ONE DIMENSIONAL DAM BREAK FLOOD ANALYSIS FOR KAMENG HYDRO ELECTRIC PROJECT, INDIA

S. Masood Husain
Director

Nitya Nand Rai
Assistant Director

Foundation Engineering & Special Analysis Directorate
Central Water Commission
Sewa Bhawan, R.K. Puram, New Delhi - 110066
India

ABSTRACT

The Kameng hydroelectric project of 600 MW located in Kameng district of Arunachal Pradesh, in the North Eastern part of India envisages the construction of two concrete gravity dams viz. Bichom and Tenga across Bichom and Tenga rivers respectively. Tenga river joins Bichom river 13.8 km downstream of the Bichom dam site and Bichom river joins the Kameng river about 42.8 km downstream of the Bichom dam site. From this point Kameng river flows another 120 km where it joins the Brahamputra river, the largest river of this region. A detailed dam break analysis for these two dams has been carried out using one dimensional model MIKE11 to estimate the maximum flood level downstream of the dam sites up to confluence of Kameng river with Brahamputra river due to a dam break event. The case of non dam break flooding has also been studied for comparison. The results of the dam break analysis can be used for the preparation of an Emergency Action Plan for the affected area. The paper presents the details of the project, the model set up and details of the studies carried out.

1.0 INTRODUCTION

1.1 Dams play a very vital role in the economy of a country by providing essential benefits like irrigation, hydropower, flood control, drinking water, recreation etc. However in the unlikely and rare event of their failure, these may cause catastrophic flooding in the downstream area which may result in huge loss to human life and property. This loss to life and property would vary with extent of inundation area, size of population at risk, and the amount of warning time available.

1.2 A distinguishing feature of dam breach floods is the great magnitude of the peak discharge in comparison to any precipitation runoff-generated floods, and its consequences are often catastrophic if human developments exist downstream of the dam. The prediction of the dam break flood is very important for the purposes of planning and decision making concerning to dam safety, controlling downstream developments, contingency evacuation planning and real time flood forecasting. For assessing the flood damage due to dam breach it is necessary to predict not only the possibility and mode of a dam failure, but also the flood hydrograph of discharge from the dam breach and the propagation of the flood waves. The studies are required to identify the inundated area, flood depth, flow velocity and travel time of the flood waves etc.

2.0 DAM BREAK MODELLING

2.1 Dam break modelling consist of i) prediction of the outflow hydrograph due to dam breach ii) routing the hydrograph through the downstream valley to get the maximum water level and discharge along with the time of travel at different locations of the river downstream of the dam.

2.2 Dam break studies can be carried out by either i) Scaled physical hydraulic models or ii) Mathematical simulation using computers. A modern tool for the dambreak analysis is the mathematical model which is most cost effective, and approximately solves the governing flow equations of continuity and momentum by computer simulation. Sophisticated computer programs such as MIKE11and DAMBRK have been developed in the recent few years, however these computer programs are dependent on certain inputs regarding the geometric and temporal characteristics of the dam breach. The state-of-art in estimating these breach characteristics is not as advanced as that of the computer programs, and therefore these are the limiting factors in the dam break analysis.

3.0 MIKE11 MODEL

3.1 MIKE11 is a professional engineering software package for the simulation of one dimensional flows in estuaries, rivers, irrigation systems, channels and other water bodies. It is a dynamic, user friendly one-dimensional modelling tool for the detailed design, management and operation of both simple and complex river and channel systems. The Hydrodynamic Module (HD) contains an implicit, finite difference computation of unsteady flows in river and estuaries. The formulation can be applied to branched and looped networks and flood plains.

3.2 The computational scheme is applicable to vertically homogeneous flow conditions ranging from steep river flows to tidally influenced estuaries. Both subcritical and supercritical flow can be described by means of a numerical scheme which adapts according to the local conditions. The complete non-linear equations of open channel flow (Saint Venant) can be solved numerically between all grid points at specified time intervals for a given boundary conditions. Within the standard Hydro Dynamic (HD) module, advanced computational formulations enable flow over variety of structures such as broad crested weirs, culverts and user-defined structures to be simulated. A number of add-on modules such as Dam Break Module (DB), Structure Operation Module exist for the Hydrodynamic Module.

3.3 The dam break model set up consists of a single or several channels, reservoirs, dam break structures and other auxiliary dam structures such as spillways, sluices etc. The river is represented in a model by cross sections at regular intervals. However, due to highly unsteady nature of dam break flood propagation, it is advisable that the river course is described as accurately as possible through the use of a dense grid of cross sections, particularly where the cross section is changing rapidly. Further, the cross sections shall extend as far as the highest modelled water level, which normally will be in excess of highest recorded flood level.

3.4 The reservoir is normally modelled as a single "h" water level point to describe the storage characteristic by the use of storage area at different levels. This point will often be the upstream boundary of the model where inflow hydrographs may be specified. However, in case of very long and wide reservoir routing of inflow flood has to be carried out and hence the reservoir itself would have to be represented by cross sections at regular intervals. The downstream boundary will be either a discharge water level relation or time series water level as in case of tidal waves.

3.5 The manner in which the failure is to commence can be specified as one of the following:

- Given number of hours after the start of the simulation
- At a specified time
- At a specified reservoir level

3.6 The breach may be specified as rectangular, triangular or trapezoidal in shape. The initial and final breach widths and levels along with the side slopes of the breach are required to be specified. The model has the option to select either the linear failure mechanism or an erosion based formulation. The linear failure mode assumes a linear increase in the breach dimensions in the time between specified limits etc. For the erosion based failure additional data such as slopes of the upstream and downstream faces of dam, width of dam crest and density, grain size, porosity and critical shear stress of dam material are required.

4.0 THE PROJECT

4.1 The Kameng Hydroelectric project of 600 MW located in Kameng District of Arunachal Pradesh, India envisages the construction of two concrete gravity dams viz. Bichom and Tenga. The

Bichom Dam across Bichom river is proposed to be constructed at 4 km downstream of the confluence of Bichom and Digo river at longitude 92^{o} 37’ 39” East and latitude 27^{o}17’57” North. The Dam with Full Reservoir Level (FRL) at EL 770 m and Maximum Water Level (MWL) at 772.5m is concrete gravity type with maximum height of 96.5 m above the deepest foundation level. The total

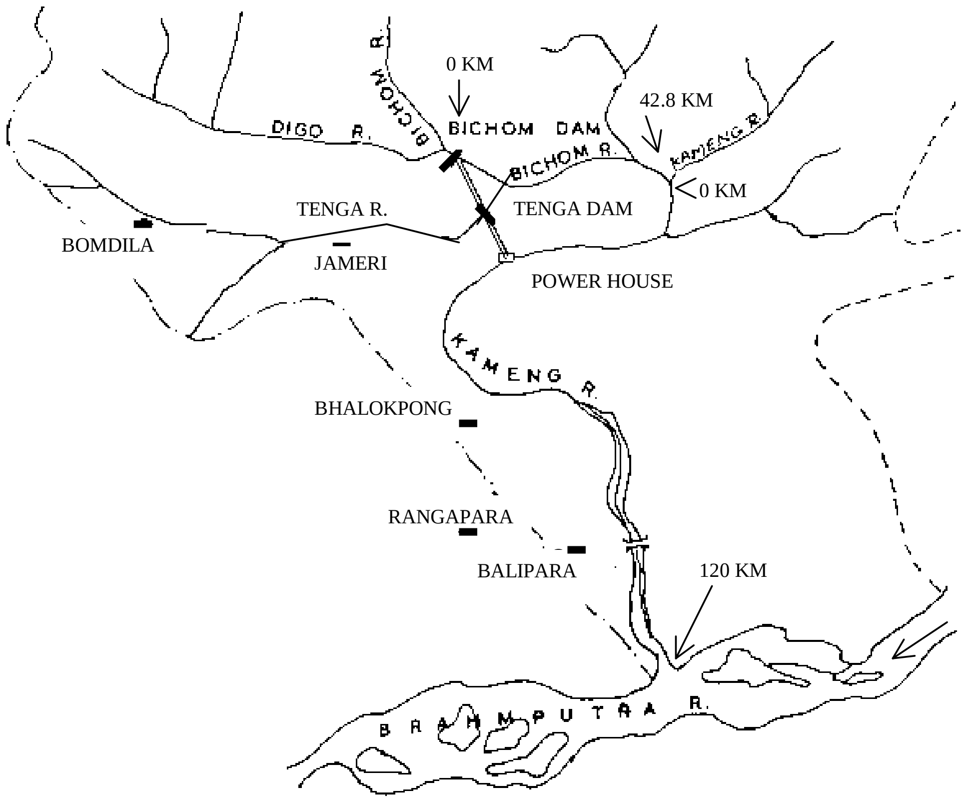

FIG.1 : INDEX MAP OF KAMENG H. E. PROJECT

length of the dam is 200 m. The catchment area of the reservoir is 3026 sq.km. The live storage capacity of the Bichom reservoir is 9.15 M.cu.m. The spillway is ogee shaped having 5 radial gates, of 13.5m x 10m with crest level at an EL. 760.0m. The discharge capacity of the spillway and sluices at FRL is 3672 cumecs against the peak of the Probable Maximum Flood (PMF) of 16166 cumecs.

4.2 The Tenga Dam across Tenga river is proposed to be constructed at 16.5 km downstream of Jameri G&D site at Longitude 92^{0}40’7” E and latitude 27^{0}13’46” N. This dam is also of concrete gravity type having maximum height of 60.5 m above deepest foundation level with FRL and MWL at EL 770 m and 772.5 m respectively. The total length of the dam is 140m. An ogee shaped concrete spillway having 3 radial gates of size 13.5 m x 8 m and crest at EL 762 m is envisaged. The discharge capacity of spillway and sluices of size 3.56 m x 6.20 m at FRL is 2016 cumecs against the PMF of 5919 cumecs. The catchment area of the Tenga reservoir is 982 sq.km. Both the dams are proposed to be connected by Bichom Tenga Tunnel having a length of 8.75 km. The power house is proposed on the right bank of Kameng river near Kimi village in Kameng District of Arunachal Pradesh and is to be connected to Tenga Dam by 5.75 km long Tenga Kimi Tunnel. The index layout plan of Kameng H.E. Project is given in Fig.1.

5.0 MODEL SET UP

5.1 The Tenga river flows about 11 km below the Tenga dam before it joins the Bichom river 13.8 km downstream of the Bichom dam. Bichom river joins the Kameng river 42.8 km downstream of the Bichom dam. From this point the Kameng river flows about another 120 km where it joins the Brahamputra river. Bichom river for a total length of 42.8 km below Bichom dam has been represented in the model by 35 cross sections. Whereas Tenga river for a length of 11 km downstream of Tenga dam has been represented by 3 cross sections. Kameng river for a length of 120 km from confluence with the Bichom river and up to the confluence point with the Brahamputra river has been modelled by 24 cross sections. The Manning's roughness coefficient has been taken as 0.025 for the last 60 km reach of Kameng considering river in fair condition. For the rest of the reaches of Bichom, Tenga and Kameng rivers, the Manning's roughness coefficient has been taken 0.045 considering mountainous stream with rocky beds. The MIKE11 model set up for the dam break study has been shown in Fig-2.

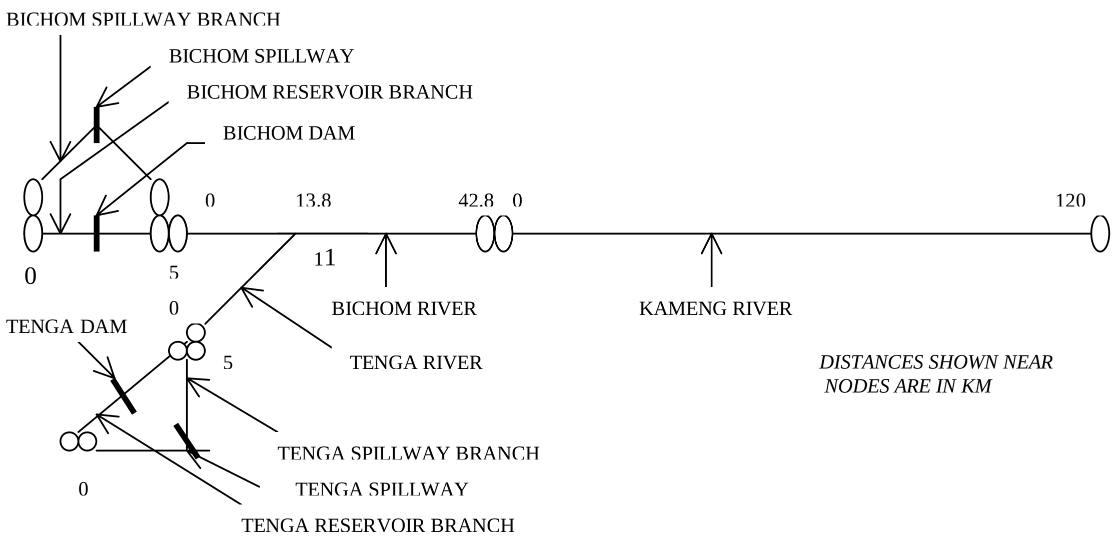

FIG.2 : MIKE11 MODEL SET UP

5.2 The reservoir and spillway for both the dams have been represented by separate branches in the model. The reservoirs have been represented by the area at different levels. The dams have been placed in the respective reservoir branch. The details of the dam have been provided in the dam break structure. The spillway and sluices have been specified as special weir in the spillway branch with discharge through the spillway and sluices specified at different water levels for all the gates fully open. The upstream boundaries for the dam break model are the PMF of Bichom and Tenga dams and have been applied to respective reservoirs. The downstream boundary specified at Ch.120 km of Kameng river is the rating curve (Discharge Vs Water levels) at this location, which has been worked out using Manning's equation.

6.0 DAM BREAK ANALYSIS

6.1 The objective of the dam break study is to estimate the maximum flood level downstream of the dam sites up to confluence of Kameng with Brahamputra due to a dam break event as compared to the case of non dam break flooding. The studies consisted of four main alternative cases as given below:

1. Failure of Bichom dam only and PMF applied at Tenga Dam
2. Failure of Tenga Dam only and PMF applied at Bichom Dam
3. Failure of both Bichom and Tenga Dams
4. Application of Bichom and Tenga PMFs without dams

The dam breach scenario consists of first three alternative cases as mentioned above and fourth case is to study the effect of non dam break flooding. Accordingly, the studies have been carried out for the above four alternatives.

6.2 Failure of Bichom dam

6.2.1 The most critical condition in the river Kameng due to Bichom dam failure is when the dam breach flood of Bichom dam and PMF of Tenga Dam occur simultaneously. The critical condition for the Bichom dam failure is when the reservoir is at FRL and PMF is impinged. Accordingly, in the present studies maintaining the Bichom reservoir at FRL of 770 m the PMF of Bichom dam impinged into Bichom reservoir and the PMF of Tenga dam impinged into Tenga river near the dam site. The maximum water level reached in the Bichom reservoir due to application of PMF is 776.20 m, which occurs at 29 hours after impingement of the flood. As the top of the dam is at EL 776.50m, the dam is not likely to fail due to overtopping. However for the hypothetical case of failure it has been assumed that the dam fails when the water level in the reservoir reaches at EL 776.20m and with this assumption of failure total five cases of study have been carried out using different breach width and depth taking into account the combination of blocks in the dam. For all these cases the breach development time has been taken as 12 minutes for the concrete gravity dam. The combination of blocks considered for the failure and discharge through the breach are as follows:

Case No.	No. of Blocks	Location		Breach width (m)	Breach Level (m)		Discharge through Breach (Cumecs)
		Main dam	Spillway		Initial	Final	
1	3	1	2	51	776.5	716.5	30579
2	4		4	66	776.5	716.5	39921
3	5	1	4	84	776.5	716.5	50364
4	6	2	4	102	776.5	716.5	60642
5	4		4	66	776.5	705.0	51841

6.2.2 Based on the results of the above five, the breach parameters corresponding to case 3 have been adopted for the detailed inundation studies. The maximum discharge through the breach with the above breach parameters is 50364 cumecs which occurs at 29 hours 15 minutes after impingement of the PMF. The plot showing the discharge against time through the dam breach is given in Fig.3.

6.3 Failure of Tenga Dam

6.3.1 The most critical condition in the river Kameng due to Tenga dam failure is when the dam breach flood of Tenga dam and PMF of Bichom dam occur simultaneously. The critical condition for the Tenga dam failure is when the reservoir is at FRL and the PMF is impinged. Accordingly, in the present studies, the PMF of Tenga dam impinged at Tenga reservoir while maintaining it at FRL of 770 m and the PMF of Bichom Dam impinged at Bichom river near the dam site. The maximum water level reached in the Tenga reservoir due to application of the above flood is 776.04 m which occurs at 28 hours after impingement of PMF. The top of the dam is at EL 776.50 and the dam is not likely to fail due to overtopping. However for the hypothetical case of failure, it has been assumed that the dam fails when the water level in the reservoir reaches at EL 776.04 m which occurs about 28 hours after the impingement of the PMF, and with this assumptions total 4 cases of linear failure taking different breach widths and depths have been simulated. For all these cases the breach development time has been taken 12 minutes as the dam is a concrete gravity dam.

The combination of the blocks considered for the failure and discharge though the breach are as follows :

Case No.	No. of Blocks	Location		Breach width (m)	Breach Level (m)		Discharge through Breach (Cumec)
		Main dam	Spillway		Initial	Final	
1	2		2	33	776.5	735.0	7471
2	3	1	2	51	776.5	735.0	9830
3	4	2	2	69	776.5	735.0	11816
4	2		2	33	776.5	725.0	9628

6.3.2 Out of the above four, the breach parameters corresponding to case 3 have been adopted for detailed inundation studies. The maximum discharge through the breach with the above breach parameter is 11816 cumecs which occurs at 28 hours 10 minutes after impingement of the PMF. The plot showing the discharge against time through the dam breach is given in Fig.4.

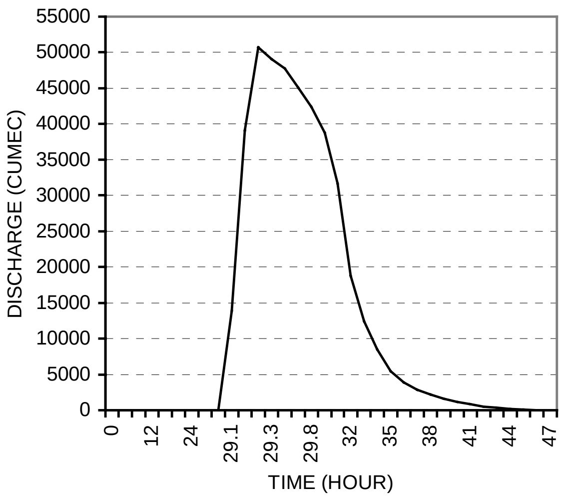

Fig.3:Plot of discharge through Bichom dam breach

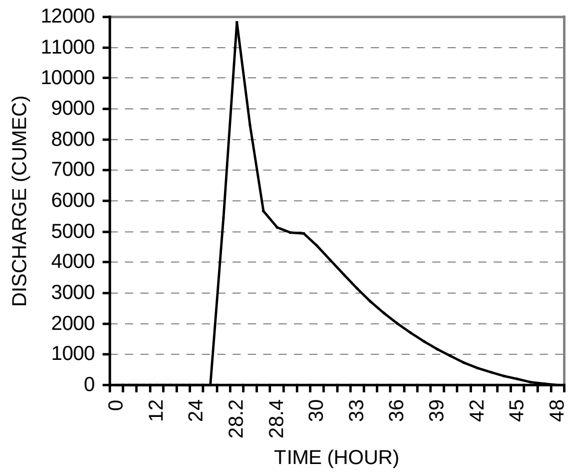

Fig.4: Plot of discharge through Tenga dam breach

6.4 Failure of both Bichom and Tenga Dams

6.4.1 As discussed in paragraphs 6.2 and 6.3, the dam break studies have been carried out considering the failure of only one dam at a time and based on the sensitivity analysis, the breach parameters have been adopted for the Bichom and Tenga Dam for preparation of inundation map. Taking the same breach parameters as adopted above detailed studies have been carried out considering the failure of both dams simultaneously.

6.5 Application of Bichom and Tenga PMFs without Dams

6.5.1 In order to analyse the effect of the PMF in natural conditions of Bichom, Tenga and Kameng i.e. without the Bichom and Tenga dams , a study has been conducted to rout the Bichom PMF and Tenga PMF through these rivers. For this the initial condition in the entire river reach has been assumed to be the base flow of the Bichom and Tenga, when the PMF of the both reservoirs are impinged.

7.0 RESULTS

7.1 The maximum water level attained at different cross sections of Bichom and Kameng for (i) Bichom dam breach only (ii) Tenga dam breach only (iii) Bichom and Tenga dam breach simultaneously and (iv) occurrence of PMF in natural conditions for the river, are given in Table-1. From the table it can be seen that the inundation of the banks is for the last 55 km of Kameng only before its confluence with Brahamaputra i.e. from the chainage 65 km to 120 km. Rest of the upstream reaches of the rivers have very high banks due to hilly terrain. The details of inundation of banks for the above four cases of study are summarised below.

		The inundation of banks varies
1. Bichom dam breach	:	from 0.29m to 4.65m
2. Tenga Dam breach	:	from 0.26m to 3.46m
3. Both Bichom and Tenga dam breach	:	from 0.30m to 4.66m
4. Application of Bichom and Tenga PMF in natural conditions of river (without dams)	:	from 0.28m to 3.47m

8.0 CONCLUSION

8.1 The spillways and sluices for both Bichom and Tenga dams have adequate capacity to negotiate the probable maximum flood (PMF) expected at the respective dam sites. Thus the two dams do not get overtopped due to impingement of PMF. Hence, there is no chance of failure of these dams due to overtopping. Dams are designed taking into account all forces which are likely to act on them during their life time and utmost quality control is exercised during their construction. Therefore, there is no possibility of dam failure in the project. The dam break studies have been done for the hypothetical case of dam break due to any unforeseen reason. It has been observed that the effect of the release of reservoirs storage due to dam break on inundation at different reaches of the downstream area is about 0.02m to 1.19m more in comparison to the inundation due to PMF in the rivers without dams. Based on the results of the above studies a detailed inundation map can be prepared for the submergence area which is in the last 55 km reach of river Kameng. Accordingly the emergency action plan can be formulated.

Table 1: Bed level, bank levels and maximum water levels at different cross sections of the river Bichom and Kameng

River name	Chainage (Km)	Bed Level (m)	Left Bank Level (m)	Right Bank Level (m)	Max. Water Level due to Tenga Dam Breach only (m)	Max. Water Level due to Bichom Dam Breach Only (m)	Max. Water Level due to Breach of Bichom and Tenga dam simultaneously (m)	Max. Water Level due to occurrence Of Bichom and Tenga PMF without dams (m)
Bichom	0.0	701.00	933.00	829.00	714.91	728.12	728.13	714.91
Bichom	10.0	533.60	666.26	612.00	549.27	565.59	565.53	549.27
Bichom	17.8	480.00	800.00	800.00	517.07	528.87	528.77	516.07
Bichom	27.8	437.00	800.00	800.00	447.79	453.01	453.01	447.55
Bichom	37.8	360.00	800.00	800.00	380.63	390.60	390.65	380.43
Kameng	0.0	360.00	800.00	800.00	365.97	370.20	370.22	365.90
Kameng	10.0	320.00	800.00	800.00	333.11	342.85	342.90	333.12
Kameng	20.0	280.00	800.00	800.00	298.24	309.46	309.51	298.28
Kameng	30.0	240.00	800.00	800.00	247.87	253.55	253.58	247.88
Kameng	40.0	200.00	800.00	800.00	207.13	211.80	211.82	207.15
Kameng	50.0	160.00	400.00	400.00	166.18	169.64	169.66	166.21
Kameng	60.0	136.47	159.00	155.28	147.83	152.61	152.64	147.89
Kameng	65.0	124.57	132.15	134.70	133.97	136.06	136.07	133.89
Kameng	70.0	117.52	122.44	122.93	122.59	123.77	123.77	122.61
Kameng	75.0	104.07	111.04	111.71	111.97	113.12	113.12	111.99
Kameng	80.0	95.04	101.03	104.03	102.53	103.80	103.80	102.54
Kameng	85.0	88.13	94.00	95.92	95.14	96.21	96.22	95.16
Kameng	90.0	77.96	85.68	86.38	87.91	89.34	89.35	87.92
Kameng	95.0	76.70	81.00	80.34	83.24	84.71	84.72	83.25
Kameng	100.0	73.11	78.61	78.16	81.62	82.81	82.82	81.63
Kameng	105.0	71.30	78.07	78.72	79.39	80.11	80.11	79.38
Kameng	110.0	66.99	72.30	73.17	73.87	75.00	75.02	73.86
Kameng	115.0	64.78	70.88	70.68	71.36	71.65	71.67	71.36
Kameng	120.0	62.72	67.90	68.00	69.72	70.42	70.43	69.71