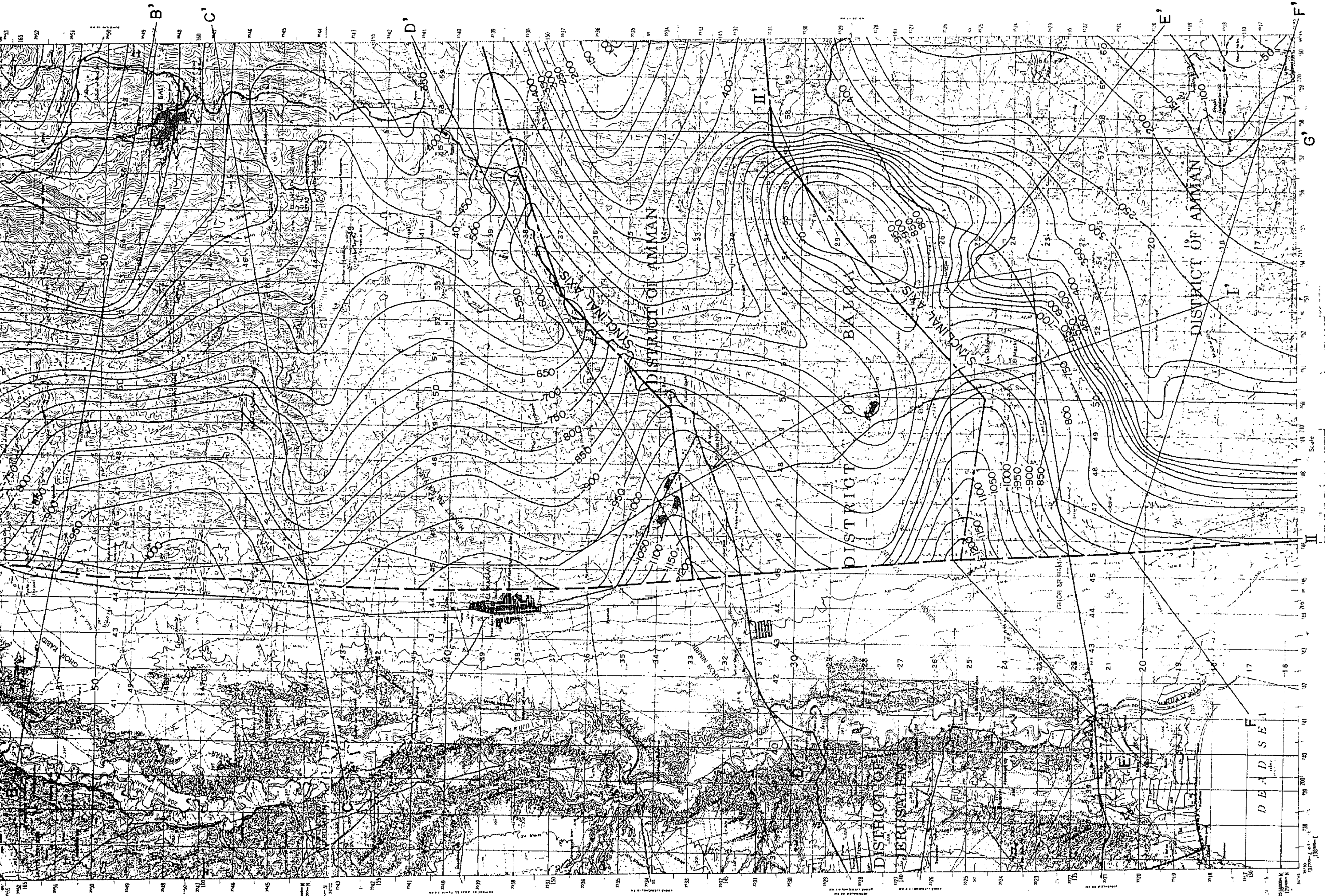
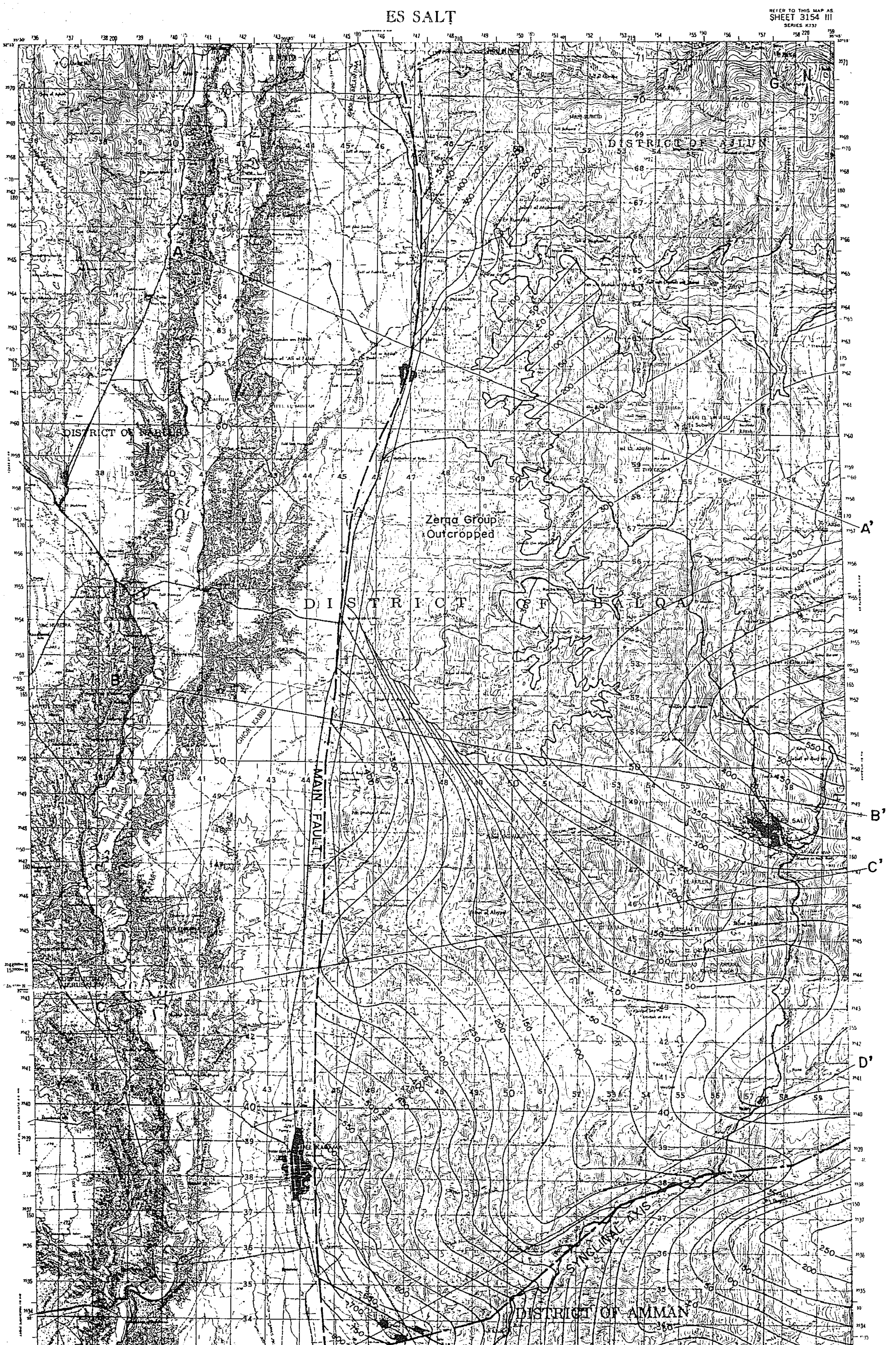


Fig. I-6.1.3 Contour Line of the Bottom of the Zerqa Group Aquifer



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DISTRICT OF AJLUN
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A
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B
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C
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D'
SALT
GHOR KABID

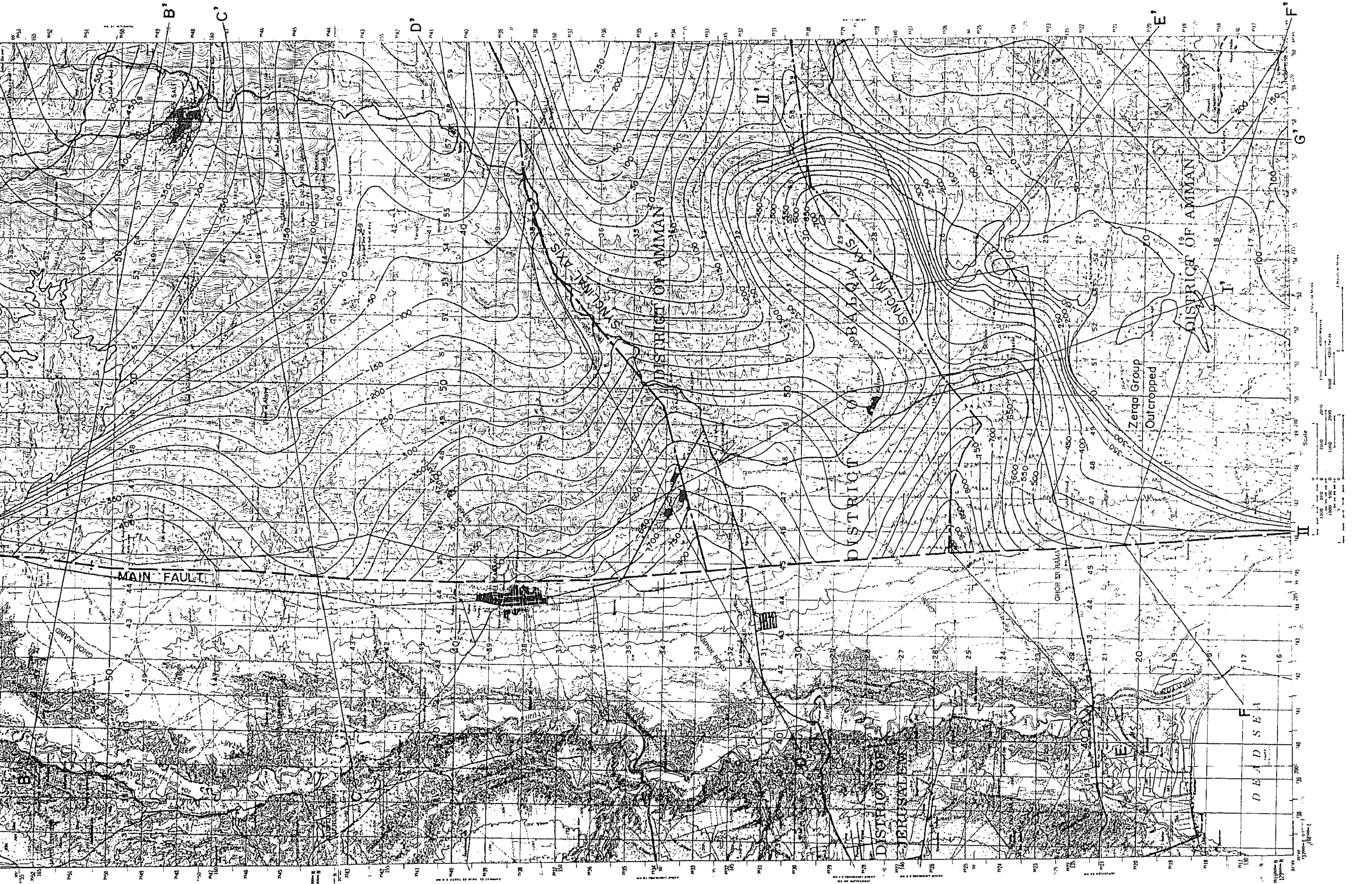

Fig. I-6.1.4 Contour Line of the Surface of the Zerqa Group Aquifer

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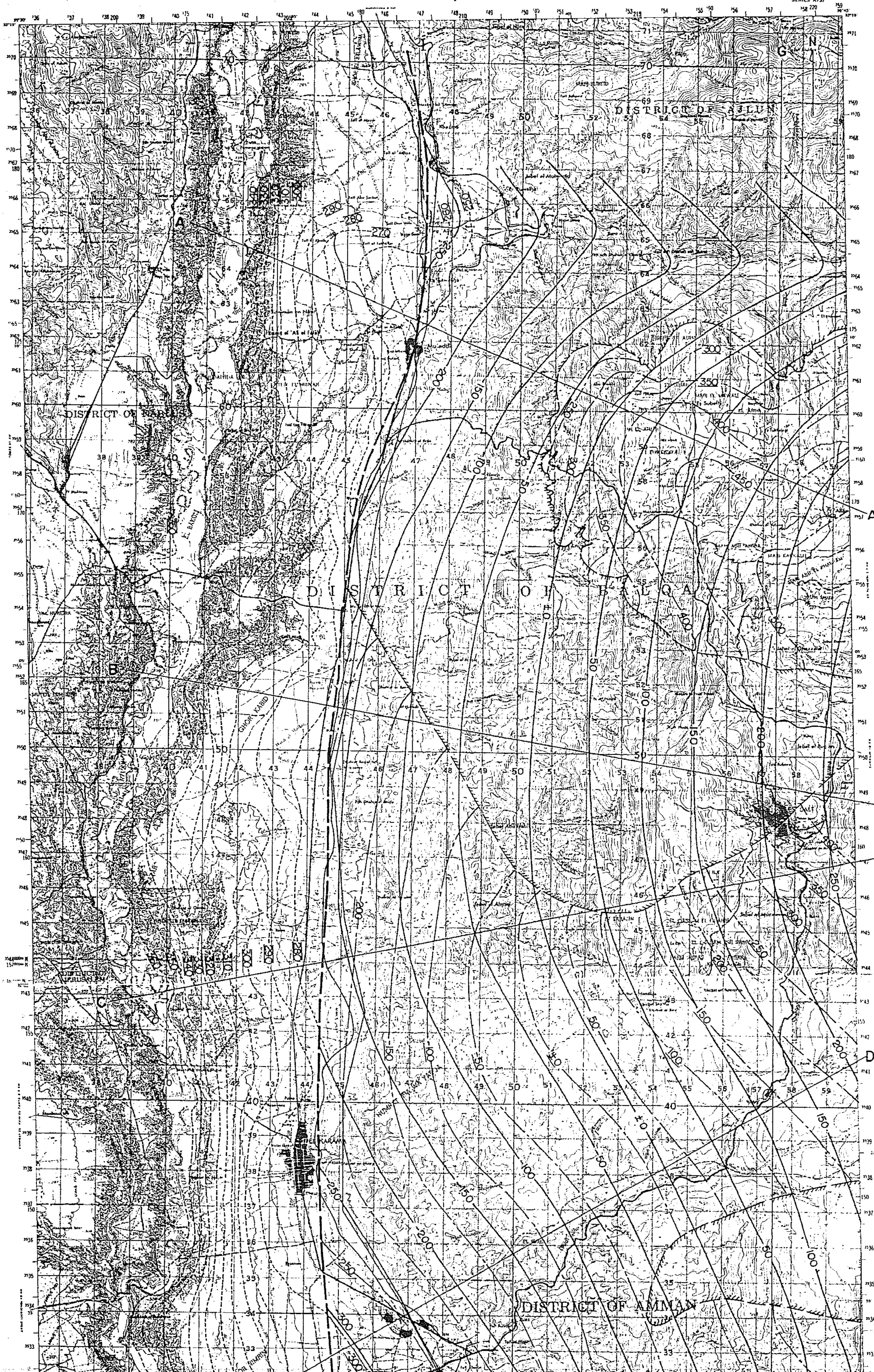

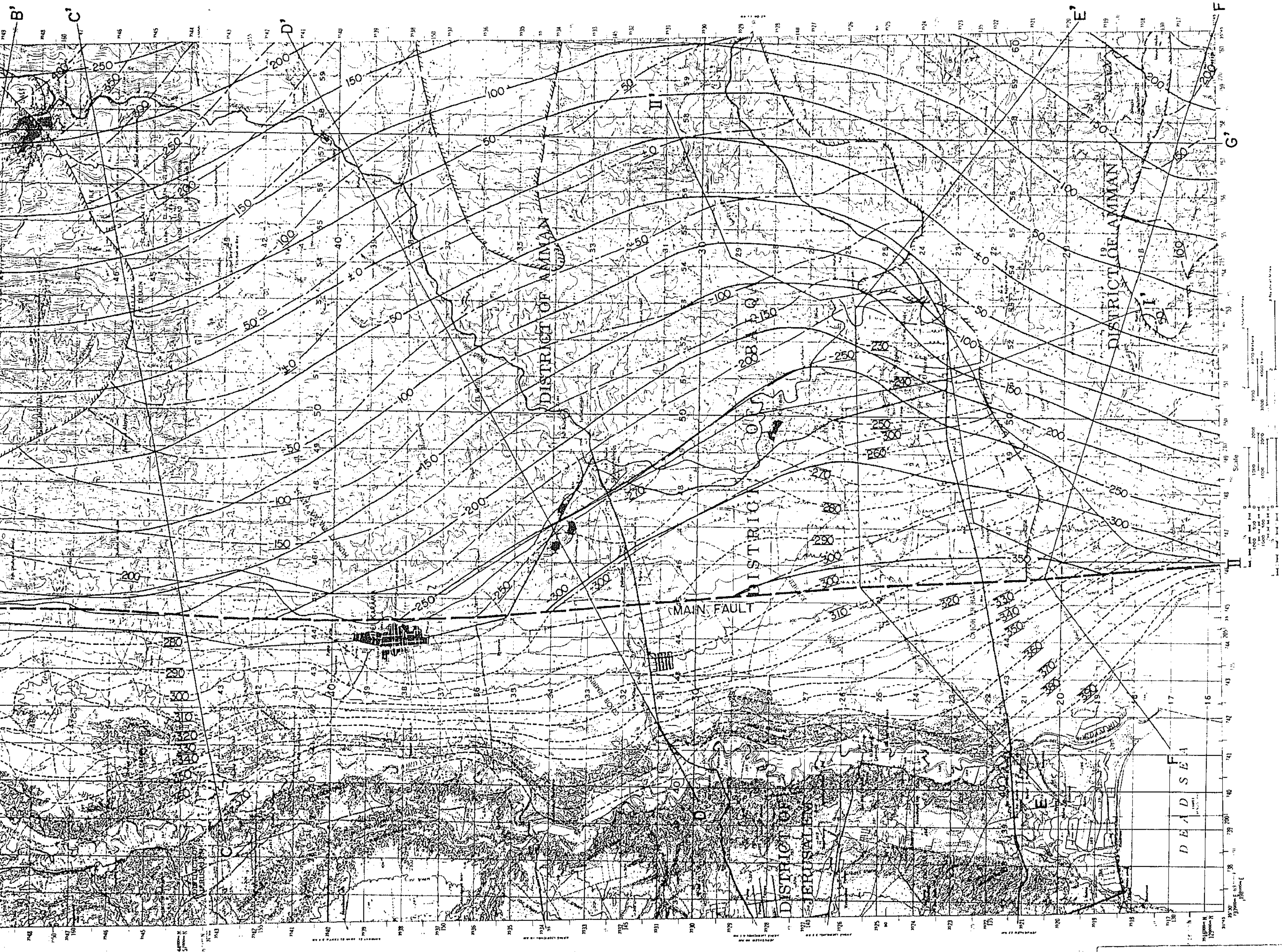

Fig. I-6.1.5 Piezometric Surface Contour Line

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- Piezometric Surface Contour Line of the Zarqa Group Aquifer
- Piezometric Surface Contour Line of the Kurnub Sandstone Aquifer
- Piezometric Surface Contour Line of the Jordan Valley Group

As shown in Fig. I-6.1.5, it is assumed that the piezometric surface of the Zerqa Group aquifer is almost parallel with the escarpment and the groundwater is flowing from highlands in the East toward the Jordan Valley in the West.

The average inclination of the piezometric surface of the Zerqa Group aquifer in the Study area is estimated to be around 3%.

Concavities in the piezometric surface can be found along the Zarqa River and in the Wadi Hisban and Wadi Kafrein area. The concavity along the Zarqa River is formed by the groundwater discharging from the Zerqa Group aquifer into the Zarqa River. It has been verified by the flow measurements conducted as part of the Study that the Zarqa River gains a recharge of 0.1 m^3/sec per kilometer from the Zerqa Group aquifer. For the concavity in the Wadi Hisban and Wadi Kafrein area, it is inferred that a high permeable zone such as faults or fractured zones might be formed along the syncline running in parallel with Wadi Kafrein as shown in Fig. I-6.1.3 and 6.1.4.

c. Kurnub Sandstone Aquifer

The piezometric surface contour line shown in Fig. I-6.1.5 was prepared on the basis of the existing well data and Well No. 3.

As shown in Fig. I-6.1.5, it is assumed that the piezometric surface of the Kurnub Sandstone aquifer is almost coincident with that of the Zerqa Group aquifer in the Southern part of the Study area. On the other hand, the piezometric surface of the Kurnub Sandstone aquifer is much higher than the Zerqa Group aquifer in the Northern part.

The groundwater of the Kurnub Sandstone aquifer also flows from the highlands toward the Jordan Valley and its average inclination is 3% to 4%.

It is inferred that the Kurnub Sandstone aquifer is in the water table condition except in the narrow strip at the foot of the escarpment.

d. Relation between the Zerqa Group Aquifer and the Kurnub Sandstone Aquifer

It is assumed that the unsaturated layer of the Zerqa Group is intercalated between two aquifers in the Northern highland part of the Study area (near Subeihi and Es Salt). Therefore, the draw-down of the Zerqa Group aquifer caused by the future brackish groundwater development will not affect the groundwater level of the Kurnub Sandstone aquifer in this part of the Study area (see Fig. I-6.1.6).

Along the foot of the escarpment and Southern boundary of the Study area, it is assumed that the piezometric potential of the Zerqa Group aquifer is higher than that of the Kurnub Sandstone aquifer. Upward leakage from the Zerqa Group to the Kurnub Sandstone takes place in these areas (see Fig. I-6.1.6). The salinity of the Kurnub Sandstone aquifer tends to increase in this area because of the leakage of brackish groundwater from the Zerqa Group aquifer. This phenomenon was clearly identified in Well No. 3 and Well No. 4. This mechanism can give the explanation for the general tendency of salinity to increase in the Kurnub Sandstone aquifer from East to West.

e. Relation between the Zerqa Group aquifer and the Ram Sandstone Aquifer

Although the limited data could be gained through the Study, it is assumed that the upward leakage (recharge) might take place from the Ram Sandstone aquifer to the Zerqa Group aquifer considering the great difference of the piezometric pressure and the similarity of the groundwater quality between two aquifers.

Further investigation, however, should be needed to verify this assumption.

f. Flowing Condition Area of the Zerqa Group Aquifer

It is assumed that the Zerqa Group aquifer is in the flowing condition along the narrow strip at the foot of the escarpment, along the Zerqa river and the downstream area of Wadi Kafrein/Hisban as shown in Fig. I-6.1.7. It is inferred that the Zerqa Group aquifer is not under the flowing condition in Karama and South Shuna area.

6.1.3 Fluctuation of Groundwater Level

Long-term groundwater level observation has been carried out on the observation wells tapped into the Sand/Gravel aquifer. Long-term groundwater level observation data is not available for the Kurnub Sandstone aquifer and the Zerqa Group aquifer. The location of the observation wells and the rain gauge station are shown in Fig. I-6.1.8 and the records are shown in Fig. I-6.1.9.

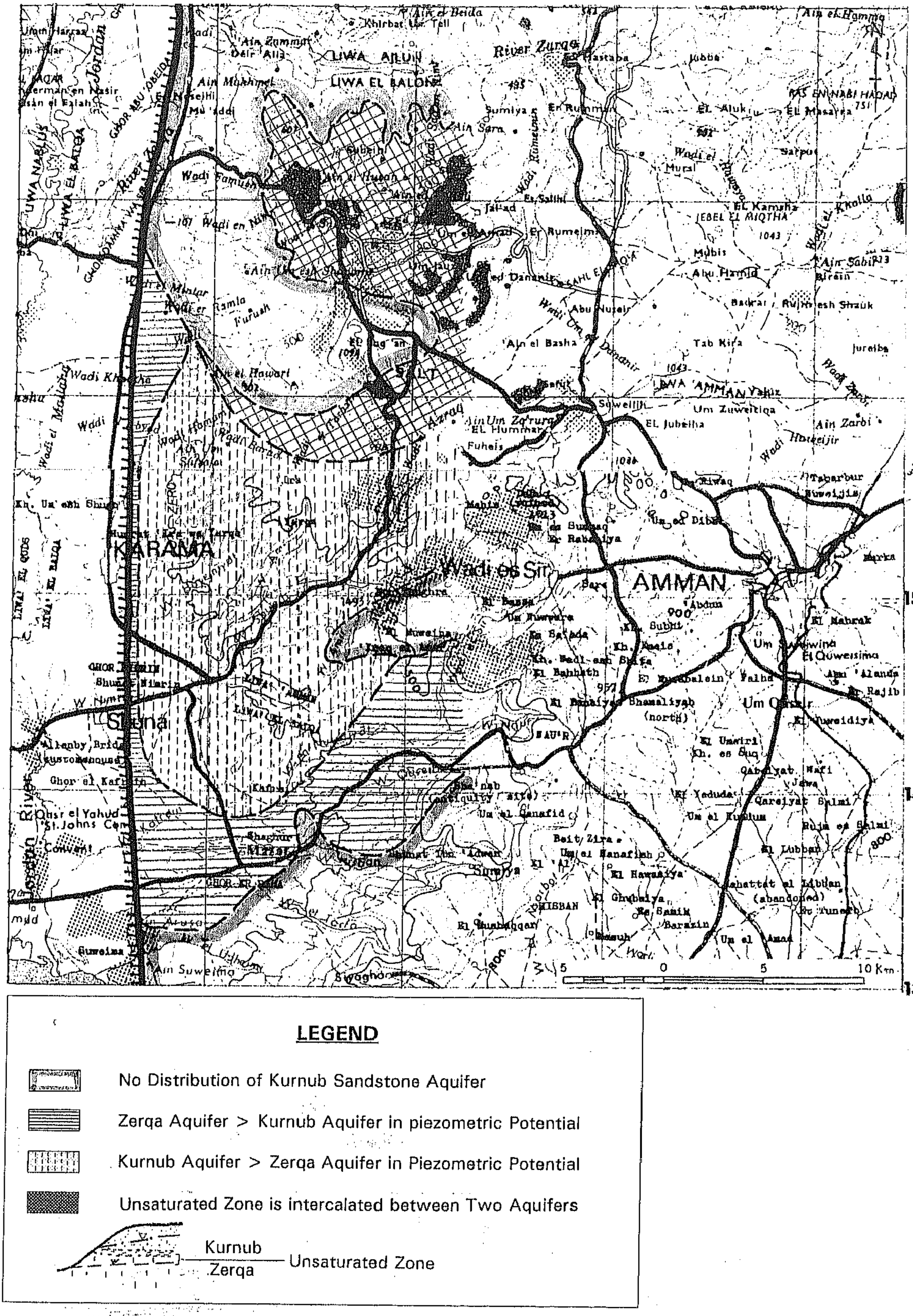
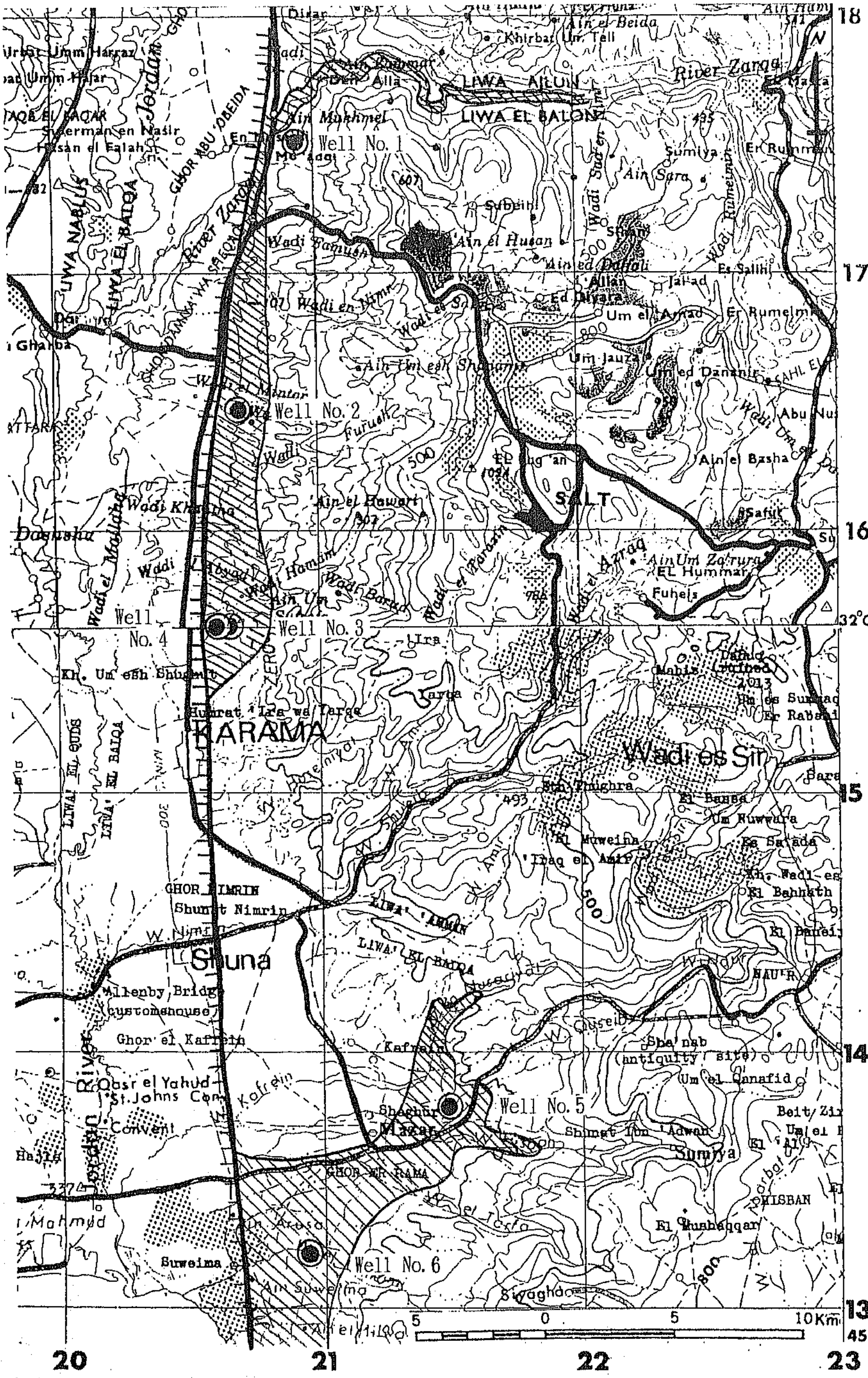


Fig. I-6.1.6 Schematic Drawing Showing the Relation between the Kurnub Sandstone Aquifer and the Zerqa Group Aquifer



Flowing Area of the Zerqa Group Aquifer

Fig. I-6.1.7 Assumed Area of the Zerqa Group Aquifer Under the Flowing Condition

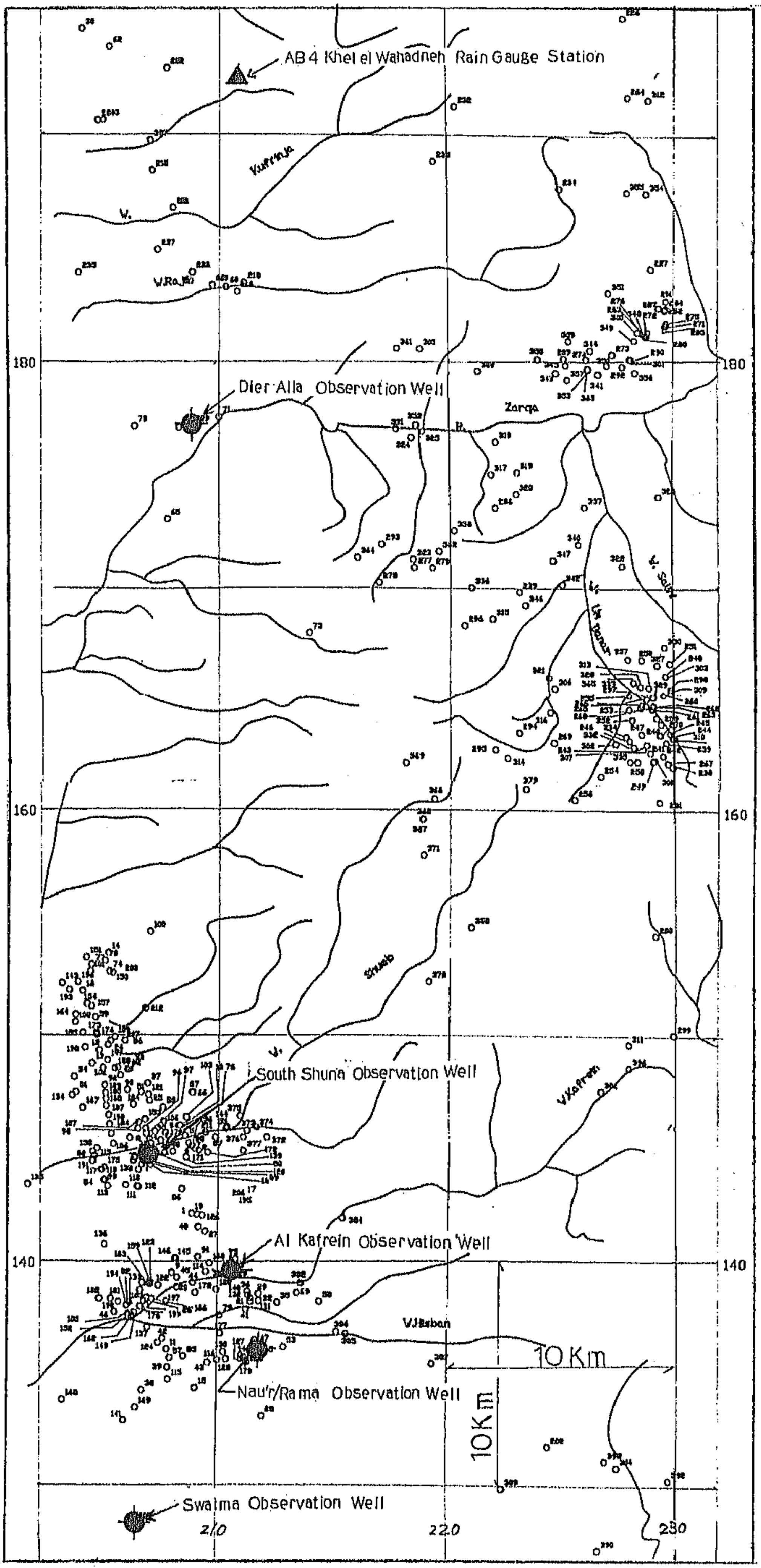


Fig. I-6.1.8 Location Map of Observation Well and Rain Gauge Station

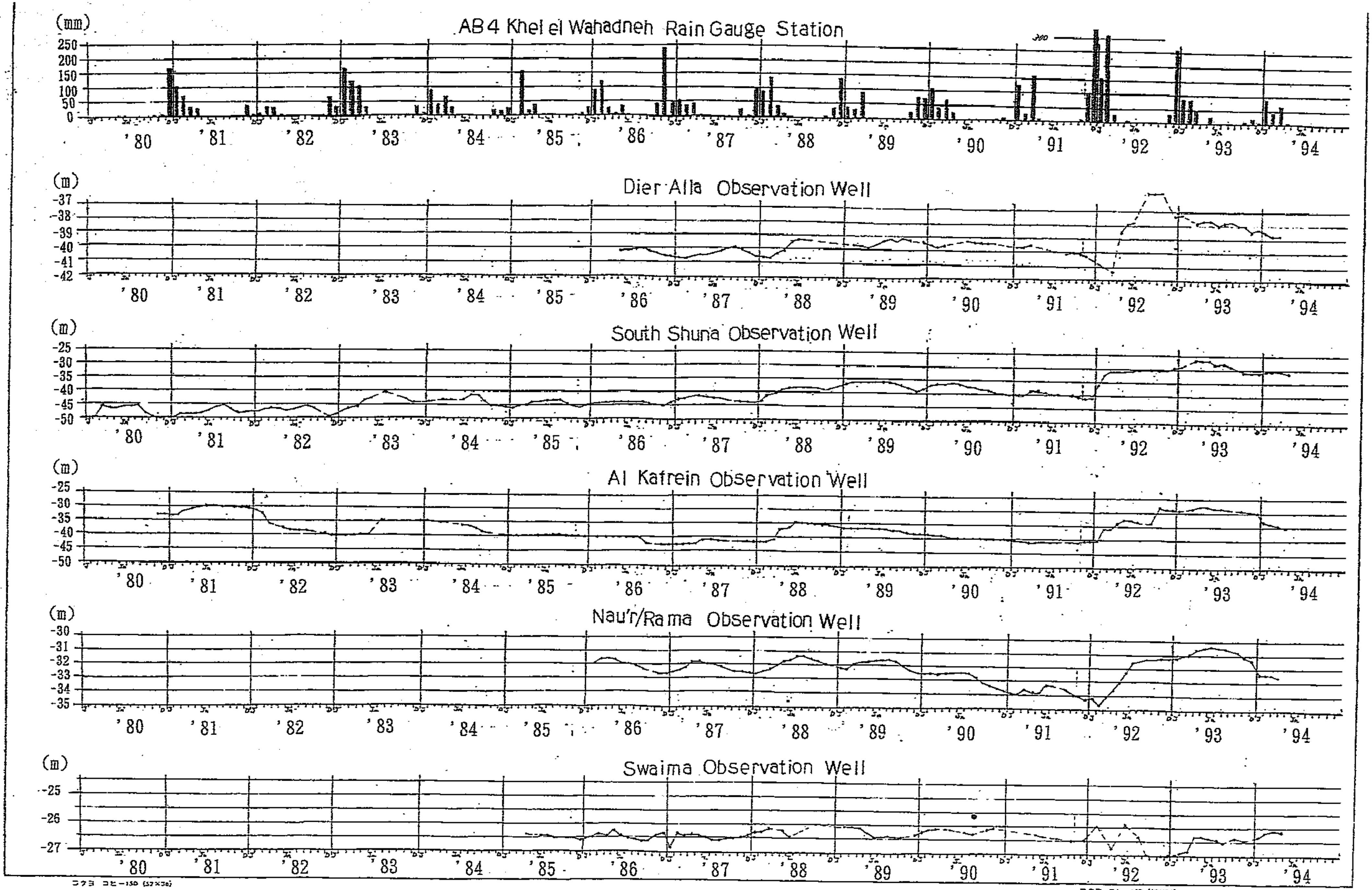


Fig. I-6.1.9 Correlation between Groundwater Level Fluctuation of Sand/Gravel Aquifer in Jordan Valley and Rainfall Record

Fig. I-6.1.9 shows the following characteristics of the groundwater level fluctuations in the Sand/Gravel aquifer.

i. The groundwater levels increase in the dry season (summer) and decrease in the wet season (winter).

ii. The high precipitation of 1991 to 1992 was reflected on the groundwater level fluctuation curves after 4 to 6 month later.

iii. A continuous increase of the groundwater level can be observed at the South Shunah observation well.

iv. Continuous decrease of the groundwater level can be observed at the Al Kafrein observation well.

The phenomena i and ii show that the Sand/Gravel aquifer does not receive direct recharge from the ground surface but receives lateral indirect recharge from other aquifers distributed in the escarpment.

For phenomenon iii, it is suggested that groundwater abstraction has greatly decreased since 1982 in the South Shuna area because the King Abdullah canal was extended to the area that this year.

For phenomenon iv, it is suggested that nine flowing wells were drilled from 1983 to 1984 in the Kafrein area and a large amount of groundwater has been discharged. The decrease of groundwater level started at the completion of these wells.

From the findings described above, it seems that the Sand/Gravel aquifer is hydraulically connected with the other aquifers in the escarpment through the Main Fault and it is further inferred that the brackish groundwater of the Zerqa Group aquifer may also flow into the Jordan Valley through the Main Fault.

One hundred thirty seven (137) wells were surveyed in the dry season (August 1994) and the wet season (January 1995).

Only eleven (11) wells were found suitable for groundwater level measuring through the well survey and groundwater level monitoring was carried out on the eleven (11) wells for eight (8) months. The well survey sheets and the groundwater level monitoring records are attached in Supporting Report.

According to the groundwater level monitoring results, the clear tendency of the groundwater level fluctuation as shown in Fig. I-6.1.9 could not be found because of the disturbance caused by the pumping and shortage of the monitoring period.

Automatic groundwater level recorder was installed at Well No. 1 and the groundwater level has been measured from January 1995. Measured data shows that any changes could not be found in the Zerqa Group aquifer during January to March 1995.

6.2 Hydrogeochemistry

6.2.1 Groundwater Salinity Distribution

An inferred iso-salinity contour map of the groundwater is shown in Fig. I-6.2.1.

(1) Ram Sandstone Aquifer

According to the drilling records of Well No. 5 and No. 6, the salinity of flowing groundwater did not change during the start of the small amount flowing from the Zerqa Group aquifer and after the start of the huge amount flowing from the Ram Sandstone aquifer. If the water quality including the salinity greatly differs among two aquifers, the salinity must change after the start of flowing from the Ram Sandstone aquifer. Therefore, it is inferred that the groundwater quality might not change greatly between the two aquifers.

The salinity of the Ram Sandstone aquifer groundwater is 5,000 mg/L to 5,200 mg/L in TDS according to the water quality analysis in Well No. 5 and No. 6. However, limited data could not show the actual groundwater salinity distribution of the Ram Sandstone aquifer.

(2) Zerqa Group Aquifer

A high salinity zone more than 9,000 mg/L TDS, is found in the middle of the Study area in which Well No. 2 and No. 4 were drilled in this area as shown in Fig. I-6.2.1. This high salinity zone is almost coincident with Area "B", (classified in the "Water Balance Analysis" in this report).

According to the groundwater simulation, the transmissibility of Area "B" is very much lower than the other areas. The groundwater seepage velocity may be assumed to be very low and to be stagnant in such an area. Accordingly, the groundwater salinity might increase in this area because the groundwater maintains contact with the strata which include minerals such as gypsum for a long time.

On the contrary, a low salinity zone around 5,000mg/L in TDS can be recognized between Wadi Kafrein/Hisban area and Wadi Shueib area as shown in Fig. I-6.2.1. This area is almost coincident with Area "C" (refer to "Water Balance Analysis" in this report).

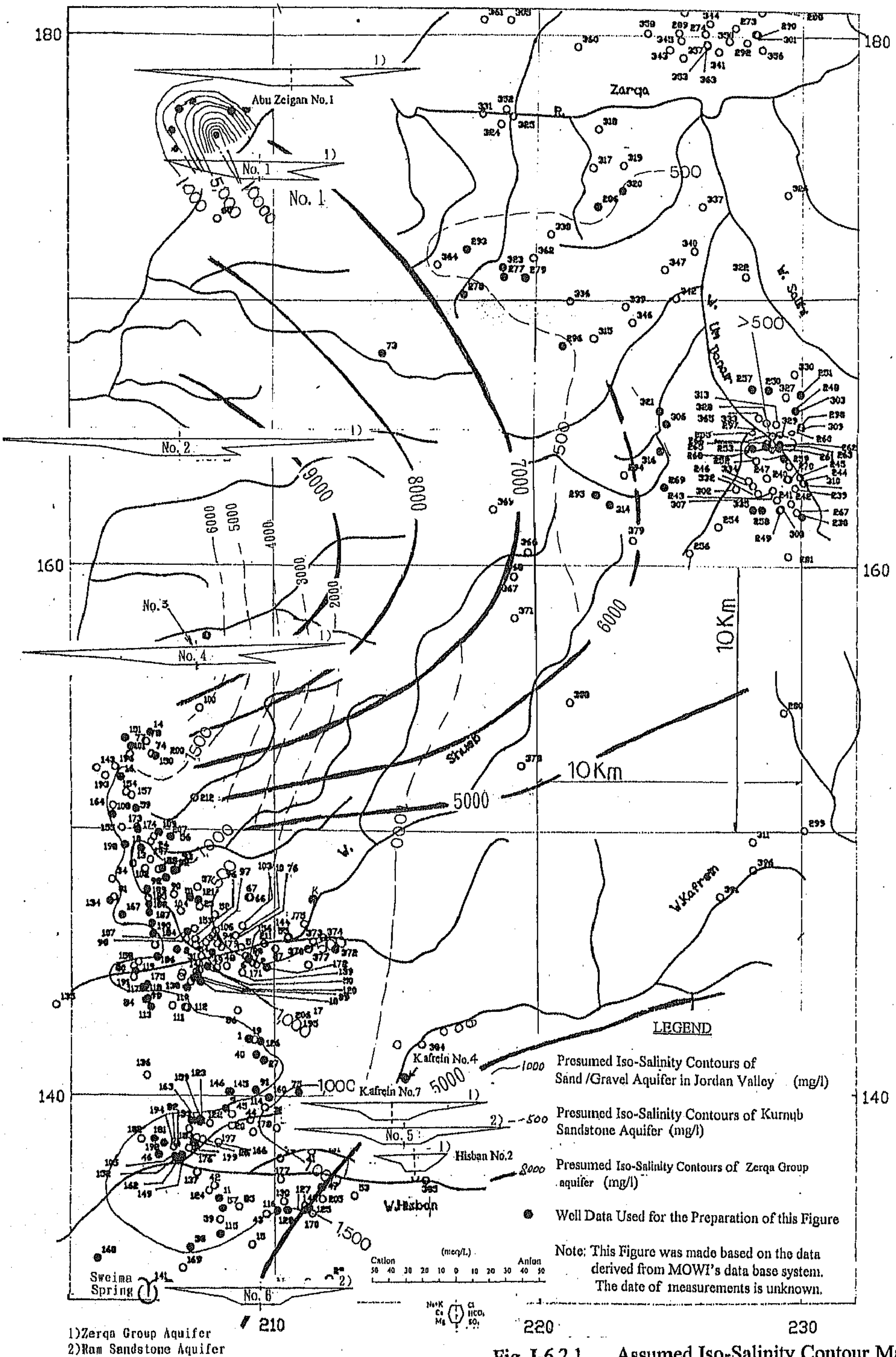


Fig. I-6.2.1 Assumed Iso-Salinity Contour Map

According to the hydrogeological analysis, it is inferred that a fault or fractured zone is running along Wadi Kafrein in WSW - ENE direction as shown in Fig. I-6.1.2 and 6.1.3. The groundwater selectively flows along this high permeable zone and contact time with the strata is much shorter. It is assumed that the salinity of the groundwater is reduced under such circumstances.

(3) Kurnub Sandstone Aquifer

Fig. I-6.2.1 shows that the groundwater salinity of the Kurnub sandstone aquifer tends to increase toward the West. The salinity is less than 500mg/L (TDS) in the upper part of the escarpment (highlands) and increases to 6,000 mg/L at the foot of the escarpment.

Two reasons can be considered for the explanation of this phenomenon;

- Interaction with rock matrix especially evaporite
- Upward leakage from the Zerqa Group aquifer at the highly faulted area in the foot of the escarpment

(4) Sand/Gravel Aquifer

According to Fig. I-6.2.1, salinity of the Sand/Gravel aquifer increases toward the East and low salinity zones appear along Wadi Kafrein and Wadi Shueib. From these findings, it is inferred that surface water seeps into the Sand/Gravel aquifer from the wadis.

At the right bank of the Zerqa river near Deir Alla, a high salinity spot named Mellaha area can be recognized in the Sand/Gravel aquifer and the groundwater table is also high (forming a groundwater mound). It is suggested that brackish groundwater originating from the brackish aquifer (Zerqa aquifer?) may be gushing into the Sand/Gravel in Mellaha area.

6.2.2 Hydrochemical Classification of the Aquifers

(1) Concentration of Major Constituents

The concentrations of major constituents of the groundwater are indicated in the hexadiagram shown in Fig. I-6.2.2. The concentration is calculated in meq/l (Mili-equivalent per litre unit). According to the hexadiagram, the chemical components of the groundwater of each aquifer can be characterized as follows:

1) Ram Sandstone Aquifer

As shown in Fig. I-6.2.2, same concentration pattern of major constituents is found between the Ram Sandstone aquifer and the Zerqa Group aquifer.

This finding shows the implication that the two aquifers hydraulically connected and the groundwater originated from same source.

2) Zerqa Group Aquifer

It is clear that the chemical composition of the Zerqa Group aquifer is different between the Northern ~ central part and the Southern part as shown in Fig. I-6.2.2. Namely, the Zerqa groundwater in the Northern ~ central part can be characterized as relatively high salinity with a preponderance of sulfate ion which shows as an arrow shape in the hexadiagram. On the other hand, the Zerqa groundwater in the Southern part can be characterized as relatively low salinity with a small content of sulfate ion which shows as a dish shape in the hexadiagram.

This finding suggests that the groundwater flow system and recharge system may differ from the Northern ~ central part to the Southern part. This suggestion will reinforce the groundwater flow system which has been inferred in Section 6.2.1 Groundwater Salinity.

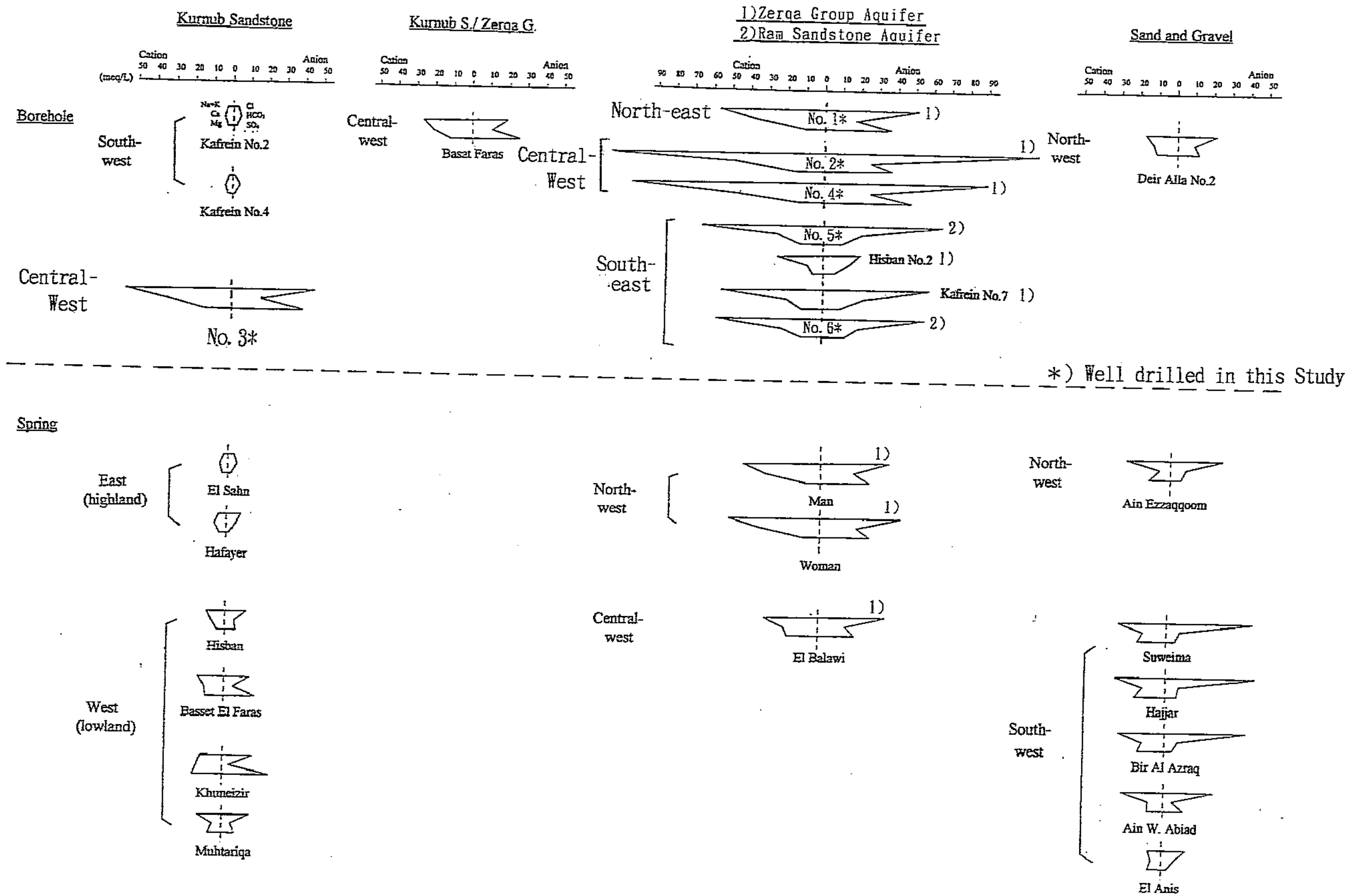


Fig. I-6.2.2 Major Constituents Hexadiagram of Groundwater and Spring Water

3) Kurnub Sandstone Aquifer

The groundwater of the Kurnub Sandstone aquifer shows low salinity in the highland area with a hexagonal shape. The salinity of the Kurnub Sandstone aquifer abruptly increases at the foot of the escarpment and its chemical composition becomes similar to that of the Zerqa Group aquifer.

As shown in Fig. I-6.2.2, it is inferred that the increase in the salinity of the Kurnub Sandstone aquifer at this point is caused by the upward leakage from the Zerqa Group aquifer which takes place through the aquitard (Marly Layer) at the foot of the escarpment.

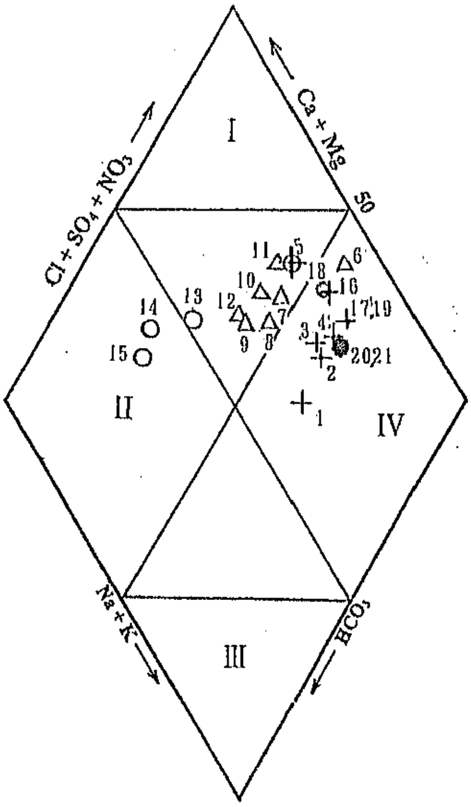
4) Sand/Gravel Aquifer

The chemical composition of the Sand/Gravel aquifer can be characterized as intermediate to high salinity with a preponderance of Na, Cl and Mg ion contents which shows as an irregular glass shape in the hexadiagram. It is supposed that the irregular shape of the hexadiagram is caused by a mixture of water which is recharged from many type of sources such as surface water, Kurnub Sandstone aquifer, Zerqa Group aquifer and so on.

(2) Major constituents Ratio

The major constituents ratios of the groundwater from the wells are plotted on the Piper Diagram shown in Fig. I-6.2.3.

● : Ram Sandstone aquifer
+ : Zerqa aquifer
⊕ : Mixture of Zerqa and Kurnub
△ : Sand / gravel aquifer
○ : Kurnub Sandstone aquifer



No.	Sampling site	TDS(mg/L)
1	Kafrein No. 6	2,623
2	Kafrein No.7	5,508
3	Hisban No.2	4,055
4	Abu Zeigan No. 1	8,707
5	Bassat el Faras	3,778
6	Deir Alla No. 7*	3,136
7	Deir Alla No.6*	844
8	Abu Zeigan No.3*	2,240
9	Deir Alla No.4*	864
10	Sakna No.3*	1,248
11	Deir Alla No.2	2,765
12	Sakna No.2*	876
13	Kafrein No.4	542
14	Kafrein No.2	431
15	Kafrein No.3*	416
16	Well No. 1	7,262
17	Well No. 2	9,724
18	Well No. 3	6,244
19	Well No. 4	9,562
20	Well No. 5	5,204
21	Well No. 6	5,082

* existing data

Fig. I-6.2.3 Piper Diagram of the Groundwater Quality of the Wells.

This Piper diagram shows that the groundwater quality of the Zerqa Group aquifer is classified as Na + K, Cl type, the Kurnub Sandstone aquifer is classified as Ca + Mg, HCO3 type and the Sand/Gravel aquifer is classified as an intermediate type between them. In addition to this, the salinity continuously decreases from the right domain to the left domain in the diagram.

In general aspects, the Piper Diagram can be divided into four domains (I to IV) as shown in Fig. I-6.2.3 and the representative kinds of water of each domain are as follows:

I : Hot spring.

II : Rainwater, Surface water, shallow groundwater (unconfined)

III : Confined deep groundwater.

IV : Hot spring, Confined deep groundwater accompanied with oil.

As for the groundwater quality of the Kurnub Sandstone aquifer, Ca and Mg represent more than 70% of the total cations, while HCO3 represents more than 55% of the total anions. This water type resembles precipitation water chemistry. On the other hand, the groundwater of the Zerqa Group aquifer is classified as hot spring or old confined groundwater. It can be assumed that the groundwater of the Sand/Gravel aquifer and Kurnub Sandstone aquifer at the foot of the escarpment may originate from the mixture of the Zerqa water and the Kurnub water because of the smooth water quality transition as shown below.

Ca+Mg, HCO3 Type	Intermediate Type	Na+K, Cl Type
Kurnub Sandstone Aquifer (high land)	Sand / Gravel Aquifer, Kurnub Sandstone Aquifer (foot of the escarpment)	Zerqa Group Aquifer

Low ——————————————————————→ High

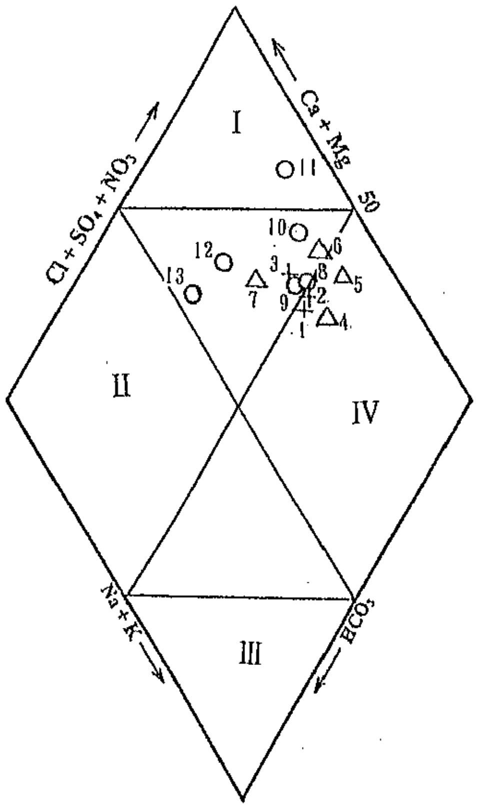
Increase of Salinity

Groundwater of the Ram Sandstone aquifer has almost same major constituents ratio with the Zerqa Group groundwater as shown in Fig. I-6.2.3.

This finding also reinforces the assumption that the two aquifers hydraulically connected and the groundwater originated from same source.

As shown in Fig.6.2.4, the aquifer to aquifer transition of the main ion component is not so clear as observed in the groundwater from the wells. A possible reason is that the groundwater from multiple aquifers might be rising and mixing at the spring points.

The same tendency can be identified in the spring water quality as shown in Fig. I-6.2.4.



┼ "Spring in Zarqa Group

△ "Spring in Jordan Valley Group (sand/gravel aquifer)

○ "Spring in Kurnub Sandstone

No.	Spring name	TDS
1	Man(Zarqa r.)	5.028
2	Woman(Zarqa r.)	5.037
3	El Balawi	4.453
4	Ain Essaggoom	2.617
5	Ain W. Abiad	2.654
6	Suweima	3.744
7	El Anis	1.438
8	Muhtraiga	1.804
9	Hisban	1.398
10	Bassat el Faras	2.365
11	Khumeizir	3.006
12	Hafayer	965
13	El Sahn	620

Fig.6.2.4 Piper Diagram of the Spring Water Quality

6.2.3 Environmental Isotope Analysis

Environmental isotope analysis results are attached in Supporting Report.

(1) Radioactive Isotope Analysis

Carbon-13 and Carbon-14 analysis were carried out in the Study in order to determine the age of the ground water. The results are summarized in Table I-6.2.1. Sampling points are shown in Fig. I-6.2.1.

As shown in Table I-6.2.1, the age of Kurnub water ranges BP 6,200 years to BP 7,200 years and the age of Zerqa and Ram water ranges BP 1,500 years to BP 22,000 years except Abu Zeigan Well No. 1. The spring water is determined as very young replenishable water from surface water.

Table I-6.2.1 Groundwater Dating Results

Well/Spring Name	Aquifer	Corrected Carbon-14 Ages (years), BP	Error (years)
Kafrein Well No. 4	Kurnub	6,197	2,325
Test Well No. 3	Kurnub	7,211	3,039
Abu Zeigan Well No. 1	Z	7,288	8,172
Hisban Well No. 2	Z	14,841	5,623
Test Well No. 1	Z	18,163	Minimum
Test Well No. 2	Z	17,396	8,150
Test Well No. 4	Z	22,035	7,216
Test Well No. 5	Ram	17,267	6,174
Test Well No. 6	Ram	16,221	5,917
Sweima Spring	Q	279	2,730

Kurnub : Kurnub Sandstone aquifer
Z : Zerqa Group aquifer
Ram : Ram Sandstone aquifer
Q : Sand/Gravel aquifer
BP : Before Present

As mentioned above, the distinctive difference of age is shown between the Kurnub water and the Zerqa water and it is concluded that the Zerqa water is very old water. For Abu Zeigan Well No. 1, mixture with young water such as surface water or Kurnub water might take place.

Tritium analysis was also conducted in order to see the recharge from the upper aquifer during the long term pumping test of Well No. 4. Tritium could not be detected at the start and the end of the pumping test. This result suggests that the young replenishable water did not flow into (recharge) the Zerqa Group aquifer during the long term discharging test.

Based on the results of Carbon-14, Carbon-13 analysis and tritium analysis, it can be concluded that the groundwater of Zerqa Group aquifer is very old and receives very few recharge from replenishable water if any. It should be also noted that the age of Zerqa water and Ram water is almost same. This finding suggests that the groundwater origin of both aquifers might be same.

(2) Stable Isotope Analysis

Stable isotope analysis of Oxygen-18 and Deuterium was carried out in order to see the origin of the Zerqa Group aquifer and Ram Sandstone aquifer groundwater.

Analysis results were plotted Oxygen-18 vs. Deutrium regression curve in Fig. I-6.2.5.

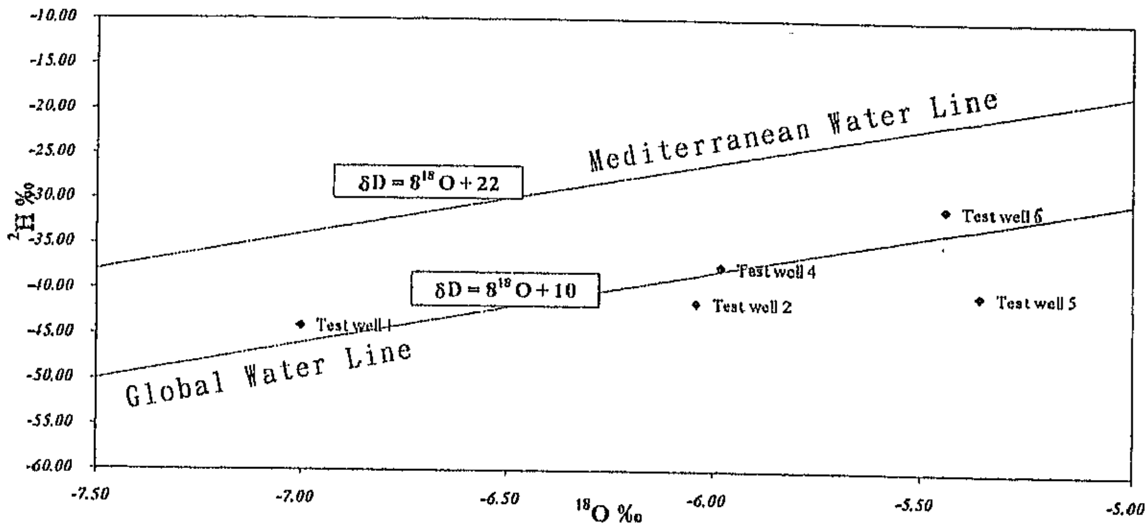


Fig. I-6.2.5 Oxygen-18 vs. Deutrium Regression Curve

As shown in Fig. I-6.2.5, the ground water of the Zerqa Group aquifer and Ram Sandstone aquifer can be plotted on the Global Water Line. Global Water Line shows average relationship of Oxygen-18 vs. Deutrium of surface water all over the world. On the other hand, Mediterranean Water Line shows average relationship in the dry mediterranean area. Mediterranean Water Line deviates high Deutrium area from Global Water Line due to the evaporation process and recent replenishable water can be normally plotted on the Mediterranean Water Line in Jordan. On the contrary, it is reported that old ground water is plotted on the Global Water Line on many cases in Jordan. The reasons of this phenomena is explained by the paleoclimatological study. That is, the mediterranean area including Jordan was humid at the latest glacier age (Würm glacier age, around 20,000 years ago) and the relationship between Oxygen-18 and Deutrium is assumed same as worldwide average. Therefore, it is inferred that the ground water plotted on Global Water Line might be recharged in this humid age.

This finding also strongly reinforce the assumption that the Zerqa and Ram water is very old and originated from same source.

6.3 Hydrogeological Model

(1) Schematic Hydrogeological Cross Section

Fig. I-6.3.1 shows the schematic hydrogeological cross section of the Study area. As shown in this figure, lateral inflow into the Zerqa Group aquifer from the highlands (Q) finally enters the Jordan River because the Jordan River flows along the deep rift valley and any water cannot flow beyond the Jordan River. Hydraulic connection with the Ram Sandstone aquifer will not be considered in the Study because the thick shale layers are intercalated at the bottom of the Zerqa Group according to the well log at Hisban No. 1.

(2) Hydrogeological Model

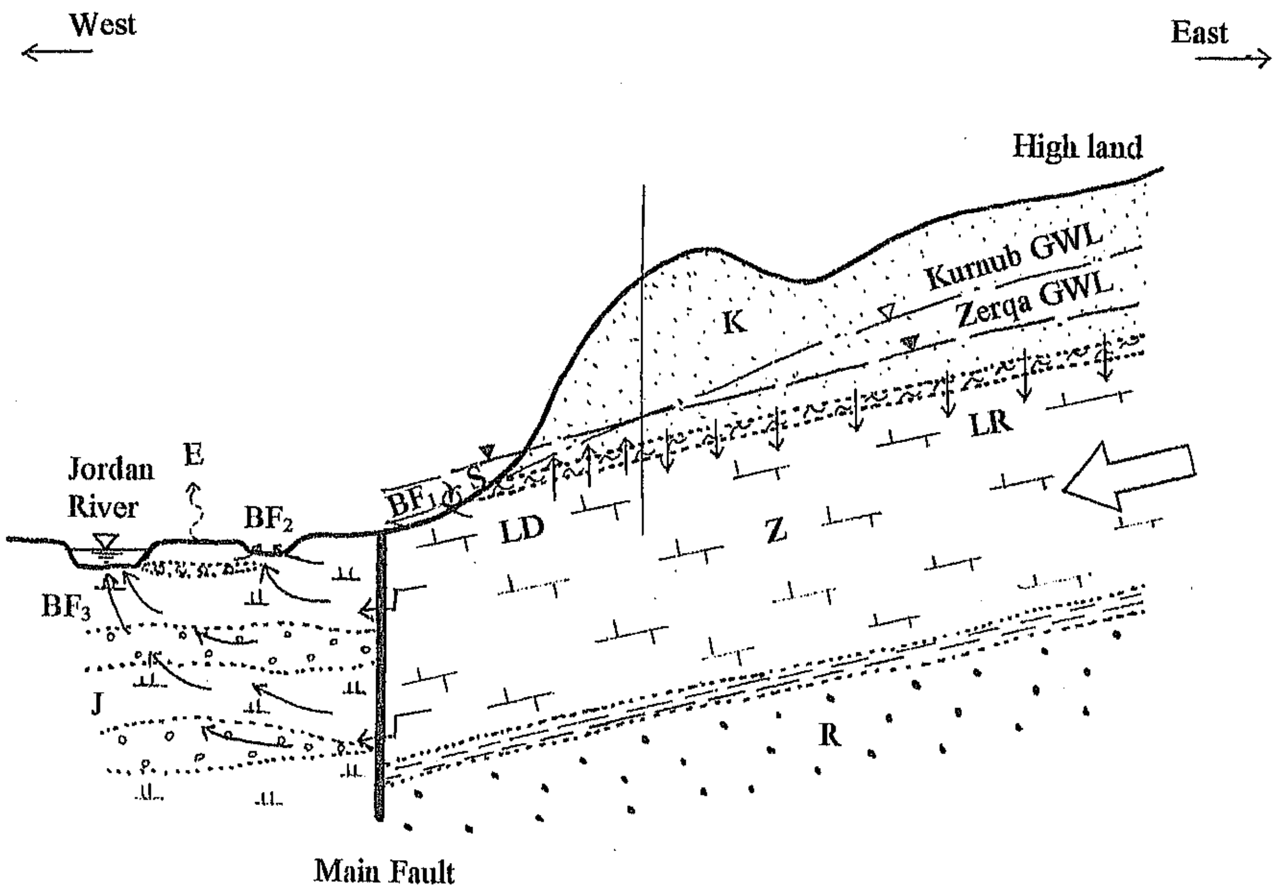
According to the schematic hydrogeological cross section mentioned above, inclined two-cylindrical-layer model plugged with the low permeability layer at the end can be adapted fro the hydrogeological model as shown in Fig. I-6.3.2.

In this model two layers connected each other through the Marly Layer (aquitard). All the groundwater which seeped to the plug layer (Jordan Valley Group) finally discharged to the Jordan River. The modeling of the groundwater simulation will be discussed in Chapter 7 based on the basic concept of the hydrogeological model mentioned above.

(3) Recharge System

As discussed in Section 6.2.3, the Zerqa Group aquifer groundwater is very old and very few water recharges the aquifer if any. Therefore, the recharge to the Zerqa Group aquifer from surface is negligible in the hydrogeological model.

However, one question arose that the groundwater table must be flat and the groundwater must be stagnant if the aquifer did not receive any recharge. The Zerqa Group aquifer, in fact, has relatively steep piezometric inclination (around 3%) and flows toward Jordan valley. The hydrogeological structure development may give answer for this question as described next.



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J : Jordan Valley Group
M : Marly Layer (Aquitard)
Z : Zerqa Aquifer
S : Shale Layer (Aquitard)
R : Rum Sandstone Aquifer

$$Q + LR - LD = S + BF_1 + BF_2 + BF_3 + E$$

Q : Lateral Inflow from eastward
LR : Leakage Recharge from Kurnub Sandstone
LD : Leakage Discharge to Kurnub Sandstone
S : Spring Outflow
BF_1 : Baseflow Discharge 1
-Zerqa River (Upstream)
-Wadi Hisban
BF_2 : Baseflow Discharge 2
-Zerqa River (Downstream)
-Wadi Melaha
BF_3 : Baseflow Discharge 3
-Jordan River
E : Evaporation from Salt Pan or Pond

Fig. I-6.3.1 Schematic Hydrogeological Cross Section of the Study Area

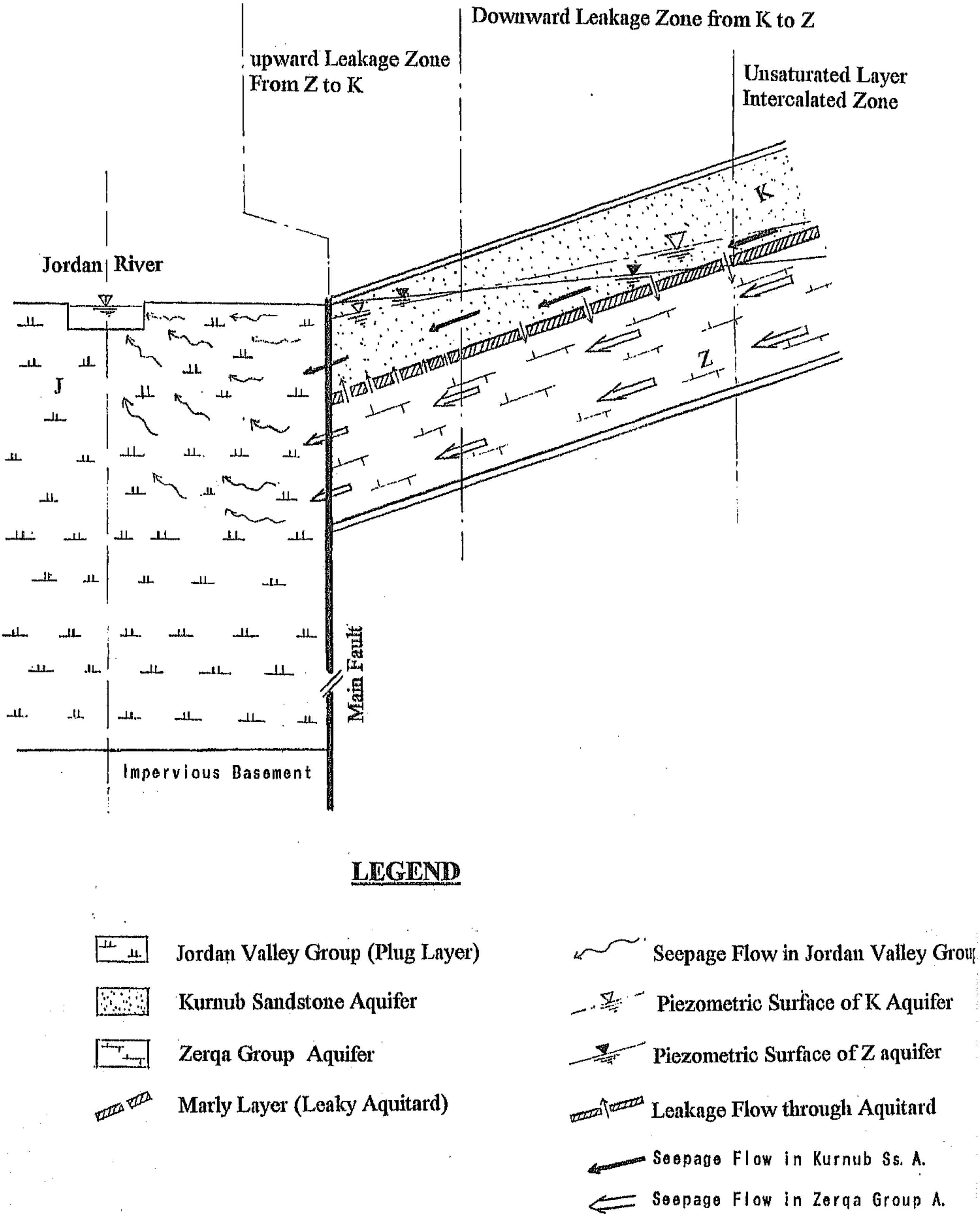

Fig. I-6.3.2 Schematic Hydrogeological Model of the Study Area

It is commonly know that Jordan valley is one of the most active mobile belt in the world. The highland (eastern flank of the Jordan valley) is still uplifting and the strata is inclining toward the valley. It is supposed that the groundwater gradient has been changed through the geological age in accordance with the inclination of the aquifers themselves. If the aquifers incline, the groundwater starts flowing without recharge. So, it is inferred that the old Zerqa groundwater is flowing without recharge due to the inclination of the aquifer caused by the uplifting of the graben side. Although the Zerqa Group aquifer cannot be regarded as replenishable, it is believed that the flow amount in the Zerqa Group aquifer toward the Jordan valley will not change within hundreds years taking the geological time scale into consideration.

(4) Recharge from Ram Sandstone Aquifer

As discussed in Chapter 6.1.2, it is assumed that the upward leakage (recharge) might take place from the Ram Sandstone aquifer to the Zerqa Group aquifer. However, the data concerning the Ram Sandstone aquifer is too limited to evaluate the actual leakage amount to the Zerqa Group aquifer.

Accordingly, the recharge, from Ram to Zerqa was not taken into consideration in the hydrogeological model.

References used in the Hydrogeological Analysis

Reports

1. Hand book of the Geology of Jordan, 1959.
2. Investigation of the Sandstone Aquifers of East Jordan, 1970.
3. Geology of Jordan, 1974.
4. National Water Master Plan to Jordan, 1977.
5. Monitoring and Evaluation of the Amman-Zerqa Aquifers, 1983.
6. Water Resources Strategy, North Jordan, 1988.
7. Water Resources Policies Planning and Management, Report on Brackish Groundwater Resources in Jordan, 1991.
8. Water Pollution in Jordan, Cause and Effects, 1991.
9. Groundwater Resources of the Deep Aquifer Systems in NW-Jordan: Hydrogeological and Hydrogeochemical quasi 3-Dimensional Modeling, 1991.
10. Groundwater Investigation in the Hammand and Sirhan Basins, 1992.
11. Water Resources of Jordan Present Status and Future Potentials, 1993.
12. Evaluation of the Groundwater Potential of the Zerqa Aquifer in Lower Wadi Hisban - Jordan Valley, 1984.
13. Hydrogeological Study of the Zerqa Aquifer for the Wadi Hisban Fish Farm Feasibility Study, 1985.

Geological maps

14. 1/250,000 Geological map of Jordan, 1954, 3 sheets.
15. 1/250,000 Geological map of Jordan, 1986, 5 sheets.
16. 1/10,000 Geological map, 2 sheets.
17. 1/25,000 Geological map, 12 sheets.

Aerialphoto

18. 1/30,000 Aerial photos, 171 copies.

<u>Well Drilling Record</u>	19.	Hisban No. 1, Hisban No. 2, Rawda No. 1, Rawda No. 2, Rawda No. 3, Wadi Shueib No. 1, Bassat el Faras, Kafrein No. 1, Kafrein No. 2, Kafrein No. 3, Kafrein No. 4, Kafrein No. 5, Kafrein No. 6, Kafrein No. 7, Kafrein No. 8, Kafrein No. 9, Kafrein No. 10, Sakna No. 1, Sakna No. 2, Sakna No. 3, Karamah JRV-9, Karamah g-b, Abu Zeigan No. 2, Abu Zeigan No. 3, Deir Alla No. 1, Deir Alla No. 2, Deir Alla No. 4, Deir Alla No. 7-A, Deir Alla No. 7-B Total 29 Wells
<u>Inventory Data</u>	20.	396 Existing well data
	21.	Existing well location map
	22.	248 spring coordination and altitude data
	23.	Spring location map