7. Groundwater Simulation

7.1 Objectives of Groundwater Simulation

The objectives of the groundwater simulation in the Second Investigation in Jordan are as follows:

a. Establishment of a Simulation Model through the Reappearance Simulation of the Present Condition Based on the Hydrogeological Model and Water Balance Calculation Results.

b. Re-assessment of the Groundwater Flow Amount of the Zerqa Group aquifer in the Study Area through the Reappearance Simulation.

c. Evaluation of the Maximum Brackish Groundwater Potential, i.e. Total Flow Amount of Brackish Groundwater of the Zerqa Group Aquifer in the Study Area.

d. Simulation of Future Groundwater Status (drawdown) Based on the Tentative Alternatives of Brackish Groundwater Development.

e. Preliminary Evaluation of Brackish Groundwater Potential Based on the results of "d".

f. Groundwater Quality Change

7.2 Work Procedure and Simulation Program

(1) Work Procedure

The procedure of the groundwater simulation is described as follows:

Step 1 : Modeling for Simulation

- Establishment of Grid System
- Input of Elevation Data of the Strata (aquifer and aquitard)
- Set-up the Boundary Condition (head constant, flow constant)
- Input of Recharge Flow into the Aquifers
- Input of the Initial Groundwater Table (Piezometric Potential)
- Input of the Initial Hydraulic Parameters (Hydraulic Conductance, Leakage Factor, Storage Coefficient)

Step 2 : Reappearance Simulation of Present Condition

- Reappearance of the Present Groundwater Table (Piezometric Surface)
- Re-assessment of the Present Brackish Groundwater Flow Amount
- Evaluation of the Maximum Brackish Groundwater Potential through the Re-assessment Mentioned above

Step 3 : Simulation of Future Groundwater Status

- Establishment of the Tentative Brackish Groundwater Development Alternatives (Location, Development Amount, Development Stage, etc.)
- Drawdown Influence Evaluation of Each Alternative (both Zerqa aquifer and Kurnub aquifer)

Step 4 : Evaluation of the Brackish Groundwater Potential

- Evaluation of the Safe and Maximum Brackish Groundwater Development Amount Based on the Results of Step 3

Flow of the Simulation work is also shown in Fig. I-7.2.1 as a flow chart.

SIMULATION FLOW

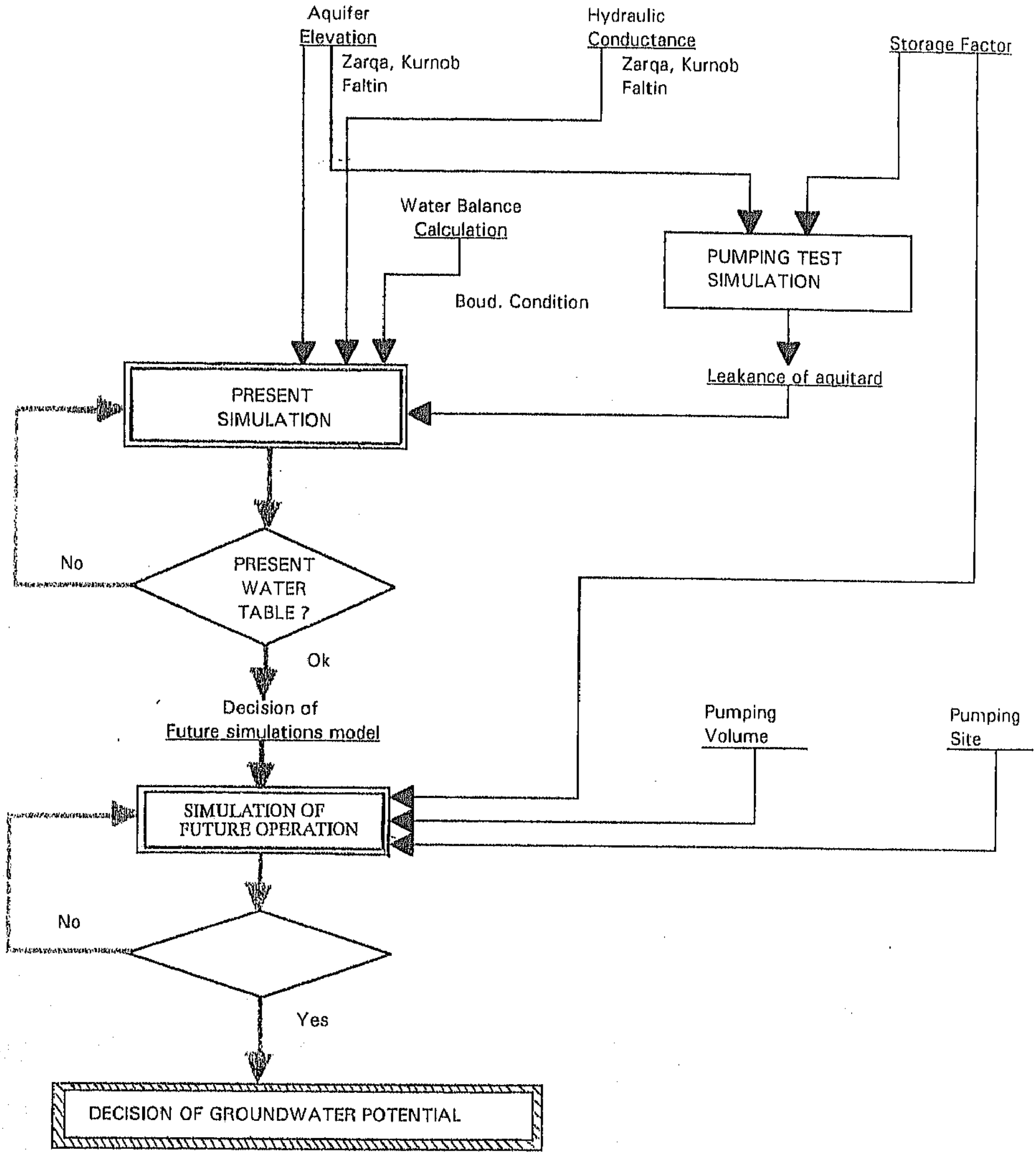


Fig. I-7.2.1 Flow Chart of the Simulation Work

(2) Selection of Simulation Program

Many groundwater simulation programs have been studied and published and they can be classified as shown in Table I-7.2.1.

Table I-7.2.1 Classification of the Simulation Program

Program Classification	Characteristics	Field of Application
Plain Two-Dimensional Program	- To analyze wide-area groundwater seepage in plain model - Easy for data processing - Not to be used for multiple layer models	Used for many fields treating wide-area groundwater seepage
Sectional Two-Dimensional Program	- To analyze the groundwater seepage in a sectional model - Relatively easy for data processing - Not to be applied for the wide-area groundwater seepage model	Used for seepage analysis on dam, embankment, etc.
Quasi-three-Dimensional Program	- To analyze the groundwater seepage in a quasi-three-dimensional model - Relatively easy for data processing - To be applied for multi layer model considering the vertical hydraulic connection	Used for many fields treating wide-area groundwater seepage
Three Dimensional Program	- To analyze the groundwater seepage in a complete three-dimensional model - Can be used for every case of model - Much data needed for modelling - Difficult for data processing - Long time needed for calculation	Used for limited fields, such as scientific study, atomic power plant site, etc. Not to be applied for practical engineering field

Based on Table I-7.2.1, it is judged that the most suitable program for the Study is the quasi-three-dimensional program, because the wide-area groundwater seepage will have to be examined for the evaluation of the brackish groundwater potential in the Study Area.

The MODFLOW program which can analyze vertical seepage flow has been selected for the Study from the many available quasi-three-dimensional programs because the seepage flow between the Zerqa Group aquifer and the Kurnub Sandstone aquifer cannot be neglected for the evaluation of the brackish groundwater potential.

MODFLOW was developed by McDonald and Harbaugh in 1988 and has been applied in various fields treating groundwater seepage around the world.

7.3 Modelling for Simulation

(1) Simulation Model

The simulation model has been established as shown in Fig. I-7.3.1 based on the hydrogeological model which was discussed in Chapter 6.

The simulation model consists of two layers of aquifer (Zerqa and Kurnub) with intercalation of an aquitard (marly layer). The Kurnub Sandstone aquifer is lacking in both the Southern and Northern parts of the Study Area along the Main Fault because of erosion.

The Jordan Valley Group in the west of the Main Fault is regarded as a homogeneous single layer in this model.

(2) Grid Model

As the MODFLOW program is based on differential equations, the grid system should be rectangular.

The grid system for the simulation has been formulated in N-S and E-W directions because the groundwater flows from East to West. In the Study area, a grid spacing of 0.5 km to 1.0 km has been used and is considered to be sufficiently accurate for the simulation.

On the East side and South side out of the Study area, a supplementary groundwater simulation has been done to grasp the extent of drawdown influence as show in Fig. I-7.3.2. The grid spacing used in these areas is 1 km in N-S direction, 2 km in E-W direction.

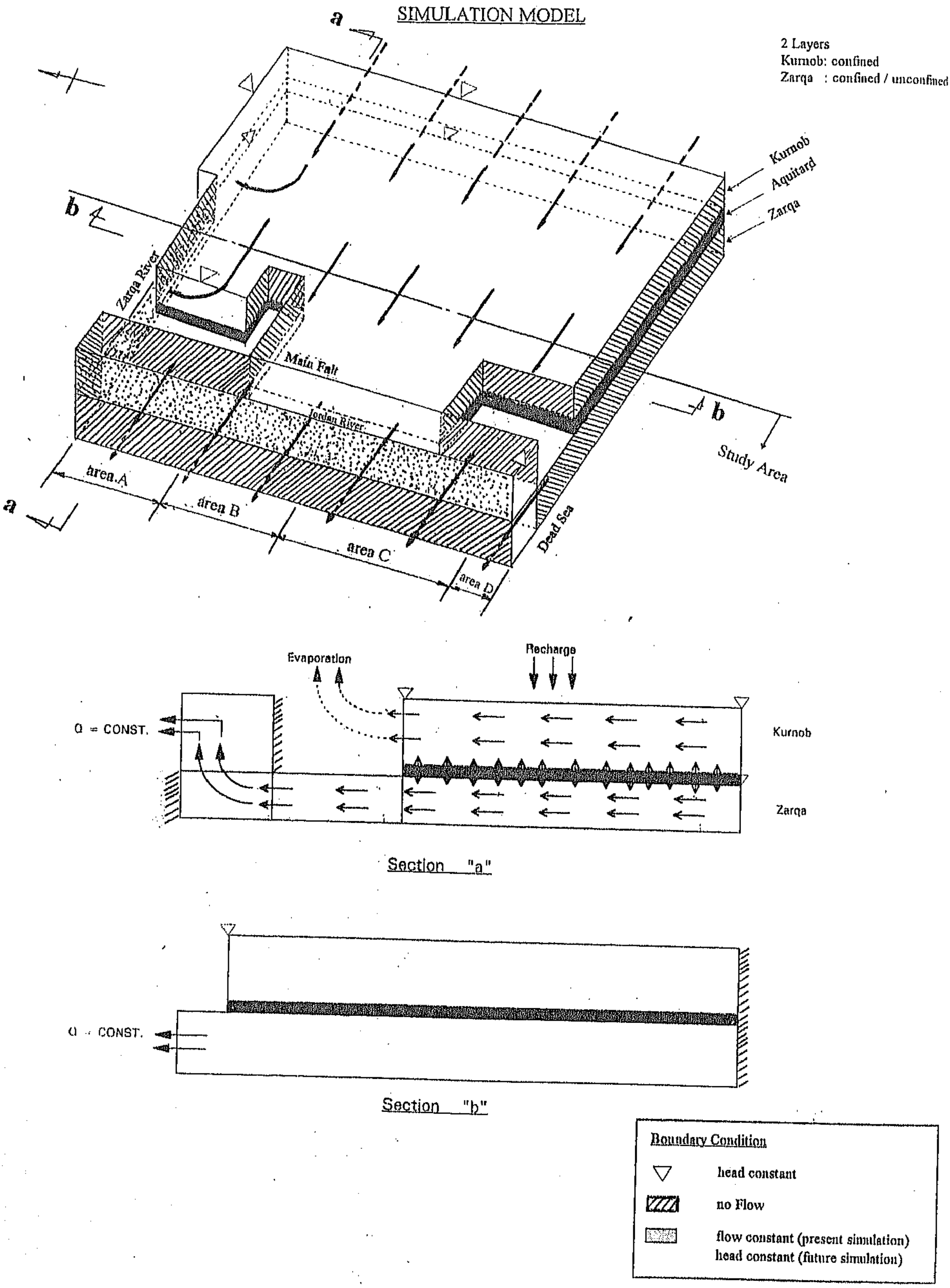


Fig. I-7.3.1 Schematic Drawing of Simulation Model

(3) Boundary Condition

The boundary conditions for the simulation have been established as shown in Fig. I-7.3.2.

1) Zerqa Group Aquifer

a. For reappearance simulation of the present piezometric surface

Eastern Boundary:	A constant head boundary was set at a line 30 km outside from the Eastern edge of the Study Area.
Western Boundary:	A constant flow boundary was set at the Main Fault. A flow amount was given to each area (Area A to Area B) based on the hydrological water balance calculation discussed in Chapter 5. The flow amount was verified through the reappearance simulation in area C.
Northern Boundary:	A constant flow boundary was set along the downstream reach of the Zarqa River and a constant head boundary was set along the upstream reach of the Zarqa River.
Southern Boundary:	A constant head boundary was set along the southern edge of the Study Area.

b. For simulation of future operation

Western Boundary:	A constant head boundary was set along the Jordan River.
Northern Boundary:	A constant head boundary was set along the Zarqa River.
Southern and Eastern Boundary:	The boundary conditions set were the same as the reappearance simulation. The Southern simulation boundary was extended 12km from the Study area in order to investigate the extent of the draw-down influence area to the South.

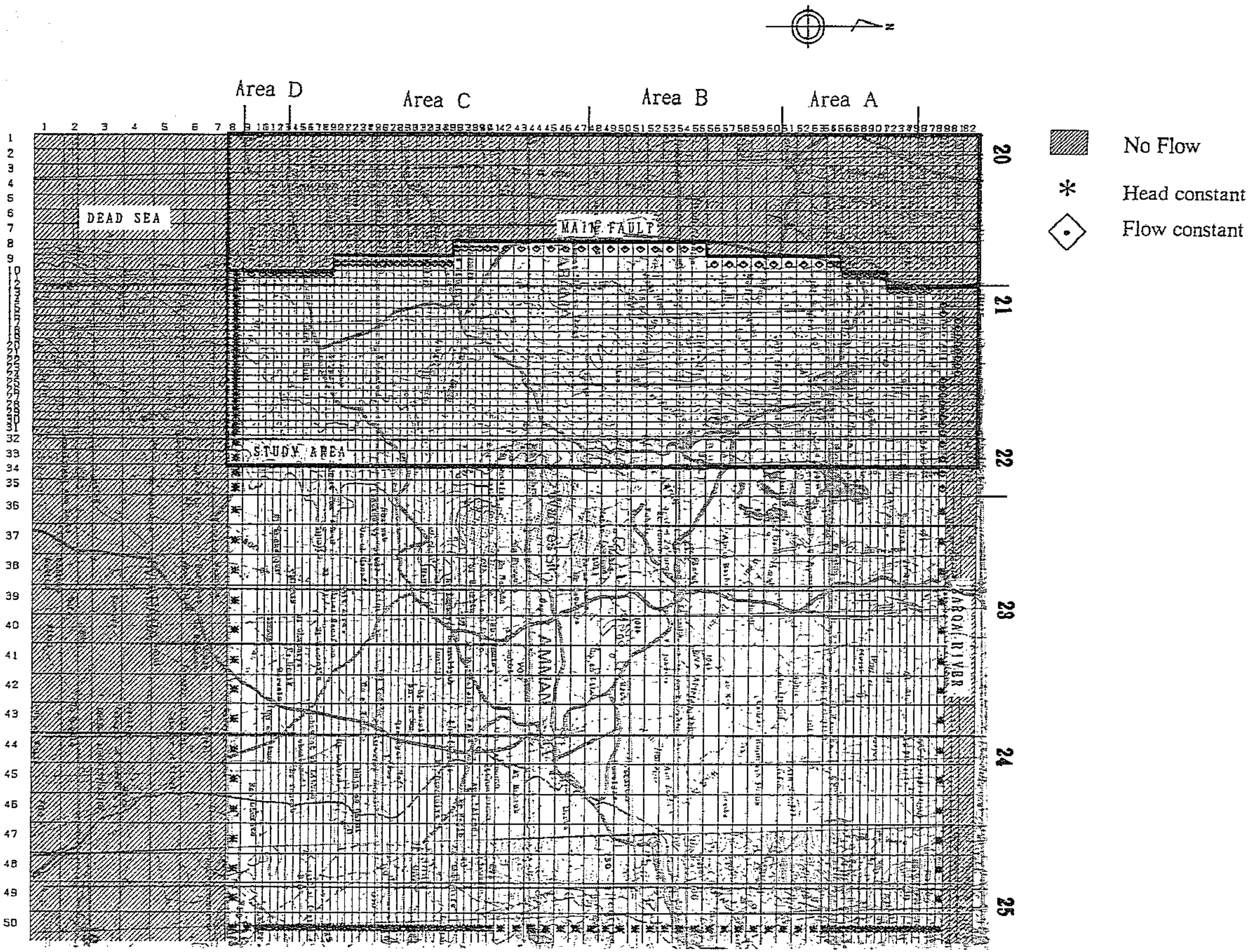


Fig. I-7.3.2 (1) Boundary Condition (for Present Simulation of the Zerqa Group Aquifer)

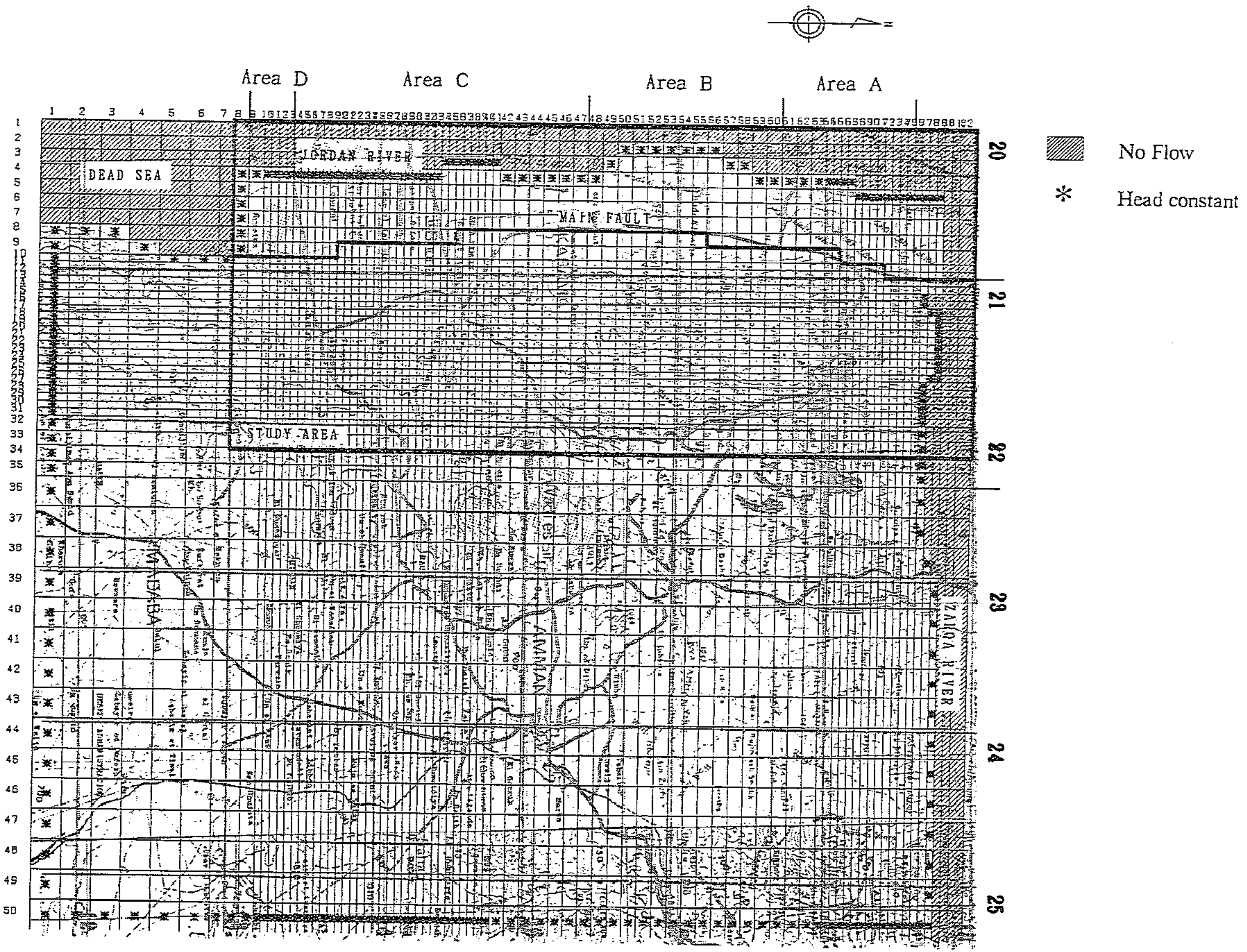


Fig. I-7.3.2 (2) Boundary Condition (for Future Simulation of the Zerqa Group Aquifer)

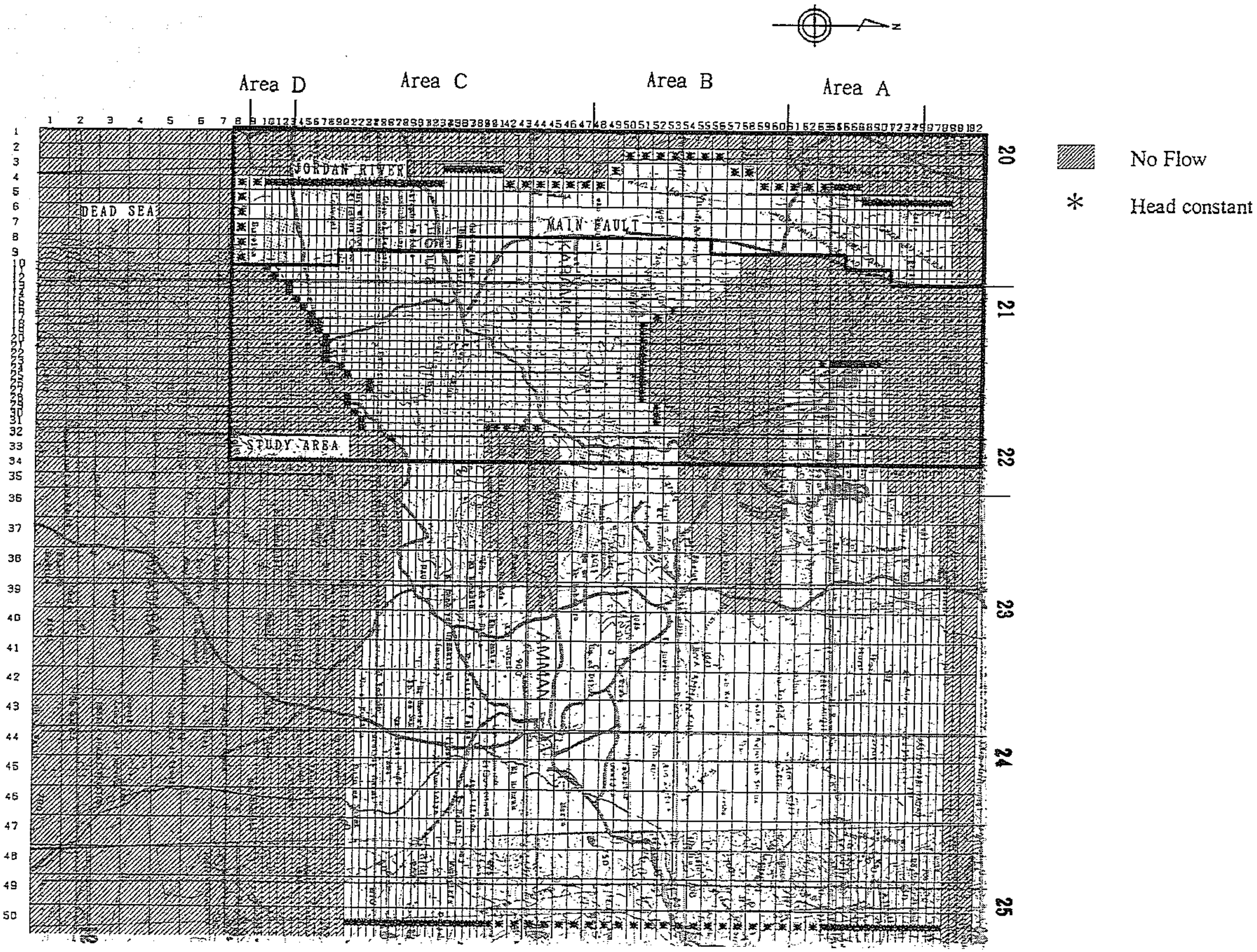


Fig. I-7.3.2 (3) Boundary Condition (for Kurnub Sandstone Aquifer)

2) Kurnub Sandstone Aquifer

For the groundwater simulation of the Kurnub sandstone aquifer, the same boundary conditions were set for both the reappearance simulation of the present condition and the future simulation.

Eastern Boundary:	A constant head boundary was set along a line 20 km outside the Study Area.
Western Boundary:	A constant head boundary was set along the Jordan River.
Northern and Southern boundary:	An impervious boundary (Zero flow boundary) was set along the Northern and Southern edges of the Study Area. For the areas where the Kurnub Sandstone was eroded out, the same boundary condition was given.

(4) Hydraulic Properties

There was insufficient data available in the Study area to determine the hydraulic properties of the target aquifers such as permeability coefficient and storage coefficient

For this reason, the hydraulic properties for each cell have been determined through the reappearance simulation trials of the present piezometric surfaces with reference to the existing data and newly obtained data from the pumping tests.

The hydraulic properties obtained through the Study are as follows:

Table I-7.3.1 Hydraulic Properties of the Strata in the Study Area

Area [1]	Strata [2]	Well	Specific Capacity (m^2/day)	Permeability (m/day)	Storage Coefficient	Leakance Factor (/ day)
A	Z2	Well No. 1	86~137	0.3~0.7	$1x10^{-2}$	-
	K	Existing [3] 36 wells	10~600	-	-	-
B	Z2	Well No. 2	55	0.5~0.6	$1x10^{-3}$~$4x10^{-3}$	-
	Z2	Well No. 4	620	0.8 [4]	-	-
	K	Well N0. 3	-	1.0~1.1	$2x10^{-3}$	-
	M	Well No. 3	-	-	-	$0.07x10^{-4}$ [4]
C	Z1	Hisban No. 1	605	9	$3x10^{-3}$	-
	Z1	Well No. 5 [5]	42~907	4.1~5.2	$4x10^{-3}$~$6x10^{-3}$	-
	J	Existing 6 wells	10~500	-	-	-
D	Z1	Well No. 6 [5]	262~3,762	5.2~16.0	$1x10^{-6}$	-

1) For the division of the areas, please refer to Section 5. 3. 4

2) J : Jordan Valley Formation

K : Kurnub Sandstone

M: Marly Layer (Aquitard)

Z2 : Azab Formation of Zerqa Group (Upper Zerqa)

Z1 : Main Formation of Zerqa Group (Lower Zerqa)

3) Located in Subeihi area

4) From Combination well pumping test

5) to be tested in near future

7.4 Reappearance Simulation of Present Piezometric Surface

7.4.1 Simulation Procedure

As the simulation using the MODFLOW program can process a multi aquifer system, the reappearance simulation of present piezometric surface has been done for both the Kurnub Sandstone aquifer and the Zerqa Group aquifer as a first step.

After caming out the reappearance simulation of the present piezometric surface of each aquifer, these aquifers were combined with intercalation of the aquitard (Marly Layer) and the plug layer (Jordan Valley Group).

The piezometric surface discrepancies caused by the combination of the aquifers were adjusted through modifications to the hydraulic properties of each aquifer.

On completion of these procedures, the reappearance simulation of the present piezometric surface of each aquifer was completed and the transmissibility distribution and flow amount of each aquifer were determined.

This procedure is shown in Fig. I-7.4.1.

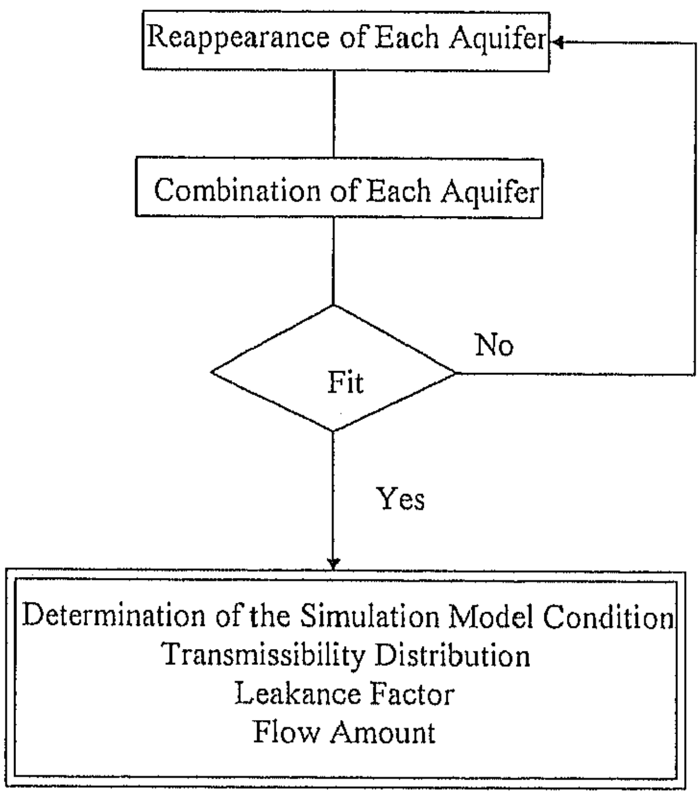


Fig. I-7.4.1 Procedure of Reappearance Simulation of Present Piezometric surface

7.4.2 Simulation Results

The results of the reappearance simulation of the present piezometric surface are described below. The results of the flow amount of the Zerqa Group aquifer will be discussed in Section 7.4.3.

(1) Transmissibility Distribution of the Zerqa Group Aquifer

The transmissibility distribution of the Zerqa Group aquifer obtained by the reappearance simulation is shown in Fig. I-7.4.2. As shown in Fig. I-7.4.2, the transmissibilities of Area B are considerably lower than the other areas. The high permeability zone near Wadi Hisban and Wadi Kaffrein in Area C can be noticed and this high permeability zone is inferred to be formed along the syncline flexure running along Wadi Kaffrein (refer to Chapter 6).

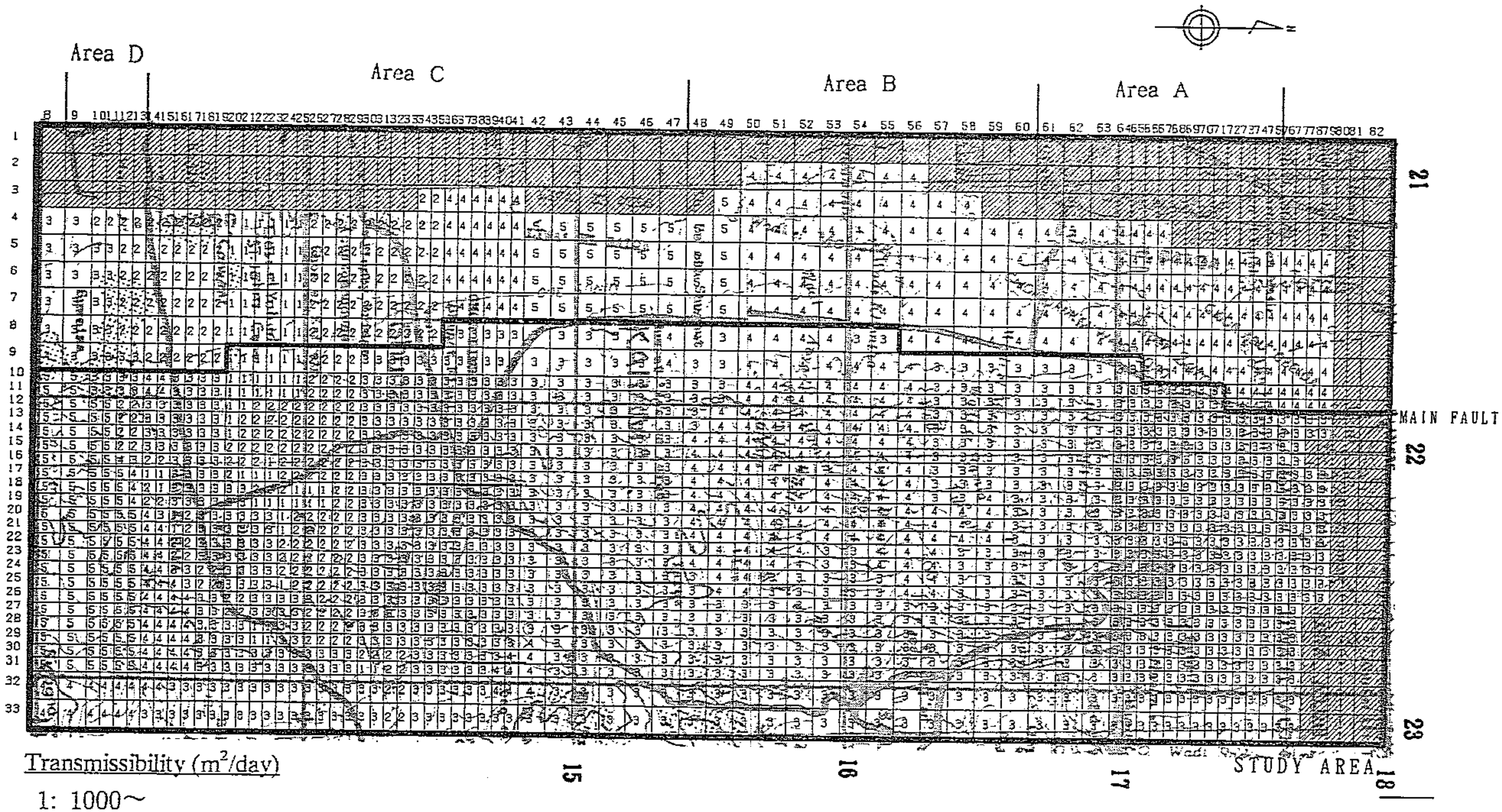
As the transmissibility of Area B is much lower than those of the other areas, the groundwater seepage velocity is supposed to be very low and to be stagnant. Actually, in Well No.2 and Well No.4 drilled in Area B, the groundwater salinity of the Zerqa Group aquifer is extremely high (more than 9,000 mg/L in TDS) and this phenomenon might be caused by the reason mentioned above. On the other hand, the inferred high permeability zone along Wadi Kafrein is almost coincident with the low salinity zone as discussed in Section 6.2.

For the reappearance of the concavity of the piezometric surface in Area C, two high permeability zones are assumed along the synclinal axis running in parallel with Wadi Kafrein and along the fault bounding the hilly area and plain area in the South of Area C (see Fig. I-6.1.2) as shown in Fig. I-7.4.2.

(2) Leakance Factor of Marly Layer

The leakage coefficient distribution of the marly layer obtained by the reappearance simulation is shown in Fig. I-7.4.3.

As shown in Fig. I-7.4.3, the leakage coefficient of the marly layer, which incompletely bind both aquifers hydraulically, is assumed to be larger at the foot of the escarpment and along the Wadi Kafrein because these areas are assumed to be highly faulted.



Transmissibility (m^2/day)

1: 1000~

2: 500~ 1000

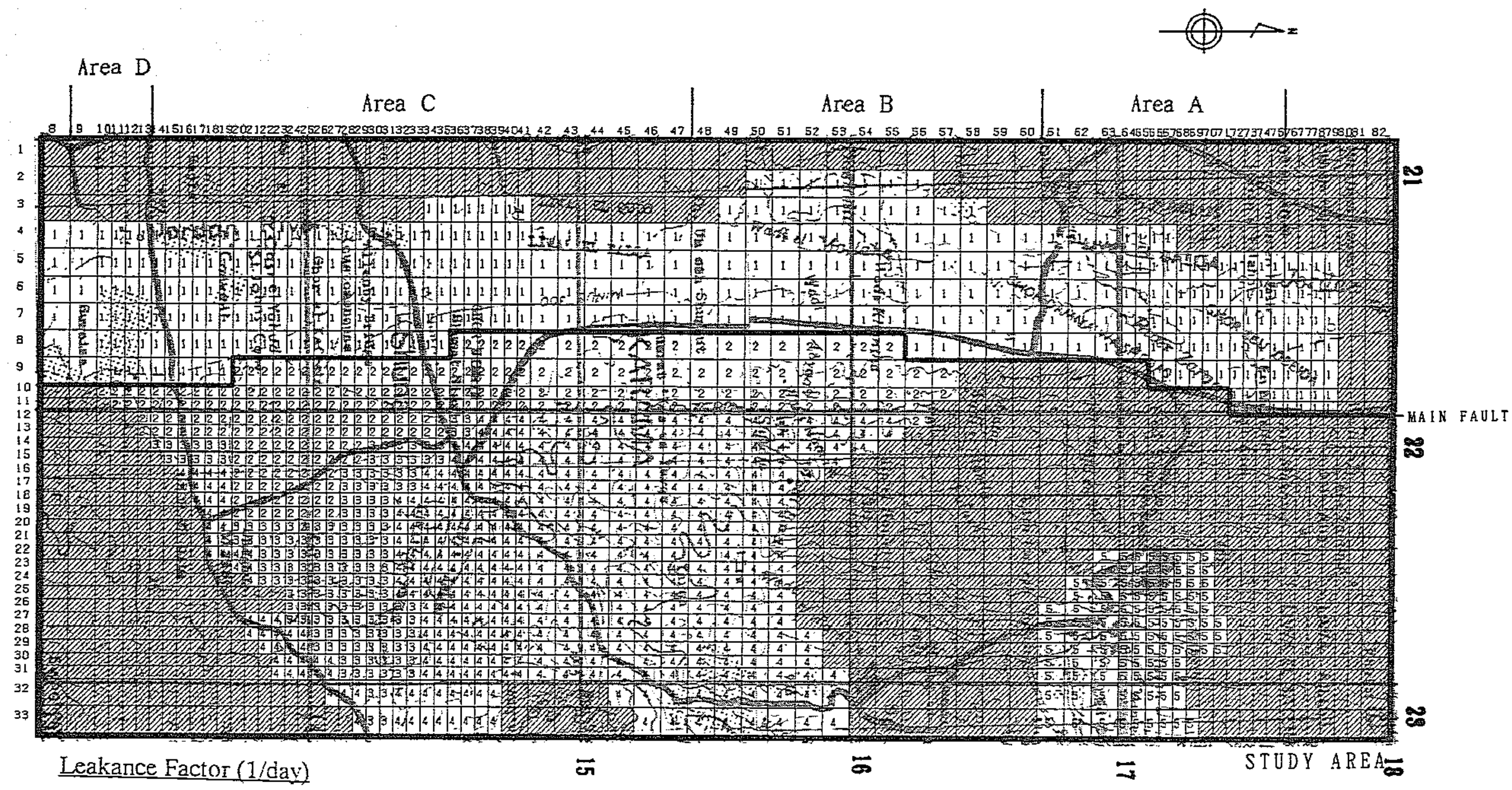
3: 100~ 500

4: 50~ 100

5: ~ 50

Fig. I-7.4.2 Transmissibility Distribution of the Zerqa Group Aquifer

5000 M



Leakance Factor (1/day)

1: 1.4×10^{-4}

2: 0.5×10^{-4}

3: 1.0×10^{-5}

4: 1.0×10^{-6}

5: 1.0×10^{-7}

Fig. I-7.4.3 Leakance Factor Distribution of Marly Layer

The piezometric potential of the Zerqa Group aquifer is higher than that of the Kurnub Sandstone aquifer at the foot of the escarpment. Accordingly, it is assumed that the upward leakage of the brackish groundwater from the Zerqa Group aquifer to the Kurnub Sandstone aquifer is accelerated and the salinity of the Kurnub Sandstone aquifer gets higher at the foot of the escarpment.

(3) Transmissibility Distribution of the Kurnub Sandstone Aquifer

The transmissibility distribution of the Kurnub sandstone aquifer obtained by the reappearance simulation is shown in Fig. I-7.4.4. As shown in Fig. I-7.4.4, it is assumed the transmissibility value does not change greatly from area to area. It is inferred that the transmissibility of the Kurnub Sandstone aquifer is slightly smaller than that of the Zerqa Group aquifer.

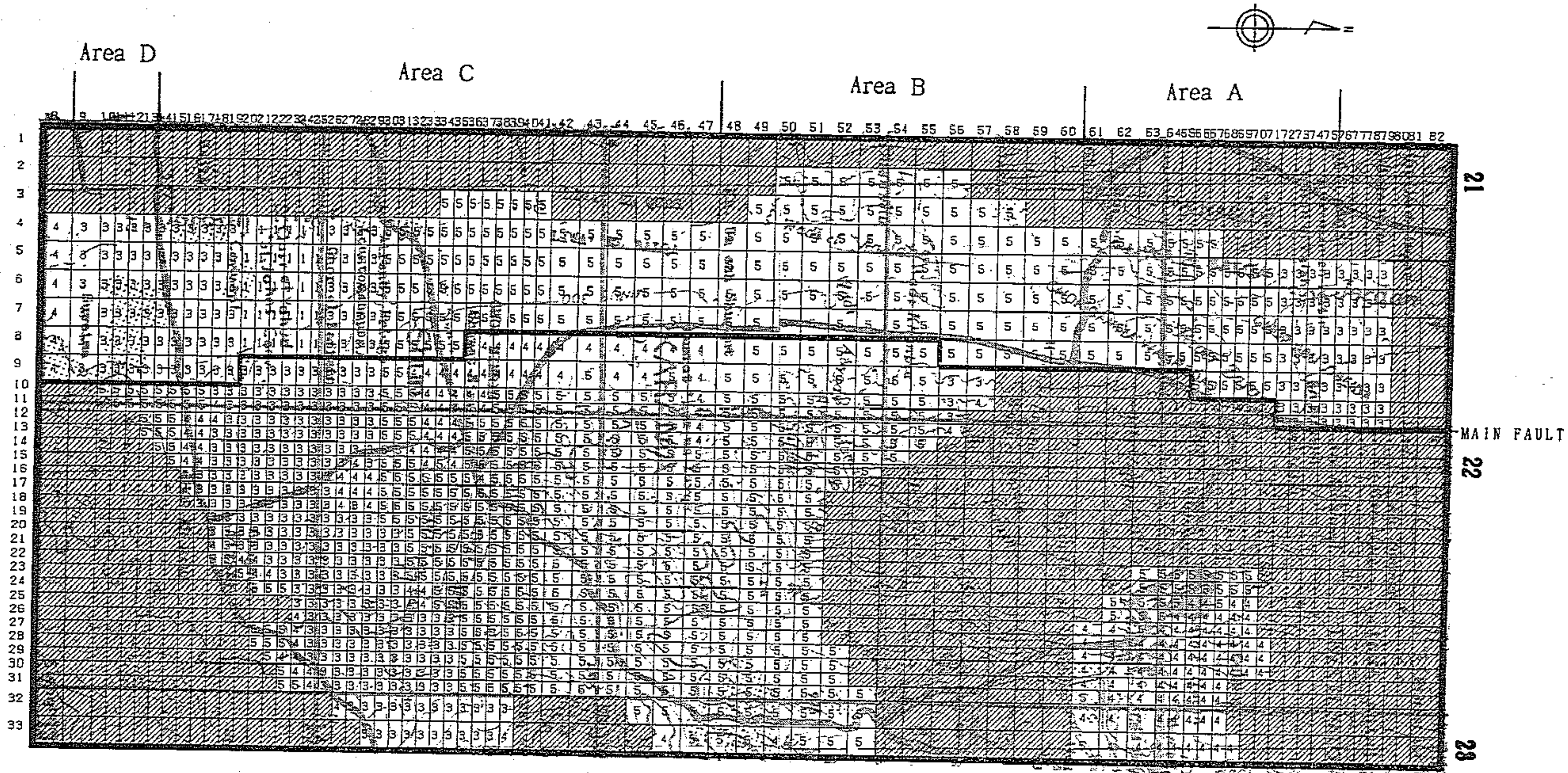
(4) Natural Seepage between Zerqa Group Aquifer and Kurnub Sandstone Aquifer

Natural groundwater seepage between the two aquifers through the aquitard was calculated in this simulation as shown in Fig.I-7.4.5. The simulation result shows that upward seepage from Zerqa to Kurnub takes place along a narrow strip at the foot of the escarpment and Southern narrow edge of the Study area and downward seepage from Kurnub to Zerqa occurs in the reminder of the Study area.

The seepage amounts between the two aquifers in the Study area are calculated as follows:

Natural seepage amount from Kurnub to Zerqa	6.5 MCM/year
Natural seepage amount from Zerqa to Kurnub	5.0 MCM/year
Total Amount	1.5 MCM/year from Kurnub to Zerqa

As mentioned above, it is estimated that, overall, the Zerqa Group aquifer receives recharge from the Kurnub Sandstone aquifer in the Study area, but the amount is much smaller than the lateral inflow amount from the east (70 MCM/year in Area C).



Transmissibility (m²/day)

1: 1000～

2: 500～ 1000

3: 100～ 500

4: 50～ 100

5: ～ 50

Fig. I-7.4.4 Transmissibility Distribution of the Kurnub Sandstone Aquifer

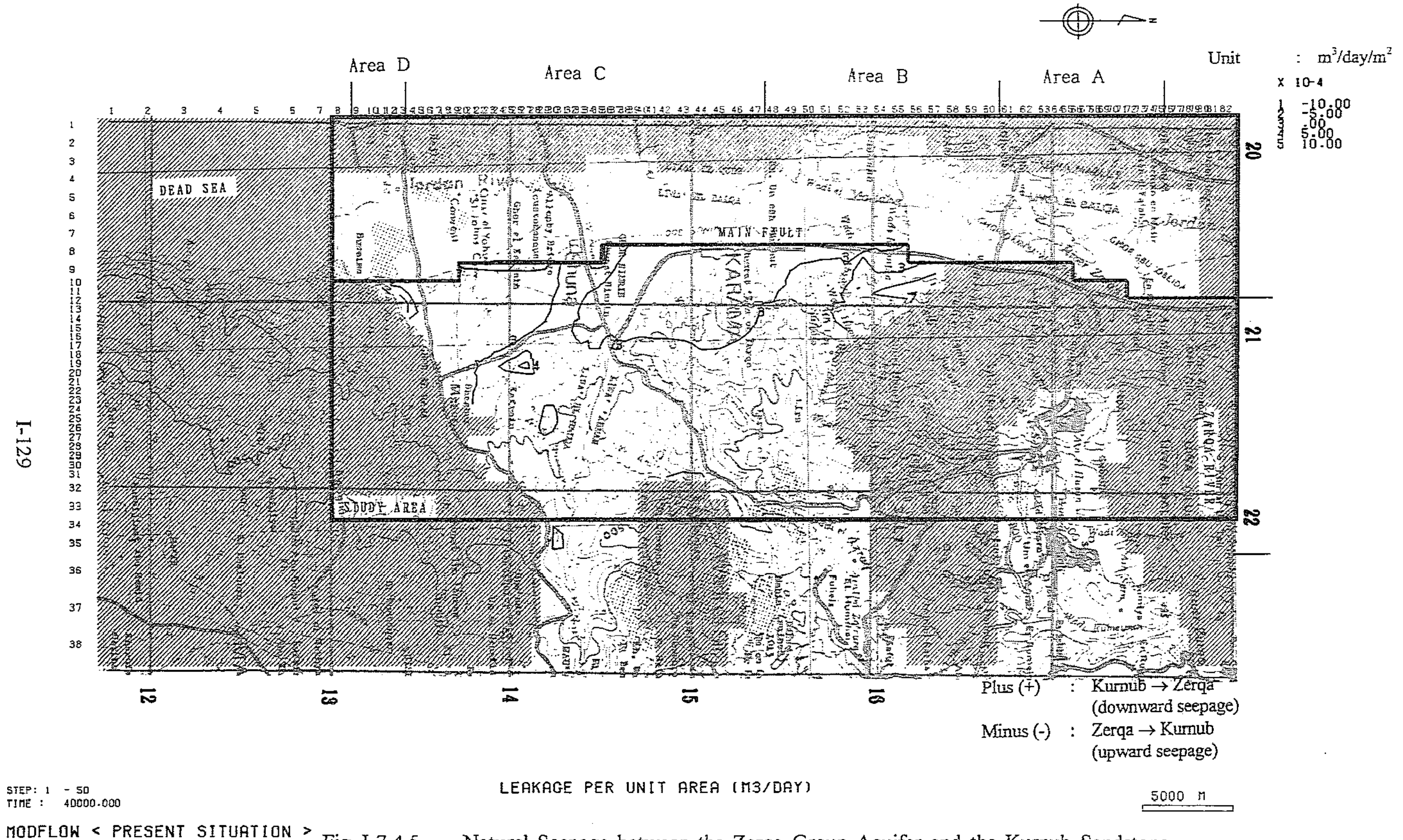


Fig. I-7.4.5 Natural Seepage between the Zerqa Group Aquifer and the Kurnub Sandstone Aquifer

7.4.3 Re-assessment of Flow Amount of the Zerqa Group Aquifer

Less data concerning the water discharge is presently available for Area C, and it is impossible to evaluate the groundwater inflow from the Zerqa Group aquifer to the Jordan Valley Plain in Area C from the hydrological analysis alone because groundwater from many sources - Zerqa aquifer, Ajlun aquifer, Kurnub aquifer and wadis - flows into Area C. Therefore, the flow amount of the Zerqa Group aquifer in Area C has been re-assessed through the reappearance simulation of the present piezometric surface of the Zerqa Group aquifer.

As for the flow amount of Area A, B and D, the present piezometric surface of the Zerqa Group aquifer could be reappeared in the simulation using the flow data obtained by the hydrological calculation (refer to Chapter 5) without a large discrepancy in the natural piezometric surface. Therefore, it is believed that the flow amounts of Areas A, B and D inferred by the hydrological calculation are reliable. For Area C, on the other hand, it was completely impossible to make the present piezometric surface of the Zerqa Group aquifer reappear by using the flow amount estimated from the hydrological calculation in Area C (6.9 MCM/year). In other works, if a flow amount of 6.9 MCM/year is employed for the reappearance simulation, an extremely low permeability must be given to Area C and the re-appearance of the concave piezometric surface detected in Area C is definitely impossible.

For the re-assessment procedure, the method of operation was the inverse of that used in the simulation. The method aims to derive the flow amount by simulation given the hypothesis that the permeability of the Area C is not greatly different from those of the other areas. The re-assessment procedure of the flow amount of the Zerqa Group aquifer in Area C is shown as a flow chart in Fig. I-7.4.6

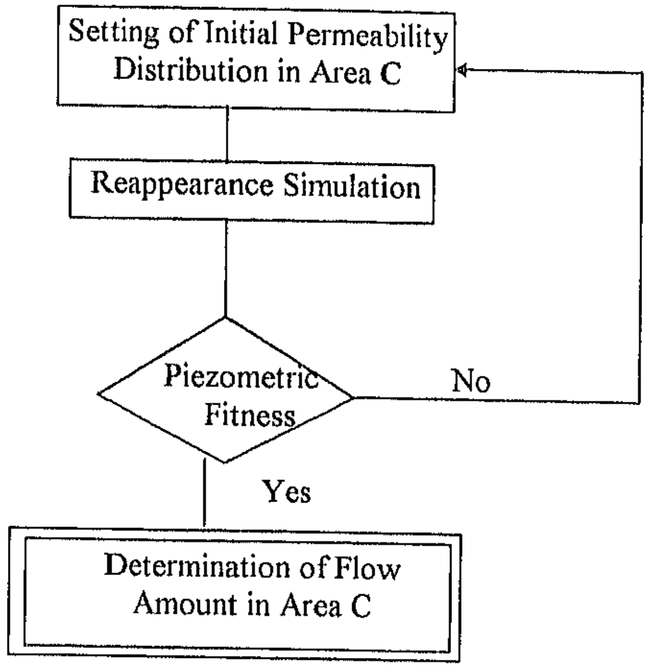


Fig. I-7.4.6 Re-assessment Procedure of the Flow Amount of the Zerqa Group Aquifer in Area C

The re-assessment results of the flow amount of the Zerqa Group aquifer are shown in Fig. I-7.4.7 with the reappearing piezometric surface.

According to the results of the re-assessment, the total flow amount of the Zerqa Group aquifer in the Study Area is estimated at around 120 MCM/year as shown in Table I-7.4.1.

Table I-7.4.1 Flow Amount of the Zerqa Group Aquifer in the Study Area

	Area A[1)]	Area B[1)]	Area C[2)]	Area D[1)]	Total
Brackish Groundwater Flow Amount of the Zerqa Group Aquifer (MCM/year)	40.8	8.4	70	2.6	121.8

1) Same as the water balance calculation results discussed in Chapter 5

2) Re-assessment result of the groundwater simulation

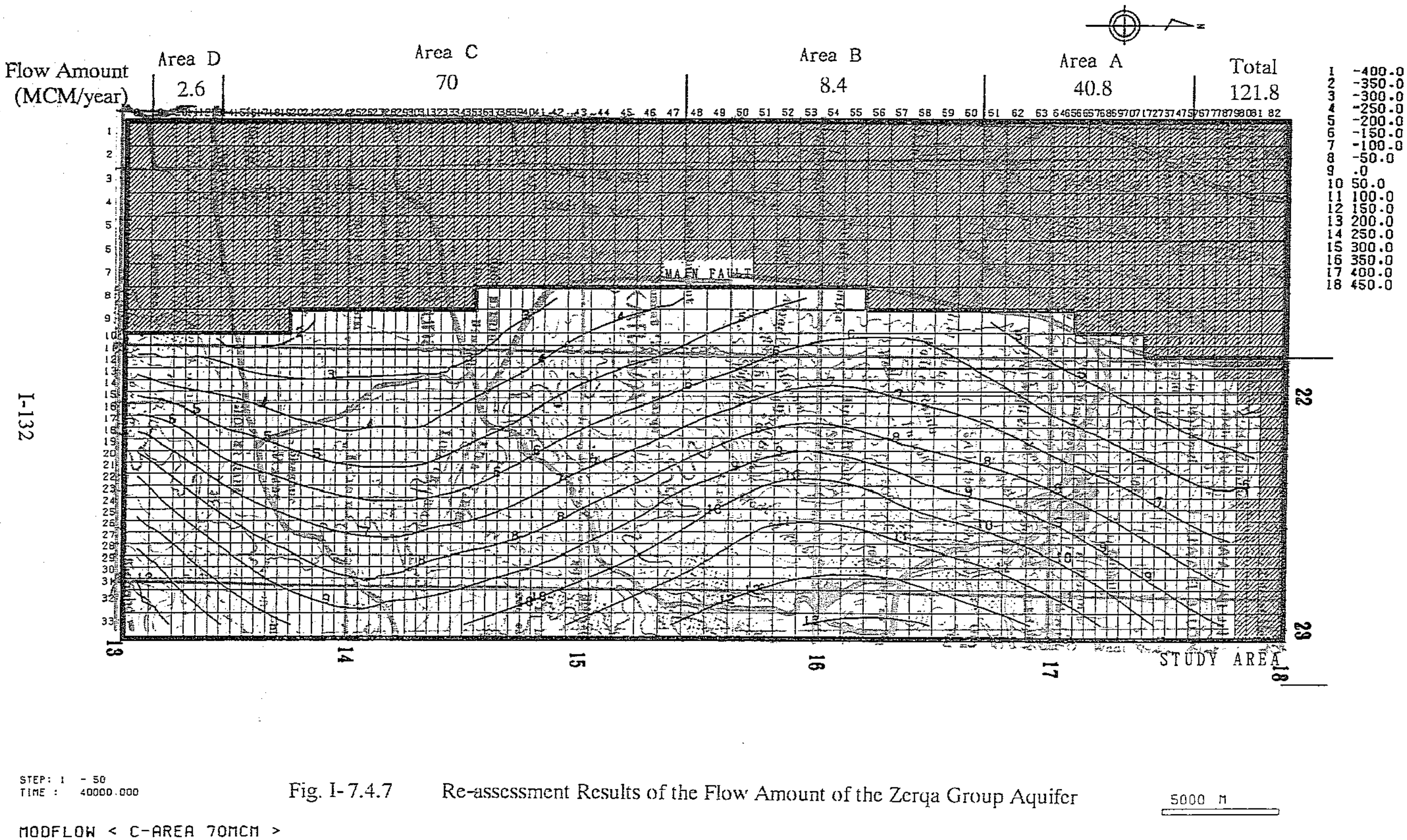


Fig. I-7.4.7 Re-assessment Results of the Flow Amount of the Zerqa Group Aquifer

7.5 Simulation of the Future Status after the Development

7.5.1 Tentative Development Alternative

Tentative development alternatives have been assumed in order to evaluate the drawdown influence to be caused by the future brackish groundwater development.

The tentative development alternatives assumed in this simulation work are subject to be revised in due course of the Study.

(1) Development Site

As shown in Fig. I-7.5.1, it is assumed that the promising areas for brackish groundwater development are Area A and Area C in terms of the flow amount of brackish groundwater in the Zerqa Group aquifer.

1) Area A

Area A is located in the North of the Study Area, and Deir Alla is situated in this area. There is a pumping station which conveys water from Deir Alla to Zai.

A tentative production well field has been selected along the foot of the escarpment and the Zarqa river taking into account the hydrogeological and topographic conditions and the assumed location of the desalination plant, as shown in Fig. I-7.5.1. The tentative well field in Area A is set in the area under the flowing condition and its piezometric potential is assumed to be 0 m to 20 m above the ground surface.

2) Area C

Area C is located in the South of the Study Area near the Dead Sea. The depth to the Zerqa Group aquifer in Area C is generally large, as shown in hydrogeological cross section I - I′ (see Supporting Report), because the strata syncline in Area C. It is inferred that the depth to the Zerqa Group aquifer is around 350 m at the downstream end of Wadi Hisban, around 200 m at Kaffrein Village and around 400 m at the downstream end of Wadi Shueib. The Zerqa Group exposed in the southern part of Area C.

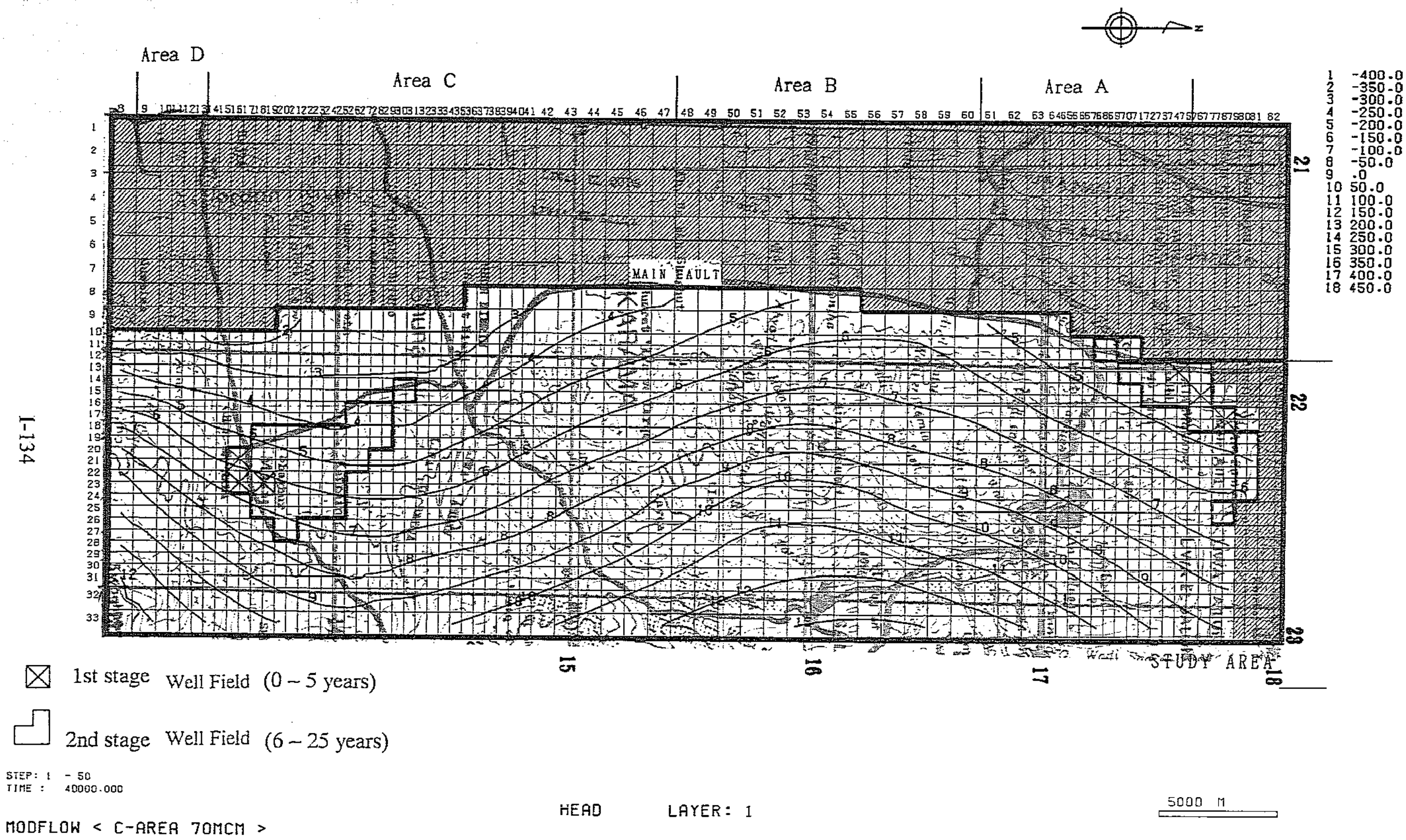


Fig. I-7.5.1 Tentative Well Field for the Simulation of the Future Status

It is proposed that the most suitable location for the well field is on the high permeability and shallower groundwater level zone. The alignment of the well field should be perpendicular to the groundwater flow line. Based on the ideas mentioned above, the proposed well field is shown in Fig. I-7.5.1 taking the topographic conditions and the assumed location of the desalination plant into consideration.

The tentative well field in Area C is set in the area where the brackish groundwater is under the flowing condition or at shallow depth. The piezometric potential in the well field is assumed between -10m and +70m from the ground surface as shown in the hydrogeological section E-E′, I-I′ and II-II′ (see Supporting Report).

(2) Development Amount

The main purpose of the simulation for future status (future simulation) is to study the groundwater draw-down influence of the future brackish groundwater development.

The maximum potential has been coincident with the total amount of flow (recharge). It has been established from experience that the maximum exploitable groundwater amount without an adverse effect is normally less than 80% of the total amount of flow (recharge).

Based on this empirical idea, four cases for brackish groundwater development schemes (shown in Table I-7.5.1) has been assumed for the simulation in order to examine the maximum exploitable potential in the Study area.

Table I-7.5.1 Tentative Brackish Groundwater Development Amount

Case	Development Amount (MCM/y)			Remarks
	Area A	Area C	Total	
Case 1	20 MCM/Year (50%)	30 MCM/Year (40%)	50 MCM/Year (45%)	Development will be carried out in both areas
Case 2	25 MCM/Year (60%)	40 MCM/Year (60%)	65 MCM/Year (60%)	Same as above
Case 3	30 MCM/Year (70%)	45 MCM/Year (70%)	75 MCM/Year (70%)	Same as above
Case 4	35 MCM/Year (80%)	55 MCM/Year (80%)	90 MCM/Year (80%)	Same as above

Note: Bracketed figures show approx. percentage of development amount to flow amount of the area

Flow amount .... Area A : 40 MCM/Year, Area C : 70 MCM/Year

(3) Development Staging

The staging for the brackish groundwater development project has been tentatively formulated based on the following supposition.

i) The project life will be twenty-five (25) years.

ii) The project will be multi stage. For the simulation work, two stages have been tentatively considered for implementation of the project.

iii) The first stage of the project will be a small scale development in order to study the actual performance of the desalination plant, production wells, actual groundwater draw-down and influence on the other aquifers.

Based on the suppositions mentioned above, the brackish groundwater development staging assumed is as shown in Table I-7.5.2.

Table I-7.5.2 Tentative Development Stage

Case	Area	Stage		Total
		1st stage (0 ~ 5 years)	2nd stage (6 ~ 25 years)	
Case 1	A C	6 MCM/year (15%) 6 MCM/year (9%)	20 MCM/year (50%) 30 MCM/year (40%)	50 MCM/year (45%)
Case 2	A C	Same as above	25 MCM/year (60%) 40 MCM/year (60%)	65 MCM/year (60%)
Case 3	A C	Same as above	30 MCM/year (70%) 45 MCM/year (70%)	75 MCM/year (70%)
Case 4	A C	Same as above	35 MCM/year (80%) 55 MCM/year (80%)	90 MCM/year (80%)

Note: This staging has been used only for the determination of the maximum exploitable brackish groundwater amount in the Study area. The actual development strategy will be formulated in the Study.

Bracketed figures show approx. percentage of development to flow amount of the area.

7.5.2 Future Simulation Results

(1) Case 1 (Total 50 MCM/year)

The calculated drawdown influence in Case 1 is shown in Fig. I-7.5.2, Fig. I-7.5.3, Fig. I-7.5.4 and Fig. I-7.5.5.

1) First Stage (6 MCM/year at Area A and C respectively, after 5 years)

a. Area A

The maximum draw-down of the Zerqa Group aquifer is about 10 m in the well field and its influence is limited to an area near the well field as shown in Fig. I-7.5.2.

The draw-down influence cannot be detected in the Kurnub Sandstone aquifer.

b. Area C

The draw-down of the Zerqa Group aquifer is about 30 m in the well field and its influence extends 3 km from the well field as shown in Fig. I-7.5.2.

The draw-down of the Kurnub Sandstone aquifer is less than 5m at the well field as shown in Fig. I-7.5.3.

2) Second Stage (Total 50 MCM/year, after 25 years)

a. Area A

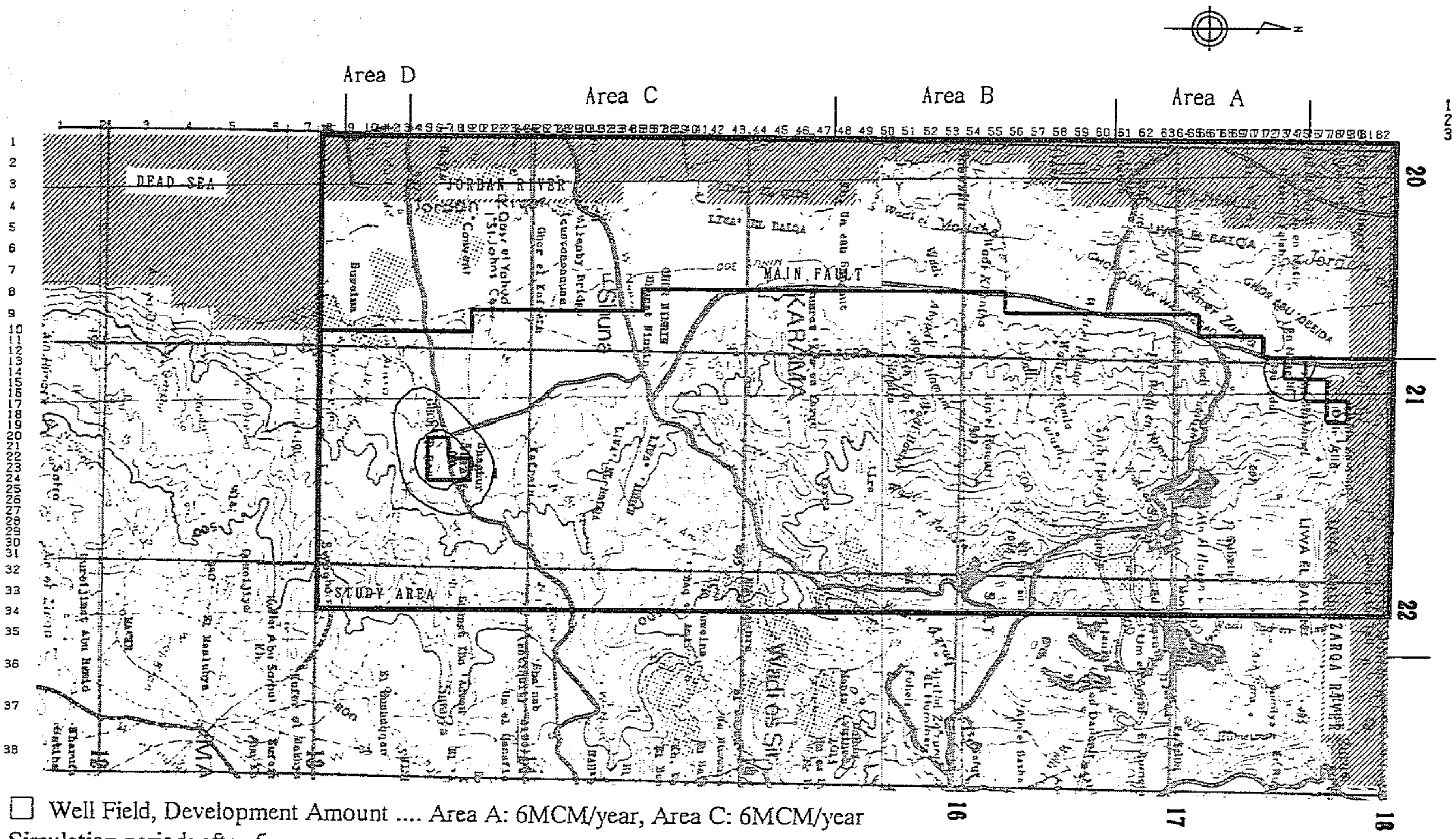
The maximum draw-down of the Zerqa Group aquifer is about 20 m in the well field and the influence distance of 10 m draw-down is about 4 km as shown in Fig. I-7.5.4.

The draw-down influence cannot be detected in the Kurnub Sandstone aquifer.

b. Area C

The maximum draw-down of the Zerqa Group aquifer is about 80 m and its center is located in the South of the well field as shown in Fig. I-7.5.4. The influence distance of 10 m draw-down is about 15 km.

The draw-down of the Kurnub Sandstone aquifer is around 20 m at the central part of the well field. The influence area of 10 m draw-down extends around 8 km from the well field as shown in Fig. I-7.5.5.



☐ Well Field, Development Amount .... Area A: 6MCM/year, Area C: 6MCM/year
Simulation period: after 5 years

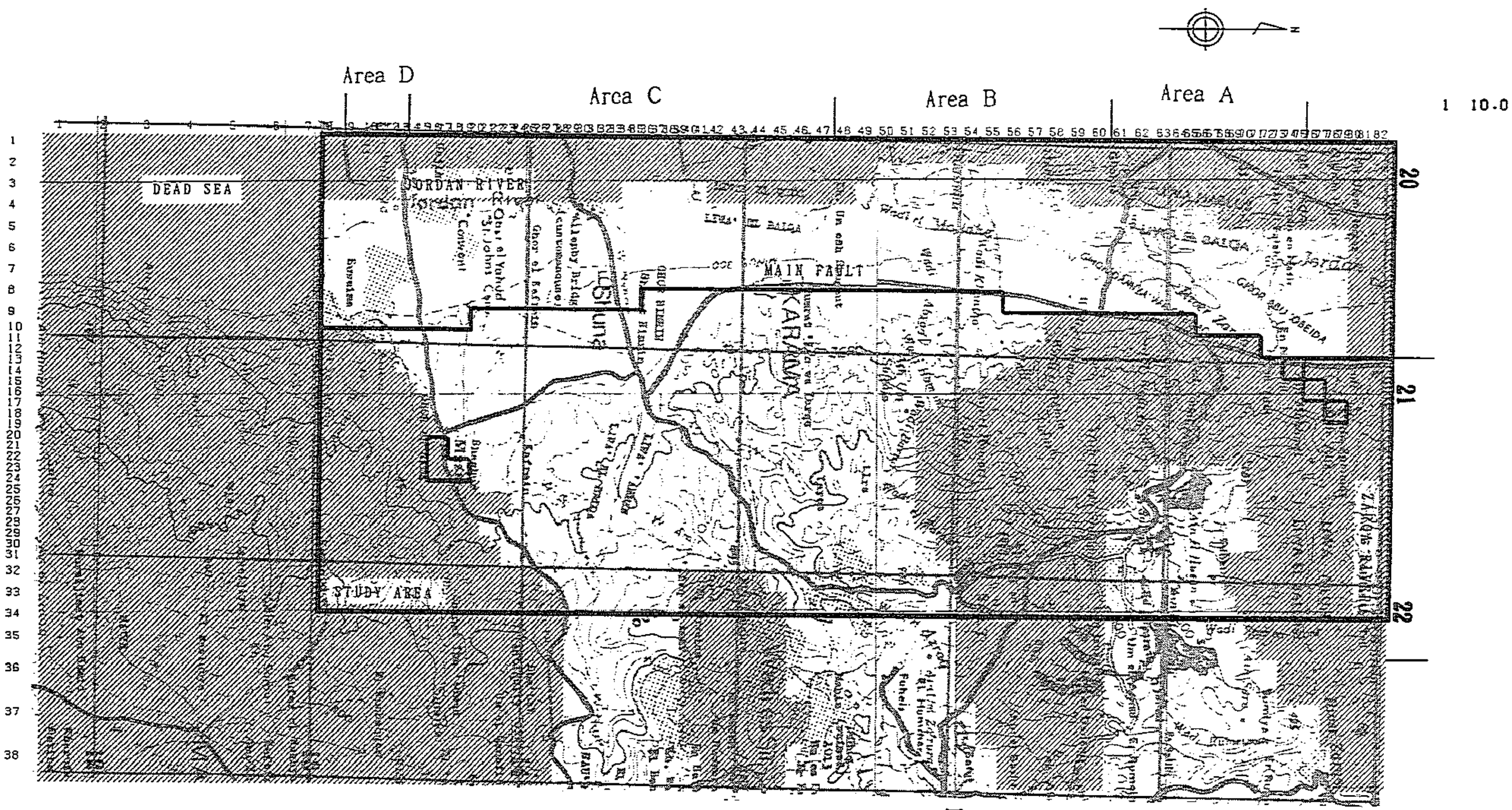
STEP: 1 - 40
TIME : 1825.000

DRAWDOWN LAYER: 2

5000 M

MODFLOW

Fig. I-7.5.2 Drawdown Influence on the Zerqa Group Aquifer after the First Stage Development



☐ Well Field, Development Amount .... Area A: 6MCM/year, Area C: 6MCM/year
Simulation period: after 5 years

STEP: 1 - 40
TIME : 1825.000

MODFLOW

DRAWDOWN LAYER: 1

5000 M

Fig. I-7.5.3 Drawdown Influence on the Kurnub Sandstone Aquifer after the First Stage Development

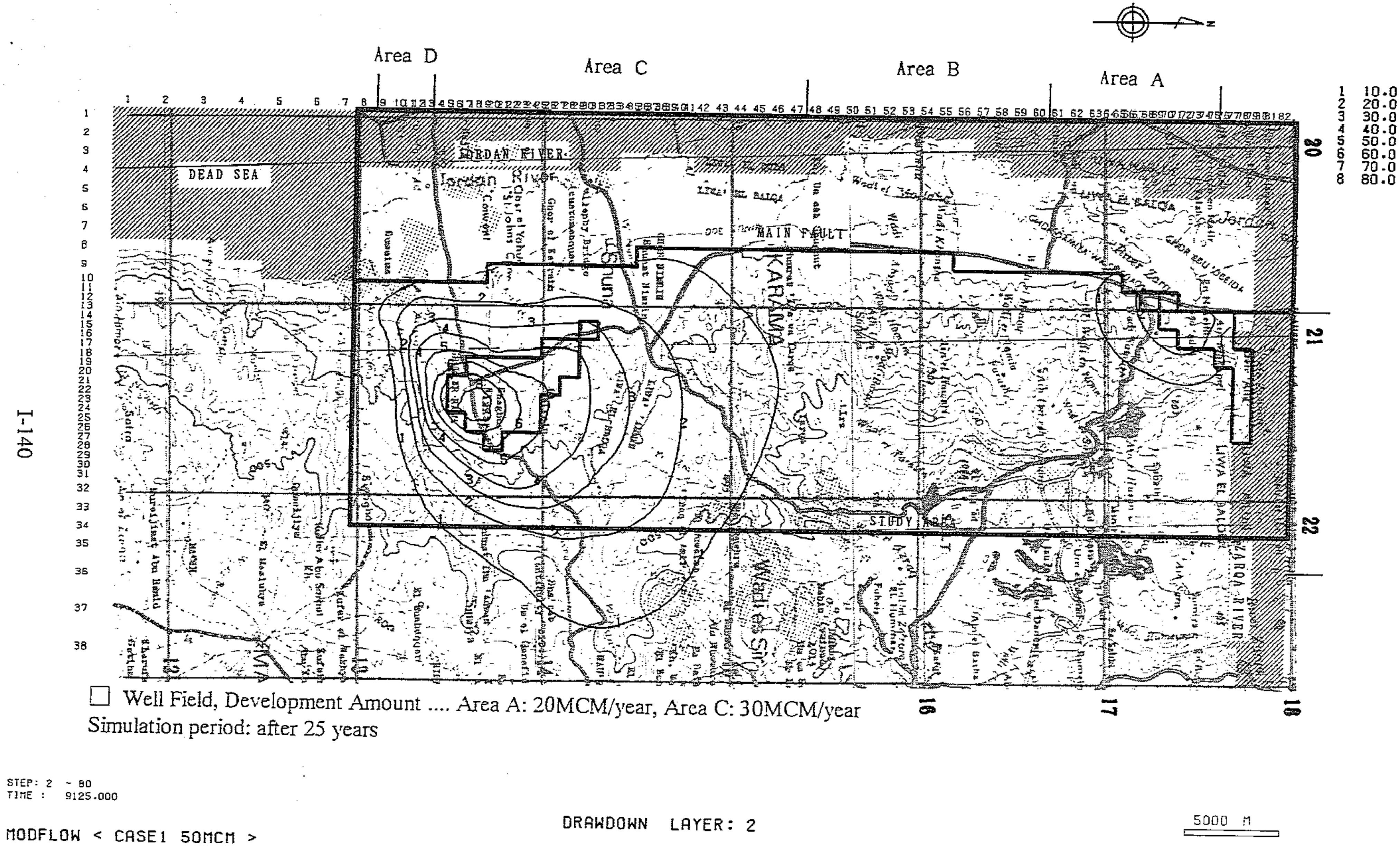
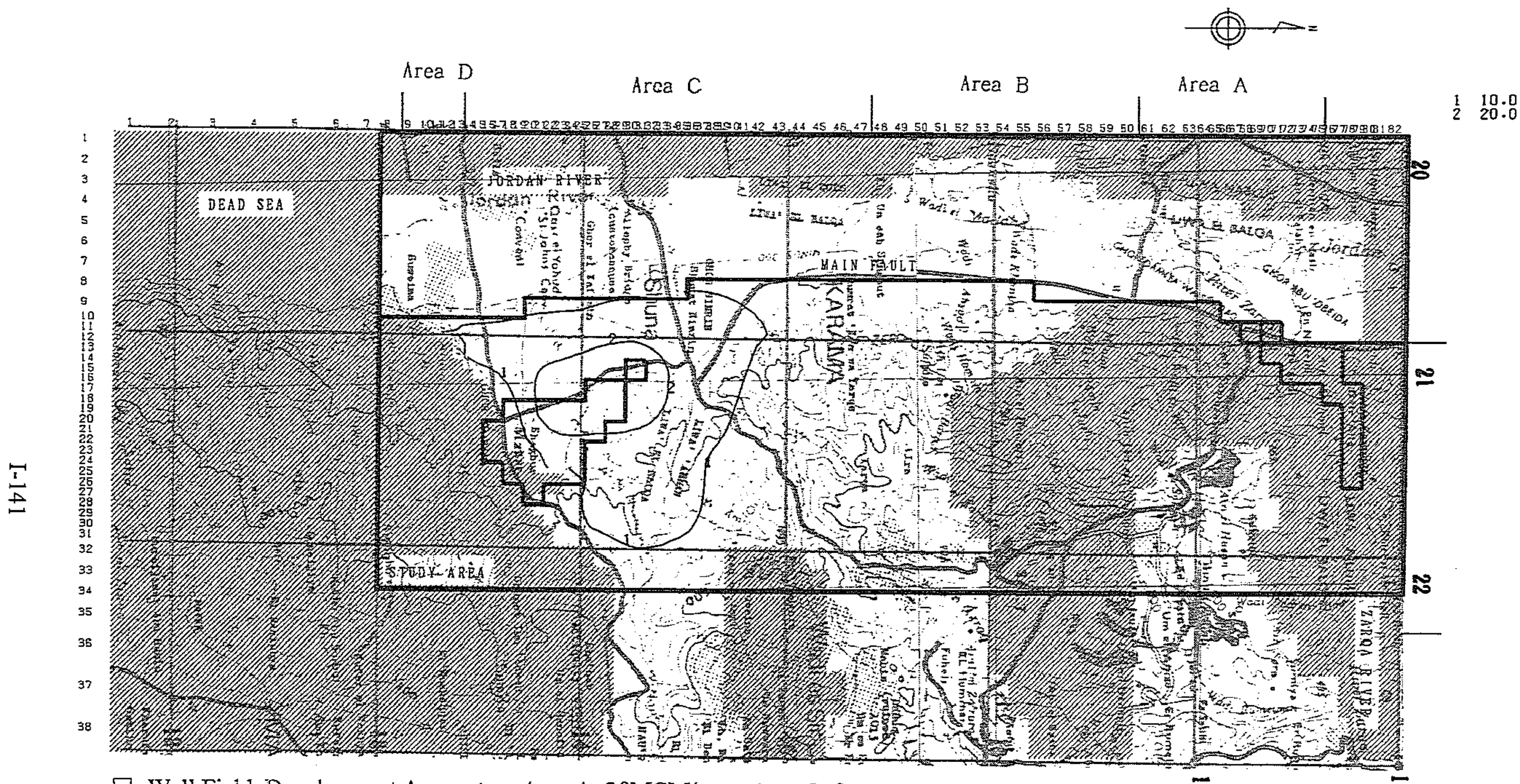


Fig. I-7.5.4 Drawdown Influence on the Zerqa Group Aquifer in Case 1 (end of the Second Stage)



□ Well Field, Development Amount .... Area A: 20MCM/year, Area C: 30MCM/year
Simulation period: after 25 years

STEP: 2 - 80
TIME : 9125.000

MODFLOW < CASE1 50MCM >

DRAWDOWN LAYER: 1

5000 M

Fig. I-7.5.5 Drawdown Influence on the Kurnub Sandstone Aquifer in Case 1 (end of the Second Stage)

(2) Case 2 (Total 65 MCM/year, after 25 years)

The calculated draw-down influence in the Second Stage of Case 2 is shown in Fig. I-7.5.6 and Fig. I-7.5.7. For to the simulation of the First Stage development, please refer to the former section (1).

a. Area A

The maximum draw-down of the Zerqa Group aquifer is about 30 m in the well field and the influence distance of 10 m draw-down is about 5 km as shown in Fig. I-7.5.6.

The draw-down influence cannot be detected in the Kurnub Sandstone aquifer.

b. Area C

The maximum draw-down of the Zerqa Group aquifer is about 110 m and its center is located in the South of the well field as shown in Fig. I-7.5.6.

The draw-down of the Kurnub Sandstone aquifer is around 30 m at the central part of the well field. The influence area of 10 m draw-down extends around 10 km from the well field as shown in Fig. I-7.5.7.

(3) Case 3 (Total 75 MCM/year, after 25 years)

The calculated draw-down influence in the Second Stage of Case 3 is shown in Fig. I-7.5.8 and Fig. I-7.5.9.

a. Area A

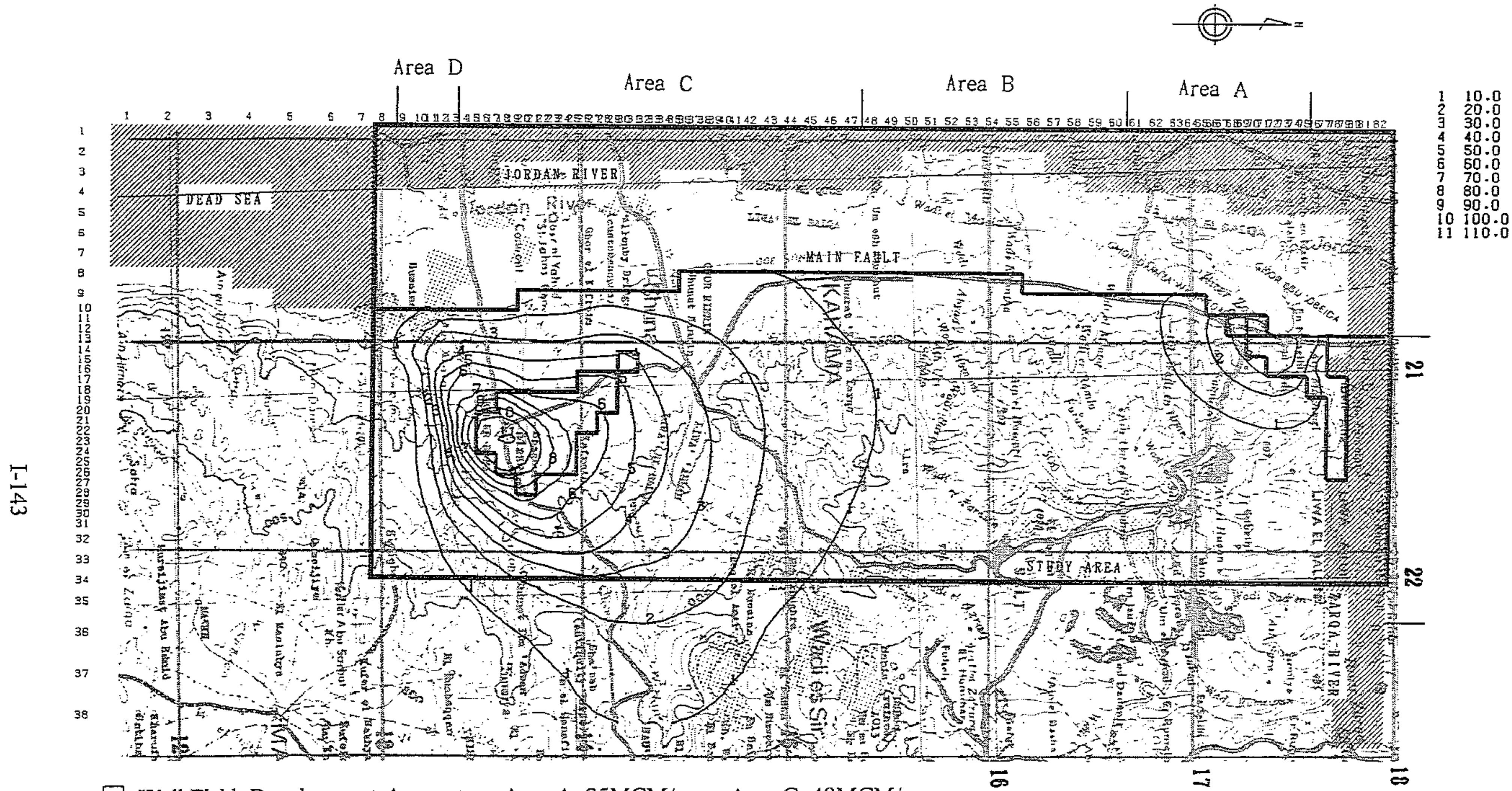
The maximum draw-down of the Zerqa Group aquifer is about 40 m in the well field and the influence distance of 10 m draw-down is about 6 km as shown in Fig. I-7.5.8.

The draw-down influence cannot be detected in the Kurnub Sandstone aquifer.

b. Area C

The maximum draw-down of the Zerqa Group aquifer is about 120 m in the well field and the influence distance of 10 m draw-down is about 9 km as shown in Fig. I-7.5.8.

The drawdown of the Kurnub Sandstone aquifer is around 40 m at the well field and the influence area of 10 m drawdown extends 12 km from the well field as shown in Fig. 7.5.9.



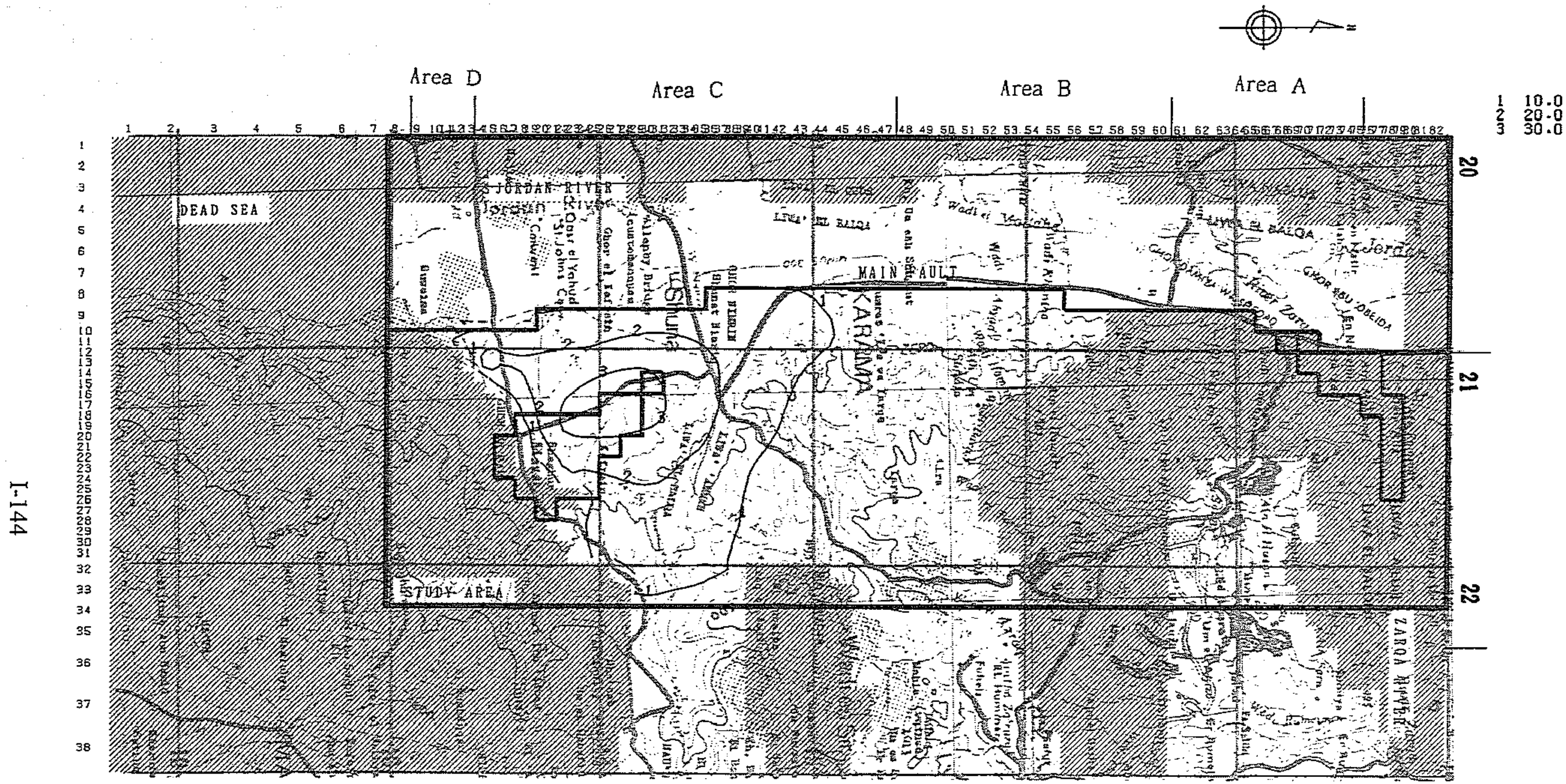
☐ Well Field, Development Amount .... Area A: 25MCM/year, Area C: 40MCM/year
Simulation period: after 25 years

STEP: 2 - 80
TIME : 9125.000

DRAWDOWN LAYER: 2

MODFLOW < CASE2 65MCM >

Fig. I-7.5.6 Drawdown Influence on the Zerqa Group Aquifer in Case 2 (end of the Second Stage)



☐ Well Field, Development Amount .... Area A: 25MCM/year, Area C: 40MCM/year
Simulation period: after 25 years

STEP: 2 - 80
TIME : 9125.000

DRAWDOWN LAYER: 1

5000 M

MODFLOW < CASE2 65MCM >

Fig. I-7.5.7 Drawdown Influence on the Kurnub Sandstone Aquifer in Case 2 (end of the Second Stage)

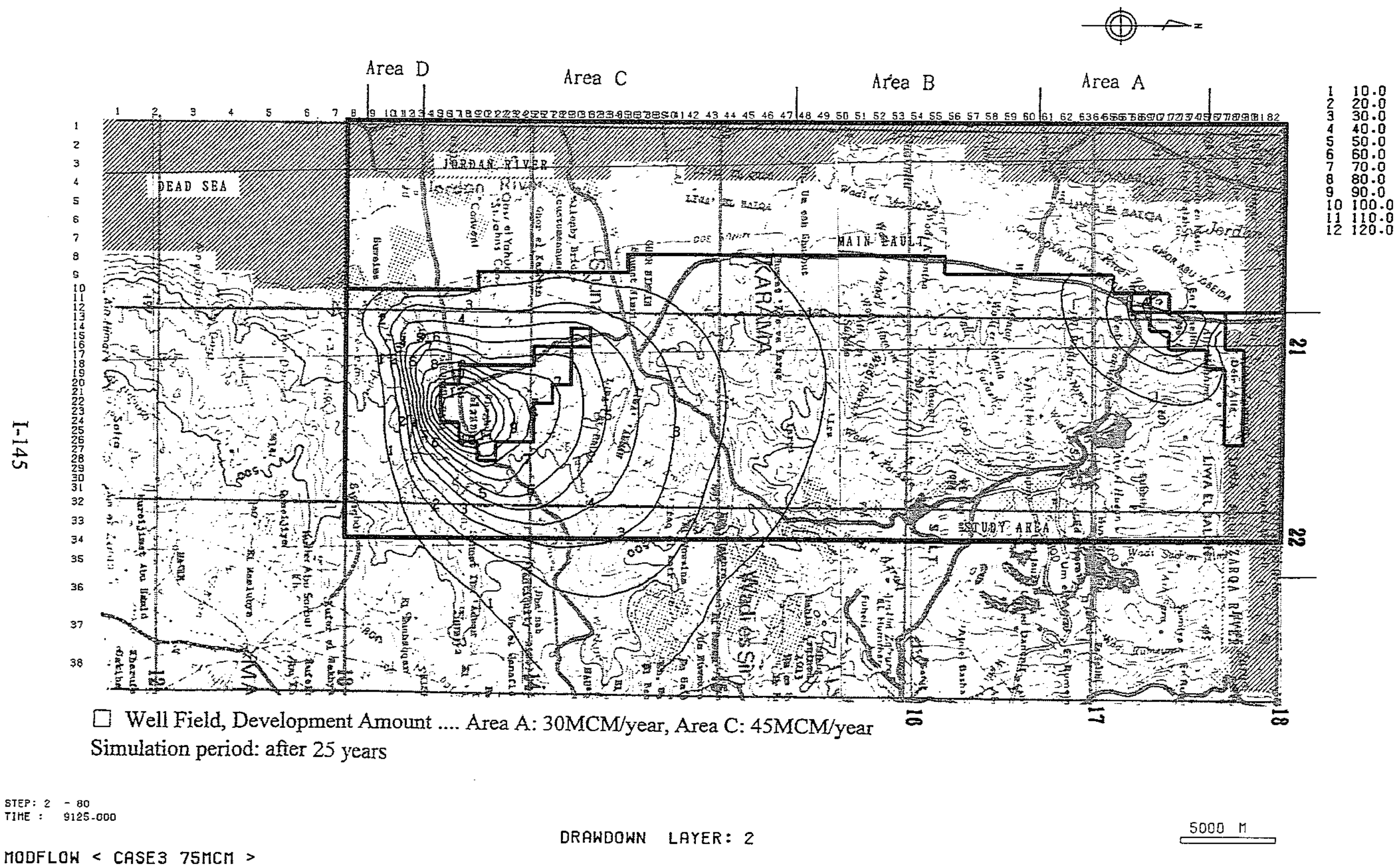
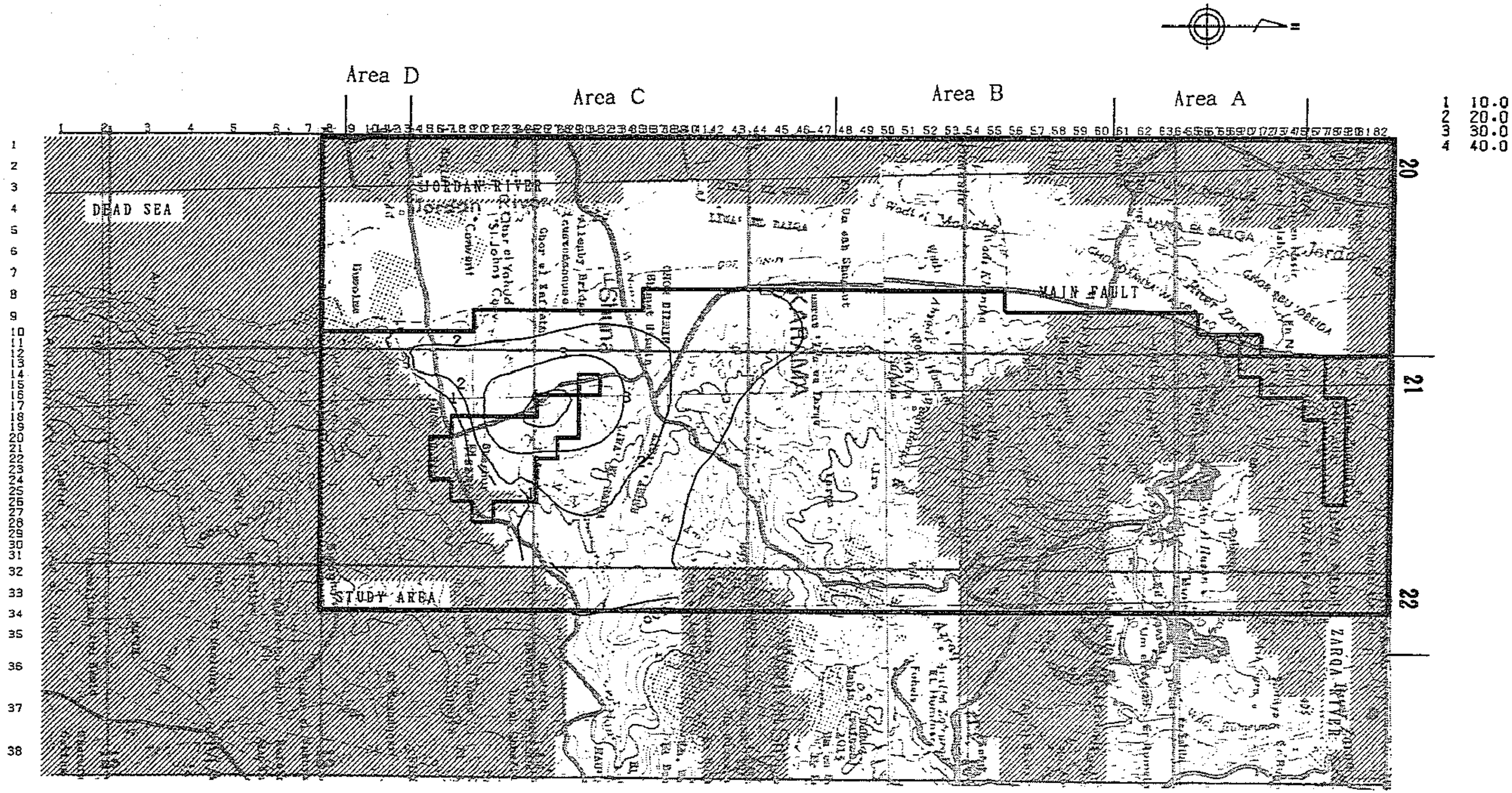


Fig. I-7.5.8 Drawdown Influence on the Zerqa Group Aquifer in Case 3 (end of the Second Stage)



☐ Well Field, Development Amount .... Area A: 30MCM/year, Area C: 45MCM/year

Simulation period: after 25 years

STEP: 2 - 80
TIME : 9125.000

DRAWDOWN LAYER: 1

5000 M

MODFLOW < CASE3 75MCM >

Fig. I-7.5.9 Drawdown Influence on the Kurnub Sandstone Aquifer in Case 3 (end of the Second Stage)

(4) Case 4 (Total 90 MCM/year, after 25 years)

The calculated draw-down influence in the Second Stage of Case 4 is shown in Fig. I-7.5.10 and Fig. I-7.5.11.

a. Area A

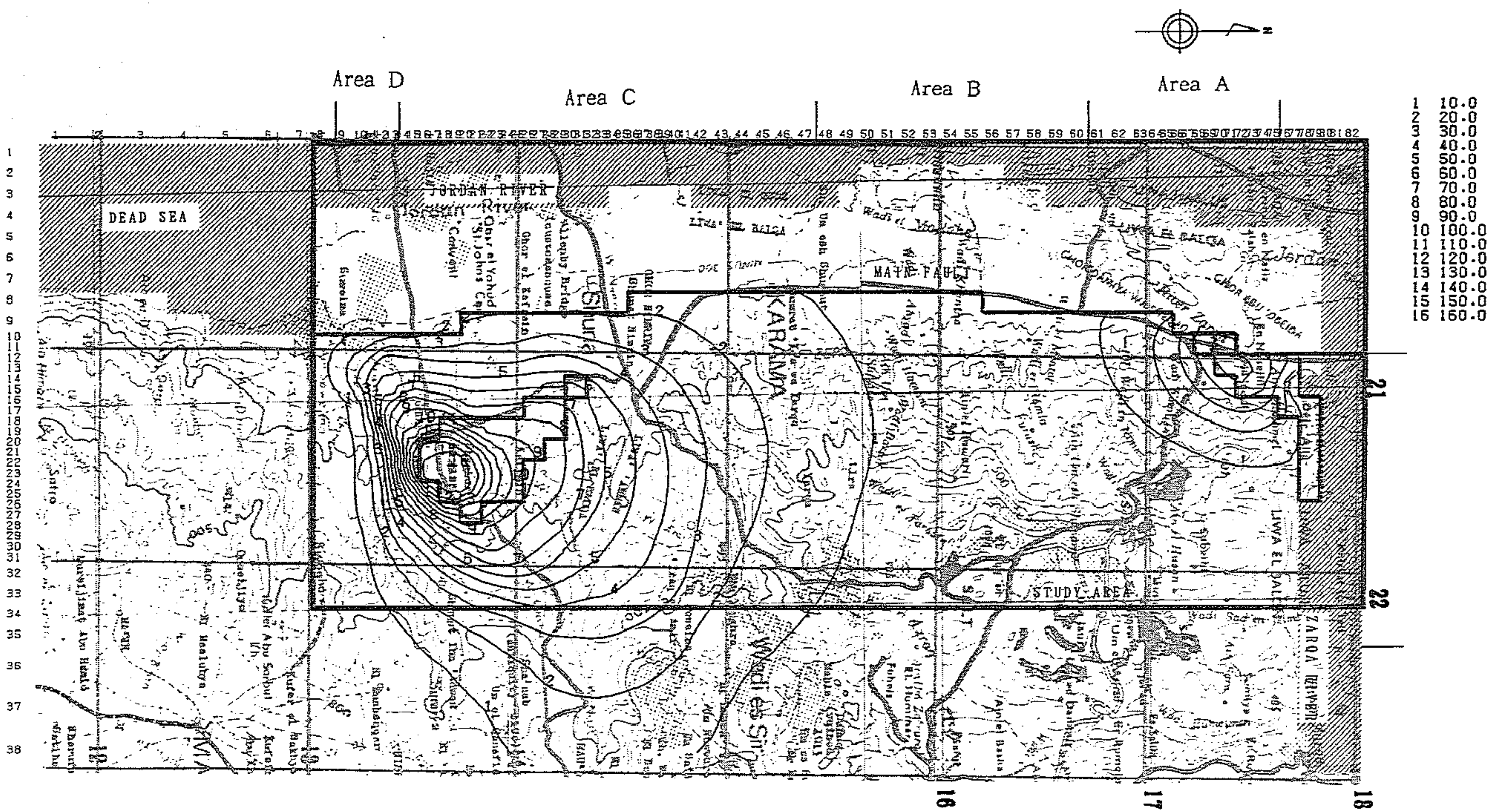
The maximum draw-down of the Zerqa Group aquifer is about 50 m in the well field and the influence area of 10 m draw-down is about 7 km as shown in Fig. I-7.5.10.

The draw-down influence cannot be detected in the Kurnub Sandstone aquifer.

b. Area C

The maximum draw-down of the Zerqa Group aquifer is about 160 m in the well field and the influence distance of 10 m draw-down is about 20 km as shown in Fig. I-7.5.10.

The draw-down of the Kurnub Sandstone aquifer is around 50 m at the well field and the influence area of 10 m draw-down extends 15 km from the well field as shown in Fig. I-7.5.11.



☐ Well Field, Development Amount .... Area A: 35MCM/year, Area C: 55MCM/year

Simulation period: after 25 years

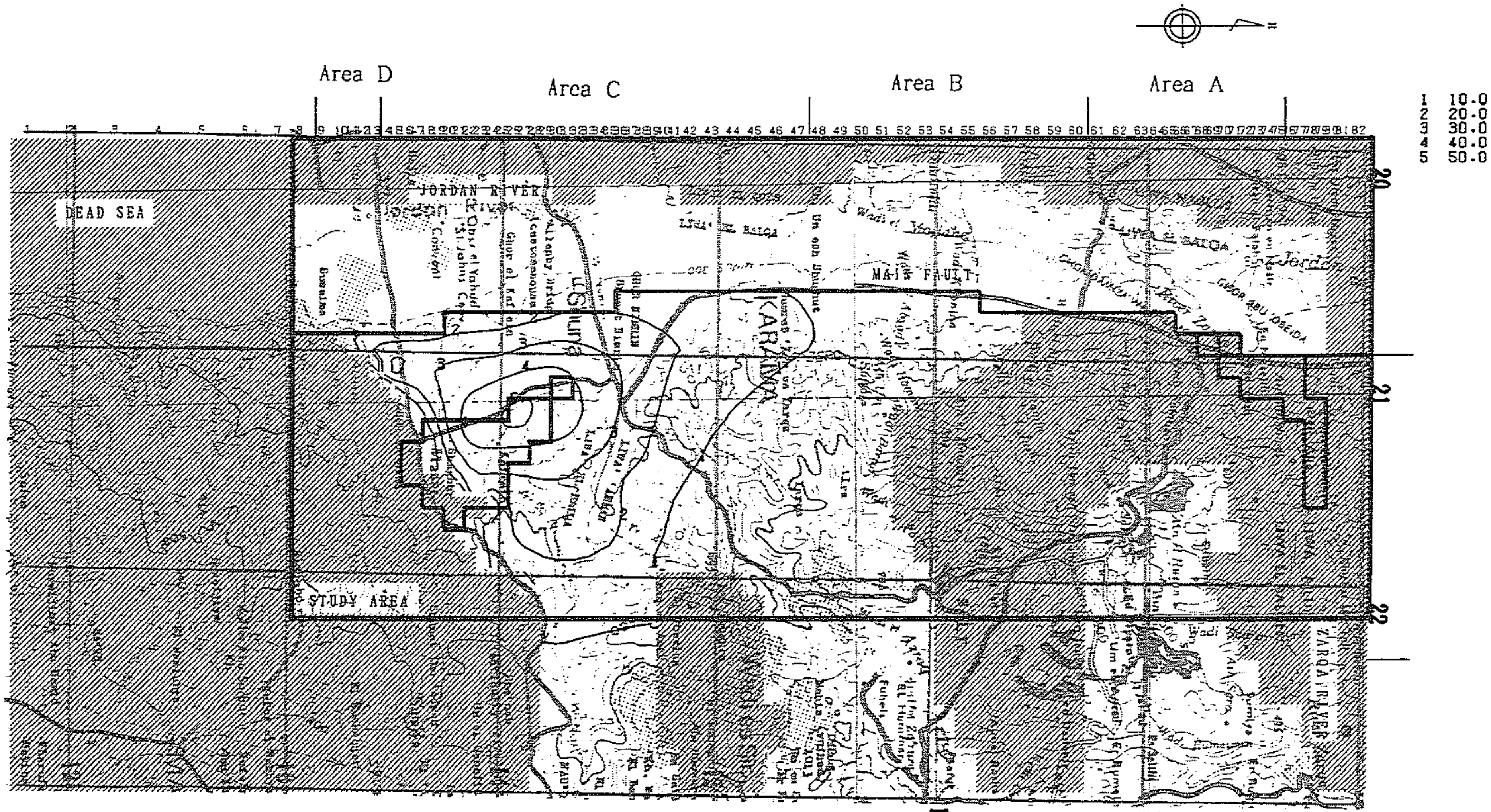
STEP: 2 - 80
TIME : 9125.000

DRAWDOWN LAYER: 2

5000 M

MODFLOW < CASE4 90MCM >

Fig. I-7.5.10 Drawdown Influence on the Zerqa Group Aquifer in Case 4 (end of the Second Stage)



☐ Well Field, Development Amount .... Area A: 35MCM/year, Area C: 55MCM/year
Simulation period: after 25 years

STEP: 2 - 80
TIME : 9125.000

DRAWDOWN LAYER: 1

5000 M

MODFLOW < CASE4 90MCM >

Fig. I-7.5.11 Drawdown Influence on the Kurnub Sandstone Aquifer in Case 4 (end of the Second Stage)