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DEVELOPMENT OF HYDROLOGICAL DROUGHT INDEX BASED ON DYNAMIC GROUNDWATER STORAGE

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ABSTRACT

The depletion time of the Unicell model, which is a function of transmissibility of the aquifer has been identified as a criteria to hydrological drought indices for dynamic ground water storage. The depletion time not only gives the criteria for drought but also the estimates of the amount of dynamic ground water storage in the aquifer. This report covers the estimation of depletion time and development of drought indices based on the analogy of Unicell model. The developed drought indices has been verified and has also been used for the forecasting of hydrological drought in respect of dynamic ground water storage. The minimum amount of dynamic ground water storage, which will be available at different recurrence interval, has also been estimated for the sites of the Krishna basin.

1. Introduction

Drought is a recurring climatic condition which affects large areas on earth. It is defined as a period of abnormally dry weather that is sufficiently prolonged to cause serious hydrologic imbalance in the affected area (Huschke, 1959). Areas affected by drought can range from a few hundred square kilometers to thousands of square kilometers. The most powerful effect of drought is to reduce agricultural production over a wide area. Other adverse impacts are: reduction in hydropower generation, shortage of drinking water, deterioration in water quality, loss of aquatic lives, and reduction in recreational facilities. Other adverse economic impacts follow these losses.

Drought is the third most geologic hazard in terms of economic losses produced, ranking only behind floods and frost damage (Haas, 1978). Agencies at various levels of engineering organizations have to take action to reduce the effect of droughts. Adjustments to drought relevant for agriculture and for urban areas include the following:

i) Conservation of water; This includes protection of water supply by eliminating leakage and evaporation; alteration of cultivation practice to include strip cropping, minimum tillage and development of wind breaks.

ii) Diversification of crop and live stock and selection of drought-resistant crops;

iii) Development of ground water resources to supplement surface water or existing ground water supplies;

iv) Integration of waste-water reuse into community management;

v) Formulation of priorities among competing demands so that less vital uses can be minimized during drought.

The wise use of ground water resources can play a significant role in reducing the impact of drought in both urban and rural environments. During years of drought, the rate of ground water recharge is usually insufficient to keep pace with withdrawals or discharge to rivers. Ground water potentials of a basin is finite. The rational limit of the rate of ground water exploitation whether during drought or normal period should be such that protection from depletion is provided, protection from pollution is provided, negative ecological effects are reduced to a minimum and economic efficiency of exploitation is attained.

2. General Review on Drought Indices

The uncertainty about drought is reflected in the varied definitions of drought as there are no standard and unified definition of drought. In spite of the lack of a unified definition of drought among the community of hydrologists, meteorologists and agriculturists, all tend to agree, that it is basically a situation of water deficit for given use caused due to occurrence of below normal natural water availability. The impact of drought is felt in the water supply for domestic uses industrial uses, agricultural and fodder production and stream water quality because the occurrence of drought leads to low stream flows and consequent reduction in reservoir levels, depletion of soil moisture and ground water. The study of droughts is extremely relevant and essential aspect of water resources planning in order to meet the increasing demands on available water resources.

Hydrological drought indices are concerned with the effects of rainfall deficiencies in hydrological components such as surface water, ground water and soil moisture. The hydrological drought has been defined by various researchers. Whipple (1966) defined a drought year as one in which the aggregate runoff is less than the long term average runoff. Yevjevich (1967) defined the term hydrologic drought as "the deficiency in water supply or deficiency in precipitation, effective precipitation, runoff or accumulated water in various storage capacities". Linsley et al. (1975) defined hydrologic drought as a "period during which stream flows are inadequate to supply established uses under a given water management system".

Six types of drought have been distinguished based upon variations in the duration, season of year, or severity by Beran and Rodier (1985) mainly relating to agricultural and irrigation needs.

1. A three week to three month runoff deficit during the period of germination and plant growth. This could be catastrophic for farming that is dependent upon irrigation drawn directly from the river without the support of reservoirs.

2. A minimum discharge significantly lower or more prolonged than the normal minimum but not necessarily advanced much in its position relative to the growing season. Because the germination period is not affected this type of drought is of less consequence to agriculture.

3. A significant deficit in the total annual runoff. This

affects hydropower production and irrigation from large reservoirs.

4. A below normal annual low water level of the river. This may introduce the need for pumping for irrigation. This type of drought is related to Type 3- deficit in annual runoff.

5. Drought extending over several consecutive years. Discharge remains below a low threshold or the rivers dry up entirely and remain dry for a very long time.

6. A significant natural depletion of aquifers. This is difficult to quantify because observation of the true level of the aquifer is distributed by the over utilization of ground water during the drought.

The hydrological variables such as stream flow & reservoir levels, ground water and catchment soil moisture can be used to define hydrological drought and develop suitable drought indices. The runoff or stream flow indices have been generally used to define hydrological drought to a limited extent.

2.1. Runoff indices

The hydrological drought is considered to be in progress when the actual flow in a stream for a selected period of time falls below a certain threshold. However, the number of days and the level of probability that must be exceeded to define a hydrologic drought period is arbitrary. These criteria are specific to individual stream or river basins and the period of intended water use demand in that area. A commonly used simplest index is to compare the depth of precipitation and runoff depth or volume for a given duration i.e. week, fortnight, month or a year, with the long term mean or standard period normal value for the given duration. The numerical value of this index will give the drought severity. This could be classified on the basis of probability also. One such scheme as found in Europe is as below (cited from Beran & Rodier, 1985).

Drought Intensity	Exceedable frequency between
Very wet	0 and 15%
Wet	15 and 35%
Normal	35 and 65%
Dry	65 and 85%
Very dry	85 and 100%

Normally 80 and 100% exceedable frequency is considered in order to develop a regional drought summary based upon a number of flow records.

The Central Water Commission (1982) while studying drought in 99 districts of the country considered hydrological drought as a situation when annual runoff for the year under consideration is less than 75% of the normal annual runoff. If there are 25 such years in the area, the area is termed as drought prone. This runoff reduction ultimately results in lowering of water levels in reservoirs, tanks and streams causing situation of water deficiency for the user in the area.

Although the Palmer drought severity index (PDSI) is basically an index of meteorological drought, but because of its ability to reflect long term moisture, runoff, recharge and evapotranspiration it is used in the USA to get an idea about the long term status of water supplies in aquifers, reservoirs and streams. Therefore, it is sometimes used as a measure of hydrological drought also. George et al. (1973) while studying drought in India using PDSI, indicated that in humid and moist sub-humid areas it may represent hydrological drought.

2.2. Surface water supply index (SWSI)

The SWSI number is a general indicator of basin wise surface water supply conditions which integrates historical data with current data of reservoir storage, stream flow and precipitation at high elevation into a single index number (Dezman, 1982). It generates monthly numerical values that express the current and future availability of water supplies to meet a multitude of competitive demands with an objective that water supply condition can be assessed to compare drought severity.

A composite reservoir datum, snowpack datum and precipitation datum is found by summing monthly station data. Frequency analysis is carried out for each component of discharge to find non exceedable probability (PN). As each component is reduced to one scale, comparisons among them becomes simple. Non exceedable probability analysis takes into account dispersion tendency also.

SWSI can be found by using following weighing equation :

$$SWSI = \frac{[(a*PN_{SforSP}) + (b*PM_{PCP}) + (c*PN_{RS})] - 50}{12}$$

where; a,b,c are weights for each component, a+b+c+ = 1 and S_{forSP}, PCP, RS = stream flow or snowpack, precipitation and reservoir components. For each basin winter & summer a, b & c values are unique.

Now drought can be classified on the basis of SWSI values as shown below;

SWSI	DESIGNATION
+4	Abundant supply
+2	Near normal
-1	Drought water availability task force activated
-2	Moderate drought
-3	Severe drought
-4	Extreme drought

The weightages a, b & c are based on components impact on water availability of the region. This index is used by Colorado State Government. They decide final weightages on the hypothesis that the additive nature of the components cause the SWSI to be normally distributed. The chi-square statistic is used to optimize goodness of fit for trial component weights.

The SWSI index shows drought severity and not duration of drought. This duration will involve gradient component in index. This step will refine the index.

2.3. Based on catchment soil water deficit

Since soil moisture status of a catchment affects infiltration and runoff, the catchment soil water deficit could also be considered an indicator of hydrological drought. Cordery (1981 & 1983) made use of probabilistic forecasting of soil water deficit (SWD) as a measure of forecasting hydrological drought. A monthly water balance model was developed to estimate soil water deficit (the difference between the actual water storage and the maximum storage that can be sustained i.e. field capacity). Drought was assumed to occur when there is a large value of SWD i.e. soil is very dry. The SWD of -100 mm of water is required to bring the soil to a state of zero deficit.

2.4. Based on ground water levels

The common approach to study hydrological drought using ground water data is to construct well hydrographs superimposed with rainfall data using long term historical record. The correct assessment of draft is one of the main problems in judging the impact of drought on ground water. Like other drought indices giving some numerical numbers, there appears to be no such attempts made in this direction to develop indices based on ground water levels.

3. General Review on Well Hydrographs

3.1. Well hydrograph approach

Ground water, which is a renewable resource, is temporarily depleted when aquifers are over pumped. Aquifer storage is commonly described as temporary or permanent. The former refers to water stored between the highest and lowest levels of the water table and thus subject to seasonal drainage, which, averaged over a long period, itself provides a measure of the average recharge. However, below the minimum level of the water table in major aquifers lies a great volume of saturated soil that provides permanent storage available to wells of adequate depth but which can not be drained naturally. A good management practice during drought period demands adequate information on how much water is in dynamic storage and how much in static and how these volumes vary with time.

Several methods are used to present water-level data. The most common are well hydrograph, and water-level contour maps. From the study of water level hydrographs at a number of observation well, the water table fluctuation in a basin could be computed. The water table fluctuation can be used to calculate changes in quantity of ground water in storage as well as to determine recharge of the aquifer or leakage from it to underlying aquifers (Hydrological Maps, Unesco W.M.O.-1977).

The visual examination of hydrographs presenting the record of several years may yield the following indications (Mandel land Shiftan, 1981):

i) Water levels fluctuating around a constant mean indicate a state of hydraulic equilibrium that is usually associated with a stable hydrologic situation. However, the mere existence of a hydraulic equilibrium does not provide guarantee against the eventual influx of low-quality water.

ii) Decreasing mean water levels associated with a constant or decreasing amplitude of yearly oscillation suggest diminished natural replenishment, which may be caused by drought years, by changes of surface cover (e.g., urbanization), or by the diversion of river flow from the area.

iii) Decreasing mean water levels accompanied by increasing yearly oscillation are the result of intensified ground water abstraction.

These indications do not prove the existence of a certain situation. They provide only hints and have to be corroborated in each case by additional lines of evidence.

3.2. Evaluation of change in ground water storage

The change in ground water storage in a basin during a certain time period can be computed from the water table fluctuation exhibited in the basin during the time period. The simplest way to show water-table fluctuations is to show water-table position at two or more different times on separate maps. This is an effective method, particularly when the maps can be shown on the same page or sheet. A second method is to show contours of the water table at two or more different times by different line patterns, or by lines of different colour, on the same map.

The extent of the fluctuations can be shown by isolines derived from two or more sets of water-table elevations. Such maps are particularly useful in areas where lowering of water table is excessive or is considered to be potentially so.

Using the elevation themselves, the change in water level can be determined by subtracting the water level at each data point at the end of the time period from the water level at the beginning of the time period. The resultant changes in water table position can then be contoured.

The change in storage in a ground water basin, ΔS, during a time period (t) can be computed using the relation;

$$\Delta S = \sum_{i=1}^{N} \Delta h_i \; A_i \; S_{y\,i} \qquad \text{----(1)}$$

in which;

$S_{y\,i}$ = specific yield of the aquifer in the area A_i;
Δh_i = water level change in the i^{th} observation well;
A_i = the area of i^{th} polygon which is the weightage of water level observation in the i^{th} observation well; water level changes are weighted by drawing a Thiessen polygon around each observation well.
N = total number of observation wells.

3.3. Trend analysis

The main objective of studying hydrologic time series is to understand the mechanism that generates the data so that the future sequences may be simulated or to forecast the future events over a short period of time. These are attempted by making inferences regarding the underlying laws of the stochastic process from the historical data and then by postulating a model that fits the data which can in turn be used for simulating or forecasting the future values. It is therefore necessary to identify the various components of the hydrologic time series and its characteristics.

In general, a time series can be divided into two components, viz., deterministic and stochastic. Deterministic components are those which can be determined by predictive means, where as the stochastic component consists of chance dependent events. Hydrologic time series has both these components. The deterministic components are the trend and the cycles. The stochastic component is due to erratic atmospheric circulation.

The trend may be loosely defined as 'long term change in the mean'. A difficulty with this definition is deciding what is meant by 'long term'. For example, climatic variable sometimes exhibits cyclic variation over a very long time period of about 50 years or so. If the data of only about 20 years are available, then the long term cyclic variation would appear to be a trend. On the other hand if the data of say 200 years are available, even the long term cyclic variation would be clearly visible. Nevertheless for all practical purposes of analysis of short term data, it may still be more meaningful to think of such long term oscillation as trend. The existence of trend in hydrological series may be due to low frequency oscillatory movement induced by climatic changes or through changes in land use and catchment characteristics. Trend analysis is generally done on annual series and not on seasonal series so as to suppress the effect of periodic component. The primary objective of ground water analysis when drought condition prevails in an area is determination of reliable aquifer yield. There are two basic approaches to the establishment of such information. The first is based upon a water balance equation which requires the identification of the various elements of the hydrologic cycle as they affect a particular system and subsequent quantification of those elements. The second approach is based upon analytical techniques which simulate ground water behaviour as it is known to conform to various physical laws. The two approaches are complementary and neither one can be regarded as a suitable substitute for the other.

The application of time-series techniques to ground water problems is a logical extension of the water balance approach, allowing a water balance equation to become dynamic and thus simulate a ground water system in time (Houston, 1983). A system model essentially consists of input which is acted upon by a transfer function in order to produce output. The input data may be represented by recharge and discharge and the output by water table data. The transfer function of a system model is estimated a posterior by statistical techniques which produce a minimum error. In this the systems model differs basically from analytical or numerical models which are based upon physical laws established a priori.

3.4. Depletion curve analysis

The dynamic storage of the ground water system can be estimated by using a unicell model and by the record of river discharge on weekly or monthly basis.

Assuming that there is no pumping and replenishment after the monsoon is over, the equation of continuing for natural drainage will be as follows (Mandel, S; 1981);

The change in storage in an aquifer is given by;

$$dS/dt = -Q(t) \qquad \text{----(2)}$$

$$S(t) = t_o \ Q(t)$$

$$dS(t)/dt = t_o \ (dQ(t)/dt)$$

$$t_o \ (dQ(t)/dt) = -Q(t)$$

$$dQ(t)/dt + (1/t_o) \ Q(t) = 0. \qquad \text{----(3)}$$

Solution of equation (3) can be given by equation (4).

$$Q(t) = A \ e^{(-t/t_o)} \qquad \text{----(4)}$$

At any time (t=0) the equation (4) yields $A=Q_o$. The value of constant is replaced in equation (4). Equation 5 can be used to estimate the dynamic ground water storage at any time t.

$$Q(t) = Q_o \ e^{(-t/t_o)} \qquad \text{----(5)}$$

The total value of dynamic storage may thus be given by;

$$Q(t) \int_0^{\alpha} Q(t) \ dt = \int_0^{\alpha} Q_o \quad e^{-(t/t_o)}$$

$$Q(t) \quad = \quad Q_o \ \frac{e^{-(t/to)}}{-(1/t_o)} \Bigg|_0^{\alpha}$$

$$Q(t) = Q_o \ t_o \qquad \text{----(6)}$$

For estimating the total volume of dynamic ground water storage {Q(t)} at any time (t), the value of depletion time (t_o) is required. The dynamic ground water storage Q(t) can be estimated by using the equation (5) as reported above;

On simplifying and taking the log, the equation 5 reduces to equation 7 as reported below;

$$\text{Log } Q(t) = \text{Log } Q_o - (t/2.3 \ t_o) \qquad \text{----(7)}$$

The graphical representation of the equation (7) and the recession curve for one log cycle is presented in Figure 1. The analogy can be used to estimate the depletion time by plotting the stream flow on a semi-log graph as shown in Fig. 1.

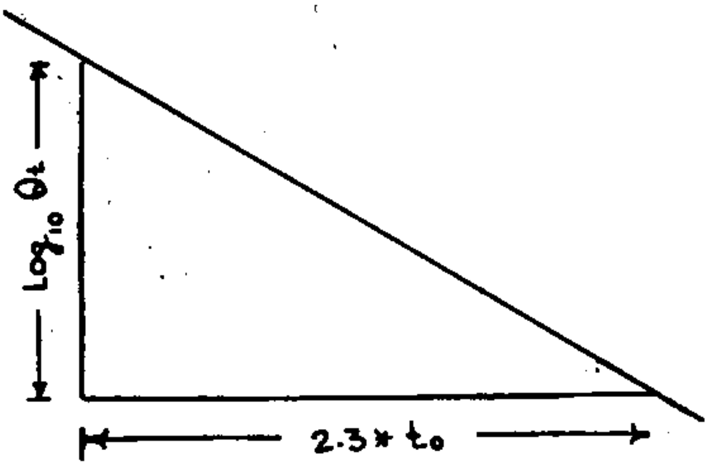

Fig. 1: Depletion time analysis from discharge versus time graph.

The slope of the plot of Log Q(t) against time (t) will estimate the value of $2.3*t_o$, which finally yields the value of depletion time (t_o).

4. General Description of Krishna basin

Krishna basin lies between 13° 30' to 18° 44' N latitude to 73° 12' to 81° 36' 10" E longitude, covering parts of Maharashtra, Karnataka and Andhra Pradesh State (Fig. 2). The climate of the basin is characterized by a hot summer and general dryness during the major part of the year except during South-west monsoon. The rainy season generally commences in the month of June and lasts till October or so, with the withdrawal of the monsoon by about the first week of October the day temperature increases slightly. However, the night temperatures decrease steadily with the day after the withdrawal of monsoon.

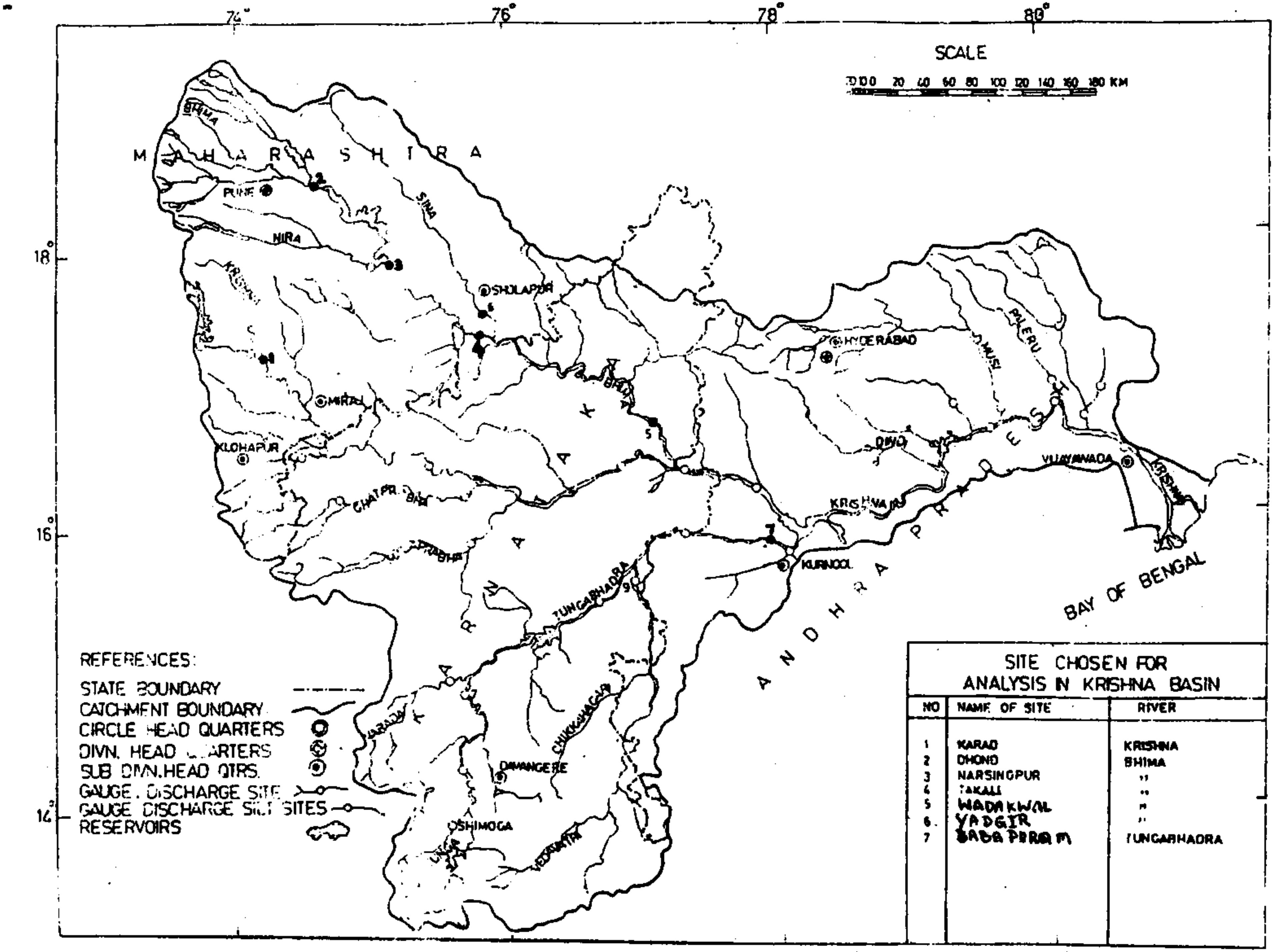

Fig. 2: Krishna basin and the gauging sites.

The Krishna basin comes under the influence of southwest monsoon and this season lasts over the basin till the end of September. Rainfall of about 564.88 mm which forms 72.08 percent of the total annual rainfall in the basin is received during the southwest monsoon season. The basin also received some rainfall during northeast monsoon season and estimates indicate that about 17.64% of total annual rainfall over the basin is received during northeast monsoon season. Evapotranspiration losses in the basin vary between 90 mm to 220 mm from winter to summer months. The details of sites chosen for the study are given in Table 1.

Table 1 : Details of sites chosen for study in Krishna basin.

Sl.No.	Name of Site	Dist.	State	Stream	Catchment area (Km^2)
1.	Karad	Satara	Maharashtra	Krishna	5462
2.	Dhond	Poona	- do -	Bhima	11,660
3.	Narsingpur	Sholapur	- do -	- do -	22,865
4.	Takali	- do -	- do -	- do -	33,916
5.	Wadakwal	Sholapur	Maharashtra	- do -	12,092
6.	Yadgir	Gulbarga	Karnataka	- do -	69,863
7.	Bawapuram	Kurnool	Andhra-Pradesh	Tunga-bhadra	67,180

4.1 Departure analysis of Krishna basin

There are many simple drought indices that can be used to see immediate effect of drought on stream flow. In the following section departure analysis of stream flow data for the selected sites of Krishna river basins was carried out as per the criteria given by C.W.C. The percent departure for annual stream flow at seven sites of the Krishna basin are reported in Table 2.

A commonly used index to see the effects of drought on stream flow is to compare the runoff depth or volume for a given duration i.e. fortnight, month or a year with long term mean or standard period normal value for the same duration. It has been suggested that if the runoff is found to be less than 75% of normal runoff at a site, the year would be considered as drought year and if it occurs in 25 or more than 25% of years, then the area would be considered as drought prone. Drought is classified as severe drought and moderate drought depending upon percentage departure of runoff volumes as given below (C.W.C., 1982) :

Percentage departure 50% - Severe drought
Percentage departure 25-50% - Moderate drought

On viewing the Table 2 as per the C.W.C. criteria, we find that the moderate and severe drought occur at all the sites.

These sites are highlighted by the notations * and $ respectively in the table.

Table 2: Departure analysis of annual stream flow (20 years average flow) for drought estimation based on C.W.C. criteria.

Year	Name of Site						
	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
	1	2	3	4	5	6	7
77-78	5.8	-5.1	1.2	-16.3	-37.6*	-16.3	-36.1*
78-79	18.8	10.6	1.5	14.6	-11.8	14.6	109.9
79-80	9.4	25.5	17.8	23.9	25.7	23.9	-32.0*
80-81	25.1	20.7	22.8	-18.2	-13.2	-18.2	60.3
81-82	-12.3	-40.2*	30.3	27.2	-44.5*	27.2	22.9
82-83	-36.4*	11.7	-56.0$	-58.6$	-86.4$	-58.6$	-10.8
83-84	-17.9	-11.7	10.9	44.8	156.6	44.8	-14.5
84-85	-18.1	-51.1$	-15.3	-26.5*	-44.4*	-26.5*	-29.9*
85-86	-34.4*	-39.4*	-57.3$	-62.3$	-80.1$	-62.3$	-77.3$

Source: Hydrological aspects of drought.(CS-37)

* : Moderate drought, 25 - 50 percent departure
$: Severe drought, above 50 percent departure

4.2 Depletion time ($2.3*t_o$) analysis

To estimate the value of depletion time, the monthly river flow data of Krishna basin at seven sights (Fig.2) from June '77 to May '86 has been subjected to depletion curve analysis. The depletion time analysis has been carried out with the analogy of unicell model as explained in section 2.4. The monthly stream flow data of nine years was plotted on semi-log for all seven sites. The data used for plotting the graphs are reported in Appendix - I. The results have been plotted in Figure 3 to Figure 9 and the estimated value of $2.3*t_o$ have been reported for years 1977 to 1985 in Table 3.

From the analysis we find that the value of $2.3*t_o$ varies in between 0.2 to 2.9 in the Krishna basin. The minimum and the maximum values at sites Karad, Dhond, Narsinghpur, Takali, Wadakwal, Yadgir, Bawapuram are respectively 1.0 to 1.75, 0.8 to 1.8, 0.3 to 2.2, 0.3 to 1.9, 0.2 to 1.5, 0.9 to 2.9 and 0.4 to 2.2. This variation is only because, the t_o is dependent on the transmissibility values of the unconfined aquifer. Since the transmissibility values changes with the boundary conditions and the saturated thickness of the aquifer, the variation in t_o is observed.

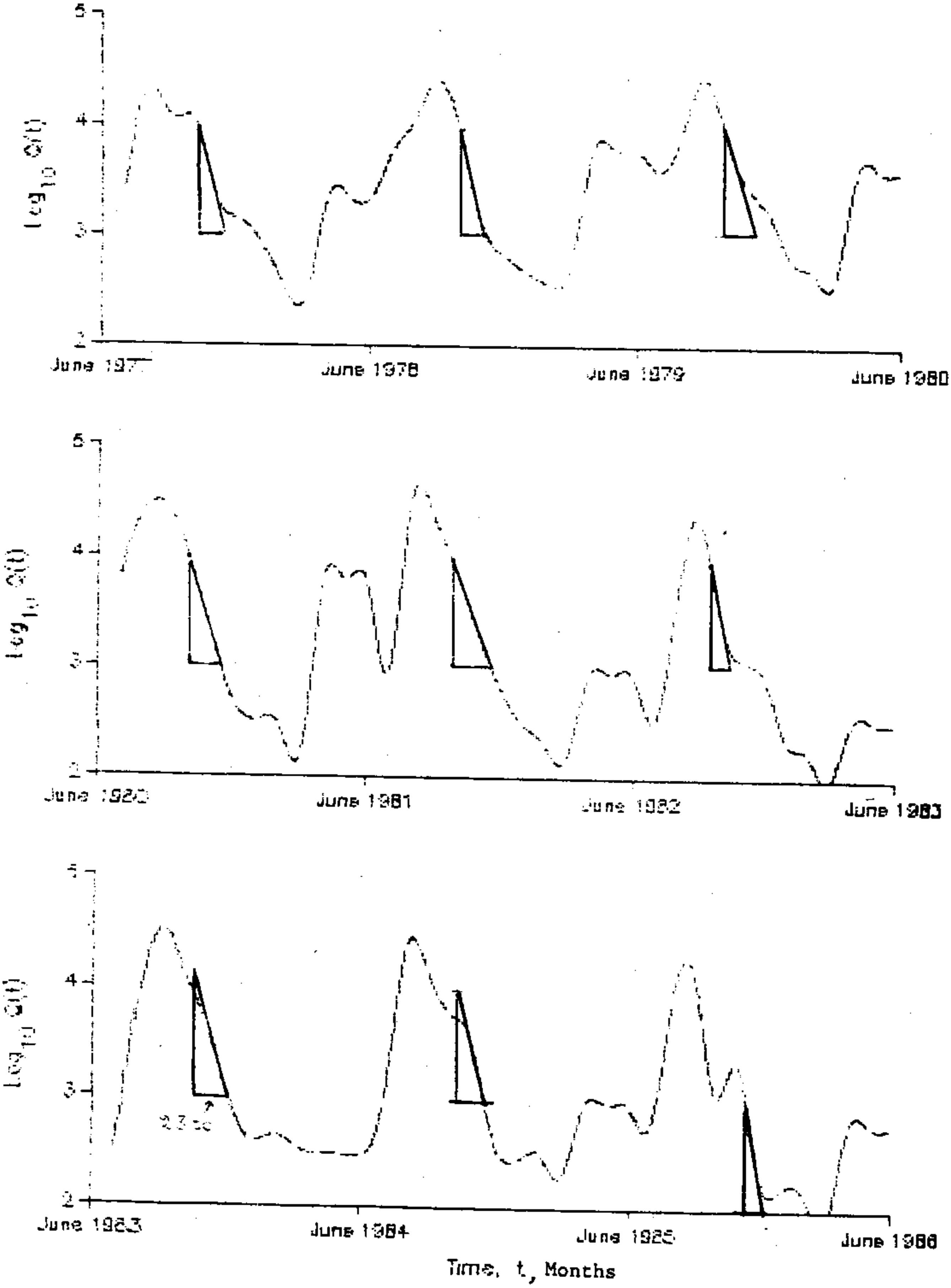

Fig. 3: Interpretation of depletion time for gauge site Karad.

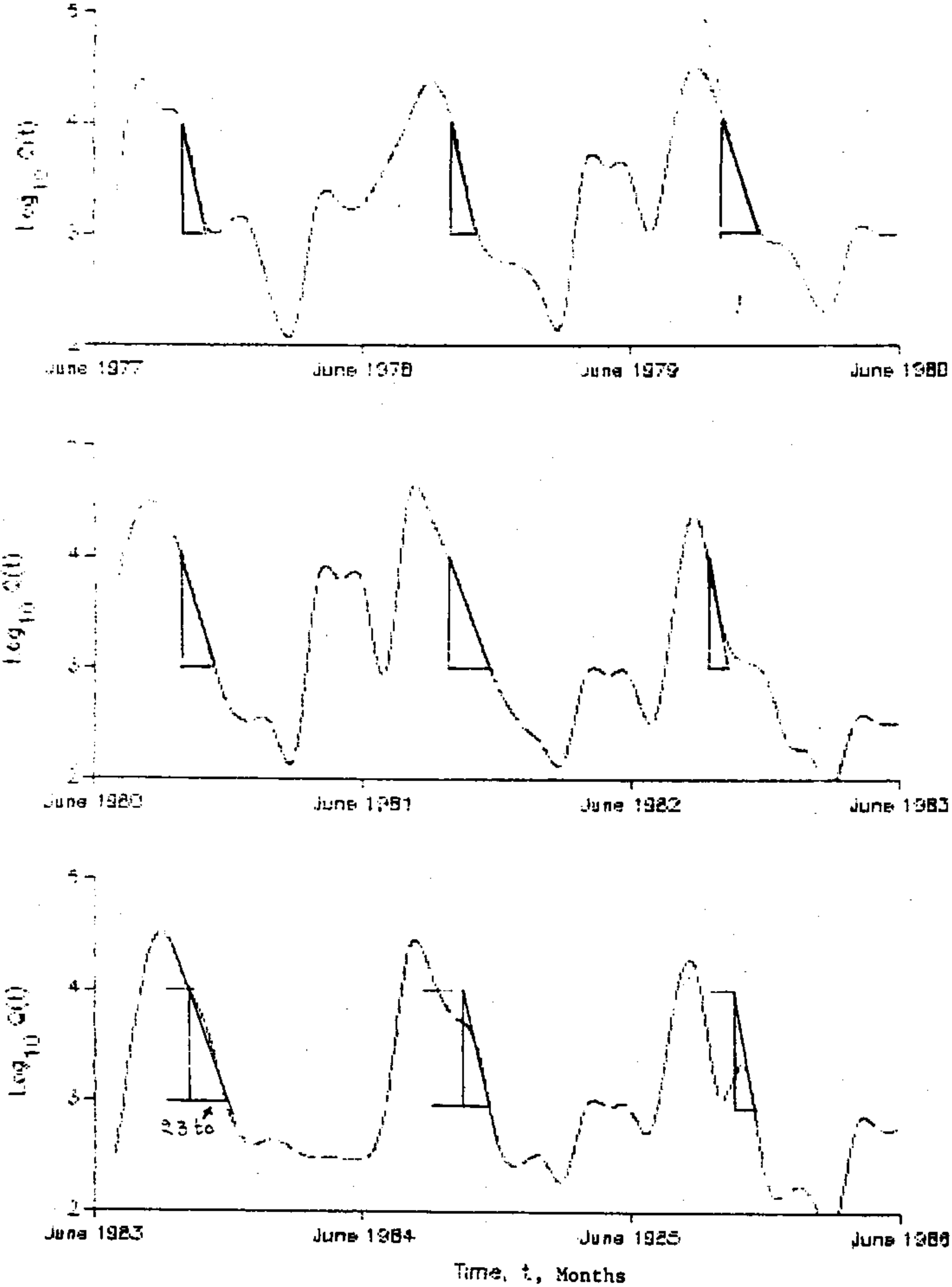

Fig. 1: Interpretation of depletion time for gauge site Dhond.

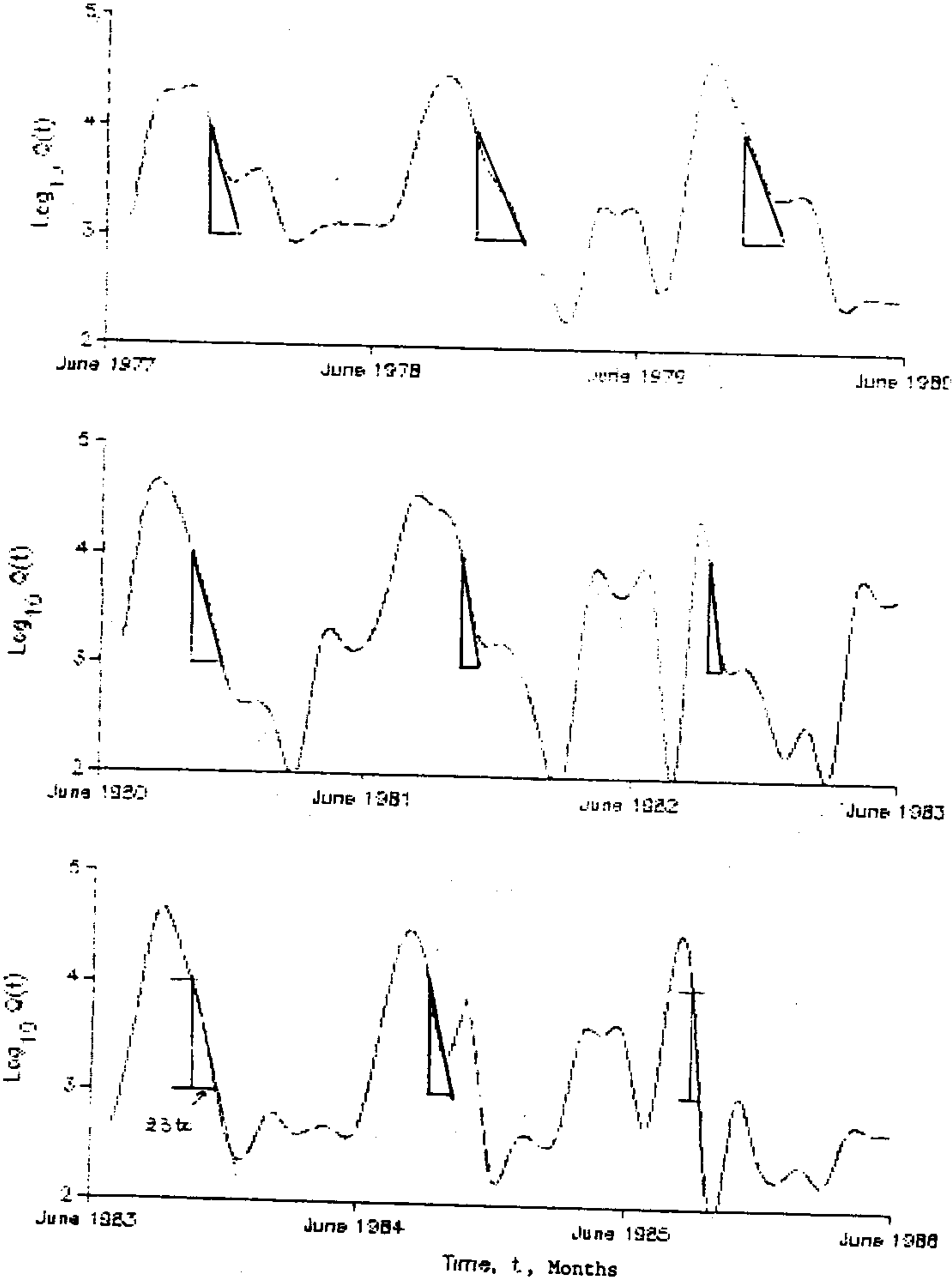

Fig. 5: Interpretation of depletion time for gauge sit Narsinghpur.

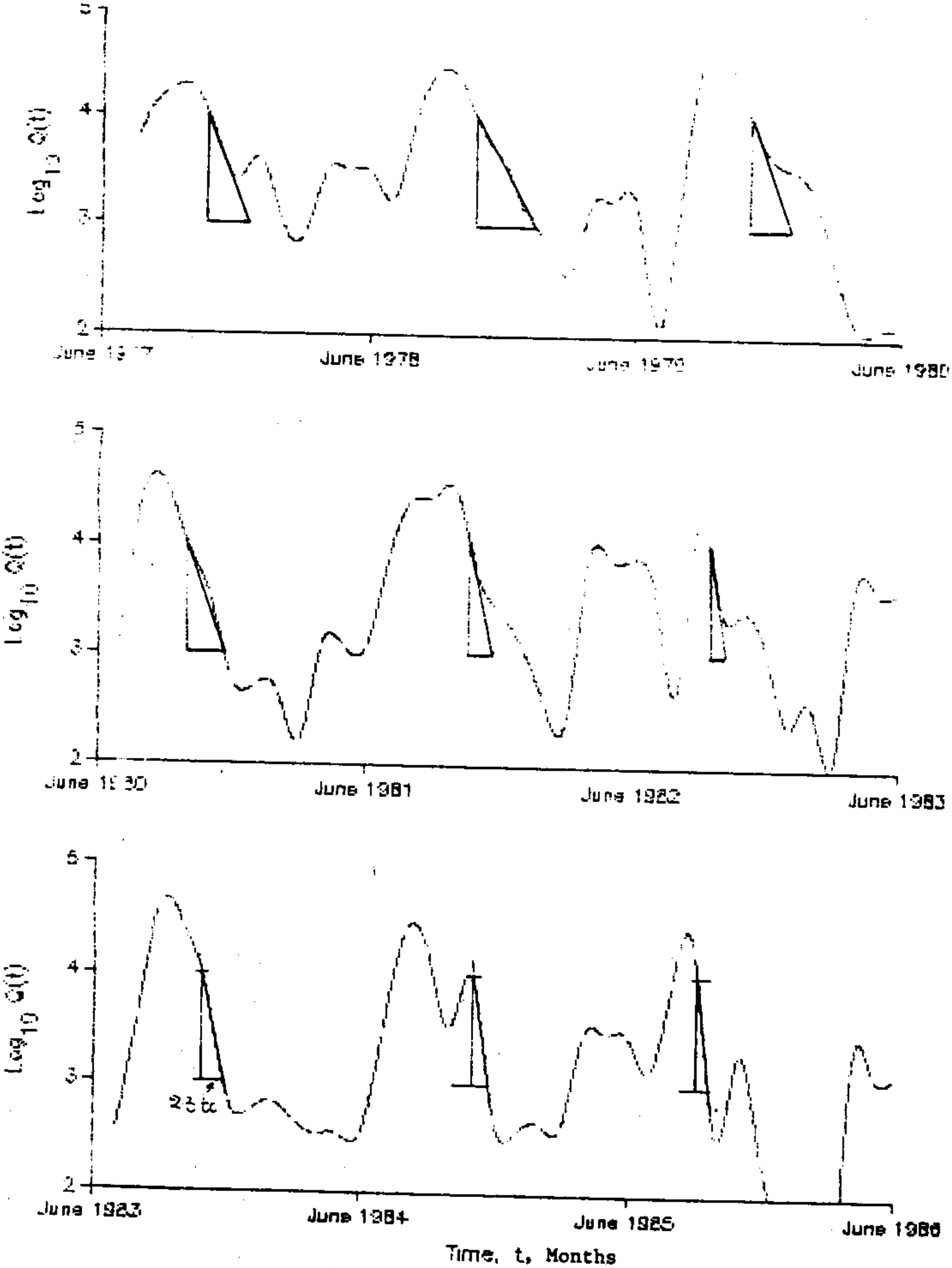

Fig. 6: Interpretation of depletion time for gauge site Takali.

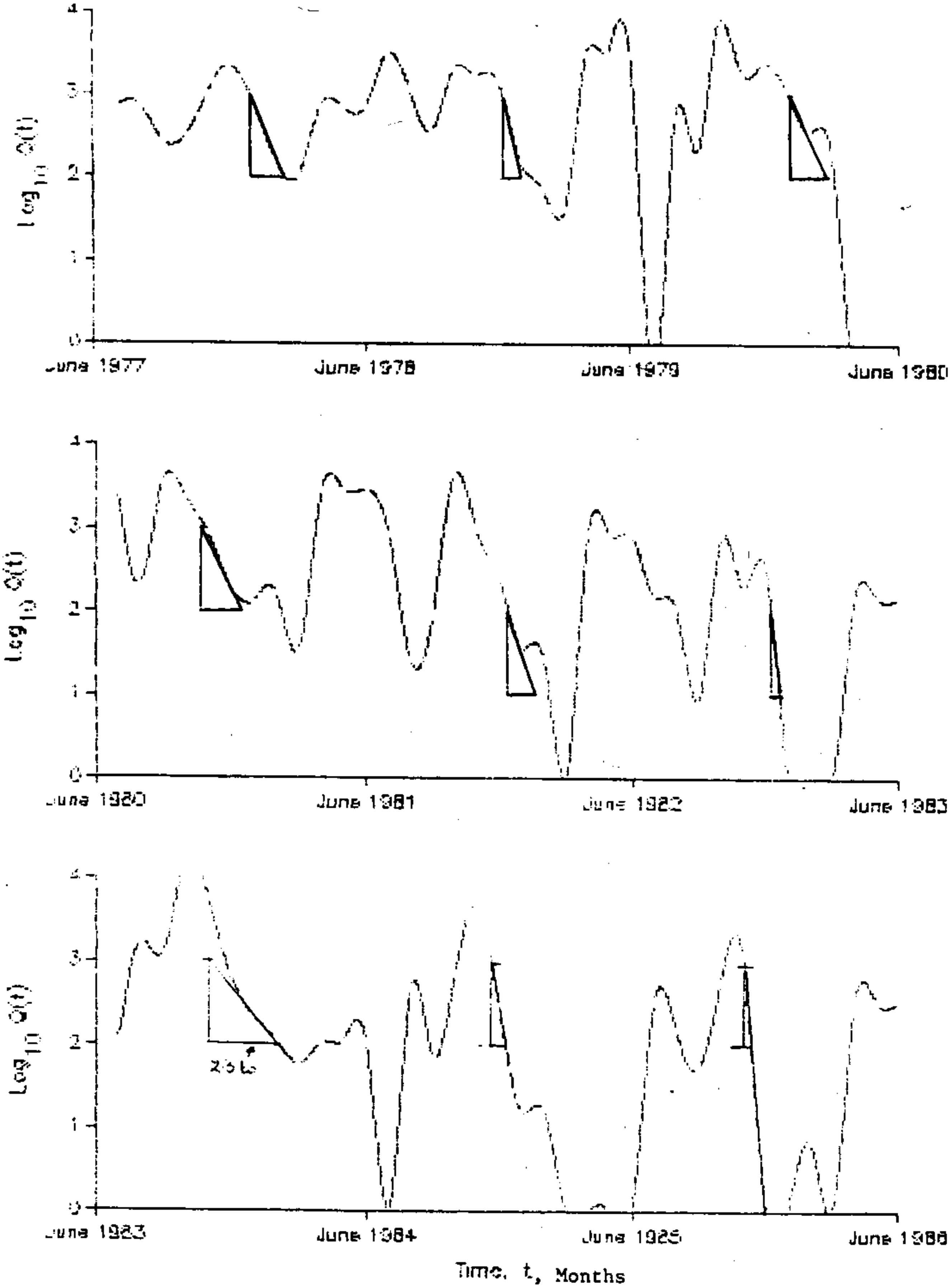

Fig. 7: Interpretation of depletion time for gauge site Wadakwal.

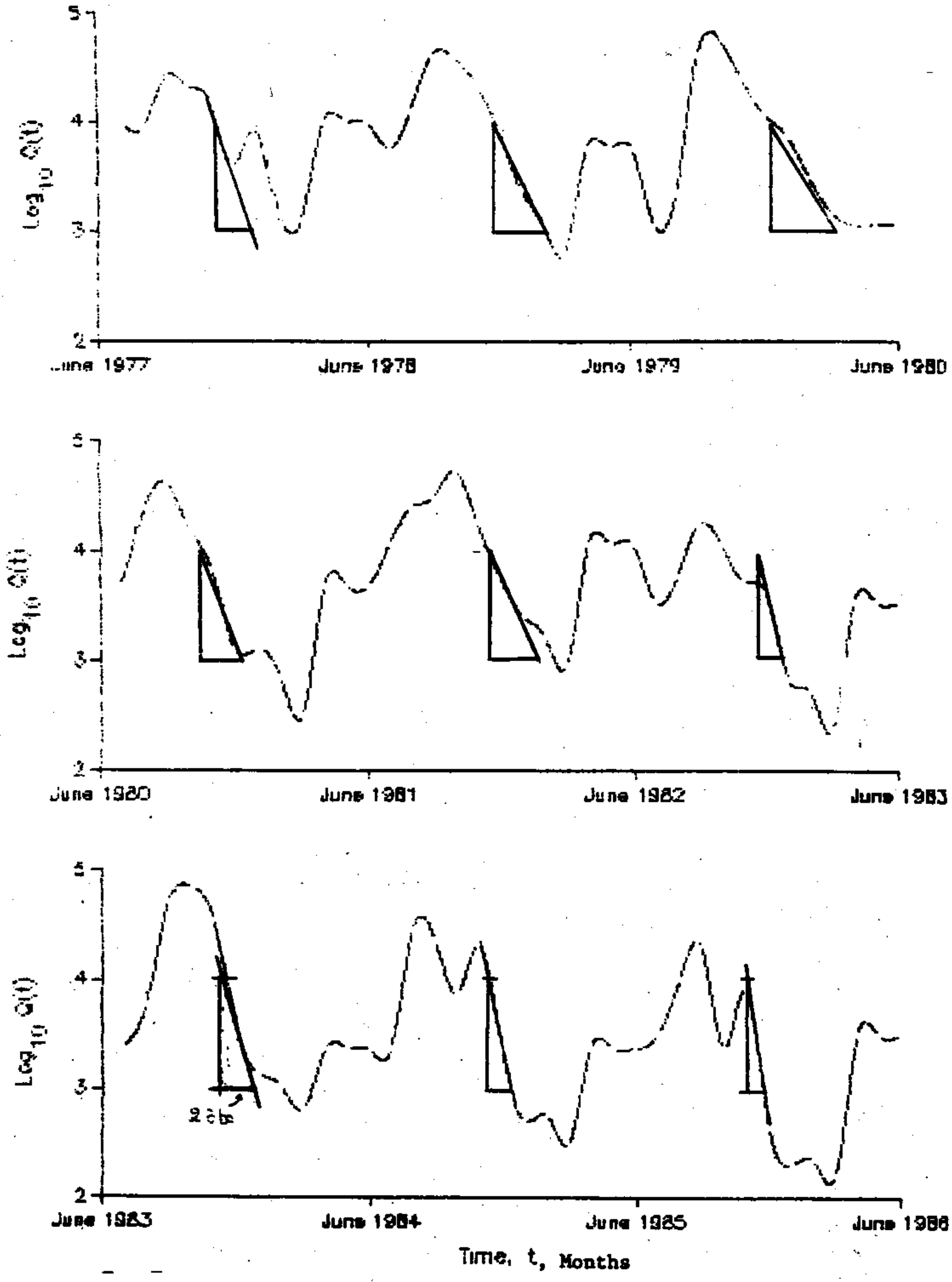

Fig. 8: Interpretation of depletion time for gauge site Yadgir.

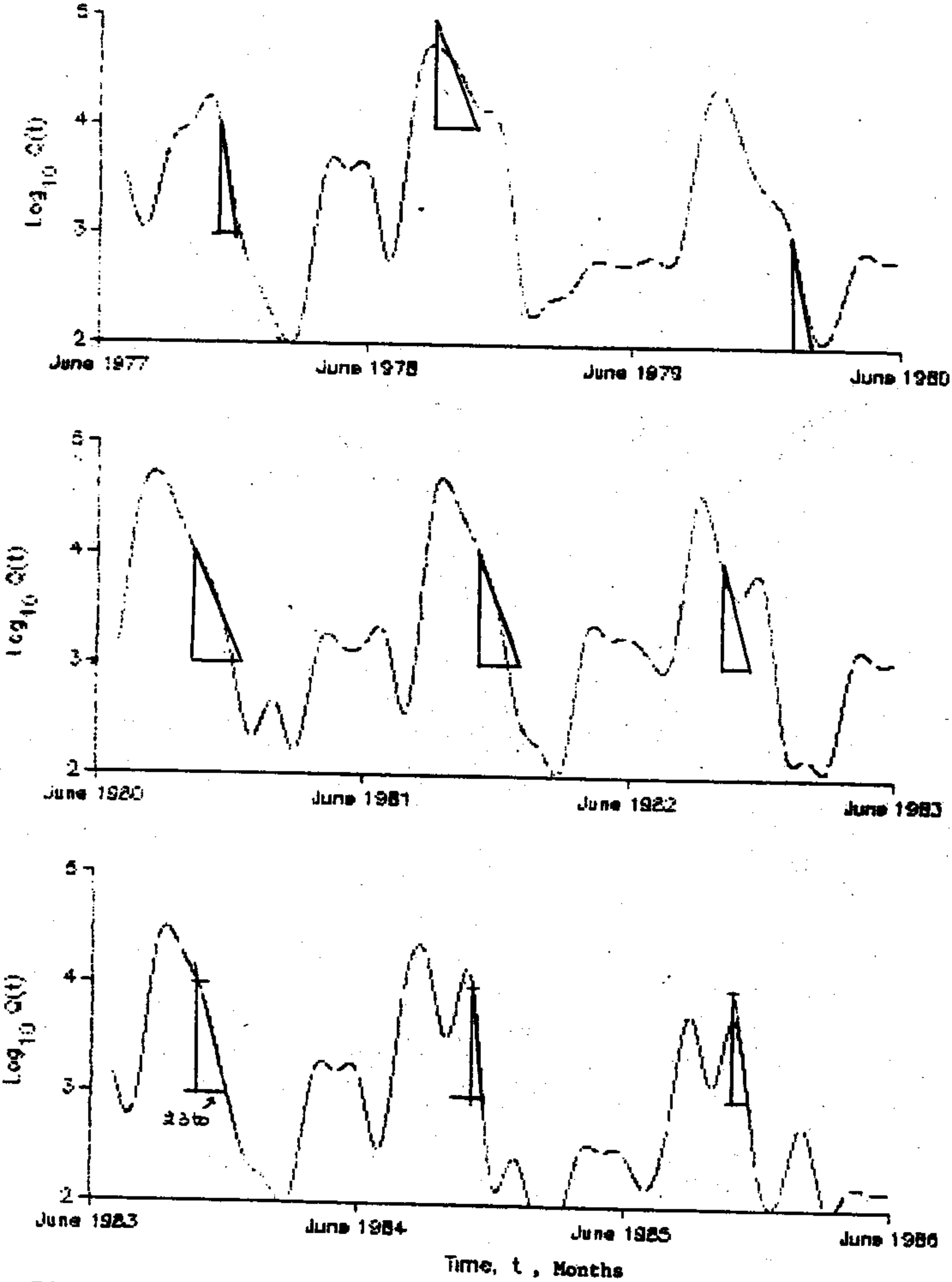

Fig. 9: Interpretation of depletion time for gauge site Bawapuram.

Table 3: Estimated value of depletion time ($2.3*t_o$), months.

Year	Name of Site						
	Karad 1	Dhond 2	Narsi-nghpur 3	Takali 4	Wada-kwal 5	Yadgir 6	Bawa-puram 7
77-78	1.37	1.1*	1.5	1.9	1.5	1.5	0.6*
78-79	1.37	1.2	2.2	2.8	0.9	2.3	2.0
79-80	1.5	1.6	2.0	2.0	1.7	2.9	0.8*
80-81	1.5	1.5	1.5	1.6	1.9	2.0	2.2
81-82	1.75	2.0	0.9	1.1	1.4	2.2	2.0
82-83	1.5	0.8$^{\$}$	0.5$^{\$}$	0.5$^{\$}$	0.2$^{\$}$	0.9$^{\$}$	1.2
83-84	1.5	1.8	1.1	1.0	3.0	1.6	1.2
84-85	1.3	1.2	0.9*	0.8*	0.4*	1.1*	0.4$^{\$}$
85-86	1.0$^{\$}$	1.0*	0.3$^{\$}$	0.3$^{\$}$	0.2$^{\$}$	0.9$^{\$}$	0.4$^{\$}$

$*$: Moderate drought: $2.3 x t_o < Mean-SD/2$
$\$$: Severe drought: $2.3 x t_o < Mean-SD$

On comparing the results of Table 2 and Table 3, we find that the values of $2.3*t_o$ does not increase with positive increase in percent departure. It may be because the dynamic ground water storage does not exactly correlate with the increase in monthly stream flow only because the process of infiltration plays an important role for the volume of dynamic ground water storage. It is, therefore, the drought indices for dynamic ground water storage developed based on river discharge may not exactly correlate with the drought identified by river flow, but to some extent a comparison can be done.

4.3. Drought indices for dynamic ground water storage.

To develop a drought indices, for dynamic ground water storage, the mean of $2.3*t_o$ for a duration of nine years was chosen as base line. On the basis of this base line, the moderate and severe drought indices were developed.

A moderate drought, as for as the dynamic ground water storage is concerned, is defined as the value of $2.3*t_o$ less than mean-SD/2. When the value of $2.3*t_o$ falls below mean-SD it is classified as severe drought.

In Table 4, the values for mean, standard deviation along with mean-SD/2 and mean-SD are reported. Based on the criteria defined above, the moderate and severe drought on seven sites of Krishna basin are identified and indicated in Table 2 by notations * and $\$$ respectively. Since, this drought identification is site specific, the generalization of the values is not possible and needs further analysis to relate depletion time with the catchment and aquifer characteristics.

Table 4: Drought indices for dynamic ground water storage based on depletion time ($2.3*t_o$).

Year	Name of Site						
	Karad	Dhond	Narsi-nghpur	Takali	Wada-kwal	Yadgir	Bawa-puram
	1	2	3	4	5	6	7
Mean	1.44	1.35	1.21	1.33	1.24	1.71	1.20
SD	0.19	0.37	0.60	0.76	0.87	0.65	0.67
Mean-SD/2	1.34	1.16	0.91	0.95	0.80	1.39	0.86
Mean-SD	1.25	0.98	0.61	0.57	0.37	1.06	0.53

4.4 Discharge analysis of Krishna basin by unicell model

The model can be used to have several information of the basin. The required parameters to have this information are the depletion time and the discharge of a month in the river during its recession. The information which could be obtained from this model are as follows;

1. The total dynamic ground water storage at any time t.
2. The dynamic ground water storage at any time t, t+1 and further.
3. Aquifer replenishment between the end of dry season and the beginning of next one.

4.4.1. Estimation of total dynamic ground water storage and dynamic ground water storage in subsequent months.

The total dynamic ground water storage in the month of October and the dynamic ground water storage in the month of October and following months are estimated using the programme listed in Appendix II.

The programme uses equations 5 and 6 respectively for dynamic ground water storage and total dynamic ground water storage using the river flow of the month of October. The results obtained from this programme are reported in Table 5 for the respective years.

4.4.2. Estimation of dynamic ground water storage corresponding to drought indices.

The dynamic ground water storage of October has been related to drought indices listed in Table 4 in order to estimate the minimum quantity of dynamic ground water storage, in the month of October, below which a moderate and a severe drought could be

Table 5: Total dynamic ground water storage (cumec x 10^6) and dynamic ground water storage (cumec x 10^6) in the aquifer at sites listed in the table.

Year	Name of Site						
	Karad 1	Dhond 2	Narsinghpur 3	Takali 4	Wadakwal 5	Yadgir 6	Bawapuram 7
Total dynamic ground water storage in October;							
77-78	3289.7	1686.5	6981.5	13410.9	1694.2	25910.3	11129.6
78-79	2128.2	1787.7	11850.6	23512.1	1859.7	60490.5	32733.4
79-80	4804.7	5577.6	18460.0	27942.2	3565.5	79906.9	5284.5
80-81	1881.6	3305.1	4087.5	6186.0	1915.5	15770.6	14730.5
81-82	3868.0	5228.4	2124.4	7152.3	1492.4	45570.6	28154.1
82-83	2187.4	1093.7	647.9	1518.6	41.7	5405.1	6034.2
83-84	2697.4	9615.4	5317.1	8981.3	20112.1	66108.7	10833.3
84-85	3235.5	4643.6	5765.5	9447.8	2295.8	26801.8	6276.2
85-86	2535.1	2582.3	307.9	715.4	277.1	8611.7	2555.8
Dynamic ground water storage in October;							
77-78	1585.4	679.5	3584.4	7922.8	869.8	13302.8	2102.1
78-79	1025.7	776.9	7522.0	16450.8	612.2	39161.9	19853.8
79-80	2466.8	2985.5	11196.6	16947.8	1980.0	56601.4	1514.0
80-81	966.1	1696.9	2098.6	3311.1	1131.7	9565.4	9350.0
81-82	2184.3	3171.2	699.3	2881.6	730.6	28925.3	17076.3
82-83	1123.1	313.3	87.7	205.5	.3	1779.3	2622.4
83-84	1384.9	5516.9	2142.2	3304.0	14411.0	35385.4	4708.1
84-85	1499.3	2018.1	1898.0	2706.8	188.5	10798.2	515.2
85-86	932.6	950.0	11.0	25.5	1.9	2834.9	209.8
Dynamic ground water storage in November;							
77-78	764.1	273.8	1840.3	4680.6	446.6	6829.9	397.0
78-79	494.3	337.6	4774.5	11510.2	201.5	25353.6	12041.9
79-80	1266.5	1598.0	6791.1	10279.4	1099.5	40093.2	433.8
80-81	496.0	871.2	1077.4	1772.3	668.6	5801.7	5934.8
81-82	1233.5	1923.4	230.2	1161.0	357.7	18360.0	10357.3
82-83	576.6	89.8	11.9	27.8	.0	585.7	1139.7
83-84	711.0	3165.3	863.1	1215.5	10325.9	18940.5	2046.1
84-85	694.7	877.1	624.8	775.5	15.5	4350.5	42.3
85-86	343.1	349.5	.4	.9	.0	933.2	17.2
Dynamic ground water storage in December;							
77-78	368.2	110.3	944.8	2765.2	229.3	3506.6	75.0
78-79	238.2	146.7	3030.5	8053.3	66.3	16414.1	7303.8
79-80	650.2	855.4	4119.0	6234.8	610.6	28399.7	124.3
80-81	254.6	447.3	553.2	948.7	395.0	3518.9	3767.0
81-82	696.6	1166.6	75.8	467.7	175.1	11653.7	6282.0
82-83	296.0	25.7	1.6	3.8	.0	192.8	495.3
83-84	365.1	1816.1	347.7	447.2	7398.8	10138.1	889.2
84-85	321.9	381.2	205.7	222.2	1.3	1752.8	3.5
85-86	126.2	128.6	.0	.0	.0	307.2	1.4

suggested. The relationship between the estimated dynamic ground water storage and $2.3*t_o$ for the month of October has been developed for all seven sites of Krishna basin. These relationships are being reported as follows;

No	Site	Equations	Correlation coefficient
1	Karad	$Q_{oct.} = -513 + 1361 * (2.3*t_o)$	0.73
2	Dhond	$Q_{oct.} = -2735 + 3502 * (2.3*t_o)$	0.83
3	Narsinghpur	$Q_{oct.} = -2898 + 5075 * (2.3*t_o)$	0.86
4	Takali	$Q_{oct.} = -3612 + 7189 * (2.3*t_o)$	0.89
5	Wadakwal	$Q_{oct.} = -171 + 839 * (2.3*t_o)$	0.87
6	Yadgir	$Q_{oct.} = -18260 + 23552 * (2.3*t_o)$	0.86
7	Bawapuram	$Q_{oct.} = -4280 + 8933 * (2.3*t_o)$	0.86

Above relationships have been incorporated in the programme listed in Appendix II in order to estimated the minimum quantity of dynamic ground water storage below which a drought could be said. The interpolated dynamic ground water storage for the month of October is reported in Table 6. These values are only for the month of October. For the subsequent months, the relationships could be developed and the minimum quantity can be estimated.

Table 6: Minimum amount of dynamic ground water storage (cumec x 10^6) in the month of October for identification of drought.

	Name of Site						
	Karad 1	Dhond 2	Narsi-nghpur 3	Takali 4	Wada-kwal 5	Yadgir 6	Bawa-puram 7
At Mean	(No drought)						
	1446.8	1992.7	3242.8	5949.4	869.4	22013.9	6439.6
At Mean-SD/2	(Moderate drought)						
	1310.7	1292.3	1720.3	3217.5	500.2	14477.3	3402.4
At Mean-SD	(Severe drought)						
	1188.3	697.0	197.8	485.7	139.4	6705.1	454.5

5. Drought forecasting

The drought forecasting for dynamic ground water storage can only be done when the direct runoff due to rainfall is over. In Krishna basin rainfall is generally in the months of June, July, August, september and some times in the month of October. The district monthly average rainfall of thirteen districts are reported in Appendix III.

The forecasting of drought could be done in following two ways.

1. By developing the relationship between cumulative rainfall and $2.3*t_o$ for the rainfall months. These relationships could be used to estimate the values of $2.3*t_o$. Further by comparing the estimated values with the established index, the drought could be forecasted.

2. By knowing the measured river flow in the month of October and estimating the total amount of d. .aic ground water storage in the month of October. The total a unt of dynamic ground water storage could be compared with the minimum amount of dynamic ground water storage listed in Table 6 for identification of drought and cross checking of the forecast done by the procedure as listed in serial number one.

5.1. Estimation of weighted rainfall

The weighted rainfall of each sub-catchment of the Krishna basin under consideration is estimated from the record of District monthly average rainfall as listed in Appendix III. A programme was developed to estimate the weighted rainfall for each month for the seven sub-catchments of the Krishna basin Appendix IV. The programme also calculates the cumulative rainfall for the months of June+July, June+July+August, June+July+August+September, June+July+August+September+October. The results are reported in Table 7.

Table 7: Cumulative rainfall (mm) for the months of June+July, June+July+August, June+July+August+September, and June+July+August+September+October for the sites listed below.

Year	Name of Site						
	Karad 1	Dhond 2	Narsi-nghpur 3	Takali 4	Wada-kwal 5	Yadgir 6	Bawa-puram 7
For the month ending June+July,							
1977	197.1	368.0	324.4	255.4	197.7	79.6	74.1
1978	111.8	158.2	148.4	136.7	144.0	92.8	125.3
1979	186.1	166.1	152.0	118.6	102.6	28.2	60.5
1980	186.1	166.3	152.2	120.7	101.3	28.7	91.1
1981	237.2	239.1	219.1	174.2	137.1	56.2	84.8
1982	121.8	117.6	114.9	111.2	147.1	79.9	104.3
1983	146.3	148.7	147.2	138.2	149.4	135.2	92.6
1984	240.6	193.8	193.1	180.8	198.2	148.1	166.1
1985	157.4	135.7	129.1	112.4	106.0	58.9	106.3
1986	100.3	76.2	72.2	62.9	65.1	23.7	54.9
1987	165.4	83.8	87.8	84.5	82.5	59.1	27.1
1988	342.6	127.0	135.4	124.5	147.3	35.7	99.7
1989	243.1	193.7	195.5	187.5	207.0	174.6	174.0

Contd.

1990	221.3	183.8	172.5	143.6	121.2	51.3	57.5
1991	250.0	151.8	151.9	139.0	140.9	82.5	76.2
For the month ending June+July+August							
1977	275.3	449.8	403.7	331.1	306.6	137.1	186.8
1978	264.3	266.7	259.0	249.4	295.9	176.1	217.1
1979	301.8	276.2	252.2	204.8	174.5	48.0	150.5
1980	301.8	275.3	251.2	202.8	233.3	45.3	183.8
1981	391.5	345.6	327.6	280.4	264.9	134.8	189.8
1982	295.5	225.3	219.6	199.3	224.2	113.6	162.6
1983	364.3	374.4	359.2	319.0	344.7	239.2	232.6
1984	347.3	265.2	265.5	250.8	262.8	193.7	196.7
1985	305.5	213.1	208.1	186.9	176.5	93.1	156.9
1986	245.0	178.3	173.4	155.8	178.8	80.9	141.3
1987	298.6	216.1	224.9	229.7	254.8	222.0	176.4
1988	472.5	175.3	194.0	199.1	286.2	104.1	266.2
1989	360.1	277.3	281.0	266.1	276.4	250.3	216.7
1990	409.8	345.2	338.8	309.4	310.7	230.1	144.0
1991	399.1	245.5	243.7	220.2	215.7	118.1	149.5
For the month ending June+July+August+September							
1977	316.7	531.3	479.4	399.6	373.3	194.2	256.1
1978	364.2	358.6	359.3	375.3	480.3	317.2	401.7
1979	394.0	379.6	345.8	309.9	362.6	79.3	374.3
1980	394.0	385.4	351.6	287.7	342.8	96.0	296.0
1981	579.7	505.4	507.5	512.3	573.9	444.7	474.0
1982	390.4	342.8	340.3	329.8	384.3	272.5	292.6
1983	498.2	580.1	572.0	535.0	603.3	577.9	434.2
1984	462.9	374.9	376.9	365.5	391.7	311.4	371.2
1985	373.5	267.4	265.9	249.7	256.5	170.4	230.6
1986	326.1	267.8	269.2	263.9	291.2	228.6	277.8
1987	380.8	263.8	278.1	296.0	338.7	287.4	278.3
1988	647.1	315.5	334.3	344.7	469.4	201.9	399.8
1989	546.0	451.0	464.8	470.2	493.1	497.7	380.2
1990	522.4	394.0	395.9	370.0	397.0	306.8	207.3
1991	443.9	300.6	298.5	278.4	276.9	177.1	241.6
For the month ending June+July+August+September+October							
1977	386.0	590.0	533.7	451.4	461.9	209.0	382.4
1978	423.1	413.6	410.4	421.1	531.1	341.0	479.1
1979	450.3	427.3	389.2	349.7	400.3	79.9	429.8
1980	450.3	433.2	395.1	322.0	365.5	96.6	321.3
1981	625.2	537.9	537.5	541.0	625.0	444.7	567.6
1982	426.6	378.7	372.4	361.2	430.7	272.5	399.8
1983	521.4	598.9	589.2	552.0	651.2	577.9	518.2
1984	552.7	450.6	445.8	425.7	461.8	311.4	478.4
1985	446.2	333.1	325.2	301.3	334.9	170.4	308.0
1986	335.1	272.4	274.0	270.8	307.6	232.2	325.1
1987	522.2	365.5	388.6	419.3	461.3	427.0	430.7
1988	653.2	327.6	345.0	357.9	480.3	204.4	414.9
1989	560.2	497.9	506.7	504.7	523.5	523.1	404.1
1990	623.7	568.1	568.1	537.0	555.5	526.6	311.6
1991	482.4	325.9	326.3	313.2	312.3	216.5	307.4

5.1.1. Relationship between 2.3*t_o versus cumulative rainfall

In order to forecast the drought, the depletion time has been related to the cumulative rainfall for the months of June+July+August, June+July+August+September, and June+July+August+September+October for all seven sites of Krishna basin. The observed relationships along with the coefficient of correlation and the degree of freedom is reported in Table 8.

Table 8: Relationships between 2.3*t_o and cumulative rainfall.

Relationship	Correlation coefficient	Degree of freedom
With the cumulative rainfall of June+July+August		
August+September+October.		
$2.3*t_{o1} = 0.76238+0.002348 * RF_1$	.87	5
$2.3*t_{o2} = -0.4853+0.0066832 * RF_2$	.90	6
$2.3*t_{o3} = -0.24291+0.004128 * RF_3$	.67	5
$2.3*t_{o4} = -0.54402+0.0089967 * RF_4$	.51	4
$2.3*t_{o5} = -2.2598+0.013077 * RF_5$	.71	6
$2.3*t_{o6} = 0.60423+0.0038353 * RF_6$	.69	3
$2.3*t_{o7} = -2.3543+0.01986 * RF_7$	.72	4
With the cumulative rainfall of June+July+August+September		
$2.3*t_{o1} = 0.96469+0.0012724 * RF_1$	.89	5
$2.3*t_{o2} = 0.022418+0.0034189 * RF_2$	.82	6
$2.3*t_{o3} = -0.06741+0.0021524 * RF_3$	.51	5
$2.3*t_{o4} = -2.062+0.011 * RF_4$	.64	4
$2.3*t_{o5} = -1.2091+0.005538 * RF_5$	.68	6
$2.3*t_{o6} = 0.71698+0.0019776 * RF_6$	.61	4
$2.3*t_{o7} = -0.74183+0.0054365 * RF_7$	.79	5
With the cumulative rainfall of June+July+August +September+ October		
$2.3*t_{o1} = 0.82118+0.0014444 * RF_1$	.92	5
$2.3*t_{o2} = -0.39671+0.0039945 * RF_2$	.83	6
$2.3*t_{o3} = -0.20838+0.0025417 * RF_3$	.55	5
$2.3*t_{o4} = -2.3436+0.010496 * RF_4$	.64	4
$2.3*t_{o5} = -1.6981+0.0058727 * RF_5$	.67	6
$2.3*t_{o6} = 0.68561+0.0020577 * RF_6$	.63	4
$2.3*t_{o7} = -1.4674+0.0059878 * RF_7$	.83	5

RF: Is the cumulative rainfall, mm.
Suffix: 1 to 7 represents the respective gauge site.

5.1.2. Verification of the estimates of 2.3*t_o.

In order to verify the estimates of 2.3*t_o, the measured and the estimated values are reported in Table 9. The measured values for years 1986 to 1988 are obtained from the stream flow versus time graph reported in Figures 10 to 12. The estimated values are those obtained using the cumulative rainfall at the end of August, at the end of September and at the end of October.

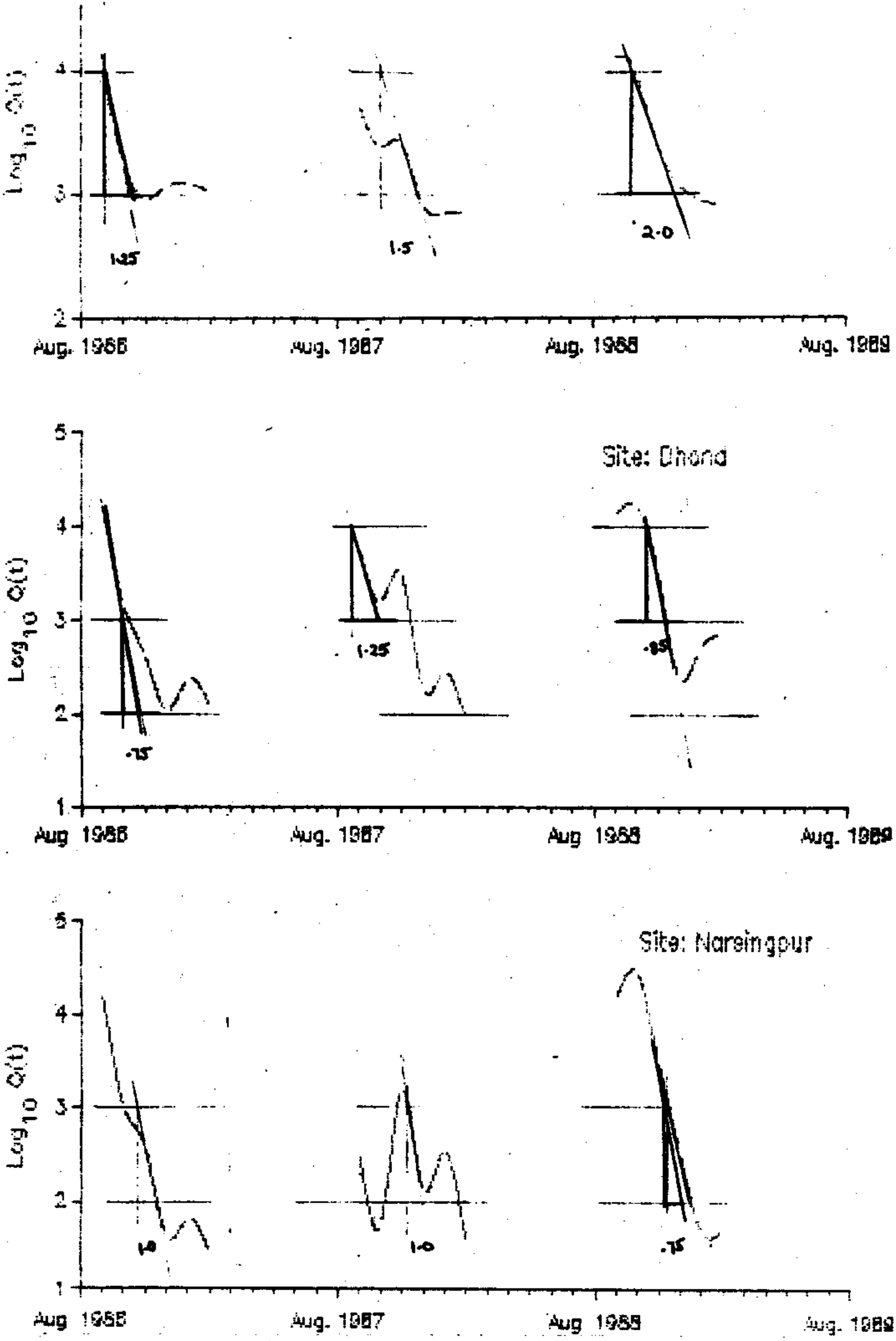

Fig. 10: Estimation of depletion time for Karad, Dhond and Narsinghpur.

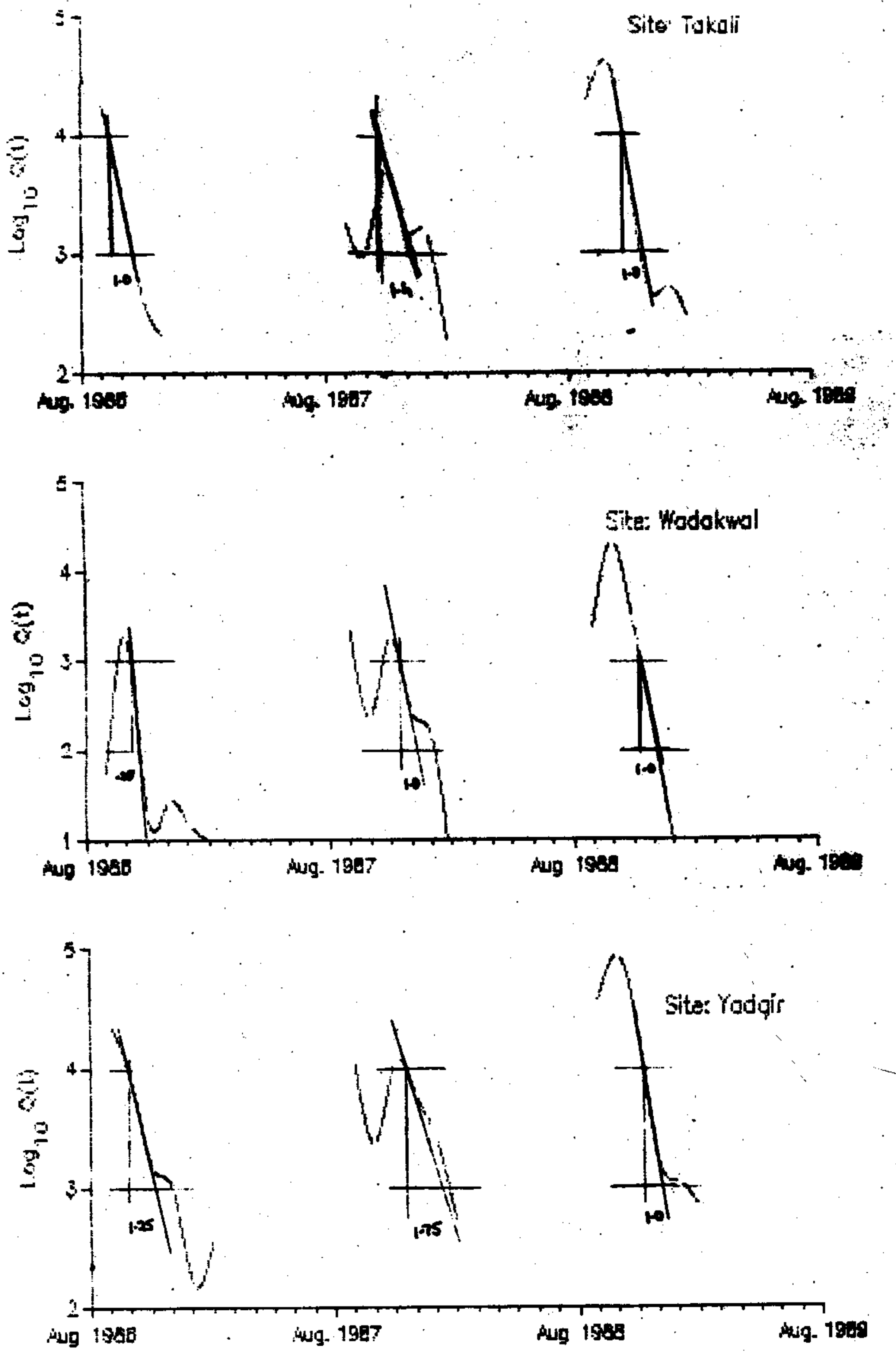

Fig. 11: Estimation of depletion time for Takali, Wadakwal and Yadgir.

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For these estimates the programme listed in Appendix-V has been used.

Table 9: Measured and estimated values of $2.3*t_o$ for years 1986 to 1988.

Sl. No.	Name of site	Year	Measured value	Estimates Ist	Estimates IInd	Estimates IIIrd	Percent error Ist	Percent error IInd	Percent error IIIrd
1.	Karad	1986	1.25	1.3	1.4	1.3	-4	-12	-4
		1987	1.50	1.5	1.4	1.6	0	7	-7
		1988	2.00	1.9	1.8	1.8	5	10	10
2.	Dhond	1986	0.75	0.7	0.9	0.7	7	-20	7
		1987	1.25	1.0	0.9	1.1	20	28	-9
		1988	0.85	0.7	1.1	0.9	18	-29	-6
3.	Narsinghpur	1986	1.00	0.5	0.5	0.5	50	50	50
		1987	1.00	0.7	0.5	0.8	30	50	20
		1988	0.75	0.6	0.7	0.7	20	7	7
4.	Takali	1986	1.00	0.9	0.8	0.5	10	20	50
		1987	1.40	1.5	1.2	2.1	7	14	50
		1988	1.00	1.2	1.7	1.4	-20	-70	-40
5.	Wadakwal	1986	0.20	0.1	0.4	0.1	50	-100	50
		1987	1.00	1.1	0.7	1.0	-10	30	0
		1988	1.00	1.5	1.4	1.1	-50	-40	-10
6.	Yadgir	1986	1.25	0.9	1.2	1.2	28	4	4
		1987	1.75	1.5	1.3	1.6	14	26	9
		1988	1.00	1.0	1.1	1.1	0	-10	-10
7.	Bawapuram	1986	0.70	0.5	0.8	0.5	28	-14	28
		1987	1.00	1.1	0.8	1.1	-10	20	-10
		1988	0.90	2.9	1.4	1.0	222	-55	-11

The percentage error for the three successive estimates at the end of August, September and October has been observed varying in between -55 to 50 leaving the exceptions of 222%, 100% and -70%. On considering the percentage error of the final estimates made at the end of October, we find that all the stations except Narsinghpur and Takali maches well.

5.1.3. Statistical analysis of measured $2.3*t_o$.

The statistical analysis of the depletion time for the duration of 1977 to 1988 has been carried out. The skewness of the data in Table 10 is not close to zero, this indicates that the data / distribution is not close to a normal. The positive values of skewness indicates that the distribution is skewed to the right and the best fitting of the normal distribution is not possible. Also the coefficient of Kurtosis not close to a value of 3.1 suggests the data / distribution is not close to a normal.

In order to bring the data close to a best fit normal distribution, the power and log transformation has been applied to the data. For the original value of Z, the transformed ZT is given by;

For power transformation:

$$ZT = \frac{Z^{\lambda} - 1}{1 * g^{\lambda - 1}} \qquad \text{for } 1>0.0 \qquad \text{----(8)}$$

For log transformation:

$$ZT = \log Z \qquad \text{----(9)}$$

Where; λ is the strength of transformation and g is the geometric mean of Z. The strength of the transformation and the statistical estimates of the transformed data / distribution is reported in Table 11. We find that the skewness of the transformed data has reduced and is closer to a value of zero. The value of Kurtosis has also approached to close to a value of 3.1. It implies that the transformation of data has brought the data closer to a normal distribution and the normal distribution is fairly well applicable.

Table 10: Statistical analysis of measured depletion time ($2.3*t_o$).

Statical parameter	Name of the site						
	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
Mean	1.457	1.254	1.137	1.283	1.117	1.617	1.117
Standard Deviation	0.253	0.399	0.568	0.700	0.844	0.635	0.631
Coff. of Skewness	0.451	0.558	0.596	0.795	0.861	0.651	0.722
Coff. of Kurtosis	5.065	3.179	3.569	4.288	4.438	3.416	2.973

Table 11: Statistical analysis of transformed depletion time ($2.3*t_o$).

Statistical parameter	Name of the site						
	Karad	Dhond	Narsinghpur	Takali	Wadakwal*	Yadgir	Bawapuram*
λ	.327	-.162	.490	.432	0.0	-.206	0.0
Mean	.390	.170	.067	.172	-.103	.379	-.177
Standard Deviation	.196	.307	.541	.619	.416	.359	.254
Coff. of Skewness	.000	-.000	.000	.000	-.505	.000	-.055
Coff. of Kurtosis	4.927	2.805	3.580	3.738	2.621	2.537	2.858

* : log transformation has been applied.

On transformed data a normal distribution has been applied and the minimum value of depletion time at different recurrence has been estimated and reported in Table 12 for all sites under consideration.

Table 12: Probable lowest depletion time (2.3^*t_o) in months for different recurrence interval.

Recurrence interval	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
10 Years	1.146	.803	.473	.485	.231	.923	.454
20 Years	1.069	.721	.348	.349	.163	.813	.367
50 Years	.987	.641	.231	.225	.110	.707	.289
100 Years	.935	.593	.166	.159	.085	.646	.246
200 Years	.889	.553	.116	.110	.067	.596	.213
500 Years	.836	.509	.068	.064	.050	.541	.179

Measuring site: Karad, Dhond, Narsinghpur, Takali, Wadakwal, Yadgir, Bawapuram

5.1.4. Statistical analysis of observed discharge

The statistical analysis of the observed discharge of the month of October for the duration of 1977 to 1988 has been carried out smiler to as explained in section 5.1.3 by taking the log transformation of data. The possible lowest discharge for the different recurrence interval has been reported in Table 13. By the use of the values reported in Table 12 and in Table 13, the minimum amount of available dynamic ground water stored at different recurrence interval can be estimated.

Table 13: Probable lowest observed discharge (m^3/sec.) of October for different recurrence interval.

Recurrence interval	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
10 Years	1124.9	888.1	802.1	1437.3	144.1	4047.8	3495.4
20 Years	983.2	700.6	584.5	1034.9	81.8	2934.7	2810.3
50 Years	844.9	536.5	409.4	715.1	43.2	2043.7	2198.7
100 Years	763.8	449.0	322.9	558.9	28.2	1605.7	1866.9
200 Years	696.3	381.6	259.8	446.1	19.1	1287.7	1607.3
500 Years	622.6	313.3	199.7	339.5	11.9	985.6	1340.7

5.2. Drought forecasting

Drought forecasting and identification has been carried out as per the procedure listed in section 5. A programme reported in Appendix V has been developed to estimate the values of 2.3^*t_o with the help of known cumulative rainfall of months

June+July+August, June+July +August+September, and June+July+ August+September+October. The estimated values of $2.3*t_o$ are compared with the drought indices at the end of each month i.e. August, September and October to forecast the drought and forecast is given. While forecasting at the end of month of October, the programme also needs the measured discharge of the month of October in order to estimate the total amount of dynamic ground water storage, monthly dynamic ground water storage of the months followed by October and the actual conditions of drought as per the criteria of measured discharge of the month of October. The data form year 1986 to 1988 has been used to forecast and identify the drought. The results are reported in Table 14 to Table 16.

Drought forecasting has also been done for years 1989 to 1991. Since for these years, the stream flow data was not available, the drought forecasting has been carried out with the cumulative rainfall of up to the end of August and up to the end of September. The results are reported in Table 17 to 19.

5.2.1. Interpretation of results

Viewing the Table 14 to 19, we find that the severity of drought changes month to month depending upon the amount of rainfall received by the end of that month. The drought prediction made at the end of October maches well with the prediction made on the basis of discharge measurement of the month of October.

In year 1986, we find that all the gauging sites experienced severe drought conditions. However, the predictions based on the rainfall classify it from moderate to severe drought.

In year 1987, which was also a meteorological drought year, has not been reflected similar for the case of dynamic ground water storage. A mixed condition of no drought to severe drought has been observed in between the gauging sites.

In year 1988, the first estimate made at the end of August end had classified a condition of no drought to severe drought in between the gauging sites. On making the final estimates the conditions has changed to no drought to moderate drought except in case of Dhond.

The year 1989 was not a drought year and therefore no drought condition has been predicted at all the sites. In the year 1990 and 1991, a mixed condition of no drought to severe drought has been indicated.

Table 14: Drought forecasting for year 1986.

Drought forecasting considering rainfall of J+J+A

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.3	.7	.5	.9	.1	.9	.5

Drought prediction

MD	SD	SD	MD	SD	SD	SD

Drought forecasting considering rainfall of J+J+A+S

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.4	.9	.5	.8	.4	1.2	.8

Drought prediction

ND	SD	SD	MD	MD	MD	MD

Drought forecasting considering rainfall of J+J+A+S+O

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.3	.7	.5	.5	.1	1.2	.5

Drought prediction

MD	SD	SD	SD	SD	MD	SD

Total dynamic ground water storage in the month of October, 10^6,cume

7205.3	1795.9	1169.8	1306.7	12.5	10312.1	6092.0

Dynamic ground water storage starting from the month of October, 10^6,cumec.

430.4	102.6	52.3	59.2	.0	629.4	264.6
200.0	24.1	6.8	8.0	.0	266.5	32.8
93.0	5.7	.9	1.1	.0	112.8	4.1
43.2	1.3	.1	.1	.0	47.8	.5
20.1	.3	.0	.0	.0	20.2	.1
9.3	.1	.0	.0	.0	8.6	.0

Drought prediction by measured discharge of October

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
SD	SD	SD	SD	SD	SD	SD

Note: ND: No drought; MD: Moderate drought; SD: Severe drought

Table 15: Drought forecasting for year 1987.

Drought forecasting considering rainfall of J+J+A

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.5	1.0	.7	1.5	1.1	1.5	1.1

Drought prediction

ND	SD	MD	ND	ND	ND	ND

Drought forecasting considering rainfall of J+J+A+S

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.4	.9	.5	1.2	.7	1.3	.8

Drought prediction

ND	SD	SD	ND	MD	MD	MD

Drought forecasting considering rainfall of J+J+A+S+O

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.6	1.1	.8	2.1	1.0	1.6	1.1

Drought prediction

ND	MD	MD	ND	ND	ND	ND

Total dynamic ground water storage in the month of October, 10^6,cumec

24983.2	20160.1	7721.6	66811.2	11406.8	106831.1	67725.7

Dynamic ground water storage starting from the month of October, 10^6,cumec.

1410.0	1241.7	461.3	3350.3	703.8	6044.9	4156.7
747.4	484.8	128.7	2060.6	261.8	3189.7	1690.6
396.2	189.3	35.9	1267.4	97.3	1683.1	687.6
210.0	73.9	10.0	779.5	36.2	888.1	279.6
111.3	28.9	2.8	479.4	13.5	468.6	113.7
59.0	11.3	.8	294.9	5.0	247.3	46.3

Drought prediction by measured discharge of October

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
ND	MD	MD	ND	ND	SD	ND

Note: ND: No drought; MD: Moderate drought; SD: Severe drought

Table 16: Drought forecasting for year 1988.

Drought forecasting considering rainfall of J+J+A

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.9	.7	.6	1.2	1.5	1.0	2.9

Drought prediction

ND	SD	SD	ND	ND	SD	ND

Drought forecasting considering rainfall of J+J+A+S

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.8	1.1	.7	1.7	1.4	1.1	1.4

Drought prediction

ND	MD	MD	ND	ND	MD	ND

Drought forecasting considering rainfall of J+J+A+S+O

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.8	.9	.7	1.4	1.1	1.1	1.0

Drought prediction

ND	SD	MD	ND	ND	MD	ND

Total dynamic ground water storage in the month of October, 10^6,cumec

28036.4	18982.5	13556.842167210.0	19343.9	150970.2	32192.9

Dynamic ground water storage starting from the month of October, 10^6,cumec.

1512.1	1166.2	764.4	2466726.0	1186.0	9270.3	1986.3
858.0	389.5	172.8	1215477.0	486.6	3754.0	743.0
486.8	130.1	39.1	598925.3	199.7	1520.2	277.9
276.2	43.5	8.8	295120.0	81.9	615.6	104.0
156.7	14.5	2.0	145420.1	33.6	249.3	38.9
88.9	4.8	.5	71655.6	13.8	100.9	14.5

Drought prediction by measured discharge of October

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
ND	MD	MD	ND	ND	MD	MD

Note: ND: No drought; MD: Moderate drought; SD: Severe drought

Table 17: Drought forecasting for year 1989.

Drought forecasting considering rainfall of J+J+A

	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
Estimated depletion time	1.6	1.4	.9	1.9	1.4	1.6	1.9
Drought prediction	ND	ND	ND	ND	ND	ND	ND

Drought forecasting considering rainfall of J+J+A+S

	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
Estimated depletion time	1.7	1.6	.9	3.1	1.5	1.7	1.3
Drought prediction	ND	ND	ND	ND	ND	ND	ND

Note: ND: No drought; MD: Moderate drought; SD: Severe drought

Table 18: Drought forecasting for year 1990.

Drought forecasting considering rainfall of J+J+A

	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
Estimated depletion time	1.7	1.8	1.2	2.2	1.8	1.5	.5
Drought prediction	ND	ND	ND	ND	ND	ND	SD

Drought forecasting considering rainfall of J+J+A+S

	Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
Estimated depletion time	1.6	1.4	.8	2.0	1.0	1.3	.4
Drought prediction	ND	ND	MD	ND	ND	MD	SD

Note: ND: No drought; MD: Moderate drought; SD: Severe drought

Table 19: Drought forecasting for year 1991.

Drought forecasting considering rainfall of J+J+A

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.7	1.2	.8	1.4	.6	1.1	.6

Drought prediction

ND	MD	MD	ND	MD	SD	MD

Drought forecasting considering rainfall of J+J+A+S

Estimated depletion time

Karad	Dhond	Narsinghpur	Takali	Wadakwal	Yadgir	Bawapuram
1.5	1.1	.6	1.0	.3	1.1	.6

Drought prediction

ND	MD	SD	ND	SD	MD	MD

Note: ND: No drought; MD: Moderate drought; SD: Severe drought

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Appendix - I

Monthly stream flow (m^3/sec) in Krishna basin at sites listed below.

Year/ month	Name of Site						
	Karad	Dhond	Narsi-nghpur	Takali	Wada-kwal	Yadgir	Bawa-puram
	1	2	3	4	5	6	7
77 June	2247	1921	1260	3000	702	9972	3840
77 July	21316	24194	14301	10358	736	8925	1127
77 Aug.	11640	13932	19759	17226	265	26468	6361
77 Sept	11470	10603	19364	17796	318	21622	10148
77 Oct.	2130	1360	4130	6263	1002	15327	16459
77 Nov.	1399	1195	3193	2435	2297	3905	1451
77 Dec.	823	1208	3531	3857	823	8228	359
77 Jan.	352	229	1006	1018	158	1528	132
77 Feb.	268	148	966	792	102	1255	150
77 Mar.	2247	1921	1260	3000	702	9972	3840
77 Apr.	2247	1921	1260	3000	702	9972	3840
77 May.	2247	1921	1260	3000	702	9972	3840
78 June	6080	3937	1704	1659	3268	5816	562
78 July	11539	10323	9939	8616	1193	12546	20928
78 Aug.	26850	24331	29070	25469	362	41261	56512
78 Sept	10550	11482	20710	22763	2152	41789	34110
78 Oct.	1378	1321	4779	7451	1833	23337	14522
78 Nov.	672	602	2348	3732	1562	8685	8192
78 Dec.	471	519	759	1293	155	2473	265
78 Jan.	367	296	351	687	74	1140	245
78 Feb.	524	169	190	376	40	630	295
78 Mar.	6080	3937	1704	1659	3268	5816	562
78 Apr.	6080	3937	1704	1659	3268	5816	562
78 May.	6080	3937	1704	1659	3268	5816	562
79 June	3878	1019	311	122	1	1135	647
79 July	7686	9072	2407	1772	521	2222	736
79 Aug.	27660	32662	38926	39765	185	40669	10441
79 Sept	8687	14080	23843	40838	8202	57260	21421
79 Oct.	2842	3093	8190	12397	1861	24450	5861
79 Nov.	1662	935	3817	4457	2476	11654	2441
79 Dec.	598	758	2611	3322	1161	7361	1139
79 Jan.	482	304	1817	2028	344	3097	148
79 Feb.	390	226	288	454	187	1492	158
79 Mar.	3878	1019	311	122	1	1135	647
79 Apr.	3878	1019	311	122	1	1135	647
79 May.	3878	1019	311	122	1	1135	647
80 June	4475	6054	1552	1199	2877	4938	1494

Contd.

80	July	20367	24381	29943	25890	206	24301	33642
80	Aug.	27250	28048	37972	35846	3611	42883	45562
80	Sept	5469	9016	11168	9407	2370	15999	15100
80	Oct.	1113	1955	2418	3430	894	6997	5941
80	Nov.	1058	466	509	567	198	1285	1387
80	Dec.	486	321	439	507	126	1273	207
80	Jan.	299	298	277	469	168	718	476
80	Feb.	703	160	98	161	33	316	162
80	Mar.	4475	6054	1552	1199	2877	4938	1494
80	Apr.	4475	6054	1552	1199	2877	4938	1494
80	May.	4475	6054	1552	1199	2877	4938	1494
81	June	1061	874	5546	7901	859	11781	1867
81	July	15247	30679	32920	26316	25	25559	397
81	Aug.	16513	24362	28065	27808	90	30958	27574
81	Sept	4992	8555	17754	33693	4464	55463	33526
81	Oct.	1961	2319	2094	5769	945	18380	12491
81	Nov.	423	701	1662	2642	272	5946	3310
81	Dec.	747	320	939	1221	34	2513	367
81	Jan.	799	210	204	390	28	1674	178
81	Feb.	458	148	103	262	1	899	127
81	Mar.	1061	874	5546	7901	859	11781	1867
81	Apr.	1061	874	5546	7901	859	11781	1867
81	May.	1061	874	5546	7901	859	11781	1867
82	June	712	327	4825	4303	152	3501	1202
82	July	7059	3954	88	480	111	6083	1453
82	Aug.	15952	24148	20947	17960	8	17645	33812
82	Sept	1973	2818	1630	2794	821	11796	10657
82	Oct.	1294	1213	1149	2695	184	5329	4462
82	Nov.	745	846	534	1302	359	4329	5719
82	Dec.	763	216	162	238	1	673	198
82	Jan.	646	175	325	407	1	527	159
82	Feb.	724	90	107	106	1	235	131
82	Mar.	712	327	4825	4303	152	3501	1202
82	Apr.	712	327	4825	4303	152	3501	1202
82	May.	712	327	4825	4303	152	3501	1202
83	June	2442	304	452	344	110	2330	1531
83	July	8509	7844	4940	4027	1702	6019	784
83	Aug.	17435	34490	45998	44393	1252	52618	22961
83	Sept	6283	12775	17968	26662	20907	70209	20225
83	Oct.	1595	4740	4289	7969	5948	36663	8010
83	Nov.	636	900	441	728	709	3764	1316
83	Dec.	692	394	240	546	217	1382	245
83	Jan.	756	451	613	669	113	1079	151
83	Feb.	567	348	440	455	59	646	109
83	Mar.	2442	304	452	344	110	2330	1531
83	Apr.	2442	304	452	344	110	2330	1531
83	May.	2442	304	452	344	110	2330	1531
84	June	2534	896	3737	3047	1	2417	313

Contd.

84 July	13888	23253	26560	25439	503	28695	8293
84 Aug.	12499	14831	17574	17328	72	23525	19110
84 Sept	3816	6091	2159	3273	733	7593	3264
84 Oct.	2208	3433	5684	10479	5093	21620	13923
84 Nov.	879	425	189	499	304	2413	175
84 Dec.	888	269	354	369	16	515	280
84 Jan.	711	313	386	455	16	588	76
84 Feb.	1262	196	455	413	1	315	58
84 Mar.	2534	896	3737	3047	1	2417	313
84 Apr.	2534	896	3737	3047	1	2417	313
84 May.	2534	896	3737	3047	1	2417	313
85 June	1585	589	527	1387	340	3160	149
85 July	6837	7718	9218	9200	159	10176	575
85 Aug.	13125	15270	16759	19344	56	20312	6011
85 Sept	1631	1096	78	342	572	2320	1240
85 Oct.	2249	2291	910	2115	1229	8490	5669
85 Nov.	757	198	311	233	1	454	231
85 Dec.	1021	157	185	26	1	204	132
85 Jan.	1020	140	257	1	7	224	578
85 Feb.	859	71	171	1	1	164	104
85 Mar.	1585	589	527	1387	340	3160	149
85 Apr.	1585	589	527	1387	340	3160	149
85 May.	1585	589	527	1387	340	3160	149
86 June	-	-	-	-	-	-	-
86 July	-	-	-	-	-	-	-
86 Aug.	14587	17170	18248	19945	52	23469	12045
86 Sept	1868	1509	1002	3161	1875	8201	6103
86 Oct.	926	435	398	439	19	1486	2132
86 Nov.	1172	108	41	200	27	955	3183
86 Dec.	1203	236	65	0	15	157	143
86 Jan.	1052	121	27	0	10	387	177
86 Feb.	-	-	-	-	-	-	-
86 Mar.	-	-	-	-	-	-	-
86 Apr.	-	-	-	-	-	-	-
86 May.	-	-	-	-	-	-	-
87 June	-	-	-	-	-	-	-
87 July	-	-	-	-	-	-	-
87 Aug.	5340	6386	354	1927	2453	11894	6494
87 Sept	2363	1529	57	1040	230	2376	2084
87 Oct.	2660	3180	1653	5447	1892	11456	10220
87 Nov.	846	190	132	1598	272	6144	3286
87 Dec.	709	281	364	1599	146	2712	1476
87 Jan.	731	92	36	176	3	519	97
87 Feb.	-	-	-	-	-	-	-
87 Mar.	-	-	-	-	-	-	-
87 Apr.	-	-	-	-	-	-	-
87 May.	-	-	-	-	-	-	-

Contd.

88 June	-	-	-	-	-	-	-
88 July	-	-	-	-	-	-	-
88 Aug.	12508	12353	14551	18696	2102	35309	17053
88 Sept	10452	16917	29619	42000	21876	88170	27144
88 Oct.	2665	3490	3382	6500	2890	22893	5310
88 Nov.	1248	242	351	522	184	1737	180
88 Dec.	873	506	48	528	9	1098	423
88 Jan.	797	682	52	272	6	686	137
88 Feb.	-	-	-	-	-	-	-
88 Mar.	-	-	-	-	-	-	-
88 Apr.	-	-	-	-	-	-	-
88 May.	-	-	-	-	-	-	-

```
$debug
C     programme for estimation of total dynamic ground water
C     storage and dynamic ground water storage in the next month.
C     IM  is the month for which total dynamic ground water
C     storage is to be estimated.
C     GDATA is the input file to this programme
      DIMENSION TO(7,9),SF(7,108),SF1(7,108),TM(3,7),
     1DIS(3,7)
      CHARACTER*12 INFIL,OUFIL
      WRITE(*,20)
   20 FORMAT(5X,'INPUT FILE NAME?')
      READ(*,32)INFIL
   32 FORMAT(A)
      WRITE(*,21)
   21 FORMAT(5X,'OUTPUT FILE NAME?')
      READ(*,32)OUFIL
      OPEN(UNIT=1,FILE=INFIL,STATUS='OLD')
      OPEN(UNIT=2,FILE=OUFIL,STATUS='NEW')
   10 FORMAT(5x,7F10.2)
   11 FORMAT(7F9.1)
   12 FORMAT(/)
   13 FORMAT('Total dynamic ground water storage')
   14 FORMAT('Dynamic ground water storage')
   15 FORMAT('Dynamic ground water storage in the month of October')
   17 FORMAT('at Mean, Mean-SD/2,Mean-SD')
   16 FORMAT(7F8.1)
      DO 100 IY=1,9
  100 READ(1,10)(TO(IS,IY),IS=1,7)
      DO 105 IR=1,108
  105 READ(1,10)(SF(IS,IR),IS=1,7)
C     CALCULATION OF TOTAL AMOUNT OF DYNAMIC G.W. STORAGE
      IM=5
      IA=1
      IB=12
      DO 102 IY=1,9
      DO 103 IR=IA,IB
      DO 104 IS=1,7
      SF(IS,IR)=(TO(IS,IY)*SF(IS,IR))/2.3
  104 SF(IS,IR)=(SF(IS,IR)*30*24*60*60)/1000000
  103 CONTINUE
      IA=IB+1
      IB=IB+12
  102 CONTINUE
      WRITE(2,13)
      IR=IM
  111 IF(IR-108)106,106,107
  106 WRITE(2,11)(SF(IS,IR),IS=1,7)
      IR=IR+12
  107 IF(IR-108)111,111,110
  110 CONTINUE
```

```
C     Estimation of dynamic ground water storage in next time step.
C     NOM  Number of months the estimate to be done.
      NOM=3
      NT=1
  120 WRITE(2,12)
      WRITE(2,14)
      IY=1
      IR=IM
  114 IF(IR-108)113,113,115
  113 DO 116 IS=1,7
  116 SF1(IS,IR)=SF(IS,IR)/(EXP(NT/(TO(IS,IY))))
      WRITE(2,11)(SF1(IS,IR),IS=1,7)
      IR=IR+12
      IY=IY+1
  115 IF(IR-108)114,114,112
  112 NT=NT+1
      IF(NT-NOM)120,120,121
  121 IR=IR
      DO 130 IC=1,3
  130 READ(1,10)(TM(IC,IS),IS=1,7)
      DO 131 IC=1,3
      DIS(IC,1)=-513+(1361*TM(IC,1))
      DIS(IC,2)=-2735+(3502*TM(IC,2))
      DIS(IC,3)=-2898+(5075*TM(IC,3))
      DIS(IC,4)=-3612+(7189*TM(IC,4))
      DIS(IC,5)=-171+(839*TM(IC,5))
      DIS(IC,6)=-18260+(23552*TM(IC,6))
      DIS(IC,7)=-4280+(8933*TM(IC,7))
      WRITE(2,12)
      WRITE(2,15)
      WRITE(2,17)
      WRITE(2,16)(DIS(IC,IS),IS=1,7)
  131 CONTINUE
      STOP
      END
```

Appendix - III

District monthly average rainfall data, mm.

Year	1 PUN	2 AHM	3 SAT	4 SOL	5 SAN	6 BIJ	7 GUL	8 DHA	9 RAI	10 BEL	11 ANA	12 KUR	13 MAH
1970	.68	.20	.00	.00	.73	.44	.00	.00	.00	.00	2.08	.00	.12
1970	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.06	.00
1970	.22	.00	.00	.00	.00	.36	.00	.99	.69	.81	.00	11.93	1.81
1970	11.69	14.12	31.76	.00	22.76	26.64	14.29	48.27	23.40	33.33	22.62	20.89	24.52
1970	23.16	38.80	32.14	.00	38.44	62.86	41.86	89.57	53.03	102.02	159.04	82.90	36.60
1970	76.99	99.56	85.12	103.96	59.78	40.82	92.22	55.73	59.00	34.52	14.62	50.20	94.31
1970	136.07	73.22	179.24	124.56	108.70	55.82	132.74	81.64	79.77	127.69	34.32	118.46	121.33
1970	125.81	90.46	136.19	179.24	121.13	123.46	240.78	122.14	146.05	128.16	39.26	245.65	256.15
1970	80.37	125.00	95.75	199.66	139.42	141.46	177.19	141.26	173.22	168.44	149.88	215.47	140.71
1970	73.90	58.76	44.53	.00	91.05	67.48	59.85	170.50	75.05	151.57	279.78	82.22	43.91
1970	3.35	.00	11.75	.00	.00	2.84	.00	.00	.00	11.55	.68	.00	.00
1970	.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1971	.00	.20	.00	.20	.00	.40	3.96	.00	.00	1.21	.00	.00	.31
1971	.00	.20	.00	.20	.00	.73	2.34	.00	.00	.00	.00	.00	.00
1971	.00	.20	.03	.20	.06	1.18	.22	.28	.00	.00	1.50	22.57	8.38
1971	.00	.70	7.60	.20	15.91	26.56	11.58	37.87	29.53	26.36	24.32	20.80	9.81
1971	29.33	22.94	42.96	.20	66.89	67.22	32.26	74.73	45.09	58.90	42.02	52.84	31.18
1971	112.44	42.82	122.65	44.58	124.00	54.90	69.43	125.96	24.08	45.44	22.44	63.47	84.09
1971	82.56	10.84	86.61	10.06	48.45	53.78	26.27	70.58	36.34	50.64	22.84	44.90	62.00
1971	133.96	103.22	70.77	155.98	115.58	116.80	94.51	96.86	91.37	217.69	84.48	132.35	135.77
1971	138.84	142.14	123.92	123.32	135.58	152.96	85.59	102.83	114.38	114.08	133.60	51.04	68.47
1971	40.15	20.84	21.63	31.60	80.99	142.46	104.37	118.80	86.36	145.12	147.84	148.04	139.79
1971	.00	.20	.00	.20	.00	5.32	3.54	3.66	.00	1.84	4.40	1.31	.00
1971	.00	.20	.00	.20	.00	1.12	.00	.00	.00	.00	2.44	.00	.00
1972	.30	.20	.00	.00	.00	.76	.59	.00	.00	.00	.00	.00	.00
1972	.08	.20	.00	.00	.00	1.11	5.17	.00	.63	2.99	.00	1.05	1.47
1972	.20	.20	.00	.00	.00	5.32	1.12	.03	.00	.00	.00	.00	.00
1972	2.60	3.16	3.31	.00	9.27	21.28	8.42	30.98	17.93	12.22	5.34	14.79	18.09
1972	17.20	6.76	15.48	.00	28.43	28.76	22.84	91.29	36.01	88.80	106.60	61.01	11.02
1972	54.26	32.46	32.49	51.84	36.70	43.06	72.19	81.88	61.04	43.70	54.86	110.23	107.48
1972	165.48	26.58	116.26	20.60	93.01	47.36	58.27	98.79	41.85	46.23	15.78	58.12	87.54
1972	68.79	28.52	15.33	8.02	8.56	33.38	39.12	50.36	17.75	49.74	8.00	23.39	9.18
1972	66.88	57.08	58.58	87.38	126.98	123.28	105.50	128.59	138.66	149.28	159.62	133.03	90.34
1972	11.62	3.94	1.97	.00	18.98	72.14	35.89	45.06	37.49	128.22	144.28	74.84	44.94
1972	15.03	3.00	24.98	.00	15.81	50.80	45.95	22.58	8.96	19.11	50.10	43.50	34.94
1972	.47	.20	.13	.00	.00	3.30	1.91	.36	1.51	3.58	12.04	17.90	.46
1973	.00	.20	.23	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00
1973	.36	.96	1.30	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00
1973	3.34	4.60	1.88	.00	.00	.24	.00	.09	.00	.00	.00	.00	.00
1973	6.91	.20	6.07	.00	4.24	14.76	5.19	16.57	.88	9.20	3.66	9.65	2.90
1973	5.12	.20	22.27	.00	55.11	23.82	11.05	53.76	11.99	37.82	16.62	18.28	5.56
1973	76.86	58.46	101.76	85.30	83.87	105.46	86.06	180.32	105.93	142.07	85.14	78.07	85.77

Contd.

1973	291.07	110.34	210.82	99.78	124.05	71.26	114.48	102.39	23.11	80.62	61.38	69.25	96.85
1973	114.34	112.30	88.15	226.56	121.59	102.70	217.07	112.59	114.84	142.85	77.62	210.77	245.03
1973	103.84	75.64	65.84	147.54	79.30	117.86	180.64	64.84	72.53	94.58	150.72	142.26	103.29
1973	94.30	48.98	117.32	.00	182.65	194.58	331.64	95.11	238.10	188.20	181.82	176.82	138.77
1973	1.88	2.68	25.02	.00	3.95	10.32	6.09	4.36	4.43	3.12	32.64	7.26	16.12
1973	.00	.20	.38	.00	.17	.00	.11	.23	2.41	1.76	4.92	.34	.00
1974	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00
1974	.00	.00	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00
1974	.09	1.78	4.72	.00	5.09	4.64	.60	9.25	.00	1.32	.80	3.54	1.64
1974	6.07	1.68	14.70	.00	28.66	9.18	38.61	37.92	9.61	28.84	11.74	17.09	14.77
1974	49.53	70.28	36.04	.00	78.45	74.08	63.03	108.73	91.56	97.11	122.00	71.14	102.01
1974	47.26	61.16	42.15	94.52	72.08	48.98	153.09	97.11	68.14	90.10	36.94	70.31	53.05
1974	134.13	72.94	132.74	53.18	119.74	38.46	92.43	110.36	37.50	17.33	59.74	48.33	68.84
1974	134.72	84.96	101.38	117.08	128.48	70.24	140.69	64.71	65.83	29.47	16.08	97.84	163.64
1974	156.90	210.02	168.47	327.48	236.86	261.08	206.40	243.11	226.79	291.85	203.30	209.90	200.63
1974	140.14	149.52	142.24	.00	177.74	165.28	302.55	122.95	143.49	138.25	138.26	179.12	216.81
1974	.00	.00	.08	.00	2.63	.28	.00	5.85	1.09	1.91	2.58	8.88	4.01
1974	.00	.00	.00	.00	.00	.00	.00	.21	.00	.00	.00	.00	.00
1975	.05	.00	.00	.00	.00	2.34	15.71	2.60	.45	1.62	.00	.60	5.16
1975	.00	.00	.00	.00	.00	.76	1.08	.03	.00	1.07	.00	.00	3.27
1975	.20	.00	.00	.00	.00	1.50	1.86	7.46	.00	1.84	5.70	13.81	16.69
1975	.00	.00	.00	.00	2.12	5.58	8.54	12.85	1.38	5.64	3.86	9.60	7.26
1975	14.31	22.16	15.72	.00	16.93	55.68	54.82	78.83	12.68	56.74	46.54	56.96	22.52
1975	130.17	81.50	108.35	52.72	112.08	83.96	68.56	89.53	16.09	64.49	20.10	57.28	65.36
1975	127.18	148.36	127.75	163.96	150.40	99.96	359.98	179.81	126.20	137.01	160.35	186.85	186.98
1975	168.42	124.20	123.14	130.44	92.51	38.96	173.25	89.01	65.75	122.69	73.08	143.25	183.33
1975	179.97	260.96	173.17	310.64	315.57	145.42	231.91	182.62	71.42	144.99	133.66	160.73	220.40
1975	96.79	77.96	110.71	.00	278.86	208.24	386.48	135.21	229.93	253.57	203.02	414.36	336.81
1975	1.26	.00	1.60	.00	2.35	10.36	5.44	54.08	10.48	86.48	79.00	32.86	10.67
1975	.00	.00	.00	.00	.00	1.00	.00	.91	.00	11.57	.88	.99	.00
1976	.42	.20	.00	.20	.00	9.98	2.27	.01	.00	.00	.00	.00	.00
1976	.13	.20	.00	.20	.00	1.70	.00	.03	.00	.00	.00	.00	.00
1976	.52	13.22	5.56	.20	17.35	7.00	.33	7.26	.55	.84	.00	.92	.36
1976	2.07	.20	5.50	.20	15.64	16.92	44.24	63.13	42.45	40.29	56.40	20.88	15.03
1976	5.11	.44	1.95	.20	11.07	34.94	10.64	11.52	20.86	19.94	12.30	27.69	19.94
1976	230.80	207.60	230.17	102.52	137.44	72.76	103.84	52.73	60.67	33.79	33.76	81.97	70.90
1976	270.24	132.64	159.47	62.38	86.16	70.94	180.56	96.35	75.60	39.44	41.32	112.34	173.91
1976	190.52	85.66	91.67	88.50	81.86	88.58	232.12	90.34	108.59	81.61	109.90	139.55	210.13
1976	82.07	41.04	44.04	48.26	64.74	126.22	132.33	69.95	56.32	49.81	24.10	88.60	104.53
1976	22.17	1.62	23.72	.20	32.04	148.06	3.69	27.47	7.93	15.32	32.30	25.49	13.08
1976	42.12	55.32	29.67	.20	59.50	22.78	42.56	95.22	23.41	40.63	22.22	41.02	67.30
1976	.77	.70	3.33	.20	2.11	2.32	.00	.21	.00	.00	.00	.77	.00
1977	.42	.00	.00	.00	.00	.00	.00	.04	.00	.00	.00	.00	.00
1977	.13	.00	.27	.00	.00	.00	.00	6.86	.00	.00	.04	.00	.00
1977	.90	3.32	3.03	.00	5.57	17.90	12.65	11.87	2.88	.78	.52	3.41	.94
1977	3.91	.00	12.82	.00	30.55	24.44	36.21	37.96	19.72	24.53	24.50	30.90	26.24
1977	24.56	25.46	24.45	.00	68.70	45.30	50.97	130.30	64.56	91.48	172.76	121.97	46.01
1977	133.77	130.80	126.60	175.86	200.04	165.28	210.84	78.01	95.12	76.44	64.56	115.92	113.22

Contd.

1977	418.75	56.24	197.10	95.20	101.56	53.76	135.08	78.17	63.06	61.67	55.02	112.47	104.00
1977	87.93	44.02	78.16	66.40	59.77	80.88	194.73	76.81	100.30	114.33	93.92	178.19	209.24
1977	85.88	54.68	41.44	58.70	50.49	35.74	73.27	83.79	38.44	79.62	99.32	45.18	38.31
1977	62.19	37.10	69.29	.00	98.14	150.42	166.70	93.94	111.99	150.40	132.96	142.58	154.85
1977	86.17	165.66	97.07	.00	75.41	90.32	76.76	85.01	49.87	47.13	59.92	93.68	38.06
1977	10.20	.00	3.81	.00	.00	.00	.45	.49	.00	14.11	.00	.00	9.99
1978	1.52	.00	1.64	.00	.00	.00	.89	.16	.00	.00	.00	.00	.06
1978	.90	11.80	2.74	.00	2.88	11.94	39.69	5.66	.51	.77	4.98	3.52	10.26
1978	2.90	4.74	2.42	.00	.00	1.22	2.32	.89	.59	.00	1.64	1.43	3.00
1978	9.79	12.76	11.39	.00	33.07	26.04	36.88	62.40	17.28	24.21	26.38	29.89	31.89
1978	34.00	23.86	39.74	.00	47.50	94.40	73.09	107.92	75.42	77.23	34.40	46.86	51.73
1978	92.85	123.22	116.15	114.60	99.63	55.50	112.82	89.51	34.28	44.02	34.84	101.12	82.06
1978	174.08	60.80	111.75	114.16	101.79	105.56	175.76	126.40	107.61	139.06	71.24	182.44	174.75
1978	120.22	36.26	152.52	114.62	112.55	91.00	256.14	102.64	68.53	60.21	34.70	192.72	283.96
1978	99.03	48.02	99.96	203.22	140.55	233.10	291.41	133.72	190.83	191.00	149.80	257.60	220.61
1978	54.29	59.52	58.86	.00	78.71	92.86	60.08	146.06	36.13	66.12	74.10	64.58	68.32
1978	20.59	79.00	29.31	.00	45.00	51.76	36.06	87.83	68.15	120.81	71.64	31.89	19.55
1978	3.56	2.80	3.04	.00	14.23	4.26	3.04	3.99	4.21	24.57	32.14	25.65	2.97
1979	1.64	.00	1.86	1.00	.00	.00	3.01	2.84	.36	.00	.04	.00	2.83
1979	.68	.00	.65	1.00	.00	17.28	19.62	.43	8.65	4.64	13.02	7.35	35.97
1979	1.74	.00	3.01	1.00	.00	1.94	5.06	5.74	.47	10.16	4.32	6.56	.87
1979	7.04	.00	10.82	1.00	2.95	.80	6.98	18.06	1.07	23.51	.84	22.96	2.00
1979	21.10	.00	25.67	1.00	24.30	29.96	104.79	46.30	45.04	34.94	41.82	97.27	228.12
1979	97.79	124.28	91.70	1.00	102.67	58.50	113.49	167.38	62.80	80.74	56.32	73.98	92.79
1979	181.96	68.90	186.13	1.00	73.16	74.82	94.50	84.80	59.93	54.30	27.68	75.87	102.79
1979	120.16	48.14	115.62	1.00	149.52	52.92	59.01	194.50	49.94	90.02	62.00	53.37	45.40
1979	107.73	76.76	92.24	1.00	348.26	336.08	359.55	223.79	279.66	249.77	190.84	175.22	198.03
1979	55.49	.00	56.32	1.00	82.32	41.08	38.50	73.63	32.72	23.58	54.98	92.60	43.66
1979	23.27	.00	25.83	1.00	85.79	146.82	64.04	106.44	50.39	61.43	101.08	71.57	63.17
1979	3.95	.00	5.38	1.00	11.04	.00	.00	2.45	.00	.30	.00	18.31	.00
1980	1.64	.00	1.86	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1980	.68	.00	.65	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1980	1.74	.00	3.01	1.00	.00	.00	.23	3.25	.00	.00	9.38	2.28	1.40
1980	7.04	.00	10.82	1.00	48.33	52.48	44.15	104.73	49.83	77.07	16.88	14.92	17.60
1980	21.10	.00	25.67	1.00	37.46	19.64	3.74	32.53	15.26	54.87	57.62	22.60	3.77
1980	97.79	120.20	91.70	1.00	134.61	110.34	130.27	170.31	74.80	111.19	52.16	106.42	98.47
1980	181.96	70.24	186.13	1.00	111.42	39.18	94.25	156.68	50.36	103.25	15.55	129.79	111.25
1980	120.16	39.96	115.62	1.00	93.46	90.66	272.87	113.44	100.40	112.68	38.80	98.29	190.44
1980	107.73	125.32	92.24	1.00	112.21	146.30	173.28	156.38	96.48	96.74	94.53	116.39	139.17
1980	55.49	.00	56.32	1.00	20.73	23.68	1.52	37.00	5.42	24.98	56.75	2.69	7.30
1980	23.27	.00	25.83	1.00	46.73	12.38	9.52	39.68	38.50	31.74	64.06	22.24	12.09
1980	3.95	.00	5.38	1.00	12.27	4.24	5.20	1.09	.10	2.58	.86	4.01	2.54
1981	10.86	.00	3.75	.00	6.05	.00	10.76	.94	3.90	6.79	.00	7.46	5.11
1981	.15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
1981	1.46	.00	2.78	.00	1.75	.00	14.91	8.15	7.85	6.59	.00	25.53	35.00
1981	1.99	.00	11.47	.00	29.46	.00	1.16	40.17	4.60	26.95	.00	25.53	32.61
1981	.88	.00	9.54	.00	19.47	29.36	29.31	79.10	21.65	49.61	66.02	43.33	35.98
1981	126.90	96.40	106.23	183.66	150.26	203.22	212.52	80.34	86.75	64.36	13.80	78.44	89.24

Contd.

1981	266.09	73.34	237.24	44.82	86.20	43.62	99.66	110.13	60.80	70.06	62.10	120.88	135.24
1981	117.76	37.42	154.28	105.96	62.72	101.20	183.28	107.30	91.11	105.86	86.68	134.09	152.93
1981	146.55	241.30	188.16	355.76	386.24	341.14	453.90	182.47	312.66	369.29	326.98	229.58	230.77
1981	37.75	.00	45.47	.00	46.01	91.26	97.38	49.44	97.26	129.22	84.14	107.75	69.05
1981	4.29	.00	14.10	.00	27.25	24.32	19.86	12.79	20.89	27.74	39.98	13.08	4.27
1981	.15	.00	.32	.00	.00	.00	.00	.00	.76	5.27	.00	4.01	.14
1982	1.10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1982	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
1982	.00	.00	.00	.00	.00	.00	2.17	1.59	.12	.00	.00	.05	.13
1982	1.78	.00	18.24	.00	7.37	.00	20.35	36.76	8.99	37.14	.00	12.89	41.20
1982	27.88	.00	39.40	.00	96.55	44.00	43.86	107.18	40.87	131.61	53.16	45.58	38.90
1982	70.64	84.32	56.83	100.56	84.11	111.56	74.94	88.73	77.99	52.23	83.10	70.60	111.68
1982	129.24	46.04	121.75	102.52	94.30	98.40	243.75	130.45	103.10	84.58	54.48	148.67	155.39
1982	117.35	48.66	173.73	23.70	70.33	21.28	76.49	92.51	48.44	65.15	13.20	72.32	92.66
1982	114.55	135.74	94.92	174.40	142.50	110.10	233.78	100.93	140.68	175.00	131.02	102.37	137.05
1982	41.66	.00	36.20	.00	67.50	89.26	75.53	147.31	90.44	130.86	49.52	118.01	90.67
1982	36.72	.00	24.34	.00	44.65	57.06	43.81	50.12	53.27	69.93	141.62	78.01	39.25
1982	.00	.00	.00	.00	.00	.00	4.59	2.48	.00	.00	.00	20.92	.14
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1983	.00	.00	12.10	.00	.00	.00	.42	.00	.00	.00	.00	.00	.05
1983	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.13
1983	.00	.00	.05	.00	.00	.00	1.09	.00	.00	.00	.00	.00	2.50
1983	.14	.00	3.49	.00	4.32	15.64	30.74	36.77	25.91	53.96	54.86	64.51	40.89
1983	75.78	50.84	101.12	80.38	113.33	102.76	202.98	164.20	87.68	107.13	112.68	80.89	78.37
1983	151.43	132.18	146.26	137.20	80.81	82.22	193.17	87.92	125.71	91.85	23.58	133.98	166.16
1983	244.88	107.52	218.00	101.72	105.37	69.02	276.63	121.71	105.70	120.07	98.08	254.38	278.73
1983	176.41	385.58	133.89	307.32	102.50	191.00	361.36	102.65	217.71	219.30	187.92	280.30	261.14
1983	21.93	.00	23.22	.00	31.92	60.98	118.95	56.89	54.43	173.85	65.20	69.78	81.83
1983	.02	.00	2.69	.00	13.04	10.44	1.44	16.19	5.33	17.77	3.00	11.44	4.39
1983	.01	.00	3.74	.00	7.13	.00	7.07	16.09	12.63	15.34	.00	4.37	3.87
1984	.00	.00	.00	.00	.00	.00	.85	.07	.00	.00	.00	.93	.01
1984	6.29	.00	12.19	.00	19.43	.00	12.10	1.08	1.18	1.93	.00	3.75	1.67
1984	.00	.00	7.85	.00	12.54	.00	.00	15.11	2.73	9.91	.00	3.56	7.46
1984	1.56	.00	5.77	.00	7.90	.00	1.40	38.53	6.52	53.24	.00	5.29	35.29
1984	.00	.00	.00	.00	1.06	16.76	6.76	17.38	6.89	27.53	13.32	16.47	7.63
1984	114.66	31.72	53.13	24.44	33.99	19.70	64.34	82.86	24.81	44.27	17.24	57.65	58.06
1984	203.82	132.38	240.62	158.56	129.05	85.34	270.80	149.12	145.07	177.50	128.86	230.08	221.75
1984	80.77	13.60	106.67	66.90	48.41	40.60	57.66	43.19	33.63	39.95	7.86	28.25	65.52
1984	110.90	102.50	115.63	127.86	107.66	126.82	159.53	106.55	123.47	472.96	96.30	73.01	91.76
1984	88.05	.00	89.82	.00	79.53	115.26	91.80	118.56	115.19	125.42	88.38	88.58	63.11
1984	9.19	.00	8.49	.00	44.09	.00	3.43	.90	.38	.05	9.14	4.21	2.48
1984	2.31	.00	2.40	.00	33.36	.00	.00	.00	.63	4.88	2.88	7.05	.66
1985	.09	.00	.47	.00	.00	.00	4.06	.00	.00	.00	.00	2.43	3.68
1985	2.71	.00	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
1985	.68	.00	.65	.00	3.04	.00	.70	23.03	.00	19.79	.00	.36	10.86
1985	1.90	.00	9.87	.00	15.46	.00	28.08	22.39	16.21	44.21	.00	45.01	19.99
1985	2.92	.00	17.97	.00	21.28	30.72	45.53	40.20	36.30	34.58	40.12	27.51	24.65
1985	91.96	74.60	100.09	117.46	76.53	60.10	135.11	54.83	55.21	58.85	30.60	71.58	63.96

Contd.

1985	147.18	64.96	157.41	54.86	76.82	99.08	103.36	85.54	93.10	97.19	49.96	205.74	172.23
1985	87.42	15.76	148.05	46.56	65.90	61.00	66.70	79.26	35.73	51.33	26.84	59.63	55.07
1985	50.47	78.42	68.07	76.46	68.36	78.56	117.51	54.76	80.70	84.00	90.10	59.15	93.19
1985	76.38	.00	72.62	.00	74.33	79.88	148.99	62.30	96.37	36.09	78.86	113.47	115.24
1985	13.48	.00	15.46	.00	2.42	7.26	1.33	3.58	4.67	28.56	8.76	13.86	1.14
1985	.34	.00	1.18	.00	.00	.00	.57	.36	.69	5.38	.00	2.57	5.66
1986	.00	.00	.21	6.61	6.15	17.17	35.75	1.90	11.87	15.42	11.47	13.49	24.86
1986	.00	.00	.00	.14	.08	.24	16.58	1.97	5.37	1.81	12.01	12.51	22.21
1986	.00	.00	.13	.00	.47	5.72	.28	3.75	.00	1.60	.00	.52	.00
1986	.00	.00	4.03	7.40	9.20	12.88	20.41	37.48	29.43	23.24	6.52	19.51	12.14
1986	6.05	1.85	15.94	9.48	17.54	54.90	24.62	39.62	28.27	79.55	16.33	15.24	9.68
1986	199.43	130.76	225.36	108.96	120.24	96.48	77.81	121.63	91.48	124.90	82.33	75.73	80.51
1986	82.94	34.64	100.26	16.38	76.24	34.38	86.17	70.96	47.52	41.33	33.96	80.72	88.75
1986	111.64	43.69	144.79	66.20	60.66	76.79	175.28	107.39	79.05	116.99	53.57	74.89	85.00
1986	84.68	119.41	81.09	166.56	99.61	103.75	113.83	100.85	141.79	167.97	148.51	123.34	85.87
1986	4.70	3.58	8.96	3.57	23.33	27.46	35.74	61.72	30.61	37.13	63.27	43.86	32.59
1986	9.46	2.03	15.84	33.73	26.91	58.81	43.31	102.70	58.97	122.64	[illegible]	[illegible]	[illegible]
1986	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1987	.35	.00	.00	.56	3.26	.00	.00	.00	.00	.00	.00	5.15	9.82
1987	.86	7.82	.65	.48	.00	.00	.00	.00	.00	.00	.00	.00	.00
1987	.17	.79	5.80	.21	.96	.57	.00	.00	.00	.00	.00	1.01	.00
1987	2.01	.71	7.36	.00	10.37	4.28	.00	.88	.00	.00	.00	.44	2.41
1987	42.34	19.62	24.22	29.00	68.28	38.70	35.04	62.92	26.12	56.06	17.42	54.16	25.50
1987	67.62	98.97	72.63	107.78	94.35	149.48	131.98	87.16	113.57	123.90	82.09	80.47	56.90
1987	88.62	54.32	165.40	62.23	88.30	28.07	93.84	52.77	22.23	19.66	7.07	33.54	109.33
1987	135.99	109.51	133.25	198.60	102.08	139.05	233.56	137.03	142.32	136.98	108.12	222.20	154.49
1987	49.98	33.38	82.11	86.65	91.34	158.31	100.31	136.46	94.77	121.94	56.31	100.25	79.16
1987	105.14	80.96	141.39	178.66	101.59	119.71	109.94	158.21	130.45	154.70	151.47	166.98	154.52
1987	19.76	29.72	31.93	67.45	32.47	106.07	109.61	43.14	73.26	58.12	43.19	98.83	178.19
1987	31.05	18.84	45.80	60.27	21.90	27.22	16.19	35.16	40.94	28.44	13.12	29.53	4.87
1988	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1988	.00	.00	.00	1.20	.00	.00	.87	.00	.00	.85	.82	2.99	.00
1988	.00	.26	.00	.00	.65	.68	.00	.00	1.40	.00	10.85	6.19	.00
1988	13.35	11.00	23.31	17.44	34.12	.00	.00	57.09	.00	32.86	34.18	39.31	16.81
1988	1.06	10.22	16.69	5.92	19.51	36.56	21.22	80.72	20.20	95.07	111.35	58.88	46.77
1988	89.59	61.76	78.12	47.80	55.69	44.69	65.01	105.33	47.67	30.18	14.44	38.44	.00
1988	146.62	6.54	342.64	55.22	100.36	67.06	227.87	130.93	92.31	87.04	.00	188.19	.00
1988	54.64	9.60	129.89	107.54	63.85	196.14	264.62	161.17	185.89	242.30	.00	243.08	192.45
1988	158.89	24.90	174.55	146.33	148.43	197.83	264.14	153.96	143.43	215.14	.00	155.40	258.37
1988	14.10	.00	6.12	4.21	54.60	16.05	5.48	18.28	12.73	22.94	.00	21.68	.00
1988	5.30	.00	.00	.00	21.69	.00	.00	.10	.00	.00	.00	.00	.00
1988	5.67	.00	1.56	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1989	.00	.01	.00	.00	.00	.00	.00	.56	.00	.00	.97	.00	.00
1989	.00	.00	.00	.32	.00	.00	.00	.00	.00	.00	.00	.00	.00
1989	4.34	20.09	6.36	8.19	16.32	25.45	36.06	15.68	21.33	19.47	15.22	55.64	54.45
1989	5.77	.88	9.84	5.14	12.44	9.54	14.99	12.97	11.03	19.02	8.01	3.08	1.75
1989	15.70	4.88	46.24	5.36	23.58	39.38	22.14	41.33	20.15	12.48	6.49	13.38	7.31
1989	101.47	114.77	99.48	90.77	125.39	94.26	97.33	61.16	34.02	94.33	35.87	74.36	111.48

Contd.

1989	196.32	177.40	243.06	172.76	148.52	126.83	274.71	116.32	111.46	132.38	246.34	263.47	353.36
1989	85.40	72.45	117.09	77.76	25.18	20.82	60.35	46.99	20.33	58.93	26.36	60.98	68.92
1989	169.36	200.67	185.85	278.58	193.49	282.02	214.83	104.72	180.44	175.65	178.73	177.78	176.12
1989	49.55	30.40	14.17	22.11	9.30	31.14	23.76	53.45	16.06	8.86	21.31	19.77	20.23
1989	.00	.32	1.60	1.66	.87	14.94	3.41	10.71	9.48	14.38	2.07	26.02	4.95
1989	.01	.65	.22	7.47	.82	32.18	20.06	7.74	7.72	11.07	2.78	.94	6.45
1990	.00	.00	.16	2.14	2.73	5.49	1.30	5.68	1.62	.25	.00	.00	1.23
1990	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1990	.52	.00	3.55	.00	.23	.56	.00	.90	.00	1.07	11.13	7.55	.88
1990	1.68	.00	.00	.00	20.53	4.86	8.05	11.21	12.81	9.78	.71	7.51	.76
1990	44.22	95.48	42.50	81.89	99.03	164.75	114.49	104.92	110.37	148.51	12.95	42.04	96.16
1990	90.53	92.76	132.20	185.07	166.47	118.31	188.79	62.74	115.74	103.53	54.97	88.23	109.11
1990	203.89	60.46	221.31	45.21	108.78	41.25	107.38	80.10	44.02	64.80	29.57	69.13	142.90
1990	164.16	144.19	188.53	201.79	105.16	75.73	266.59	85.39	106.91	91.50	30.38	118.03	175.37
1990	45.01	72.52	112.55	79.58	30.22	54.91	148.82	28.16	69.91	39.16	50.18	129.27	125.18
1990	161.23	253.19	101.28	197.47	129.61	64.53	160.14	48.52	108.06	99.77	95.57	169.72	101.24
1990	8.82	11.51	26.16	13.23	17.93	12.01	8.99	33.55	17.81	26.38	55.26	19.61	20.82
1990	3.41	3.46	.00	.00	.00	1.01	.00	.28	.00	.91	6.04	1.91	.00
1991	.00	.00	.00	.00	.00	.00	.44	.00	1.48	.00	.00	.00	.00
1991	.00	.00	.00	.29	.00	.00	.00	.00	.00	.00	.00	.00	.00
1991	.00	.00	.00	.00	.11	2.99	.78	1.68	.00	3.81	.64	1.93	.00
1991	6.47	7.05	19.00	15.84	29.37	40.33	29.73	61.09	53.44	54.90	.00	.00	8.21
1991	17.91	53.62	11.52	35.69	104.31	57.07	34.47	102.54	47.59	91.03	.00	.00	12.11
1991	278.23	245.39	239.08	186.47	242.56	250.14	204.22	237.20	202.06	208.85	127.49	206.31	230.57
1991	160.40	98.99	249.97	71.53	142.23	92.59	167.95	110.82	60.99	54.15	28.72	126.50	192.02
1991	102.32	40.92	149.11	31.99	75.21	52.22	73.69	101.29	55.95	70.76	25.36	112.95	111.74
1991	55.35	53.16	44.81	62.95	76.57	73.50	64.07	93.51	74.36	104.19	63.03	125.42	172.22
1991	22.46	43.26	38.49	36.77	80.02	60.84	28.95	60.37	30.07	49.81	167.58	21.12	20.97
1991	4.88	3.26	19.45	12.76	3.88	3.83	23.24	11.32	13.16	19.64	55.94	57.14	53.80
1991	3.40	.00	8.58	.00	.00	1.01	.00	.28	.00	.00	.00	.00	.00

Appendix - IV

```
$debug
C     RFA: programme for weighted rainfall at each gauging site of krish
C          basin and the cumulative rainfall.
C     RFA is the input data file to this programme.
      DIMENSION PUN(180),AHM(180),SAT(180),SOL(180),SAN(180),
     1BIJ(180),GUL(180),DHA(180),RAI(180),BEL(180),ANA(180),
     1KUR(180),MAH(180),KAR(180),DHO(180),NAR(180),TAK(180),
     1WAD(180),YAD(180),BAW(180),SKAR(15,6),SDHO(15,6),SNAR(15,6),
     1STAK(15,6),SWAD(15,6),SYAD(15,6),SBAW(15,6)
      REAL KUR,MAH,KAR,NAR
      CHARACTER*12 INFIL,OUFIL
   10 FORMAT(4X,13F7.2)
   11 FORMAT(I4,7F9.1)
   12 FORMAT(/)
   13 FORMAT('Cumulative rainfall,mm of June+July, June+July+August,')
   14 FORMAT('June+July+August+September,')
   15 FORMAT('June+July+August+September+October')
   16 FORMAT(8X,'Karad',4X,'Dhond',2X,'Narsinghpur',1X,'Takali',
     11X,'Wadakwal',2X,'Yadgir',2X,'Bawapuram')
   20 FORMAT(5X,'INPUT FILE NAME?')
   21 FORMAT(5X,'OUTPUT FILE NAME?')
   32 FORMAT(A)
      WRITE(*,20)
      READ(*,32)INFIL
      WRITE(*,21)
      READ(*,32)OUFIL
      OPEN(UNIT=1,FILE=INFIL,STATUS='OLD')
      OPEN(UNIT=2,FILE=OUFIL,STATUS='NEW')
      N=180
      NY=15
      NST=1977
      READ(1,10)(PUN(I),AHM(I),SAT(I),SOL(I),SAN(I),BIJ(I),
     1GUL(I),DHA(I),RAI(I),BEL(I),ANA(I),KUR(I),MAH(I),I=1,N)
      DO 100 I=1,N
      KAR(I)=SAT(I)
      DHO(I)=0.86*PUN(I)+0.14*AHM(I)
      NAR(I)=0.70*PUN(I)+0.14*AHM(I)+0.08*SAT(I)+0.08*SOL(I)
      TAK(I)=0.48*PUN(I)+0.09*AHM(I)+0.09*SAT(I)+0.23*SOL(I)
     1+0.08*SAN(I)+0.03*BIJ(I)
      WAD(I)=0.28*PUN(I)+0.05*AHM(I)+0.06*SAT(I)+0.19*SOL(I)
     1+0.05*SAN(I)+0.09*BIJ(I)+0.28*GUL(I)
      YAD(I)=0.4*AHM(I)+0.6*SOL(I)
  100 BAW(I)=0.2*(DHA(I)+RAI(I)+BEL(I)+ANA(I)+KUR(I))
C     WRITE(2,11)(KAR(I),DHO(I),NAR(I),TAK(I),WAD(I),YAD(I),
C    1BAW(I),I=1,N)
      WRITE(2,12)
C     Cumulative rainfall from June to October
      WRITE(2,13)
      WRITE(2,14)
      WRITE(2,15)
```

```
      WRITE(2,16)
      IY=1
      IS=7
  112 IN=2
      ISS=IS+3
      SKAR(IY,IN-1)=0.0
      SDHO(IY,IN-1)=0.0
      SNAR(IY,IN-1)=0.0
      STAK(IY,IN-1)=0.0
      SWAD(IY,IN-1)=0.0
      SYAD(IY,IN-1)=0.0
      SBAW(IY,IN-1)=0.0
  110 SKAR(IY,IN)=SKAR(IY,IN-1)+KAR(IS)
      SDHO(IY,IN)=SDHO(IY,IN-1)+DHO(IS)
      SNAR(IY,IN)=SNAR(IY,IN-1)+NAR(IS)
      STAK(IY,IN)=STAK(IY,IN-1)+TAK(IS)
      SWAD(IY,IN)=SWAD(IY,IN-1)+WAD(IS)
      SYAD(IY,IN)=SYAD(IY,IN-1)+YAD(IS)
      SBAW(IY,IN)=SBAW(IY,IN-1)+BAW(IS)
      IN=IN+1
      IS=IS+1
      IF(IS-ISS)110,110,111
  111 IS=IS+8
      IY=IY+1
      IF(IS-N)112,112,113
  113 IS=IS
      DO 115 IN=2,5
      DO 116 IY=1,NY
      NSY=NST+IY-1
  116 WRITE(2,11)NSY,SKAR(IY,IN),SDHO(IY,IN),SNAR(IY,IN)
     1,STAK(IY,IN),SWAD(IY,IN),SYAD(IY,IN),SBAW(IY,IN)
      WRITE(2,12)
  115 CONTINUE
      STOP
      END
```

Appendix - V

```
$debug
C      Drought forecasting for dynamic ground water storage.
C      DFF is the input data file to this programme.
C      NM= Cumulative rainfall (mm) starting from July to
C      July+August+September+October.
C      DIS= Is the measured discharge of the month of October,cum/sec
C      IT= Number of months for which DGWS is to be estimated
C          starting from the month of October.
C      If NM=3, the discharge of October is to be given.
       DIMENSION RF(7),TO(7),AMDT(7),AMD(7),DIT(7),DIS(7),QT(7)
      1,QTD(10,7),AFDT(7),AFD(7),DIQ(7)
       CHARACTER*12 IN,OUT,DIT,DIQ
     8 FORMAT(/)
     9 FORMAT(7F8.2)
    10 FORMAT(6X,'Karad',5X,'Dhond',3X,'Narsinghpur',2X,'Takali',
      12X,'Wadakwal',3X,'Yadgir',2X,'Bawapuram')
    11 FORMAT('Total dynamic ground water storage in the month of')
    13 FORMAT(' October, 1000000*cumec')
    12 FORMAT('Dynamic ground water storage starting from the')
    14 FORMAT('month of October, 1000000*cumec')
    16 FORMAT('ND: No drought; MD: Moderate drought; SD: Severe drought')
    17 FORMAT('Drought prediction')
    22 FORMAT('Drought prediction by measured discharge of October')
    18 FORMAT(7F10.1)
    23 FORMAT('Drought forecasting considering rainfall of J+J+A')
    24 FORMAT('Drought forecasting considering rainfall of J+J+A+S')
    25 FORMAT('Drought forecasting considering rainfall of J+J+A+S+O')
    26 FORMAT(4X,7F9.1)
    27 FORMAT('Estimated depletion time')
    20 FORMAT(5X,'INPUT FILE NAME?')
    21 FORMAT(5X,'OUTPUT FILE NAME?')
    32 FORMAT(A)
    33 FORMAT(8X,7A10)
       WRITE(*,20)
       READ(*,32)IN
       WRITE(*,21)
       READ(*,32)OUT
       OPEN(UNIT=1,FILE=IN,STATUS='OLD')
       OPEN(UNIT=2,FILE=OUT,STATUS='NEW')
       DATA AMDT/ 1.34, 1.165,  0.91,  0.95, 0.80,  1.39,  0.86/
       DATA  AMD/ 1.25, 0.980,  0.61,  0.57, 0.37,  1.06,  0.53/
       IT=6
       READ(1,*)NM
       READ(1,26)(RF(I),I=1,7)
       IF(NM-1)101,100,101
   100 WRITE(2,23)
       WRITE(2,8)
       TO(1)= 0.76238+0.002348*RF(1)
       TO(2)=-0.4853+0.0066832*RF(2)
       TO(3)=-0.67177+0.005175*RF(3)
```

```
      TO(4)=-0.54402+0.0089967*RF(4)
      TO(5)=-2.9753+0.015156*RF(5)
      TO(6)= 0.60423+0.0038353*RF(6)
      TO(7)=-2.3543+0.01986*RF(7)
  101 IF(NM-2)103,102,103
  102 WRITE(2,24)
      WRITE(2,8)
      TO(1)= 0.96469+0.0012724*RF(1)
      TO(2)= 0.022418+0.0034189*RF(2)
      TO(3)=-0.35708+0.0028885*RF(3)
      TO(4)=-2.062+0.011*RF(4)
      TO(5)=-1.6674+0.0062912*RF(5)
      TO(6)= 0.71698+0.0019776*RF(6)
      TO(7)=-0.74183+0.0054365*RF(7)
  103 IF(NM-3)105,104,105
  104 WRITE(2,25)
      WRITE(2,8)
      TO(1)= 0.82118+0.0014444*RF(1)
      TO(2)=-0.39671+0.0039945*RF(2)
      TO(3)=-0.75968+0.0034603*RF(3)
      TO(4)=-2.3436+0.010496*RF(4)
      TO(5)=-2.5452+0.0072688*RF(5)
      TO(6)= 0.68561+0.0020577*RF(6)
      TO(7)=-1.4674+0.0059878*RF(7)
  105 WRITE(2,27)
      WRITE(2,10)
      WRITE(2,18)(TO(I),I=1,7)
      DO 106 I=1,7
      IF(TO(I)-AMDT(I))108,107,107
  107 DIT(I)='ND'
  108 IF(TO(I)-AMDT(I))109,106,106
  109 DIT(I)='MD'
  106 CONTINUE
      WRITE(2,8)
      WRITE(2,17)
C     WRITE(2,18)(DIT(I),I=1,7)
      DO 116 I=1,7
      IF(TO(I)-AMD(I))118,117,117
  117 DIT(I)=DIT(I)
  118 IF(TO(I)-AMD(I))119,116,116
  119 DIT(I)='SD'
  116 CONTINUE
      WRITE(2,33)(DIT(I),I=1,7)
      WRITE(2,16)
      IF (NM-3)120,121,120
  121 READ(1,26)(DIS(I),I=1,7)
      WRITE(2,8)
      WRITE(2,11)
      WRITE(2,13)
      DO 122 I=1,7
      QT(I)=DIS(I)*TO(I)*2.3
  122 QT(I)=QT(I)*30*24*60*60/1000000
      WRITE(2,18)(QT(I),I=1,7)
```

```
      WRITE(2,8)
      WRITE(2,12)
      WRITE(2,14)
      DO 124 J=1,IT
      DO 123 I=1,7
  123 QTD(I,J)=DIS(I)/EXP(J/TO(I))
      WRITE(2,18)(QTD(I,J),I=1,7)
  124 CONTINUE
      DATA AFDT/1310.7, 1292.3, 1720.3, 3217.5, 500.2, 14477.3, 3402.4/
      DATA  AFD/1188.3,  697.0,  197.8,  485.7, 139.4,  6705.1,  454.5/
      DO 126 I=1,7
      IF(QTD(I,1)-AFDT(I))128,127,127
  127 DIQ(I)='ND'
  128 IF(QTD(I,1)-AFDT(I))129,126,126
  129 DIQ(I)='MD'
  126 CONTINUE
      WRITE(2,8)
      WRITE(2,22)
      WRITE(2,10)
C     WRITE(2,18)(DIQ(I),I=1,7)
      DO 136 I=1,7
      IF(QTD(I,1)-AFD(I))138,137,137
  137 DIQ(I)=DIQ(I)
  138 IF(QTD(I,1)-AFD(I))139,136,136
  139 DIQ(I)='SD'
  136 CONTINUE
      WRITE(2,33)(DIQ(I),I=1,7)
      WRITE(2,16)
  120 STOP
      END
```