central part of the Jafr basin, and 4,000 to 6,000 micromho/cm in the east of the "Karak Wadi Al Fiha fault". The E.C value is as low as 400 to 1,100 micromho/cm in the northern part of the Salwan fault, while it rises to 1,800 micromho/cm in the east of the "Karak - Wadi Al Fiha" fault. The values of T.D.S follow the same pattern, showing T.D.S of 390 mg/l at JT-1, 635 mg/l at JO-3, and 1,171 mg/l at JO-5. Three groups of the quality types are plotted on the Piper's tri-linear diagram, including i) "carbonate hardness" at Western Highlands and western part of upper Hasa basin, ii) "no one cation-anion pair exceeds 50 %" at central part of the Jafr basin and eastern part of upper Hasa basin, iii) "non carbonate alkali exceeds 50 %" at eastern part of Jafr basin. Groundwaters are pure and fresh in the Western Highlands, slightly saline in the central part of the Jafr basin, and saline in the eastern part of the Jafr basin. The regional water salinity (E.C) of the B2/A7 is mapped in the Fig.3.24.

3.5.4 Rijam (B4) aquifer

Flood flows, which are impounded temporarily in the lower reaches of wadis on the B4 formation, are the main source of groundwater recharge. Water salinity in the flood water is as low as less than 400 micromho/cm of E.C, while it increases from west to east in B4 aquifer. The E.C value is 600 micromho/cm in the recharging area and 1,800 micromho/cm in and around the eastern aquifer limit.

In the central Rijam groundwater basin, where intensive groundwater irrigation has been carried out by local farms in and around the Al Jafr town since 1966, the E.C increased from 500 micromho/cm to 2,000-5,200 maximum. The VLF survey was carried out in and around the irrigated land, to delineate the areal extent of the contamination by irrigation return flow. The apparent resistivity in the shallow Rijam (B4) aquifer is as low as less than 10 ohm-m in and around J-1 and J-17 where intensive groundwater irrigation has been performed using the wells in the farms, while it is as high as more than 100 ohm-m in the surrounding areas where no intensive irrigation has been carried out. From the resistivity map in Fig.4.61, it is interpreted that the polluted area and/or aquifer has a limited extent which corresponds to the areal limit of the irrigated land. Fig.3.25 shows the regional water salinity (E.C) of the Rijam (B4).

3.6 Model Simulation Study

3.6.1 Model construction

Regional groundwater flows in the aquifers of both B2/A7 and A1-6 are confined by three major faulting structures, "Karak - Wadi Al Fiha" fault, "Salwan" fault and "Arja - Uweina" flexure. These faults are complicated in their structures with irregular boundaries. The finite element method (FEM) is used to interpret the complicate boundary conditions in the simulation models. Aquifer hydraulics are also complicated by inclusion of both unconfined and confined conditions in the single aquifer unit. The UNISSF groundwater model takes account of the following hydrogeological data:

- Elevation contours of ground surface
- Geological structure; Elevation contours of the bottom of the aquifer
- Geological structure; Elevation contours of the top of the aquifer
- Boundary conditions
- Regional permeability and storage coefficient / specific yield
- Initial (static) piezometric surface
- Groundwater hydrograph of monitoring well
- Pumping record and program

The simulation model is based on diffusion type of partial equations with linear and non-linear steady-state and transient conditions. Potential analysis was carried out by using FEM/UNISSF simulation model including the following;

- Steady state calibration of B2/A7 and A1-6 aquifer models.
- Non-steady calibration and prediction of B2/A7 aquifer model.

3.6.2 Mathematical models

Groundwater flow in the aquifers of the Jafr basin are assumed to be governed by the a two dimensional non-steady equation, which is based on a diffusion type of the partial differential equation with no-linear parameters of hydraulic conductivity and specific strativity. The governing equation of the two dimensional groundwater flow is described below.

$$S(h)\frac{dh}{dt} + \frac{d}{dx}\left(T_x(h)\frac{dh}{dx} \right) + \frac{d}{dy}\left(T_y(h)\frac{dh}{dy} \right) = q$$

where S : coefficient of storage

T_x, T_y : coefficient of transmissivity in x, y directions

q : discharge/recharge per unit time

t : time

h : head

The equation above can be applied to a multi-layered aquifer by considering T and S as functions of the groundwater head.

<u>Confined aquifer</u>

$$T = \sum_{i=0}^{n} K_i\, b_i$$

$$S = \sum_{i=0}^{n} Ss_i\, b_i$$

<u>Unconfined aquifer</u>

$$T = \sum_{i=0}^{n} K_{i-1}\, b_{i-1} + K_i(h - h_{i-1}) \quad (h_{i-1} < h < h_i)$$

$$S = Sy_i + \sum_{i=0}^{n} Ss_{i-1}\, b_{i-1}$$

where K_i : coefficient of infiltration capacity of i-layer

Ss_i : coefficient of specific storage i-layer

Syi : specific yield of i-layer

b_i : thickness of i-layer

The numerical analysis of the simulation model was performed by finite element method (FEM), which is now widely used to solve regional aquifer problems.

The partial differential equation is formulated by the Galerkin finite element procedure, which is basically a rule for reducing the governing partial differential equations to a matrix statement involving a matrix of the unknown state variables.

The numerical solution of the matrix statement is accomplished by the band matrix method, which is mainly used for matrix calculations by the computer to save the computational time and memory.

3.6.3 Steady state calibration of A1-6

The finite-element grid mesh of A1-6, which is composed of tri-angular and/or quadrilateral elements, includes 223 elements with 231 nodes. The mesh map was designed to delineate the finer geological structures of "Karak - Wadi Al Fiha" fault, "Salwan" fault and "Arja - Uweina" flexure. These faulting structures require finer mesh grids as shown in Fig.3.26.

The boundary conditions are either of the specified-flow or specified-head type. Nodes along the western basin boundary, where average annual rainfall exceeds 150 mm in the outcrop area , are of specified-head type of the boundary condition. The specified-flow of the outflow type is given to the node along the eastern boundary of the model, where groundwater flows out to the further east-northeast areas. There is neither springs nor pumping wells from the A1-6 aquifer.

The steady state model was calibrated by comparing the difference between the piezometric surface in the monitoring well (JT-3; EL=877 m) and the computed head on the corresponding node (No.89; El=870 m). Fig.3.27 shows the calibrated piezometric surface and the computed regional flow vector.

3.6.4 Steady state calibration of B2/A7

The finite-element grid mesh of the B2/A7, which is composed of triangular and/or quadrilateral elements, includes 386 elements with 361 nodes. The mesh map is designed to delineate the complicated linearment with discontinuous faulting structures including "Karak - Wadi Al Fiha" fault, "Salwan" fault and "Arja - Uweina" flexure. These discontinuous faulting structures require finer mesh grids as indicated in Fig.3.28.

The boundary conditions are either of the specified-flow or specified-head type. Nodes along the western basin boundary, where average annual rainfall exceeds 150 mm in the outcrop area, are of specified-head type of the boundary condition. The specified-flow of the outflow type is given to the node along the eastern boundary of the model, where groundwater flows out to further east to northeast. Water balance of the simulated model through the boundaries is estimated at approximately +/- 16 MCM per annum. Spring waters from B2/A7 aquifer are located in the Western Highland of the Jafr basin, which are estimated to yield approximately 0.75 MCM per annum. From the surface runoff simulation analysis using the tank model method, groundwater recharge through the wadi beds on the outcrops of B2/A7 in the Jafr basins estimated at approximately 6.7 MCM per annum.(See Section 3.2 of this chapter)

The steady state is based on the simple assumption that there are no artificial abstractions from the target aquifer. A semi-steady state condition is assumed to calibrate the simulation model, which is based on assumptions that artificial abstractions does not exceed the annual average groundwater recharge without any influences on the regional piezometric surface. It is assumed that the piezometric surface in the study area was in a steady state and/or semi-steady state before 1970.

The steady state model was calibrated by comparing the difference between the piezometric surface in the monitoring wells (JO-5; EL=724m, JT-4; EL=785m, S-121;988m, JT-1; EL=880m, JO-3; EL=790m, JT-2; EL=794m, S-111; EL=1,179m, S-65; EL=1,193m, S-118; EL=1,271m) and the computed head on corresponding mesh nodes (No.50; EL=728m, No.87; EL=741m, NO.94; EL=990m, No.114; EL=884m, No.128; EL=772m, No.160; EL=804m, No.185; EL=1,176m, No.197; EL=1,202m, No.214; EL=1,277m). Fig.3.29 shows the calibrated piezometric surface and the computed regional flow vector.

3.6.5 Non-steady calibration and predictions of B2/A7

Successive decreases in the piezometric head have been monitored in the WAJ monitoring well at S-121 (Palestine grid; E=228.70, N=002.08) since 1973. The non-steady state model assumes that the regional piezometric surface was in a steady state and/or semi-steady state before 1973. Fifteen years of monitoring records (1973-1988) are used to calibrate the computed piezometric head. The calibrated storage coefficient in and around the S-121 is in the range between 1.4×10^{-4} and 5.2×10^{-5}, while the coefficient of permeability is in the range between 1 and 0.1 m/day. The computed drawdown from 1973 to 1988 is estimated at 8.4 m, which is 98 % of the measured drawdown of 8.3 m in the monitoring well S-121. The calibrated non-steady piezometric surface by the year 1988 is shown in Fig.3.30.

3.6.6 Model predictions

The simulation model predicts the influences of future groundwater exploitation such as at "South Hasa" and "East Ma'an" on the regional groundwater flows. (See Fig.3.31) Each experimental wellfield assumes production wells of 10 to 20 in number with a unit pumping rate at 0.5 to 1 MCM/y located at a distance from each other of 1 to 2 km. From the model analysis, which assumes the abstraction of 10 MCM/y from each proposed wellfield, the piezometric surface is estimated to be lowered by 40 to 55 m in the "South Hasa" wellfield and 25 to 30 m in the "East Ma'an" wellfield by the year 2010 and 2040. The estimated piezometric surface after 20 and 50 years pumping is shown in Figs.3.32 and 3.33. The estimated drawdown at representative mesh nodes in each wellfield are shown on Fig.3.34.

The model prediction also includes the alternative studies on the groundwater recharge dam. The conjunctive development study is also carried out by using the simulation model. The model is based on groundwater exploitation by coupling with the two groups of recharge dams such as A1-2-3 and B1-2-3 which assume the commencement of the impounding in 1993 with net infiltration capacity of 5.2 MCM and 3.2 MCM per annum respectively. The piezometric levels in and around the damsites are estimated to be raised by 5 to 10 m after 20 and 50 years pumping by adding the groundwater recharge dams, of which contour maps are shown on Figs.3.35 and 3.36. The estimated changes in the piezometric surface in and around dam sites are shown on the groundwater profile of Fig.3.37.

REFERENCES (3-1/2)

3.1 Water Authority of Jordan, April 1986,"Professional Paper No.3, Rainfall Intensity - Duration - Frequency in Jordan"

3.2 Bureau of Reclamation, the United States Department of the Interior,"Design of Small Dams"

3.3 German Agency for Technical Cooperation Ltd.,Federal Republic of Germany,July 1977,"National Water Master Plan of Jordan", Vol.III,Surface Water Resources

3.4 Binnie and Partners et.al., Jordan Valley Authority, January 1979,"Mujib and Southern Ghors Irrigation Project, Appendices to Feasibility Report, Vol.I, Appendix B"

3.5 Water Authority of Jordan, October 1988, "Prefeasibility Study for Selected Dam Site in El-Jafr Basin"

3.6 Howard Humphreys Ltd., Natural Resources Authority, January 1986,"Groundwater Resources Study in the Shidiya Area, Report"

3.7 Harza Overseas Engineering Company, Jordan Valley Authority, March 1982, "The Raising of King Talal Dam, Preliminary, Design Report"

3.8 Harza Overseas Engineering Company, Jordan Valley Authority, January 1978,"Jordan Valley Irrigation Project, Stage II, Feasibility Study,Vol.II, Appendix A"

3.9 Japan International Cooperation Agency (JICA), Jordan Valley Commission, November 1976, "Feasibility Report on Wadi Arab Dam and Irrigation Project, Annexes"

REFERENCES (3-2/2)

3.10 Japan International Cooperation Agency (JICA), Water Authority of Jordan, July 1987, "Hydrogeological and Water Use Study of the Mujib Watershed, Final Report, Appendix(I)"

3.11 Abu Ajamieh,M.M., 1967, "A Quantative Assessment of the Groundwater Potential of the Rijam Formation Aquifer in the Jafr Basin", UN Special Fund - FAO, Sandstone Aquifers of East Jordan Project Report, Amman

3.12 United Nation (FAO), 1970, "Investigation of the Sandstone Aquifers of East Jordan, Main Report and Annex I"

3.13 German Agency for Technical Cooperation Ltd., Federal Republic of Germany, 1977, "National Water Master Plan", Vol.I,II,III,IV,V,VI and VII

3.14 Howard Humphreys, 1986, "Groundwater Resources Study in the Shidiya Area"

IV. ALTERNATIVE DEVELOPMENT STUDY

IV. ALTERNATIVE DEVELOPMENT STUDY

4.1 Dam Planning

4.1.1 Storage dam

A study on the wadis in the Jafr basin was made to identify the best construction sites of dams for the purpose of water supply for irrigation use and livestock husbandry, water supply to local people, a phosphate mine in Shidiya and a stone mine in Ma'an, flood protection of local areas, creation of recreation sites and artificial recharge of groundwater. (Ref.4.1)

The wadis on which the construction of a dam is proposed are wadi Jurdhan, wadi Abu Safat, wadi Usheishat, wadi Matkh, wadi Fassua, wadi Abyad, wadi Uqeiqa and wadi El Jahdaniya. Among these dams, the dams proposed at wadi Jurdhan and wadi Abu Safat are planned to have their catchments increased by diversion of streamflow from nearby small wadis. The main features of the proposed dams are shown in Table 4.1.

4.1.2 Recharge dams

A. <u>General</u>

Altogether eight recharge dams (A-1,A-2,A-3,B-1,B-2,B-3,and C-1,C-2) are planned to recharge B2/A7 aquifers by infiltration along riverbeds in the western watershed where the pervious B2 formation outcrops directly. (See Figs.4.1 to 4.4)

From the results of the hydrogeological survey conducted by JICA team, the B2/A7 aquifers to be recharged by the recharge dams (A-1,A-2,A-3 and B-1,B-2,B-3) are known to be saturated while all wells existing downstream from the planned recharge dams (C-1 and C-2) are known to be nearly dry with low water table and poor in water quality, of which improvement is considered far from attainable even by groundwater recharge by the recharge dams (C-1 and C-2). Therefore, the construction of recharge dams (C-1 and C-2) are considered not feasible and are excluded from further study.

B. Affect on localities and a WAJ's existing study of dam

The recharge dams A-3 and B-3 are planned in adjacent upstream catchment areas of reservoirs conceived by an ongoing surface water resources study (Ref.1). Hence, flood flows which are spilt from the proposed recharge dams A-3 and B-3 should be designed to be diverted to the catchment areas of the said surface water resources study to raise the catchment capacity of the downstream reservoir projects.

By the construction of recharge dam A-1, agricultural land and roads will be submerged. By the construction of recharge dam B-2, roads and railway will be submerged.

As for water requirements in areas to the west of the Al Jafr town, a sufficient amount of surface runoff is considered still available from the basin downstream from the recharge dams A-1, A-2 and A-3 even after construction of these recharge dams,judging from a water balance calculation of long-term average annual runoff (See Fig.4.1).

C. Dam Type

As for the type of recharge dams, two kinds of dam type are generally conceivable for the selected recharge dam sites, namely, a concrete gravity dam and a fill dam. Though more detailed site investigation has still to be performed before final selection of dam type, the following information common to all the recharge dam sites will be very helpful in preliminary selection:

1) Bed rock consisting of silicified or marly limestone, chert and phosphate of the B2 Formation has sufficient bearing capacity for construction of a concrete gravity dam of more than 15 m in height.
2) The alluvial wadi deposits covering a part or whole of the proposed recharge dam foundations is up to 5 m thick except for B-2 recharge

dam site where a limited part of the wadi beds is covered by alluvial deposits of 5 to 10 m in thickness and the cost for excavation of foundations for a concrete gravity dam might be relatively low.

3) Construction materials for a fill dam such as rock and impervious soil are available sufficiently near the proposed recharge dam sites. Construction materials for a concrete gravity dam such as concrete and gravel are also locally available.
4) Generally, unlike a fill dam which requires the firm rock abutment for a spillway, while the spillway of a concrete gravity dam can be integrally with the dam body, which may reduce excavation costs.
5) As shown in a Japanese design standard for dams the requirement for freeboard at the crest of a concrete gravity dam is lower by 1 m than that of a fill dam, since a fill dam would be far more sensitive to overtopping than a concrete gravity dam.

D. <u>Reservoir Storage Capacity</u>

The reservoir storage capacity of the recharge dams (A-1, A-2, A-3 and B-1,B-2,B-3) was determined from the following relations, using the calculated inflow discharges for the 23-year period between 1963/64 and 1985/86.

$$S(i) = S(i-1) + Q(i) - R(i) - E(i)$$

and

$$S(i) = SD(i), \text{ if } S(i) < SD(i)$$

$$SW(i) = S(i) - SD(i)$$

where

S(i) : Gross storage volume including sediment at the end of i-th day

S(i-1) : Gross storage volume including sediment at the end of (i-1)th day

SD(i) : Sediment volume at the end of i-th day

SW(i) : Reservoir water volume at the end of i-th day

Q(i) : Inflow at i-th day

R(i) : Infiltration at i-th day estimated by the Wedernikow's formula in Section 3.5.2. Effective infiltration is assumed to be a half of that estimated by the Wedernikow's formula because of reservoir sedimentation.

E(i) : Evaporation at i-th day which is based on evaporation records of the Udruh climatological station.

The required gross storage capacity is determined as the sum of (1) maximum annual inflow excluding sediment (or effective storage capacity) during 23 years and (2) 50-year cumulative sediment volume so that the largest flood between 1963/64 and 1985/86 can be completely retained by the proposed reservoir. Accordingly, the gross storage capacity is estimated as shown on Table 4.2. It is worth mentioning that the scale of the recharge dams is determined based on 23-year-long streamflow data in which at least two climatic cycles are considered to be reflected on. Generally, a climatic cycle period in Jordan is considered to be about 10 years, being affected by the activity of sunspots.

On Table 4.2, also shown are such items as catchment area, annual average inflow into reservoir, evaporation from reservoir surface, effective storage capacity,dam height ,dam concrete volume and cost of concrete dam body excluding cost of land acquisition and relocation of road,railroad and house under assumption that dam type is concrete gravity dam with vertical upstream slope, downstream slope of 1 vertical to 0.8 horizontal and crest width of 10 m.

4.2 Groundwater Development Plan

4.2.1 Lower Ajlun (Al-6) Aquifer

The highly confined groundwater in the lower Ajlun (Al-6) remains untapped. The aquifer will be promising in the area to the north of the Salwan fault, however, of which potential is preliminarily estimated at 5 to 10 MCM/y with excellent water quality with T.D.S. of less than 350 mg/l. The "East Hasa" wellfield, which is located in and along the wadi Rigl, is proposed to examine the aquifer potential in the simulation model. The model assumes the group of production wells 10 to 20 in number with pumping rate at 0.5 MCM/y each. The depth of the wells is in the range between 350 to 500 m. Grouting will be made in the section of B2/A7, to maintain the high aquifer pressure of 30 kg/cm^2 from the A1-6. The locality of the proposed "East Hasa" , which is 40 km to the southeast of the desert highway (Hasa town) and 160 km to the south of Amman, may still be in a range of economic distances. (See Fig.4.5)

4.2.2 Amman - Wadi Sir (B2/A7) aquifer

Abstractions from the unconfined B2/A7 aquifer in the Hasa mining area is estimated at 7 MCM/y in 1988, which is the approximate limit of the safe yield. Wellfield management will be needed to sustain the development in very near future. More concentrated groundwater monitoring will be required to control the aquifer life in and around the Hasa mine.

In the Western Highlands in the Jafr basin, it is estimated that the abstractions from the existing wells is 9.35 MCM/y. No serious regional drawdowns have been recorded in the WAJ monitoring wells except the Shoubak well. The Western Highlands are a major source of the groundwater recharge to the B2/A7 aquifer. The groundwater recharge dams such as A-1-2-3 and B-1-2-3 will increase the potential of groundwater resources in the Western Highlands.

In the area to the east of the Desert Highway, the groundwater in the confined B2/A7 aquifer is untapped. From the model simulation study, two potential wellfields tentatively called "East Ma'an" and "South Hasa" are proposed to coordinate with the increase in the water demands in the regions and/or the entire Kingdom of Jordan. "East Ma'an" wellfield, which is located about 20 km to the north of the Shidiya mine, is estimated to produce 5 to 10 MCM/y by installing production wells 10 to 20 in number with a depth of 250 m each. "South Hasa" wellfield, which is situated 10 km to the south of the Hasa town, is also estimated to produce 5 to 10 MCM/y by installing production wells 10 to 20 in number with depths of 350 m each. These two experimental wellfields are located about 1 to 15 km distant from the route of the national water carrier (Disi - Mudawwara - Amman route, proposed by WAJ).(See Fig.4.5)

4.2.3 Rijam (B4) Aquifer

The sustained yield of the Rijam (B4) aquifer is evaluated to be as small as less than 2 MCM per annum, due to the limited groundwater recharge through the wadi beds during the occasional floods. No extensive exploitation will be recommended without counter-measures to protect the salt accumulation in both surfacial soils and underlying aquifer of B4. Groundwater use for the irrigation purposes is not promising without counter-measures such as desalination of groundwater and/or replacing the irrigation method from the existing gravity flow to the drip method.

4.3 Conjunctive development plan

The average annual runoff at the proposed recharge dam sites is estimated at 8.7 MCM/y in total, consisting of 5.4 MCM/y in group-A and 3.3 MCM/y of group-B. The recharge dams are located in the outcrop area of the B2/A7 which are highly pervious with fissures, open cracks and caves. Volume of infiltration through the reservoir is estimated to be equal to the average annual inflow minus annual evaporation from the reservoir surface.

The group-A dams, of which infiltration capacity is estimated at 5.2 MCM/y, will be significant source of the groundwater recharge in the northwestern part of the Western Highlands where intensive agricultural development is being practiced.

The group-B dams, of which infiltration capacity is estimated at 3.2 MCM/y, are located in an area in the southwestern part of the Western Highlands where water is taken both for irrigation and water supply to the Ma'an city from the wells in the B2/A7 aquifer.

These recharge dams may act as a significant source for increasing the potential of groundwater in the B2/A7. The recharge dam development scheme will be incorporated in the future groundwater development in the Western Highlands. (See Fig.4.5)

REFERENCES (4)

1. Water Authority of Jordan, October 1988,"Prefeasibility Study for Selected Dam Sites in El-Jafr Basin"

V. SALT ACCUMULATION PROBLEMS IN RIJAM (B4) AQUIFER

V. SALT ACCUMULATION PROBLEMS IN RIJAM (B4) AQUIFER

5.1 Present Conditions

At Al Jafr town in the central Jafr basin, irrigation has been practiced by pumping groundwater from shallow unconfined aquifers in the Rijam (B4) formation since 1965. Since around 1971, salinity of the Rijam (B4) aquifer increased. The yield has already become unsuitable for irrigation use on farmland at Al Jafr town. (See Fig.5.1) At the Jafr No.17 well located in the farmland, salinity increased from 500 ppm to 2,000 ppm after 6 years of pumping and reached 3,400 ppm in 1975 (See Figs 5.1 and 5.2). Because of the saline contamination of the aquifer, two wells in the farmland have been temporarily abandoned and the pumping amount of other wells have been decreased.

5.2 Mechanism of Salinity Accumulation

Where saline contamination has become a serious problem, the Rijam (B4) aquifer is intercalated between the Alluvium layer and the impervious Muwaqqar (B3) formation. The part near the ground surface of the Alluvium layer is a root zone where plants are able to absorb water for growth (See Fig.5.3).

With downward movement of the irrigation water, salt is transported to the root zone. Once a year before sowing, initial leaching is conducted to remove concentrated salt from the root zone. Annually, about 10 % of leaching water is considered to reach the saturated Rijam (B4) aquifer as deep percolation. This is based on agronomic findings that 10 % in volume of the pores in the unsaturated soil layer below the root zone is pores of a size larger than several microns through which free movement of pore water is possible, not being surrounded by capillary pores, and the remaining 90 % is capillary pores with the size less than several microns in which free movement of pore water is impossible due to capillary attractions. The remaining 90 % of leaching water is trapped in the unsaturated soil layer underneath the root zone.

The VLF (Very Low Frequency) survey conducted by JICA study team in 1988 has shown that the salinity-affected aquifer is known to be quite limited and stagnant in movement in the horizontal direction; transmissivity of adjacent salinity-less B4 aquifers which are situated west of the salinity-accumulated aquifer is 50 m^2/day and is considered to contribute to dilution of the salinity-accumulated aquifer

Accordingly, it is assumed that accumulation of salinity in the Rijam (B4) aquifer is caused by the annual 10 % of leaching water which transports salt accumulated at the root zone by irrigation water together with salt contained in the 10 % of leaching water itself, while the salinity-accumulated aquifer is continually diluted by adjacent salinity-less aquifers.

5.3 Simulation of Salinity Accumulation

Based on the conditions described in Section 5.2, a simulation model of salinity accumulation of the Rijam (B4) aquifer is constructed as shown in Fig.5.3. T.D.S. of the salinity-accumulated Rijam (B4) aquifer is derived from the equations as follows.

$$W31(i) = W32(i-1) + I2(i) + I3(i) + I4$$
$$W32(i) = W31(i) - I5(i)$$
$$H32(i) = W32(i)/A2/B/SY \times 100$$

and

$$I2(i) = Q1(i) \times A1 \times X1(i)$$
$$I3(i) = Q2 \times Y/100 \times X1(i) \times A1/1000$$
$$I4 = TR \times 365 \times W \times X4/10^6$$
$$I5(i) = (Q2 \times Y \times A1/100 + TR \times 365 \times W/1000) \times H31(i)/1000$$

where

W31(i) (ton) : Cumulative salt content of the salinity-accumulated Rijam (B4) aquifer before dilution at the end of i-th year

W32(i) (ton) : Cumulative salt content of the salinity-accumulated Rijam (B4) aquifer after dilution at the end of i-th year

H32(i) (ppm) : T.D.S.of the salinity-accumulated Rijam (B4) aquifer at the end of i-ty year

I2(i) (ton) : Transport of salt contained in irrigation water to the salinity-accumulated Rijam (B4) aquifer during i-th year

I3(i) (ton) : Transport of salt contained in leaching water to the salinity-accumulated Rijam (B4) aquifer during i-th year

I4 (ton) : Transport of salt contained in neighboring salinity-less aquifer to the salinity-accumulated Rijam (B4) aquifer during i-th year

I5(i) (ton) : Salt removed from the salinity-accumulated Rijam (B4) aquifer due to dilution

Q1(i)(m/year) : Irrigation water supply during i-th year

A1 (km^2) : Irrigation area

A2 (km^2) : Area of the salinity-accumulated Rijam (B4) aquifer

B (m) : Thickness of the salinity-accumulated Rijam (B4) aquifer

SY (%) : Specific yield of the salinity-accumulated Rijam (B4) aquifer

X1(i) (ppm) : T.D.S.of irrigation water during i-th year

X4 (ppm) : T.D.S.of neighboring salinity-less aquifer

Q2 (mm/year) : Amount of leaching water

Y (%) : Rate of leaching water transformed into deep percolation which transports salt to the salinity-accumulated Rijam (B4) aquifer

TR (m^2) : Transmissivity of salinity-less aquifer around the salinity-accumulated Rijam (B4) aquifer

W (m) : Width of an assumed groundwater channel through which salinity-less groundwater flows into salinity-accumulated aquifer for dilution

In the simulation, the following parameters are assumed.

a) A1 : Area of the irrigation area = 1 km^2

b) A2 : Area of the Rijam (B4) aquifer = 1 km^2

c) B : Thickness of the saturated Rijam (B4) aquifer = 22 m

d) SY : Specific yield of the saturated Rijam (B4) aquifer (Ref.1) = 10 %

e) Q1 : Annual irrigation water requirement :

- Year 1966 to 1975 = 1.00 m/year
- Year 1976 to 1983 = 0.31 m/year
- Year 1986 to 1987 = 0.55 m/year

f) Q2 : Annual water requirement for initial leaching = 300 mm/year

g) Y : Rate of leaching water causing the salinity accumulation of the Rijam (B4) aquifer = 10 %

h) X1 : T.D.S. of irrigation water = 500 ppm

i) Initial value of T.D.S. of the saturated Rijam (B4) aquifer = 500 ppm

j) X4 : T.D.S. of adjacent salinity-less Rijam (B4) aquifer = 500 ppm

k) TR : Transmissivity of adjacent salinity-less Rijam (B4) aquifer = 50 m^2/day

l) W : Width of an assumed groundwater channel through which salinity-less groundwater flows into salinity-accumulated aquifer for dilution = 4 m

It is assumed that no leaching has been made at the irrigation area in year 1966, 1967,1968 and 1986,1987.

As a result of simulation, T.D.S.(Total Dissolved Solid) of the saturated Rijam (B4) aquifer is estimated as shown on Table 5.1.

The simulated T.D.S. values are plotted with actually recorded T.D.S values of the Jafr No.17 well and average T.D.S values over the irrigation area. (See Fig.5.2)

According to the simulation, the salinity-accumulation of the irrigation area is expected to decline to T.D.S. of about 1,000 ppm in year 2000, which is considered acceptable for irrigation use.

REFERENCES (5)

5.1 Stanley N.Davis, Roger J. M. DeWiest, John Wiley & Sons "Hydrogeology"

VI. PROJECT OPPORTUNITIES

VI. PROJECT OPPORTUNITIES

6.1 Groundwater Development

6.1.1 Deep sandstone aquifer

The deep sandstone aquifers are recognized in the argillaceous sediments in the lower Ajlun (A1-6) formation, Kurnub (K) formation, Khreim (Kh) and Disi (D) formation.

The potential aquifer of the lower Ajlun (A1-6) is found to be confined in the area between north of the Salwan fault and west of the "Karak - Wadi Al Fiha" fault. While the A1-6 is not promising in the area of the south of the Salwan fault. The locality of the proposed wellfield of "East Hasa", which is 40 km to the southeast from the Hasa town may still be in the range of economic distance to cope with both Hasa mines and/or national water carrier scheme. (See Fig.4.5)

The extent and/or distance of the outcrops of lower Ajlun (A1-6) and Kurnub (K) and the rainfall distribution on the western escarpment of the Western Highland in the area from Tafila to Shoubak may suggest a promising groundwater development in the upper Hasa groundwater basin. The feasibility study on the deep sandstone aquifers such as lower Ajlun (A1-6) and Kurnub (K), which comprises a series of test well drillings, will be required to evaluate the potential in each aquifer. Proposed sites and the design of the test well drillings are shown on Fig.6.1.

6.1.2 Amman - Wadi Sir (B2/A7) aquifer

The groundwater in the unconfined B2/A7 aquifer is being exploited in the Western Highlands and Hasa mine area by both government sector and private sector. While the confined B2/A7 is untapped in the area of the east of the Desert Highway. The B2/A7 aquifer is the main productive aquifer except the area to the east of the "Karak - Wadi Al Fiha" fault and southeastern part of the Jafr basin.

The proposed "East Ma'an" groundwater development project, which is located at linear distance with 20 km from the Shidiya phosphate mine and 15 km from the proposed route of the national water carrier (Disi-Mudawwara-Amman line), will be able to contribute to the progress in the regional economic development such as including the Shidiya phosphate mining project. Quality of the groundwater is fair in the range of water salinity in T.D.S from 700 to 800 mg/l. From the model simulation study, the potential yield is estimated at 10 MCM/y which will satisfy the part of the maximum water requirement of 20 MCM/y in the Shidiya phosphate mine development program. The purpose of water use for the Shidiya mine is, however, to wash the ore, that does not require any fresh water with low salinity. The major part of the water requirement in the mining development can be replaced by the less quality of groundwater with higher salinity such as brackish water in the deep sandstone aquifers. The life and the scale of the mining development will be discussed after examining the alternatives which include the future development of the deep sandstone aquifers in line with national water carrier. (See Fig.4.5)

The proposed "South Hasa" groundwater development project, which is situated at 10 km to the south of the Hasa town, will be able to contribute to the progress of the regional economic development such as including the Hasa phosphate mine. Quality of groundwater is excellent with water salinity in T.D.S of as low as 330 to 400 mg/l, of which the most beneficial use will be for the drinking purposes. From the model simulation study, the potential yield is estimated at 10 MCM/y. While the present consumption of 7 MCM/y of the fresh groundwater in the Hasa phosphate mine is mostly to wash the ore, that can also be replaced by water of higher salinity. A preliminary design of the proposed wellfields is shown in Fig.6.2.

6.1.3 Rijam (B4) aquifer

The sustained yield of the Rijam (B4) aquifer is evaluated to be as small as less than 2 MCM/y per annum, due to the limited groundwater recharge through the wadi beds during the occasional floods.

Groundwater irrigation in the arid area, where annual rainfall is as low as 35 mm such as at Al Jafr, is not recommended without countermeasures to reduce salt accumulations in both surfacial soils and/or underlying aquifer. The following countermeasures will help to sustain the groundwater irrigation and/or to refresh the Rijam aquifer;

a) To reduce the groundwater abstraction and/or irrigation return.
b) To replace the irrigation method from furrow gravity to drip.
c) To purify the contaminated groundwater by desalination such as by RO (Reverse Osmosis).

6.2 Recharge dams

Groundwater recharge dams were evaluated not only to increase the groundwater potential but also to dilute the water salinity in and around the area of the reservoir.

The recharge dams for A1-2-3 are designed to increase the groundwater potential in the northwestern part of the Jafr basin where extensive groundwater irrigation is being practiced privately by the farms in the Western Highlands.

The recharge dams for B1-2-3 are designed to increase the groundwater potential in the southwestern part of the Western Highlands, where groundwater is being abstracted both for local irrigation and water supply to the Ma'an city.

Priority ranking of "A" (No restricting factor), "B" (Cost effectiveness will be checked for the high dam) and "C" (Problem in compensation), which is based on the environmental aspect of compensation problem and dam cost, is examined to delineate the feasible sites for the succeeding studies. Following is the summary of ranking;

Dam	Environment Aspect	Dam Height (m)	Storage Ratio/1	Priority
A-1	Trunk road and farm land	19	66.7	"C"
A-2		18	98.1	"A"
A-3		39	62.4	"B"
B-1		20	84.0	"A"
B-2	Trunk road	19	97.4	"C"
B-3		10	212.5	"A"

Remark; /1; (Effective storage capacity)/(Dam embankment volume)

The proposed recharge dams of A2, B1 and B3 may not have any serious restricting factors, so that it is recommended to perform the succeeding feasibility studies.

From the ranking study, the A-2 recharge dam is selected to evaluate the effect of infiltration on the unconfined aquifer in the Shoubak area, where the piezometric surface is being lowered by intensive groundwater irrigation. The model simulation assumes the conjunctive development plans, which include different pumping programs for the irrigation. The model predictions comprise the following four alternatives and/or cases;

1) 3.27 MCM/y of abstraction without recharge dam
2) 3.27 MCM/y of abstraction with 1.81 MCM/y of A-2 recharge dam
3) 6.54 MCM/y of abstraction without recharge dam
4) 6.54 MCM/y of abstraction with 1.81 MCM/y of A-2 recharge dam

From the model simulation study on the alternatives 1) and 3) which assume the abstraction from existing 3.27 MCM/y to the double 6.54 MCM/y without recharge dam, a critical drawdown which will make a part of aquifer dry is predicted in some parts of the Shoubak wellfield. No extensive and/or intensive groundwater abstractions in the Shoubak wellfield is recommended without counter-measures. While the alternatives 2) and 4) which assume to incorporate the A-2 dam predict the recovery of piezometric surface in the northern part of the

Shoubak wellfield to sustain the future exploitation. Figs.6.3 to 6.8 show the area affected by A-2 recharge dam, groundwater profiles and groundwater hydrographs at the selected mesh nodes in the Shoubak wellfield for the alternatives 1) to 4).

6.3 Project Opportunities in the National Water Carrier

The Study area is located within a distance of between 130 and 250 km from Amman. The northern part of the Study area, where the promising aquifers underlie, is at a distance of approximately 160 km from Amman. The proposed wellfields of "South Hasa", "East Ma'an" and "East Hasa" are located within 1 to 40 km of the planned route of the national water carrier (Disi-Mudawwara-Amman route). The national water carrier scheme will be economically and financially feasible if the carrier taps the huge sandstone aquifers of "Disi". The alternatives of the water resources development plan which include the national water carrier scheme will be examined at the level of the national water master plan. (See Fig.4.5)

VII. CONCLUSIONS AND RECOMMENDATIONS

VII. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

As the result of the Master plan level study, the distribution, location and potential of the water resources, consisting of ground and surface water, in the upper Hasa and Jafr watershed have been clarified.

Of the potential clarified, the sustained yield of groundwater in the B2/A7 aquifer is worthy of future development. From the steady-state model simulation study, the deep aquifer of the lower Ajlun (A1-6) is preliminarily evaluated to be promising. The salt accumulation problems in the Rijam (B4) aquifer are critical and require the counter-measures. Groundwater recharge dams are worthy of future development in the Western Highlands.

7.2 Recommendations

7.2.1 Schemes

Of the schemes formulated under the present study, the most promising ones are for development of groundwater in the B2/A7 aquifer. After confirming the water use plan of these watersheds, it is recommended that test well drillings be made in the respective wellfields namely "South Hasa" and "East Ma'an" whenever such schemes become needed.

To re-confirm the quantity and quality of the groundwater in each wellfield, production wells in the wellfields, "South Hasa" and "East Ma'an", will be constructed in two stages. Each wellfield will be developed for 5 MCM/y by installing 10 wells in the first stage, and adding thereafter 5 MCM/y in the 2nd stage.

For the purpose of optimal groundwater management of the proposed wellfields of "South Hasa" and "East Ma'an", management model simulation will have to be performed using data from the constructed wells mentioned above.

The deep aquifer of the lower Ajlun (A1-6) will be promising in the area of the confined upper Hasa groundwater basin. It is recommended that a series of test well drillings be carried out to evaluate the feasibility.

Intensive groundwater irrigation in Shoubak area where unconfined aquifer thins with complicated geological structures, lowers the piezometric surface in the northwestern part of the Jafr basin. Of the schemes formulated for conjunctive water development, groundwater recharge dams are deemed to be effective for the area of the Western Highlands. It is recommended that further studies on particular dam schemes be made whenever such irrigation development become needed.

Domestic sewerage and/or irrigation return flow in the outcrop area of the B2/A7 in the Western Highlands should be controlled to protect the quality of groundwater in the B2/A7 aquifer from the contamination.

7.2.2 Monitoring

WAJ's efforts in the groundwater monitoring need to be continued. It is recommended that the amount of pumping discharge of each production well be monitored not only in respect of the government owned wells but also of the private owned ones.

As to groundwater monitoring in the lower Ajlun (A1-6) aquifer, it is recommended that water quality monitoring and isotope dating in the test well of JT-3 be carried out, by using the depth water sampler.

Prior to development of any potential wellfields, it is recommended that a monitoring well be constructed in the center of the group of wells.

Salt accumulation problems in the Rijam (B4) aquifer are still critical. It is recommended that monitoring work which comprises the measurement of both soil salinities and water salinities be continued. Counter-measures including replacement of the existing gravity flow irrigation method from by the drip method, will be useful in reducing salt accumulation in the Rijam (B4) aquifer.

TABLES

Table 1.1 List of Counterpart Personnel

Ministry of Planning (MOP)

Mr.Bolus Kifayeh
Miss Lina Jardaneh
Miss Muna Jawhari

Water Authority of Jordan (WAJ)

Project Coordinatosr

Dr. Kamel Radaideh
Dr. Abdul Aziz Wishah

Project Counterpart Team

Mr. Abdul Rahaman Mustafa
Mr. Anwar Naim
Mr. Adnan Al Masri
Mr. Issa Al Abra

Associated Counterpart Team

Dr. Jamil Rashdan (Hydrogeology and computer simulation)
Dr. Samir Hijazine (Groundwater monitoring)
Dr. Josef Saman (Stratigraphy and micro-paleontology)
Mr. Amin J.Wardem (Hydrology)
Mr. Rakad Ayed Abdurrahim (Hydrology)
Mr. Ali Yousef Saad (Meteorology)
Mr. Mohammed Saud (Geophysics)
Mr. Zuhear Heasat (Computer system)

Table 2.1 Population by Governorates

Governorates	1987	1986	1985	1984	1983
Amman	1,203.0	1,160.0	1,114.6	1,446.2	1,386.9
Zarqa*	419.1	404.5	389.6	-	-
Amman+Zarqa	(1,622.1)	(1,564.5)	(1,504.2)	(1,446.2)	(1,386.9)
Increase Rate	3.7	4.7	4.0	4.3	-
Irbid	704.1	680.2	656.7	727.9	702.9
Mafraq*	102.0	98.6	95.5	-	-
Irbid+Mafraq	(806.1)	(778.8)	(752.2)	(727.9)	(702.9)
Increase Rate	3.5	3.5	3.3	3.6	-
Balqa	200.6	193.8	187.2	179.6	172.8
Increase Rate	3.5	3.5	4.2	3.9	-
Karak	124.2	120.1	116.1	150.7	145.4
Tafila*	42.8	41.4	40.0	-	-
Marak+Tafila	(167.0)	(161.5)	(156.1)	(150.7)	(145.4)
Increase Rate	3.4	3.4	3.6	3.6	-
Ma'an	101.0	97.5	94.0	90.7	87.3
Increase Rate	3.6	3.7	3.6	3.9	-
National Total	1,896.8	2,796.1	1,693.7	2,595.1	2,495.4
Increase Rate	3.60	3.80	3.80	4.00	-

Remarks:

Unit: Population in 1,000, Increase rate (Annual) in %

* : Became Governorates since 1985

Source: Annual Statistical Booklet, Department of satistics with Study Team's elaboration

Table 2.2 STRATIGRAPHIC SECTION

<table>
<tr><th>ERA</th><th colspan="2">PERIOD</th><th>EPOCH</th><th>GROUP</th><th colspan="2">FORMATION</th><th>SYMBOL</th><th>GENERAL LITHOLOGY</th></tr>
<tr><td rowspan="3">Cainozoic</td><td colspan="2" rowspan="2">Quaternary</td><td>Recent</td><td>–</td><td colspan="2">–</td><td>R</td><td>Fluviatile deposits - sands, gravels etc. aeolean sands</td></tr>
<tr><td>Pleistocene</td><td>Plateau</td><td colspan="2">Jafr</td><td>Ja</td><td>Lacustrine limestone</td></tr>
<tr><td colspan="2">Tertiary</td><td>Eocene Paleocene</td><td rowspan="3">Belqa</td><td colspan="2">Rijam</td><td>B4※</td><td>Limestone with chert, Nummulitic Limestone.</td></tr>
<tr><td rowspan="10">Mesozoic</td><td rowspan="10">Cretaceous</td><td rowspan="2">Upper</td><td>Maestrichtian</td><td colspan="2">Muwaqqar</td><td>B3</td><td>Chalky marls, bituminous, Limestones and marls</td></tr>
<tr><td>Campanian Santonian</td><td colspan="2">Amman Ruseifa</td><td>B1 - 2</td><td>Silicified and chert limestone Phosphorites, coquina - Minor marl Marl and marly limestone</td></tr>
<tr><td rowspan="2">Middle</td><td>Turonian</td><td rowspan="2">Ajlun</td><td rowspan="2">Fassua</td><td>Wadi Sir</td><td>A7※</td><td>Sandy limestones dolomites calcareous sandstone and marl</td></tr>
<tr><td>Cenomanian</td><td>undifferentiated Lower Ajlun</td><td>A1 - 6※</td><td>Nodular limestones, clays, marls, interbedded sandstones change laterally to dominantly sandstones</td></tr>
<tr><td rowspan="6">Lower</td><td rowspan="2">Albian</td><td rowspan="6">Kurnub</td><td colspan="2" rowspan="3">Subeihi</td><td rowspan="3">K2</td><td rowspan="3">Varicoloured sandstones, silts ; brown coarse sands minor shales clays and marls interbeded</td></tr>
<tr></tr>
<tr><td rowspan="2">Aptian</td></tr>
<tr><td colspan="2" rowspan="3">Aarda</td><td rowspan="3">K1※</td><td rowspan="3">Massive light coloured sandstones with minor shales clays and marls interbeded</td></tr>
<tr><td rowspan="2">Neocomian</td></tr>
<tr></tr>
<tr><td>Palaeozoic</td><td colspan="2">Silurian</td><td>Llandovery</td><td>Khreim</td><td colspan="2">Mudawwara</td><td>Kh2</td><td>Flaggy micaceous greenish grey argillaceous sandstones and shales</td></tr>
</table>

Remark ; ※ Aquifer

Table 2.3 Climatological Data of Study Area (1/3)

Station Name : Hasa Evaporation Station
Agency In-Charge : WAJ Altitude (m) : 900
PG North : 30.600 PG East : 243.600
(PG; Palestine Grid)

	Max of Max Temp (C deg)	Min of Min Temp (C deg)	Average Max Temp (C deg)	Average Min Temp (C deg)	Average Relative Humidity (%)	Average Total Evap (mm)	Average Total Sunshine Hours	Average Wind Vel (km/hr)	Daily Evap (mm/day)
Oct	37.0	3.0	27.0	13.0	58	236		7.8	7.6
Nov	33.0	0.0	21.5	8.9	59	149		7.2	5.0
Dec	28.0	-3.0	16.4	4.9	71	103		7.9	3.3
Jan	25.0	0.0	14.8	3.9	70	103		8.5	3.3
Feb	28.0	-2.0	16.6	5.5	69	134		9.7	4.8
Mar	32.0	-1.0	19.1	7.3	60	190		10.4	6.1
Apr	36.0	2.0	25.2	9.4	48	276		10.2	9.2
May	39.0	6.0	29.5	13.7	42	377		9.7	12.2
Jun	41.0	7.0	32.1	16.2	38	455		10.7	15.2
Jul	45.0	7.0	33.3	18.5	44	488		10.4	15.7
Aug	42.0	11.0	29.9	18.4	70	451		10.2	14.5
Sep	40.0	12.0	32.1	16.7	56	346		8.9	11.5
Total						3,306			

Note :
(1) Maximum, minimum and average are derived for the period between 1977/78 and 1987/88.
(2) Blank means no data is available. (3) Evaporation is measured by a class-A pan.

Station Name : Abur
Agency In-Charge : Meteorological Dept Altitude (m) : 1,200
PG North : 23.300 PG East : 218.200
(PG; Palestine Grid)

	Max of Max Temp (C deg)	Min of Min Temp (C deg)	Average Max Temp (C deg)	Average Min Temp (C deg)	Average Relative Humidity (%)	Average Total Evap (mm)	Average Total Sunshine Hours	Average Wind Vel (km/hr)	Daily Evap (mm/day)
Oct	33.3	5.0	24.8	12.1	48	198	279	10.1	6.4
Nov	28.0	-3.5	17.6	7.0	57	118	236	11.2	3.9
Dec	24.6	-3.0	13.0	3.6	64	81	204	12.4	2.6
Jan	24.4	-4.0	11.6	2.5	65	91	209	13.0	2.9
Feb	25.2	-2.8	12.5	3.0	65	89	203	14.9	3.2
Mar	27.5	-3.0	15.5	4.8	58	132	250	14.7	4.3
Apr	33.0	0.0	21.0	8.3	44	193	275	13.0	6.4
May	35.8	2.8	25.6	11.8	36	261	324	10.6	8.4
Jun	36.6	6.5	28.4	14.6	37	288	365	10.6	9.6
Jul	41.0	10.3	30.0	17.0	38	329	382	11.7	10.6
Aug	38.6	11.0	30.1	16.8	40	303	363	11.0	9.8
Sep	36.4	8.4	28.9	15.2	42	255	313	8.5	8.5
Total						2,338	3,403		

Note :
(1) Maximum, minimum and average are derived for the period between 1977/78 and 1987/88.
(2) Blank means no data is available. (3) Evaporation is measured by a class-A pan.

Table 2.3 Climatological Data of Study Area (2/3)

Station Name : Shaubak
Agency In-Charge : Meteorological Dept Altitude (m) : 1,365
PG North : 991.500 PG East : 200.500
(PG; Palestine Grid)

	Max of Max Temp (C deg)	Min of Min Temp (C deg)	Average: Max Temp (C deg)	Average: Min Temp (C deg)	Average: Relative Humidity (%)	Average: Total Evap (mm)	Average: Total Sunshine Hours	Average: Wind Vel (km/hr)	Daily Evap (mm/day)
Oct	31.4	-2.0	22.7	6.7	54	144	283	5.9	4.7
Nov	26.4	-11.2	15.6	2.4	64	86	219	7.6	2.9
Dec	22.5	-10.0	11.0	-0.2	74	55	181	8.5	1.8
Jan	22.6	-9.0	9.9	-1.1	73	65	187	9.8	2.1
Feb	23.8	-9.6	10.7	-0.1	72	63	177	10.5	2.2
Mar	28.0	-11.6	13.5	0.5	65	98	231	10.9	3.2
Apr	31.0	-3.7	17.8	4.8	54	153	272	9.4	5.1
May	33.0	-3.2	23.2	7.4	46	200	314	8.1	6.5
Jun	33.6	2.0	25.8	10.8	47	227	366	7.8	7.6
Jul	38.2	4.2	27.1	13.4	46	250	379	9.3	8.1
Aug	36.8	5.2	27.4	13.4	50	227	366	7.1	7.3
Sep	34.0	2.2	26.3	10.7	52	199	317	5.3	6.6
Total						1,768	3,293		

Note :
(1) Maximum, minimum and average are derived for the period between 1977/78 and 1987/88.
(2) Blank means no data is available. (3) Evaporation is measured by a class-A pan.

Station Name : Udruh Evaporation Station
Agency In-Charge : WAJ Altitude (m) : 1,350
PG North : 973.600 PG East : 206.300
(PG; Palestine Grid)

	Max of Max Temp (C deg)	Min of Min Temp (C deg)	Average: Max Temp (C deg)	Average: Min Temp (C deg)	Average: Relative Humidity (%)	Average: Total Evap (mm)	Average: Total Sunshine Hours	Average: Wind Vel (km/hr)	Daily Evap (mm/day)
Oct	32.0	-1.0	21.9	7.3	51	287	276	12.2	9.3
Nov	25.0	-6.0	15.4	2.2	63	159	224	12.2	5.3
Dec	24.0	-9.0	10.4	-1.2	69	115	65	14.9	3.7
Jan	20.0	-10.0	9.4	-2.6	68	121	119	16.2	3.9
Feb	22.0	-9.0	9.6	-2.0	65	137	167	17.9	4.9
Mar	25.0	-8.0	12.2	0.2	60	198	179	19.0	6.4
Apr	30.0	-5.0	18.4	4.2	54	287	302	17.3	9.6
May	32.0	0.0	23.3	7.8	46	390	352	17.1	12.6
Jun	34.0	3.0	26.1	11.0	46	488	368	20.0	16.3
Jul	39.0	4.5	27.6	13.3	45	488	211	25.3	15.7
Aug	35.5	6.0	28.1	13.1	44	503	363	18.9	16.2
Sep	33.0	5.0	27.3	11.7	47	391		14.6	13.0
Total						3,564	2,624		

Note :
(1) Maximum, minimum and average are derived for the period between 1977/78 and 1987/88.
(2) Blank means no data is available. (3) Evaporation is measured by a class-A pan.

Table 2.3 Climatological Data of Study Area (3/3)

Station Name : Jafr Evaporation Station
Agency In-Charge : WAJ Altitude (m) :865
PG North : 970.000 PG East : 267.000
(PG; Palestine Grid)

	Max of Max Temp (C deg)	Min of Min Temp (C deg)	Average						
			Max Temp (C deg)	Min Temp (C deg)	Relative Humidity (%)	Total Evap (mm)	Total Sunshine Hours	Wind Vel (km/hr)	Daily Evap (mm/day)
Oct	37.2	5.7	28.1	12.2	50	140	282	8.3	4.5
Nov	29.7	-2.6	20.4	5.9	59	120	244	7.7	4.0
Dec	24.3	-5.5	15.8	1.9	62	98	214	6.8	3.2
Jan	25.4	-6.0	15.2	1.3	62	180	224	8.2	5.8
Feb	28.2	-4.0	16.6	2.5	58	213	213	11.4	7.6
Mar	31.6	-3.5	19.9	5.4	51	285	245	12.7	9.2
Apr	36.7	2.0	24.1	8.6	46	405	273	13.2	13.5
May	39.7	7.0	29.8	13.4	40	515	298	12.7	16.6
Jun	39.0	10.0	33.3	16.3	40	612	361	16.0	20.4
Jul	41.5	11.7	35.3	17.9	41	741	375	15.3	23.9
Aug	42.0	12.6	35.5	18.2	43	632	352	12.6	20.4
Sep	39.6	11.5	33.8	16.9	37	246	264	9.7	8.2
Total						4,186	3,344		

Note :
(1) Maximum, minimum and average are derived for the period between 1980/81 and 1987/88.
(2) Blank means no data is available. (3) Evaporation is measured by a class-A pan.

Station Name : Ma'an Airport
Agency In-Charge : Meteorological Dept Altitude (m) : 1,069
PG North : 952.500 PG East : 224.000
(PG; Palestine Grid)

	Max of Max Temp (C deg)	Min of Min Temp (C deg)	Average						
			Max Temp (C deg)	Min Temp (C deg)	Relative Humidity (%)	Total Evap (mm)	Total Sunshine Hours	Wind Vel (km/hr)	Daily Evap (mm/day)
Oct	35.8	3.9	27.2	12.0	46	275	255	7.8	8.9
Nov	29.0	-2.5	19.0	6.1	56	143	220	8.0	4.8
Dec	26.0	-8.5	14.3	2.8	64	107	191	9.2	3.5
Jan	25.2	-5.7	14.5	2.0	61	117	227	11.2	3.8
Feb	26.5	-5.0	15.4	2.7	60	138	244	13.6	4.9
Mar	31.5	-4.0	18.8	5.3	53	210	250	15.6	6.8
Apr	35.2	-1.3	24.6	9.5	43	315	269	15.4	10.5
May	37.6	0.0	26.3	12.0	35	390	301	14.1	12.6
Jun	38.5	0.0	29.4	14.1	36	370	312	13.0	12.3
Jul	40.5	9.2	33.5	17.2	40	377	358	13.1	12.2
Aug	42.0	11.4	34.4	17.4	43	425	343	12.0	13.7
Sep	38.0	9.0	32.6	15.9	39	284	253	6.5	9.5
Total						3,151	3,225		

Note :
(1) Maximum, minimum and average are derived for the period between 1977/78 and 1987/88.
(2) Blank means no data is available. (3) Evaporation is measured by a class-A pan.

Table 2.4 Rainfall Gaging Stations (1/2)

	Id. No.	Station Name	Palestine Grid		Altitude	Date Established and Type of Gaging			Date Closed
			North	East	(m)	Automatic Recording	Daily Reading	Totalizer	
a. East Side of Dead Sea									
1	CA 0002	Khanzira	51.800	207.300	1,000		9/1945		
2	CA 0005	Al Aina	42.200	224.000	775		10/1967		
3	CA 0006	Muhai	44.500	231.800	1,000		10/1967		
b. Wadi Mujib									
4	CD 0013	Mazar	52.000	216.500	1,140	10/1963	10/1934	12/1962	
5	CD 0033	Jabel Sakhriyat	26.600	274.000	910			10/1968	
c. Wadi Hasa									
6	CF 0003	Jurf Ed-Darawish	11.800	233.000	940	10/1970	1/1938	11/1962	
7	CF 0005	Hasa Police Station	25.800	243.000	825		11/1962	11/1962	
8	CF 0007	Hasa Evapo. Station	30.600	243.600	900	10/1967	10/1967	10/1967	
9	CF 0008	Hasa Gaging Station	41.600	220.400	380	10/1966	10/1968		
d. Wadi Araba									
10	DA 0001	Shaubak School	992.000	202.000	1,300	10/1977	11/1933		
11	DA 0002	Shaubak Agr. Station	991.500	200.500	1,475		10/1962	1/1963	
12	DA 0003	Beir Ed-Dabbaghat	980.000	198.000	1,600		1/1963		
13	DA 0004	Ifjeij	994.000	209.000	1,275		1/1963		
14	DA 0005	Uneiza Railway Station	989.000	226.500	1,050	10/1967	1/1963		
15	DA 0006	Al Husseiniya School	999.400	226.200	1,062				
e. Wadi Feifa									
16	DB 0001	Tafile	27.500	208.000	1,000	10/1965	1/1963	1/1963	
17	DB 0002	Abur (Prince Hassan Nursery)	23.300	218.200	1,220		10/1967		
f. Wadi Khuneizeer									
18	DC 0001	Buseira	17.000	208.000	1,100	10/1973	12/1934		
19	DC 0002	Rashadiya Police Station	12.500	210.000	1,500	10/1973	10/1969	10/1945	
g. Wadi Feedan									
20	DE 0001	Dana	9.500	208.300	1,230	10/1973	9/1945		
h. Wadi Mousa									
21	DG 0001	Wadi Mousa	970.000	196.000	1,100	10/1963	11/1933		
22	DG 0002	Hay	974.000	197.000	1,500		3/1963		
i. Wadi Howar									
23	DH 0001	Taiyiba Janoubiya	963.000	194.000	300		1/1963		
24	DH 0002	Dilagha	949.300	189.000	1,350		2/1963		
j. Wadi Yutum									
25	ED 0002	Ras En-Naqb	935.000	197.000	1,570	10/1963	10/1951		
26	ED 0003	Ram Police Post	887.500	191.000	950		10/1937		
27	ED 0004	Quweira Evap. Station	914.000	181.000	800	10/1963	10/1967	10/1962	
28	ED 0006	Al Khaldy	896.500	172.000	725	10/1963	10/1968	1/1962	
29	ED 0010	Wadi Yutum Gaging Station	880.600	160.300	350	10/1966	10/1964		
30	ED 0012	Ram(Qa' Disi) Evap. Station	896.000	199.800	790	10/1965	10/1965	10/1968	
31	ED 0015	Fassu'a Station	908.500	236.200	1,150			10/1965	

Table 2.4 Rainfall Gaging Stations (2/2)

Id. No.	Station Name	Palestine Grid North	Palestine Grid East	Altitude (m)	Date Established and Type of Gaging: Automatic Recording	Daily Reading	Totalizer	Date Closed
k. Jafr Basin								
32 G 0001	Udruh School	971.200	207.000	1,300		11/1962	10/1945	
33 G 0002	Jafr Police Station	969.000	269.000	900		10/1947		
34 G 0003	Ma'an School	956.500	221.000	1,080	10/1970	10/1934	9/1967	
35 G 0004	Basta	960.300	201.800	1,450		1/1962		
36 G 0005	Sadaqa	952.500	196.500	1,500		1/1963		
37 G 0006	Qurein	945.300	195.000	1,500		3/1963		
38 G 0007	Ma'an Railway Station	954.000	223.000	1,006		10/1963		
39 G 0008	Jafr Evaporation Station	970.000	267.000	900	10/1965	10/1963	9/1968	
40 G 0009	Udruh Evaporation Station	973.600	206.300	1,350	10/1963	10/1967		
41 G 0010	Jurdhan Gaging Station	965.900	221.900	1,082	10/1970	10/1968		10/1973
42 G 0011	Jabel Quzemeh	995.500	284.300	920			9/1967	(Daily
43 G 0012	Qabr Es-Sawwa	984.000	247.000	945			9/1967	Recording)
44 G 0013	Abu Tarafa	935.000	239.000	990			9/1967	
45 G 0014	Inab	932.200	331.400	950			9/1967	
46 G 0015	Kabid	929.500	296.200	870			9/1967	
47 G 0016	Jabel Batra	924.000	210.000	1,300			5/1967	10/1973 (Totalizer)
l. Eastern Desert Basin								
48 J 0001	Bayir Evaporation Station	20.000	310.500	902	10/1965	10/1947		10/1980
49 J 0003	Wadi Bayir	42.400	359.600	650			9/1967	(Daily
50 J 0004	Qa' Es Siq	972.500	365.400	870			9/1967	Recording)
m. Southern Desert Basin								
51 K 0001	Al Mudawwara	859.000	249.000	820	10/1967	10/1934	10/1968	
52 K 0003	Muheish	866.000	234.000	800			5/1967	
53 K 0004	Wadi Dureiba	866.000	215.000	950			5/1967	

Table 3.1 Probable Rainfall in and around Study Area (1/3)

Station No.: CD 0013

Return Period	Duration									
	Minutes						Hours			
(year)	5	10	15	20	30	60	2	3	6	24
2	45.0	26.9	20.3	17.1	14.5	10.1	7.8	6.7	5.1	2.3
5	66.1	38.8	29.5	24.7	20.4	14.3	11.1	9.8	7.5	3.0
10	80.1	46.7	35.6	29.7	24.3	17.0	13.3	11.7	9.1	4.4
25	97.7	56.6	43.3	36.1	29.1	20.5	16.1	14.2	11.1	5.4
50	110.8	64.0	49.0	40.8	32.8	23.1	18.2	16.0	12.5	6.2
100	123.8	71.3	54.7	45.5	36.4	25.3	20.3	17.8	14.0	7.0
200	136.8	78.7	60.3	50.1	39.9	28.3	22.4	19.6	15.5	7.8
500	153.9	88.3	67.8	56.3	44.7	31.6	25.1	22.0	17.4	8.8

Station No.: CF 0007

Return Period	Duration									
	Minutes						Hours			
(year)	5	10	15	20	30	60	2	3	6	24
2	21.3	16.3	13.6	12.4	9.2	5.3	3.2	2.4	1.48	0.51
5	43.0	30.5	24.5	20.7	15.7	8.8	5.2	4.0	2.5	1.0
10	57.4	39.9	31.8	26.2	20.1	11.1	6.5	5.0	3.2	1.3
25	75.5	51.8	40.9	33.1	25.6	14.1	8.2	6.3	4.0	1.7
50	85.0	60.6	47.7	38.3	29.7	16.2	9.4	7.3	4.6	2.0
100	102.4	69.3	54.4	43.4	33.7	18.4	10.6	8.2	5.2	2.3
200	115.7	78.1	61.1	48.5	37.7	20.5	11.8	9.2	5.8	2.6
500	133.2	89.6	69.9	55.2	43.1	23.3	13.4	10.5	6.7	3.0

Station No.: CF 0008

Return Period	Duration									
	Minutes						Hours			
(year)	5	10	15	20	30	60	2	3	6	24
2	32.8	20.6	15.2	12.4	9.6	6.2	4.3	3.5	2.4	1.03
5	55.8	30.8	22.7	17.9	13.3	8.7	6.2	5.2	3.7	1.9
10	71.6	37.9	27.7	21.5	15.7	10.3	7.6	6.2	4.6	2.4
25	90.3	46.9	34.0	26.1	18.7	12.3	9.1	7.6	5.7	3.1
50	104.5	53.6	38.7	29.6	21.0	13.8	10.3	8.6	6.6	3.6
100	118.7	60.2	43.3	32.9	23.3	15.3	11.5	9.6	7.4	4.1
200	132.8	66.8	47.9	36.3	25.5	16.8	12.7	10.5	8.2	4.6
500	151.5	75.5	54.0	40.8	28.4	18.8	14.2	11.8	9.3	5.3

Table 3.1 Probable Rainfall in and around Study Area (2/3)

Station No.: DB 0001

Return Period	Duration									
	Minutes						Hours			
(year)	5	10	15	20	30	60	2	3	6	24
2	46.8	28.3	21.3	17.7	13.8	9.3	6.9	6.0	4.6	2.1
5	63.0	35.5	26.2	21.4	16.7	11.4	8.8	7.9	6.3	3.2
10	73.7	40.3	29.4	23.8	18.7	12.8	10.1	9.1	7.5	3.9
25	87.3	46.3	33.5	26.9	21.2	14.5	11.6	10.7	8.9	4.8
50	97.3	50.8	36.6	29.2	23.0	15.9	12.8	11.9	10.0	5.4
100	107.3	55.2	39.6	31.5	24.8	17.1	14.0	13.0	11.1	6.1
200	117.3	59.6	42.6	33.8	26.7	18.4	15.2	14.2	12.2	6.8
500	130.4	65.4	46.6	36.8	29.1	20.1	16.7	15.7	13.6	7.7

Station No.: DC 0002

Return Period	Duration									
	Minutes						Hours			
(year)	5	10	15	20	30	60	2	3	6	24
2	37.5	23.0	17.6	14.5	11.3	7.9	5.9	5.6	3.7	1.64
5	64.0	36.3	26.9	21.8	16.6	11.1	8.1	7.1	5.5	2.54
10	81.5	45.1	33.1	26.6	20.1	13.2	9.6	8.5	6.6	3.1
25	103.7	56.2	40.8	32.7	24.5	15.9	11.5	10.2	8.0	3.9
50	120.2	64.5	46.6	37.3	27.8	17.9	12.9	11.6	9.1	4.5
100	136.5	72.7	52.3	41.8	31.1	19.9	14.3	12.8	10.2	5.0
200	152.9	80.8	58.6	46.2	34.3	21.8	15.6	14.1	11.2	5.6
500	174.2	91.6	65.6	52.2	38.6	24.4	17.4	15.8	12.6	6.3

Station No.: DG 0001

Return Period	Duration									
	Minutes						Hours			
(year)	5	10	15	20	30	60	2	3	6	24
2	33.8	21.2	16.4	13.9	11.1	7.7	5.7	4.8	3.4	1.4
5	48.0	30.2	23.1	19.7	15.6	10.7	8.0	7.0	5.1	2.1
10	57.4	36.1	27.7	23.5	18.6	12.8	9.5	8.4	6.3	2.5
25	69.3	43.6	33.3	28.4	22.3	15.3	11.4	10.2	7.7	3.1
50	78.1	49.2	37.5	32.0	25.1	17.2	12.9	11.6	8.8	3.6
100	86.8	54.7	41.7	35.6	27.9	19.1	14.3	12.9	9.9	4.0
200	95.6	60.2	45.8	39.1	30.7	21.0	15.7	14.2	10.9	4.4
500	107.1	67.4	51.3	43.8	34.3	23.5	17.6	16.0	12.3	5.0

Table 3.1 Probable Rainfall in and around Study Area (3/3)

Station No.: DH 0003

Return Period (year)	Duration									
	Minutes						Hours			
	5	10	15	20	30	60	2	3	6	24
2	27.8	20.5	16.9	14.7	11.6	7.6	5.2	4.9	3.6	1.44
5	52.2	33.5	25.9	21.7	16.9	11.3	8.4	7.3	5.5	2.4
10	68.4	42.1	31.9	26.3	20.4	13.7	10.2	8.9	6.7	3.0
25	88.8	53.0	39.4	32.2	24.7	16.8	12.4	10.9	8.2	3.8
50	103.9	61.0	45.0	36.5	28.0	19.1	14.1	12.4	9.4	4.4
100	118.9	69.1	50.5	40.8	31.2	21.3	15.7	13.9	10.5	5.0
200	133.9	77.0	56.0	45.1	34.4	23.6	17.4	15.3	11.6	5.6
500	153.7	87.6	63.3	50.8	38.7	26.6	19.5	17.3	13.1	6.4

Station No.: G 0003

Return Period (year)	Duration									
	Minutes						Hours			
	5	10	15	20	30	60	2	3	6	24
2	15.5	10.2	7.9	6.6	5.0	3.1	1.9	1.4	0.85	0.35
5	22.6	16.1	12.9	11.1	8.7	6.0	4.0	3.2	2.2	0.88
10	27.3	20.6	16.3	14.1	11.2	7.9	5.4	4.4	3.1	1.23
25	33.2	24.9	20.5	17.8	14.4	10.4	7.2	6.0	4.2	1.7
50	37.6	28.6	23.6	20.6	16.7	12.2	8.5	7.1	5.1	2.0
100	42.0	32.2	26.6	23.4	19.1	14.0	9.8	8.2	5.9	2.3
200	46.4	35.9	29.7	26.2	21.4	15.8	11.2	9.3	6.7	2.7
500	52.1	40.6	33.8	29.8	24.4	18.1	12.9	10.8	7.8	3.1

Table 3.2 Peak Discharges of Probable Floods of Hasa River

Return Period (year)	Peak Discharge (m^3/sec)	Runoff Coefficient (%)	Creager's C Value
2	36	10	0.4
5	195	27	1.9
10	314	35	3.1
25	526	44	5.2
50	690	49	6.8
100	826	53	8.2
200	1,001	56	9.9
500	1,219	60	12.0

Table 3.3 Peak Discharges of Probable Floods of Wadi Jurdhan

Return Period (year)	Peak Discharge (m^3/sec)	Runoff Coefficient (%)	Creager's C Value
2	36	18	1.2
5	90	31	3.1
10	128	37	4.4
25	190	44	6.5
50	245	49	8.5
100	291	52	10.0
200	339	55	11.7
500	411	59	14.2

Table 3.4 Location, Catchment Area and Annual Rainfall of Recharge Dams

Recharge Dam No.	Location		Drainage Area (km^2)	Annual Mean Rainfall of Drainage Area (mm)	Adjustment Factor of Probable Floods
	PG North	PG East			
A1	992.1 (N 30° 31'	204.3 E 35° 34')	24.3	307	0.65
A2	989.5 (N 30° 30'	204.8 E 35° 34')	32.2	295	0.76
A3	976.6 (N 30° 23'	205.1 E 35° 35')	31.1	272	0.68
B1	950.0 (N 30° 08'	203.2 E 35° 33')	55.7	154	0.57
B2	948.2 (N 30° 07'	204.6 E 35° 34')	135.9	140	0.91
B3	946.6 (N 30° 06'	210.4 E 35° 38')	71.7	149	0.65
C1	925.1 (N 29° 55'	226.8 E 35° 48')	89.3	113	0.57
C2	915.2 (N 29° 49'	237.7 E 35° 55')	115.3	94	0.56

Note : (1) PG denotes Palestine Grid.
(2) Figures in Parentheses are latitude and longitude, respectively.
(3) Annual mean rainfall is an average between 1937/38 and 1987/88.

Table 3.5 Peak Discharges of Probable Floods of Recharge Dams

(Unit : m^3/sec)

Probable Year	Recharge Dam No. A1	A2	A3	B1	B2	B3	C1	C2
2	23	27	24	21	33	23	21	20
5	59	68	61	51	82	59	51	50
10	83	97	87	73	116	83	73	72
25	124	144	129	108	178	124	108	106
50	159	186	167	140	223	159	140	137
100	189	221	198	166	265	189	166	163
200	220	258	231	193	308	220	193	190
500	267	312	279	234	374	267	234	230

Table 3.6 Simple Correlation Factors and Linear Regression Formulas of Monthly Rainfall (1/4)

	Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient
1 - 2	0.919	0.914	4 - 1	0.955	1.018	7 - 1	0.808	0.397
3	0.939	1.447	2	0.940	0.979	2	0.778	0.374
4	0.955	0.914	3	0.913	1.496	3	0.791	0.584
5	0.936	1.417	5	0.924	1.531	4	0.837	0.386
6	0.802	1.759	6	0.799	1.721	5	0.848	0.630
7	0.808	1.878	7	0.837	2.009	6	0.868	0.869
8	0.689	1.557	8	0.632	1.533	8	0.688	0.679
9	0.806	1.752	9	0.831	1.697	9	0.778	0.859
2 - 1	0.919	0.966	5 - 1	0.936	0.618	8 - 1	0.689	0.396
3	0.856	1.391	2	0.928	0.597	2	0.562	0.329
4	0.940	0.933	3	0.881	0.904	3	0.750	0.617
5	0.928	1.502	4	0.924	0.583	4	0.632	0.348
6	0.797	1.609	6	0.865	1.114	5	0.613	0.588
7	0.778	1.873	7	0.848	1.257	6	0.821	1.029
8	0.562	1.406	8	0.613	0.890	7	0.688	0.889
9	0.775	1.533	9	0.758	1.054	9	0.779	1.001
3 - 1	0.939	0.634	6 - 1	0.802	0.427	9 - 1	0.806	0.432
2	0.856	0.576	2	0.797	0.462	2	0.775	0.470
4	0.913	0.586	3	0.821	0.627	3	0.869	0.713
5	0.881	0.925	4	0.799	0.430	4	0.831	0.463
6	0.821	1.225	5	0.865	0.740	5	0.758	0.659
7	0.791	1.235	7	0.868	0.947	6	0.793	0.851
8	0.750	1.099	8	0.821	0.747	7	0.778	0.829
9	0.869	1.163	9	0.793	0.859	8	0.779	0.715

Station Name :

(No.)	(Id. No.)	(Station Name)
1.	DA 0002	Shaubak Agricultural Station
2	DA 0003	Beir Ed-Dabbaghat
3	DA 0004	Ifjeij
4	DE 0001	Dana
5	DG 0001	Wadi Mousa
6	DH 0002	Dilagha
7	ED 0002	Ras En-Naqb
8	G 0005	Sadaqa
9	G 0009	Udruh Evaporation Station

Note :

1. These 9 rainfall stations are located in and near the Jafr basin and long-term annual rainfall of most of them is more than 100 mm.
2. Linear regression formulas are given by y = a x, where "a" is shown on the table above ,and "y" and "x" are rainfall at two stations.

Table 3.6 Simple Correlation Factors and Linear Regression Formulas of Monthly Rainfall (2/4)

	Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient
1 - 2	0.734	0.417	3 - 1	0.845	0.945	5 - 1	0.781	1.467
3	0.845	0.854	2	0.829	0.505	2	0.803	0.755
4	0.782	0.451	4	0.936	0.555	3	0.911	1.528
5	0.781	0.497	5	0.911	0.581	4	0.925	0.868
6	0.814	0.483	6	0.910	0.564	6	0.882	0.879
2 - 1	0.734	1.635	4 - 1	0.782	1.621	6 - 1	0.814	1.593
3	0.829	1.566	2	0.906	0.998	2	0.886	0.898
4	0.906	0.871	3	0.936	1.655	3	0.910	1.568
5	0.803	1.002	5	0.925	1.040	4	0.957	0.885
6	0.886	0.941	6	0.957	1.061	5	0.882	0.966

Station Name :

(No.)	(Id. No.)	(Station Name)
1.	CA 0006	Muhai
2	CD 0013	Mazar
3	CF 0008	Hasa Gaging Station
4	DB 0001	Tafile
5	DB 0002	Abur(Prince Hassan Nursery)
6	DC 0001	Buseira

Note :

1. These 6 rainfall stations are located in and near the Upper Hasa basin and long-term annual rainfall of most of them is more than 100 mm.
2. Linear regression formulas are given by y = a x, where "a" is shown on the table above ,and "y" and "x" are rainfall at two stations.

Table 3.6 Simple Correlation Factors and Linear Regression Formulas of Monthly Rainfall (3/4)

	Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient
1 - 2	0.848	1.257	4 - 1	0.613	0.588	7 - 1	0.178	0.053
3	0.380	2.751	2	0.688	0.889	2	0.257	0.093
4	0.613	0.890	3	0.246	1.294	3	0.546	0.412
5	0.587	3.114	5	0.503	2.206	4	0.152	0.079
6	0.758	1.054	6	0.779	1.001	5	0.442	0.402
7	0.178	2.504	7	0.152	1.499	6	0.181	0.109
2 - 1	0.848	0.630	5 - 1	0.587	0.156			
3	0.452	2.043	2	0.658	0.237			
4	0.688	0.679	3	0.769	0.905			
5	0.658	2.373	4	0.503	0.184			
6	0.778	0.859	6	0.675	0.262			
7	0.257	1.994	7	0.442	0.822			
3 - 1	0.380	0.098	6 - 1	0.758	0.659			
2	0.452	0.162	2	0.778	0.829			
4	0.246	0.129	3	0.458	1.948			
5	0.769	0.743	4	0.779	0.715			
6	0.453	0.166	5	0.675	2.221			
7	0.546	0.976	7	0.181	1.504			

Station Name :

(No.)	(Id. No.)	(Station Name)
1.	DG 0001	Wadi Mousa
2	ED 0002	Ras En-Naqb
3	G 0002	Jafr Police Station
4	G 0005	Sadaqa
5	G 0007	Ma'an Railway Station
6	G 0009	Udruh Evaporation Station
7	K 0001	Al Mudawara

Note :

1. These 7 rainfall stations are located in the Jafr basin and long-term annual rainfall of most of them is less than 100 mm.
2. Linear regression formulas are given by y = a x, where "a" is shown on the table above ,and "y" and "x" are rainfall at two stations.

Table 3.6 Simple Correlation Factors and Linear Regression Formulas of Monthly Rainfall (4/4)

	Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient		Simple Correlation Factor	Linear Regression Coefficient
1 - 2	0.734	0.417	4 - 1	0.524	0.310	7 - 1	0.663	0.255
3	0.603	1.686	2	0.714	0.171	2	0.507	0.105
4	0.524	1.511	3	0.801	0.885	3	0.564	0.540
5	0.670	0.888	5	0.519	0.299	4	0.734	0.516
6	0.782	0.451	6	0.738	0.164	5	0.721	0.538
7	0.663	2.259	7	0.734	1.242	6	0.474	0.085
2 - 1	0.734	1.635	5 - 1	0.670	0.618			
3	0.737	4.065	2	0.602	0.265			
4	0.714	3.720	3	0.891	1.227			
5	0.602	1.800	4	0.519	1.314			
6	0.906	0.871	6	0.570	0.278			
7	0.507	4.102	7	0.721	1.168			
3 - 1	0.603	0.311	6 - 1	0.782	1.621			
2	0.737	0.163	2	0.906	0.998			
4	0.801	0.826	3	0.760	4.492			
5	0.891	0.686	4	0.738	4.020			
6	0.760	0.152	5	0.570	1.589			
7	0.564	0.870	7	0.474	4.459			

Station Name :

(No.)	(Id. No.)	(Station Name)
1.	CA 0006	Muhai
2	CD 0013	Mazar
3	CF 0003	Jurf Ed-Dawawish
4	CF 0007	Hasa Evaporation Station
5	DA 0006	Al Husseinya School
6	DB 0001	Tafile
7	J 0001	Bayir Evaporation Station

Note :

1. These 7 rainfall stations are located in the Upper Hasa basin and long-term annual rainfall of most of them is less than 100 mm.
2. Linear regression formulas are given by y = a x, where "a" is shown on the table above ,and "y" and "x" are rainfall at two stations.

Table 3.7 Comparison of Runoff Characteristics Based on Observed Discharge Data

Item	Upper Hasa Basin (1968/69 - 1985/86)	Jurdhan Basin (1963/64 - 1985/86)	Mujib Basin (1960/61 - 1984/85)
Catchment Area (km2)	2,198	182.7	6,600
Average Annual Rainfall (mm)	85	130	154
Average Annual Runoff (mcm)	8.0	0.37	54
Runoff Coeffcient (%)	4.3	1.6	5.3

Table 3.8 Observed Runoff Characteristics of Wadi Jurdhan

Year	Basin Rainfall (mm)	Observed Discharge (mm)	Runoff Coefficient (%)
1963 /64	246.3	6.1	2.5
1964 /65	219.1	7.6	3.5
1965 /66	96.1	0.6	0.6
1966 /67	161.4	2.1	1.3
1967 /68	114.3	0.2	0.2
1968 /69	178.2	8.3	4.7
1969 /70	67.0	0.1	0.2
1970 /71	125.6	6.3	5.0
1971 /72	198.6	1.4	0.7
1972 /73	35.6	1.0	2.7
1973 /74	214.5	0.7	0.3
1974 /75	147.4	4.0	2.7
1975 /76	72.0	0.0	0.0
1976 /77	89.8	0.0	0.0
1977 /78	98.3	0.0	0.0
1978 /79	104.8	0.0	0.0
1979 /80	173.8	5.5	3.2
1980 /81	120.8	3.0	2.5
1981 /82	103.4	0.2	0.2
1982 /83	161.3	-	-
1983 /84	39.1	-	-
1984 /85	107.4	-	-
1985 /86	116.0	-	-
Average	135.1	2.5	1.8

Table 3.9 Parameters of Tank Model for Study Area

	Top Tank	Second Tank	Third Tank		Fourth Tank
			Non-B4 Layers	B4 Layers	
a. Discharge Coefficient (1/day)					
Side Holes	0.10 0.16	0.10	0.003	0.00	0.00015
Bottom Holes	0.30	0.05	0.025	0.00	0.00
b. Height of Side Holes (mm)	8 2	2	10	0	20
c. Initial Storage of Tank (mm)	0	0	0	0	100
d. Capacity of Soil Moisture (mm)					
- Primary (PS)	17 (30)	-	-	-	-
- Seconday(SS)	66 (120)	-	-	-	-
e. Conductivity of Soil Moisture (mm/day)					
- From second tank to primary soil moisture	0.2	-	-	-	-
- From primary soil moisture to secondary soil moisture	1.0	-	-	-	-

Note : Figures in the parentheses are of the Jafr basin and the recharge dam sites.

Table 3.10 Comparison of Observed and Calculated Discharge of Hasa River

Year	Rain	Observed Discharge	Calculated Discharge	Runoff Coefficient (%)	
	(mm)	(mm)	(mm)	Observed	Calculated
1968 /69	72	1.1	1.5	1.6	2.1
1969 /70	52	2.7	0.1	5.3	0.1
1970 /71	74	6.0	2.8	8.2	3.8
1971 /72	135	4.3	8.5	3.1	6.3
1972 /73	40	1.0	0.3	2.5	0.8
1973 /74	126	3.2	13.2	2.5	10.5
1974 /75	128	4.7	13.4	3.7	10.5
1975 /76	48	-	0.1	-	0.2
1976 /77	62	0.3	0.1	0.5	0.2
1977 /78	76	0.6	0.1	0.8	0.1
1978 /79	54	0.9	0.2	1.7	0.4
1979 /80	134	17.5	2.3	13.1	1.7
1980 /81	94	6.7	6.4	7.2	6.8
1981 /82	75	3.3	0.1	4.4	0.1
1982 /83	112	2.3	0.8	2.0	0.7
1983 /84	86	0.4	10.1	0.5	11.8
1984 /85	69	2.1	0.1	3.1	0.1
1985 /86	89	5.0	5.7	5.6	6.4
Average	85	3.7	3.7	4.3	4.3

Table 3.11 Summary of Runoff Analysis for Period Between 1963/64 and 1985/86

	Upper Hasa Basin			Jafr Basin			Recharge Dam							
	Entire Basin	Subbasin 1	Subbasin 2	Entire Basin	Subbasin 1	Subbasin 2	A1	A2	A3	B1	B2	B3	C1	C2
Catchment Area (km2)	2,198	1,400	798	13,427	2,521	10,906	24.3	32.2	31.1	55.7	135.9	71.7	89.3	115.3
Length of Riverbed (km)	300	200	100	1,500	600	900	10	15	11	22	65	20	35	40
Length of Permeable Riverbed (km)														
B2/A7 Aquifers	80	80	0	290	160	130	5	8	6	9	28	11	19	8
B4 Aquifers	25	10	15	80	30	50	0	0	0	0	0	0	0	0
Area of Permeable Zones (km2)														
B2/A7 Aquifers	586	586	0	2,221	826	1,395	20.2	30.6	31.1	32.6	108.5	67.0	89.3	78.5
B4 Aquifers	273	120	153	774	212	562	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average Annual Rainfall (mm)	92	115	53	51	128	33	302	291	271	146	136	134	108	91
Average Annual Runoff (mcm)	13.8	13.2	0.6	22.9	20.8	2.1	1.5	1.9	2.0	0.8	1.6	0.9	0.7	0.5
Runoff Coefficient (%)	6.8	8.2	1.5	3.3	6.5	0.6	20.1	20.8	23.3	10.3	8.7	9.1	7.6	4.7
Average Annual Sediment														
(mcm)	0.17	0.16	0.01	0.32	0.29	0.03	0.01	0.01	0.01	0.005	0.01	0.01	0.005	0.003
(% of runoff)	1.2	1.2	0.1	1.4	1.4	1.5	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6
(m3/km2/year)	77	114	13	24	115	3	352	363	406	90	84	74	52	26
Annual Recharge Through Riverbed (mcm)														
B2/A7 Aquifers	2.4	2.4	0.0	6.7	6.0	0.7	0.5	0.8	0.5	0.4	1.3	0.5	0.7	0.3
B4 Aquifers	0.6	0.4	0.2	2.0	1.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note:
On average between 1937 and 1988, annual rainfall of Subbasin 1 is more than 50 mm and that of Subbasin 2 is less than 50 mm.

Table 3.12 Water Quality of Hasa River at Ghor Safi

Electrical Conductivity (Mmhos/cm)	Total Dissolved Solids (mg/lit)	CA++ (mg/lit)	Mg++ (mg/lit)	Na+ (mg/lit)	K+ (mg/lit)	Cl- (mg/lit)	SO4- (mg/lit)	CO3- (mg/lit)	HCO3- (mg/lit)	Na% (mg/lit)	PH	Sodium Absorption Ratio (SAR)	Total Cations (mg/lit)
0.575	368	2.4	1.6	1.7	0.1	2.23	1.2	0.0	2.33	29.31	7.4	1.2	5.8

Table 4.1 Main Features of Proposed Storage Dams

Name of wadi	Jurdhan	Abusafat	Usheishat	Matkh	Fassua	Abyad	Uqeiqa	El Jahdaniya
Catchment area (km2)	709	839	-	1,000	-	-	-	-
Dam type	Rockfill	-	-	-	-	-	-	-
Dam height (m)	18	13	12	-	15	12	17	13
Dam volume (m3)	146,000	-	-	-	-	-	-	-
Crest length (m)	-	-	2,000	800	1,200	300	300	1,000
Reservoir volume (MCM)	-	2.0	2.4	-	-	-	-	-

Table 4.2 Storage Capacity and Construction Cost of Recharge Dams

Recharge Dam	Catchment Area (km2)	Average Annual Inflow (1) (mcm)	Average Annual Evapolation (2) (mcm)	Maximum Annual Inflow (3) (mcm)	Gross Storage Capacity (4) (mcm)	Effective Storage Capacity (mcm)	Dam Height (m)	Dam Concrete Volume (m3)	Construction Cost of Concrete Dam Body (1000 US$)
A1	34.3	1.5	0.06	5.6	3.7	3.2	19	48,000	4,320
A2	32.2	1.9	0.09	9.1	6.0	5.3	18	54,000	4,860
A3	31.1	2.0	0.05	12.0	8.5	7.8	39	125,000	11,250
B1	55.7	0.8	0.03	3.6	2.4	2.1	20	25,000	2,250
B2	135.9	1.6	0.07	8.9	4.2	3.7	19	38,000	3,420
B3	71.7	0.9	0.06	4.8	2.0	1.7	10	8,000	720

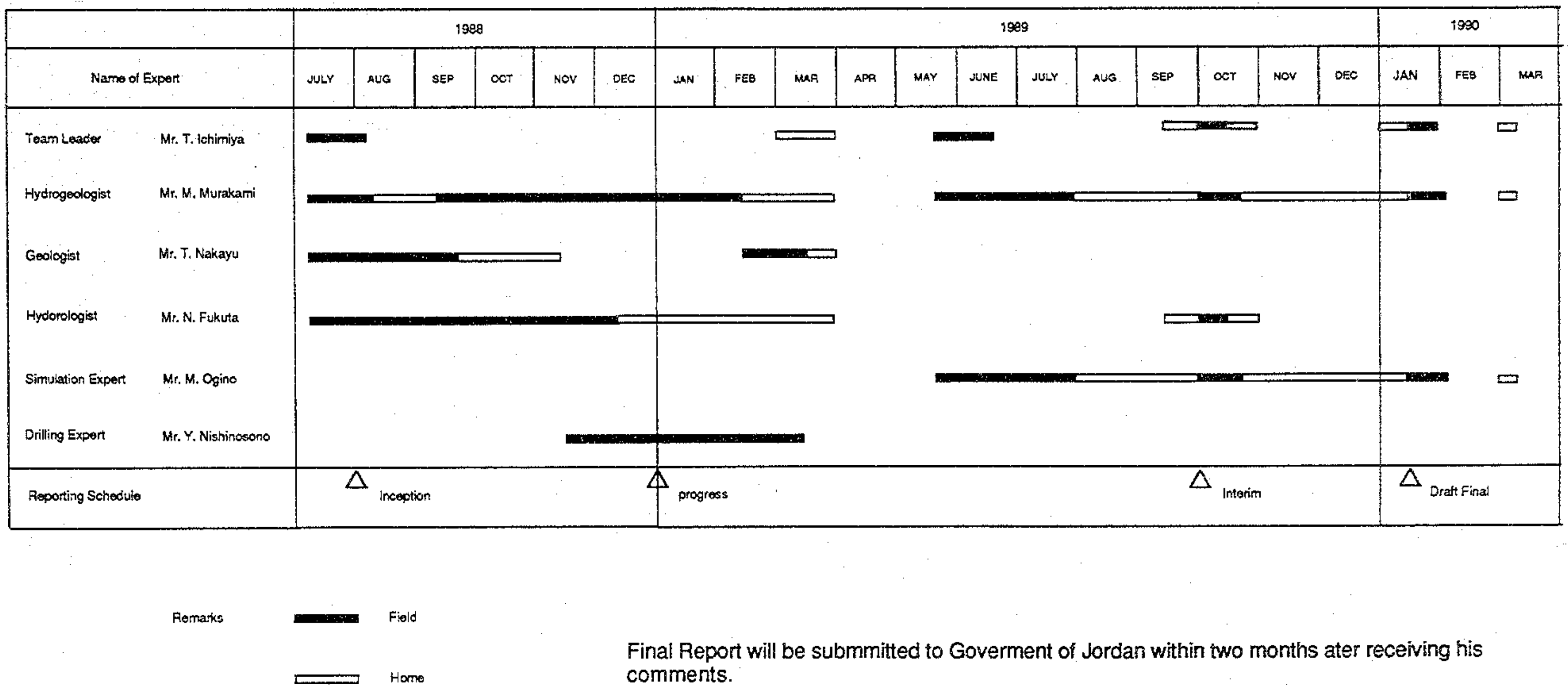
Note
(1) Average of 23 years between 1963/64 and 1985/86
(2) Maximum of 23 years between 1963/64 and 1985/86
(3) Gross storage capacity is equal to effective storage capacity plus dead storage due to 50-year sedimentation.

Table 5.1 Simulated TDS of 1-km2-Large Irrigation Area

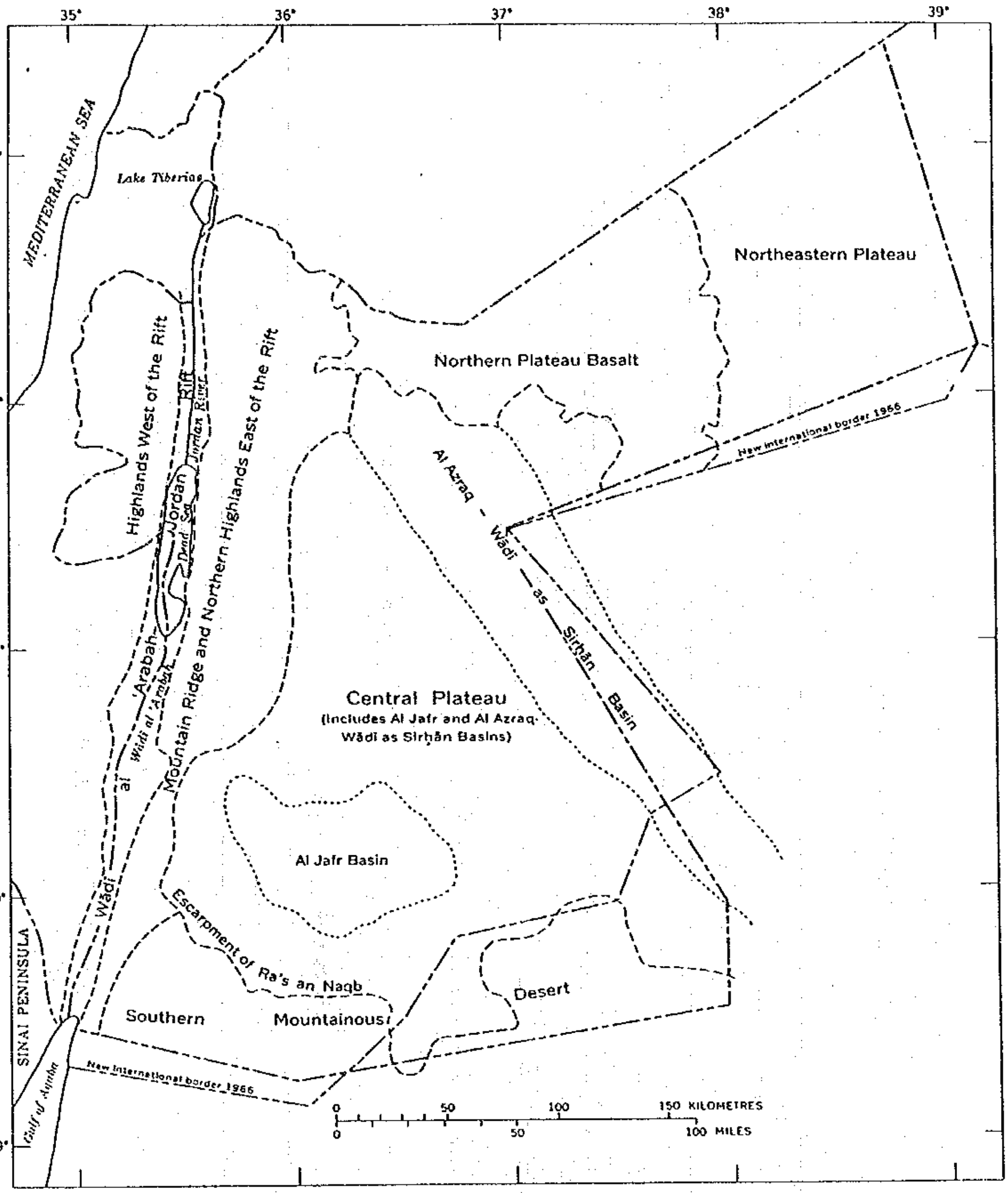
Year	Simulated TDS at Year End (ppm)	Year	Simulated TDS at Year End (ppm)
1966	500	1986	1,687
1967	500	1987	1,624
1968	500	1988	1,564
1969	715	1989	1,506
1970	1,017	1990	1,452
1971	1,208	1991	1,400
1972	1,390	1992	1,350
1973	1,564	1993	1,303
1974	1,730	1994	1,258
1975	1,888	1995	1,215
1976	1,889	1996	1,174
1977	1,890	1997	1,135
1978	1,891	1998	1,097
1979	1,892	1999	1,062
1980	1,893	2000	1,028
1981	1,894	2001	995
1982	1,895	2002	965
1983	1,895	2003	935
1984	1,823	2004	907
1985	1,753	2005	880

FIGURES

Fig. 1.1 Assignment Schedule



Final Report will be submmitted to Goverment of Jordan within two months ater receiving his comments.



Source : Geology of the Arabian Peninsula Jordan
By FRIEDRICH BENDER (1975)

Fig. 2.1

Index Map of Physiographic-Geologic Provinces, Jordan

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JAPAN INTERNATIONAL COOPERATION AGENCY

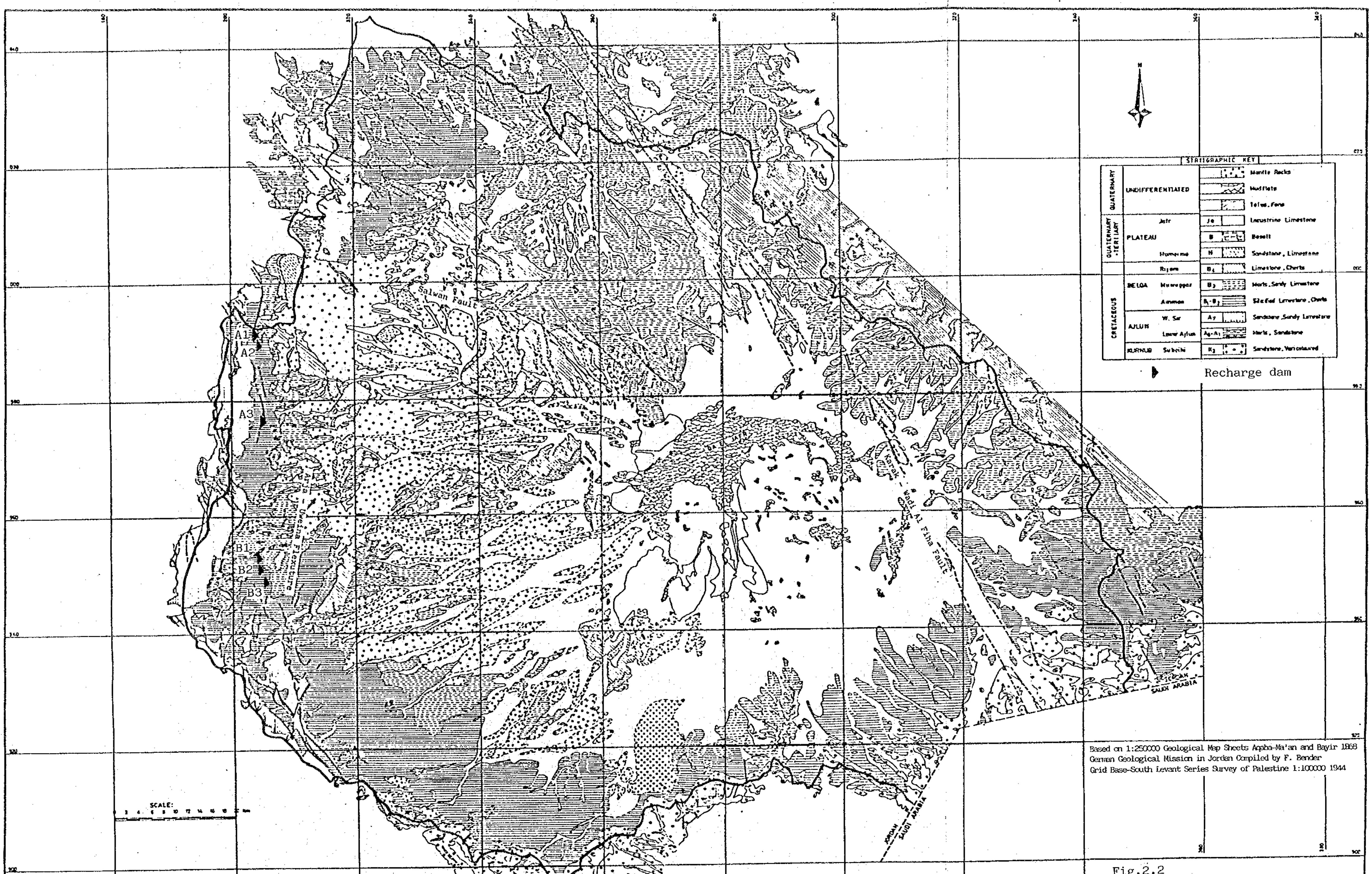

Fig.2.2
Geological Map of Study Area

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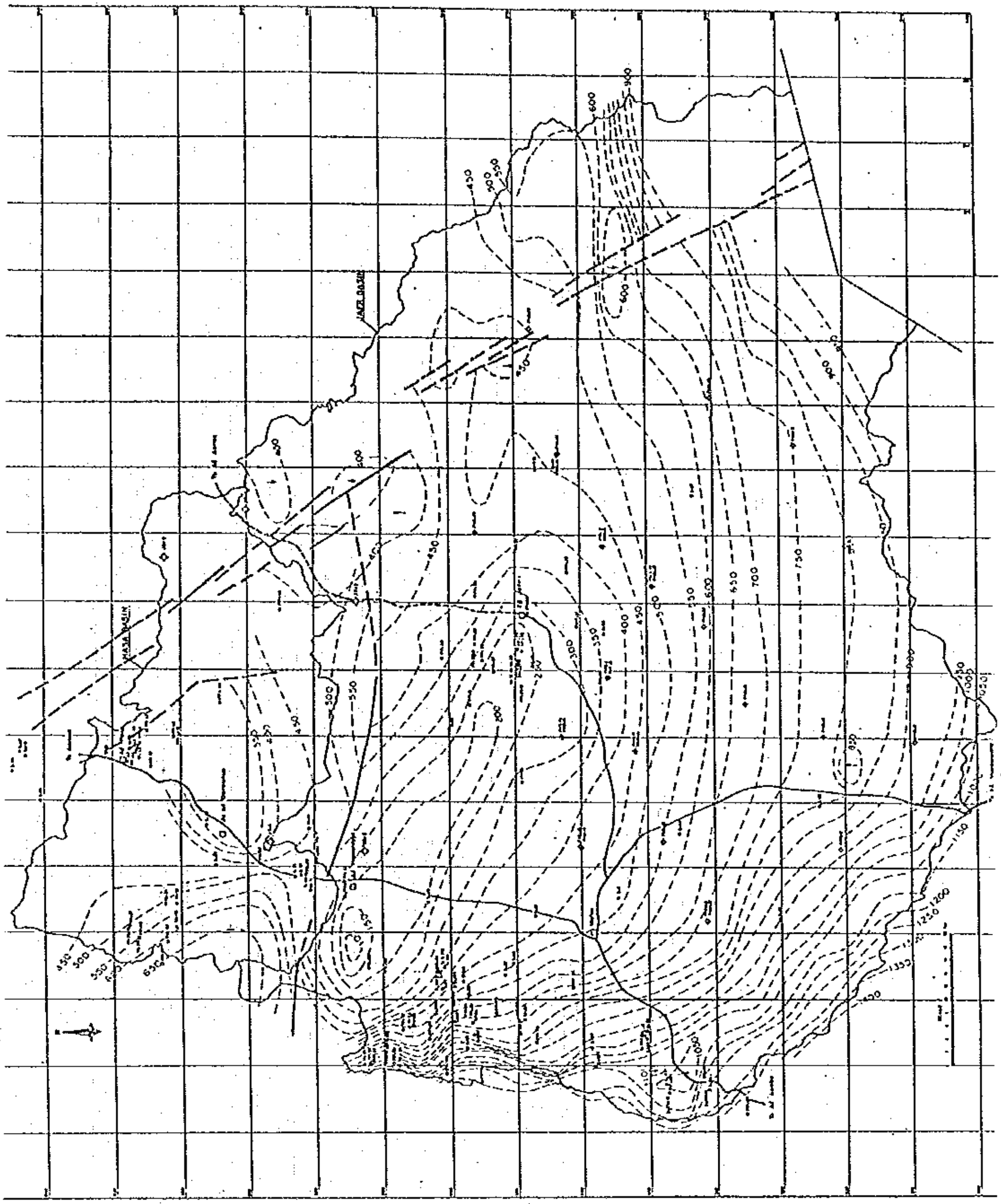

Fig.2.3

Structural Contour Map of Top of Kurnub (K) Formation

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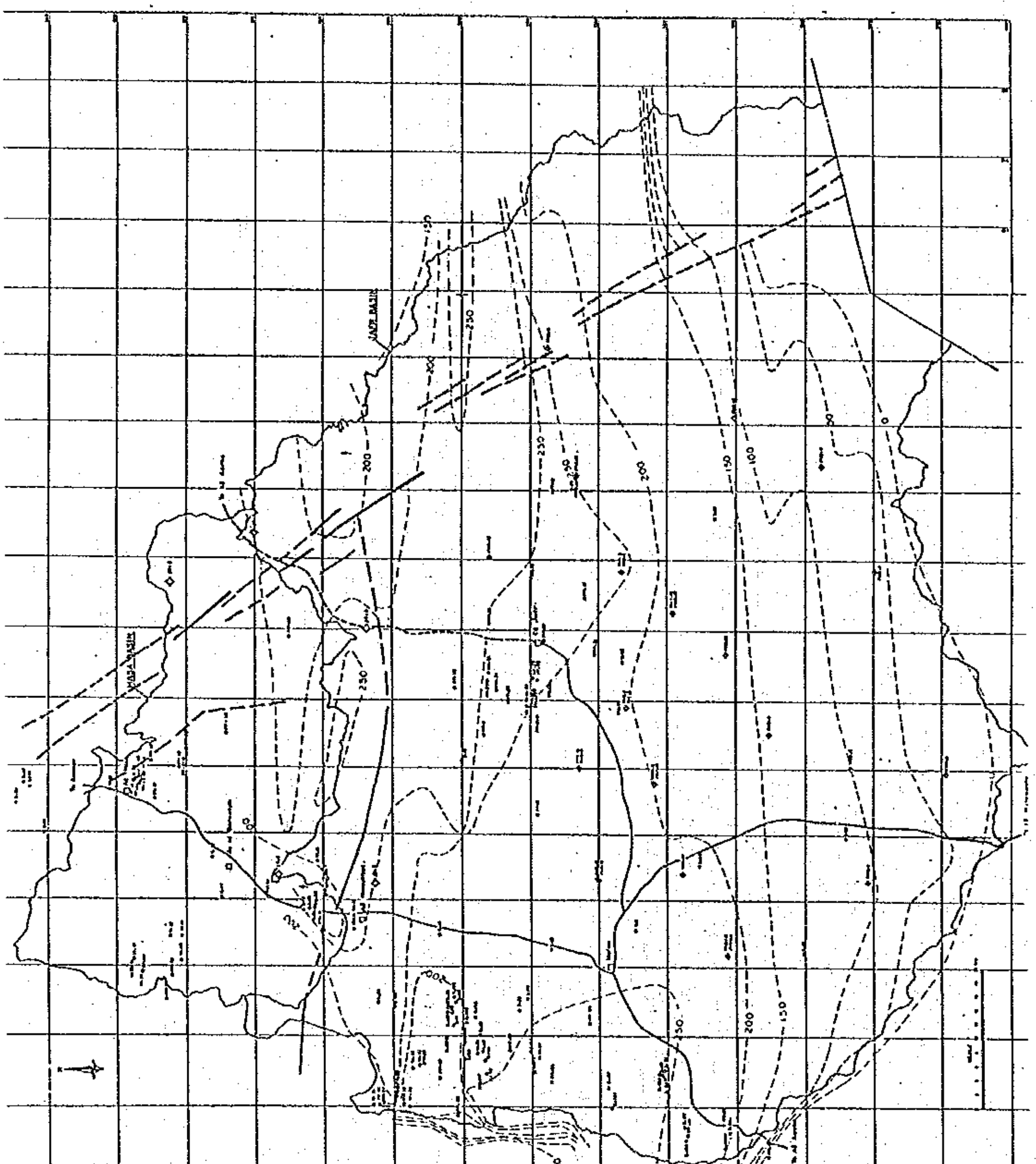

Fig. 2.4

Isopach Contour Map of Lower Ajlun (A1-6) Formation

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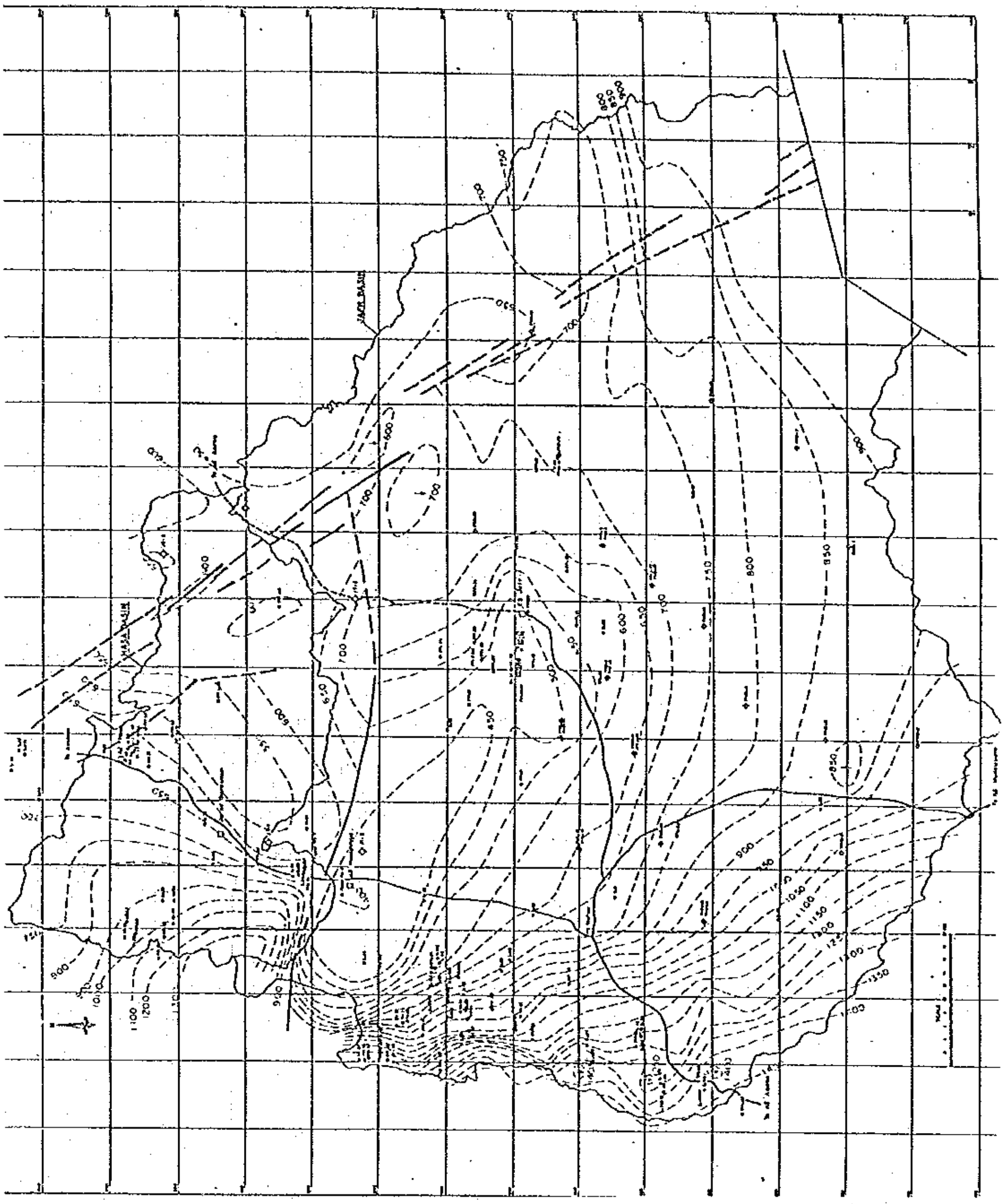

Fig.2.5

Structural Contour Map of Top of Lower Ajlun (A1-6) Formation

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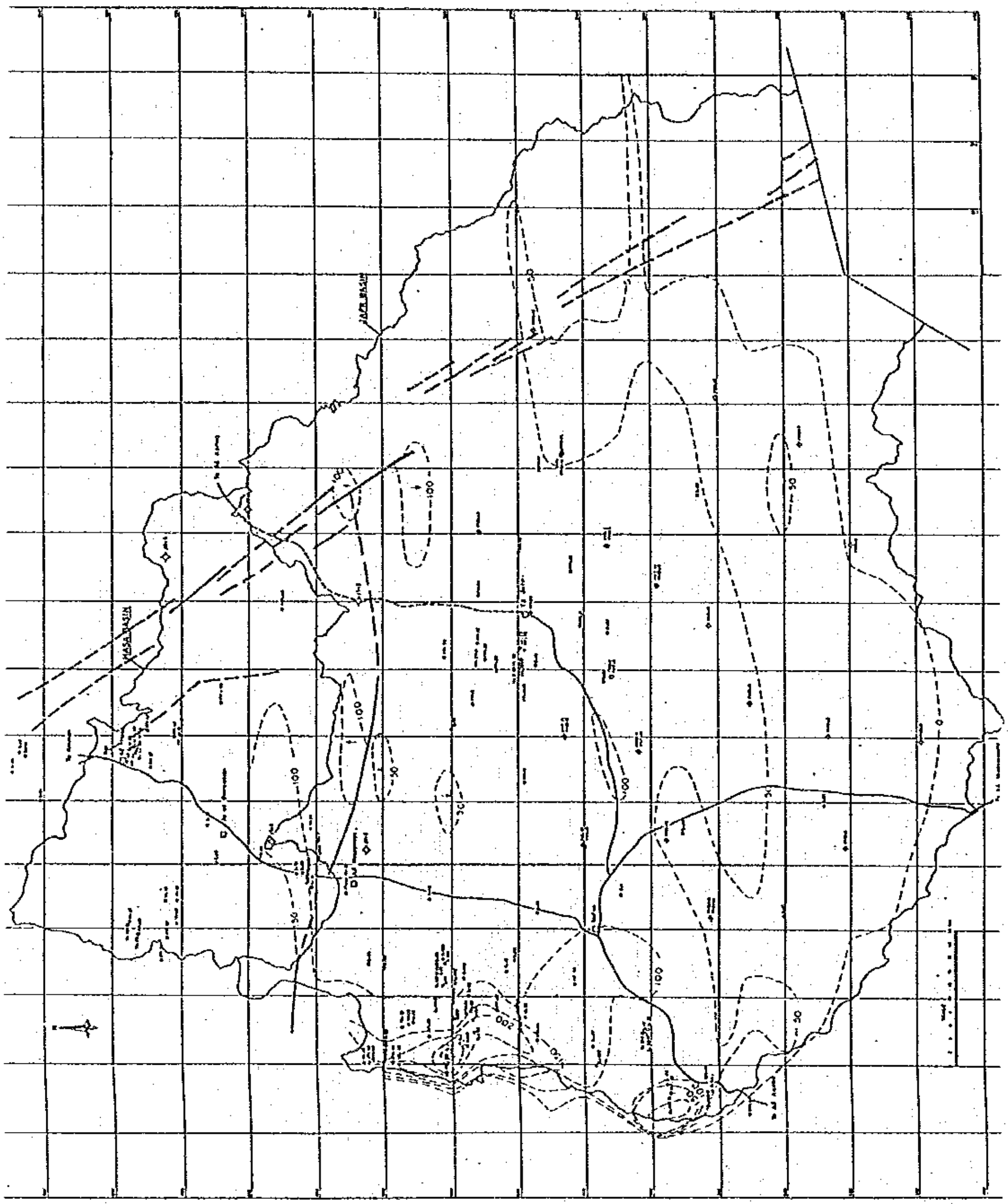

Fig. 2.6

Isopach Contour Map of Wadi Sir (A7) Formation

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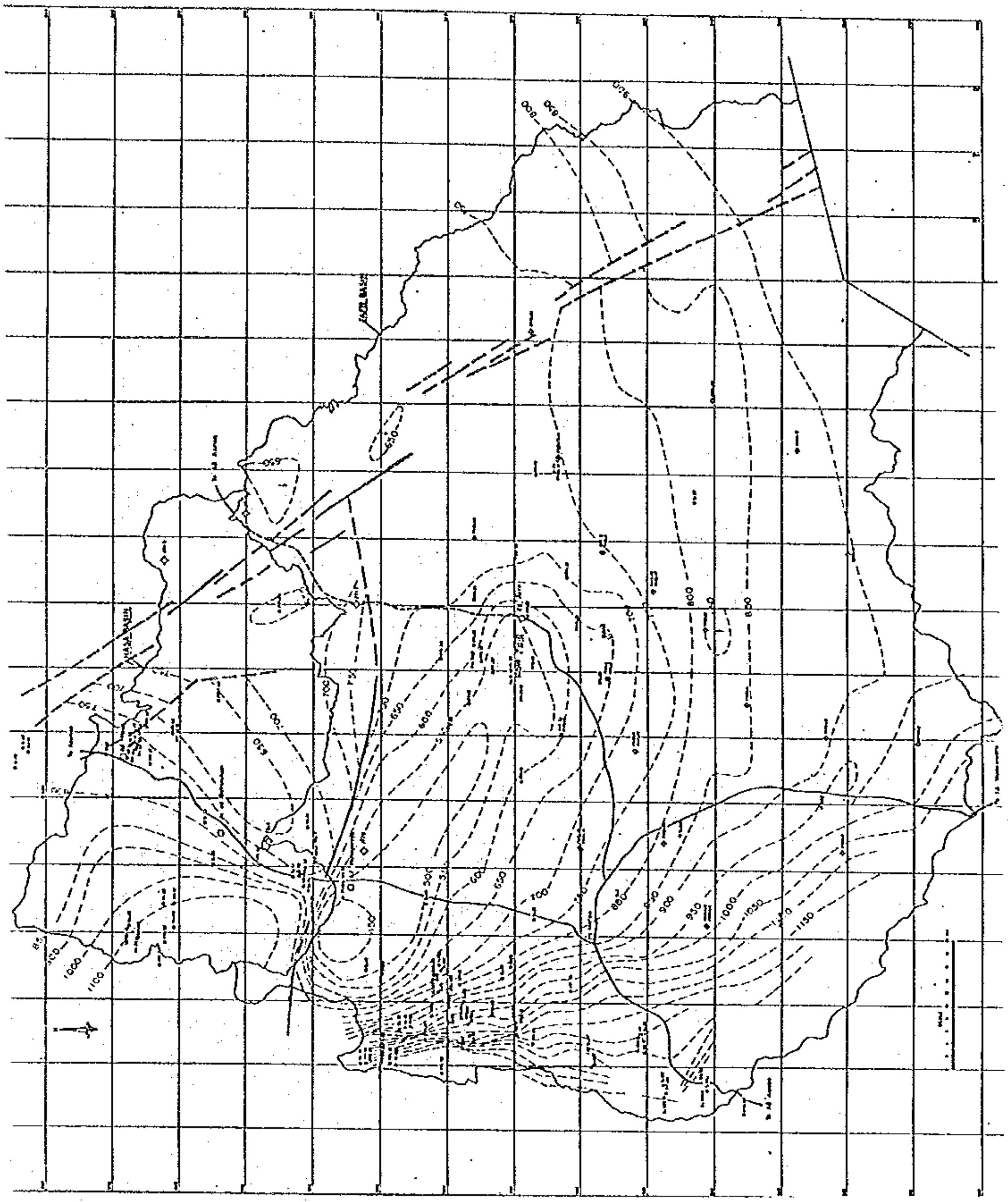

Fig. 2.7

Structural Contour Map of Top of Wadi Sir (A7) Formation

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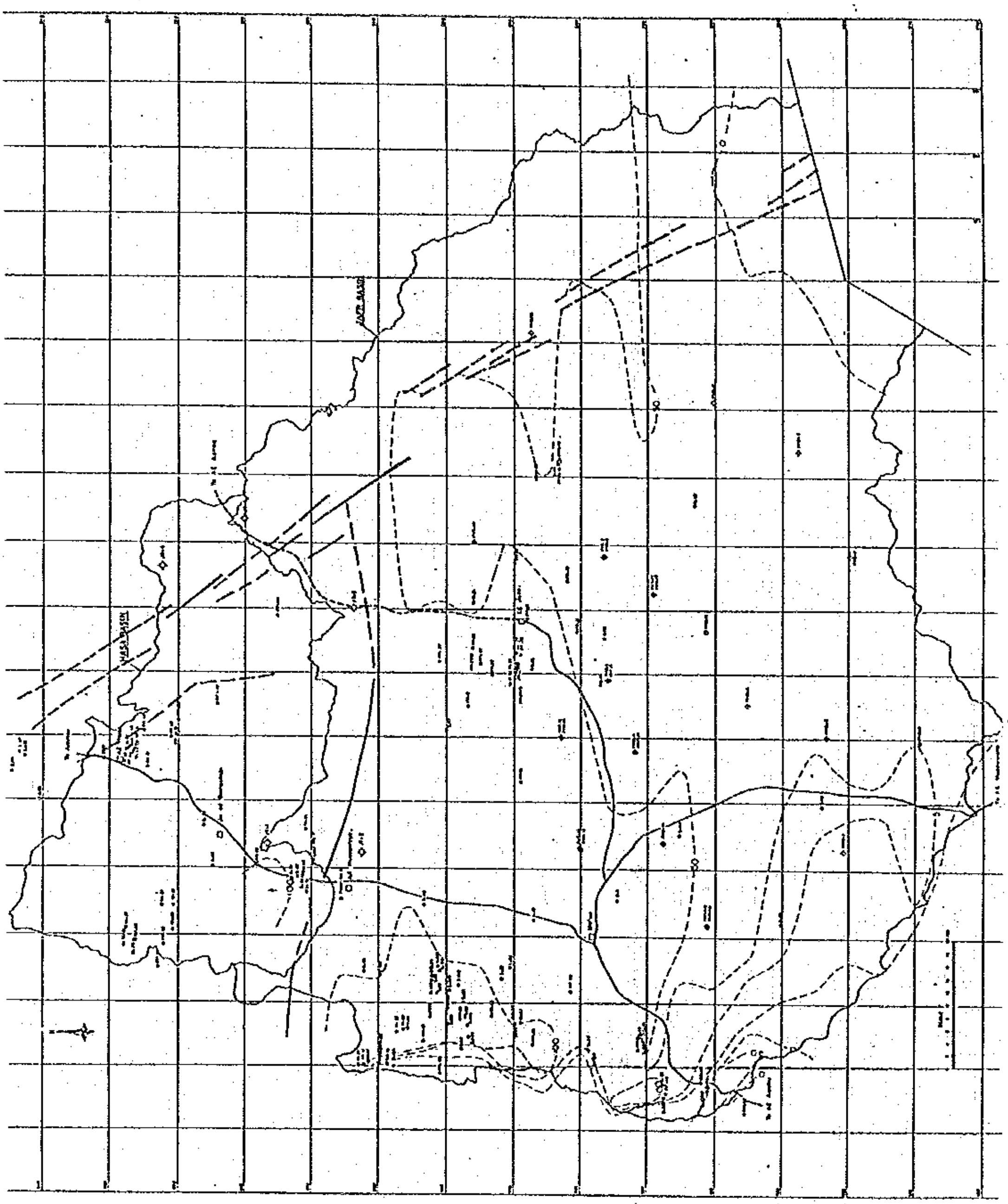

Fig. 2.8

Isopach Contour Map of Amman-Ruseifa (B1/2) Formation

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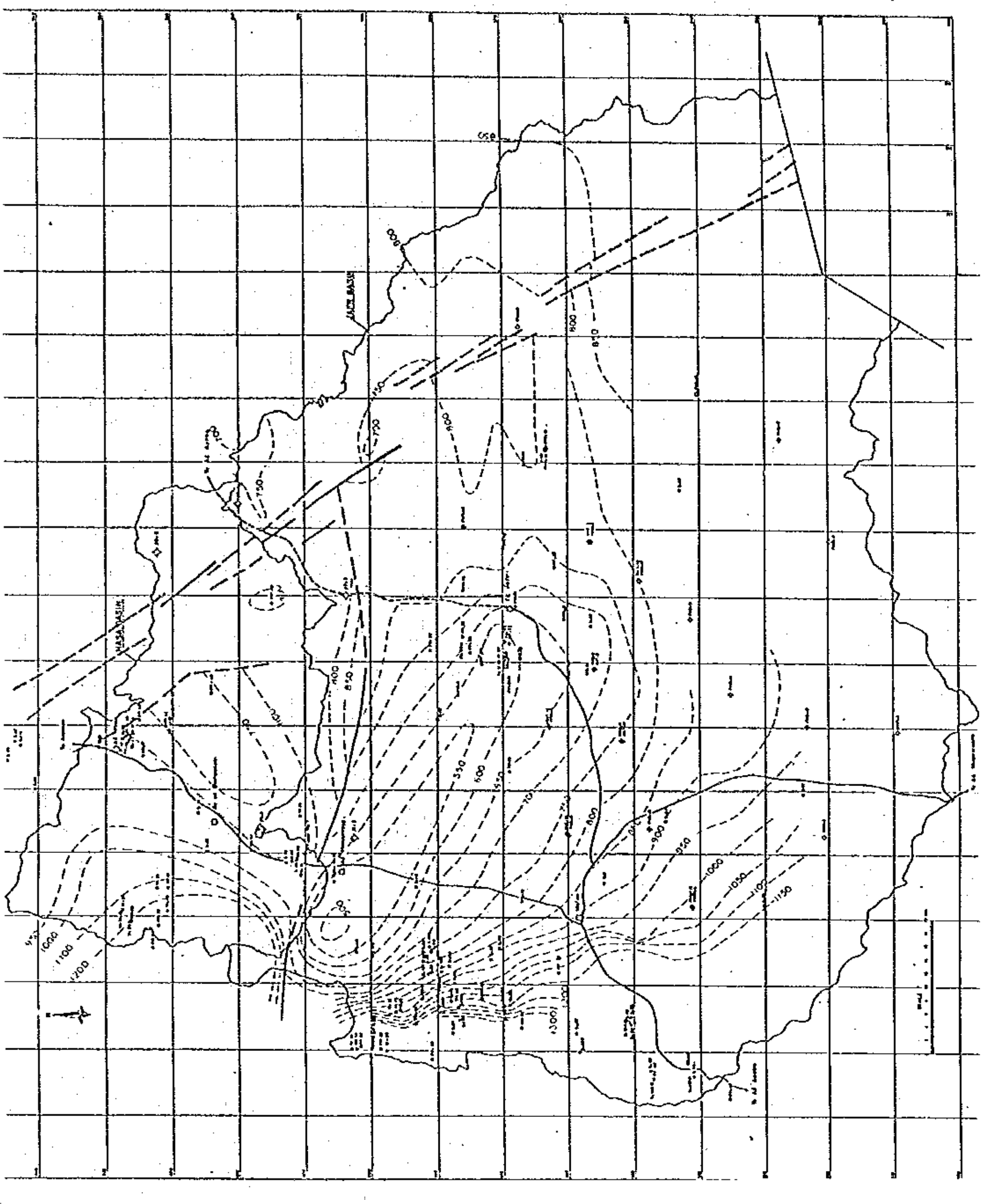

Fig. 2.9

Structure Contour Map of Top of Amman-Ruseifa (B1/2) Formation

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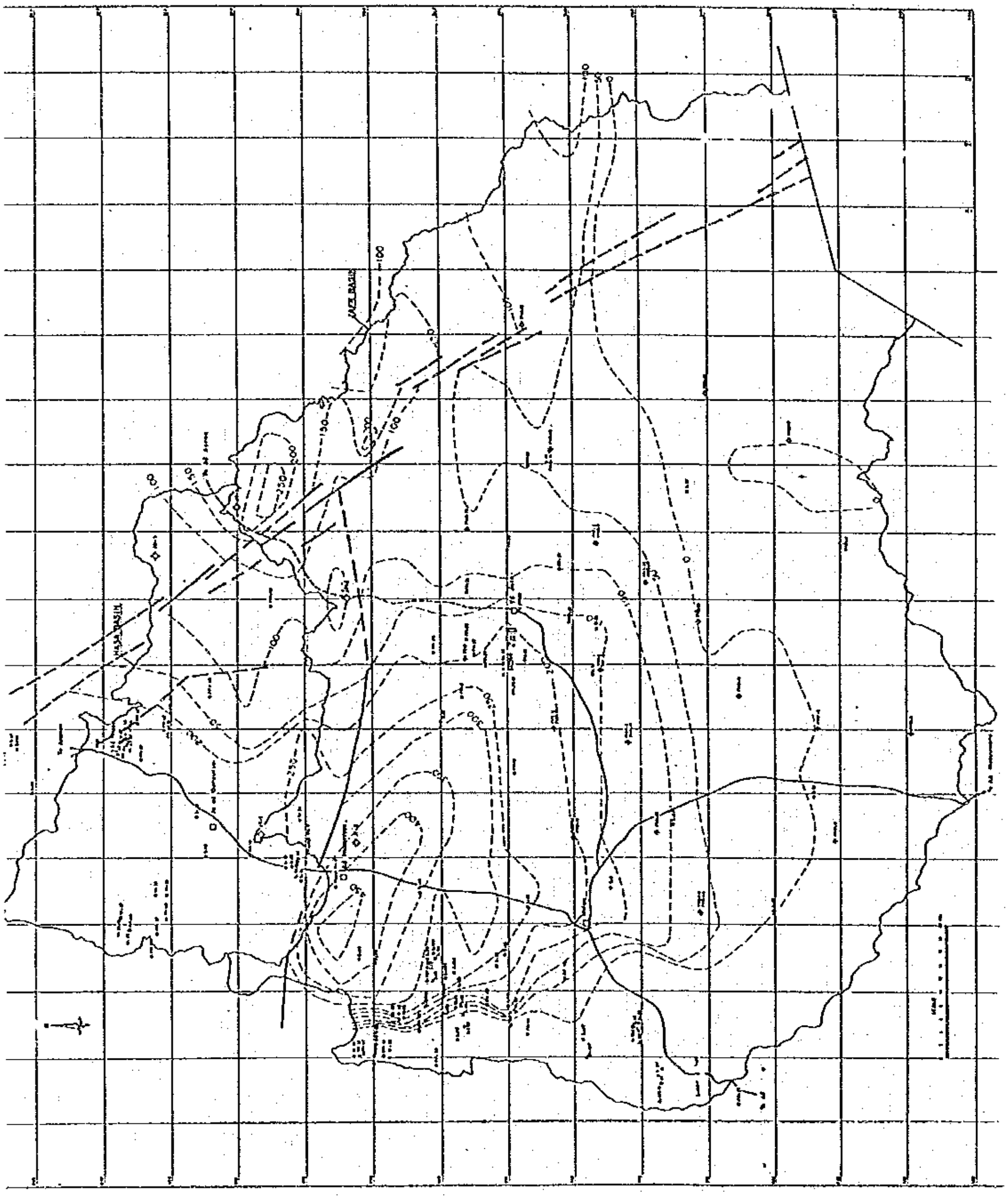

Fig. 2.10

Isopach Contour Map of Muwaqqar (B-3) Formation

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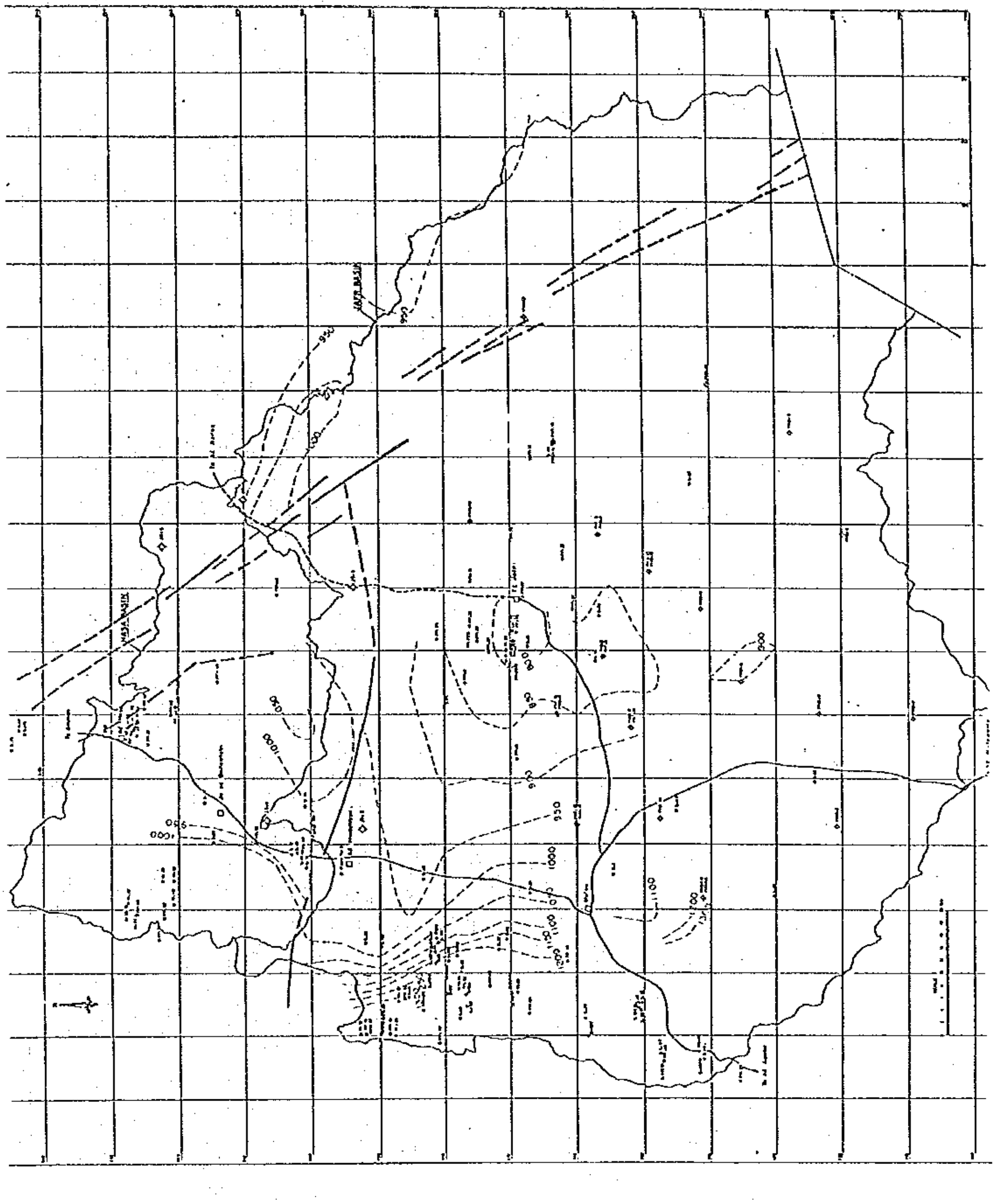

Fig. 2.11

Structural Contour Map of Top of Muwaqqar (B-3) Formation

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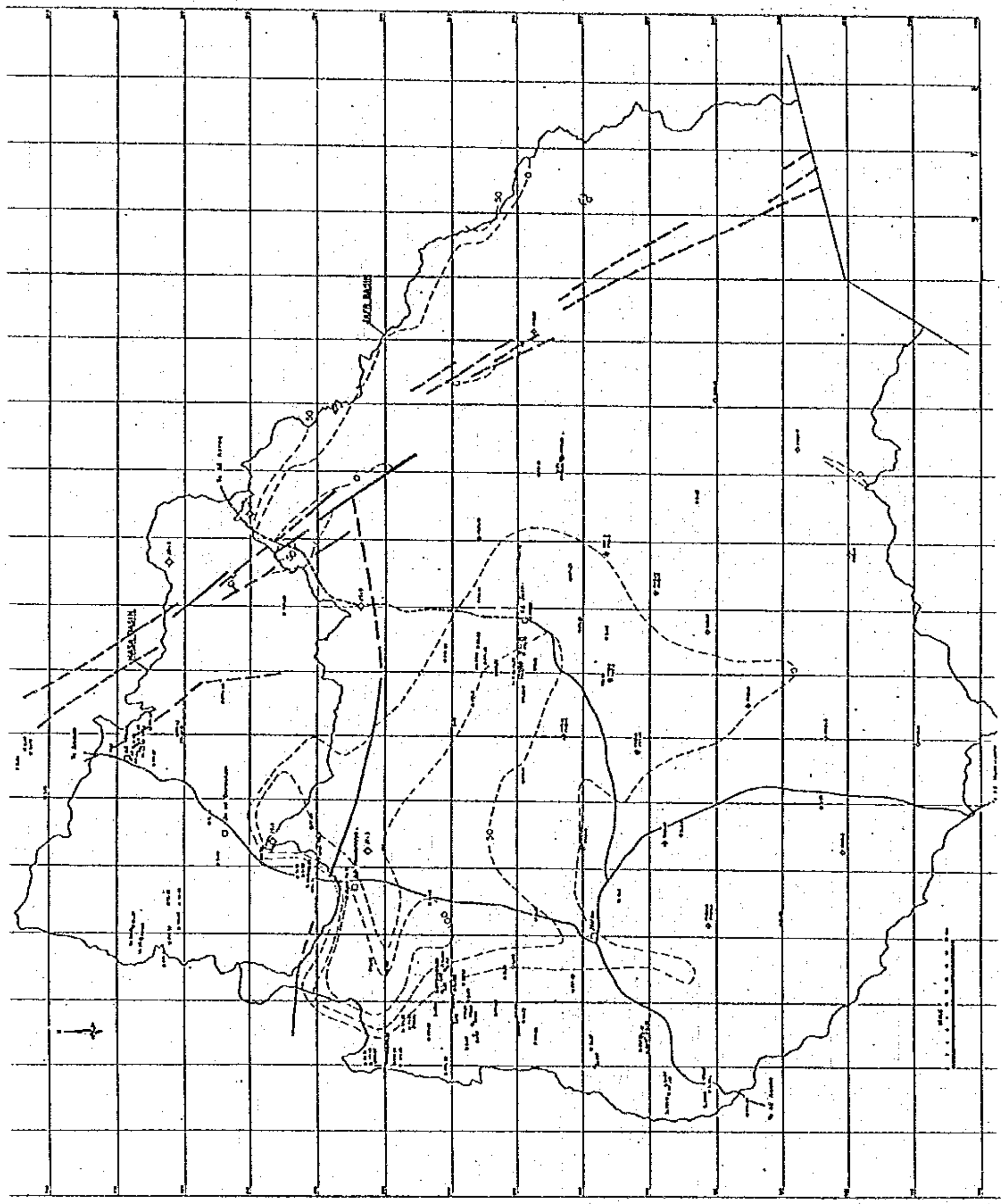

Fig. 2.12

Isopach Contour Map of Rijam (B-4) Formation

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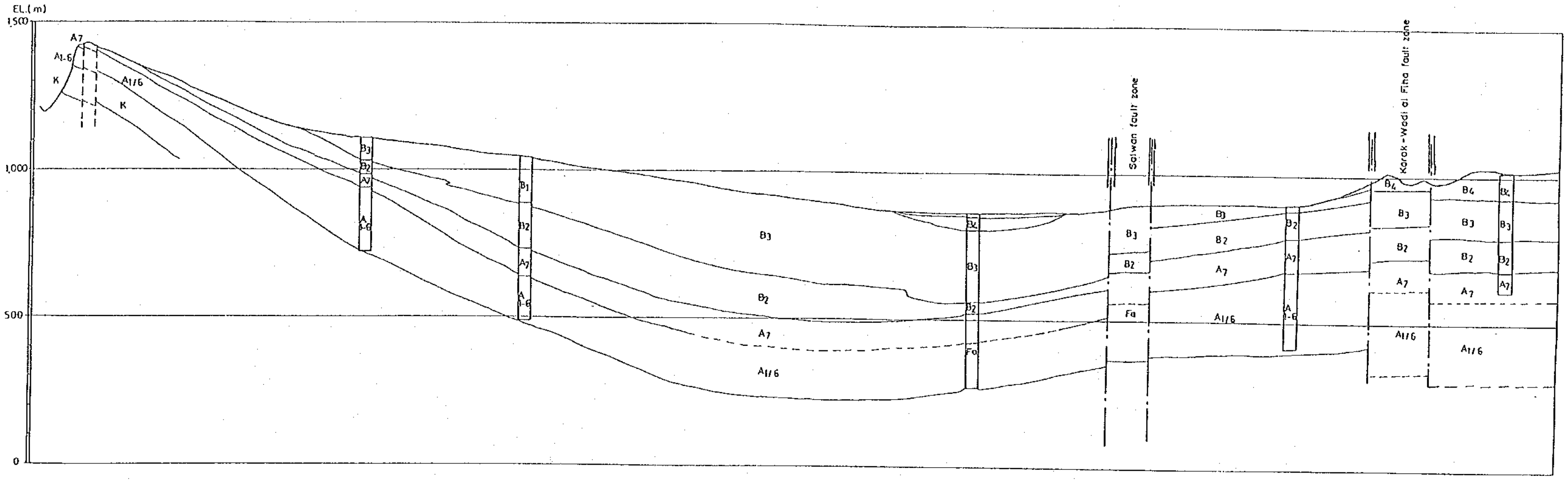

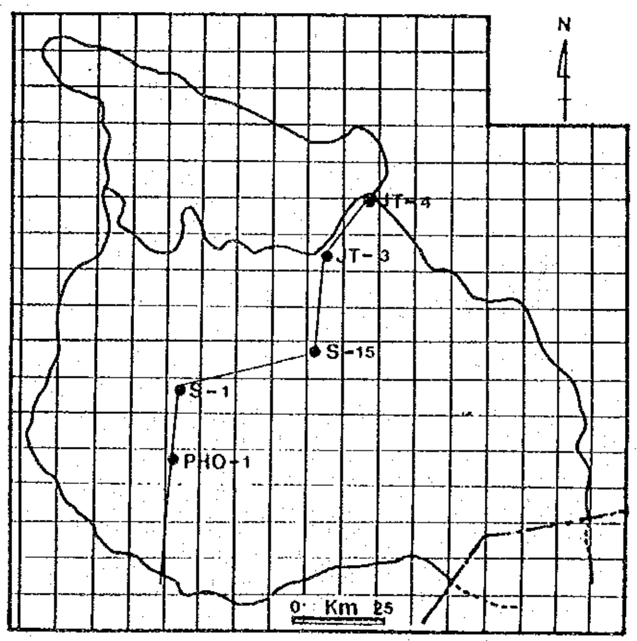

STRTIGRAPHIC KEY

QUATERNARY	UNDIFFERENTIATED			Mantle Rocks
				Mudflats
				Talus, Fans
QUATERNARY -TERTIARY	PLATEAU	Jafr	Ja	Lacustrine Limestone
			B	Basalt
		Humeima	H	Sandstone, Limestone
CRETACEOUS	BELQA	Rijam	B_4	Limestone, Cherts
		Muwaggar	B_3	Marls, Sandy Limestone
		Amman	B_1-B_2	Silicified Limestone, Cherts
	AJLUN	W. Sir	A_7	Sandstone, Sandy Limestone
		Lower Ajlun	A_6-A_1	Marls, Sandstone
	KURNUB	Subeihi	K_2	Sandstone, Varicoloured

Fig. 2.13

Geological Profile of the Jafr Basin

THE HASHEMITE KINGDOM OF JORDAN

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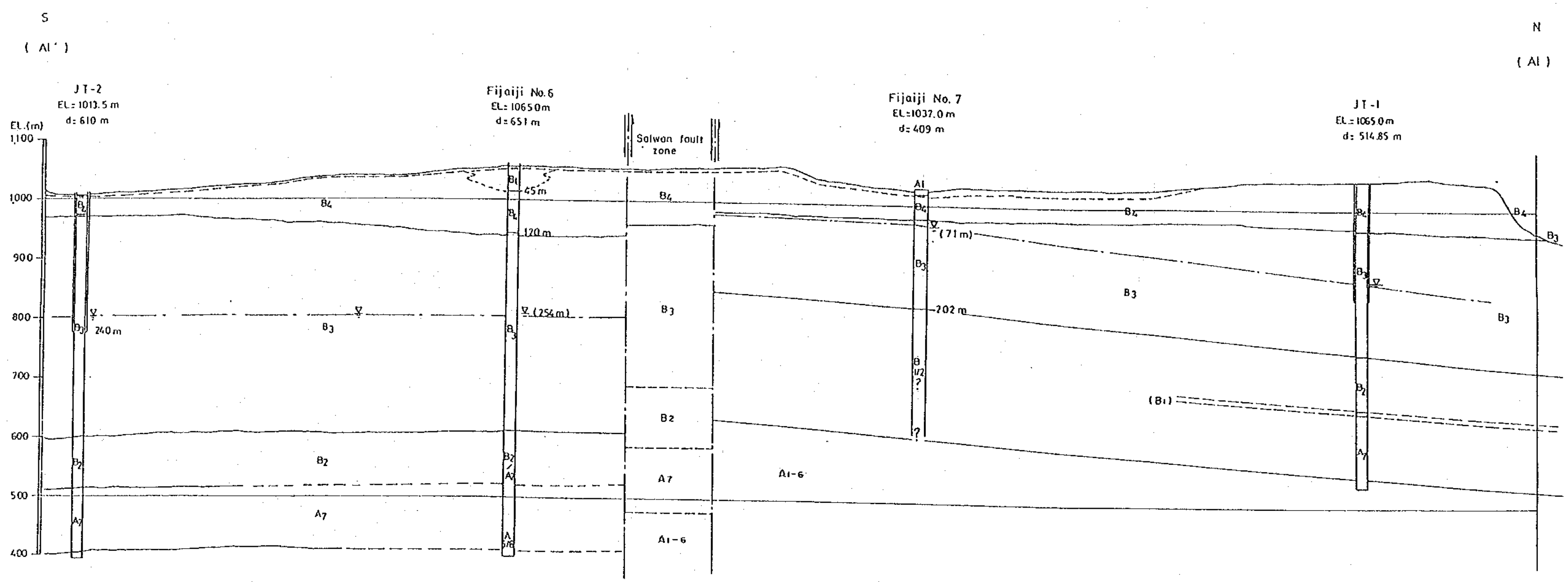

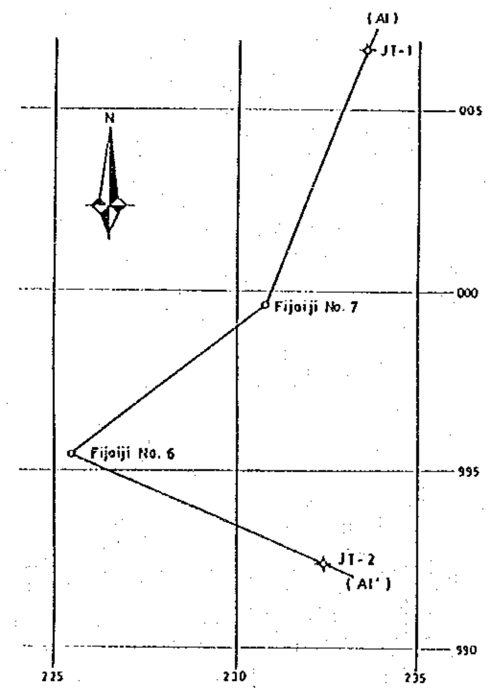

STRTIGRAPHIC KEY

QUATERNARY	UNDIFFERENTIATED			Mantle Rocks
				Mudflats
				Talus, Fans
QUATERNARY -TERTIARY	PLATEAU	Jafr	Ja	Locustrine Limestone
			B	Basalt
		Humeima	H	Sandstone, Limestone
CRETACEOUS	BELQA	Rijam	B4	Limestone, Cherts
		Muwaggar	B3	Marls, Sandy Limestone
		Amman	B1-B2	Silicified Limestone, Cherts
	AJLUN	W. Sir	A7	Sandstone, Sandy Limestone
		Lower Ajlun	A6-A1	Marls, Sandstone
	KURNUB	Subeihi	K2	Sandstone, Varicoloured

Fig.2.14

Geological Profile of Northwest Jafr Basin ; JT1-JT2

THE HASHEMITE KINGDOM OF JORDAN

WATER RESOURCES STUDY OF THE JAFR BASIN

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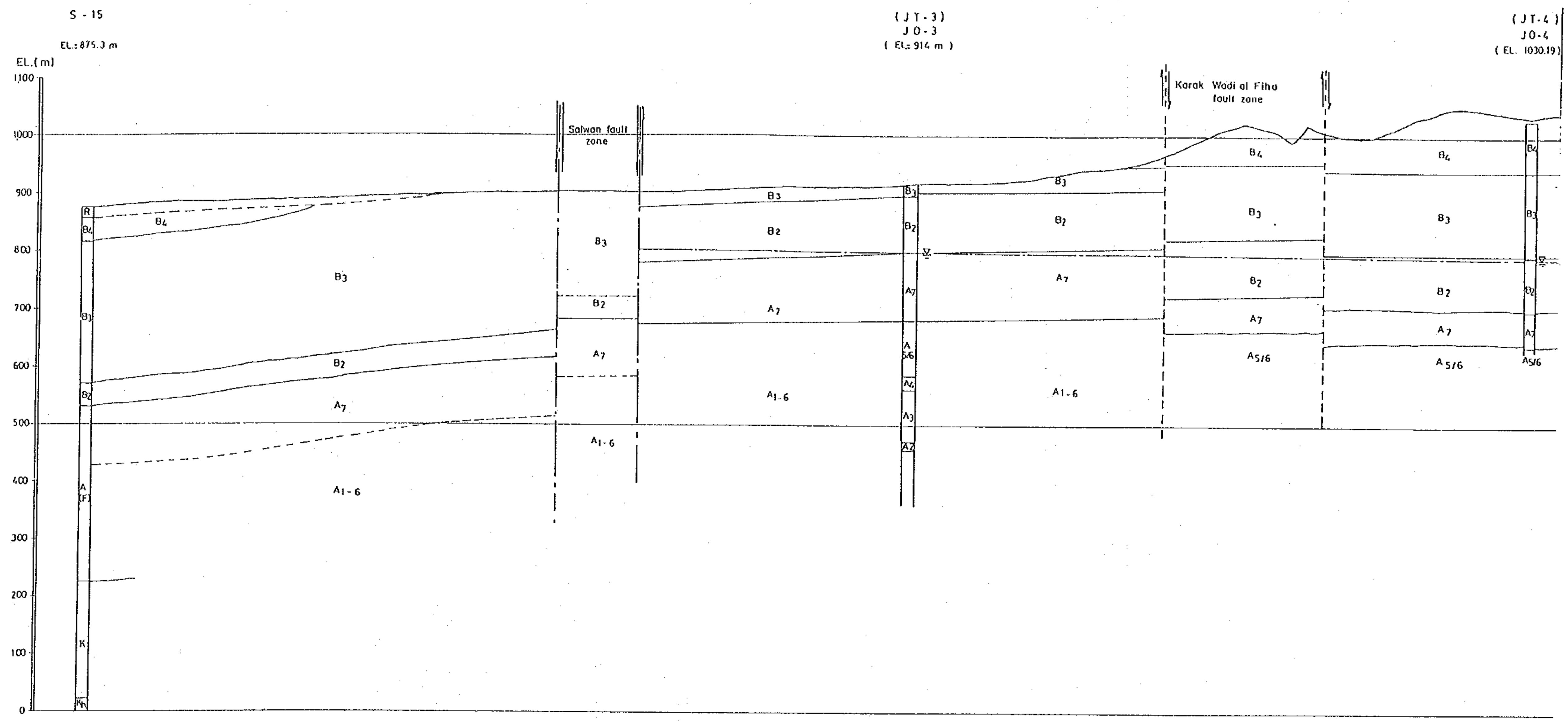

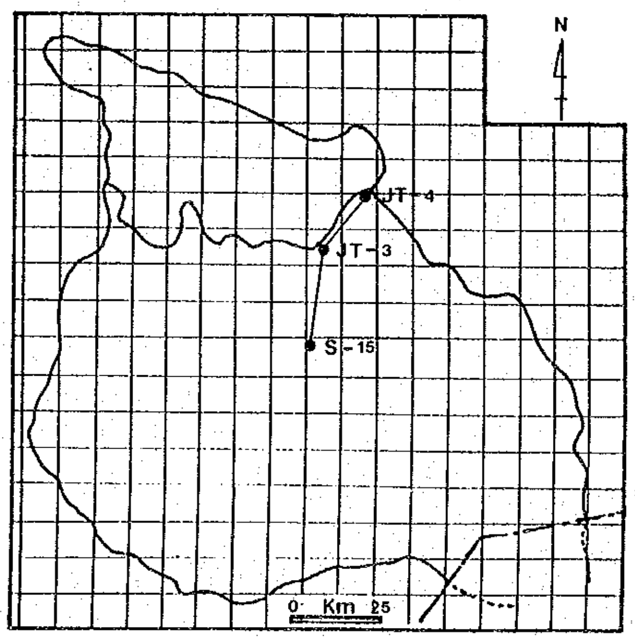

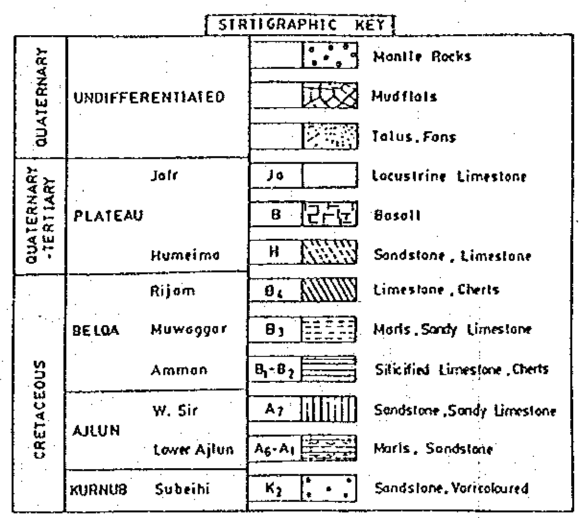

Fig. 2.15

Geological Profile of Northeast Jafr Basin (1/2) ; JT3-JT4

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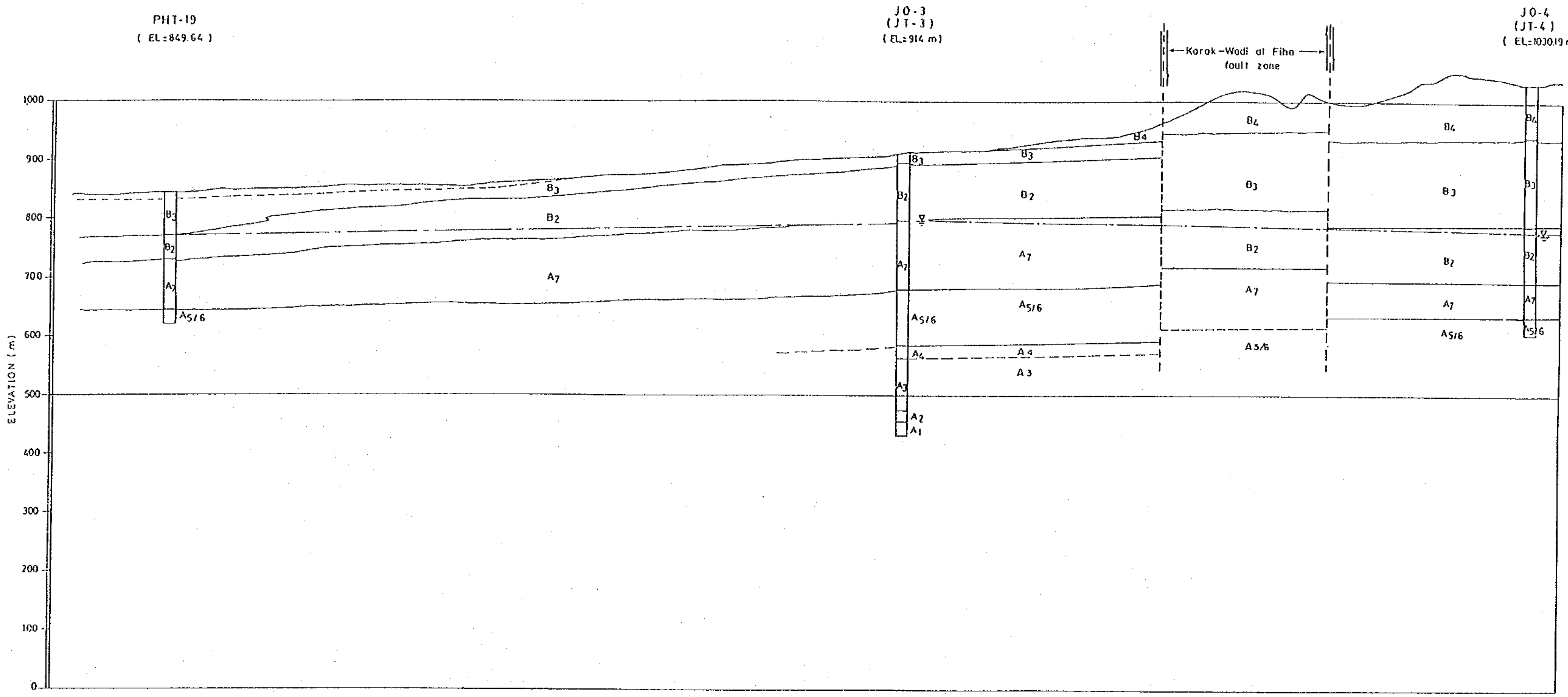

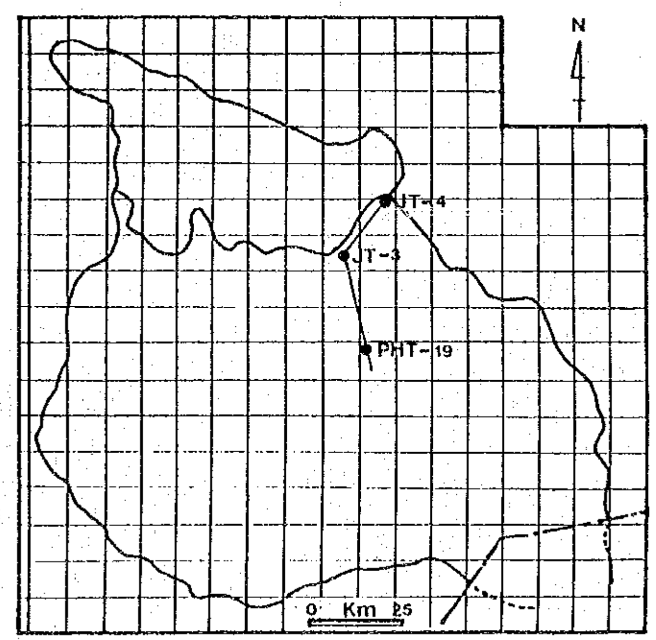

STRITIGRAPHIC KEY

QUATERNARY	UNDIFFERENTIATED			Mantle Rocks
				Mudflats
				Talus, Fans
QUATERNARY -TERTIARY	PLATEAU	Jafr	Ja	Lacustrine Limestone
			B	Basalt
		Humeima	H	Sandstone, Limestone
CRETACEOUS	BELQA	Rijam	B4	Limestone, Cherts
		Muwaqqar	B3	Marls, Sandy Limestone
		Amman	B1-B2	Silicified Limestone, Cherts
	AJLUN	W. Sir	A7	Sandstone, Sandy Limestone
		Lower Ajlun	A6-A1	Marls, Sandstone
	KURNUB	Subeihi	K2	Sandstone, Voricoloured

Fig. 2.16

Geological Profile of Northeast Jafr Basin (2/2) : JT3-JT4

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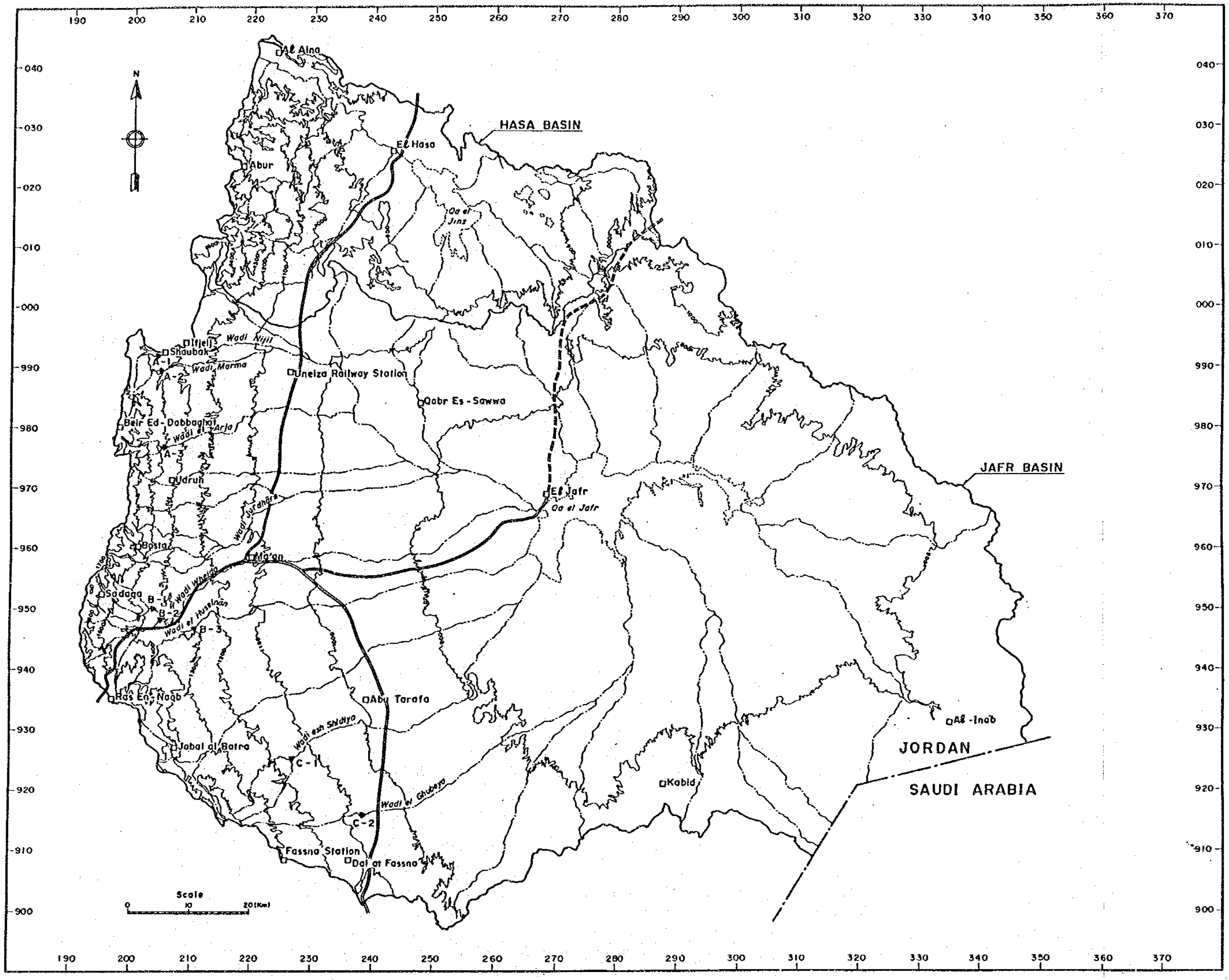

Fig. 2.17
Topography of Study Area

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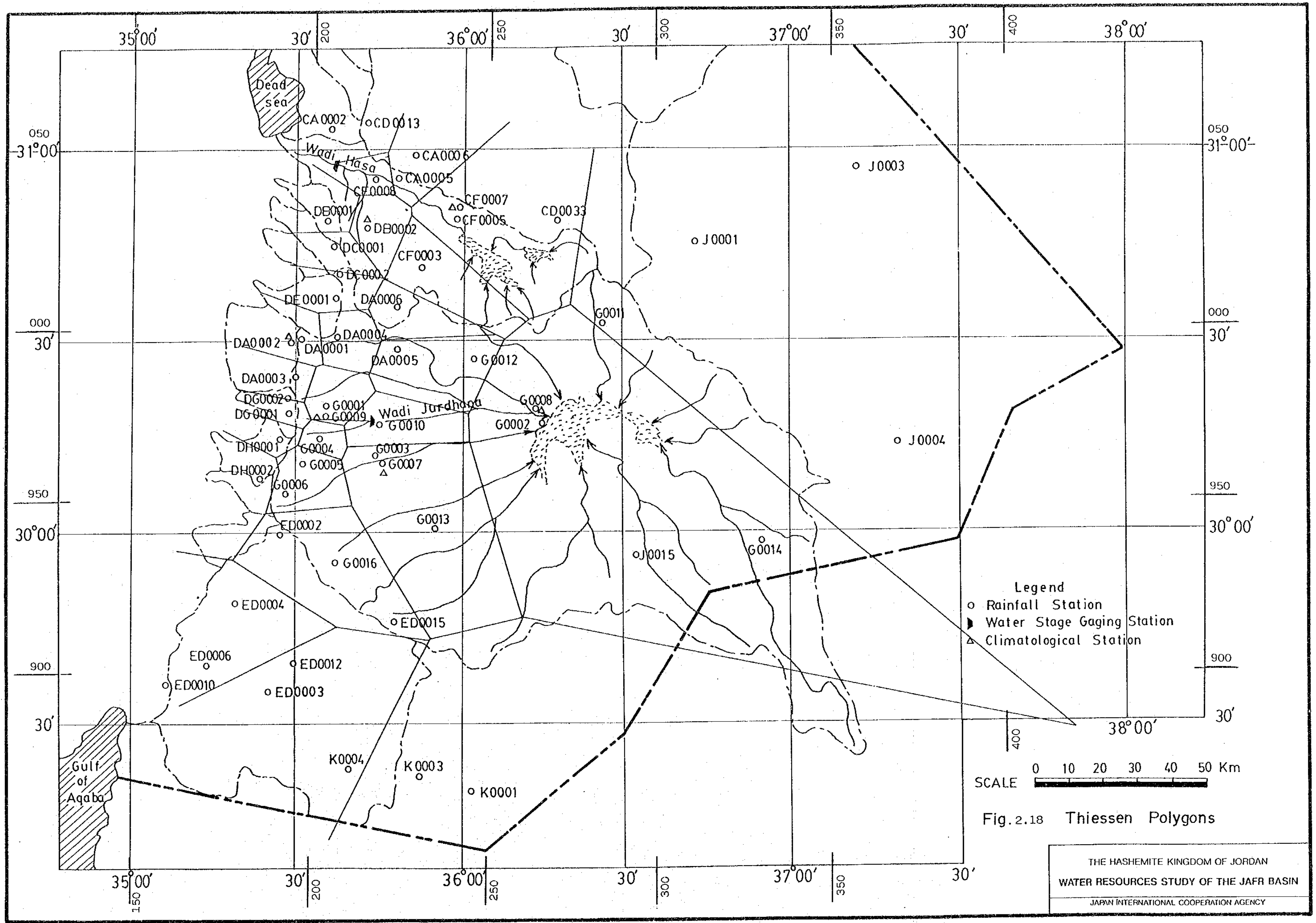

Fig. 2.18 Thiessen Polygons

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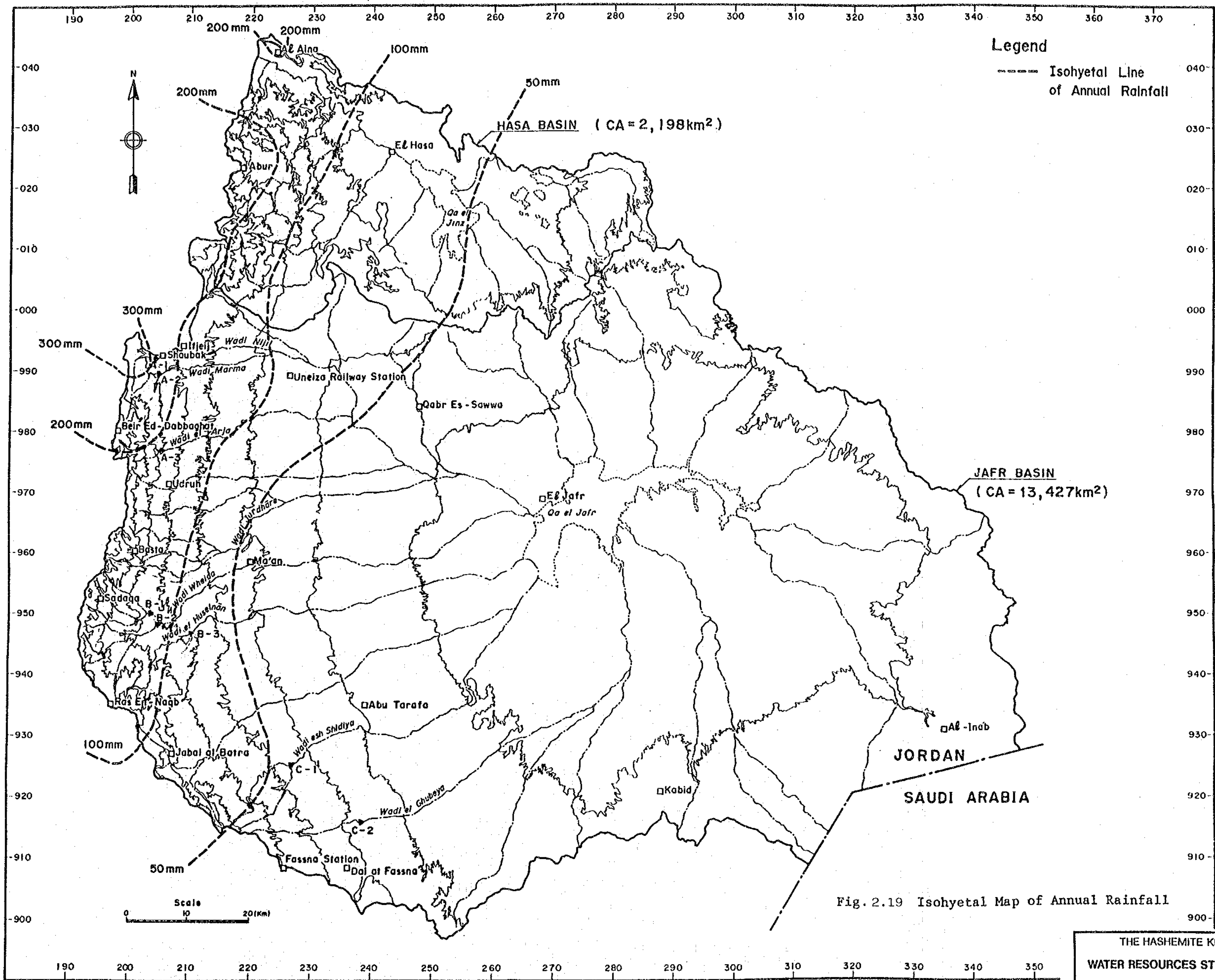

Fig. 2.19 Isohyetal Map of Annual Rainfall

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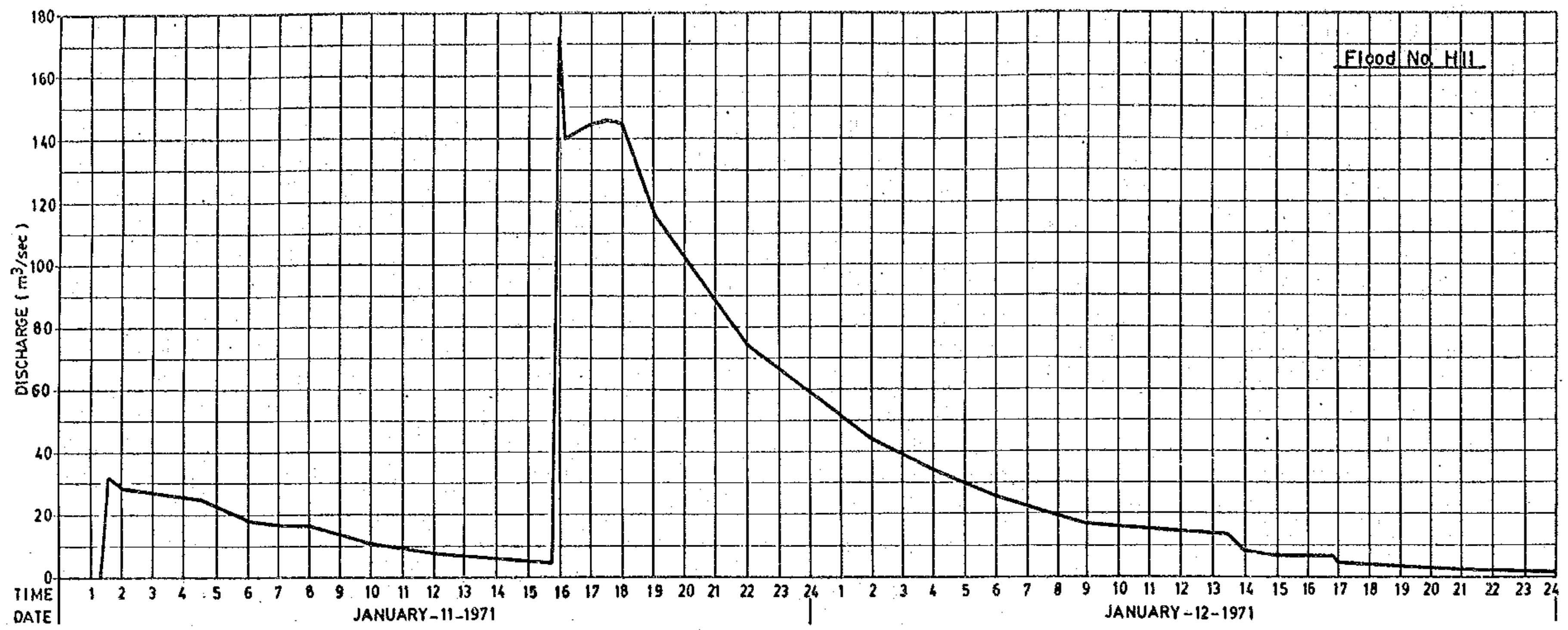

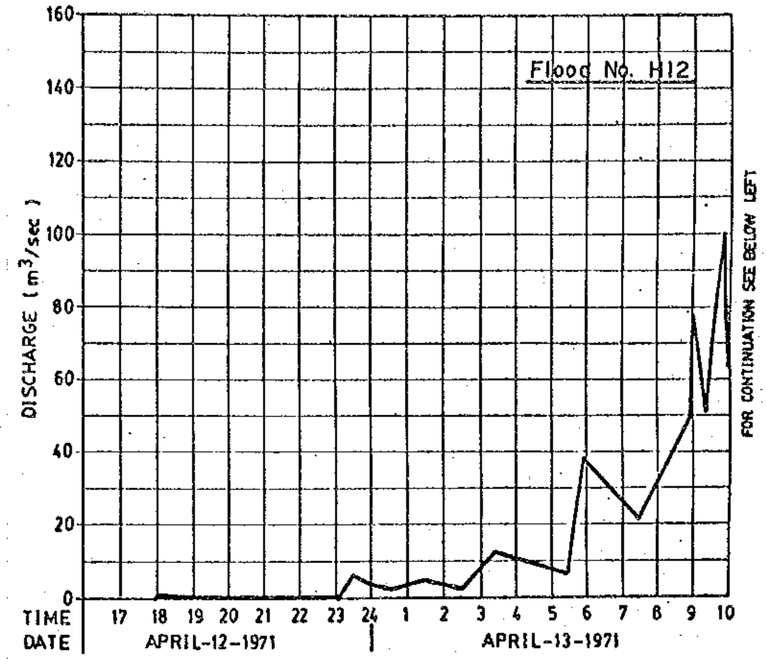

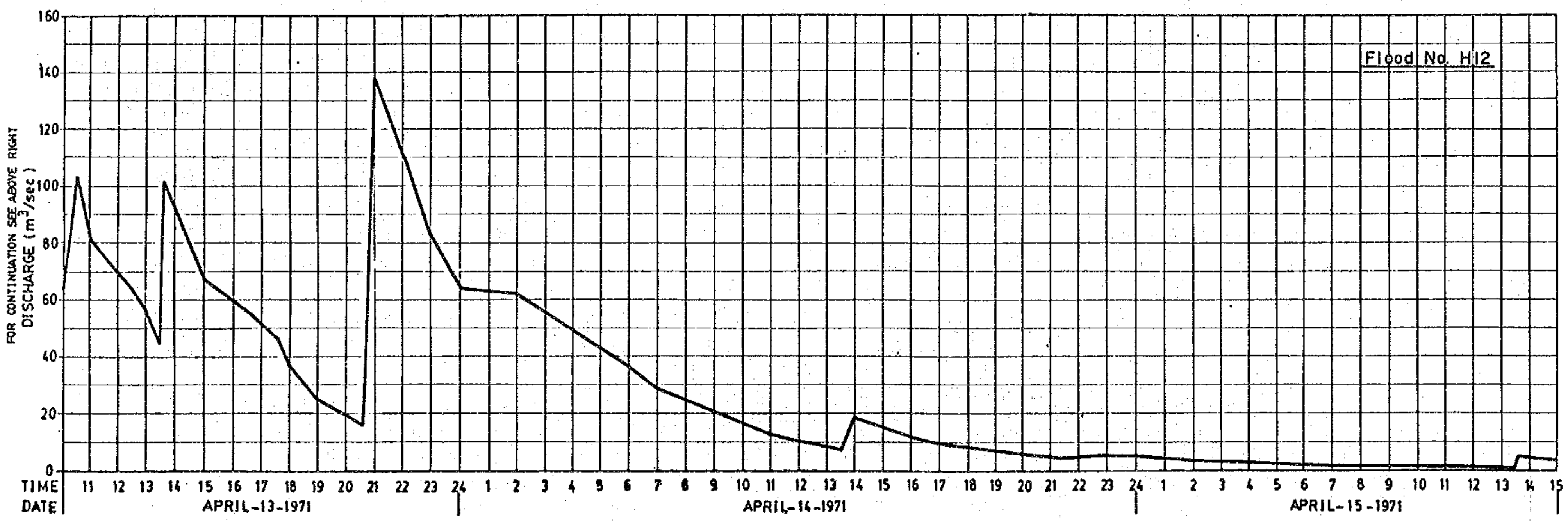

Fig.3.1 Hydrographs of Observed Large Floods of Hasa River (1/6)

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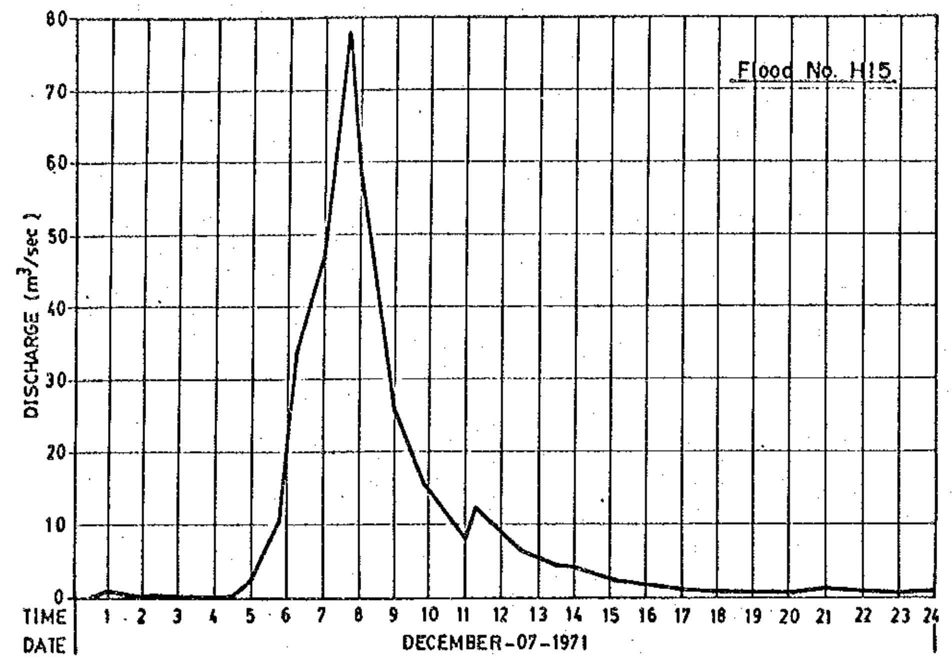

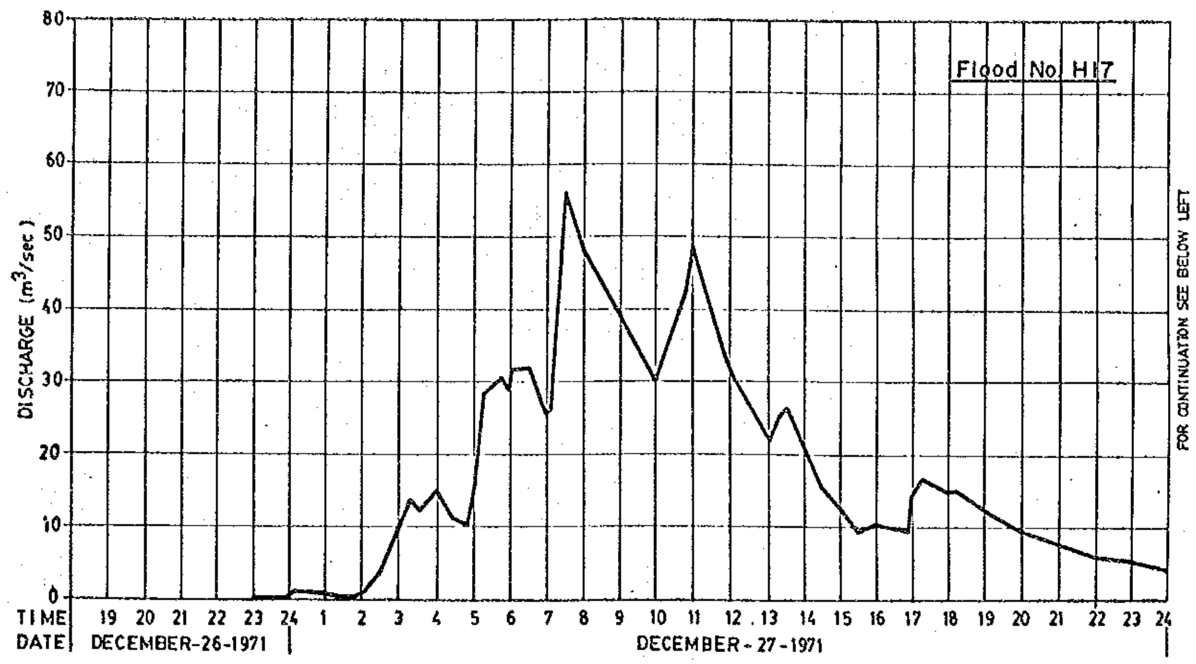

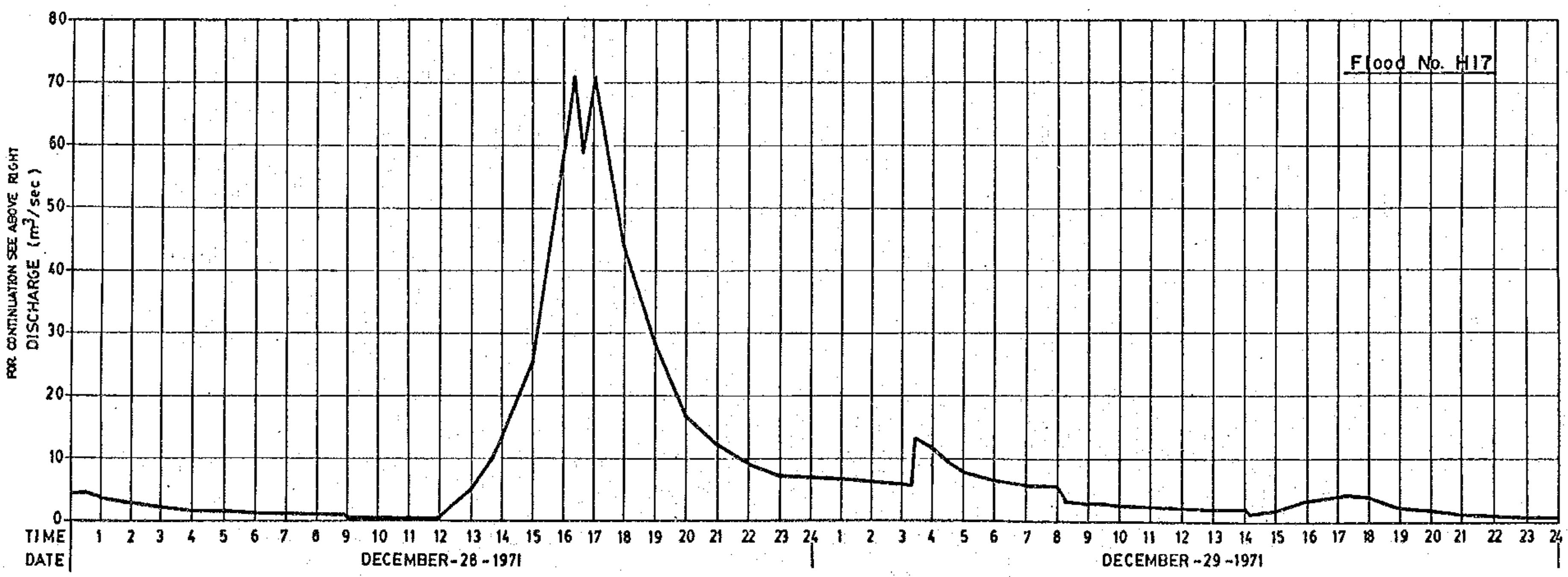

Fig.3.1 Hydrographs of Observed Large Floods of Hasa River (2/6)

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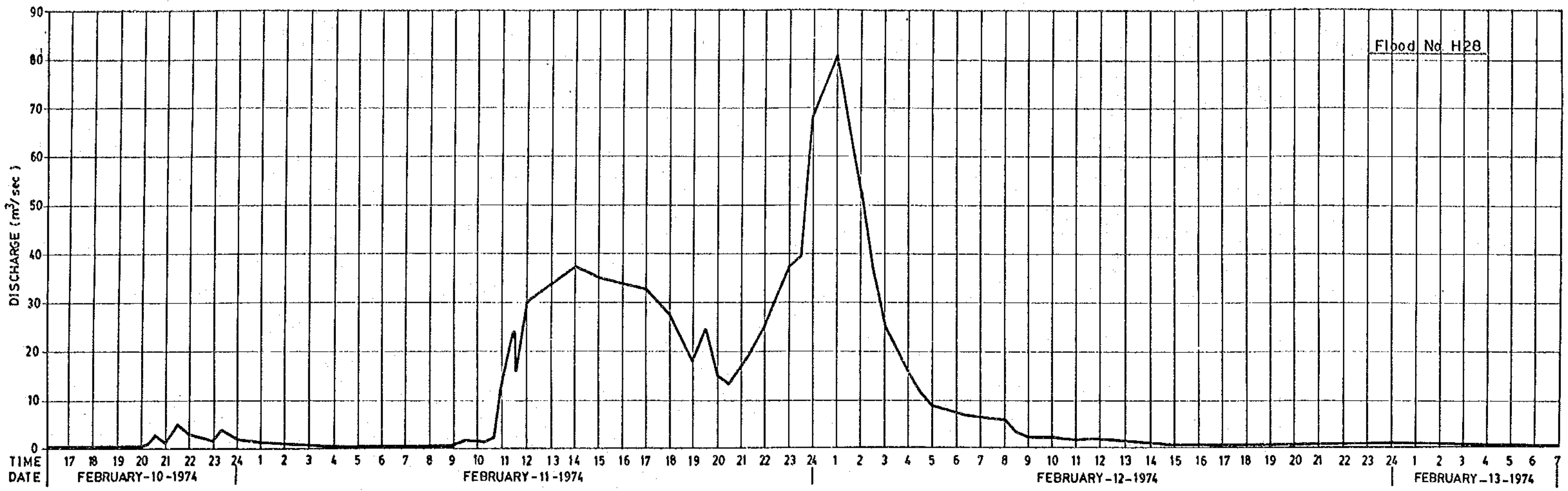

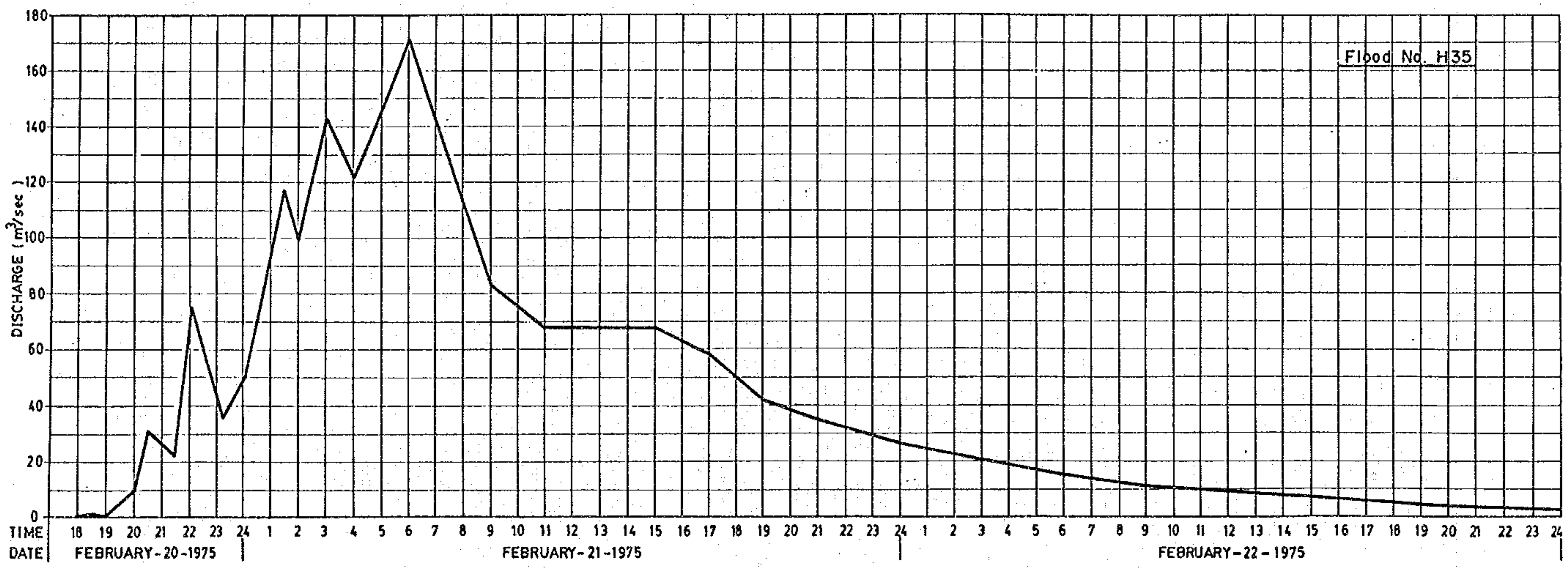

Fig. 3.1 Hydrographs of Observed Large Floods of Hasa River (3/6)

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WATER RESOURCES STUDY OF THE JAFR BASIN

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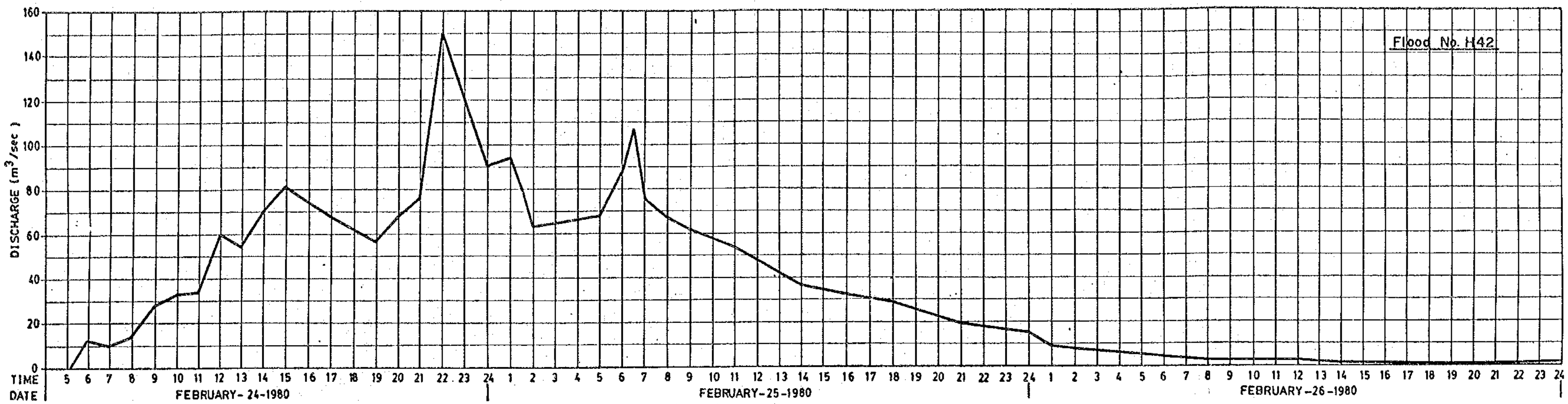

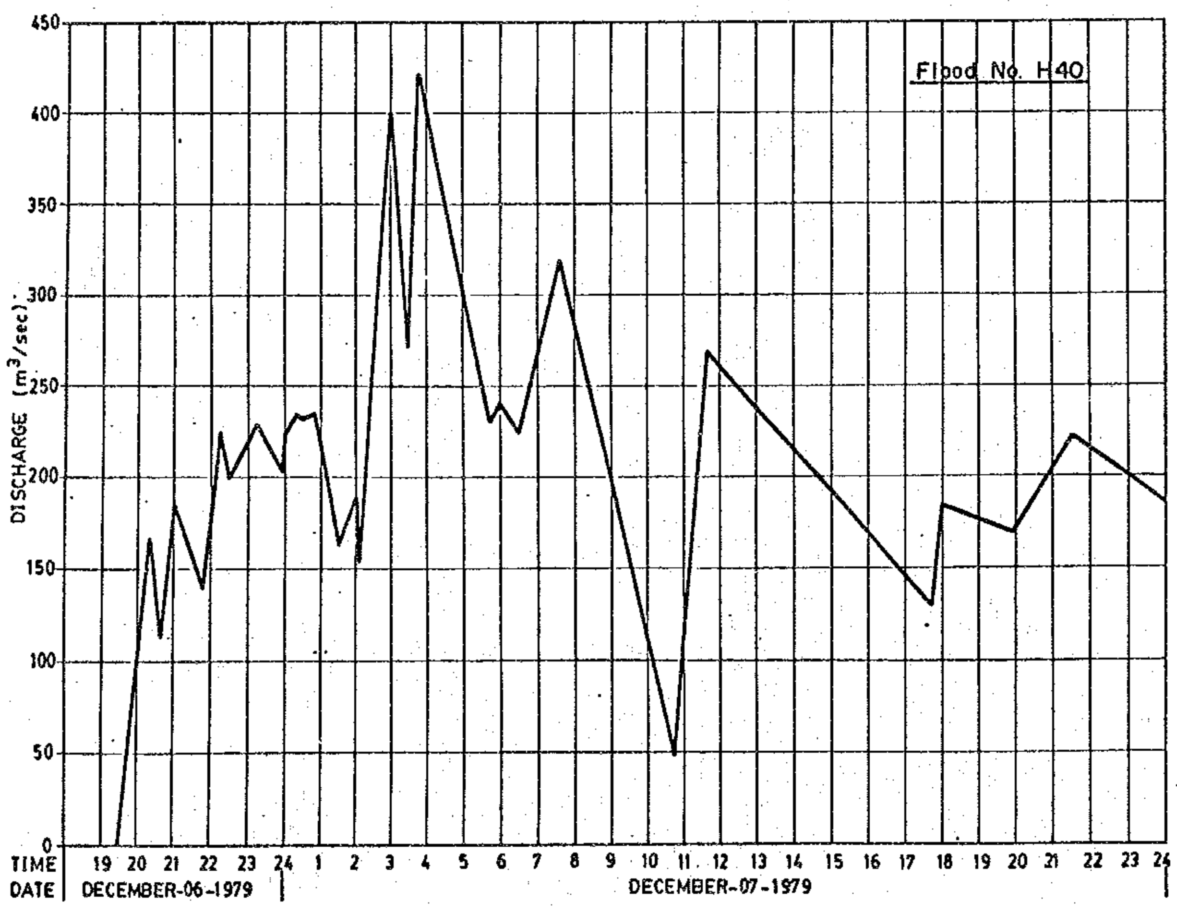

Fig. 3.1 Hydrographs of Observed Large Floods of Hasa River (4/6)

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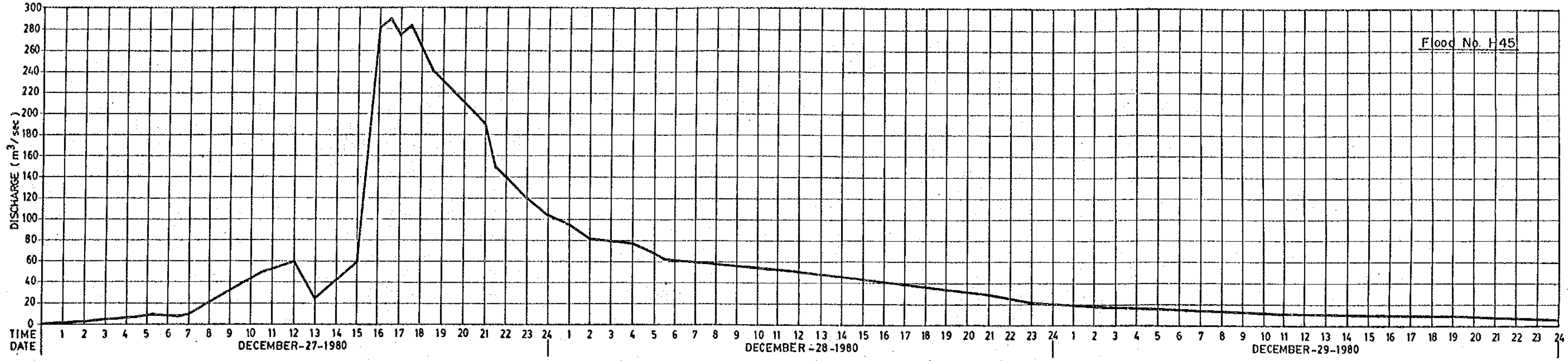

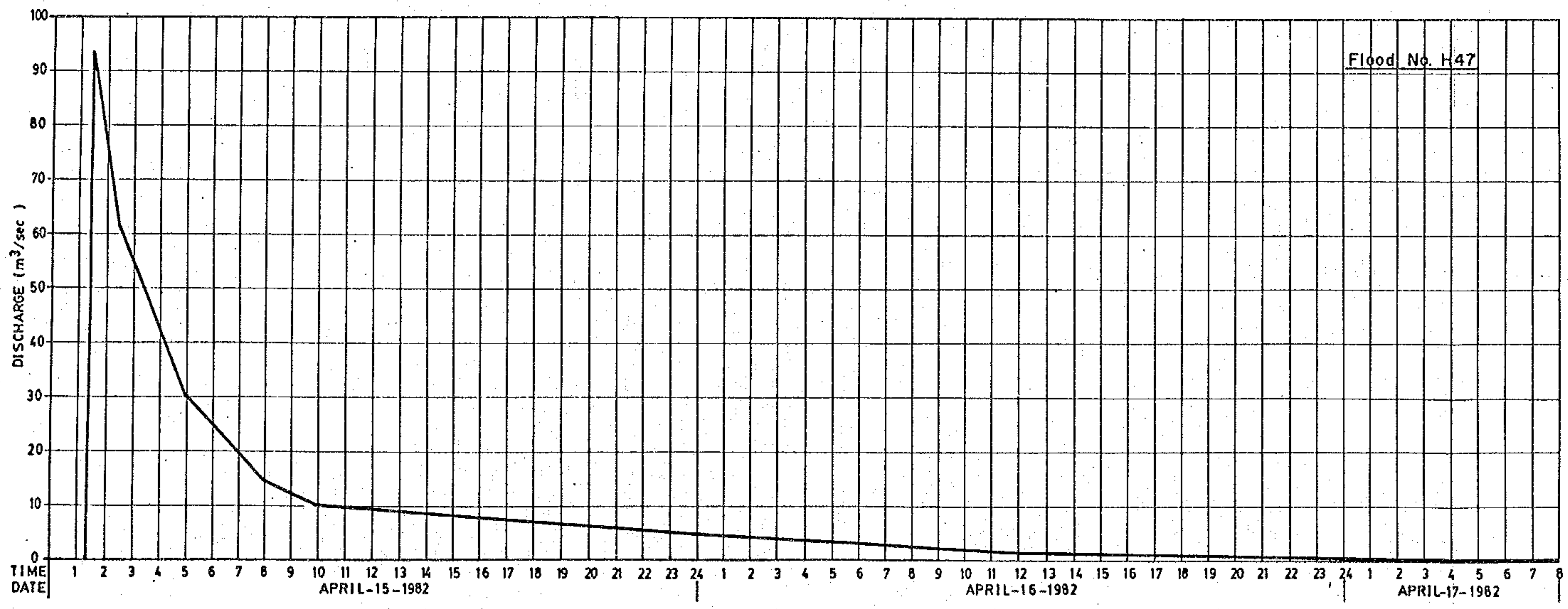

Fig. 3.1 Hydrographs of Observed Large Floods of Hasa River (5/6)

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WATER RESOURCES STUDY OF THE JAFR BASIN

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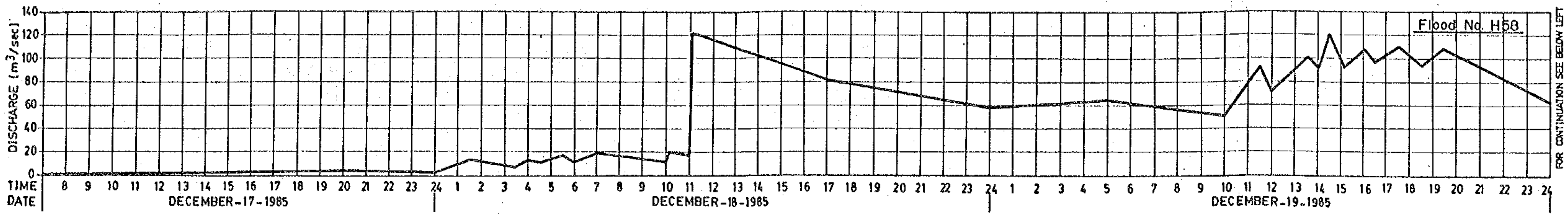

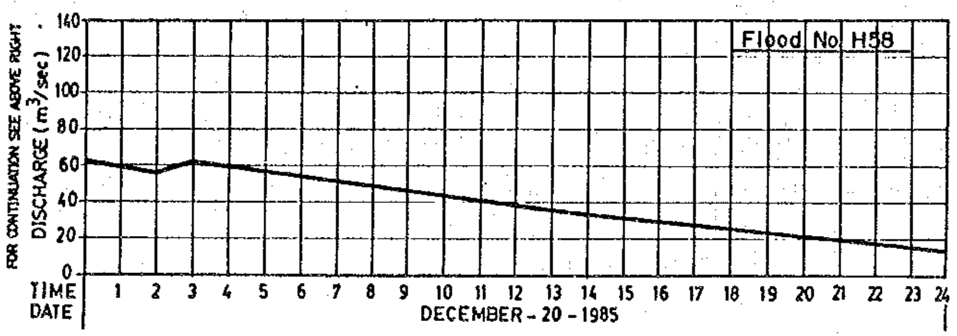

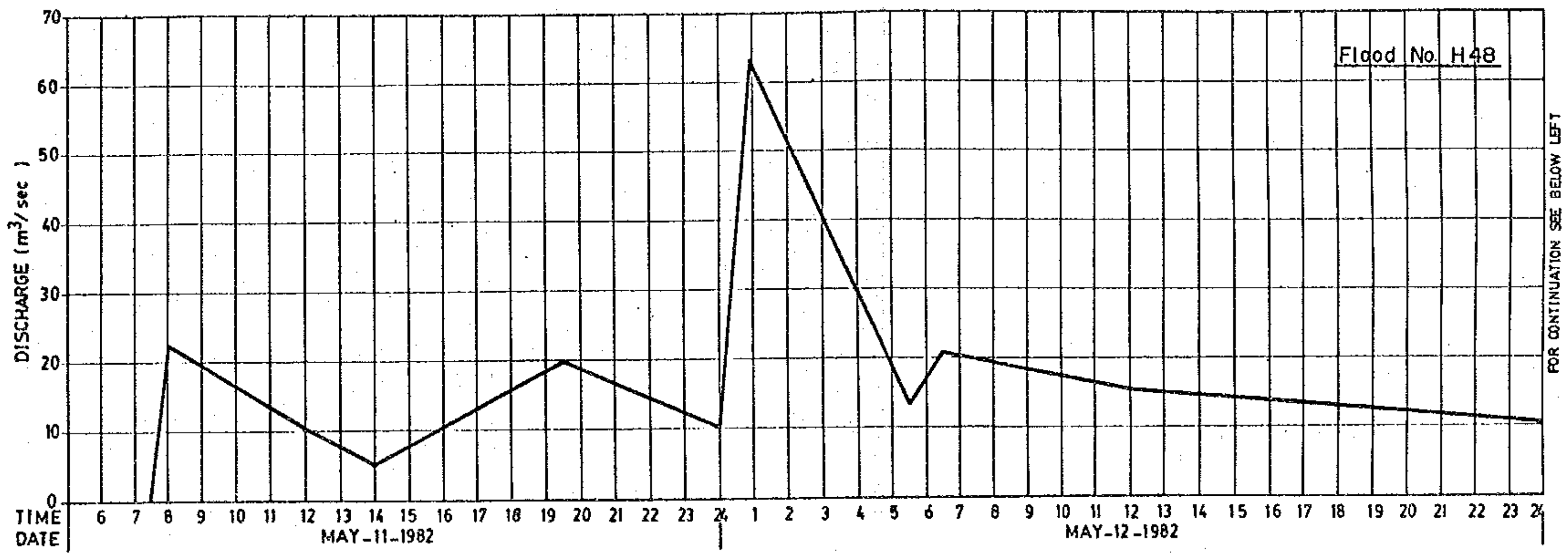

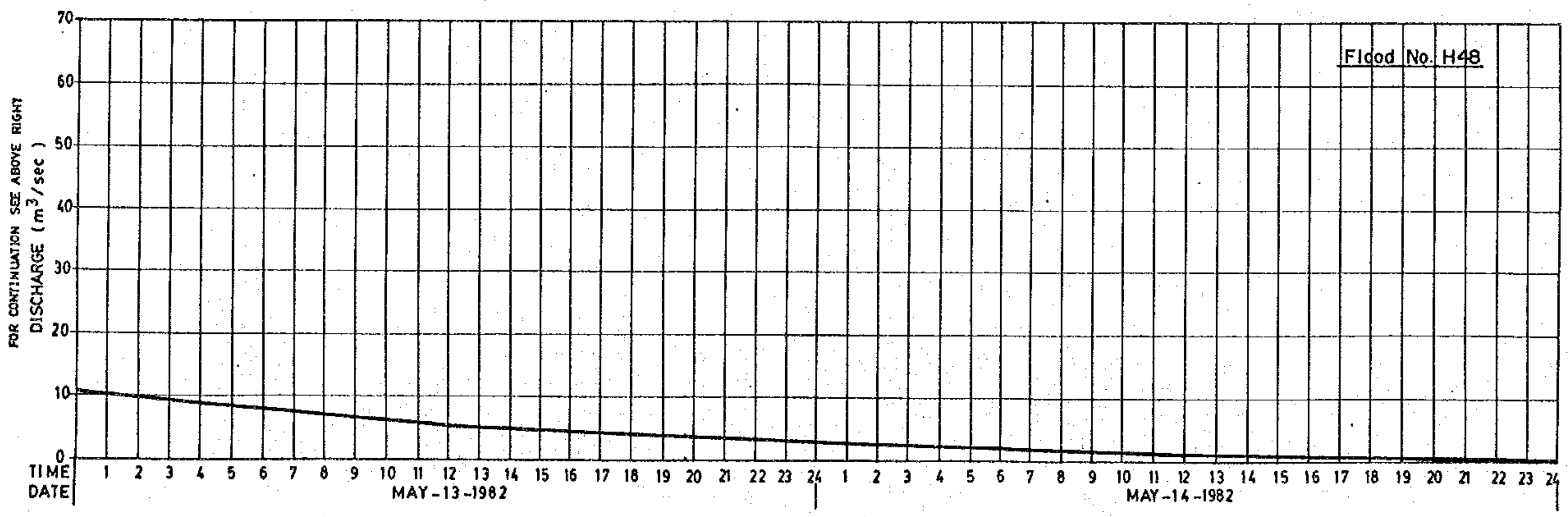

Fig. 3.1 Hydrographs of Observed Large Floods of Hasa River (6/6)

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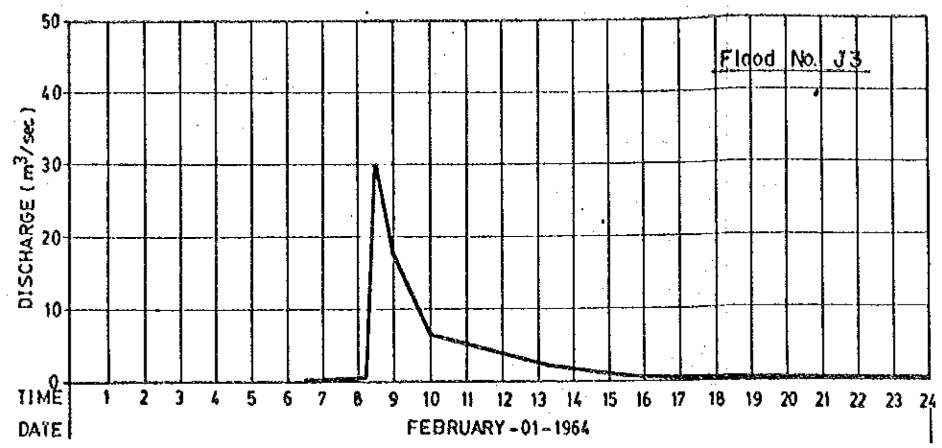

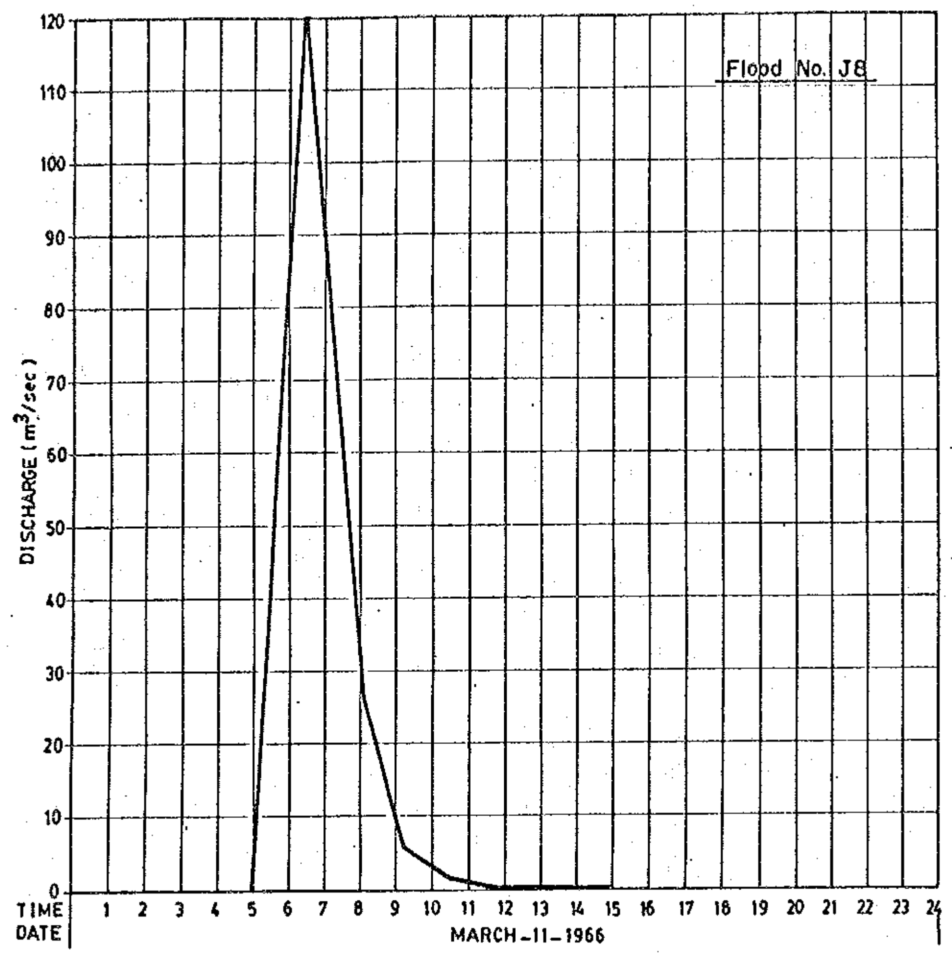

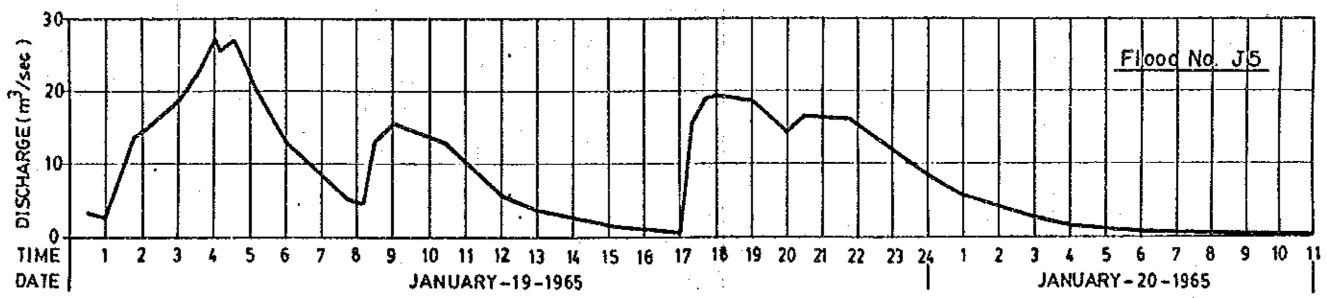

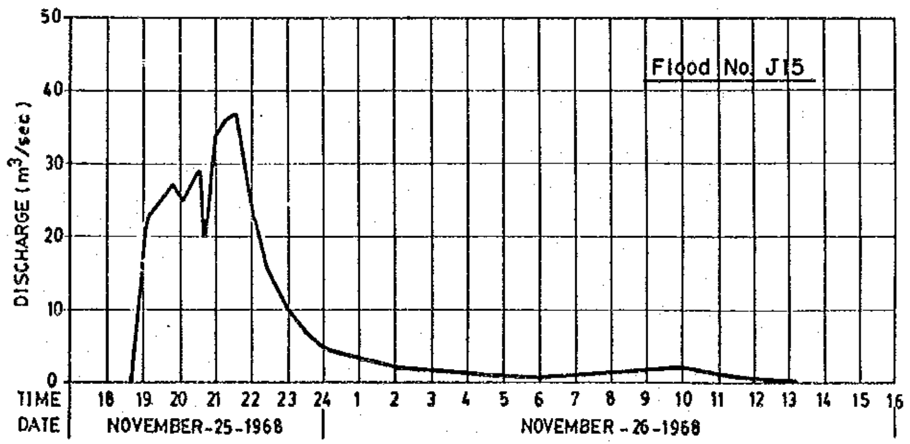

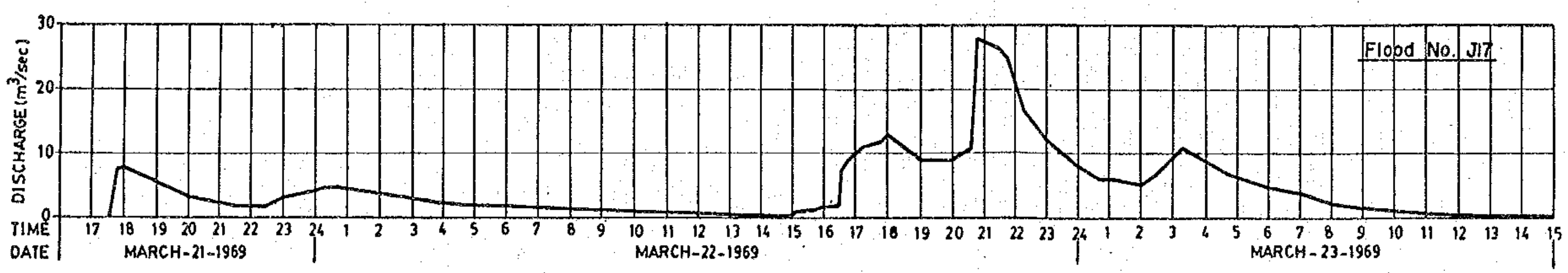

Fig. 3.2 Hydrographs of Observed Large Floods of Wadi Jurdhan (1/2)

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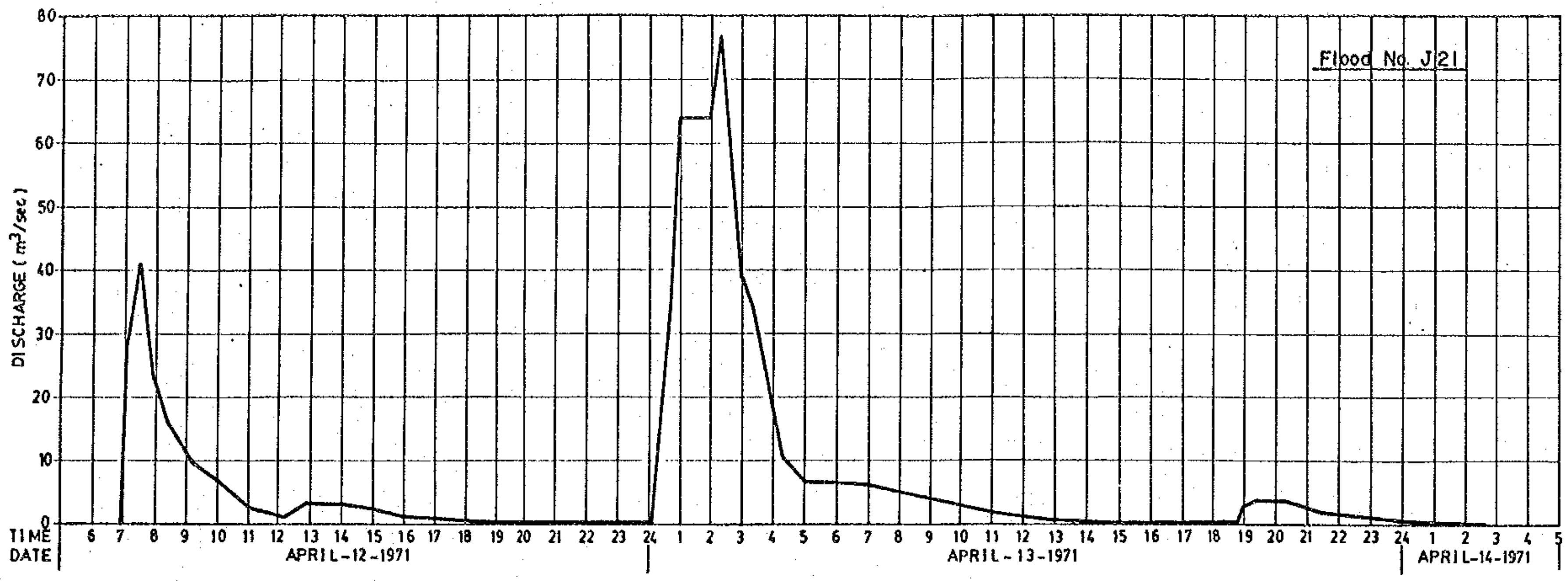

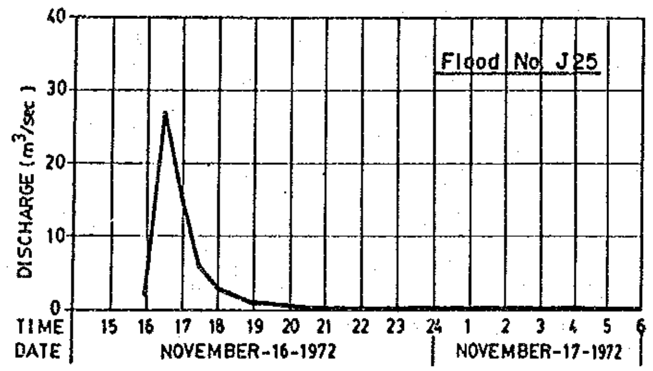

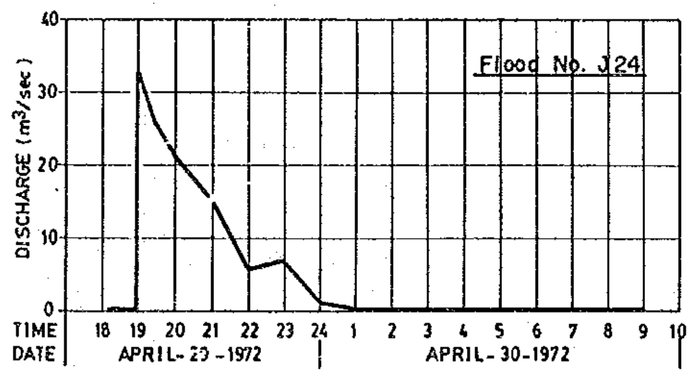

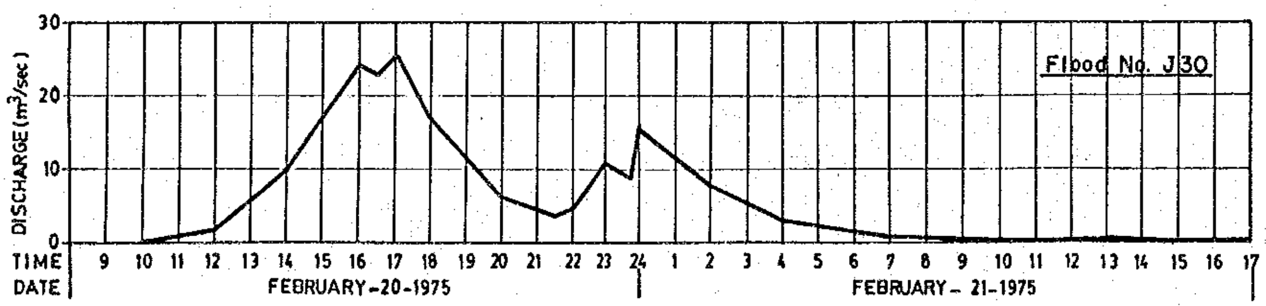

Fig. 3.2 Hydrographs of Observed Large Floods of Wadi Jurdhan (2/2)

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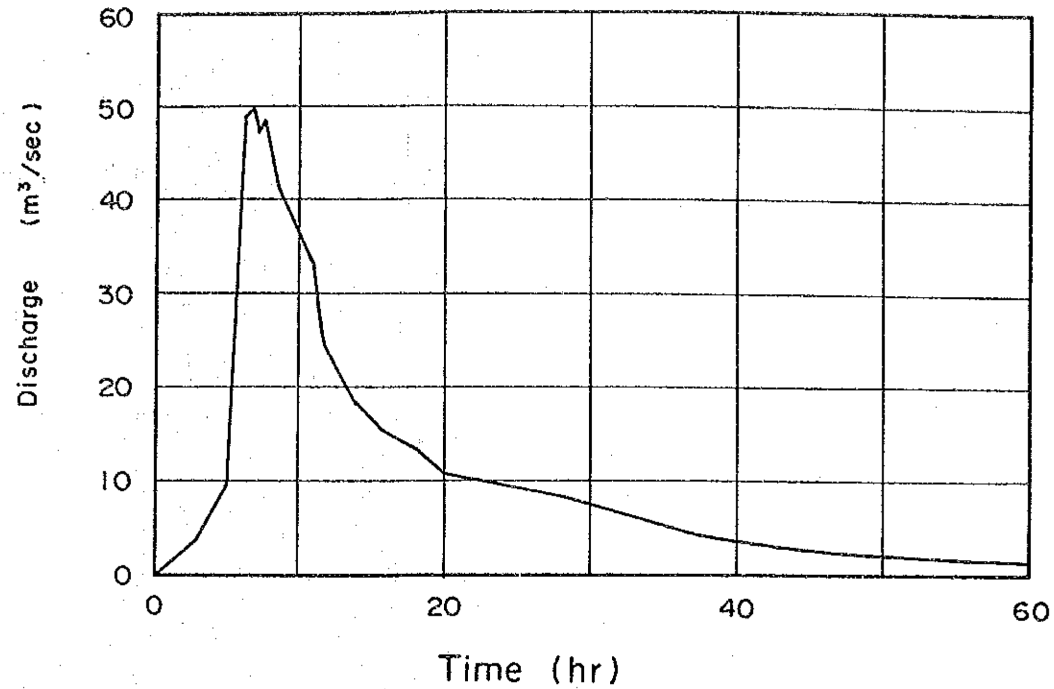

Fig. 3.3
Unitgraph of Hasa River at Hasa Water Stage Gaging Station

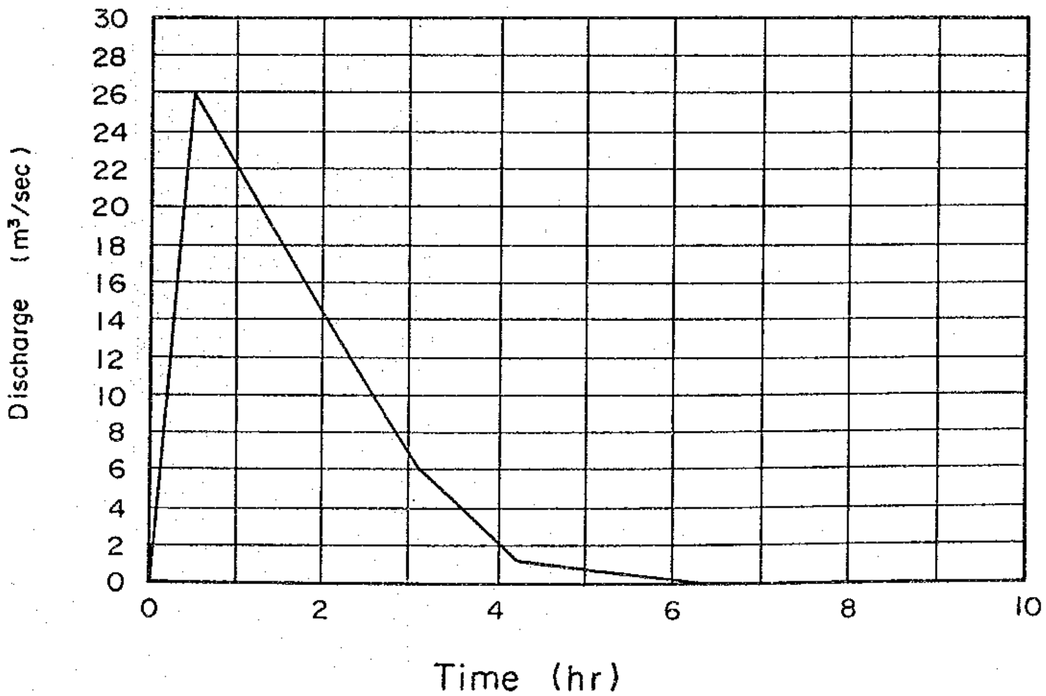

Fig. 3.4
Unitgraph of Wadi Jurdhan at Water Stage Gaging Station

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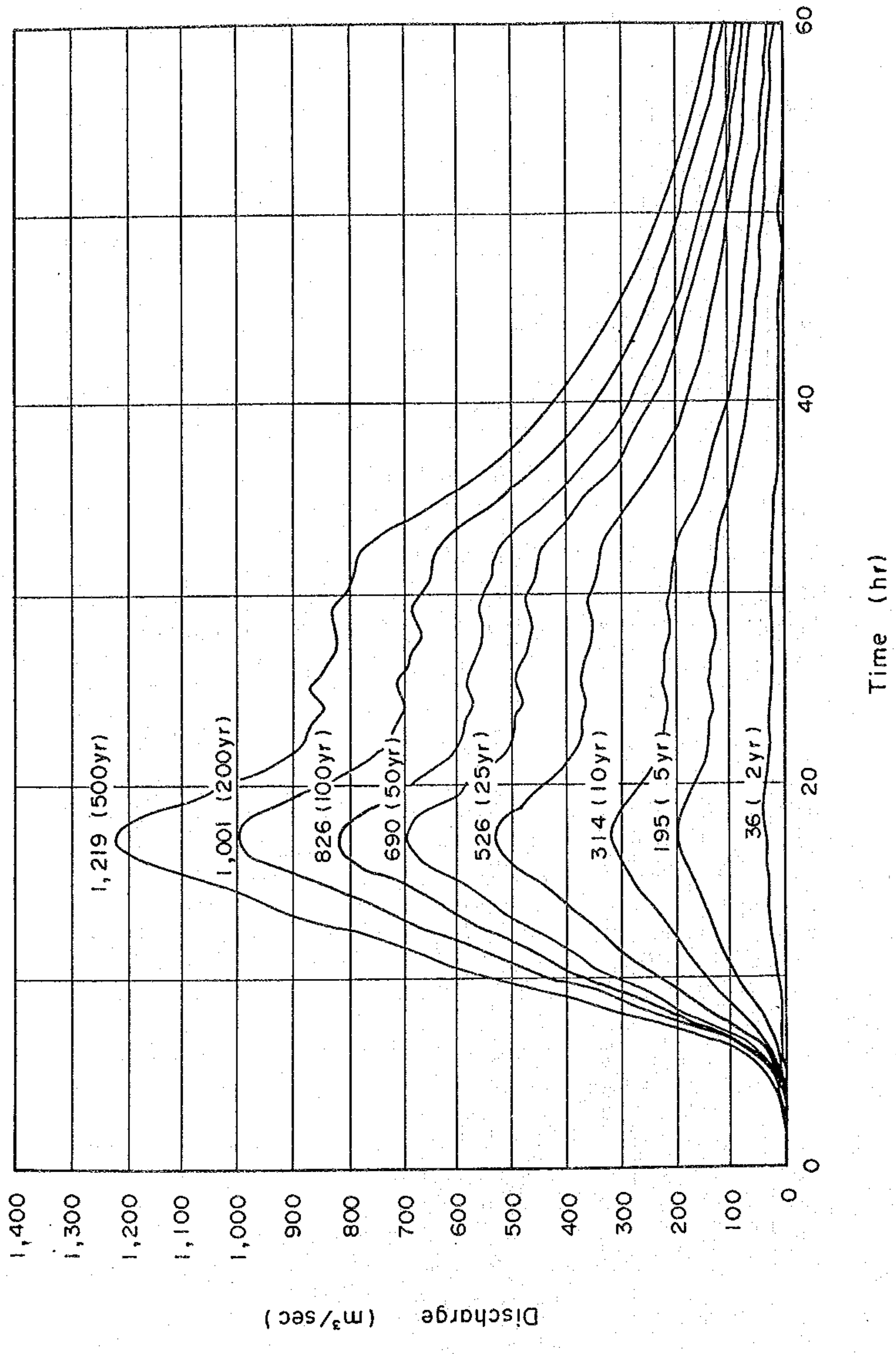

Fig. 3.5
Hydrographs of Probable Floods of Hasa River

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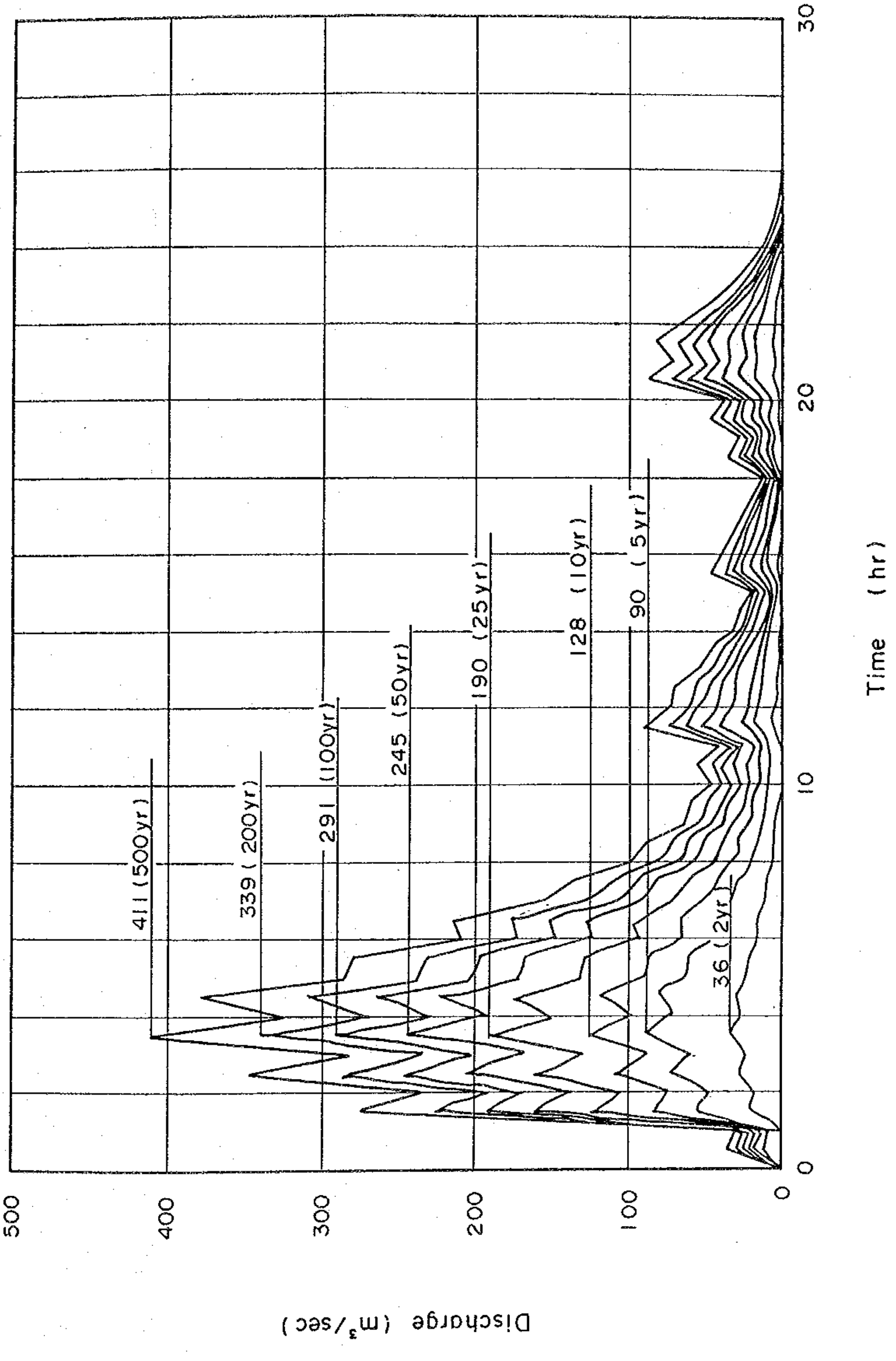

Fig. 3.6
Hydrographs of Probable Floods of Wadi Jurdhan

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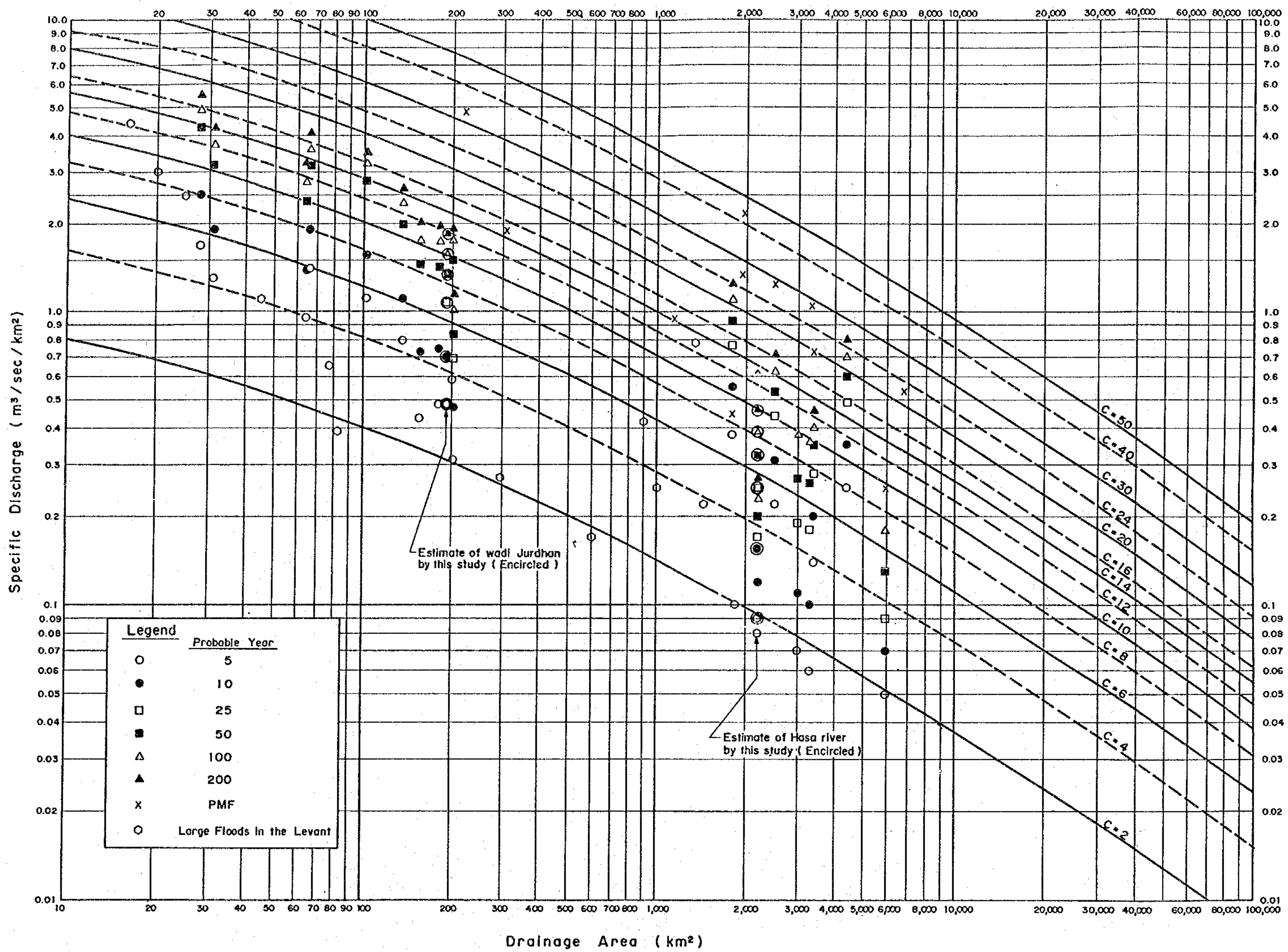

Fig. 3.7
Creager's Curves of Large Floods in Jordan and Levant

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