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JORDAN VALLEY IRRIGATION PROJECT

STAGE II

FEASIBILITY STUDY

VOLUME II

APPENDIX A
HYDROLOGY

APPENDIX B
ENVIRONMENTAL ASSESSMENT

APPENDIX C
OPERATION STUDIES

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HYDROLOGY

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1. The Hydro-meteorological Network and Data

Appendix A

HYDROLOGY

Summary

The proposed Jordan Valley Irrigation Project, Stage II, will be an important addition to agricultural and hydroelectric power development in Jordan. This stage of development will include a dam and a powerplant at the Maqarin site, diversion facilities at Adasiye and a sprinkler irrigation system for about 25,000 hectares (ha). To fully develop the water resources of the Yarmouk River, a second dam will be built most likely at the Khalid site, in a later stage. At full development, up to 41,000 ha of land including existing and new areas could be irrigated. Project elements described in this appendix include hydrologic analyses pertaining to Maqarin and Khalid dams on the Yarmouk River and water availability studies for the Zarqa River and nine principal side wadis (streams) tributary to the Jordan River.

Hydrologic investigations for the Jordan Valley Irrigation Project were based on available streamflow and precipitation records from Jordan and Syria.

The inspection of selected existing meteorological and hydrologic stations indicated that the number and locations of stations are generally adequate for project planning and design. Streamflow data availability is generally good for the Jordan portion of the Yarmouk and Zarqa River basins and poor for the side wadis. A summary of the inspection of meteorological and hydrologic stations and recommendations for improvement of the hydro-meteorological network are given in Attachment 1 of this appendix.

Average annual flow of the Yarmouk River at the proposed Maqarin damsite will be 240.3 million cubic meters (MCM), after adjustment for anticipated upstream diversions, and the corresponding flow at Adasiye will be 393.3 MCM. The Khalid damsite is located about 14.5 km upstream from the Adasiye station and the inflow between this site and the upstream Maqarin site is estimated to average 127.5 MCM annually. The intervening inflow is from Wadi Raqqad and from local springs. An additional annual inflow of 25.5 MCM occurs between Khalid damsite and Adasiye.

Flow of the Zarqa River and principal side wadis totals 160.5 MCM annually. Average annual runoff from all potential sources is 553.8 MCM, equivalent to about 50 mm per year, or about 15 percent of 331 mm average annual precipitation.

Observed low flow at Maqarin, during the period from water years 1954 to 1975 was 169.0 MCM for a 12-month period and 364.8 MCM for a 24-month period. Estimated intervening low flows between Maqarin and Khalid during the same period were 49.2 MCM for the 12-month duration and 134.3 MCM for the 24-month duration. Mean annual reservoir evaporation is estimated to be about 1.7 meters and would reduce available water 4 to 9 MCM per year for the Maqarin Reservoir and 3 to 8 MCM per year for the Khalid Reservoir.

The probable maximum flood inflow to Maqarin Reservoir is estimated to have a peak discharge of 6,420 cubic meters per second (m^3/s) and an 8-day volume of 660 MCM. The PMF inflow to Khalid Reservoir, developed for the ultimate scheme, is estimated to have a peak discharge of 5660 m^3/s and a 7-day volume of 789 MCM including discharges from the Maqarin Reservoir at El. 193. The maximum observed flood peak discharge at Maqarin was 412 m^3/s as recorded in 1969.

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Flood frequency analyses for the damsites resulted in an estimate of 550 m^3/s and 210 m^3/s respectively for the 20-year floods at Maqarin and for the intervening area between Maqarin and Khalid. However, due to the limitation in data available for analyses, these estimates may be subjected to considerable uncertainty. There are also indications that a much larger flood (750 m^3/sec) than that recorded at Maqarin has been observed on the Zarga River. It is, therefore, desirable that a conservative approach be adopted in choosing the diversion flood.

Sedimentation for the Maqarin and Khalid Reservoirs was estimated to be 90 and 15 MCM respectively for the 100-year period following completion of the project. These volumes are equivalent to about 28 percent of the initial capacity of the Maqarin Reservoir and about 5 percent of that of the Khalid Reservoir.

The Basin

The project area comprises the Yarmouk and Zarqa River Basins and the drainage areas of nine side wadis tributary to the Jordan River: Arab, Ziglab, Jurum, Yabis, Kufrinja, Rajib, Shueib, Kafrein, and Hisban (Exhibit A-1).

Physiographically, the project area may be divided into two regions: namely the Jordan Valley and the eastern highlands. The Jordan Valley connects Lake Tiberias to the Dead Sea through a down-faulted extension of the Rift Valley. East of the Jordan Valley are the Jordanian Highlands which merge gradually with the elevated plains and deserts of the Arabian and Syrian Plateaus. The Yarmouk and Zarqa Rivers and the side wadis drain the eastern plateaus and the foothills, respectively, and discharge to the Jordan River.

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Table A-1 lists drainage areas of these streams and the corresponding mean annual precipitation and runoff of their basins.

The Yarmouk River Basin extends from the high plains of Golan in Syria to the desert plateaus of both Syria and Jordan. The entire watershed is characterized by poorly developed or no drainage channels. Even major tributaries such as Wadis Raqqad, Allane, and Hasir in Syria and Shallah in Jordan are shallow swales with considerable growth of phreatophytes. The plain from Dera'a to Quneitra is extremely flat and contains fertile soils developed principally from basalts. Good soil infiltration and permeability through fractured basalts of the parent material preclude the development of secondary channels.

The plateau area of Jordan is covered by a thin soil mantle underlain by limestone. The topography is generally flat except for steep terrain adjacent to the lower Yarmouk gorge and broken relief of the Jordanian Highlands. Poor soil infiltration and rapid descent from the Jordanian Highlands and nearby plateaus cause high runoff potential.

Six wadis (Arab, Ziglab, Jurum, Yabis, Kufrinja, and Rajib) drain the plateau foothills and valley areas which lie between the Yarmouk and Zarqa Rivers. Three wadis (Shueib, Kafrein and Hisban) drain the area northeast of the Dead Sea.

Climate

General Climatology

The project area comprises a transition between Mediterranean and arid climates. Altitude and latitude are effective factors which control prevailing weather. Average annual

maximum and minimum temperatures in the northern Jordan Valley are about 46°C and 0°C, respectively. The average extremes of temperature near the Dead Sea in the south are a maximum of 45°C and a minimum of 5°C. East of the Jordanian Highlands, first steppe and then desert exhibit the rapid decrease of relative humidity and precipitation and the increasingly continental temperatures.

In winter, northeast winds bring continental polar air from the interior of Asia and make the project area cool for its latitude. The mean temperature on the plateau at Amman during January is about 8°C and in the Valley about 14°C. Ground frosts are frequent on the plateau during winter nights.

During spring, khamsinic frontal depressions travelling from the North African coast occasionally cause abnormally increased surface winds and temperatures. Associated unstable air at higher altitudes often develops into thundershowers with occasional hail.

In summer, a seasonal low pressure trough over the Arabian Gulf, Iraq, Syria, and Cyprus causes westerly winds to enter Jordan from the Mediterranean. The mean temperature for August at Amman is about 25°C and in the Valley the temperature is about 31°C.

Average relative humidity in the Jordan Valley ranges between 30 percent during day-time and 70 percent during night-time.

Fall is associated with a change in the pressure system as the seasonal trough extending over Cyprus to Iraq begins to migrate southeast. The development of Mediterranean depressions brings in continental air from the Asiatic steppes, and warmer moist air from the Mediterranean Sea,

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causing a decrease in temperature and the onset of seasonal frontal rains.

Precipitation

The Jordan Valley is in a narrow rain shadow caused by surrounding highlands. Rainfall occurs generally between October and May. Mean annual precipitation decreases north to south from above 400 millimeters (mm) near Lake Tiberius to about 150 mm in the vicinity of the Dead Sea as shown on Exhibit A-2.

Mean annual precipitation generally exceeds 500 mm on the elevated eastern edge of the Jordan Valley between the Zarga and Yarmouk Rivers, and the amount increases to 700 mm at the northern boundary of the Yarmouk River Basin and to 1500 mm at the northern boundary of the Wadi Raqqad Basin. Annual precipitation decreases gradually toward the eastern deserts, except that a small easterly portion of the Yarmouk River Basin receives over 500 mm. Mean monthly precipitation and temperature are shown for Amman in the highland and for Shuneh North in the Valley in Table A-2.

Water Supply

Available Streamflow Records

Recorded or synthesized streamflow data are available for the Yarmouk and Zarqa Rivers and nine principal side wadis for various periods between 1926 and early 1976. Except for records of Yarmouk River flow, most streamflow data which predate 1950 were synthesized. The location of stream gaging stations is shown on Exhibit A-1 and periods of available streamflow records are shown on Exhibit A-3.

Base Flow and Flood Flow. With the exception of the Yarmouk River, published records present streamflow in terms of base flow and flood flow. Such classification of stream-

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flow was considered desirable in previous studies which sought to estimate firm water supply, mainly for irrigation. Runoff which could be directed into canals without resort to reservoir storage was designated as base flow. Flood runoff in excess of the diversion was termed flood flow. The present study deals only with total flows which are the sum of base and flood flows.

Streamflow Transposition. A review of available monthly streamflow data, both recorded and synthesized, indicated that data for water years[1/] 1954 to 1975 are adequate for the present study. A long precipitation record at Jerusalem (verbal communication) indicates that this period may be slightly drier than average, giving a small degree of conservatism to the estimates of water supply. Data prior to water year 1954 are mostly synthesized and are of relatively poor quality. Several periods with missing streamflow data between water years 1954 and 1975 are shown on Exhibit A-3. Methods used to estimate missing monthly streamflows for each stream are described in Table A-3. In general, the procedures used included the following:

1. Transposition of streamflow from other watersheds using ratios of drainage area and mean annual precipitation;
2. Transposition of streamflow from other watersheds using monthly streamflow ratios based on concurrent periods of record; and
3. Estimation of streamflow using monthly total flow/base flow ratios for the periods during which only base flows are available.

Monthly Streamflow. Tables A-4 to A-16 give monthly streamflow for 13 locations on the Yarmouk and Zarqa Rivers and the nine side wadies.

1/ A water year is the period from October to September, with the year designation being the calendar year in which the water year ends.

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Streamflows of the Yarmouk River are affected by upstream diversions. A double mass curve analysis based on streamflows at Maqarin and precipitation in the watershed indicated that the diversions increased gradually between 1958 and 1966. Information obtained from the Jordan Valley Authority (JVA) indicated that an irrigation scheme utilizing larger springs at Mzeireeb and Zeizoun in Syria for an area of 2200 ha was constructed in 1949. This scheme was subsequently expanded to supply 6800 ha in 1966 and it is likely to be further expanded in the future.

Monthly streamflow data at Maqarin was, therefore, adjusted downward to reflect the changes due to historical and future diversions (Table A-4a). The adjustment was based on the assumptions that the historial change has been gradual, that increased Syrian water use would follow a monthly pattern similar to the present estimates of withdrawals and that the maximum monthly base flow usage would be about $3.6m^3/s$ as estimated by the JVA. However, it was assumed that it would not be economic for Syria to actually withhold those flows from Maqarin Reservoir during the period used for economic analysis of the Stage II development.

The flows from the intervening area between Maqarin and Khalid sites are primarily from Wadi Raqqad with some contribution from local springs. They were estimated by subtracting flows at Maqarin site from those at Adasiye station and adjusting for drainage areas. The monthly intervening flows are shown in Table A-5.

Adjusted average annual streamflow at the proposed Maqarin dam is 240.3 MCM, the intervening inflows between Maqarin and Khalid sites is 127.5 MCM, and the inflow between Khalid and Adasiye is 25.5 MCM. Water in the Zarqa River at

Deir Alla and flow of the principal side wadis contribute an additional 160.5 MCM annually. Total mean water supply from all potential sources (Yarmouk River at Adasiye, Zarqa River at Deir Alla and the nine side wadis) is 553.8 MCM annually. If the base flow of the springs around Mzeireeb and Zeizoun are diverted away from Maqarin Reservoir for the entire year, the average annual streamflow at Maqarin would be reduced to about 184 MCM.

Yield Considerations. The minimum unadjusted flows of record at Maqarin are 169 MCM and 364.8 MCM, respectively for 12-month and 24-month durations (see Table A-17). These flows are estimated to correspond to a drought recurrence interval in the order of 20 and 50 years, respectively, based on the flow-duration-frequency relationships determined at Adasiye.

These relationships at Adasiye suggest also that the recorded high flow at Maqarin during the 1966 to 1969 period probably has a recurrence interval in the order of 30 years. The relationships are based on flow-frequency curves developed from independent sequences of water-year total flows (Exhibit A-4). The 50-year period of data used in the analysis includes transposed flow data for about four years, and it also includes records before 1953 that are considered to be of relatively poor quality.

Reservoir Evaporation

Monthly evaporation for the Maqarin and Khalid Reservoirs was estimated from Class A pan evaporation observed at Irbid Nursery and Shuneh North. The arithmetic average of monthly pan evaporation of the two stations was adjusted by a pan coefficient of 0.75 to estimate reservoir evaporation. The

pan coefficient of 0.75 was selected based on the region's similarity to the Central Valley of California.[2/]

Although both stations have less than two years of record, a comparison with long term Piche evaporation measurements indicates that the pan evaporation data are reasonably representative of long term averages. Calculated average monthly reservoir evaporation and observed monthly precipitation for Maqarin and Khalid are shown in Table A-18.

Surface Water Quality

Currently, only limited surface water quality data are available for the Yarmouk and Zarqa Rivers. Values for quality constituents and corresponding daily discharges are summarized in Table A-19 for two locations on the Yarmouk River and three locations on the Zarqa River.

Ground Water Assessment

The local and unpredictable occurrence of ground water precludes its development as a major water source. Sporadic lenses of sand, gravel, and gypsiferous, calcareous clays provide irregular potential for development. Valley alluvium and fan formations occasionally contain fresh water, though generally they are composed of or are contaminated by saline formations. Salinity of ground water commonly increases with proximity to the Jordan Valley; specific conductance exceeding 1000 micromhos per centimeter (mmhos/cm) is common and may, in certain locations, reach as high as 5000 mmhos/cm.

Baker-Harza in 1955[3/] estimated safe yield to be 40 MCM. Jordan Valley sediments are generally recharged by

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2/ U.S. Weather Bureau, 1959, Evaporation Maps of the United States; TecH. Pater No. 37, Plate 3.

3/ Harza Engineering Co. and M. Baker and Jr., Inc., 1955, Yarmouk-Jordan Valley Project; Master Plan Report.

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ground water from aquifers located in the highlands which border the valley.

Sir M. MacDonald and Partners[4/] in 1965 estimated that ground-water usage (abstractions) totalled 44.7 MCM for the 1959-1964 period form the Southern Jordan Valley.

Spillway Design Flood

To design the spillway of a project whose failure would result in a large risk to human life and economic endeavor, it is customary to design the works for the worst conditions that could reasonably be postulated. This is referred to as the probable maximum flood (PMF). It is not possible to assign a probability of occurrence to such conditions except to say that it approaches zero.

In the case of Maqarin Dam, these risk conditions exist, so the probable maximum flood was selected for design. In general, the estimation of the probable maximum flood consists of analyzing the basic factors that cause the occurrence of great floods, maximizing these factors to their highest reasonable physical limits, and then combining them within acceptable conditions from a hydrologic point of view, in a manner which produces the maximum flood.

Probable Maximum Precipitation (PMP)

The first step in determining the PMF consists of estimating the PMP that could fall on the project basin during various periods of time. There are various procedures[5/] for estimating the PMP. The most common are: (1) the analysis of major recorded storms in the project basin or

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4/ Sir M. MacDonald & Partners, 1965, East Bank Jordan Water Resources; Vol.6.

5/ Weisner, C.J., 1970, Hydrometeorology, Chaps. 13-18, Chapman, Hall Ltd.

adjacent regions with necessary adjustments for moistures and other factors, (2) the Hershfield statistacal method, and (3) the development of storm models into which are introduced optimum values of storm factors for estimating PMP. The results obtained from the application of the first two methods to the Yarmouk River Basin are given in the following sections. The third method was not tried since data required for the development of a reliable storm model were not available.

Storm Transposition and Maximization

Maximization of observed storm precipitation for estimating PMP normally involves adjustment for maximum available and for moisture-inflow barrier elevation.

The basic assumption for moisture adjustment is that the PMP would have been realized had the maximum moisture supply been available and storm efficiency had also been at a maximum. Since there is yet no reliable method for evaluating storm efficiency directly, it is generally assumed that major observed storms have approached maximum efficiency, and moisture is often the only storm factor maximized.

The storm of January 29, 1958, was selected for estimating the PMP. Available data indicated no other storm approaching the 1958 storm in intensity and areal coverage. It covered the entire east bank of the Jordan Valley and produced a maximum observed 24-hour point precipitation of about 140 millimeters. This storm was used by Sir M. MacDonald & Partners[6/] in their studies for the Zarga River and the side wadis. The MacDonald map of observed storm rainfall was

6/ Sir M. MacDonald & Partners, 1965, East Bank Jordan Water Resources, Vol. 4.

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accepted for transposition and maximization. It was noted that this map, although assumed to depict 24-hour rainfall, was based on 3-day totals, and that this introduces an element of maximization called sequential maximization.[7/] This was considered justified in view of te few occurrences of major storms during the short period of rainfall records available.

The storm studies for the MacDonald report were made by the British Meteorological Office (B.M.O.) in Bracknell, England. The basic data used by the B.M.O. were accepted for the present studies. The center of the transposed storm (Exhibit A-5) was placed in the northern part of the Wadi Raggad Basin, where the greatest mean annual precipitation is observed. The orientation of the transposed storm was the same as that of the original storm because the topographic pattern is reasonably similar. The 24-hour rainfall of the transposed storm averaged 54 millimeters over the project basin above Maqarin Dam, and 69 millimeters over the area between Maqarin and Khalid damsites.

Transposition of the January 29, 1958, storm in the Zarga Basin to the Yarmouk Basin is considered reasonable in veiw of the frequency analyses of annual maximum daily precipitation. A station indicating heavy precipitation and having a long period of record was selected to represent each of the basins. The selected stations were El Jubeiha and Kharja for the Zarqa and Yarmouk basins, respectively. Each stations is located near the center of its basin. Comparison of the storm-frequency curves for the two stations (Exhibit A-6) indicates that differences in storm magnitude

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7/ World Meteorological Organization, 1973, Estimation of Probable Maximum Precipitation, WMO-No. 332,pp. 24-25.

and variability between the two basins are not sufficient to preclude transposition.

The 2500-foot m.s.l. moisture-inflow barrier elevation used in the B.M.O. studies is an average over a considerable distance. The barrier elevation is lower than 2500 feet (762 meters) for about 75 kilometers, with the lowest two points being about 17 and 4 kilometers south of the south end of Lake Tiberias. This 75-kilometer gap can influence the probable maximum storm. With a northwest wind the gap would tend to increase rainfall in the Zarqa River Basin, while with a southwest wind it would tend to increase precipitation in the Yarmouk River Basin. Both effects appear to be refliected in the mean annual precipitation map (Exhibit A-2). Since the effects of this gap and other elevations along the barrier are highly dependent on wind direction, different a/barrier adjustment for the Yarmouk River Basin did not appear to be warranted.

Moisture maximization consisted of multiplying the transposed storm rainfall by the ratio of the precipitable water computed for the maximum persisting 12-hour dewpoint to that computed for the storm persisting 12-hour dewpoint. The dewpoints used were taken from the MacDonald report. The maximum observed January sea temperature (20°C) taken from Table 4.1 in that report was used for the maximum persisting 12-hour dewpoint. The representative storm persisting 12-hour dewpoint was taken from Table 5.2 of the same report; it was 3°C, or 37°F, at the 920-milibar level, and this becomes 7°C when reduced to 1000 millibars.

Maximized Precipitation

The average basin precipitation of 54 millimeters for the transposed storm was multiplied by 3.7, the ratio of

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maximum precipitable water to that in the storm, to obtain the 24-hour PMP of 200 millimeters for the basin above Maqarin dam site. The 24-hour PMP for the drainage area between Maqarin and Khalid was 255 millimeters. the 48-hour basin PMP of 230 millimeters was estimated for Maqarin by multiplying the 24-hour PMP by 1.15. The factor of 1.15 was based on the depth-duration curve discussed in a following section entitled "Time Distribution of PMP". The 48-hour PMP for the drainage area between Maqarin and Khalid was estimated to be about 295 millimeters.

The Hershfiled statistical method[8/] was used to provide a check of the PMP derived by transposition and maximization. Seventeen precipitation stations on the Jordan side of the Yarmouk River Basin, each having 8 to 35 years of record, were analyzed. The 24-hour basin PMP of 250 milimeters calculated by the Hershfield procedure is 25 percent greater than the 200 millimeters obtained for the basin above Maqarin dam site by transposition and maximization. The 250-millimeter value appears excessive considering that the 200-millimeter amount was based on both misture and sequential maximization, the latter value was accepted as the more reliable estimate of PMP.

Since precipitation data in the Syrian side of the Yarmouk River Basin were not available at the time of the PMP analysis, the effect of excluding the Syrian data from the estimation of PMP was investigated. By analyzing subsequently available daily precipitation (1959-1976) at 18 stations in the Syrian side of the Yarmouk basin, it was

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8/ Hershfield, D.M., 1963, Estimating the Probable Maximum Precipitation, Trans. ASCE, Vol. 128, Part 1, pp. 534-551.

found that the storm frequency for the western portion of the area where the transposed storm was lcoated is similar to that in the Zarqa basin, where the storm of January 29, 1958, occurred. It was therefore condluded that inclusion of the Syrian data would not affect the PMP estimate.

Time Distribution of PMP. A number of observed storms in the Yarmouk Basin and other Jordan Valley areas were reviewed and four critical storms were selected to derive depth-duration relationships. The selected storms had depths of 42 to 82 mm and their durations ranged from 33 to 39 hours (Table A-20). Dimensionless depth-duration curves were constructed and an envelope curve was drawn as shown on Exhibit A-7. The envelope curve was used to determine incremental depths for the 48-hour PMP (main storm) and for the antecedent storm. The antecedent rainfall and PMP were divided into 4- and 2-hour incremental values for the Maqarin site and the intervening area between the Maqarin and Khalid sites, respectively, based on the depth-duration curve.

Rainfall increments derived from the estimated PMP are normally rearranged in a more critical flood-producing time sequence than for the observed storm. 9/ Therefore, these values were arranged in critical flood producing sequences (approximately a mirror image of the unit hydrographs) before subtracting retention losses to determine the rainfall excesses.

Antecedent Storm.

Since the PMP could occur shortly after another storm, it is necessary to evaluate the rainfall in this antecedent storm and the interval between it and the probable maximum

9/ World Meteorological Organization (1975) Guide To Hydrological Practices, Geneva.

storm. A value of 40 percent of the 48-hour basin PMP (92 mm) was selected as the antecedent storm rainfall. The selection was based on standards of the American National Standards Institute [10/]. A two-day interval between the end of the antecedent storm and the beginning of the probable maximum storm was selected as a reasonable period for the accumulation of the atmospheric moisture charge to produce the PMP.

Determination of Probable Maximum Flood

Unit Hydrograph. A unit hydrograph was derived for the Yarmouk basin above the Maqarin site by applying the dimensionless graph method.[11/] A number of recorded hydrographs at Maqarin and Adasiye were studied and four isolated floods resulting from relatively uniform rainfall in the project basin were selected for final analysis. The four floods used in the analysis were recorded at Maqarin during February 8-11, 1954 and February 10-12, 1974 and at Adasiye during February 5-8, 1964 and February 10-12, 1974. No other storms had adequate coverage of both precipitation and streamflow.

The average dimensionless graph was used to compute a 4-hour unit hydrograph for the Yarmouk River above the Maqarin site and a 2-hour unit hydrograph for the intervening area between the Maqarin and Khalid sites. The resulting unit hydrograph for the Maqarin site has a peak discharge of 73 m^3/s for one millimeter of rainfall excess over the

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10/ American National Standards Institute, Standards for Determining Design Basis Flooding at Power Reactor Sites, ANSI N170-1976.

11/ U.S. Bureau of Reclamation, 1974, Design of Small Dams.

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drainage area of 5,950 km^2. The unit hydrograph for the intervening area (700 km^2) has a peak discharge of 14.7 m^3/s. The dimensionless graph and the unit hydrographs are shown in Exhibit A-8.

Basin Retention and Rainfall Excess. Hydrologically, the area may be classified as 75 percent of Soil Group B and 25 percent of Group C, 12/ 13/ 14/ using U.S. Soil Conservation Service criteria. Based on these classifications, an equilibrium retention rate of 5 mm per hour was estimated for the basin. There is no known non-contributing area.

Probable Maximum Flood. The PMF hydrographs were obtained by applying rainfall excesses to the corresponding unit hydrographs. A base flow of 42 m^3/s was assumed for the Maqarin site and 35 m^3/s was assumed for the intervening area. The 42 m^3/s is the highest monthly average flow at Maqarin during the period from 1953/54 to 1975/76. The 35 m^3/s is the difference between the flow at Adasiye and Maqarin for the same month. The relatively high flows were used as base flow in the flood analyses because the PMF is likely to occur in the months of high flows. The resulting PMF hydrograph for the Maqarin site has a peak discharge of 6,420 m^3/s and an 8-day volume of 660 MCM (Exhibit A-9) and the PMF hydrograph for the intervening area has a peak discharge of 1,810 m^3/s and a 7-day volume of 138 MCM

12/ Burdon, H.J., 1959, Handbook of the Geology of Jordan, Government of the Hashemite Kingdom of Jordan.

13/ Reifenberg, A. and Whittles, C.L., 1947, the Soil of Palestine; Thomas Murby and Co., Jordan.

14/ U.S. Bureau of Reclamation, 1973, Design of Small Dam.

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(Exhibit A-10). The PMF inflow to Khalid Reservoir, developed for the ultimate scheme, has a peak discharge of 5660 m^3/s and a 7-day volume of 789 MCM including discharges from the Maqarin Reservoir, at elevation 193.

Comparison With Previous Studies

Comparisons with previous flood studies conducted on the Yarmouk and similar river basins are shown in Table A-21. Comparisons with Harza-Binnie's previous extensive studies of the Tigris Basin in Iraq 15/ provide valuable information. The computed PMF peak for the current study has a Creager's "C" value 16/ of about 42 for the dendritic basin above Maqarin and of about 30 for the long and narrow intervening drainage area.

The C value for the Maqarin site is close to that for the Tigris River above Samarra and below ESK: Mosul, Bekhine and Dokan damsites in Iraq. By comparison, the Yarmouk Basin is on the downwind side of a steep escarpment. The principal orographic effect is to the west of the basin with some spillover along the western watershed boundary. This basin is much closer to the moisture source, the Mediterranean Sea, than are the Tigris sub-basin. The intervening area between the Yarmouk and Tigris Basins, however, is nearly all flat desert which abstracts only minimal moisture from passing storm systems.

The Tigris Basin described above for comparative purposes is largely desert and dry foothill areas. It has areas of high mountains and higher mean annual precipitation in the downwind (for maximum storms) direction. This does not

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15/ Harza-Binnie, (1963), Hydrological Survey of Iraq.

16/ Creager, W.P., Justin, J.D., and Hinds, J., 1949, Engineering for Dams, Vol. I, John Wiley and Sons, New York, N. Y.

negate the comparison because it is possible for a cold front over the Maqarin Basin to take the place of the down-wind orographic effect of the Iraq mountains.

Evaluation of the Probable Maximum Flood

Both the PMP and Creager's C are substantially higher than previous estimates by Baker-Harza and Energoprojekt. The present study is based on a considerably larger body of applicable data than was available for the previous studies, so the present estimate is considered to be applicable for feasibility purposes.

It is emphasized that the present state of the art does not permit an exact mathematical determination of the probable maximum flood. Of necessity, a great deal of engineering judgement is unavoidable. The hydrometerological determination of the PMP, the determination of rainfall excess from PMP and basin retention, and the converting of the rainfall excess into storm runoff breaks down the problem into component parts to better facilitate the exercise of this judgement

Since each element of the probable maximum flood is a range of values rather than an absolute value, the estimate of the probable maximum flood itself is a range of values. The better and more extensive the basic data and the more studies that have been made in the general area, the smaller this range becomes.

Normally it would be very wasteful to adopt a value for the probable maximum flood from near the top of the range. This is because the cost of any spillway capacity above that which is actually required is a total economic waste. Where the range of probable maximum flood is comparatively large, as is the case for Maqarin Dam, complete safety of the dam against failure from floods cannot be assured without the probable waste of a considerable amount of money.

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For probable maximum floods near the lower part of the possible range, there is a tradeoff of cost versus safety. The ultimate goal is to obtain a readily acceptable level of safety without undue waste of money. It is believed that the Marqarin probable maximum flood represents an acceptable, though not excessive, level of safety.

The principal difficulty is to evaluate safety to determine whether or not it is readily acceptable. This also is subject to much judgement, because the probability of dam failure from overtopping is indeterminate. It is necessary to use all available information in order to apply the best judgement.

Flood Frequency

Derivation of diversion flood to be protected against during the construction period requires determination of the probability distribution of floods at the dam sites. The analysis was made using annual maximum flood peaks observed at Maqarin for the water years from 1954 to 1974 with five years of missing data (Table A-22). The maximum observed peak flood discharge at Maqarin was 442 m^3/s as recorded in 1969. The frequency curve is shown on Exhibit A-11 and frequency values derived from a Log Pearson Type III probability distribution are summarized in Table A-23. Floods of corresponding recurrence intervals were derived for the area between Maqarin and Khalid by using the Creager's C values for the Maqarin site.

Considering the limited amount of data available for analyses, the resulting flood-frequency relationship may be subjected to considerable uncertainty. A flood (750 m^3/s) considerably larger than the 442 m^3/s recorded at Maqarin

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has been reported to be observed on the Zarqa River which has a considerably similar drainage area. It is, therefore, desirable that a conservative approach be adopted in selecting the diversion flood.

Sedimentation

Sediment Load

The average annual total sediment load, as the sum of measured (suspended) and unmeasured (bed) loads at Maqarin damsite, was estimated to be 1.22 million tons. The measured load was determined by applying a sediment rating curve to a daily flow duration curve. The unmeasured load was estimated to be 30 percent of the measured load.

The sediment rating curve for the damsite was constructed based on instantaneous sediment discharges measured during water years from 1965 to 1970. A limiting concentration of 50,000 milligrams per liter (mg/l) was used in constructing the curve (Exhibit A-12). Due to a considerable scatter in the plotted data, a dimensionless sediment rating curve was prepared, based on Zarqa River data, and used as a guide for defining the curve. The Zarqa River sediment rating curve was well defined.

The flow duration curve was based on 14 years of daily discharges observed at Maqarin between October 1961 and April 1976 (Exhibit A-13).

A sediment load for the area between Maqarin and Khalid was estimated on the basis of unit sediment yield from the Yarmouk watershed above Maqarin. An upward adjustment was made to account for the effect of the smaller size of drainage area on sediment yield.[17/] The resulting average annual total sediment load excluding sediment discharges from the Maqarin Reservoir was 0.19 million tons.

17/ ASCE Task Committee on Sedimentation, 1975, Sedimentation Engineering; Edited by V.A. Vanoi, New York, N.Y., p. 462.

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Higher precipitation in the Wadi Raqqad Basin above the diversion site could cause a higher sediment production, but the drainage system on the Golan plateau is poorly developed. The computed sediment load of 0.19 million tons per year is, therefore, considered to be somewhat conservative (on the high side).

Reservoir Sedimentation

Sediment deposition in Maqarin Reservoir was estimated for 1, 50 and 100 years of reservoir operation as shown in Table 24.

The initial sediment trap efficiency for the Maqarin Reservoir was estimated, using Brune's 18/ median curve, to be 98 percent. The trap efficiency will remain practically the same after 100 years of operation. This is mainly due to the large reservoir capacity (about 700 MCM) as compared to average annual streamflow (240.3 MCM). The reservoir area-capacity curves are shown on Exhibit A-14.

The change of unit weight of deposited sediment due to compaction on the reservoir bottom was estimated by using the Koelzer and Lara 19/ method. The initial weight of the sediment was estimated to be 1.3 tons per cubic meter. Therefore, the annual deposition in the reservoirs, prior to compaction, is 0.92 MCM for Maqarin Reservoir and 0.155 MCM for Khalid Reservoir, including sediment outflow from Maqarin Reservoir.

The volumes of deposited sediment after 1, 50, and 100 years are shown for both reservoirs in Table A-24. The very small amount of compaction is due to the high percentage of sand in the sediment.

18/ Brune, G.M., 1953, Trap Efficiency of Reservoirs; Trans. Am. Geophys. Union, Volume 34, pp. 407-418.

19/ Koelzer, V.A. and Larza, J.M. 1958, Densities and Compaction Rates of Deposited Sediment; Jor. of Hydraul. Division, ASCE, Vol. 84, No. HY2.

Table A-1

DRAINAGE AREAS AND MEAN ANNUAL PRECIPITATION AND RUNOFF

Location	Drainage Area (km^2)	Mean[a/] Annual Precipitation (mm)	Mean[b/] Annual Runoff (MCM)
Yarmouk River at			
Adasiye	6,790	390	408.6
Maqarin	5,950	330	255.6
Zarqa River at Deir Alla	3,400	250	67.3
Side Wadis tributary to the Jordan River:			
Wadi Arab	267	485	28.8
Wadi Ziglab	106	520	9.5
Wadi Jurum	20	450	11.2
Wadi Yabis	125	540	3.3
Wadi Kufrinja	111	530	6.1
Wadi Rajib	84	530	7.1
Wadi Shueib	178	445	7.9
Wadi Kafrein	163	370	14.3
Wadi Hisban	60	340	5.0

a/ Mean over the period from 1931-1960

b/ Mean over the period from 1953/54-1975/76

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Table A-2

MEAN MONTHLY PRECIPITATION AND TEMPERATURE

	AMMAN		SHUNEH NORTH	
Month	Precip.[a/] (mm)	Temp.[b/] (°C)	Precip.[c/] (mm)	Temp.[b/] (°C)
January	66.4	8.1	79.1	14.0
February	57.0	9.0	59.2	14.7
March	53.5	11.8	49.2	17.3
April	11.0	16.0	17.0	21.2
May	5.1	20.7	9.3	25.8
June	0	23.7	0	28.7
July	0	25.1	0	30.3
August	0	25.6	0	31.0
September	0	23.5	0	29.0
October	5.9	20.6	14.4	26.7
November	29.7	15.3	44.6	21.6
December	51.9	10.0	82.6	16.5
Total	280.5	-	355.4	-
Mean	-	17.4	-	23.1

a/ 34 year average, water years (October-September) 1937 through 1970, from: Jordan Natural Resources Authority. Rainfall in Jordan.

b/ 43 year average from: Unpublished records, Jordan Natural Resources Authority.

c/ 19 year average, water years (October-September) 1950 through 1968, from: JOrdan Natural Resources Authority. Rainfall in Jordan.

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Table A-3

METHOD OF ESTIMATION OF MISSING

MONTHLY STREAMFLOW DATA

Stream	Location	Period of Missing Record	Method of Estimation
Yarmouk	Maqarin	Oct.-Nov.,1971; Oct. 1972-Sep. 1973;	Estimated from Adasiye streamflow using drainage area and mean annual precipitation ratio.
		Oct.-Dec.,1973; Oct., 1974.	Long term monthly mean based on observed discharge.
	Adasiye	Oct. 1968-Sep. 1970; Jan. 1974-Apr. 1976;	Estimated from Maqarin streamflow using drainage area and mean annual precipitation ratio.
		Oct.-Dec., 1973; Oct., 1974.	Long term monthly mean based on observed discharge.
Zarqa	Deir Alla	Dec. 1965-Jan. 1966; May-Sep., 1966; Oct. 1968-Sep. 1971; Oct. 1974-Mar. 1976;	Estimated by seasonal correlation from monthly streamflows at New Jarash Bridge, based on concurrent period of records.
		Oct. 1966-Nov. 1967; May-Sep., 1968;	Estimated by adding to the recorded diversions, the long-term average "base" and "flood" flows.
		Oct.1973-Sep. 1974	Estimated by adding to the recorded "base" and "flood" flows, the long term average diversions.

Table A-3

(Continued)

Stream	Location	Period of Missing Record	Method of Estimation
Wadi Arab	Shuneh North	Oct. 1953-Sep. 1962;	Total flow estimated by Sir M. MacDonald and Partners.
		Oct.-Dec, 1962;	Estimated from observed base flow using appropriate monthly total flow/base flow ratios.
		Jan., 1974; Nov., 1974; Jan.-Sep., 1975	Estimated from monthly streamflow ratios of Wadi Arab and Wadi Ziglab based on concurrent period of record.
Wadi Ziglab	Approximately 6 Km upstream of mouth.	Oct. 1953-Sep. 1962;	Flood flow estimated by Sir M. MacDonald and Partners.
		Oct.-Dec., 1962;	Estimated from monthly streamflow ratios of Wadi Yabis and Wadi Ziglab based on concurrent period of record.
		Jan.-Sep,1963; Dec. 1963-May 1964; Jan.-Mar.1965; Nov., 1969; Oct.-Nov.,1970; Feb., 1971; Apr., 1971;	Estimated from monthly streamflow ratios of Wadi Arab and Wadi Ziglab based on concurrent period of record

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Table A-3

(continued)

Stream	Location	Period of Missing Record	Method of Estimation
		Dec. 1973-Feb. 1974.	Estimated from monthly streamflow ratios of Wadi Jurum and Wadi Ziglab based on concurrent period of record.
Wadi Jurum	Approximately 3 km upstream of mouth	Oct.-Dec.,1953.	Flood flow estimated by Baker-Harza;
		Dec. 1963-Mar. 1964; Feb.-Mar.1965; Oct. 1965-Jan. 1966; Dec. 1968; May-Sep.1975;	Estimated from monthly streamflow ratios of Wadi Jurum and Wadi Ziglab based on concurrent period of record.
		Jan., 1954-Nov. 1963; Apr. 1964-Jan. 1965; Apr. 1965-Sep. 1965; Feb. 1966-Sep. 1966.	Estimated from observed base flow using appropriate monthly total flow/base flow ratios.
Wadi Yabis	Approximately 4 Km upstream of mouth.	Oct. 1953-May 1957	Total flow estimated by Baker-Harza, Harzint and Sir M. MacDonald and Partners.
		Jun. 1957-Sep. 1962;	Flood flow estimated by Baker-Harza and by Sir M. MacDonald and Partners.

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Table A-3

(continued)

Stream	Location	Period of Missing Record	Method of Estimation
		Oct. 1963-Jun. 1967; Jun.-Oct.,1973; Jan. 1974; May-Sep.1975.	Estimated from monthly streamflow ratios of Wadi Yabis and Wadi Ziglab based on concurrent period of record.
Wadi Kufrinja	Approximately 4 km upstream of mouth	Oct. 1954-Sep. 1963;	Estimated from observed base flow using monthly total flow/base flow ratios.
		Oct. 1963-Sep. 1964; Jul. 1972-Sep. 1973; Jun.-Sep.,1974; Jun.-Sep.,1975.	Estimated from Wadi Ziglab streamflow using drainage area and mean annual precipitation ratio.
Wadi Rajib	Approximately 6 km upstream of mouth.	Oct.-Dec.1953;	Flood flow estimated by Baker-Harza.
		Jan. 1954-Feb. 1960;	Estimated from observed base flow using monthly total flow/base flow ratios.
		Mar. 1960-Sep. 1975.	Estimated from Wadi Ziglab streamflow using drainage area and mean annual precipitation ratio.
Wadi Shueib	Shunat Nimrin	Oct. 1953-	Estimated by Baker-Harza and

Table A-3

(continued)

Stream	Location	Period of Missing Record	Method of Estimation
		Jan. 1954;	by Sir M. MacDonald and Partners.
		Feb. 1954-Sep. 1962;	Flood flow estimated by Sir M. MacDonald and Partners.
		Oct. 1963-Sep. 1975.	Estimated from monthly streamflow ratios of Wadi Shueib and Wadi Ziglab based on concurrent period of published data
Wadi Kafrein	Approximately 9 km upstream of confluence with Wadi Hisban	Oct. 1953-Sep. 1974;	Estimated by Sir M. MacDonald and Partners.
		Oct. 1974-Sep. 1975.	Estimated from monthly streamflow ratios of Wadi Kafrein and Wadi Ziglab based on concurrent period of published data.
Wadi Hisban	Approximately 6 km upstream of confluence with Wadi Kafrein.	Oct. 1953-Sep. 1974;	Estimated by Sir M. MacDonald and Partners.
		Oct. 1974-Sep. 1975.	Estimated from monthly streamflow ratios of Wadi Hisban and Wadi Ziglab based on concurrent period of published data.

Table A-4

MONTHLY STREAMFLOW
(Before Adjustment for Upstream Diversion)

Yarmouk River At Maqarin
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	15.0	16.0	19.0	55.0	110.0	33.0	25.0	15.0	14.0	15.0	15.0	16.0	348.0
1954/55	19.0	20.0	22.0	21.0	15.0	16.0	14.0	13.0	11.0	12.0	13.0	14.0	190.0
1955/56	15.0	24.0	31.0	42.0	31.0	26.0	21.0	18.0	17.0	19.0	19.0	19.0	282.0
1956/57	19.0	19.0	23.0	23.0	30.0	41.0	20.0	18.0	17.0	19.0	19.0	18.0	266.0
1957/58	19.0	20.0	24.0	31.0	23.0	20.0	18.0	16.0	16.0	18.0	18.0	17.0	240.0
1958/59	17.0	16.0	17.0	17.0	16.0	19.0	16.0	17.0	16.0	16.0	17.0	17.0	201.0
1959/60	17.0	16.0	17.0	18.0	17.0	18.0	18.0	18.0	17.0	16.0	17.0	16.0	205.0
1960/61	17.0	18.0	19.0	23.0	27.0	23.0	19.0	20.0	17.0	16.0	16.0	17.0	232.0
1961/62	19.3	18.9	36.4	27.6	31.0	20.6	14.3	14.5	13.7	14.5	16.1	18.1	245.0
1962/63	20.3	16.5	21.5	21.4	25.6	25.8	17.1	16.3	14.4	14.4	16.2	17.2	226.7
1963/64	17.4	17.0	22.1	19.7	45.9	34.8	17.4	16.1	14.7	14.4	16.0	16.0	251.5
1964/65	16.1	17.2	28.1	58.5	51.1	22.3	18.6	15.9	14.5	15.5	15.8	15.5	289.1
1965/66	16.9	15.8	17.7	17.2	17.8	24.2	15.1	12.0	11.9	12.4	13.0	14.8	188.8
1966/67	20.4	18.8	41.8	34.2	62.3	98.6	31.3	19.6	20.4	22.7	25.4	25.4	420.9
1967/68	7.8	9.2	11.7	69.4	37.8	9.0	8.1	8.6	9.8	9.3	10.6	11.7	203.0
1968/69	16.6	17.3	67.4	141.9	81.8	112.3	31.0	17.0	12.5	12.8	13.4	13.2	537.2
1969/70	15.8	19.6	17.5	27.3	21.5	44.8	15.4	13.9	11.8	12.2	12.2	11.8	223.8
1970/71	12.2	11.8	12.2	20.3	22.9	24.6	(49.6)	14.9	11.9	11.4	11.9	11.6	215.3
1971/72	(11.7)	(14.2)	13.2	19.7	24.7	18.8	18.1	17.2	12.0	10.8	11.8	11.6	(183.8)
1972/73	(11.5)	(13.9)	(16.7)	(20.9)	(23.5)	(34.9)	(11.8)	(10.6)	(10.1)	(9.0)	(8.9)	(9.2)	(181.0)
1973/74	(16.5)	(16.7)	(23.6)	53.3	71.2	62.4	17.4	13.9	11.7	11.2	11.7	12.1	(321.7)
1974/75	(16.5)	8.0	17.2	15.4	21.8	24.1	11.3	11.3	11.5	13.5	10.7	11.3	(172.6)
1975/76	12.9	14.0	16.7	17.1	22.5	29.9	18.0	-	-	-	-	-	-
Mean	16.2	16.5	23.6	35.3	36.7	34.2	19.4	15.3	13.9	14.3	14.9	15.2	255.6

Remarks:

Total flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.
Oct, 1963 through Sep, 1971: Jordan Natural Resources Authority records. (Unpublished)
Dec, 1971 through Sep, 1972: Jordan Natural Resources Authority records. (Unpublished)
Jan through Sep, 1974: Jordan Natural Resources Authority records. (Unpublished)
Nov, 1974 through Apr, 1976: Jordan Natural Resources Authority records. (Unpublished)
( ) = Harza estimate, 1976.

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Table A-4a

ADJUSTED MONTHLY STREAMFLOW

Yarmouk River at Maqarin
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	11.9	16.0	19.0	55.0	110.0	33.0	22.0	8.7	7.9	8.2	8.2	9.9	309.8
1954/55	15.9	20.0	22.0	21.0	15.0	16.0	11.2	7.1	5.3	5.7	6.7	8.3	154.2
1955/56	12.1	24.0	31.0	42.0	31.0	26.0	18.4	12.6	11.8	13.2	13.2	13.8	249.1
1956/57	16.3	19.0	23.0	23.0	30.0	41.0	17.6	13.0	12.2	13.7	13.7	13.2	235.7
1957/58	16.5	20.0	24.0	31.0	23.0	20.0	15.8	11.5	11.7	13.2	13.2	12.7	212.6
1958/59	14.8	16.0	17.0	17.0	16.0	19.0	14.0	13.0	12.1	11.6	12.6	13.1	176.2
1959/60	15.0	16.0	17.0	18.0	17.0	18.0	16.3	14.4	13.5	12.1	13.1	12.5	182.9
1960/61	15.2	18.0	19.0	23.0	27.0	23.0	17.5	16.9	14.0	12.6	12.6	14.0	212.8
1961/62	17.7	18.9	36.4	27.6	31.0	20.6	13.0	11.8	11.1	11.6	13.2	15.5	228.4
1962/63	19.0	16.5	21.5	21.4	25.6	25.8	16.0	14.1	12.2	12.0	13.8	15.0	212.9
1963/64	16.3	17.0	22.1	19.7	45.9	34.8	16.5	14.3	13.0	12.5	14.1	14.3	240.5
1964/65	15.2	17.2	28.1	58.5	51.1	22.3	18.0	14.6	13.2	14.1	14.4	14.2	280.9
1965/66	16.2	15.8	17.7	17.2	17.8	24.2	14.7	11.1	11.0	11.4	12.0	13.9	183.0
1966/67	20.0	18.8	41.8	34.2	62.3	98.6	30.9	18.7	19.5	21.7	24.4	24.5	415.4
1967/68	7.4	9.2	11.7	69.4	37.8	9.0	7.7	7.7	8.9	8.3	9.6	10.8	197.5
1968/69	16.2	17.3	67.4	141.9	81.8	112.3	30.6	16.1	11.6	11.8	12.4	12.3	531.7
1969/70	15.4	19.6	17.5	27.3	21.5	44.8	15.0	13.0	10.9	11.2	11.2	10.9	218.3
1970/71	11.8	11.8	12.2	20.3	22.9	24.6	(49.2)	14.0	11.0	10.4	10.9	10.7	209.8
1971/72	(11.3)	(14.2)	13.2	19.7	24.7	18.8	17.7	16.3	11.1	9.8	10.8	10.7	(178.3)
1972/73	(11.1)	(13.9)	(16.7)	(20.9)	(23.5)	(34.9)	(11.4)	(9.7)	(9.2)	(8.0)	(7.9)	(8.3)	(175.5)
1973/74	(16.1)	(16.7)	(23.6)	53.3	71.2	62.4	17.0	13.0	10.8	10.2	10.7	11.2	(316.2)
1974/75	(16.1)	8.0	17.2	15.4	21.8	24.1	10.9	10.4	10.6	12.5	9.7	10.4	(167.1)
1975/76	12.5	14.0	16.7	17.1	22.5	29.9	17.6	-	-	-	-	-	-
Mean	14.9	16.5	23.6	35.3	36.8	34.2	18.2	12.8	11.5	11.6	12.2	12.7	240.3

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Table A-5

MONTHLY INTERVENING FLOW BETWEEN MAQARIN AND KHALID
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	6.7	9.2	12.5	87.5	91.7	14.2	17.5	5.8	4.2	4.2	5.0	5.0	263.5
1954/55	5.0	4.2	5.8	6.7	7.5	11.7	7.5	5.8	7.5	7.5	7.5	5.8	82.5
1955/56	5.8	5.0	26.7	48.3	21.7	14.2	5.8	6.7	4.2	2.5	2.5	2.5	145.9
1956/57	3.3	2.5	1.7	14.2	31.7	15.0	3.3	0.8	1.7	0.8	1.7	1.7	78.4
1957/58	2.5	1.7	10.0	65.8	8.3	3.3	3.3	5.8	4.2	0.8	1.7	3.3	110.7
1958/59	5.0	4.2	5.0	8.3	23.3	19.2	5.8	2.5	2.5	2.5	2.5	3.3	84.1
1959/60	4.2	4.2	4.2	7.5	4.2	4.2	2.5	0.8	0.8	1.7	0.8	2.5	37.6
1960/61	1.7	3.3	3.3	4.2	21.7	0.8	1.7	5.8	0.8	1.7	1.7	0.8	47.5
1961/62	2.3	3.8	35.3	20.9	36.2	6.0	3.1	3.4	3.8	2.8	1.7	1.4	120.7
1962/63	0.3	1.7	1.8	26.3	23.4	18.1	3.1	4.8	1.3	1.8	1.4	1.0	85.0
1963/64	7.8	7.0	14.0	9.0	57.3	41.8	14.1	13.7	13.5	12.9	12.3	11.4	214.8
1964/65	11.8	21.3	17.7	50.3	56.8	15.1	15.6	12.1	11.1	11.4	11.6	11.9	246.7
1965/66	10.8	10.0	9.7	20.0	25.1	21.5	12.3	12.7	11.1	11.2	12.1	13.0	169.5
1966/67	8.0	10.5	21.5	48.3	50.9	79.9	22.2	11.4	7.2	5.6	3.7	3.5	272.7
1967/68	8.0	7.9	2.8	1.4	4.2	32.5	7.6	6.8	5.3	5.5	0.8	0.8	83.6
1968/69	4.8	5.1	19.7	41.4	23.8	32.8	9.1	5.0	3.7	3.8	3.9	3.8	156.9
1969/70	4.6	5.8	5.1	8.0	6.3	13.1	4.5	4.1	3.4	3.6	3.6	3.4	65.5
1970/71	10.1	37.4	45.2	1.4	18.2	62.4	1.7	15.2	6.8	18.1	19.9	15.5	251.9
1971/72	3.4	4.2	13.8	13.1	27.1	7.4	2.7	0.8	1.5	3.3	2.5	1.8	81.6
1972/73	3.3	4.1	4.8	6.1	6.9	10.2	3.4	3.1	2.9	2.6	2.6	2.7	52.7
1973/74	5.3	7.8	11.7	15.6	20.8	18.2	5.1	4.1	3.4	3.3	3.4	3.5	102.2
1974/75	5.3	2.4	5.0	4.5	6.3	7.0	3.3	3.3	3.3	3.9	3.1	3.3	50.7
1975/76	3.8	4.1	4.8	5.0	6.6	8.8	5.3	-	-	-	-	-	-
Average	5.5	7.4	12.6	23.1	26.0	20.4	7.0	6.1	4.8	5.1	4.8	4.7	127.5

Remarks:

Computed from intervening flow between Maqarin and Adasiye, using coefficient:

$$C = \frac{\text{D.A. MQ-KH}}{\text{D.A. MQ-AD}} = 0.83$$

Table A-6

MONTHLY STREAMFLOW
(Before Adjustment for Upstream Diversion)

Yarmouk River at Adasiye
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	23.0	27.0	34.0	160.0	220.0	50.0	46.0	22.0	19.0	20.0	21.0	22.0	664.0
1954/55	25.0	25.0	29.0	29.0	24.0	30.0	23.0	20.0	20.0	21.0	22.0	21.0	289.0
1955/56	22.0	30.0	63.0	100.0	57.0	43.0	28.0	26.0	22.0	22.0	22.0	22.0	457.0
1956/57	23.0	22.0	25.0	40.0	68.0	59.0	24.0	19.0	19.0	20.0	21.0	20.0	360.0
1957/58	22.0	22.0	36.0	110.0	33.0	24.0	22.0	23.0	21.0	19.0	20.0	21.0	373.0
1958/59	23.0	21.0	23.0	27.0	44.0	42.0	23.0	20.0	19.0	19.0	20.0	21.0	302.0
1959/60	22.0	21.0	22.0	27.0	22.0	23.0	21.0	(19.0)	(18.0)	18.0	18.0	19.0	250.0
1960/61	19.0	22.0	23.0	28.0	53.0	24.0	21.0	27.0	18.0	18.0	18.0	18.0	289.0
1961/62	22.0	23.5	78.8	52.7	74.4	27.8	18.0	18.6	18.2	17.8	18.1	19.8	389.7
1962/63	20.7	(18.5)	23.7	52.9	53.7	47.5	20.8	22.0	15.9	16.5	17.9	18.4	328.5
1963/64	26.7	25.4	38.9	30.5	114.7	84.9	34.3	32.5	30.9	29.9	30.7	29.7	509.1
1964/65	30.3	42.7	49.3	118.9	119.3	40.4	37.3	30.4	27.8	29.2	29.7	29.8	585.1
1965/66	29.9	27.8	29.3	41.2	47.9	50.0	29.8	27.2	25.2	25.8	27.5	30.4	392.0
1966/67	30.0	31.4	67.6	92.2	123.4	194.5	57.9	33.3	29.0	29.4	29.8	29.6	748.1
1967/68	17.4	18.7	15.1	(71.1)	(42.8)	48.0	17.2	16.8	16.2	15.9	(11.6)	(12.7)	303.5
1968/69	(22.4)	(23.4)	(91.0)	(191.6)	(110.4)	(151.6)	(41.9)	(23.0)	(16.9)	(17.3)	(18.1)	(17.8)	(725.4)
1969/70	(21.3)	(26.5)	(23.6)	(36.9)	(29.0)	(60.5)	(20.8)	(18.8)	(15.9)	(16.5)	(16.5)	(15.9)	(302.2)
1970/71	24.3	56.7	66.4	22.0	44.7	99.5	51.6	33.1	20.1	33.1	35.8	30.2	517.5
1971/72	15.8	19.2	29.8	35.4	57.2	27.7	21.3	(18.2)	13.8	14.8	14.8	13.8	281.8
1972/73	15.5	18.8	22.5	28.2	31.8	47.1	15.9	14.3	13.6	12.1	12.0	12.4	244.2
1973/74	(22.9)	(26.1)	(37.6)	(72.0)	(96.1)	(84.2)	(23.5)	(18.8)	(15.8)	(15.1)	(15.8)	(16.3)	(444.2)
1974/75	(22.9)	(10.9)	(23.2)	(20.8)	(29.4)	(32.5)	(15.3)	(15.3)	(15.5)	(18.2)	(14.4)	(15.3)	(233.7)
1975/76	(17.4)	(18.9)	(22.5)	(23.1)	(30.4)	(40.4)	(24.3)	-	-	-	-	-	-
Mean	22.8	25.4	38.7	63.1	68.0	58.7	27.9	22.6	19.6	20.4	20.7	20.7	408.6

Remarks:

Total flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.
Oct, 1963 through Sep, 1968: Jordan Natural Resources Authority records.
Oct, 1970 through Sep, 1973: Jordan Natural Resources Authority records.
( ) = Harza estimate, 1976.

Table A-7

MONTHLY STREAMFLOW

Zarqa River at Deir Alla
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	5.2	5.7	5.3	6.7	12.4	7.4	4.6	5.3	5.0	4.3	4.2	4.7	70.8
1954/55	5.1	5.1	7.2	6.0	3.8	4.1	3.4	3.3	2.6	2.2	2.0	2.6	47.4
1955/56	3.5	9.9	8.2	6.1	3.8	5.8	5.5	4.3	3.6	3.5	3.2	3.0	60.4
1956/57	3.3	3.1	6.6	6.3	22.9	19.1	5.2	5.7	4.7	4.0	3.7	3.6	88.2
1957/58	4.1	4.9	6.0	7.5	21.3	4.4	4.2	4.1	3.3	3.0	3.0	3.2	69.0
1958/59	3.4	3.2	3.5	13.8	8.1	9.1	3.0	3.1	2.6	2.7	2.6	2.7	57.8
1959/60	3.0	3.0	3.8	4.7	3.2	3.4	2.7	1.5	1.2	1.1	2.1	2.1	31.8
1960/61	2.1	3.0	4.1	10.1	12.7	4.2	4.8	3.7	1.0	1.8	1.9	1.8	51.2
1961/62	2.8	4.8	18.5	12.3	15.7	5.2	2.4	2.4	2.6	3.0	3.6	3.7	(77.0)
1962/63	3.4	3.4	4.8	4.7	21.1	4.5	3.7	12.7	3.0	2.8	2.9	2.8	69.8
1963/64	4.6	5.4	16.4	10.8	12.0	10.4	6.9	5.3	3.5	1.9	1.8	1.8	80.8
1964/65	4.4	3.8	10.0	43.6	14.9	4.7	7.9	3.1	2.6	2.3	1.9	1.8	101.1
1965/66	(4.4)	(2.2)	(3.2)	(3.4)	(4.7)	(17.5)	(4.0)	(3.3)	(2.6)	(2.3)	(1.8)	(2.4)	(51.8)
1966/67	(2.7)	(3.7)	(7.4)	(15.5)	(9.7)	(8.7)	(4.8)	(3.1)	(2.7)	(2.5)	(2.5)	(2.8)	(66.1)
1967/68	(2.7)	(2.4)	(11.0)	(20.8)	(12.8)	(8.8)	(5.7)	(4.0)	(3.2)	(2.6)	(2.5)	(2.2)	(78.7)
1968/69	(3.0)	(3.6)	(5.6)	(7.1)	(7.2)	(28.2)	(7.7)	(4.8)	(3.8)	(3.2)	(2.7)	(3.3)	(80.3)
1969/70	(3.8)	(3.9)	(5.0)	(7.3)	(5.5)	(9.0)	(5.3)	(3.8)	(3.5)	(3.2)	(4.7)	(5.0)	(60.0)
1970/71	(3.2)	(3.4)	(5.1)	(6.8)	(4.5)	(5.3)	(24.2)	(2.7)	(2.1)	(1.7)	(1.6)	(1.3)	(61.9)
1971/72	1.5	2.2	9.9	3.9	5.8	7.8	5.9	2.4	1.5	1.4	1.3	1.3	44.9
1972/73	1.7	3.7	2.9	6.8	4.0	5.0	1.8	1.8	1.6	1.6	1.6	1.5	34.0
1973/74	(3.1)	(6.8)	(6.4)	(44.6)	(32.2)	(20.0)	(11.0)	(7.0)	(4.3)	(3.8)	(3.6)	(3.3)	(146.1)
1974/75	(1.8)	(3.1)	(6.3)	(5.0)	(13.0)	(7.5)	(7.3)	(1.7)	(1.2)	(1.2)	(1.2)	(1.2)	(50.5)
1975/76	(1.4)	(2.3)	(4.4)	(5.2)	(5.2)	(13.0)	-	-	-	-	-	-	-
Mean	3.3	4.1	7.1	11.5	11.5	9.1	6.0	40.1	28.0	26.0	2.6	2.6	67.3

Remarks:

1) Base flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.
Oct, 1965 through Sep, 1971: Jordan Natural Resources Authority records. (Unpublished)

2) Flood flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

3) Total flow:

Oct, 1963 through Nov. 1965: Jordan Natural Resources Authority records. (Unpublished)
Feb. -Apr. 1966 : Jordan Natural Resources Authority records. (Unpublished)
Dec., 1967 through Apr.1968: Jordan Natural Resources Authority records. (Unpublished)
Oct, 1971 through Sep, 1973: Jordan Natural Resources Authority records. (Unpublished)
( ) = Harza estimate, 1976.

Table A-8

MONTHLY STREAMFOW

Wadi Arab at Shuneh North
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	2.9	5.3	3.1	3.3	3.9	3.5	3.5	3.5	3.3	3.2	3.2	3.3	42.0
1954/55	3.5	3.5	3.9	4.1	3.9	3.1	3.6	3.2	3.1	2.8	2.9	2.9	40.5
1955/56	3.1	3.9	4.1	3.7	3.4	3.5	2.8	2.7	2.6	2.6	2.5	2.6	37.5
1956/57	2.8	2.7	3.6	3.6	3.4	3.6	2.8	2.6	2.6	2.7	2.7	2.7	35.8
1957/58	2.1	3.1	4.5	3.6	3.1	2.1	2.2	2.3	2.6	2.5	2.7	2.6	33.4
1958/59	2.7	2.7	2.9	3.0	3.1	3.3	2.6	2.7	2.6	2.8	2.7	3.3	34.4
1959/60	2.7	2.7	2.8	2.6	2.1	2.9	2.3	2.4	2.3	2.4	2.7	2.5	30.4
1960/61	3.0	3.0	2.8	3.0	2.2	2.0	1.9	1.7	1.4	1.5	1.5	1.5	25.5
1961/62	1.5	1.6	4.0	2.0	1.9	1.9	1.4	1.4	1.3	1.4	1.3	1.4	21.1
1962/63	(1.6)	(1.8)	(2.2)	1.6	2.3	1.6	1.3	1.5	1.3	1.3	1.4	1.4	19.3
1963/64	1.5	1.6	1.8	1.6	1.7	1.5	1.5	1.2	1.6	1.3	1.4	1.2	17.9
1964/65	1.5	1.7	1.8	1.9	1.6	1.8	1.7	1.4	1.3	1.3	1.4	1.3	18.7
1965/66	1.7	1.7	1.6	1.6	1.6	1.8	1.6	1.7	1.5	1.5	1.5	1.4	19.2
1966/67	1.6	1.6	2.5	3.0	3.9	4.3	1.8	1.8	1.7	1.7	1.8	1.8	27.5
1967/68	2.0	2.0	2.6	5.2	2.3	2.1	2.2	2.3	2.1	1.9	1.9	1.9	28.6
1968/69	2.0	2.0	2.3	2.8	1.9	2.0	1.7	1.8	1.8	1.9	1.9	1.9	24.0
1969/70	2.2	2.1	2.2	2.7	2.5	2.9	2.6	2.6	2.7	2.6	2.6	2.4	30.2
1970/71	2.6	2.5	3.0	3.1	2.8	3.0	3.0	2.6	2.5	2.5	2.4	2.5	32.5
1971/72	2.7	2.8	3.1	3.1	2.6	3.1	2.7	2.5	2.5	2.5	2.5	2.6	32.7
1972/73	2.9	2.7	2.9	2.9	2.5	2.7	2.5	2.3	2.1	2.2	2.1	2.2	30.0
1973/74	2.1	2.4	2.6	(1.7)	2.4	2.5	2.3	1.7	1.9	2.2	2.8	3.0	27.6
1974/75	2.6	(2.1)	2.6	(2.3)	(2.1)	(2.1)	(1.9)	(1.8)	(1.8)	(1.5)	(1.6)	(1.9)	24.3
Mean	2.3	2.5	2.9	2.8	2.6	2.6	2.3	2.2	2.1	2.1	2.2	2.2	28.8

Remarks:

1) Base flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

2) Flood flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

3) Total flow:

Oct, 1963 through Dec, 1973: Jordan Natural Resources Authority records.
Feb through Oct, 1974: Jordan Natural Resources Authority records.
Dec, 1974: Jordan Natural Resources Authority records.

Table A-9

MONTHLY STREAMFLOW

Wadi Ziglab
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	1.0	2.0	1.3	1.2	1.8	1.0	1.1	1.1	1.0	1.0	1.1	1.1	14.7
1954/55	1.2	1.1	1.4	1.2	0.9	1.1	1.0	1.0	0.9	0.9	0.9	0.9	12.5
1955/56	0.9	1.3	1.4	1.3	0.8	1.1	0.8	0.8	0.8	0.8	0.8	0.8	11.6
1956/57	0.8	0.8	1.7	1.6	1.1	1.2	0.8	0.8	0.8	0.9	0.9	0.9	12.3
1957/58	1.0	1.1	1.8	1.7	0.9	0.9	0.8	0.9	0.8	0.9	0.9	0.9	12.6
1958/59	0.9	0.9	0.8	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	9.9
1959/60	0.8	0.7	0.8	0.7	0.6	0.9	0.7	0.6	0.6	0.6	0.5	0.5	8.0
1960/61	0.6	0.7	0.7	0.7	0.8	0.5	0.7	0.6	0.6	0.5	0.5	0.5	7.4
1961/62	0.5	0.5	1.5	1.1	1.0	1.0	0.7	0.5	0.8	0.5	0.5	0.5	9.1
1962/63	(0.7)	(0.4)	(0.7)	(0.6)	(0.8)	(0.5)	(0.4)	(0.5)	(0.4)	(0.4)	(0.5)	(0.4)	(6.3)
1963/64	0.4	0.5	(0.6)	(0.6)	(0.6)	(0.5)	(0.5)	(0.4)	0.6	0.5	0.5	0.5	(6.2)
1964/65	0.6	0.5	0.5	(0.7)	(0.5)	(0.6)	0.2	0.3	0.5	0.6	0.6	0.6	(6.2)
1965/66	0.7	0.7	0.7	0.3	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	6.9
1966/67	0.8	0.7	1.0	1.2	0.7	1.0	0.6	0.7	0.8	0.8	0.8	0.8	9.9
1967/68	1.0	1.0	0.9	1.0	0.9	0.9	0.9	1.0	0.9	0.9	0.8	0.8	11.0
1968/69	0.8	0.7	0.8	0.9	0.9	1.0	0.7	0.8	0.8	0.8	0.8	0.9	9.9
1969/70	1.0	(0.7)	1.0	1.1	0.8	1.0	0.8	0.7	0.7	0.8	0.8	0.8	(10.2)
1970/71	(0.8)	(1.8)	1.0	1.0	(0.9)	0.9	(1.0)	0.8	0.7	0.7	0.8	0.6	(10.0)
1971/72	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6	9.1
1972/73	0.7	0.7	0.8	0.8	0.7	0.8	0.6	0.7	0.6	0.6	0.5	0.6	8.1
1973/74	0.7	0.7	(0.6)	(0.6)	(0.7)	0.8	0.7	0.7	0.7	0.7	0.7	0.7	(8.3)
1974/75	0.7	0.7	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.6	7.8
Mean	0.8	0.9	1.0	1.0	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	9.5

Remarks:

1) Base Flow:

Oct. 1953 through Sep. 1962: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

2) Flood flow:

Oct. 1953 through Sep, 1962: Review of Streamflow Data, Technical Paper No. Jordan Central Water Authority, 1964.

3) Total flow:

Oct through Nov, 1963: Jordan Natural Resources Authority records.
Jun through Dec, 1964: Jordan Natural Resources Authority records.
Apr, 1965 through Oct, 1969: Jordan Natural Resources Authority records.
Dec, 1969 through Sep, 1970: Jordan Natural Resources Authority records.
Dec, 1970 through Jan, 1971: Jordan Natural Resources Authority records.
Mar, 1971: Jordan Natural Resources Authority records.
May, 1971 through Nov, 1973: Jordan Natural Resources Authority records.
Mar, 1974 through Sep, 1975: Jordan Natural Resources Authority records.
( ) = Harza estimate, 1976.

Table A-10

MONTHLY STREAMFLOW

Wadi Jurum
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	1.1	1.2	1.2	(1.4)	(1.2)	(1.1)	(1.2)	(1.3)	(1.4)	(1.3)	(1.3)	(1.2)	(14.9)
1954/55	(1.3)	(1.3)	(1.4)	(1.3)	(1.2)	(1.2)	(1.1)	(1.2)	(1.1)	(1.1)	(1.0)	(0.9)	(14.1)
1955/56	(1.0)	(1.0)	(0.9)	(0.8)	(0.7)	(0.8)	(0.9)	(0.9)	(0.9)	(1.0)	(1.0)	(0.9)	(10.8)
1956/57	(0.9)	(0.9)	(1.0)	(1.0)	(0.9)	(0.9)	(0.9)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(11.5)
1957/58	(1.1)	(1.0)	(1.1)	(1.2)	(1.1)	(1.0)	(1.0)	(1.0)	(1.0)	(1.1)	(1.1)	(1.0)	(12.7)
1958/59	(1.1)	(1.1)	(1.0)	(1.0)	(1.0)	(1.0)	(0.9)	(0.9)	(1.0)	(0.9)	(0.9)	(0.9)	(11.7)
1959/60	(0.9)	(0.8)	(0.8)	(0.9)	(0.8)	(0.8)	(0.7)	(0.8)	(0.7)	(0.7)	(0.7)	(0.7)	(9.3)
1960/61	(0.7)	(0.7)	(0.7)	(0.7)	(0.6)	(0.7)	(0.8)	(0.9)	(0.9)	(0.7)	(0.6)	(0.6)	(8.6)
1961/62	(0.7)	(0.7)	(0.6)	(0.6)	(0.5)	(0.7)	(0.8)	(0.9)	(0.9)	(0.9)	(0.9)	(0.8)	(9.0)
1962/63	(1.0)	(0.8)	(1.1)	(0.9)	(1.2)	(0.8)	(0.7)	(1.0)	(0.8)	(0.7)	(0.9)	(0.9)	(10.8)
1963/64	(0.7)	(0.7)	(0.6)	(0.6)	(0.7)	(0.5)	(0.8)	(0.8)	(0.9)	(0.9)	(1.0)	(0.9)	(9.1)
1964/65	(0.8)	(0.8)	(0.9)	(0.9)	(0.6)	(0.6)	(1.0)	(1.0)	(1.0)	(0.9)	(1.0)	(1.0)	(10.5)
1965/66	(0.9)	(0.8)	(0.7)	(0.3)	(0.3)	(0.9)	(0.7)	(0.7)	(0.8)	(0.8)	(0.8)	(0.7)	(8.4)
1966/67	0.7	0.7	0.8	0.8	0.7	0.8	0.9	1.0	1.0	1.1	1.0	1.1	10.6
1967/68	1.2	1.3	1.2	1.3	1.1	1.1	1.1	1.0	0.9	0.9	1.0	0.9	13.0
1968/69	1.1	1.1	(0.8)	1.3	1.2	1.1	1.1	1.2	1.1	1.1	1.3	1.3	(13.7)
1969/70	1.4	1.2	1.3	1.3	1.2	1.3	1.1	1.2	1.2	1.3	1.3	1.3	15.1
1970/71	1.3	1.3	1.4	1.4	1.6	1.3	1.3	1.0	0.9	1.0	1.0	1.0	14.5
1971/72	1.0	1.0	1.2	1.2	1.2	1.0	1.0	1.0	1.0	1.0	1.0	0.8	12.4
1972/73	0.8	0.8	0.7	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.7	0.6	8.3
1973/74	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.7	8.2
1974/75	0.8	0.8	0.8	0.7	0.7	0.7	0.6	(0.8)	(0.8)	(0.7)	(0.7)	(0.8)	(8.9)
Mean	1.0	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9	0.9	1.0	0.9	11.2

Remarks:

1) Base flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.
Oct through Nov, 1963: Jordan Natural Resources Authority records.
Apr, 1964 through Jan, 1965: Jordan Natural Resources Authority records.
Apr, 1965 through Sep, 1965: Jordan Natural Resources Authority records.
Feb, 1966 through Sep, 1966: Jordan Natural Resources Authority records.

2) Flood flow:

Oct. 1953 through Sep, 1954: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

3) Total flow:

Oct, 1966 through Nov, 1968: Jordan Irrigation Department records.
Jan, 1969 through Apr, 1975: Jordan Irrigation Department records.
( ) = Harza estimate, 1976.

Table A-11

MONTHLY STREAMFLOW

Wadi Yabis
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	0.4	0.8	0.6	0.6	1.2	1.0	0.7	0.5	0.4	0.3	0.3	0.3	7.1
1954/55	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	3.0
1955/56	0.2	0.3	0.4	0.8	1.2	0.6	0.5	0.4	0.3	0.3	0.2	0.3	5.5
1956/57	0.3	0.3	0.5	0.4	0.7	1.2	0.8	0.4	0.3	0.2	0.2	0.2	5.5
1957/58	0.3	0.5	0.8	0.7	0.6	0.4	0.3	0.3	0.3	0.2	0.2	0.2	4.8
1958/59	0.2	0.2	0.3	0.4	0.5	0.6	0.3	0.2	0.2	0.2	0.2	0.2	3.5
1959/60	0.1	0.2	0.2	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	2.0
1960/61	0.1	0.2	0.2	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	2.2
1961/62	0.1	0.1	0.7	0.5	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.1	3.1
1962/63	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	1.7
1963/64	(0.1)	(0.1)	(0.2)	(0.2)	(0.3)	(0.3)	(0.2)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(2.0)
1964/65	(0.2)	(0.1)	(0.1)	(0.3)	(0.3)	(0.4)	(0.1)	(0.1)	(0.1)	(0.2)	(0.2)	(0.1)	(2.2)
1965/66	(0.2)	(0.2)	(0.2)	(0.1)	(0.2)	(0.3)	(0.3)	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)	(2.4)
1966/67	(0.2)	(0.2)	(0.3)	(0.5)	(0.4)	(0.6)	(0.3)	(0.2)	(0.2)	0.2	0.3	0.2	(3.6)
1967/68	0.4	0.3	0.4	0.7	1.0	0.7	0.3	0.2	0.2	0.2	0.2	0.2	4.8
1968/69	0.2	0.2	0.2	0.4	0.3	0.5	0.6	0.4	0.3	0.2	0.2	0.2	3.7
1969/70	0.3	0.2	0.3	0.3	0.3	0.7	0.6	0.1	0.2	0.2	0.2	0.1	3.5
1970/71	0.2	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.3	0.2	0.2	0.1	3.1
1971/72	0.2	0.2	0.2	0.2	0.5	0.9	0.6	0.2	0.2	0.2	0.2	0.1	3.7
1972/73	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	(0.2)	(0.2)	(0.1)	(0.1)	(1.6)
1973/74	(0.2)	0.1	0.1	(0.1)	0.6	0.6	0.2	0.1	0.1	0.1	0.1	0.1	(2.4)
1974/75	0.1	0.1	0.1	0.1	0.2	0.3	0.1	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(1.7)
Mean	0.2	0.2	0.3	0.4	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	3.3

Remarks:

1) Base flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

2) Flood flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

3) Total flow:

Jul, 1967 through May, 1973: Jordan Natural Resources Authority records. (Unpublished)
Nov through Dec, 1973: Jordan Natural Resources Authority records. (Unpublished)
Feb, 1974 through Apr, 1975: Jordan Natural Resources Authority records. (Unpublished)
( ) = Harza estimate, 1976.

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Table A-12

MONTHLY STREAMFLOW

Wadi Kufrinja
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	0.4	0.4	0.6	1.0	3.0	2.8	1.5	1.0	0.8	0.6	0.5	0.4	13.0
1954/55	(0.5)	(0.4)	(0.5)	(0.4)	(0.4)	(0.2)	(0.2)	(0.3)	(0.2)	(0.2)	(0.2)	(0.2)	3.7
1955/56	(0.2)	(0.6)	(0.9)	(1.5)	(2.4)	(1.3)	(1.1)	(0.7)	(0.5)	(0.4)	(0.3)	(0.4)	(10.3)
1956/57	(0.4)	(0.4)	(0.5)	(0.6)	(1.4)	(2.1)	(1.8)	(0.8)	(0.6)	(0.4)	(0.4)	(0.4)	(9.8)
1957/58	(0.5)	(0.5)	(0.7)	(0.6)	(1.2)	(0.9)	(0.4)	(0.5)	(0.3)	(0.2)	(0.2)	(0.2)	(6.2)
1958/59	(0.3)	(0.3)	(0.3)	(0.4)	(0.5)	(1.0)	(0.4)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(4.2)
1959/60	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(1.8)
1960/61	(0.2)	(0.3)	(0.4)	(0.4)	(0.4)	(0.9)	(0.3)	(0.2)	(0.2)	(0.1)	(0.1)	(0.2)	(3.7)
1961/62	(0.2)	(0.2)	(0.9)	(1.4)	(2.1)	(1.6)	(0.3)	(0.3)	(0.2)	(0.2)	(0.2)	(0.2)	(7.8)
1962/63	(0.3)	(0.3)	(0.5)	(0.5)	(1.0)	(0.4)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(3.8)
1963/64	(0.4)	(0.5)	(0.6)	(0.6)	(0.6)	(0.5)	(0.5)	(0.4)	(0.6)	(0.5)	(0.5)	(0.5)	(6.2)
1964/65	0.2	0.3	0.3	2.1	2.1	0.1	1.8	0.3	0.2	0.2	0.2	0.2	8.0
1965/66	0.2	0.4	0.3	0.4	0.4	0.1	0.2	0.2	0.0	0.1	0.1	0.1	2.5
1966/67	0.1	0.1	0.0	0.3	0.6	0.6	0.5	0.4	0.3	0.3	0.2	0.2	3.6
1967/68	0.3	0.3	0.3	3.3	0.5	0.7	0.3	0.2	0.1	0.1	0.1	0.1	6.3
1968/69	0.1	0.1	0.2	0.2	0.1	0.8	0.7	0.6	0.3	0.3	0.2	0.2	3.8
1969/70	0.2	0.3	0.0	0.3	0.3	0.8	0.7	0.4	0.3	0.2	0.2	0.2	3.9
1970/71	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.8	0.4	0.3	0.2	0.2	4.0
1971/72	0.2	0.2	1.2	0.4	0.1	0.8	0.7	0.5	0.3	(0.7)	(0.6)	(0.6)	(6.3)
1972/73	(0.7)	(0.7)	(0.9)	(0.9)	(0.7)	(0.9)	(0.6)	(0.7)	(0.6)	(0.6)	(0.5)	(0.6)	(8.4)
1973/74	0.4	0.6	0.7	2.0	0.6	0.8	0.5	0.4	(0.7)	(0.7)	(0.7)	(0.7)	(8.8)
1974/75	0.4	0.4	0.6	0.5	0.9	1.2	0.5	0.4	(0.6)	(0.5)	(0.5)	(0.6)	(7.1)
Mean	0.3	0.4	0.5	0.8	0.9	0.9	0.6	0.4	0.3	0.3	0.3	0.3	6.1

Remarks:

1) Base flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

2) Flood flow:

Oct. 1953 through Sep, 1954: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

3) Total flow:

Oct, 1964 through Jun, 1972: Jordan Natural Resources Authority records. (Unpublished)
Oct, 1973 through May, 1974: Jordan Natural Resources Authority records. (Unpublished)
Oct. 1974 through May, 1975: Jordan Natural Resources Authority records. (Unpublished)
( ) = Harza estimate, 1976.

Table A-13

MONTHLY STREAMFLOW

Wadi Rajib
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	0.2	0.3	0.3	(1.9)	(1.6)	(3.3)	(1.6)	(0.7)	(0.5)	(0.4)	(0.4)	(0.3)	(11.5)
1954/55	(0.3)	(0.3)	(0.3)	(0.6)	(1.0)	(0.7)	(0.4)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(4.3)
1955/56	(0.2)	(0.4)	(0.5)	(1.5)	(2.6)	(2.0)	(0.9)	(0.4)	(0.3)	(0.3)	(0.2)	(0.3)	(9.6)
1956/57	(0.3)	(0.3)	(0.3)	(0.8)	(2.0)	(3.0)	(1.3)	(0.4)	(0.4)	(0.3)	(0.3)	(0.3)	(9.7)
1957/58	(0.3)	(0.4)	(0.4)	(1.0)	(2.0)	(1.8)	(0.5)	(0.3)	(0.3)	(0.2)	(0.2)	(0.2)	(7.6)
1958/59	(0.2)	(0.2)	(0.2)	(0.6)	(1.3)	(2.2)	(0.5)	(0.2)	(0.1)	(0.1)	(0.2)	(0.1)	(5.9)
1959/60	(0.2)	(0.2)	(0.3)	(0.4)	(0.7)	(0.7)	(0.6)	(0.5)	(0.5)	(0.5)	(0.4)	(0.4)	(5.4)
1960/61	(0.5)	(0.6)	(0.6)	(0.6)	(0.6)	(0.4)	(0.6)	(0.6)	(0.5)	(0.4)	(0.4)	(0.4)	(6.2)
1961/62	(0.4)	(0.4)	(1.2)	(0.9)	(0.8)	(0.8)	(0.6)	(0.4)	(0.6)	(0.4)	(0.4)	(0.4)	(7.3)
1962/63	(0.6)	(0.3)	(0.6)	(0.5)	(0.6)	(0.4)	(0.3)	(0.4)	(0.3)	(0.3)	(0.4)	(0.3)	(5.0)
1963/64	(0.3)	(0.4)	(0.5)	(0.5)	(0.5)	(0.4)	(0.4)	(0.3)	(0.5)	(0.4)	(0.4)	(0.4)	(5.0)
1964/65	(0.5)	(0.4)	(0.4)	(0.6)	(0.4)	(0.5)	(0.2)	(0.2)	(0.4)	(0.5)	(0.5)	(0.5)	(5.1)
1965/66	(0.6)	(0.6)	(0.6)	(0.2)	(0.3)	(0.4)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(5.7)
1966/67	(0.6)	(0.6)	(0.8)	(1.0)	(0.6)	(0.8)	(0.5)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(7.9)
1967/68	(0.8)	(0.8)	(0.7)	(0.8)	(0.7)	(0.7)	(0.7)	(0.8)	(0.7)	(0.7)	(0.6)	(0.6)	(8.6)
1968/69	(0.6)	(0.6)	(0.6)	(0.7)	(0.7)	(0.8)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.7)	(7.7)
1969/70	(0.8)	(0.6)	(0.8)	(0.9)	(0.6)	(0.8)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(8.1)
1970/71	(0.6)	(0.6)	(0.8)	(0.8)	(0.7)	(0.7)	(0.8)	(0.6)	(0.6)	(0.6)	(0.6)	(0.5)	(7.9)
1971/72	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.5)	(0.5)	(7.0)
1972/73	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.5)	(0.6)	(0.5)	(0.5)	(0.4)	(0.5)	(6.6)
1973/74	(0.6)	(0.6)	(0.5)	(0.5)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(7.0)
1974/75	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.5)	(0.5)	(0.5)	(0.4)	(0.4)	(0.5)	(6.4)
Mean	0.5	0.5	0.6	0.8	0.9	1.0	0.6	0.5	0.5	0.4	0.4	0.4	7.1

Remarks:

1) Base flow:

Oct. 1953 through Feb, 1960: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

2) Flood flow:

Oct. 1953 through Dec, 1953: Yarmouk - Jordan Valley Project, Master Plan Report Harza, 1955.

3) Total flow:

Jan, 1954 through Sep, 1975: Harza estimate, 1976.

Table A-14

MONTHLY STREAMFLOW

Wadi Shueib at Shunat Nimrin
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	0.5	1.8	1.6	1.3	2.0	1.9	1.6	1.3	1.0	0.9	0.8	0.7	15.4
1954/55	0.6	0.7	1.2	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	6.8
1955/56	0.4	0.9	1.0	1.5	1.1	1.4	1.0	0.9	0.7	0.7	0.6	0.5	10.7
1956/57	0.5	0.5	1.0	1.6	1.1	1.7	1.2	1.1	1.0	0.9	0.8	0.7	12.1
1957/58	0.7	0.7	1.3	1.5	1.0	0.8	0.7	0.6	0.5	0.5	0.4	0.4	9.1
1958/59	0.4	0.4	0.5	1.1	1.5	1.1	0.8	0.7	0.6	0.6	0.5	0.5	8.7
1959/60	0.5	0.5	0.5	0.7	0.4	0.7	0.3	0.3	0.3	0.3	0.3	0.2	5.0
1960/61	0.2	0.7	0.4	1.3	1.0	0.8	0.7	0.5	0.5	0.4	0.4	0.4	7.3
1961/62	0.4	0.4	1.5	0.8	0.9	0.8	0.6	0.4	0.4	0.4	0.4	0.3	7.3
1962/63	0.3	0.3	0.4	0.5	1.6	0.6	0.3	0.5	0.2	0.2	0.2	0.2	5.3
1963/64	(0.2)	(0.4)	(0.5)	(0.6)	(0.7)	(0.6)	(0.5)	(0.4)	(0.5)	(0.4)	(0.3)	(0.3)	(5.4)
1964/65	(0.3)	(0.4)	(0.4)	(0.7)	(0.6)	(0.7)	(0.2)	(0.3)	(0.4)	(0.4)	(0.4)	(0.4)	(5.2)
1965/66	(0.4)	(0.5)	(0.5)	(0.3)	(0.5)	(0.6)	(0.6)	(0.5)	(0.5)	(0.4)	(0.4)	(0.4)	(5.6)
1966/67	(0.4)	(0.5)	(0.8)	(1.2)	(0.8)	(1.1)	(0.6)	(0.6)	(0.6)	(0.6)	(0.5)	(0.5)	(8.2)
1967/68	(0.5)	(0.7)	(0.7)	(1.0)	(1.0)	(1.0)	(0.9)	(0.9)	(0.7)	(0.7)	(0.5)	(0.5)	(9.1)
1968/69	(0.4)	(0.5)	(0.6)	(0.9)	(1.0)	(1.1)	(0.7)	(0.7)	(0.6)	(0.6)	(0.5)	(0.5)	(8.1)
1969/70	(0.5)	(0.5)	(0.8)	(1.1)	(0.9)	(1.1)	(0.8)	(0.6)	(0.5)	(0.6)	(0.5)	(0.5)	(8.4)
1970/71	(0.4)	(0.6)	(0.8)	(1.0)	(1.0)	(1.0)	(1.0)	(0.7)	(0.5)	(0.5)	(0.5)	(0.4)	(8.4)
1971/72	(0.4)	(0.6)	(0.6)	(0.8)	(0.9)	(0.9)	(0.8)	(0.7)	(0.6)	(0.5)	(0.4)	(0.4)	(7.6)
1972/73	(0.4)	(0.5)	(0.6)	(0.8)	(0.8)	(0.9)	(0.6)	(0.6)	(0.5)	(0.4)	(0.3)	(0.4)	(6.8)
1973/74	(0.4)	(0.5)	(0.5)	(0.6)	(0.8)	(0.9)	(0.7)	(0.6)	(0.5)	(0.5)	(0.5)	(0.4)	(6.9)
1974/75	(0.4)	(0.5)	(0.8)	(0.8)	(0.8)	(0.8)	(0.6)	(0.5)	(0.5)	(0.4)	(0.3)	(0.4)	(6.6)
Mean	0.4	0.6	0.8	1.0	1.0	1.0	0.7	0.6	0.5	0.5	0.5	0.4	7.9

Remarks:

1) Base flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

2) Flood flow:

Oct. 1953 through Sep, 1963: Review of Streamflow Data, Technical Paper No. 33, Jordan Central Water Authority, 1964.

3) Total flow:

Table A-15

MONTHLY STREAMFLOW

Wadi Kafrein
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	0.4	1.4	1.1	1.0	2.6	2.6	2.1	1.7	1.3	1.0	0.7	0.6	16.5
1954/55	0.5	0.5	1.3	0.9	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.3	7.2
1955/56	0.3	0.7	1.2	1.9	1.4	2.1	1.5	1.2	0.9	0.7	0.6	0.4	12.9
1956/57	0.4	0.4	0.5	1.6	2.7	4.3	3.2	2.6	2.0	1.6	1.2	0.9	21.4
1957/58	0.7	0.6	0.9	1.9	1.1	0.9	0.7	0.6	0.5	0.4	0.4	0.3	9.0
1958/59	0.3	0.3	0.3	0.4	1.4	0.9	0.8	0.6	0.5	0.4	0.4	0.3	6.6
1959/60	0.3	0.3	0.3	0.4	0.3	0.5	0.5	0.4	0.4	0.4	0.3	0.3	4.4
1960/61	0.3	0.4	0.4	1.2	2.0	1.0	0.9	0.8	0.6	0.5	0.4	0.4	8.9
1961/62	0.3	0.3	2.7	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4	0.3	9.0
1962/63	0.3	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.3	0.3	4.3
1963/64	0.3	0.3	3.3	1.1	2.2	2.6	2.0	1.6	1.2	0.9	0.7	0.5	16.7
1964/65	0.5	0.6	0.7	4.8	2.6	2.6	2.2	1.8	1.3	1.0	0.8	0.6	19.5
1965/66	0.6	0.6	0.6	0.7	0.7	1.3	0.9	0.7	0.6	0.5	0.4	0.4	8.0
1966/67	0.4	0.4	2.4	4.2	2.9	10.2	4.4	3.1	1.9	1.5	1.1	0.8	33.3
1967/68	0.7	0.7	0.9	2.6	1.2	1.2	1.0	0.8	0.6	0.5	0.4	0.4	11.0
1968/69	0.4	0.4	1.2	1.4	0.9	6.1	3.4	2.7	1.9	1.5	1.1	0.8	21.8
1969/70	0.7	0.6	0.5	1.1	0.8	1.6	1.0	0.9	0.7	0.5	0.4	0.4	9.2
1970/71	0.4	0.3	0.4	0.5	0.6	0.8	3.7	1.4	1.0	0.8	0.6	0.5	11.0
1971/72	0.4	0.5	2.9	1.6	2.1	2.5	2.1	1.7	1.3	1.0	0.7	0.6	17.4
1972/73	0.5	0.5	0.5	2.2	0.9	1.1	0.9	0.7	0.5	0.5	0.4	0.3	9.0
1973/74	0.3	0.6	0.6	10.1	17.3	6.7	4.1	2.2	1.6	1.3	0.9	0.7	46.4
1974/75	(0.4)	(0.4)	(0.8)	(1.5)	(1.7)	(1.4)	(1.4)	(1.0)	(0.8)	(0.5)	(0.4)	(0.4)	(11.2)
Mean	0.4	0.5	1.1	1.9	2.1	2.4	1.8	1.3	1.0	0.8	0.6	0.5	14.3

Remarks:

Total flow:

Oct. 1953 through Sep, 1974: Hisban - Kafrein Feasibility Study, Sir M. MacDonald and Partners, 1975.
( ) = Harza estimate, 1976.

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Table A-16

MONTHLY STREAMFLOW

Wadi Hisban
(MCM)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1953/54	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	4.6
1954/55	0.3	0.3	0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.2	3.8
1955/56	0.2	0.4	0.4	0.7	0.6	0.8	0.7	0.6	0.5	0.5	0.4	0.4	6.2
1956/57	0.4	0.3	0.4	0.5	0.7	0.9	0.8	0.8	0.7	0.6	0.5	0.4	7.0
1957/58	0.4	0.4	0.5	0.6	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	4.7
1958/59	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	3.7
1959/60	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	2.8
1960/61	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	3.7
1961/62	0.3	0.2	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	3.6
1962/63	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.4
1963/64	0.2	0.2	0.6	0.5	0.8	1.0	0.8	0.7	0.6	0.6	0.5	0.4	6.9
1964/65	0.4	0.4	0.4	0.8	0.7	0.8	0.7	0.6	0.5	0.5	0.4	0.4	6.6
1965/66	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.3	0.3	0.3	4.6
1966/67	0.3	0.3	0.5	0.7	0.7	0.8	0.7	0.6	0.5	0.5	0.4	0.4	6.4
1967/68	0.4	0.4	0.4	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	5.0
1968/69	0.3	0.3	0.4	0.4	0.4	0.6	0.5	0.4	0.4	0.4	0.3	0.3	4.7
1969/70	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	3.9
1970/71	0.3	0.2	0.3	0.3	0.3	0.3	0.5	0.4	0.4	0.3	0.3	0.3	4.1
1971/72	0.3	0.3	0.6	0.5	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.3	5.6
1972/73	0.3	0.4	0.3	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	4.3
1973/74	0.3	0.3	0.3	2.3	3.3	1.6	1.1	0.8	0.6	0.6	0.5	0.4	12.1
1974/75	(0.3)	(0.3)	(0.3)	(0.4)	(0.5)	(0.5)	(0.4)	(0.4)	(0.3)	(0.3)	(0.2)	(0.3)	(4.2)
Mean	0.3	0.3	0.4	0.5	0.6	0.6	0.5	0.4	0.4	0.4	0.3	0.3	5.0

Remarks:

Total flow:

Oct. 1953 through Sep, 1974: Hisban - Kafrein Feasibility Study, Sir M. MacDonald and Partners, 1975.
( ) = Harza estimate, 1976.

Table A-17

MINIMUM LOW FLOW SEQUENCES

YARMOUK RIVER

(MCM)

(MCM)

	12 Months		24 Months	
	Nov. 1974-Oct. 1975		Oct. 1971-Sep. 1973	
Month (1)	Maqarin (2)	Intervening Flow[a/] (3)	Maqarin[b/][c/] (4)	Intervening Flow[a/] (5)
1	8.0	2.4	11.7	3.4
2	17.2	5.0	14.2	4.2
3	15.4	4.5	13.2	13.8
4	21.8	6.3	19.7	13.1
5	24.1	7.0	24.7	27.1
6	11.3	3.3	18.8	7.4
7	11.3	3.3	18.1	2.7
8	11.5	3.3	17.2	0.8
9	13.5	3.9	12.0	1.5
10	10.7	3.1	10.8	3.3
11	11.3	3.3	11.8	2.5
12	12.9	3.8	11.6	1.8
13			11.5	3.3
14			13.9	4.1
15			16.7	4.8
16			20.9	6.1
17			23.5	6.9
18			34.9	10.2
19			11.8	3.4
20			10.6	3.1
21			10.1	2.9
22			9.0	2.6
23			8.9	2.6
24			9.2	2.7
Total	169.0	49.2	364.8	134.3
Mean	14.1	4.1	15.2	5.6

a/ Intervening inflows between Maqarin and Khalid

b/ Monthly streamflows at Adasiye were estimated by transposing the corresponding flows at Maqarin using the drainage area and mean annual precipitation ratios.

c/ Monthly streamflows for the period from October 1972 to September 1973 were estimated from the Adasiye flows using the drainage area and mean annual precipitation ratios.

Table A-18

MEAN MONTHLY PRECIPITATION AND EVAPORATION
FCR MAQARIN AND KHALID RESERVOIRS

Month	Mean Monthly Precipitation[a/] (mm)	Mean Monthly Reservoir Evaporation[b/] (mm)
January	114.5	49.5
February	53.5	49.5
March	86.4	79.5
April	30.4	127.5
May	1.5	213.0
June	0	238.5
July	0	259.5
August	0	214.5
September	0	175.5
October	15.1	147.0
November	38.7	90.8
December	83.7	54.0
Annual	423.8	1,698.8

a/ Approximated by the 8-year record (1964-1971) observed at Maqarin, from: Jordan Natural Resources Authority, "Rainfall in Jordan" Water year 1970.

b/ Based on arithmetic mean of class A pan evaporation observed at Shuneh North (water years 1966-1974) and at Irbid Nursery (water year 1974). Pan coefficient = 0.75.

Data Source:

Irbid Nursery: Jordan Meteorological Department, "Climatological Data", Water Year 1974.

Shuneh North: NEDECO, "Jordan Valley Project Agro and Socio-Economic Study", 1969. Jordan Meteorological Department, "Climatological Data", Water Year 1974.

Table A-19

SURFACE WATER QUALITY[a]

Location	Date	Mean Daily Discharge (m^3/sec.)	Specific Conductance (mhos/cm)	Total Dissolved Solids (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	Sodium Absorption Ratio	Boron (ppm)	pH	Temperature (°C)
Yarmouk River at Adasiye	21 Apr 71	-	-	320	44.3	101	1.60	-	7.4	-
	27 Dec 71	12.2	-	349	61.0	65.0	1.50	-	8.2	15
	14 Jan 72	3.82	675	432	75.2	105	2.01	-	8.4	17
	31 Jan 72	6.20	-	390	65.9	92.2	1.64	-	8.3	13
	1 Mar 73	4.35	675	432	85.4	77.7	1.80	-	8.0	-
Yarmouk River at Maqarin	14 Mar 71	5.60	630	402	60.3	86.4	1.51	-	7.6	-
	8 Jun 71	4.80	740	474	78.3	141	2.41	-	7.0	-
	9 Jun 71	4.80	460	294	31.6	29.1	0.42	-	8.0	-
Zarqa River at Deir Alla	27 Dec 71	1.26	-	730	160	250	1.95	-	7.6	-
Zarqa River at Jerash	12 Mar 73	1.12	1,080	691	145	223	1.87	-	7.8	-
	Nov 76	-	-	922	-	-	-	0.38	-	-
Zarqa River at New Jerash Bridge	2 Oct 70	0.92	1,300	832	205	223	2.53	-	-	-
	2 Dec 70	1.52	1,150	736	157	194	1.75	-	-	-
	13 May 71	0.44	1,020	653	123	187	2.50	-	-	-
	9 Jun 71	0.32	1,120	717	148	204	1.88	-	-	-

a/ Unpublished records from Jordan Natural Resources Authority.

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Table A-20

OBSERVED MAJOR STORMS SELECTED FOR DEPTH-DURATION ANALYSIS

Station	Date	Duration (hours)	Depth (mm)
Tel. Shehab	Dec 25-26, 1968	33	45.2
Sweida	Nov. 22-23, 1973	39	41.6
Salt	Dec. 8-10, 1963	36	81.9
Wadi Shueib	Dec. 8-10, 1963	36	76.0

Data Source: Jordan Natural Resources Authority, Rainfall in Jordan.

Table A-21

COMPARISON OF FLOOD ESTIMATES WITH PREVIOUS STUDIES

Study	Date	Basin	Probable Maximum Precipitation Storm Maximization 24 Hour (mm)	Probable Maximum Precipitation Storm Maximization 48 Hour (mm)	Probable Maximum Precipitation Hershfield 24 Hour (mm)	Probable Maximum Precipitation Hershfield 48 Hour (mm)	Probable Maximum Flood Peak Discharge (m^3/sec)	Probable Maximum Flood Creager' C
Baker-Harza	1955	Yarmouk R. above Maqarin	180	-	-	-	3,750	25
Energoprojekt	1966	Yarmouk R. above Maqarin	169	220	-	-	3,100	21
Harza (Current Study)	1976	Yarmouk R. above Maqarin	200	230	250	288	6,420	42
Harza (Current Study)	1976	Yarmouk R. between Maqarin and Khalid	255	295	-	-	1,810	30
Harza	1963	Tigris R. above Samarra and below Eski Mosul, Bekhme & Dokan damsites	-	-	-	-	-	40

Table A-22

RECORDED FLOOD PEAK DISCHARGES
YARMOUK RIVER AT MAQARIN

Year	Discharge (m^3/s)
1954	335
1955	nd[a/]
1956	121
1957	70
1958	97
1959	123
1960	nd
1961	37
1962	160
1963	51
1964	124
1965	242
1966	nd
1967	298
1968	261
1969	442
1970	134
1971	289
1972	nd
1973	nd
1974	270

Data Source:

1954-1965: Attour, I.S. and M.E. Ibbit (1966) Flood Probabilities of Yarmouk and Zarqa Rivers, Professional Paper No. 1, Jordan Division of Hydrology, Natural Resources Authority.

1967-1974: Harza computation from gage height and appropriate rating table.

a/ nd - denotes no data.

Table A-23

FLOOD PEAK FREQUENCY FOR THE YARMOUK RIVER

Recurrence Interval (years)	At Maqarin (m^3/s)	At Khalid[a/] (m^3/s)
5	280	110
10	400	160
20	550	210
50	800	310
100	1,100	430

a/ Not including release from the Maqarin Reservoir.

Table A-24

SEDIMENT DEPOSITION IN MAQARIN AND KHALID RESERVOIRS

Duration (years)	Maqarin[a/] (MCM)	Khalid[b/] (MCM)
1	0.92	0.155
50	45.2	7.63
100	89.9	15.2

a/ Assuming a trap efficiency of 98%

b/ Assuming a trap efficiency of 95%

Attachment 1

The Hydro-meteorological Network and Data

The purpose of a hydro-meteorological network is to provide specific data for project planning, design and operation and for broader national needs. Therefore the following comments are directed as much to data collection and processing as to the physical network.

The comments are the result of field inspection of selected stations and determinations of data availability and quality in the course of project studies.

Inspection Results- The inspection of existing stream flow and climate stations in the project area and tributary watersheds included those in Jordan and Syria. The numbers and locations of stations are generally adequate for project planning and design. Streamflow data collection is generally good in the Jordanian portion of the Yarmouk and Zaqa River basins and poor at all but a few diversion stations on the wadis. Personnel are stationed at key stations, such as Maqarin, on the two rivers and more than 100 discharge measurements may be made annually. Therefore, record reliability at these stations should be very good. No streamflow records are avaialbe for Syrian stations.

Preparation of records is minimally adequate and publication is infrequent.

Precipitation records for both Syria and Jordan are generally well kept by the observers. Evaporation pans need more frequent cleaning and installation of water temperature thermometers and wind instruments.

Personnel at field locations and at the Natural Resouces Authority in Amman were competent, dedicated and generally cooperative.

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Recommendations- No New stations are required for project purposes, but a number of actions are required to increase the quantity, quality and availability of data. They are:

1. Increase frequency of observations on the Wadis. The records tend to malfunction during floods. Therefore visual observations of gage heights should be made frequently during floods. This may entail hiring a local person to tend the gage while it rains or stationing NRA personnel at the gage site full time during the wet season.

   Discharge measurements hsould be made by a modile party when they are alerted by field observers. These parties should quickly reestablish low flow ratings at the end of the flood season at each station. They should adjust or clean low level intakes at recorders and clean gage wells.

2. Preliminary streamflow and canal diversion records should be published, subject to possible revision, for each month, and they should be issued no later than 6 to 12 months elapse of calendar time. This will be facilitated by not developing annual rating curves. Rating curves should be revised only when a permanent shift has occurred. Shift corrections presently are calculated and should continue being used.

3. The Adasiye gage should be repaired. The assess walk was damaged by rock dumped from the new road being constructed above.

4. The Syrians should be encouraged to reactivate the Wadi Raggad gage at RAfid, and a new precipitation

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station should be installed in the vicinity of Quneitra.

5. Class A type evaporation pans should be equipped with floating or pan bottom thermometers and wind travel recorders.

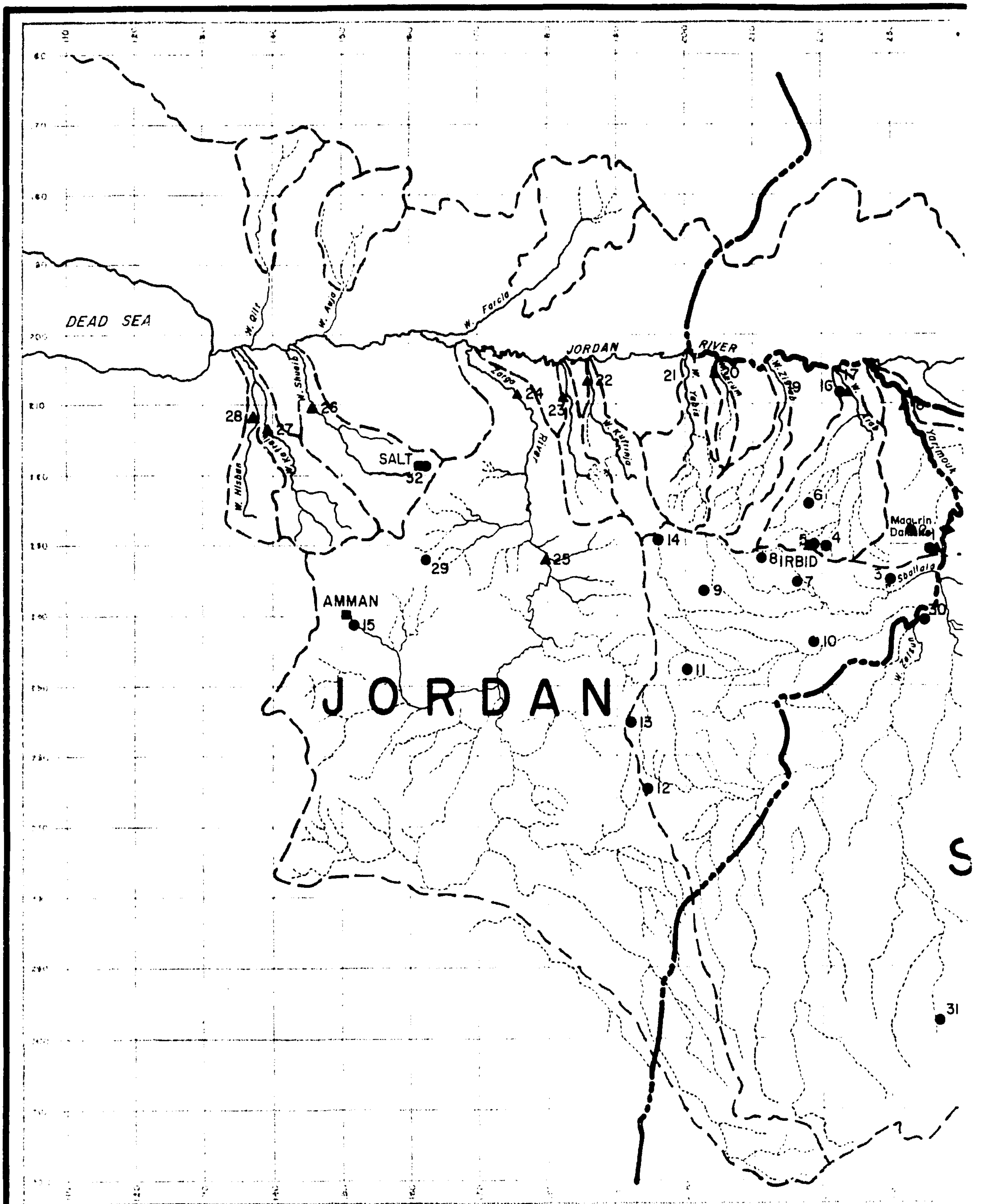

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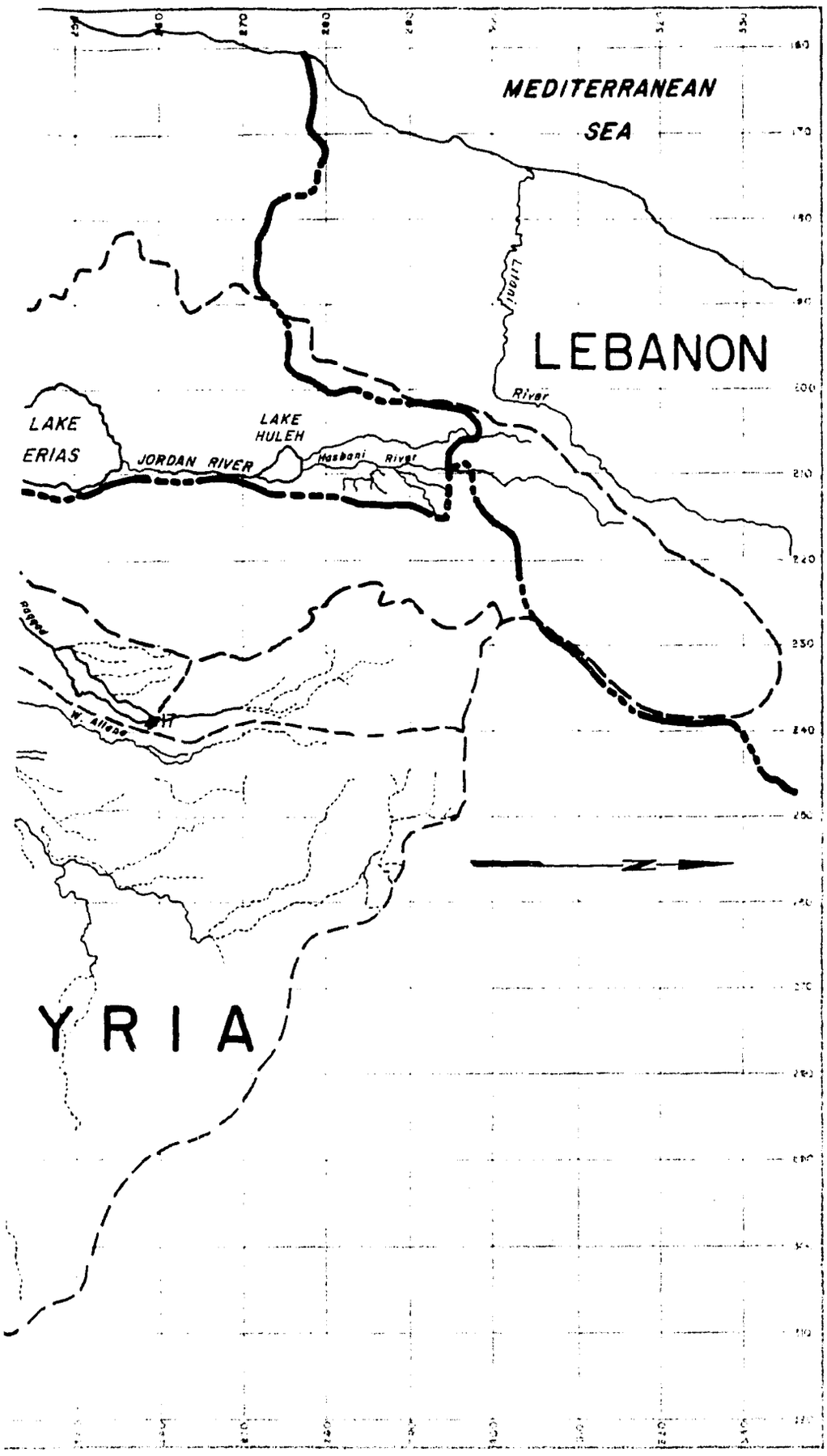
EXHIBIT A-1



LEGEND

- ▲ Stream Gaging Station
- ● Meteorological Station

1. Yarmouk River at Maqarin
2. Kufr Saum
3. Kharja
4. Irbid School
5. Irbid Nursery
6. Kufr Yuba
7. Hawara
8. Husn
9. En-Nueiyima
10. Ramtha
11. Khanasira
12. Mafraq
13. Rihab
14. ibbin
15. Amman Air Port
16. Wadi Arab near Shuna North
17. Wadi Raqqad near Rafid
18. Yarmouk River at Adasiya
19. Wadi Ziglab
20. Wadi Jurum
21. Wadi Yabis
22. Wadi Kufrinja
23. Wadi Rajib
24. Zarqa River at Deir Alla
25. Zarqa River at New Jerash Bridge
26. Wadi Shueib
27. Wadi Kafrein
28. Wadi Hisban
29. El Jubeiha
30. Tel Shehab
31. Sweida
32. Salt

- International Boundaries
- Drainage Area Boundaries
- Rivers and Wadis

SCALE 0 20 KILOMETERS

LOCATION OF HYDROLOGIC AND METEOROLOGICAL STATIONS

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

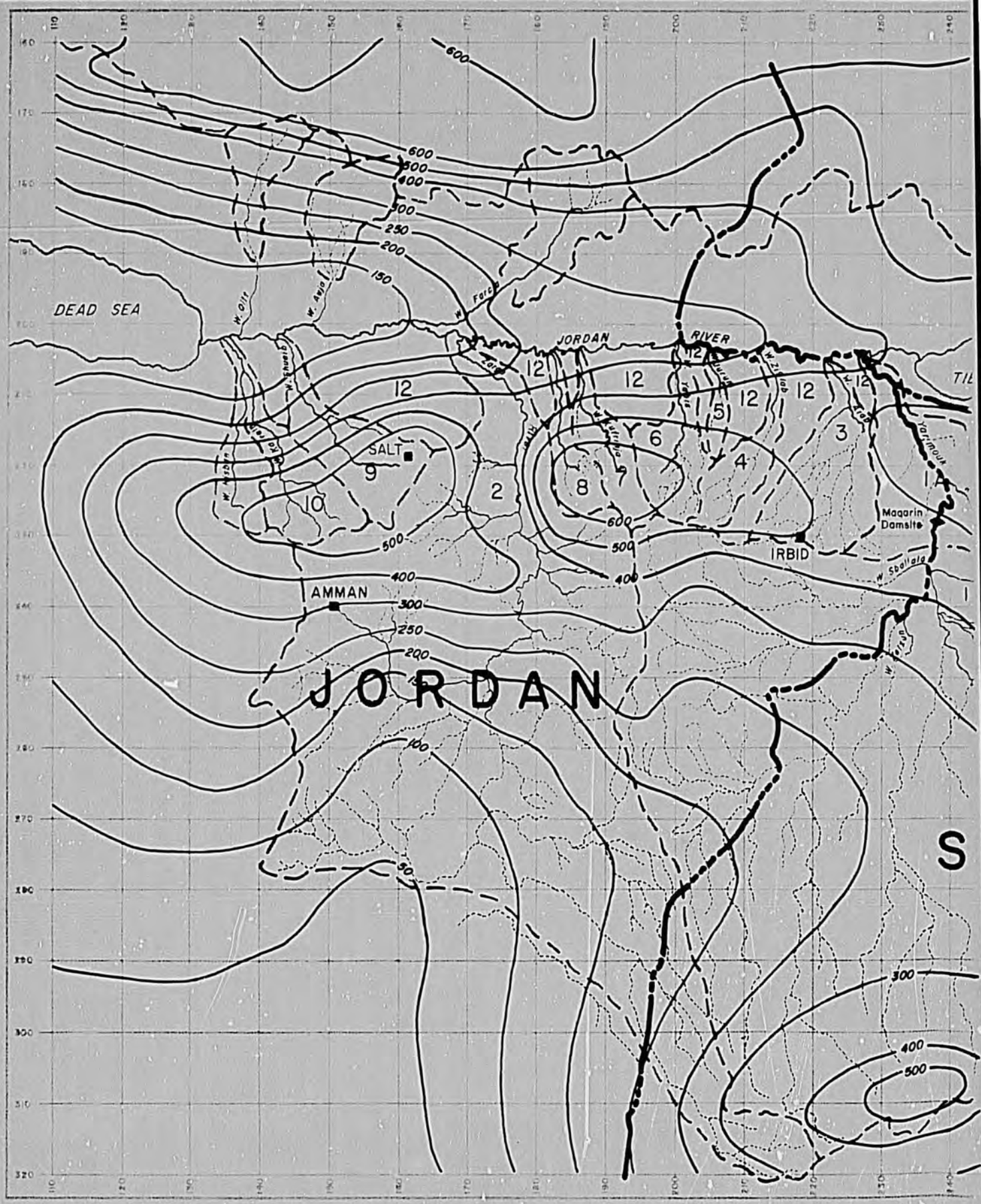


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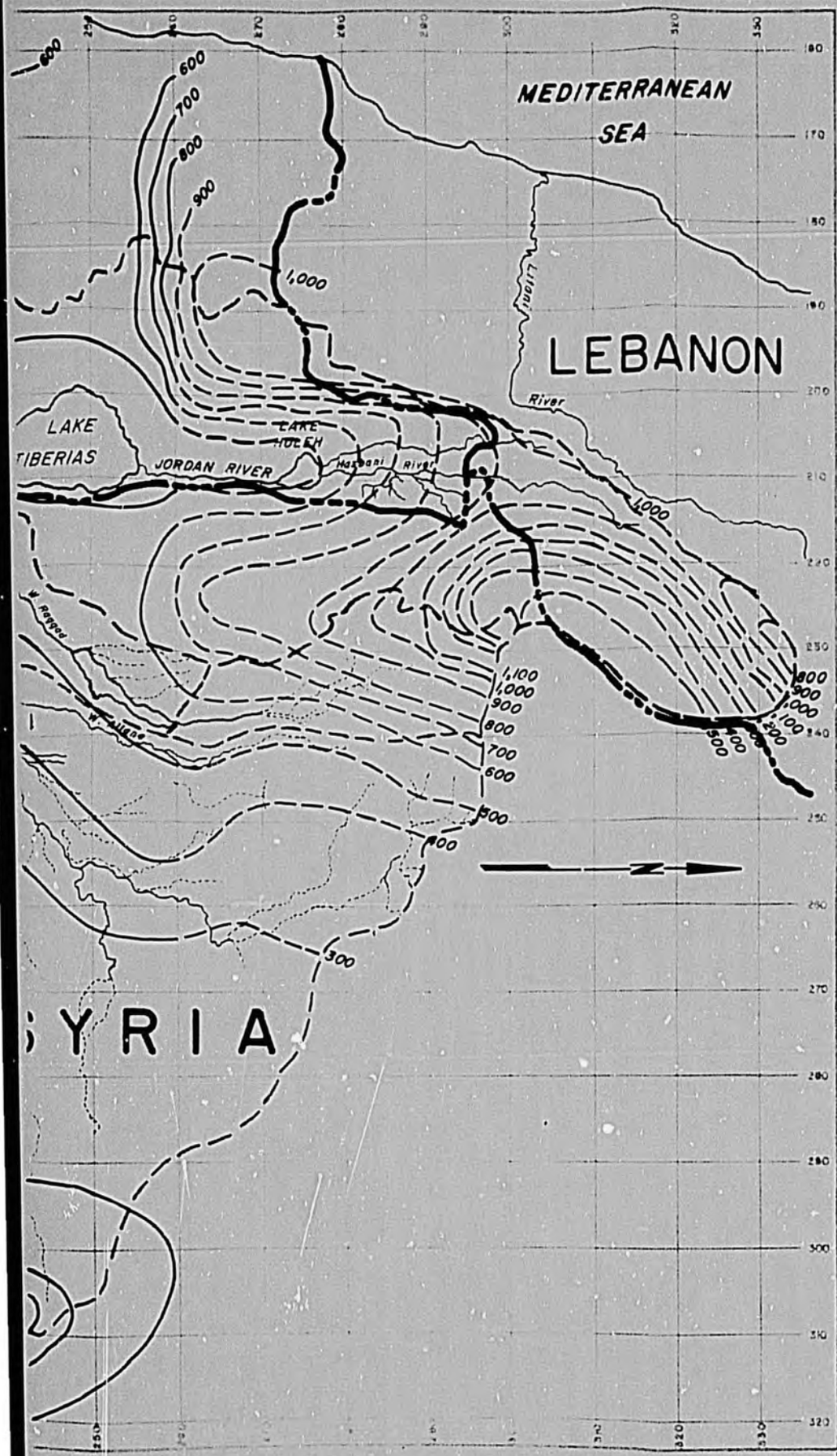
EXHIBIT A-2



DRAINAGE BASINS

1. Yarmouk River
1A. Yarmouk River above Maqarin Damsite
2. Zarqa River
3. Wadi Arab
4. Wadi Ziglab
5. Wadi Jurum
6. Wadi Yabis
7. Wadi Kufrinja
8. Wadi Rajib
9. Wadi Shueib
10. Wadi Kafrein
11. Wadi Hisban
12. Local Inflow to Jordan River

400 Isohyets
Drainage Area Boundaries
International Boundaries
Rivers and Wadis

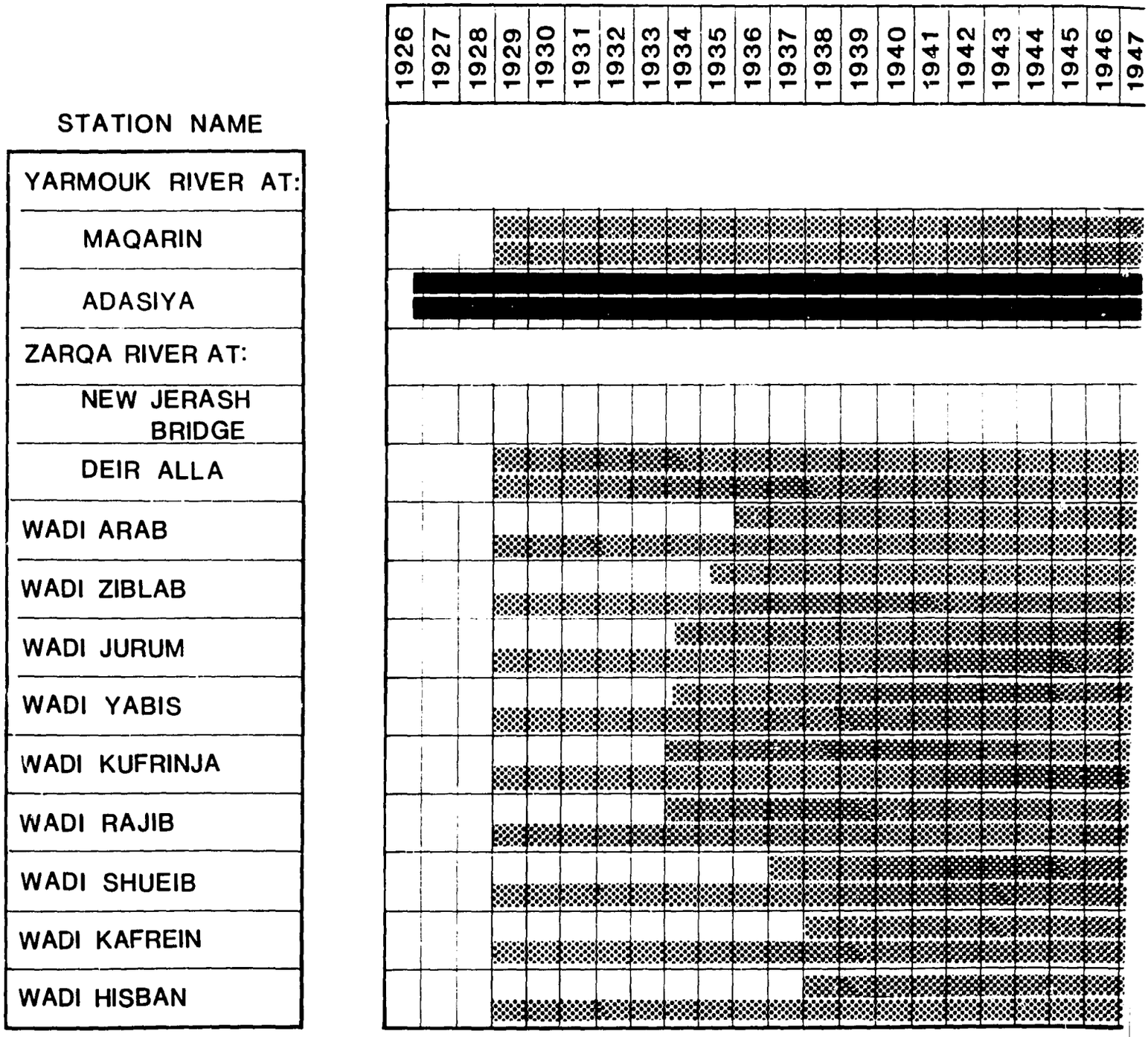
SCALE 0 20 KILOMETERS

ANNUAL MEAN PRECIPITATION MAP

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

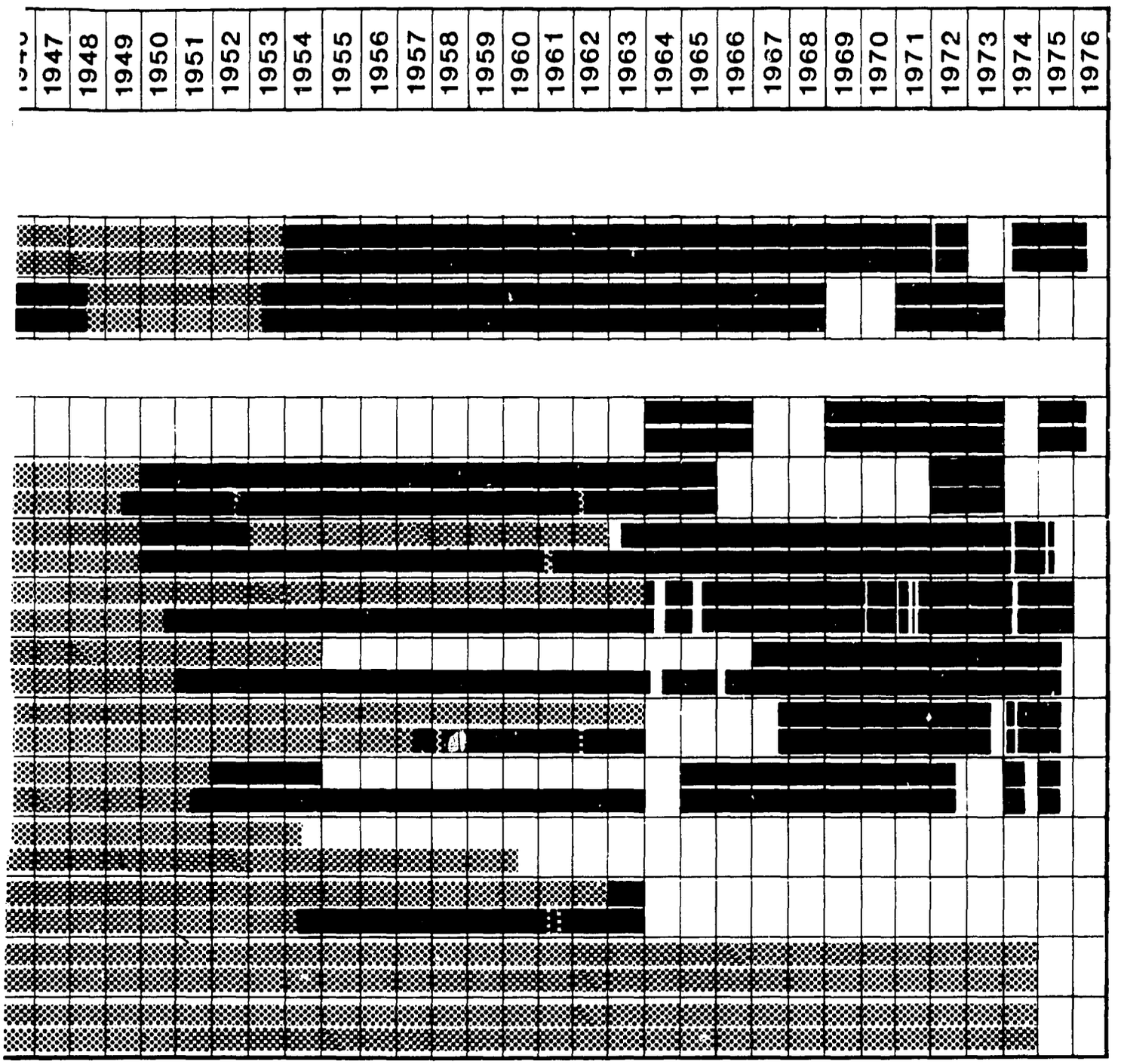
W



LEGEND
RECORDED
SYNTHESIZED

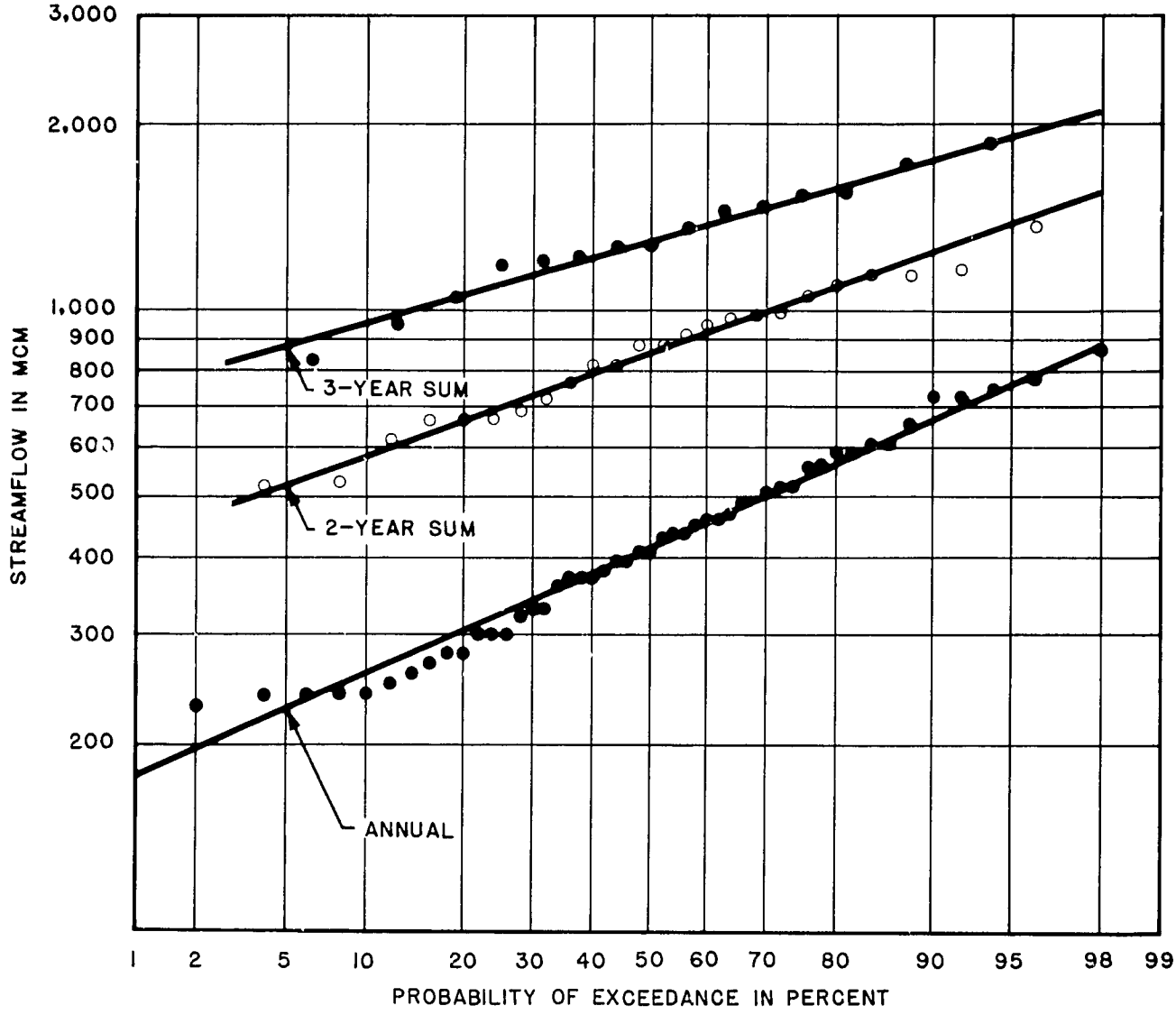
NOTE:
UPPER BARS RE
LOWER BARS RI

WATER YEAR



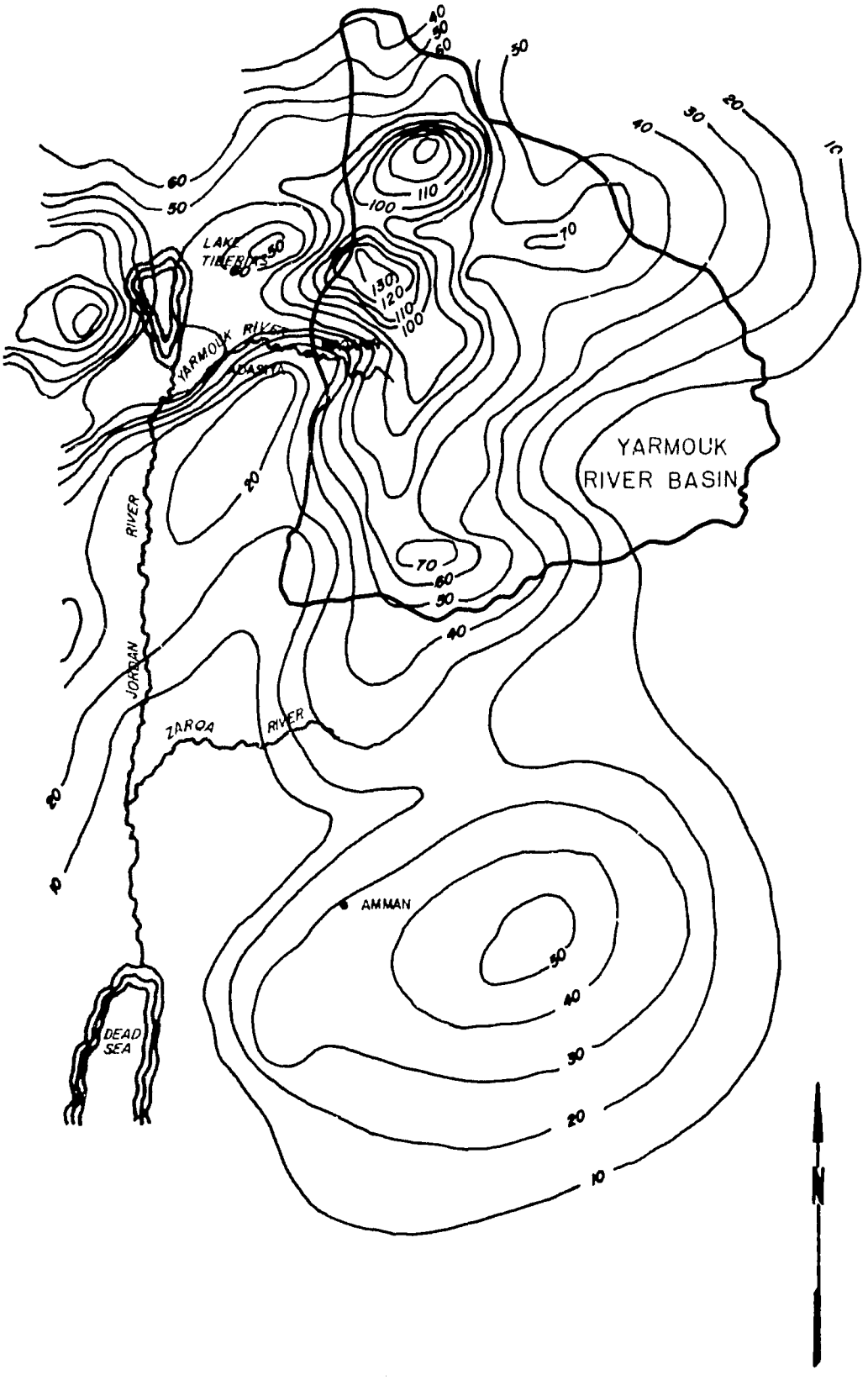
REPRESENT 'FLOOD FLOWS'
REPRESENT 'BASE FLOWS'

PERIODS OF
RECORD OF STREAMFLOW
JORDAN VALLEY IRRIGATION PROJECT
STAGE II



LOW-FLOW FREQUENCY
YARMOUK RIVER AT ADASIYE
JORDAN VALLEY IRRIGATION PROJECT
STAGE II

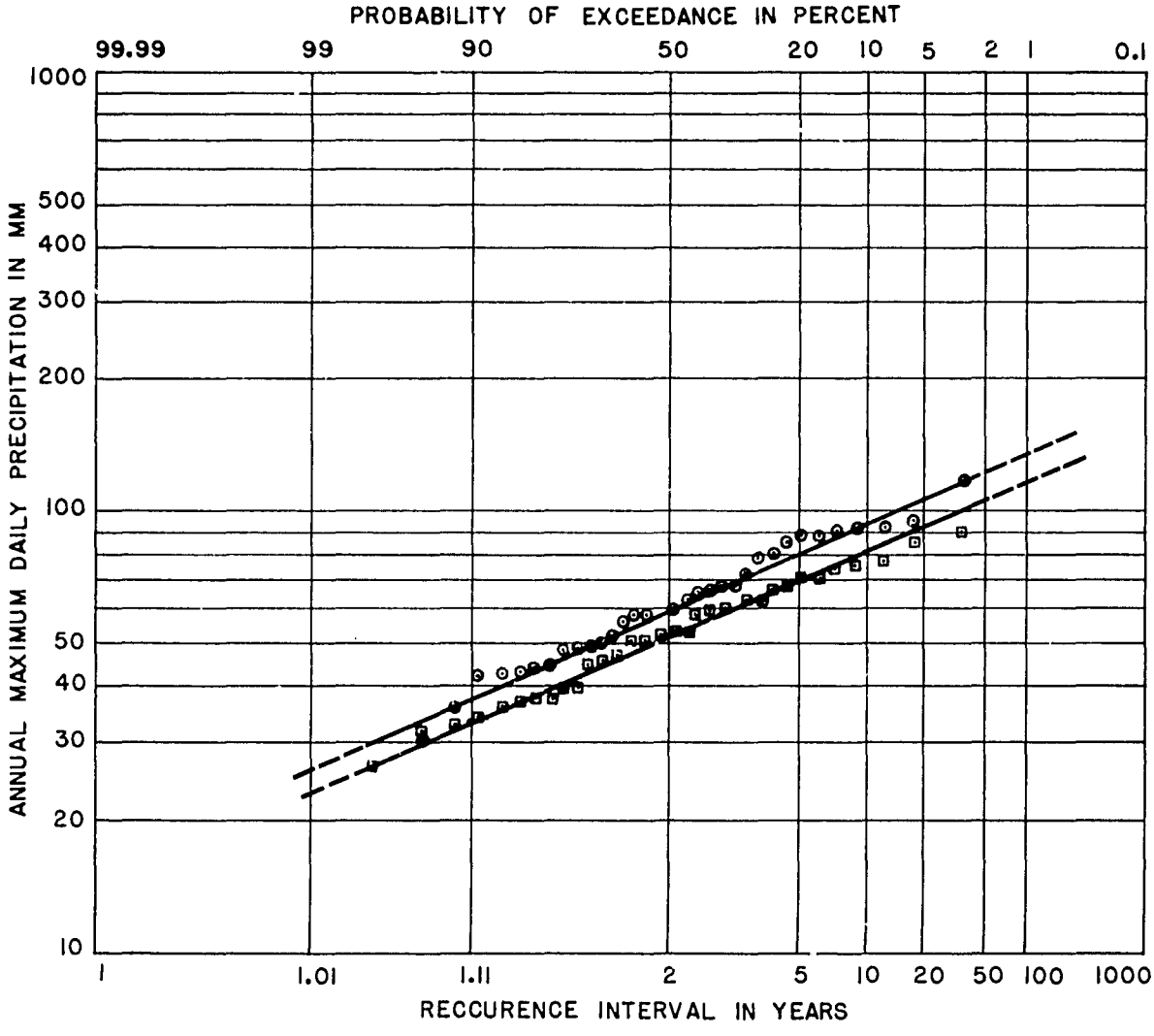
HARZA ENGINEERING COMPANY · JANUARY 1978



ISOHYETAL MAP OF TRANSPOSED STORM

JORDAN VALLEY IRRIGATION PROJECT

STAGE II



PERIOD OF RECORD: 1937/38 - 1971/72

LEGEND

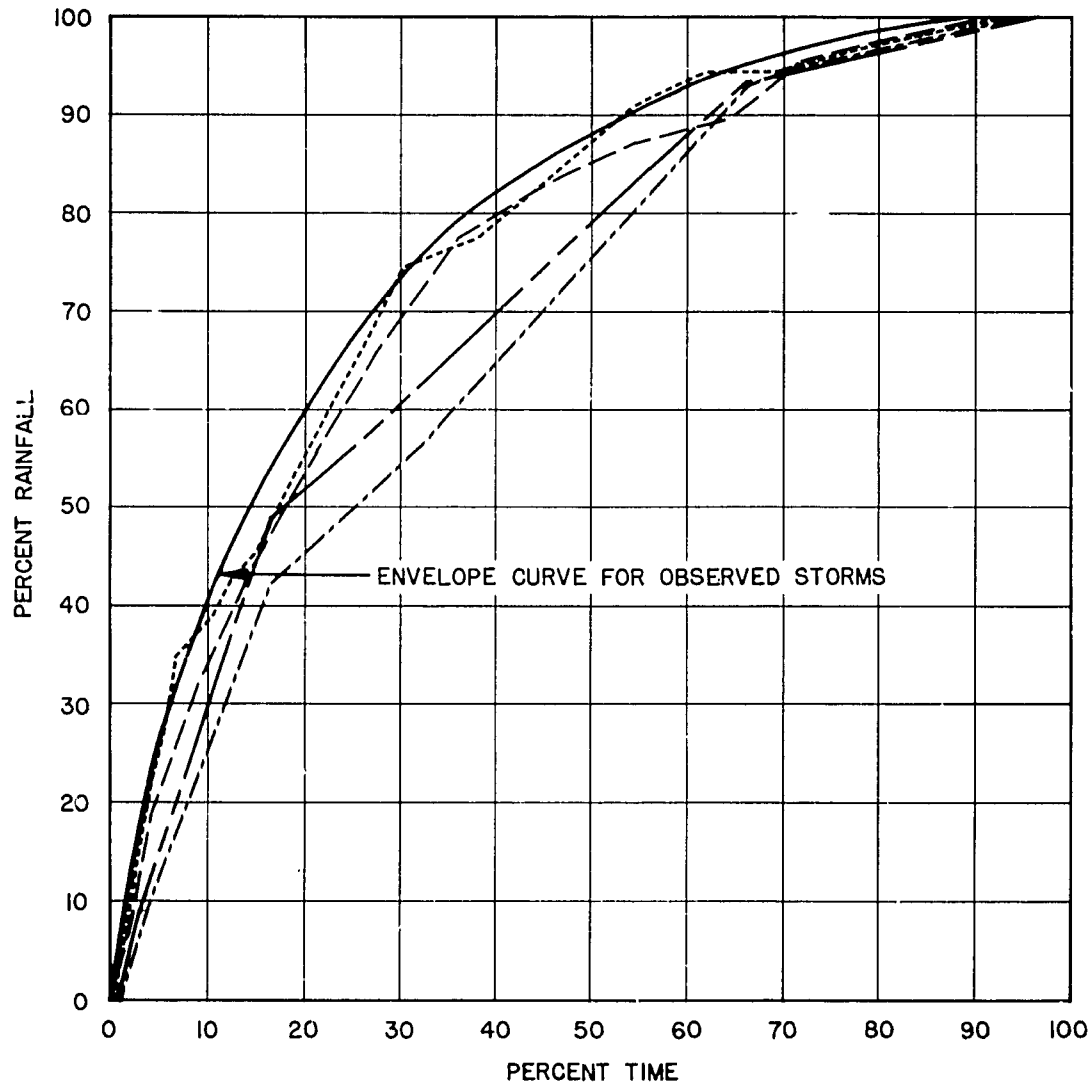
o ZARQA (EL JUBEIHA STATION)

□ YARMOUK-JORDAN SIDE (KHARJA STATION)

STORM FREQUENCY COMPARISON

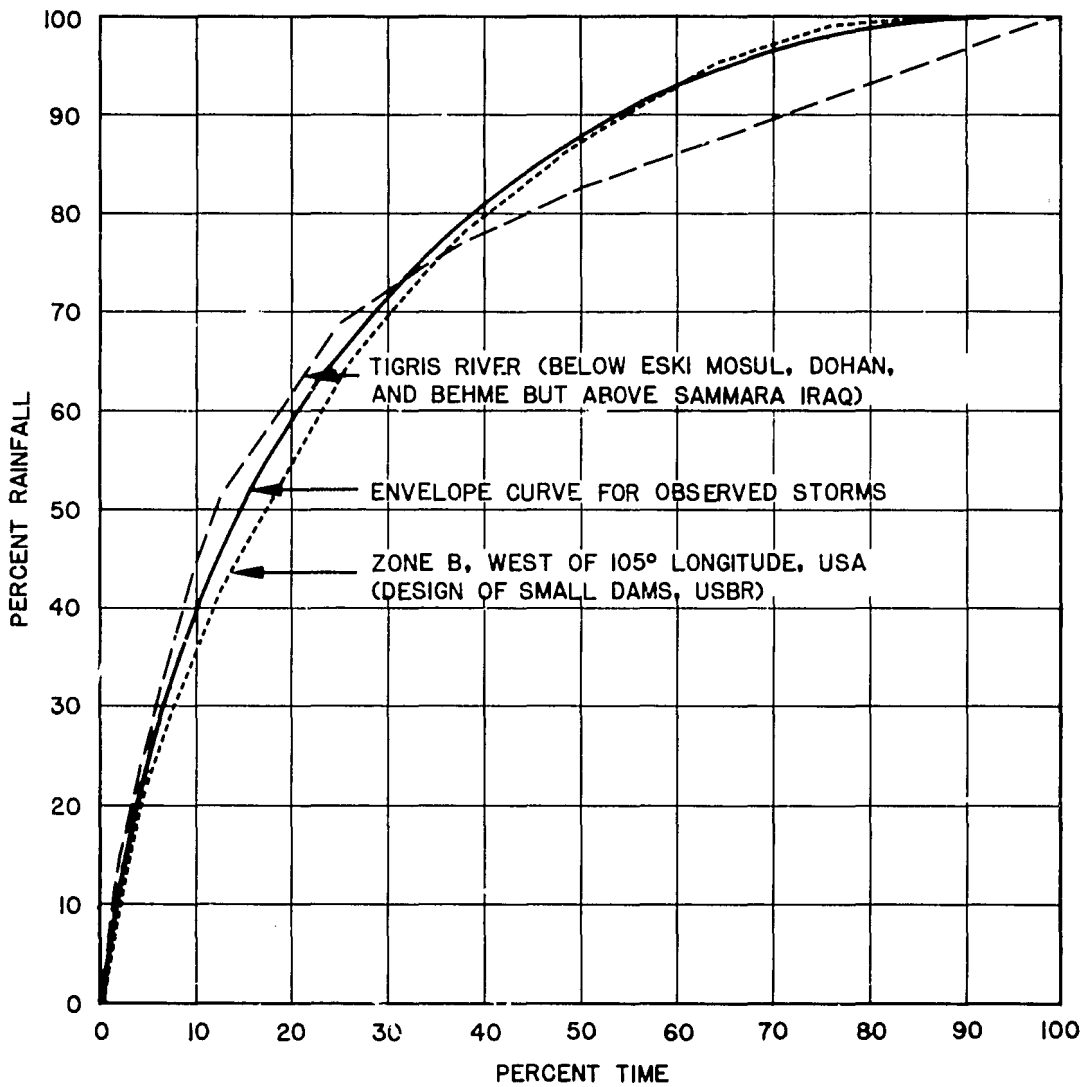
JORDAN VALLEY IRRIGATION PROJECT

STAGE II



JORDAN

STATION	STORM	DURATION (HOURS)	DEPTH (MM)	SYMBOL
TEL SHEHAB	DEC 25-26, 1968	33	45.2	— — —
SWEIDA	NOV 22-23, 1973	39	41.6	---------
ES SALT	DEC 8-10, 1963	36	81.9	———
WADI SHUEIB	DEC 8-10, 1963	36	76.0	-—-—-

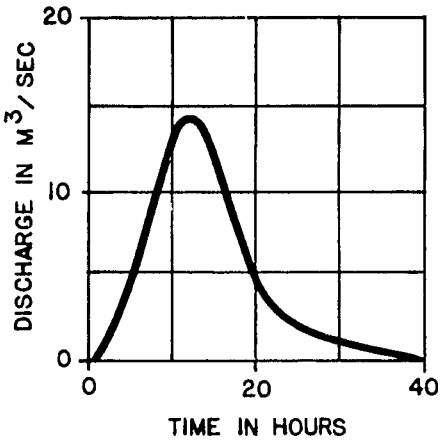


IRAQ AND USA

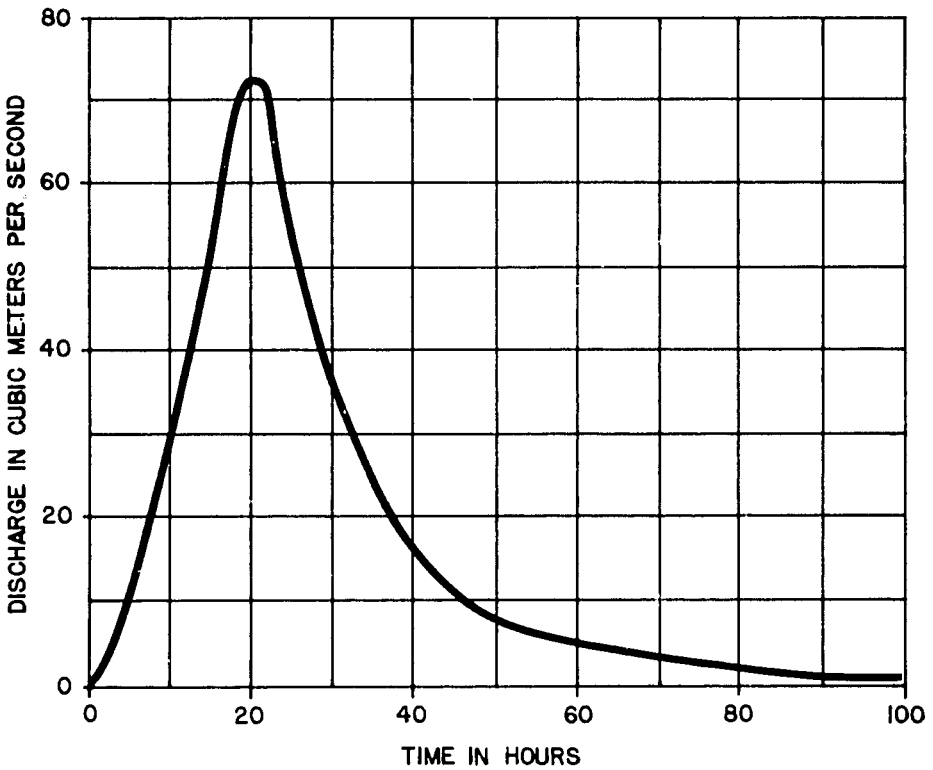
DEPTH-DURATION CURVES FOR PROBABLE MAXIMUM PRECIPITATION

JORDAN VALLEY IRRIGATION PROJECT

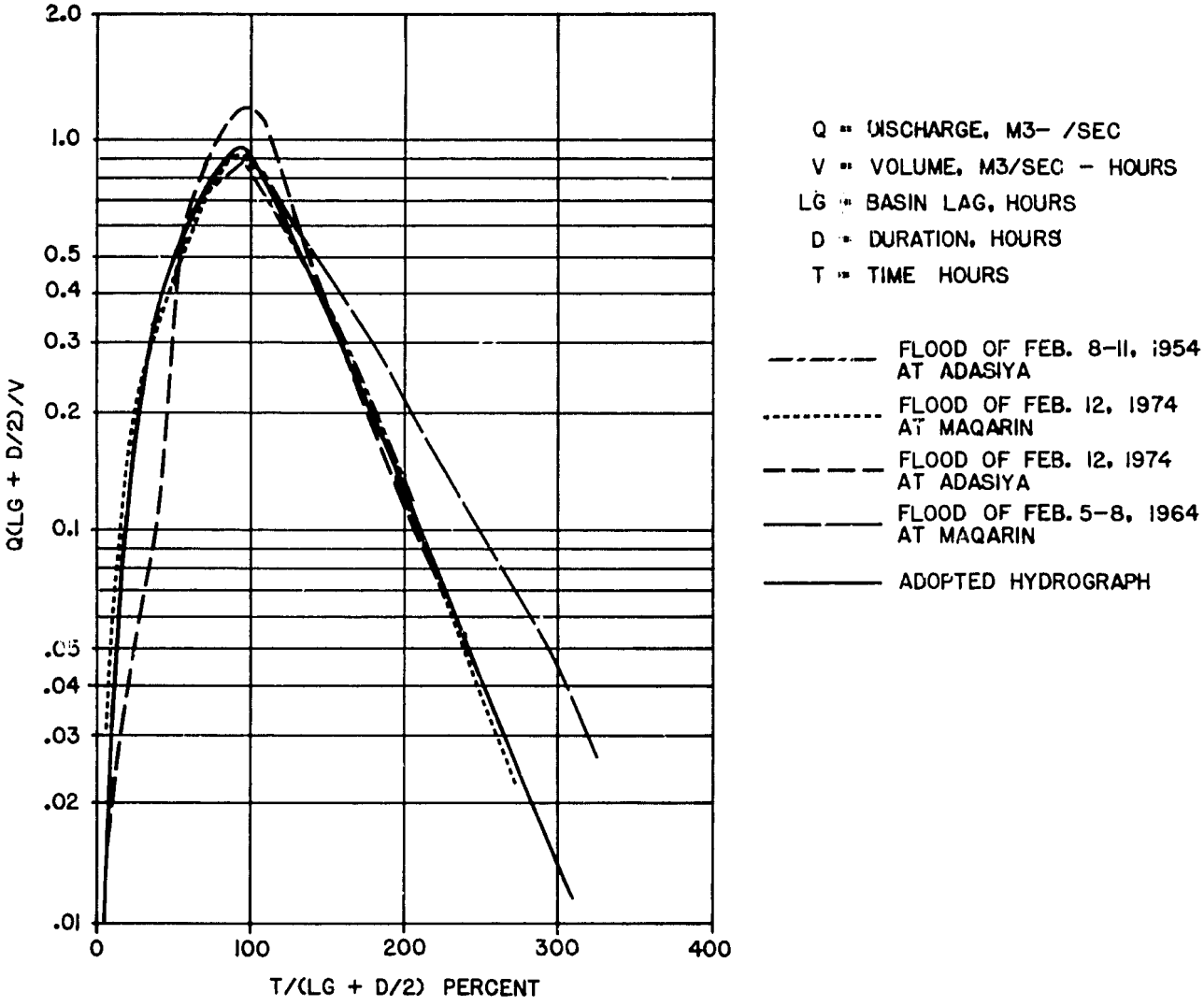
STAGE II



UNIT HYDROGRAPH FOR AREA
BETWEEN MAQARIN AND KHALID



UNIT HYDROGRAPH FOR MAQARIN

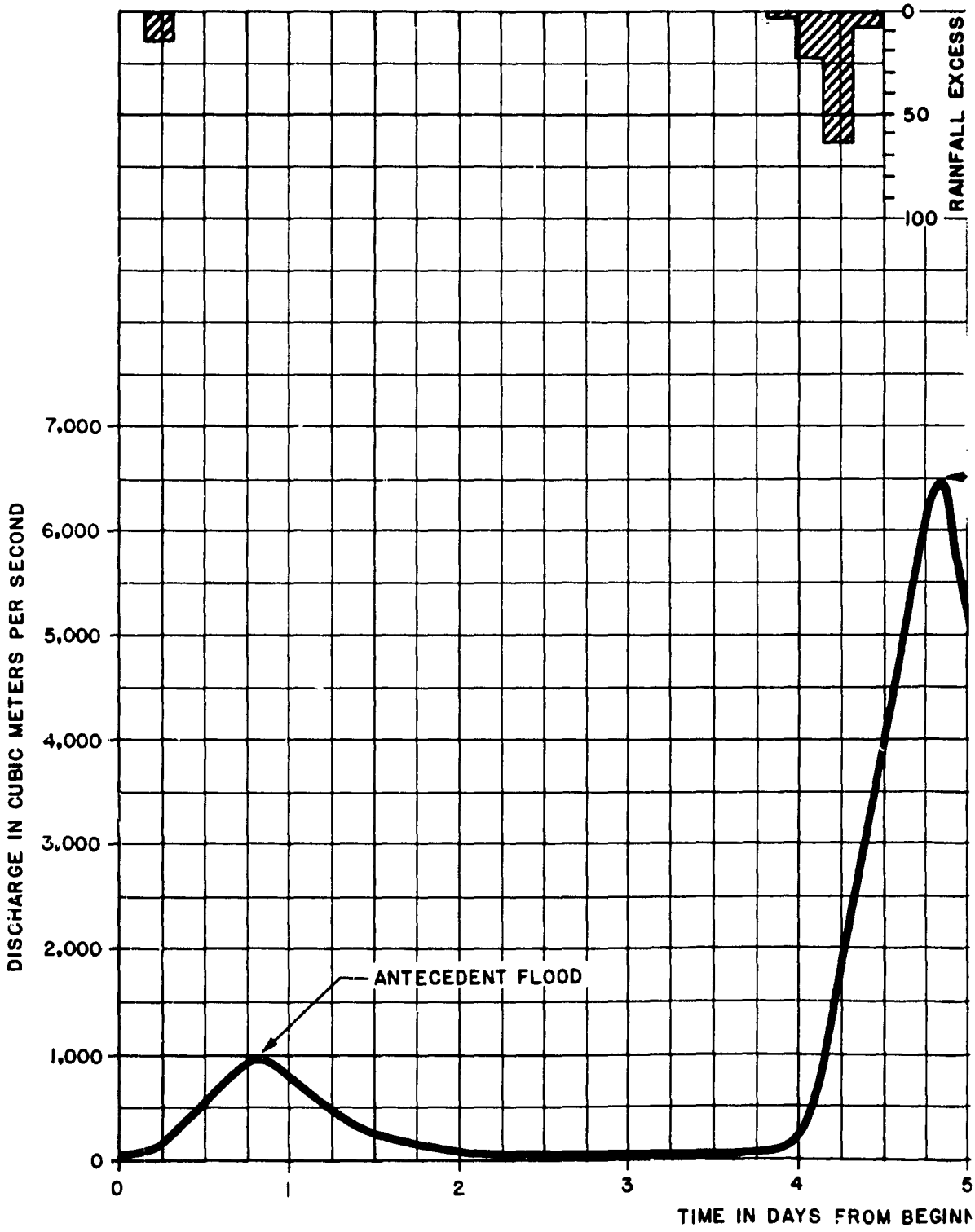


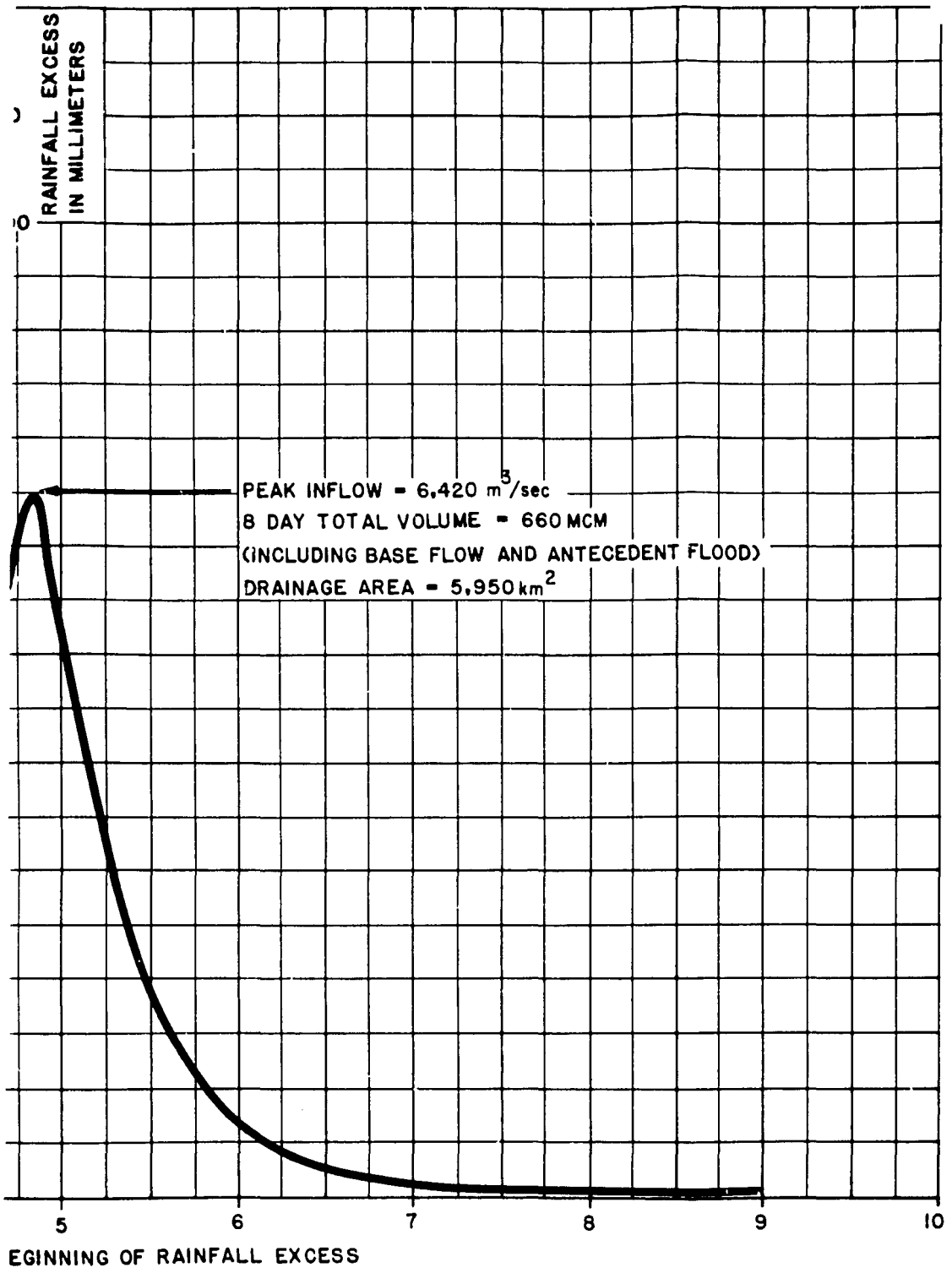
DIMENSIONLESS HYDROGRAPH

DIMENSIONLESS GRAPHS AND UNIT HYDROGRAPHS

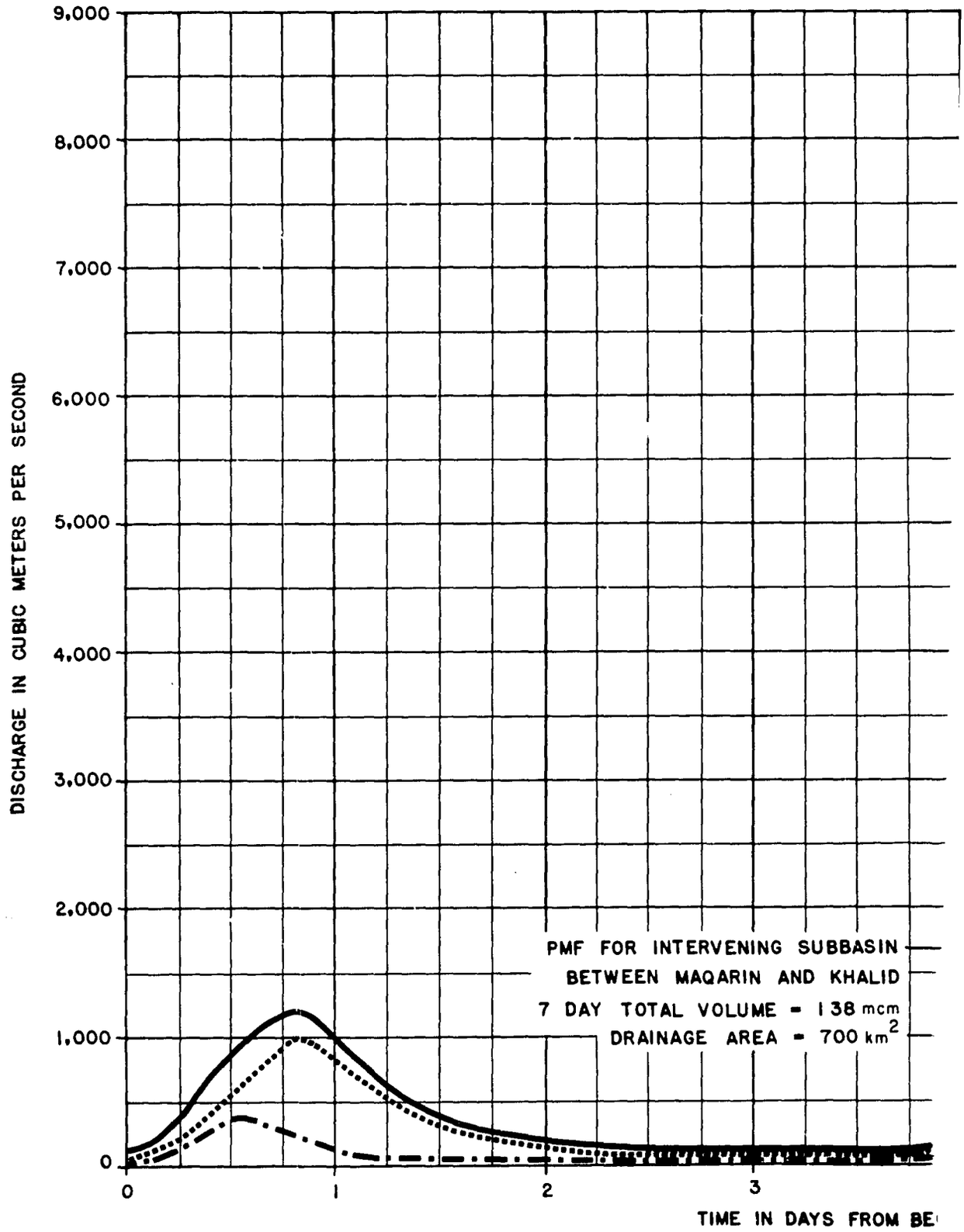
JORDAN VALLEY IRRIGATION PROJECT

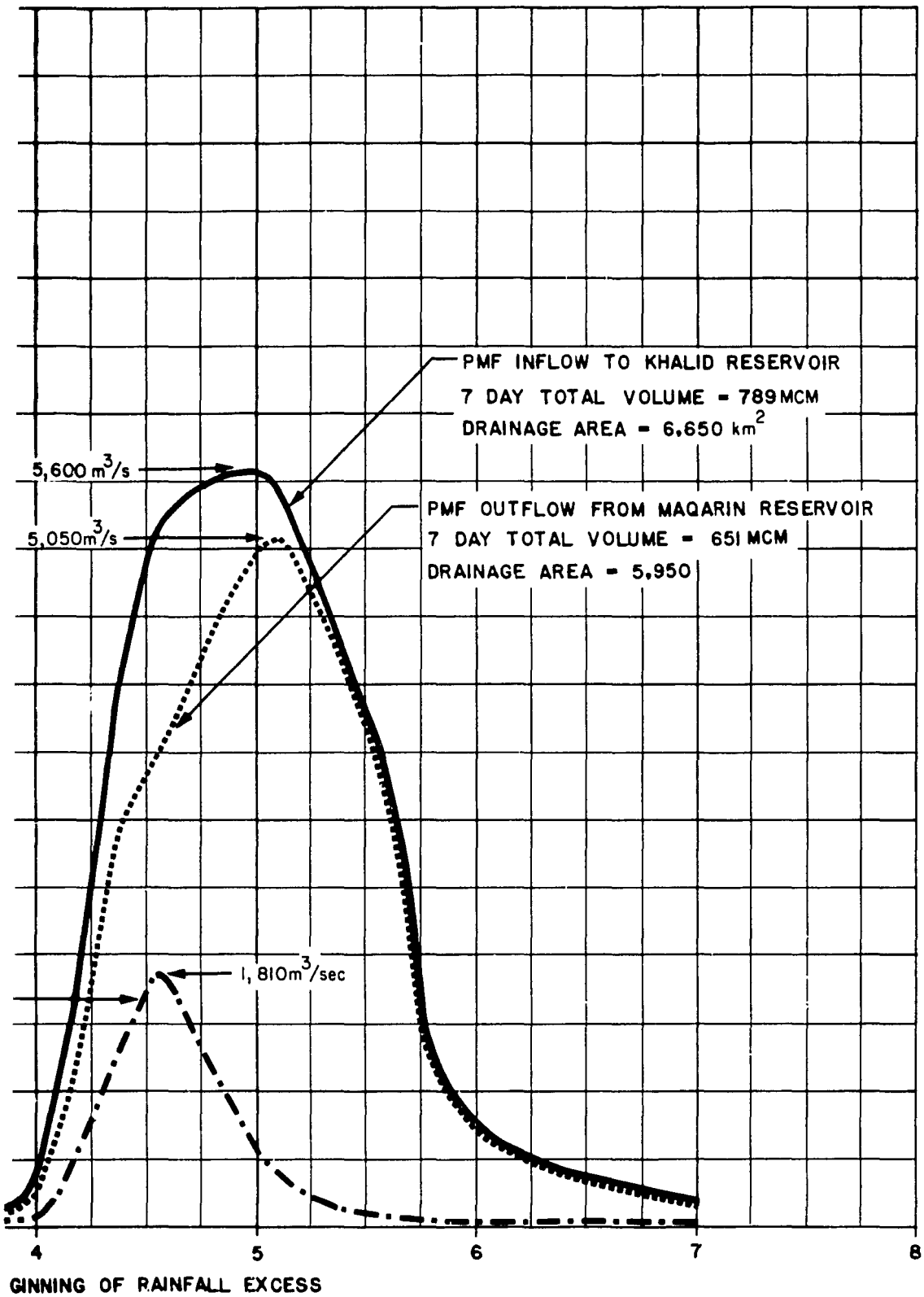
STAGE II


RAINFALL EXCESS
0
50
100
DISCHARGE IN CUBIC METERS PER SECOND
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
ANTECEDENT FLOOD
0
1
2
3
4
5
TIME IN DAYS FROM BEGINN



PROBABLE MAXIMUM FLOOD INFLOW
YARMOUK RIVER AT MAQARIN RESERVOIR
JORDAN VALLEY IRRIGATION PROJECT
STAGE II


9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
DISCHARGE IN CUBIC METERS PER SECOND
0
1
2
3
TIME IN DAYS FROM BE
PMF FOR INTERVENING SUBBASIN
BETWEEN MAQARIN AND KHALID
7 DAY TOTAL VOLUME = 1 38 mcm
DRAINAGE AREA = 700 km2

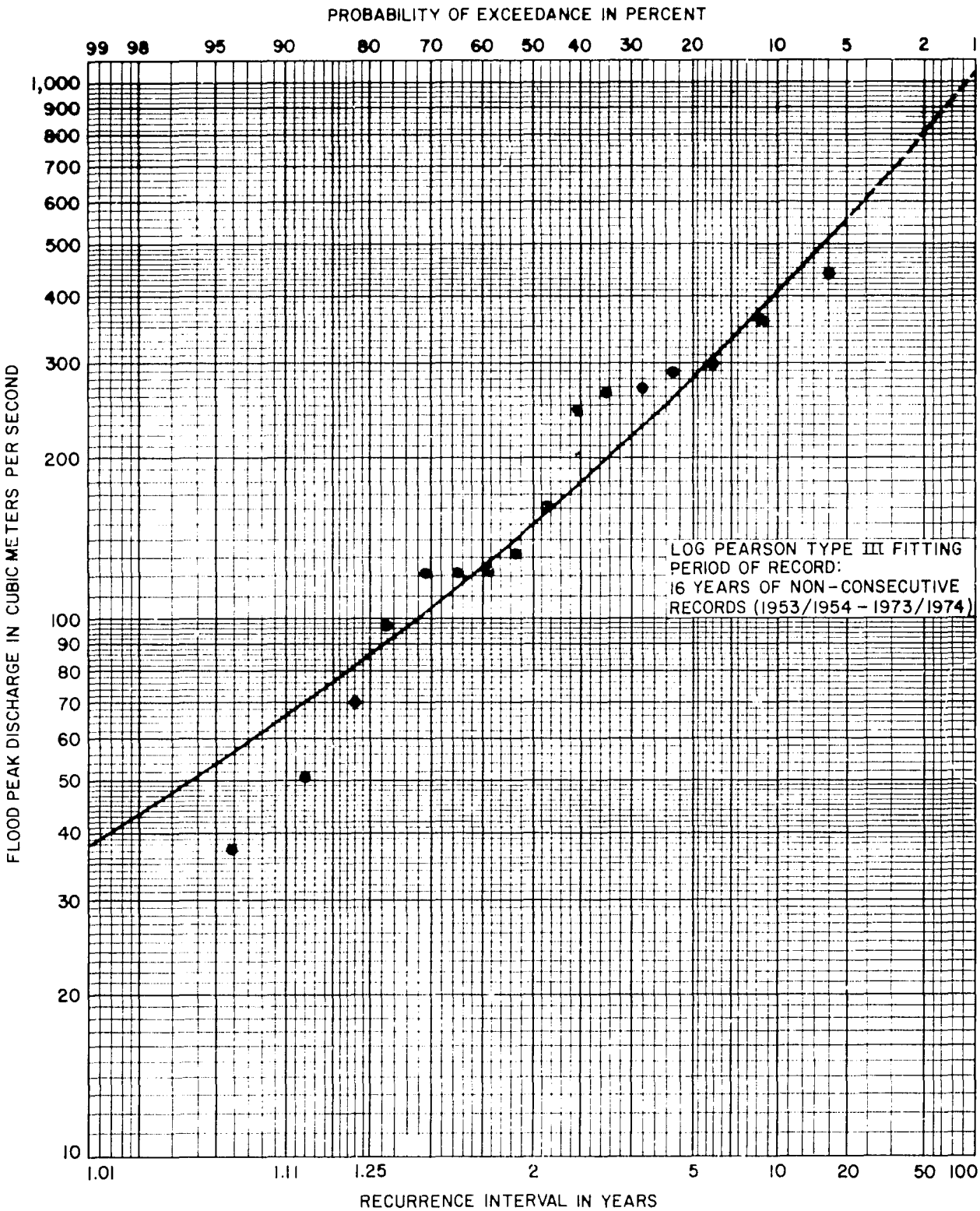


PROBABLE MAXIMUM FLOOD INFLOW TO THE KHALID RESERVOIR

JORDAN VALLEY IRRIGATION PROJECT

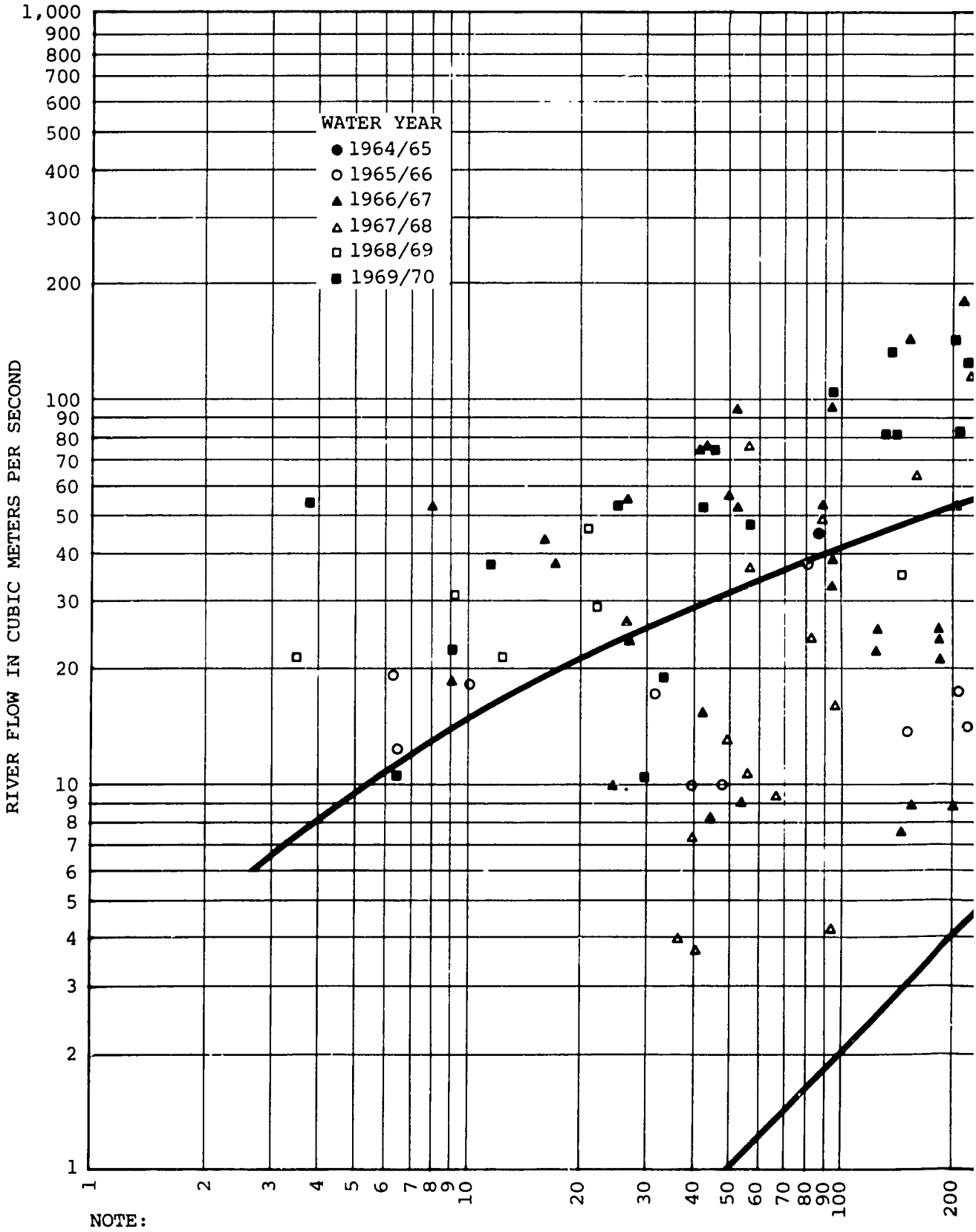
STAGE II

EXHIBIT A-11



FLOOD FREQUENCY
YARMOUK RIVER AT MAQARIN DAMSITE
JORDAN VALLEY IRRIGATION PROJECT
STAGE II

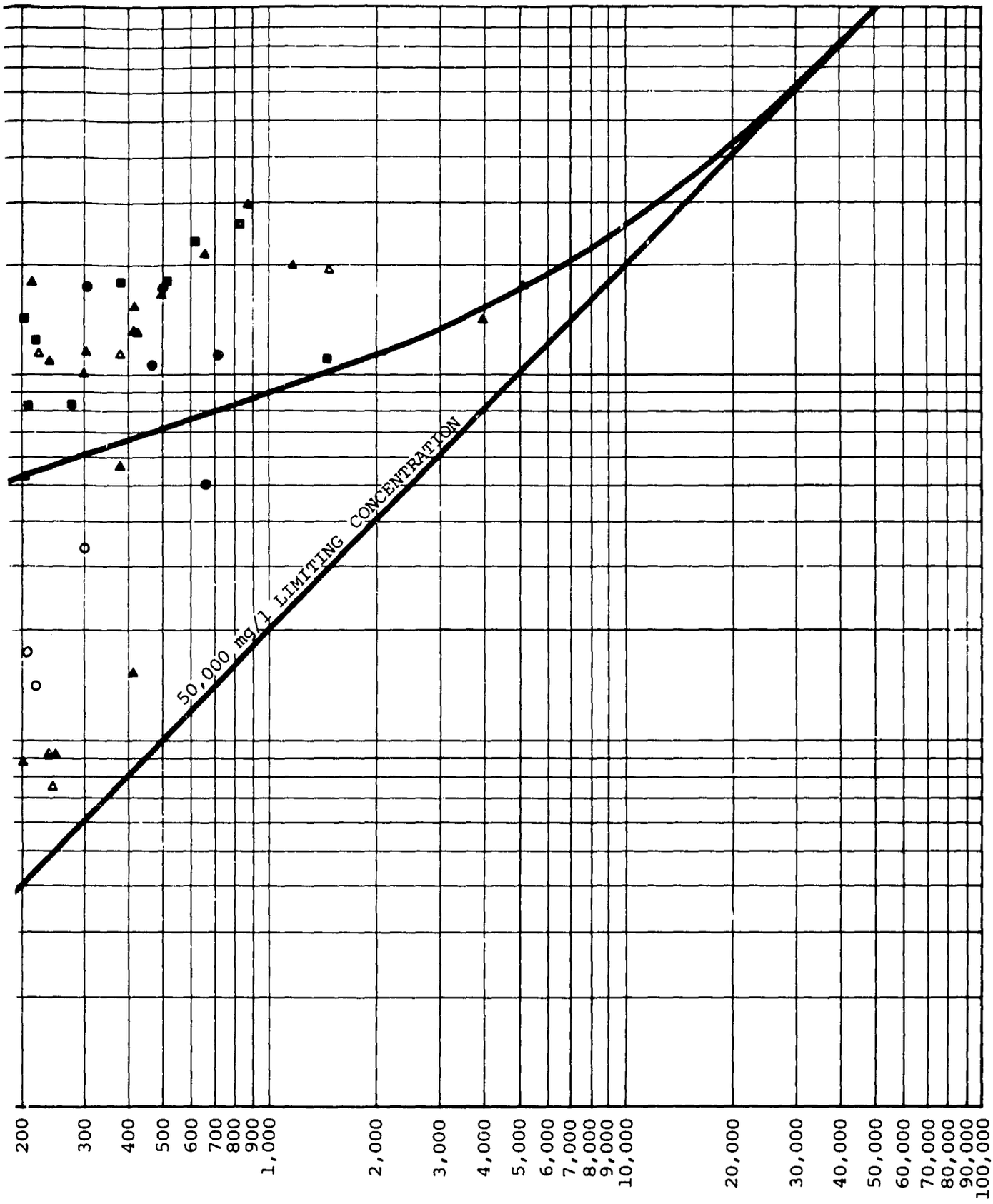
HARZA OVERSEAS ENGINEERING COMPANY · JANUARY 1978



NOTE:

Data Source: Jordan Natural Resources Authority

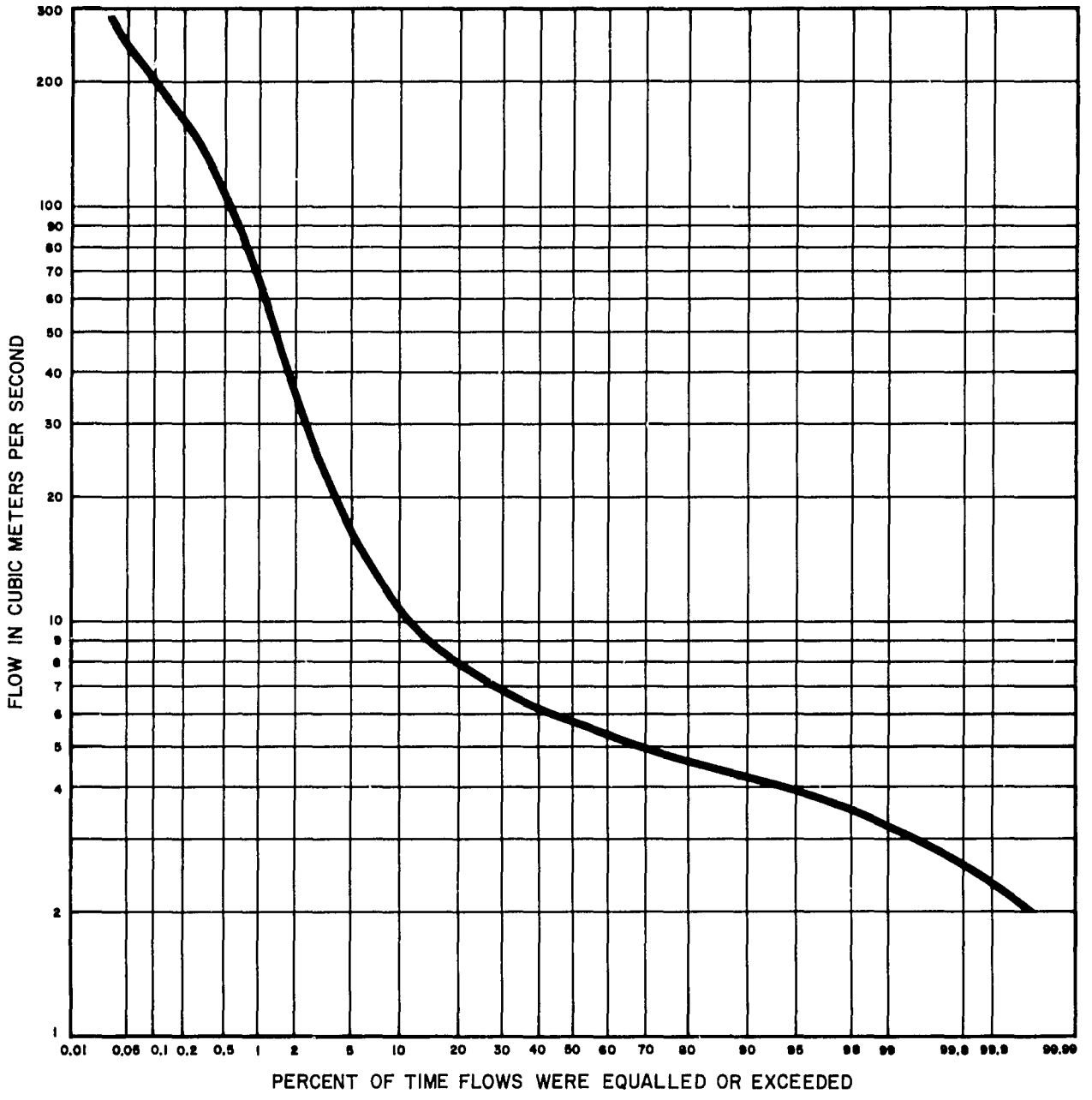
SEDEMENT DISCHARG



SUSPENDED SEDIMENT-DISCHARGE
RATING CURVE YARMOUK RIVER AT MAQARIN

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

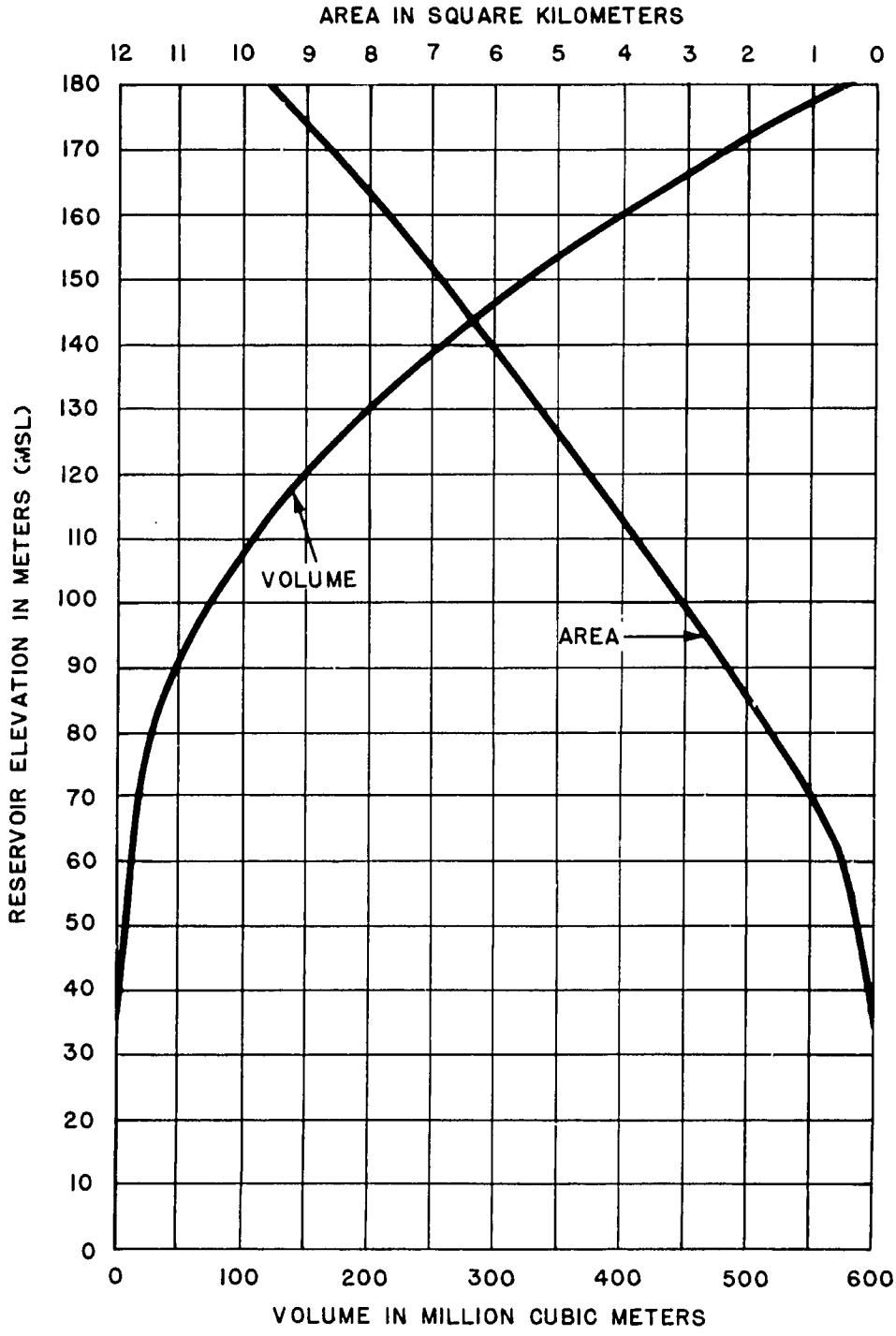


NOTE
BASED ON 14 YEARS OF RECORDED
DAILY STREAMFLOW 1961/62 – 1971/72
AND 1973/74 – 1975/76

FLOW DURATION CURVE
YARMOUK RIVER
AT MAQARIN STATION

JORDAN VALLEY IRRIGATION PROJECT
STAGE II

HARZA OVERSEAS ENGINEERING COMPANY · JANUARY 1978



MAQARIN RESERVOIR
AREA AND VOLUME

JORDAN VALLEY IRRIGATION PROJECT
STAGE II

Appendix B

ENVIRONMENTAL ASSESSMENT

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FOREWORD

Ecological investigations were undertaken as one aspect of the technical studies of Stage II of the Jordan Valley Irrigation Project. These studies were conducted for the Jordan Valley Commission of the Hashemite Kingdom of Jordan by Harza Overseas Engineering Company in joint venture with Dar Al-Handasah and Consulting Engineering Center, Amman, Jordan. Field investigations were conducted between June 25 and July 25, 1976.

Objectives

The objectives of Stage II of the Jordan Valley Irrigation Project are to improve and modernize the existing Stage I irrigation facilities, to extend the irrigation system to include presently unirrigated areas, to develop a reliable water supply for irrigation and domestic use, and to exploit the hydropower potential of the area. The irrigation service area is located along the east bank of the Jordan River between Lake Tiberias and the Dead Sea. The primary water source is the Yarmouk River which is tributary to the Jordan River immediately south of Lake Tiberias.

The objectives of the environmental investigations are to identify and analyze any environmental problems likely to arise from the construction of the Project and to advise on measures to minimize any adverse effects arising therefrom.

Scope of Environmental Investigations

The environmental investigations for Stage II of the Jordan Valley Irrigation Project were designed to identify, evaluate, and suggest mitigating measures, as necessary, for all foreseeable adverse environmental effects of the Project. Investigations were conducted in accordance with the published guidelines of AID and the World Bank. The study examined the environmental impacts in the following areas:

1. Terrestrial resource impacts (i.e., land use, vegetation and wildlife, mineral deposits).

2. Aquatic resource impacts (i.e., water quality, fisheries, aquatic plant pests, water-borne pathogens).

3. Socio-cultural impacts (i.e., resettlement, protection of archaeological or historical sites, changing cultural values).

4. Public health impacts (i.e., introduction of new diseases via project work force or environmental changes conducive to spread of pathogens and or vectors).

5. Long term impacts including future demands on local agricultural infrastructure and governmental services.

The investigations included field investigations in the Project area, review of available information, and consultation with appropriate Government agencies.

Acknowledgemen

We wish to express our appreciation to the many agencies and individuals who provided valuable assistance during the conduct of these investigations. Particular appreciation is expressed to the following agencies and individual:

Jordan Valley Authority
Ministry of Antiquities and Tourism
    Department of Antiquities
    Department of Tourism
Natural Resources Authority
Ministry of Health
Ministry of Agriculture - Dept. of Animal
    Production and Health
Royal Society For the Conservation of Nature
University of Jordan, Faculty of Agriculture
American Center for Oriental Research.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

The field reconnaissance trips to the Project area and discussion with Governmental and private agencies identified the existing environmental characteristics of the area and the environmental considerations that should be incorporated into Project planning.

Existing Resources

Natural Resources. The natural vegetation and animal life within the Project area are not known with any degree of certainty. The consensus of persons familiar with the natural resources of Jordan is that there are no unusual, rare, endangered, or other forms which warrant detailed study. Native fishery resources seem to be almost totally lacking. Snail vectors (Bulinus) of schistosomiasis have been identified at two locations, but they were not infected. The only unusual natural area identified during the investigation was a small, permanent pond in the Yarmouk Valley near the abandoned Mukheibe damsite. This pond supports moderately large populations of frogs and turtles in an otherwise dry environment.

History and Archaeology. The most significant characteristic of the Project area is its history. The Jordan Valley and the side valleys leading to it have been a setting for major stages in the development of civilization. The Valley represents one of the richest archaeological regions in Jordan. A recent survey of the East Bank of the Jordan Valley identified 225 archaeological sites between the Yarmouk River and the Dead Sea. Many of these sites should be excavated as soon as possible either because of their intrinsic value or because they have been or are threatened

with damage in the near future, primarily from on-going agricultural development and military operations in the area. No comparable survey has been made of the Yarmouk Valley, although evidence of sites has been found within the Maqarin Reservoir area.

Project Impacts

The primary potential sources of Project impact were identified as the inundation of the Maqarin site and the construction and land preparation activities in the proposed new irrigation areas of the Jordan Valley. These activities may adversely affect archaeological sites of possible significance if proper caution is not taken.

Secondary Project impacts may result from changes in population density in the Jordan Valley. Programs for the development of the social institutions and facilities required to support and maintain the agricultural production are being formulated by the Jordan Valley Commission. During the formulation of these programs, particular attention should be paid to domestic water supply and sanitation, public health, and community development.

Opportunities for Enhancement

Development of the Project will provide an opportunity for the concurrent development of a fish culture program utilizing surplus or marginal land and water in a manner that is not competitive with irrigation or Project needs. The reservoirs, due to their morphology and operating criteria, appear to provide only marginal opportunity for development of reservoir fisheries. Possibilities exist, however, for the development of fish culture in floating cages in the reservoir, and in ponds designed to utilize either irrigation or irrigation return water. Additional investigations, as

discussed in this report, are required to ensure that such a program is fully and successfully implemented.

Recreation and tourism development opportunities will also be created. Such opportunitites should be considered as Project plans progress and should be incorporated into the master plan for the development of tourism in the northern portion of the Country that is presently being developed by the Department of Tourism.

Recommendations and Conclusions

It is recommended that planning be continued to minimize potential archaeological and social impacts in the Project area and to take advantage of opportunities for development of commercial fisheries. An archaeological team should visit the Maqarin Reservoir area as soon as possible to conduct a survey comparable to that recently completed for the Jordan Valley. The level of this effort would probably be on an order of two to three man-months.

Identified significant sites in the Maqarin Reservoir area and the Jordan Valley should be excavated or protected until detailed evaluation can be made as part of the ongoing program of the Ministry of Antiquities and Tourism.

The potential relationships between identified archaeological sites and/or opportunities for tourist development should be considered during the formulation of the social and community development programs presently being planned by the JVC for the Jordan Valley.

Programs for fishery development should be undertaken. Initial steps should be the detailed study of alternative sites for fish culture, and the training of local personnel in fish culture technology.

It does not appear that there will be any impact on the pond near the Mekheibe site, but Project activities should be controlled to prevent unnecessary damage to this biologically interesting area.

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PROJECT SETTING

The Project area is located in the Hashemite Kingdom of Jordan on the east Bank of the Jordan River in the desert and semi-desert of the Middle East. The Jordan Valley is known as one of the cradles of civilization, with identified settlements dating back some 10,000 years. Climatic conditions are primary limiting factors controlling both natural and social development in the area.

Location and Description of the Area[1/]

The Jordan Valley extends approximately 100 kilometers (km) from Lake Tiberias in the north to the Dead Sea in the south. Elevations of the valley floor range from 212 meters below sea level (msl) at Lake Tiberias to -400 meters msl at the Dead Sea. The width of the Valley varies from 4 to 16 km. The uplands bordering the Valley on the east rise to elevations exceeding 1000 meters above sea level.

The Valley forms part of the northern portion of the Great Rift Valley that extends from Syria in the north, through the Gulf of Aqaba, and southward through East Africa. The shore of the Dead Sea is the lowest surface elevation in the world.

The floor of the Jordan Valley consists of east and west terraces separated by the meandering Jordan River. Each terrace is divided into the lower, flood plain, portion, or Zor, and the upper portion, or Ghor. In many areas, the lower portion of the Ghor has been highly eroded; this break between the Ghor and the Zor is known as the Kattar.

Eleven perennial streams and wadis rise in the eastern uplands and flow across the eastern slopes of the Valley to the river. The largest tributary to the Jordan is the Yarmouk River, which enters approximately 8 km downstream

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1/ Adapted from: Jordan Valley Development Plan, 1975-1982. Jordan Valley Commission, November 1975.

from Lake Tiberias. The second in importance among the tributaries is the Zarqa River, which enters from the east approximately midway between Lake Tiberias and the Dead Sea (see Exhibit B-1).

The Yarmouk River drains an area of 6,900 km^2, of which 1,800 km^2 are within the Hashemite Kingdom of Jordan and the remaining 5,100 km^2 are in the Syrian Arab Republic. Several tributaries join together just upstream of the Maqarin damsite to form the Yarmouk River, which flows approximately 35 km west-southwest to its confluence with the Jordan River. Major tributaries forming the Yarmouk include the Wadis Shallala, Zerzum, Harir, and Allane. The Yarmouk River itself is deeply incised into the surrounding plateau, forming a narrow gorge several hundred meters deep.

Climate

Climate and the availability of water have been major factors shaping the area and its people. The climate is Mediterranean, with characteristic hot, dry summers and moderately cool, wet winters. Clear skies are typical. Sunshine hours range from 54 percent in January to 90 percent in August. High temperatures and dry air in summer, as well as cool weather in winter, are constraints for certain crops.

Extreme temperatures in the Jordan Valley range from a maximum of 47°C in the south to a minimum of about 0°C in the northern portion. The mean monthly temperatures for three stations, located in the north, middle, and south portions of the Valley, respectively, are tabulated in the Summary of Climatological Data (Table B-1). Monthly mean maximum and mean minimum temperatures are about 12° above or below these values. Minimum temperatures generally occur in

Table B-1

EAST JORDAN VALLEY
SUMMARY OF CLIMATOLOGICAL DATA

Months	Shuneh North				Deir Alla				Shuneh South			
	T°C (1)	RH% (2)	WT/D (3)	Pmm (4)	T°C (1)	RH% (2)	WT/D (3)	Pmm (4)	T°C (1)	RH% (2)	WT/D (3)	Pmm (4)
Jan.	14	69	-	79	15	68	181	57	15	65	161	42
Feb.	16	67	-	60	16	68	192	54	16	62	157	24
Mar.	18	64	-	48	18	61	167	37	19	56	175	21
Apr.	21	56	-	17	22	54	151	14	23	48	213	7
May	26	51	-	8	26	47	133	6	27	42	221	2
Jun.	29	51	-	-	30	46	93	-	31	41	221	-
Jul.	31	55	-	-	31	46	89	-	32	46	42	-
Aug.	31	59	-	-	32	50	144	-	33	47	228	-
Sept.	29	57	-	-	30	52	194	-	30	51	226	-
Oct.	27	54	-	12	27	49	177	5	28	45	196	3
Nov.	22	52	-	49	22	49	256	31	23	51	186	18
Dec.	17	66	-	86	17	60	286	58	17	60	171	38
TOTAL				359	TOTAL			262	TOTAL			155

(1) Mean Monthly Temperature (°C) (2) Mean Monthly Relative Humidity (%)
(3) Mean Monthly Wind Travel (Km/Day) (4) Mean Monthly Rainfall (mm)

Source: Jordan Valley Development Plan, 1975-1982.

January and February and maximum temperatures from May to August. The average monthly temperatures throughout the year are slightly higher in the southern part of the Valley as compared to the northern part.

Snow is virtually unknown in the Valley, and frost occurs only rarely. Some snow occurs annually in the highlands, including Amman, to the east. For the most part, rainfall is orthographic in character and tends to increase over the higher topographic areas and to decrease over the lower areas. Precipitation is heaviest at the northern edge of the Jordan Valley with average annual rainfall of about 380 mm south of Lake Tiberias. Rainfall decreases to less than 200 mm in the extreme south of the Valley near the Dead Sea. About 90 percent of the rainfall occurs during November to March and 45 percent is in December and January.

There is a general reduction in humidity from north to south. Extremes of relative humidity vary from about 84 percent in winter to 28 percent in summer, and mean monthly relative humidity ranges between 35 and 76 percent in summer. The minimum relative humidity precedes maximum temperatures by a month. The maximum relative humidity occurs at the time of minimum temperatures and greatest rainfall in January and February.

Prevailing winds are from the west and southwest. The fairly uniform westerly summer wind exerts a considerable moderating influence on the summer climate. During the winter, the winds shift to the southwest, and with this shift come the winter rains. Periodically during the winter and spring, but rarely during the summer, the wind may shift to the east. These rare east winds are called the "Khamsin" and are cold and dry in winter and dusty and scorching in the spring.

PROJECT DESCRIPTION

Previous Studies

Many plans have been proposed for the development of the Jordan Valley, dating as far back as 1939. The 1955 Yarmouk-Jordan Valley Project Study by Harza/Baker proposed the gravity distribution of irrigation water to the Valley lands to the maximum practicable extent, thereby encompassing the complete utilization of the water resources of the Project area. The study included a detailed land classification and an updated inventory of all water resources.

That study was supplemented by further work in 1962. Stage I development proposed the use of unregulated water supply from the Yarmouk River, supplemented by the water available from the perennial streams tributary to the east side of the Jordan Valley. Stage II of the Project called for the extension of full irrigation to additional lands in the lower East Ghor. It was considered essential that use be made of some of the flood waters of the Yarmouk River, through storage, to supply the additional irrigation needs of this area. Further studies by ENERGOPROJECT (1966) and NEDECO - Dar Al-Handasah (1969) refined and evaluated these proposals.

Jordan Valley Irrigation Project, Stage I

Development for irrigated agriculture in the Valley was begun in 1961. At the beginning of 1976, about 16,000 hectares (ha) were being irrigated by surface irrigation methods along the east bank of the Jordan River. Of those, about 13,700 ha were irrigated from a government constructed concrete lined irrigation system, the East Ghor Main Canal (EGMC). The remaining area was being served from old, unlined canals using inefficient methods and procedures or from wells.

After completion of the projects included in the 1973/75 Development Plan, the irrigated area in the Valley is expected to increase by about 6,000 ha to 22,040 ha. About 9,300 ha of these lands will be irrigated by sprinkler methods. Anticipated development of the Wadi Arab Dam and Irrigation Project would increase the irrigated area by about 1,250 ha to a total of 23,290 ha of which 10,590 ha will be irrigated from a sprinkler irrigation system. The area presently irrigated by substandard facilities will be included in the projects now under construction.

The existing irrigation projects and the projects included in 1973/75 Development Plan are collectively referred to as the Stage I development of the Jordan Valley Irrigation Project.

Jordan Valley Irrigation Project, Stage II

The objective of the Stage II development program is to increase the total irrigated area in the East Jordan Valley to approximately 36,000 ha, irrigated with sprinklers, including the conversion to sprinklers of 12,700 ha currently irrigated by surface irrigation methods. Additional water storage facilities on the Yarmouk River, the major source of water supply to the East Jordan Valley, must be provided in order to accomplish this objective. The initial Stage II development program, therefore, includes the following physical elements:

1. A dam and spillway to provide a reservoir to regulate wet season flows at the Maqarin Site on the Yarmouk River.

2. A diversion dam near Adasiye to direct Yarmouk flows to the East Ghor Main Canal.

3. Sprinkler irrigation and drainage systems for approximately 11,400 ha not included in the Stage I development.

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4. Conversion of existing gravity irrigation systems to sprinkler irrigation for approximately 14,000 ha.

5. Facilities required to develop hydroelectric power at Maqarin Dam and King Talal Dam, and along the conveyance alignments; and facilities to transmit energy from the generating sources to the local centers.

Subsequent expansion of the development will provide a second dam and storage reservoir on the Yarmouk River near Wadi Khalid, downstream of the confluence of the Wadi Raqqad.

Maqarin Dam and Reservoir

A principal feature of the Stage II development will be the Maqarin Dam and Reservoir on the Yarmouk River, just downstream of the confluence of the Wadis Shallala, Zeizun, Harir, and Allane. The dam will be an earth and rockfill structure, designed so it can be raised from an initial height of 128 m to 170 m at ultimate development. With a normal maximum reservoir elevation of approximately 195 meters (msl), at ultimate development, the reservoir will have a surface area of 10.9 km^2, a total volume of 747 MCM, and a useful storage volume of 657 MCM. At El. 150, maximum normal water surface level for the initial development, the surface area will be about 7.0 km^2. Approximately 45 percent of the reservoir area will be located on the Syrian side of the international boundry.

Khalid Dam and Reservoir

Ultimate Project development will include a dam at the Khalid site to store flood discharges from Wadi Raqqad and provide re-regulation of releases from the Maqarin Dam. Detailed planning for this development will not be completed until after completion of the Maqarin Project.

Water Diversion Facilities

Most of the 657 MCM of active storage in the reservoir will be utilized for irrigation in the East Jordan Valley. Other water diversions include:

1. approximately 30 MCM per year for municipal water supply for Irbid and the surrounding area;
2. approximately 17 MCM per year for downstream use in the Yarmouk Triangle; and
3. approximately 17 MCM per year for municipal and industrial use in the Jordan valley.

The proposed development plan will release water from the Maqarin Dam, as required, through a powerhouse located at the dam. The water will flow via the existing, natural channel of the Yarmouk River to a diversion structure at the site of the existing Yarmouk River diversion to the EGMC near Adasiye.

An alternative diversion scheme would be to release the stored water via a gravity tunnel from the Maqarin reservoir to a reservoir to be constructed on the Wadi Arab. Releases from there would connect directly with the EGMC. Under this alternative, the power generation facilities would be located between the diversion tunnel and the Wadi Arab Reservoir.

Construction

Construction materials required for the earth and rock fill Maqarin Dam will be obtained primarily in the immediate vicinity (within two kilometers) of the site. Borrow areas upstream from the site will be inundated by the reservoir. Those overlooking or downstream from the site will be protected so as to minimize erosion and safety hazards.

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OTHER DEVELOPMENT TRENDS INFLUENCING THE AREA

The only significant factors presently influencing development of the Project area, including both the East Jordan Valley and the Yarmouk Valley, are the programs and policies of the Jordan Valley Authority(JVA) and the political-military conditions existent in the region.

The JVA is responsible for development of all areas in or adjacent to the Project within the Hashemite Kingdom of Jordan. It acts cooperatively with the government of the Syrian Arab Republic regarding that portion of the Project area, the Yarmouk Valley and Maqarin Dam and Reservoir, that are astride the border between the two countries.

The JVA is also assuming the initiative in the development and implementation of social programs, such as housing, schools, and other facilities, necessary for the orderly development of community structures capable of providing the agricultural sector with its man-power requirements as and when required. Activities and programs of other agencies, e.g., rural public health, tourism, etc., are coordinated through the JVA as they relate to the Project area.

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EXISTING ENVIRONMENTAL CONDITIONS

Physical Characteristics

Water Resources

Water resources of the Project area are limited because of limited rainfall. The Jordan Valley Irrigation Project is being designed to utilize efficiently all available water supplies tributary to the East Bank (Exhibit B-1.).

Hydrologic Network. The Jordan River, emerging from Lake Tiberias and flowing to the Dead Sea, is the largest river in the area; but its waters are not suitable for irrigation, due to high salinity. Water from Lake Tiberias of suitable quality for irrigation is not at present available to Jordan. These conditions, therefore, restrict available water supplies to those rivers and wadis entering from the east.

Following full implementation of the Project all tributary waters entering the Jordan River downstream from Lake Tiberias will be intercepted and utilized for Project purposes. In addition, some existing groundwater utilization will continue, particularly in the southern portion of the area.

The streamflows of the tributaries and wadis follow the seasonal pattern of rainfall with heavy winter and low summer flows. The notable exceptions are the side wadis Arab, Ziglab, and Jurum. The annual variations also depict wide variations similar to those of rainfall. This is reflected in a very wide range between the annual maximums and minimums. Specific information on streamflows is contained in Appendix A, Hydrology.

Water Quality. On the basis of numberous analyses of surface flows of rivers and streams tributary to the Jordan River, it has been concluded that water quality of these

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sources is satisfactory for irrigation. Generally the salt content varies inversely with the discharge, winter flows being lower in salt content and better irrigation waters than summer flows.

The Yarmouk River waters upstream of village Al-Mukheibeh range in conductivity from 420-720 micromhos (medium salinity hazard or Class 2 according to USDA standards). Below this site the quality gets slightly poorer because of the mineral springs flowing mainly from Al-Hamma into the Yarmouk.

The average conductivity of the Zarqa Water is approximately 850 micromhos (Class 3 according to USDA standards). Construction of dams on the Yarmouk and Zarqa Rivers is expected to improve the quality of the water by minimizing periods when salt content is undesriably high. For the remaining side wadis, the average conductivity, in general, is between 400 and 500 micromhos, indicating water presenting medium salinity hazards.

Water Use. Existing use of these waters is for irrigation and domestic purposes. Some settlements in the Jordan Valley have piped water supplies, but others have to rely or supplies provided by the irrigation facilities. On-going projects are being implemented to provide adequate domestic and municipal supplies to the population of the Valley.

The canals are also used for play, swimming, and bathing. Such use will probably continue in the future.

Mineral Resources

Mineral resources of the Project are limited to deposits of clay, sand, limestone, and gravel.

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Land Resources

The total land area of Jordan is approximately 93,000 Km^2. 2/ This land can be divided into four climatic regions:

Region	Average Rainfall (mm)	Area (1000 Km^2)	Percent
1. Dry (Desert)	less than 200	85	91.3
2. Marginal	200 - 300	5	5.4
3. Semi-arid	300 - 500	2	2.2
4. Semi-humid	500 - 800	1	1.1

There are approximately 600 Km^2 in the East Jordan Valley of which approximately 360 Km^2 have been classified as arable, provided sufficient water supplies are available. The Valley can be divided as follows among the four climatic regions:

Region	Percent
1. Dry (Desert)	45
2. Marginal	36
3. Semi-arid	18
4. Semi-humid	1

With supplemental water supplies, these lands are capable of sustaining intensive agricultural production, whereas under natural conditions only limited, marginal production is possible.

Additional information concerning land capabilities in the Project area is contained in the Soils and Irrigation Appendix.

Natural Resources

The characteristics and identification of the natural vegetation and animal life within the Project area, partic-

2/ Five-year Plan, 1976-1980 National Planning Council.

ularly the Yarmouk Valley, are not known with any degree of certainty. The Jordan Valley has been subject to human disturbance for more than ten thousand years, and, although the Yarmouk Valley is less disturbed, few, if any, collections have been made. The consensus of persons familiar with at least certain aspects of the natural resources of Jordan is that the Project area is known in the most general terms and nothing of unusual interest has been noted. Thus, more detailed study is devoted to other "more interesting" areas within the country.

Vegetation

Water, soil, salinity, and slope are the major natural factors controlling vegetation in the area. There is no rainfall during the hot summer months, and existing natural vegetation is limited to herbaceous species except where streams or springs provide supplemental sources of water.

Probably the work by Poore and Robertson[3/] and the 1963 British Jordan Expedition contains the best approximation of present and probable past vegetative cover of the Project area. They have classified the vegetation of the country into range types grouped into four climatic and geomorphologica regions. Like other studies of the natural resources of Jordan, this work does not treat the Project area specifically and the study team did not visit the Yarmouk area.

The Project areas in the Jordan and Yarmouk Valleys contain portions of three of these regions: the Mediterranean Region, the Steppe Region, and the Sandstone and Granite Desert Region. The fourth region - the Limestone and Basalt Desert Region - is found in the eastern and southern parts of the country, roughly east of a line from Azraq to Ma'an.

3/ Poore, M.E.D. and Robertson, V.C. 1964. An Approach to Rapid Description and Mapping of Biological Habitats, based on a survey of the Hashemite Kingdon of Jordan. Sub-Commission on Conservation of Terrestrial Biological Communities of the International Biological Program.

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The highlands overlooking the valleys lie within the Mediterranean Region. The common features of this region are a sub-arid Mediterranean climate with rainfall usually exceeding 300 or 350 mm, and a climax vegetation of forest dominated by Quercus aegilops and/or Pinus halepensis. Range types within this region are distinguished by the degree of degradation from this climax and also by steepness of slope.

Although some forest types characteristic of this region are still found in the highlands of northwest Jordan, the only forest range type within the areas under consideration is known as the Scattered Trees in Northern Forest Region. This is the last degradation stage of the original Mediterranean pine or oak woodland that retains a designation as a forest type. The presence of trees indicates that clearance has not been complete and the ground vegetation and soils are not as degraded as the various brush types.

Further degradation of the Mediterranean forest results in either the Steep Limestone Scarps in the Mediterranean Region or the Degraded Mediterranean Dwarf-shrub Communities, depending upon slope. The former classification is for slopes of over 35°; soils are skeletal over the limestone. Vegetation consists of various species of scattered shrubs and grasses. The latter type is found on lesser slopes, including degraded pasture land. In the Project area, it grades gradually into the adjoining steppe type. Because of intensive grazing over long periods, boundaries are very difficult to determine and broad transition zones occur.

The Steppe Region in the Project area forms a narrow band along the escarpment between the Mediterranean Region

of the uplands and the desert of the Jordan Valley. The range type found in the area is know as the Steppe Communities of the Escarpment. The open vegetation is composed of dwarf-shrubs and herbaceous annuals and perennials.

The final range type characteristic of the Project area, except for Bare Bed Rock, is the Desert Region Scrub on Limestone and Marls. This type consists of a variety of species[4/], rarely covering much more than 10 percent of the ground surface. This type is characteristic of those portions of the Jordan Valley that are not devoted to cultivation.

In general appearance, the side slopes of the Maqarin Reservoir are well covered with herbaceous vegetation although slopes in places may exceed 45°. Adjacent to the stream courses, woody shrubs, consisting primarily of oleander (Nerium oleander), are present.

The Jordan Valley has been devoted to agricultural production wherever possible. Saline soils unsuitable for agriculture under past conditions are either devoid of vegetation, or contain sparce cover of highly salt-tolerant species.

A more detailed publication on the vegetation of Jordan is presently being prepared by Jordan University, Amman. Information available at the present time indicates that there are no unusual, rare, or endangered species that will be affected by the Project.

Aquatic Ecology

Little is known of the aquatic ecology of the area. All waters eventually drain to the Dead Sea. Species of fish reported to be present in the Jordan and Yarmouk Rivers include two or three species of Tilapia, a species of carp (Barbus sp., locally called gishre), and a species of catfish

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4/ Poore & Robertson list Zygophyllum dumosum, Chemoles arabica, Suaeda vermiculata, Traganum nudataum, and Anabasli articulate as characteristic of the type in general.

(*Clarias* sp., locally known as balbooth). It appears that none of these species provides a significant resource. Carp and tilapia are consumed locally, but the bulk of the estimated 3,000 tons of fish consumed annually in the country consists of imported marine species.

Limited governmental and private efforts have been made within the past decade to develop commercial scale fish farms in Jordan, but no such facility is presently operating. Efforts to date have been directed towards the production of mirror carp.

Snail vectors (*Bulinus*) of schistosomiasis have been identified from two locations in the Jordan Valley, but they were not infected. Population densities of other snail groups were high at the Maqarin site, but no specimens of *Bulinus* were observed.

The final aspect of the aquatic ecology of the area that should be mentioned is a small, permanent pond in the Yarmouk Valley, Birket al Arayes, immediately upstream of the abandoned Mukheibe damsite. This pond is located in a small depression and has no direct outlet to the river. It is ringed by a small band of cattail, oleander, and other vegetation. Algae were present in dense clumps in portions of the pond on the day it was observed.

This pond is worthy of special mention because it supports moderately large populations of turtles and frogs in an otherwise dry environment. The pond is approximately 1.5 hectares in area and the turtle population has been estimated in excess of 200 individuals[5/] ranging in size up to 35 cm. Tentatively they have been identified as *Testudo graeca*. Whether they occur naturally elsewhere in Jordan or neighboring Syria is unknown. Recently, efforts have been

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5/ Information from Mr. A. Bankak, Director of Conservation, Royal Society for the Conservation of Nature.

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made to transplant populations from there into other potentially suitable habitats. Results of these efforts have not yet been evaluated.

Wildlife

Wildlife populations in the Project area are limited by available water, food, and cover. As with other aspects of the fauna and flora of the region, population densities and distributions are incompletely known, but there are no reports of unusual forms. The introductory section of the book by Harding, "The Antiquities of Jordan[6/] mentions jackals, fox, wolves, hyenas, martens, mongooses, and hares (but no rabbits) as being fairly common in the country in general. Bird life is mentioned as being abundant.

The investigations for the Project did not permit field identification of species occuring in the area. No mammals were observed, and the only moderate to large mammalian species mentioned as being present in the Yarmouk area are fox, hare, and wild boar. The wild boar is noted for the hunting opportunities which it provides. There are also reports of limited numbers of mountain gazelles in the hills overlooking the Project site and the Yarmouk River. Rodents and other small mammalian species are probably also present in the area, but nothing is reported concerning of their species composition or population densities.

Bird life in Jordan, and presumably in and adjacent to the Project area, is varied, but again few details are known. Game birds including chukar, quail, black francolin, sand partridge, rock partridge, snipe, rock dove, and turtle dove are among the game birds reported to be present in the Yarmouk and/or Jordan Valley. Hunting regulations including season and bag limits are in effect for these species.

Sparrows are reported to be agricultural pests in the Jordan Valley.

Several species of snakes have been collected from the Deir Alla Agricultural Experiment Station in the Jordan Valley, but they have not been identified. Only three poisonous snakes are reported to be in the general area of the Project, the Near East viper (*Vipera xanthina*), the horned viper (*Cerastes cerastes*), and the desert black snake (*Walterinesia aegyptia*). Scorpions and a type of centipede can cause painful stings or irritation, but are not fatal. Field personnel should be aware of the possible presence of these pests and should take reasonable measures against injury.

Social and Cultural Characteristics

The social and cultural characteristics of the Yarmouk and Jordan Valleys are quite different. The Yarmouk Valley is an isolated and moderately inaccessible area straddling the Jordan-Syrian border approximately 10 kilometers east (upstream) of the Golan Heights. At the present time the area is under military control because of the international tensions. The East Jordan Valley includes some 600 km^2 of land that has been settled and cultivated for at least ten thousand years. Some archaeological sites in the Valley are believed to be even older.

Population

Few, if any, permanent residents are present in the Maqarin Reservoir area. The limited agricultural land in the Valley is tended by the residents of the villages on the plateaus overlooking the Valley.

The present population of the East Jordan Valley is estimated at approximately 70,000, consisting mostly of

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farmers and animal herders, in 19 towns and villages. Archaeological information indicates that the density of human population in the Valley from the fifth millenium (5000) BC until the middle of the twelfth century (1200) AD probably exceeded that at the present time. Utilization of the commercial and agricultural resources of the Valley at that time was on a much larger scale than at present.

Transportation and Communication

All parts of the Project area are easily reached by paved highway from Amman. The Maqarin site is accessible by a road extending north from Irbid and four major roads traverse the east rim of the Jordan Valley to connect it with the highlands. An improved road from Adasiye on the north to the Dead Sea on the south serves as the major route through the Valley. Plans are in preparation to extend this route along the shore of the Dead Sea to ultimately connect with Aqaba on the Gulf of Aqaba.

A branch of the Syrian State Railway presently passes through the Maqarin site. The line was originally constructed in the early 1900's when Jordan and Syria were parts of the Ottoman Empire. The branch connected the main Istanbul-Damascus-Amman-Arabia line at Dera'a with the Mediterranean Sea at Haifa. The western portion of the line was destroyed during the Arab-Israeli conflicts, and the track now extends only approximately ten kilometers west of the damsite. Trains now run once a week from Dera'a to downstream of the damsite to collect local produce and deliver goods.

Economy and Agriulture

The economy of both the Yarmouk and Jordan Valleys is based almost exclusively on agriculture. Past, present, and future agricultural characteristics of the Jordan Valley

Project area are discussed in detail in the Appendix on Agricultural Development. The necessary social institutions and facilities to adequately support this development are also considered. Administratively, all aspects of this development are under the control of the Jordan Valley Commission.

Existing agricultural characteristics of the Maqarin Reservoir area, including lost agricultural and social opportunities, are included in these evaluations as Project costs. At the present time, the limited existing agricultural production in the reservoir area includes pomegranates and tomatoes.

Public Health

Public health programs are well established in the Project area and there are no present health problems associated with the Project. Malaria and other vector-borne diseases have not been present or are under control. Snail hosts for Schistosomiasis have recently been found in isolated locations of the irrigation water supply system, but the disease organism is not present. Programs for identification and control of this vector are being implemented.

Archaeology and History

The most significant "resource" of the Project area is its history. The Jordan Valley and the wadis leading to it have played a major role in the development of civilization, particularly of the western world. The Valley represents one of the richest and most promising archaeological regions in Jordan. Past surveys have described numerous low prehistoric sites, large tells, and dolmen fields located in the East Jordan Valley.

During January 1975, it was decided to conduct a new archaeological survey of the Valley, sponsored jointly by the Jordan Department of Antiquities the Department of History and Archaeology of the Jordan University, and the American Center of Oriental Research. This survey was conducted over a two-year period. A report on the first year's work has recently been published[7/]

"The goals of the survey fieldwork were to visit, describe, photograph, locate on maps and collect artifacts from as many archeological sites as possible in the east Jordan Valley from the Yarmouk River in the north to the Dead Sea in the south and from the Jordan River on the west to the first rise of the foothills on the east. It was decided to visit all of the known sites, to check the existing evidence from them, and to locate and date any new sites which might have been missed by the earlier surveys and excavations. It was also planned while visiting the sites to note those sites which seemed to have great potential for future excavation, as well as those sites which might require protection or salvage excavation because of past, present, or future action by man and/or nature.

"There were other goals of the survey as well, goals of a more interpretive nature. It was hoped that on the basis of the evidence from the individual sites, it would be possible to draw synthetic conclusions about the occupational history and the settlement patterns in the east Jordan Valley as a region and to compare that region with other regions in Jordan and elsewhere. It was also hoped that such a synthetic study might produce conclusions which could eventually

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7/ Ibraham, M., Sauer, J.A. and Yassine, K., 1976. The East Jordan Valley Survey, 1975. BASOR 22

be of use to the Jordan Valley Commission in planning the present and the future economic development of the valley."

During the survey, a total of 225 sites were identified in the Valley. Results of the 1976 work in the southern half of the Valley have not yet been analyzed, but it was noted that the area between the Zarqa River and Wadi Shueib had virtually no sites, presumably because water was not available. The Zarqa area and the area south of Shueib are very rich from an archaeological viewpoint.

Only the north half of the Valley, from the Yarmouk River to the Wadi Rajib, was covered by the survey in 1975. In that area, 106 sites were visited, of which 54 were known from previous archaeological surveys and 52 were new ones. It is believed that additional sites, missed in the survey, may be present in the area.

Results of the 1975 survey indicate that:

> "almost every major archaeological period is represented in the Valley, although some periods are better represented than others. Sites were present in almost every part of the [northern half of the] valley although in most periods they tended to be located near the primary and secondary wadis. Since there are so many wadis which flow into the north Jordan Valley from the east, it is not surprising that some sites had fairly short-lived settlements while others which had special natural advantages (e.g., heights, fords, fields), were occupied intermittently for longer periods of time.

"The shallow Pre-Pottery Flint sites, which were located near the east foothills [some dating back to 10,000 B.C.] could represent seasonal camp sites. There was a very strong Neolithic Chalcolithic occupation[8/] in the valley, and the many small tells and large sprawling areas may have been more permanent agricultural settlements. The many Early Bronze sites which were located primarily on the higher hills, apparently were fortified villages or cities. It is striking that the well-attested EBIV-MBI (Early Bronze-Middle Bronze) sites were not located near the major wadis, and the saddle querns which were found at these thin and sprawling sites suggest that they were primarily agricultural

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8/ Chronolgy of Ages	Circa
Palaeolithic to Neolithic Period	10000 - 4000 B.C.
Chalcolithic Period	4000 - 3000 B.C.
Early Bronze Age	3000 - 2000 B.C.
Middle Bronze Age	2000 - 1600 B.C.
Late Bronze Age	1600 - 1200 B.C.
Early Iron Age	1200 - 950 B.C.
Late Iron Age	950 - 549 B.C.
Persian Period	549 - 331 B.C.
Hellenistic Period	331 - 63 B.C.
Roman Period	62 - 330
Byzantine Period	330 - 636
Arabic Period	636 - 1517
Umayyad	
Abbasid	
Ayyuid	
Mamluk	
Ottoman Period	1517 - 1921

settlements (usually unfortified). There was an extensive MBII occupation in the valley, but rather than consisting of large fortified cities, the sites were small or medium-sized villages. The Late Bronze period was not very well represented in the north, except at several sites which became major centers in the Iron Age. There were a great many Iron Age sites in the valley especially Iron IB, Iron IC, and Iron II, most of them seem to have been abandoned at the end of Iron II. Only a few small Persian sites were attested, and at some of them there may have been continuity from the Persian period into the Hellenistic period. There were a large number of Hellenistic sites including some rather large tells: most of these seem to have reoccupied in the Early Roman period. There was a very strong Early Roman occupation in the valley, including sites on the higher peaks of the east foothills, which probably were military forts, as well as sites in the valley itself, which probably were small villages and farms. The Late Roman period was not well represented in the valley, but most of the Late Roman sites seemed to reflect continued occupations (forts, villages) from the Early Roman period. There was a very substantial Byzantine occupation in the valley, both Early Byzantine and Late Byzantine, and in the Late Byzantine period quite a few sites apparently were settled as small agricultural villages on the valley floor. Most of the Byzantine sites appear

to have been abandoned at the end of the Late Byzantine period, and the Umayyad period was represented definitely at only a few sites. There were even fewer Abbasid sites, and from the Abbasid period to the Ayyubid period there may have been a general gap in occupation (except at a few sites). The Ayyubid/Mamluk period, with its sugar mills, its large agricultural villages, and its caravanserai, was the best represented period in every part of the valley. Most of the Ayyubid/Mamluk sites were abandoned after the Mamluk period, but some of the settlements may have continued into the Ottoman period."

The survey determined that there are many sites in the Jordan Valley, from many periods, which should be excavated for study. A list of 35 sites with the greatest potential for future excavation has been developed on the basis of the 1975 survey of the northern portion of the Valley. In addition, a large number of sites in the Jordan Valley are being encroached upon by modern villages and cemeteries, and many of them have been cut into by roads, by the East Ghor Canal (and its branches), by the army, by agricultural leveling and plowing, and by natural erosion.

The survey of the northern portion of the Valley identified 43 sites which have been damaged or which are threatened with damage in the near future, and which should be protected and/or excavated as soon as possible. Table B-2 shows the relationship among previously known (old) and new sites, those with potential for future excavation, and those threatened with damage.

Table B-2

STATUS OF ARCHAEOLOGICAL SITES[a/]

Category	Old	New	Total
Total Sites	54	52	106
With Potential for Future Excavation	22	13	35
Threatened with Damage	28	15	43
On Both of Above Lists	10	2	12

a/ Sites identified in northern portion of Valley in 1975 only.

So far, no comparable survey of archaeological sites has been made for the Maqarin Damsite or the Yarmouk Valley. A very brief reconnaissance was made of that area with Dr. James A. Sauer, one of the Principal Investigators for the Jordan Valley Survey. During that survey, flints and pieces of pottery were found, indicating that a systematic survey of the area would be desirable.

Publications from previous archaeological surveys also indicate the presence of sites in and adjacent to the Yarmouk Valley, including the possibility of a Roman road crossing the Valley through the reservoir area. The town of Um Qais, the Roman Decapolis City of Gedara, overlooks the lower Yarmouk River and Lake Tiberias. The Roman City of Capitolas, present day Beit Ras, is 15 km south of the damsite. The modern and Roman thermal baths at El Hamma are in the Yarmouk Valley immediately adjacent to the river. Other tells are also listed on the topographic maps of the area.

Recreation and Tourism

Tourism development on the East Bank of the Jordan River, including the Project area, Amman, and Aqaba, has received emphasis only since 1967. Prior to that time, tourism facilities were developed primarily in Jerusalem and neighboring areas on the West Bank. The Department of Tourism is presently developing a master plan for the country.

The Department believes that tourism and recreation development of the reservoir will come naturally, and that it needs to be worked into the master plan presently under development. There are many other potential tourist attractions in the northern part of Jordan, and the Department plans to develop the area on a regional basis. The cornerstone of this regional development is, and probably will remain, Jerash. The forests and castle at Ajlun and the Thermal Hot Springs at El-Hamma are also existing attractions in the area. The Department of Tourism also has plans to relocate the present town of Um Qais and to excavate and restore Gedara much as has been done at Jerash. Future plans also call for the development of the thermal springs near Dier Alla and the archaeological site at Tabaqat Fahil (the Decapolis city of Pella) for tourism.

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ANALYSIS OF IMPACTS

Primary Sources of Impact

The primary sources of impact on existing environmental conditions resulting from construction and operation of Stage II of the Jordan Valley Irrigation Project will be:

1. Construction and land preparation activities,
2. Inundation of the Maqarin site,
3. Changes in stream flow patterns,
4. Changes in agricultural practices, and
5. Changes in demographic and social characteristics.

Construction Activity

It is anticipated that construction activity for the Project will consist of:

1. Dam construction including spillway facilites and powerhouse,
2. Reservoir clearing,
3. Construction of conveyance facilities,
4. Railroad relocation, and
5. Land preparation in the Jordan Valley, including sprinkler irrigation and drainage systems.

Borrow areas, access roads, construction camp, and necessary appurtenant facilities for dam construction will be located as close to the construction site as is feasible. An access road to the river at the site has recently been completed, and access through the reservoir area and the dam alignment is available by railroad from Dera'a.

Woody vegetation within the reservoir area is limited almost exclusively to the Valley bottom adjacent to the stream courses. This vegetation consists largely of oleander, and other large shrubs, and groves of pomegranite. Shortly before dam closure, this woody vegetation should be cut and

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either removed from the reservoir area or burned so as to minimize debris and water quality problems in the reservoir. The vegetation on the side slopes of the reservoir is primarily herbaceous and will not require clearing.

Water conveyance facilities for the Project will need to be planned so as to minimize erosion and other disruption of existing resources and landscape features. Such conveyance facilities include those required for the irrigation water, and for municipal supply to Irbid. The latter will be by buried pipeline and will result in no permanent impact if properly designed and constructed. Water for the Jordan Valley and Yarmouk Triangle will be released down the existing, natural channel of the Yarmouk River to an improved diversion structure at the site of the existing diversion. No adverse effects are expected due to this diversion system with the possible exception for minor amounts of channel degradation.

If it is considered necessary to relocate the railroad from the head of the reservoir to its terminus a few kilometers downstream, such activity should incorporate adequate erosion control provisions. It is also desirable that any railroad relocation, or other construction activity, avoid, if possible, the Wadi Shallala arm of the reservoir. This is the only arm that is wholly within Jordan and it appears to offer the best opportunity for future recreation and aesthetic development in conjunction with the Project. These options should not be foreclosed by actions during construction that could be avoided entirely or located elsewhere.

Land preparation activities in the Jordan Valley provide the greatest source of potential impact, primarily because of the extensive area involved. Planning and supervision of

these activities will be less intensive on a unit area basis than elsewhere. This increases the potential for unnecessary damage to archaeological or other cultural landmarks present in the area.

Inundation of the Maqarin Site

Construction of the dam and inundation of the reservoir area will have minimum impact, primarily because of the limited nature of existing resources in the area. It is possible however, that some archaeological sites could be affected.

Stream-Flow Patterns

Construction of the dam and diversion of the water for agricultural and municipal use will greatly alter stream-flows in the Yarmouk River downstream from the Maqarin site. If, as presently planned, the Yarmouk is to be utilized to convey the irrigation water downstream to an improved diversion structure at the intake to the EGMC, seasonal flow patterns in the river will be greatly modified. An improved diversion facility near Adasiye will minimize flows from that point to the confluence with the Jordan River. If the water is diverted from the Maqarin Reservoir by tunnel to the Wadi Arab diversion reservoir, flows downstream in the Yarmouk River will be reduced to only that level necessary to accommodate identified downstream uses. Either way, Yarmouk River water that is relatively low in total dissolved solids will be diverted away from the Jordan River, increasing total dissolved solids concentrations somewhat in the downstream reaches of the Jordan River. However the existing quality of the Jordan River water is too poor to permit its use for agricultural, domestic, or industrial purposes so increasing the dissolved solids will not have a damaging impact.

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Agricultural Practices

Increased use of agricultural fertilizer and pesticides is anticipated as agricultural production is expanded in the Project area. Increased nitrogen, phosphorus, and total dissolved solids concentrations in the irrigation return waters will not significantly increase the already high salinity of the Jordan River flows.

No information is as yet available on proposed use of pesticides in the Project area. Plans for the use of such chemicals must take into account the susceptibilities of the human population and of the bird life of the area to certain pesticides (especially the chlorinated hydrocarbons). The impact of pesticides can be minimized through careful choice of the chemicals to be applied, methods of application, and quantities to be used, coordinated with rigorous monitoring and control of all pesticide use.

Demographic and Social Characteristics

Full development of the Project, expected the mid-1980's, will greatly expand the population in the East Jordan Valley from the present level of 70,000. The influx of families and individuals attracted to the area by Project development and related employment opportunities will tend to create some socio-cultural stress and secondary Project impacts unless careful advance planning and implementation of adequate control measures are undertaken in a timely manner. Programs for the development of the social institutions and facilities required to support and maintain the agricultural production are being formulated by the Jordan Valley Commission. These programs need to be formulated with great care, particularly relating to domestic water supply and sanitation, public health, and community development.

Discussion of Resultant Impacts

Existing Natural Resources

Apart from the agricultural resources, existing natural resource values in the areas to be affected by the Project are of very limited value. Therefore, it is not anticipated that implementation will result in adverse impacts on existing resources. Increased human population and increased irrigation water supply in the Jordan Valley, however, may increase the potential for the introduction and spread of both the snails (*Bulinus*) and the pathogen of schistosomiasis. Existing monitoring and control programs for these organisms should be increased in scope and frequency.

Potential for Fishery Development

Although the existing freshwater fishery resource in the Jordan Valley area is extremely limited, the development of irrigation offers a good possibility for the concurrent development of a fish culture program. A well managed fish culture operation utilizing carp or one of several species of Tilapia[9/] can reasonably be expected to produce from 500 to 1,000 kilograms of good quality food fish per hectare per year. The economic desirability of this potential should be seriously investigated.

Development of a fish culture program can be done in conjunction with irrigation projects, utilizing surplus or marginal Project land and water in a manner that is not competitive with irrigation or other needs. If properly developed, such a program could significantly increase the Project benefits and improve the level of nutrition of the populace.

In addition to the more traditional method of fish culture in earthen ponds, possibilities for the Jordan

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9/ Both *Tilapia* species and carp, as well as other promising species of fish, are found in Jordan.

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Valley Project include the use of screened off sections of the irrigation canal for fish culture, as recommended in a recent United Nations FAO report[10/]. The culture of fish in floating cages in reservoirs also merits consideration.

Required Work Program. The basic technology for the culture of carp and *Tilapia* is well developed, and successful fish culture industries of various types are in operation throughout the world. Adaptation of this technology to the specific biological and socioeconomic conditions of Jordan will, however, require both a short term program of pilot studies and the eventual development of a long term program designed to provide continuous technical aid and extension services to local fish culturists. The items discussed below provide a preliminary outline of the type of work necessary for implementing a fish culture program as a part of the Jordan Valley Irrigation Project.

Exhibit B-2 outlines in general form, the major tasks to be accomplished during the first few years of development. As shown, the initial program consists first of a short period (one year) for preliminary analysis, site selection, organization of a technical team, final program design, and construction of the necessary facilities (i.e.; ponds for pilot studies). Approximately two more years would then be dedicated to pilot studies designed to establish the technical feasibility of the various fish culture methods. During this initial phase of the program the services of an experienced fisheries consultant would be required to set up the program and to train and direct the Jordanian professional and technical staff. A complete list of the required personnel is given in Table B-3.

10/ FAO Report to the Government of Jordan on Inland Fisheries Development and Fish Culture. UNDP Report No. TA-3186. Rome, 1973.

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As indicated in Exhibit B-2, the initial program, wherein the technical feasibility of the various methods is established, would be completed during the fourth year. At that time, the long term program would begin, utilizing the same personnel and facilities, with the exception of the fisheries consultant, who would be required only if unforeseen difficulties arise. Emphasis would shift to work designed to improve the efficiency of the established fish culture methods and to the development of an extension service to transfer the technology of fish culture to local farmers or landowners. From this point, the size and nature of the program would be adjusted to the developing fish culture industry of the area, increasing in size or shifting its investigative effort as conditions warrant.

Costs. Although it is beyond the scope of the present study to prepare detailed cost analyses for the proposed fish culture development, it should be pointed out that the program, as envisioned, does not represent a major expenditure in comparison to overall project costs. In addition to the salaries of the professional, technical and non-technical staff, major expenses include the land aquisition and construction costs for approximately ten earthen ponds, ranging in size from 0.04 to 1.0 hectare (400-10,000 m^2), a vehicle, and miscellaneous field and laboratory equipment such as cages, balances, nets, water quality equipment, and glassware. Annual operating expenses include feed costs for maintaining experimental fish as well as expenses for vehicle and equipment maintenance.

Development of the fisheries program should be done in cooperation with personnel of the Animal Husbandry Branch of the Department of Agricultural Research, which already has fisheries programs and trained personnel.

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Table B-3

PERSONNEL REQUIRED FOR DEVELOPMENT

OF FISHERIES PROGRAM AND FISH CULTURE EXTENSION SERVICE

Consulting Biologist	(1)	18 month resident plus 5 man-months non-resident time
Fish Culture Biologist[a/]	(1)	Full time
Extension Biologist[a/]	(1)	Full time
Technical Assistants		
Culture[b/]	(2)	Full time
Extension[b/]	(2)	Full time
Laborers	(4)	Full time

a/ University graduates, previous experience desirable but not necessary.

b/ High school graduates, no previous experience required.

Water Resources

One of the primary objectives of the Project is to develop a reliable water supply for irrigation and domestic use in the Project area. It appears that this can be accomplished without major adverse impacts on water resources. Adequate water supplies of good quality will be provided to downstream users. Return flows to the Jordan River are not expected to significantly increase the already high salinity of the existing Jordan River flows. There has been some question as to the effects of the Project on the overall water balance and water quality of the Dead Sea. It is beyond the scope of the present assignment to determine a complete water and salt balance for the Dead Sea under with and without Project conditions. It is understood that such a study may be undertaken in the near future.

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Ultimate development of the Maqarin Dam will create a reservoir with an area of 10.9 km^2 and a total volume of 747 MCM. Dead storage volume in the reservoir initially will be 90 MCM and will provide sufficient storage for 100 years of sediment accumulation.

Available water quality data indicate that water quality of the reservoir will be good. Steep rock side slopes and large annual drawdowns will prevent the growth of rooted aquatic vegetation. Some algae and floating aquatic vegetation may develop on the surface of the reservoir, but it is not anticipated that such growth will create problems.

Land Resources

Project implementation will not adversely affect land resources. The only land lost will be that occupied by the Maqarin Dam and Reservoir, approximately 11 km^2. This will be more than compensated by land reclamation and increased productivity within the Jordan Valley.

Social and Cultural Characteristics

Planning for the social and cultural development necessary for the Project has been underway by JVA for several years. Programs to accomodate anticipated changes in social and cultural characteristics within the Project area are being developed. Particular consideration needs to be undertaken for three aspects: future sociocultural conditions in the area, preservation or excavation of significant archaeological sites, and planning for recreation and tourism in the area.

Archaeological Sites. Archaeological sites of significance have been identified within the Jordan Valley and sufficient artifacts have been found to warrant an arch-

aeological survey of the Maqarin Reservoir area. A survey of the reservoir area, similar to that recently completed for the Jordan Valley, should be undertaken as soon as possible. The level of this effort would probably be on an order of two to three man-months.

It is also suggested that, as part of the on-going program of the Ministry of Antiquities and Tourism to excavate, study, and preserve the cultural heritage of the Nation, identified significant archaeological sites in the Jordan and Yarmouk Valleys be protected until detailed evaluations can be made. Arrangements should be made with archaeological scholars for the investigation and excavation of identified important sites as soon as possible so to avoid further damage to the identified sites. Monitoring of construction activities by the Department of Antiquities should also be considered.

Recreation and Tourism. The Maqarin Reservoir may provide opportunities for the development of water-oriented recreation. The dam itself would be an attraction for tourists traveling in the area. A visitor's center should be provided at the damsite. Detailed plans for other recreation and tourist facilities can best be developed after the reservoir has been filled and an evaluation made of the physical and aesthetic impacts of reservoir fluctuations. Recreational facilities developed in conjunction with the Project will have to be designed to allow for this reservoir fluctuation and the steep valley side slopes. For example, marinas and boat launching areas should be so located and designed that they are usable over the entire range of reservoir elevations. Likewise, swimming and other developments will have to be planned in accordance with projected

reservoir operations, as well as seasonal weather variations, water quality, and user preferences.

At this time, it would appear that the Wadi Shallala arm of the reservoir would offer the greatest potential for development for tourism and recreation. It is the only arm totally within Jordan and would have the best access to Irbid and the main highway network. Recreation facilities at this location could be integrated with tourist facilities located at the dam.

RECOMMENDATIONS

Mitigating Measures

Anticipated Project impacts are minor in nature and will not require the implementation of extensive mitigating measures. The only identified impact that may require mitigation is the possible loss of or damage to archaeological sites. Arrangements should be made for the protection or excavation of identified key sites.

Opportunities for Enhancement

Development of the Project will provide an opportunity for the concurrent development of a fish culture program utilizing Project lands and water in a manner that is not competitive with other Project features. Additional investigations, as discussed in this report, are required to ensure that such a program is fully and successfully implemented.

Recreation and tourism development opportunities will also be created. Such opportunities should be considered as Project plans progress and should be integrated into the planning process now in progress for the development of tourism in the northern portion of the Country.

Monitoring

Routine monitoring that presently is underway to detect the presence of vectors and/or pathogens responsible for schistosomiasis should be expanded in both scope and intensity. As such organisms are found; appropriate control measures should be instituted.

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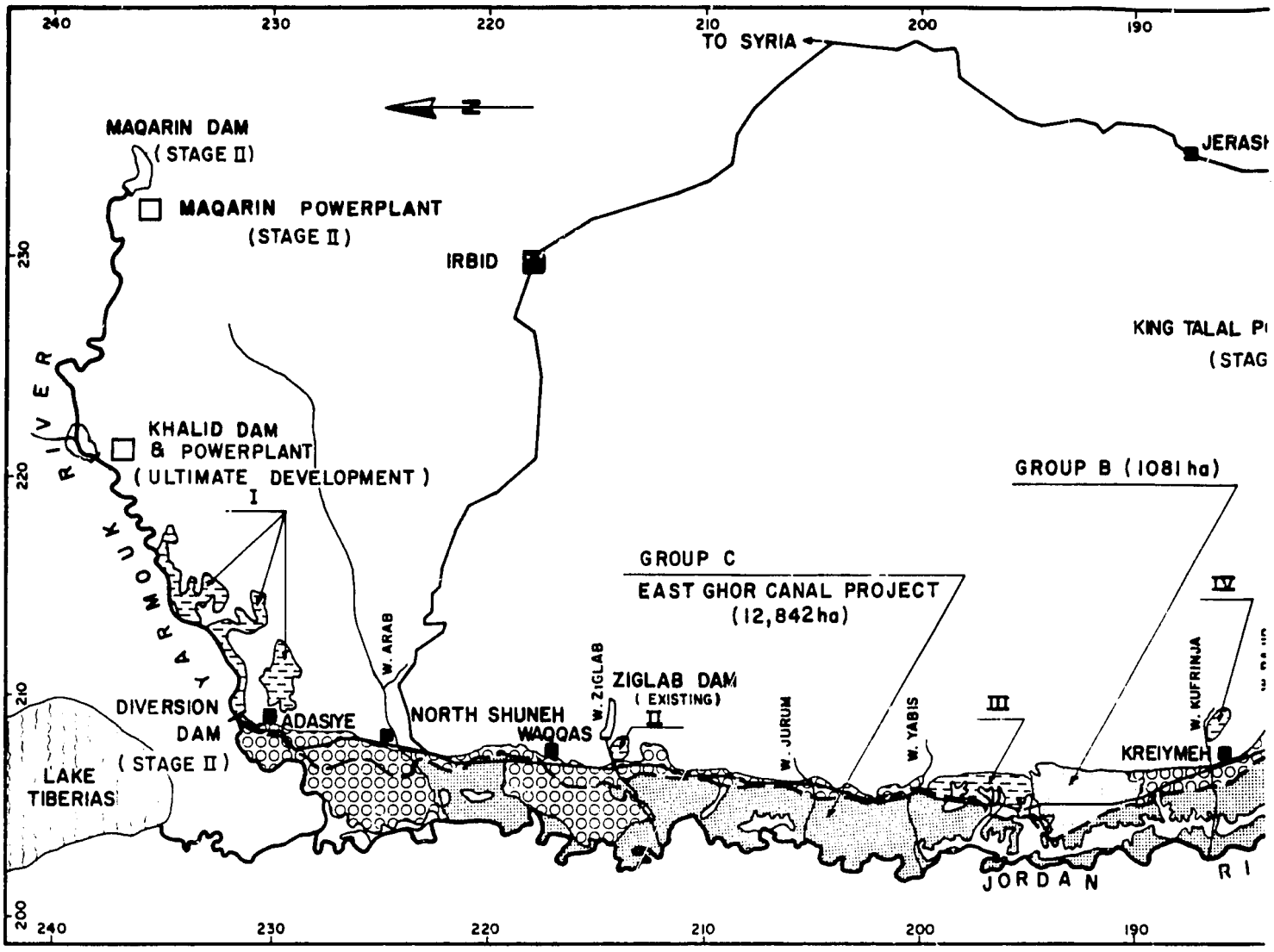


LEGEND

- ROADS
- EAST GHOR MAIN CANAL
- RIVERS
- STAGE I PROJECTS
- STAGE II - NEW LANDS - GROUPS A & B
- STAGE II - CONVERSION LANDS - GROUP C
- STAGE II - POTENTIALLY IRRIGABLE LANDS - GROUP D

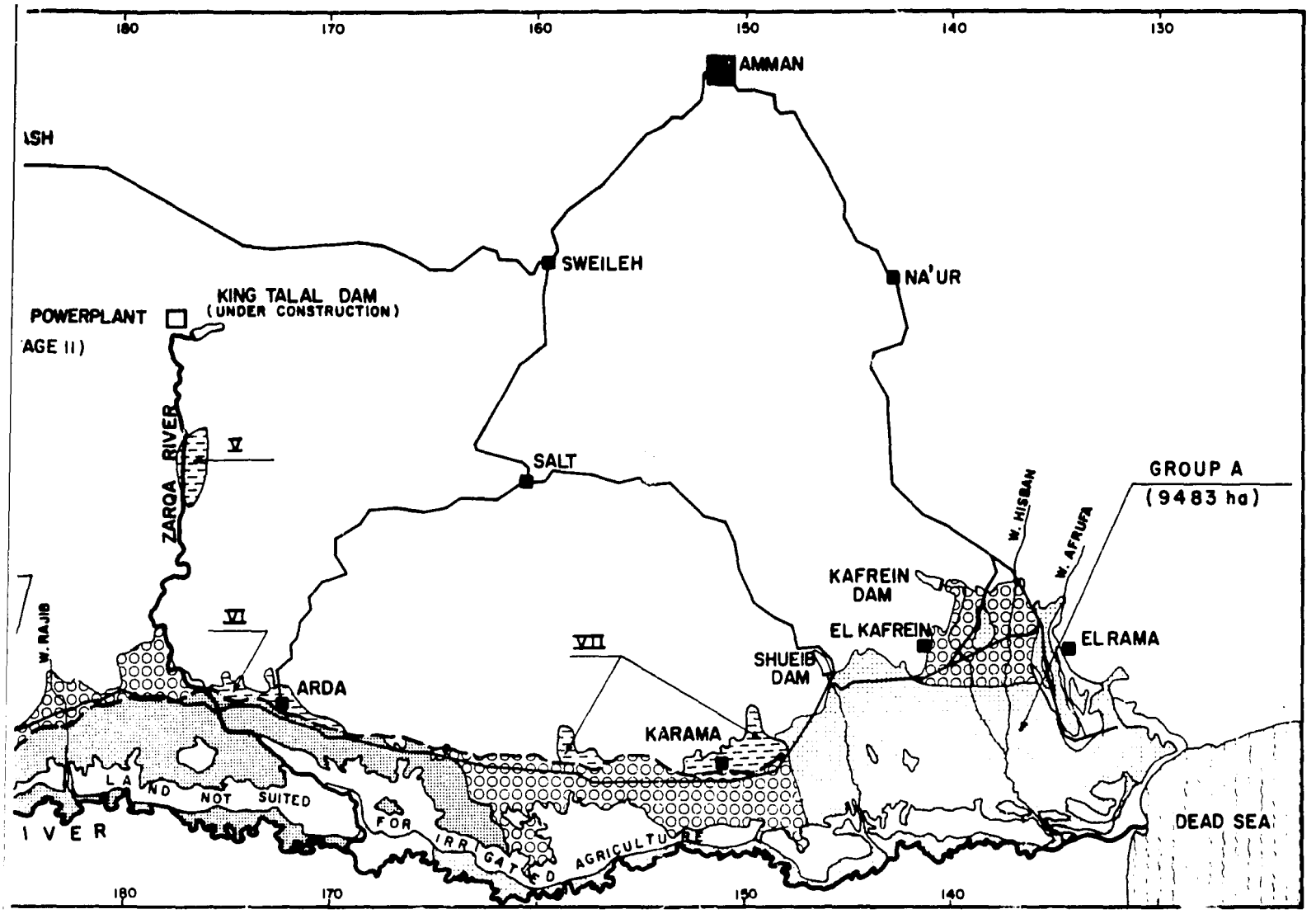
NOTES

1. - GRID FIGURES ARE
2. - POTENTIAL AREAS

I - YARMOUK GOR
II - ZIGLAB GOR
III - BETWEEN KUF
IV - KUFRINJA GO
V - ZARQA GORGI
VI - SOUTH OF ZA
VII - ABOVE 18 Km E

Dar Al - Handasah Consultants (Shair and Partners) January 1978

EXHIBIT B-1



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ARE KILOMETERS
AS INCLUDE

	HECTARES
GORGE	331
ORGE	50
KUFRINJA & YABIS	432
GORGE	100
RGE	216
ZARQA	293
m EXTENSION	525
TOTAL	1947

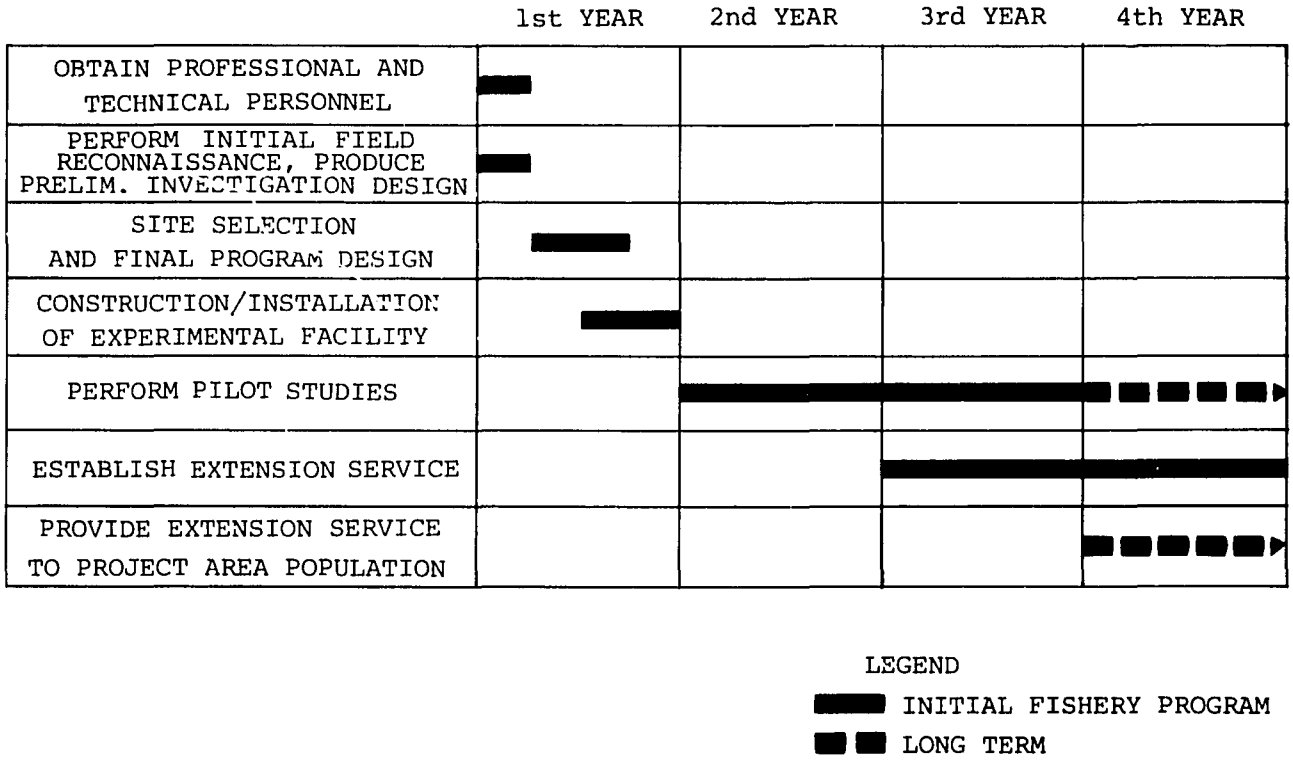
STAGE II PROJECT AREA

	HECTARES
CONVERSION LANDS (INCLUDES UPGRADED AREAS)	12,842
NEW LANDS	10,564
POTENTIALLY IRRIGABLE LANDS	1,947
TOTAL	25,353

TOTAL AREA

ON GOING PROJECTS	9,397
JAPANESE PROJECT ON WADI ARAB	1,250
STAGE II LANDS	25,353
TOTAL	36,000

GENERAL PLAN OF DEVELOPMENT
JORDAN VALLEY IRRIGATION PROJECT
STAGE II



PRELIMINARY SCHEDULE FOR DEVELOPMENT OF FISHERY AND FISH CULTURE EXTENSION PROGRAMS

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

Appendix C

OPERATION STUDIES

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C-9	Irrigated Area vs. Storage
C-10	Average Reservoir Elevation

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Appendix C

OPERATION STUDIES

Introduction

Operation studies were done to determine the storage requirements of Maqarin Reservoir for Stage II development and of the combination of Maqarin and Khalid or Maqarin and Mukheibeh Reservoirs for Stage III development. In addition, studies were done to evaluate existing conditions and the conditions that will occur during the transition form Stage I to Stage II development. A mathematical model was prepared for use on a Univac Computer, Model 1108. The reservoir operation studies included consideration of the existing and on-going sprinkler irrigation projects, the unregulated side wadi flows, and the regulated and unregulated flow of the Yarmouk River. Releases were made from the Project storage facilities to meet the irrigation requirements of the Jordan Valley, the municipal and industrial water needs of the Jordan Valley and Irbid, and the requirements of the Yarmouk Triangle Area.

The East Bank of the Jordan Valley ranges from 4.0 km to 9.0 km in width and is slightly more than 100 km long. Two rivers and nine major wadis flow through the Project Area and enter the Jordan River. From north to south, they are the Yarmouk River, Wadi Arab, Wadi Ziglab, Wadi Jurum, Wadi Yabis, Wadi Kufrinja, Wadi Rajib, the Zarqa River, Wadi Shueib, Wadi Kafrein and Wadi Hisban. The drainage basin boundaries are shown on Exhibit C-1.

Developments and Alternatives Studied

The recommended plan for Stage II Development consists of storage facilities at the Maqarin site, a powerplant at

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the dam, a powerplant at King Talal Dam on the Zarqa River, a diversion dam near Adasiye, an extension of the East Ghor Main Canal (EGMC), and sprinkler irrigation facilities for about 25,000 ha. Exhibit C-2 shows the location of Project features and the general plan of development.

The objective of the operation studies for Stage II development was to determine the storage requirements at Maqarin Reservoir to irrigate a total of 25,353 ha using sprinkler irrigation methods, provide 20 MCM per year for M&I use and 25 MCM per year for the Yarmouk Triangle Area while allowing storage for 50 years of sediment accumulation. The 25,353 ha of irrigation area will be in addition to 10,647 ha developed for Stage I, bringing the total irrigation area to 36,000 ha.

The Ultimate Development Plan (Stage III) includes Maqarin Dam, a storage project and powerplant at the Khalid site or the Mukheibeh site, and irrigation facilities to use the fully controlled water resource.

The objective of the operation studies for ultimate development was to determine what area could be irrigated from the Project storage facilities while providing 47 MCM per year for M&I use and 25 MCM per year for the Yarmouk Triangle area. For ultimate development, a storage allocation for 100 years of sediment accumulation was made for both reservoirs.

Two alternatives to the selected Stage II development were studied. The first alternative has the same facilities as the recommended plan except that the diversion facilities near Adasiye consist of two uncontrolled intakes rather than a diversion dam. The uncontrolled intakes can divert only 90 percent of the flow in the river and, therefore, more

water must be released from Maqarin Reservoir to supply the Stage II service area. Operation studies were necessary to estimate the revised storage requirements. Second, a transbasin diversion to the Wadi Arab was considered. This scheme requires the construction of a 25-km long tunnel from Maqarin Reservoir to the Wadi Arab Dam reservoir. The tunnel would be hydraulically connected to Maqarin reservoir and would develop the head from Maqarin Reservoir to the Wadi Arab Reservoir for power generation.

Operation studies were done to evaluate the irrigation conditions that could occur during the transition from Stage I to Stage II development. Four studies were done, each subsequent study assuming completion of additional irrigation development.

1. After completion of the East Ghor Canal Project (12,300 ha) and the 8-Km Extension Project (1,457 ha). The irrigation area totals 13,757 ha and is irrigated by surface methods. The sources of irrigation water are the Yarmouk and Zarqa Rivers and Wadis Arab, Ziglab, Jurum, Yabis and Kufrinja. It was assumed that only the small storage facility on Wadi Ziglab was in operation.

2. After completion of the King Talal Project on the Zarqa River and the North East Ghor Irrigation and Rural Development (NEG) Project on Wadis Arab, Jurum, and Ziglab. The irrigation area would be reduced to 12,757 ha (1,000 ha would be irrigated from the NEG Project) and irrigated by surface methods. The sources of water would be the Yarmouk River, the Zarqa River which must also supply the Zarqa Triangle Area (1,527 ha), the 18-Km Extension

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Area (3,550 ha), and provide 10 MCM per year to Amman for municipal and industrial uses, and Wadis Kufrinja and Yabis.

3. After conversion from surface irrigation to sprinkler irrigation. The irrigation area would be 13,762 ha; including 12,757 ha which were formerly irrigated by surface methods and 915 ha which were not irrigable by surface methods but which are irrigable using sprinkler methods. The sources of irrigation water would be the same as for Study 2 plus Wadi Rajib.

4. After completion of Wadi Arab Dam. The irrigation area would be reduced to 12,842 ha (830 ha would be irrigated from Wadi Arab Dam reservoir). This area is referred to as the conversion area under Stage II development. The sources of irrigation water would be the Yarmouk River, the surplus flows from the Zarqa River, and Wadis Yabis, Kufrinja and Rajib.

The Model

A mathematical model was developed, specifically for this study, which evaluates the combined operation of the Stage I, Stage II, and ultimate development (Stage III) facilities.

The model simulates the operation of the facilities, on a monthly basis, as individual projects or as any combination of projects, to determine the area that can be irrigated from a designated water supply and storage condition. The input necessary for operation simulation includes monthly water supply, reservoir evaporation, a storage allocation for

sedimentation, reservoir area and volume data, irrigation diversion requirements, municipal and industrial water requirements, requirements of the Yarmouk Triangle area, irrigation shortage criterion, and the area to be irrigated. The model determines the storage required to irrigate a given area, the amount of spill, the amount and timing of irrigation shortages, monthly power and energy production and the amount of water lost to the Project.

The model was operated so that the initial elevation of the reservoirs and the elevation after operation over the 22-year period of record was the same. This ensured that no requirements would be met by using water that could not be replaced during the record period.

The operation simulation was done for two conditions: 1) Flow regulated by a reservoir, and 2) unregulated flow.

When the flow is regulated by a reservoir, the final volume is calculated by adding the initial volume to the period inflow and subtracting evaporation and release requirements. Evaporation is calculated using the reservoir area and the appropriate monthly evaporation rate. The release is tested against the irrigation requirement and the spill, if any, is calculated. If the volume is the minimum allowable storage volume, the release is equal to the inflow minus evaporation. Shortages occur when the releases are insufficient to meet irrigation requirements. If there is no reservoir, the monthly surplus or shortage is calculated as the difference between inflow and irrigation requirements. A shortage occurs when the irrigation requirements are not met. These procedures are repeated for each month in the period of record. If the shortage criterion is not met, the reservoir characteristics are revised and the computations repeated until the number of months of shortage meets the criterion.

Operation Procedure

The operation procedure for irrigating Project lands is first to attempt to meet irrigation requirements from the side-wadi flow, then from the flow of the Yarmouk River generated below the storage facilities and finally with releases from the storage facilities.

Side Wadi Operation

Proposed or on-going projects will use or are currently using the flow of many of the side wadis. Based on information presented in the Development Plan[1/], it was assumed for all Stage II development operations that the Kafrein-Hisban Project and the Wadi Arab Complex would make use of all the water in Wadis Kafrein, Hisban, Arab, Jurum, and Ziglab. The Wadi Arab Complex is a combination of the North East Ghor and Rural Development (NEG) Project, which makes use of the base flows of Wadis Arab and Jurum and the regulated flow of Wadi Ziglab, and the Wadi Arab Dam Project, which controls and distributes the flood flows of Wadi Arab. No water will be supplied to Project lands from the wadis associated with the Kafrein-Hisban Project or the Wadi Arab Complex.

Wadi Shueib is controlled by a small dam which impounds the flow until it can be used to recharge the ground water supply. None of the flow from Wadi Shueib was included as a Project supply.

The Zarqa River was included in the side-wadi operation. The Zarqa Project was included to confirm that the area in the Zarqa Triangle and the 18-km Extension Area could be

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1/ Jordan Valley Development Plan 1975-1982, Jordan Valley Commission, November 1975.

irrigated using the most recent estimates of water supply for the Zarqa River while allowing for a release of 10 MCM per year to Amman. In the final Project plan, the Zarqa River was used as a supply for lands which could be served by gravity rather than the 18-Km Extension Area, which required pumping. The total area served from the Zarqa River Project; however, remained the same. Surplus flow from the Zarqa Project, up to an amount estimated to represent the base flow, was used to supply Project lands. Estimation of the base flow is discussed below.

The three remaining principal wadis, Wadi Rajib, Wadi Kufrinja, and Wadi Yabis were included in the operation study as contributing directly to the Stage II land served from the EGMC. The amount of water contributed to the Project operation by these wadis was difficult to assess because the streamflow records represented average monthly flows and did not indicate the amount of water included in flash-type floods which would not be available for diversion. The estimate of water that could be diverted from these wadis was based on the summer flows, which as a rule do not contain any flood flow. The maximum contribution of these side wadis and of the surplus from the Zarqa River was assumed to equal the average of the monthly runoff for the five-month period June through October. The maximum contribution of the wadis and the Zarqa River is shown in Table C-1.

Table C-1

DIVERSION CAPACITY OF SIDE WADIS

Source	Maximum Diversion Capacity MCM/month
Wadi Rajib	0.4
Wadi Kufrinja	0.3
Wadi Yabis	0.2
Zarqa River	2.8

Interflow

Interflow is defined as the water in the Yarmouk River developed between the storage facility and the intake to the EGMC. A special study was done to estimate the amount of interflow which could be diverted into the EGMC. A perusal of the daily records of the interflow showed that a major portion of the runoff occurred in short periods at a rate of flow that exceeded the capacity of the EGMC. Using 20 months of daily records, a relationship between monthly runoff and divertable flow was established. The monthly divertable flow was defined as the total of average daily flows which were limited to a maximum of 20 m^3/s (1.73 MCM per day), the capacity of the EGMC. Up to a monthly runoff of 10 MCM, the divertable flow was equal to the runoff. A linear regression was used to establish the relationship for larger flows.

Diversion to the EGMC

The amount of flow that is assumed to enter the EGMC depends on the type of diversion facility at the intake. If a diversion dam is included as a part of the Project facili-

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ties, 100 percent of the divertable flow up to a maximum of 52 MCM/month can be diverted. Exhibit C-3 shows the relationship between flow in the river and the flow diverted into the EGMC. If uncontrolled-diversion intakes are used, 90 percent of the divertable flow in the river will enter the EGMC up to a maximum of 52 MCM per month. Under existing conditions, it was assumed that 70 percent of the divertable flow in the river enters the EGMC up to a maximum of 52 MCM per month.

Releases from Yarmouk River Storage Facilities

Maqarin Reservoir is the major source of the water for the irrigation system. The demand for water from Maqarin Reservoir is computed as the Project Area requirement minus the requirements for any lands that can be irrigated by side-wadi flow or interflow. If the latter two components can provide all required water, no release will be made from Maqarin Reservoir to the irrigation system.

The operation study was modified to include a second dam at a downstream location on the Yarmouk River for Stage III development. In the modified operation, releases first were made from the downstream reservoir to meet the irrigation requirements. If sufficient water was not available, releases were made from Maqarin Reservoir. If neither dam could supply the required irrigation water, the M&I water for Irbid and the Valley was released and the remaining water was used for irrigation. The month was counted short and the shortage computed.

Power and energy were computed for the releases at both the Maqarin and the downstreams sites.

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Input Data

Water Supply

Recorded and synthesized streamflow data are available for the Yarmouk River, the Zarqa River, and nine principal side wadis for various periods between 1926 and 1976. Most of the streamflow data which predate 1950 were synthesized.

The operation studies were made using monthly inflow for a period of 22 years from October 1953 through September 1975. This period essentially corresponds to the period of record of the gage near the Maqarin site. Monthly streamflow records for the selected period are shown in Appendix A, Hydrology. A histogram of monthly runoff at Maqarin is shown on Exhibit C-4.

Jordan and Syria, as the major riparian countries to the Yarmouk River, reached an agreement, which was signed in Damascus on June 4, 1953, to regulate their rights to the water in the Yarmouk River. As a part of that agreement, Syria reserved the right to dispose of the waters of all streams springing in its lands in the basin of the Yarmouk and its tributaries with the exception of waters which spring upstream of Maqarin Dam below the 250 meter contour. Jordan was given the right to use within Jordanian boundaries the water which is in excess of Syrian needs.

With the assistance of the JVA, an estimate was made of the water requirements of Syria which could be met from the Yarmouk River in the foreseeable future. This estimate is discussed in Appendix A, Hydrology. An adjustment was made to the recorded streamflow of the Yarmouk River to reflect historical and anticipated diversions from the river above the Maqarin damsite. Mean annual runoff for the two rivers and nine wadis are given in Table C-2. The Project sizing studies were done using this estimate of water supply.

A second estimate was made to reflect the more severe condition of Syria using all spring flow issuing above elevation 250. Under this condition, the mean annual runoff at Maqarin is estimated to be about 184 MCM per year.

Table C-2

HYDROLOGIC DATA FOR JORDAN VALLEY STREAMS

Location	Drainage Area (km^2)	Mean Annual Runoff (MCM)
Yarmouk River at		
Adasiye	6790	393.3 a/
Maqarin	5950	240.3 a/
Zarqa River at Deir Alla	3400	67.3
Sidi Wadis		
Wadi Arab	267	28.8
Wadi Ziglab	106	9.5
Wadi Jurum	20	11.2
Wadi Yabis	125	3.5
Wadi Kufrinja	111	6.1
Wadi Rajib	84	7.1
Wadi Shueib	178	7.9
Wadi Kafrein	163	14.3
Wadi Hisban	60	5.0

a/ Adjusted to include historical and anticipated future changes in upstream diversion

The runoff at the Kahlid site was computed by subtracting flows at Maqarin from those at Adasiye and reducing the resultant runoff by a ratio of the drainage area from Magarin to Khalid to the drainage area from Magarin to Adasiye. The mean annual runoff at Khalid is estimated to be about

368 MCM/yr. The runoff at the Mukheibeh site was assumed to be the same as at the Khalid site.

No adjustment was made to the water supply component of the water budget because of the increase in runoff from the reservoir area under Project conditions. This increase is negligible.

Reservoir Evaporation. The estimated reservoir evaporation was based on two years of data from Class A pan installations at the Irbid Nursery and Shuneh supplemented with long-time Piche evaporation measurements. Gross reservoir evaporation is estimated to be 1699 mm per year; after deducting mean monthly precipitation, the net annual average evaporation is 1275 mm. Table C-3 shows monthly evaporation and precipitation rates.

Table C-3

MONTHLY EVAPORATION AND PRECIPITATION

Month	Mean Precipitation[a/] (mm)	Mean Reservoir Evaporation (mm)	Net Reservoir Evaporation (mm)
January	114.5	49.5	(65.0)
February	53.5	49.5	(4.0)
March	86.4	79.5	(6.9)
April	30.4	127.5	97.1
May	1.5	213.0	211.5
June	0.0	238.5	238.5
July	0.0	259.5	259.5
August	0.0	214.5	214.5
September	0.0	175.5	175.5
October	15.1	147.0	131.9
November	38.7	90.8	52.1
December	83.7	54.0	(29.7)
Annual	423.8	1698.8	1275.0

a/ 1964-1971 Jordan Natural Resource Authority Records.

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Sedimentation. The minimum reservoir elevation used in the operation studies was based on an estimated rate of sediment deposition. For Stage II studies storage was provided for 50 years of sediment deposition; for Stage III studies, storage was provided for 100 years of deposition. The quantity deposited and the corresponding minimum reservoir elevation are shown in Table C-4. The basis for the estimates of sediment deposition is given in Appendix A, Hydrology.

Table C-4

SEDIMENT DEPOSITION

	Deposition MCM	Minimum Reservoir Elevation m
50-year Duration		
Maqarin Reservoir	45	90
100-year Duration		
Maqarin Reservoir	90	105
Khalid Reservoir	15	-54
Mukheibeh Reservoir	15	-107

Reservoir Area and Volume

The volume and area versus elevation curves for Maqarin, Khalid, Mukheibeh, and King Talal reservoirs are shown on Exhibit C-5. The curves for Maqarin reservoir and Khalid reservoir were taken from the Master Plan Report[2/]. The

2/ Yarmouk-Jordan Valley Project Master Plan Report, Appendix VI-D Project Description Harza Engineering Company, Michael Baker Jr., Inc., 1955.

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curve for Mukheibeh reservoir was taken from the Yarmouk Project report[3/]. The curve for the King Talal reservoir was taken from the Zarqa River Project Feasibility Study[4/]. The curves presented for Maqarin reservoir have been extrapolated above elevation 180 m as shown on the exhibit.

Irrigation Diversion Requirements

The irrigation requirements were estimated using the Blaney-Criddle method and crop factors modified to compensate for humidity and wind. Mean effective precipitation was assumed to equal 90 percent of the mean monthly precipitation, when the mean value was less than 50 mm, and 80 percent when the mean was more than 50 mm. The mean effective precipitation was multiplied by a probability factor to obtain the effective precipitation expected to be equalled or exceeded 80 percent of the time. The net irrigation requirements were computed by adding the crop consumptive use and a pre-irrigation application, and subtracting effective rainfall and a fraction of soil moisture depletion. These net irrigation requirements were increased to allow for an application efficiency (75 percent) and a conveyance efficiency (94 percent), yielding a system efficiency of 70 percent.

Detailed studies of cropping patterns, crop production, and crop water requirements are presented in Appendix G Agricultural Development. The water requirements used in the model to size the Project facilities are shown in Table C-5.

3/ The Yarmouk Project - Preliminary Study, Volume 3, Energoprojekt, 1964.

4/ Zarqa River Project, Feasibility Study General Report, Volume 1, Energoprojekt 1971.

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Table C-5

DIVERSION REQUIREMENTS

	North Area (m^3/ha)	South Area (m^3/ha)	Valley Average (m^3/ha)
January	340	560	450
February	530	700	615
March	780	1,020	900
April	1,020	1,120	1,070
May	1,070	1,210	1,140
June	1,110	1,180	1,145
July	1,000	1,040	1,020
August	1,030	1,110	1,070
September	1,090	1,140	1,115
October	1,070	1,180	1,125
November	650	800	725
December	410	660	535
Total	10,100	11,720	10,910

The Zarqa River has been assumed to be the demarcation between north and south zone requirements. The operation studies were done using the Valley average because the Project lands irrigated from Maqarin Reservoir are about equally divided, north and south of the Zarqa River.

In the sensitivity studies done for the Project evaluation, two other cropping patterns were considered. The first pattern represents a low summer water use condition, and the second a vegetable-intensive condition. The requirements for these patterns which are given below were used in an operation simulation to determine the shortages which might occur if the recommended Project facilities were available.

Month	Diversion Requirements (m^3/ha)	
	Low-Summer Use	Vegetable-Intensive
Jan	572	368
Feb	653	463
Mar	899	706
Apr	1,048	941
May	999	1,212
Jun	954	1,259
Jul	860	1,128
Aug	951	1,181
Sep	995	1,257
Oct	1,097	1,273
Nov	857	804
Dec	538	464
Total	10,423	11,056

The Stage II demands are met from three sources. The major source is the flow generated above Maqarin Dam which is controlled and released from the reservoir. The second source is the flow generated in the Yarmouk River watershed below Maqarin Dam, referred to as the interflow. This water is primarily made up of flows from the Wadi Raqqad and springs draining into the Yarmouk River. The third source is the small side wadis.

Municipal and Industrial Water Requirements

An allocation of water for municipal and industrial (M&I) use has been made for the Irbid Governorate and the Jordan Valley. M&I water includes domestic and industrial needs, and livestock watering. These requirement met without shortage.

The water requirements were based on estimates of population and daily use. Table C-6 shows these estimates and the annual requirements.

Table C-6

M&I WATER REQUIREMENTS

Year	Population	Per Capita Use l/c/d	Annual Water Requirement MCM/yr.
		Jordan Valley	
1976	70,000	70	1.8
1987	156,800	81	4.6
2000	230,300	94	8.0
		Irbid	
1976	150,000	80	4.4
1987	207,600	91	6.9
2000	304,000	104	12.0

The population of the Jordan Valley was estimated for 1976 and 1987 by the Jordan Valley Authority (JVA) in their Development Plan[5/]. The 1987 estimate was increased at a rate of three percent per year to arrive at the population in the year 2000. The Irbid population requiring project water was estimated to be 150,000 in 1976 and increased at a rate of three percent per year. Water use was estimated at 1976 levels for each area and increased 1.0 liter per capita per day (l/c/d) per year to arrive at an estimate for the year 2000.

5/ Jordan Valley Development Plan, 1975-1982, Jordan Valley Commission, November 1975.

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The operation studies of King Talal Dam include an allocation of 10 MCM/year for M&I use in Amman. It is assumed that the 10 MCM/yr represents a net depletion rather than the total diversion from the reservoir. Amman lies almost wholly within the Zarqa River watershed and it is assumed that all but 10 MCM/yr of the withdrawal will return to the system.

The monthly distribution of the M&I requirements for year 2000 are shown in Table C-7. These requirements were used in determining the Maqarin reservoir capacity for Stage II development.

Table C-7

M&I WATER SUPPLY IN YEAR 2000

	Amman a/ (MCM)	Irbid b/ (MCM)	Jordan Valley b/ (MCM)
January	0.30	0.72	0.48
February	0.30	0.72	0.48
March	0.50	0.84	0.56
April	0.72	0.96	0.64
May	1.23	1.20	0.80
June	1.23	1.20	0.80
July	1.33	1.32	0.88
August	1.33	1.32	0.88
September	1.23	1.20	0.80
October	0.83	0.96	0.64
November	0.50	0.84	0.56
December	0.50	0.72	0.48
Annual	10.00	12.00	8.00

a/ Supplied from the King Talal Reservoir.
b/ Supplied from the Maqarin Reservoir.

For ultimate development, 47 MCM per year were allocated to M&I use. The JVA has directed that a quantity of 30 MCM per year be available for use in the Irbid Governorate. The ultimate requirement of the Jordan Valley was based on a population of 300,000 persons and a per-capita use of 150 l/c/d which will be realized in about year 2060.

Downstream Releases

An annual release of 25 MCM will be made for use in the Yarmouk Triangle area. The quantity of the release was specified by the Jordan Valley Authority.

Shortage Allowance

The shortage allowance used in the operation studies was based on the number of months that less than 100 percent of the irrigation requirement was supplied. The allowable shortage was assumed to be six percent of the months in the 22-year period of record. It is expected that the projected with-project yields can be obtained, on the average, with this shortage. The degree and timing of the shortages for project conditions are shown on Exhibit C-6.

Power and Energy Criteria

To estimate the amounts of power and energy which could be developed from the Project facilities, the following criteria were assumed.

1. Energy would be generated using irrigation releases and uncontrolled releases up to the capacity of the turbines.
2. Plant efficiency would average 85 percent.
3. The coefficient of roughness in the water conductor would be 0.015.

Output

The model output consists of a summary of the irrigation and M&I requirements, shortages, irrigated area, and the maximum reservoir elevation. In addition, the irrigation release, spill, average monthly surface elevation, monthly power production, monthly energy production, irrigation shortages, and system waste are shown for each month of the operation period. The computer output for the reservoir operation study which was used to select the reservoir size for Stage II development is shown on Exhibit C-7.

Study Results

Operation studies were done to estimate storage requirements for both Stage II and Stage III development, for alternatives to Stage II development, and to evaluate existing and transition period conditions. Storage for 50 years and 100 years of sediment accumulation were included for Stage II and Stage III respectively, two diversion conditions were analyzed, and two M&I requirements were considered.

Irrigation

The operation studies determined the storage required at Maqarin Reservoir to irrigate the Stage II service area (25,353 ha) in conjunction with the interflow and side-wadi flow. This area, together with the area irrigated from Stage I development (10,647 ha), meets the Stage II goal of irrigating 36,000 ha. In addition, the operation model determined the largest area that can be irrigated using all the water available. Several alternatives were also studied in order to determine the staging of the project. The results of these studies are described below.

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Operation for Stage II Development. The following tabulation shows the areas irrigated and the source of irrigation water.

Project	Area in ha	Source of Water
Kafrein-Hisban	1,560	Wadis Kafrein, Hisban
King Talal Dam	5,077	Zarqa River
NEG Project	2,760	Wadis Arab, Ziglab, Jurum
Wadi Arab Dam	1,250	Wadi Arab
Stage II	25,353	Yarmouk River, Wadis Yabis, Rajib, Kufrinja
Total	36,000	

Stage II demand can be met with Maqarin Reservoir at El. 150. A curve of Stage II area irrigated versus normal maximum water surface elevation at Maqarin Dam is shown on Exhibit C-8. A tabulation of reservoir data is shown below:

Crest Elevation m	Reservoir Elevation m	Total Storage MCM	Active Storage MCM
158	150	320	275

Table C-8 shows the disposition of the useable flow from all major water sources in the Valley under Stage II development conditions.

Table C-8

DISPOSITION OF FLOW UNDER STAGE II CONDITIONS

Source	Average Flow (MCM/yr)	Regulated or Useable Flow (MCM/yr)	Average Spill (MCM/yr)	Evaporation (MCM/yr)
Maqarin Reservoir	240.3	209	25.0	6.3
Interflow	153.0	93	60	
Side Wadis	93.4	11[a/]		
Zarqa River	67.3	1[a/]		
Total	554.0	314		
M&I Demand		20 MCM/yr		
Irrigation Demand (25,353 ha)		277 MCM/yr		
Yarmouk Triangle Releases		25 MCM/yr		
Total		322		
Average Irrigation Shortage		8 MCM/yr		

a/ Remaining flow after meeting requirements of Stage I Projects.

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During the period of operation, the reservoir spilled in five years and was drawn down to the minimim operating level five times. The maximum shortage in one water year was equal to 25 percent of the annual irrigation requirement and the maximum one-month shortage was equal to 60 percent of the requirement. The maximum consecutive two-year shortage was equal to 22 percent of the annual irrigation requirement. The average irrigation shortage over 22 years was equal to about 2.7 percent of the annual requirement. Average monthly reservoir elevation is shown on Exhibit C-9.

A curve of total area irrigated in the Jordan Valley versus volume in the Yarmouk River storage facilities is shown on Exhibit C-10.

If, as discussed previously and in Appendix A, Hydrology, all spring flow issuing above elevation 250 is diverted away from the Yarmourk River, irrigation shortages would occur on the Project lands about 32 percent of the time. If the allowable shortage criterion is maintained, 17,700 ha could be irrigated.

Operation for Stage III Development. Stage III development will provide control and regulation of as much of the Yarmouk River as is technically and economically feasible. From Exhibit C-8 the storage required to regulate essentially all of the water developed above the Maqarin site is provided by a reservoir at El. 193. A study was done to evaluate a project with Maqarin Reservoir raised to reservoir El. 193 and a storage project at the Khalid site or the Mukheibeh site. Storage for 100 years of sediment accumulation was included in the storage requirements for the reservoirs and releases totaling 47 MCM per year were made for M&I uses. The downstream releases were maintained at 25 MCM/yr. The

maximum area that can be irrigated from the combined operation of Maqarin Dam, and a downstream dam, the interflow, and the available side-wadi flow is 30,500 ha. A tabulation of reservoir data is given below:

Reservoir	Reservoir Elevation (m)	Total Storage (MCM)	Active Storage (MCM)
Maqarin	193	720	630
and Khalid	12	310	295
or Mukheibeh	-39	310	295

Table C-9 shows the disposition of useable flow of the major water sources under Stage III conditions.

Table C-9

DISPOSITION OF FLOW UNDER STAGE III CONDITIONS

	Average Flow (MCM/yr)	Regulated or Useable Flow (MCM/yr)	Average Spill (MCM/yr)	Average Evaporation (MCM/yr)
At Khalid	367.8	357 a/	0	10.8
Interflow	25.9	24	1	
Side Wadis	93.4	11 b/		
Zarqa River	67.3	1 b/		
Total	554.0	393		
M&I Demand		47 MCM/yr		
Irrigation Demand (30,500 ha)		332 MCM/yr		
Yarmouk Triangle Releases		25 MCM/yr		
Total		404 MCM/yr		
Average Irrigation Shortage		11 MCM/yr		

a/ Includes releases from Maqarin.
b/ Remaining flow used in Stage I Projects.

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Alternatives. For alternative 1, the diversion dam at Adasiye was replaced by two uncontrolled intakes to the EGMC. The uncontrolled intakes would have a overall diversion efficiency of 90 percent. Under this condition the requirements of Stage II development can be met with Margin Reservoir at El. 160.

Alternative 2 consists of a trans-basin diversion to the Wadi Arab Reservoir. The required reservoir storage at margarin for this alternative would be the same as for the recommended plan.

Transition From Stage I to Stage II Development. For the period prior to conversion from surface to sprinkler methods, operation studies were made using a cropping pattern and an irrigation efficiency reflecting present conditions in the Valley. The 1974-1975 cropping pattern for the Valley, as reported in the Development Plan[6/], was used with the irrigation requirements computed for the Stage II studies. The irrigation efficiency is estimated to be 50 percent. This estimate was based on water delivery records for the EGMC in 1966 and on-farm studies done for the Agro- and Socio-Economic Study[7/]. The diversion requirements are shown below:

Diversion Requirements - Present Conditions (MCM)

Jan	Feb	Mar	Apr	May	Jun	Jul
630	680	840	1,290	1,280	920	720
Aug	Sep	Oct	Nov	Dec	Annual	
910	1,280	1,370	1,190	600	11,710	

6/ See footnote 5.

7/ Jordan Valley Project Agro- and Socio-Economic Study Final Report, Vol. I, Main Report, Dar Al-Handasah NEDECO, 1969.

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The flow passing the existing intake to the EGMC on the Yarmouk River was assumed to equal 30 percent of the flow in the river. This assumption is consistent with the operation records supplied by the JVA.

After completion of the East Ghor Canal Project and the 8-Km Extension Project, the operation simulation indicates that enough water was available to supply the irrigation requirements for 13,757 ha with only minor shortages. During the 22-year operation period, shortages occurred only in nine months. A substantial portion of the requirements was met from the Zarqa River and the side-wadis. If actual shortages were more severe than indicated by the simulation, it is likely that the diversion assumptions used in the operation study were not met or that a portion of the supply was used for other than irrigation uses.

After construction of the King Talal Project and the NEG Project, the contribution of the Zarqa River and Wadis Arab, Jurum, and Ziglab to the irrigation supply would be virtually eliminated and the irrigation area would be reduced to 12,757 ha. With the existing intake facilities to the EGMC, irrigation shortages would occur about 14 percent of the months. If a diversion dam were constructed at the intake, the occurrence of shortages would be reduced to about 11 percent of the time.

After conversion from surface methods to sprinkler irrigation, the irrigation area would increase to 13,672 ha as explained earlier. Using the current diversion criteria, shortages would occur about 20 percent of the time. If the intake was modified to allow diversion of 90 percent of the river flow, shortages would occur 17 percent of the time. With a diversion dam at the intake to the EGMC, shortages

would occur 14 percent of the time. In the latter two cases, provision was made for a release of 25 MCM/yr below the intake. No provision was made for any non-irrigation use.

After completion of Wadi Arab Dam, the area converted to sprinkler irrigation would be reduced by 830 ha to 12,842 ha - the Stage II level of development. Under current diversion conditions, shortages would occur 13 percent of the time; with a modified intake structure the shortages could be reduced to 10 percent of the time; and with a diversion dam, shortages would be reduced further to about 6 percent of the time - which is the allowable shortage criteria used in sizing Maqarin Reservoir.

Power and Energy

The computer model was also used to determine the monthly average power and the total monthly energy production for all of the schemes.

Energy production was calculated using the required releases and the uncontrolled releases up to the maximum of 20 m^3/s. The turbines are sized to match the maximum irrigation and M&I demand. It was assumed for the studies that all of the irrigation releases will be discharged through the powerplant. The M&I requirements for the Jordan Valley also will be released through the powerplant; however, the M&I allocation for Irbid will be taken directly from the reservoir.

Stage II Development. The powerplant at Maqarin Dam will be located approximately 2.0 km downstream of the dam. Average tailwater level is at El. 8 Maximum and minimum reservoir elevations are El. 150 and El. 90 respectively. The installed capacity of the plant is 20 MW. Average annual energy production will be 58 GWh.

The King Talal powerplant will be located immediately downstream from the dam. The reservoir was operated between the design estimates of maximum and minimum pool, El. 164 and El. 123 respectively. The average tailwater level is about El. 80, based on available mapping. Installed capacity will be 2.0 MW and the average annual energy will be 8.7 GWh.

Stage III Development. At ultimate development, the powerplant at Maqarin will be increased to an installed capacity of 28 MW and a powerplant will be constructed at the downstream Reservoir.

The Khalid powerplant will be located immediately downstream from the dam and the tailwater is estimated to be at El. -78 Khalid Reservoir was operated in conjunction with Maqarin Reservoir at El. 193 and the Khalid Reservoir at El. 12. The maximum pool at Khalid Reservoir will be at El. 12 and the minimum pool at El. -54. Installed capacity of the powerplant will be 10 MW. Average annual energy will be 23 GWh. Under Stage III conditions, the Marqarin powerplant will generate an average of 71 GWh per year. The combined annual average energy of the Maqarin and Khalid powerplants will be 94 GWh. The King Talal powerplant will not be modified. The total installed capacity of the three plants will be 40 MW, producing an average of 102.7 GWh per year.

Alternatives. The alternative to the Stage II power development is a powerplant located on the Wadi Arab reservoir. The powerplant was located at the end of a 25 km conveyance tunnel which is hydraulically connected to Maqarin Reservoir. The maximum elevation of the Maqarin reservoir was at El. 150 and the tailwater was assumed to equal the maximum elevation of Wadi Arab Reservoir (El. -115.5) into

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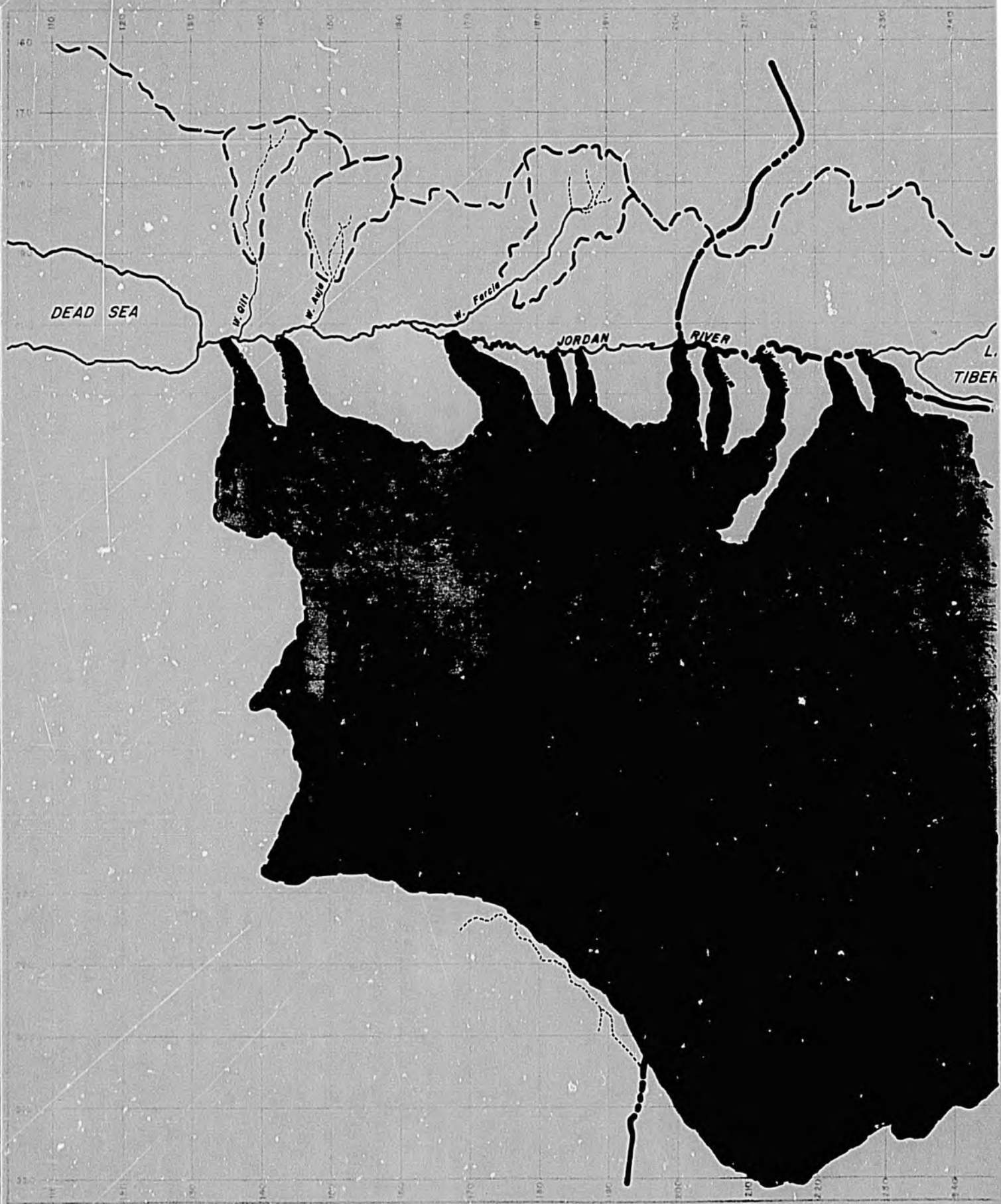
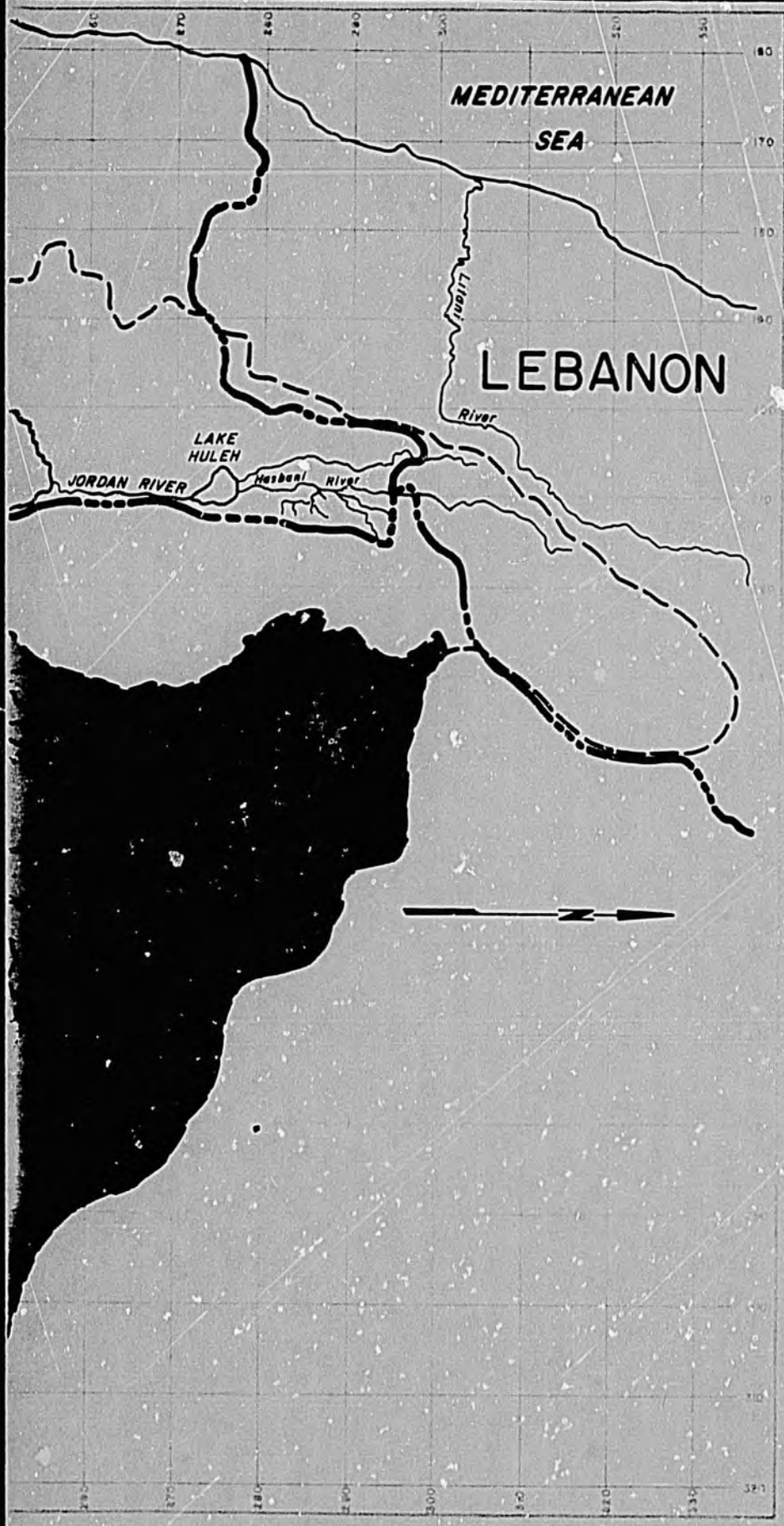
which the power releases were made. Installed capacity will be 40 MW; producing an annual average energy of 85 GWh.



HARZA OVERSEAS ENGINEERING COMPANY JANUARY 1978

EXHIBIT C-1



LEGEND

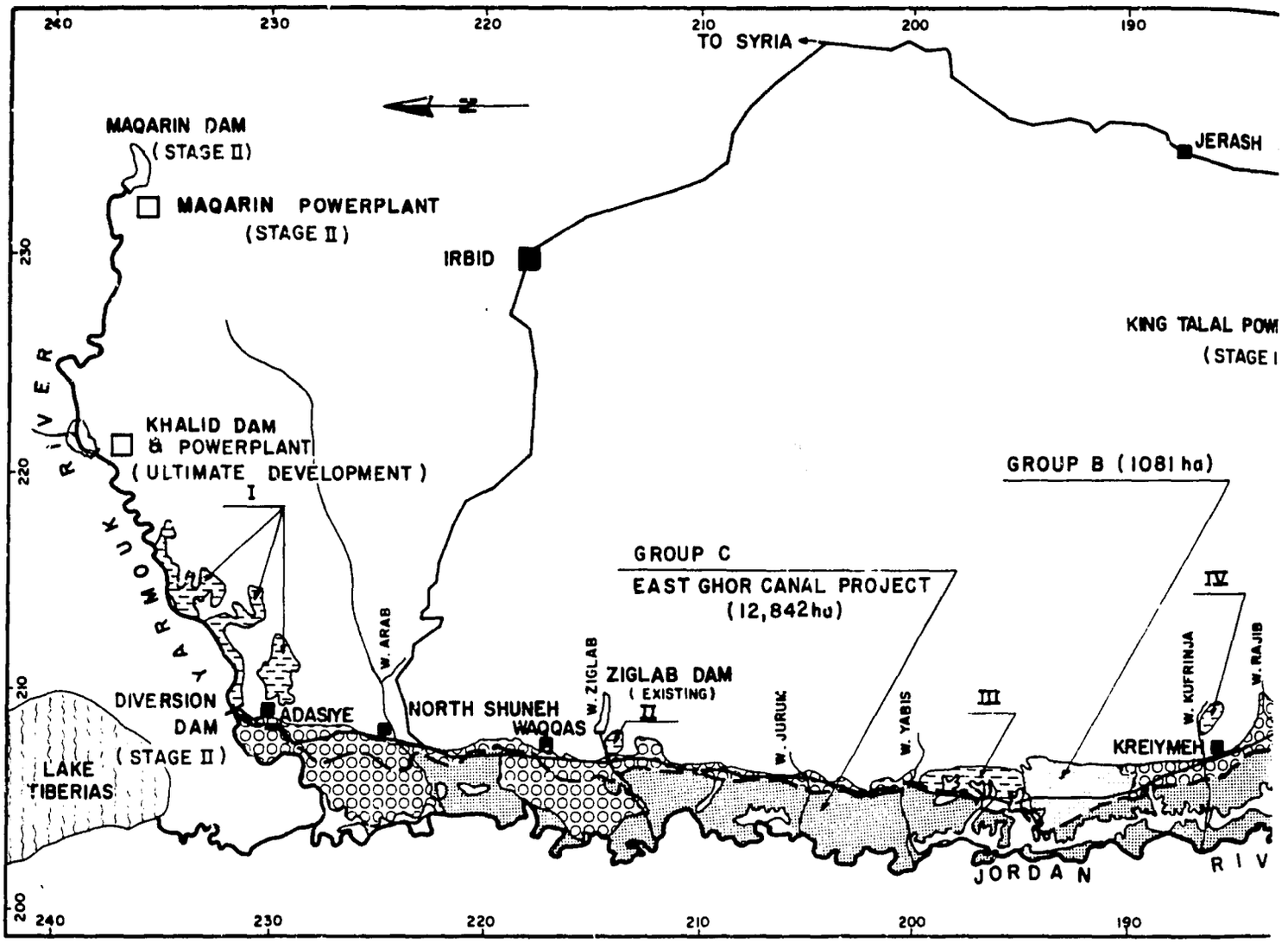
DRAINAGE BASIN BOUNDARIES

INTERNATIONAL BOUNDARIES

INTERMITTANT STREAMS

SCALE 0 20 KILOMETERS

JORDAN RIVER
DRAINAGE BASIN BOUNDARIES
JORDAN VALLEY IRRIGATION PROJECT
STAGE II



LEGEND

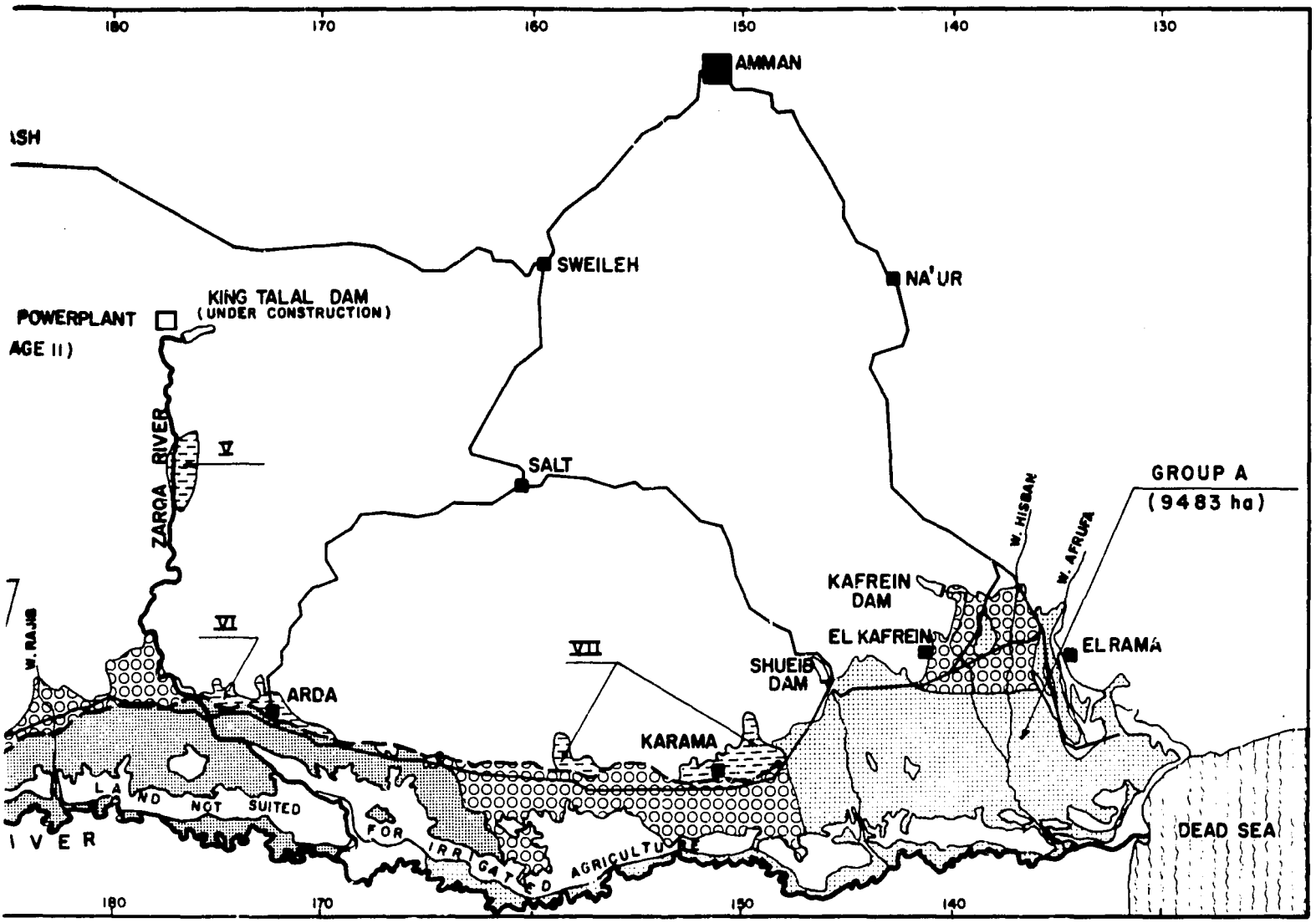
- ROADS
- EAST GHOR MAIN CANAL
- RIVERS
- STAGE I PROJECTS
- STAGE II - NEW LANDS - GROUPS A & B
- STAGE II - CONVERSION LANDS - GROUP C
- STAGE II - POTENTIALLY IRRIGABLE LANDS - GROUP D

NOTES

1 - GRID FIGURES ARE
2 - POTENTIAL AREAS

I - YARMOUK GOR
II - ZIGLAB GORG
III - BETWEEN KUFR
IV - KUFRINJA GOR
V - ZARQA GORGE
VI - SOUTH OF ZAR
VII - ABOVE 18 Km EX

Dar Al - Handasah Consultants (Shair and Partners) January 1978



STAGE II PROJECT AREA

	HECTARES
CONVERSION LANDS (INCLUDES UPGRADED AREAS)	12,842
NEW LANDS	10,564
POTENTIALLY IRRIGABLE LANDS	1,947
TOTAL	25,353

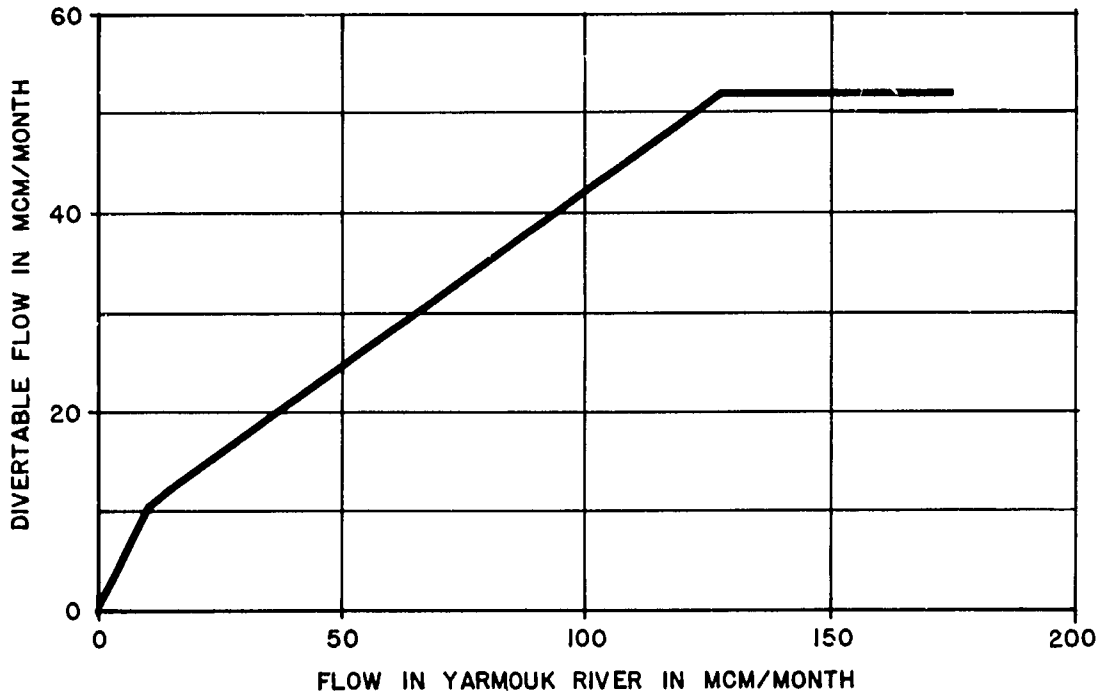
TOTAL AREA

ON GOING PROJECTS	9,397
JAPANESE PROJECT ON WADI ARAB	1,250
STAGE II LANDS	25,353
TOTAL	36,000

ARE KILOMETERS
AS INCLUDE

	HECTARES
GORGE	331
ORGE	50
UFRINJA & YABIS	432
GORGE	100
RGE	216
ZARQA	293
n EXTENSION	525
TOTAL	1947

GENERAL PLAN OF DEVELOPMENT
JORDAN VALLEY IRRIGATION PROJECT
STAGE II



DIVERTABLE FLOW AT EGMC INTAKE NEAR ADASIYE

JORDAN VALLEY IRRIGATION PROJECT
STAGE II

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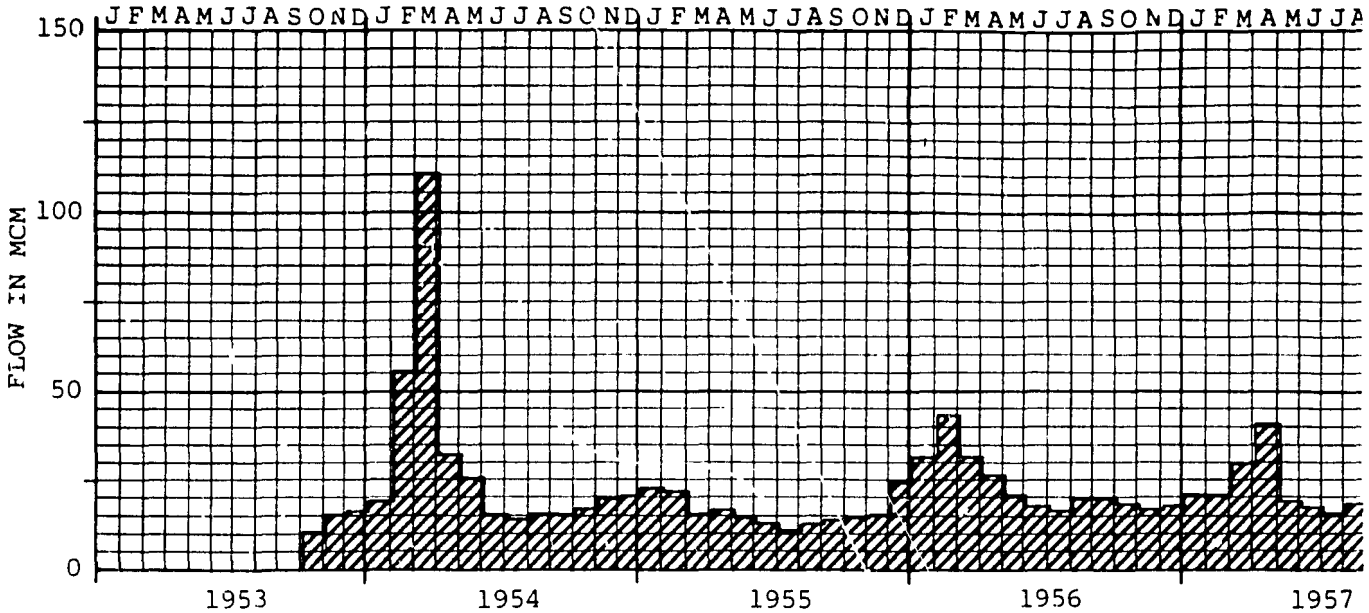
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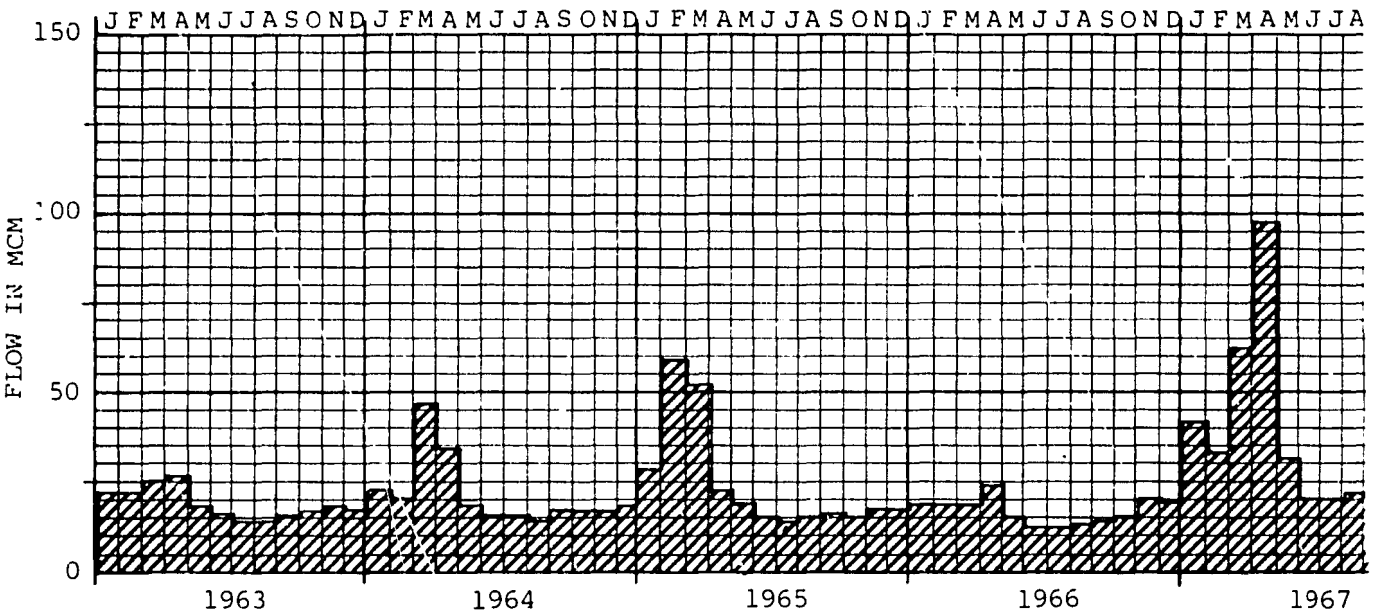
150
100
50
0
FLOW IN MCM
1953
1954
1955
1956
1957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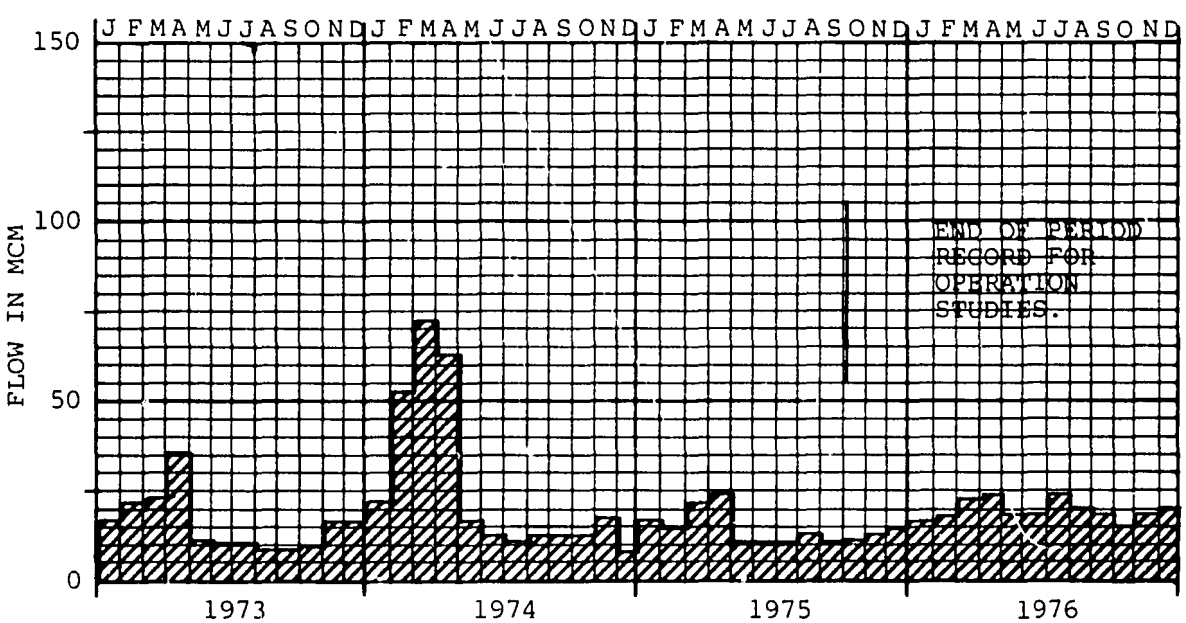
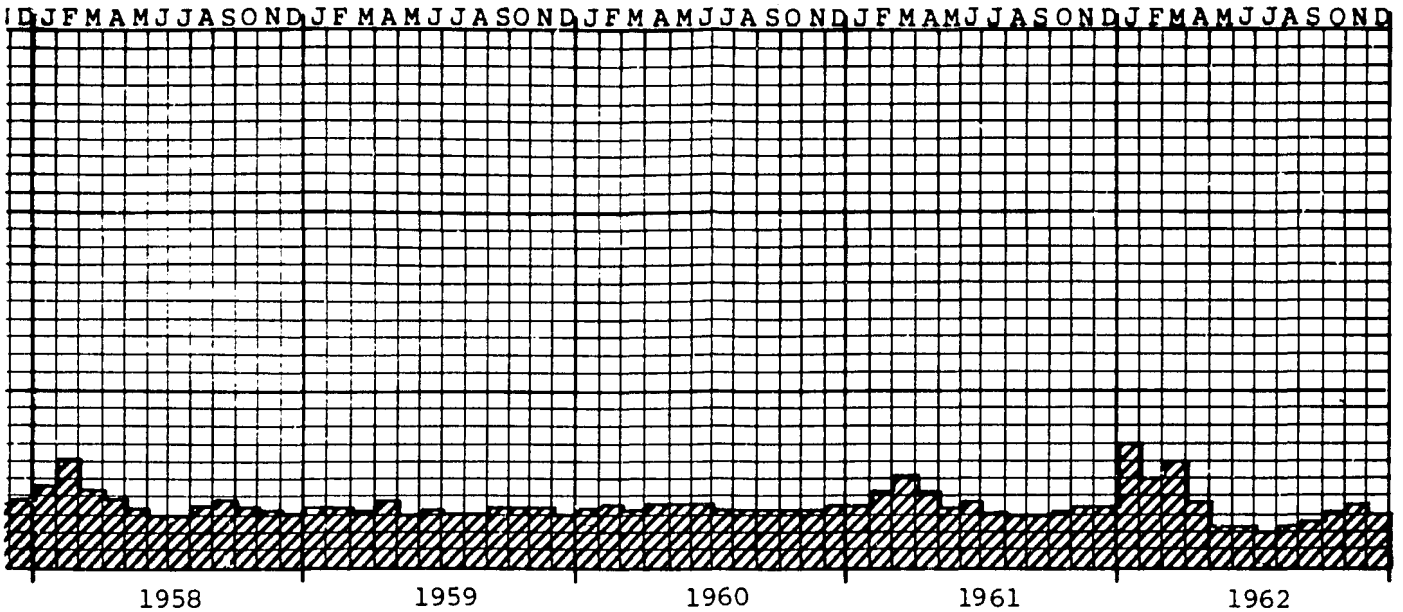
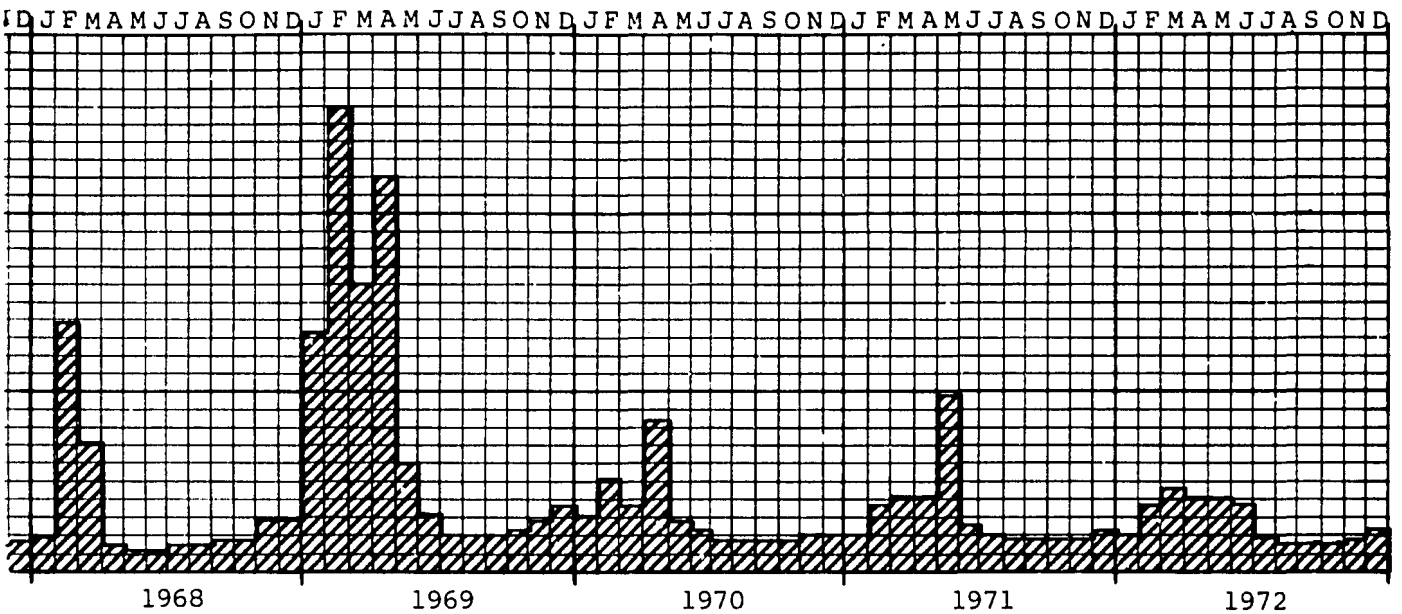
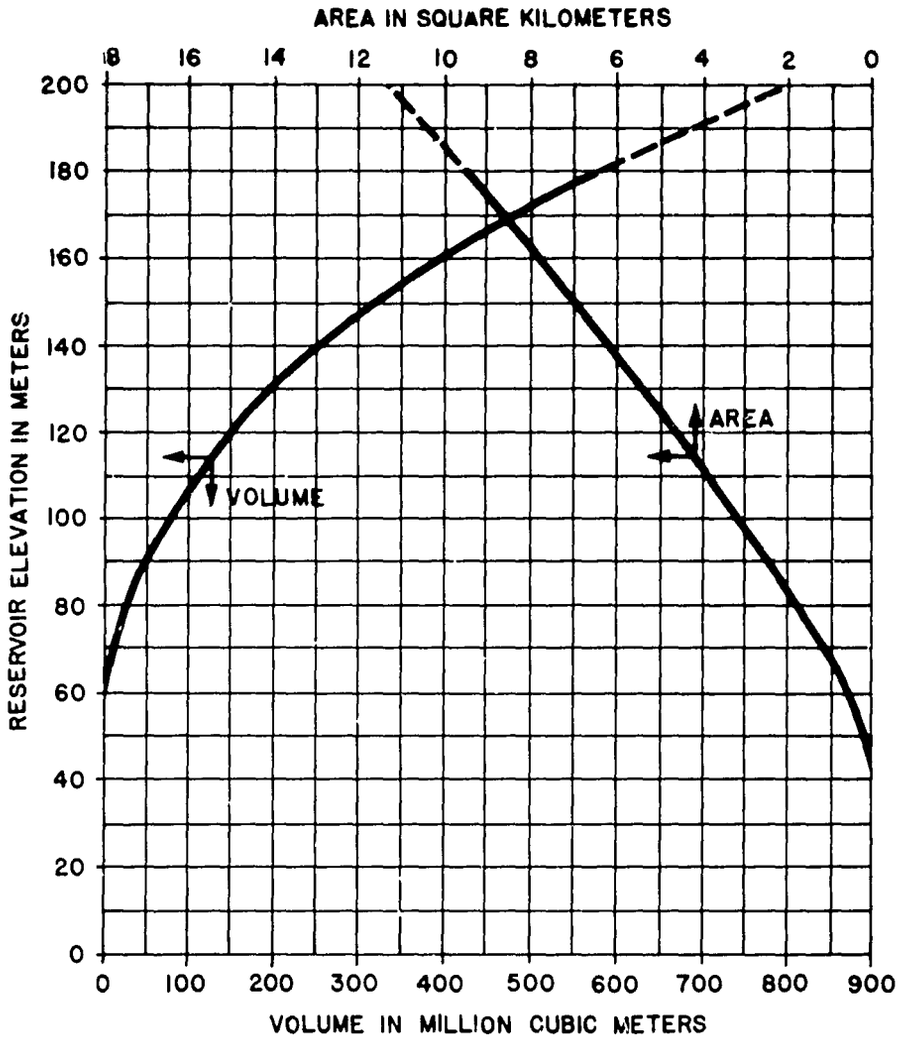
150
100
50
0
FLOW IN MCM
1963
1964
1965
1966
1967


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
150
100
50
0
FLOW IN MCM
END OF PERIOD
RECORD FOR
OPERATION
STUDIES.
1973
1974
1975
1976

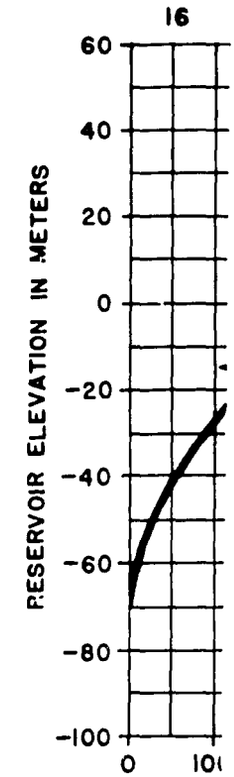


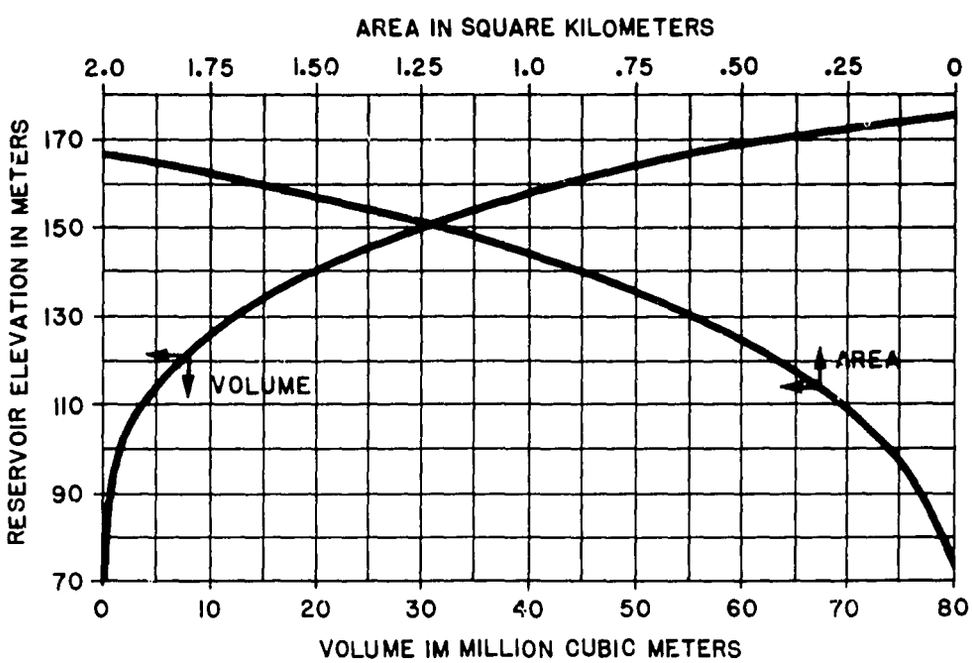


MONTHLY STREAMFLOW
YARMOUK RIVER AT MAQARIN
JORDAN VALLEY IRRIGATION PROJECT
STAGE II

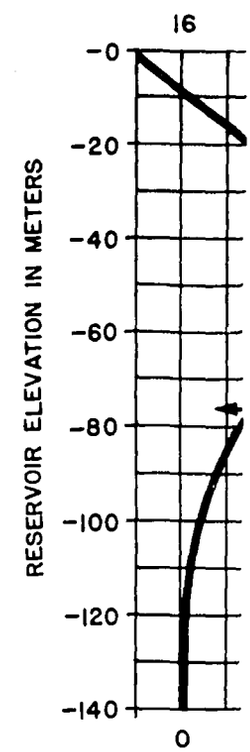


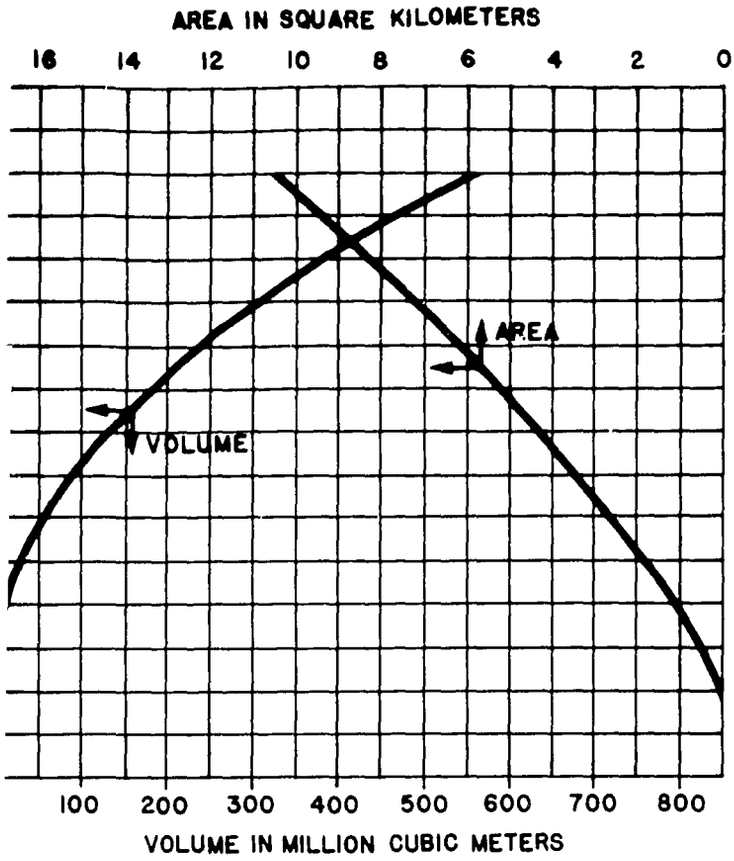
MAQARIN RESERVOIR



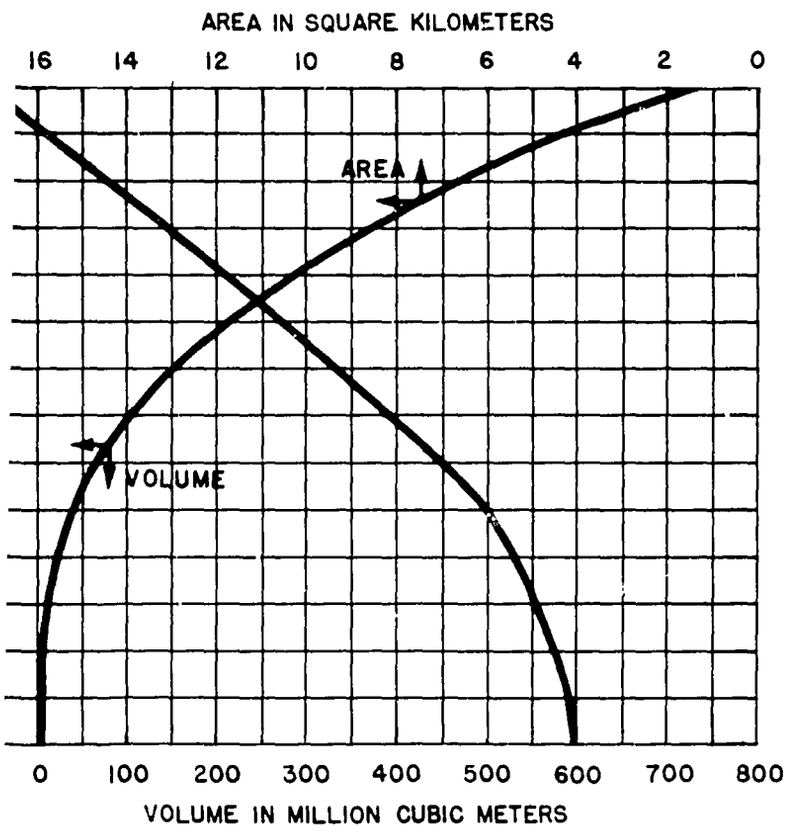


KING TALAL RESERVOIR





KHALID RESERVOIR



MUKHEIBEH RESERVOIR

LEGEND

- - - - EXTRAPOLATION
——— DATA FROM SOURCE DOCUMENTS

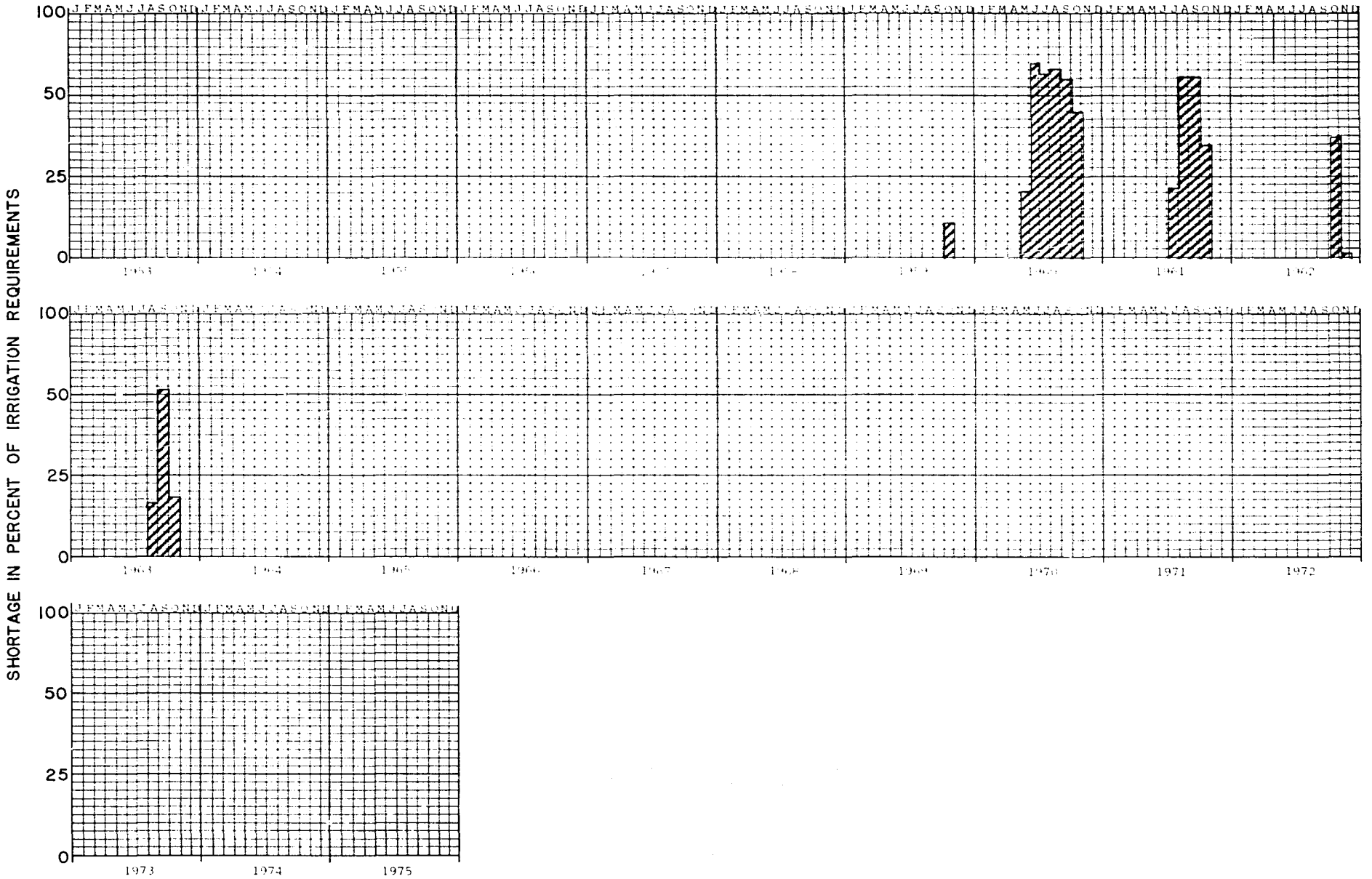
SOURCE DOCUMENTS

MAQARIN AND KHALID RESERVOIRS:	YARMOUK-JORDAN VALLEY PROJECT, MASTER PLAN REPORT, APPENDIX VI-D, PROJECT DESCRIPTIONS, HARZA ENGINEERING COMPANY MICHAEL BAKER JR., INC., 1955.
KING TALAL RESERVOIR:	ZARQA RIVER PROJECT, A FEASIBILITY STUDY, GENERAL REPORT, VOLUME I, ENERGOPROJEKT, 1971.
MUKHEIBEH RESERVOIR:	THE YARMOUK PROJECT, PRELIMINARY STUDY, VOLUME 3, ENERGOPROJEKT, 1964.

PROJECT RESERVOIRS AREA AND VOLUME

JORDAN VALLEY IRRIGATION PROJECT
STAGE II

EXHIBIT C-6



IRRIGATION SHORTAGE

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

HARZA OVERSEAS ENGINEERING COMPANY · JANUARY 1978

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MAQARIN RESERVOIR OPERATION STUDY. MAXIMUM RESERVOIR VOLUME = 320.25. ELEV= 150.00

RESERVOIR ELEVATION-VOLUME-AREA DATA

ELEVATION	40.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0	180.0	190.0	200.0
VOLUME	.00	10.76	24.42	45.03	72.37	107.86	150.04	199.36	255.77	320.25	394.05	477.27	569.53	688.00	806.00
AREA	.000	1.000	1.733	2.477	3.158	3.901	4.577	5.409	5.996	7.000	7.861	8.727	9.513	10.400	11.310

THE MINIMUM VOLUME IS 45.000
THE MAXIMUM VOLUME IS 320.250

YARMOUK RIVER STREAMFLOW RECORD AT MAQARIN

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL INFLOW
1	0	11.90	16.00	19.00	55.00	110.00	33.00	22.00	8.70	7.90	8.20	8.20	9.90	309.80
2	0	15.90	20.00	22.00	21.00	15.00	16.00	11.20	7.10	5.30	5.70	6.70	8.30	154.20
3	0	12.10	24.00	31.00	42.00	31.00	26.00	18.40	12.60	11.80	13.20	13.20	13.80	249.10
4	0	16.30	19.00	23.00	23.00	30.00	41.00	17.60	13.00	12.20	13.70	13.70	13.20	235.70
5	0	16.50	20.00	24.00	31.00	23.00	20.00	15.80	11.50	11.70	13.20	13.20	12.70	212.60
6	0	14.80	16.00	17.00	17.00	16.00	19.00	14.00	13.00	12.10	11.60	12.60	13.10	176.20
7	0	15.00	16.00	17.00	18.00	17.00	18.00	16.30	14.40	13.50	12.10	13.10	12.50	182.90
8	0	15.20	18.00	19.00	23.00	27.00	23.00	17.50	16.90	14.00	12.60	12.60	14.00	212.80
9	0	17.70	18.90	36.40	27.60	31.00	20.60	13.00	11.80	11.10	11.60	13.20	15.50	228.40
10	0	19.00	16.50	21.50	21.40	25.60	25.80	16.00	14.10	12.20	12.00	13.80	15.00	212.90
11	0	16.30	17.00	22.10	19.70	45.90	34.80	16.50	14.30	13.00	12.50	14.10	14.30	240.50
12	0	15.20	17.20	28.10	58.50	51.10	22.30	18.00	14.60	13.20	14.10	14.40	14.20	280.90
13	0	16.20	15.80	17.70	17.20	17.80	24.20	14.70	11.10	11.00	11.40	12.00	13.90	183.00
14	0	20.00	18.80	41.80	34.20	62.30	98.60	30.90	18.70	19.50	21.70	24.40	24.50	415.40
15	0	7.40	9.20	11.70	69.20	37.80	9.00	7.70	7.70	8.90	8.30	9.60	10.80	197.30
16	0	16.20	17.30	67.40	141.90	81.80	112.30	30.60	16.10	11.60	11.80	12.40	12.30	531.70
17	0	15.40	19.60	17.50	27.30	21.50	44.80	15.00	13.00	10.90	11.20	11.20	10.90	218.30
18	0	11.80	11.80	12.20	20.30	22.90	24.60	49.20	14.00	11.00	10.40	10.90	10.70	209.80
19	0	11.30	14.20	13.20	19.70	24.70	18.80	17.70	16.30	11.10	9.80	10.80	10.70	178.30
20	0	11.10	13.90	16.70	20.90	23.50	34.90	11.40	9.70	9.20	8.00	7.90	8.30	175.50
21	0	16.10	16.70	23.60	53.30	71.20	62.40	17.00	13.00	10.80	10.20	10.70	11.20	316.20
22	0	16.10	8.00	17.20	15.40	21.80	24.10	10.90	10.40	10.60	12.50	9.70	10.40	167.10

MODEL OUTPUT
JORDAN VALLEY IRRIGATION PROJECT
STAGE II

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THE CONTRIBUTION OF THE SIDE WADIS IS

		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL
1	0	.700	.800	2.897	3.600	3.600	3.284	.900	.900	.900	.900	.900	.800	20.180
2	0	.800	.800	.800	.900	.900	.800	.800	.700	.600	.500	.500	.500	8.598
3	0	.600	.900	.900	.900	.900	.900	.900	.900	.800	.800	.700	.800	9.999
4	0	.800	.800	.800	.900	.900	.900	.900	.900	.900	.800	.800	.800	10.199
5	0	.800	.900	.900	.900	3.600	.900	.900	.800	.800	.600	.600	.600	12.298
6	0	.700	.700	.700	.900	.900	.900	.900	.600	.500	.500	.600	.500	8.598
7	0	.500	.600	.700	.800	.800	.800	.700	.600	.600	.600	.600	.600	7.897
8	0	.700	.900	.900	.900	.900	.900	.900	.700	.700	.600	.600	.700	9.398
9	0	.700	.700	.900	.900	.900	.900	.900	.900	.700	.700	.700	.700	9.598
10	0	.900	.800	.900	.900	.900	.900	.700	.700	.600	.600	.600	.600	9.098
11	0	.700	.900	.900	.900	3.600	3.600	1.507	.900	.900	.900	.800	.600	16.405
12	0	.800	.900	.900	3.600	3.600	.700	1.890	.700	.800	.800	.600	.600	16.288
13	0	.800	.900	.900	.600	.800	.700	.800	.800	.600	.700	.700	.700	8.998
14	0	.700	.700	.600	.900	.900	.900	.900	.900	.900	.900	.800	.600	9.899
15	0	.900	.900	.900	.900	.900	.900	.900	.800	.700	.700	.700	.700	9.899
16	0	.700	.700	.800	.600	.700	3.600	2.307	.900	.900	.900	.600	.600	15.905
17	0	.800	.900	.600	.900	.900	.900	.900	.800	.900	.800	.800	.700	9.899
18	0	.800	.700	.900	.900	.900	.900	.900	.900	.900	.900	.800	.700	10.199
19	0	.800	.800	.900	.900	.700	.900	.900	.900	.900	.900	.900	.600	10.299
20	0	.800	.800	.800	.800	.800	.900	.800	.800	.900	.900	.800	.900	9.999
21	0	.900	.800	.800	3.600	3.600	3.600	3.600	.800	.800	.600	.800	.600	20.899
22	0	.800	.800	.800	.800	.900	.900	.800	.900	.900	.900	.800	.900	10.199

MODEL OUTPUT

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

INTERFLOW DIVERTED EGMC (MCM)

		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	
1	0	6.900	9.580	12.900	44.450	45.930	14.380	17.220	5.950	4.250	4.280	5.170	5.110	176.120
2	0	5.100	4.250	6.180	7.050	7.890	11.980	7.700	5.950	7.850	7.880	7.870	6.010	85.710
3	0	6.000	5.150	21.560	29.350	19.310	14.380	5.900	6.850	4.250	2.470	2.470	2.410	120.100
4	0	3.300	2.450	1.680	14.460	23.330	15.180	5.200	.550	1.550	.670	1.570	1.510	69.450
5	0	2.400	1.550	10.500	35.770	8.790	5.350	3.200	5.950	4.250	.670	1.570	3.310	81.310
6	0	5.100	4.250	5.280	8.850	20.110	18.090	5.900	2.350	2.450	2.470	2.470	5.310	80.630
7	0	4.200	4.250	4.380	7.950	4.290	4.250	2.300	.550	.650	1.570	.670	2.410	37.470
8	0	1.500	3.350	3.480	4.350	19.310	.650	1.400	5.950	.650	1.570	1.570	.610	44.390
9	0	2.130	3.890	24.680	18.970	24.950	6.230	2.930	3.340	3.800	2.740	1.570	1.240	98.470
10	0	.060	1.550	1.680	21.400	20.150	17.570	2.930	4.780	1.100	1.660	1.300	.790	74.970
11	0	8.070	7.310	14.340	9.500	33.430	26.950	14.170	13.810	13.740	13.200	12.550	11.700	178.770
12	0	12.100	19.090	17.430	30.090	33.190	15.260	15.610	12.290	11.420	11.760	11.910	12.160	202.330
13	0	11.140	10.380	10.180	18.530	20.950	19.210	12.410	12.850	11.420	11.520	12.390	13.220	164.200
14	0	8.340	10.860	19.270	29.350	30.350	41.690	19.460	11.650	7.490	5.800	3.730	3.490	191.480
15	0	8.340	8.300	2.940	1.380	4.290	23.620	7.790	7.030	5.510	5.710	.670	.610	76.190
16	0	4.920	5.240	18.390	26.860	20.350	23.710	9.370	5.050	3.710	3.830	4.000	3.850	129.280
17	0	4.650	5.960	5.370	8.490	6.540	13.340	4.460	4.060	3.440	3.640	3.640	3.400	66.990
18	0	10.420	25.390	28.220	1.380	17.630	34.920	1.400	15.250	7.130	17.560	18.460	15.620	193.400
19	0	3.390	4.250	14.180	13.420	21.680	7.760	2.480	.550	1.370	3.370	2.470	1.690	76.610
20	0	3.300	4.160	5.100	6.420	7.260	10.540	3.290	2.980	2.900	2.560	2.560	2.590	53.660
21	0	5.460	8.210	12.100	15.820	18.870	17.610	5.090	4.060	3.440	3.280	3.460	3.490	100.890
22	0	5.460	2.360	5.280	4.710	6.630	7.310	3.200	3.250	3.350	4.000	3.100	3.310	51.960

YARMOUK TRIANGLE REQUIREMENTS (MCM)

		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	
1	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
2	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
3	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
4	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
5	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
6	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
7	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
8	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
9	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
10	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
11	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
12	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
13	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
14	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
15	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
16	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
17	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
18	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
19	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
20	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
21	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000
22	0	2.800	-.000	-.000	-.000	-.000	-.000	-.000	2.800	3.200	6.500	6.500	3.200	25.000

MODEL OUTPUT

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

THE IRRIGATED AREA IS 25022.00 HECTARES

	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL
THE UNIT IRRIGATION REQUIREMENTS ARE (MCM/HA)													
	.0011	.0007	.0005	.0004	.0006	.0009	.0011	.0011	.0011	.0010	.0011	.0011	
THE IRRIGATION REQUIREMENTS ARE (MCM)													
	28.07	18.12	13.46	11.23	15.39	22.54	26.82	28.53	28.63	25.50	26.77	27.90	272.96
THE JORDAN VALLEY MUNICIPAL REQUIREMENTS ARE (MCM)													
	.65	.41	.41	.24	.24	.42	.49	1.00	1.00	1.07	1.07	1.00	8.00
JORDAN VALLEY DEMAND (MCM)													
	28.72	18.53	13.87	11.47	15.63	22.96	27.31	29.53	29.53	26.57	27.84	28.90	280.96
IRBID WITHDRAWLS (MCM)													
	.97	.61	.61	.36	.36	.60	.74	1.51	1.51	1.61	1.61	1.51	12.00

****

SHORTAGES OCCUR IN 16 OUT OF 264 MONTHS (6.06 PERCENT OF THE TIME)
TARGET PERCENTAGE = 6.00 TOLERANCE = .50 RESERVOIR ELEV. MAXIMUM/ START= 150.00 / 109.00
IRRIGATED AREA = 25022.0 HECTARES [a] ITERATION NUMBER 0

****

ICOUNT	X	K1	K2	Y	D	S	T	TOL	PCT
0	25022.00	0	0	.06	1251.10	1	6.00	.50	6.06

IRRIGATION RELEASE (MCM)

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL RELEASE
1	0	23.92	8.15	.00	.00	.00	5.30	9.19	25.48	27.68	27.89	28.27	26.19	182.07
2	0	25.62	13.48	6.89	3.52	6.84	10.19	18.81	25.68	24.38	24.69	25.97	25.59	211.66
3	0	24.93	12.48	.00	.00	.00	7.68	20.51	24.58	27.78	29.80	31.17	28.89	207.81
4	0	27.42	15.28	11.39	.00	.00	6.88	23.21	30.88	30.38	31.60	31.97	29.79	238.80
5	0	28.32	16.08	2.47	.00	3.24	18.71	23.21	25.58	27.78	31.80	32.17	28.19	237.55
6	0	25.73	13.58	7.89	1.72	.00	3.97	20.51	29.38	29.68	30.10	31.27	15.09	209.12
7	0	13.70	13.68	8.79	2.72	10.54	17.91	24.31	31.18	13.46	9.85	10.96	10.56	167.66
8	0	13.90	14.28	9.49	6.22	.00	21.42	25.01	25.68	31.48	27.17	10.46	12.06	197.17
9	0	16.40	13.94	.00	.00	.00	15.83	23.48	28.09	28.53	29.63	32.07	24.31	212.08
10	0	17.70	15.76	11.29	.00	.00	4.49	23.68	26.85	31.13	30.81	22.19	13.06	196.96
11	0	15.00	10.32	.00	1.07	.00	.00	11.64	17.62	18.19	18.97	20.99	19.60	133.39
12	0	18.62	.00	.00	.00	.00	7.00	9.81	19.34	20.61	20.51	21.63	19.12	136.65
13	0	19.58	7.25	2.79	.00	.00	3.06	14.10	18.68	20.81	20.85	21.25	18.18	146.54
14	0	22.48	6.97	.00	.00	.00	.00	6.95	19.78	24.44	26.37	29.81	27.81	164.61
15	0	22.28	9.33	10.03	9.19	10.44	.00	18.62	24.50	26.62	26.66	32.97	30.79	221.43
16	0	25.90	12.59	.00	.00	.00	.00	15.64	26.38	28.22	28.34	29.54	27.45	194.05
17	0	26.07	11.67	7.90	2.08	8.19	8.72	21.95	27.47	28.49	28.63	29.90	28.00	229.08
18	0	20.30	.00	.00	9.19	.00	.00	25.01	16.18	24.80	14.59	15.08	15.78	140.93
19	0	27.33	13.48	.00	.00	.00	14.30	23.93	30.88	30.56	28.80	30.97	29.61	229.86
20	0	27.42	13.57	7.97	4.25	7.57	11.52	23.22	28.55	29.03	29.61	30.98	28.61	242.31
21	0	25.16	9.52	.97	.00	.00	1.75	18.62	27.47	28.59	28.99	30.08	27.81	198.96
22	0	25.26	15.37	7.79	5.96	8.10	14.75	23.31	28.18	28.58	28.17	30.44	27.89	243.81

[a] TOTAL AREA = 25,353 HA; ALLOWANCE FOR 331 HA IN YARMOUK GORGE WAS SUBTRACTED FROM THE INTERFLOW.

MODEL OUTPUT
JORDAN VALLEY IRRIGATION PROJECT
STAGE II

SPILL (MCM)

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL SPILL
1	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
4	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
5	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
9	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
10	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
11	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
13	0	.00	.00	.00	.00	.00	10.73	.00	.00	.00	.00	.00	.00	10.73
14	0	.00	.00	.00	26.19	61.97	98.05	22.53	.00	.00	.00	.00	.00	208.73
15	0	.00	.00	.00	8.99	27.03	8.45	.00	.00	.00	.00	.00	.00	44.47
16	0	.00	.00	.00	78.40	81.47	111.75	13.54	.00	.00	.00	.00	.00	285.16
17	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
18	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
19	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
21	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
22	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

MONTHLY AVERAGE WATER SURFACE ELEVATION

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL AVERAGE
1	0	107.10	106.20	109.71	118.39	134.60	146.02	149.00	148.36	145.06	141.51	137.66	133.97	131.46
2	0	131.29	130.78	132.57	135.42	137.67	138.83	138.50	135.82	131.99	127.83	123.38	119.01	131.92
3	0	115.01	114.58	119.37	126.88	133.72	138.01	139.28	137.67	134.70	131.28	127.38	123.51	128.45
4	0	120.44	119.37	120.88	124.34	129.60	135.32	137.68	135.24	131.55	127.53	123.30	119.10	127.03
5	0	115.31	114.10	116.96	122.67	127.78	129.82	129.01	126.45	122.86	118.57	113.51	108.63	120.47
6	0	104.43	102.92	104.36	107.71	111.72	115.29	116.10	112.96	108.02	102.22	95.25	90.16	105.93
7	0	89.99	90.28	91.97	96.14	99.95	100.81	99.27	94.19	90.03	89.99	89.99	89.99	93.55
8	0	89.99	90.53	92.72	97.40	104.09	107.99	106.92	104.15	99.59	92.52	89.99	89.99	97.16
9	0	89.99	90.76	97.91	107.44	114.75	118.89	118.00	114.40	109.73	104.17	97.75	91.27	104.59
10	0	89.99	89.99	91.76	97.39	104.56	110.82	112.28	109.31	104.23	97.68	90.97	89.99	99.08
11	0	89.99	91.08	96.11	102.64	111.26	120.65	124.58	124.35	122.96	121.22	119.20	117.18	111.77
12	0	115.70	117.05	121.93	130.44	140.11	145.31	146.98	146.92	145.51	143.95	142.41	141.04	136.44
13	0	140.04	140.24	141.96	144.42	147.12	149.63	149.94	149.05	147.23	145.24	143.31	141.83	145.00
14	0	140.96	141.48	145.53	149.85	150.00	150.00	150.00	149.69	148.74	147.49	146.22	145.10	147.09
15	0	143.34	141.97	141.98	146.62	150.00	150.00	149.04	146.56	143.42	140.09	135.93	131.61	143.38
16	0	128.42	127.66	134.21	147.76	150.00	150.00	150.00	148.97	146.42	143.35	140.23	136.96	142.00
17	0	134.29	133.82	135.25	138.30	141.48	145.24	147.35	145.35	142.41	139.09	135.37	131.73	139.14
18	0	128.96	129.04	131.17	133.19	136.18	140.22	143.90	145.28	143.58	141.70	140.58	139.36	137.76
19	0	137.11	135.52	136.63	139.48	142.99	145.19	144.90	142.96	139.80	135.91	131.92	127.70	138.34
20	0	123.72	121.85	122.63	125.15	128.42	132.02	132.88	129.73	125.32	120.50	114.73	108.80	123.31
21	0	104.20	103.63	107.64	116.89	129.75	141.30	145.81	144.23	141.28	137.68	133.77	130.06	128.02
22	0	127.10	125.17	125.24	127.10	129.40	131.45	131.01	127.70	123.54	119.46	114.56	109.31	124.25

MODEL OUTPUT

JORDAN VALLEY IRRIGATION PROJECT

STAGE II

IRRIGATION SHORTAGES (MCM)

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL TOTAL
1	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
4	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
5	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	10.00	10.00
7	0	10.32	.00	.00	.00	.00	.00	.00	.00	14.92	14.55	15.61	15.33	70.74
8	0	12.62	.00	.00	.00	.00	.00	.00	.00	.00	.00	15.21	15.53	43.37
9	0	9.49	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.65	12.14
10	0	10.06	.42	.00	.00	.00	.00	.00	.00	.00	.00	3.75	14.45	28.68
11	0	4.95	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.95
12	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
13	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
15	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
16	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
17	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
18	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
19	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
21	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
22	0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

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SHORTAGES OCCUR IN 16 OUT OF 264 MONTHS (6.06 PERCENT OF THE TIME)
TARGET PERCENTAGE = 6.00 TOLERANCE = .50 RESERVOIR ELEV. MAXIMUM/ START= 150.00 / 109.00
IRRIGATED AREA = 25022.0 HECTARES ITERATION NUMBER 0

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TOTAL SYSTEM WASTE (MCM) (EXCLUDING WADDI RAGGAD

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL TOTAL
1	0	.30	.70	.70	4.17	11.22	6.20	2.90	1.30	.80	.40	.30	.20	29.18
2	0	.30	.20	.40	.40	.80	.30	.00	.00	.00	.00	.00	.00	2.40
3	0	.00	.40	.90	2.90	5.30	3.00	1.60	.60	.30	.20	.00	.20	15.40
4	0	.20	.20	.50	.90	3.20	5.40	3.00	.70	.40	.10	.10	.10	14.80
5	0	.30	.50	1.00	1.40	6.75	2.20	.30	.30	.10	.00	.00	.00	12.85
6	0	.00	.00	.10	.50	1.40	2.90	.30	.00	.00	.00	.00	.00	5.20
7	0	.00	.00	.00	.10	.30	.40	.20	.10	.10	.10	.00	.00	1.30
8	0	.10	.20	.30	.50	.50	.60	.20	.20	.10	.00	.00	.00	2.70
9	0	.00	.00	1.90	1.90	2.50	1.90	.20	.00	.20	.00	.00	.00	8.60
10	0	.20	.20	.40	.50	.90	.30	.20	.20	.20	.20	.20	.20	3.70
11	0	.10	.20	.90	1.20	1.02	3.78	.80	.80	.40	.20	.20	.20	9.80
12	0	.10	.00	.00	23.61	11.02	.50	1.50	.00	.00	.10	.10	.10	37.03
13	0	.30	.40	.30	.10	.10	10.83	.30	.20	.10	.10	.10	.10	12.93
14	0	.30	.30	.60	27.09	62.67	99.15	23.03	.50	.30	.20	.30	.20	214.63
15	0	.60	.50	.50	12.89	28.33	9.65	.40	.40	.30	.30	.20	.20	54.27
16	0	.20	.20	.20	78.90	81.87	113.78	14.54	.70	.30	.20	.20	.30	291.39
17	0	.50	.20	.50	.60	.30	1.40	1.00	.30	.20	.20	.20	.20	5.60
18	0	.20	.20	.40	.40	.30	.60	.50	1.00	.40	.20	.20	.10	4.50
19	0	.20	.20	1.10	.30	.50	1.40	1.00	.40	.20	.60	.40	.40	6.70
20	0	.60	.60	.80	.80	.60	.90	.40	.60	.40	.40	.20	.40	6.70
21	0	.40	.50	.60	3.38	27.02	13.38	2.41	.30	.60	.60	.60	.60	50.38
22	0	.30	.30	.50	.40	.80	1.20	.30	.30	.40	.20	.20	.40	5.30

GRAND TOTAL SYSTEM WASTES (MCM) IS======= 795.

MODEL OUTPUT

JORDAN VALLEY IRRIGATION PROJECT
STAGE II

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MONTHLY POWER PRODUCTION (MW)

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL AVERAGE
1	0	7.32	2.57	-.00	-.00	-.00	2.27	4.16	11.05	12.09	11.49	11.31	10.52	6.07
2	0	9.76	5.31	2.67	1.40	3.05	4.14	7.86	10.14	9.65	9.14	9.25	9.05	6.78
3	0	8.23	4.26	-.00	-.00	-.00	3.11	8.62	9.85	11.21	11.32	11.45	10.62	6.56
4	0	9.51	5.45	3.99	-.00	-.00	2.72	9.62	12.10	11.94	11.62	11.33	10.52	7.40
5	0	9.36	5.46	.84	-.00	1.34	7.06	8.97	9.35	10.16	10.80	10.42	9.02	6.90
6	0	7.65	4.13	2.36	.53	-.00	1.33	7.09	9.49	9.48	8.71	6.36	3.97	5.26
7	0	3.48	3.60	2.29	.75	3.33	5.15	7.07	8.23	3.53	2.51	2.79	2.78	3.79
8	0	3.53	3.77	2.50	1.73	-.00	6.62	7.88	7.61	9.12	7.07	2.66	3.17	4.64
9	0	4.16	3.49	-.00	-.00	-.00	5.44	8.24	9.20	9.16	8.76	8.82	6.45	5.33
10	0	4.49	4.14	2.94	-.00	-.00	1.44	7.88	8.38	9.49	8.47	5.68	3.43	4.69
11	0	3.81	2.75	-.00	.32	-.00	-.00	4.35	6.35	6.69	6.65	7.22	6.84	3.75
12	0	6.21	-.00	-.00	-.00	-.00	2.99	4.38	8.32	9.07	8.64	9.00	8.14	4.73
13	0	8.01	3.08	1.16	-.00	-.00	1.35	6.42	8.17	9.27	8.86	6.90	7.79	5.25
14	0	9.25	2.99	-.00	-.00	-.00	-.00	3.17	8.68	10.99	11.36	12.71	12.16	5.94
15	0	9.34	4.01	4.18	3.96	5.10	-.00	8.41	10.50	11.50	10.87	12.97	12.10	7.74
16	0	9.63	4.83	-.00	-.00	-.00	-.00	7.12	11.49	12.45	11.84	12.04	11.28	6.72
17	0	10.17	4.71	3.13	.84	3.76	3.72	9.78	11.65	12.20	11.58	11.74	11.04	7.86
18	0	7.60	-.00	-.00	3.58	-.00	-.00	10.85	6.89	10.74	6.05	6.21	6.64	4.88
19	0	10.89	5.51	-.00	-.00	-.00	6.09	10.47	12.84	12.81	11.36	11.82	11.27	7.76
20	0	9.79	4.95	2.84	1.55	3.14	4.44	9.26	10.71	10.83	10.25	10.16	9.16	7.26
21	0	7.46	2.92	.30	-.00	-.00	.73	8.22	11.55	12.14	11.59	11.66	10.81	6.45
22	0	9.29	5.77	2.84	2.21	3.38	5.65	9.16	10.40	10.51	9.67	9.97	8.98	7.32

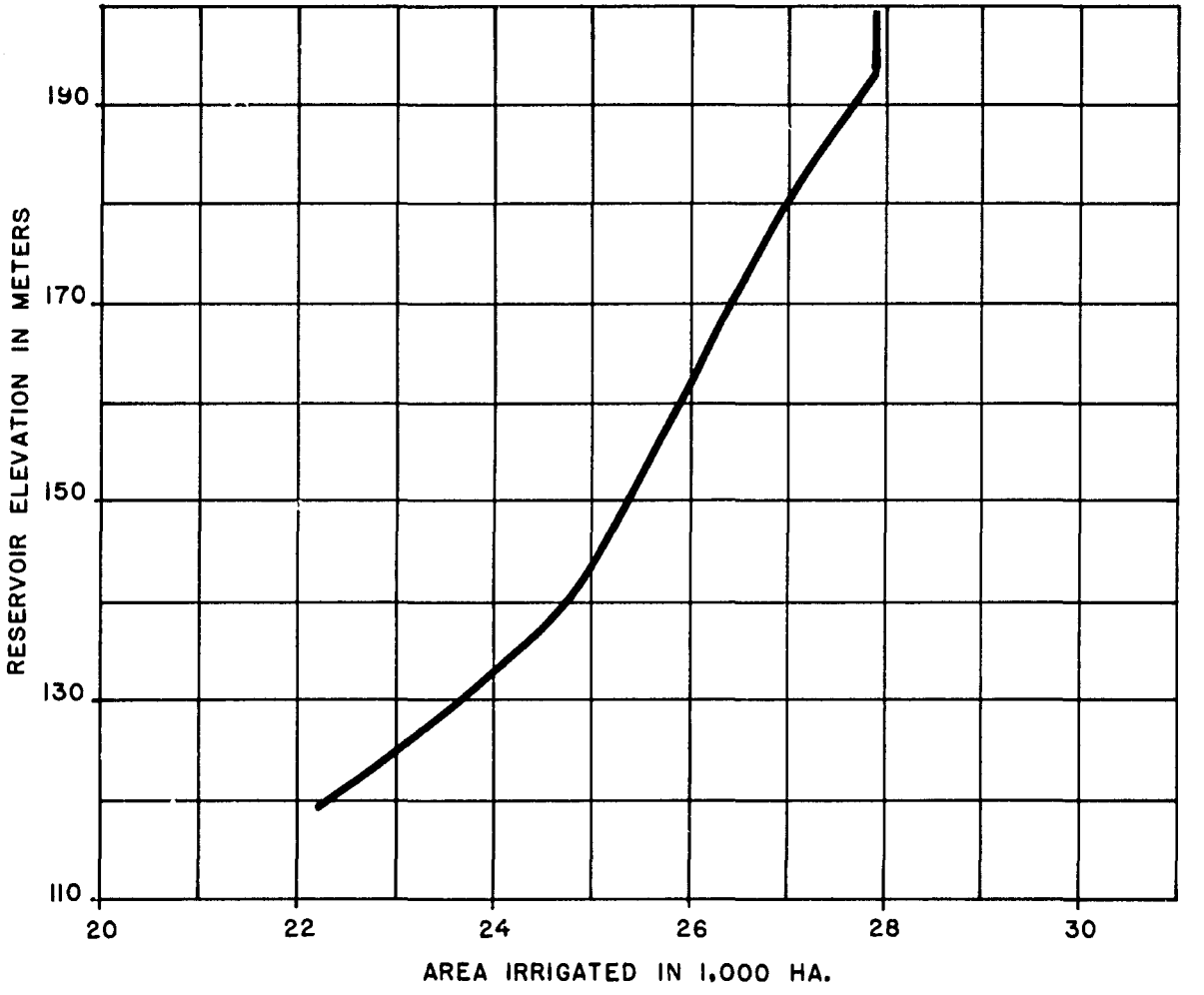
MONTHLY ENERGY PRODUCTION (GWH)

YEAR		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	ANNUAL ENERGY
1	0	5.44	1.85	.00	.00	.00	1.69	3.00	8.22	8.71	8.55	8.41	7.58	53.45
2	0	7.26	3.82	1.99	1.04	2.05	3.08	5.56	7.54	6.95	6.80	6.88	6.52	59.58
3	0	6.12	3.07	.00	.00	.00	2.31	6.20	7.33	8.07	8.42	8.52	7.64	57.70
4	0	7.07	3.93	2.97	.00	.00	2.03	6.93	9.00	8.59	8.64	8.43	7.57	65.16
5	0	6.96	3.93	.62	.00	.90	5.26	6.46	6.96	7.31	8.04	7.75	6.49	60.69
6	0	5.69	2.97	1.76	.40	.00	.99	5.10	7.06	6.83	6.48	6.22	2.86	46.35
7	0	2.59	2.60	1.71	.56	2.24	3.83	5.09	6.13	2.54	1.87	2.07	2.00	33.21
8	0	2.63	2.72	1.86	1.29	.00	4.93	5.67	5.66	6.57	5.26	1.98	2.28	40.85
9	0	3.10	2.66	.00	.00	.00	4.05	5.94	6.85	6.59	6.51	6.56	4.64	46.91
10	0	3.34	2.98	2.18	.00	.00	1.07	5.67	6.23	6.83	6.30	4.23	2.47	41.32
11	0	2.84	1.98	.00	.24	.00	.00	3.13	4.73	4.82	4.95	5.37	4.93	32.98
12	0	4.62	.00	.00	.00	.00	2.22	3.15	6.19	6.53	6.42	6.70	5.86	41.71
13	0	5.96	2.22	.87	.00	.00	1.00	4.62	6.08	6.67	6.59	6.63	5.61	46.24
14	0	6.88	2.15	.00	.00	.00	.00	2.28	6.46	7.91	8.46	9.45	8.75	52.35
15	0	6.95	2.89	3.11	2.95	3.43	.00	6.06	7.81	8.28	8.09	9.65	8.71	67.91
16	0	7.17	3.48	.00	.00	.00	.00	5.13	8.55	8.96	8.81	8.96	8.12	59.17
17	0	7.57	3.39	2.33	.63	2.53	2.77	7.04	8.67	8.78	8.61	6.73	7.95	68.99
18	0	5.66	.00	.00	2.66	.00	.00	7.82	5.13	7.73	4.50	4.62	4.78	42.89
19	0	8.10	3.97	.00	.00	.00	4.53	7.54	9.55	9.23	8.45	8.79	8.12	68.28
20	0	7.28	3.57	2.11	1.15	2.11	3.30	6.67	7.97	7.80	7.63	7.56	6.60	63.75
21	0	5.55	2.10	.22	.00	.00	.54	5.92	8.60	8.74	8.62	8.67	7.78	56.76
22	0	6.91	4.15	2.11	1.64	2.27	4.20	6.59	7.74	7.56	7.20	7.42	6.47	64.28

TOTAL ENERGY FOR THE PERIOD OF RECORD IN GWH = 1170.54

MODEL OUTPUT

JORDAN VALLEY IRRIGATION PROJECT
STAGE II



NOTE:
FOR STAGE II CONDITIONS : 50 YEARS SEDIMENT STORAGE
20 MCM/YEAR FOR M&I

MAQARIN RESERVOIR
IRRIGATED AREA VS ELEVATION
JORDAN VALLEY IRRIGATION PROJECT
STAGE II

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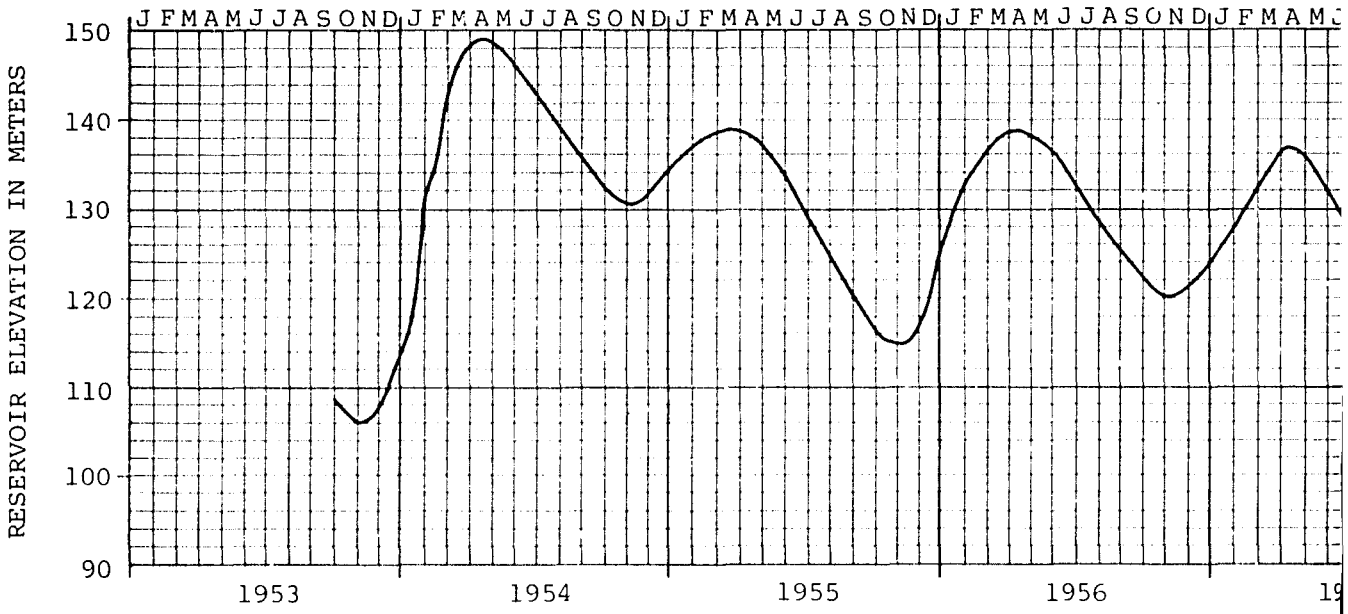
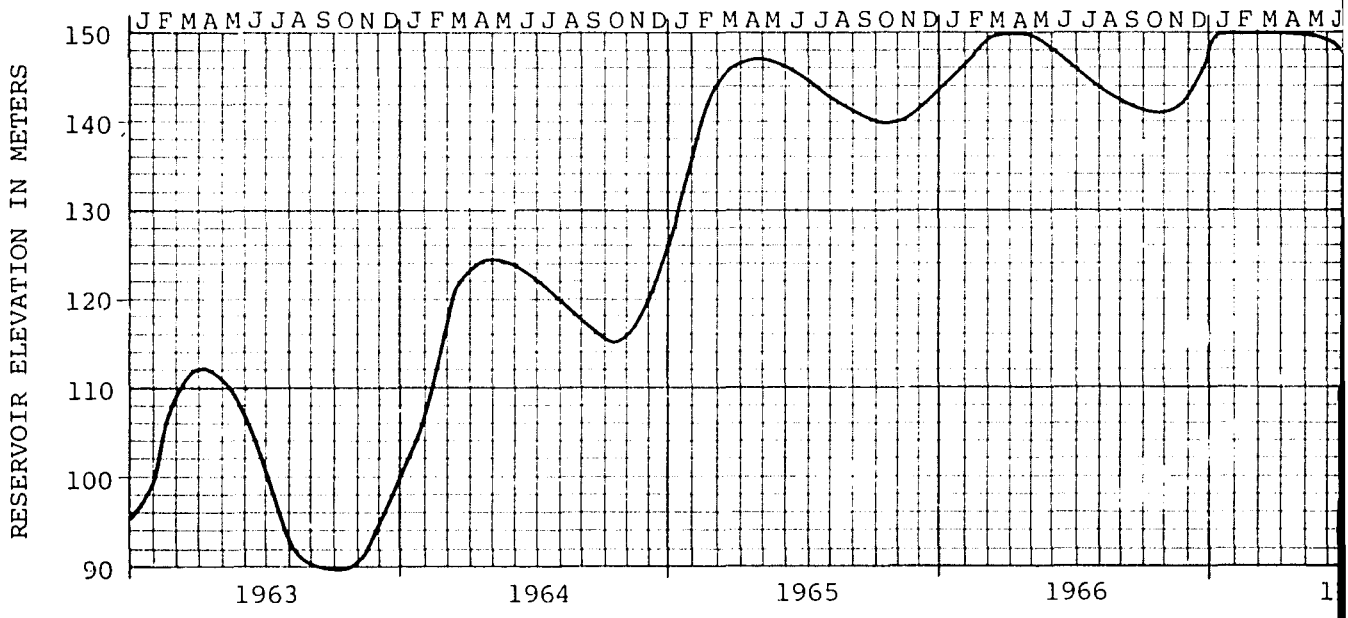

J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
150
140
130
120
110
100
90
RESERVOIR ELEVATION IN METERS
1953
1954
1955
1956


J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
150
140
130
120
110
100
90
RESERVOIR ELEVATION IN METERS
1963
1964
1965
1966

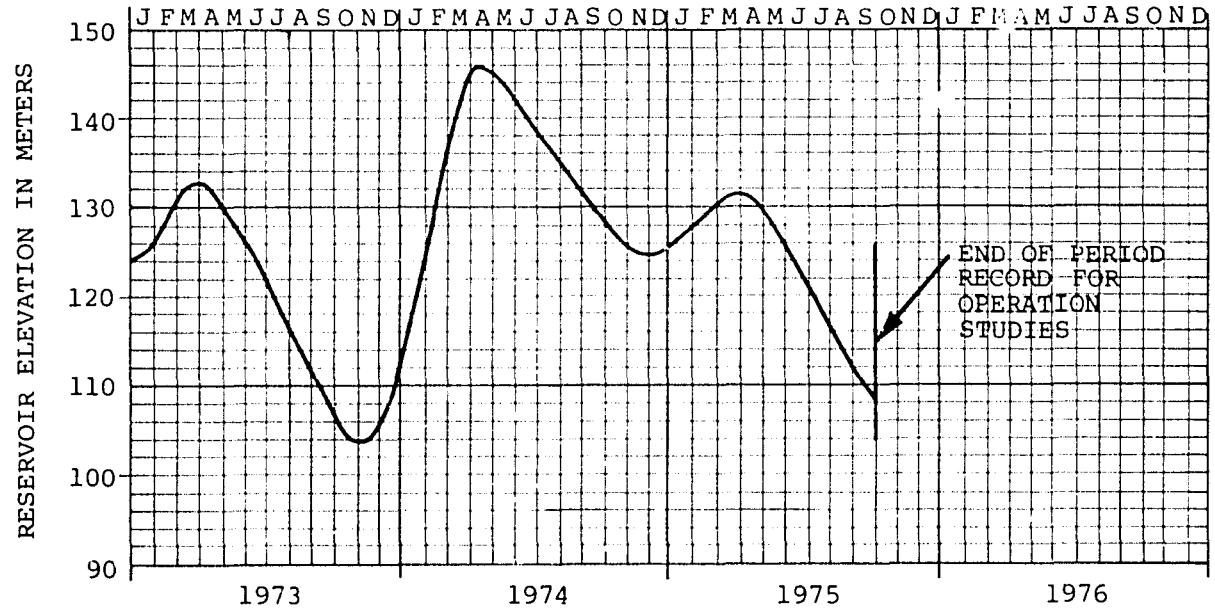
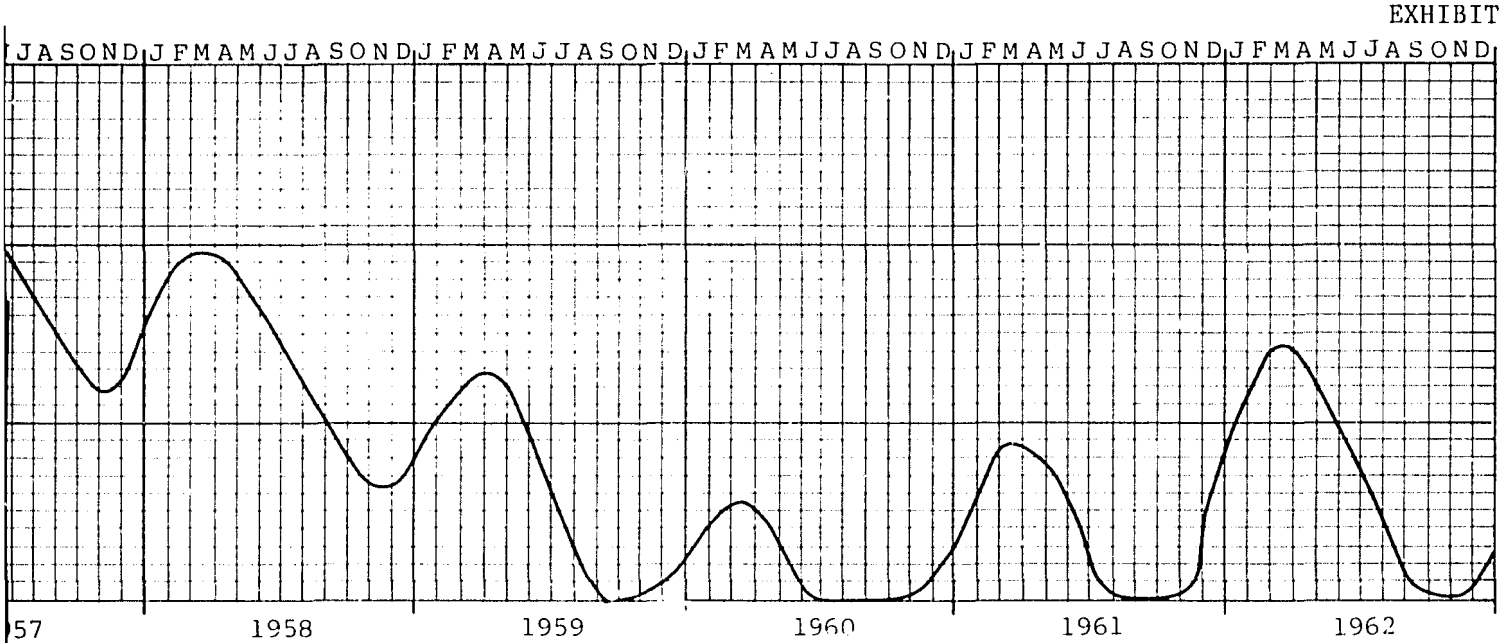
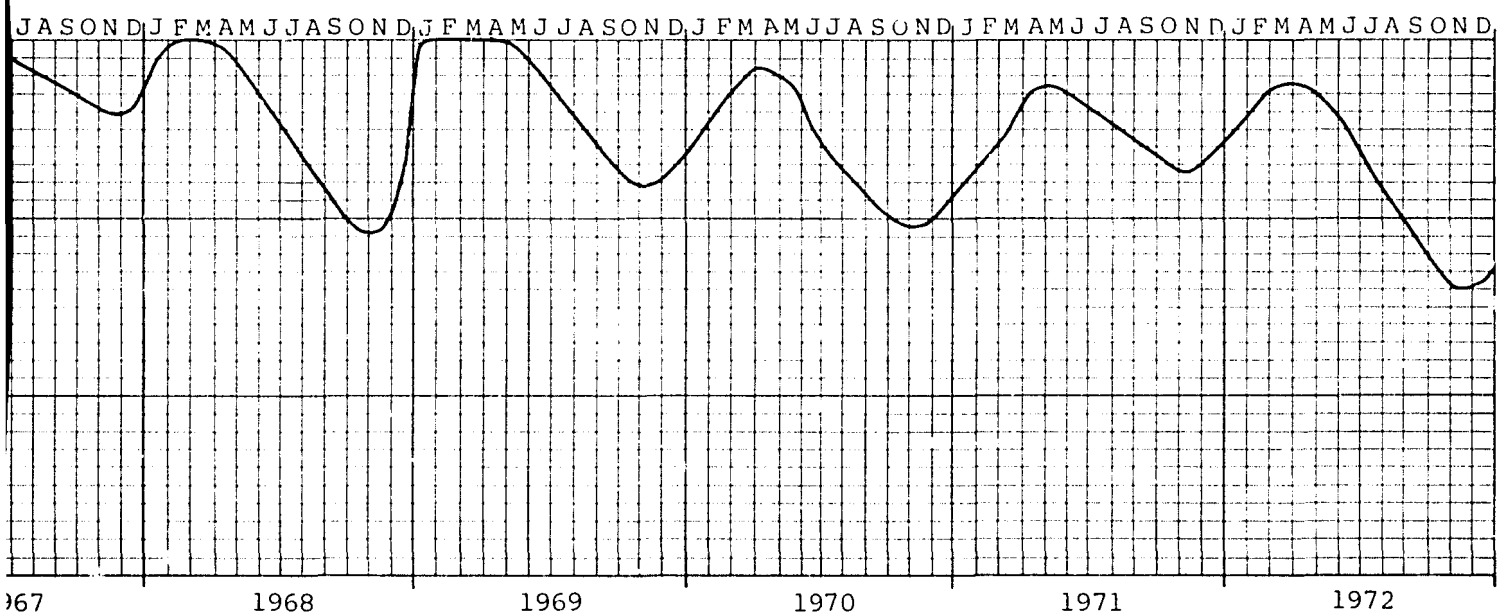
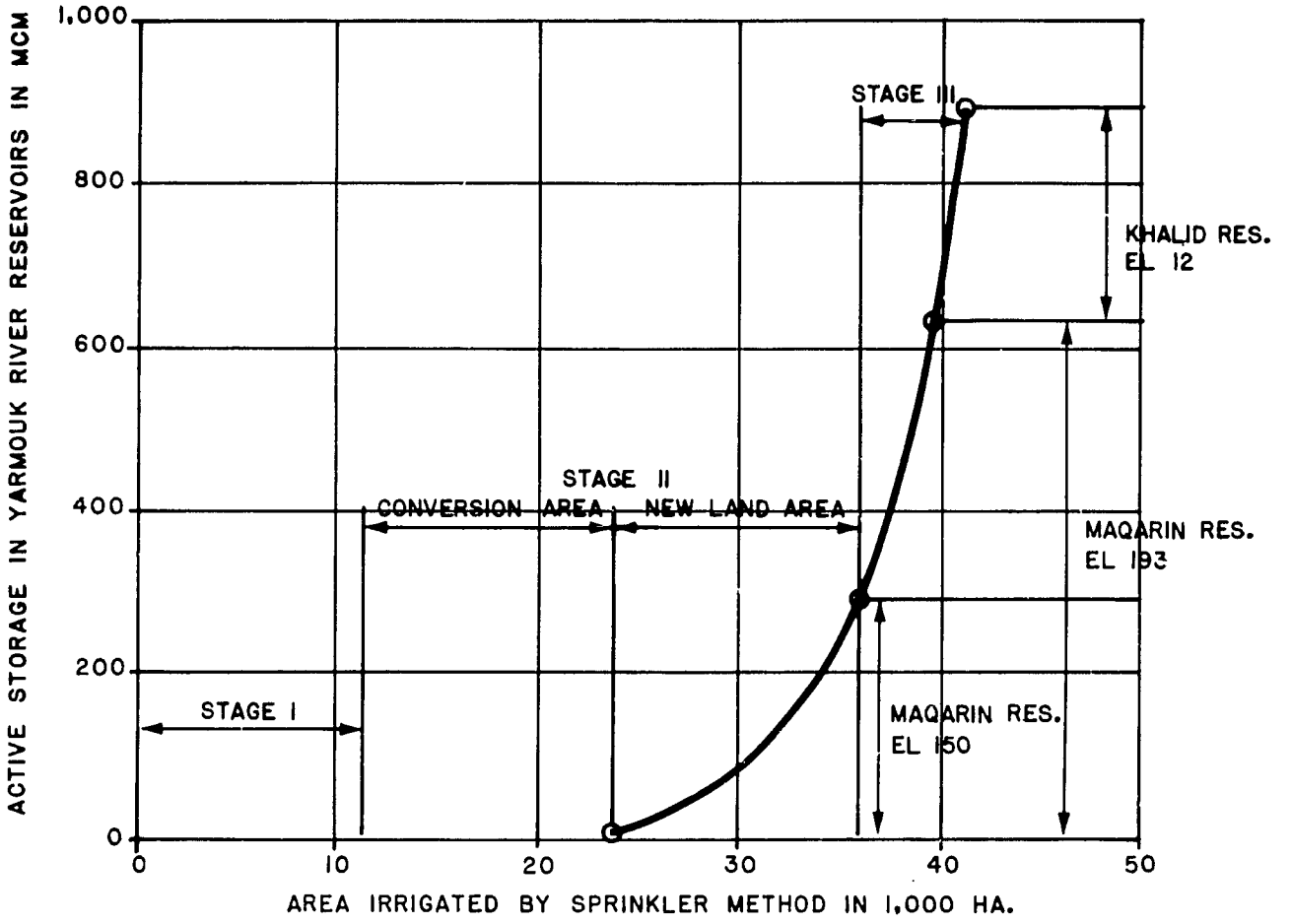

J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
150
140
130
120
110
100
90
RESERVOIR ELEVATION IN METERS
END OF PERIOD RECORD FOR OPERATION STUDIES
1973
1974
1975
1976

EXHIBIT C-9





HISTOGRAM OF
MAQARIN RESERVOIR ELEVATION
JORDAN VALLEY IRRIGATION PROJECT
STAGE II



NOTE:

STAGE II INCLUDES PROVISION FOR 20MCM/YEAR FOR M&I USE.

STAGE III INCLUDES PROVISION FOR 47MCM/YEAR FOR M&I USE.

IRRIGATED AREA VS STORAGE

JORDAN VALLEY IRRIGATION PROJECT

STAGE II