WATER ISSUES IN THE MIDDLE EAST

TURKEY: HYDROLOGICAL (1987)

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TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF GRAPHS

LIST OF GRAPHS

LIST OF MAPS

LIST OF MAPS

LIST OF DIAGRAMS

NOTE CONCERNING NOMENCLATURE

The usual policy in these reports has been to use standard English journalistic spellings of place names. However, here the original Turkish spellings, minus diacritics, are employed. The reason is that most modern maps use the Turkish spellings, and consistency in this regard will facilitate map consultation.

Chapter 1

THE IMPACT OF DEVELOPMENT UPON THE WATERS OF THE EUPHRATES RIVER AND ITS TRIBUTARIES

The preceding overview of the Southeast Anatolia Project (GAP) leads inevitably to the focus of this report. That is, what impact will developments -- both in place and planned -- on the Euphrates River in Turkey and in Syria have on the three riparian users of those waters? (The inclusion of similar questions for the Tigris River is at this juncture less critical for two reasons. Turkish development of the Tigris and its basin have scarcely begun, and the regime of the Tigris downstream in Iraq presents special problems unlike those relating to the Euphrates. This latter condition results from the Tigris' receiving large increments of water from left bank tributaries throughout its course in Iraq, while the Euphrates is an exotic stream in Iraq and even in Syria far more dependent upon Turkish sources than usually thought.)

In order to address the above question a step by step review of the Euphrates from its source to its mouth must be made in terms of the dams, reservoirs, and diversions for irrigation as well as of evaporation, evapotranspiration, water losses, and return flows. This, in turn, emphasizes two sets of problems. The first is the defining of the above terms as they are used, or can be expected to describe, activities and phenomena referred to in the various articles and technical reports upon which this commentary is based. In order to do this, it is necessary to refer not only to Turkish materials but to Syrian references and research as well. In this way, the results garnered from both countries can serve as cross-checks on each other, as well as material from one general source filling in gaps which appear in materials from the other. The second refers specifically to the spotty and less complete information on certain aspects of Syrian Euphrates development activities which must be worked out in detail in the pages ahead before the total review referred to above can be attempted.

1.1. Organization of the Analysis

While the majority of these topics are dealt with under "Syria" headings, one group of definitions are of a more general nature and serve to introduce the approach used in the pages that follow. These definitions relate to *System Efficiency* and *Return Flow*. It is these characteristics that either balance the budget of river water use or throw it into disarray and therefore they make a suitable introduction to the problems under discussion.

Having introduced the subject of analyzing the use of Euphrates River waters, the sections which follow consider additional questions of definition in terms of Syrian activities. The next section considers *The Annual Discharge of the Euphrates River: Turkey into Syria and Syria into Iraq*. Such a discussion is critical to any planning and/or negotiations regarding the amount of water available to be used by each of the three riparian states involved.

The nature of *The Euphrates System in Syria* follows and allocates average discharge increments to the tributaries in that country. The defining of such shares of river flow is necessary before an analysis of Syrian use -- actual and projected -- can be attempted.

A further step must precede such an analysis. This refers to the actual amounts of water that must be applied to each unit of developed land in order to meet irrigation requirements based on climatological, soil, and crop conditions. *Water Use per Hectare and Anticipated River Depletion* undertakes this task in terms of both Syrian and Turkish usages.

Once the amount of water necessary for successful irrigated farming has been determined, it is necessary to learn the actual amounts of land currently irrigated and subsequently scheduled for irrigation. The section entitled *Irrigated Agriculture in the Syrian Euphrates Drainage Basin* considers the numerous reports associated with this topic and suggests figures compatible with available data. A similar presentation will be made in the summary section for Turkish irrigated lands although these have already been referred to in the introductory pages of this study.

One further area of investigation must be considered before a final summary analysis of the Euphrates is given. This is the nature of the Khabur River and its tributaries in the Jezirah of northeast Syria. As this section points out, the flow of the Khabur upon which Syria places so much emphasis is in fact largely derived from and controlled by catchment areas inside Turkey. *The Khabur River and Its Tributaries* spells this out in detail sufficient to make this an issue of concern to planners and politicians.

The summary portion of this study, *Static and Dynamic Views of the Euphrates River System*, will it is hoped speak for itself.

1.2. System Efficiency and Return Flow

System efficiency is defined as that proportion of water removed from a river or reservoir that actually serves the evapotranspiration needs of a particular crop in a particular field. It may be further divided into *delivery efficiency* -- the corollary of which is *conveyance loss*, i.e. depletions from spills, leakage, evaporation from canal surfaces, management mistakes, misdirections, etc. -- and *on-farm efficiency* -- the corollary of which is on-farm loss, i.e. spills, leaks, over-irrigation, evapotranspiration by weeds, deep percolation, etc.

Table T-1 lists a number of values for the overall efficiency of farm irrigation systems in the Middle East. This *system efficiency* reflects both delivery efficiency and on-farm efficiency. A second term is introduced, the *coefficient of efficiency* -- i.e. the factor by which the calculated water needs of a given crop which are left unsatisfied either by precipitation and/or soil moisture must be multiplied to ensure a sufficient amount of water's being diverted from river or reservoir so that after all losses have occurred the water needed for healthy plant growth will arrive at the plant.

Efficiency ranges from 69.8 percent (coefficient of efficiency: 1.43) to 35 percent (coef. of ef.: 2.86). The former value is cited by Waterbury in his *Hydropolitics of the Nile*(2765-2771) as that given by the Egyptian Ministry of Irrigation and is contrasted by him with another value arrived at by a USAID team(3045-3049) of 50.8 percent (coef. of ef.: 1.97). The Ministry's figure is considered to be far too optimistic. In both these cases, the unusual field conditions in the Nile Valley preclude the use of these values in calculations for either Turkey or Syria. The highest coefficient of efficiency (i.e. the least efficient system) is that given by Karataban(3058) for the Adapazari Plain. Karataban's work is considered to be especially pertinent for this discussion because of his taking into account social, economic, and technical conditions in Turkey as well as climatological and phytological considerations. Nevertheless, when this high value is contrasted with two values from Syria and also the full range of efficiencies for Egypt, Karataban's value seems somewhat pessimistic. Tables T-2 and T-3 show what might be considered a "most expensive" case (i.e. in terms of water consumed) for the Urfa-Harran and Mardin-Ceylanpinar portions of the GAP irrigation scheme. In these cases Karataban's efficiency values have been combined with total evapotranspiration needs (as given in GAP III-36(3081)) for 136,000 and 206,000 hectares respectively.

At this point a second definition must be given, that is, the amount of *return flow* -- defined as that portion of the water removed from river or reservoir to meet irrigation needs that finds its way back into the system. It should be noted that water in addition to that needed for evapotranspiration must be provided in the fields in order that salts -- either from leaching of local soils followed by capillary movement upward and evaporation, or by the evaporation of introduced mineralized waters -- can be washed from the soil and carried away from the fields. In some cases it is assumed that on-farm losses will include water sufficient to carry away such salts. On the other hand, in none of the examples found for this analysis was such an inclusion made specific and in some cases it was clear that that increment was not included. Close inspection of the cases listed in Table T-4 suggests that a return flow of 35 percent, while generous, is within realistic limits. This value has been used in Tables T-2 and T-3 and in subsequent calculations.

The results of the calculations given in the above two tables indicate an overall depletion of river water of 6220 Mcm/yr for the 342,000 ha of land in question. As will be seen in section *Water Use per Hectare* this estimate does not effectively take precipitation and soil moisture into account and also uses Karataban's[3058] high coefficient of efficiency (in the case of his actual calculations: 2.88). A return flow of 3160 Mcm/yr would issue from the same fields in addition to the 6220 Mcm/yr consumed. While these figures will be refined in the summary portion of this analysis, they are included at this point as examples of the range of values possibly used during the planning stages of GAP.

After careful consideration, it was decided to use an overall *system efficiency* of 40 percent (coef. of ef.: 2.5) for calculations in this analysis. This lesser value somewhat ameliorates the pessimistic view taken by Karataban[3058] and assumes that the return flow is included in the initial figures calculated for diversions from rivers and reservoirs. Needless to say, all such estimates must be recalculated as more data relating to actual crops, field size, condition of delivery systems, etc., become available. What is offered here is an outline painted with the broadest of brush strokes.

Table T-1

SYSTEM EFFICIENCY IN NEAR EASTERN IRRIGATION SYSTEMS

Value or % Efficiency	Coefficient of Efficiency*	Source	Comments
55	1.82	Samman, p. 24 Euphrates Project	Conveyance loss = 10%; "Field efficiency from water course head regulator" = 60%.
46**	2.17	USAID, V-2, p. II-24 (1980) "Syria"	"54% of water diverted into the Homs-Hama canal is lost before it reaches the farmer."
69.8	1.43	Ministry of Irrigation, Egypt: Waterbury, p. 219	Conveyance loss = 14%; On-farm loss = 16.2%.
35.0	2.86	Conservative estimate for Adapazari Plain, Karataban/ CENTO, pp. 474-475.	"Delivery Eff. = 70%"; "Farm Eff. = 50%".
50.8	1.97	USAID, Egypt as in Waterbury, Table 23	Conveyance loss = 21.9%; On-farm loss = 27.3%.
0.0	-	Qasim in Khayyat interview	Rasafah area #4 of Syrian Euphrates project - (abandoned)

Sources: Samman(0993), USAID(3046), Waterbury(2771), Khayyat(1902), Karataban(3058).

* Coefficient of efficiency = The factor by which the amount of water needed for irrigation must be multiplied to indicate the amount needed to be withdrawn from the original source.

** Does not include on-farm loss.

Table T-1 continued

WATER USE EFFICIENCIES IN EGYPT

SITUATION	Lowland	Lowland	Highland	Highland	Highland
SOIL TYPE (carrier)	Clay	Sand	Sand	Sand	Sand
CONDITION OF CARRIER (main canal to farm and farm to field)	Unlined	Unlined	Unlined	Lined	Piped
MAIN CANAL TO FARM	.85	.80	.80	.90	.90
FARM TO FIELD	.85	.80	.80	.90	.90
SOIL TYPE (in field)	Clay	Clay	Sand	Sand	Sand
METHOD OF APPLICATION	Surface	Surface	Surface	Sprinkler	Drip
PLANT USE	.65	.65	.55	.70	.90
EFFICIENCY	.47	.42	.35	.57	.73
COEFFICIENT OF EFFICIENCY*	2.13	2.38	2.86	1.75	1.37

Source: After Huntington Tech. Services as in Beaumont & McLachlan[3068], p. 81.

* Coefficient of efficiency = The factor by which the amount of water needed for irrigation must be multiplied to indicate the amount needed to be withdrawn from the original source, has been computed for this report.

Table T-2

URFA-HARRAN WATER USE - URFA TUNNEL
(136,000 ha per GAP)

Month	I[a] Evapotrans. (cu m/ha/mo)	II Total Project Demand (Mcm) (I x area)	III[b,c] Amt. Necessary to be Delivered to Fields (Mcm) (II x 2.88)	IV[d] Amt. Returned to Streams (34% of III) (Mcm)	V Total Deficit (66% of III) (Mcm)
April	337.09	45.84	132.00	lag	87.11
May	572.36	77.84	224.18	44.89	147.96
June	1694.31	230.43	663.63	76.22	438.00
July	2654.71	361.04	1039.80	225.63	686.27
August	2324.13	316.08	910.32	353.53	600.81
September	1140.81	155.15	446.83	309.51	294.91
October	196.67	26.75	77.03	151.92	50.84
November	---	---	---	26.19	---
Total	8920.08	1213.10	3137.80	1143.90	2305.90

Source: GAP[3081], pp. V-4/5.

a. Equivalent to mm standing water. E.g. "Total" is equivalent to 892 mm water/m^2.

b. According to "conservative" estimates by Karataban[3058] in CENTO, "Farm efficiency" in Turkey = 50% and "delivery efficiency" = 70%. In order to deliver a required amount to the plants (Col. II) the evapotranspiration need must be multiplied by 2.88 (i.e. Col. III less 70%, less 50% = amt. in Col. II).

c. The terms "farm efficiency" and "delivery efficiency" assume sufficient rain during the wet season to wash away accumulated salts.

d. Kilic[0272] in CENTO (p. 70) gives a value of 17/50th, i.e. 34%, for return of water from irrigated fields to streams for all Turkey. Al-Hadithi[3067] uses values of aprox. 25% (p. 245) and 30% (Table 14, p. 78). U.N. Special Report on the Jezirah[3065] (p. 79) allows "30% to 40%" for return to streams from fields.

Table T-3

MARDIN-CEYLANPINAR WATER USE (EST.) - HILVAN PUMPAGE
(206,000 ha per GAP)
(see previous page for explanation of entries)

	I[a]	II	III[b,c]	IV[d]	V
Month	Evapotrans. (cu m/ha/mo)	Total Project Demand (Mcm) (I x area)	Amt. Necessary to be Delivered to Fields (Mcm) (II x 2.88)	Amt. Returned to Streams (34% of III) (Mcm)	Total Deficit (66% of III) (Mcm)
April	505.34	83.50	240.48	lag	158.72
May	832.87	171.57	494.13	81.76	326.13
June	2090.56	430.66	1240.29	168.00	818.59
July	2890.21	598.38	1714.70	421.70	1131.70
August	2438.08	502.24	1446.45	583.00	954.66
September	1169.28	204.87	693.71	491.79	457.85
October	172.37	35.51	102.30	235.86	67.53
Nov	---	---	---	34.77	---
Total	9998.71	2059.73	5932.03	2016.89	3915.18

This does not include 60,000 ha to be watered by pumping from local aquifer.

Source: GAP(3081), pp. V-4/5.

Table T-4

RETURN FLOW IN NEAR EASTERN IRRIGATION SYSTEMS

Value %	Comments	Source
30	For Euphrates systems in Syria in general	Samman, p. 24
30-40	To the Khabur at Suwar -- the shortening of the period of extreme low flow due to increased return flow was mentioned.	FAO, p. 79
25	Assumed for all irrigation in Turkey, Syria, and Iraq along the Euphrates.	al-Hadithi, Table G-4, p. 245
30	Turkey and Syria	al-Hadithi, Table 14, p. 78
34	All of Turkey	Kilic, et al, in CENTO Symposium, p. 70
51	All of Egypt, ca 1977. This high value reflects special conditions of water-logging and presents problems of salination, etc.	Waterbury, p. 218

Sources: Samman(0993), FAO(3065), al-Hadithi(3067), Kilic(0272-0274)(0287), Waterbury(2771).

Chapter 2

AVERAGE ANNUAL DISCHARGE OF THE EUPHRATES RIVER: TURKEY INTO SYRIA, SYRIA INTO IRAQ

If and when tripartite negotiations take place concerning the use of Euphrates River waters, much will depend upon a clear understanding of the quantity available at any given time to be shared among the riparian users. The first such measure concerns the average annual discharge of the river. This is no simple matter to determine, for it seems that every report and evaluation quotes a different set of figures. Moreover, Turkish reports disagree with other analyses for the same gauging stations, as do those for Syria and Iraq. Table EF-1 lists six stations along the river from Birecik, near the border in Turkey, to Hit in Iraq. Eleven sources of information list seventeen values, none of which agree and few of which offer consistent data. Possibly other references could be found listing still more flow or discharge data, but those would only add to the confusion. The only new materials which could clarify the situation would be complete flow records from at least one major station in each country for the same long span of years, measured in the same way in each case. It is unlikely that such a data trove will become available. On the other hand, some sense can be made of all this if the accompanying tables and graphs are carefully examined along with the text that follows.

Graph EF-1 shows the information given in Table EF-1, with upstream data on the left and downstream data on the right. The points indicated in every case are identified by the source from which that value is derived. A discussion of these sources of data helps to identify what may be the most accurate picture of average yearly discharge. The lines joining the upper row of values, as well as the ones joining the lower values, do not imply natural sequences of flow, but rather are meant to indicate reasonable upper and lower limits on such data.

Birecik, Turkey, shows two divergent values for discharge at that point. The greater value is drawn from the *Southeast Anatolia Project Report* (labelled GAP)[3081]. (These comments also apply to the single value for Karkamis, downstream from Birecik almost to the Syrian border.) In this case, neither the number of years nor the specific years involved are mentioned in the original report. The lower value for Birecik is drawn from Clawson et al. (CLA)[3088], who in turn cite Hathaway et al. and their 1965 IBRD report on the Keban Dam (Table EF-2). This is based on 27 years from 1937 through 1963, with partial data for 1964.

Evidence discussed below suggests that the GAP figures are for a shorter and more recent period of time. The accuracy of the CLA data might be questioned pro forma, but at least the time span is known. Similar data from CLA for Hit, Iraq (Table EF-3) can be shown by inspection to be a subset of the data provided al-Hadithi[3067] by the Iraqi Ministry of Irrigation. As will be seen, these data seem to be consistent and usable. By inference, the CLA data for Birecik should be reasonably reliable. GAP data are probably accurate for the years they represent, but much depends upon the number of years and the time span chosen when considering a river with as irregular a regime as that of the Euphrates.

The slightly higher figure given by GAP[3081] for Karkamis, downstream from Birecik, is consistent with the former's geographical situation. As mentioned in Section 3 regarding the Euphrates in Syria, tributary flow from the Nizip and other small streams in Turkey should account for this increase. Nevertheless, both these GAP values appear unusually large.

The GAP[3081] data are in sharp contrast with the next two values on this chart. The USAID report on Syrian agriculture[3045-3049] quotes an overall flow for the Euphrates of 27,000 Mcm/yr, but qualifies its statement by adding, "The flow of the Euphrates the last seven years has averaged substantially less, however, about 22.1 billion cu m; measurements at the Syrian-Turkish border." The report also lists the flow for the years 1967 and 1970-77 (Table EF-5). Flows for 1978, 1979, 1980, 1982, and 1984 are also available from the SAR *Statistical Abstracts*[3050][3216-3219]. The average flow for the years 1973-1979 (i.e., "the last seven years") is 747 cu m/s or 23,566 Mcm/yr, somewhat more than the quoted 22,100 Mcm shown on the graph, but the question remains that the location where these data were taken is unspecified and may be downstream beyond the confluence with the Sajur, thus possibly accounting for the increased value.

Inspection of these data (Table EF-5 and Graph EF-2) shows wide fluctuations ranging from 12,800 Mcm/yr to 32,860 Mcm/yr in the space of 36 months. Values for the earlier years in this series come close to the 27,000 Mcm quoted by USAID[3045-3049] and seem consistent with CLA[3088] data if an additional downstream increment were taken into consideration. Values for 1973-74-75 appear anomalous at first and far too low. It was, however, in the winter of 1973-74 that the Keban and Lake Assad reservoirs began to be filled. On the other hand, inspection of flow data for other rivers and streams in Syria (Table EF-6 and Graph EF-2) for the same time period show a significant diminution of discharge throughout the country, outside as well as inside the Euphrates drainage basin. This period of low discharge on the Euphrates cannot be explained through reservoir filling alone.

The next value is given by Beaumont[0033] for Yusuf Pasha near the head of Lake Assad, upstream from the Tabqa (ath-Thawrah) Dam in Syria. This is an average for 17 years from 1950 through 1966, a period of relatively low water in the entire system (Graph S-7). It should be kept in mind that the close correlation between Hit data and Birecik data shown in Graph S-3 permits some interpretation of points in between the two stations.

The fourteen year average (Table EF-5) cited above has been placed on the graph at ath-Thawrah, where it still appears as a somewhat low value for the site. Shchukin[2102] gives the lowest value without reference to the time span or dates covered. Indeed, it is so low that it suggests that he may be citing a single year's discharge. The value quoted by Samman[0993] (Table EF-1) is inconsistent with USAID data and suggests that he has cited a wrong year (possibly 1972). Therefore, his datum is not shown on the graph, and is mentioned here only to illustrate the difficulties surrounding these evaluations. Low, medium and high USAID[3045-3049] averages are also shown for comparison.

It should be noted that the average value for fourteen years shown in Table EF-5 is consistent with the low value given upstream by Beaumont[0033] Little is known regarding Wirth's value, discussed in Bourgey[0040]. It merely reinforces the idea that long-run average flow rates should have lower values than that quoted by al-Hadithi[3067], whose higher value is for 21 unidentified years, presumably in a consecutive sequence. The top USAID[3045-3049] datum is as unusually high as Shchukin's[2102] is low. This figure lacks time-span (only 2 years) and represents an infrequent period of flooding.

Eight values are available for Hit, Iraq, and it is these which allow some estimation and evaluation of the correctness of the various data given in Graph EF-1. The lowest al-Hadithi[3067] datum is for a single year and is consistent with the lower range of river flow. The second and larger value (moving up the column) is for 49 years from 1924-25 through 1972-73 (Table EF-1). Al-Hadithi cites the Iraqi Ministry of Irrigation as his source for these data. Inspection shows that CLA[3088] use a subset of these data, but since CLA's publication date precedes that of al-Hadithi, the two authors must draw their data from a third common independent source, undoubtedly that cited by al-Hadithi.

The data clustered about the average value (n = 4; see Table EF-1) in the column include one based by CLA[3088] upon a shorter run of years. The same is true for al-Hadithi's[3067] value given in that grouping. The next highest al-Hadithi value is for 30 years, but is lower than that given by Ubell[3063] for the same period: 1940-1969. This inconsistency persists when the data provided by both are compared by decades as well as for the entire 30 year period. (Ubell presents his data in increments of 10-year averages.) No reason is given for the discrepancies shown by Table EF-7, and it is unlikely that either writer knew of their existence. While various explanations suggest themselves, it would serve little purpose to pursue them at this point. Rather, the al-Hadithi data (Table EF-4) provide us with a fairly long and consistent view of river flow. (This includes by extension the subset used by CLA as given in Table EF-3, but the longer time span is preferable.) Ubell's data would seem consistent with a higher range of values, and as such may be misleading. The present analysis prefers to adopt the more conservative view of the situation. The very high value of 33,700 Mcm/yr for "natural flow" at Hit -- the last item on Graph EF-1 -- is conjectural and will be discussed below.

What then can be said about the quantity of water in the Euphrates at Birecik, Tabqa, and Hit? It appears that the sequence of data used by CLA[3088] at Birecik is better than the higher figures shown by GAP[3081]. How were the GAP data derived? Table EF-8 suggests an explanation. This table shows the data used by al-Hadithi[3067] for Hit aggregated in ten, twenty, thirty, forty, and forty-nine year periods. Note how river flow can vary from one ten-year period to the next (left-hand column). Also note how increasing aggregations can change and/or obscure high and low periods of flow. While these data represent conditions at Hit, the figures in parentheses are approximations of matching flow leaving Turkey. These latter values were derived by reducing the Hit figures by 6.6 percent, the average amount shown to enter the system from the Balikh and Khabur rivers in Syria. Without claiming overmuch for evidence such as this, the correspondence between the derived flow for the period 1963-64 through 1972-73 and the data given by GAP for Karkamis should be noted. One may ask if the unspecified time period upon which GAP data are based perhaps corresponds to this decade of river flow.

Table EF-9 further illustrates the variability and complexity of discharge. The four years of greatest flow (1965-66 through 1968-69) have the phenomenal average of nearly 50,000 Mcm/yr. The four smallest consecutive years average about 17,000 Mcm/yr. Within those four year periods, the single largest annual flow equaled 63,000 Mcm and the least 10,700 Mcm. Graph S-7 shows the 49 year series at Hit. The flood of 1969 catches the eye and dominates. One may ask in P.J. Weatherhead's words, "How unusual are unusual events?"[3087] (p. 1385). In his review of unusual events and their impact on ecological and biological systems he concludes, "We tend to overestimate the importance of some unusual events when we lack the perspective provided by a longer study." In this case, 49 years of data do not seem long enough to provide an objective perspective. Again, as the statistician M.J. Moroney says, "I dislike time series and index number men. The plain truth is that we can never -- except by an act of great faith -- say that an existing trend will be maintained even for a short time ahead."[3072] (p. 372). If one were to fit trend lines to the data shown in Graph S-7, there would be some upward slope from 1930 to 1969. But the period from 1941 to 1961 would show a downward trend. We are even further blinkered by lacking data for the last 12 years (1974-1985). At least, with 49 years available, the lean years of the thirties tend to balance out the abundant late sixties. Such differences present opportunities for choices based on political points of view -- a fact to be remembered.

To continue downstream from Birecik, the slight increase at Karkamis is consistent with the regime of the river, but would a parallel upward value persist at that point if long-run data were available? It seems likely that that would be the case. USAID's[3045-3049] average "for the last seven years" reflects the unusually low water from 1973 through 1975. Whether drought or removals account for such a deficit, this seems far too low for long-range planning. Beaumont's[0033] datum for Yusuf Pasha is in a range similar to the lower values shown for Tabqa (Graph EF-1). Should we then reject the high values at Tabqa cited by al-Hadithi[3067]? After all, he says they are for 21 years. Since only the Sajur contributes to the river between this location and the Turkish border, a slight increase suggested by the lower limit line seems more consistent. It may be that al-Hadithi's choice of 21 years included years with relatively high water levels. If we accept CLA's[3088] data for Birecik, it is reasonable to expect slightly higher values than those given by the SAR[3050] and USAID's nine-year average for Tabqa. (There is also the possibility that the USAID figures refer to a point at the Syrian-Turkish border, which might account for their being somewhat lower.) It also appears that al-Hadithi's higher value for Tabqa is inconsistent with his other data for Hit. These latter reflect tributary flows downstream from Tabqa -- the Balikh and Khabur -- and should be greater. This increase between the two stations is shown by the lower limit line. Nevertheless, about 500 Mcm of the difference is not accounted for with these data.

Finally, at Hit, al-Hadithi's[3067] data are most complete. Except for the unexplained disagreement between Ubell's[3063] and his data, the 49 year series al-Hadithi presents is convincing.

The gist of all this is that the longer run, lower average values seem safest for talking about future river use. Thus, the data given by CLA[3088] for Birecik (26,990 Mcm/yr) and the 49 year record provided by al-Hadithi[3067] for Hit (28,400 Mcm/yr) represent the best data sets this study can provide (Table EF-10). The data for Tabqa (ath-Thawrah) are less certain; a middle range average value (27,230 Mcm/yr), although less thoroughly substantiated than the values for Birecik and Hit, is consistent with them.

There remains the question of "natural flow" versus measured flow, which further complicates this discussion. That, however, will be considered in the section on the Khabur in Syria, as well as in the part of this report analyzing Turkish use of Euphrates waters.

Table EF-1

DISCHARGE OF THE EUPHRATES
FROM BIRECIK, TURKEY, TO HIT, IRAQ

Location	Flow in cu m/s min	max	ave	Flow in Mcm/yr	Time Period	Data Source
Birecik	484	1356	856	26,990	1937-63	CLA
Birecik	--	--	--	30,970	?	GAP
[Average, N=2]				28,980	?	
Karkamis	--	--	--	31,380	?	GAP
Syrian/Turkish Border	--	--	--	22,100	7 yrs.	"last 7 yrs" USAID, p. II-7
Yusuf Pasha	--	--	--	26,050	1950-66	UNESCO, noted in Beaumont, p. 40
Tabqa-Thawrah	--	--	--	26,000	1973	Samman
Tabqa-Thawrah	--	--	913	28,790[1]	21 yrs?	al-Hadithi
Tabqa-Thawrah	--	--	810	25,543[1]	14 yrs	See Table EF-5
Tabqa-Thawrah	--	--	735	23,180[1]	?	Shchukin
Tabqa-Thawrah	--	--	--	26,200	?	Wirth/Bourgey, p. 343
Tabqa-Thawrah	--	--	--	23,950	10 yrs	USAID
[Average]				27,230	31 yrs	al-Hadithi & USAID
Hit	--	--	927[2]	29,240	?	CLA, p. 205
Hit	--	--	--	33,690[3]	?	CLA, p. 205
Hit	535	1378	934	29,450	1937-63	CLA[4]
Hit	--	--	902	28,400[1]	1924-73	al-Hadithi
Hit	--	--	931	29,600[1]	1924-78	GOI[5]
Hit	--	--	1009	31,820[1]	1940-69	Ubell, p. 4
[Unweighted average, N=4]				29,800		
Hit	--	--	853	26,900	1978	al-Hadithi

Sources: CLA(3088), GAP(3081), USAID(3046), Beaumont(3068), Samman(0993) al-Hadithi(3067), SAR(3050), Shchukin(2102), Bourgey(0040), Ubell(3063).

1 Computed from average flow.
2 Measured flow.
3 Estimated "natural flow."
4 By inspection, CLA Table B-10 is a subset of al-Hadithi, Table E-1, the next reference.
5 Government of Iraq, Ministry of Irrigation, as cited in al-Hadithi, p. 52.

Table EF-2

DISCHARGE OF EUPHRATES RIVER AT BIRECIK, TURKEY
1937 - 1964
(Average flow in cu m/s)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Average
1937	496	667	1328	2644	1753	870	522	370	336	369	573	798	894
1938	680	647	873	3257	2686	1084	638	398	347	345	448	557	997
1939	558	620	1061	2382	2126	717	482	349	445	316	374	547	831
1940	848	947	985	4081	2742	1190	677	391	326	458	503	837	1165
1941	725	1362	2669	3188	2434	750	483	344	304	330	379	473	1120
1942	504	581	1038	3105	2886	994	448	323	292	360	898	957	1032
1943	603	544	696	2853	2548	853	421	308	278	311	340	514	856
1944	468	699	2019	2336	3339	1129	563	387	351	361	500	518	1056
1945	560	531	697	1911	1871	868	361	271	241	238	268	472	691
1946	417	422	947	2337	2868	1246	571	397	307	617	416	499	920
1947	580	620	1697	1839	1028	570	328	252	227	232	620	448	703
1948	442	627	583	3216	3376	1566	583	356	297	297	320	426	1007
1949	381	420	644	1773	2234	737	349	278	250	254	258	371	662
1950	359	423	824	2164	2305	727	399	313	282	405	358	472	753
1951	505	501	1203	1983	1449	676	355	271	279	408	432	534	716
1952	440	838	989	3438	2418	957	458	315	289	285	299	456	932
1953	462	643	743	2927	2658	1207	538	332	285	292	365	419	906
1954	430	476	1184	3382	2972	1234	609	345	302	304	340	561	1012
1955	505	545	802	1367	1424	560	238	279	249	252	277	465	588
1956	440	509	689	2720	2300	1080	488	335	304	309	316	437	827
1957	420	577	1641	1766	2336	1027	455	303	270	271	301	449	818
1958	450	506	1059	1943	1385	740	347	268	240	240	259	419	655
1959	369	315	754	1701	1351	718	302	249	239	261	301	327	574
1960	640	529	1055	3005	2098	740	400	297	272	252	297	326	826
1961	363	495	534	1409	1038	426	219	174	156	177	293	525	484
1962	434	805	1443	1710	1240	637	359	254	229	239	293	659	692
1963	1008	1118	1025	3291	4115	2321	951	508	410	510	507	512	1356
1964	369	540	1837	2528	1781	911	400	267	249				
Mean in													
cu m/s	516	625	1108	2509	2241	948	466	319	288	324	393	521	
Mcm	1380	1520	2970	6500	6000	2460	1250	850	750	870	1010	1400	

Source: CLA[3088], Table B-9, p. 217.

Table EF-3

DISCHARGE OF EUPHRATES RIVER AT HIT, IRAQ
1937 - 1964
(Average flow in cu m/s)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Average
1937	525	620	1070	2080	1800	1090	558	343	275	291	679	1090	862
1938	1130	971	966	2220	3200	1450	778	461	355	359	491	528	1076
1939	731	761	1120	2000	2530	1230	685	452	375	352	395	586	935
1940	1010	1080	1270	3060	2950	1330	700	418	343	407	708	908	1182
1941	922	1300	2700	2700	2420	1040	549	303	321	341	417	390	1117
1942	603	821	1220	2640	3030	1190	451	281	238	329	919	1210	1078
1943	1220	979	990	2350	2990	1190	573	376	309	330	483	485	1023
1944	666	754	1650	2250	3210	1400	622	394	359	379	634	513	1069
1945	904	726	847	1670	2120	1420	630	358	290	304	371	574	851
1946	580	656	1130	2160	3100	1660	765	463	376	591	612	473	1047
1947	870	900	1560	2080	1140	745	449	301	261	281	549	575	809
1948	554	1160	919	2560	3560	1950	749	408	349	356	368	495	1119
1949	407	542	585	1670	2200	1120	472	319	273	283	311	355	711
1950	448	354	1010	1970	2520	1130	494	311	264	315	401	373	799
1951	554	503	764	1870	1580	836	371	246	226	399	471	576	700
1952	451	1270	1140	2940	2350	1160	558	334	281	308	343	416	963
1953	537	1030	1310	3010	3110	1660	712	397	342	359	483	478	1119
1954	644	890	1630	3820	3380	1670	761	423	336	373	508	617	1254
1955	1090	706	899	1410	1720	777	340	228	228	284	318	521	710
1956	751	819	988	1750	2730	1230	558	314	269	328	370	402	876
1957	362	441	1580	1640	2690	1520	588	293	238	300	417	649	893
1958	679	644	1080	1820	1560	1140	414	219	196	307	373	495	744
1959	502	474	664	1672	1513	1029	364	209	194	290	390	360	638
1960	881	607	1298	2684	2766	1177	522	303	253	355	418	412	973
1961	494	571	466	1338	1209	475	197	94	99	191	377	905	535
1962	694	979	1338	1835	1454	883	298	153	317	248	297	491	749
1963	851	1300	1365	2585	4368	2819	931	422	311	451	630	505	1378
1964	398	468	1218	2621	1597	1075	373	168	172				
Mean in													
cu m/s	695	797	1171	2229	2457	1264	552	321	280	337	468	576	
Mcm	1860	1940	3140	5770	6540	3270	1480	860	730	900	1210	1540	

Source: CLA[(3088)], Table B-10, p. 218.

Table EF-4

MEAN MONTHLY AND MEAN ANNUAL DISCHARGES
OF EUPHRATES RIVER AT HIT, IRAQ
1924 - 1973
(Flow in cu m/s)

Years	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1924-25	261	299	713	369	309	650	1014	1117	829	555	255	212	549
1925-26	229	288	488	714	737	1086	2296	2344	1416	646	357	270	906
1926-27	256	374	375	344	356	507	1284	1506	729	354	260	222	547
1927-28	231	266	264	291	388	543	1951	1718	651	345	241	230	593
1928-29	227	277	587	507	710	885	2198	3358	1758	712	460	337	1001
1929-30	346	334	435	335	342	344	481	533	249	268	202	283	338
1930-31	225	265	367	568	605	798	1794	1898	1367	635	355	278	763
1931-32	303	308	350	343	350	750	1270	1620	834	375	242	213	580
1932-33	232	250	270	275	313	481	501	1600	1110	443	236	215	495
1933-34	209	231	317	398	448	687	1530	1270	930	413	306	242	582
1934-35	236	341	268	681	885	1260	2560	2330	939	528	397	350	889
1935-36	356	747	1310	879	1140	1290	2250	2530	1630	811	519	331	1140
1936-37	321	382	757	525	620	1070	2080	1800	1090	558	343	275	819
1937-38	291	679	1090	1130	971	966	2220	3200	1450	778	461	355	1130
1938-39	359	491	528	731	761	1120	2000	2530	1230	685	452	375	939
1939-40	352	395	586	1010	1080	1260	3060	2950	1330	700	418	343	1120
1940-41	407	708	908	922	1300	2700	2700	2420	1040	549	303	321	1190
1941-42	341	417	390	603	821	1200	2640	3030	1190	451	281	238	969
1942-43	329	919	1210	1220	979	990	2350	2990	1190	573	376	309	1120
1943-44	330	483	485	666	754	1650	2250	3210	1400	622	394	359	1050
1944-45	379	634	513	904	726	847	1670	2120	1420	630	358	290	874
1945-46	304	371	574	580	656	1130	2160	3100	1660	765	463	376	1015
1946-47	591	612	473	870	900	1560	2080	1140	745	449	301	261	830
1947-48	281	549	575	554	1160	919	2560	3560	1950	749	408	349	1130
1948-49	356	368	495	407	542	585	1670	2200	1120	472	319	273	734
1949-50	283	311	355	448	354	1010	1970	2520	1130	494	311	264	789
1950-51	315	401	373	554	503	764	1870	1580	836	371	246	226	670
1951-52	399	471	576	451	1270	1140	2940	2350	1160	558	334	281	991
1952-53	308	343	416	537	1030	1310	3010	3110	1660	712	397	341	1100
1953-54	359	483	478	644	890	1630	3820	3380	1670	761	423	336	1240

Table EF-4 continued

Years	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1954-55	373	508	617	1090	706	899	1410	1720	777	340	228	228	742
1955-56	284	318	521	751	819	988	1750	2730	1230	558	314	269	877
1956-57	328	370	402	362	441	1580	1640	2690	1520	588	293	238	874
1957-58	300	417	649	679	644	1080	1820	1560	1140	414	219	196	760
1958-59	307	373	495	502	474	664	1672	1513	1029	364	209	194	650
1959-60	290	390	360	881	607	1298	2684	2766	1177	522	303	253	961
1960-61	355	418	412	494	571	466	1338	1209	475	197	94	99	510
1961-62	191	377	905	694	979	1338	1835	1454	883	298	153	317	785
1962-63	248	297	491	851	1300	1365	2585	4368	2819	931	422	311	1332
1963-64	451	630	505	398	468	1218	2621	1597	1075	373	168	172	806
1964-65	291	333	603	467	841	1210	2120	2245	1210	483	256	218	855
1965-66	408	513	652	1194	2118	1514	2241	2649	1451	583	325	304	1155
1966-67	534	634	849	988	968	1281	2787	4920	2199	999	491	408	1424
1967-68	644	1091	1259	1319	1263	2376	3794	4185	2271	956	495	467	1677
1968-69	557	725	1586	2448	1697	2732	4589	5460	2307	968	535	488	2011
1969-70	526	567	569	641	761	1122	1786	1114	602	249	147	165	595
1970-71	297	332	582	386	350	830	2522	1717	1027	402	249	254	746
1971-72	376	413	516	406	401	700	1495	2319	1367	511	229	243	809
1972-73	330	461	414	317	337	595	1130	1280	608	192	81	89	526

Source: al-Hadithi(3067), Table-1, pp. 225-27.

Table EF-5

DISCHARGE OF EUPHRATES RIVER IN SYRIA[1]
(Data for Available Years)

Year	cu m/s	Mcm/yr		Average
1967	830.0	26,170		
1970	835.0	26,330[2]		
1971	835.0	26,330[2]		
1972	835.0	26,330[2]	...	(n = 4) 26,290 Mcm
1973	476.0	15,010		
1974	406.0	12,800		
1975	428.0	13,500	...	(n = 3) 13,770 Mcm
1976	1100.0	34,690		
1977	1042.0	32,860	...	(n = 2) 33,780 Mcm
1978[3]	971.0	30,621		
1979[3]	808.0	25,480		
		22,100[4]	...	7 yr average
1980[3]	1013.0	31,944		
	998.0	25,172	...	12 yr average
1982[3]	1063.0	33,522		
1984[3]	698.0	22,012		
	810.0	25,543	...	14 yr average

Source: USAID 1980[3046], Tables 3 & 4, II 32-34.

[1] Location of the gauging stations unidentified in original source.
[2] Values for these three years are identical in USAID.
[3] Source: SAR *Statistical Abstracts*[3050][3216-3219]
[4] USAID (1980), p. II-7: "The long-term annual quantity of water in streams and rivers in Syria is quoted at 32 billion m^3 of which 27 billion m^3 is in the Euphrates River .... The flow of the Euphrates the last seven years has averaged substantially less, however, about 22.1 billion m^3; measurements at the Syrian-Turkish border."

Table EF-6

DISCHARGE DATA FOR SELECTED RIVERS IN SYRIA (in cu m/s)

Year	Euphrates	Khabur[1]	Barada	Afrin[1]	Sajur	Orontes[1]
1967	830.0	48.0	8.8	8.0	4.0	
1970	835.0[2]	48.0	11.0	8.0	3.0	
1971	835.0[2]	50.0	11.0	8.0	4.0	
1972	835.0[2]	43.0	10.0	4.0	3.0	50.0
1973	476.0	35.0	2.4	3.0	1.5	25.0
1974	406.0		3.0	0.7	0.4	
1975	428.0	18.0	4.2	5.3	3.9	16.9
1976	1100.0	56.4	8.7	9.3	4.8	49.7
1977	1042.0	43.0	8.8	8.0	4.2	51.1
1978[3]	971.0		10.4	9.7	4.2	60.1
1979[3]	808.0		3.6	9.7	1.9	34.3

Source: USAID 1980(3046), Tables 3 & 4, II 32-34.

[1] And tributaries.

[2] Three consecutive years with same figure in the original source.

[3] Source: SAR *Statistical Abstracts* (3050)(3216)

Table EF-7

DIFFERENCES IN DATA REGARDING DISCHARGE OF EUPHRATES AT HIT, IRAQ: 1940 - 1969

(in ten year averages)

	Ubell		al-Hadithi	
Years	cu m/s	Mcm/yr	cu m/s	Mcm/yr
1940-49	1004	31,700	891	28,100
1950-59	871	27,500	965	30,400
1960-69	1151	36,300	1056	33,300
1940-69	1009	31,800	971	30,600

Sources: Ubell[3063], p. 4; al-Hadithi[3067], Table E-1.

Table EF-8

CUMULATIVE MEAN ANNUAL DISCHARGES AT HIT, IRAQ

(in multiple decade intervals)

Decade Ending	10 year Average	20 year Average	30 year Average	40 year Average	49 year Average
1933-34	20,040 (18,800)				
1943-44	32,690 (30,670)	26,370 (24,740)			
1953-54	29,560 (27,730)	31,130 (29,200)	27,430 (25,730)		
1963-64	26,170 (24,550)	27,870 (26,140)	29,470 (27,650)	27,150 (25,470)	
1972-73	33,440 (31,370)	29,810 (27,960)	29,720 (27,880)	30,470 (28,580)	28,380 (26,620)*

Source: al-Hadithi[3067], Table E-I.

N.B. Figures in parentheses ( ) represent the estimated flow at Birecik based on an average contribution from Syrian tributaries of the Euphrates of 6.6%, i.e., the flow at Hit equals 106.6% of the flow at Birecik.

* This figure differs slightly from the true 49 year average for 1924-25/1972-73 (28,440 Mcm/yr) because of the double counting of 1963-64 and rounding errors.

Table EF-9

TEN-YEAR AVERAGE DISCHARGES ON EUPHRATES AT HIT, IRAQ FOR PERIOD 1924 - 1973

	Years (Oct-Sep)	Flow in cu m/s	Flow in Mcm
	24/25-33/34	635.4	20,040
	34/35-43/44	1036.6	32,690
	44/45-53/54	937.3	29,560
	54/55-63/64	829.7	26,170
	63/64-* 72/73	1060.4	33,440
Forty nine years	24/25-72/73	901.8	28,440
Four largest consecutive years	65/66-68/69	1566.75	49,410
Four smallest consecutive years	29/30-32/33	544.0	17,160
Largest year	68/69	2011.0	63,420
Smallest year	29/30	338.0	10,660

Source: Iraqi Ministry of Irrigation, given in al-Hadithi[3067], Table E-I. Breakdown computations by Kolars.

* The year 1963-64 (which was used in the preceding decade's calculations) is included here to give a ten-year average.

Table EF-10

BEST ANNUAL ESTIMATE OF EUPHRATES FLOW TO THE YEAR 1973 (in Mcm)

	Birecik		Tabqa		Hit	
	Year	Amount	Year	Amount	Year	Amount
Maximum recorded[a]	1963	42,760[1]	1976	34,690[2]	68-69	63,420[3]
Minimum recorded[b]	1961	15,260[1]	1974	12,800[2]	29-30	10,660[3]
Average discharge	37-63	26,990[1]	31yrs	27,230[4]	24-73[c]	28,400[3]
Est. discharge at Karkamis[d]		27,400				

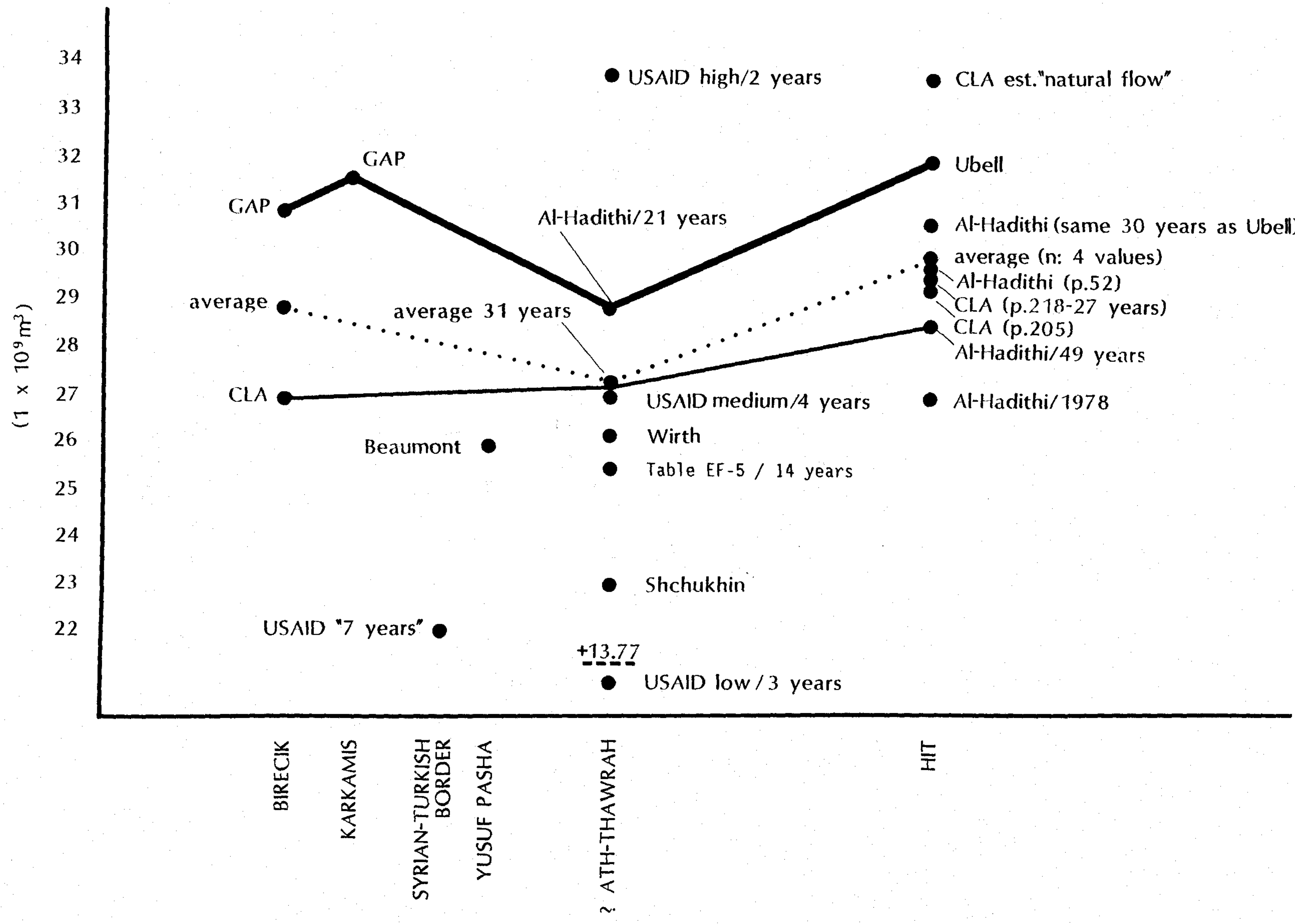
[1] CLA(3088) [2] USAID(3045-3049) [3] al-Hadithi(3067) [4] See Table EF-1

[a] Higher discharges no doubt occurred at Birecik and Tabqa in 1969. However, no specific and reliable data are available for that year for those stations.

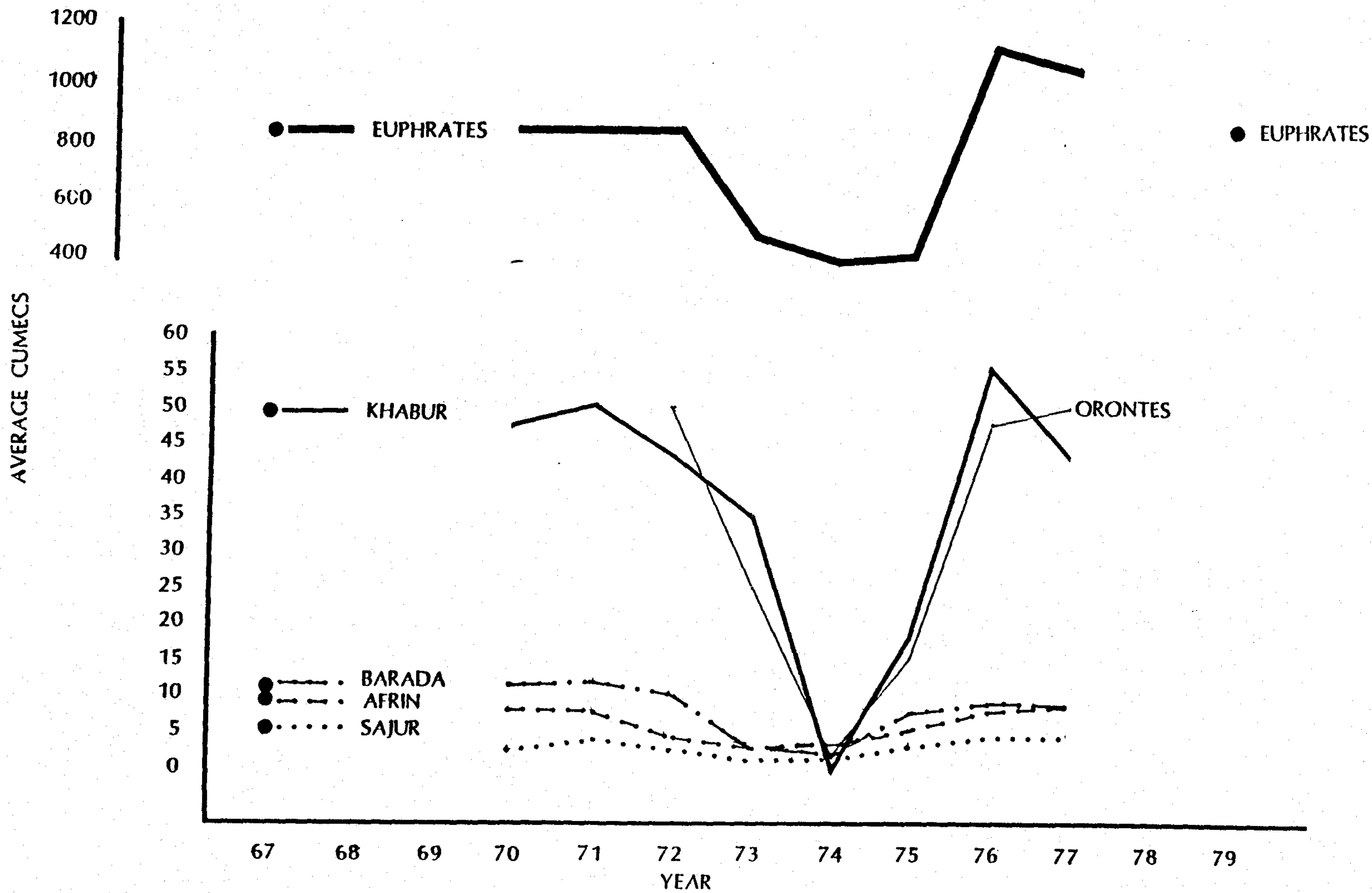
[b] The same may be said of low water years such as 1929-30 at Hit. Lack of data for Turkey permit only estimates for such periods, as well as for those at Tabqa.

[c] CLA (as a subset of al-Hadithi) provides a value for 1937-63 of 29,450 Mcm. This provides consistency along the average discharge row, but the longer record for Hit is preferable for many purposes.

[d] This estimate is based upon the materials shown in Table S-1 and would include the flow of the Nizip tributary. This figure is shown only to remind the reader that additional water can enter the system in Turkey downstream from Birecik. The total, however, is not intended to match this table or the discussion upon which it is based.



Graph EF-1: **REPORTED AVERAGE YEARLY DISCHARGE OF THE EUPHRATES**



Graph **EF-2:** ANNUAL DISCHARGE OF SELECTED SYRIAN RIVERS

Sources: USAID, 1980, Tables 3 and 4, SAR Statistical Bulletin, 1980

Chapter 3

THE EUPHRATES SYSTEM IN SYRIA

Syria, as the second riparian user of the Euphrates River, contributes water to the system as well as extracting larger amounts of water from it. Small quantities of runoff enter the mainstream from wadis along its right bank, but, with the exception of the flow of the Sajur (Turkish: Sacir), this contribution is ephemeral, unpredictable, and negligible. The discharge of left bank tributaries into the Euphrates is much more significant. The Balikh (Turkish: Culap) and Khabur (Turkish: Habur and/or Circip) support considerable agriculture in Turkey and downstream in Syria[1]; these add from 7 percent according to Kolars (this report) to 12 percent according to Beaumont[(0033)] toward the discharge downstream into Iraq. A further issue is raised if the source of the water in these two streams is considered. Because these tributaries have their headwaters in Turkey, an additional 5.8 to 10 percent of the Euphrates' total volume may be influenced by Turkish water resource planning.

The questions that need to be asked at this point are: How much water do the Euphrates and its tributaries discharge into Syria from Turkey, and from Syria into Iraq? What are the sources of that water? What demands (extractions, polluting return flows) are currently placed on the stream, and what can be expected in the near future? These questions are not easily answered because of the scattered and widely varying bodies of data and estimates that are available to investigators. The discussion, graphs, and tables that follow will try to give the range of such information, to evaluate available data, and to assess which answers are most likely to be correct.

3.1. Relative Shares of Euphrates Water: Birecik, Turkey to Hit, Iraq

Table S-1 addresses the amount of water provided by each of the sources mentioned above. Despite the fact that a wide range of data exists for discharge along its course, the figures in this table have been chosen for their internal consistency and chronological span. The magnitude of Euphrates flow has been discussed in Section 2. At issue here are the relative proportions of that flow.

Given a volume of 27,000 Mcm at Birecik, an additional 410 Mcm enters the main stream before reaching the Turkish-Syrian border at Karkamis. This is a fairly large amount for such a short distance (approximately 25 km), but includes the flow of the Nizip and several smaller streams. Precipitation is approximately 400 mm annually; runoff is about 100 mm per year along this stretch of the river.

The next measured increment of stream flow is from the Sajur, which rises in Turkey and enters the Euphrates a short distance inside Syria on the right bank (Table S-2). While somewhat greater flow values are shown for Turkey, the diminished downstream flow in Syria can easily be the result of small-scale private irrigation in both countries. A small reservoir reportedly planned for irrigation in Syria might further reduce stream flow through evaporation and extraction (USAID, 1980[3045]; RPU 57, p. I-184). A small dam and reservoir are planned for the west branch of the Sacir in Turkey (the Tuzel Suyu). The Tuzel has an average annual natural flow of 40.15 Mcm, and the reservoir will have an effective capacity for irrigation purposes during the months of June-July-August of 46.3 Mcm. No indication is available of the area to be irrigated, but assuming a 50 percent use of the available water (minimum reservoir capacity 5.7 Mcm), a total of 20.3 Mcm could be removed from the Sajur's flow downstream. This is not a significant amount, but it is one which may necessitate international negotiation for the optimum use of this stream by both countries. (All Turkish data from GAP[3081], V-24.)

Continuing downstream, the head of Lake Assad formed by the Tabqa/Thawrah Dam is encountered south of Yusuf Pasha at the village of Remis. This reservoir has a storage capacity when filled to a crest height of 40 m (300 m above sea level) of 11,600 Mcm (SAR, Statistical Abstract, 1980[3050]) and a surface area of 625 sq km. Loss by evaporation from this surface is significant, and will be discussed elsewhere in this report.

An underground aqueduct leads from a pumping station on Lake Assad, southeast of Khafsah Kabir, to the city of Aleppo. This is apparently the major and perhaps the only source of water for that city at present. Use amounts to 220,000 cu m/day, which is about 145 liters per capita, for a total of 80.3 Mcm/yr. (USAID[3045], RPU 20, p. I-69.) It is not the purpose of this section to consider the impact of withdrawals of this nature. However, it is interesting to note that this amount is approximately equal to that added by the Sajur upstream. Domestic demand will soon exceed this amount. At the same time, fruit canning at Idlib, two cement plants, a glass plant, and a sugar factory are all significant water users. Further details of this situation are given in Table S-3, which discusses the Qweik River.

While this river does not feed into the Euphrates drainage system, it relates to water use problems common to both systems. Sewage facilities in Aleppo are considered to be "totally inadequate" (RPU 20).

The Balikh (Turkish: Culap) is the next tributary. It enters on the left bank, and receives the bulk of its water from the Ain Arous (spring) in Syria, near Tel Abyad on the Turkish border. Additional flow crosses the border from Turkey, but the consistency of this is uncertain from the data available (Table S-4). The 116 km length of the Balikh in Syria (SAR, *Statistal Abstract*[3050], Table 4/1) is heavily utilized for irrigation. The same is true for the Culap (Balikh) in Turkey, where the stream and its tributaries are apparently dry for varying periods of time. No data are available in usable form to indicate the exact amount of land irrigated or water used in either country along the Balikh/Culap River system. The quantity must be considerable.

Some estimate of the impact of Turkish use in future years may be made. According to plans, some 160,000 ha will be irrigated on the Urfa-Harran Plain (GAP[3081], p. V-4). Water for this will come through the Urfa Tunnel from the lake behind the Ataturk Dam. Return flow from these fields may range between 2300 and 5800 cu m per hectare, depending upon the interpretation chosen for the data (see Tables N-4 and V-3). This would increase the flow of the Balikh by amounts ranging from 368 to 928 Mcm/yr. This would essentially double to quintuple the downstream flow. While this may present new opportunities for irrigation in Syria, the quality of this water may be poor as a result of upstream leaching and/or dissolved fertilizers, herbicides, and pesticides. Flooding might also present problems. Again, while mention should be made of these issues, they remain secondary to the main purpose of this section's discussion.

The final contribution to the flow of the Euphrates comes from the Khabur River system, which joins the mainstream at Deir ez-Zor. The use of this stream in Turkey and Syria, and the complexities relating to its various tributaries and ground water resources, justifies a detailed analysis in the pages that follow. At this point, it is sufficient to say that the "natural" flow of the stream at Suwar is about 56.5 cu m/s (1780 Mcm/yr). It should also be noted that, wherever possible, data have been used in the calculations for Table S-1 that pre-date major dams and developments along the rivers concerned.

3.2. The Relationship Between Euphrates Flow and that of its Syrian Tributaries

Just as the discharge of the Euphrates varies widely from year to year, the difference in discharge between Birecik, Turkey, and Hit, Iraq, varies greatly. Sometimes, as in 1941, 1951, and 1959, there was actually less water at Hit than in Turkey. On the other hand, positive increments have varied from as much as 7,600 Mcm (in 1954) to as little as 400 Mcm (in 1944). The average difference is 2,470 Mcm more at Hit than in Turkey, based on 27 years of measurements (1937-1963). These variations are shown by Tables S-5, and by Graphs S-1 through S-6.

Graph S-1 shows the incremental differences between discharge at Birecik, Turkey, and Hit, Iraq, from 1937 through 1963. (This is the longest consecutive record for both gauging stations available for this analysis.) Discharge at Birecik is indicated as a flat line by the abscissa. As can be seen, no particular trend is evident in the variation of these differences. Graph S-2 shows the correlation -- or lack thereof -- between the quantity of water discharged at Birecik and the incremental difference recorded at Hit, when data from both sites are plotted for the same year.

On the other hand, Graph S-3 shows a clear positive correlation (r = 0.92) between the total discharge at Birecik and the total discharge at Hit. This indicates that the amount of water discharged across the border from Turkey into Syria will definitely affect the amount of water arriving downstream in Iraq. However, it is the flow of the main stream and not the flow of its tributaries in Syria which underlies this phenomenon. This implies that variations in the flow of the Khabur in Syria, whether from natural or human causes, may increase or decrease the amount of water available in any given year, but that significant deficits downstream in Iraq are either the result of water removals from the main stream by human action in Turkey or Syria, or of major climatic variations in the catchment area in Turkey.

The question of why, in terms of flow, some years are lean and some abundant on the Khabur and/or Balikh remains to be discussed. If these two streams were to be dried up completely, the flow of the Euphrates would on the average be reduced by 6.6 percent in Iraq, but year to year variation in the incremental flow reaching Hit has a more complex relationship to variations in the flow of the Syrian tributaries (Graph S-4).

The nature of this relationship is shown by Graphs S-5 through S-7. In the first of these graphs, the discharge of the Euphrates at Birecik has been taken as a general indicator of conditions throughout the region, including the headwaters of the Syrian tributaries. Runoff appears to be a function of the holding capacity and permeability of the soil and perhaps of major underground aquifers. Thus, the lack of correlation shown in Graphs S-2 and S-4 (where mainstream flow peaks appear, if anything, to be diametrically opposed to incremental peaks) has been largely eliminated by taking two-year running averages at Birecik and plotting them against increments at Hit. This assumes that one-half the water within the watershed will be retained for a given year and run off in the next. It should be noted that the correlation is good for the years from 1945 to 1961 when each two-year average is plotted against the same year at Hit, but that for the sequences 1940-1944 and 1962-1963 -- as shown for the former on Graph S-6 -- the diametric opposition of flows to increments is accentuated by the averaging process. This, in turn, has been overcome (Graph S-5) by staggering the downstream values by two years (e.g., 1941 is correlated with 1938-39). Before suggesting an explanation of this delayed arrival downstream, it is reasonable to suggest that, given the flow at Birecik in Turkey, it should be possible to predict the "natural" flow of the tributaries in Syria. This may be of considerable importance in the future. (The one caveat to this statement is that the discharge data at Birecik must be accurately equated with "natural" flow.)

Graph S-7 suggests an explanation of the incremental lag described above. This shows the measured flow at Hit for each year beginning in October and ending with September of the following year for the period 1924-25 through 1972-73. (A similar time span for Birecik is, unfortunately, unavailable, so some of the ideas that follow must remain as untested speculations.) Inspection shows that the lag period 1940-1944 (Graph S-5) followed the severe drought of 1930-1936 (Graph S-7). A critical transition year was 1945, when the lagged arrival of the increment ended and a year-to-year correspondence began. This was the eighth year after the drought that flow had been above average (as shown by the five-year running average also plotted on Graph S-7). This suggests that considerable time is necessary to recharge groundwater reservoirs before they are full enough to allow an added increment to be passed downstream in the same year.

The impact of excess runoff is less certain, and because of the shortness of the available record it is not possible to test the effect of the great discharge of 1969 against later years. Some lag effect is indicated for the years 1957-58 (Graph S-5) following the heavy discharge at

Birecik in 1954, but the data do not warrant much speculation. Nevertheless, the above discussion allows a clearer view of the situation on the tributaries in Syria. As mentioned earlier, the complexity of the Khabur system and the emphasis placed on its future development by the Syrians justifies a detailed look at it in the section that follows.

Endnotes

1. It is difficult to estimate exactly how much water is removed from the Khabur in Turkey for agricultural purposes. GAP[3081] reports that 6700 ha are irrigated at the State Production Farm (Devlet Uretme Ciftligi) and that an "important part" of the water comes from underground sources. It also states that four pumps are used to supply water from the Habur to the "upper elevations." It should also be noted that a reservoir called the "Aride" appears upstream from Ceylanpinar on the Habur on GAP maps although no reference to it is made in the text. Finally, GAP reports a total of an additional 2186 ha irrigated in the same region from small ponds or reservoirs.

General descriptions of the State Produce Farm (D.U.C.) can be found in: Urfa Provincial Government, *Urfa -- Il Yilligi, 1967* (Dogus Matbaasi, Sivas, Turkey: no date), pp. 207-212[3221].

Additional information on agriculture in the Urfa-Harran watershed (i.e. the headwaters of the Culap/Balik) is available in: M. Ayyildiz, et al., "G.A.P. de Uygulanabilecek Sulama Teknolojileri," in Ankara University Faculty of Agriculture, *G.A.P. Tarimsal Kalkinma Simpozyumu -- 18-21 Kasim 1986* (Ankara Universitesi Basimevi, Ankara: 1986), pp. 305-328[3222]. However, no exact figures are provided from which to estimate exact water extractions.

Table S-1

EUPHRATES RIVER DISCHARGE FROM BIRECIK, TURKEY, TO HIT, IRAQ

	Flow Added in Mcm/yr	Cum. Flow in Mcm/yr	Percent of Total
Flow at Birecik (1937-1963)		26,990	91.7%
Added in Turkey	410	27,400	1.3%
Added in Syria			
by Sacir/Sajur	80	27,480	0.4%
by Balikh/Culap	190	27,670	0.6%
by Khabur	1,780	29,450	6.0%
Total added in Syria	2,050		7.0%
Total added Syr/Tur	2,460		8.3%
Flow at Hit		29,450	

The purpose of this table is to approximate the various shares of water added to the Euphrates between Birecik and Hit. CLA[3088] data were used for their length of coverage and seeming internal consistency. In some instances, FAO[3065] data were used for tributaries because they are the only record available.

The point made here is to show the relative volumes of water each stream contributes. A discharge value of 29,450 Mcm at Hit may be low, but the internal consistency and proportions are more important than the actual value.

Table S-2

THE SAJUR/SACIR RIVER
Yearly Average Flows

Length in km	Flow in cu m/s max	min	ave	Flow in Mcm/yr	Data Source
In Syria					
	25.0	0.5	3.0	94.510	FAO, p. 24
48	13.6	0.0	1.9	59.920	SAR, Stat. Abstract Table 4/1
	--	--	2.8*	88.000	USAID RPU 57, p. I-184
Ave. of above			2.56	80.800	
In Turkey					
60			4.4*	138.600	GAP III-27

Sources: FAO[3065], SAR[3050], USAID[3045], GAP[3081].

* Computed from annual value.

Table S-3

THE QWEIK/BALIK RIVER*
Yearly Average Flows

Location	Flow in Mcm/mo max	min	ave	Flow in Mcm/yr	Data Source
Yagiz Kopru (6 yrs.)	5.05	0.30	1.84	22.02	GAP, III-27
Syria-unspecified	7.0	0.0	0.5	15.8	SAR Stat. Abstract Table 4/1
Kemlim Dam** site				19.84	GAP, V-24
near Aleppo***			2.79	88.0	USAID RPU 20, I-69

Sources: GAP[3081], SAR[3050], USAID[3045].

Notes:

* The Turkish name for this stream is the Balik. This should not be confused with the Syrian name for the Turkish Culap, which is Balikh.

** The Kemlim Dam is planned by the Turks for the Balik River. Minimum reservoir capacity 2.78 Mcm, effective reservoir capacity 31.72 Mcm. No irrigation hectarage available.

*** "...it appears that most of this water is used in Irrigation Network 8 downstream in RPU 26." Network 8 at Matkh has 14,860 ha. (USAID[3045].)

Table S-4

THE BALIKH/CULAP RIVER
Yearly Average Flows

Location	Length of Record	Flow in Mcm/mo max	min	ave	Flow in Mcm/yr	Data Source
In Turkey						
Incirli	14 yrs	5.09	0.40	2.28	27.39	GAP, III-22
Horozkoy	2 yrs	25.20	0.02	7.96	95.48	GAP, III-22
Kopruluk*	2 yrs	4.45	0.09	1.30	15.59	GAP, III-22
SUB-TOTAL**					111.07	
In Syria						
Ain Arous	?			15.77	189.22	FAO & USAID
SUB-TOTAL					300.29	
Cermelik Kopru***	1 yr	0.25	0.00	0.03	0.38	GAP, III-22
TOTAL****					300.65	

Sources: GAP[3081], FAO[3065], USAID[3045-3049].

* Kopruluk is on the Cavsak tributary in Turkey.

** Subtotal is sum of flow of Horozkoy and Kopruluk, two tributaries measured individually. The Incirli measurement is far upstream above Horozkoy.

*** Cermelik Kopru is on the Karacurum in Turkey, but enters the mainstream in Syria.

**** Despite this total, the more conservative value based on the flow of Ain Arous (189.22 Mcm/yr) has been used in Table S-1 because that is the value reported downstream in Syria.

Table S-5

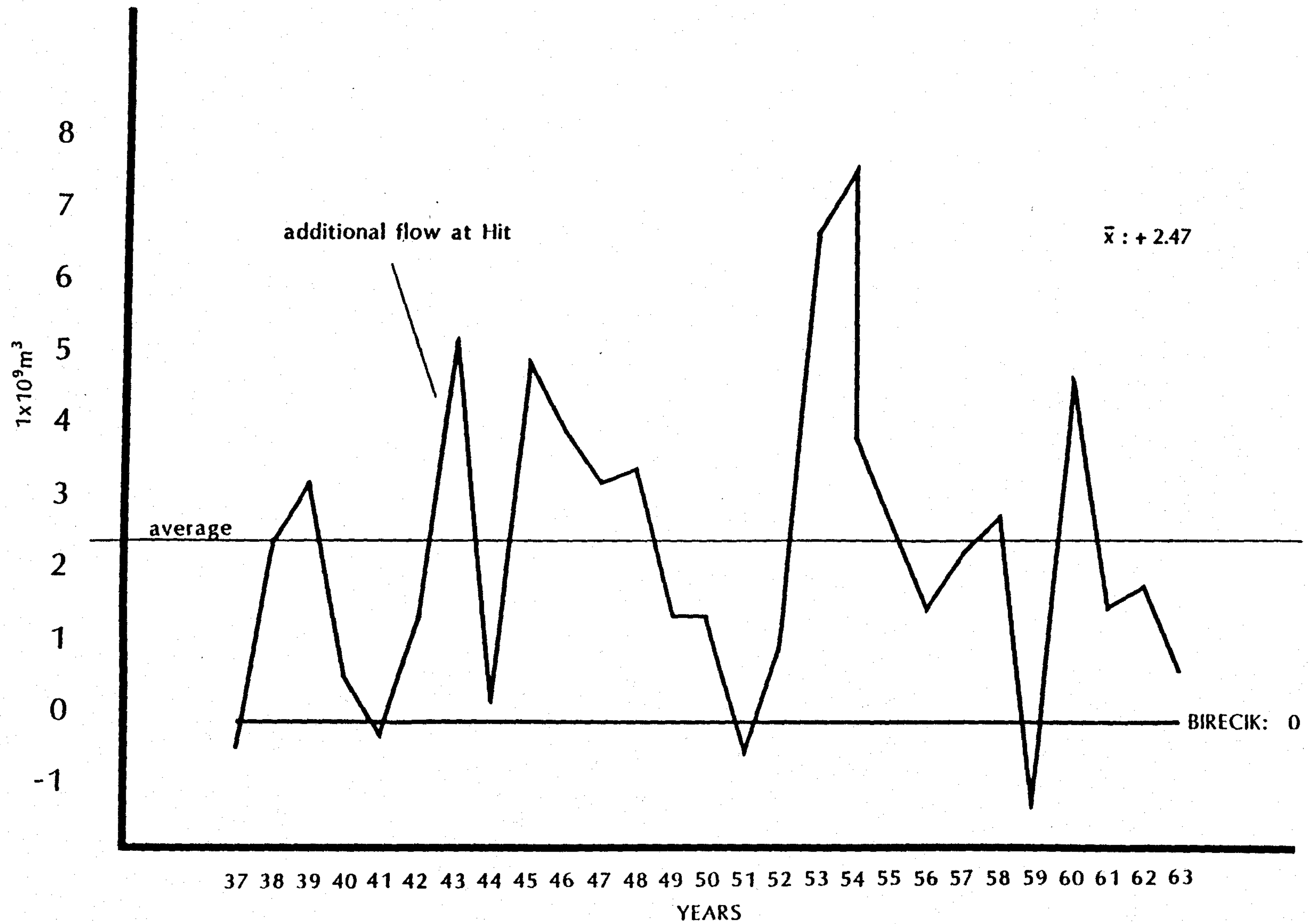
YEARLY FLOWS AT BIRECIK AND HIT
In Chronological Order

	At Birecik			At Hit		
Year	Flow in cu m/s	Flow in Mcm	2-Yr Ave.	Flow in cu m/s	Flow in Mcm	Difference in flows
1937	894	28,200		862	27,800	- 400
1938	997	31,400	29,800	1,076	33,900	+ 2,500
1939	831	26,200	28,800	935	29,500	+ 3,300
1940	1,165	36,700	31,500	1,182	37,300	+ 600
1941	1,120	35,300	36,000	1,117	35,200	- 100
1942	1,032	32,500	33,900	1,078	34,000	+ 1,500
1943	856	27,000	29,800	1,023	32,300	+ 5,300
1944	1,056	33,300	30,200	1,069	33,700	+ 400
1945	691	21,800	27,600	851	26,800	+ 5,000
1946	920	29,000	25,400	1,047	33,000	+ 4,000
1947	703	22,200	25,600	809	25,500	+ 3,300
1948	1,007	31,800	27,000	1,119	35,300	+ 3,500
1949	662	20,900	26,400	711	22,400	+ 1,500
1950	753	23,700	22,300	799	25,200	+ 1,500
1951	716	22,600	23,200	700	22,100	- 500
1952	932	29,400	27,000	963	30,400	+ 1,000
1953	906	28,600	29,000	1,119	35,300	+ 6,700
1954	1,012	31,900	30,300	1,254	39,500	+ 7,600
1955	588	18,500	25,200	710	22,400	+ 3,900
1956	827	26,100	22,300	876	27,600	+ 1,500
1957	818	25,800	26,000	893	28,200	+ 2,400
1958	655	20,600	23,200	744	23,500	+ 2,900
1959	574	21,300	21,000	638	20,100	- 1,200
1960	826	26,000	23,700	973	30,700	+ 4,700
1961	484	15,300	20,700	535	16,900	+ 1,600
1962	692	21,800	18,600	749	23,600	+ 1,800
1963	1,356	42,800	32,300	1,378	43,500	+ 700

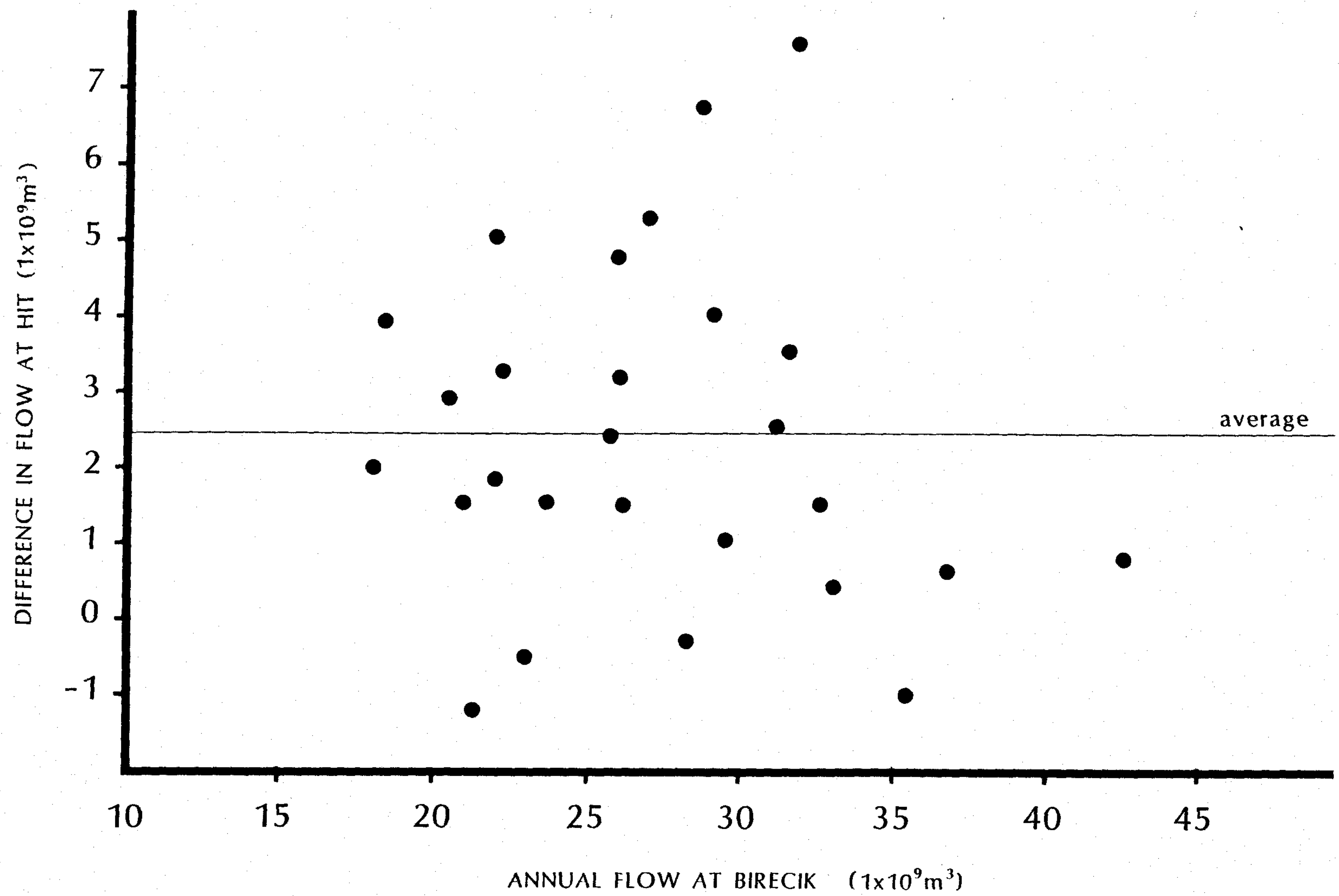
At Birecik:
N = 27
x = 856 cu m/s
x = 27,000 Mcm/yr (= 6070)

At Hit:
N = 27
x = 934 cu m/s
x = 29,500 Mcm/yr (= 6380)

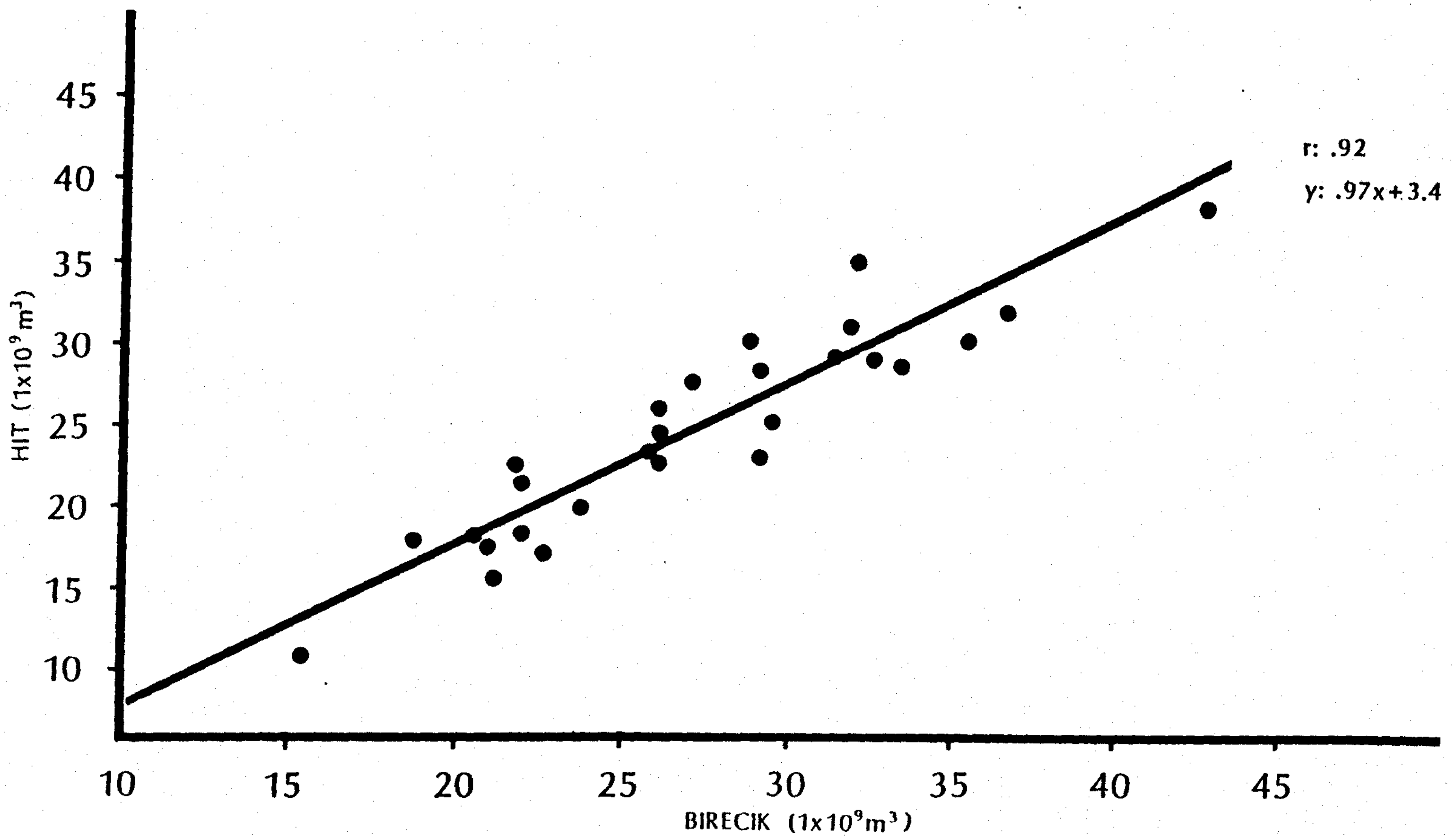
Source: CLA[3088]; computations by author.



Graph S-1: DIFFERENCE IN DISCHARGE AT BIRECIK TURKEY, AND HIT, IRAQ - 1937-1963

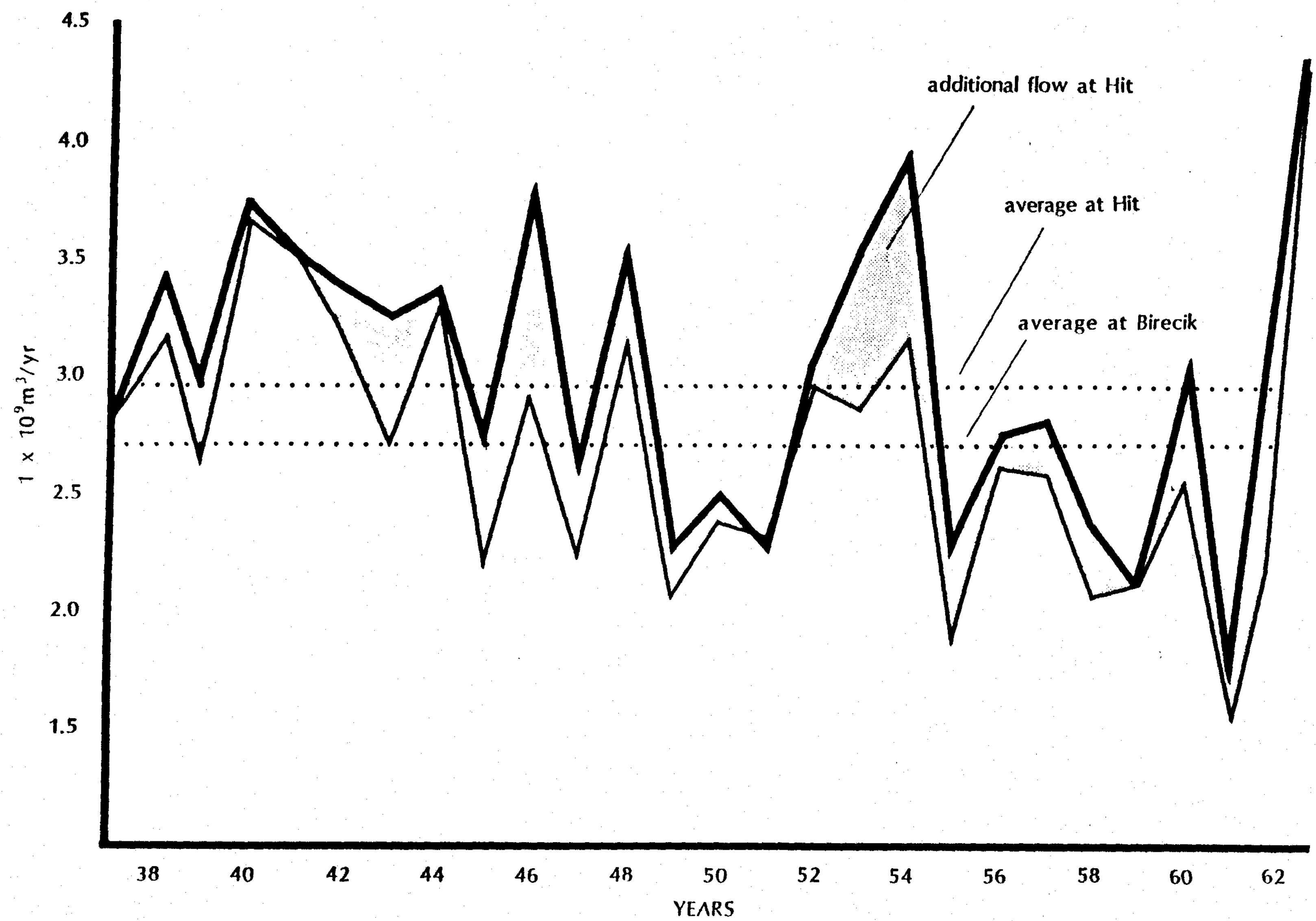


Graph S-2: **RELATIONSHIP BETWEEN FLOW AT BIRECIK AND INCREMENTAL DIFFERENCE IN FLOW AT HIT**
Source: CLA / Computations by Kolars

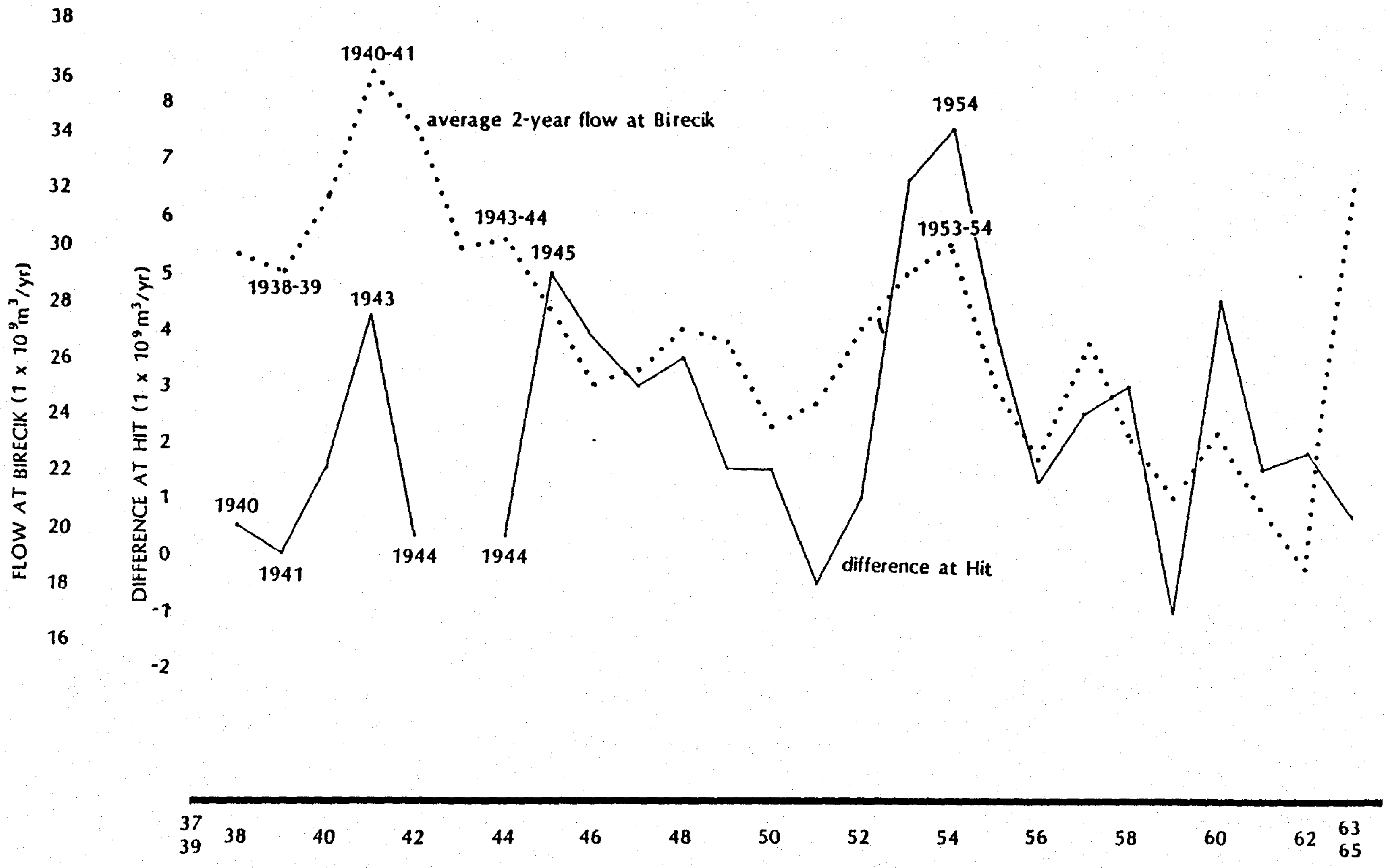


Graph S-3: ANNUAL DISCHARGE AT BIRECIK, TURKEY AND HIT, IRAQ - 1937-1963

Source: CIA



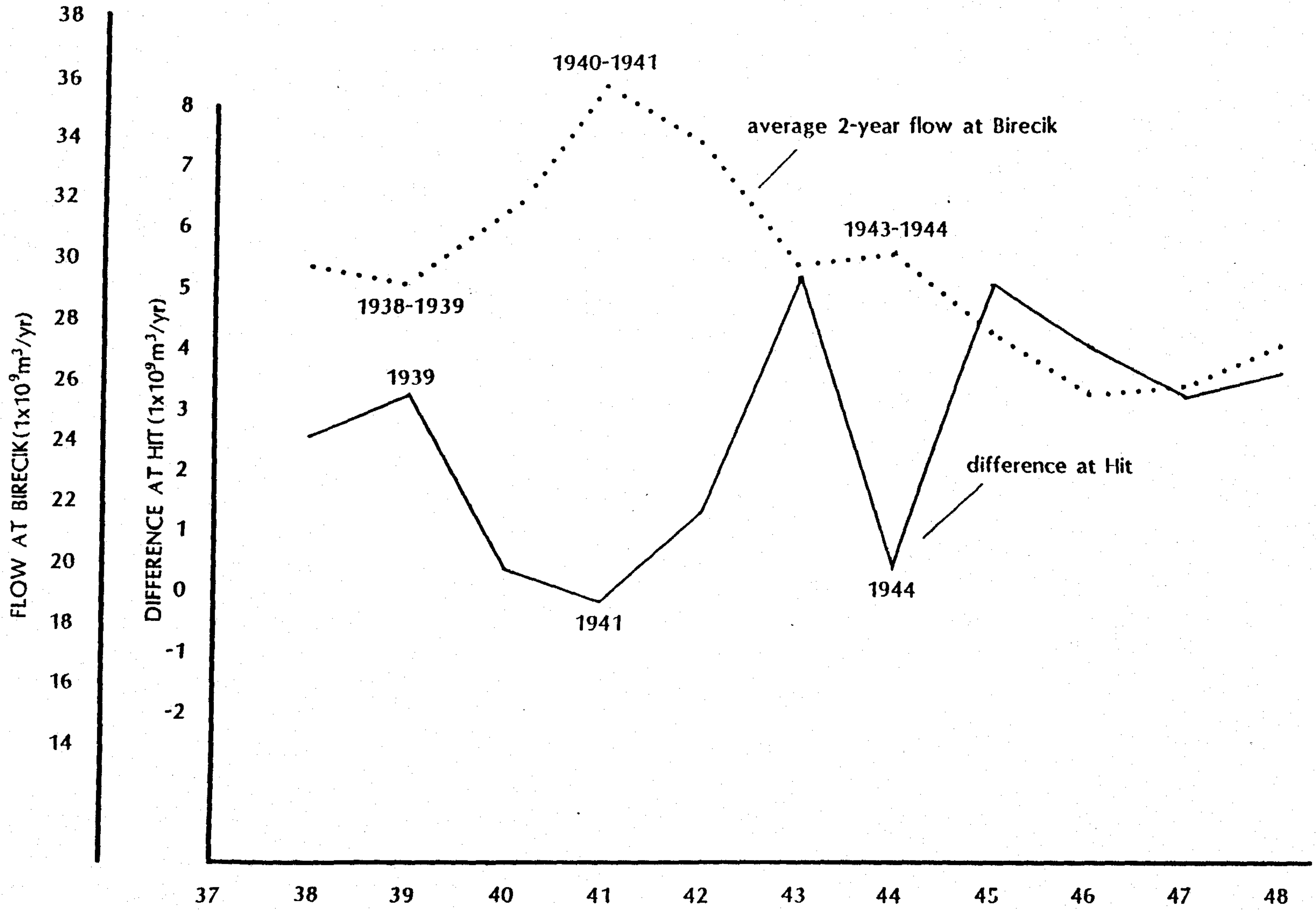
Graph S-4 DISCHARGE OF THE EUPHRATES AT BIRECIK, TURKEY AND HIT, IRAQ - 1937-1963



Graph S-5 CORRELATION BETWEEN BIRECIK AND HIT - 1937-1963

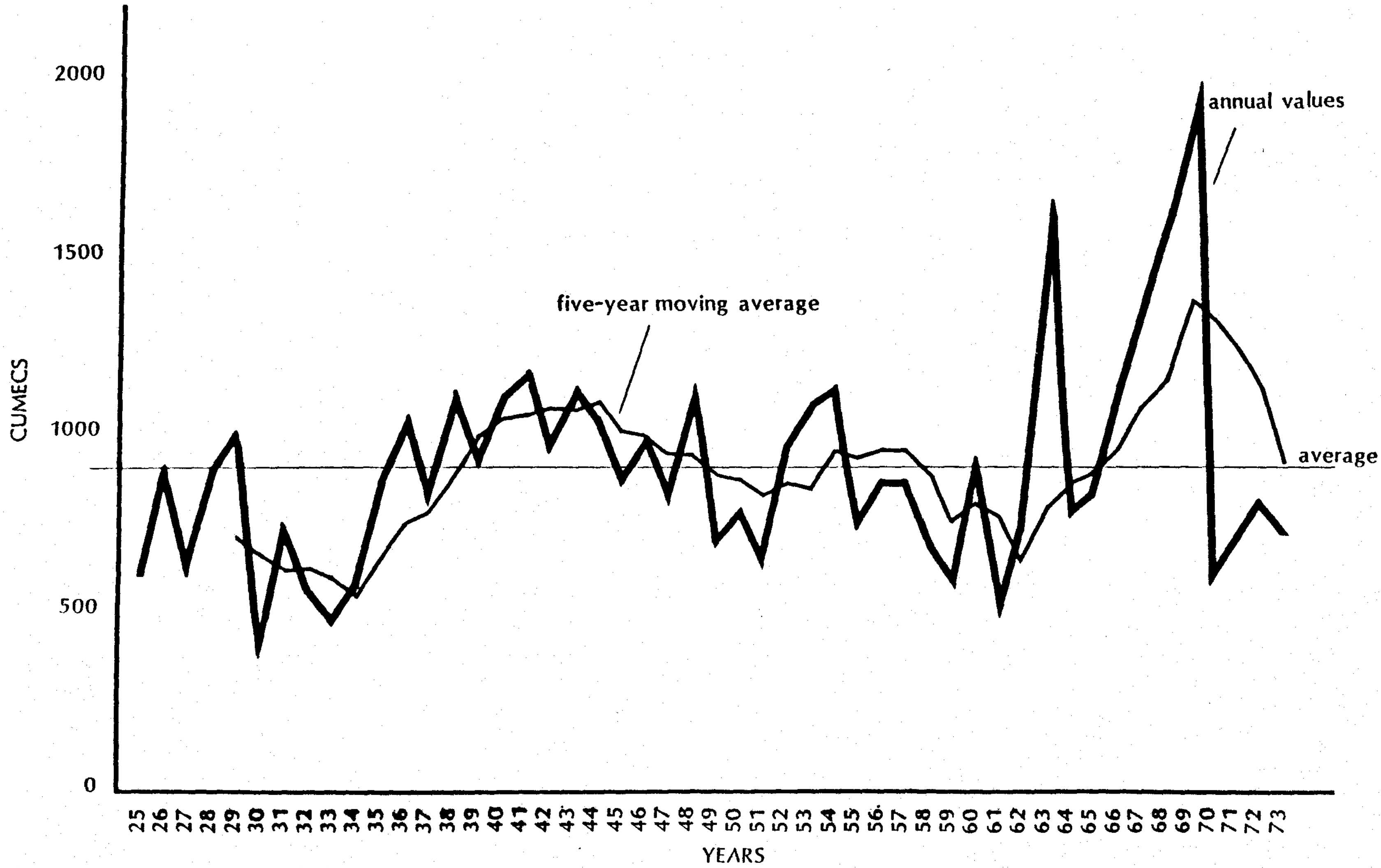
Source: CLA / Computations by Kolars

N.B. Average increments for 1940-1944 are staggered by two years against Birecik values. Beginning with the second 1944 values coincide annually (e.g. 1953-54/1954).



Graph 5-6: CORRELATION BETWEEN FLOW AT BIRECIK AND HIT - 1937-1944

Source: CLA/Computations by Kolars



Graph 5-7: DISCHARGE OF THE EUPHRATES RIVER AT HIT, IRAQ – 1924-25 / 1972-73

Source: Hadithi, appendix E (Ministery of Irrigation)/ Five-year averages computed for present study

Chapter 4

WATER USE PER HECTARE AND ANTICIPATED RIVER DEPLETION

It is of particular importance to establish a reasonable expectation of water use per hectare of farmland (irrigated) in the GAP area. By extension, this discussion can be applied to similar circumstances in Syria. (Iraq with its severe drainage problems leading to salination requires separate consideration.)

Because temperature increases rapidly from north to south in the Euphrates river basin, and because precipitation decreases in the same direction but is also affected by topography, the amount of water needed to supply the demands of irrigation varies from site to site as well as the supply naturally available for plant growth. The critical measure in this case is *potential evapotranspiration* (PE). This refers to the amount of water a field crop needs in its immediate surroundings to meet evaporation demands from its own surfaces and from the ground upon which it grows and also its own transpiration demands in order to ensure a healthy metabolism throughout its growing season. Potential evapotranspiration is calculated in several ways, each beginning with monthly and annual air temperatures. More complex methods include wind speed and other criteria. Evapotranspiration measures are usually computed for an entire year although the growing season (in the case of the Euphrates roughly from April through October) is the period which will interest us here.

Two methods have been used to compute water needs by the various authors of the source materials referred to in this report. The two are the Blaney-Criddle formula (GAP 1980[3081], p. III-20) and the Thornthwaite method[2]. Both use day-length and temperature as major independent variables. Thornthwaite's method does not refer to crop type while Blaney-Criddle's does by reference to an empirical crop factor "k" which varies with crop type and stage of growth. Neither method takes existing precipitation or soil moisture into account. Part of a crop's (or plant's) PE need will be met with water supplied by natural precipitation and/or water stored in the soil. The amount thus supplied without supplemental irrigation is referred to as *actual evapotranspiration*, which in arid regions may be significantly less than the PE. What remains is the "water deficit" (D), which must be compensated for by irrigation.

Thornthwaite[3089] subsequently devised a method of computing the "Water Balance" for a given crop area. With this method, available moisture -- either as precipitation or as soil moisture -- is subtracted from the potential evapotranspiration need computed for a given area with a particular soil type (sand, loam, clay), temperature, and crop (deep rooted, shallow rooted, etc.)[3]. In this way, the amount of water needed to be supplied by irrigation can be computed.

Table N-1 illustrates the type of data available from Turkish sources for some but not all locations. Given a reasonable distribution of such data sites, extrapolations between them for the entire area are possible. Another source of water use data are values calculated using one of the methods described above. Turkish sources present computations based on the Blaney-Criddle method (GAP, 1980[3081] p. III-20). The Thornthwaite method has been used here to check such values.

The first question to be asked is what is meant by "Irrigation Water Needs," the direct translation of the Turkish phrase quoted in Table N-1. Both Blaney-Criddle and Thornthwaite equate their formulas with the *potential evapotranspiration needs of the crop*. This refers directly to the amount of water a field crop needs but does not take into account precipitation and soil moisture which may be available. The Turkish usage might mean one of three things:

1. potential evapotranspiration only;

2. the total amount withdrawn from the reservoir -- which would include potential evapotranspiration, water losses resulting from system inefficiency, and the amount of water which eventually finds its way back into the system farther downstream;

3. potential evapotranspiration plus the amount lost to system inefficiency but excluding the amount returned to the system.

These three possibilities are shown in Table N-2.

As Dunne and Leopold[3059] point out (p. 162) significant additional water loss beyond evapotranspiration needs occurs during transfers from reservoir to the farm and from the main canal to individual fields. They suggest that as a rule of thumb evapotranspiration needs should be doubled to account for such losses. This problem in terms of Turkey and Syria is discussed elsewhere in this report, but for this analysis is taken to be 2.5 times the evapotranspiration. At this juncture, 35 percent of the total amount withdrawn from the reservoir is assumed to be "return flow" to the Euphrates at some point in the system. The components considered by Table N-2 are:

The Stated Value -- a value given without definition in the Turkish example (i.e., just what is meant by the term "irrigation water need" and by the figure 9998.71 cu m/ha/April-Oct.?)

The Amount Withdrawn -- the quantity of water that would actually be withdrawn from the reservoir given a particular definition of the first term, that is, 2.5 x deficit replacement (once deficit replacement has been determined. See definition below.)

The Amount Returned -- It is assumed that 35 percent of all water drawn from the reservoir will eventually find its way back into the river system. This is often referred to as *return flow*.

Potential Evapotranspiration -- the amount of water required as defined in the preceding text during the growing season April through October.

Water Deficit or Deficit Replacement -- that portion of the potential evapotranspiration which cannot be made up by precipitation or soil moisture and must be met by added irrigation water. (This term used in Table N-3 and N-4.)

Water Loss -- that portion of the water withdrawn from the reservoir that neither returns to the river (return flow) nor is used to satisfy *deficit replacement*. This disappears through seepage, evaporation from canal surfaces, evapotranspiration from wild vegetation, etc.

Fund Depletion -- the amount withdrawn from the reservoir less return flow. In other words, the absolute drain on the river system (measured per hectare of irrigated land) which diminishes downstream flow. This would consist of "water loss" as described above plus the "deficit replacement" which is used to supply direct crop/plant needs unmet by precipitation or groundwater.

Row one of Table N-2 assumes that the figure quoted in the Turkish source (9998.71; here rounded off to 10,000 for convenience) represents Potential Evapotranspiration (PE) for the period April through October. The total amount withdrawn given the criteria described above would be 25,000 cu m/ha of which 16,250 cu m/ha would constitute an absolute loss to the system (i.e., diminishing downstream flow for use in Syria and/or Iraq). Row 2 assumes that the 10,000 cu m quoted refers to the total amount withdrawn for all purposes. This would allow potential evapotranspiration of only 4,000 cu m/ha during the entire growing season and can be dismissed as unrealistically low. Row 3 assumes that the 10,000 cu m refers to the fund depletion (that is, the amount lost absolutely to downstream flow). This would allow 6,154 cu m/ha for April through October. While this might be a possibility, the PE was recalculated using the Thornthwaite method and Turkish temperature and precipitation data. The result is 9730 cu m/ha for April/Oct. as shown in row 6, Table N-3. Since the Thornthwaite method results in *lower* estimates than does the Blaney-Criddle method which the Turks used, it is obvious that row three does not offer the correct definition of the term in question.

The above discussion constitutes a tortuous but necessary checking of the meanings used. *It may be assumed that the Turks are referring to potential evapotranspiration alone for the months April through October.* It now becomes possible to assign evapotranspiration values elsewhere in the river basin and to consider the water deficit or deficit replacement in terms of the *water balance*, a more realistic measure of the basic water needs of the various irrigation projects planned for Turkey and Syria.

Table N-3 lists the potential evapotranspiration rates available for various locations in the two countries. Attention should be given to the top row which lists annual temperatures from south to north. This gives a good indication of the relative standing of the various stations involved. Because PE is a function of temperature and day length it is logical to expect diminishing water needs as annual temperatures decline.

Values given in the FAO survey[3065] of the Khabur region are consistent with our expectations. Penman values in row 3 are higher than those derived from the Thornthwaite method which is again consistent with the two techniques. An anomaly exists with the GAP[3081] data. The PE cited for Ceylanpinar is greater than that given for Nusaybin although the annual temperature for the latter is higher. On the other hand, values calculated for this study using the Thornthwaite method show a consistent diminishing from south to north. Thus, FAO data and those derived for the present study are preferred to the ones given in GAP.

A more meaningful value for water use is shown at the bottom of this table. The water balances as given by the FAO[3065] for Syrian stations and as computed for Turkish stations in this study show a consistent decline from south to north. Moreover, these values take into account the precipitation and ground water available during the entire growing season for each station. (A soil moisture retention of 200 mm was assumed for the Turkish calculations.) It should be noted that the reversal of values for Nusaybin and Ceylanpinar in these data is consistent with the greater rainfall at the former location. (This may account for the inconsistent reversal of the Turkish data mentioned above if the "k" values used in the Blaney-Criddle method took this into account through plant type or time within the season, but since there is no explanation of the technique used the GAP[3081] data must still be treated with caution.) The important thing to note at this point is that values for the Thornthwaite[3089] water balance are only 70 percent of the values cited in GAP for the same stations. Despite the fact that Thornthwaite underestimates PE compared to the Blaney-Criddle method, the difference even if only partially accepted still represents a significant saving in water *if the farm/irrigation managers carefully follow the water balance method of applying water to their fields and do not over irrigate*, a common failing in such situations.

Given the amounts of water necessary to make up the seasonal deficit, there remains the question of how much water each hectare will require when deficit and water loss are both considered. Also, the question of absolute hectarage planned leads to estimations of total loss to the system.

Table N-4 provides information regarding total water demand from irrigation in Turkey and Syria. Beginning with Siverek in the north five locations in Turkey and four locations in Syria allow a transect of the major areas where irrigation is planned. (Two locations in Syria and Turkey, Nusaybin/Qamishli and Ceylanpinar/Ras Al-Ayn, share single values.) Total water demand (i.e., fund depletion per ha x total hectarage) is omitted from this table for Syria and will be considered in the section that follows. Total water demand for Turkey is given in an abbreviated form and is discussed more completely in other sections of this study. Computations of the water balance for four Turkish stations are shown in Tables N-5/N-8.

Column 2 lists the water deficit per hectare for each location. (Note that the value for Birecik is an extrapolated value.) As discussed elsewhere the amount withdrawn from reservoirs will be 2.5 times the stated deficit per hectare (col.3)[4]. The amount of the water which reenters the river system is assumed to be 35 percent of that withdrawn (col.4). The water loss per hectare is the total amount withdrawn less the amount returned and the deficit replacement (col.5). The total amount of water per hectare disappearing from the system not to be returned is the fund depletion shown in col. 6. Each of these values can be multiplied by the hectarage found near the station listed in column 1. The results are given for the total fund depletion and for the total returned to the system. *Because these values are based on Thornthwaite's method which underestimates PE compared with Penman's or Blaney-Criddle's methods, these figures should be considered as minimal, conservative estimates of fund depletion and return flow, all else being equal.* Sixty thousand hectares near Ceylanpinar which will be irrigated by water pumped from the aquifer supplying the Ras Al-Ayn (springs) is shown separately in parentheses. However, this water, which contributes to the flow of the Khabur in Syria will still have its impact downstream either through reduced flows (total fund depletion) and/or water quality (return flow).

Even this partial listing of projects indicates that the Turks will irrigate 792,700 (+ 60,000) hectares from the Euphrates River, this would result in an absolute depletion of 8,500 Mcm (+ 700 Mcm) and a return flow essentially down the Balikh and Khabur systems of 5,200 Mcm. This, in addition to evaporation from reservoirs and additional water use from smaller projects, would have a significant impact upon the downstream river system. An accounting of water uses based on the complete inventory of projects is found on pages 107-08 and in Table V-4.

Endnotes

2. For description of these two methods and a comparison of them with a third, the Penman method, see: Dunne and Leopold (1978)(3059), pp. 136-141. Computations by the author of this text were based on Thornthwaite's Water Balance for two reasons. The data (air temperature and precipitation) were available where other measures (wind velocity, etc.) were not, and the Water Balance takes precipitation and ground water into account, thus presenting a more realistic view of the agricultural process. Calculations were based on: C.W. Thornthwaite and J.R. Mather(3089).

3. It should be noted that Thornthwaite's method tends to underestimate need while the Blaney-Criddle method is somewhat more exact. The Thornthwaite method was used herein out of necessity (see footnote above). On the other hand, such low estimates may be taken to represent the absolute minimum amount of water necessary, thus establishing a base line for discussion purposes.

4. An independent check on these figures is provided by data relating to Soviet irrigation practiced in Uzbekistan, a temperate desert area. Micklin(3085) reports that "the implied withdrawal rate in 1978 was 15,436 cu m per hectare." Micklin refers to: (K.I. Lapkin, Ye. D. Rakhimov, and A.V. Pugachev, "Improvement of water supply reliability and problems of partial diversion of Siberian rivers," *Obshchestvenniye nauki v Uzbekistane*, No. 1 (1981), pp. 59-62; *Narodnoye khozyaystvo SSSR v 1978g* (Moscow: "Statistika", 1979), p. 240.) Column 3 shows withdrawals ranging from 13,625 at Siverek to 17,635 at Ceylanpinar/Ras al-Ayn and 25,900 cu m/ha at Deir ez-Zor. Considering the more northerly latitude of Uzbekistan and its shorter summers, the value cited by the Soviets falls reasonably within this range.

Table N-1

IRRIGATION WATER NEEDS: "SULAMA SUYU GEREKSINIMI"

Mardin-Ceylanpinar

	cu m/ha/mo
Apr	405.34
May	832.87
Jun	2090.56
Jul	2890.21
Aug	2438.08
Sep	1169.28
Oct	172.37
Total	9998.71

Source: GAP, 1980[(3081)], p. III-36.

Table N-2

INTERPRETATIONS OF "SULAMA SAYU GEREKSINIMI"
(Irrigation Water Needs) Presented in GAP 1980[a]

[b]Stated Value 9998.71 (10,000)	Interpretation/ Explanation	Amount Withdrawn W 2.5 PE	Amount Returned R .35 (2.5PE)	Potential Evapotrans-piration Apr-Oct PE (as stated or computed)	Water Loss L W-(PE+R)	Fund Depletion FD L+PE
1. 10,000	Potential Evapo-transpiration only PE	25,000	8,750	10,000[c] (9998.71)	6,250	16,250
2. 10,000	Total Amount Initially Withdrawn PE+L+R=W	10,000 (9998.71)	3,500	4,000	2,500	6,500
3. 10,000	Potential Evapo-transpiration Plus Amt Lost (Excludes Amt Returned) PE+L=FD	15,385	5,385	6,154	3,846	10,000 (9998.71)

Source: (irrigation water needs) Presented in GAP[(3081)].

[a] Time Period: April through October; All values in cu m/ha.
[b] As Stated in GAP -- Computed by Blaney-Criddle method; "k" unspecified in text.
[c] CF. Calculated PE (April-Oct.), Table N-3, Ceylanpinar.

Table N-3

POTENTIAL EVAPOTRANSPIRATION: TURKISH AND SYRIAN LOCATIONS

Locations:	Deir ez-Zor	Tel Tamir	Qamishli/ Nusaybin	Ras al-Ayn Ceylanpinar	Urfa	Siverek
Annual Precip.[a]	(148 mm)	(300 mm)	(452Q/463N mm)	(R-A 315 mm est.)	(462 mm)	--
Annual Temp (C) GAP	--	--	18.9	18.2	18.0	16.2
Annual Temp (C) Map #1(pocket),FAO	20.00*	18.0**	19.3*	"<18"**	18.1**	--
PE[f] April-Oct. Penmann Method FAO, p. 62	1,302	--	1,193	--	--	--
PE[f] April-Oct. Thornthwaite Meth. FAO p. 61	1,128		1,121	--	--	--
PE[g] April-Oct. "Sulama Suyu Gereksinimi" GAP pp. III-36	--	--	9,805[b]	9998.7[b]	8920.1	10461.3[b]
PE[g] Using Thornthwaite Method and GAP T&P data Apr-Oct	--	--	9,984	9730[c]	9649	8811
Water Balance[g] Deficit Using Thornthwaite Method & FAO p. 62	10,360	7720	--	--	--	--
Water Balance[g] Deficit Using Thornthwaite Meth.[e]	--	--	6910[d]	7070[d]	6618	5450

Sources: FAO(3065), GAP(3081).

[a] Precipitation as per FAO Map I (pocket).

[b] As stated, but questionable (i.e., out of sequence with N-S temperature sequence).

[c] This figure, being lower than that given by GAP is consistent with the difference between Penmann's and Thornthwaite's methods.

[d] The reversal of the logical sequence (based on temperature alone results from greater annual precipitation at Qamishli-Nusaybin (485 mm) than Ras al-Ayn-Ceylanpinar (328 mm).

[e] Based on soil moisture retention of 200 mm.

[f] Values in mm.

[g] cu m/ha/growing season.

* 1950-1960 ** 1957-1960

Table N-4

ANNUAL WATER FUND DEPLETION (cu m/ha/yr and total irrigated area per Mcm/yr)
Based on Deficit Computed According to Thornthwaite's Method (See Table N-2)

Location	Deficit Replacement cu m/ha D=See Table N-3	Amount Withdrawn 2.5xD=W	Amount Returned 0.35xW=R	Water Loss W-(D+R) =L	Fund Dupletion cu m/ha D+L=FD	Area To Be Irri-gated ha	Total Fund Depletion Mcm	Total Returned To Sys.@@ Mcm
Siverek GAP V-4	5,450	13,625	4,769	3,406	8,856	147,000	1,301.8	701.0
Urfa GAP V-4	6,618	16,545	5,791	4,136	10,754	136,000	1,462.5	787.6
Birecik ??? 1984	est. 6,500	16,250	5,688	4,062	10,562	92,700	979.1	527.2
Nusaybin GAP V-4/ Qamishli	6,910	17,275	6,046	4,319	11,229	47,000	527.8	284.2
Ceylanpinar GAP V-4/ Ras al-Ayn	7,070	17,675	6,186	4,419	11,489	UPPER		
						206,000	2366.7	1404.1
						LOWER		
						164,000	1884.3	1117.8
						FROM AQUIFER		
						(60,000)	(689.3)	(371.2)
				TOTAL FROM CANALS		792,700	8522.1	4821.9
				TOTAL FROM AQUIFER		(60,000)	(689.3)	(371.2)
				TOTAL		852,700	9211.4	5193.1
SYRIAN VALUES								
Tel Tamir	7,720	19,300	6,755	4,825	12,545	(For Syrian totals see next section)		
Deir ez-Zor	10,360	25,900	9,065	6,475	16,835			

Source: GAP(3081).

N.B. The list of projects and locations given here is incomplete. For a total accounting see Table V-4.

Table N-5

WATER-BALANCE FOR SIVEREK (37° 50')
Per Thornthwaite Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
T°(C)	2.8	4.4	8.9	13.8	19.7	25.8	30.2	29.6	24.8	18.1	11.0	5.4	16.2
I	.42	.82	2.39	4.65	7.97	11.99	15.22	14.77	11.30	7.01	3.30	1.12	82.2
Unadj. PE	.1	.2	.7	1.4	2.7	4.2	5.4	5.3	4.0	2.3	1.0	.3	
PE	2.6	5.0	21.6	46.2	99.6	156.2	202.5	186.0	124.8	65.8	25.2	7.5	943.0
P(mm)	92.9	81.1	76.9	65.4	44.2	7.5	1.5	1.0	3.0	31.5	60.4	82.5	547.9
P-PE	90.3	76.1	55.3	19.2	-55.4	-148.7	-201	-185	-121.8	-34.3	35.2	75.0	-395
AP WL				0	-55.4	-204	-405	-590	-712	-746			
ST	200	200	200	200	151	71	26	10	5	5	40	115	
△ ST	85	0	0	0	-49	-80	-45	-16	-11	0	35	75	
AE	2.6	5.0	21.6	46.2	93.2	87.5	46.5	17	14	31.5	25.2	7.5	398
D	0	0	0	0	-6.4	68.7	156.0	169.0	110.8	34.3	0	0	545
S		76	77	65									218
RO		38	58	61	31	15	8	4	2	1			218

Soil moisture = 200mm.

Table N-6

WATER-BALANCE FOR URFA 37° 10' APPOX. N LAT. (46 YEAR PERIOD)
Per Thornthwaite Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
T° C	5.0	6.5	10.2	15.7	21.7	27.7	31.6	31.2	26.6	19.9	13.1	7.3	18.0
I	1.00	1.49	2.94	5.65	9.23	13.36	16.30	15.99	12.56	8.10	4.30	1.77	92.69
Unadj. PE	.1	.3	.7	1.6	3.0	4.8	5.7	5.6	4.5	2.6	1.1	.3	
PE	2.58	7.65	21.63	52.8	109.8	177.1	213.8	196.6	139.1	75.66	25.05	7.47	1032.2
P(mm)	99.8	69.7	64.2	55.4	26.3	2.6	0.5	0.6	1.2	22.1	42.4	85.3	470.1
P-PE	97.2	62.0	42.6	2.6	-83.5	-174.5	-213.3	-196.0	-137.9	-53.6	14.3	77.8	-562.3
AP WL				0	-83.5	-258.0	-471.3	-667.3	-805.2	-858.8			
ST	192.3	200.0	200	200	131	54	18	7	4	3	17.3	95.1	
Δ ST	111	8	0	0	-69	-77	-36	-11	- 3	1	14	81	
AE	2.6	7.7	21.6	52.8	95.3	79.6	36.5	11.6	4.2	23.1	28.05	7.47	370.6
D	0	0	0	0	-14.5	97.5	177.3	185	134.9	52.6	0	0	661.8
S		54.3	42.6	2.6									99
RO		27	35	19	9	5	2	1	1				99

Soil moisture = 200mm.
PE of April-October = 964.86 = 9649 cu m/ha.

Table N-7

WATER-BALANCE FOR CEYLANPINAR 37°N
Per Thornthwaite Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
T°C	5.4	7.2	11.1	16.0	22.5	28.7	32.1	31.0	25.6	19.1	11.9	7.2	18.2
I	1.12	1.74	3.34	5.82	9.75	14.09	16.70	15.84	11.85	7.61	3.72	1.74	93.32
Unadj. PE	.2	.6	.8	1.7	3.2	5.1	5.8	5.6	4.2	2.3	.9	.3	
PE	5	15	25	56	117	188	218	197	130	67	23	7	1,048
P(mm)	63	49	46	44	23	1	trace	0	1	16	26	59	328
P-PE	58	34	21	-12	-94	-187	-218	-197	-129	-51	3	52	-720
AP WL			(-32)	-44	-138	-325	-543	-740	-869	-920			
ST	115	149	170	160	99	39	13	5	3	2	5	57	
△ ST	58	34	21	-10	-61	-60	-26	-21	-2	-1	3	52	
AE	5	15	25	54	84	61	26	21	3	17	23	7	341
D				-2	-33	-127	-192	-176	-127	-50			-707
S													
RO													

Soil Moisture = 200mm.
Soil Moisture Cap = 200 for Silt-Loam (Ave.) for Corn, Cotton, Tobacco, Cereals.

Table N-8

WATER-BALANCE FOR NUSAYBIN 37°N
Per Thornthwaite Method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
T°C	5.8	7.6	11.6	16.4	22.9	28.8	32.5	31.5	27.3	20.9	13.6	7.8	18.9
I	1.25	1.89	3.58	6.04	10.01	14.17	17.01	16.23	13.07	8.72	4.55	1.96	98.48
Unadj. PE	.2	.3	.7	1.7	3.4	5.1	5.8	5.7	4.7	2.3	1.1	.3	
PE	5.16	7.65	21.6	56.1	124.4	188.2	217.5	200.1	145.2	66.9	28.1	7.47	1,069
P(mm)	93.9	75.3	68.8	72.2	37.5	1.2	.7	0	.5	15.8	38.2	80.9	485
P-PE	88.7	67.6	47.2	16.1	-86.9	-187	-217	-200	-145	-51.1	10.1	73.4	-584
AP WL				(0)	-87	-274	-491	-691	-836	-887			
ST	174	200	200	200	128	50	17	6	3	2	12	85	
△ ST	89	26	0	0	-72	-78	-33	-9	-3	-1	10	73	
AE	5.2	7.7	21.6	56.1	110	79.2	33.7	9.0	3.5	16.8	28.1	7.5	378
D	0	0	0	0	15	109	184	191	142	50	0	0	691
S		42	69	72									183
RO		21	45	59	29	15	7	4	2	1			183

Soil moisture = 200 mm.
PE April-October.

Chapter 5

IRRIGATED AGRICULTURE IN THE SYRIAN EUPHRATES DRAINAGE BASIN

An examination of this topic presents serious difficulties, not the least of which is the paucity of current information. There are four categories of investigation: where and how much land was originally proposed for irrigation, where and how much land did subsequent revisions deem irrigable, where and how much land has actually been prepared for irrigation through state run projects, and where and how much irrigated land have private farmers and entrepreneurs brought under cultivation? The first is a matter of record and can be spoken of with some confidence. The second presents a less clear picture but can be estimated with a certain amount of research. The third becomes much more a matter of hearsay dependent upon poor sources of information. Moreover, the amounts are so small that though apparently correct they are given with some hesitation. Fourth, certain problems surround the data available for examining private activities which make their disaggregation difficult. In the last two instances the data are from four to ten years old. Despite such caveats the picture which emerges does allow projections of water use to be made for the long term.

5.1. Background to the Problem

Prior to 1950 the waters of the Euphrates were little used. Traditional lifts, often camel powered, brought what little water reached fields on the river's banks. Following independence, however, speculation in cotton by Syrian merchants led to a rapid increase in the number of gasoline pumps drawing water from the river. The amount of irrigated land along the Orontes, the Euphrates and its tributary the Khabur increased from 284,000 ha in 1956 to 583,000 ha in 1957 (Sanlaville[0064], p. 231). Exploitation by settled nomads and the peasantry, as well as serious problems of salination and drainage, necessitated agrarian reform and the organization of cooperatives and state farms. At the same time the need to utilize the water resources of the Euphrates received high priority.

A major dam on the Euphrates had been envisaged as early as 1927 by the French, but not realized. Shortly after independence in 1946, Sir Alexander Gibbs and Co. conducted a preliminary study for a dam near Yusuf Pasha which would have irrigated 100,000 ha. Nothing came of it however, and this effort was followed by a twelve volume study by the Soviets published in 1960. Reference will be made to estimates given in the Soviet study which will be contrasted with a study by the West German Government in 1961. The disruption of the U.A.R. and the breakdown of relations with the Germans in 1965 left the way open for Soviet participation in the building of the Tabqa (Al-Thawra) Dam which was officially inaugurated in July of 1973. The use of the waters of Lake Assad behind the dam has had a mixed history still to be resolved.

5.2. Proposed Irrigation

Table I-1 outlines the proposed, revised, and actual irrigation projects relating to the Tabqa Dam. The Soviet proposal originally spoke of some 850,000 ha that could be irrigated with the waters of Lake Assad. This estimate was quickly down-graded by the Germans to 650,000 ha and then slightly revised by the Syrians to 640,000 ha. This total consisted of the six districts shown on Map I-1 and below as well as in Table I-1.

Balikh (area #1)	185,000 ha
Lower Euphrates Valley (area #2)	165,000 ha
Lower Khabur Valley (area #3)	75,000 ha
Rasafah (area #4)	25,000 ha
Mayadin Plain (area #5)	40,000 ha
Maskanah-Aleppo (area #6)	150,000 ha
Total	640,000 ha

A Pioneer or Pilot Project was initiated (Table I-2) in May 1973 on the left bank of the Euphrates 18 km from the Tabqa Dam. The purpose of this project was to resettle nearly 60,000 villagers who had been flooded out by Lake Assad. Fifteen villages were built to replace the 43 that were abandoned. The original plan called for 18,000 ha to be irrigated, a figure which was to have been increased to 38,700 ha by the end of the third Five-Year Plan. The crops to be grown were primarily cotton but also barley, forage crops, sugar beets, corn, beans, fruit, and (for the first time) rice.

5.3. Revisions of Proposed Irrigation Goals

It was sometime after this that serious problems began to develop with regard to the application of water to the land. As summarized in the USAID 1980 report[3046] (pp. II-1 and II-4) and intimated by various press releases from Syria, the Euphrates Basin soils are in large part gypsiferous, crusty, prone to erosion,and suitable only for careful applications of irrigation water. In a November 1982 interview with the press, Dr. Abduh Qasim, General Director of the Public Establishment for Utilization of the Euphrates River Basin, spoke of the collapse of the canals leading to the Pioneer Project when water was channeled through them as well as of the loss of 5 cubic meters per second into the ground (Khayyat Interview)[1902]. As recently as July 1984 *Tishrin*[3097] (p. 4) reported that "cracks" had appeared in the Balikh canal.

USAID[3046] goes on to state that, "Class IV land is marginal at best for agriculture. Since only 64 percent of the land [in the Euphrates Project] is in classes I through IV, and 48 percent is Classes I through III, this suggests that less than half of the 640,000 ha is reasonably good land for irrigation purposes." (II-4) This report then mentions and suggests a goal of 240,000 ha by 1980 "but by 1978 only 7,400 ha had been prepared," and suggests a projection for 1980 of 43,200 ha. In the interview cited above[1902] Dr. Qasim speaks of the possibility of up to 345,000 ha being irrigated eventually.

To these figures should be added the lands of the upper Khabur basin which will also receive irrigation water. These were originally estimated to be 400,000 ha but a recent news release (*Al-Thawra*, Damascus, March 12, 1983[1852]) gives a total of 137,900 ha for three sub-projects (Table I-3).

Thus, it would seem realistic to anticipate water being applied to a maximum of 345,000 ha from Lake Assad plus another 137,900 ha farther downstream on the Khabur. This is not the entire story, however, the details of which follow.

In Rasafah (area #4) the Soviets suggested 150,000 ha; the Germans proposed 20,000 ha because of the gypsiferous soils; and the Syrians apparently planned on 25,000 ha. Qasim indicates in his interview[1902] that the entire project has been abandoned. He also mentions that while large tracts of the original Maskanah-Aleppo district have been withdrawn from possible irrigation, new lands in the northern and southern Aleppo region totaling 180,000 ha are to be added. (These changes are apparently taken into account in the total quoted in the above paragraph).

5.4. Production Achieved by State Run Projects

There remains the question of just how much land has actually been prepared and how much is actually being cultivated. As mentioned earlier, no current data are available and these comments may need upgrading. Nevertheless, the actual amount of land successfully brought into production seems remarkably small. Qasim gives 13,100 ha for a "Central Euphrates Project" [presumably part of the Euphrates Valley Project previously mentioned by Qasim (Khayyat interview[1902])]. The Pioneer Project was revised downward to 32,000 and then to 19,000 ha but in 1983 only 11,500 ha were under cultivation. Another 13,282 ha in the Maskanah-Aleppo area seem to round out this accounting. The slow progress being made can be appreciated by contrasting the status report on the Euphrates River Irrigation Project for 1976 (USA/Syrian Agreement[1860]) described in Table I-4 with the amounts given above and in Table I-1.

Can such a shortfall be possible? When one reads the Qasim/Khayyat interview[1902] in full the litany of bureaucratic ineptitude, engineering over-optimism and the true difficulty of the region itself makes this track record seem within reason. Another indicator of the seriousness of production problems in the Euphrates Valley is the call for bids for work on drainage systems by the Irrigation Ministry (MEED February 3, 1984[3116], p 33). This same article mentions a report made by the French consortium of Gersar and SCET International which found about 3,000 ha per year being affected by salinity and poor drainage. Add to this the 25,000-28,000 ha lost when Lake Assad was formed (Pitcher[0749], p. 15; Samman[0993], p. 23) and the lack of results comes into focus. On the other hand, it should be kept in mind that large tracts of land are being irrigated and cultivated by private farmers large and small.

5.5. Privately Cultivated Land

Privately cultivated land is the major consumer of Euphrates water in Syria. As with other data, statistics relating to the exact amount are sparse, incomplete, and seldom current. There are two main sources of these data.

The Syrian government releases figures from time to time which have been available to this writer largely through references in secondary sources. Another group of data comes from LANDSAT imagery and an evaluation of "intensively cultivated" and other categories of land included in the USAID (1980)[3045-3049] report. By their definition, "intensively cultivated land" is considered to be irrigated.

The problem with the latter data, aside from technical difficulties always associated with imagery interpretation, is that that report uses a series of land classifications which are discontinuous in space. That is, the areal units used to define and aggregate information may occur in two or more widely separated places with only cursory indications of what is found within subunits. Syria has been divided into 58 "Resource Planning Units" by the USAID report[3045-3049]; each RPU in turn consists of several Production Planning Areas (PPA). Discriminating among PPAs in a given RPU can seldom be exact. Table I-5 shows the amount of irrigated land in selected regions of northern Syria as reported from several sources. In this case, general geographic and/or political subunits are the basis for reporting. Table I-6 relies upon LANDSAT data presented in table form elsewhere in the USAID report. Map I-2 shows the RPUs for northern Syria. The discontinuous character of units 31, 32, 40 and 57 should be noted.

Given the above caveats, the following may be stated. Treakle (*Foreign Agriculture*[3062]) reported as of 1970 that 160,000 ha of irrigated land were found in the Euphrates valley. This was clearly before Lake Assad was filled. Samman[0993] and Pitcher[0749] both report about 25,000 ha of land lost due to flooding. USAID[3045-3049] in 1976 observed/estimated 142,000 ha of land irrigated in the "lower Euphrates." These latter LANDSAT data are consistent with Treakle's figure given losses from flooding and perhaps a slight increase in irrigation along the edges of the reservoir.

A cross-check on these figures comes about when irrigated land in Raqqa Mohafaza (60,773 ha) is combined with that in Deir ez-Zor Mohafaza (85,676 ha) giving a total irrigated land downstream from Tabqa of 146,449 ha--close to the 142,000 ha cited above (Table I-5). While both of these sources come from USAID[3045-3049], the slightly smaller figure apparently is derived from Syrian sources while the larger is the result of LANDSAT analysis.

In the same way, two corroborating figures are given in USAID[3045-3049] for the Khabur tributary. Hasakah Mohafaza is listed as having 80,909 ha of irrigated land while areas "around Al-Hasakah and in the Upper Khabur" are listed as having "approximately 25,000 ha" and 60,000 ha respectively.

Table I-6 allows a slightly different view of the situation but with approximately the same results. Resource Planning Units 32, 40, and 42 essentially comprise the valley of the Euphrates River. Two additional parcels of RPU 40 are found along the Balikh and west of the lower Khabur. Little irrigated land is currently found in the latter unit; it would appear that most of the 50,000 ha attributed to this RPU are in the basin of the Balikh. In any event, water use and depletion from such fields will decrease downstream discharge of the main stream. RPU 42 is in the Al-Raqqa area, while RPU 32 would represent the Deir ez-Zor area as will as part of the lower Khabur and an area downstream from the Tabqa Dam.

RPUs 50, 38 and 41 cover most of the upper Khabur system and as such also diminish downstream flow. These six units in sum account for 232,100 ha. Combined with the 8,940 ha in units 19 and 31 (which in all likelihood receive pumped water from the Euphrates and Khabur), the 241,040 ha thus noted are close to the 231,449 ha listed in Table I-5.

RPUs 39, 45, 46, 48, 49, 50, and 57 are more difficult to assign to river flow or groundwater use. The latter is probably more the case and will be treated again in the special section of this report relating to the Khabur.

The Queik River, while outside the Euphrates drainage is mentioned for two reasons. Although previously the source of water for Aleppo, its waters are no longer sufficient for that purpose, in large part because of upstream diversions in Turkey and Syria. As a result, the city of Aleppo now depends upon Euphrates waters pumped from Lake Assad. Current use of 80.3 Mcm/yr is considered inadequate and this city's dependency upon the Euphrates must continue and grow. (See p. 32 of this report.)

The remaining RPUs -- 33, 51, 53, 54 -- while within the study area show no intensive agriculture and in part fall outside the drainage basin.

In summary, a round figure of 241,000 ha is assumed for actual irrigation using waters of the Euphrates and its Syrian tributaries[5]. Another 80,000 ha use groundwater completely or in large part[6]. It should be noted that much of the area now privately farmed will eventually be included in the proposed 345,000 ha cited above by Qasim[(1902)] plus developments on the Khabur. Thus, included within this LANDSAT based total would be the 47,582 ha which apparently are now on-line through government sponsored projects (see below). This would reduce the independent farming total to about 190,000 ha, although the amount of land actually receiving irrigation water would remain the same. In any event, the above total represents recent usage and should be close to what is being consumed in 1986 (despite the lack of data to confirm this).

On-Line Government Project Lands
(See Table I-1)

Balikh	21,200 ha
Central Euph.	1600 ha
Project	11,500 ha
Maskanah	13,282 ha
Total	47,582 Ha

NB: The 20,240 ha cited by Pitcher(0749) on Table I-1 are undoubtedly an early reference to the Pioneer Project and as such should not be double counted.

5.6. Water Depletion from Syrian Irrigation on the Euphrates

The method by which depletion of river water through evapotranspiration and system inefficiency is computed was presented for Turkey with best estimates of such demands given in Table N-4. A similar presentation for Syria is now possible using the values already derived and with reference to the amounts of irrigated land discussed above. Table I-7 presents two sets of values. The first is based on the revised plans for irrigating Syrian lands with Euphrates waters. The second presents best estimates for the actual amount of water removed from the system on or about 1980[7]. As mentioned above, data are lacking for more recent periods but the slow addition of new irrigated lands, the probable loss of land through salination and drainage problems, and the substitution of government sponsored irrigation projects in areas previously privately farmed mean that the amount under actual production today is likely to approximate the amounts shown in this table.

In summary, 241,000 ha of private and government lands require about 3,600 Mcm of water per year. An estimated return flow of about 2,000 Mcm (making a total withdrawal of approximately 5,600 Mcm) while augmenting stream flow cannot help but increase downstream salinity.

If the full 345,000 ha planned for the Euphrates are realized along with another 137,900 ha on the Khabur, water depleted from the system will double as will return flow. In order to fully evaluate the impact of these volumes upon the total Euphrates system, upstream uses in Turkey must be considered along with another major source of water loss, evaporation from reservoirs and canals. The special case of the Khabur with its source areas in Turkey also must be considered before turning to a final accounting of Euphrates waters in both countries.

Endnotes

5. New data received at press time (see Tables I-8 and I-9) provide information about irrigated areas in the mohafazats of Al-Hassakeh, Al-Raqqa, and Deir ez-Zor. (Similar data for Aleppo, whlie available, have not been used, for at the present time little or no water is apparently being taken from Lake Assad for the use of that unit's agriculture.)

Both tables show some variation from year to year which falls within a reasonable range. The greatest difference comes between yearly totals for the two tables. No immediate explanation of such variation is forthcoming, but may be explained if one set of data comes from canal gauges and the other from aerial or other surveys.

In any event, the average of all five values given on these two charts is 240,711 hectares. This is for all practical purposes exactly the same as the value given on page 68 which was arrived at through completely different data sources. Again, one may attribute such correspondence to coincidence or to the correctness of these estimates, but the reader should be reassured that the earlier figure was <u>not</u> consulted in order to compute the later one.

6. The impact of uncontrolled pumping on groundwater in Syria as well as the use of groundwater drawn by the Turks from aquifier recharge areas in Turkey will have a profound affect on this resource. This topic is discussed in the section of this report dealing with the upper Khabur and Ceylanpinar areas.

7. While the EP values given in Tables N-4 and I-7 have been calculated, the FAO report[3065] on the Khabur (pp. 79-80) gives two similar empirical values. Cotton in the Khabur area requires 120 days (15 May to 1 Oct) and 10,000 to 12,000 cu m water per ha. (This would not include losses due to system inefficiency.) Another study showed that 17,700 ha cotton 2,200 ha fruit and legumes, and 4,400 ha cereals used 240 X 10^6 cu m water or approximately 1 cu m per m^2. These examples are in essential agreement with the values used for the computations described here.

Table I-1

PROPOSED, REVISED, AND ACTUAL IRRIGATED LAND PROJECTS
IN THE SYRIAN EUPHRATES DRAINAGE AREA
(all figures in ha)

Location	Proposed Amt.	Revised Amt.	Actual Amt.	Comments	Reference
Tabqa/ Ath-Thawra	850,000 (Soviet estimate)	650,000 (German estimate)		See also LANDSAT reference sheet estimates for	Bourgey, p. 346
		640,000 (Syrian decision)		private lands	Khayyat Interview
		345,000 (1983)			
		135,000 (Rev. for 1980)		Deemed unrealistic	World Bank, p.248
		40-60,000		Deemed more realistic	World Bank
		240,000 by 1980 "but by 1978 only had been prepared"		prepared"	USAID 1980 V. I, pp. I-31
		"43,200 by 1980"		Projection	USAID, V. I, pp. I-31
Balikh	185,000	185,000**	--		Bourgey,p.346
(area #1)	200,000		--		Pitcher, p.14
Euphrates Valley	240,000				Bourgey, p.346
			1,600 11,500	"Central Euphrates Project"	Khayyat Interview
-Lower Valley	165,000	165,000**	See Table I-2		Sanlaville, p.235
-(area # 2)	160,000		20,240 "left bank near Ar-Raqqa"	"Underway 1974"	Pitcher, p.14
-Lower Khabur	70,000				Pitcher, p.14
-(area #3)	75,000	75,000**			Sanla., p. 235

Table I-1 continued

IRRIGATED LAND PROJECTS ON THE SYRIAN EUPHRATES

Location	Proposed Amt.	Revised Amt.	Actual Amt.	Comments	Reference
Rasafah (area #4)	150,000 (Soviet estimate)	20,000 (German estimate)			Bourgey, p.346
					Sanlaville, p. 235
		25,000**	none (1983)	abandoned because of gypsiferous soils	Khayyat Interview
Mayadin Plain (area #5)	40,000	40,000**			Pitcher, p. 14 Bourgey, p. 346
Maskanah-Aleppo (area #6)	150,000 (125,000)	150,000**			Khayyat Interview (Ivanov, p. 77)
			15,000/ 13,282		Khayyat Interview
-("near Aleppo")		(100,000)			(Ivanov, p. 77)
-northern and southern Aleppo region		180,000		Possibly recent addition to area #6 in place of original lands	Khayyat Interview
Khabur (upper)	400,000				Bourgey, p. 346
		137,900		See references this report	Al-Thawra, pp. pp. 41-42
Total: areas 1-6 Areas 1-6		640,000**		original	
Total per Khayyat Interview Khayyat Interview		345,000		revised	
Total including revised Khabur estimate		482,900			

(See also: Table I-4: U.S./S.A.R. "Status Report..."

Sources: Bourgey(0040), Khayyat(1902), World Bank(1262), USAID(3045), Pitcher(0749), Sanlaville(0064), Ivanov(2362), Al-Thawra(1852).

Of the 640,000 ha originally planned, 110,000 ha were to be irrigated by gravity flow from Lake Assad and 530,000 to be irrigated by water pumped from the reservoir. Pitcher, p. 14.

Table I-2

THE EUPHRATES VALLEY PILOT/PIONEER PROJECT

Begun: May 1973

Location: 18 km from Tabqa on the left bank of the Euphrates

Water: Served by Pump Station Kdeirane--6 pumps with a capacity of 25 cu m and a lift of 20 m.

Area:	Original	Third 5 Yr. Plan	Revised	Actual
	18,000 (1973)*	38,700*	32-19,000*	11,500 (1983)

*Proposed but not attained

This project was intended to resettle nearly 60,000 villagers who had been flooded out by the Al-Assad Reservoir. Fifteen villages have been built replacing the original 43 that were abandoned.

The downward revision of the area cultivated was apparently the result of the large scale collapse of the original canals and the loss of up to 30,000 cu m per hour of water into the gypsiferous soils. While the canals have apparently been repaired, as recently as 29 July 1984 *Tishrin*(3097), p. 4, reported that "cracks" had appeared in the Balikh Canal.

The crops grown on the pilot project land were primarily cotton, but also barley, forage crops, sugar beets, corn, beans, fruit, and (for the first time) rice.

Sources: Bourgey(0040), Khayyat Interview(1902), *Tishrin*(3097)

Table I-3

DAMS IN THE EUPHRATES RIVER BASIN, SYRIA

Name	Storage Cap.	Reservoir Area	Area to be Irrigated
Tishreen (1.6 MW)	1.3 Mcm (planned)	--	planned MEED, 1986
Tabqa/Al-Thawra (800 MW HEPP)	11,600 Mcm	625 km^2	see text and tables
Baath (64 MW)	--	--	completed 1986 MEED, 1986
Western Al-Hasakah*	91 Mcm	1,020 ha	
Eastern Al-Hasakah*	232 Mcm	3,100 ha	49,450 ha combined
Al-Khabur*	665 Mcm	9,580 ha	46,450 ha

Note: Diversions from the springs at Ras al-Ayn will irrigate an additional 42,000 ha along this portion of the Khabur.

TOTAL: 137,900 ha

Source: Al-Thawra, 12 Mar 1983[(1852)], p. 5

*Under construction March 1983.

Bab el Hadeed	--	--	2,800 ha combined
Al-Jawayda			
Al-Jarah	23 Mcm	--	--
Mashouq	2.5 Mcm	--	300 ha
Jagh Jagh	--	--	1,200 ha
Malkeva	61 Mcm	--	600 ha
Al-Hakima	1 Mcm	--	400 ha combined
Al-Mansouria			

TOTAL: 5,300 ha

Source: Syria Times, 16 Aug 1982[(1956)], p. 3

Al-Wa'ar (Deir ez-Zor)	3.345 Mcm	805,000 m^2	--
Karima (Al-Hasakah)	1.9 Mcm	800,000 m^2	--
Abou Al-Kahef (Al-Raqqa)	.62 Mcm	390,000 m^2	--

Source: SAR (1980)[(3050)], Table 8/1, p. 68.

Table I-4

STATUS REPORT ON EUPHRATES RIVER IRRIGATION PROJECT

Date: July 22, 1976:		Area ha
Pilot Project	developed	20,000
Balikh (sect 1)	construction contracts signed	10,000
Balikh remaining	bids invited	12,000
Balikh (sect 2)	designs completed	26,000
Mid-Euphrates Valley	construction contracts signed	27,000
	Total ha:	95,000

Main and branch canals	800 km
Secondary canals and flumes	900 km
Main drains (surface)	500 km

Source: U.S. Dept. of State[1860], "Syria: Euphrates Basin Maintenance Project Agreement," signed at Damascus July 22, 1976.

Table I-5

USAID/SAR ESTIMATES OF "INTENSIVELY CULTIVATED LAND"*
IN SELECTED REGIONS OF NORTHERN SYRIA
(includes LANDSAT imagery)

Location	Amount in ha	Comments	Source
Euphrates Valley	160,000	as of 1970	Treakle, Foreign Agriculture, p. 9
	(-28,000)	flooded by Lake Assad	Samman, p. 23
	(-25,000)	flooded by Lake Assad	Pitcher, p. 15
Lower Euphrates	142,000	USAID (1980) While private these wil be integrated into the completed project.	RPU - 32 V. 2, p. i-111
Raqqa Mohafaza	60,773	USAID (1980) LANDSAT	V. 3, pp. 1-85
Dier ez-Zor Mohafaza	85,676	LANDSAT	V. 3, pp. 1-87 N.B. This figure approximates both USAID and Treakle above.
Total	146,449		
Hasakah Mohafaza	80,909	USAID LANDSAT	V. 3, pp. 1-82
"around Al-Hasakah"	25,000 "approximately" ("irrigation network #2" 4,542)	location unclear	USAID (1980) RPU 50 V. 2, pp. 1-163
"Upper Khabur"	60,000	"irrigation network #3"	RPU 40 V. 2, pp. 1-137 N.B. This total approximates LANDSAT data although drawn apparently from Syrian sources.
Total	85,000		

Sources: Treakle(3062), Samman(0993), Pitcher(0749), USAID(3046-3047), SAR(3050).

* "Intensively cultivated land" by USAID definition is considered to be irrigated and in the cases cited here such water would come from the surface sources.

Table I-6

INTENSIVE AGRICULTURE: NORTHEAST SYRIA* AS DETERMINED FROM LANDSAT (28 JULY 1976)

Euphrates, Balikh, Lower Khabur (pumped from river)		Khabur Tributary System (pumped from river and groundwater)		Partially within Euphrates drainage (probably pumped from river)		Within Euphrates Basin (probable groundwater usage)		Queik System		Within Basin (no observed intensive agriculture)	
RPU	ha	RPU	ha	RPU	ha	RPU	ha	RPU	ha	RPU	ha
32	145,000	50	24,500	19	1,700	39	7,100	20	31,200	33	--
40	50,000	38**	3,400	31	7,240	45	200			51	--
42	9,200	41**	2,500			46	27,300			53	--
						48	4,600			54	--
						49	12,000				
						50	200				
						57	19,800				
TOTAL	201,700		30,400		8,940		71,200		31,200		

Source: USAID (1980)[3045], Table 3, p. I-210.

* Tigris Drainage excluded

** Partially within basin but all irrigation included.

N.B. See Map I-2 for location of RPUs.

Table I-7

WATER FUND DEPLETION RESULTING FROM EVAPOTRANSPIRATION AND RELATED DEFICITS
(See Table N-4 for supporting materials and discussion)

Location	Area Irrigated 1000 ha	Deficit Replacement cu m/ha	Fund Depletion cu m/ha	Total System Depletion Mcm	Amt Returned to System cu m/ha	Total Returned to System Mcm
			Planned Program (See Table I-1)			
Lower Euph. (Deir ez-Zor)	345	10,360	16,835	5808	9,065	3127
Ras al-Ayn (Upper Khabur)	42	7,070	11,489	483	6,186	260
Tel Tamer (Hasakah)	95.9	7,720	12,545	1203	6,755	648
Totals	482.9	--	--	7486	--	4035
			Private Lands (As of aprox. 1980) Per LANDSAT Imagery (May include government sponsored irrigation--see below)			
RPUs						
Euphrates						
32,42	151.7	10,360	16,835	2554	9,065	1375
40	50.0	7,070	11,489	574	6,186	309
Khabur						
50	24.5	7,070	11,489	281	6,186	152
38, 41	5.9	7,720	12,545	74	6,755	40
19, 31	8.94	10,360	16,835	151	9,065	81
Totals	241.040	--	--	3634	--	1957
			Government Sponsored Irrigation*			
--	47,582	7,720	12,545	597	6,755	321

* Probably included in LANDSAT totals given below.

Table I-8

IRRIGATED LAND IN THE EUPHRATES DRAINAGE BASIN, NORTHERN SYRIA -- 1979/80/81
(Values in Hectares)

Year	Mohafazat	Winter Crops	Summer Crops	Fruit Trees	Total	Year Total
1979	Al-Hassakeh	49,126	42,412	1893	93,431	
	Al-Raqqa	27,823	26,341	136	54,300	
	Deir ez-Zor	45,892	59,455	3406	108,753	256,484
1980	Al-Hassakeh	45,820	44,217	2218	92,255	
	Al-Raqqa	20,981	22,883	43	44,001	
	Deir ez-Zor	47,455	72,584	3710	123,749	260,005
1981	Al-Hassakeh	41,762	42,829	2325	86,916	
	Al-Raqqa	20,829	18,853	186	39,868	
	Deir ez-Zor	48,454	70,134	4022	122,610	249,394

Source: Syrian Arab Republic, The Annual Agricultural Statistical Abstract, 1979/1980/1981, Table 9[3213-3215].

Table I-9

SOURCES OF IRRIGATION WATER IN THE EUPHRATES DRAINAGE BASIN, NORTHERN SYRIA -- 1980/81
(Values in Hectares)

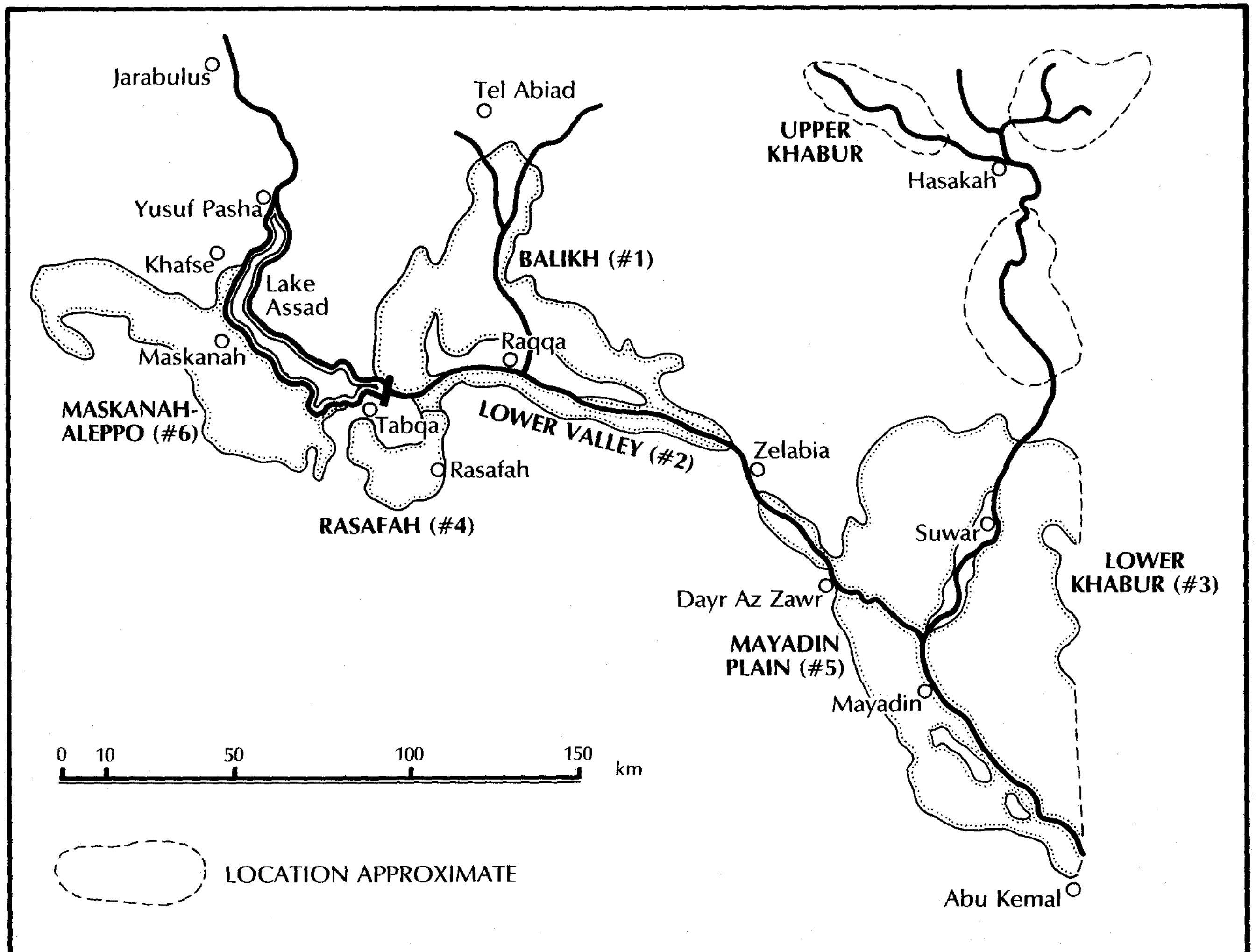
Year	Mohafazat	Pumped from Wells	Pumped or Free Flow from Rivers	Total	Year Total
1980	Al-Hassakeh	33,479	49,164	82,643	
	Al-Raqqa	16,098	34,067	50,165	
	Deir ez-Zor	1170	79,548	80,718	213,526
1981	Al-Hassakeh	34,828	52,413	87,241	
	Al-Raqqa	17,698	41,779	59,477	
	Deir ez-Zor	1170	76,260	77,430	224,148

Source: Syrian Arab Republic, The Annual Agricultural Statistical Abstract, 1980/1981, Table 6[3214][3215].

MAP I-1

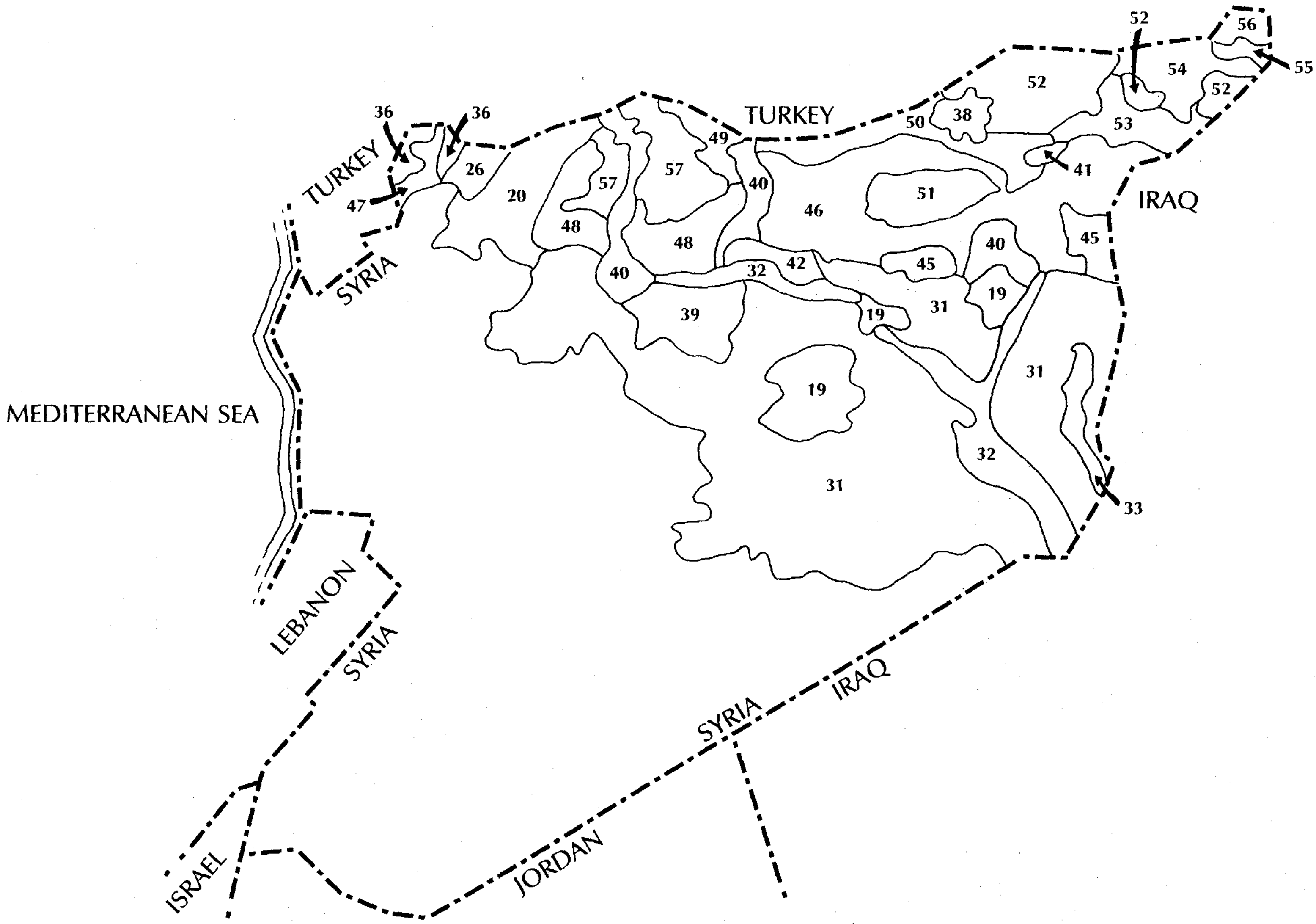
IRRIGATION REGIONS WITHIN THE EUPHRATES RIVER BASIN, SYRIA

(Turkish Border Not Shown)



Source: Bourgey, p. 347, 1979. (Upper Khabur: Syria Times, 1985)

MAP I-2
RESOURCE PLANNING UNITS OF NE SYRIA



Source: USAID, Vol. I, 1980.

Chapter 6

THE KHABUR RIVER AND ITS TRIBUTARIES

Syria north and east of the Euphrates River is drained by the Balikh and Khabur River systems. These streams enter the Euphrates from the left bank below the Tabqa dam and provide on the average 0.6% and 6.0% of the total flow of the river (Table S-1). While this amount is relatively small, the significance of these tributaries is disproportionately great, particularly in the case of the Khabur. The reasons for this are threefold. Syrian efforts at agricultural development have met with numerous frustrations along the mainstream of the Euphrates, while the lands of the upper Khabur offer promise of success. The Khabur is cited as Syria's significant contribution to the discharge of the Euphrates and offers a *quid pro quo* basis for Syrian claims to use of the river. Discharge from these tributaries significantly affects the amount and quality of water passing into Iraq.

Evidence will be presented that more than 80% of the waters of the Khabur and its tributaries originate in Turkey and can and will be affected by that country's development plans. This, in turn, will affect Syria's plans for the area as well as affecting the third riparian user, Iraq.

This region is known in Syria as the Jezirah and is further divided into the Lower Jezirah which stretches north from Deir ez-Zor on the Euphrates to the Jebel Abd El-Aziz on the west and the Jebel Sinjar (mountains) on the east of the Khabur River. North of this barrier is found the High Jezirah which extends from Hasakah in Syria at the confluence of the Khabur and Jagh Jagh Rivers to the anti-Taurus Mountains in Turkey. This gently rolling plain is the catchment area for the waters of the Khabur system which lies 45 per cent within Turkey (10,722 km^2) and 55 per cent within Syria (23,575 km^2). Another approximately 1600 km^2 falls within the borders of Iraq to the southeast. However, this area as open desert contributes nothing to stream flow. Rainfall in the Lower Jezirah is less than 300 mm per year and near Deir ez-Zor evapotranspiration (1504 mm per year) is more than ten times annual precipitation (148 mm). Elevations as well as rainfall increase steadily to the north:

Location	Elevation m	Avg. Annual Precipitation
Hasakah	300	267
Ras al-Ayn	350	292
Siverek	850	548
Mardin	1150	714

(See Table K-3, Map K-1)

The highest elevations in the upper basin of the Khabur are 1919 m at Karacali Dag (mountain); near Mardin, Turkey (1200 m); and in the south the Jebel Abd el-Aziz (920 m) and the Jebel Sinjar (1460 m). The course of the Khabur River extends for approximately 120 km in Turkey with a slope varying between 5.2°/00 and 31°/00. It flows for another 486 km in Syria to its confluence with the Euphrates at Bseira near Deir ez-Zor. In Syria its descent is much more gradual, ranging from .27°/00 to .5°/00. Near Ras al-Ayn the valley of the Khabur is two to four km wide, while south of Suwar it flows across a desert plain. A number of tributaries enter the Khabur from its left bank. Among these, the Djirdjib, the Zergane, and the Jagh Jagh would be permanent streams save for summer depletions of irrigation water. Others, the Breibitch, the Jarrah, Khneizir and the Roumelie flow only during the height of the rainy season (e.g., in 1963 they had gone dry by July). The disposition of these streams is shown on maps K-2 and K-3.

A main feature of the eastern Jezirah is the Radd Marsh formed by the uplift of the Jebel Sinjar in the late Quaternary. This blocking of the south flowing streams diverted them westward to the Jagh Jagh. Evapotranspiration in the Radd is so great, however, that only in times of flood does water find its way in any quantity west to the Khabur.

6.1 Hydro-geology of the High Jezirah

The High Jezirah is bounded structurally on the north by the Mardin anticline and fault line. To the south the anticline and uplift of the Jebel Abd el-Aziz disrupts the stratigraphic continuity of the region. Within these limits are a series of south dipping strata ranging in age from the Middle Cretaceous to the Quaternary and Pliocene. These beds are of great importance for among them are aquifers which provide the overwhelming share of water found in the Khabur and its tributaries (Diagram K-1).

Four distinct assemblages of strata have been identified which constitute the major aquifers of the Jezirah (Map K-4 and Table K-4).

1. Eocene/Oligocene limestones and dolomites: these strata where they are exposed to the north in Turkey serve as the principal recharge area and subsequently form the major aquifer providing water for the Ras al-Ayn and other Syrian springs. They have numerous open passageways for direct flow as well as being fissured and possessing great storage capacity. It is estimated that of the two billion cubic meters of water supplied to the catchment area in Turkey by precipitation each year, perhaps 400 Mcm consist of runoff while the remaining 1,600 Mcm recharges this aquifer. The major exfluents of all this are the Ras al-Ayn and the Ayn Aarus near Tel Abiad on the Balikh. Even more impressive are the subterranean reserves which account for the steady and nearly unvarying flow of these springs. A minimum of at least eight times the annual volume of flow would account for such regularity. The quality of the water thus delivered is good, with some exceptions where sulphur content makes them less acceptable for agriculture. Of the more than ten springs making up the Ras al-Ayn, two are named Ayn Kibrit (the Spring of the match) indicating the presence of sulphur.

2. Gyspiferous and calcareous rock of the Middle and Upper Miocene: less porous and permeable than the strata described above, these beds have varying capacities as aquifers with the best occurring where fissuring due to tectonism has taken place. The exposure of these beds largely near the Jebel Abd el-Aziz in an area of greatly reduced precipitation also limits both their recharge capacity and the total amount of water which they provide. A total flow of 2 to 3 cu m/s of which 1 to 2 cu m/s surfaces as springs and the remainder as evaporation limits the effectiveness of this source. Furthermore, karst solution in the gypsum makes the quality of the water highly variable.

3. Argellites of the Pontico-Pliocene: while these rocks are not entirely impermeable, they provide little opportunity for storing large amounts of water. An estimated total flow of 0.5 cu m/s and poor quality characterizes these waters.

4. Pliocene-Quaternary unconsolidated materials: these sands, sandstones, gravels, conglomerates and basalts have excellent porosity and permeability and, where either precipitation or infiltration from streams is available, provide good stores of immediately available groundwater for the upper saturated zone. These formations are of parti-

cular importance to the east and southeast of Qamishli where they acquire waters of the Jagh Jagh, the Brebich-Jarrah, and the Roumelie, and in turn release large amounts into the Radd for subsequent evaporation.

6.2 Turkish-Syrian Shares of Khabur Waters

The above description of the Khabur basin provides the basis for an analysis of both how water is utilized within the basin, where it comes from and where it goes[8]. Obviously, the Khabur is an independent system receiving no water from the Euphrates but contributing to the larger stream. Therefore, precipitation is considered to be the sole source of water passing through the system. The geologic structures mentioned previously preclude the addition of underground waters from outside the topographic basin. On the other hand, the sub-systems of the Khabur, each within its own smaller drainage area, exchange water both above and below the ground with adjoining sub-basins.

The basic problem facing this analysis was two-fold: to assign amounts of precipitation to the Turkish and Syrian segments of the system, and to assign final values regarding runoff in the same way but also to take into account differences in evapotranspiration and use from one place to another.

Table K-1 presents the first half of this task. Sections of each sub-basin were carefully measured and assigned to either Turkey or Syria. In turn, the precipitation falling on each area was calculated and weighted according to north-south variations in annual amounts. The last two columns on the right of this table present the calculated amounts of precipitation in each subsystem for each country. Such percentages can then serve as a means of weighting the amount of runoff from each subsystem. (It should be noted that this table has an internal means of balancing its values which may be summed from top to bottom.) What becomes apparent may at first seem somewhat anomalous. That is, only 34 per cent of the basin and 47 per cent of the precipitation are found within Turkey. Yet all the discussion to this point implies that Turkey is the predominant supplier of water to the system. This can be explained and verified with reference to two facts. Average precipitation in the pertinent portions of Turkey is 506 mm per year while that in the Syrian portion is only 294 mm. Second, evapotranspiration is significantly greater in Syria. In large tracts of the latter country included in this analysis, even in the rainiest month of the year, evapotranspiration exceeds precipitation with no resulting surplus to runoff. In those cases, where average precipitation figures were lacking, proportional estimates based on spatial distributions were used (Map I, Endpapers, FAO)[3065].

Table K-2 provides a detailed analysis of water use in each sub-basin. (It should be noted that sections of the tributaries analyzed separately in Table K-1 have been aggregated in Table K-2. Capital letters identify such groupings.) Because of the complexity of the data, sub-basins shown on Map K-5 have been stylized for clarity on Map K-6 and laid out schematically on Diagram K-2.

In order to explain the analysis the following description traces Row "a" from left to right. (The following explanation may also be followed on Diagram K-2.)

F	This provides the descriptive location of the river segment referred to in Table K-1.
P	FAO data indicated that this area provided 7.0 cu m/s per year to the system.
$G\text{-}W_1$	Of these 7 cu m/s 2.5 infiltrated into groundwater and/or aquifers.
$G\text{-}W_2$	At the same time, 2.0 cu m/s entered the sub-basin from the Jagh Jagh between Qamishli and Sfaya. N.B. that this latter exchange is between sub-systems and must be accounted for separately.
R	Surface flow removed another 2.0 cu m/s downstream.
S	Another 1 cu m/s of spring flow also moved downstream.
UF	A similar sub-system exchange of underflow in the river alluvia removes 1.5 cu m/s into the Jagh Jagh between Qamishli and Sfaya. There is an apparent two-way exchange of underflow and groundwater in this area. The end result is a net loss of 0.5 cu m/s from the Jagh Jagh at this point. (See $G\text{-}W_1$ above.)
$E_m, E_{m\text{-}s}$	In this case no water is lost by evapotranspiration from marshes or semi-marshes although in other sub-systems, such is the case.
E_i	Irrigation removes 2.0 cu m/s per year from the system through evapotranspiration losses.

Total In/Out	Summing the plusses and minusses balances this row.
$R+E_i+S$	The *natural flow* of this sub-system is equal to that from the rivers and springs plus what is lost through human activity. (Sub-system exchanges are accounted for in other subsections.) The amount of water entering the Khabur from this sub-basin is equal to 5 cu m/s/year.
% from Turkey Est. nat. flow	Since 100 per cent of the precipitation--i.e., the source of the above flow--has been shown in Table K-1 to have come from Turkey, 5 cu m/s have been assigned to Turkey.

The conclusions reached by this accounting show that 47.7 cu m/s of the natural flow of the Khabur and its tributaries should be assigned to Turkey as surface runoff or from aquifers whose catchments in Turkey. Another 9.8 cu m/s originate in Turkey, making a total of 57.5 cu m/s natural flow. *In other words, 83 per cent of the total flow of the Khabur originates in Turkey; that is 1.5 x* 10^9 *cu m.* Irrigation in Syria removes at least 4.5 cu m/s and probably much more of the total 9.0 cu m/s lost. Evapotranspiration from marshes and semi-marshes represents another significant loss which will be considered again in the summary section of the study. (Diagram K-3 further summarizes these remarks.)

If we return to the considerations posed at the beginning of this section, we find a new perspective on the use of water for irrigation in this section of the Euphrates basin. While a detailed analysis of the Balikh sub-system has not been possible because of lack of data, it may be assumed with considerable certainty that similar amounts of water can be assigned to that portion of Euphrates supply. Indications are that a similar conclusion may be reached regarding the waters of the Sajur to the west. *This means that if roughly 80 per cent of the waters named above come in actuality from Turkey, that country's contribution to the total Euphrates system--as demonstrated in Table S-1--is 29.04* km^3/yr *out of an average of 29.45* km^3/yr *or 98.6%!* This conclusion might be of little importance if it were not for Turkey's plans to establish large-scale pumping of the aquifers to the north of the Syrian border. This may be off-set by the return flow from Turkish fields which promises to be great. However, such a return flow, as has been mentioned previously, might well bring new problems of pollution to downstream areas. This will also be considered in the final section of this report.

Endnotes

8. While many sources have been consulted during the analysis and writing of the materials presented here, one above all has provided the necessary background information. This is the *Etudes des ressources en eaux souterraines de la Jezirah Syrienne* prepared by the Food and Agriculture Organization of the United Nations in cooperation with the Government of Syria[3065]. This undertaking covered the full spectrum of subject matter from basic climatology and geology to land use and agricultural economics. While many of the data used within it are of necessity of short time span, the workers exercised the utmost caution and modesty in making their analyses. Much of the material, however, was presented solely in terms of Syrian use of the area. While this was entirely natural and proper, the fact that Turkey may have rival claims to some of the water resources involved was noted but scarcely taken into consideration by the FAO team. It has been necessary, therefore, to rework sections of the report in order to give a more international perspective to the questions involved.

Table K-1

COEFFICIENTS OF PRECIPITATION IN THE BASIN AND SUB-BASINS OF THE KHABUR RIVER

Description of sub-basin (Table III-c, p. 67, FAO)	Total Area km^2	Avg Precip. per year mm	Total Precip. per year 1000s cu m	Area in Turkey km^2	Ave Precip. per year in Turkey mm	Total Precip. per year in Turkey 1000s cu m	% Watershed in Turkey	Area in Syria km^2	Ave Precip. per year in Syria mm	Total Precip. per year in Syria 1000s cu m	% Precip. from Turkey	% Precip. from Syria
A: Khabur to Ras al-Ayn	3,175	466	1,479,550	3,175	466	1,479,550	100	--	--	--	100	--
B: Djirdjib to confluence with the Khabur	2,775	495	1,371,775	2,540	510*	1,295,400	91.5	235	325*	76,375	94.4	5.6
C: Khabur Basin between R. a-A. and Tel Tamer	1,500	263	394,500	--	--	--	--	1,500	263	394,500	--	100
D: Zergane to Tel Tamer	2,575	470	1,208,052	1,822	525*	956,550	70.8	753	334*	251,502	79.2	20.8
SUBTOTAL: Khabur to T. T.	10,025	455	4,453,877	7,537	xx	3,731,500	75.2	2,488	xx	722,377	83.8	16.2
E: Khabur Basin between T.T. and Hasakah	1,000	282	282,000	--	--	--	--	1,000	282	282,000	--	100
SUBTOTAL: Kh. to Hasakah	11,025	430	4,735,877	7,537	xx	3,731,500	69.4	3,488	xx	1,004,377	78.8	21.2
F: Jagh Jagh to Qamishli	1,025	596	610,900	1,025	596	610,900	100	--	--	--	100	--

Table K-1 continued

PRECIPITATION IN THE KHABUR BASIN

Description of sub-basin (Table III-c, p. 67, FAO)	Total Area km²	Avg Precip. per year mm	Total Precip. per year 1000s cu m	Area in Turkey km²	Ave Precip. per year in Turkey mm	Total Precip. per year in Turkey 1000s cu m	% Water-shed in Turkey	Area in Syria km²	Ave Precip. per year in Syria mm	Total Precip. per year in Syria 1000s cu m	% Precip. from Turkey	% Precip. from Syria
G: J.J. between Qamishli and Sfaya	10,800	384	4,190,400	2,160	500*	1,080,000	20.0	8,640	360*	3,110,400	25.8	74.2
H: J. J. between Sfaya and Hasakah	675	311	209,925	--	--	--	--	675	311	209,925	--	100
SUBTOTAL: J. J. Basin to Hasakah	12,500	xx	5,011,225	3,185	xx	1,690,900	25.5	9,315	--	3,320,325	33.7	66.3
I: Khabur Basin between Hasakah and Suwar	7,675	222	1,703,850	--	--	--	--	7,675	222	1,703,850	--	100
TOTAL: The Khabur to Suwar	31,200	366	11,450,952	10,722	506	5,422,400	34.4	20,478	294	6,028,552	47.4	52.6
	100%		100%	34.4%		47.4%		65.6%		52.6%		

Based on FAO(3065), Tables III-5 and III-6, pp. 66-67, and on Map #1, endpapers.

* Estimate made from FAO materials

Table K-2

TURKISH-SYRIAN SHARES OF AVAILABLE WATER--ALLOCATION OF PRECIPITATION IN THE KHABUR BASIN, SUB-BASINS, AND CATCHMENT AREA *

Hydro-area	Basin Area Equivalent See: Table K-1	Precipitation P	Ground-water G-W	Surface Flow (Rivers) R	Surface Flow (Springs) S	Under-flow UF	Evaporation from Marshes E_m	Evap. from Semi-Marshes E_{s-m}	Evap. from irrigation (1961) E_i	Total in	Total out	Natural flow $R+E_i+S$	% from Turkey (See Table K-1)	Est. nat. flow orig. in Turkey
a	F The Jagh Jagh to Qamishli	7.0	-2.5 +2.0	-2.0	-1.0	-1.5 subsystem exchange	--	--	-2.0	+9.0	-9.0	5.0	100	5.0
b	G J. J. between Qam. and Sfaya	15.5	-2.0 subsystem exchange	-2.5	--	+1.5	-2.0 -3.0	-3.0 -4.0	-0.5	+17.0	-17.0	3.0	25.8	.8
c	H J. J. between Sfaya and Hasakah	4.5	-2.0	-1.0	--	--	--	-1.5	--	+4.5	-4.5	1.0	--	--
SUBTOTAL	Jagh Jagh System	27.0	-4.5	-5.5	-1.0	--	-5.0	-8.5	-2.5	+27.0 (+30.5)	-27.0 (-30.5)	9.0 (includes subsystem exchange)	xx	5.8
d	A Rabur to Ras al-Ayn "Geol" B Djirdjib to the Khabur C Ras al-Ayn to Tel Tamer D The Zergane to Tel Tamer	33.0 13.5	+2.5 +2.0	-5.0	-42.0	--	-1.0	--	-3.0	+51.0	-51.0	50.0	83.8	41.9

TABLE SUMMARY

Natural Flow:
- Flow originating in Turkey = 47.7 = 1.5×10^9 cu m/yr.
- Flow originating in Syria = 9.8 = $.3 \times 10^9$ cu m/yr.
- Total flow = 57.5 = 1.8×10^9 cu m/yr.

47.7/57.5 = 83% of total flow originates in Turkey.

Table K-2 continued

TURKISH-SYRIAN SHARES OF KHABUR WATER *

Hydro-area	Basin Area Equivalent See: Table K-1	Precipitation P	Ground-water G-W	Surface Flow (Rivers) R	Surface Flow (Springs) S	Under-flow UF	Evapor-ation from Marshes E_m	Evap. from Semi-Marshes E_{s-m}	Evap. from irri-gation (1961) E_i	Total in	Total out	Nat-ural flow $R+E_i+S$	% from Turkey (See Table K-1)	Est. nat. flow orig. in Turkey
e	E Khabur between Tel Tamer and Hasakah	0.5	--	+3.5 from upstream flow	--	-0.5	--	--	-3.5	+4.0	-4.0	0.0	--	--
--	I Hasakah to Suwar	2.0	--	+1.5	--	--	--	-3.5 includes E_i	--	+3.5	-3.5	-1.5	--	--
SUBTOTAL		49.0	+4.5	--	-42.0	-0.5	-1.0	-3.5	-6.5	+53.5 (+58.5)	-53.5 (-58.5)	48.5 (includes subsystem exchanges)	xx	41.9
BASIN TOTAL BELOW SUWAR		76.0	--	-5.5	-43.0	-0.5	-6.0	-12.0	-9.0	+76.0	-76.0	57.5	xx	47.7

Source: Based on information in FAO[3065], Chapter IX, and Table K-1

* Figures in cu m/s.

Table K-3

**LOCATIONS, ELEVATIONS, AND PRECIPITATION
SYRIA AND TURKEY**

Location	Elevation in meters	Annual Avg. Precip. mm FAO	GAP	Years Record	Period of Observation FAO Data
Mardin	1150	686	714	(39)	1930-1960
Siverek	850	546	548	(48)	1930-1959
Gaziantep	840	550	555	(46)	1930-1959
Diyarbakir	677	488	488	(49)	1930-1959
Viransehir	575	537	540	(27)	1930-1959
Nusaybin /Qamishli	500	463*	485	(25)	1954-1960
Urfa	547	452	470	(46)	1930-1960
Qamishli /Nusaybin	467	452*	485	(25)	1952-1960
Ras al-Ayn /Ceylanpinar	350	292*	333	(23)	1957-1961
Tel Tamer	335	309			1948-1961
Hasakah	300	267			1931-1960
Raqqa	251	174*			1953-1960
Deir ez-Zor	200	148*			1931-1960
Abu Kemal	174	100*			1959-1960
Khafsa	350	201			1957-1960
Maskanah	350	201			1957-1960
Jarabulus	350	331			1949-1960

Source: FAO[3065], Table III-1, GAP[3081], Table III-1.

* Adjusted by FAO to reflect long-term projections.

Table K-4

SPRINGS OF THE HIGH JEZIRAH

Northeast

More than 100 springs; most with flow less than 0.0025 cu m/s.
Water quality is excellent.
Temperature less than 18° C.
Residue less than 0.5 g/l. (.0005 g/cu m.)

	Flow
Ain Divar	0.015 cu m/s
Hanauye	0.012 cu m/s
Baba Sinar	0.032 cu m/s
Der Guessen	0.030 cu m/s

Mid-Central

Approximately 35 springs; highly variable flow.
Grouped around the Jebel Abd Al-Aziz.
Water quality varies; that from limestones is good.
Temperature: 19°/24°C.
Residue: 2.7/26* g/l. (.0027/.026 g/cu m.)
*Ayn Jibissa

	Flow
Lake Khatunye	0.500 cu m/s
Ayn Hol	0.300 cu m/s
Tel Tabane	0.600 cu m/s
Ain Aissa	0.050 cu m/s
Um Madfa	0.030 cu m/s

North Central

Few in number.
Water quality apparently good.

Ayn al-Qerd	Very small	
Qamishli	See below.	(Mainly in Turkey)

Northern Frontier

	Flow
Ayn al-Arab	0.150 cu m/s
Ayn Sluq	?
Ayn Arus	See below.
Ras al-Ayn	See Table K-5.

	Natural Flow (cu m/s)		Flow (cu m/s) After Irrigation		Total Flow (cu m/s)
	Spring	Surface	Spring	Surface	
Qamishli	3	2	1 or 2	2	3 or 4
Ayn Arus	6	?	2 est.		2

Source: FAO[3065], pp. 12, 26-27, and 195.

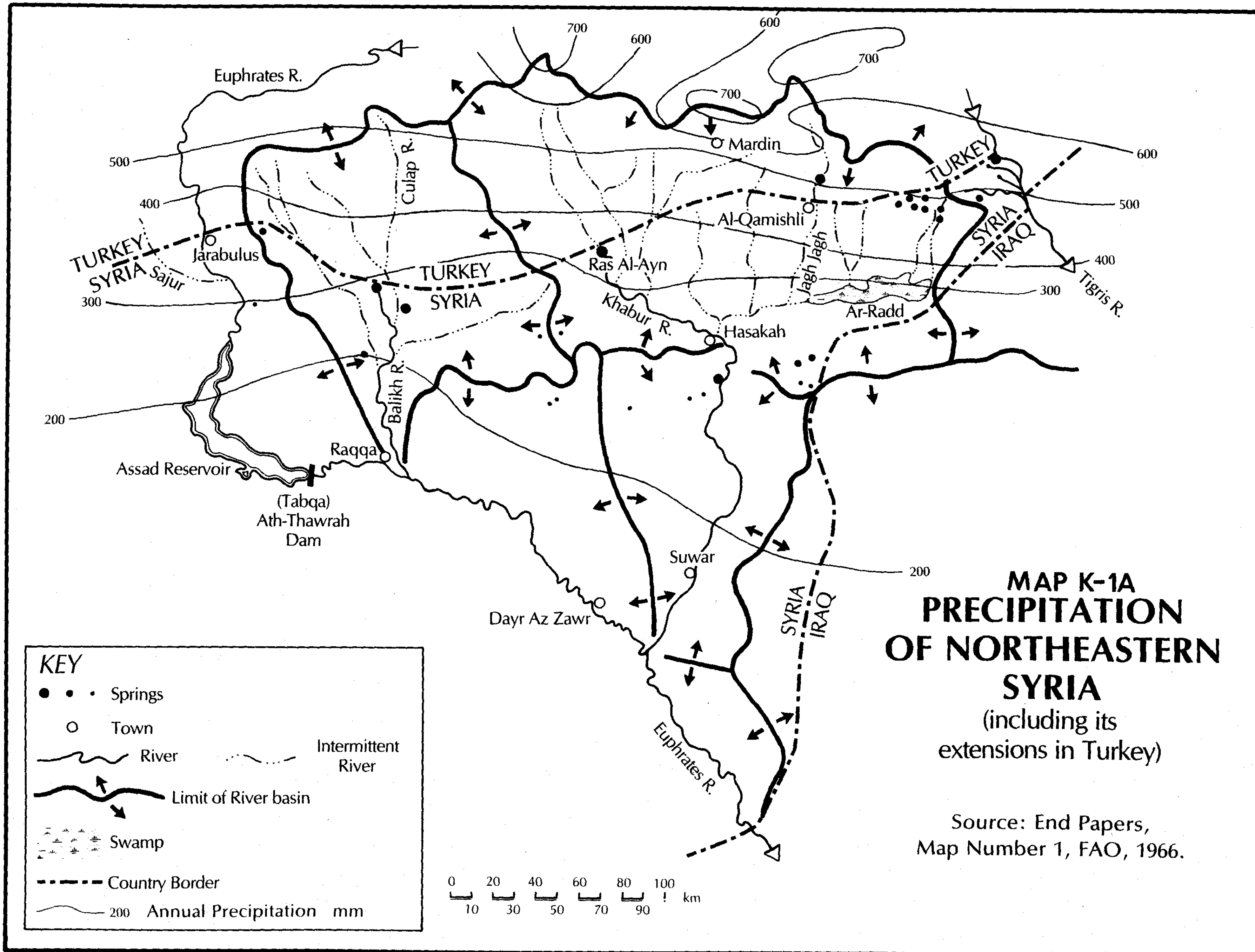
Table K-5

THE RAS AL-AYN (SPRINGS)

Name	Altitude m	Flow in cu m/s	Date
A. Hassan (south)	345.3	2.73	15/4/60
		1.86	11/8/60
A. Kibrit (south)	344.3	4.16	22/4/60
		4.16	14/8/60
		5.52	21/3/60
A. Zerga (south)	344.3	5.15	15/4/60
		6.35	11/8/60
Number 2 (North)	344.5	3.11	15/4/60
Number 7 (Zerga N.)	347.5	0.42	23/4/60
The Khabur River (100 m downstream from the frontier)			
	344.5	1.93	2/8/60
The Khabur River (Right branch upstream of the confluence)			
		21.6	2/8/60
		20.7	9/8/60
The Khabur River (Left branch 350 m upstream of the confluence)			
	344.3	21.4	3/8/60
		20.8	8/8/60
The Khabur River (Downstream from the confluence two branches.)			
	344.1	40.7	4/8/60
		41.6	4/8/60
		41.0	9/8/60

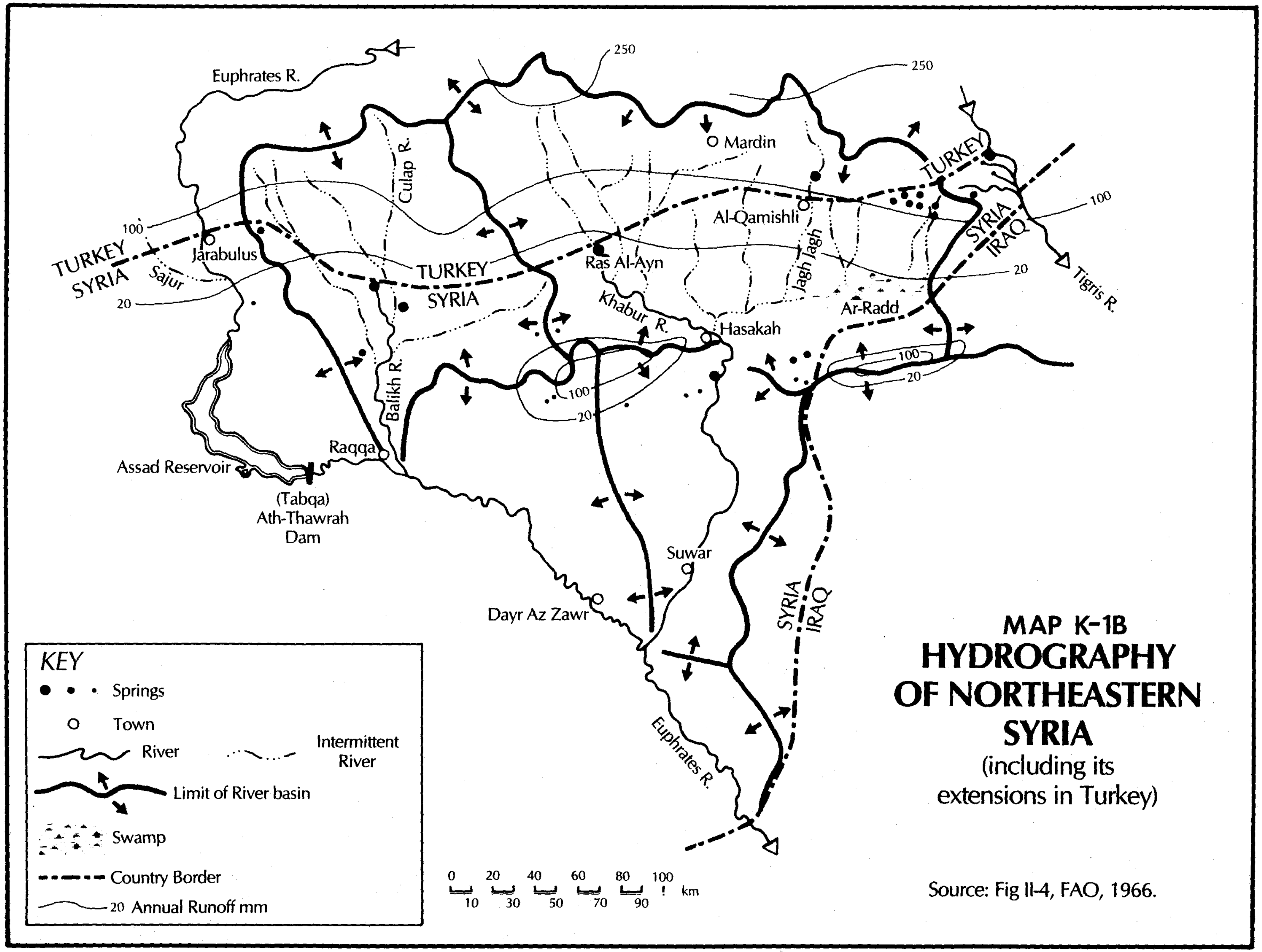
Names of springs:	Left Branch:	Arkhum	Right Branch:	Halaf
		Zerkan		Hassan
		Djamus		Jabbar
		Banos		Zerga
				Kibrit-1
	Main stream:			Kibrit-2

Source: FAO(3065), Fig. II-7 and Table II-1.



MAP K-1A
PRECIPITATION OF NORTHEASTERN SYRIA
(including its extensions in Turkey)

Source: End Papers, Map Number 1, FAO, 1966.

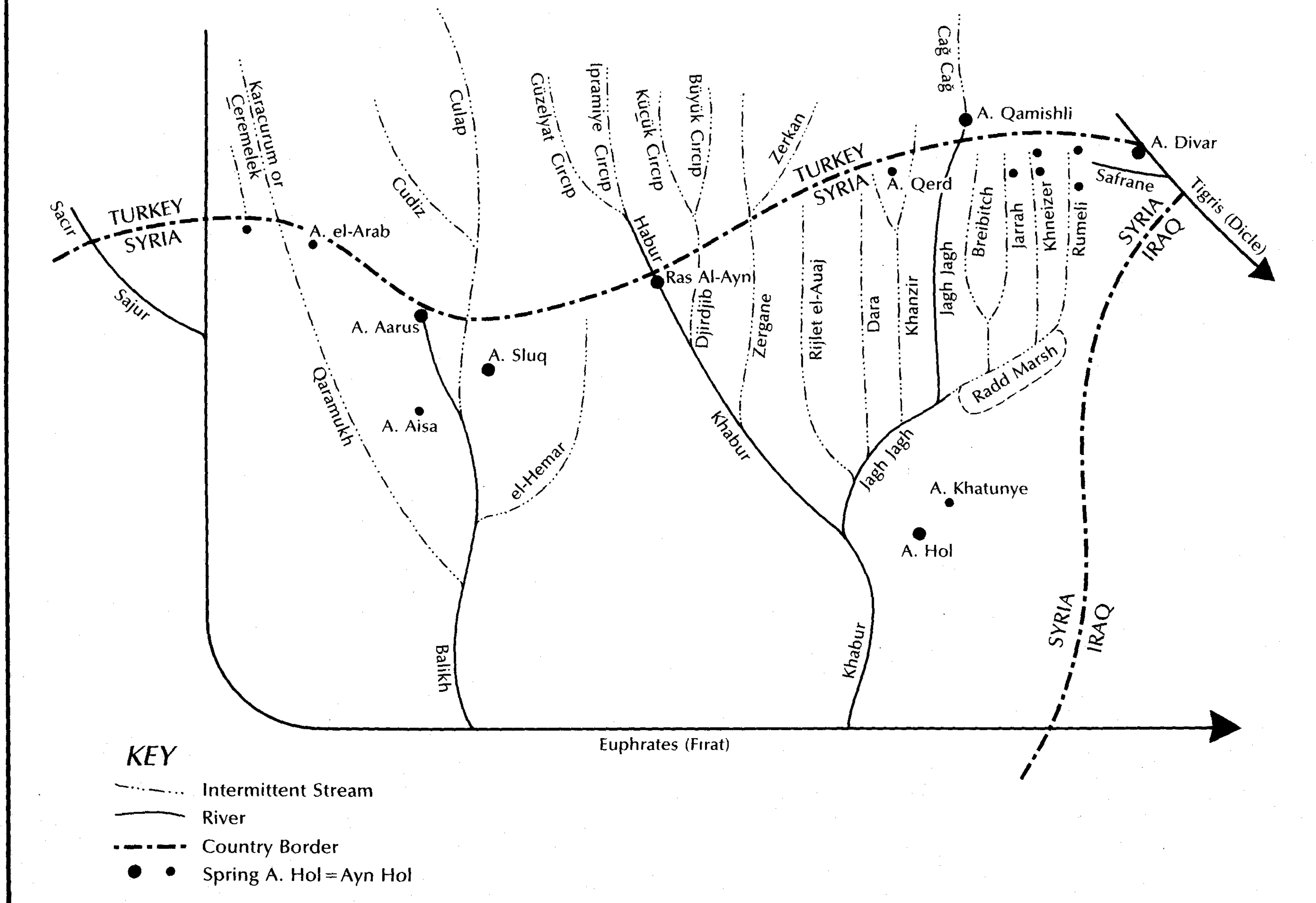


MAP K-1B
HYDROGRAPHY OF NORTHEASTERN SYRIA
(including its extensions in Turkey)

Source: Fig II-4, FAO, 1966.

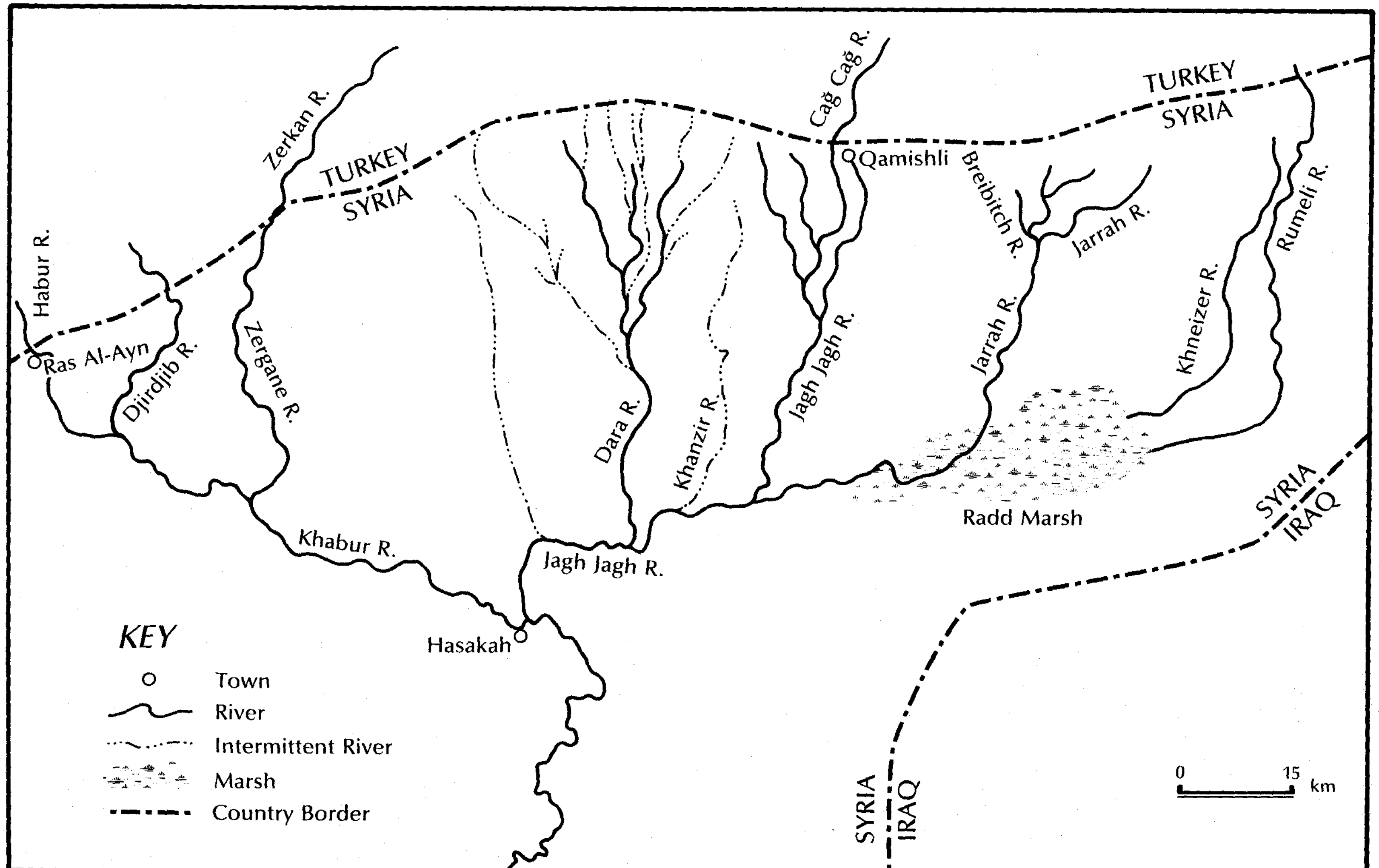
MAP K-2

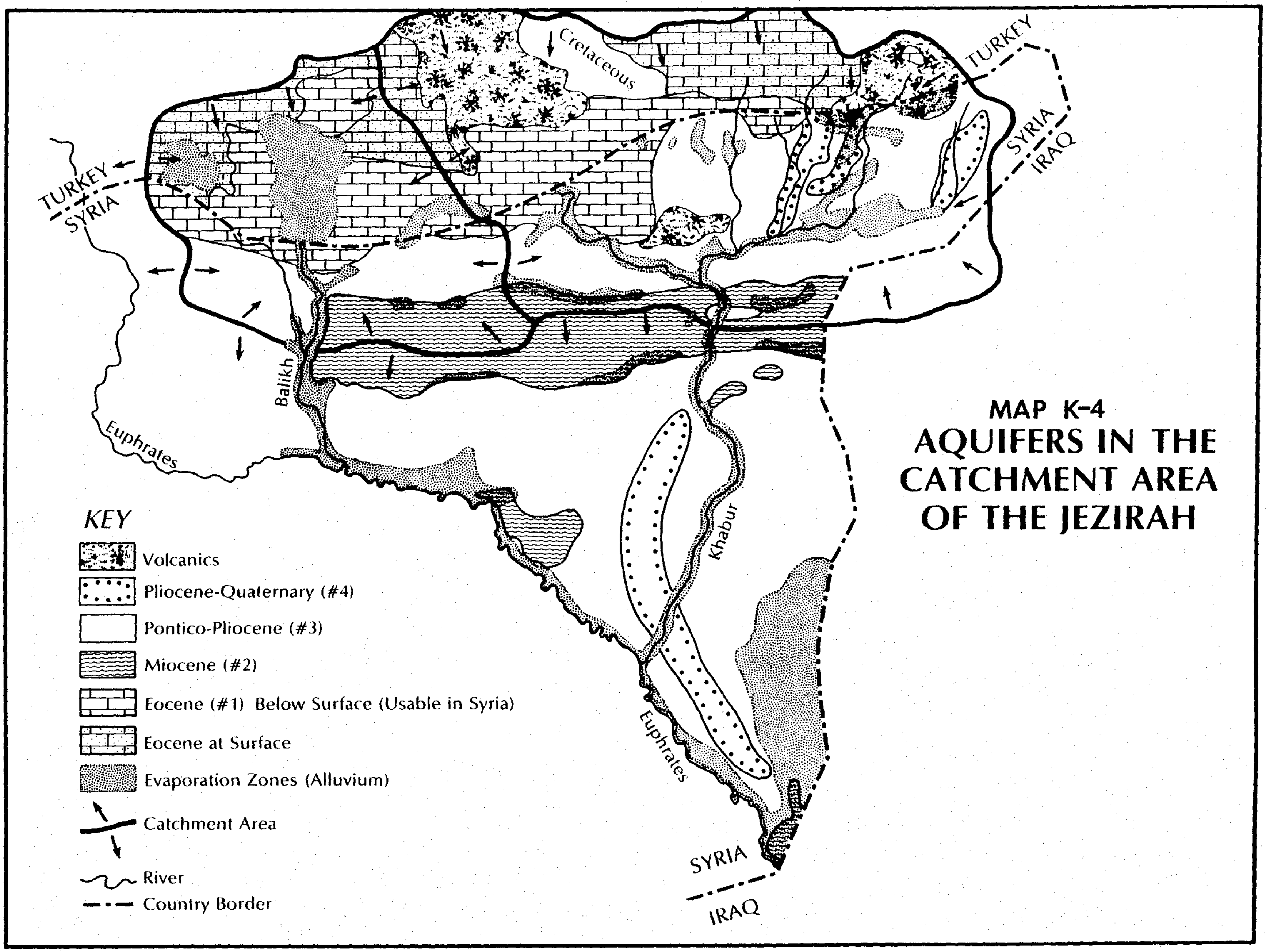
STREAMS AND SPRINGS OF THE JEZIRAH



MAP K-3

THE KHABUR RIVER AND ITS TRIBUTARIES

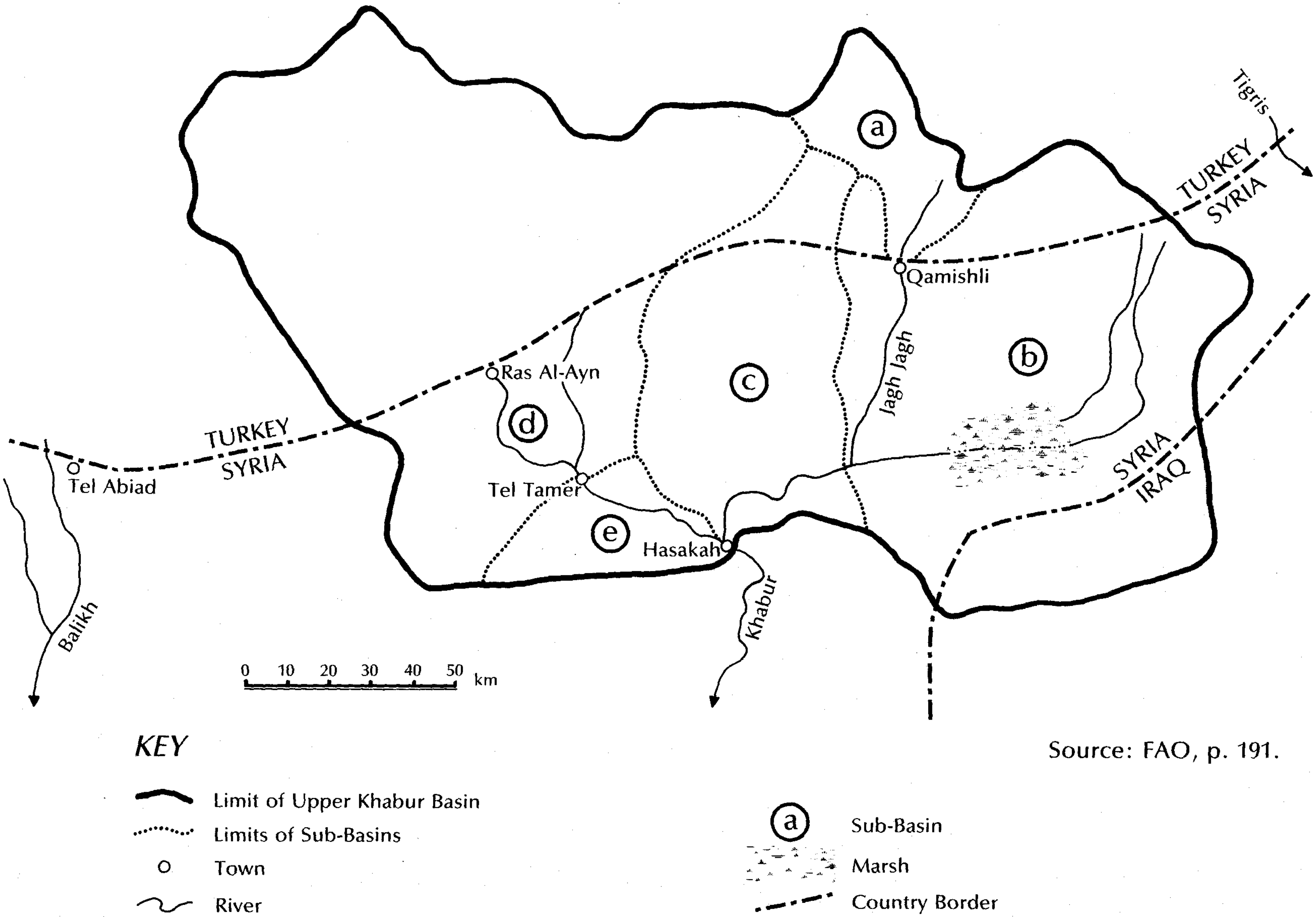




Sources: FAO 1980; Ali Tanoglu, Sirri Erinc, & Erol Tumertekin, *Turkiye Atlasi* (Istanbul, Milli Egitim Basimivi, 1961), Pl. 4.

MAP K-5

SUB-DRAINAGE BASINS OF THE KHABUR RIVER



Source: FAO, p. 191.

MAP K-6

HYDROLOGIC SUBDIVISIONS OF THE KHABUR RIVER BASIN

(see text for explanation)

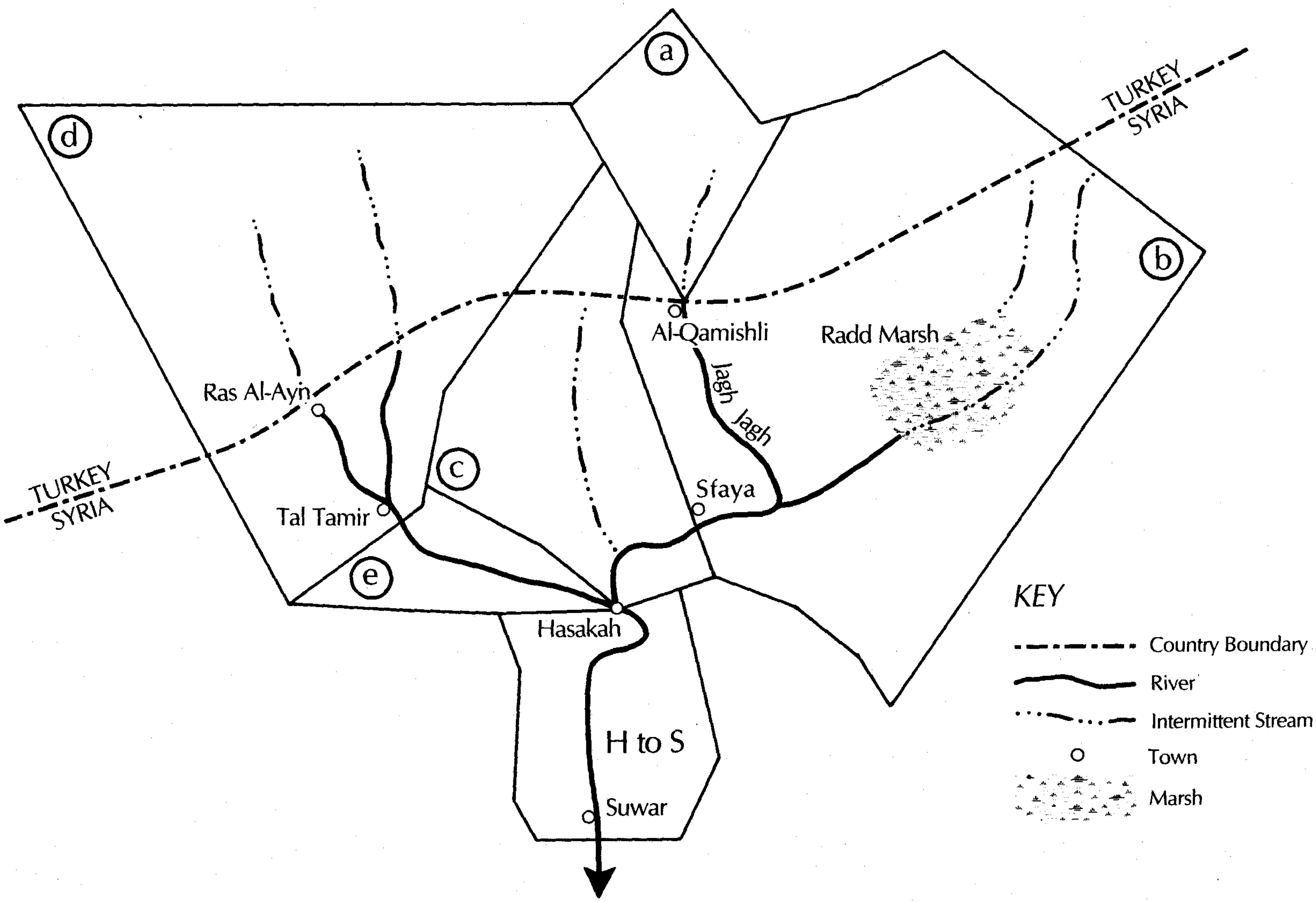
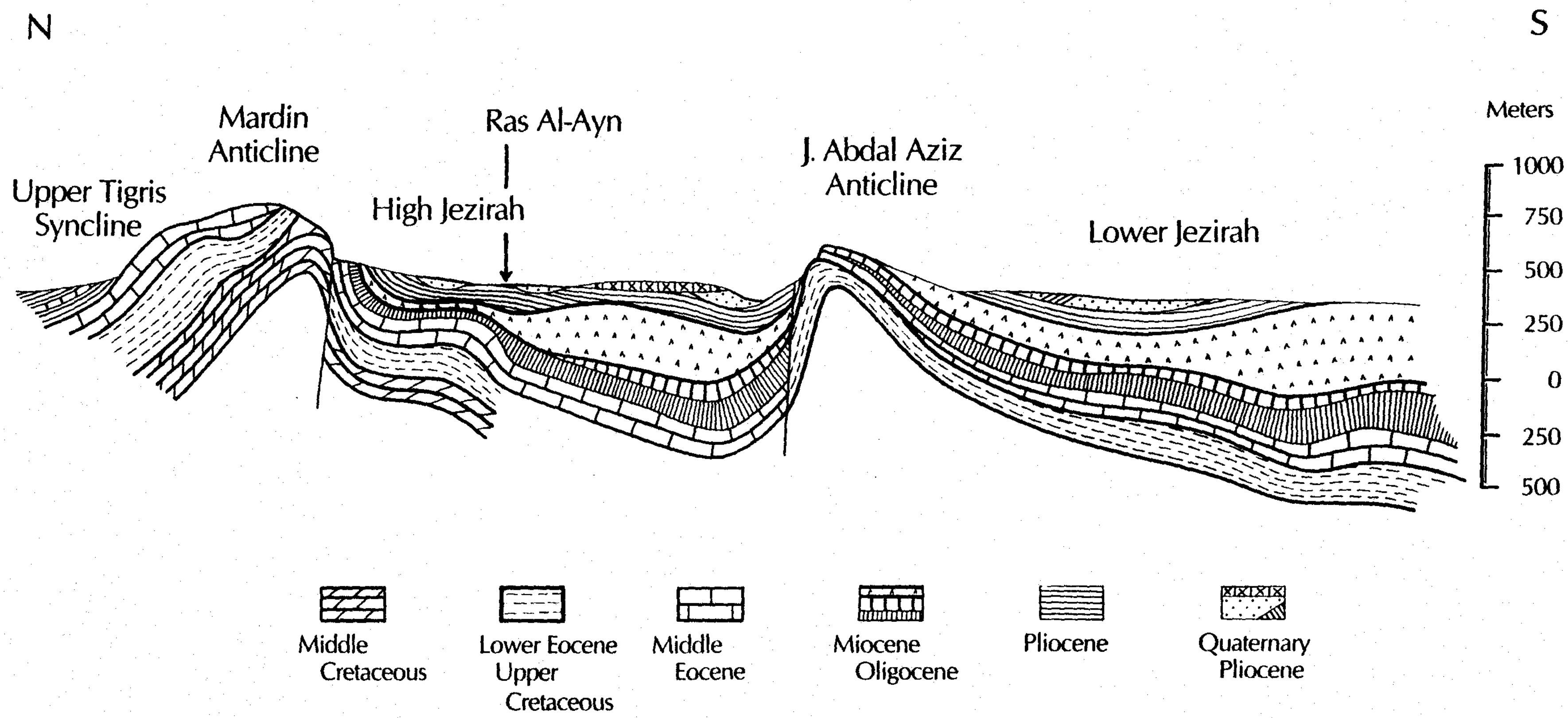


DIAGRAM K-1
SCHEMATIC NORTH-SOUTH GEOLOGIC CROSS-SECTION OF THE JEZIRAH



Based on Figure IV-8, FAO, 1966.

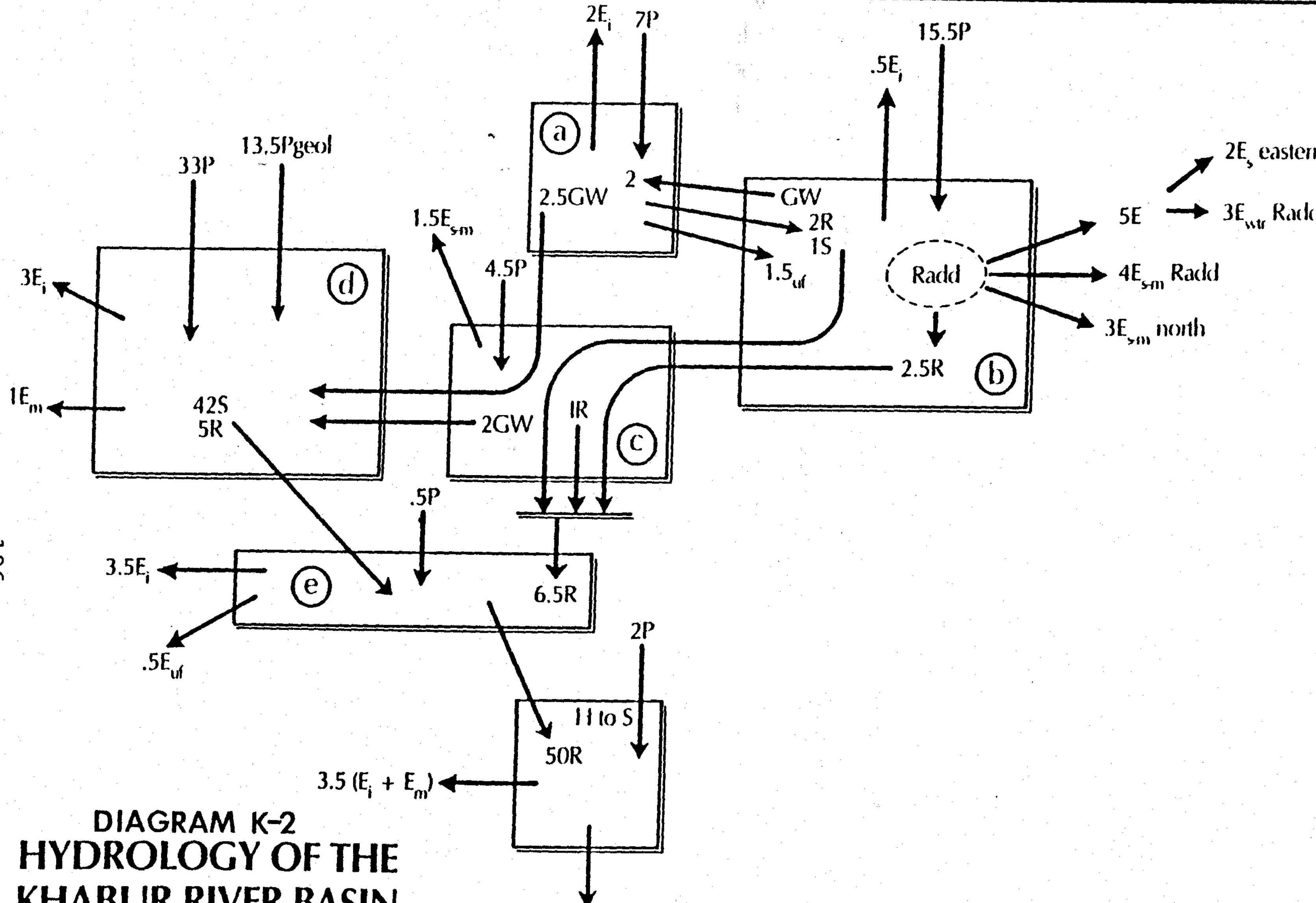


DIAGRAM K-2

HYDROLOGY OF THE KHABUR RIVER BASIN BY SUBDIVISIONS

48.5	R (After irrigation)
9.0	E_I (Total loss from irrigation as of study period 1961)
57.5	Natural flow at Suwar

Diagram K-2

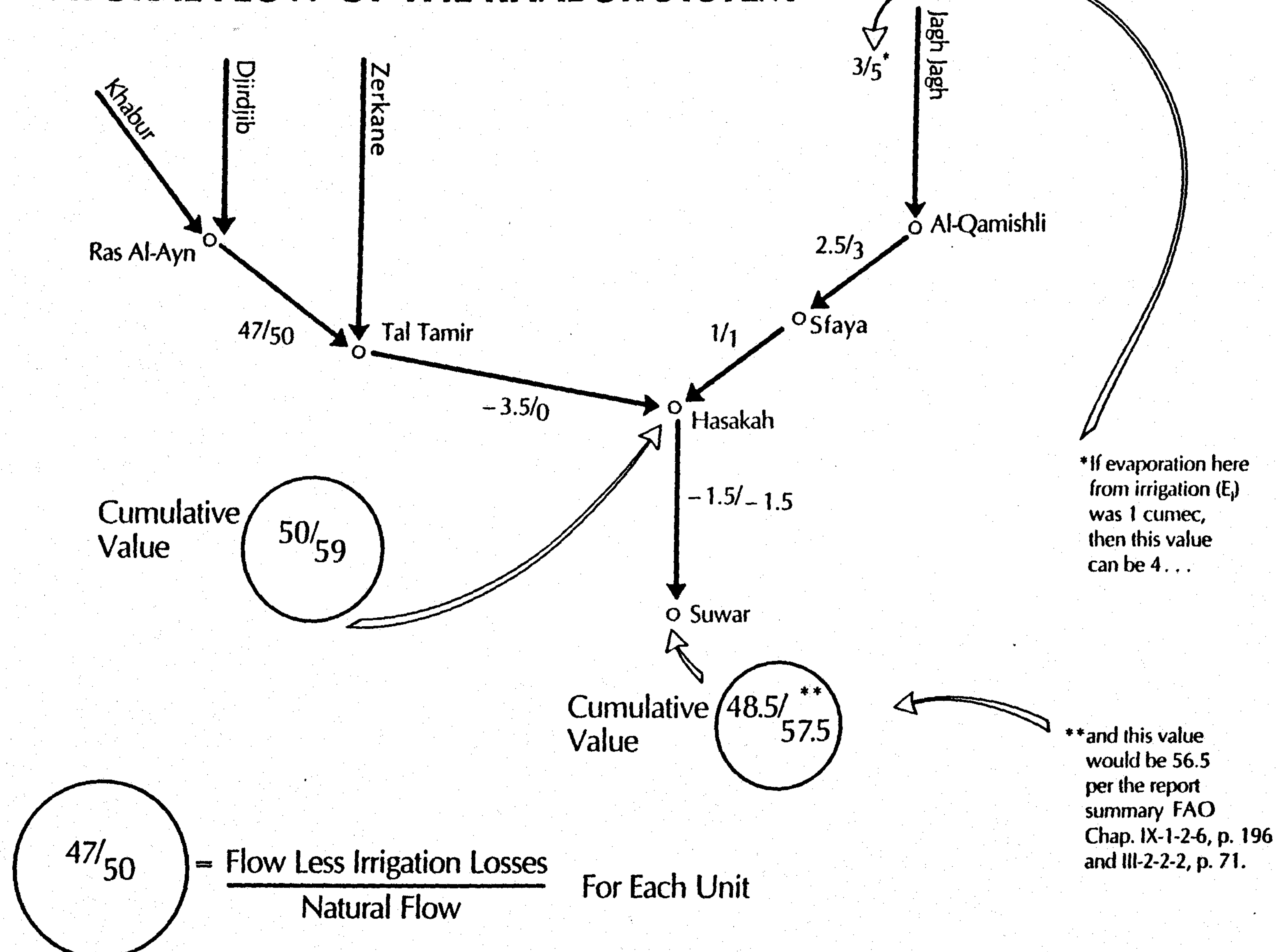
LEGEND

E_i	Evapotranspiration from irrigation
P	Precipitation
P_{geol}	Additional precipitation added as groundwater
GW	Groundwater
R	Surface runoff from precipitation
S	Additional discharge from springs
$--_{uf}$	Underflow in stream alluvia
E_m	Evapotranspiration from marshes
E_{s-m} north	Evapotranspiration from semi-marshes (seasonal), northern
E_s eastern	Evapotranspiration during summer from eastern Radd
E_{wtr}	Evapotranspiration during winter from main Radd
H to S	Hasakah to Suwar

Circled letters a-e refer to hydrologic subdivisions shown on Maps K-5 and K-6.

DIAGRAM K-3

CHANGES PER STREAM UNIT OF ACTUAL FLOW (1961) AND NATURAL FLOW OF THE KHABUR SYSTEM



Chapter 7

STATIC AND DYNAMIC VIEWS OF THE EUPHRATES RIVER SYSTEM

7.1. Constraints on Dynamic Modeling

The analysis presented in the preceding sections allows a more comprehensive view of the entire Euphrates system. The Tigris River has been excluded from this study because it is being scheduled for development at a later date. This omission does not preclude the necessity of taking the Tigris portions of the GAP[3081] into consideration, but to do so would double the length (and time needed) of this report. Moreover, far fewer data are readily available concerning that stream and its more complex regime vis-a-vis the flow of the left bank tributaries flowing from the Zagros Mountains. In the same manner, this study touches the upon but does not consider the situation in Iraq in great detail for all the above reasons and also the fact that the current political situation there would again slow the analysis of conditions there.

A further caveat must be made regarding this analysis. When, and if, the development plans of all three countries are in place and functioning, the fair and efficient management of the river will be an exceedingly complex operation. Each of the three riparian users intends to utilize the river for both hydro-electric production and for irrigation. Even within the boundaries of a single user balancing these needs is no small task. For example, Raif Ozenci, local deputy manager of the Turkish State Waterworks (DSI) at the Ataturk Dam site in a recent interview (Turkish Daily News, 2 Oct. 1986[1821]) points out that while the Ataturk Dam is designed to produce 8.9 billion kilowatt-hours (kWh) annually, electric production will be reduced to 8.1 billion kWh per year when the proposed irrigation projects come on line. Furthermore, a significant quantity of the power produced will be used locally for pumping water to project fields. These demands will have to be balanced against upstream hydro-electric production at Karakaya and Keban and similar production plus removals for irrigation downstream at Birecik and Karkamis.

Operating in counterpoint to all such variations will be the changes in natural stream flow tied to climatic variations. Moreover, beyond the initial dead-water storage filling of reservoirs, there will be annual fluctuations induced by human needs. Should water be reserved for uninterrupted hydro-electric production or released both for irrigation purposes and in order to ensure reservoir capacity in the event of unexpected flood conditions?

Table V-1 illustrates the intricacies of such questions in terms of a situation which has already taken place. Average monthly flow of the Euphrates at Keban is shown in the left-hand column. This varies from a maximum in April of 5,127 Mcm to a minimum of 562 Mcm in September. Making the impractical and politically unrealistic assumption that *all* the flow of the stream will be held back until the reservoir is filled, considerable variation in the length of time necessary to reach total reservoir capacity occurs depending upon the month of the year in which filling begins. If the gates are closed in March or April capacity will be reached in May or June of the following year. If the gates were to be closed in June, capacity would not be reached until early in April *23 months later*. The reason for this is whether or not spring floods can be retained at optimum times. An interesting situation developed along these lines in 1986 when the reservoir behind the Karakaya Dam began to be filled in June of this year. Obviously, all the water in the river cannot be withheld from downstream users in these cases, but the two confrontations between Iraq and Syria over shortages in the flow of the river indicated the delicacy of such timing. In a similar vein, year to year variations in flow resulting from climatic changes can create difficult situations as shown by Graph EF-2[9].

Table V-2 represents a further complication in river management resulting from monthly variation in evaporation rates from reservoir surfaces. Such evaporation is in turn a function of the size of the surface involved. Since reservoirs will be changing volume and surface area depending upon natural conditions and human demands, evaporation losses vary considerably. For example, given a maximum volume of 30,500 Mcm in the Keban reservoir, its surface area would be 675 km^2 with evaporation losses per year of approximately 1,000 Mcm. If the minimum operating level were maintained, volume would be 9,500 Mcm with a surface area of 260 km^2 and an annual loss of 390 Mcm per year. It can safely be assumed that volume and surface area will vary throughout each year and that, therefore, evaporation losses will follow such changes as well as reflecting annual conditions of temperature, wind turbulence, humidity, cloud cover, etc.

The above considerations dictate the ultimate necessity of a dynamic model of the river, but also preclude an attempt given the limited resources and time allowed for this report. One suggestion is that LANDSAT or other imagery made available on an ongoing basis could provide surface areas of both large and small reservoirs. These in turn could be translated into volumes and flow and evaporation rates. Once such an analytical system were in place, river management and surveillance would become considerably simpler.

7.2. A Static Model of the Euphrates River and its Uses

Given the above considerations, what remains possible is a static model or picture of the river with approximations of demands for several time periods and using average data which have been discussed in previous sections of this report.

A Word on the Values Used in the Computations

Without detailed on-site measurements of a number of variables, the values used in computing evaporation, evapotranspiration, irrigation water needs, conveyance and farm efficiency, return flow and water quality must be based on available data and intelligent estimates of conditions. Evapotranspiration and irrigation water needs have been discussed at length in previous sections of this report. Evaporation from reservoir surfaces has been computed using values provided by al-Hadithi(3067) which fall within the expected range.

Return flow values shown on Table T-4, while falling within a relatively narrow range, have presented some difficulty in making a final choice for this analysis. A round figure of 35 per cent has been chosen. This is perhaps generous and Table V-3 shows the consequences of choosing a more conservative 30 per cent and 25 per cent for selected cases. On the one hand, this relatively high return flow (RF) value gives the benefit of the doubt to upstream users that much of what they remove will find its way to downstream riparians. On the other hand, considering the very large volumes of water involved upstream, RF may present serious problems of flooding, water-logging and/or pollution to downstream users. These are matters that should be resolved first by on-the-spot experts and then through negotiations regarding removal and use rates.

Conveyance and on-farm efficiency and their corollary, water loss, have also been discussed in a previous section. For this summary water lost to the system has been computed in the following manner. Irrigation water needs (i.e., the amount of water needed for optimum crop production less the amounts of water provided naturally by effective rainfall and soil moisture recovery) based on Thornthwaite's method of computation have been used as the base value. (As mentioned earlier, while the Blaney-Criddle method gives a closer and usually higher value, data constraints limited this analysis to the use of Thornthwaite. The values given herein, may be considered as minima for the above reason and also because all such methods assume exact and rational application of water, something unlikely under the best of circumstances.)

Given such a value for a specific area, it has been assumed that 2.5 times that amount of water per unit area must be removed from river or reservoir in order that all other losses and demands be met and the plants satisfied. Dunne and Leopold[3059] (p. 162) suggest doubling the amount of water needed as a rule of thumb compensating "nonproductive" uses[10]. This value, however, is thought to be too low given the conditions anticipated throughout the GAP region[11]. The inexperience of the users, the extreme length and complexity of the canal delivery system, and perhaps even the social instability of the area dictate less efficiency of water use.

Given the above, the following relationships are made: Total water removed from reservoir or river = 2.5 (evapotranspiration less natural water supply during growing season.)

Return Flow = .35 (total water removed).

Water loss (i.e., nonproductive use) = Total water removed less return flow less water needed to supply irrigation deficit.

System depletion (i.e. total unreturned for all purposes) = water loss plus water needed for irrigation.

7.3. The Use of the Euphrates in Turkey

Map V-1 and Map V-2 show the Euphrates River system in Turkey in its entirety. Table V-4 traces developments along the river from its headwaters to its debouchement into Syria as well as showing related irrigation projects on streams which flow first into Syria before joining the Euphrates. (In the case of the Balik River west of Karkamis this stream, while not part of the Euphrates drainage system, is shown because of its involvement in the supply of water to the Aleppo area downstream.) The numerous minor projects detailed in Table V-4 are summarized for five sections of the river in Table V-5. Irrigation areas are shown on Map V-3 and reservoirs on Map V-4.

The Keban Dam and reservoir and the smaller projects upstream from that site were among the first developments to be completed on the Turkish Euphrates. Irrigated fields, while developed at an early stage in this area, are of relatively little importance compared to the hydroelectric power plants (HEPP) found here. (Details of this and other installations are found in Mitchell earlier in this report.) At this writing approximately 35,000 hectares are under irrigation with perhaps 58,231 ha scheduled for about the year 2000. At that time, depletion of river flow after RF has taken place will be 1430 Mcm.

Downstream from the Keban as far as the Karakaya Dam is a second section of the developments scheduled by Turkey. At the present time, there is apparently no irrigated farmland, but by the year 2000 about 42,000 ha are scheduled. As noted earlier, the Karakaya reservoir began filling in June 1986. When full that reservoir may lose as much as 435 Mcm of water from evaporation annually. By the year 2000 total depletion of river water should be for this section about 658 Mcm.

The area between the Karakaya and the Ataturk Dams is by far the most complex and ambitious part of the GAP. When fully completed after the year 2000 -- and if stated GAP goals are met -- 370,911 ha will drain into the Euphrates above the Ataturk Dam. Of this amount, 220,511 ha will enter from projects on the right bank (Cat, Adiyaman/Kahta) and the remainder (150,400 ha) from the Siverek-Hilvan area on the left bank.

The Lower Euphrates Project which is the core of the GAP is based upon the Ataturk Dam and its vast reservoir. Eight different irrigation projects totalling 1,148,511 ha are projected for completion sometime after the year 2000. A tentative schedule of when these are expected to come on line is found at the bottom of Table V-4. In addition to the 370,911 ha in the above paragraph, 777,600 ha will be irrigated on the southern slopes of the Anti-Taurus Mountains and the plains stretching to the Syrian border. Of this large area, runoff from 378,800 ha will reach the Colap/Balikh system and that from 398,800 ha will flow into the Khabur by way of its many northern tributaries (Table V-4). At its fullest, the Ataturk may lose as much as 1470 Mcm annually to evaporation, and sometime after the year 2000 depletion of the river from evaporation, water loss, and evapotranspiration might reach the astonishing amount of 11,360 Mcm along this section of the stream. (At this point it seems necessary to pause and assert the care with which these figures have been estimated. Moreover, these values represent a complete realization of the project's many features, an event that seems less likely to happen as the magnitude of the venture becomes apparent.) This depletion will be paralleled by a return flow of 5389 Mcm, of which roughly one third will return to the reservoir and the remaining 3600 Mcm will flow into the Balikh and Khabur systems in Syria.

Downstream from the Ataturk Dam is found the Euphrates Border Project. This includes the Birecik and Karkamis Dams, both of which are intended to generate large amounts of electricity. In addition to hydropower 101,573 ha are scheduled for irrigation largely from Lake Birecik and the Araban, Hancagiz, and Kayacik reservoirs. Return flow in this case will be about 578 Mcm and total depletion for this section by the year 2000 about 541 Mcm rising to 1257 Mcm sometime after that.

In sum, these ambitious plans foresee a region which sometime after the year 2000 will have 1,350,243 ha of irrigated land. Return flow from that land will total 7,408 Mcm. In the near future -- within the next four years -- non-recoverable water loss (including some evapotranspiration) will reach 1972 Mcm per year. If all goes according to schedule and to plan this figure should jump to 7,783 Mcm by 1995. By the year 2000 it may reach 12,300 Mcm per year and sometime after that date might even soar to 16,680 Mcm. Whether or not this is possible either technologically, ecologically, or politically is the issue.

7.4. The Use of the Euphrates in Syria

Less detail will be given at this point because much of what is summarized in Part II of Table V-4 has been covered in the preceding sections. One further item will be examined at length, that is, the relationship between the Syrian Jezirah and the Mardin-Ceylanpinar portions of GAP[3081].

Moving downstream in Syria from the Turkish border the first withdrawal of water will be on the Syrian portion of the Sajur which enters from the right bank. Little is known about this project and at all events its magnitude cannot be great.

Next will be the proposed Tishreen Dam which will create a lake with a volume of 1300 Mcm (MEED, 8/9/86) and an area estimated to be about 70 km^2 with evaporation loss of 157.5 Mcm/yr. Immediately downstream Lake Assad and the Aleppo diversion will remove another 1570 Mcm and 80.2 Mcm annually. Lake Assad will also serve five of the six originally proposed irrigation districts. (Rasafah #4 at last account has been abandoned.) Depletions from these various projects are shown on Table V-4, Part II. Another dam, the 64 MW Baath, 25 km downstream from Tabqa, was completed in 1986 though few details are known concerning it. Because of the importance of the Khabur and its development projects it will be treated next as a separate element of this study. Before that, note should be taken of developments in both Syria and Turkey on the Balikh/Culap and its tributaries. Table V-5 lists the Turkish projects which will be found in the upper basin of the Balikh (i.e. the Culap). While irrigation of such magnitude (378,800 ha) would totally dry up any local sources many times over, the major problem facing the lower Balikh in the years ahead would appear to be the problem of managing the return flow which might reach 2125 Mcm/yr. Reference is again made to the difficulty in making such estimates and to the variation in quantities depending upon the values chosen (as demonstrated in Table 3). Nevertheless, this becomes a major factor in the rational planning of future river use.

Anticipating what will be discussed regarding the Khabur, it is possible to estimate that Syrian activities will reduce Euphrates flow by 2100 Mcm by 1990; by 3500 Mcm perhaps in an additional five years; and by the year 2000 may be in a position to either take (or lose through evaporation from reservoir surfaces) a total of 12,100 Mcm annually. As in the Turkish case, reality must rest in a lesser figure.

7.5. A Critical Pressure Point: The Ceylanpinar/Ras al-Ayn Area

The sources of the Khabur River are shown in Map K-1. The major perennial source of this stream is a giant spring, the Ras al-Ayn, at the town of the same name immediately across the border from Ceylanpinar, Turkey. This perennial spring which in reality consists of a number of outlets (Table K-4) is one of the largest in the world. Additional water is added to the river by seasonal surface flows from Turkey in the late winter and early spring (Diagram V-1a). Other smaller streams also contribute lesser amounts of water to the Khabur. These come from a combination of smaller springs and seasonal runoff. To the east the Jagh

Jagh flows from Turkey into Syria as a perennial stream. Farther east and somewhat south is a large marsh, the Radd, which impounds significant quantities of water, much of which is lost through evapotranspiration. The other streams are seasonal in character.

The perennial flow of these streams with few exceptions stops just short of the Turkish border. This is the result of a diplomatic and technological coincidence. When the extension of the so-called Berlin to Baghdad Railroad was constructed across this territory, the tracks were located far enough up each stream to avoid the expensive bridging of year-round stream flow. Subsequently, when the Turkish-Syrian border was drawn following World War I, the railroad was included in Turkish territory, but so close does the border come to the tracks that in many places one actually steps out of the south side of the train onto Syrian soil. An unforeseen result of all this was that while the perennial streams and springs feeding the Khabur are in Syrian territory, a large portion of the catchments and aquifers for such springs and streams are located under Turkish administration.

The Ras al-Ayn spring flows at a nearly invarying rate of 35 cu m to 40 cu m per second. (It should be noted that the figure "40" in this case represents a real estimated value and not the Middle Eastern "forty".) Diagram V-1a shows this base flow for the Khabur downstream near Suwar and is plotted as a more conservative 37 cu m/sec. Winter and spring rains create surface runoff which begins in January and peaks sometime in April. Spring floods would thus provide an important part of the reservoir storage planned for Syria on the Khabur. At the same time, base flow represents a significant part of the system. The karstic waters of the Ras al-Ayn derive from the aquifer which is located largely across the Turkish border to the north. One account of this recharge area describes it as "7,500 km^2" (UN Report No. 9[3060]), although estimates made for the present study (Table K-1) are somewhat larger: 10,025 km^2. Water bearing strata dip southward from Turkey into Syria, reaching the surface at Ras Al-Ayn and producing enough head for natural or artesian flow of the waters. Turkish surveys list two areas of underground water availability in the Mardin-Ceylanpinar district: that surrounding Ceylanpinar and another near Mardin-Kiziltepe. The latter is relatively insignificant having an estimated 13 Mcm/yr of water recharge, but the former is said to contain a rechargeable supply of 852 Mcm/yr available for pumping (GAP, 1980[3081], p. III-20). Diagram V-1b indicates that if all recharge of the Ras al-Ayn spring were to cease, the spring would exhaust its stored supply of water in approximately four years (graph line q) although the invarying rate of spring flow suggests a much larger fund of stored water.

Two main sources of water ultimately provide for the Mardin-Ceylanpinar/Ras al-Ayn-Jezireh combined region. These are precipitation over the watershed which occurs in the winter and early spring and which declines from 1306 mm/yr at Lice in the north to 333 mm/yr at Ceylanpinar, and to less than 200 mm/yr at Deir ez-Zor (Map K-1a). This both provides surface runoff and recharges the underlying aquifers. A second source of water will be that brought into the region from the Ataturk Reservoir. While this water's ultimate source is precipitation farther up the Euphrates River, it is assumed here that such supplies can and will be provided as needed and will be independent of local variation in precipitation at Ceylanpinar.

Seasonal runoff will be partially stored in local reservoirs such as those at Mardin, Aride and Derik. Another part will flow downstream into Syria as shown in Diagram V-1 as the peak spring flow. Evaporation from these reservoirs will represent a net loss from the system; seepage from them into the aquifer will help to recharge losses from planned pumping. Locally stored waters as well as water from the main canals leading from the Ataturk Reservoir will irrigate fields. Additional fields will be served by water pumped from the local aquifer. Evapotranspiration from fields will represent a net loss to the system. Infiltration will partially recharge the aquifer and in addition considerable quantities of runoff will move downstream into Syria. In the latter country plans are underway to irrigate as much as 137,900 ha of land in the upper Khabur basin. The complexity of this situation is such that reference is made at this point to Diagrams V-2 and V-3 which diagram those parts of the overall Khabur/Habur system which are quantifiable. (The following numbered statements refer to corresponding numbers on Diagram V-2.)

1. Precipitation is estimated as the average for the Ceylanpinar-Mardin region times the area of the catchment.

2. The yearly fund of water from the Ceylanpinar aquifer is found in GAP[3081] II-6.

3. The Mardin-Kiziltepe fund (GAP[3081] II-6).

4. Water use from pumpage is based on GAP plans to irrigate 60,000, he in the immediate vicinity of the State Farm at Ceylanpinar. This amount is computed as: 60,000 ha x 11,489 cu m water need/ha (as shown in Table N-4) and equals 689.3 Mcm/yr.

5. Remaining flow towards Syria does not take infiltration from fields into account and represents the Ceylanpinar fund less the amount pumped.

6. Evaporation from reservoirs will be an overall withdrawal from the Euphrates system but may be replaced locally from the Ataturk Reservoir according to need.

7. Areas of fields receiving pumped water (see #4).

8. Area of fields receiving water from the Urfa Canal: 140,000 ha (Table V-5).

9. Area total: note 7 plus note 8.

10. Water Need is that portion of evapotranspiration met by irrigation water supplied by canals or pumping. Natural evapotranspiration and evaporation also represent withdrawals from original precipitation. A value of 11,489 cu m/ha (Table Water Use 4) may be considered as a conservative value.

11. No infiltration value has been calculated for this diagram.

12. Based on a downstream flow in Syria from this area (exclusive of spring flow) of 4.5 cu m/s (Table K-2).

13. Return flow based on 35 percent of water withdrawn for irrigation times 200,000 ha.

Summary: the overall picture given by this diagram is that pumping will reduce the aquifer fund by about four-fifths of its annual recharge increment or about 57 per cent of the annual flow of the Ras al-Ayn. Return flow will provide 804 Mcm/yr leaving a positive increment of 114.7 Mcm/yr or an overall flow of 966.7 Mcm on the western (Khabur) portion of the Khabur system. While this may seem a positive factor in the picture presented, water quality of the return flow is also important because the open channels of the karstic aquifer as well as surface streams will serve as poor filters compared to sandy strata. It must also be remembered that while the Khabur may actually gain water, all of the depletion occurring in this sub-region of the Euphrates Basin ultimately reduces downstream flow into Iraq.

Surface and spring water for the Jagh Jagh/Radd tributaries to the east are shown in Diagram V-3 along with downstream uses of the Ras al-Ayn/Khabur western tributaries. Precipitation is estimated to add 851 Mcm to the eastern area of the Jezirah in Syria. Of all the eastern tributaries, only the Jagh Jagh has perennial flow and some of the water of this stream has been used in Turkey above Nusaybin for at least a quarter of a century. Downstream in Syria there is an average flow of 205 Mcm/yr, a relatively small amount compared to the flow of the Khabur to the west. Part of these waters flow directly into the system via the Jagh Jagh; the remainder are filtered through the Radd Marshes where some 425 Mcm/yr are lost to evapotranspiration (Table K-2). Total irrigation water needs for the 137,900 ha of fields in the entire Khabur system would equal some 1686 Mcm/yr (12,226 cu m/ha), almost the amount of the Khabur's average an- nual flow.

Also at issue at this point is the question of return flow into the eastern tributaries of the Khabur system. Depletion of the existing systems there is less of a question than the one raised concerning the Ras al-Ayn aquifer. On the other hand, as much as 258,800 ha of additional irrigation may be implemented in the eastern portions of the Mardin Ceylanpinar region. Return flow from these fields would be -- at 35 percent of the total water involved -- 1538 Mcm/yr. If this were actually to take place, the entire ecology of the downstream area might be drastically altered. Moreover, the question of water quality addressed in section 7.7 is again a major issue. Water loss from the reservoirs planned along the Khabur is estimated to approach half a billion cu m per year.

Analysis of these data indicates that water loss, as stated, will possibly exceed the annual flow of the Khabur, particularly if evaporation losses from reservoirs take place. Groundwater can supply some of the needed water as long as this source is not seriously depleted in the Turkish catchment area. On the other hand a significant amount of return flow should find its way downstream from Turkey. If this water is of suitable quality the immediate crisis of competition for a limited resource may be averted but only at an ultimate downstream cost through diminution of the total system beginning back at Lake Ataturk. The system closes upon itself at Deir ez-Zor. Downstream returns via the Khabur and Balikh are simply upstream removals less evapotranspiration and evaporation and system inefficiency losses. The overall result will likely be a decreasing of flow and increases in impurities.

7.6. "Natural Flow" of the Euphrates

Perhaps the most difficult task of an analysis such as this is attempting to learn what the "natural flow" of a river is when so many humans are manipulating it, measuring it, and using its waters. All such activities take place against a constantly changing natural history of climatic variation. In the case of the Euphrates only the broadest speculations can be made regarding what amount of water the river would have in it if people would leave it alone.

The true natural volume of flow in a river should equal whatever reasonable measured flow can be learned plus some estimate of the upstream uses and/or nonproductive losses.

Mitchell (p. 93, Table 52) lists "Irrigated Land Use in GAP Provinces." Of the provinces listed, two will effect the Balikh and Khabur drainage systems through removals for irrigation.

Mardin	22,256 ha irrigated	Khabur system
Sanliurfa	33,694	Balikh system

Two more may have irrigated lands which either remove water from the mainstream of the Euphrates or deny water to the Mainstream by removing quantities from its tributaries.

Adiyaman	11,102	(10% subtracted for exterior drainage)
Gaziantep	20,065	(20% subtracted for exterior drainage)

This might account for a total of 87,117 hectares-worth of water removed from the system. At an average of 10,000 cu m/ha (i.e. 1 cu m/m^2) -- a figure well within the range used within this study, this would deplete the system by 817 Mcm/yr. [However, the GAP[3081] prospectus details only 58,309 ha of irrigated land, using 583 Mcm/yr, in 1980 (Table V-6).]

Syria has losses of 1570 Mcm/yr from Lake Assad, plus those from another estimated 241,000 ha of irrigated land (see: section: Irrigation in Syria) of which 100,000 ha may have been added in the years since 1973. This would give a possible depletion of 3100 Mcm/yr (based on an overall depletion rate of 1340 cu m/ha for 140,000 ha).

Returning to the conclusions of the section of this analysis entitled "Average Annual Discharge of the Euphrates River", we might take the 28,400 Mcm/yr discharge at Hit, Iraq and add to it those portions of the above estimates which fall within the calendar range of the observations. That is, evaporation from Lake Assad is not an issue when considering al-Hadithi's[3067] average value, for the lake had not yet been formed at the time his observations were made.

Even using the 141,000 ha of irrigated land in the Syrian Euphrates basin is suspect, for there is strong evidence that most of that irrigation began no earlier than the mid-1950s. We therefore must use data covering only the time since that date or 29,800 Mcm/yr (Table EF-8). By the same token we must stretch our credulity to add an increment for Turkey of 820 Mcm/yr although for want of clearer data this will be done. (See Appendix A.)

The end result of all such speculations is:

29,800	Hit, Iraq
3100	Syria
820	Turkey
33,720	Mcm/yr.

This figure is remarkably close to that quoted by Clawson, et al[3088] from Gail A. Hathaway, Harry W. Adams and George D. Clyde, *Report on International Water Problems,* Keban Dam-Euphrates River, Report to International Bank for Reconstruction and Development (December 1965). Their discussion is given in full in Appendix A. It should be recognized that the reference given here was not consulted in arriving at the value given above.

7.7. Sedimentation and Water Quality

There remains the question of the quality of the water presently flowing, and which will flow in the future, along the length of the Euphrates River. Generally speaking, turbidity or suspended solid load increases with volume, while salinity (dissolved load of cations and anions) increases with diminishing volume. Thus, before considering these elements of water quality it is necessary to discuss the range of volume of water carried by the Euphrates between extreme flood peaks and extreme low water.

Graph V-1 shows the variation in mean monthly flow of the Euphrates at Hit, Iraq for the 49 year period 1924-25/1972-73 as recorded in Table V-1. The maximum monthly flow which occurred in May 1969 was 5460 cu m/s. The extreme monthly low water which occurred in August 1961 was 94 cu m/s. The average annual flow for the 49 year period was 902 cu m/s. Momentary peak and minimum flows do not coincide with extreme monthly and yearly averages. Table V-8 shows the momentary high and low water values for the above period of time. In 1969 an absolute momentary high value of 7390 cu m/s was reached (month unspecified), and in 1973 an extreme momentary low value of 81 cu m/s occurred. (Note that in the latter case the low monthly average was in 1961, not 1973.) Dunne and Leopold suggest that momentary discharges be used for computing the frequency of high and low water and the return probabilities of such events[3059].

Graph V-2 shows the frequency of momentary maximum high water on the Euphrates River. This graph has been prepared using al-Hadithi's data and Gumbel's technique[3059][3067]. Extrapolations from this graph should be considered approximate. Nevertheless, using this it is possible to obtain an idea of the frequency of flooding on the river assuming that the future record will remain typical of the stream's hydrological past. Thus, a flood of the magnitude of that occurring in 1969 will occur on the average every 51 years with about 98 percent of all highwater occurrances being less in volume. A maximum flow of 3525 cu m/s will occur about every two years, while maximum high water of *at least* 4600 cu m/s will take place every four years and will be exceeded in volume approximately 25 percent of the time.

Graph V-3 shows the recurrance interval of low water conditions. Minimum flows of 81 cu m/s or less will occur with a frequency of about 2 percent. On the other hand, low water conditions of 250 cu m/s or less will take place 50 percent of the time, that is about once every two years.

Very few data concerning the suspended load of the Euphrates River are available for this analysis. The river has been described traditionally as extremely turbid during high water periods. Al-Hadithi[3067] states, "The average sediment load of the Euphrates River at Hit is about 2 kg/cu m", but he does not specify how this figure was reached. He also cites an extreme load of 10 kg/cu m and a low of from .1 to .5 kg/cu m. He also indicates that Soviet engineers measured the suspended load "near Deir ez-Zor" sometime prior to 1971 and estimated the annual load as 55 million tonnes per year. Graph V-4 uses Soviet data given in al-Hadithi for the river at Deir ez-Zor. The direct relationship between the amount transported and the volume of discharge is clearly evident.

It is necessary to point out here that much of this discussion has become moot with the building of the Keban, Karakaya and Ath-Thawra (Tabqa Dams) on the river. Each of the reservoirs created by these dams now serves as a settling basin and with the addition of still more dams and reservoirs the river will become less and less turbid. Nor will early estimates of the life of reservoirs remain valid, for the addition of each new settling basin will change and lengthen the life-span of those farther downstream.

It should be noted, as shown in Map V-5 that the river in Syria is incised within the north Syrian upland and has a rather narrow flood-plain bordered by bluffs and upland surfaces some 60-80 meters higher than the river. The effect there is three-fold. First, the easily irrigated land reached by pumping directly from the river is restricted to the flood-plain. Second, the water table beneath flood-plain soil is near the surface with consequent problems of drainage and salination. Third, as reservoirs are put in place along the river in Syria much of the land formerly cultivated by means of small-scale, pumped irrigation will be flooded and new soils at higher elevations must be utilized.

The outcome of the impounding of the river may be somewhat similar to the problems encountered along the Nile. Less suspended load will increase the velocity of the water in the mainstream with subsequent undercutting of manmade emplacements downstream and the reshaping of the channel in unpredictable ways. (In the absence of up-to-date and/or complete observations these comments must remain speculative.)

Water quality in terms of the dissolved load is an even more important issue than suspended solid load. Graphs V-5 and V-6 illustrate two characteristics of streams vis-a-vis dissolved load. The first relationship simply stated is: the less water in the stream the more concentrated will be the dissolved load it carries; the more water in the stream the more diluted will that load become. That this holds true for the Euphrates is further illustrated by Graph V-7 which plots average monthly water volumes (at Hit, which is assumed to be a surrogate measure of conditions at Deir ez-Zor where the salinities were measured) against total salinity measured in micromhos/cm. While the two data sets shown are separated in time and space, it is assumed that the general condition they illustrate will hold true.

Graph V-6 displays a further relationship common to streams used for multiple irrigation projects. That is, the farther downstream and the more times the water in the stream has been passed through irrigated fields the more concentrated will its various dissolved salts become. Dunne and Leopold[3059] cite the case of the Colorado River where the salinity of the river at Lee's Ferry is rising 32.8 mg/l for every 100,000 hectares of newly irriagted land. Comparison with the multiple irrigation projects along the Euphrates and its tributaries is obvious. That this holds true is also indicated by the two salinity curves shown on Graph V-7 where the salinity curve for Tabqa is consistently lower than the curve for Deir ez-Zor farther downstream.

Available values for the salinity of the Euphrates fall between 427 and 760 mmhos/cm. Diagram V-1 shows the USDA classification of irrigation waters with regard to dissolved salts. Thus, the quoted salinities (Tables V-2 and V-3) fall within the medium hazard range, with the exception of October (year unspecified) at Deir ez-Zor. The FAO report for the Jezirah[3065] states that the rivers of the Jezirah are only slightly salinized (.27 to .72 mg/l) and can be used for irrigation without difficulty. By the same token the two river samples shown in Table V-3 fall within the USDA classification of C2-S1 of medium salinity and medium sodium hazard. On the other hand, Withers and Vipond[3223] believe that such medium sodium-rich waters should be used only with coarse textured, permeable soils.

There remains the question of how dramatically increased hectarages of irrigated land with subsequent return flow to the tributaries and the mainstream of the Euphrates will effect downstream users. Maps V-6, V-7 and V-8 show the concentration and distribution of the most prevalent dissolved salts in the underground waters of the Jezirah. The general distribution of cations and anions is shown on Map V-6. Dilute bicarbonates predominate along the Turkish border. This is typical of the good quality of the Jezirah streams at their point of origin in the north. Nevertheless, greater concentrations of bicarbonates occur along the southern border of this zone. Excessive concentrations of chlorides are found in the Radd Marsh (the result of high evapotranspiration) and in the south along the Euphrates River as well as in the east along the Iraqi border where temporary seasonal accumulations of water evaporate. Sulfates predominate in areas with lower precipitation and ephemeral streams. While many wells produce water suitable for agriculture, drinking water from these sources is less available.

There is a question relating to the above FAO survey of underground waters of the Jezirah[3065]. The suggestion made in the conclusion of that report is that skillful management of pumped wells would provide the best means of farming in the Syrian Jezirah. However, little subsequent effort seems to have been made to follow that plan, and instead, the use of surface waters impounded by dams (described elsewhere in this chapter) has predominated. High salinities in a number of wells (see Table V-10) may account for this change in development priorities, but the question remains unanswered.

An early review of the problem of salinity in the Euphrates Valley of Syria estimates that more than 20,000 ha had already been taken out of production because of high salinity; that in another 20,000 ha the yield had been decreased by 50 percent; and in 60,000 more ha yield was lowered by 20 percent. This amounted to a total loss of about 70,000 tonnes of cotton per year[2710]. That this remains a problem is indicated by current reports (MEED, 4 Oct 1986)[3224] that the World Bank is considering loans to Syria to provide for a second stage Lower Syrian Euphrates drainage and irrigation scheme. First stage work, to be completed in mid-1987, has already been financed by the World Bank and entails more than 200,000 ha. Second stage work is intended to reduce salinity and create an effective irrigation network for an additional 120,000 ha of reclaimed land. From these efforts it is clear that excess salinity remains a significant problem in that area.

Turkish data referring to water quality in the GAP area have yet to become available for analysis. The original GAP prospectus[3081] devotes only a brief, non-detailed commentary to this subject. Ayyildiz, et al[3222], indicate that some drainage problems must be dealt with, particularly in the more southerly portions of the Harran Plain. They state that given a salinity measure of 400 mmhos/cm as an average value for waters in the Urfa-Harran region and an estimated irrigation need of 1148 mm in order to produce a cotton crop[12], such waters will deliver approximately three tonnes of salt per year per hectare (261 mg/l) which must be carefully leached away. This inevitably implies that such materials would be transported farther downstream.

The above brief review of water quality in the Euphrates basin assumes relatively few problems will occur for Turkish use of the water either from sedimentation or salinity. In Syria, however, problems are already occurring along the mianstream. That these will be even more serious in the future becomes evident when a sequential water budget of the combined Turkish and Syrian river system is made. Diagram V-2 depicts the elements and values in such an accounting. All data are drawn from this report and are summarized in Table V-4. What this schemata attempts to show is how demands made upon the river's water resources will vary sequentially with withdrawals (w_t, w_s) and return flows (RF_t, RF_s). Evaporation from reservoir surfaces will also take its toll (E_t, E_s). (Other symbols used in the diagram are "Alep" for the water withdrawn to provide the city of Aleppo, "Sa" for the input of the Sajur in Syria, and "E.B.P." for Euphrates Border Project.)

The results of this preliminary bookkeeping vis-a-vis the river's waters show that after the year 2000, *if all the proposed projects described in this report were to actually be put in place*, Syria would receive 11.785 km^3 (378 cu m/s annual average) from Turkey at the point where the river crosses the border. Initial withdrawals and return flows in Syria would reduce river volume just below the Tabqa Dam to a mere 3.408 km^3 (108 cu m/s annual average). Additions from the Balikh plus return flows from Turkey (originating from Lake Ataturk but brought across country to the large southeastern irrigation projects) would increase mainstream flow to 4.703 km^3 (149 cu m/s annual average). Similar inputs from the Khabur farther downstream would mean that Iraq might expect from 5.405 to as little as 4.716 km^3 (171 cu m/s to 150 cu m/s annual average).

It was assumed in making these computations that reservoirs in Turkey would reduce or eliminate extreme variation in the flow of the stream between flood peaks and drought defficiencies both on an annual and long-term basis. Nevertheless, severe diminution of flow would result from human activities, and all return flows would be heavily salinized. Thus, it can be reasonably predicted that the water entering Iraq under such conditions would be of little or no use save for flushing the main channel of the stream.

7.8 Conclusion

"Total Depletions to the Iraqi Border" concludes Table V-4. Given the caveats expressed throughout this analysis the picture revealed is a sobering one. Table V-7 and Graph V-8 illustrate the increasing strain on water resources which Iraq must inevitably feel if all the Turkish and Syrian projects were to be realized.

It will be noted that the amount of water received by Iraq varies from 5404.8 Mcm in Diagram V-5 to 4960 Mcm in Graph V-8. This difference stems from a more exact accounting for return flow in the former case. It also should be kept in mind that "natural flow" and actual river conditions seldom coincide. Moreover, year to year fluctuations such as those discussed in sections 2, 3 and 7.7 of this study further complicate matters, especially if they coincide with reservoir filliing, or conversely, include exceptionally large flood stages. Nevertheless, the general pattern of steadily impending crisis is clear.

Endnotes

9. In the same interview cited above Ozenci also is cited as saying that "...it was hoped the year-long process of filling the lake (i.e, Ataturk Reservoir) would start in late 1988." (TDN, 2 Oct. 1986[1821], p. 3.) It is to be hoped that more than one year will be used in reality for this task.

10. A complete discussion of this question and related matters is found in: U.S. Dept. of Agriculture *Irrigation Water Requirements*[3066], p. 88.

11. This would be consistent with observations made in southwestern Turkey by this author. (See Kolars: *On-farm Water Management in Aegean Turkey*[3061].)

12. This is apparently based on PE values rather than on the water deficit shown by a computed water balance, which would be less. (See Table N-3, p. 56.)

Table V-1

KEBAN RESERVOIR - RECHARGE RATES
Top Capacity = 30,500 Mcm

Month	Ave. Flow (Thousands of Mcm)	Recharge of Reservoir in Thousands of Mcm - Running Total / Beginning Date of Recharge: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	.774	.77	-	-	-	-	-	-	-	-	-	-	-
Feb	.890	1.66	.89	-	-	-	-	-	-	-	-	-	-
Mar	1.900	3.56	2.79	1.90	-	-	-	-	-	-	-	-	-
Apr	5.127	8.69	7.92	7.03	5.13	-	-	-	-	-	-	-	-
May	4.802	13.49	12.72	11.83	9.93	4.80	-	-	-	-	-	-	-
Jun	2.053	15.55	14.77	13.88	11.98	6.86	2.05	-	-	-	-	-	-
Jul	.970	16.52	15.74	14.85	12.95	7.83	3.02	.97	-	-	-	-	-
Aug	.659	17.18	16.40	15.51	13.61	8.48	3.68	1.63	.66	-	-	-	-
Sep	.562	17.74	16.96	16.07	14.17	9.05	4.24	2.19	1.22	.56	-	-	-
Oct	.667	18.40	17.63	16.74	14.84	9.71	4.91	2.86	1.89	1.23	.67	-	-
Nov	.783	19.19	18.41	17.52	15.62	10.50	5.69	3.64	2.67	2.01	1.45	.78	-
Dec	.812	20.00	19.23	18.33	16.44	11.31	6.51	4.45	3.48	2.82	2.26	1.60	.81
Jan	.774	20.77	20.00	19.11	17.21	12.08	7.28	5.23	4.26	3.60	3.04	2.37	1.59
Feb	.890	21.66	20.89	20.00	18.10	12.97	8.17	6.12	5.15	4.49	3.93	3.26	2.48
Mar	1.900	23.56	22.79	21.90	20.00	14.87	10.07	8.02	7.05	6.39	5.83	5.16	4.38
Apr	5.127	28.69	27.92	27.03	25.13	20.00	15.20	13.14	12.17	11.52	10.95	10.29	9.50
May	4.802	33.49	32.72	31.83	29.93	24.80	20.00	17.95	16.99	16.32	15.76	15.09	14.31
Jun	2.053	-	-	-	31.98	26.85	22.05	20.00	19.03	18.37	17.81	17.14	16.36
Jul	.970	-	-	-	-	27.82	23.02	20.97	20.00	19.34	18.78	18.11	17.33
Aug	.659	-	-	-	-	28.48	23.68	21.63	20.66	20.00	19.44	18.77	17.99
Sep	.562	-	-	-	-	29.05	24.24	22.19	21.22	20.56	20.00	19.33	18.55
Oct	.667	-	-	-	-	29.71	24.91	22.86	21.89	21.23	20.67	20.00	19.22
Nov	.783	-	-	-	-	30.50	25.69	23.64	22.67	22.01	21.45	20.78	20.00
Dec	.812	-	-	-	-	-	26.51	24.45	23.48	22.82	22.26	21.59	20.81
Jan	.774	-	-	-	-	-	27.28	25.23	24.26	23.60	23.04	22.34	21.59
Feb	.890	-	-	-	-	-	28.17	26.12	25.15	24.49	23.93	23.26	22.48
Mar	1.900	-	-	-	-	-	30.07	28.02	27.05	26.39	25.83	25.16	24.38
Apr	5.127	-	-	-	-	-	35.20	33.14	32.17	31.51	30.95	30.29	29.50
May	4.802	-	-	-	-	-	-	-	-	-	-	35.09	34.30

Source: al-Hadithi[3067].

Table V-2

KEBAN RESERVOIR AVERAGE EVAPORATION
AVE. INFLOW

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Inflow Ave. (in Mcm)	774	890	1900	5127	4802	2053	970	659	562	667	783	812	19,999
Evap. Ave. (mm)	15.5	8.1	56.5	96.6	159.8	215.6	290.6	284.8	174.4	113.3	48.8	21.1	1484.6

EVAPORATION BY AREA AND BY MONTH
(In Mcm)

Elev. (m)	Area (km^2)	Vol.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
FULL SUPPLY															
845	675	30,500	10.4	5.5	38.1	65.2	107.9	145.5	196.2	192.2	117.7	76.5	32.9	14.2	1002.4
840	620	27,000	9.6	5.0	35.0	59.9	99.1	133.7	180.1	176.5	108.1	70.3	30.2	13.1	920.6
NORMAL LEVEL															
835	570	24,200	8.8	4.6	32.2	55.1	91.1	122.9	165.6	162.3	99.4	64.6	27.8	12.0	846.4
830	525	21,700	8.1	4.3	29.7	50.7	83.9	113.2	152.6	149.5	91.6	59.5	25.6	11.1	
825	480	19,200	7.4	3.9	27.1	46.4	76.7	103.5	139.5	136.7	83.7	54.4	23.4	10.1	
818	430	16,000	6.7	3.5	24.3	41.6	68.7	92.7	125.0	122.4	75.0	48.7	21.0	9.1	
815	385	14,600	6.0	3.1	21.8	37.2	61.5	83.0	111.9	109.7	67.1	43.6	18.8	8.1	
805	300	11,000	4.7	2.4	17.0	29.0	47.9	64.7	87.2	85.4	52.3	34.0	14.6	6.3	
MIN. OPERATING LEVEL															
800	260	9500	4.0	2.1	15.4	25.1	41.5	56.0	75.5	74.0	45.3	29.5	12.7	5.5	386.7
794	225	8000	3.5	1.8	12.7	21.7	36.0	48.5	65.4	64.1	39.2	25.5	11.0	4.8	
784	180	6000	2.8	1.5	10.2	17.4	28.8	38.8	52.3	51.3	31.4	20.4	8.8	3.8	
777	160	5000	2.5	1.3	9.0	15.5	25.6	34.5	46.5	45.6	27.9	18.1	7.8	3.4	
772	140	4000	2.2	1.1	7.9	13.5	22.4	30.2	40.7	39.9	24.4	15.9	6.8	3.0	
760	107	2800	1.7	0.9	6.1	10.3	17.1	23.1	31.1	30.5	18.7	12.1	5.2	2.3	
753	90	2000	1.4	0.7	5.1	8.7	14.4	19.4	26.2	25.6	15.7	10.2	4.4	1.9	
746	75	1500	1.2	0.6	4.3	7.3	12.0	16.2	21.9	21.4	13.1	8.5	2.6	1.6	110.7
738	55	1000	0.9	0.5	3.1	5.3	8.8	11.9	16.0	15.7	9.6	6.2	2.4	1.2	
734	45	800	0.7	0.4	2.5	4.4	7.2	9.7	13.1	12.8	7.9	5.0	2.2	1.0	
720	20	300	0.3	0.2	1.1	1.9	3.2	4.3	5.8	5.7	3.5	2.3	1.0	0.4	
700	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Source: Based on al-Hadithi[3067] - Tables 8,9,13 (but a 365 day year).

Table V-3

VARIATIONS IN ESTIMATED WATER USE, LOSS, AND DEPLETION AS A FUNCTION OF VALUES CHOSEN

Assumed Need	Amount Withdrawn	RF	=	Return Flow	Nonproductive Loss	Comments
10	(2.5)	(0.35)	=	8.75	6.25	selected for this study
	depletion		=	16.25		
10	(2.5)	(0.30)	=	7.50	7.50	
	depletion		=	17.50		
10	(2.5)	(0.25)	=	6.25	8.75	most pessimistic
	depletion		=	18.75		
10	(2.0)	(0.35)	=	7.00	3.00	most optimistic
	depletion			13.00		
10	(2.0)	(0.30)	=	6.00	4.00	
	depletion			14.00		
10	(2.0)	(0.25)	=	5.00	5.00	
	depletion		=	15.00		

	Selected Value	Most Pessimistic	Most Optimistic
Nonproductive Loss	6.25	8.75	3.00
% Change	0.0	+40%	-52%
Return Flow	8.75	6.25	7.00
% Change	0.0	-28%	-20%

Table V-4

OFFICIALLY ANTICIPATED OR ENACTED DAMS, RESERVOIRS, AND IRRIGATION ON THE EUPHRATES RIVER
1986 TO POST 2000
Part I: Headwaters to the Syrian Border

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Tercan (Tuzla)	op (178)	8.85 (1.2) est.	10.62	32,000 (6642) est.**	212.544	114.5*	223.16				(DHPPT/Newspot)
Kalecik (Kalecik)	op (12.5)	1.16 (1.2) est.	1.39	1300 (6642) est.	9.635	4.7	11.00				(DHPPT)
Cip (Cip)	op (7.0)	1.10 (1.2) est.	1.32	800 (6642) est.	5.31	2.9	6.63				(DHPPT)
Gayt (Gayt)	UC (23)	2.92 (1.2) est.	3.50	3200 (6642) est.	21.25	11.5		24.75			(DHPPT)
Mercan-HEPP	FDC			---	---	---					(DHPPT)
Girlevik-HEPP	op			---	---	---					(DHPPT)
Hazar I-HEPP	op			---	---	---					(DHPPT)

* RF = 3577/ha

** See Table N-4, p. 57, est. values based on Siverek value.

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Hazar II-HEPP	op			---	---	---					(DHPPT)
Sekerova (Badisan)	UFD (90.2)	3.81 (1.2) est.	4.57	15,938 (6642) est.	105.86	57.0*			110.4		(DHPPT)
Patnos (Gevi)	UFD (33.4)	4.65 (1.2) est.	5.58	4993 (6642) est.	33.16	17.6			38.7		(DHPPT)
Ozluce-HEPP (Peri Suyu)	op (1075)	6.2 (1.2) est.	31.44	---	---	---	31.4				(DHPPT)
Keban-HEPP (Euph.)	op (30,600)	675.0 (1.46) Al-H.	985.5	---	---	---	985.5				(DHPPT/GAP)
Mursal (Hikme)	UFD (17.6)	62 (1.46) est.	2.37	1665 (8081) est.	13.45	7.24**			15.82		(DHPPT)
Medik (Tohma)	op (22.0)	1.62 (1.46) est.	2.37	15,800 (8081) est.	127.7	68.7		130.1			(DHPPT)
Yazihan (Tohma)	UC ?	?		9500 (8081) est.	76.77	41.3		76.8[t]			(TSI-1980)

* RF = 3577/ha
** RF = 4351/ha

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Sultan Suyu (Sultan Suyu)	UFD (53.3)	2.6 (1.46) est.	3.80	14,963 (8081) est.	120.9	65.1					(DHPPT)
Kermek-HEPP (Tohma?)	op			---	---	---					(DHPPT)
Tohma-HEPP (Tohma)	op			---	---	---					(DHPPT)
Karakaya-HEPP (Euph.)	Filling June '86 (9580)	298.0 (1.46) Al-H.	435.1	---	---	---	435.1				(DHPPT/MEED)
Cat (Abdulharap)	op (240)	14.3 (1.6) est.	22.88	22,091 (8856)	195.64	105.4	218.5				(DHPPT/TDN)
Adiyaman/Kahta											
Adiyaman (Kahta)	UC? (617)	?		80,000 (8856)	708.48	381.5		708.5[t]			(GAP)
Kahta (Kahta)	UC? (1887)	?		80,000 (8856)	708.48	381.5		708.5[t]			(GAP)
Cankara (Goksu)				38,420 (8856)	340.25	183.2		340.3[t]			(GAP)

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Lower Euphrates Project											
Ataturk (Euph.)	UC (48,700)	817.0 (1.80) Al-H.	1470.6	see below	---	---		1407.6			(GAP)
Urfa/Harran	UC	---	---	157,000 (10,754)	1688.4	909.2		1688.4			(GAP pp. V-8/14 for all Lower Euphrates Project)
Tektek Plateau	UFD	---	---	20,000 (10,754)	215.1	188.2			215.1		
Lower Mardin-Ceylanpinar	UC	---	---	140,000 (11,489)	1608.5	866.0			1608.5		
Derik-Mardin	UC			192,100 (11,229)	2157.1	1161.4		2157.1			
Derik	(345)	?									
Mardin	(335)	?									
Nusaybin-Cizre	UFD	?		47,000 (11,229)	527.8	284.2			527.8[t]		

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr				Data Source
							1986-90	1990-95	1995-2000	2000+	
Siverek-Hilvan* (16 small dams and reservoirs)	UFD (407.3)	42.52 (1.6) est.	68.03	164,300 (8856)	1455.0	783.5				1523.0	
Hacihidir	op (67.6)	4.40 (1.6) est.	7.04	3400 (8856)	30.1	16.2	37.14				(TDN/GAP)
Dumluca	op (22.06)	2.23 (1.6) est.	3.57	2400 (8856)	21.3	11.4	24.87				(TDN 8/30/84)
Bozova (pumped from Ataturk Res.)	---	---	---	55,300 (10,754)	594.7	320.2				594.7	
Suruc-Baziki (Yaylak) (pumped in large part from Ataturk Res.)	UFD										
Baziki	---	---	---	44,900 (10,754)	482.9	260.0				482.9	
Suruc Tozluca	UFD (12.35)	?		101,600 (10,754)	1092.6	588.3				1092.6	
Aylan	UFD (6.95)	?									
Tasbasan	UFD (7.68)	?									

* Of this, 147,000 ha drains to Euphrates; 17,300 ha to Khabur

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Euphrates Border Project	FDC										
Birecik-HEPP	FDC (1220)	56.25 (2.0) est.	112.5	See Araban and Gaziantep Projects						112.5	
Karkamis-HEPP	FDC (157)	28.4 (2.0) est.	56.8	---	---	---				56.8	
Araban (Karasu)	FDC	?		1610 (10,562)	17.0	9.16		17.0			
	---	(pumped from Birecik Res.)		21,738 (10,562)	229.6	123.6		229.6			

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km² (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Gaziantep	(pumped from Birecik Res.)			51,789 est. (10,562)	547.0	294.6				547.0	
Hancagiz (Nizip)	FDC (31.72)	7.5 (2.0)	15	10,736 (10,562)	113.4	66.1		128.4			
Kayacik (Tuzel Suyu that flows into the Sajir)	FDC	?		15,700 est. (10,562)	165.8	89.3		165.8			
Kemlim (Balik which becomes the Queiq/Kweik in Syria but is outside the Euphrates drainage)	FDC (31.72)	?		10,736 est. (10,562)	113.4			113.4[t,x]			

Table V-4 Continued

TOTALS FOR TURKEY

(Does not include values for reservoir areas and irrigation projects the sizes of which are not available.)

Total ha Irrigated Potential	Return Flow Mcm	Total Estimated Water Depletion* Mcm/yr 1986-90	1990-95	1995-2000	2000+
1,350,243	7408	1972.33	7782.85	2516.32	4409.50
	(post 2000)		9755.18		
				12,271.50	
					16,681.00

* Does not include losses from pumping of groundwater and aquifers in Lower Euphrates Project.
t Partial value.
x Not included in totals.

op = operational.
UC = under construction.
UFD = under final design.
FDC = final design completed.
DHPPT = Dams and Hydroelectric Power Plants in Turkey, Ministry of Energy and Natural Resources, 1980[0644].
TDN = Turkish Daily News.
MEED = Middle East Economic Digest.
GAP = Southeast Anatolia Project Report, 1980[3081].

Table V-4 Continued

OFFICIALLY ANTICIPATED OR ENACTED DAMS, RESERVOIRS, AND IRRIGATION ON THE EUPHRATES RIVER
1986 TO POST 2000
Part II: Turkish Border to the Iraqi Border

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
? (Sajur)	? (2)	?		?		?					(USAID 1980)
Tishreen Dam (Euph.)	planning (1300)	70 est. (2.25) est.	157.5	?		?		157.5^{t}			(MEED 8/9/80)
Aleppo Diversion	op	---	80.2	---	---	---	80.2				
Lake Assad (Euph.) (Tabqa Dam)	op (11,700)	628 (2.5)	1570.0	---	---	---	1570.0				(Al-H. Table 13)
Maskanah-Aleppo #6 (Euph.)	UC	---	---	150,000 (12,545) est.	1882	1013			1882		
Rasafah #4	------------------------------			abandoned	-----------------------						
Balikh #1 (Balikh)	UC	---	---	185,000 (10,754) est.	1989.5	1071			1989.5		

Table V-4 Continued

In Operation Ca 1986-1990

Project Name (River Name)	Status (Vol. in Mcm)	Res. Area km^2 (Evap. Rate m/yr)	Water depletion per yr in Mcm	Irrig. Area ha (depletion rate in cu m/ha/yr)	Ave. Water depletion per yr in Mcm	Return Flow in Mcm	Projected Evaporation From Reservoir and Loss From Fields Mcm/yr 1986-90	1990-95	1995-2000	2000+	Data Source
Lower Valley #2 (Euph.)	UC	---	---	165,000 (16,835)	2777.8	1496			2777.8		
Baath Dam (Euph.)	OP ?			Unclear -- but could serve Lower Khabur or Mayadin Plain							
Upper Khabur (Khabur & tribs.)	UC (irrig. from Ras Al-Ayn)	---	---	42,000 (11,489)	483	260	483				(see Table I-1)
W. Al-Hasakah	UC (91)	.00102 (2.3) est.		49,450	1203	648		1203			
E. Al-Hasakah	UC (232)	.00310 (2.3) est.		combined (12,545)							(see Table I-1)
Al-Khabur	UC (665)	.00958 (2.3) est.		46,450 (12,545)	combined	combined		combined			
Lower Khabur #3 (Khabur/Euph.)	FDC	---	---	75,000 (16,835)	1262.6	679			1262.6		(see Table I-1)
Mayadin Plain #5 (Euph.)	FDC	---	---	40,000 (16,835) est.	673.4	363			673.4		(see Table I-1)

Table V-4 Continued

TOTALS FOR SYRIA

Total ha Irrigated Potential	Ave. Water Depletion per yr in Mcm	Return Flow Mcm	Total Estimated Water Depletion Mcm/yr 1986-90	1990-95	1995-2000	2000+
752,900 (Planned)		5530 (Planned)	2133.2	1360.5	8585.3	
				3493.7		
482,900 (Estimate*)	7486 (Estimate*)	4035 (Estimate*)			12,079.0	
Cumulative Totals for Turkey			1972.3	9755.2	12,271.5	16,681.0
TOTAL DEPLETIONS TO IRAQI BORDER			4105.5	13,248.9	24,350.5	28,760.0

* See text, Irrigation in Syria, p. 66.

t Partial value.

op = operational.
UC = under construction.
UFD = under final design.
FDC = final design completed.
MEED = Middle East Economic Digest.
Al-H. = al-Hadithi[3067].
USAID = USAID[3045-3049].

Table V-5

DISTRIBUTION OF IRRIGATED AREAS OF THE LOWER EUPHRATES PROJECT BY RIVER INTO WHICH RETURN FLOW DRAINS

To Mainstream and Lake Ataturk

Cat	22,091 hectares
Adiyaman/Kahta	160,000 hectares
Cankara	38,420 hectares
Hacihidir	3,400 hectares
Siverek-Hilvan	147,000 hectares
	370,911 (32.3%)

To Balikh in Syria (and thence to the Euphrates)

Urfa-Harran	157,000 hectares
Tektek	20,000 hectares
Bozova	55,300 hectares
Baziki (Yaylak)	44,900 hectares
Suruc	101,600 hectares
	378,800 (33%)

To Khabur (via Khabur, Jagh Jagh, and other tributaries to the Euphrates

Lower Mardin-Ceylanpinar	140,000 hectares
Derik-Mardin	192,100 hectares
Nusaybin-Cizre	47,000 hectares
Dumluca	2,400 hectares
Siverek-Hilvan	17,300 hectares
	398,800 (34.7%)

To Syria (Balikh and Khabur combined)

777,600 hectares (67.7%)

Total (Turkey and Syria)

1,148,511 (100%)

Table V-6

EXISTING IRRIGATED LAND IN THE GAP AREA CA. 1980
(see also: Table 52, Mitchell, p. 93)

Stream/Reservoir Fed

Name	Stream	Euphrates Hectares	Khabur Hectares	Comments
Hacikamil (Siverek)	Cam	470	...	enters mainstream
Nusaybin	Cagcag	...	7,820	enters Khabur in Syria
Ceylanpinar (State Production Farm -- D.U.C.)	Habur	...	6,700	enters Khabur in Syria
	(Small reservoirs)	...	2,186	enters Khabur in Syria
Stream Total		470	16,706	

Pumped from aquifers

Name	Estimated reserve		year begun	Comments
Suruc	(Estimated reserve 47 Mcm/yr)	6,900	(1956)	enters Balikh in Syria
Harran	(Estimated reserve 190 Mcm/yr)	15,203	(1974)	enters Balikh in Syria
Akcakale Soil and Agriculture Reform Project (TTRM)				
subtotal		22,103	(Balikh sytem)	
Ceylanpinar	(Estimated reserve 852 Mcm/yr)	8,850	(1957)	enters Khabur in Syria
State Production Farm -- D.U.C.				
Iki Circiparasi (TTRM)		10,000	(1968-80)	enters Khabur in Syria
Mardin-Kiziltepe	(Estimated reserve 13 Mcm/yr)	180	(1956)	
subtotal		19,030	(Khabur system)	
Pumped Total		41,133		

Total Estimated Water Depletion (i.e. use plus loss)

Mainstream	#ha	Depletion/ha (see: Table N-4)	Total Depletion m^3	Return Flow m^3
	470	8,856	4,162,320	2,241,313
Khabur	35,736	10,754	384,305,000	244,293,000
Balikh	22,103	10,754	237,695,000	151,097,000
Balikh/Khabur	57,839	...	622,000,000	395,390,000
All Euphrates	58,309	...	626,162,000	397,631,000

Source: GAP 1980, pp. II-4/II-7.
See this text for source of computations.

Table V-7

IRAQ'S PROJECTED SHARE OF EUPHRATES WATER: 1986 - 2000+
In Mcm

	1986-1990	1990-1995	1995-2000	2000+
Estimated "Natural Flow" entering Iraq	33,730	33,730	33,730	33,730
Combined Turkish and Syrian Use of Water	4,106	13,249	24,351	28,760
Share Remaining for Iraq	29,614	20,471	9,369	4,960

Table V-8

PART I -- PEAK RECORDED FLOWS AT HIT, IRAQ
(1924-1973)

Year	Peak Flow cu m/s	m	$T=\frac{n+1}{m}$	Year	Peak Flow cu m/s	m	$T=\frac{n+1}{m}$
1969	7390	1	51.00	1964	3548	26	1.96
1968	6654	2	25.50	1936	3450	27	1.89
1967	6072	3	17.00	1965	3422	28	1.82
1929	4980	4	12.75	1926	3320	29	1.76
1963	4816	5	10.20	1937	3320	30	1.70
1972	4810	6	8.50	1928	3240	31	1.65
1954	4730	7	7.29	1935	3200	32	1.59
1948	4670	8	6.38	1949	2950	33	1.55
1940	4660	9	5.67	1947	2900	34	1.50
1952	4610	10	5.10	1959	2770	35	1.46
1953	4540	11	4.64	1955	2600	36	1.42
1944	4530	12	4.25	1970	2550	37	1.38
1938	4500	13	3.92	1945	2510	38	1.34
1966	4484	14	3.64	1958	2480	39	1.31
1971	4435	15	3.40	1951	2470	40	1.28
1956	4430	16	3.19	1962	2224	41	1.24
1957	4420	17	3.50	1933	2170	42	1.21
1941	4220	18	2.83	1924	2120	43	1.19
1960	4080	19	2.68	1973	2055	44	1.16
1942	4040	20	2.55	1927	1850	45	1.13
1943	3900	21	2.43	1925	1750	46	1.11
1939	3850	22	2.32	1961	1732	47	1.09
1946	3750	23	2.22	1934	1730	48	1.06
1950	3690	24	2.13	1932	1630	49	1.04
1931	3630	25	2.04	1930	850	50	1.02

Source: al-Hadithi[3067], Table E-2, p. 228 & Table E-5, p. 236.

N.B. Peak and minimum momentary flows do not coincide with peak and minimum monthly and/or yearly averages at all times. Nevertheless, Dunne and Leopold[3059], suggest that momentary discharges be used for these computations.

Table V-8 continued

PART II -- MINIMUM RECORDED FLOWS AT HIT, IRAQ
(1925-1973)

Year	Minimum Flow cu m/s	m	$T=\frac{n+1}{m}$	Year	Minimum Flow cu m/s	m	$T=\frac{n+1}{m}$
1973	81	1	50.00	1960	253	26	1.92
1961	94	2	25.00	1947	261	27	1.85
1970	150	3	16.70	1950	264	28	1.79
1962	153	4	12.50	1956	269	29	1.72
1964	162	5	10.00	1949	273	30	1.67
1925	177	6	8.30	1937	275	31	1.61
1959	194	7	7.10	1952	281	32	1.56
1958	196	8	6.30	1948	281	33	1.52
1927	196	9	5.60	1945	290	34	1.47
1930	201	10	5.00	1938	291	35	1.43
1928	208	11	4.60	1929	298	36	1.39
1934	209	12	4.20	1941	303	37	1.35
1932	213	13	3.90	1946	304	38	1.32
1933	215	14	3.60	1966	304	39	1.28
1965	218	15	3.30	1953	308	40	1.25
1972	224	16	3.10	1943	309	41	1.22
1951	226	17	2.90	1944	330	42	1.19
1926	228	18	2.80	1936	331	43	1.16
1955	228	19	2.60	1954	336	44	1.14
1935	236	20	2.50	1940	343	45	1.11
1942	238	21	2.40	1939	359	46	1.09
1957	238	22	2.30	1969	404	47	1.05
1931	240	23	2.20	1967	408	48	1.04
1963	248	24	2.10	1968	453	49	1.02
1971	251	25	2.00				

Source: al-Hadithi[3067], Table E-2, p. 228 & Table E-5, p. 236.

N.B. Peak and minimum momentary flows do not coincide with peak and minimum monthly and/or yearly averages at all times. Nevertheless, Dunne and Leopold[3059], suggest that momentary discharges be used for these computations.

Table V-9

SALINITY AT TWO DIFFERENT LOCATIONS ON THE EUPHRATES RIVER*
(micromhos/cm)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Tabqa	550	530	475	420	420	430	480	505	525	565	615	450	497
Deir ez-Zor	660	610	600	455	560	480	625	725	735	760	700	480	616

Source: Raslan and Fardawi[2710], p. 216.

* Number of years unspecified; probably a one year sample.

Table V-10

COMPOSITION AND CONCENTRATION OF SALINITY IN THE SYRIAN JEZIRAH

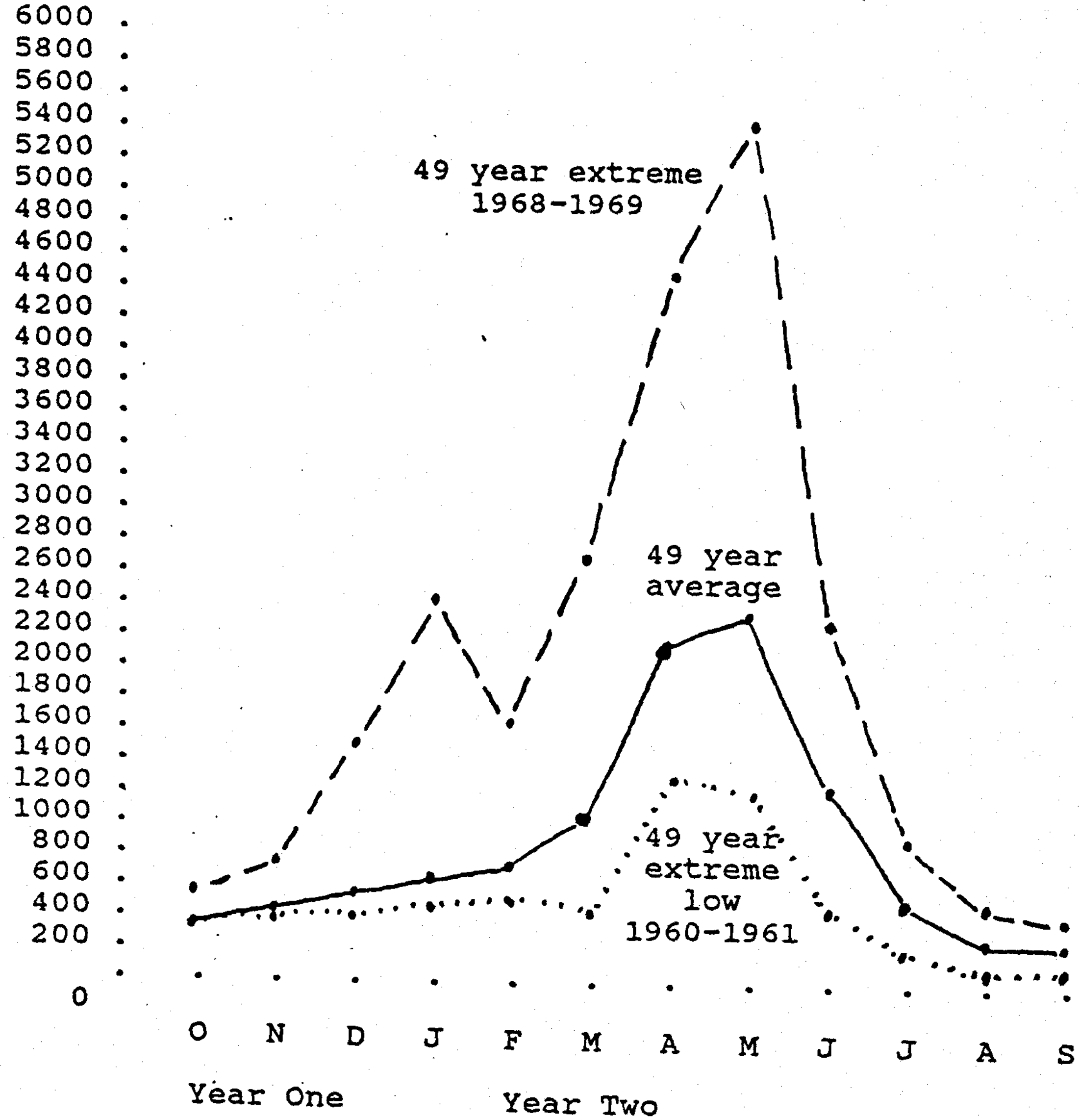
Sample*	EC x 10^3 mmhos/cm	pH	Ca	Mg	K	Na	NH_4	CO_3	HCO_3	Cl_4	SO_4	NO_3	SAR	Class†
Euphrates	0.484	7.3	2.90	1.53	0.33	1.87	0.11	---	3.72	0.24	0.63	0.06	1.25	C2-S1
Euphrates	0.427	7.4	0.88	1.72	0.13	2.48	0.11	0.17	2.60	0.92	1.08	0.02	2.07	C2-S1
Well	1.420	7.4	7.80	3.36	0.18	5.65	0.06	0.33	3.64	6.53	3.37	0.02	2.40	C3-S1
Well	12.100	7.1	24.20	58.60	1.03	78.26	0.11	0.25	2.44	62.10	83.20	11.60	12.20	C4-S2
Well	27.923	7.4	18.00	179.20	1.03	230.40	0.33	0.83	8.06	173.80	244.70	0.02	23.20	C4-S3

SAR = Sodium Absorption Ratio
* Sample locations unspecified except as shown.
† See Diagram V-8.

Source: Raslan and Fardawi[2710], p. 217.

Graph V-1

VARIATION IN MEAN MONTHLY FLOW OF THE EUPHRATES AT HIT, IRAQ
(in cubic meters per second)

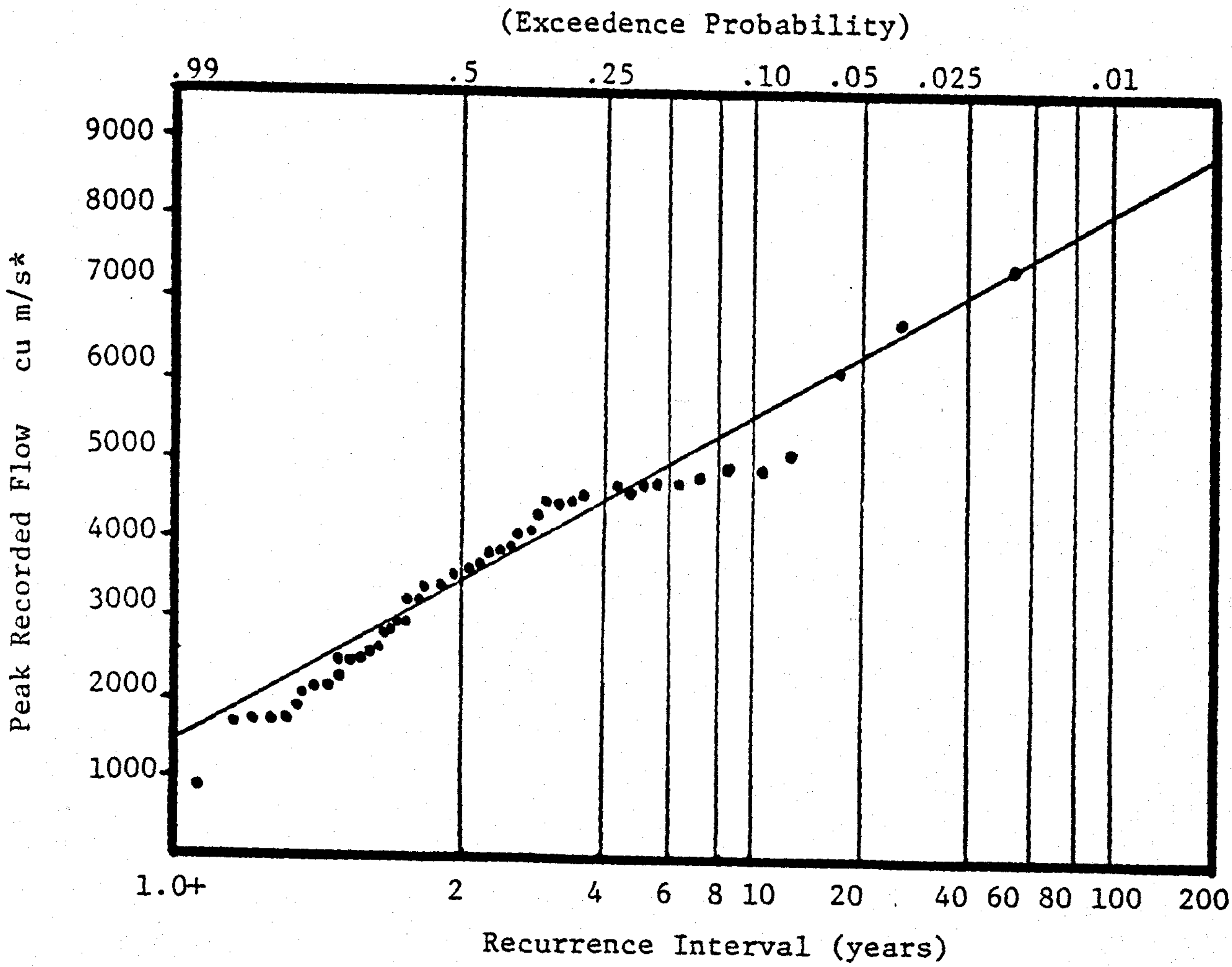


Source: al-Hadithi[3067], Table 1, pp. 225-227. Computations by Kolars.

Graph V-2: Euphrates River at Hit, Iraq

1924-1973

Flood-frequency Curve   Arithmetic Gumbel Type I



Source: al-Hadithi(3067), pp. 228-231; Dunne and Leopold(3059), pp. 305-309.

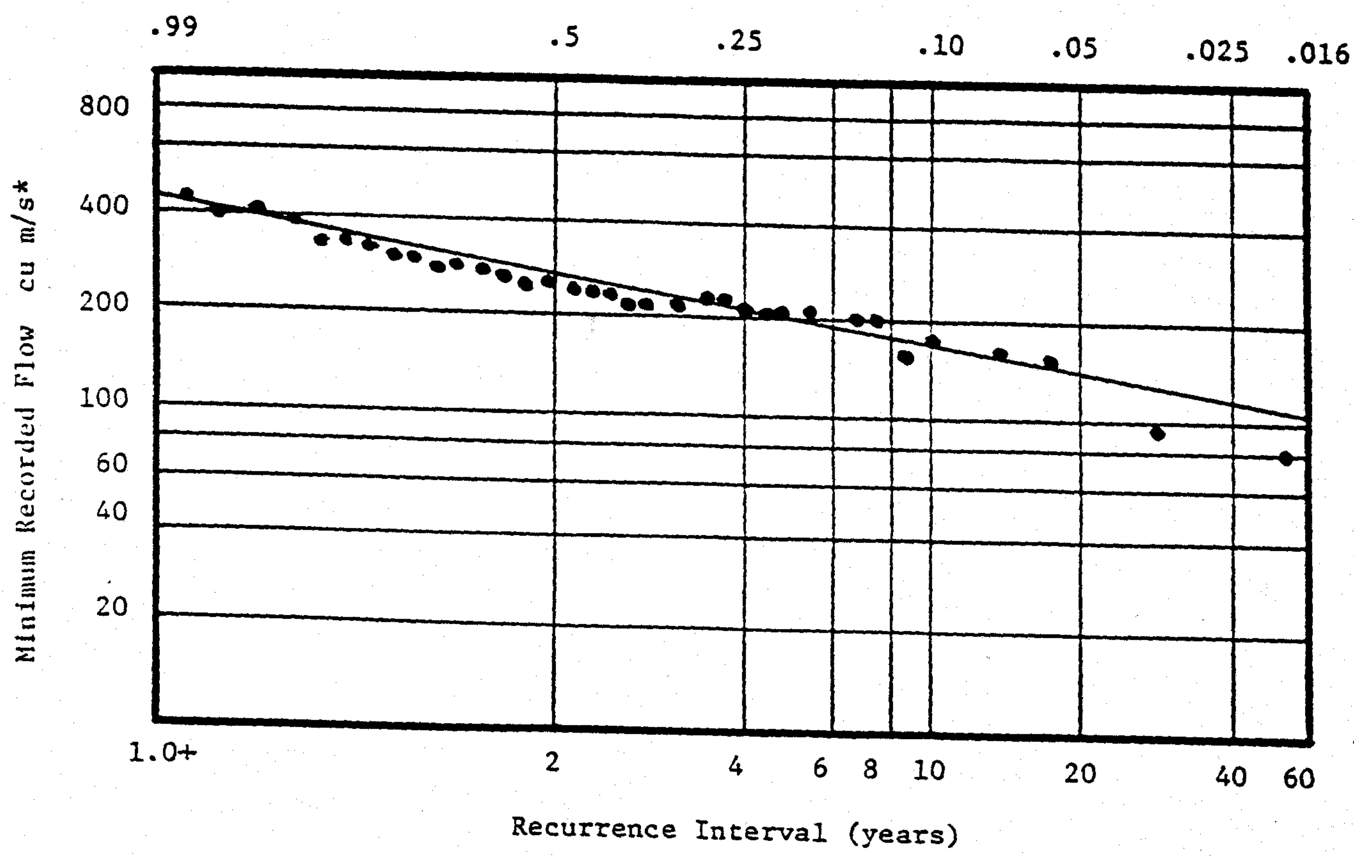
*Some observations not plotted to avoid crowding.

Graph V-3: Euphrates River at Hit, Iraq

1925 - 1973

Low-water Frequency Curve

(Exceedence Probability)

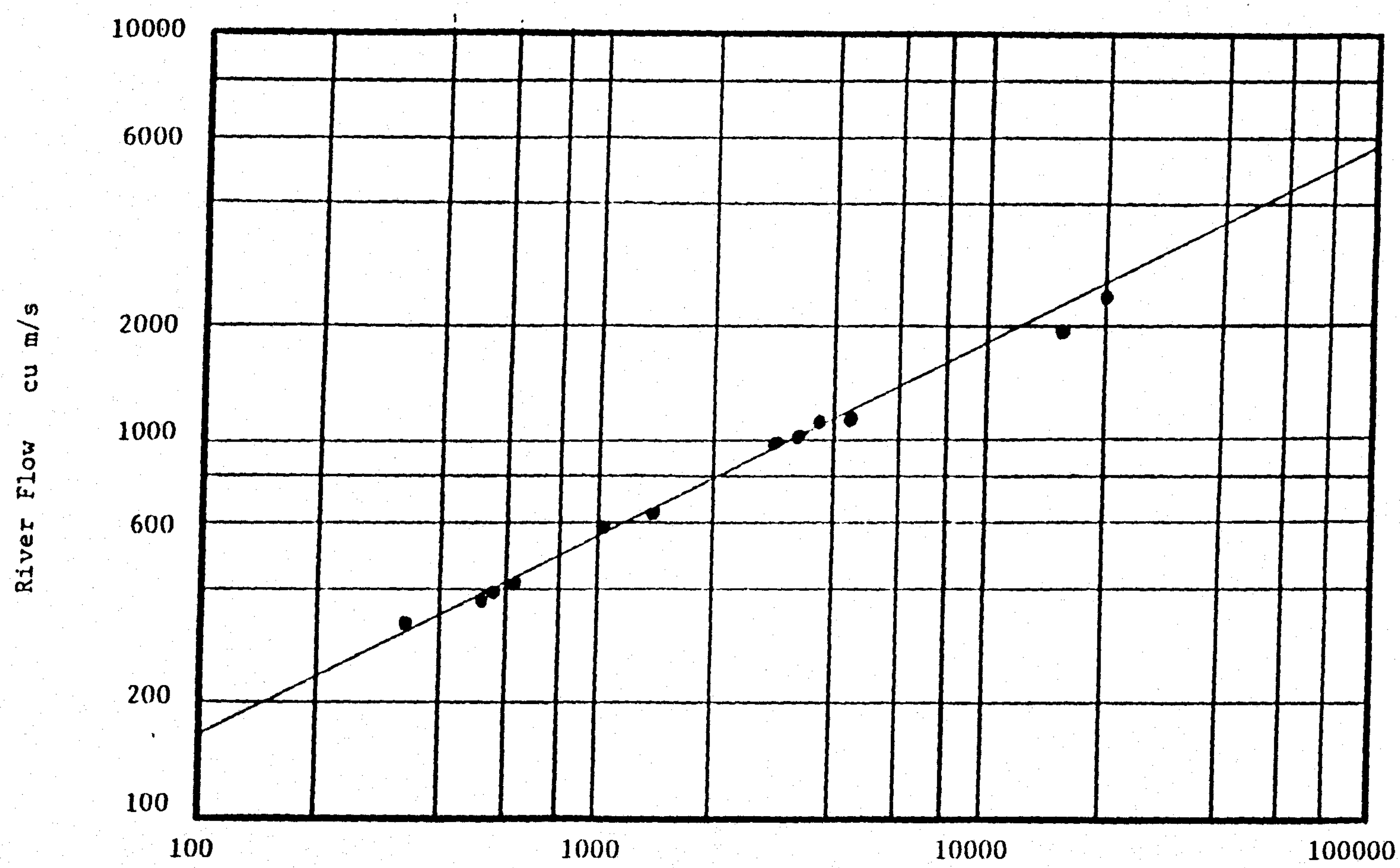


Source: al-Hadithi(3067), pp. 236-37.

*Some observations not plotted to avoid crowding.

Graph V-4: Euphrates River Sediment Discharge at Deir ez-Zor, Syria

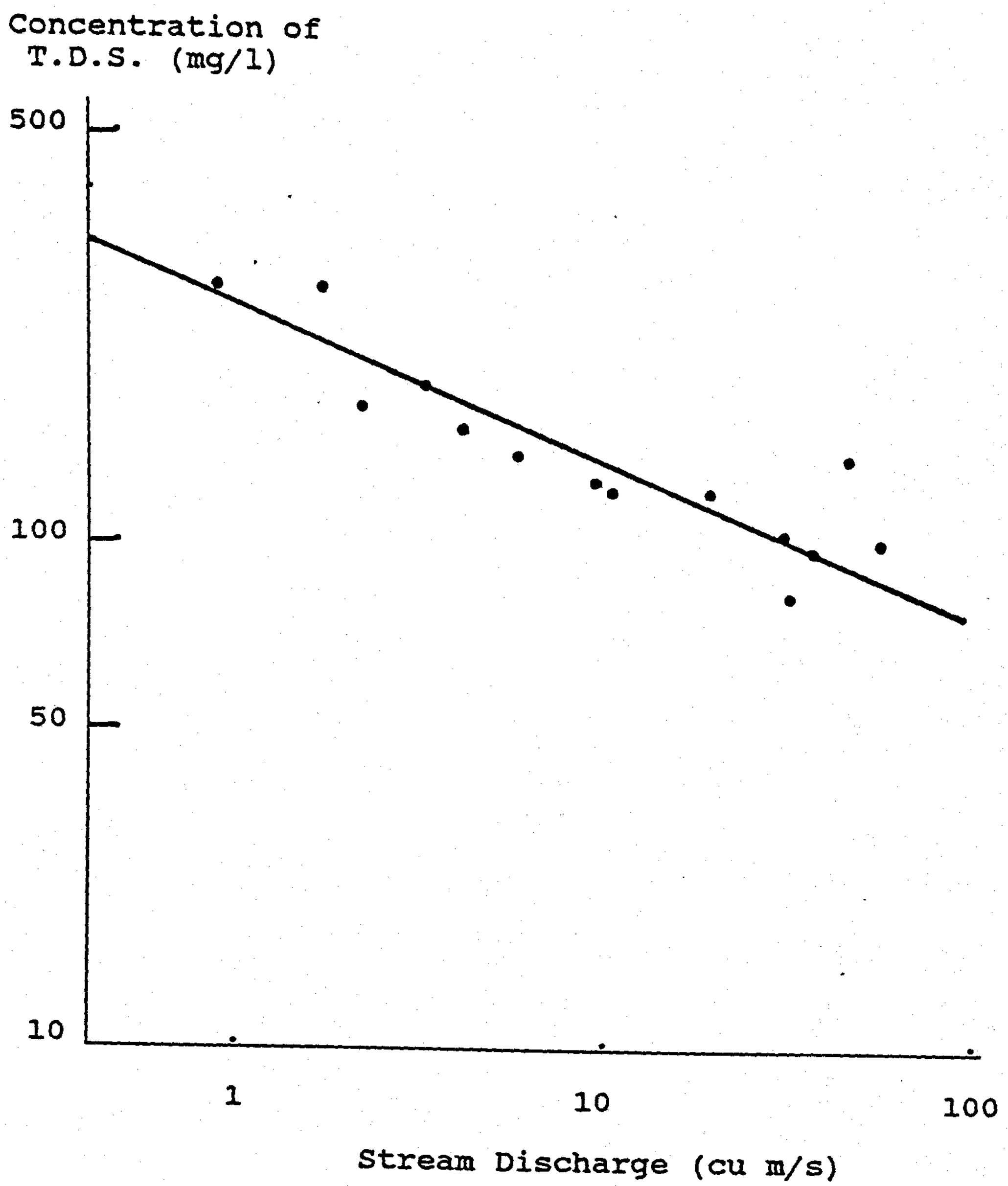
Prior to Keban and Tabqa Dams



Source: After al-Hadithi[3067], Fig. D-1, p. 218, attributed to: Hydroproject, Rawa Hydroelectric Project on the Euphrates River, Moscow, 1971.

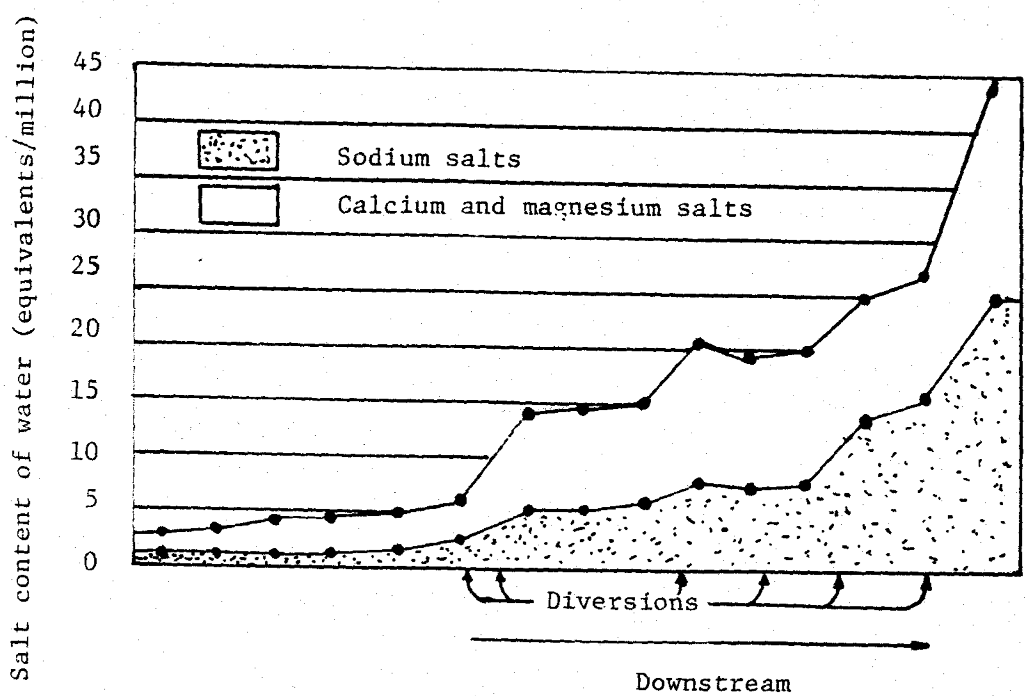
Graph V-5

VARIATION OF TOTAL DISSOLVED SOLIDS CONCENTRATION WITH STREAM DISCHARGE FOR THE ATHI RIVER AT OL DONYO SABUK, KENYA



Source: Dunne & Leopold[3059].

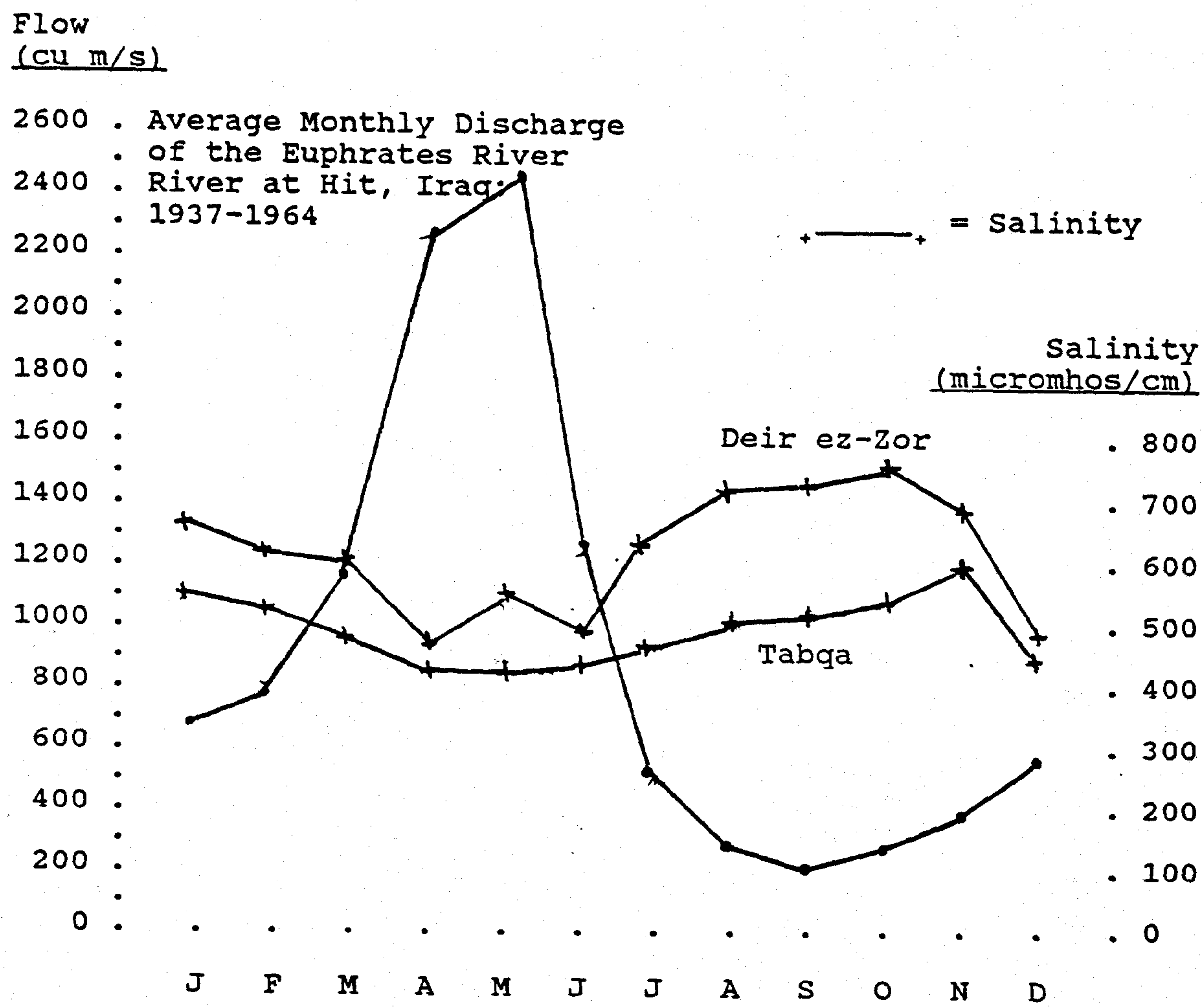
Graph V-6: **Changes in Salt Content of the Sevier River, Utah, as a Result of Repeated Diversion for Irrigation.**



Source: Dunne and Leopold[3059], p. 153: from Thorne and Peterson, 1967, copyright 1967 by the American Association for the Advancement of Science.

Graph V-7

SALINITY AND AVERAGE MONTHLY DISCAHRGE OF THE EUPHRATES RIVER

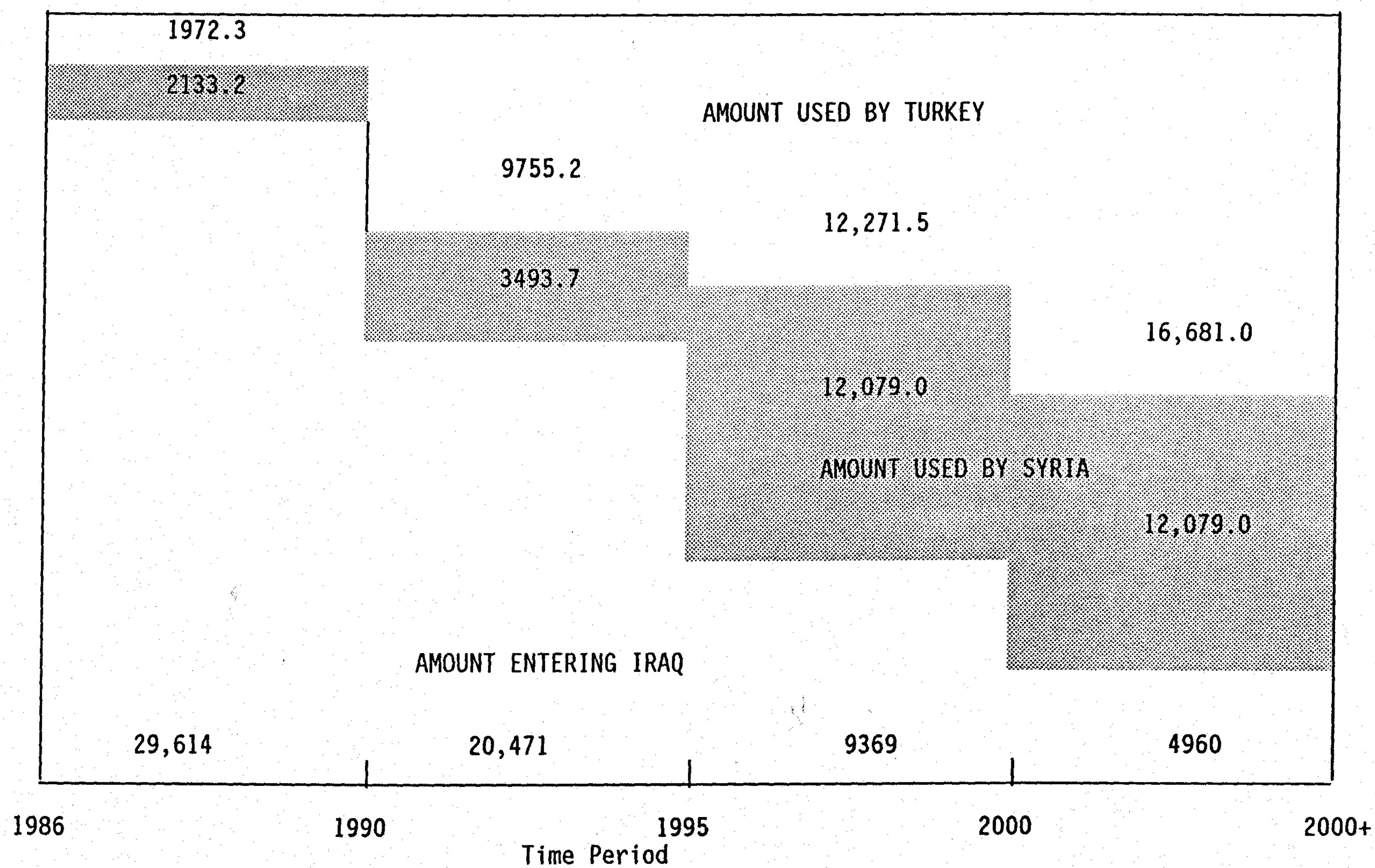


Source: Raslan and Fardawi[2710], p. 216; CLA[3080], Table B-10, p. 218.

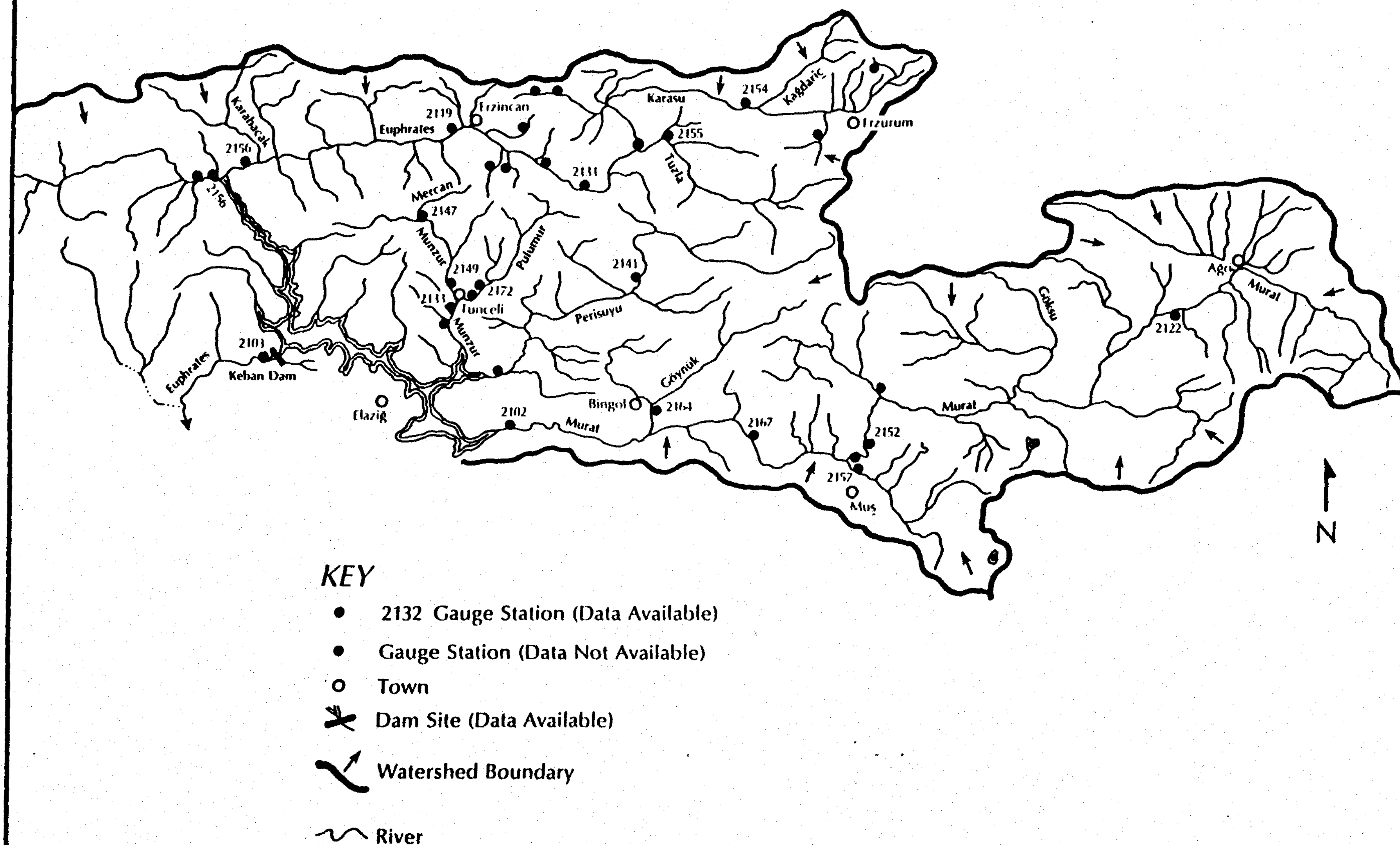
Graph V-8

WATER SUBTRACTIONS EUPHRATES RIVER: UPSTREAM USERS OPTIMUM SCENARIOS -- 1986-2000+
(Amounts in Mcm/yr)

Total Annual Natural Flow = 33,730 Mcm/yr

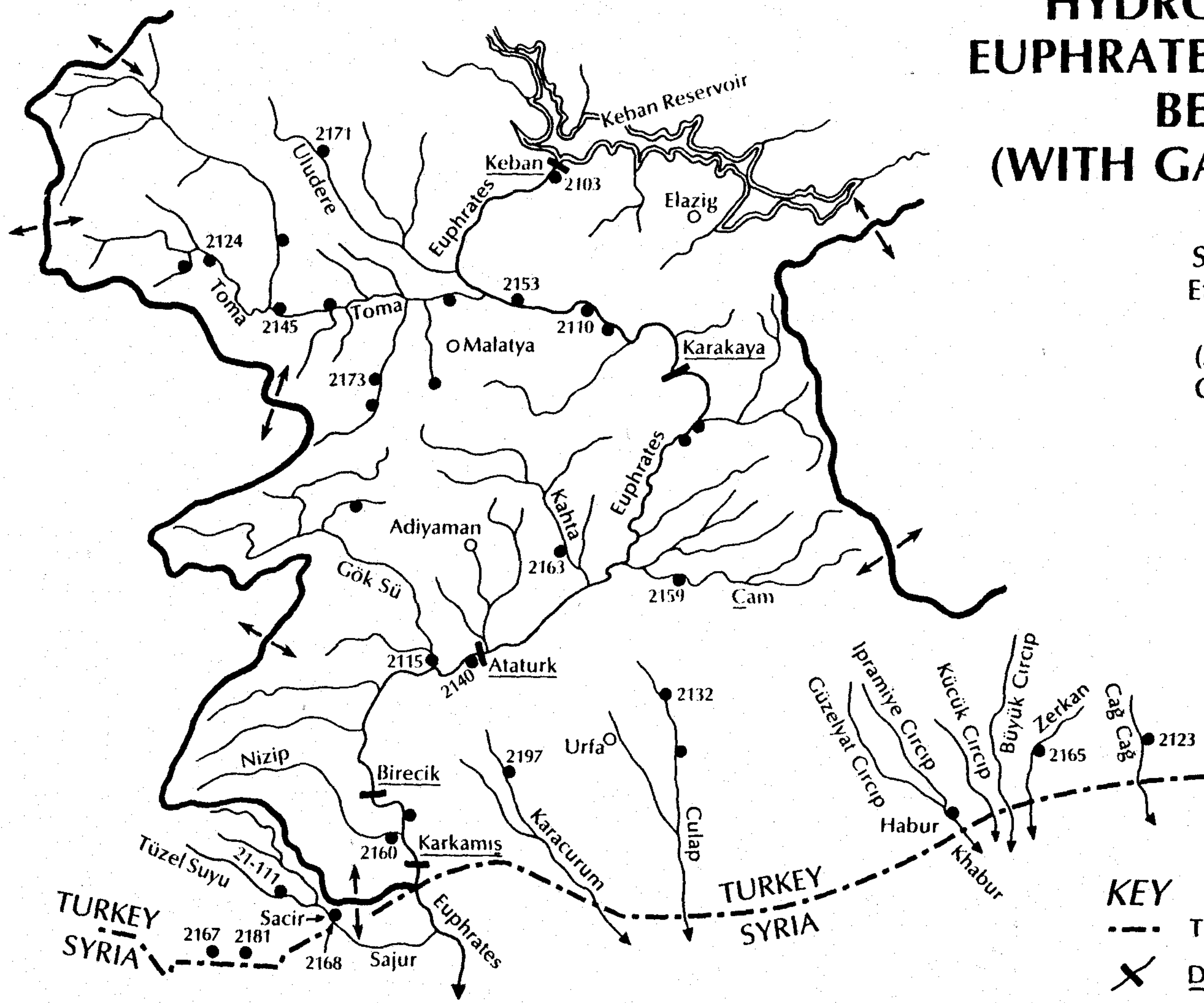


MAP V-1
HEADWATERS OF THE EUPHRATES RIVER



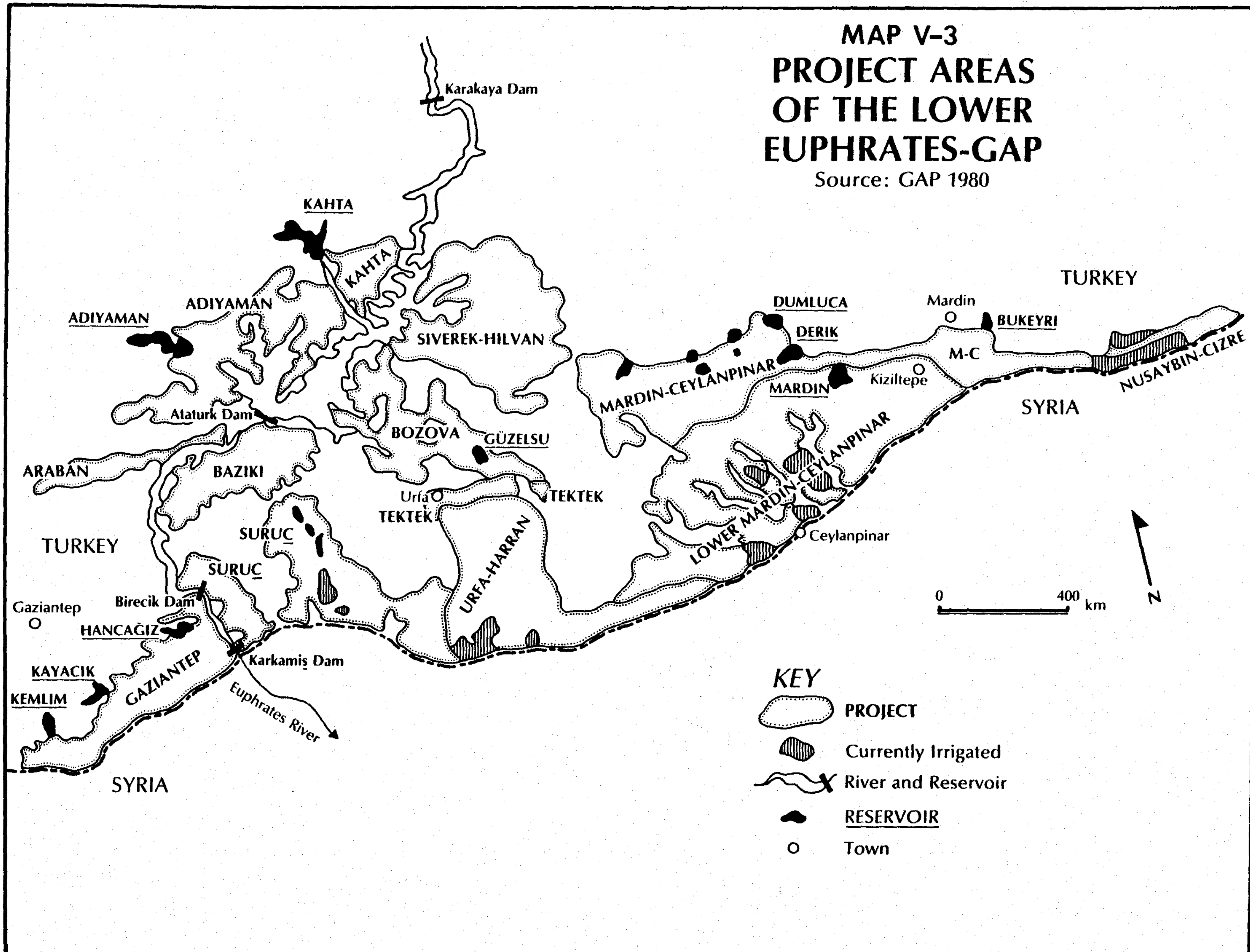
MAP V-2
HYDROGRAPHY OF THE EUPHRATES (FIRAT) IN TURKEY BELOW KEBAN (WITH GAUGING STATIONS)

Source: Elektrik Isl. Etüd Id., 1982 Water Year Discharges, (Ankara, 1958), and GAP (Ankara, 1980)

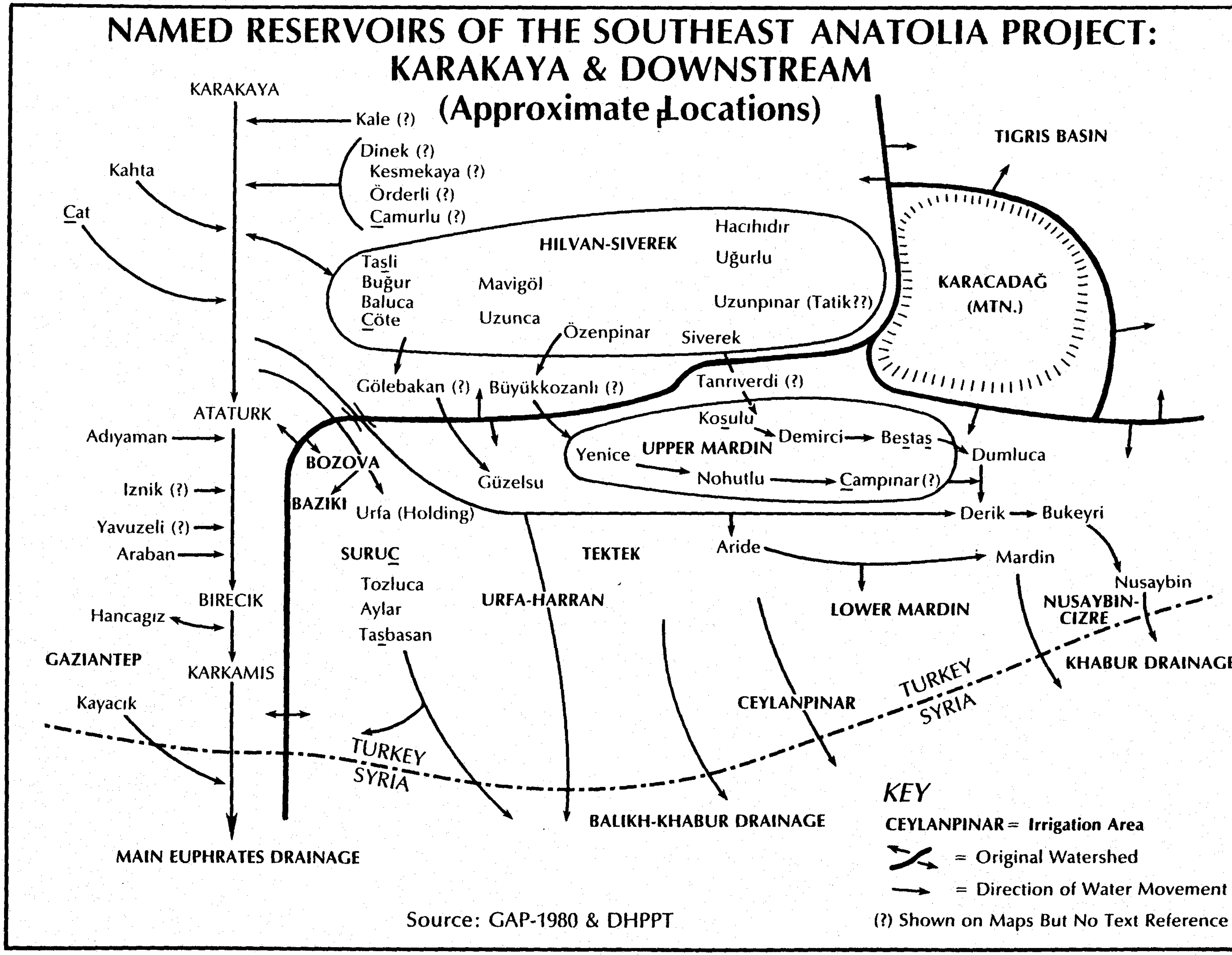


KEY

- Turkish-Syrian Border
- Dam Site (Data Available)
- City
- Watershed Boundary
- 2132 Gauge Station (Data Available)
- Gauge Station (Data Not Available)

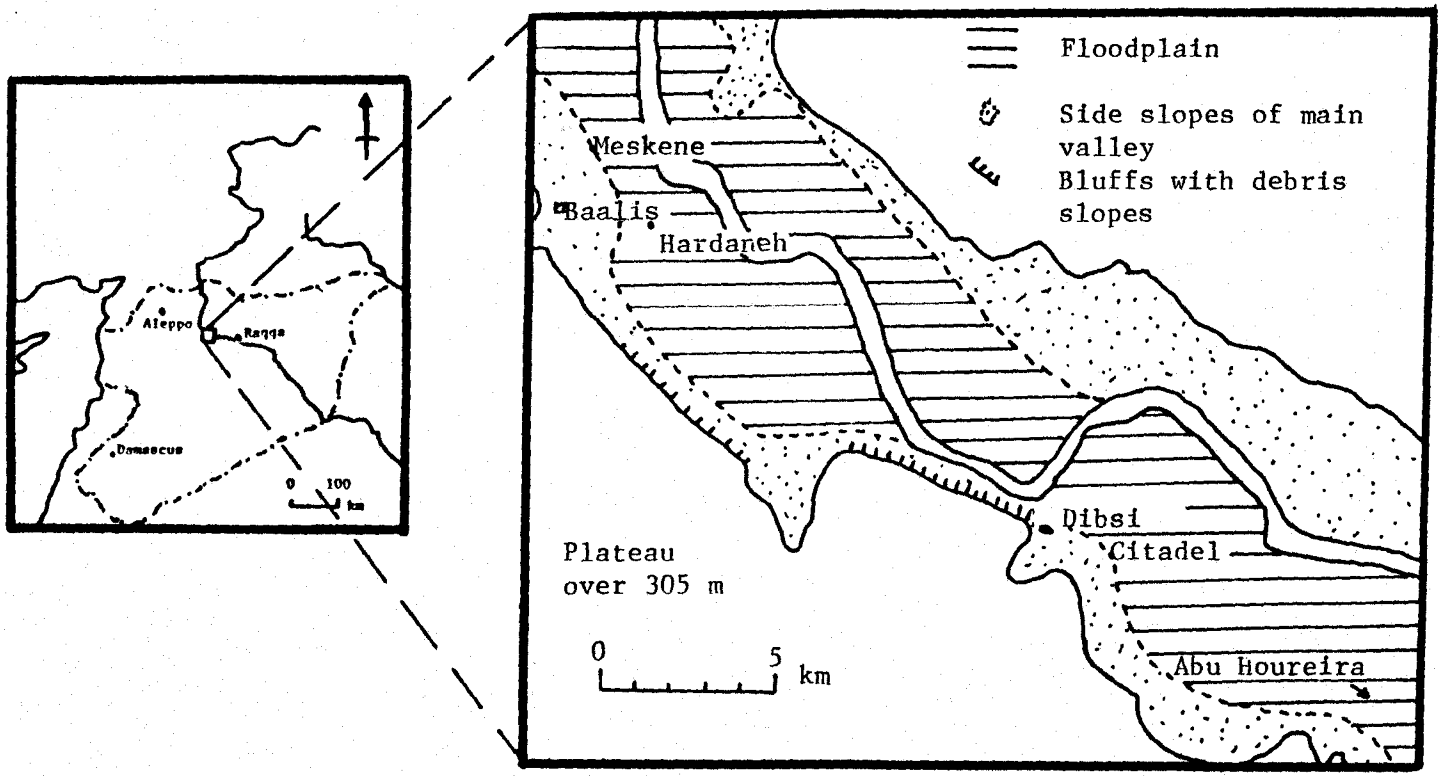

MAP V-3
PROJECT AREAS OF THE LOWER EUPHRATES-GAP
Source: GAP 1980
Karakaya Dam
KAHTA
KAHTA
ADIYAMAN
ADIYAMAN
SIVEREK-HILVAN
Ataturk Dam
BOZOVA
GÜZELSU
ARABAN
BAZIKI
Urfa
TEKTEK
TEKTEK
SURUC
SURUC
URFA-HARRAN
TURKEY
Gaziantep
Birecik Dam
HANCAĞIZ
KAYACIK
KEMLIM
GAZIANTEP
Karkamiş Dam
Euphrates River
SYRIA
DUMLUCA
DERIK
Mardin
BUKEYRI
M-C
MARDIN-CEYLANPINAR
MARDIN
Kiziltepe
TURKEY
NUSAYBIN-CIZRE
SYRIA
LOWER MARDIN-CEYLANPINAR
Ceylanpinar
0
400
km
N
KEY
PROJECT
Currently Irrigated
River and Reservoir
RESERVOIR
Town

MAP V-4


NAMED RESERVOIRS OF THE SOUTHEAST ANATOLIA PROJECT:
KARAKAYA & DOWNSTREAM
(Approximate Locations)
KARAKAYA
Kale (?)
Dinek (?)
Kesmekaya (?)
Örderli (?)
Camurlu (?)
Kahta
Cat
TIGRIS BASIN
HILVAN-SIVEREK
Hacıhıdır
Uğurlu
Tasli
Buğur
Baluca
Côte
Mavigöl
Uzunca
Uzunpınar (Tatik??)
Özenpinar
Siverek
KARACADAĞ
(MTN.)
Gölebakan (?)
Büyükkozanlı (?)
Tanrıverdi (?)
ATATURK
Kosulu
Demirci
Bestas
Dumluca
Adıyaman
Yenice
UPPER MARDIN
BOZOVA
Güzelsu
Nohutlu
Campınar (?)
Iznik (?)
BAZIKI
Urfa (Holding)
Derik
Bukeyri
Yavuzeli (?)
Araban
SURUC
TEKTEK
Aride
Mardin
Tozluca
Aylar
Tasbasan
URFA-HARRAN
Nusaybin
BIRECIK
Hancagız
LOWER MARDIN
NUSAYBIN-CIZRE
GAZIANTEP
KARKAMIS
KHABUR DRAINAGE
Kayacık
TURKEY
SYRIA
CEYLANPINAR
TURKEY
SYRIA
KEY
BALIKH-KHABUR DRAINAGE
CEYLANPINAR = Irrigation Area
MAIN EUPHRATES DRAINAGE
= Original Watershed
= Direction of Water Movement
Source: GAP-1980 & DHPPT
(?) Shown on Maps But No Text Reference

Map V-5: Valley of the Euphrates River near Meskene, Syria

(Showing the floodplain and bluffs)*



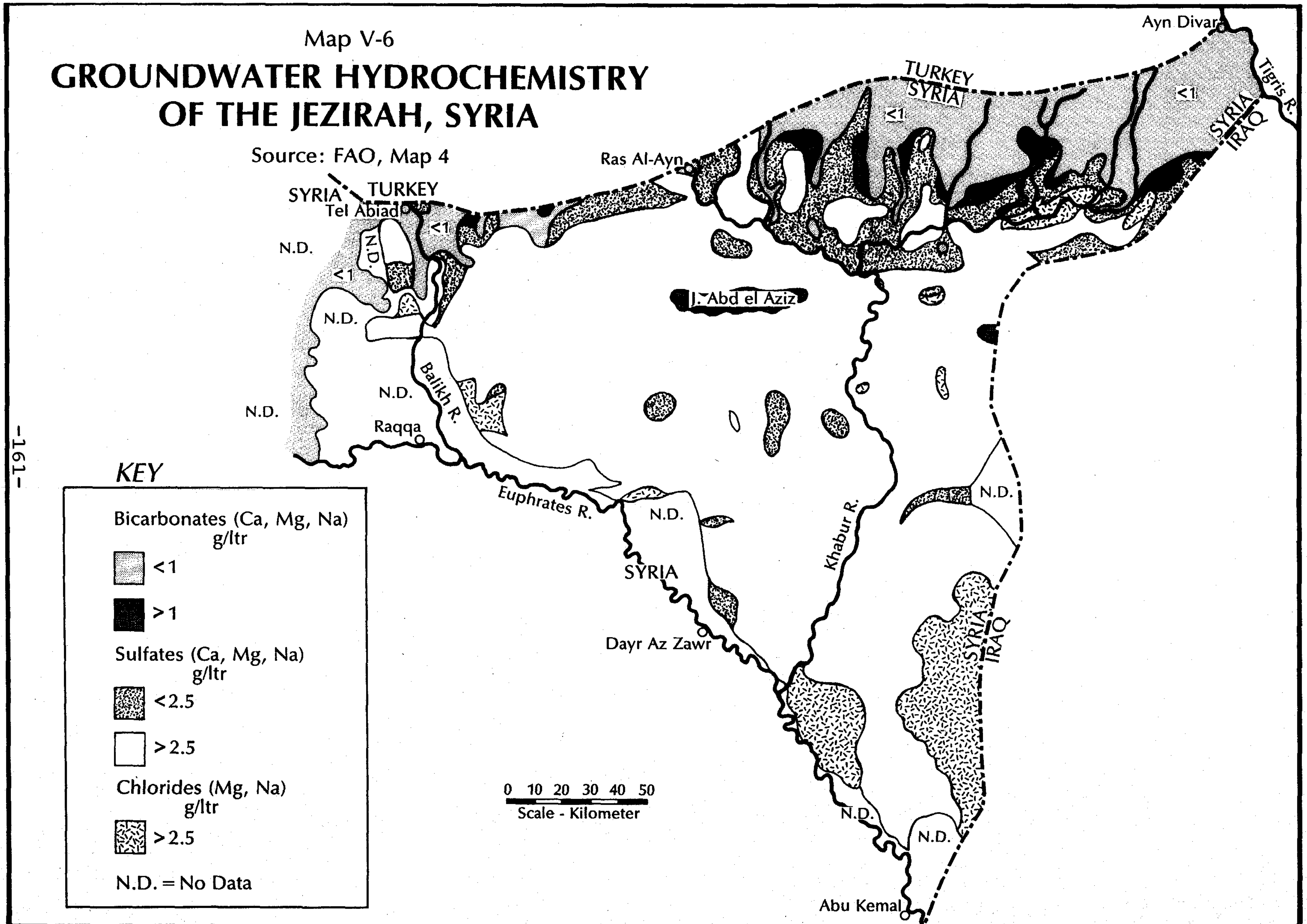
Source: Wilkinson[3253].

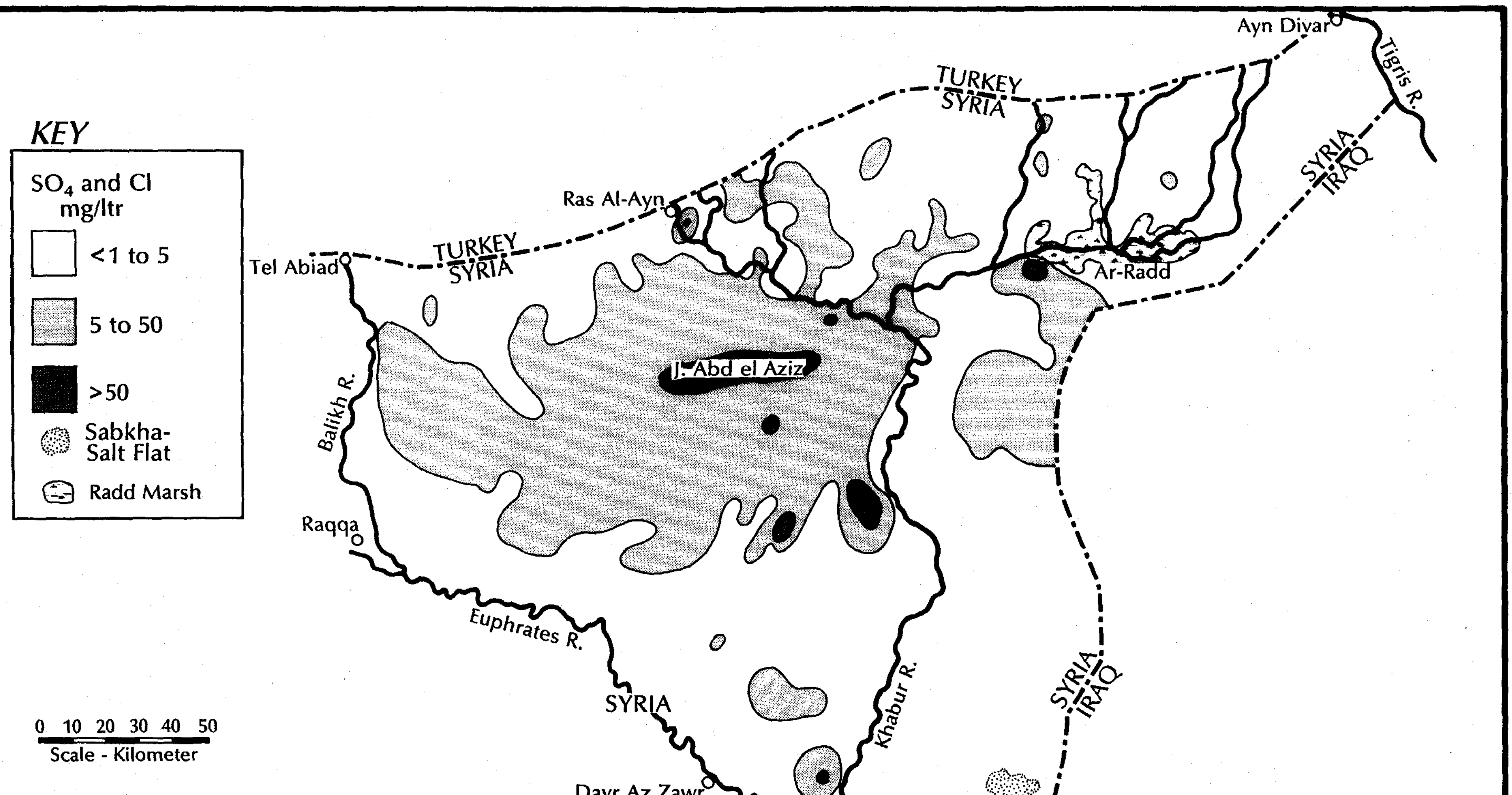
* This area now flooded.

Map V-6

GROUNDWATER HYDROCHEMISTRY OF THE JEZIRAH, SYRIA

Source: FAO, Map 4

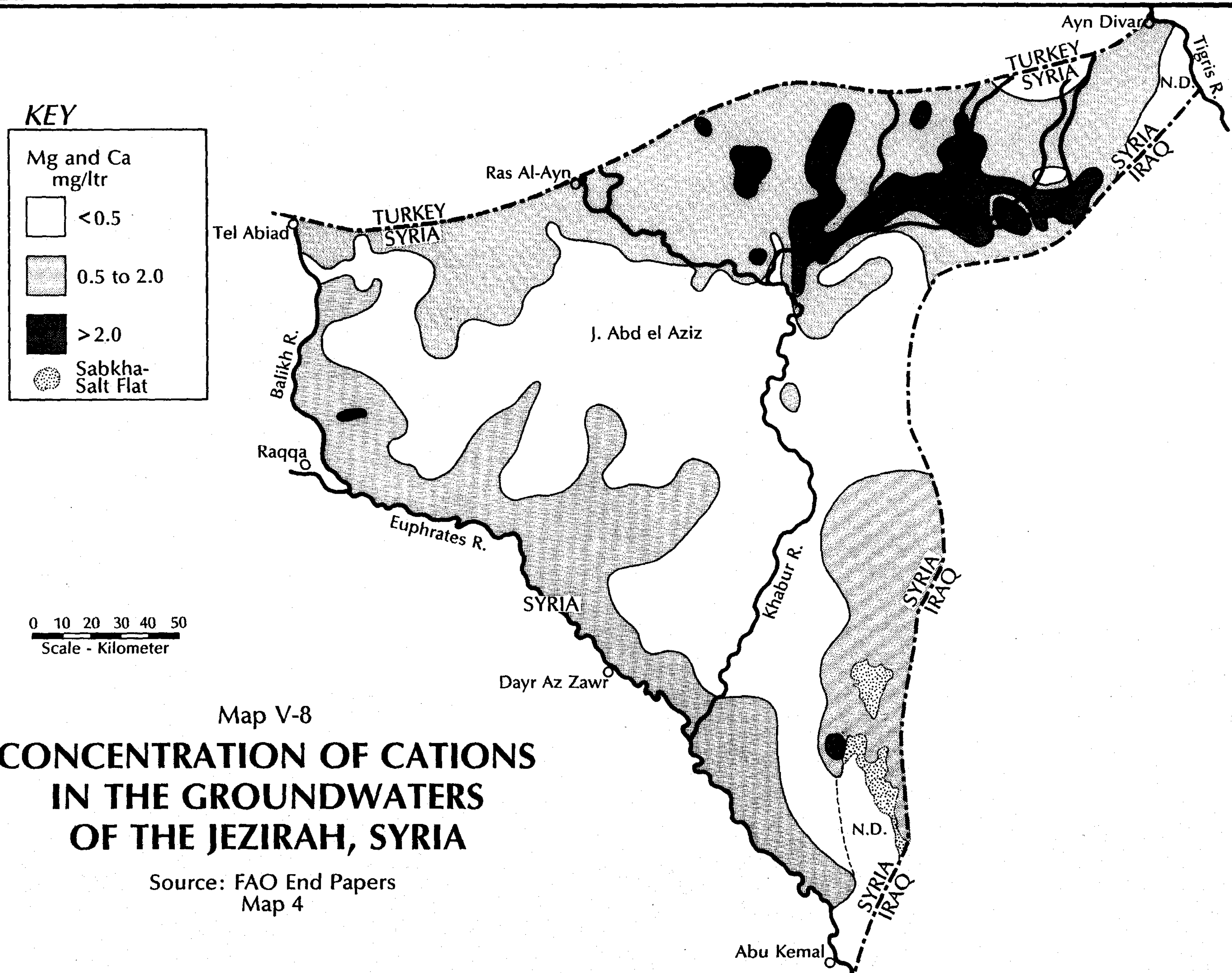




Map V-7

CONCENTRATION OF ANIONS IN THE GROUNDWATERS OF THE JEZIRAH, SYRIA

Source: FAO End Papers
Map 4



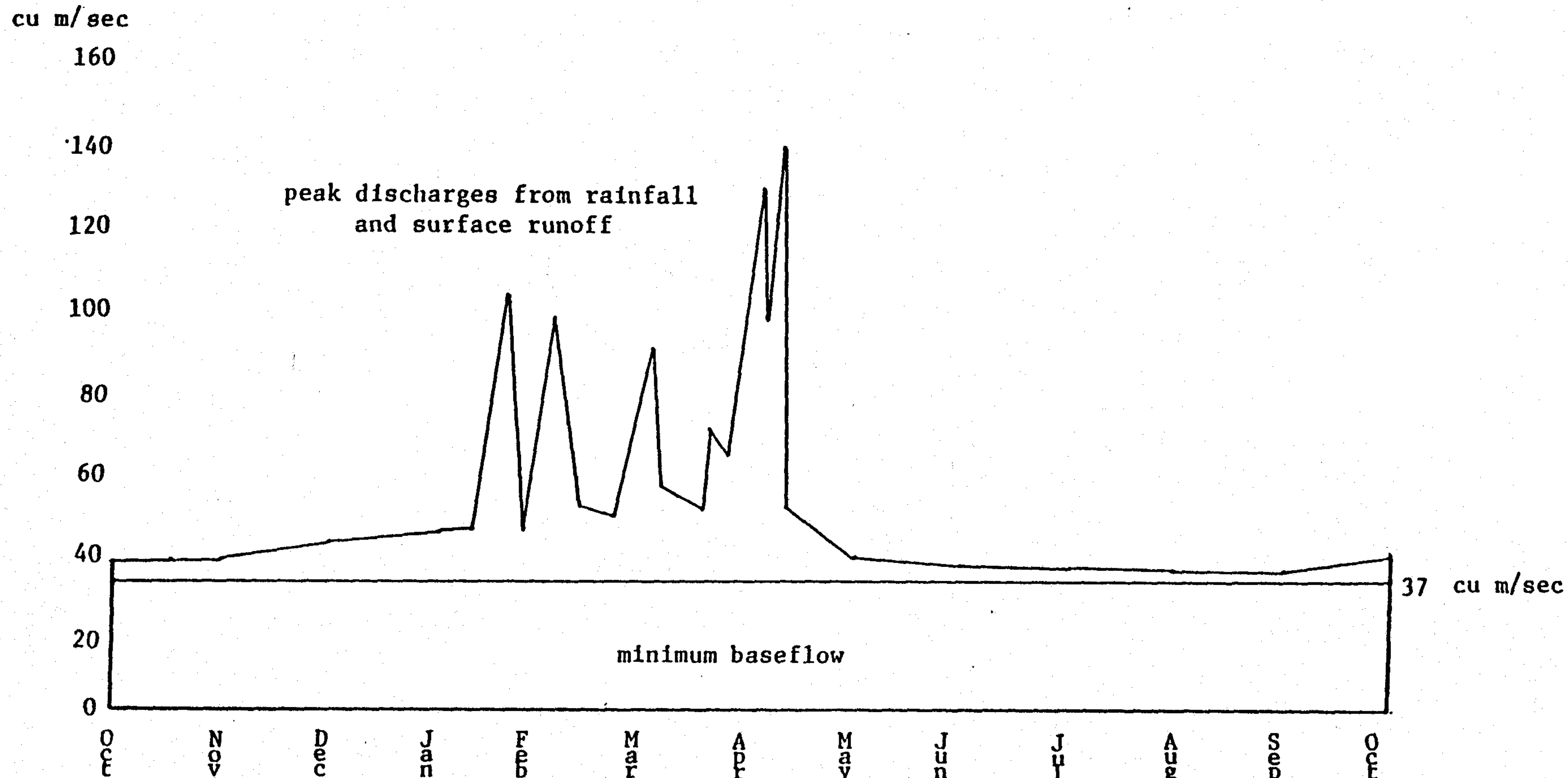
Map V-8

CONCENTRATION OF CATIONS IN THE GROUNDWATERS OF THE JEZIRAH, SYRIA

Source: FAO End Papers
Map 4

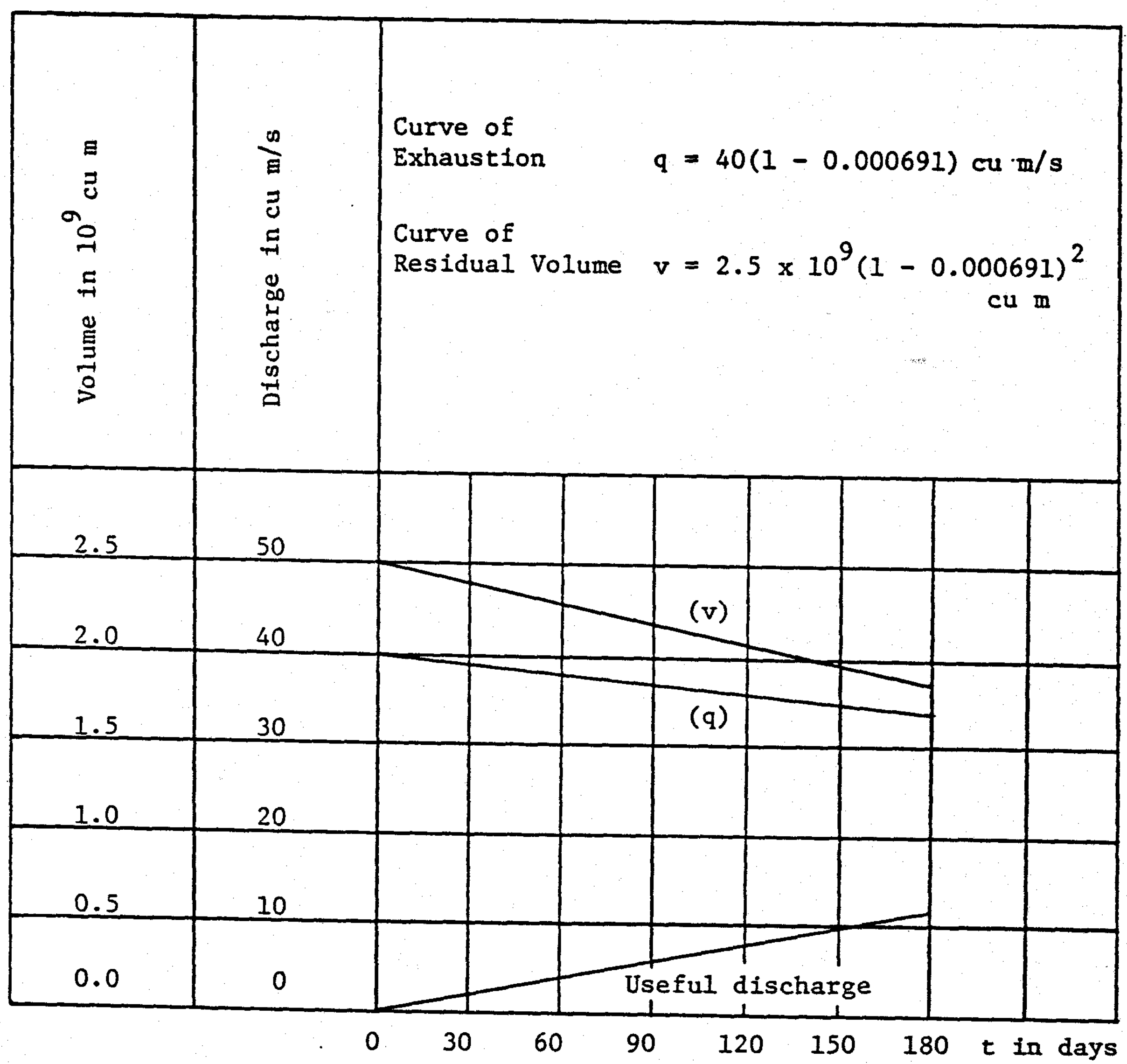
Diagram V-1a: Stream Flow of the Khabur River at Suwar, Syria

1932-1933



Source: L. Dubertret and J. Weulersee[3073], p. 62, Fig. 57.

Diagram V-1b: Ras al-Ayn Exhaustion Time



Source: Abd-El-Al[382], p. 73.

Diagram V-2: Schematic Representation of Proposed Hydrologic Relationships in the Ceylanpinar/Ras al-Ayn Region (Estimated and Announced Values Added Where Possible)

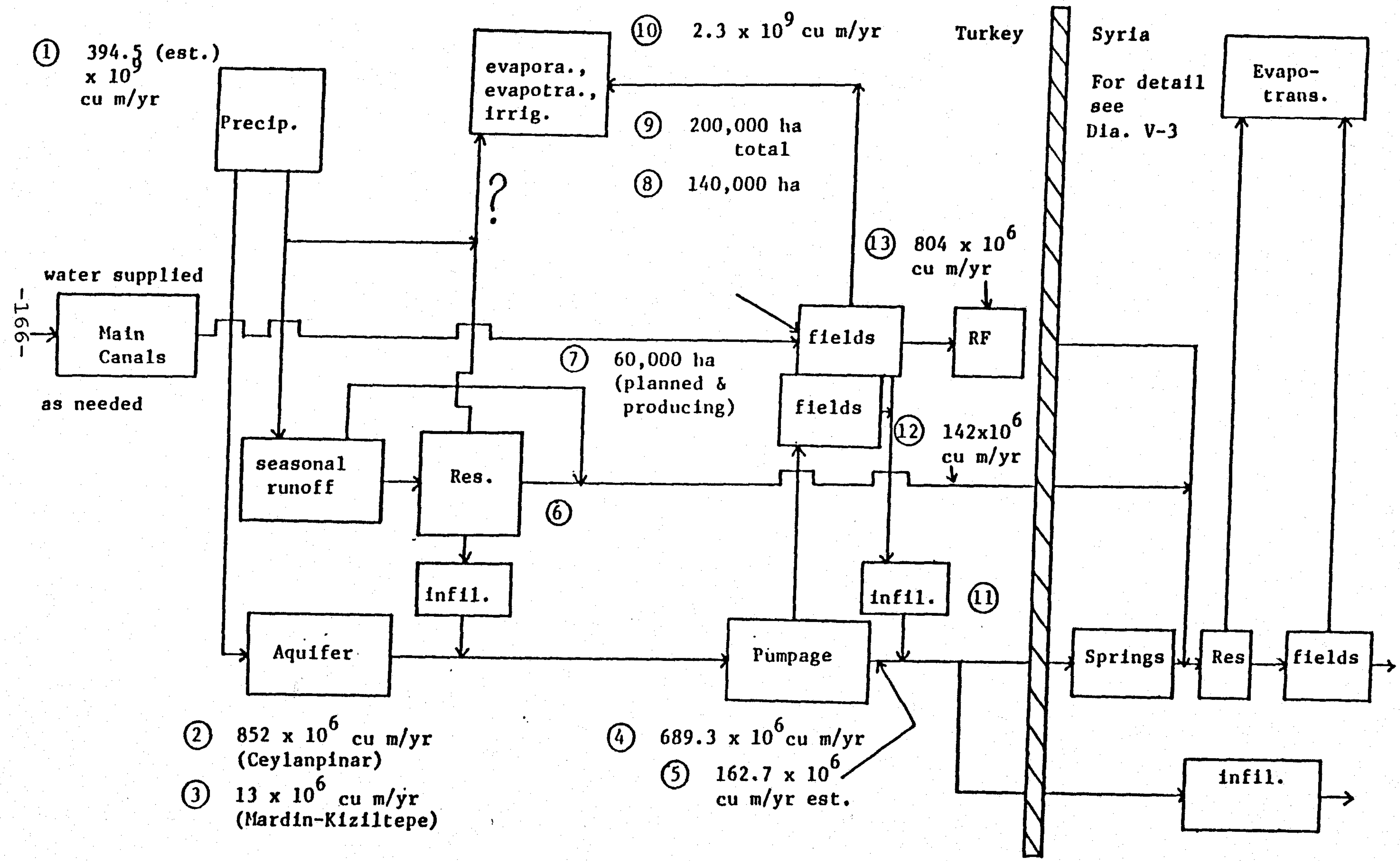


Diagram V-3: Schematic Representation of Proposed Hydrologic Relationships in the Ras al-Ayn/Jezirah Region

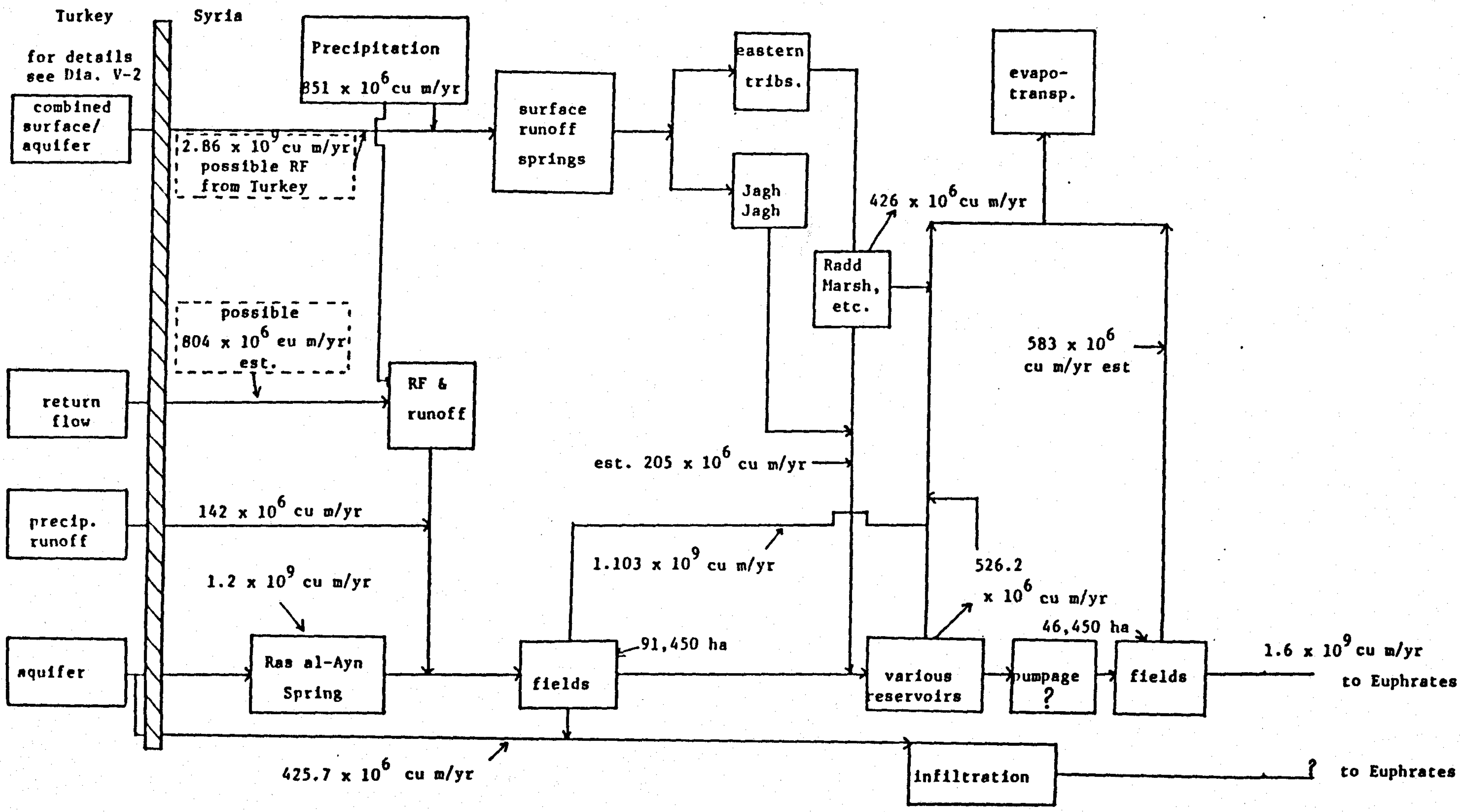
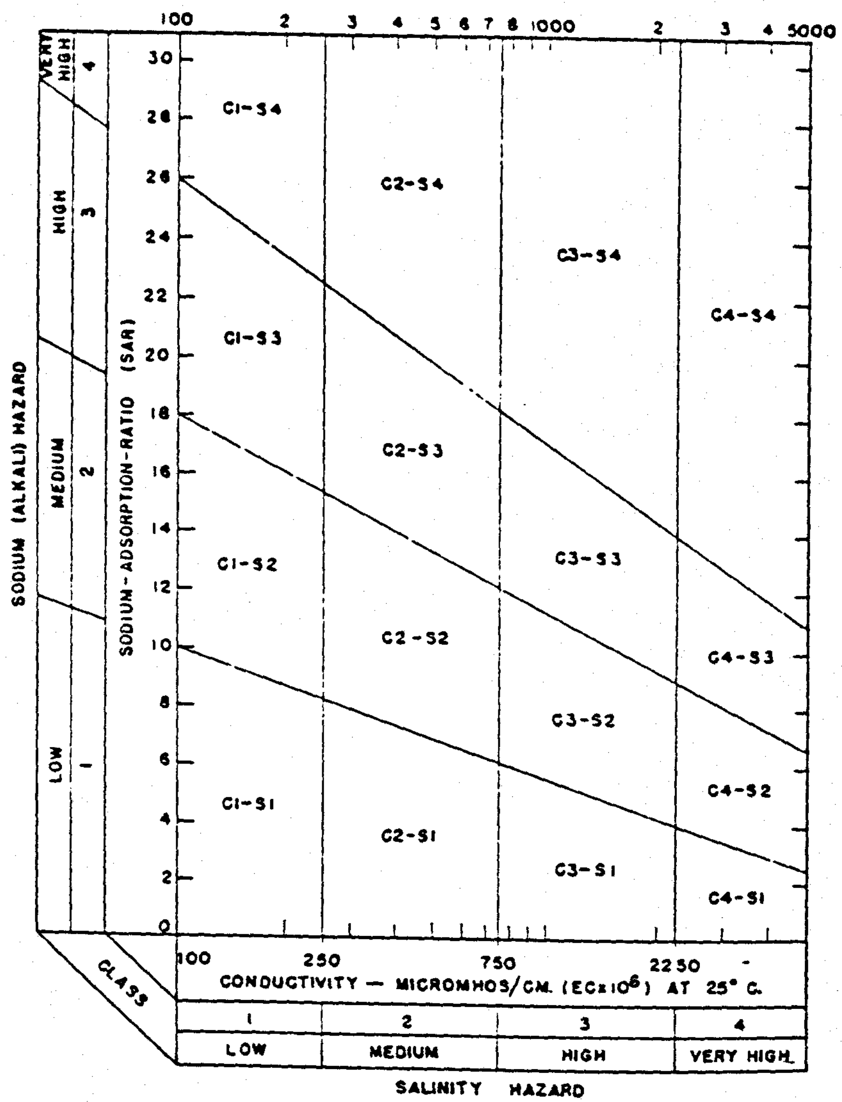


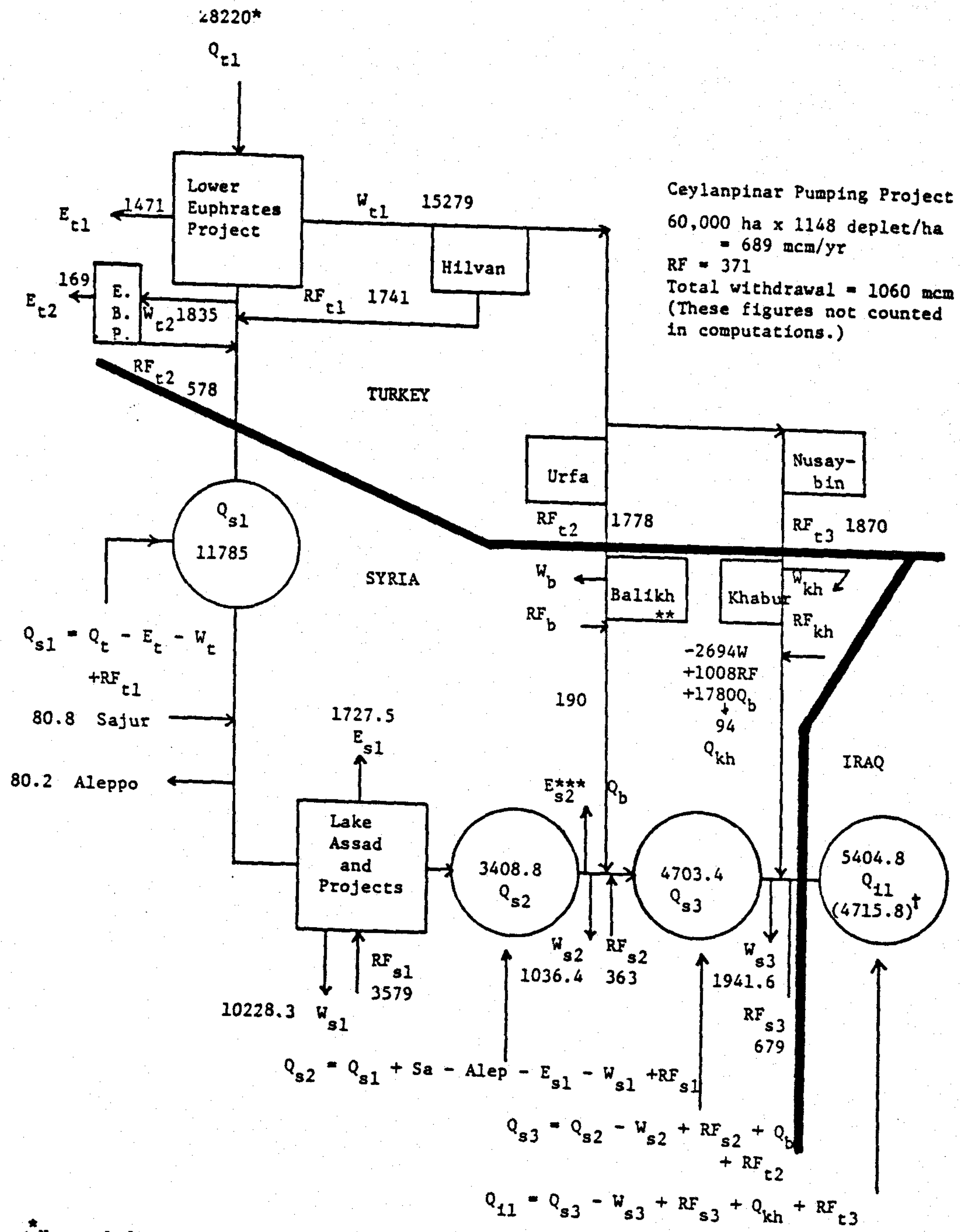
Diagram V-4: USDA Classification of Irrigation Waters



Source: Withers and Vipond(3223), p. 114; from USDA, "Diagnosis and Improvement of Saline and Alkaline Soils," Agricultural Handbook, No. 60.

Diagram V-5

Sequential Water Budget of the Euphrates River ca. 2000+



*Natural flow at Karkamis (Table EF 10, p.

**Balikh # 1 counted with Euphrates projects.

***Reservoir size unknown and evaporation not included.

†Lower value includes depletion estimated for Ceylanpinar project.

APPENDIX A

None of the Euphrates records cited above represents the natural river flow. In order to estimate the average "natural" river flow, it is necessary to add the amounts of water diverted to the flow measured at some point below all major tributaries. Using figures from the report of Hathaway, Adams, and Clyde - in which estimates of irrigation diversions in Turkey, Syria, and Iraq are made - it is possible to calculate an estimated natural river flow as follows:

CALCULATIONS OF AVERAGE "NATURAL" FLOW
OF EUPHRATES RIVER AT HIT, IRAQ
(Milliards of Cubic Meters)

	Measured River Hit, Iraq	Diversions in Turkey	Diversions in Syria	Total "natural" river at Hit
Jan	1.86	0	0.05	1.91
Feb	1.94	0	0.07	2.01
Mar	3.14	0	0.24	3.38
Apr	5.77	0.07	0.24	6.08
May	6.54	0.17	0.37	7.08
Jun	3.27	0.30	0.46	4.03
Jul	1.48	0.37	0.52	2.37
Aug	0.86	0.33	0.44	1.63
Sep	0.73	0.18	0.29	1.20
Oct	0.90	0.07	0.14	1.11
Nov	1.21	0	0.09	1.30
Dec	1.54	0	0.05	1.59
Total	29.24	1.49	2.96	33.69

Adapted from Hathaway, et. al., ibid. Diversions were estimated as net diversions after taking into account "return flow" from irrigated lands whose areas and cropping patterns were made available to the authors.

Source: Gail A. Hathaway, Harry W. Adams, and George D. Clyde, *Report on International Water Problems, Keban Dam -- Euphrates River*, Report to IBRD (Dec. 1965) as given in CLA[3088], p. 205.

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