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Forecasting of the Chindwin River, Burma, Using the Tank Model

By

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Abstract

This paper describes an attempt to apply the tank model to the task of forecasting the flows of the Chindwin River at Monywa (catchment area 110,350 km^2), near the confluence with the Irrawaddy River, Burma, using discharge data at five stations and rainfall data at five stations.

Several problems were studied as follows:

(1) To calculate daily discharge at Monywa from daily rainfall data at five stations.

(2) To calculate daily discharge at Monywa from daily discharge data at one upstream station and several daily rainfall data.

(3) To calculate daily discharge at Monywa from daily discharge data at one upstream station.

Of the results, the case, in which daily discharge data at Homalin (catchment area 43,174 km^2) and daily rainfall data at four stations (Homalin, Mawlaik, Kalewa and Monywa) were used, gave the best result and can forecast the discharge three days ahead.

The present study has shown that the tank model can be used to improve discharge forecasting along the Chindwin River in Burma.

If more good data were available, it would be possible to improve and extend the present work.

1. Introduction

The Chindwin River is the major tributary of the Irrawaddy, the largest river in Burma. The Chindwin River basin covers an area of about one hundred twenty thousands square km and has a range in elevation of about 100 m to 3826 m.

The Burma Department of Irrigation, Hydrology and Meteorology has carried out many studies of flow forecasting on the Chindwin and Irrawaddy Rivers (U Hla Tin, 1984).

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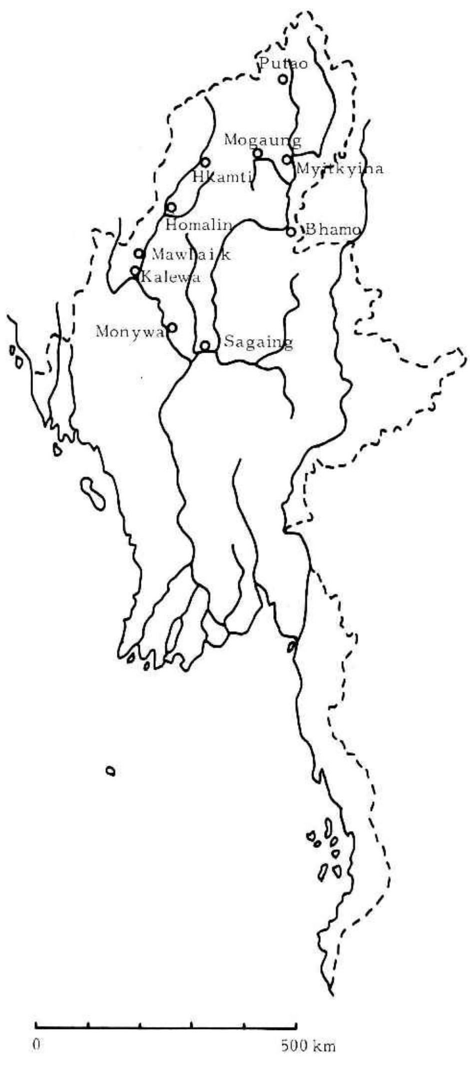

Fig. 1 Map of Burma

This paper describes an attempt to apply the tank model (Sugawara, et al., 1984) to the task of forecasting the flows of the Chindwin River at Monywa, near the confluence with the Irrawaddy.

The river basin and the precipitation and discharge stations are shown on Fig. 1.

2. Available data

In the Chindwin River basin rainfall and daily discharge at the five stations shown in Fig. 1 and Table 1 are available for the four years 1980 to 1983.

Evaporation data are not available and have been assumed as shown in Table 2.

Table 1 Discharge stations and their catchment areas (km^2) within the Chindwin River basin

Hkamti	Homalin	Mawlaik	Kalewa	Monywa
27,420	43,174	69,339	72,848	110,350

Table 2 Daily evaporation (mm/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.0	4.5	6.5	8.0	8.0	5.0	5.0	4.5	4.0	4.0	3.0	3.0

In comparing the hydrographs at the five stations, the discharge data at Hkamti were found to be unreliable in 1983 because the rating curves were not appropriate and also in the dry seasons of 1980—1981 and 1981—1982. The discharge data at Homalin are also questionable. At Mawlaik, some part of the discharge must be below the river bed and were therefore initially neglected. Fortunately, the discharge data at Kalewa and Monywa seem to be reliable.

3. Initial objectives

As a first step, the following problems were studied.

1) To calculate daily discharge at Monywa from daily rainfall data at five stations.

2) To calculate daily discharge at Monywa from daily discharge data at Kalewa and daily rainfall data.

3) To calculate daily discharge at Monywa from daily discharge data at Kalewa.

The results obtained from these studies are shown in Fig. 3, Fig. 7 and Fig. 9, respectively. The simplest procedure 3) gave the best results but it can forecast discharge only one day ahead. The result of procedure 1) is not so good but it can forecast discharge two days ahead.

To extend the forecasting range, the following procedures were studied.

4) To use daily discharge data at Hkamti as input:
   a) By itself
   b) With daily rainfall data from five stations

5) To use daily discharge data at Homalin as input:
   a) By itself
   b) With daily rainfall data from four stations

The results obtained are shown in Fig. 12, Fig. 15, Fig. 18 and Fig. 21. Of them, the procedure 5) b) gives the best result. It is much better than procedure 1) and, moreover, it can forecast discharge three days ahead. The result of procedure 5) a) is somewhat worse than that of 5) b) but it can forecast four days ahead. The results of procedure 4) are worse than those of procedures 5) although, if the rating curves at Hkamti are revised, then procedure 4) can give almost as good results as procedures 5).

4. Forecasting the daily discharge at Monywa from daily rainfall at five stations

4.1 Derived model and obtained result

The tank model used for the Monywa catchment is shown in Fig. 2 and the hydrograph calculated by the derived model is shown in Fig. 3 together with the observed hydrograph. The observed and calculated monthly hydrographs are also shown in Fig. 4.

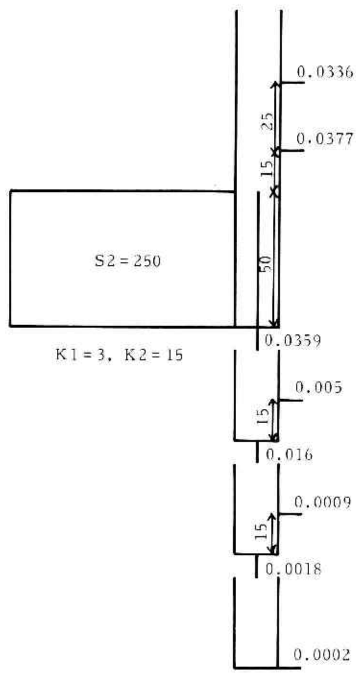

Fig. 2 Derived tank model for Monywa catchment

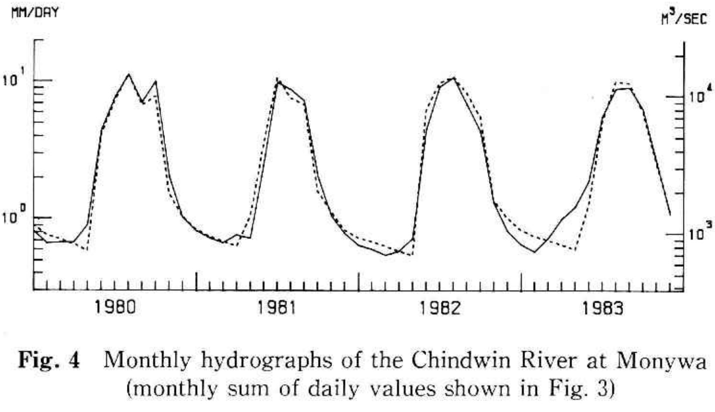

Fig. 4 Monthly hydrographs of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 3)

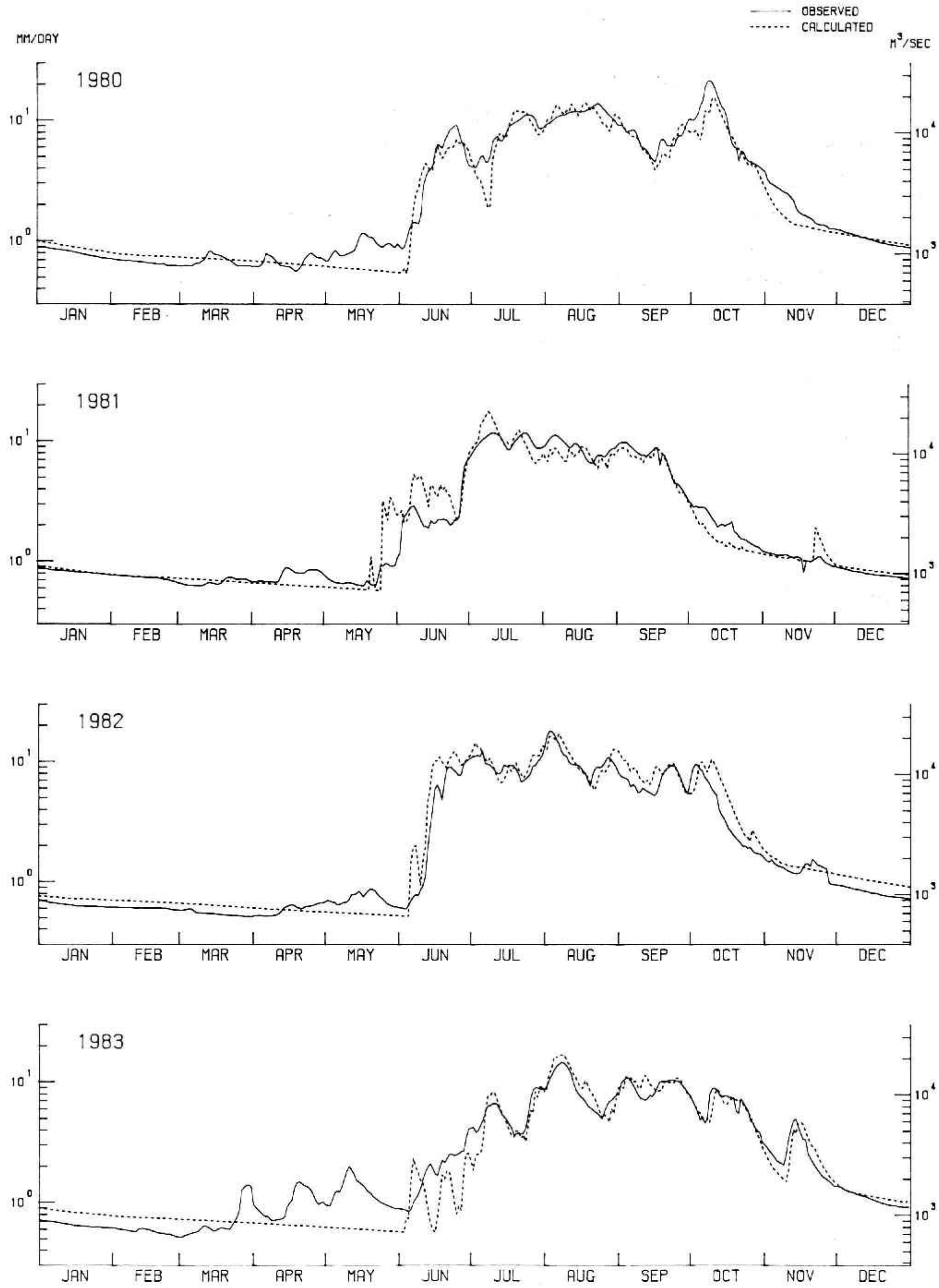

Fig. 3 Daily discharge of the Chindwin River at Monywa (calculated discharge are derived from rainfall at five stations)

The calculated values of daily discharge were obtained by the following procedures:

1) Daily rainfall data at each of the five stations were put into the tank model after multiplication by a factor CP = 1.12 (Sugawara, et al., 1984, p. 11).

The daily evaporation data given in Table 2 were subtracted from the top tank after modification by a factor CE = 0.60.

2) The output series from the tank model, each of which corresponded to one station, were modified by the weights and time lags shown in Table 3.

3) The model shown in Fig. 2 was obtained by the automatic calibration program using duration curve comparisons (Sugawara, et al., 1984, pp. 18-25 and pp. 248-254) from the initial model shown in Table 4 and the initial values were determined by the subroutine INVAL3 (Sugawara, et al., 1984, pp. 255-257).

Table 3 Weights and time lags used in making composed discharge

	Hkamti	Homalin	Mawlaik	Kalewa	Monywa
weight	1.5	1	0.5	0.5	1
time lag (day)	5	4	3	3	3

Table 4 Parameter values of the initial tank model

No. of trial	A0	A1	A2	B0	B1	C0	C1	D1
1	0.05	0.025	0.025	0.01	0.01	0.002	0.002	0.0005
2	0.03	0.03	0.03	0.006	0.006	0.001	0.001	0.0002
3	0.025	0.03	0.03	0.006	0.003	0.0008	0.0004	0.0002
4, 4′ 5, 5′	0.03	0.035	0.035	0.01	0.005	0.001	0.0005	0.0002

other parameters e. g. positions of side outlets, parameters of soil moisture structure, are fixed as follows in all trials:

HA1 = 15, HA2 = 40, HB = 15, HC = 15
S1 = 50, S2 = 250, K1 = 3, K2 = 15

4.2 Modeling procedure

1) Trial No. 1 was made assuming CE = 0.6 and CP = 1.3. The value CP = 1.3 was based on the four year average annual runoff at Monywa, the annual rainfall at five stations and an annual evaporation of 1,068 mm, 60% of the annual total evaporation given in Table 2. Often, however, the value of CP determined by such a procedure is too large, because the actual evaporation from the tank model in the dry season is smaller than the input potential evaporation CE×E. In trial No. 1, the rainfall input was the mean of five stations and the time lag was set to four days. Parameter values of the initial model are shown in Table 4.

2) In trial No. 2, the time series of rainfall at each station were transformed

separately into runoff, and then the five series of output from the tank model were treated with equal weights and a time lag of four days. In this trial, CP was set to 1.25 and there were some change in parameter values of the initial tank model as shown in Table 4.

3) In trial No. 3, CP was decreased to 1.20 and time lags were set to 4 days, 4 days, 3 days, 3 days and 2 days from Hkamti to Monywa, respectively. In these computations, the input rainfall data were shifted beforehand, corresponding to the time lag for each station. To use a time lag of two days for Monywa, which is located at the exit of the basin, may seem to be unreasonable; however, as the rainfall at Monywa is usually not heavy, its effect on calculated discharge is small and so, the effect of time lag for Monywa is not important.

4) Inspecting the results of trial No. 3, the bad fit of calculated and observed hydrographs seemed to have its cause mostly in the rainfall at Mawlaik and Kalewa. These two stations are located close to each other and the patterns of rainfall are similar, which must have some effect on the calculated discharge. Considering this effect, the weights of these two stations were halved. On the other hand, station Hkamti, as representative of the wide upper region, should have a larger weight. The weights and time lags for the five stations used in the new trial are shown in Table 5.

Table 5 Weights and time lags used in trial No. 4

	Hkamti	Homalin	Mawlaik	Kalewa	Monywa
weight	2	1	1/2	1/2	1
time lag (day)	5	4	3	3	2

As the calculated discharge of trial No. 3 was too small, CP was increased to 1.22 in trial No. 4.

5) It was decided that the decision in trial No. 4 to increase CP was a misjudgement in that it increased the discharge too much. To correct this, trial No. 4′ was made by putting CP=1.10 leaving the other parameters the same as before.

6) The weight 2 for Hkamti seemed to be too large and in trial No. 5 it was revised to 1.5. Correspondingly, CP was revised to 1.15 and the other parameters were left the same as trial No. 4′.

7) Calculated discharge of trial No. 5 was slightly large and in trial No. 5′ it was adjusted by putting CP=1.12. This was final trial which gave the results shown in Fig. 3 and Fig. 4.

5. Forecasting daily discharge at Monywa from discharge at Kalewa and rainfall at Mowlaik, Kalewa and Monywa

5.1 Preliminary consideration

The results of the previous trials, shown in Fig. 3 and Fig. 4, were not considered satisfactory. However, to obtain much better results seemed to be very difficult, because the unsatisfactory result must have its cause in the rainfall data. To get a good estimate of discharge from rainfall data at few stations seems to be nearly impossible in tropical regions where it rains very randomly and locally. In the Chindwin River basin, there are only five rainfall stations and they are located along the river. Moreover, there is no station in the upper part of the basin where rainfall must be very heavy to judge from the large river discharge at Hkamti.

Then, the idea occured to use upstream discharge data as input instead of rainfall data in the upper part of the basin. As the discharge data at Hkamti are not reliable and as the Homalin discharge data are also not too good, this new way would use Kalewa discharge as input. In this way, discharge at Monywa is derived partly from observed discharge at Kalewa and partly from the calculated discharge of the residual catchment as derived from rainfall data.

The procedure is composed of two parts.

1) To determine the model for routing the hydrograph from Kalewa to Monywa.

2) To calibrate the tank model for the residual part of the basin.

The catchment areas above Kalewa and Monywa are about 73×10^3 km^2 and 110×10^3 km^2 and their ratio is about 2 : 3. Therefore, the residual part is about 1/3 of the total and it is a rather dry area as can be seen from the annual rainfall at Monywa which is 700 mm or so. The annual runoff of Kalewa catchment is about 1,500 mm— 2,000 mm or so and that of the residual part of the basin is only about 300 mm— 400 mm or so. Therefore, the main part of the Monywa discharge must be composed of Kalewa discharge.

5.2 Deformation of the hydrograph between Kalewa and Monywa

The deformation effect of the hydrograph from Kalewa and Monywa was studied by neglecting the runoff from the residual part of the basin as this is rather small compared with the total discharge of the Monywa catchment. At the beginning, linear structures shown in Fig. 5(1) and (2) were applied but the results were not good as deformation seemed to be caused by some nonlinear transformation. Next, some nonlinear structures, shown in Fig. 5(3) and (4), were applied and, finally the structure shown in Fig. 5(5) gave a considerably good results.

In this final case, the input to the tank with three side outlets is the Kalewa discharge (mm/day). A time lag of one day was given to the output (also in mm/day) when compared with the Monywa discharge.

5.3 Estimation of runoff from the Monywa catchment excluding the Kalewa catchment and runoff analysis for the residual part of the basin

The runoff from the part of the basin between Kalewa and Monywa was estimated by taking the difference between the Monywa discharge and the Kalewa discharge calculated by the procedure described above. It was recognized that this method would give an unreliable result, since both Kalewa and Monywa discharge are similar in amount and both include errors. Therefore, by taking differences, the signal decreases but the noise increases. However, there was no other way.

The runoff from the residual part of the basin was calculated in the following ways:

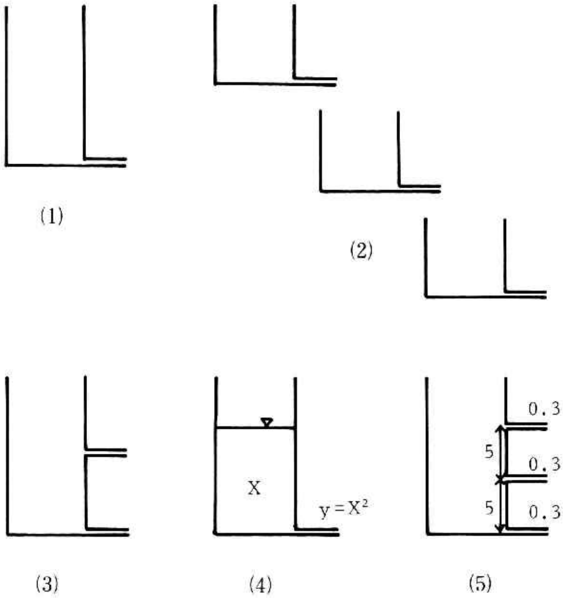

Fig. 5 Structures used in trials for the deformation of hydrograph from Kalewa to Monywa

Let Q1 (mm/day) be the Kalewa discharge obtained as the output of the structure shown in Fig. 5(5) using the time lag of one day, and Q2 (mm/day) be the observed Monywa discharge. Then, the runoff (mm/day) from the residual part of the basin is given by,

$$Q = (Q2 \times S2 - Q1 \times S1) / (S2 - S1),$$

where S1 and S2 are the catchment areas above Kalewa and Monywa, respectively.

The hydrograph obtained was not so reliable and negative discharge values often appeared. Negative discharges and those values less than 0.1 mm/day were replaced by 0.1 mm/day to avoid problems such as plotting the hydrograph in a logarithmic scale and evaluation of the result in a logarithmic scale.

Using the unreliable discharges, the runoff analysis was made using automatic calibration method of duration curve comparison. In this procedure, the evaluation criterion CR was made up of only of CRDC, the criterion for duration curves, instead of the usual sum of CRDC and CRHY (Sugawara, et al., 1984, pp. 23-24), the criterion for hydrographs, since the hydrograph to be simulated was not considered reliable. Even if the hydrograph is not reliable the duration curve is usually much more reliable.

The tank models for the residual part of the basin are shown in Fig. 6, where the left-hand model is the initial one and the right-hand one is the model derived by the automatic calibration procedures. In this model, the factor for evaporation and rainfall were set as CE=0.7 and CP=1.10, respectively. For the whole Monywa basin the evaporation factor was set to CE=0.6. However, for the residual basin, which is located southward and at a comparatively low elevation, CE was assumed to be 0.7. When the factor for rainfall was set to CP=1.20, the calculated discharge was too large and so it was revised to CP=1.10.

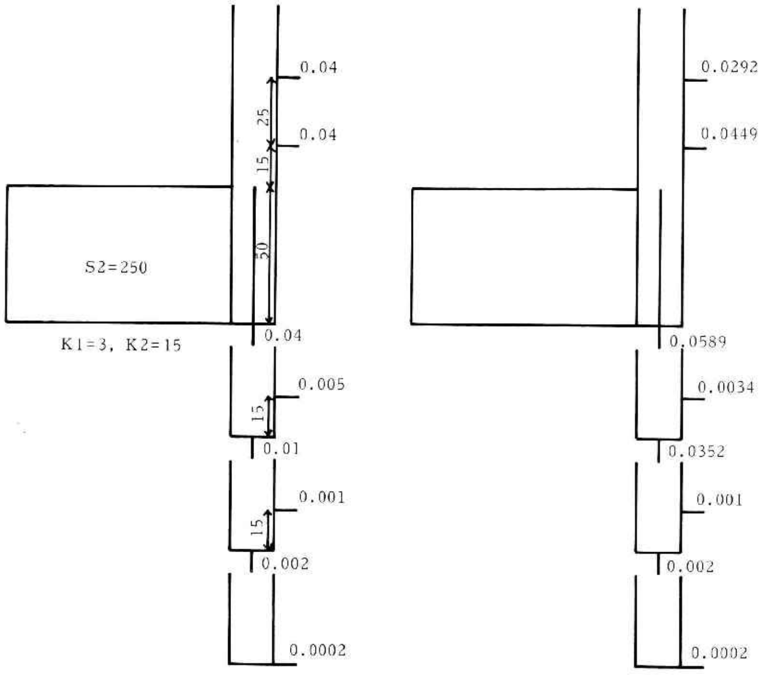

Fig. 6 Tank model for the residual part of the Monywa basin excluding the Kalewa basin

The procedure for deriving the calculated discharge from the residual basin is as follows:

Rainfall data at Mawlaik, Kalewa and Monywa were put into the tank model, separately, and the output series of the tank model were combined with the weights 1 : 1 : 2 and time lags of one day.

Then, the Monywa discharge Q (mm/day) was derived by combining the routed Kalewa discharge Q1 (mm/day) and the calculated runoff Q3 (mm/day) from the residual basin as follows:

$$Q = (Q1 \times S1 + Q3 \times (S2 - S1))/S2,$$

where S1 and S2 are the catchment areas of Kalewa and Monywa, respectively.

The result is shown in Fig. 7 and it is far better than the previous result shown in Fig. 3. However, using this method forecasting can be only one day ahead. The monthly hydrograph obtained by this method is shown in Fig. 8.

6. Forecasting the daily discharge at Monywa from the daily discharge at Kalewa

In the forecasting method for Monywa discharge described above, the Kalewa discharge played the main part. Consequently, an attempt was made to derive the Monywa discharge from the Kalewa discharge only, without using any rainfall data.

The procedure was very simple. Kalewa discharge (mm/day) was put into the structure shown in Fig. 5(5) and the output was lagged by one day. Then, it was

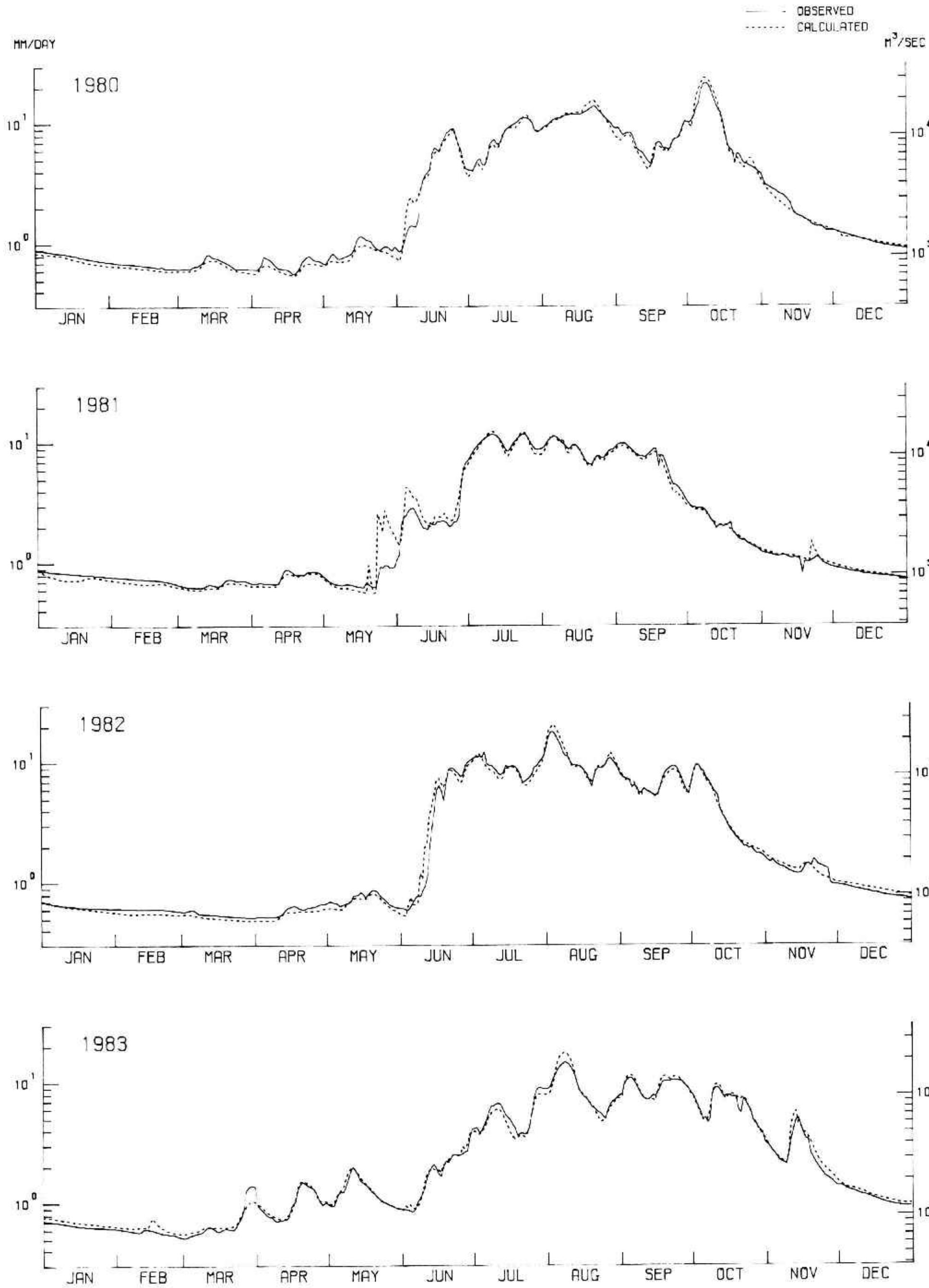

Fig. 7 Daily discharge of the Chindwin River at Monywa (calculated discharge is derived from Kalewa discharge and rainfall at three stations: Mawlaik, Kalewa and Monywa)

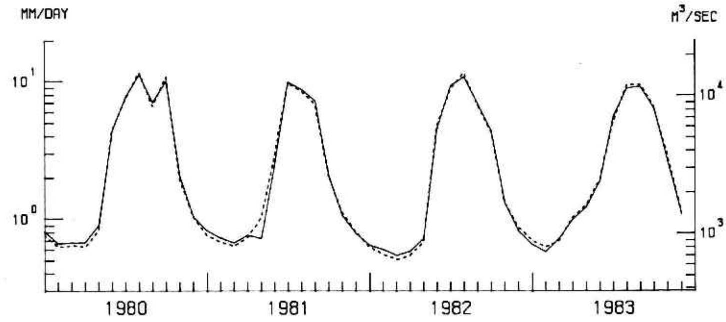

Fig. 8 Monthly hydrographs of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 7)

multiplied by a correction factor of 0.725 which was calculated as the ratio of the total sum (mm) of Monywa runoff over four years to that of Kalewa runoff.

The result is shown in Fig. 9 and the monthly hydrographs are shown in Fig. 10. The result is slightly better than the result of Fig. 7, i. e. the inclusion of rainfall on the residual basin is not necessary. In this method, forecasting can also be only one day ahead.

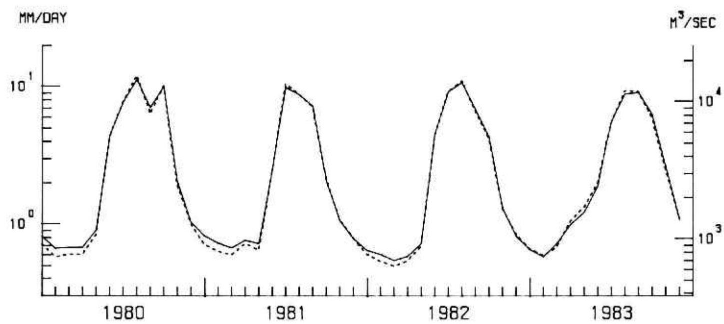

Fig. 10 Monthly hydrographs of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 9)

7. Forecasting the daily discharge at Monywa using discharge data at Hkamti

The forecasting of Monywa discharge from Kalewa discharge can give a very good result but the forecast can be for only one day ahead. Then, the idea occured, that by using Hkamti discharge instead of Kalewa, the forecast lead time could be extended to three or four days. At first, we hesitated to use Hkamti discharge because the data seemed to be unreliable. However, the data are unreliable mostly at the low water stage in the dry season and so we can neglect these periods.

The procedure for deriving the model was the same as those used in the case in which Kalewa discharge was used as input data.

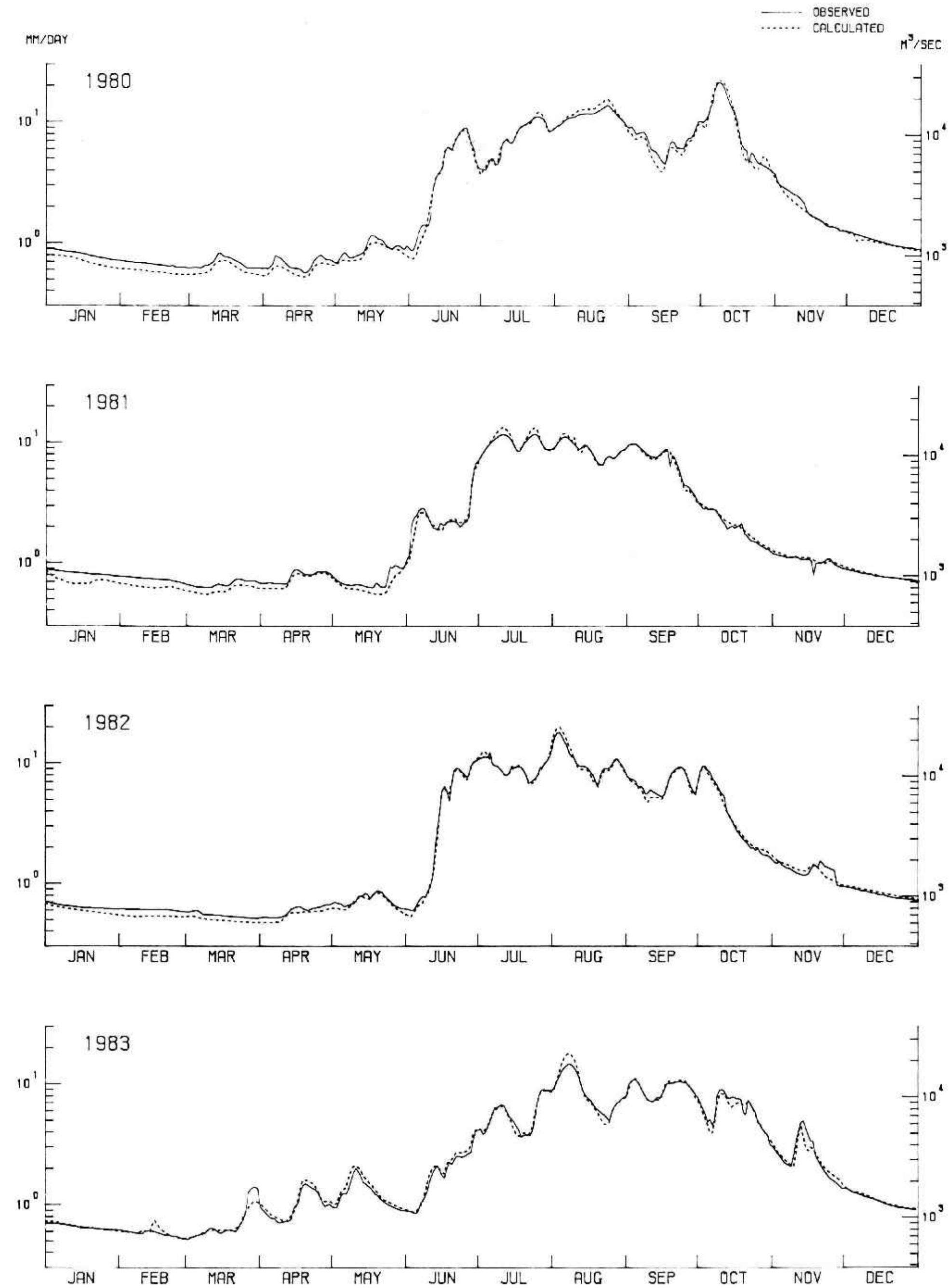

Fig. 9 Daily discharge of the Chindwin River at Monywa
(calculated discharge is derived from Kalewa discharge)

1) Routing of hydrograph from Hkamti to Monywa

The discharges at Hkamti (mm/day) were put into the structure shown in Fig. 11 and the output was lagged and multiplied by a correction factor of 0.46 to give Monywa discharge (mm/day).

As a first step, the structures shown in Fig. 11(1) and (2) were applied with a time lag of six days. Then, the derived hydrographs were compared with the observed and the model was modified a little. The structure for routing was modified to the one shown in Fig. 11(3) and the time lag was revised to five days. The correction factor 0.46 was determined as the ratio of total runoff at Monywa to that of Hkamti in the period in which the data at Hkamti seemed to be reliable.

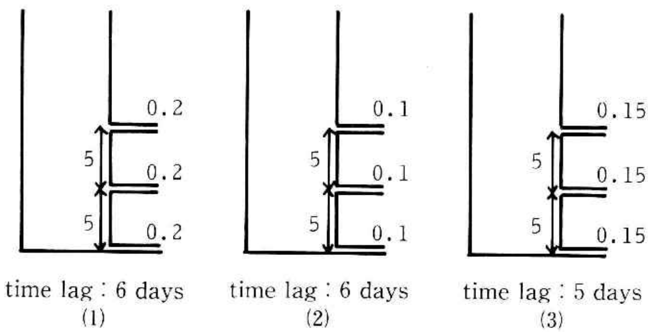

Fig. 11 Structures used in trials for the deformation

The result obtained is shown in Fig. 12 and the monthly hydrographs are shown in Fig. 13. As can be seen the results are not good. This is partly due to the unreliable Hkamti discharge data and partly to the fact that the effect of runoff from the residual part of the basin is large.

2) Derivation of discharge from the residual part of Monywa basin excluding Hkamti basin and runoff analysis using the derived discharge

The discharge from the residual part of the basin can be derived in the same way as in the case of Kalewa. Let Q1 (mm/day) be the routed discharge of Hkamti, i. e.

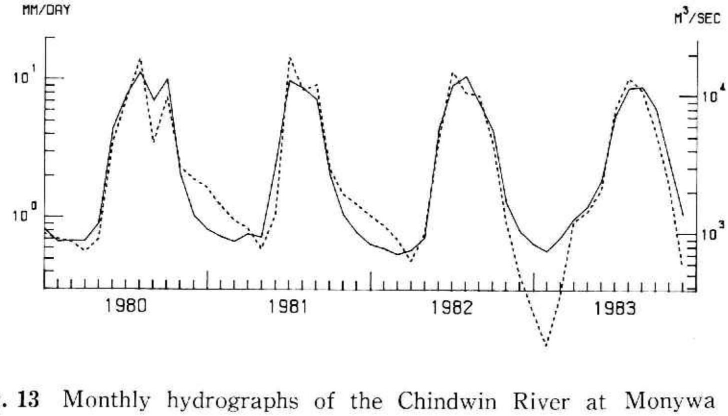

Fig. 13 Monthly hydrographs of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 12)

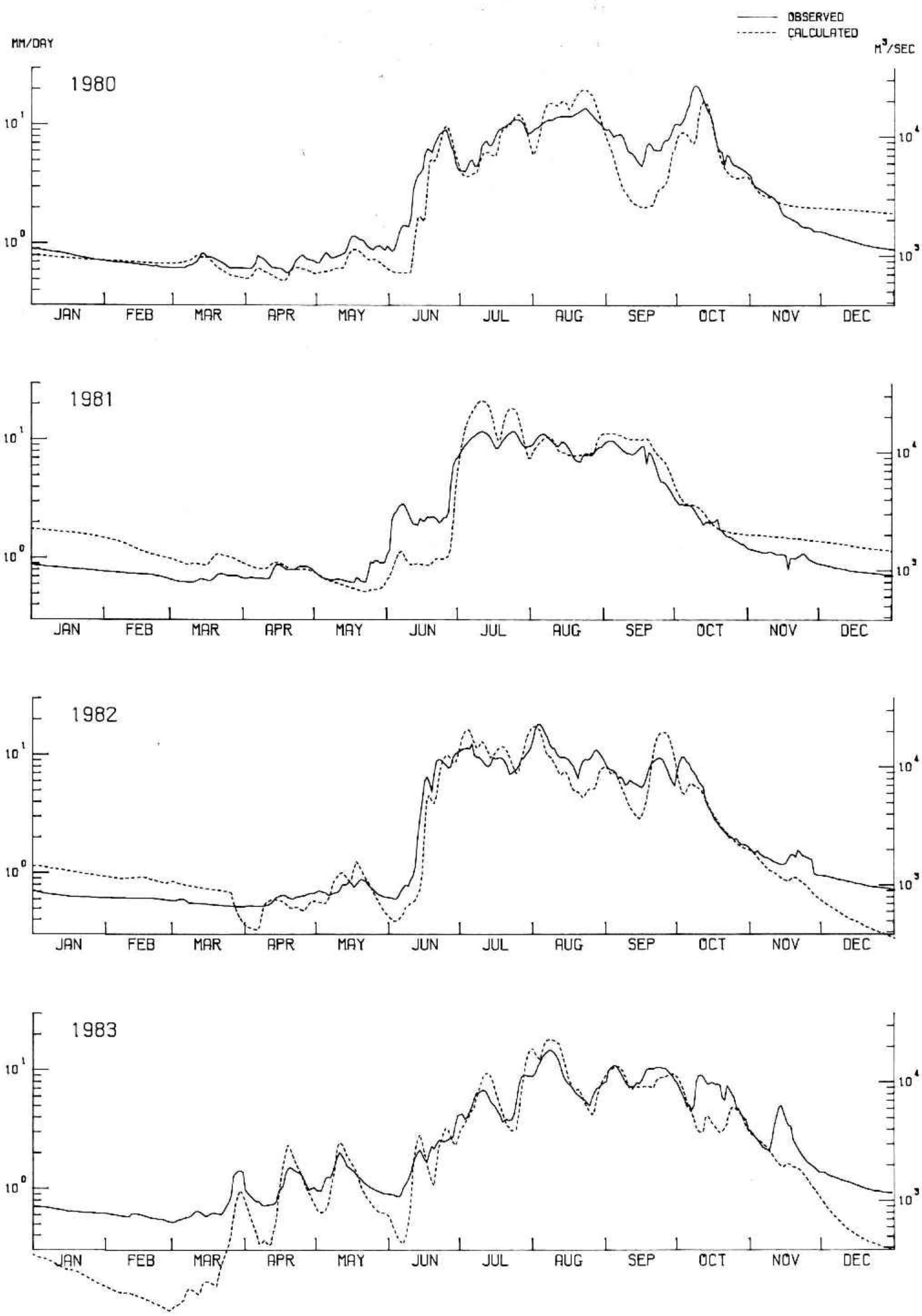

Fig. 12 Daily discharge of the Chindwin River at Monywa
(calculated discharge is derived from Hkamti discharge)

Hkamti discharge (mm/day) deformed by the structure shown in Fig. 11(3) and the output lagged by five days, and let Q2 (mm/day) be the observed Monywa discharge. Then, the discharge (mm/day) from the residual part of the basin is given by,

$$Q = (Q2 \times S2 - Q1 \times S1) / (S2 - S1),$$

where S1 and S2 are the catchment areas of Hkamti and Monywa, respectively.

The derived discharge shows frequent negative values in those periods in which Hkamti discharge seems to be unreliable. Discharge values less than 0.1 mm/day were replaced by 0.1 mm/day. The derived hydrograph seems to be not too bad after neglecting those periods of unreliable data.

Runoff analysis of the residual basin was carried out using the derived discharge and rainfall data at five stations, i. e. Hkamti, Homalin, Mawlaik, Kalewa and Monywa. To neglect the unreliable data, the following periods were masked (Sugawara, et al., 1984, p. 246) in the calibration procedures.

1980 :	10 Nov.	— 31 Dec.		
1981 :	1 Jan.	— 10 Apr.	and 1 Nov.	— 31 Dec.
1982 :	1 Jan.	— 31 Mar.	and 15 Nov.	— 31 Dec.
1983 :	1 Jan.	— 15 Apr.	and 1 Dec.	— 31 Dec.

The automatic calibration program using the duration curve comparison method was applied to calibrate the tank model and the usual evaluation criterion CR= CRHY+CRDC was used because the derived hydrograph of the residual basin seemed to be not too bad. The tank model derived is shown in Fig. 14.

The discharge of the residual basin was calculated as follows:

Rainfall data at each of the five stations were put into the tank model shown in Fig. 14(2) using the correction factors CE=0.65 and CP=1.05. The output series from the tank model were combined using the weights and time lags given in Table 6.

The time lag of three days for Monywa which is located at the exit of the basin is necessary to forecast the discharge three days before. The runoff derived from Monywa rainfall is rather small and, accordingly, the time lag for Monywa is not so important.

Table 6 Weights and time lags used in calculating the discharge of the Monywa basin excluding Hkamti basin

	Hkamti	Homalin	Mawlaik	Kalewa	Monywa
weight	1	1	1	1	1
time lag (day)	4	4	3	3	3

The first trial was made with the correction factors CE=0.6 and CP=1.1. As the calculated discharge of the first trial was too large, the second trial was made with the revised correction factors CE=0.65 and CP=1.05. The hydrograph obtained seemed to be not too bad and this model was retained as the final one. As the derived

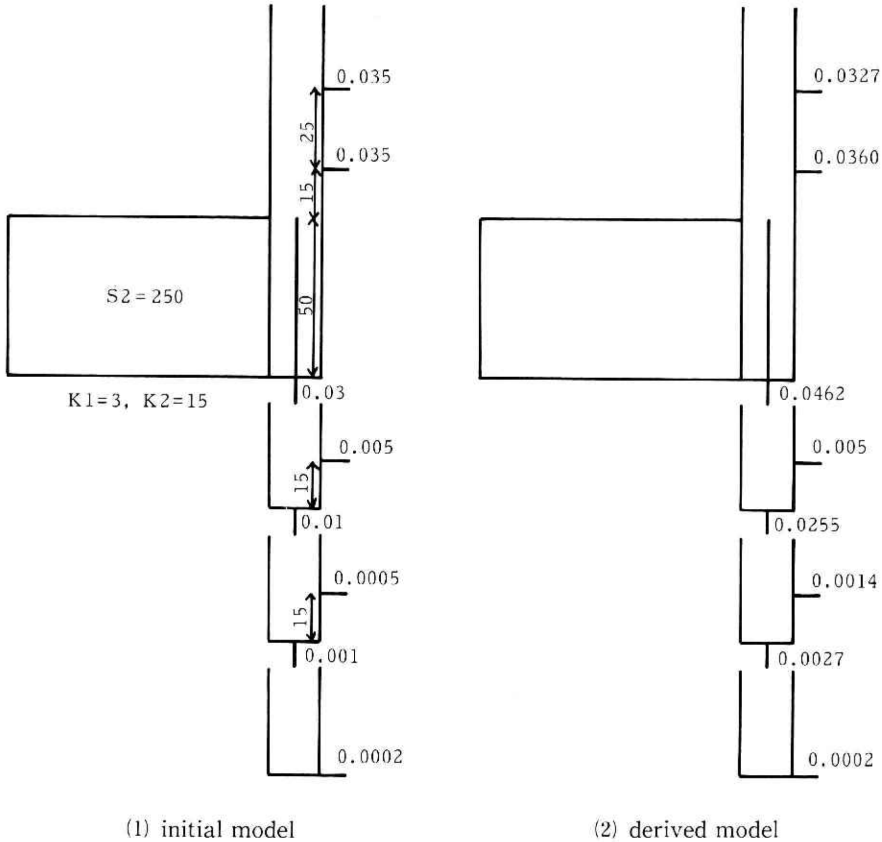

Fig. 14 Tank model for the residual part of Monywa basin excluding Hkamti basin

discharge from the residual basin was not very reliable, further trials seemed to be unnecessary.

3) *Derivation of Monywa discharge using routed Hkamti discharge and calculated discharge from the residual basin*

Using the derived discharge of the residual basin calculated from rainfall data by the procedures described above, Monywa discharge was derived in the following way:

Let Q1 (mm/day) be the routed Hkamti discharge; i. e. Hkamti discharge (mm/day) deformed by the structure shown in Fig. 11(3) with a time lag of five days, and let Q3 (mm/day) be the calculated discharge of the residual basin derived from rainfall data. The calculated discharge (mm/day) at Monywa is then given by,

$$Q = (Q1 \times S1 + Q3 \times (S2 - S1)) / S2,$$

where S1 and S2 are the catchment areas of Hkamti and Monywa, respectively.

The calculated hydrograph is shown in Fig. 15. This result is much better than the one shown in Fig. 12. In contrast to those cases in which Kalewa discharge was used as input, the use of rainfall data improves the calculated Monywa discharge. In this

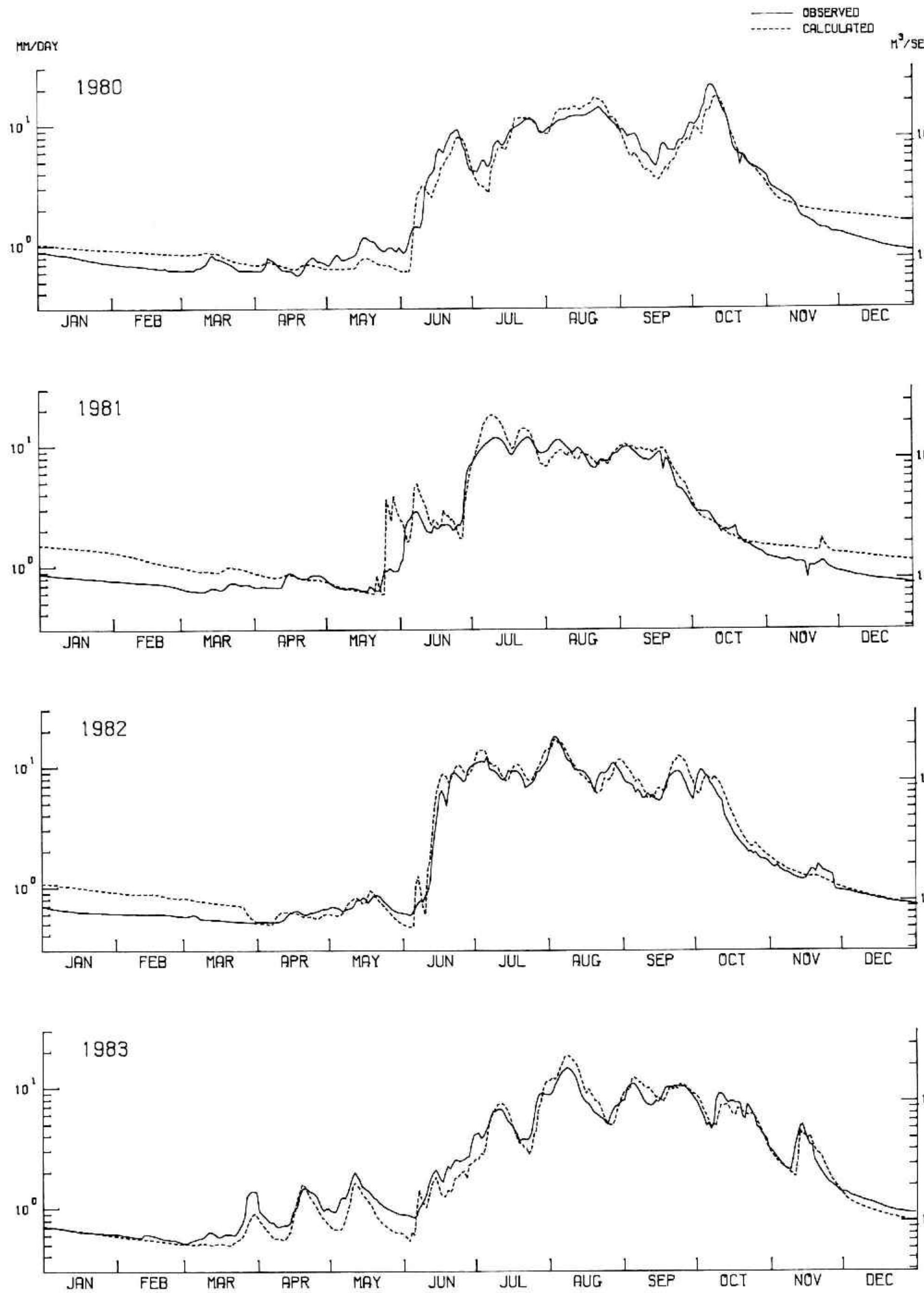

Fig. 15 Daily discharge of the Chindwin River at Monywa (calculated discharge is derived from Hkamti discharge and rainfall at five stations)

case, forecasting lead time is three days. The points of bad fit between observed and calculated hydrographs shown in Fig. 15 is probably caused by the unreliable discharge data at Hkamti. The monthly hydrographs are shown in Fig. 16.

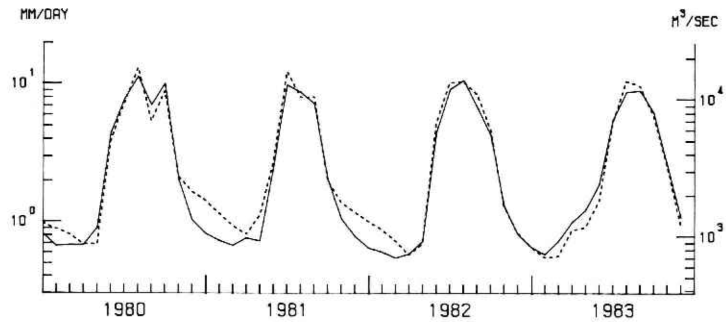

Fig. 16 Monthly discharge of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 15)

8. Forecasting daily discharge at Monywa from discharge at Homalin

Since forecasting using Hkamti discharge could not give a good result because of the unreliable discharge data, it was decided to use Homalin discharge instead of Hkamti discharge.

The methods applied are the same as before.

1) Routing of hydrograph from Homalin to Monywa

Discharges (mm/day) at Homalin were put into the structures shown in Fig. 17, the output was lagged by four day and multiplied by a correction factor of 0.55 and the hydrograph obtained was compared with the observed hydrograph at Monywa. The structure shown in Fig. 17(1) seemed to be the better one. The correction factor 0.55 was determined as the ratio of the total runoff for four years at Monywa and Homalin. The result obtained is shown in Fig. 18. This result is far better than the one derived from Hkamti discharge data and forecasting can lead by four days. The monthly hydrographs are shown in Fig. 19.

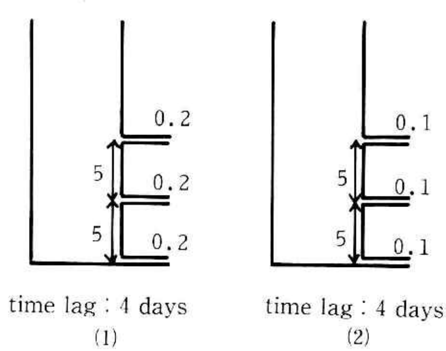

Fig. 17 Structures used in trials for the deformation of hydrograph from Homalin to Monywa

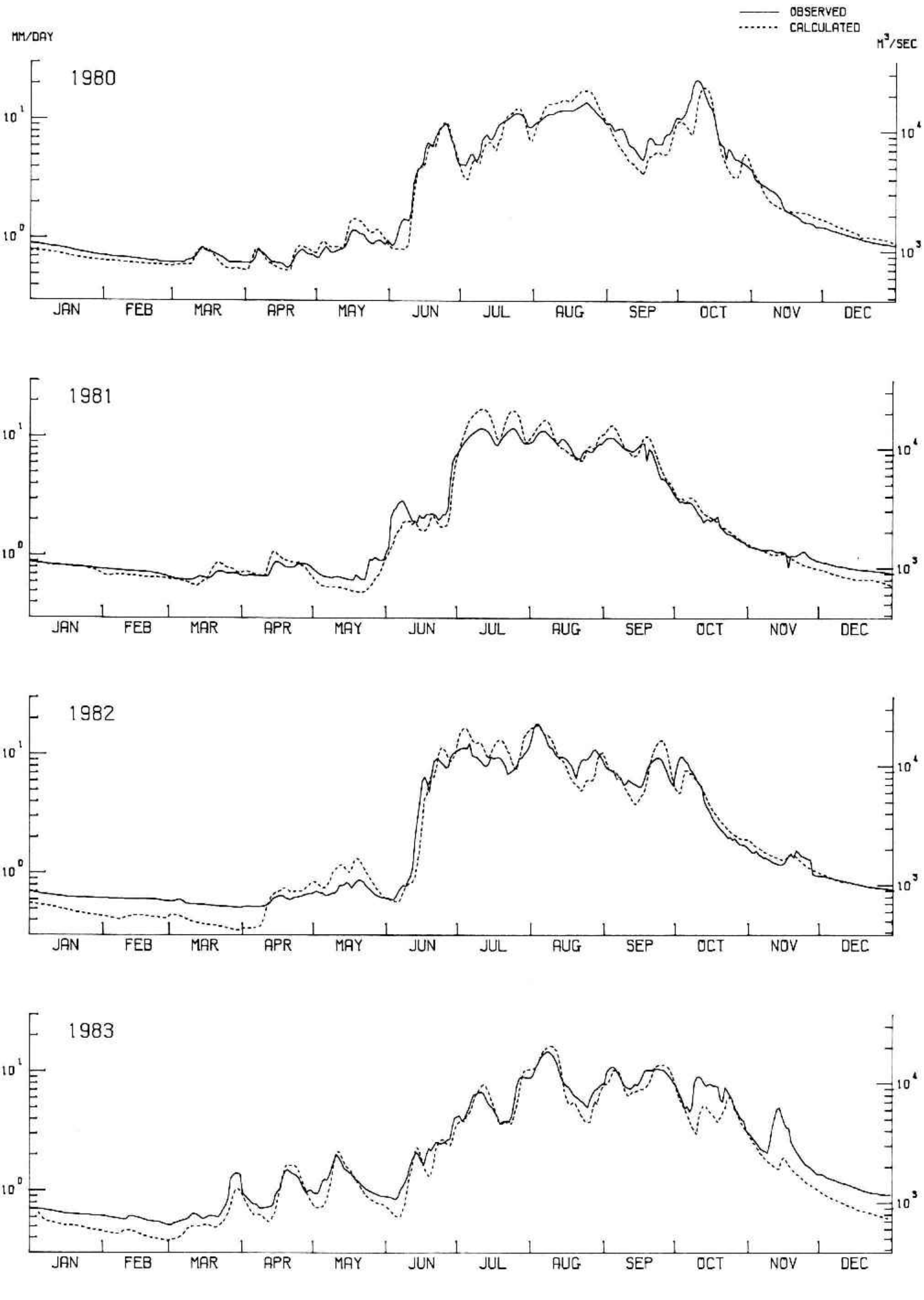

Fig. 18 Daily discharge of the Chindwin River at Monywa (calculated discharge is derived from Homalin discharge)

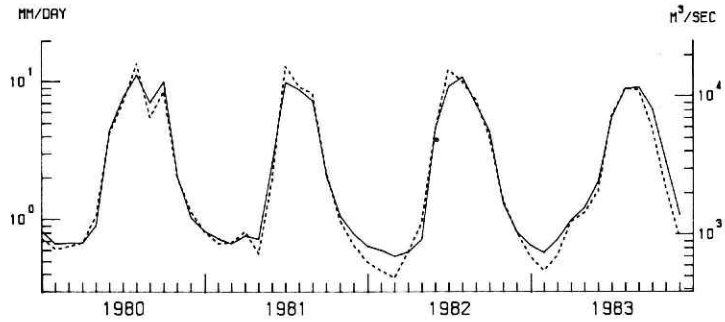

Fig. 19 Monthly hydrographs of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 18)

2) Derivation of discharge from the Monywa basin excluding Homalin basin and runoff analysis using the derived discharge

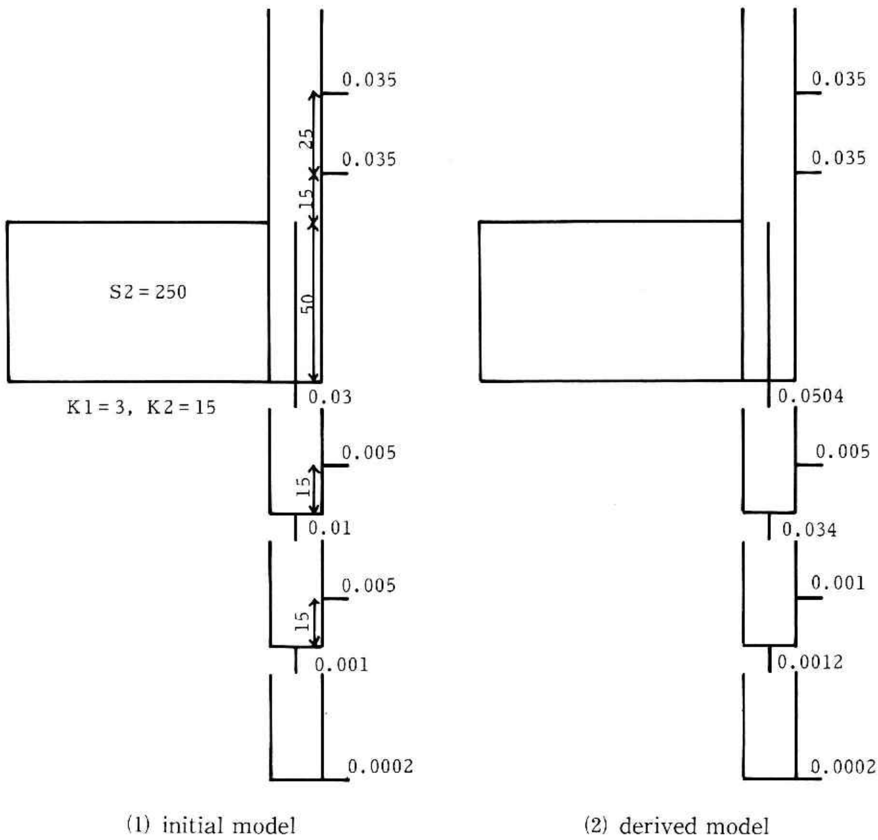

Fig. 20 Tank model for the residual part of Monywa basin excluding Homalin basin

The discharge from the residual part of the basin was derived in the same way as before by making difference of observed Monywa discharge and routed Homalin discharge.

To simulate the derived discharge, runoff analysis was made using rainfall data at four stations: Homalin, Mawlaik, Kalewa and Monywa.

Rainfall data at each of the four stations were put into the tank model shown in Fig. 20(2) with the correction factors CE=0.65 and CP=1.10. The output series from the tank model were combined using the weights and time lags shown in Table 7.

Table 7 Weights and time lags used in calculating the discharge of the Monywa basin excluding Homalin basin

	Homalin	Mawlaik	Kalewa	Monywa
weight	1	1	1	1
time lag (day)	4	3	3	3

The first trial was made with CE=0.6 and CP=1.15 and the calculated discharge was too large. In the second trial, CE was set to 0.65 and the calculated discharge was still too large. Next, the factors were set to CE=0.65 and CP=1.10 and the result was fairly good.

3) *Calculation of Monywa discharge using the routed Homalin discharge and the calculated discharge from the residual basin*

To derive the Monywa discharge, the routed Homalin discharge and the calculated discharge of the residual basin were combined in the same way as before. Let Q1 (mm/day) be the routed Homalin discharge (i. e. Homalin discharges (mm/day) were put into the structure shown in Fig. 17(1) and the output was lagged by four days) and let Q3 (mm/day) be the derived discharge of the residual basin calculated from rainfall data

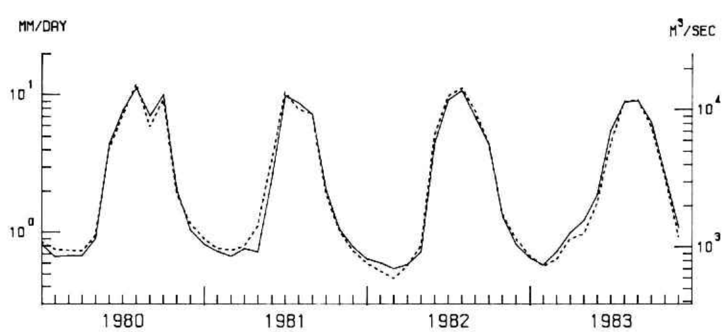

Fig. 22 Monthly hydrographs of the Chindwin River at Monywa (monthly sum of daily values shown in Fig. 21)

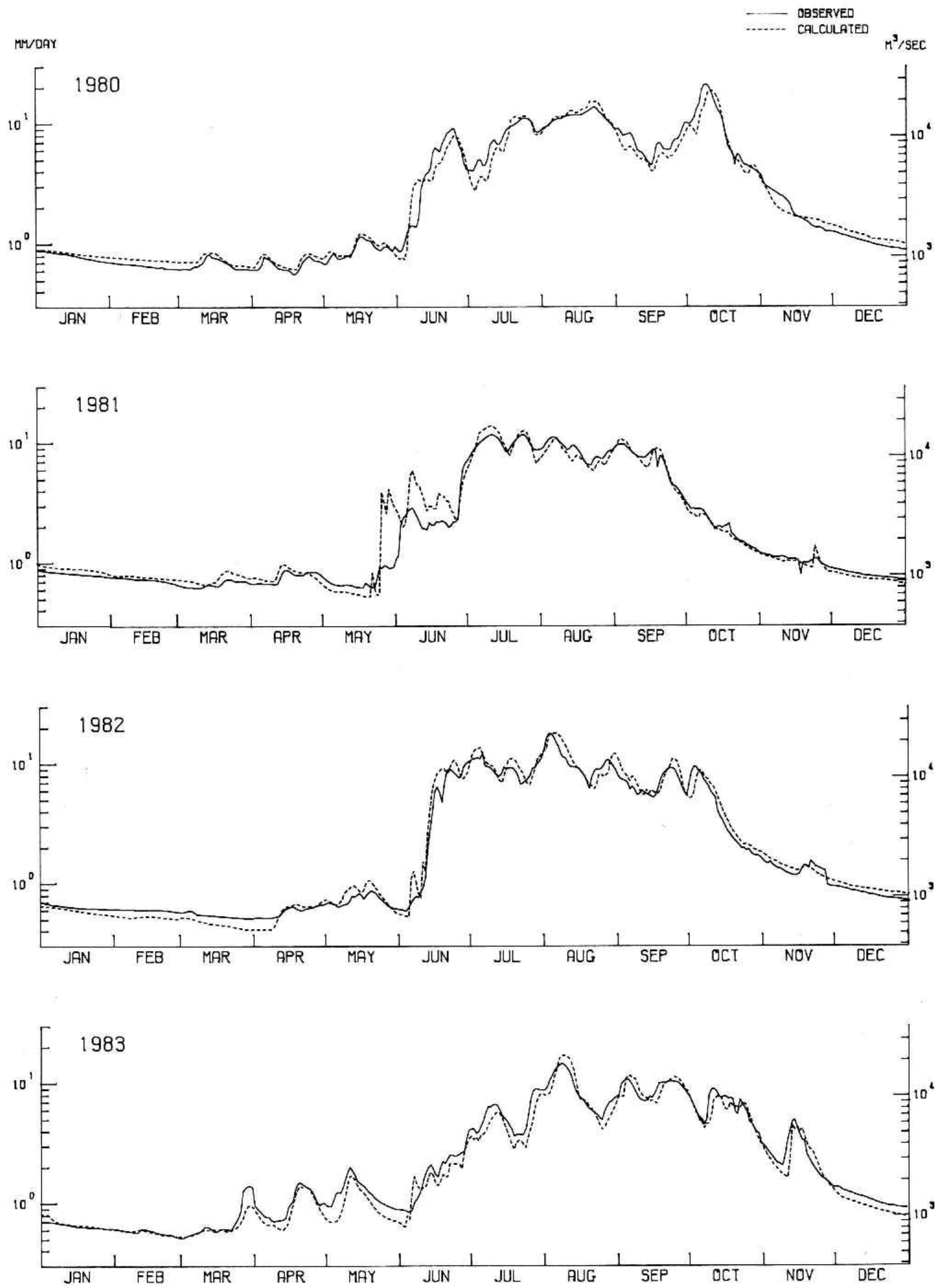

Fig. 21 Daily discharge of the Chindwin River at Monywa
(calculated discharge is derived from Homalin discharge and rainfall at four stations)

at four stations; then the discharge at Monywa (mm/day) is given by,

$$Q = (Q1 \times S1 + Q3 \times (S2 - S1)) / S2,$$

where S1 and S2 are the catchment areas of Homalin and Monywa, respectively.

The result is shown in Fig. 21. It is quite good and can forecast the discharge three days ahead. The monthly hydrographs are shown in Fig. 22.

9. Conclusions

The present study has shown that the tank model can be used to improve discharge forecasting along the Chindwin River in Burma. Future developments will be able to improve and extend the present work.

At the present time, discharge data at Hkamti do not seem to be good, probably because the rating curves are not appropriate. Consequently, Monywa discharge calculated using Hkamti discharge as input cannot show a good fit with the observed discharge. However, by revising the rating curves, the forecasting of Monywa discharge using Hkamti discharge will become as good as the case in which Homalin discharge is used as input. At such time the forecasting of Monywa discharge using both Hkamti and Homalin discharge as inputs will give a better result than the case in which discharge data at only one station are used as input. These are problems which should be considered in the future.

Efforts were also made to forecast the discharge of the upper Irrawaddy River at Sagaing from rainfall data at four stations: Putao, Mogaung, Myitkyina and Bhamo (Fig. 1). However, as there seemed to be evidence of snow daily temperature data at Putao would be necessary. However, even if temperature data were available, the calculated hydrograph at Sagaing probably would not show a good fit with the observed one, considering the result obtained in calculating Monywa discharge from rainfall data (as shown in Fig. 3). If discharge data at Myitkyina or Bhamo were available, forecasting of Sagaing discharge would show a much better result. In such a case, temperature data at Putao would not be necessary.

If good forecasts of the Sagaing and Monywa discharge were possible for a lead time of three or four days, they would be very useful for the eventual forecasting along the lower Irrawaddy River.

References

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タンク・モデルによるビルマ，チンドウィン川の流出予測

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要　旨

タンク・モデルを用いて，ビルマ Irrawaddy 川支流の Chindwin川の流出解析を行った．Chindwin 川と Irrawaddy 川の合流点近くのMonywa（流域面積 110,350 km²）の流量を，5地点の観測雨量及び上流5地点の観測流量を用いて予測する方式を求めた．

種々の試み（5地点の観測雨量のみを用いる場合，上流1地点の観測流量のみを用いる場合，及び上流1地点の観測流量とその流量観測点より下流に位置する地点の観測雨量を用いる場合）を行った結果，Homalin（流域面積 43,174 km²）における流量とHomalin, Mawlaik，Kalewa，Monywa 4地点の観測雨量を用いた場合，3日前の予測が可能であり，しかも計算流量と観測流量がよく一致する結果を得ることができ，タンク・モデルがChindwin 川の流出解析にとって有用であることを示した．

もし，より詳細な，そして誤りの少ないデータが得られるならば，さらによい結果を得ることができるであろう．

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