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PAPER 15

Irrigation and Drainage Networks of 17 July Project - A Case Study

by

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INTRODUCTION

The "17 July Project", which is one of the biggest agricultural projects in Iraq is located in the alluvial plain of the Tigris river, south-west of Kut, approximately halfway between Baghdad and Basrah. The project covers a total area of about 25,000 hectares. Two distinct hydraulic systems, namely the 17 July canal system and the Ishtiraki canal system, exist within the area. The hydraulic systems are supplied by the Gharraf river which is an outgoing tributary of the Tigris river.

The project, which has been of significant benefit to the first stage of the 1969 development scheme, has made it possible to grow cereal crops over a few thousands of hectares. However, the project has been affected by increasing salinity of the soil due to the existing irrigation system being carried our without proper drainage facilities; hence crop yields have dropped.

In this paper the present irrigation scheme and the various networks involved in the project are evaluated and the salient features presented and discussed. Also, new proposals, including the design of essential components of a system based on the principle of optimal use of available water resources, which have wide seasonal fluctuations in quality as well as quantity, are presented the objective being to achieve harmonious overall development in the area concerned.

ENVIRONMENTAL CONDITIONS

Topography

The ground in the area has a small overall slope namely about 0.16% (0.0016) mean, a fugure taken from the available topographical survey (1).

Climatology

The climatic data are obtained from the meteorological station at Hai (2). The climate is of the sub-desert type: that is continental, arid and hot, with large daily and seasonal temperature variations and infrequent but violent and higly irregular winter showers (annual mean rainfall = 143mm); hot and dry winds blow from the north-west in late spring, often loaded with dust.

Temperature and humidity

The maximum temperature and minimum relative humidity occur in July and August and the minimum temperature occurs in January (coldest month) with maximum relative humidity. Temperatures below 0°C have been recorded in December, January and February.

Fortunately, the likelihood of frost with temperatures below -4°C is very limited during the critical months.

Winds

The dominant winds blow from the West to Northwest on average for 192 days a year. The sub-dominant winds blow from the East between May and October. The windy days per year for each direction are shown in Figure 1.

The maximum wind velocity occurs in June and July and peak velocity usually occurs at mid-day; while minimum wind velocity usually is experienced in November. The mean wind speeds at 6 a.m, 12 a.m and 6 p.m during June are 15.9 km/hr, 21.1 km/hr and 12.6 km/hr respectively, and during November 9.8 km/hr, 11.8 km/hr and 9.2 km/hr respectively.

Rainfall

The period within which rain falls is between october and May; there is no rain between June and september. However, the rainfall is non-uniform and has a wide variation from year to year and from month to month between October and May.

The monthly average rainfall (2) is presented in Table I, together with the range of the rainfall from October to May. Because of the wide range of rainfall in any month, the effective rainfall which is of use to the crops, has been defined as the rainfall which could occur with 80% probability.

Water resources

The project area is located on the west bank of the Gharraf river, which is controlled by a head regulator located immediately upstream of a barrage at Kut (160 km from Baghdad). The Gharraf river, 168 km long, serves several irrigated areas on both banks. it is equipped with four check structures which, to some extent control the water levels in the river. Two distinct hydraulic systems feed the Al-Shtiraki and the 17 July canals. The intake structures are located between two check structures.

Quality of water

The quality of water for the project is taken from the data obtained from Tigris water samples taken at the Kut barrage which is fairly close to the water supply to the project. The seasonal fluctuations of the water salinity are shown in Table II; the values are the average of the available data. The water is slightly saline and can be used as irriation water if drainage conditions are good. It is to be noted that the SAR (Sodium absorption ratio) values lie between 1 and 5 and so the water can be classified as being low-alkali hazard.

There is a large variation in water salinity during the year because of the influence of melting snow and rainfall and also due to the low run-off during the dry period. For that reason, monthly salinity values are used in the computation of the water-salt balance and the leaching requirement is also based on monthly figures instead of annual average figures.

Soil conditions

The project is located in the Mesopotamian lowland, which is characterized by alluvial soils. The alluvial material has been deposited in thick layers either in the form of medium-to-fine particles (loam-to-clay textures) corresponding to spreading phases generalized throughout the area in the course of several seasons, alternating with sudden flood phases depositing coarse to verycoarse particles (sandy loam to coarse sand textures). These variations result in a very intricate stratification of the soil and, often in very wide heterogeneity vertically as well as horizontally.

Although the water used for irrigation is not really saline, the summer season, especially, causes excessive salt concentration in the upper soil layers.

Because of the lack of drainage and the fact that there is absence of leaching, some important surface areas have become very saline. The salinity of the surface-layers of the soil varies widely, between 8 mmhos/cm and over 15 mmhos/cm (for the saturation extract).

The values of hydraulic conductivity vary widely, due to variations in soil texture and the effect of depth. The average hydraulic conductivity of the soil up to 250 cm below the ground surface is between 1.75 to 3.00 m/day, in the area which is classified as being good drainage. However, there are some areas which have a hydraulic conductivity of less than 1.75 m/day, a figure which is classified as representing poor drainage. However, areas of this type are small compared to the area as a whole.

IRRIGATION, DRAINAGE AND SALINITY

Crop consumptive use

The actual evapotranspiration of a given crop at a given stage of growth depends upon the climatic factors. The potential evapotranspiration is calculated on a monthly basis from the available climatic data by means of the Blaney-Criddle formula (3). The series of potential evapotranspiration values is shown in Table III and a sample of statistical distribution is represented in Figure 2. The statistical distributions reveal that the inter-annual variation in the monthly potential evapotranspiration is very high for the off-season months, namely November, March and April. However, the variation is lower in winter and summer.

For the project design reference to potential evapotranspiration had to be made and regard taken of the risks initiated by a temporary inadequacy between water demand and water availability. Several values of frequencies (probabilities) have been chosen to find the potential evapotranspiration, depending upon the statistical distribution.

The chosen frequencies are

- in January, February and July to September 0.6
- in October, December and March to June 0.7
- in November 0.8

As mentioned previously, some of the rainfall, ie: with 0.8 frequency, can be considered useful to the crop. Then the potential evapotranspiration is calculated by deducting the effective rainfall from the reference potential evapotranspiration. Table IV shows the monthly means of potential evapotranspiration that have been instrumental for calculating the actual evapotranspirations (crop consumptive use) for each crop with related corrective coefficients for the entire duration of growth cycle. Five crops can be suggested to be grown in the project, an area of 20% being allocated for each crop. The consumptive use figures for the five crops are shown in Table V.

Estimation of leaching requirements

The leaching requirement is the quantity of water brought in as a supplement to normal irrigation which allows leaching of the soil in such a manner as to maintain the salinity at a suitable level. The major objective of leaching and drainage consists of reducing the soil salinity to a level consistent with crop yields that yield optimum financial return on capital investment.

A salinity level is selected which is admissible for most of the crops planned for the project. Soil salinity of 3.7 mmhos cm for the saturation extract (6mmhos/cm for the field capacity) has been chosen as an objective.

The leaching requirement, LR, is given by

$$LR = \frac{D_{dw}}{D_{iw}} = \frac{EC_{iw}}{EC_{dw}} \qquad (1)$$

where,

D_{dw} = depth of drainage water,

D_{iw} = depth of irrigation water,

EC_{iw} = electrical conductivity of irrigation water, and

EC_{dw} = electrical conductivity of drainage water.

Electrical conductivity of the drainage water, EC_{dw}, represents a salinity level which is tolerant to the crops to be grown. The depth of irrigation water is equal to the sum of the consumptive use and the drainage water. The depth of irrigation water in terms of conductivity ratio can be given as

$$D_{iw} = \frac{EC_{dw}}{(EC_{dw} - EC_{iw})} D_{iw} \qquad (2)$$

where

D_{cw} = depth of the consumptive use.

The leaching requirement is calculated using the monthly salinity of the available water as a base.

Irrigation - Frequency and depth

The irrigation frequency and depth depends upon the infiltration rate and the available water depth between the field capacity and the wilting point. An efficiency of 90% has been assumed for the various methods of irrigation which are to be used in the project. The total irrigation depth for various crops, including the consumptive use and the leaching requirements, are shown in Table V. The common irrigation depths will be used, namely 60mm, 90mm, 120mm, 150mm, 180mm and 240mm per month. The adjustable irrigation depths for the various crops are given in Table VI; however, the adjustable total depth for each crop is greater or equal to the required depth.

According to the suggested irrigation depth the salinity of the soil will be slightly different from that of the allowable value, but remains within the allowable value at the end of irrigation cycle. Depending on the field capacity of the soil and the consumptive use to the crops, the minimum irrigation frequency occurs in the summer for a period within 6 days. The maximum irrigation frequency occurs in winter for a period of about 30 days.

Irrigation canals: Discharge rates and design

To satisfy the required demand each 24 hours continuous discharge is required at the farm. The maximum weighted affective water depth desired is 4.2 mm/day, which is required particularly in the period January to May. Then the continuous discharge corresponding to that required water depth is:

$$\frac{4.2 \times 10,000}{24 \times 3600} = 0.5 \text{ l/sec per hectare.}$$

A field canal running between two farms, 50 hectares each, can be used for irrigation. The productive area of each farm can be considered as 85% of the total area. The canals can be lined with concrete, to minimize the loss of the rare water resource in the project.

Lining all irrigation canals is a costly operation; however, this practice will cover the cost of seepage water and the maintenance of the unlined canals. A conveyance loss of 10% is considered in the design of the canals.

The design discharge of the farm canal is 50 l/sec. The network design is based in the Manning formula. The Manning roughness coefficient is taken as 0.014, the side slope of the cross-section being 1:1. The canal bottom slope is the range of 0.01%. Table VII lists typical canal sections and the estimated discharges which are needed in the distribution of water from the intake structure on Gharraf river to the various farms.

Drainage

Field drains

The design of field drains should be based completely on experience and observations made on the existing networks under similar soil and water conditions and also on appropriate theory. In the arid conditions prevailing in southern Iraq, irrigated land requires intensive field drainage for permanent control of salinity.

The drainage water reaches a depth based on a distance of 100 mm per month (3.4mm per day), obtained from Tables V and VI. The drain level is fixed at a depth of 1.8m to prevent resalination of the root zone, which is in the range of 1.2m, due to capillary rise.

The calculation of the spacing of field drains can be made according to the steady-state formulae or, alternately, to the non-steady-state formulae. The Hoghoudt formula and the Glover-Dumm equation will be used for the steady-state and non-steady-state respectively. The Hoghoudt formula (3) is:

$$S^2 = \frac{8K_b dh}{q} + \frac{4K_a h^2}{q} \qquad (3)$$

where;

s = the spacing between two field drains,

q = the discharge of the field drains,

h = the maximim height of the water table above drains level,

d = the equivalent depth of the impermeable layer below drains level,

k_a and k_b = the horizontal hydraulic conductivity above and below drain level respectively.

However, the Glover-Dumm (4) equation, for an initial water table that is not completely flat but has the shape of a fourth-degree parabola, can be given as:

$$L = \pi \left[\frac{KD_t}{\eta} \right]^{1/2} \left[\ln 1.16 \frac{h_o}{h_t} \right]^{-1/2} \qquad (4)$$

where,

L = the spacing between the drains,

K = hydraulic conductivity of the soil,

η = drainable porosity of the soil,

h_o = initial height of water table above the drains level, taken midway between the drains.

h_t = height of the water table above the drains level, taken midway between the drains at time t after the drainage cycle starts,

D = average depth of the flow = $d + \frac{h_o}{2}$,

d = the equivalent depth of the impermeable layer below drains level.

The drainage criteria which are used in the calculation of spacing are given in Table VIII. Accordingly the calculated spacing from the Hoghoudt formula and the Glover-Dumm equation are 150 m and 160 m respectively. Then, the field drain spacing can be 150 m.

CONCLUSION

A case study is made of the "17 July Project" in Iraq. The present irrigation practice and networks of the project are evaluated. The various environmental conditions of the project are presented and discussed. New proposals including the design of essential components of the system are made, based on the principle of the optimal use of the available water resources.

References

1 Sabti, N.A., et al., "Evaluation of 17 July Project". Report submitted to the Ministry of Irrigation. Iraq, 1978.

2 "Meteorological data at Hai station". Unpublished report.

3 Luthin, J.N., "Drainage Engineering", John Wiley & Sons, INC, 1966.

4 Dumm, L.D. "Transient Flow Concept of Sub-Surface Drainage", Transactions of the American Society of Agriculture Engineers, 1964, 7 (2).

Table I; Rainfall Data

Rainfall (mm)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Year
Average Value	3	19	23	28	20	23	20	7	143
Lowest Value	0	0	0	0	0	0	0	0	-
Highest Value	20	134	70	98	64	117	102	30	-
Effective Value (P=80 %)	0	0	9	11	5	6	3	0	-

Table II, Seasonal fluctuations of water salinity

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	mean
Water Salinity (ppm)	460	406	423	447	464	380	400	280	306	388	413	436	400
Electrical* Conductivity (mmhos/cm)	.72	.64	.66	.70	.73	.59	.63	.44	.48	.61	.65	.68	.63

* EC (mmhos/cm = Salinity/ppm)/640

Table III, Series of potential evapotranspiration values.

Oct.		Feb.		Jun.	
154	165	72	44	295	273
172	165	61	76	265	276
178	155	67	69	300	287
181	158	59	69	285	276
178	174	60	72	278	264
163	177	62	70	296	291
179	147	68	69	283	284
149	184	64	75	296	300
164	167	65	49	271	258
176	172	67	64	289	270
160	180	77	71	271	290
177	186	68	80	278	287
172	164	68	68	285	264
176	159	74	56	291	278
166	183	75	80	279	270
159	177	65	59	255	286
169	172	63	60	271	298

Table IV, Potential evapotranspiration data

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Reference P.E.T. (mm)	173	112	73	70	78	117	167	242	287	312	298	235	2164
Effective rainfall (mm)	0	0	9	11	5	6	3	0	0	0	0	0	34
P.E.T (mm)	173	112	64	59	73	111	164	242	287	312	298	235	2130

Table V, Consumptive use and total irrigation depth for various crops

Crop	Cropping Percentage	Consumptive Use (mm)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Alfalfa	0.2	140	100	60	40	60	90	160	230	270	245	240	200
Wheat	0.2	0	40	45	65	120	125	45	0	0	0	0	0
Barley	0.2	60	80	70	75	60	20	0	0	0	0	0	0
Berseem	0.2	30	70	70	75	80	105	160	200	0	0	0	0
G. Barley G. Maize	0.2	0	45	60	75	20	0	0	95	260	275	0	0

Table V (continued)

Crop	Cropping Percentage	Total irrigation depth (mm)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Alfalfa	0.2	193	134	81	55	83	119	215	289	345	327	323	273
Wheat	0.2	0	54	88	133	174	165	61	0	0	0	0	0
Barley	0.2	83	108	95	103	83	26	0	0	0	0	0	0
Berseem	0.2	41	94	95	103	111	139	215	251	0	0	0	0
G. Barley G. Maize	0.2	0	61	81	103	28	0	0	119	332	367	0	0

Table VI; Adjustable irrigation depth

Crop	Irrigation Depth (mm)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Alfalfa	240	120	150	150	150	180	240	240	240	290	240	240
Wheat	0	60	90	150	180	150	60	0	0	0	0	0
Barley	90	120	90	120	60	60	0	0	0	0	0	0
Berseem	60	90	90	90	120	150	240	240	0	0	0	0
G Barely & Maize	0	60	90	120	60	60	60	120	240	240	120	0

Table VII, Typical Canal Sections

Type	Max. Discharge (m^3/sec)
b=0.4 , h=0.7m , f=0.5m	0.22
b=0.7 , h=1.0m , f=1.0m	0.60
b=0.7 , h=1.2m , f=1.0m	0.92
b=1.0 , h=1.0m , f=1.5m	0.75
b=1.0 , h=1.2m , f=1.5m	1.12
b=1.0 , h=1.5m , f=1.5m	1.71
b=2.0 , h=1.2m , f=2.0m	1.86
b=2.0 , h=1.5m , f=2.0m	2.73
b=2.0 , h=1.8m , f=2.0m	3.78
b=2.0 , h=2.3m , f=2.0m	6.50
b=2.0 , h=2.5m , f=2.0m	7.50

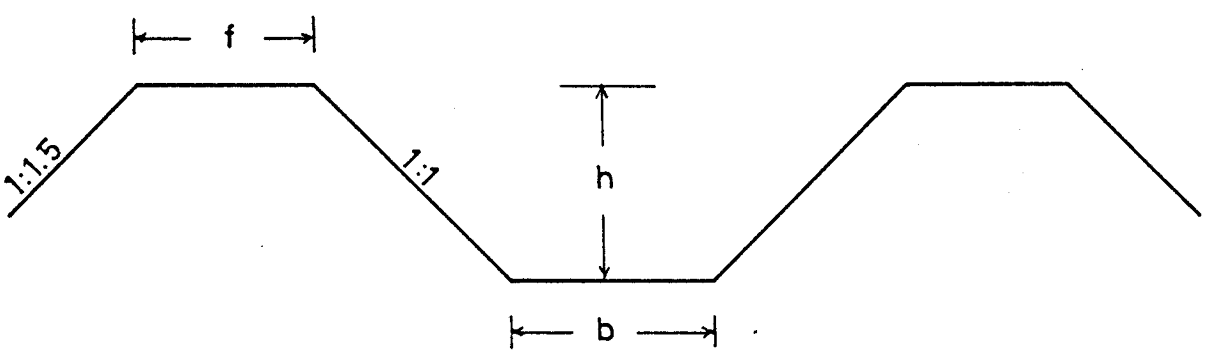

Table VIII, Drainage Criteria

Depth of impermeable layer		= 5m
Depth of drains		= 1.8m
Horizontal hydraulic conductivity,	K_a	= 4.8m/day
	K_b	= 4.3m/day
Depth of water level		= 1.2m

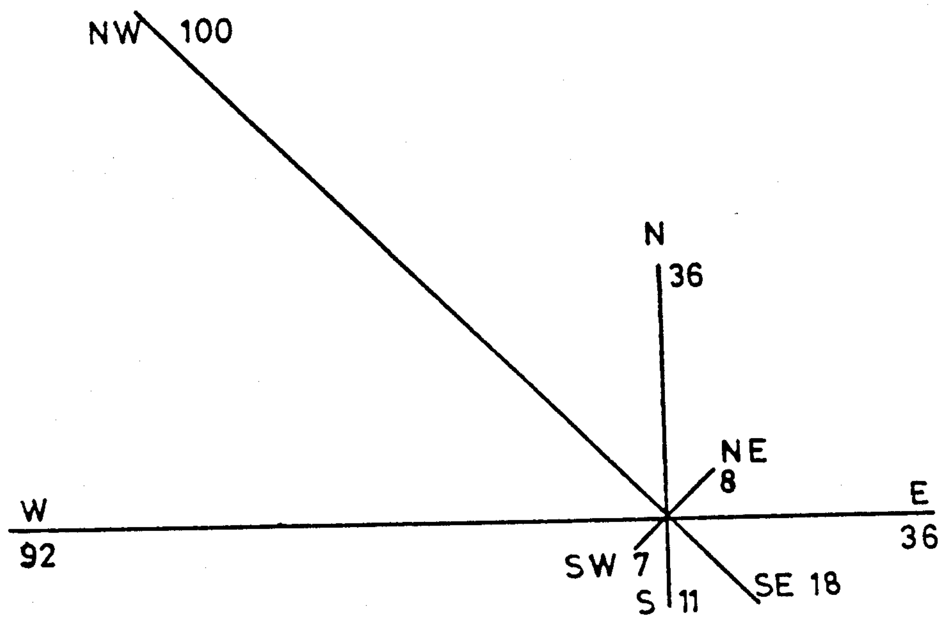

Figure 1 Number of windy days per year for each direction

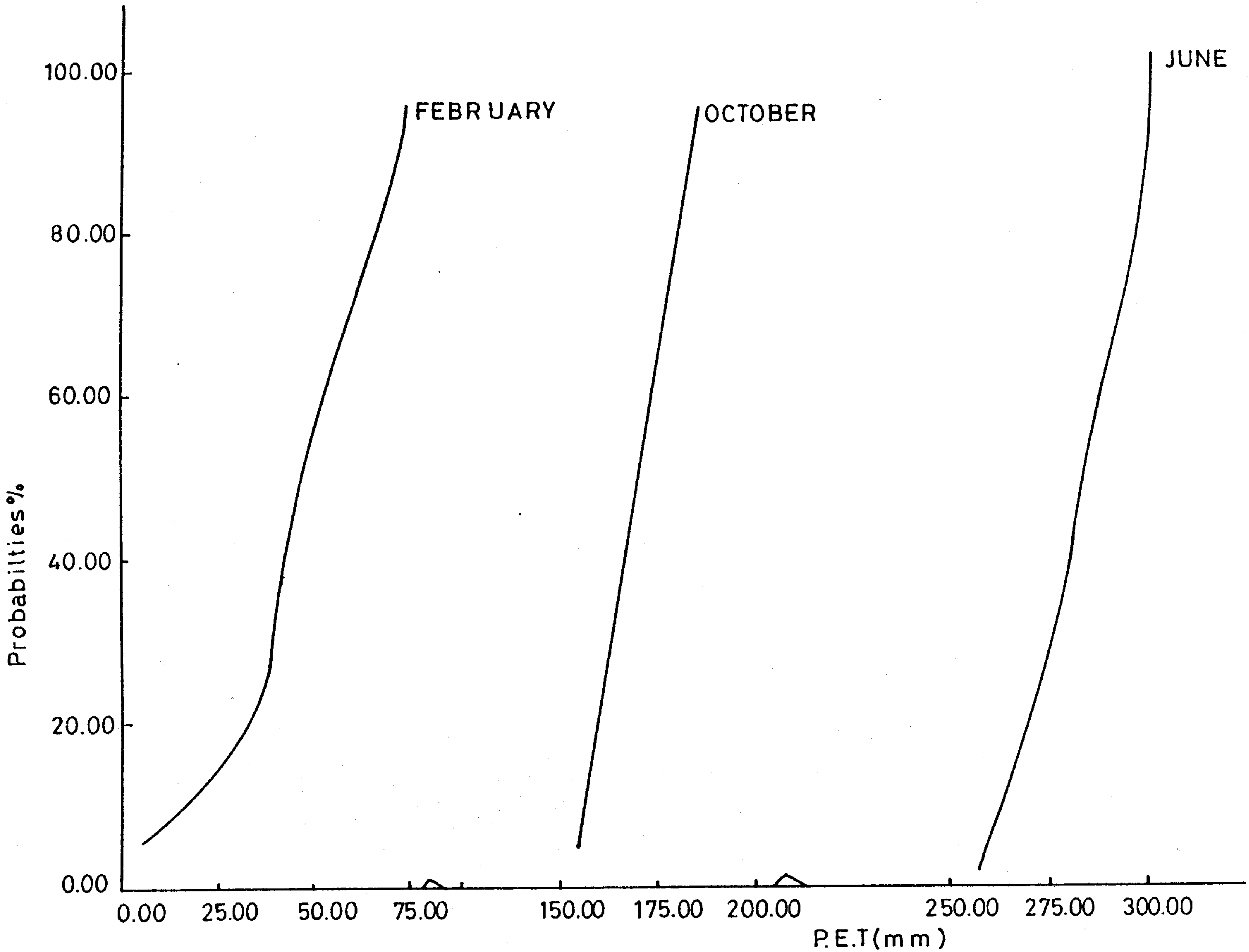

Figure 2 Cumulative probabilities curve for monthly P E T