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HYDROLOGIC DROUGHT CHARACTERISTICS OF THE UPSTREAM REACHES OF THE MAE KLONG RIVER

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Abstract

A study of the drought conditions in the headwater zones is intended to help assess future storage conditions and impact on water resources management . So many hydrologists have systematically carried out on the extraction and diagnosis of the hydrologic drought characteristics in the upstream reaches so far.

In this paper we statistically attempt an analysis for stream flow drought characteristics of two research catchments (Srinagarind Dam (A=10,880 km^2) and Khao Laem Dam basin area(A=3,720 km^2)) located at the headwater zone of the Mae Klong river, and in addition compare drought conditions of the two dam basin areas. The correlogram of the monthly discharge time series shows that the seasonal variation is almost the same with an annual cycle for the two basins. Judging from the correlogram of the daily discharge time series it is concluded that the recession in the Srinagarind Dam basin is stronger than that in the Khao Laem Dam basin suggesting a more reliable baseflow contribution from the Srinagarind Dam basin. This phenomena coincide with the analytical results according to the recession constant of a master recession curve for the flow data.

The estimation of a flow duration curve is improved in order to encourage a wise use, and in addition is applied to the two dam basin areas. The flow duration curves for both basins show that the ordinary and low-water discharge values for exceedence probability levels of (95 and 90 percent) is higher for the Srinagarind Dam basin than that of the Khao Laem Dam basin. It is therefore concluded that even though the amount of rainfall at the Srinagarind Dam basin is less than that of the Khao Laem Dam, the Srinagarind Dam basin is a more reliable source of water during prolong drough conditions within an annual cycle. It is expected that storage conditions in the headwater zone can be assessed through the improved development of a flow duration curve.

Keywords; drought characteristics, frequency analysis, gamma distribution, flow duration curve

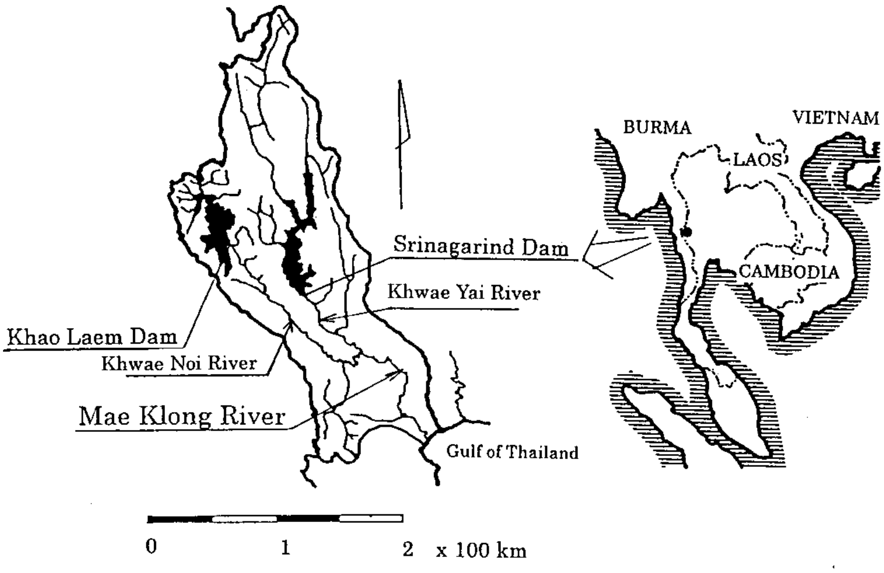


Figure 1. Map of study area

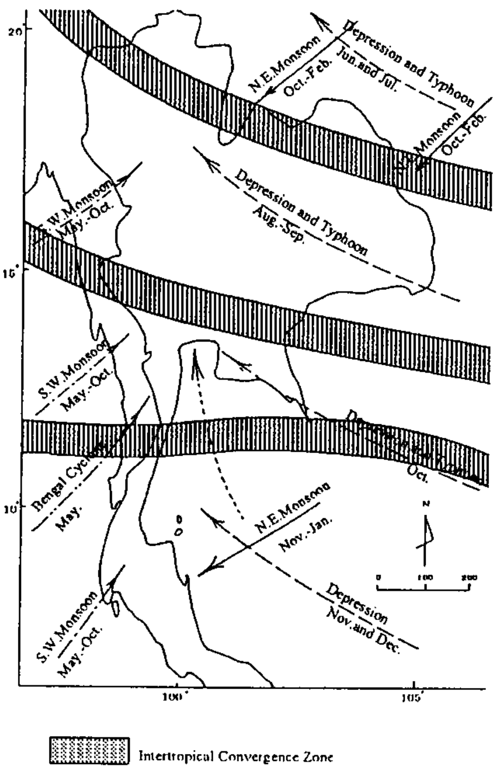


Figure 2. Storm tracks in Thailand.

1. INTRODUCTION

In general , two aspects of drought are important. One is the socio-economic impact of drought when demand exceeds the rate of supply. The other aspect relates to the hydrology, namely when the stream flow is much smaller than the required supply. This paper deals with the latter issue.

Since the water resources situation will be increasingly tight in future, water resources planners need the effective hydrologic information in the source area of a river through the statistical and/or runoff analysis. And then it is particularly required to provide an effective water resources management in ungauged sites.

Now it is very easy to get various Satellite Data. Then using those data , many hydrologists and meteorologists have so far presented effective and interesting research results for the global water balance and climate change and so on (For example, Nathan J. Mantua et al.,1977 ; Kelly T. Redmond and Roy W. Koch ,1991; Donald W. Cline, Roger C. Bales et al., 1998) On the other hand , a statistical analysis on regional low flow have lively been carried out using the observation data from the earth (H.C. Riggs,1961; F.A.Huff et al.,1964 ; William J. Schneider, 1965 ; Richard M. Vogel and Charles N. Kroll,1989,1992 ; Gustard,A. et al.,1992). Besides the estimation approach of low flow has been discussed considering basin area characteristics (S.Lawrence Dingman et al.,1995) and GIS analysis(Andres R. et al.,1996).

The objective of this paper is to extract and discuss drought characteristics of the headwater zones with very different rainfall regimes through the statistical anylysis and the use of flow duration curve.

2. DESCRIPTION OF THE STUDY AREA

The two headwater catchment areas in the upper reaches of the Mae Klong river were selected for the study with the restriction that there are no regulation or diversion structures. Moreover this zone has the high possibility for water resources exploration.

2.1.Outline

The research catchment is the Srinagarind Dam (called S-Dam) (A=10,880 km^2) and Khao Laem Dam basin area(called K-Dam)(A=3,720 km^2) located in the upstream reaches of the Mae Klong River in the western Thailand which has the border with Burma(Figure 1). The Mae Klong River is composed of the two main tributalies, the Khwae Yai (L=450m) and Khwae Noi River(L=320m). Its border has the mountain range of the altitude of over 1,000 m is the source area of the two tributaries. The divide between S-Dam and K-Dam is bordered with the mountainous zone which has the altitude of about 2,000m.

The climate characteristics in Thailand depends on the direction of the monsoon wind , an occurrence of depression(mainly Typhoon) ,and the staying period of the intertropical convergence zone. The storm tracks in Thailand is shown in Figure 2.

The southwest monsoon season begins in mid-May and ends in late October. At this season , if the intertropical convergence zone stays and in addition the southwest monsoon is strongly affected by the depression , the heavy rain is occurred . So this period is called rainy season. The northeast monsoon starts at the end of October and ends in next February . This period is generally called dry season.

2.2. Data collection

Although there are many rainfall stations that are managed by RID(Royal Irrigation Department), EGAT(Electricity Generating Authority of Thailand) and Meteorological Department from the middle to the downstream area of the Mae Klong River basin , the rainfall observation system in the upstream reaches of two dam basin areas is scarcity, and the length of records is respectively different.
There are two rainfall observation stations in each catchment study area, but each record length is different ,and the overlapping period is too short. Then the rainfall data of the dam site is only used in this paper. The streamflow data is arranged and estimated with the stage-dischrage relationship at the gaging station before the construction of dam, and from reservoir water balance before and after the construction of dam respectively.

2.3. Principal rocks type

The principal rock feature is shown in Table 1. The K- Dam is mainly composed of alluvial with gravel and sand element (31 %), and shale, sandstone and limestone and so on (35%) . On the other hand , the S- Dam is composed of dolomitic limestone and sandstone (23%) and limestone (46%).

Table 1 Description of the two research catchments

Dam station	Catchment Area (km^2)	Period of Data		Principal rocks
		Rainfall	Streamflow	
Srinagarind	10,880	1954 ～ '94 (Si Sawat)	1952 ～ '97	Allurial deposits (31%) Shale,sandstone,and limestone (35%)
Khao Lean	3,720	1952 ～ '94 (Thong Pha Phum)	1952 ～ '97	Dolomitic limestone sandstone; thick bedded to massive (23%) Limestone,well bedded (46%)

3. DISCUSSION ON RAINFALL AND DISCHARGE CHARACTERISTICS

3.1 Relation between rainfall and discharge

The relation between annual rainfall and discharge is given in Figure 3. There are several points that runoff depth is larger than annual rainfall. That's why the point rainfall at the dam site was used against runoff depth over the dam basin area . So it is hard to understand correctly the relation between rainfall and runoff depth over the study basin area. However the difference of runoff depth and rainfall in the two study basin areas is shown in Figure 3. The annual rainfall of the S-Dam ranges from 500 to 1,300 mm and K-Dam basin rainfall ranges between 1,000mm to 2,400 mm. The annual runoff ratio of S-Dam catchment ranges between 0.25-0.50, and for the K-dam basin between 0.55-0.80.

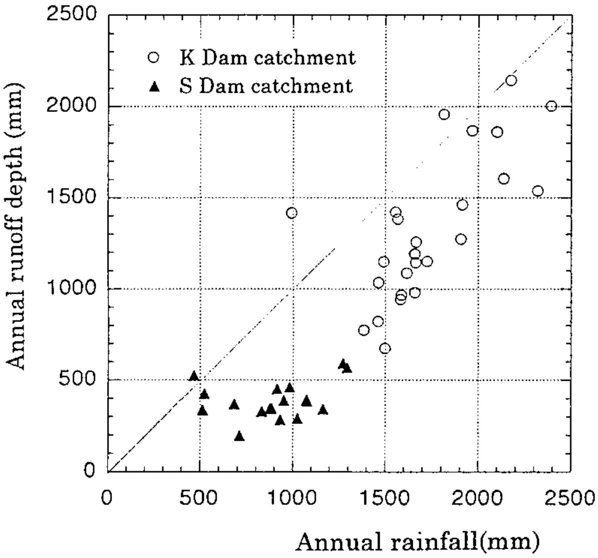


Figure 3. Relation between rainfall and runoff depth.

3.2 Characteristics of the discharge time series

Figure 4 is a comparison of the two dam basin areas for the annual flow. The marked difference of annual flow is shown in this picture. The correlogram of the monthly discharge time series is shown in Figure 5. It is illustrated that the period of cycle for the two dam basin areas is about one year, and a periodic component, such as a wet and dry seasons ,is contained in the time series of discharge data. The seasonal characteristics of the K-Dam basin area is a little stronger than that of the S-Dam basin area. In Figure 6 ,the correlogram of the daily discharge time series is drawn using 10 year records arranged with high accuracy. It is concluded that the reliable base flow contribution from the S-Dam basin area is stronger than that from the K-Dam basin area.

The recession constant of a master recession curve ,defined as one of the expressional styles that represents the low flow recession characteristics, is graphically estimated. The value for the K-Dam basin area is 0.024(d^{-1}), that for the S-Dam 0.013(d^{-1}). This tendency coincides with the analytical results shown by the correlogram of the monthly discharge time series.

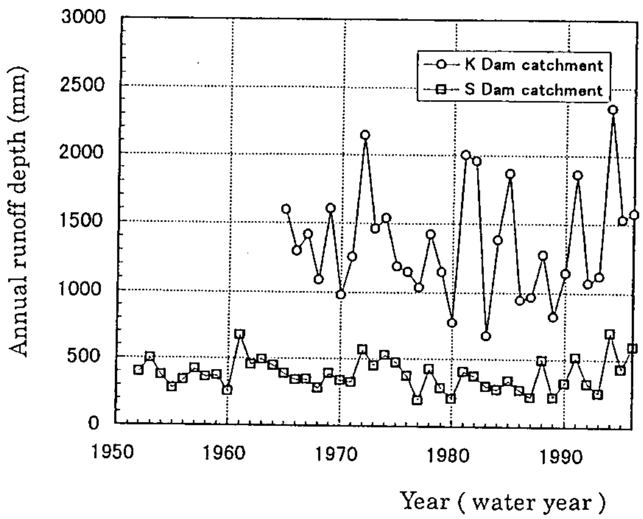


Figure 4. Comparison of the annual flow variation.

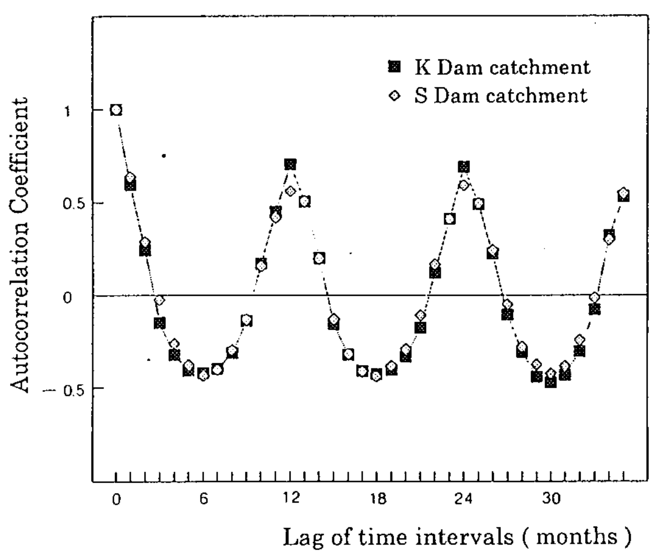


Figure 5. Comparison of the correlogram based on monthly flow.

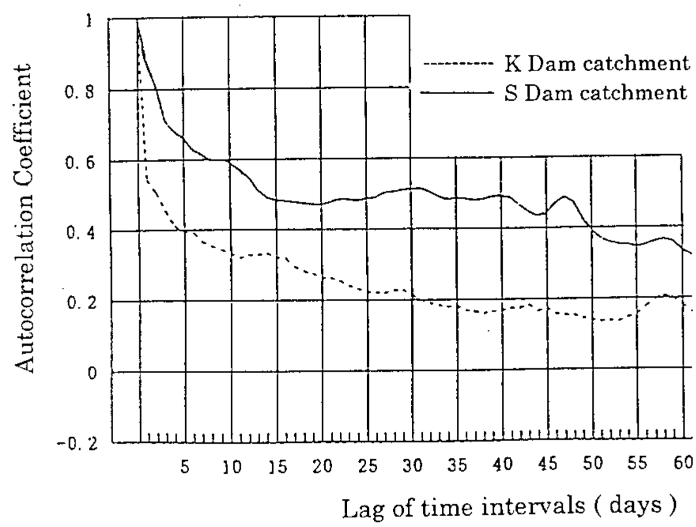


Figure 6. Comparison of the correlogram based on daily flow.

3.3 Probability distribution of discharge

The gamma distribution has been widely used in hydrology. It's density function can be written as

$$f(x)=\frac{a}{\Gamma(h)}\left[a(x-v)\right]^{h-1}e^{-a(x-v)} \quad , \qquad v<x<\infty \qquad (1)$$

Where h, a and v are shape, scale, location parameters respectively, and Γ(h) is a gamma fuction.

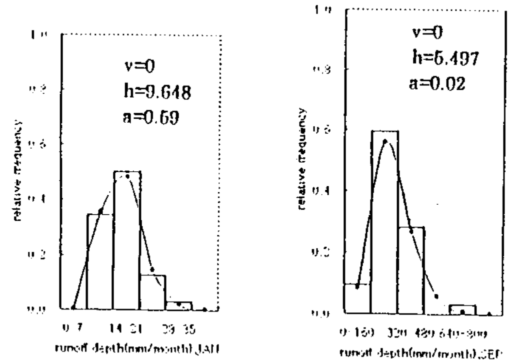
The parameters of the gamma distribution for each monthly flow data are estimated, and the example of comparison between estimated histogram and observed one of the two dam basin areas is given in Figure 7.

Testing for goodness of fit was carried out with the chi-square test. The test results are shown in Table 2. These results (Figure 7 and Table 2) mean that the gamma distribution function is a good approximation for the each monthly flow data.

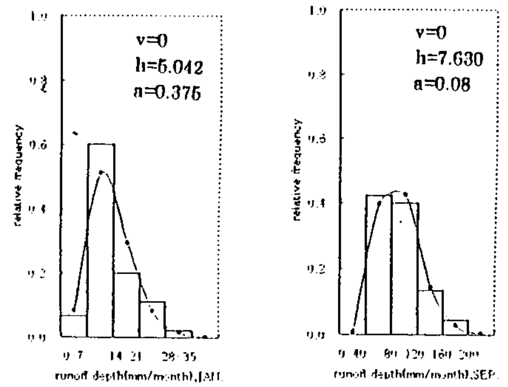
In this paper, the number of classes is estimated according to Sturges ,H.A.(1926); namely

$$m=1+3.3 \log n \qquad (2)$$

Where m is the number of classes, and n is the number of observations.



(a) Example of the K Dam catchment



(b) Example of the S Dam catchment

Figure 7. Comparison of observed and expected histogram.

(according to the gamma distribution)

Table 2. Results of the chi-square test

S-Dam catchment

	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
X^2	2.40	5.03	10.65	3.25	3.52	1.11	2.08	2.07	1.33	2.43	2.18	10.25
$X^2_{D.F}$ (5%)	12.59	11.07	11.07	9.49	11.07	11.07	11.07	9.49	9.49	11.07	11.07	9.49
$X^2_{D.F}$ (10%)	18.48	15.09	15.09	13.28	15.09	15.09	15.09	13.28	13.28	15.09	15.09	13.28

K-Dam catchment

	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
X^2	6.51	2.00	3.15	7.02	11.76	2.16	0.05	0.23	0.47	0.27	0.64	6.51
$X^2_{D.F}$ (5%)	11.07	11.07	11.07	14.07	11.07	11.07	9.49	11.07	11.07	11.07	11.07	11.07
$X^2_{D.F}$ (10%)	15.09	15.09	15.09	18.48	15.09	15.09	13.28	15.09	15.09	15.09	15.09	15.09

4. DISCUSSION ON DROUGHT CHARCTERISTICS

In the first half of this century (Foster,1934) the flow duration curve was widely used in order to solve a diverse of water resources problems like water supply, hydropower ,and irrigation. However it is difficult to extract the sequential nature of streamflow using this curve. Thus an improvement for the use of the flow duration curve has been carried out (Neil Fennessey et al. ,1990).

4.1 Improvement of a flow duration curve

The procedure for constructing an improved curve is as follows;

Step 1. Construct a simple flow duration curve of one water year period by arranging in the order of discharge values descending magnitude (Figure 8).

Step 2. Read the values of daily discharge parallel to the ordinate and cross to the flow duration curve at suitable intervals from 0 to 100 percent of the time (Figure 9).

The 8-15 plots are at least needed in order to successfully draw a new flow duration curve. In this paper, 8 percent intervals of the time is used.

Step 3. Continue above-mentioned step 1 through step2 for each year.

As a result, the values of daily discharge at each intervals from 0 to 100 percent of the time are read every the given water years.

Do the next step using the new data read at each intervals of the time.

Step 4. Compute and plot on a sheet of logarithmic probability paper the probability values estimated using the following formula.

$$P = \frac{m}{(n+1)} \times 100\,\% \qquad (3)$$

Where P : the percentage of all events less than or equal to each discharge values,

m : the ranked position on the listing,

n : the number of events of record.

Step 5. Fit a straight line through estimated values by eye (Figure 10).

Step 6. Read the values of discharge across to the best fit line from the needed probability values on the ordinate.

Continue above-mentioned step 4 through step 6 at suitable intervals from 0 to 100 percent of the time.

Step 7. Plot on a sheet of semi-logarithmic paper the values of discharge against the percentage of the time discharge is exceeded (Figure 11) .

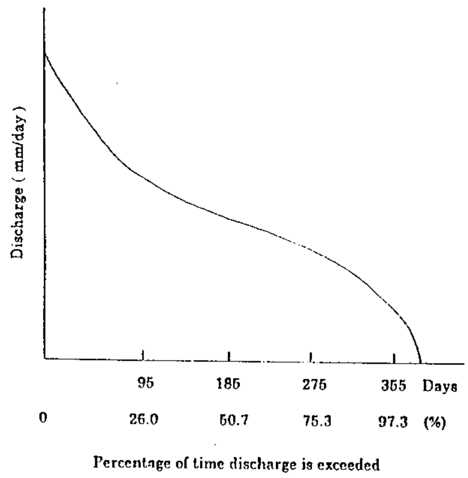
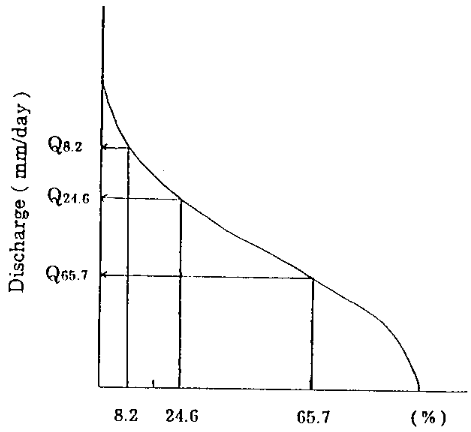
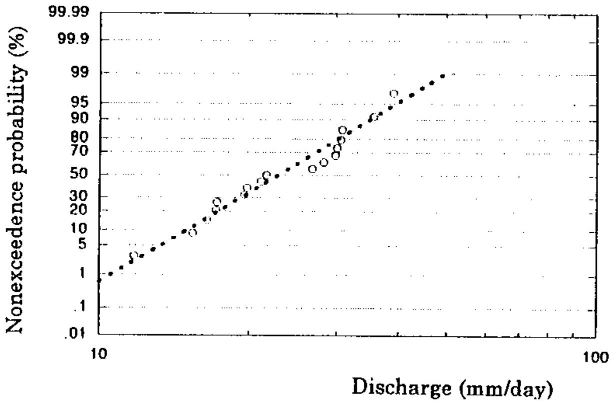


Figure 8. A simple flow duration curve.

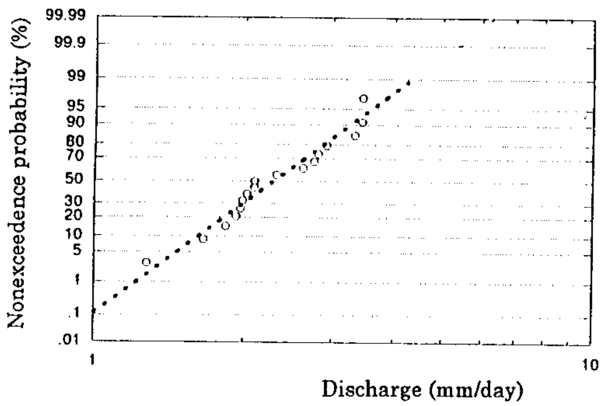


Percentage of time discharge is exceeded

Figure 9. Illustration of discharge values identification at suitable intervals of the time.



(a) Example at 8.2 percent of the time.



(b) Example at 65.7 percent of the time.

Figure 10. Example of the discharge values against the probability at suitable intervals of the time in the S-Dam catchment

4.2 Application to the study catchment basin area

Figure 11 and 12 show the flow duration curve improved with the probability factors. In Figure 11, the flow condition of the heavy droughty year 1989 is drawn in order to show the situation of droughty level. These curves are labeled with values of probability (5,10,25 and 50 percent) that daily discharge will be less than the amount indicated on the ordinate. Figure 11 is an example of the S-Dam basin area, using from the line of 5 percent it is read that the ordinary –water discharge (50.5 % of time) is 2.1 (mm/d), low-water discharge (75.1 % of time) 1.0 (mm/d). On the other hand, Figure 12 is an example of the K-Dam basin area. It is shown that the ordinary –water discharge is 1.6(mm/d), low –water discharge 0.34(mm/d).Finally the comparison of the improved flow duration curves for two dam basin areas is given in Figure 13. The flow duration curves for both basin areas show that the ordinary and low-water discharge values for nonexceedence probability levels of (5 and 10 percent) is higher for the S-Dam basin than that of the K-Dam basin. It is therefore concluded that even though the amount of rainfall at the S-Dam basin is less than that of the K-Dam, the S-Dam basin is a more reliable source of water during prolong drought conditions within an annual cycle.

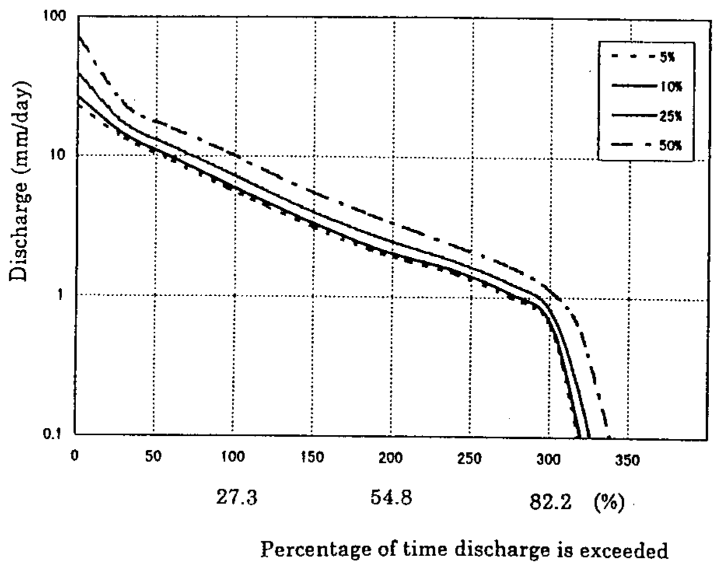


Figure 11. Example of the flow duration curve in the S-Dam catchment.

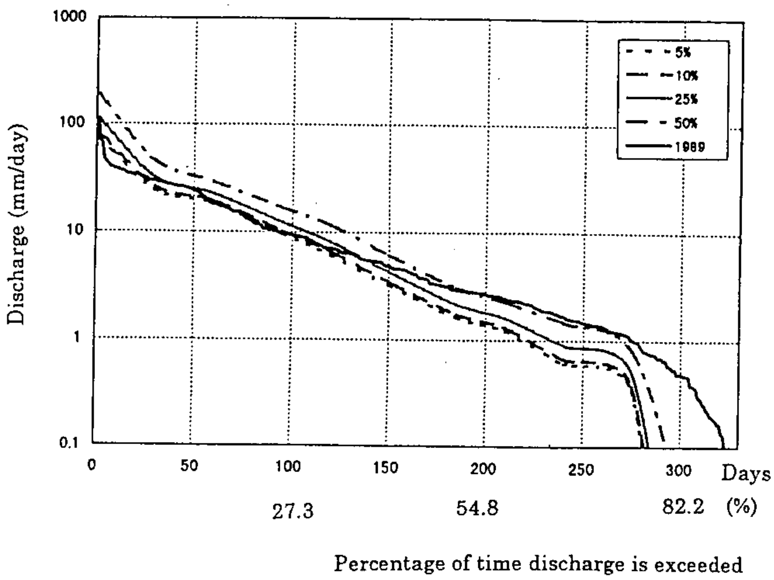


Figure 12. Example of the flow duration curve in the K-Dam catchment.

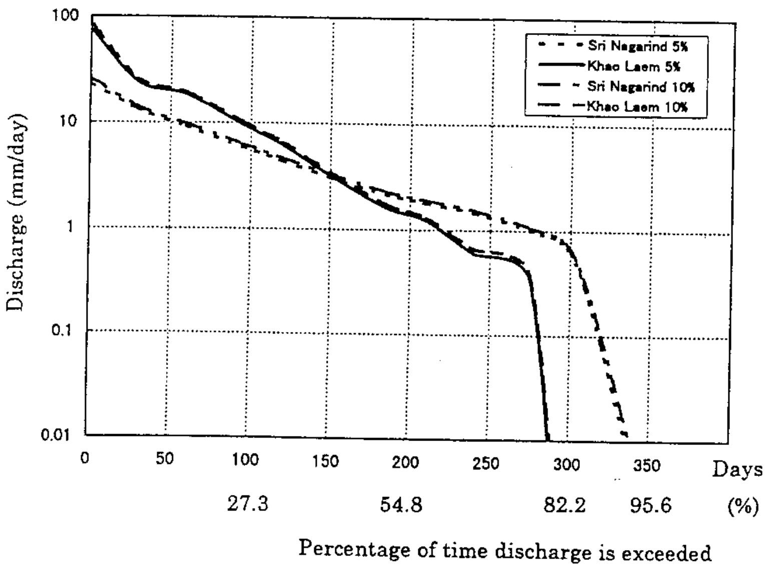


Figure 13. Comparison of the flow duration curve in two dam catchments.

5. CONCLUSIONS AND FUTURE RESEARCH

Our goal is to examine and analyze drought characteristics of the headwater zones of two Thailand basin with very different rainfall regimes. Study of the drought conditions in two basins are intended to help assess future storage conditions and impact on water resources management.

The first research catchment is the Srinagarind Dam with headwater catchment area of A=10,880 km^2 and second one is the Khao Laem Dam with the headwater catchment area of A=3,720 km^2. The annual rainfall of the S-Dam ranges from 500 mm to 1,300 mm and K-Dam basin rainfall ranges between 1,000 mm to 2,400 mm. The annual runoff ratio of the S-Dam basin ranges between 0.25-0.50, and for the K-Dam basin between 0.55-0.80.

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The future objective of our study is to provide national design technique for estimating at ungauging sites.

ACKNOWLEDGEMENT

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