SECTOR 2 HYDROLOGY AND HYDRAULICS

SUPPORTING REPORT

SECTOR 2

TABLE OF CONTENTS

Page

LIST OF TABLES IN REPORT

LIST OF FIGURES IN REPORT

LIST OF TABLES AT THE BACK OF REPORT

LIST OF FIGURES AT THE BACK OF REPORT

SECTOR 2. HYDROLOGY AND HYDRAULICS

2.1 HYDROLOGY

2.1.1 Outline of Pyanj River Basin

The Pyanj River, a part of the Amu Darya River that flows along the country's border with Afghanistan, has a catchment area of around 82,500 square kilometers at the head of the Pyanj Fan. It originates from the Zorkul Lake, in the Glacier at the Pamir, which thaws from May to August. Precipitation is low in the upper areas of the basin, but significant falls of snow in the southern mountains and glacial melt generate high flows in the spring and summer seasons. Annual average discharge at the Khirmanjo Station is approximately 900 m^3/s. The Pyanj river system is as shown in Fig. 2.1.1.

The largest tributary is the Bartang River, which originates in the northeast of the Pyanj river basin and flows into the Pyanj River at Rushan Rayon. The tributaries of Bartang River are Lake Sarez and the Murgab River, which originates in Afghanistan and flow northward at first, then changes direction to the west at Murgab and finally, flows into Lake Sarez.

The second largest tributary is the Gunt River, which originates at nearly the center of the Pamir and merges with its tributary, Shakhdara River, just before flowing into the Pyanj River at Khorog City.

Yazuglom River and Vanj River are located adjacent to each other and flow almost in a parallel direction. There are mountains that hold glaciers in both uppermost streams that flow into Pyanj River at the downstream of Rushan Rayon.

Kara-kul Lake, located in the northern side of the upper basin of Bartang river, is sealed off and located out of the Pyanj river basin.

The parameters of main rivers are as shown in the table below.

Table R 2.1.1 Parameter of Main Rivers

River Name	River Length (km)	Catchment Area (km^2)
Pyanj River	801.7	82,534
Gunt River	267.5	13,464
Shakhdara River	117.0	4,228
Bartang River	226.3	29,938
Murgab River (Sarez Lake)	303.7	20,122
Yazugulom River	74.4	2,435
Vanj River	90.3	2,050

Notes: Parameters of Pyanj River are values of upper basin from Chubek.
The catchment area of Vanj River includes the remaining basin of Pyanj River.

The average altitude of the Pyanj river basin is approximately EL 3,900 m. Altitude ranges from approx. EL 7,000 m in the highest area to approx. EL 500 m in the lowest area.

In the meteorological observation in 2005, the lowest temperature was minus 42.8ºC at Bulunkul Station and the highest was 33.3ºC at Parkar Station, or a difference of more than 76ºC. There are four (4) stations with annual average temperatures of below zero.

2.1.2 Hydro-Meteorological Data

1) Related Agencies

The Tajikmeteorology conducts hydrological and meteorological observation in the whole of Tajikistan. The Usoy Department of MoES monitors data regarding Lake Sarez, filtration discharge, lake level, etc.

a) Tajikmeteorology

The first meteorological and water level gauging stations appeared in the second half of the 19th century on the territory of Tajikistan. The first one was Khujand that became operational in 1866. Up to the beginning of the 20th century there were six (6) meteorological stations and two (2) water level gauging stations in Tajikistan.

Hydro-meteorological observations were being developed since 1926, the year when the Hydro-Meteorological Committee of Tajikistan was established. The Organization Chart of Tajikmeteorology is shown in Fig. 2.1.2.

Since 1995, Tajikmeteorology has been receiving technical assistance from Switzerland. In 2001 the Regional Centre of Hydrology (RCH) was established and the monitoring system was strengthened. Experts of the RCH were trained in monitoring, data processing, communication, data provision and flow forecasting.

Tajikmeteorology forecasts short and long-term flows based on snow-cover maps derived from satellite data, hydro-meteorological data and basin characteristics. The river flow is forecasts on one to three-day basis for Vaksh River using the ERDAS Image Processing and Geographic Information System and the Snowmelt Runoff Model (SRM). The discharge forecasting system for Pyanj River has not been established yet. At present, the agency conducts hydro-meteorological observation manually in almost all observations conducted.

As to meteorological observation (precipitation, temperature, humidity, pressure, wind), there are the observation equipment installed at seven (7) stations (Dushanbe, Dangara, Anzob, Shakhristan, Kalai-Labi-Ob, Navabad, Fedchenko Glacie) in 2005 by the project known as the “Integration and Management of Natural Resources of the Central Asia” with USAID assistance. The equipment is still in experimental operation period and not yet fully operational at present.

As to hydrological observation, equipment with telemeter system has been installed in three (3) stations with technical cooperation from Switzerland. However, they are not yet operational at present.

Tajikmeteorology has a long-term plan of ten years and plans to carry out observation starting from fiscal year 2007. The reconstruction of hydro-meteorological stations is given much importance and the budget for 10 years is planned to be 24 million Tjs, 40% of which will be borne by the Tajikistan Government and the other 60% will be come from loans with international financing agencies. A copy of the program is attached as Annex.

b) Usoy Department

The Usoy Department of MoES was established for the purpose of distributing information on Lake Sarez via satellite to Moscow and Dushanbe in 1991. At the time of start-up, only the warning device for the announcement of warning water level was equipped along the Batarang River at 36 km downstream from Usoy Dam. The existing monitoring and warning system was installed with Swiss assistance from 2000 to 2004.

Since the observations from November 2004 using the monitoring system are quite primitive, the data were not utilized for the analysis of the Study Team.

2) Hydro-Meteorological Stations

a) Meteorological Stations

The number of meteorological stations in the whole of Tajikistan is 58 and 21 of them are located in the Pyanj river basin upstream from the Hamadoni area. Meteorological stations are rarely distributed in the basin and all of the stations are equipped with manual instruments only.

The name and location of meteorological stations are given in Table R2.1.2 and also indicated in Fig. R 2.1.1.

Table R 2.1.2 Location of Meteorological Stations

	Name of Station	Elevation (m. MSL)	Position	
			Latitude	Longitude
1	Shaimak	3,840	37° 32'	74° 49'
2	Bulunkul	3,744	37° 42'	72° 57'
3	Javoshangoz	3,410	37° 21'	72° 27'
4	Ishkoshim	2,524	36° 43'	71° 36'
5	Murgab	3,576	38° 10'	73° 58'
6	Irkht	3,300	38° 10'	72° 38'
7	Sovnob	2,800	38° 18'	72° 28'
8	Kara-kul	3,930	39° 01'	73° 33'
9	Khorog	2,077	37° 30'	71° 30'
10	Navobod	2,566	37° 40'	71° 50'
11	Rushan	1,978	37° 57'	71° 33'
12	Khumrogi	1,737	38° 17'	71° 20'
13	Darvoz	1,279	38° 28'	70° 53'
14	Parkhar	447	37° 29'	69° 23'
15	Khovaling	1,437	38° 21'	69° 59'
16	Murminabad	1,191	38° 07'	70° 02'
17	Kulyab	512	37° 55'	69° 47'
18	Moskovski	489	37° 37'	69° 39'

Elevation: Baltic system

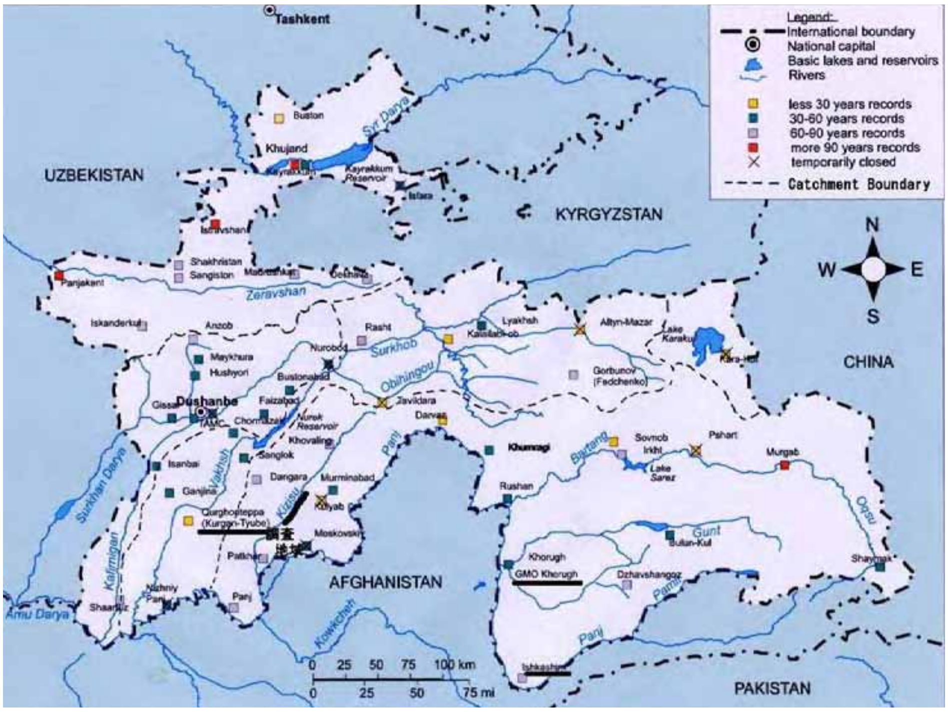


Fig. R 2.1.1 Location of Meteorological Stations

b) Hydrological Stations

The number of hydrological stations in the whole of Tajikistan is 97 and 34 of them have radio communication systems. In the Pyanj river basin, there are 20 manual observation stations.

The name and location of hydrological stations are given in Table R2.1.3 and also indicated in Fig.R 2.1.2.

Table R 2.1.3 Location of Hydrological Stations

Station No.	Name of Station	Elevation (m. MSL)		Position	
				Latitude	Longitude
6	Ishkashim_Panji R.	35.0	Prov.	36° 44’	71° 36’
7	Shidz_Panji R.	1,954.26	BS	37° 56’	71° 17’
8	Khirmanjo_Panji R.	811.32	BS	37° 54’	70° 11’
9	Nizhni Panji_Panji R.	320.00	BS	37° 12’	68° 37’
10	Langar_Kishtijarob R.	46.70	Prov.	37° 03’	72° 41’
11	Garmchashma _Garmchashma R.	45.00	Prov.	37° 12’	71° 32’
13	Khorog_Gount R.	2,070.32	BS	37° 26’	71° 32’
19	Khobost_Shohdara R.	2,095.46	BS	37° 29’	71° 34’
22	Murgab_Bartang R.	3,582.00	BS	38° 10’	73° 58’
23	Pshart_Batarang R.	3,250.00	BS	38° 15’	73° 16’
24	Barchidiv_Batarang R.	2,510.30	BS	38° 18’	72° 29’
25	Nisur_Batarng R	42.60	Prov.	38° 18’	72° 47’
26	Shouchand_Bartang R.	90.00	Prov.	37° 57’	71° 37’
34	Rushan_Vomardara R.	2,049.93	BS	37° 57’	71° 32’
35	Motravn_Yazgulom R.	83.44	Prov.	38° 12’	71° 25’
36	Bichkharv_Vanji R.	35.00	Prov.	38° 22’	71° 27’
38	Khourk_Obiskharvi R.	2.00	Prov.	38° 31’	71° 02’
39	Ustie_Obikhmbou R.	4.86	Prov.	38° 27’	70° 47’
02	I.Yashilkul-SB	3,734.00	BS	37° 47’	72° 45’
03	I.Sarez-Irkht	3,239.00	BS	38° 10’	72° 38’

Note: “Prov.” – provisional system: “BS” – Baltic system

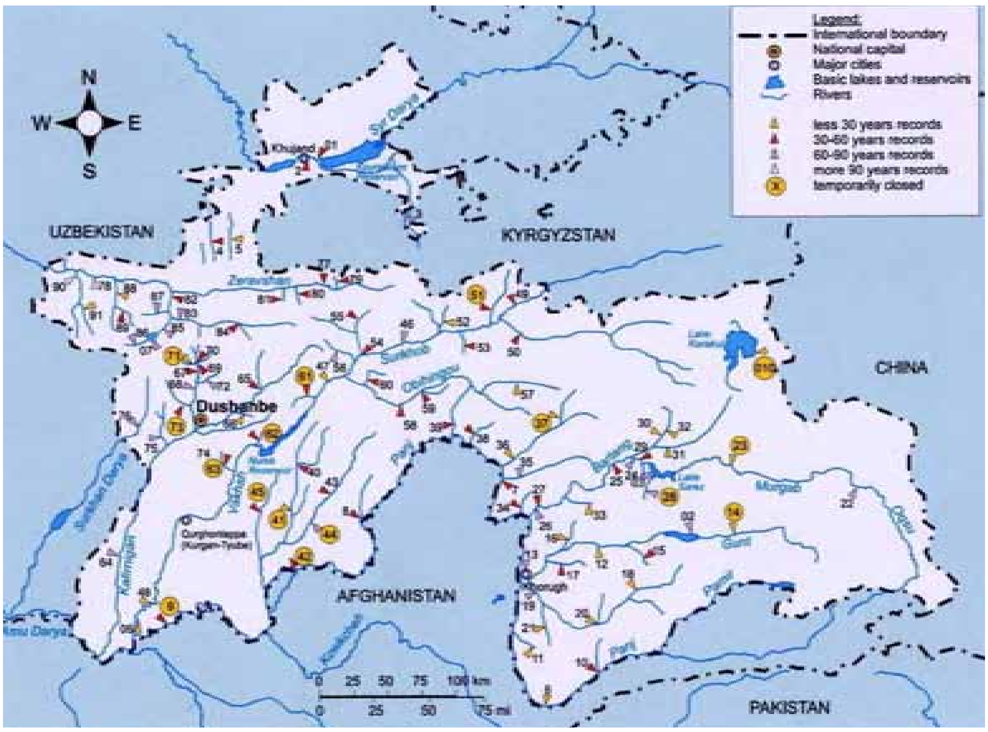


Fig. R 2.1.2 Location of Hydrological Stations

3) Availability of Hydro-Meteorological Data

The availability of meteorological data is as shown in Table 2.1.1, while the availability of hydrological data is in Table 2.1.2. Water level data before 1994 were not corrected because discharge data were obtained already.

The observations have continued since the 1960's. From 1992, however, some stations suspended operation due to the disintegration of the Soviet Union. Particularly, discharge measurements have discontinued since 1994 except the measurements at the Khorog Station on the Gunt River.

Since rating curves made in 1991 exist in some stations, discharge could be estimated roughly for the stations with water level data after 1994 using the rating curve. The year 1991 is the year with the latest rating curve.

As to evaporation and solar radiation, they are not being observed at present but they were observed from the 1960's to 1980's during the rule of the Soviet Union. Monthly average data on evaporation and solar radiation at that time were obtained from two stations. The station for evaporation is Rushan and the station for solar radiation is located at the northern part outside of the Pyanj river basin. (Refer to Table R2.1.7 and Table R2.1.8 in the next section.)

2.1.3 Runoff Characteristic of Pyanj River Basin

1) Runoff Characteristic

Peak discharges and specific discharges at the Ishkashim, Shidz, Khirmanjo stations in the upstream, midstream and downstream of Pyanj River, respectively, are as shown in Table 2.1.3. From the point of view of specific discharge, the value at the Shidz Station is smaller than those of the other two stations and the reason could be the influence of the confluence of Bartang River, which has the basin with few precipitations, at a little upstream of the Shidz Station.

The accrual date of peak discharge at the Ishkasim and Shidz stations located in the upstream area comes later than the accrual date at Khirmanjo Station in the downstream area. It is thought that the great deal of precipitation in the middle and downstream areas have a more significant impact on the formation of peak discharge at Khirmanjo Station than the few precipitations in the upstream area.

The catchment area covered by the Shidz Station is approx. 80% in Tajikistan territory and approx. 20% in Afghanistan territory. The proportion of covered Afghanistan territory increases to approx. 28% at the Khirmanjo Station (refer to Table R2.1.4). As the proportion of Afghanistan territory without meteorological station increases, the uncertainties also increase.

As mentioned above, runoff from the downstream area has an impact on the Khirmanjo Station. For instance, by comparing the annual runoff amount estimated by runoff simulation to be hereinafter described with the catchment area, the catchment area between the Shidz and Khirmanjo stations is approx. 20% of the total area but the runoff volume from this area accounts for approx. 50% of the total runoff volume (refer to Table R2.1.5).

Table R 2.1.4 Catchment Area in Hydrological Stations

(Unit: Square km)

Hydrological Station	Catchment Area (km^2)			Catchment Area Increase Ratio		
	Tajikistan Territory	Afghanistan Territory	Total	Tajikistan Territory	Afghanistan Territory	Total
Ishkashim	4,197	10,121	14,318			
	29.3%	70.7%	100.0%			
Shidz	47,867	13,679	61,545	43,669	3,558	47,227
	77.8%	22.2%	100.0%	92.5%	7.5%	100.0%
Khirmanjo	55,914	21,681	77,595	8,048	8,002	16,050
	72.1%	27.9%	100.0%	50.1%	49.9%	100.0%

Table R 2.1.5 Comparison of Catchment Areas and Runoff Volume in 2005

River Basin	Catchment Area		Runoff Volume in 2005	
	(km^2)	Rate (%)	(x 10^6 m^3)	Rate (%)
Upper Basin from Shidz	61,545	79.3	9,708	49.2
Basin between Shidz and Khirmanjo	16,050	20.7	10,021	50.8
Khirmanjo	77,545	-	19,729	-

2) Characteristic of Precipitation Distribution

Monthly precipitation at each station in the three (3) biggest floods with complete data, namely, the 1969, 1978 and 2005 floods, is as presented in Fig. 2.1.3.

As mentioned before, the amount of precipitation at the Shaimak, Bulunkul, Murghab, Irkht stations in the eastern area of the Pyanj river basin and the Ishkashim Station in the southern area of the basin is small, while the amount of precipitation at the Khorog, Rushan, Khumragi, Darvoz, Parkar, Kulyab stations in the western area of the basin is large every year. Moreover, precipitation concentrates in the period between October and May and the amount during this period is over 90% of the annual precipitation.

3) Timing of Peak Discharge Occurrence

Fig. 2.1.4 shows the timing of peak discharge occurrence at the Khirmanjo and Khorog stations. Twenty (20) out of the 28 floods (71.4%) at Khirmanjo Station and 31 out of the 42 floods (73.8%) at Khorog Station generated peak discharges in a one-month period from 21 June to 20 July. The scale of peak discharge tends to be large with the early generation of peak occurrence without the 1969 floods at the Khirmanjo Station.

4) Degree-Day Factor

In this section, the data of Khorog Station at the downstream end of the Gunt river basin will be studied because its data is complete.

Degree-day factors of the five (5) largest floods and the five (5) smallest floods at the Khorog Station are shown in Fig. 2.1.5. Degree-day factor is the value which converts runoff volume into the depth per unit area, and divided by accumulated temperature over 0ºC. It is expressed in mm/day/ºC. The reason for showing the graph from the end of May is that the discharge before the middle of May is not snowmelt runoff but base flow of the basin. The estimated degree-day factor is small in comparison with the general value because the catchment area substitutes for the snow coverage area due to the unclear value of the snow coverage area. Degree-day factors have a characteristic that the value is small at the beginning of snow melting and it afterward tends to rise in steps.

As shown in the figure, the shape of the graph of the large-flood group is different from the shape of the small-flood group. The graph of the small-flood group is almost flat while that of the large-flood group go up rapidly in June. The rising begins to concentrate in a short period from the end of May to the beginning of June, and continues until the middle of July. All factors have almost the same maximum value. The graph starts to go down in the middle of August and become flat in October.

The analysis at the point of Khorog proceeded additionally responding to the result of the first field survey. This analysis includes comparison between degree-day factor and the distributions of integration of temperature and runoff volume in each group of large-scale floods and small-scale floods. (Refer to Fig. 2.1.6.)

- The distributions of integration of temperature of both large-scale and small-scale flood groups are not different, mostly.
- Regarding the distribution of runoff volume, the large-scale flood group shows the inflection point clearly but the inflection point of the small-scale flood group is unclear and the values are small.
- The difference between the large-scale flood group and the small-scale flood group is in the distribution of runoff volume only.
- The degree-day factor distributes in conjunction with the runoff volume and depends on it.
- Consequently it is judged that the need to compute the degree-day factor is low and the information identified from the change of degree-day factor is less than the information from the change of runoff volume.

The analysis at the point of Khirmanjo was not conducted for these reasons.

5) Snow Coverage Area

The images of snow coverage areas from 2003 to 2006 are shown in yellow color in Fig. 2.1.7. Tajikmeteorology provided the data in August 2006.

As can be seen from the images, the snow coverage area in June 2005 is larger than in the other years as proven by measurement (refer to the table below). The snow coverage areas in May in each year are about 60%, and the areas in July are about 38%. Unfortunately, the area in May 2005 could not be measured but the scale of the area could be similar to that of the other years. As shown in Fig. 2.1.8, however, the rise of temperature from 01 May to 01 June in 2005 is smaller than the rise in 2003 and 2004. For this reason, the snow coverage area in June 2005 could be the same as the scale in May.

Adversely, the rise of temperature from 01 June to 01 July in 2005 is larger than the rise in 2003 and 2004 for all stations. This temperature rising may have a significant influence on the snow melt at the Pyanj river basin and the snowmelt runoff may have concentrated in this period. The whole basin area is 82,533,620 km^2.

Table R 2.1.6 Snow Coverage Area in Each Month

(Unit: Square km)

	May		June		July	
	Snow Cover Area	%	Snow Cover Area	%	Snow Cover Area	%
2003	51,883,917	62.9%	No data		31,404,388	38.1%
2004	48,197,601	58.4%	39,497,804	47.9%	29,477,281	35.7%
2005	No measurement by cloud		46,245,370	56.0%	31,808,078	38.5%
2006	48,433,799	58.7%	42,140,352	51.5%	31,015,674	37.6%

2.1.4 Runoff Analysis

1) Snow-melt Runoff Routine

The Study Team established the runoff model with snow-melt runoff routine by using the software called Mike 11 that was developed by DHI (Danish Hydraulic Institute).

The snow-melting process is calculated by the Degree-Day Method, which could be considered under the field of meteorology. Snowmelt amount is calculated by the following formula. In the simulation, snowmelt amount due to solar radiation and rainfall is added to this amount.

$$q = c \cdot \sum T$$

where, q: Snowmelt Amount (mm/day)

c: Degree-Day Factor (mm/day/ºC)

ΣT: Accumulated Temperature (ºC/day)

The Tank Model, a model superior for the modeling of long-term runoff, is used to calculate the runoff process. This is called the NAM model in Mike 11. NAM simulates the rainfall-runoff process by continuously accounting for the water content in four different and mutually interrelated storages that represent different physical elements of the catchment. These storages are:

- Snow storage
- Surface storage
- Lower or root zone storage
- Groundwater storage

Normally, the precipitation enters directly into the surface storage. However, during cold periods precipitation is retained in the snow storage from which it is melted in warmer periods. A simplified schematic diagram is shown in Fig. R 2.1.3. The model divides the catchment into a number of altitude zones with separate snowmelt parameters, temperature and precipitation input for each zone.

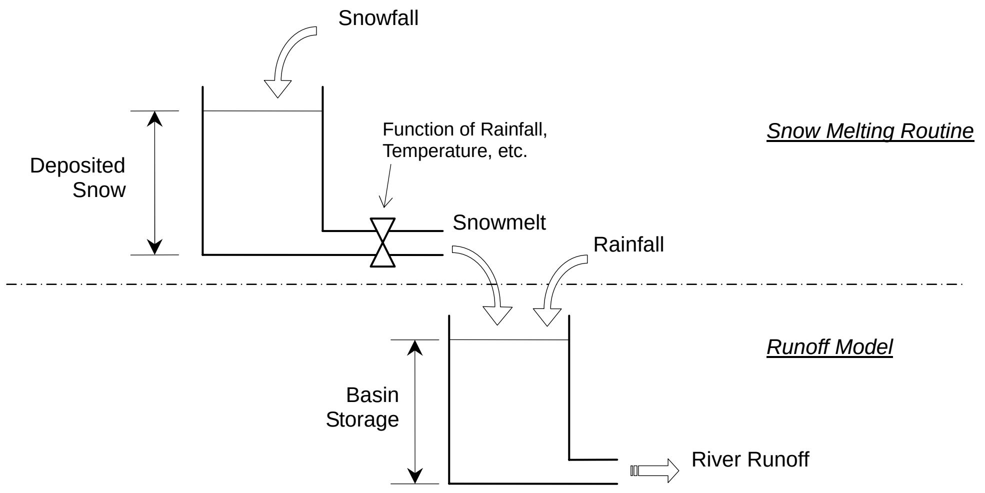


Fig. R 2.1.3 Conceptual Diagram of Snow Melting Routine and Runoff Model

2) Sub-catchment Description and Delineation

The Pyanj river basin is divided into sub-catchments with consideration on the distribution of hydro-meteorological stations and the scale of sub-catchment area. The sub--catchment areas and the runoff model are as shown in Figs. 2.1.9 and 2.1.10. The area of each sub-catchment and the catchment area in each altitude zone are shown in Tables 2.1.4 and 2.1.5 respectively.

3) Time Series of Meteorological Data

a) Precipitation

Precipitation is given a time series, representing the average catchment rainfall. The time interval between values may vary through the input series. The rainfall specified at a given time should be the rainfall volume accumulated since the previous value.

The precipitation value of representative stations is utilized as the value in each catchment because precipitous and high mountains divide the sub-catchments in the Pyanj river basin and correlation with the next stations is quite low when the sub-catchment changes. As the precipitation of representative stations, the precipitation is multiplied with lapse rate, 91% reading from Fig. R2.1.4.

As for interpolating the missing data, since the correlation in each station is quite low, the missing data is interpolated by the average depth of rainfall over the catchment using the Thiessen Method.

In the model, precipitation is multiplied by a correction coefficient in each altitude zone. The value is 2 mm/100 m, basically.

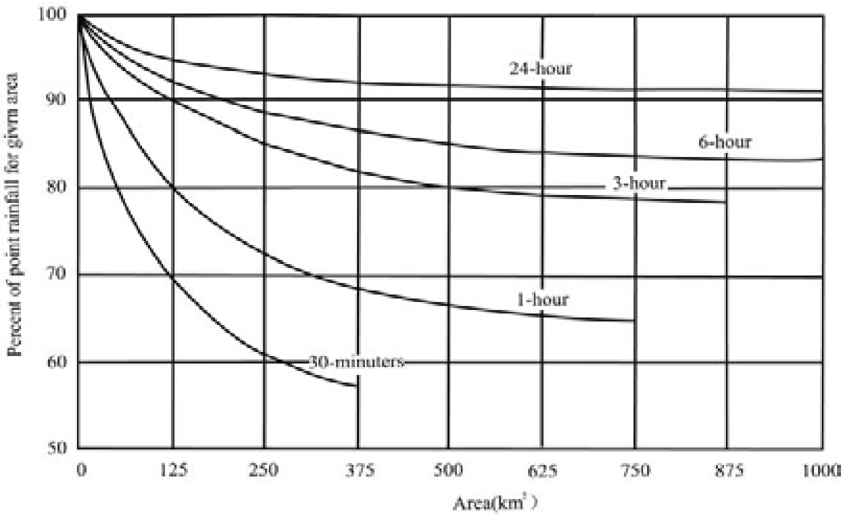


Fig. R 2.1.4 Depth-Area Curves for Reducing Point Rainfall to Obtain Areal Average Value

(Source: Applied Hydrology, 1988)

b) Evaporation

Potential evaporation is typically given as monthly values. The value should be the accumulated volume at the end of the period it represents.

Evaporation has not been observed in recent years. In the early period of the Soviet Union governance, evaporation was observed at the Rushan Station located around the middle reach of Pyanj River. The monthly average in the period from 1962 to 1975 is shown in the table below.

Table R 2.1.7 Evaporation at Rushan Station

(Unit: mm/month)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
112	156	236	266	273	205	115	55

Source: Dry Land Hydrology, Hydro-Meteo Publication, 1976

c) Temperature

A time series of temperature, usually mean daily values, is required.

In the model, temperature is multiplied by a correction coefficient in each altitude zone. The value is 0.7ºC/100 m based on the height of meteorological station. The missing data is interpolated linearly with the temperature before and after the period of missing data.

d) Solar Radiation

A time series of incoming solar radiation can be used as input to the snow-melting routine.

Solar radiation has not been observed in recent years. The monthly average of solar radiation data is available only from 1966 to 1980 for Badakhshan Oblast at the north, outside of the Pyanj river basin. Observations had been conducted several times during day-time, and the total radiation on level surface replacing actual surface observed around noon will be utilized.

Table R 2.1.8 Monthly Average of Sun Radiation

(Unit: kw/m^2)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
0.32	0.56	0.69	0.85	0.96	1.01	0.98	0.95	0.84	0.63	0.49	0.40

Source: The scientifically applied directory on the climate of USSR, 1988

4) Calibration and Verification of the Runoff Model

The runoff model of the Pyanj river basin has been calibrated at several points representing Ishkashim and Khirmanjo in Pyanj River, Khorog in Gunt River and Nisur in Gartang River. Parameter calibration has been conducted for the five (5) biggest floods with complete data. The calculation started from the previous year in order to have a longer running period.

Parameters of the model are as given below. Refer to the user manual of MIKE 11 for the normal range of values.

a) Parameters for Surface Runoff

- Maximum water content in surface storage (Umax) - Represents the cumulative total water content of the interception storage (on vegetation), surface depression storage and storage in the uppermost layers of soil.
- Maximum water content in root zone storage (Lmax) - Represents the maximum soil moisture content in the root zone, which is available for transpiration by vegetation.
- Overland flow runoff coefficient (CQOF) - Determines the division of excess rainfall between overland flow and infiltration.
- Time constant for interflow (CKIF) - Determines the amount of interflow, which decreases with larger time constants.
- Time constants for routing overland flow (CK1, 2) - Determines the shape of hydrograph peaks. The routing takes place through two linear reservoirs (serial connected) with the same time constant.

- Root zone threshold value for overland (TOF) - Determines the relative value of the moisture content in the root zone (L/Lmax) above which overland flow is generated.
- Root zone threshold value for inter flow (TIF) - Determines the relative value of the moisture content in the root zone (L/Lmax) above which interflow is generated.

b) Parameters for Ground Water

- Time constant for routing base flow (CKBF) - It can be determined from the hydrograph recession in dry periods.
- Root zone threshold value ground water recharge (Tg) - Determines the relative value of the moisture content in the root zone (L/Lmax) above which ground water recharge is generated. The main impact of increasing TG is less recharge to the ground water storage.

c) Overall Parameters for Snow Melt

- Constant degree-day coefficient (Csnow) - The content of snow storage melts at a rate defined by the degree-day coefficient multiplied with the temperature deficit above the base temperature.
- Base temperature snow/rain (T0) - The precipitation is retained in the snow storage only if the temperature is below the base temperature, whereas it is by-passed to the surface storage in situations with higher temperature.

d) Extended Snow Melt Component

- Seasonal variation of Csnow - It is assumed to vary over the year. Variation of Csnow is given as monthly values in mm/day/C.
- Radiation coefficient - Total snowmelt is calculated as a contribution from the traditional snowmelt approach based on Csnow (representing the convective term) plus a term based on radiation.
- Rainfall degree-day coefficient - This effect is represented in the snow module as a linear function of the precipitation multiplied by the rainfall degree coefficient and the temperature deviation above the base temperature.

e) Elevation Zones

- Number of elevation zones - Defines the number of altitude zones, which subdivide the catchment. In each altitude zone the temperature and precipitation is calculated separately.
- Reference level for temperature stations - Defines the altitude at the reference temperature station. This station is used as a reference for calculating the temperature and precipitation within each elevation zone.
- Dry temperature lapse rate - Specifies the lapse rate for adjustment of temperature under dry conditions. The temperature in the actual elevation zone is calculated based on linear transformation of the temperature at the reference station to the actual zone defined as the dry temperature lapse rate (ºC/100m) multiplied by the difference in elevations between the reference station and the actual zone.

- Wet temperature lapse rate - Specifies the lapse rate for adjustment of temperature under wet conditions defined as days with precipitation higher than 10 millimeters.
- Reference level of for precipitation station - Defines the altitude at the reference precipitation.
- Correction of precipitation - Specifies the lapse rate for adjustment of precipitation. Precipitation in the actual elevation zone is calculated based on a linear transformation of the precipitation at the reference station to the actual zone defined as precipitation lapse rate (mm/100m) multiplied by the difference in elevation between the reference station and actual zone.

The results of parameter calibration are shown in Table R2.1.9. The runoff ratio (CQOF) of Sarez Lake adopts 0.1 in consideration of the storage effect of Sarez Lake due to unclear details of runoff function.

At present, the parameters are changed to fit each flood. In addition, the volume of annual precipitation is quite smaller than the annual runoff volume, occasionally. In this case, runoff volume is adjusted by increasing the correction of precipitation and the values of evaporation are left out of consideration also.

The fitting results are shown in Fig. 2.1.11 and Fig. 2.1.12 for Khirmanjo and Khorog stations, respectively. The fitting result of Khorog might be precise comparatively, but the result at Khirmanjo has low accuracy especially in the part of recession period of the flood hydrograph.

Table R 2.1.9 Result of Parameter Calibration

Parameters	The Range of Values
Umax	10 – 20
Lmax	150 – 500
CQOF	0.1 – 0.8
CKIF	500 – 1000
CK1,2	24 – 72
TOF	0.9
TIF	0.1 – 0.9
TG	0.2
CKBF	1000 – 6000
Csnow	1 – 4.5
T0	0
C rain	1 – 10
C radiation	0.5

5) Computation of Runoff

The results of simulation for the five (5) biggest floods with complete data are shown in Fig. 2.1.13. The peak of the floods is as described below.

The observed flood in 1983 has two peaks and the second peak is higher than the first peak at the Khirmanojo Station. In the simulation result, the first peak is higher than the second one and the result at Chubek is in the same situation also.

Although the analysis was continued in the second field survey, the accuracy could not be improved. The Study Team thus concluded that the results of runoff simulation could not improve the accuracy of simulation results by adjusting only the parameters under the existing data situation, especially the low density of meteorological observation.

Table R 2.1.10 Peak Discharge of Five Biggest Floods at Chubek

(Unit: m^3/s)

	Peak Discharge
1969	5,027
1978	4,945
2005	4,419
1990	3,989
1983	4,065

2.1.5 Recommendations for Hydro-Meteorological Observations

One of the issues in the future may be the shortage of meteorological observatories. Definitely, the observation network in the downstream area should be reinforced. There are 18 observatories in and around the Pyanj river basin, which is 77,595 km^2, at present. It means that one observatory covers an area of 4,300 km^2. In contrast, observatories of the Automated Meteorological Data Acquisition System (AMeDAS) of the Meteorological Agency of Japan, of which more than 1,100 are unmanned, are located at an average interval of 17 km (289 km^2) throughout the country of Japan. On the other hand, the Ministry of Land, Infrastructure and Transport (MLIT) of Japan targets to provide an observatory per 50 km^2.

The book of "Hydrological Observation" published by the Japan Construction Engineers' Association mentions the allocation and installation of observatories as: "Precipitation stations should be allocated to the key points of the whole river system considering adequate observation network for the planning and administration of river. The adequate observation network is to allocate observatories in the whole basin evenly without planar bias and the place is to be representative of precipitation characteristics of the basin considering altitude distribution".

The density of observation network is not expected to be as high as in Japan because the floods in the Pyanj river basin are caused by snowmelt, not by localized torrential rainfall. However, the Pyanj river basin is divided into sub-basins by high and precipitous mountains and the weather condition might be different even with adjacent sub-basins. Therefore, one or more observatories should be allocated to each sub-basin, at least.

Hydrological observatories also could not measure accurate discharge at present because of lacking cross section in the Pyanj mainstream.

1) Hydrological Observatory

- Hydrological observatories are located around the outlet of main tributaries and at key points on the Pyanj main stream. These have sufficient observation periods and significantly contribute to grasp the flow regime of the Pyanj River. However, discharge observation is not conducted at present because no cross section survey was conducted after the collapse of Soviet Union. Therefore, the system and facilities should be consolidated urgently for discharge measurement.
- Considering that runoff discharge from the downstream area is dominant, a hydrological observatory should be allocated for the section between Shidz and Khirmanjo, which is approx. 250 km long, because there is no observatory in this section. The middle section downstream of the confluence with the Obikhunbour River is a suitable location. (Refer to the table below.) This point can grasp the runoff discharge from Afghanistan and sub-basin Nos. 5 and 6, which have glacier in the upstream area, and this point can grasp the runoff discharge from approx. 12,100 km^2 out of the 21,000 km^2 downstream from Shidz. Additionally, the observation of this point will contribute to the flood forecasting at Chubek because the flood travel time to Chubek from this point is approx. 16 hours.

- A hydrological observatory should be allocated for Chubek, which is located at the head of the Hamadoni Fan. Chubek is key point to grasp the discharge for forecasting and warning of flood and flood fighting for the Hamadoni District.

Table R 2.1.11 Interval of Hydrological Observatories on Pyanj Mainstream

	Interval (km)	Cumulative Distance (km)	Interval Travel Time (hr)	Cumulative Travel Time (hr)
Chubek - Khirmanjo	112.6		7.8	
Khirmanjo - Shidz	252.9	365.5	17.6	25.4
Shidz - Ishkashim	186.3	439.2	12.9	30.5
Chubek-Obikhumbou	224.3		15.6	

In consideration of the observation network and the real-time analysis in the future, the proposed observation items and necessary equipment for the existing and proposed observatories are as given in the table below. The proposed sites are as shown in Fig. R 2.1.5

As for discharge measurement, since the channel condition may change every year, the cross section and the rating curve should be reviewed every year.

Table R 2.1.12 Necessary Equipment for Existing and Proposed Observatories

	Observatory	Proposed Items of Observation	Necessary Equipment
Existing Observatories			
1	Ishkashim-Panji R.	WL, Q	Automated Water Level Gauge with Telemeter System using HF Radio Discharge Measurement (current meter, gondola with cable crossed river)
2	Shidz-Panji R.	WL, Q	
3	Khirmanjo-Panji R.	WL, Q	
4	Nizhni Panji-Panji R.	WL, Q	
5	Langar-Kishtijarob R.	WL, Q	
6	Garmchashma Garmchashma R.	WL, Q	
7	Khorog-Gunt R.	WL, Q	
8	Khobost-Shohdara R.	WL, Q	
9	Murgab-Bartang R.	WL, Q	
10	Pshart-Batarang R.	WL, Q	
11	Barchidiv_Batarang R.	WL, Q	
12	Nisur-Batarng R	WL, Q	
13	Shouchand-Bartang R.	WL, Q	
14	Rushan-Vomardara R.	WL, Q	
15	Motravn-Yazgulom R.	WL, Q	
16	Bichkharv-Vanji R.	WL, Q	
17	Khourk-Obiskharvi R.	WL, Q	
18	Ustie-Obikhmbou R.	WL, Q	
Proposed Observatories			
19	Chubek	WL, Q	Water Level Gauge (Radio Type) with Telemeter System using HF Radio Discharge Measurement (Floating Cylinder)
20	The Middle of Shidz and Khirmanjo	WL, Q	Water Level Gauge with Telemeter System using HF Radio Discharge Measurement (current meter, gondola with cable crossed river)

WL: Water Level, Q: Discharge; Existing observation devices in all observatories are manual

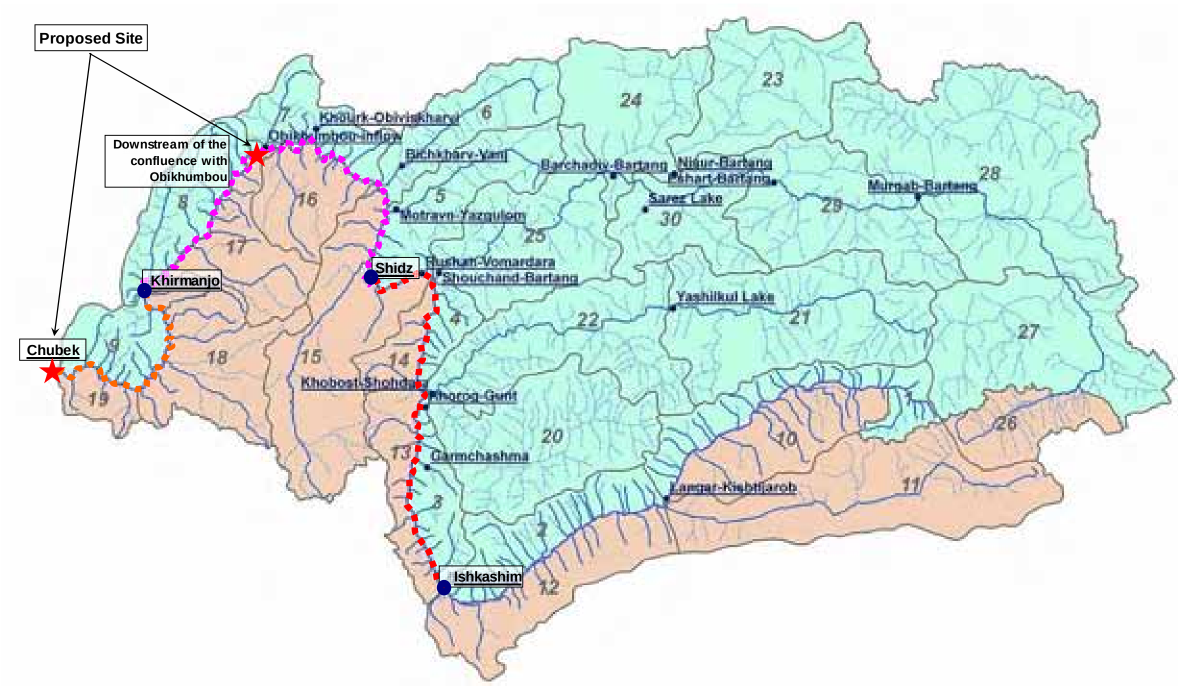


Fig. R 2.1.5 Proposed Sites of New Hydrological Observatories

2) Meteorological Observatory

- The meteorological situation of the basin is such that snow is scarce in the upper areas because of low precipitation. In contrast, the lower area has a significant snowfall and the amount of runoff due to snow-melt is great.
- As for the topographic feature, the basin is divided into sub-basins by high and precipitous mountains and the weather condition is different in adjacent sub-basins.
- The number of meteorological observatories is quite few for the basin area.
- Tajikimeteorology aims to rehabilitate the existing observatories in its 10-year program without considering the allocation of new ones.
- Existing observatories are located in comparatively low areas such as towns along rivers and rarely in high altitudes. The ease of maintenance should be considered of course, however, observation at high altitudes is important because the altitude of basins vary considerably. In case of the new allocation of observatories, altitude distribution of the basin should be considered.
- In the lower area from Darvoz, there are observatories only outside of the basin at present. At least two (2) observatories should be allocated for the area considering the scale of the basin.
- There are no observatories in sub-basin Nos. 1 and 2, which are long and thin in the upper area from Ishkashim. Hence, the estimation of weather condition for runoff simulation in these basins utilized the data outside of the basin. At least two (2) observatories should be allocated for the upper area from Ishkashim considering the scale of the basin.
- The basins of Vanj River (No. 6) and Yazgulom River (No. 5) and sub-basin No. 24 have glaciers in their upper areas and the runoff due to snow melt from these basins affects the runoff volume from the main stream. A new observatory should be allocated to each basin in order to grasp the condition of glaciers.

- There is no observatory in sub-basin No. 23. At least one (1) observatory should be allocated for each sub-basin.
- As for sub-basin No. 20, there are two (2) observatories but they are located in the upstream and downstream ends. Both of these observatories may not represent the weather condition of the basin because they are located at opposite ends. A new observatory should be allocated for the gravity point of the basin.

In consideration of the enhancement of observation network in Pyanj river basin and the contribution of the forecasting of snowmelt runoff in the future, the proposed observation items and necessary equipment for the existing and proposed observatories are as given in the table below. The proposed sites are as shown in Fig. R 2.1.6.

Table R 2.1.13 Necessary Equipment for Existing and Proposed Observatories

	Observatory	Proposed Items of Observation	Necessary Equipment
Existing Observatories			
1	Shaimak	R, T, E, S, D	Automated Devices for Observation Items with Telemeter System using HF Radio
2	Bulunkul	R, T, E, S, D	
3	Javoshangoz	R, T, D	
4	Ishkoshim	R, T, E, S, D	
5	Murgab	R, T, E, S, D	
6	Irkht	R, T, D	
7	Sovnob	R, T, E, S, D	
8	Khorog	R, T, E, S, D	
9	Navobod	R, T, D	
10	Rushan	R, T, E, S, D	
11	Khumrogi	R, T, E, S, D	
12	Darvoz	R, T, D	
Proposed Observatories			
13	Sub-Basin 1	R, T, D	Automated Devices for Observation Items with Telemeter System using HF Radio
14	Sub-Basin 2	R, T, D	
15	Upper Area of Sub-Basin 5	R, T, D	
16	Upper Area of Sub-Basin 6	R, T, D	
17	Sub-Basin 8	R, T, D	
18	Sub-Basin 9	R, T, E, S, D	
19	Center of Sub-Basin 20	R, T, D	
20	Sub-Basin 23	R, T, E, S, D	
21	Upper Area of Sub-Basin 24	R, T, D	

R: Precipitation, T: Temperature, E: Evaporation, S: Solar Radiation, D: Snow Depth

As for solar radiation and evaporation, since it is not necessary to observe it at near positions, the equipment shall be installed at a certain distance. And the device of evaporation could not be allocated in remote area due to the maintenance of water in the tub.

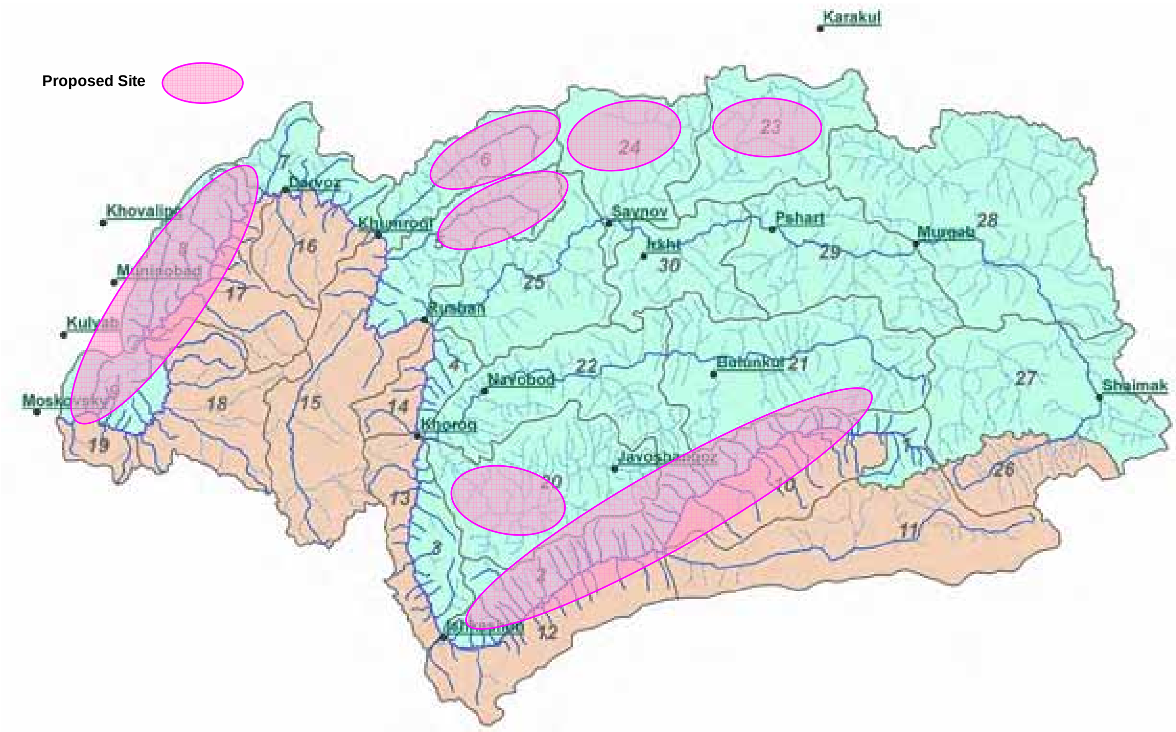


Fig. R 2.1.6 Proposed Sites of New Meteorological Observatories

2.2 HYDRAULICS

2.2.1 Verification of Data of Khrimanjo Station

Hydrological observations have not been conducted at Khirmanjo Station since the disintegration of the Soviet Union until recently. In this section, the relation between water level and past discharges is verified, and the flow discharge will be estimated from the water level observed in recent years using the relation.

1) Variation of Cross Section

Variation of cross section due to aging at Khirmanjo Station is shown in Fig. 2.2.1. The height of riverbed was almost constant from 1977 to 1983. The riverbed has risen once due to sediment influx in 1984; however, the sediment was flushed out in the following year, and the height of riverbed in 1985 and 1986 almost got back to the former height in 1977.

Variations of cross section within one year in 1977 at Khirmanjo Station are shown in Fig. 2.2.2. Although the riverbed was stable from January to March, the riverbed rose in April together with the increase of discharge. After the peak discharge, the riverbed started to erode in the recession period and almost got back to the former height in August.

According to these verifications, the results suggest that variations of cross section due to aging were few.

2) Verification of Rating Curve

Superimposition of rating curves from 1969 to 1991 is shown in Fig. 2.2.3. Rating curves from 1969 to 1983 are distributed in a narrow range. On the other hand, rating curves after 1984 are widely distributed.

In 1984, sediment influx from the right tributary happened and the station was damaged. Staff gauges were reinstalled during the year. According to Tajikmeteorology, the reasons of wide distribution of rating curves after 1984 might be the inexperience of observers due to replacement of measuring equipment once in every two years, the unskilled observers, and the reading error of staff gauges.

It is not enough also for each reason to dismiss data. In consideration that the cross section is stable, the rating curve in 1991 is adopted because it is located around the center of the distribution and it is the latest among them. On the other hand, since the rating curve in 1991 has only 600 cm or less data in depth, the rating curve in 1978 is adopted for depths of over 600 cm. The rating curve in 1978 is also situated almost at the center of the distribution and the biggest discharge was observed in the observation period.

The values of both rating curves were plotted and the approximate formula was estimated by the least square method. The estimated rating curve is as shown in Fig. 2.2.3.

3) Estimation of Discharge

Discharges at Khirmanjo after 1994 were calculated using the estimated rating curve. Peaks of discharge in each year are shown in Table 2.2.1. Flood peak at Khrimanjo Station in 2005 was estimated to be 4,149 m^3/s.

2.2.2 Estimation of Flood Discharge in Hamadoni

1) Discharge Estimation by Specific Discharge Conversion

Generally, the discharge at a downstream point could be estimated by enlarging the discharge at an upstream point depending on the ratio of catchment area on an occasion when rainfall is uniformly distributed. In the case of Kirmanjo and Chubek, the catchment area ratio would be 1.064 because the catchment areas are 77,595 km^2 at Khirmanjo and 82,534 km^2 at Chubek.

In the Pyanj river basin, it rains little in the upstream area, which is the Pamir area, and it rains much in the downstream area as already mentioned in Subsection 2.1.3. Therefore, it is undesirable to enlarge the discharge at Khirmanjo using the ratio of catchment area in order to estimate the discharge at Chubek.

To reflect the characteristics of runoff, the discharge at Chubek was estimated using the ratio of peak discharges calculated by runoff simulation of the biggest 5 floods with complete data. The estimated peak discharge ratio and peak of floods in each year at Chubek estimated by using the ratio are shown in Table 2.2.1. The peak of flood in 2005 is estimated to be 4,664 m^3/s by using the ratio.

Table R 2.2.1 Peak Discharge Ratio by Runoff Simulation

(Unit: m^3/s)

Year	Khirmanjo		Chubek	Peak Discharge Ratio
	Observed	Simulated	Simulated	
1969	4,370	4,390	5,027	1.145
1978	4,230	4,291	4,945	1.152
2005	4,149	4,118	4,419	1.073
1990	3,600	3,632	3,989	1.098
1983	3,540	3,533	4,065	1.151
Average				1.124

2) Probability Analysis of Discharge

Probability analysis was carried out using the annual maximum of discharges for 32 years of observed discharge and the discharge estimated by using the estimated rating curve collectively. Employed for the probability calculation was the Gumbel Method. Based on the results, the flood in 2005 (4,664m^3/s) was the fourth biggest flood and probability was estimated in the range of 1 in 10 years and 1 in 20 years. Probability distribution is shown in Fig. 2.2.4

Table R 2.2.2 Probable Discharge

(Unit: m^3/s)

Probable Year	Khirmanjo	Chubek
1/100	5,215	5,862
1/50	4,839	5,439
1/30	4,561	5,126
1/20	4,338	4,875
1/10	3,951	4,440
1/5	3,547	3,987
1/2	2,937	3,301

3) Installation of Gauging Station at Chubek

In this study, the discharge at Chubek Station was estimated together with the discharge at Khirmanjo Station. Technically speaking, the data is not accurate because Khirmanjo Station is located at 80 km upstream from Chubek. Originally, the discharge should be observed at Chubek.

To grasp the discharge at Chubek or the Hamadoni area more accurately, the Study Team, after writing a letter on 12 May2006 to obtain permission from MMWR which manages the spur dikes around the Chubek Intake, installed water level gauges on the spur dike near the Chubek Intake for water level measurement at first. Firm structures in the channel were selected for the location of water level gauges, and the gauge points can be seen during floods, as shown in Fig. 2.2.5.

However, the water level and flow velocity in the 2006 flood season was hardly observed because the flood scale was small. River flow came around the gauge but the current was small. The water level was not equal to the main streams.

In addition, the Study Team could not obtain the cross section to be provided from the Tajikistan side hence the discharge at Chubek could not be observed for the 2006 flood season.

2.2.3 Prospect of Riverbed Fluctuation in Hamadoni

For the planning of facility such as dike in Hamadini area, the trend of riverbed variation should be considered. For the purpose, the trend of riverbed variation mainly at Chubek was checked from the existing data.

1) Using DEM of Satellite Image

The Study Team tried the analysis as follows. From the river width estimated from the satellite image around Chubek and the observed discharge of the day, the average height of riverbed was to be estimated and the variation of height due to aging shall be checked. However, it turned out that the analysis was difficult due to reasons, as follows:

The vertical accuracy of DEMs made by satellite images are:

SPOT: Resolution is 20m meshes, vertical error is approx. 10m

ASTER: Resolution is 30m meshes, vertical error is approx. 15m

Since the error of images was quite large, the data was not suitable for the analysis.

(SPOT and ASTER are the names of satellite.)

2) Discrimination of Satellite Image

There are satellite images from 1972 to 2005 of approximately every 5 years. Discrimination of satellite images may reveal the following:

- The holm around Chubek has been variable since 1986. The anterior edge of the large holm located at the Afghanistan side around Chubek suggests that the holm had moved forward. The area into which the holm had moved forward must have risen.
- Around the short holm in the east and west direction located at 3 km downstream from Chubek, the main stream has moved to the Tajikistan side since 1995. The area into which the main stream has moved might have decreased.
- The inland might be higher than the riverside. It suggests that the riverbed would rise after dike installation.

The riverbed in the whole area might have the rising trend without local degradation of riverbed due to scouring and displacement of the water colliding front. However, quantitative analysis is impossible with this factor taken into consideration.

3) Interview with People Concerned

The former First Deputy Minister of MMWR, Mr. Ashurov, had made arrangements for the provision of cross sections around Chubek which is Gyprowodkhoz property. Cross sections in the years 1984, 1989, 1995, and 2000 were provided. However, the cross sections were not at the same point and the locations were unclear also. The situation was confirmed as soon as the second field survey started but cross sections at the same point in various years were not acquired. Thus, enough analysis could not be carried out.

2.2.4 Riverbed Material Survey

Riverbed material survey was conducted to grasp the river course fluctuation and its causal relationship. Riverbed materials were collected from the sedimentation area and the alluvial fan, and a comparison of constituent materials from each point was made to grasp the trend of movement of sand and gravel in the vicinity such as sedimentation, erosion or transition segment. The results could be utilized as source material of riverbed variation analysis.

The survey was conducted by a local contractor, ASL Ltd., and the survey items are as listed in the table below.

Table R 2.2.3 Contents of Riverbed Material Survey

Item	Survey Contents
Objective of Survey	To grasp the condition of river course and riverbed fluctuation to be utilized as source material of riverbed variation analysis.
Location and Quantities	In Pyanj river channel in alluvial fan: 12 points In sedimentation area in alluvial fan: 6 points Around Khirmanjo station: 2points Total: 20 points
Survey Item	Particle size analysis (particle size distribution curve, average particle size, etc.) Specific weight
Period	15 May to 31 May 2006

The locations of the survey are as shown in Fig. 2.2.6. Survey points at Hamadoni were distributed evenly from upstream to downstream. The results of survey are as shown in Fig. 2.2.7 and Table 2.2.2.

In the Pyanj river channel, average particle sizes at the designated points are from 21.8 mm to 89.1 mm, as shown in Fig. R2.2.1. Particle sizes tend to be smaller towards the downstream. Since the particle size of 89.1 mm in Point No. 4 seems to be an abnormal value, the entire average was calculated without the data of No. 4 and the entire average of 44.0 mm was obtained. The average particle size was calculated with intermediate size of each sieve opening Riverbed variation analysis was conducted by using this value.

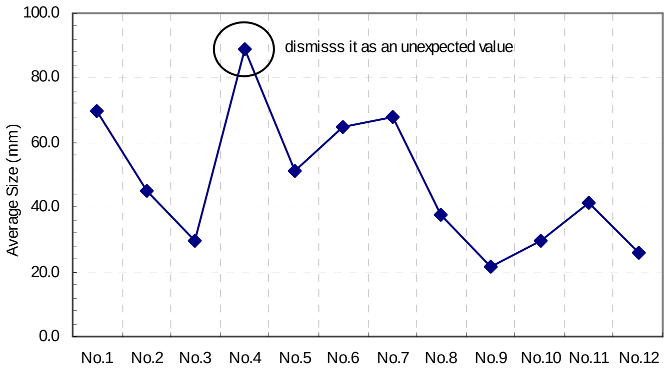


Fig. R 2.2.1 Distribution of Average Particle Size

In the sedimentation area in the alluvial fan, the average particle size widely distributed is from 10.5 mm to 89.2 mm and the particle size distribution curve also show a wide distribution. The composition of riverbed material is different according to the location of survey point. A detailed examination will be executed hereafter.

Around the Khirmano Station where the survey points were close to each other, the average particle size and particle size distribution curve had similar results. The average for 2 points is 41.2 mm. This average value is smaller than the result in Hamadoni. The station is located in the outlet of the right tributary and the result suggests that the influence of the discharged sediment has been received.

2.2.5 Riverbed Variation Analysis in Alluvial Fan

1) Analysis Policy

a) Two-Dimensional Flow Distribution Analysis with Fixed Bed

The analysis was made to estimate the proportion of discharge in each water route and waterway in the alluvial fan and the scale of discharge flowing in the water route along the dike in Tajikistan.

b) Riverbed Variation Analysis with Fixed Bed

The analysis was made to grasp the variation characteristics of the main stream in the alluvial fan by the vector distribution of flow velocity and the comparison of the critical traction force of the representative particle size of 40 mm and the traction force in each mesh. Two (2) cases were analyzed.

- Understanding of the characteristics of river course variation
- Verification of the facilities arrangement of the Master Plan
- Verification of the flow condition in the vicinity of Metintugay

c) Riverbed Variation Analysis with Moving Bed

The analysis was made to verify the riverbed variations of the river channel with the proposed facilities in the selected area.

2) Analysis Condition

a) Computation Area and Mesh data

There were two cases of computation areas:

Fixed bed: Flow Direction: 18 km x Transverse Direction: 13 km (181 x 131 grids)

Moving bed: Flow Direction: 10.2 km x Transverse Direction: 3.6 km (102 x 36 grids)

At first, the computation area was 20 km in the flow direction. However, since the stream is ramified significantly into the flows in the Tajikistan side and the Afghanistan side, the ends of flow were divided into the west side and the south side. Since water levels at the ends of flow might be significantly different, the computation area was decreased to 18 km to have the same water level at the ends considering topography in order to stabilize the calculation. (Refer to Fig. 2.2.8.)

As for the moving bed, the area was reduced for the same reasons. (Refer to Fig. 2.2.9.)

The meshes were 100 m^2 and the elevations were made from DEM of satellite SPOT images shot in 2003.

b) Analysis Model

The Two-Dimensional Model was employed. The basic formulas of flow were the continuity equation and the equation of motion of two-dimensional flows. The equation is shown with Cartesian coordinate system as follows:

Continuity Equation

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

Equation of Motion

$$\frac{\partial M}{\partial t}+\frac{\partial uM}{\partial x}+\frac{\partial vM}{\partial y}=-gh\frac{\partial z_s}{\partial x}-\frac{\tau_{bx}}{\rho}+\frac{\partial}{\partial x}\left(-\overline{u'^2}h\right)+\frac{\partial}{\partial y}\left(-\overline{u'v'}h\right)$$

$$\frac{\partial N}{\partial t}+\frac{\partial uN}{\partial x}+\frac{\partial vN}{\partial y}=-gh\frac{\partial z_s}{\partial y}-\frac{\tau_{by}}{\rho}+\frac{\partial}{\partial x}\left(-\overline{u'v'}h\right)+\frac{\partial}{\partial y}\left(-\overline{v'^2}h\right)$$

where, t: time, (x, y): space coordinates, (u, v): depth average velocity in direction of (x, y), (M, N): discharge flux in direction of (x, y), g: gravitational acceleration, h: depth, ρ: water density, z_s: water level from datum level, (τ_{bx}, τ_{by}): element of bottom shear stress in coordination of (x, y), $-\overline{u'^2}, -\overline{u'v'}, -\overline{v'^2}$: depth average Reynolds stress in coordination of (x, y).

Pyanj River is rapid current. The impact of advection term becomes remarkable in such rivers. The following formula is the Navier-Stokes Equation.

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\frac{\partial^2 u}{\partial x^2}+f$$

where, u: velocity, ρ: density of water, υ: coefficient of kinematics' viscosity,
p: pressure, f: external forces

From the left of the equation, the terms are Inertia term, Advection term, Pressure term, Viscosity term and External forces.

Advection term is physical quantity described as "velocity u × velocity gradient $\Delta u/\Delta x$". For this reason, when the velocity or the velocity change is large, the impact of advection term becomes remarkable. When the advection term is quite big, the pressure term in the right side counterbalances and an abnormal high water level or large discharge will be estimated. This is the reason that the calculation result for a steep-sloped river with an extremely changing section is not stable.

Since the equation of motion does not always express the flow adequately, the model should be close to the flow of actual river with a reducing advection term in case of steep-sloped rivers.

c) Average Particle Size and Roughness Coefficient

The value of 40 mm was adopted from the riverbed material survey and single particle size was utilized for the calculation.

The average particle size was within the range of 20 mm and 70 mm in the Hamadoni area. The slope was approximately 1/350. The roughness coefficient of 0.035 was adopted to follow the roughness coefficient of similar rivers in Japan, which is within the range of 0.033 and 0.038, basically.

d) Water Level at the Downstream End

The water levels at the downstream end were estimated by the ground level of DEM in the surface position of the satellite image at the time of discharge data available and adjusted by the calibration.

2,500 m^3/s scale: 473.0 m at Tjikistan side, 467.5 m at Afghanistan side

3,400 m^3/s scale: 473.36 m at Tjikistan side, 468.4 m at Afghanistan side

5,900 m^3/s scale: 474.36 m at Tjikistan side, 470.45 m at Afghanistan side

e) Model Calibration

Calibration of the Model was conducted by fitting the surface width of the simulation result with the satellite image because there were no water level data in the area. The satellite image was taken on July 31, 2006 and the flow discharge at Chubek was 2,500 m^3/s at the time. The fitting result is as shown in Fig. 2.2.10.

A small current was confirmed near the center of the figure or the south side of the main stream in Afghanistan territory. The current was however not confirmed in the satellite image, although traces of the current were confirmed in the area. This is because the points of time of the ground level of the calculation and the satellite image were different and the ground levels were corrected. Nevertheless, the result was assessed as acceptable and the gravel bars in 2005 were presumed from the rise of 3 m of the ground level at the location of large gravel bars in the upstream area in the satellite image.

f) Correction of DEM Data

DEM data based on satellite images include large errors. The accuracy of DEM made by SPOT image is approximately 10 m to 20 m. Even if the topographic condition could be assumed by using the DEM data, the topography will become markedly uneven and the condition would be inadequate for the calculation.

In this study, an attempt was made to correct the ground level of meshes based on the ground level of surrounding meshes and whether the shape is rhombic or square, which resulted in the change of number of meshes, as shown in the figure below. The square shape with seven-by-seven meshes totaling 47 meshes was finally adopted.

In the analysis using the mesh data, the ground levels were corrected to produce a smooth topography in order to have a stable calculation. Therefore, the analysis result needs to be grasped on the situation that the flow is shallower and spread in a wider area than the actual flow.

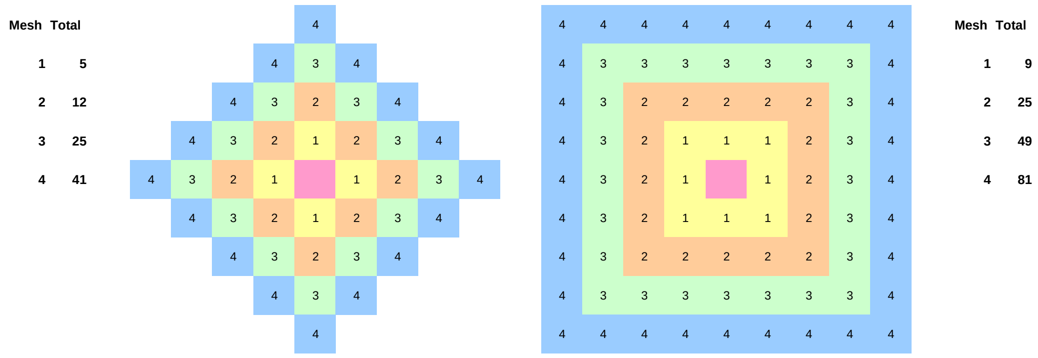


Fig. R 2.2.2 Interpolation of Ground Level

3) Two Dimensional Flow Distribution Analysis with Fixed Bed

Four (4) discharge cases, namely; 2,000 m^3/s, 3,000 m^3/s, 4,000 m^3/s and 5,000 m^3/s, were analyzed and the flow ratio between the discharge along the dike and at Chubek was estimated. (Refer to Fig. 2.2.11.)

The width of water route along the dike was set by the mathematical table of calculation results, according to the point where the discharge in each mesh was zero or almost zero at the assumed gravel bar and at the line connecting the gravel bars at the upper and lower streams in the section of no gravel bars.

The analysis results are shown in the table below.

Table R 2.2.4 Flow Ratio between the Discharge along the Dike and at Chubek

Chubek	1.45k - 3.9k		4.05k - 5.15k		5.2k - 7.5k		7.9k - 8.55k		9.05k - 9.7k		9.95k - 11.7k		12.0k - 13.25k		13.4k - 15.0k	
2,000	1,107	55.4%	1,732	86.6%	1,613	80.7%	903	45.1%	163	8.1%	407	20.4%	585	29.2%	747	37.3%
3,000	1,681	56.0%	2,545	84.8%	2,318	77.3%	1,299	43.3%	247	8.2%	623	20.8%	860	28.7%	1,181	39.4%
4,000	2,247	56.2%	3,334	83.3%	2,957	73.9%	1,642	41.1%	325	8.1%	761	19.0%	1,036	25.9%	1,439	36.0%
5,000	2,723	54.5%	4,076	81.5%	3,539	70.8%	1,945	38.9%	406	8.1%	922	18.4%	1,197	23.9%	1,636	32.7%
Distribution Rate		55.5%		84.1%		75.7%		42.1%		8.2%		19.6%		26.9%		36.3%

According to the flow ratio of the table, the flooding hydrograph was estimated at the assumed point in the flood analysis.

4) Riverbed Variation Analysis with Fixed Bed

a) Characteristics of River Course Variation

Four (4) discharge cases were analyzed, namely; 2,000 m^3/s, 3,000 m^3/s, 4,000 m^3/s and 5,000 m^3/s, considering the flow regime at Chubek. The vectors of flow velocity and the rate of critical traction forces of riverbed materials, representative particle size of 40 mm, and traction forces of each mesh in each discharge scale are shown in Fig. 2.2.12.

In the figure, red means that the rate is less than 1 and tends to be smaller and accumulated as the color becomes deeper; whereas, blue means that the rate is more than 1 and tends to be bigger and scoured as the color becomes deeper.

The considerations from the result are described as follows:

- In all discharge cases, almost all meshes are indicated in red or pink, which means that the whole fan tends to accumulate sediment and the places subject to scouring are limited. Inflow to the Afghanistan area in the middle reach was found in all cases. This might be due to the correction of ground level.
- In the case of small-scale discharge such as less than 3,000 m^3/s, the lower section has a high tendency of sedimentation since pink is highly visible in the upper section and red is highly visible in the lower section.
- Inflow to the Afghanistan area in all cases indicates a high tendency of sediment deposition since the velocity is small. The tendency is unchanged even if the discharge scale is enlarged.
- The places subject to scouring are located in the upper part along the dike of Tajikistan where large gravel bars are situated. It is speculated that scouring is caused by super-elevation flow due to the gravel bars.
- The scouring shapes horizontally long in the flow direction. This might be due to the discontinuity and drop of the riverbed.
- The places subject to scouring coincide with the places where the riverbed varies widely according to the longitudinal section of riverbed (refer to Fig. 2.2.13). In the downstream section from the 9-km point, there are some places of widely varying riverbed but these are not affected by scouring significantly because 80% of the main discharge flows to the Afghanistan side at the 9-km point and the discharge of the river course along Tajikistan downstream of the 9-km point is decreased drastically.
- Since the analysis was conducted for only a representative single particle size, the actual scale of scouring might be bigger than the simulation results in cases where more fine particles are included. Additionally, the places found to accumulate sediment such as the Afghanistan area where the flow velocity is low and the frequency of flood is also low might develop a stronger tendency of sedimentation.

In addition, the following could be said of the flow regime:

- The riverbed material, which is the representative particle size 40 mm, moves to over 1,000 m^3/s at Chubek as estimated by uniform flow calculation. The cross section at Chubek is estimated by the river width of satellite image at the 2,500 m^3/s flow and the river width coefficient of the regime theory.
- As for the flow regime at Chubek, approximately 70% of daily discharges are less than 1,000 m^3/s in a year. Thus, it could be expected that sediment inflow is scarce in 70% of the year.
- Floods of over 3,000 m^3/s might continue for a month in some years. In such years, sediment might accumulate in the Afghanistan area where flow velocity is low.
- Since it is impossible to cut the inflow of sediment from the upper basins, sediment will accumulate in the existing river channel if no countermeasures are implemented.

Based on the circumstances mentioned above, sediment tends to accumulate at the Afghanistan side while local scouring tends to occur along the dike at the Tajikistan side. Therefore, the flow of Pyanj River has the trend to go to the Tajikistan side, gradually. However, the analysis result needs to be grasped on the situation that the flow is shallower and spread in a wider area than the actual flow due to the correction of ground level.

Table R 2.2.5 Days in Discharge Scale

	Less than 1,000m³/s	1,000m³/s - 2,000m³/s	2,000m³/s - 3,000m³/s	3,000m³/s - 4,000m³/s	Over 4,000m³/s
1967	255	50	59	1	0
1970	239	104	18	4	0
1971	260	54	50	1	0
1977	258	61	32	14	0
1978	215	73	45	21	11
1979	272	40	41	12	0
1980	252	60	54	0	0
1981	259	78	28	0	0
1982	262	78	23	2	0
1983	247	68	37	13	0
1984	257	16	82	11	0
1985	247	67	35	16	0
1986	276	46	38	5	0
1987	230	57	62	16	0
1990	220	84	42	18	1
1991	246	65	54	0	0
1994	238	44	55	23	5
1995	259	46	56	4	0
1997	278	66	21	0	0
1998	232	77	32	19	5
1999	242	66	57	0	0
2000	250	116	0	0	0
2001	266	84	15	0	0
2002	252	32	72	9	0
2003	245	62	52	6	0
2005	246	55	36	21	7
Average	250	63	42	8	1
	68.5%	17.4%	11.5%	2.3%	0.3%

Note: The missing data in winter season was estimated from the values before and after the missing period.

For Reference

Generally, the scouring shapes vertically long in the flow direction. However in the case of Pyanj River, it shapes horizontally long in the flow direction. The reasons are as stated below.

- Generally, in the riverbed fluctuation analysis of bed load, the riverbed material moves to the lower mesh in cases where tractive force exceeds the critical tractive force of the riverbed material. The mesh might be decided as to whether or not sedimentation or scouring depends on the balance of transfer to the left and right, and to upper and lower. The places where rapid flow continues uniformly result in consecutive scouring trend. On the other hand, the places where river width extends and flow velocity slows down result in accumulative trend.
- In the topography of Pyanj River, the height of riverbed is uneven and some meshes have significant gaps of elevation. Rapid flow happens at these places. There is no place in Pyanj River where the riverbed continues at uniform elevation.
- In this analysis, the elevations of meshes were set from the DEM with low accuracy made by satellite image and elevations were revised based on the elevation of the surrounding meshes. As shown in the figure of vector of simulation result, there is no place where flow velocity continues uniformly and great magnitude of vector occurs locally. Therefore, the scouring could not continue toward the flow direction and not shaped vertically long in the flow direction.

b) Verification of the Facilities Arrangement of Master Plan

The analysis was conducted through the comparison of vector diagrams of the existing river channel in 2005 and the river channel with the guide dike extension and excavation of two large gravel bars in the upper reach along the dike in Tajikistan. The impact to Afghanistan could be estimated by the holistic variation of vector in the whole area and the submerged area in each land use in reference to the satellite image.

The river channel in 2005 was estimated by the rise of 3 m of the ground level at the location of two large gravel bars in the upstream area found in the satellite image.

The improvement works of the alternatives proposed in the master plan are: (1) the guide dike extension to the gravel bar; and (2) the excavation of two large gravel bars of 400 m in width and the channel bed connecting the upper and lower riverbeds. The channel is designed to flow the discharge of 3,400 m^3/s of average annual maximum flow and to be excavated along the border with Afghanistan. (Refer to Fig. 2.2.14.)

When the annual maximum flood scale flows, a super-elevation flow is generated and the velocity could be faster than the velocity of the design discharge. According to the simulation result, however, the flow velocity of the annual maximum discharge is lower than the velocity of the design discharge (refer to Fig. 2.2.15). Thus, the estimation of impact to Afghanistan was conducted by the situation of design discharge flow only.

The simulation results of the existing river channel in 2005 and the river channel with the guide dike extension and excavation of two large gravel bars in the upper reach are as shown in Fig. 2.2.16 and Fig. 2.2.17 respectively. Considerations taken for the vector diagrams are as summarized below.

i) "A" Area

The velocity of flow along the dike at the place between gravel bar and dike is large in the existing channel and thus considered as super-elevation flow. The velocity could be reduced by the excavation of channel in the gravel bar of upstream side and the extension of the guide dike could lead the discharge to the excavated channel thereby reducing the discharge at the "A" area.

There is the area where velocity is continuously large in the lower side. This rapid flow is caused partially by the steep riverbed slope and the excavation of channel would not settle the cause of rapid flow.

ii) "B" Area

This place is also wedged between dike and gravel bars. The velocity at the place is large and complicated. Excavation of the channel in the second gravel bar could also reduce the velocity.

iii) "C" Area

The drop of riverbed causes the large velocity in this area. Thus, the excavation of channel would not settle the cause of rapid flow.

iv) "D" Area

Improvement works increases the blank area in comparison with the existing channel in this area. The second gravel bar disturbs the flow to the direction of the main stream in the existing channel and it seems that the flow hits the gravel bar and inflows to the Afghanistan area. The main flow could become smooth with the excavation of gravel bar and the inflow to the Afghanistan area would be reduced.

As mentioned above, there are areas where velocity could not be reduced by the excavation of gravel bar. The revetment and foundation of dike in these sections should be strengthened.

Improvement works by the excavation of gravel bars could eliminate super-elevation flow and reduce the velocity along the dike. The combination of excavation of channel and extension of guide dike especially will function well for the upper gravel bar. In addition, the flow direction will lead to the downstream and the inflow to Afghanistan could be reduced.

v) Reduction of flow velocity along dike

The velocity and depth in the following figures are the values at the second mesh from the dike. In the existing channel, the velocity reaches almost 5.0 m/s at the 3.5-km point and there are some points of over 4.0 m/s. These rapid flows are caused by super-elevation flow due to gravel bars. Excavation of channel and guide dike extension could reduce these velocities along the dike. After the improvement works, the velocity is reduced to less than 4.0 m/s in the whole section, and the improvement works also reduced the depth due to the reduction of discharge along the dike.

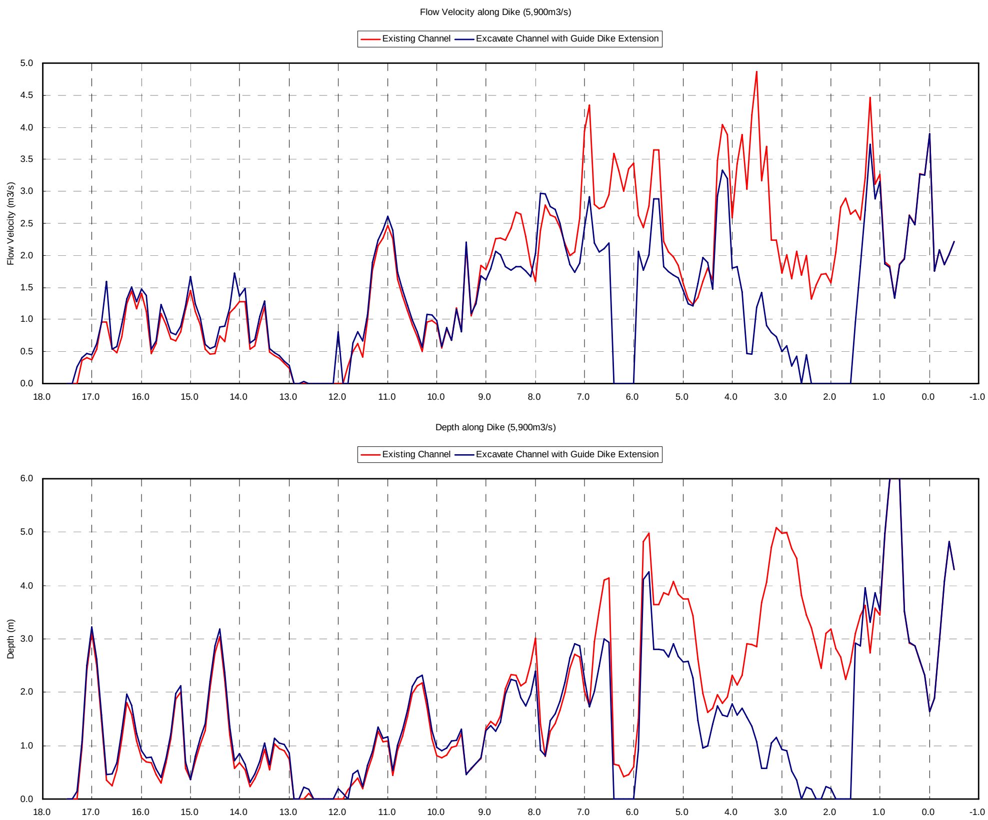


Fig. R 2.2.3 Distribution of Flow Velocity and Depth along Dike

vi) Impact to Afghanistan

The following table gives the variation of numbers of submerged meshes in the Afghanistan area in the cases of existing channel and the river channel with guide dike extension and excavation of two large gravel bars. The impact to Afghanistan was estimated by the variation. The land use in Afghanistan was determined from the satellite image by visual inspection. The land uses distinguished are the cultivated field and the housing area, and other lands are deemed as wasteland (refer to Fig. 2.2.18).

The number of meshes excluded the result of channel with improvement works from the result of the existing channel.

As understood from the result, the improvement works of excavation of channel significantly reduced the submerged area in the left bank in the middle reach but slightly increased the submerged area in the lower right bank in Afghanistan. However, since most of the influenced area consists of wasteland, it is hard to say that the improvement works will have an adverse impact to Afghanistan.

Table R 2.2.6 Impact to Afghanistan Area

(Unit: number of mesh)

Item	Variation of Submerged Area	
	Left Bank of Pyanj River	Right Bank of Lower Pyanj R.
Cultivated Field	-43	21
Housing Area	0	0
Wasteland	-637	28

5) Riverbed Variation Analysis with Moving Bed

The analysis was implemented to verify the sustainable condition of the excavated channel. The calculation area was limited so as to obtain a stable calculation result. The model channel is as shown in Fig. 2.2.19.

Since the objective was to verify the sustainable condition of the excavated channel, the objective discharge adopted was not the design discharge scale but the high frequency flood. The peak of the flood in 2005 was 4,700 m^3/s and the probability was 1/10 to 1/20; hence, the flood in 2005 was adopted as the objective flood because the data in flood season also was complete.

The model could not calculate floods of long duration because the computation time for flood duration of one month takes approximately two weeks even if the calculation area is limited. Therefore, the calculation period should be selected considering the computation time.

According to the uniform flow calculation, the riverbed material of 40 mm will be moved at over 1,600 m^3/s at the channel width of 400 m and the riverbed slope of 1/350. The flow discharge ratios between the whole river channel and the excavated channels at the flow of 5,900 m^3/s will then be 83.5% at the first channel and 49.5% at the second channel. The discharge of the whole river channel that was calculated back from the ratio based on the discharge in the first channel was 2,000 m^3/s and in the second channel was 3,300 m^3/s.

The flow discharges in each channel could be estimated from discharges, as follows:

(unit: m^3/s)

Discharge at Upstream End of Whole River Channel	First Channel with Dug Upper Gravel Bar	Second Channel with Dug Lower Gravel Bar
2,000	1,600	1,000
3,300	2,800	1,600

When the discharge of 2,000 m^3/s at the upstream end is adopted, the discharge in the second channel is 1,000 m^3/s, which could not move the riverbed material. Thus, the discharges of over 3,300 m^3/s were selected from the flood in 2005, together with the peak of flood. The extracted discharge hydrograph is as tabulated below.

(unit: m^3/s)

Date	Discharge	Date	Discharge
June 18	3,374	July 3	3,416
19	3,487	4	3,126
20	3,430	5	2,966
21	3,502	6	2,953
22	3,705	7	2,914
23	3,855	8	3,059
24	4,069	9	3,221
25	4,450	10	3,388
26	4,664	11	3,603
27	4,515	12	3,735
28	4,337	13	3,855
29	4,337	14	3,870
30	4,257	15	3,750
July 1	3,900	16	3,487
2	3,691	17	3,235

The calculation of riverbed variation in a month was conducted and the verification for a sustainable channel was made. The simulation results are shown as the distribution of vectors, ground level changes and differences from the initial height in every five days. (Refer to Fig. 2.2.20 and Fig. 2.2.21 respectively.)

The following could be deduced from the above figures:

- From the distribution of vectors in the upstream, the distribution shaped clumpy at first. The shape changed longer in the flow direction with time. This indicates that scouring proceeded in the direction of flow and the water route is seen as narrow and long.
- The place along the guide dike and the upper side of the first channel has the tendency of scouring continuously from the beginning due to discharge flows along the guide dike. The maximum scouring depth reached 5 m, which was the maximum scouring depth in the analysis. Thus, the scouring scale could be bigger than the result.
- Around the inlet of the first channel and in the channel also, the riverbed has the trend of scouring from the beginning and was significantly scoured at around 2.4 m in average and 5 m in maximum in 30 days. Thus the scouring scale could be bigger than the result.
- In the first 10 days, the discharge was increased. In the second excavated channel, the riverbed tends to be scoured in the first 10 days. After that, the sediment adversely accumulated in the channel in the recession term. The riverbed rise was around 1.6 m in average and 3.2 m in maximum in 30 days. The sediment accumulation was small around the inlet, and was large in the middle area and outlet of the channel.
- The vicinity of outlet of the section wedged between the dike and the second gravel bar indicate the tendency of scouring.
- The area between the first channel and the second channel, and the vicinity of outlet of the second channel had the trend of riverbed rise from the beginning of analysis. These places that went out of narrow channel to wide width could accumulate sediment. The result of analysis also proved the tendency.

Table R 2.2.7 Maximum Difference of Riverbed Variation

	Along Guide Dike	First Channel	Between First and Second Channel	Second Channel	Lower Reach of Second Channel
Differences of Riverbed Variation	-5 m	-5 m	+3.8 m	+3.2 m	+2.8 m

Note: Since "-5m" was the maximum scouring depth in the calculation, the scouring depth could be deeper than the result.

As mentioned above, to sustain the channel, the first channel needs bed protection works and not only the second channel but also the wide channel areas need periodic dredging. Thus, the excavated channel would be unsustainable.

The period of less than 500 m^3/s accounts for more than 80% of the non-flood season. In this discharge scale, the sediment inflow is substantially decreased and sediment will accumulate in the wide and low flow area before inflowing to the excavated channel. Thus, the riverbed variation analysis was not carried out.

6) Verification of Flow Condition in the Vicinity of Metintugay

Metintugay is located in the downstream end of the Hamadoni fan and could not be accurately analyzed in the model. Thus, individual analysis was carried out to grasp the situation of flood intrusion to Metintugay. The objective discharge was 2,400 m^3/s, which is 40% of the 5,900 m^3/s design discharge. The ratio was referred to 36.3% in the section of 13.4km to 15km estimated by flow distribution analysis. The other calculation conditions were the same with the analysis mentioned above. In the model, discharge should be allocated to the meshes at the upstream end as the initial condition. Thus, discharge was also allocated to the meshes at the upstream end of the former river inside the dike and the proportion was 20 m^3/s to the former river and 2,380 m^3/s to the main stream in consideration of the condition of the former river.

The depth distribution of analysis result is shown below. The color differences give the differences in depth, such as light blue is less than 0.5 m, blue is 0.5 m to 1.0 m, yellow is 1.0 m to 2.0 m and red is 2.0 m to maximum (4.4 m).

As can be seen from the figure, the flood did not intrude into the housing area of Metintugay. However, the flood slightly intruded into the cultivation area in the upstream side of the housing area and the depth is less than 0.5 m and less than 1.0 m in spots. The intrusion velocity was around or less than 0.5 m/s and the velocities in the former river channel around Metintugay were around 1.0 m^3/s. Since the velocity and amount of discharge in the former river are low, the risk due to scouring or erosion of the bank around Metintugay could be low because of the existing dike at the upstream end of the former river.

The flood got over the gravel bar located between the former river channel and the existing river channel but the flood did not intrude into the inland significantly. Eventually, the flood flowed to the downstream along the former river channel.

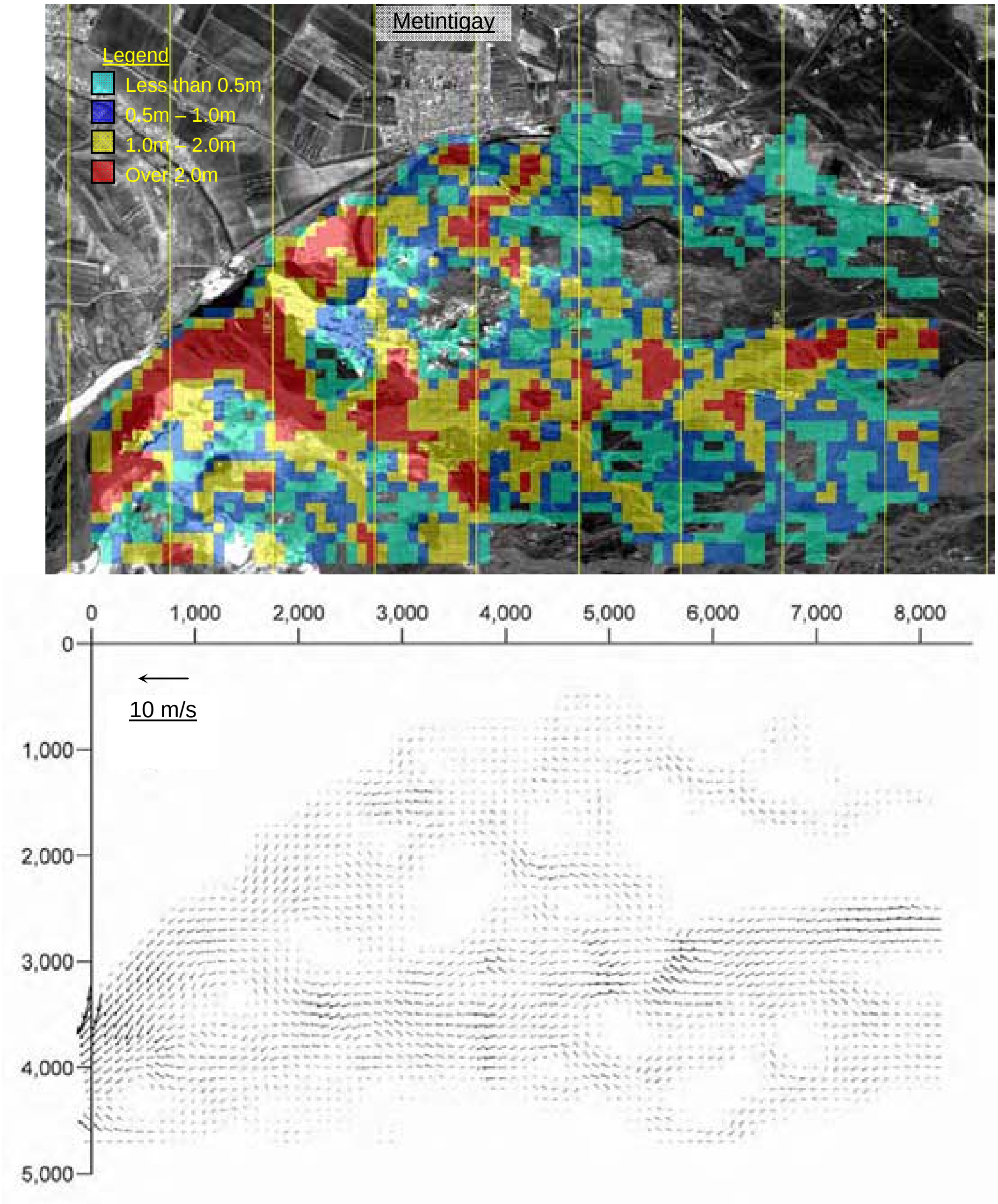


Fig. R 2.2.4 Distribution of Depth and Flow Velocity in the Vicinity of Metintugay

2.2.6 Riverbed Variation Analysis around Spur Dike

1) Analysis Policy

The objective of analysis was to calculate the riverbed variation around the spur dikes using the discharge estimated by two-dimensional flow distribution analysis with fixed bed.

2) Analysis Condition

The Study Team constructed a model channel because the Tajikistan side could not provide a topographic map of 1/2,000 in scale.

a) Computation Area and Model Channel

The model channels were of two types; namely, Type A which has the flow direction of 650 m and transverse direction of 300 m (for large scale flood); and Type B which has the flow direction of 650 m and transverse direction of 390 m (for annual maximum flood).

The channel width was decided from the narrow channel along the dike in the satellite image shot on July 31, 2005. The model channel bed was flat with dike of 1:2 in slope and the riverbed slope was 1/350 (0.286%).

The mesh size was 5 m by 2.5 m and the number of meshes was 15,851 (131 by 121 grids) and 20,567 (131 by 157 grids).

b) Analysis Model

The Two-Dimensional Model was employed instead of the Quasi-Three-Dimensional Model which could not describe the flow of reflection from dike suitably.

c) Average Particle Size and Roughness Coefficient

The value of 40 mm was adopted from the riverbed material survey and the single particle size was utilized for the calculation.

Manning’s roughness coefficient adopted the constant value of 0.035.

d) Calculation Cases

Discharge Cases:

- 4,000 m^3/s in case of large scale flood (Flood in 2005 was 4,700 m^3/s at peak)
- 3,000 m^3/s in case of annual maximum flood (3,400 m^3/s, the case of super-elevation flow due to holm)

The discharges were estimated by the two-dimensional flow distribution analysis with fixed bed along the dike.

Spur Dike Cases:

The calculation for length of spur dike involved 2 cases of 30 m, 10% of channel width and 50 m for comparison.

- For the comparison of interval of spur dike with fixed length of 30 m (4 cases: 3L, 4L, 5L and 6L)
- For the comparison of angle of spur dike with fixed length of 30 m in the direction of the center of river (3 cases: 90˚, 63˚ and 45˚)
- For the comparison of length of spur dike under 2 cases of angles, i.e., 90˚ and 45˚(2 cases: 30 m and 50 m)

3) Analysis Result

In Tables 2.2.3 to 2.2.6 giving a summary of the analysis results, the flow velocities are summarized at the center point of channel and at 5 m, 10 m and 15 m from dike at the middle of the interval of spur dikes. The “plus” direction is the same as the direction of river flow and the “minus” direction means reverse flow. The scouring depth picked out the maximum value around the front edge of spur dike. The flow velocity at the front edge of spur dike is fastest at the point of approximately 10 m distance.

The calculation results vary widely depending on the case. This might be due to the computation time. In this analysis, the time was 9 hours in order to increase efficiency of calculation. If the computation time was longer, the trend of each case might be clearer.

In addition, the computation result of spur dike near the downstream end has a proclivity to indicate unduly due to the fixed water level at the downstream end. The figure of contour of riverbed indicates stripes in transverse direction. This is due to the same reason.

a) The comparison of interval of spur dike with fixed length of 30 m

The contour of riverbed variation and the vector of flows are as shown in Fig. 2.2.22.

- In the case of 3L and 4L, the diffracted flow could not reach up to the dike in both cases of large-scale flood and the super-elevation flow.
- The diffracted flows almost reached up to the dike in the cases of 5L and 6L.
- The scouring depths of 5L and 6L are larger than the 3L and 4L; especially, the second scouring depth is significant.
- In the case of super-elevation flow, the flows in all cases do not hit the dike directly in this analysis.

b) The comparison of angle of spur dike with fixed length of 30 m in the direction of the center of river

The contour of riverbed variation and the vector of flows are as shown in Fig. 2.2.23.

The analysis was conducted in 3 cases: 90˚, 63˚ and 45˚. Basically, since these cases have the same inhibitory length in the transverse direction and the cross sectional area, the scouring depth were nearly equal because the volumes flowing at the front edge of the spur dike are almost the same.

The place of scouring varies depending on the shape of spur dike. In addition, the case of 63˚ had a problem in modeling. As shown in the figure below, the shape of the spur dike may not have been described well in the model. The minimum mesh size depends on the flow velocity and could not be smaller further. The result of calculation could have fallen out of the almost the same results of the case of 90˚.

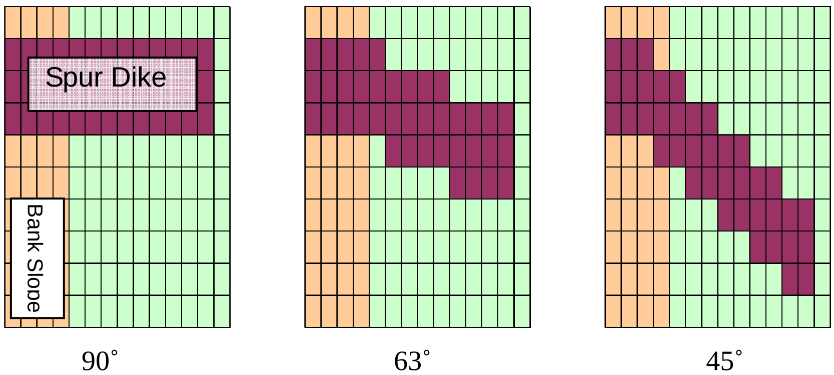


Fig. R 2.2.5 The Model of Spur Dike

According to the summarized table:

- The scouring depths of 63˚ are nearly equal to the results of 90˚. The reason might be due to the problem with modeling.
- The scouring depths of 45˚ are a little shallower than the results of 90˚. Since the cross-sectional area of flow is the same, the result could be due to the angle of spur dike.
- The flow velocities at the front edge of spur dike are nearly equal.
- According to the results for super-elevation flow, since the relation between the place of water colliding front and the place of spur dike are different, the

super-elevation flows could not be simply compared. However, the scouring depths and flow velocities at the front edge of spur dike almost show no differences. The super-elevation flow of all cases did not intrude significantly in the area between spur dikes.

c) The comparison of length of spur dike in cases of 90˚ and 45˚ angles

The contour of riverbed variation and the vector of flows are as shown in Fig. 2.2.24.

In the cases of 30 m in length, the scouring depths show no difference due to the angle. However, in the cases of 50 m in length, the depths show a significant difference.

As compared with the length of the case of 90˚, the scouring depths in the cases of 30 m and of 50 m vary according to the length of spur dike. The results are much the same in the case of super-elevation flows.

In the case of super-elevation flow with 50 m length, the flows intrude significantly in the area between spur dikes in both cases of 90˚ and 45˚.

d) The comparison of discharges of the cases of 4,700 m^3/s and 5,900 m^3/s

The contour of riverbed variation and the vector of flows are as shown in Fig. 2.2.25.

This comparison analysis was conducted to confirm the scouring depth according to the discharge scale. The scouring depth increases as the discharge increases. However, the width of the model channel is fixed and the actual channel will extend accordingly as the discharge increases. Therefore, the result will be utilized for reference and the actual value observed should be utilized for the design.

4) The Angle and the Interval of Spur Dike

The following figure shows the flow velocity at the middle of spur dikes in cases of 30 m in length with an angle of 45˚ and interval of 4L, and 30 m in length with an angle of 90˚ and intervals of 4L, 5L and 6L. This L is the length of spur dike.

As shown in the figure, the velocity distribution of spur dikes angled at 45˚ is close to the distribution of spur dikes angled at 90˚ of 5L and 6L rather than 4L. This reason depends on the estimate of interval using the length of spur dike. If the diagonal spur dike is substantially short in the transverse direction, the interval becomes too large. Since the length of spur dike angled at 45˚ in the transverse direction is 21 m, the actual interval is 5.7L.

To estimate the interval of diagonal spur dike, the estimation should be based on the length in the transverse direction and not on the length of spur dike.

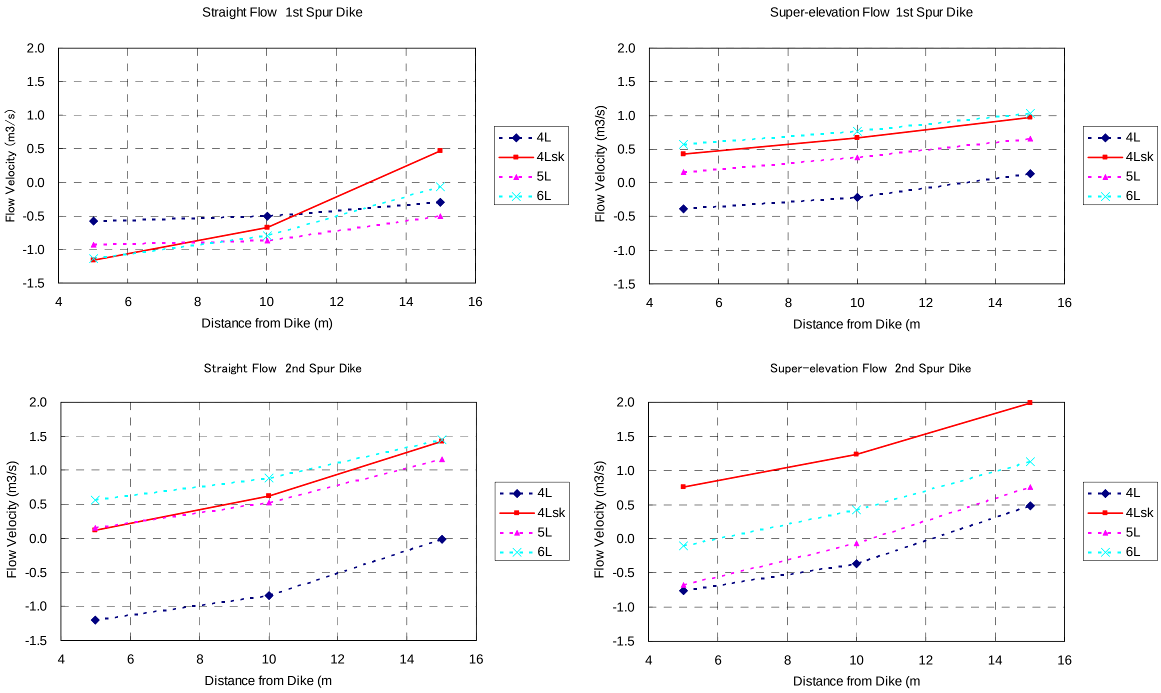


Fig. R 2.2.6 Velocity Distribution

5) Add-Up

The length of spur dike is recommended to be approximately 10% of the channel width and the interval is less than 4L. The L is the length of spur dike in the transverse direction. The diagonal spur dike is preferable to the rectangular spur dike to reduce the scale of scouring. The angle should refer to the effective practical accomplishment.

The place where the super-elevation flow is generated is unforeseeable and the spur dikes after the second also need the same protection at the scale of the first spur dike.

2.3 FLOOD FORECASTING SYSTEM

2.3.1 Present Situation

At present, the Tajikmeteorology conducts the forecasting of snowmelt runoff but the objective is not for flood forecasting but the uses of water resources, and focuses on securing the minimum runoff volume. The following table gives the result of the forecasting in 2006.

Table R 2.3.1 Forecast of Water Volumes of Pyanj River in 2006 (April-September)

River	Point	Expected Range of Values		Average (m^3/s)
		Discharge (m^3/s)	Total Discharge (mln m^3)	
Pyanj	Ishkashim	200 - 300	3,200 - 4,700	210
	Shidz	620 - 920	9,800 - 14,500	745
	Khirmanjo	1,300 - 1,500	20,500 - 24,000	1,360
	Nizhno Panj	1,440 - 1,740	23,000 - 27,000	1,560

Since the peak of flood at Khirmanjo in 2006 was 2,490 m^3/s, the values forecasted above are rather low. However, the forecasting method could be applied to flood forecasting by improving the accuracy.

The forecasting method of Tajikmeteorology is a statistical method. Firstly, the amount of snow cover in the whole basin is estimated by conducting a field survey in the tributary basins of Gunt and Vanj to know the snow depths at some points in the reach of 70 km onwards. The iso snow depth line is defined from the relationship between the elevation and snow depth at the points, and the area of the equivalent snow depth is calculated. The snow depth and the area in other basins are estimated with the correlation between the data of the two basins and the observatory in the objective area. The observation frequency is once a month at the end of the month from January to March. Thus, the amount of snow cover in the whole basin is calculated and the runoff discharge at key points is then estimated using the following formula. Here, the statistical data at the time of forecast is used for each parameter.

(Snow coverage area × Snow depth × Density) × Temperature + Rainfall = Runoff Discharge

The items of statistical data are snow depth, density, precipitation (amount of 10 day, 5 observatories), monthly average temperature and monthly average discharge. The period of the data is more than 30 years. Data had been missing for a while after the independence and observed data were added in recent days.

Another forecasting method being utilized for the Vaksh River at present is the snowmelt runoff model (SRM). The relevance ratio is 90–95% in the Vaksh River. However, the model is not employed for the Pyanj River because the discharge data of the main stream has been missing in recent years.

The snowmelt runoff model project, which is part of this Aral Sea Basin project conducted by the Swiss Aral Sea Mission (SASM), is to set up a forecasting scheme for snowmelt runoff and is expected to be a significant contribution to the forecasting of runoff in Amdarya and Syrdarya.

Using satellite remote sensing data, the snow cover variations can be determined and input – in addition to hydrological and meteorological information – to the Snowmelt Runoff Model (SRM). The necessary ground data are precipitation, temperature (maximum, minimum) and discharge at the downstream end of the objective area, and the outputs are daily discharge and three days discharge. The system became operational in October 1997.

2.3.2 Forecasting Procedure

The runoff model developed in the study is called the characteristic model hereafter in order to distinguish from other models. The characteristic model is difficult to apply for long range forecasting. It is possible for the characteristic model to forecast for the time of the runoff process and flood travel time; however, in the case of Pyanj River where runoff from the lower basin is dominant, short time forecasting is only available.

Consequently, the method being used by Tajikmeteorology could be applied to the long term forecasting by improving its accuracy. The characteristic model is applied to the short time forecasting.

The flow chart of the forecasting using the characteristic model is as shown in the figure below. Parameter calibration is necessary to improve the accuracy with the accumulation of data.

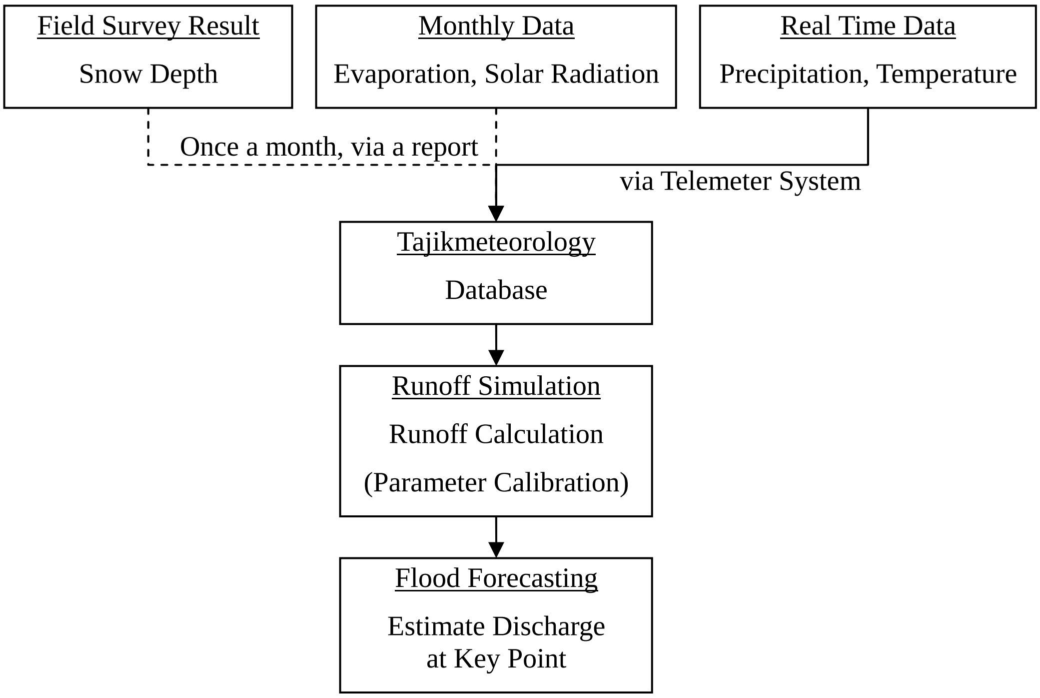


Fig. R 2.3.1 Flow Chart of Flood Forecasting of the Characteristics Model

The procedures of flood forecasting according to the periods are as described below.

1) Long Range Forecasting (Before the Snowmelt Period)

Since the runoff model is not suitable for long range forecasting, the method being used by Tajikmeteorology could be utilized by improving its accuracy.

a) Master Plan Level

- Utilization of the forecasting method of Tajikmeteorology with accuracy improvement by observation network expansion until the adoption of SRM
(10 years program of Tajikmeteorology along with the addition of new observatories and increase of observation points for snow depth)
- Application of SRM to the Pyanj River (Rehabilitation of hydrological observatories along the Pyanj main stream)

b) Interim Measure

- Utilization of the forecasting method of Tajikmeteorology with accuracy improvement by the progressive addition of new observatories.

2) Medium Range Forecasting (2 or 3 weeks ahead of flood)

Basically, the medium range forecasting is the same as the long range forecasting. The improvement of forecast accuracy is expected and the variation of amount of snow cover is grasped because field surveys are done several times in the season and snow depth is observed right before the snowmelt.

a) Master Plan Level

- Utilization of forecasting method of Tajikmeteorology with the accuracy improvement by the observation network expansion until the adoption of SRM (10 years program of Tajikmeteorology along with the addition of new observatories and increase of observation points for snow depth)
- Application of SRM to the Pyanj Rriver (Rehabilitation of hydrological observatories along the Pyanj main stream)

b) Interim Measure

- Utilization of the forecasting method of Tajikmeteorology with accuracy improvement by the progressive addition of new observatories.

3) Short Range Forecasting (Right before Floods; 2 or 3 days before Floods)

In the Master Plan Level, since real time data could be obtained through the telemeter system, forecasting by the characteristic model could be done. In addition, the accuracy improvement is expected due to the increase of hydro-meteorological observatories. The trend of flood scale could be predictable from the discharge observation in the upper basin.

a) Master Plan Level

- The forecasting of the characteristic model with the observation network expansion and telemeter system for real time data acquisition. (The forecast period is the time of runoff process and flood travel.)
- Real-time monitoring of water level using telemeter system. (Ishkashim, Shidz, Khirmanjo and new observatory between Shidz and Khirmanjo)

b) Interim Measure

- Water level monitoring at the existing observatories of Ishkashim, Shidz and Khirmanjo. (It is necessary to rehabilitate the observatories.)

4) Current Situation Report (During Floods)

In the initial stage of flood, water level monitoring is conducted at Khirmanjo and the new observatory between Shidz and Khirmanjo. When the water level exceeds the stand-by water level, water level monitoring is conducted at Chubek and along the dike.

a) Master Plan Level

- Real-time monitoring of water level through the telemeter system at Khirmanjo and the new observatory between Shidz and Khirmanjo.
- Real-time monitoring of water level through the telemeter system at Chubek and along the dike.

b) Interim Measure

- Water level monitoring at Khrimanjo by manual and handy radio communication.
- Water level monitoring at Chubek and along the dike by manual and handy radio communication.

2.3.3 Necessary Facilities for Flood Monitoring and Forecasting

The rehabilitation plan of existing observatories is mentioned in the 10-years program of Tajikmeteorology. The observatories will be improved with automated observation devices and automated communication in the plan. However, there is no mention about the definite method of improvement of equipment. Therefore, the types of water level observation and communication are hereafter recommended considering with the river channel condition and the communication circumstances at the site.

1) Water Level Monitoring

Considering the condition at Chubek key point,

- Pressure Type: There is a risk that the sensor will be buried because sediment will move drastically in the channel.
- Float Type with Observation Well: Maintenance will be difficult because sediment will go into the well. The water level in the well will pulsate due to the rapid current.

In view of the reasons mentioned above, the radio water level sensor, which can observe water level by non-contact, is recommendable.

Fig. R 2.3.2 Radio Water Level Sensor

2) Telemeter System

The objective area is mountainous and the HF radio of CODAN, Australia is used mainly as the existing communication tool.

Considering the condition, the telemeter system using digital HF radio is recommendable.

3) Meteorological Observation Devices

In the case of short period forecasting of snow melt runoff using the characteristic model, it is necessary that meteorological data be obtained on time through the telemeter system. The necessary data are precipitation, temperature, evaporation and solar radiation. Automated devices for these items are expected to be installed in each observatory.

The observation device of precipitation should be equipped with a heater for snowfall measurement.

2.3.4 Setting of Beginning of Snowmelt and Flood Seasons

The beginning of the snowmelt season and the beginning of the flood season are set by superimposing the hydrographs of 32 years at Khirmanjo. The attention of local residents is then drawn on the occurrence of floods.

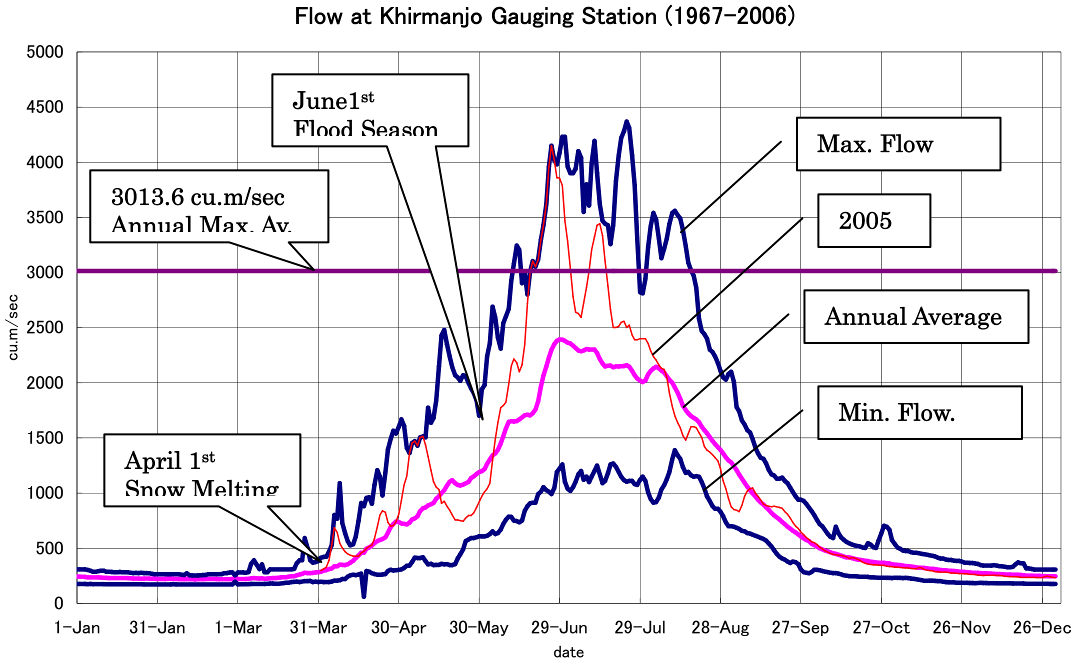


Fig. R 2.3.3 Superimposing of Hydrographs

1) Beginning of Snowmelt Season

Based on the superimposing of hydrographs, the rising of snow-melt runoff starts in April almost without exception. Thus, the beginning of the snow-melt season is set on April 1st and the local residents are informed once the snow-melt has begun.

2) Beginning of Flood Season

There are no cases of floods in May in the past years, and the floods in each year fully rise beyond 2,000 m^3/s after June. Floods that exceeded 2,000 m^3/s occurred twice before June in the past years but both floods did not rise again after they had subsided.

Likewise, the beginning of the flood season is set on June 1st. Local residents are thus informed and their attention is drawn on impending floods.

2.3.5 Setting of Warning Levels

1) Warning Levels in Japan

Since each warning level of medium and small-size rivers and the required actions in Japan are easily understandable, the setting of warning levels in Pyanj River are drawn upon the cases in Japan.

a) Stand-by Water Level

Upon issuance of warning for flood protection (to relevant organizations and bodies only), the flood fighting groups shall stand-by for mobilization.

b) Warning Water Level

Upon issuance of flood advisory, the head of municipality shall issue instructions to prepare for evacuation, remind the local residents about the flood information, and order mobilization of the flood fighting corps.

c) Alert Water Level

Upon issuance of flood warning, the head of municipality shall issue evacuation instructions to the local resident.

d) Critical Water Level

Upon issuance of flood information, the critical water level with risk of inundation and damage to houses and properties at specified locations.

When the floods happen, flood information is issued regardless of the water level, and the beginning of flood is warned.

2) Concept of Each Water Level Setting for Pyanj River

a) Stand-by Water Level

Stand-by water level is set at the water level in which the height of increase during mobilization of the flood fighting corps is subtracted from the warning water level.

The level is set lower in rivers where water level rises quickly and set comparatively higher in large rivers where water level rises slowly.

b) Warning Water Level

Warning water level is set at the water level in which occurrence of some damage is expected. The water level is set referring to HWL, the existing height of crown of dike, the water level of passed floods and the past disaster cases.

In Pyanj River, the occurrence situation of the 2005 flood serves as the reference.

c) Alert Water Level

Alert water level is set at the water level in which the height of increase during the dissemination of information and evacuation of local residents is subtracted from the critical water level.

Since the water level of Pyanj River increases slowly and the rising of water level takes a long time, enough time for the evacuation of local residents could be secured according to the rising time of water level.

d) Critical Water Level

Critical water level is essentially set at HWL and Chubek is assigned as the station for flood forecasting. When the design dike is under completion, the water level is set at the level in which the freeboard is subtracted from the existing height of crown of dike.

The water level at the critical point in Hamadoni dike reach is computed and converted to critical water level at the point of Chubek using non-uniform flow calculation. Since the channel condition will change every year, the relation should be reviewed every year.

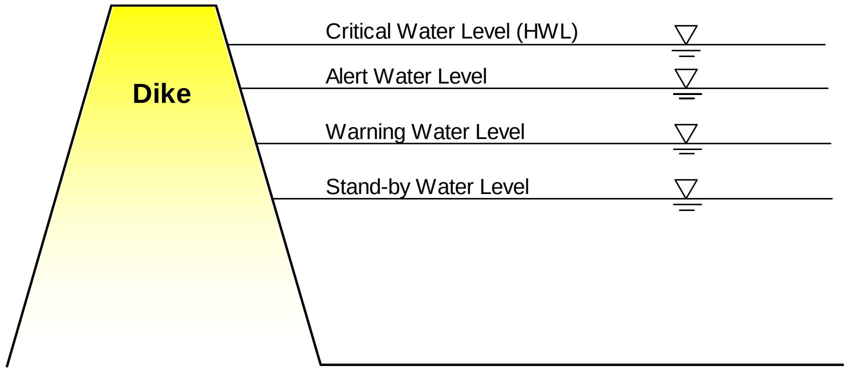


Fig. R 2.3.4 Image of Warning Level Setting

3) Time Required for Discharge Increase and the Evacuation of Local Residents

a) Time Required for Discharge Increase

The speed of flood discharge increase was extracted from the past floods. The times required to reach 4,000m^3/s from the 3,000m^3/s scale in the past large scale floods are summarized in the following table. The discharge is converted to the value of Chubek from Khirmanjo.

Table R 2.3.2 The Time Required for Discharge Increasing of Large Scale Floods

Year		3,000m^3/s scale	4,000m^3/s scale	Days	Increasing amount of Discharge per day
1969	Date	Jul. 1	Jul. 4	3	363.4
	Discharge	3,001.1	4,091.4		
1978	Date	Jun. 23	Jun.27	4	255.7
	Discharge	3,102.2	4,125.1		
1990	Date	Jun. 22	Jun.25	3	322.2
	Discharge	3,079.8	4,046.4		
1994	Date	Jun. 22	Jul. 3	11	94.6
	Discharge	3,059.1	4,099.8		
1998	Date	Jun. 28	Jul. 10	12	67.0
	Discharge	3,248.8	4,053.2		
2005	Date	Jun. 17	Jun. 24	7	144.2
	Discharge	3,059.1	4,068.7		

The speed of discharge increase in 1969 was the fastest at 363.4 m^3/s/day or 15.14 m^3/s/hour.

b) Time Required for Evacuation of Local Residents

The evacuation distance for residents of Hamadoni is approximately 10 km in maximum in consideration of residents living in the center of the area. Assuming that the migration velocity is 4 km/hr, the time for evacuation would be approximately 3 hours. On the other hand, the dissemination of information from the observers at the dike through Hukumat and the administrative level of each stage to local residents might take approximately 1 hour. Hence, the total time of dissemination of information and the termination of evacuation would be approximately 4 to 5 hours.

In addition, the time needed for stand-by and mobilization of the flood fighting corps could be 2 hours.

4) Issues of the Setting of Warning levels for Pyanj River

The water level rising speed of Pyanj River is slow due to the snow melt runoff. However, the super-elevation flow occurs due to the gravel bars in the channel in the Hamadoni fan and the dike in the fan has risks of erosion and dike breaks even if the water level is comparatively low. Actually, a dike break happened at 3,700 m3/s on 22 June before the peak discharge of 4,700 m^3/s on 26 June in the 2005 flood event.

Therefore, the warning system in consideration of the dike condition should be established.

- The case of warning system in consideration of bank erosion in Japan

  In Kinu-gawa (Kinu River) in Japan, bank erosion is significant and the flood channel has been washed out to about 100 m in width although the water level was low.

  Since there is concern of erosion of the flood channel even if the water level is still low, the warning water level to be set for that damaged portion was studied.

  Not all the damage happens at the proven water level and the damage could happen at the lower water level. However, the setting of a lower level will prolong the alert status and it is undesirable.

5) Setting of Warning Levels for Pyanj River

There are four (4) warning levels set for the Pyanj River referring to the case of Japan. In the stage of stand-by water level, the warning is informed to the relevant organizations and bodies but not to the local residents.

a) Critical Water Level

It is set at HWL or the water level of 5,900 m^3/s flow (433.25 MSL). When the design dike is under completion, the water level is set at the level in which the freeboard is subtracted from the existing height of crown of dike.

The water level at the critical point in Hamadoni dike reach is computed and converted to become the critical water level at the point of Chubek using non-uniform flow calculation.

b) Alert Water Level

It is set at the water level in which the height of increase during 5 hours of distributing information and evacuation of local residents in Hamadoni is subtracted from the critical water level. The resulting alert water level is the water level of 5,824 m^3/s flow (433.23 MSL).

c) Warning Water Level

Considering the 2005 flood event when the dike break happened at the flow of 3,700 m^3/s (432.72 MSL), the warning water level is set to the water level of 3,400 m^3/s of average annual maximum discharge (432.62 MSL).

d) Stand-by Water Level

It is set at the water level in which the height of increase during 2 hours of mobilization of the flood fighting groups is subtracted from the warning water level. The resulting stand-by water level is the water level of 3,369 m^3/s flow (432.61 MSL).

In addition, if the dike begins to erode, the warning level should at once shift from the lower levels to critical level and the evacuation of residents should start immediately.

REFERENCES

1. Applied Hydrology, Ven Te Chow, David R. Maidment, Larry W. Mays, 1988
2. Dry Land Hydrology, Hydro-Meteo Publication, 1976
3. The scientifically-applied directory about the climate of the USSR, 1988
4. Mike 11, A Modelling System for Rivers and Channels, User Guide, DHI

Tables

Table 2.1.1 Meteorological Data Availability

Precipitation

	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82
Shaimak	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Bulunkul	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Djanshavgoz	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Ishkashim	△	△	△	△	△	△	O	△	O	O	△	△	△	△	△	O	O	O	O	O	O	O	O
Murghab	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Irkht	O	O	O	O	O	O	△	O	△	O	O	O	O	△	O	O	O	△	△	O	O	△	△
Savnob	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kara-kul	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Khorog	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Navabad	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	O	O	O
Rushan	△	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Khumragi	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Darvoz	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Parkhar	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Khovaling	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Muminobod	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Kulyab	O	△	△	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Moskovsky	x	△	△	O	△	△	△	△	△	O	△	△	△	△	O	△	△	△	△	△	△	O	O

	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
Shaimak	O	O	O	O	O	O	O	O	O	O	x	△	x	x	x	x	O	O	O	O	O	O	O
Bulunkul	O	O	O	O	O	O	O	O	O	O	△	△	x	x	x	x	O	O	O	O	O	O	O
Djanshavgoz	O	O	O	O	O	O	O	O	O	O	O	O	△	x	x	x	x	O	x	O	O	O	O
Ishkashim	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O	O	O	O	O	O
Murghab	O	O	O	O	O	O	O	O	△	△	△	△	x	x	x	△	O	O	O	O	O	O	O
Irkht	△	△	△	O	O	△	O	O	O	O	O	△	△	△	△	O	O	O	O	O	O	O	△
Savnob	x	x	x	O	O	O	O	O	O	O	△	O	△	△	O	O	O	O	O	O	O	O	△
Kara-kul	O	O	O	O	O	O	O	O	O	O	O	△	x	x	x	x	x	x	x	x	x	△	O
Khorog	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O	O	O	O	x	x	x
Navabad	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Rushan	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O	O	O	O	O	O	O
Khumragi	O	O	O	O	O	O	O	O	O	O	O	O	x	△	x	x	x	△	O	O	O	O	O
Darvoz	O	O	O	O	O	O	O	O	O	O	O	O	△	x	△	O	O	O	O	O	O	O	O
Parkhar	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Khovaling	x	x	x	x	x	O	O	O	O	O	O	O	O	△	O	O	O	O	O	O	O	O	x
Muminobod	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Kulyab	O	O	O	O	O	O	O	O	O	△	x	x	x	x	x	x	x	x	x	x	x	x	x
Moskovsky	△	△	△	△	△	△	O	△	△	△	△	△	△	x	x	x	x	x	x	x	x	x	x

Temperature

	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82
Shaimak	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O
Bulunkul	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Djanshavgoz	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Ishkashim	O	O	O	O	O	△	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Murghab	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O	O	O
Irkht	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O	△	O
Savnob	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kara-kul	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O
Khorog	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Navabad	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	O	O	O
Rushan	△	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Khumragi	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Darvoz	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Parkhar	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Khovaling	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Muminobod	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	△
Kulyab	O	△	△	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Moskovsky	x	△	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
Shaimak	O	O	O	O	O	O	O	O	O	O	x	△	x	x	x	x	△	△	△	O	O	△	O
Bulunkul	O	O	O	O	O	O	O	O	O	O	△	△	x	x	x	x	O	△	O	O	O	O	O
Djanshavgoz	O	O	O	O	O	O	O	O	O	O	O	O	△	x	x	x	x	△	x	△	O	O	O
Ishkashim	O	O	O	O	O	O	O	O	O	O	O	O	O	O	△	O	△	O	O	O	O	O	O
Murghab	O	O	O	O	O	O	O	O	O	△	△	△	x	x	x	△	O	O	O	O	O	O	O
Irkht	O	O	O	O	O	O	O	O	O	O	O	△	△	△	△	O	O	O	△	△	△	O	△
Savnob	x	x	x	O	O	O	O	O	O	O	△	O	△	△	O	O	O	O	O	O	O	O	△
Kara-kul	O	O	O	O	O	O	O	O	O	O	O	△	x	x	x	x	x	x	x	x	x	△	O
Khorog	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Navabad	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Rushan	O	O	O	O	O	O	O	O	O	O	O	O	O	△	△	O	O	O	O	O	O	O	O
Khumragi	O	O	O	O	O	O	O	O	O	O	O	O	x	△	x	x	x	△	O	O	O	O	△
Darvoz	O	O	O	O	O	O	O	O	O	O	O	O	△	x	△	O	O	O	O	O	O	O	O
Parkhar	O	O	O	O	O	O	O	O	O	O	O	△	O	O	O	O	O	O	O	O	O	O	△
Khovaling	x	x	x	x	x	O	O	O	O	O	O	O	O	△	O	△	O	O	O	O	O	O	x
Muminobod	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Kulyab	O	O	O	O	O	O	O	O	O	△	x	x	x	x	x	x	x	x	x	x	x	x	x
Moskovsky	O	O	O	O	O	△	O	O	△	△	O	O	△	x	x	x	x	x	x	x	x	x	x

O: Completed data　　△: Partialy missing values　　x: Totally missing Values　　−: Not Collected or no observation

Table 2.1.2 Hydrological Data Availability

Discharge

	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
Ishkashim	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	x	x	x	x	x	x	x	x	x	x	x	x
Shidz	x	x	x	x	x	x	x	○	△	x	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Khirmanjo	x	x	x	x	x	x	x	○	x	△	○	○	△	x	x	x	x	○	○	○	△	○	○	○	○	○	○	△	△	x	△	△	△	x	x	x	x	x	x	x	x	x	x	x	x	x
N.Pyanj	x	x	x	x	x	○	○	○	x	x	△	○	△	x	x	x	△	△	○	○	○	○	○	○	△	○	○	○	△	△	○	○	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Obihumbow-Ustye	○	x	x	x	○	○	○	○	○	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Khurk-Obiskharvi	x	x	x	△	○	○	○	○	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Bichkharv-Vanj	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	△	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Motravn-Yazgulyam	○	○	○	○	○	○	○	○	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Rushan-Vomardara	○	○	○	○	○	○	○	○	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Shuchand-Bartang	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	○	○	○	x	x
Khorog –Guht	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	△	○	○	○	○	○	○	○
Khobost-Shakhdara	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Garmchashma	x	x	x	x	x	x	x	x	x	x	x	x	x	x	○	○	○	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Langar -Kishtidjarob	x	x	x	x	x	x	x	x	x	x	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Murghob-Bartang	△	△	△	△	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	x	x	x	x	x	x	x	x	x	x	x	x	x
Barchidiv-Bartang	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Nisur -Bartang.	x	x	x	x	x	x	x	x	x	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	x	x	x	x	x	x	x	x	x	x	x
Yashilkul	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Sarez-1	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

Water Level

	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
Ishkashim	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	x	x	x	x	x	○	x	△	x	○	○
Shidz	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○	○	○	○	○	○	○	○	x
Khirmanjo	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	△	△	△	△	△	△	△	○	○	△	x	△
N.Pyanj	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	x	x	x	x	x	x	x	x	x	x	x	x
Obihumbow-Ustye	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○	○	○	○	○	○	○	○	○
Khurk-Obiskharvi	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○	○	○	○	○	○	○	○	○
Bichkharv-Vanj	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	△	○	○	○	○	○	○	○	○
Motravn-Yazgulyam	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	△	○	○	○	○	○	○	○	x	○	○
Rushan-Vomardara	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○	△	○	○	○	○	○	○	x
Shuchand-Bartang	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	○	○	○	○	○	x	x	x	○	x
Khorog –Guht	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	x	○	○	○	○	○	○	○	○	○	○
Khobost-Shakhdara	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	○	△	△	○	○	○	○	○	x	○	○
Garmchashma	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	△	x	x	x	x	○	△	△	△	○	○
Langar -Kishtidjarob	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	x	x	x	x	x	○	○	△	○	x	○
Murghob-Bartang	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	x	x	x	x	x	x	x	x	x	x	x	x
Barchidiv-Bartang	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	○	△	x	△	○	x	○	○	○	○	x	○
Nisur -Bartang.	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	x	△	x	△	○	x	○	○	○	○	x	○
Yashilkul	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Sarez-1	−	−	−	−	−	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

○: Completed data   △: Partialy missing values   x: Totally missing Values   −: Not Collected or no observation

Table 2.1.3 Specific Discharge

	Peak Discharge (m^3/s)						Specific Discharge ($m^3/s/km^2$)		
	Ishkashim		Shidz		Khirmanjo		Ishkashim	Shidz	Khirmanjo
	Date	Peak Q	Date	Peak Q	Date	Peak Q			
1967			7/24	1,790	7/25	2,670		0.029	0.034
1969					7/24	4,370			0.056
1970			6/30	1,770	7/1	2,780		0.029	0.036
1971			7/30	1,990	7/30	2,710		0.032	0.035
1972			6/26	1,220	6/27	2,560		0.020	0.033
1977	6/25	558	6/25	1,890	6/26	3,160	0.039	0.031	0.041
1978	7/1	788	7/1	2,640	7/1	4,230	0.055	0.043	0.055
1979	7/12	643	7/12	2,410	7/12	3,140	0.045	0.039	0.040
1980	6/25	410	6/25	1,570	6/25	2,460	0.029	0.026	0.032
1981	7/17	664	7/17	1,930	7/16	2,630	0.046	0.031	0.034
1982	8/4	674	8/6	1,660	8/5	2,670	0.047	0.027	0.034
1983	8/3	704	8/3	2,310	8/3	3,540	0.049	0.038	0.046
1984	6/29	726	6/28	2,040	6/28	3,170	0.051	0.033	0.041
1985	7/13	550	7/13	1,840	7/13	2,960	0.038	0.030	0.038
1986	7/7	702	7/7	2,350	7/7	3,350	0.049	0.038	0.043
1987	7/8	370	7/6	1,670	7/6	3,200	0.026	0.027	0.041
1988	6/28	584	6/29	2,560	6/28	3,490	0.041	0.042	0.045
1990	6/25	608	6/25	2,070	6/25	3,600	0.042	0.034	0.046
1991	7/12	479	7/12	1,030	7/11	2,510	0.033	0.017	0.032
1994					7/5	3,901			0.050
1995					7/22	2,793			0.036
1996					6/13	3,244			0.042
1997					7/21	2,301			0.030
1998					7/12	4,194			0.054
1999					7/19	2,628			0.034
2000					7/14	1,728			0.022
2001					6/16	1,949			0.025
2002					6/16	2,989			0.039
2003					6/28	2,989			0.039
2005	8/13	985			6/26	4,149	0.069		0.053
2006					7/11	2,490			0.032
Average		630		1,930		3,050	0.044	0.031	0.039

Hatching shows that the dates of peak discharge get behind the date of Khirmanjo station.

Table 2.1.4 Catchment Area of Sub Basins

(Unit: Square km)

No.	Catchment Area	note
1	2,167	
2	2,030	
3	1,187	
4	622	
5	2,435	Yazugulom River
6	2,050	Vanj River
7	1,562	
8	2,001	
9	1,312	
10	2,343	Afghanistan
11	5,087	Afghanistan
12	2,691	Afghanistan
13	1,278	Afghanistan
14	739	Afghanistan
15	4,428	Afghanistan
16	1,615	Afghanistan
17	1,959	Afghanistan
18	3,003	Afghanistan
19	624	Afghanistan
20	4,228	Shakhdara River
21	5,235	Alichur River, Yashilku Lake
22	4,000	
23	3,207	
24	3,047	
25	3,561	Bartang River
26	1,542	
27	4,701	
28	7,669	Aksu River
29	3,901	Murgab River
30	2,309	Sarez Lake
Total	82,534	

Table 2.1.5 Catchment Area in Each Altitude Zone

Basin 1

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,500 - 5,225	5,363	22.60
2	5,225 - 4,950	5,088	165.76
3	4,950 - 4,676	4,813	427.97
4	4,676 - 4,401	4,538	534.97
5	4,401 - 4,126	4,263	534.97
6	4,126 - 3,851	3,989	311.94
7	3,851 - 3,576	3,714	93.43
8	3,576 - 3,302	3,439	45.21
9	3,302 - 3,027	3,164	15.07
10	3,027 - 2,752	2,889	15.07
			2167.00

Basin 2

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,812 - 5,480	5,646	40.39
2	5,480 - 5,149	5,314	220.43
3	5,149 - 4,817	4,983	378.53
4	4,817 - 4,485	4,651	334.68
5	4,485 - 4,154	4,319	302.36
6	4,154 - 3,822	3,988	221.58
7	3,822 - 3,490	3,656	180.03
8	3,490 - 3,158	3,324	122.33
9	3,158 - 2,827	2,993	105.02
10	2,827 - 2,495	2,661	124.64
			2030.00

Basin 3

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,393 - 5,063	5,228	15.62
2	5,063 - 4,734	4,898	38.45
3	4,734 - 4,404	4,569	112.93
4	4,404 - 4,074	4,239	167.00
5	4,074 - 3,745	3,909	193.43
6	3,745 - 3,415	3,580	199.44
7	3,415 - 3,085	3,250	173.00
8	3,085 - 2,755	2,920	124.95
9	2,755 - 2,426	2,591	104.52
10	2,426 - 2,096	2,261	57.67
			1187.00

Basin 4

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,898 - 4,602	4,750	36.83
2	4,602 - 4,305	4,454	94.12
3	4,305 - 4,009	4,157	95.14
4	4,009 - 3,713	3,861	93.10
5	3,713 - 3,417	3,565	74.68
6	3,417 - 3,120	3,268	61.38
7	3,120 - 2,824	2,972	49.11
8	2,824 - 2,528	2,676	43.99
9	2,528 - 2,231	2,379	32.74
10	2,231 - 1,935	2,083	40.92
			622.00

Basin 5

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,239 - 4,871	5,055	15.40
2	4,871 - 4,503	4,687	161.65
3	4,503 - 4,134	4,319	440.04
4	4,134 - 3,766	3,950	450.31
5	3,766 - 3,398	3,582	391.29
6	3,398 - 3,030	3,214	324.58
7	3,030 - 2,662	2,846	242.47
8	2,662 - 2,293	2,478	195.01
9	2,293 - 1,925	2,109	147.54
10	1,925 - 1,557	1,741	66.71
			2435.00

Basin 6

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,330 - 4,947	5,139	13.52
2	4,947 - 4,564	4,756	104.78
3	4,564 - 4,181	4,373	300.82
4	4,181 - 3,798	3,990	339.69
5	3,798 - 3,415	3,607	297.44
6	3,415 - 3,032	3,224	265.33
7	3,032 - 2,649	2,841	231.53
8	2,649 - 2,266	2,458	190.97
9	2,266 - 1,883	2,075	201.11
10	1,883 - 1,500	1,692	104.78
			2050.00

Basin 7

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,714 - 4,366	4,540	31.44
2	4,366 - 4,018	4,192	76.11
3	4,018 - 3,670	3,844	102.59
4	3,670 - 3,322	3,496	277.98
5	3,322 - 2,974	3,148	324.31
6	2,974 - 2,625	2,799	233.31
7	2,625 - 2,277	2,451	180.36
8	2,277 - 1,929	2,103	122.44
9	1,929 - 1,581	1,755	124.10
10	1,581 - 1,233	1,407	89.35
			1562.00

Basin 8

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,219 - 3,875	4,047	30.02
2	3,875 - 3,531	3,703	124.06
3	3,531 - 3,188	3,360	249.12
4	3,188 - 2,844	3,016	288.14
5	2,844 - 2,500	2,672	322.16
6	2,500 - 2,156	2,328	318.16
7	2,156 - 1,812	1,984	244.12
8	1,812 - 1,469	1,641	194.10
9	1,469 - 1,125	1,297	146.07
10	1,125 - 781	953	85.04
			2001.00

Basin 9

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	2,691 - 2,471	2,581	33.56
2	2,471 - 2,252	2,361	66.07
3	2,252 - 2,032	2,142	112.22
4	2,032 - 1,812	1,922	153.12
5	1,812 - 1,593	1,702	148.92
6	1,593 - 1,373	1,483	162.56
7	1,373 - 1,153	1,263	218.14
8	1,153 - 933	1,043	201.36
9	933 - 714	824	137.39
10	714 - 494	604	78.66
			1312.00

Basin 10

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,906 - 5,592	5,749	13.60
2	5,592 - 5,278	5,435	108.83
3	5,278 - 4,964	5,121	347.42
4	4,964 - 4,650	4,807	461.48
5	4,650 - 4,337	4,493	477.18
6	4,337 - 4,023	4,180	602.75
7	4,023 - 3,709	3,866	256.38
8	3,709 - 3,395	3,552	53.37
9	3,395 - 3,081	3,238	16.74
10	3,081 - 2,767	2,924	5.23
			2343.00

Basin 11

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,780 - 5,478	5,629	85.16
2	5,478 - 5,176	5,327	356.31
3	5,176 - 4,873	5,025	914.32
4	4,873 - 4,571	4,722	1205.64
5	4,571 - 4,269	4,420	811.23
6	4,269 - 3,967	4,118	472.84
7	3,967 - 3,665	3,816	466.12
8	3,665 - 3,362	3,514	333.90
9	3,362 - 3,060	3,211	340.63
10	3,060 - 2,758	2,909	100.84
			5087.00

Basin 12

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	7,043 - 6,585	6,814	10.57
2	6,585 - 6,127	6,356	21.14
3	6,127 - 5,669	5,898	67.37
4	5,669 - 5,211	5,440	243.08
5	5,211 - 4,753	4,982	537.67
6	4,753 - 4,294	4,523	578.62
7	4,294 - 3,836	4,065	435.95
8	3,836 - 3,378	3,607	326.30
9	3,378 - 2,920	3,149	217.97
10	2,920 - 2,462	2,691	252.32
			2691.00

Basin 13

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,963 - 4,670	4,817	32.15
2	4,670 - 4,377	4,524	102.48
3	4,377 - 4,085	4,231	200.94
4	4,085 - 3,792	3,938	219.03
5	3,792 - 3,499	3,645	190.90
6	3,499 - 3,206	3,353	162.76
7	3,206 - 2,913	3,060	135.64
8	2,913 - 2,621	2,767	107.50
9	2,621 - 2,328	2,474	94.44
10	2,328 - 2,035	2,181	32.15
			1278.00

Basin 14

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,819 - 4,531	4,675	24.03
2	4,531 - 4,243	4,387	112.15
3	4,243 - 3,956	4,100	138.19
4	3,956 - 3,668	3,812	111.15
5	3,668 - 3,380	3,524	90.12
6	3,380 - 3,092	3,236	73.10
7	3,092 - 2,804	2,948	52.07
8	2,804 - 2,517	2,661	46.06
9	2,517 - 2,229	2,373	40.05
10	2,229 - 1,941	2,085	52.07
			739.00

Basin 15

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,778 - 4,450	4,614	74.37
2	4,450 - 4,122	4,286	281.98
3	4,122 - 3,795	3,959	491.66
4	3,795 - 3,467	3,631	650.72
5	3,467 - 3,139	3,303	934.77
6	3,139 - 2,811	2,975	967.82
7	2,811 - 2,483	2,647	648.66
8	2,483 - 2,156	2,320	227.24
9	2,156 - 1,828	1,992	118.78
10	1,828 - 1,500	1,664	32.02
			4428.00

Basin 16

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,750 - 4,397	4,574	50.97
2	4,397 - 4,044	4,221	235.85
3	4,044 - 3,692	3,868	310.81
4	3,692 - 3,339	3,515	228.86
5	3,339 - 2,986	3,162	229.86
6	2,986 - 2,633	2,810	192.88
7	2,633 - 2,280	2,457	134.92
8	2,280 - 1,928	2,104	100.94
9	1,928 - 1,575	1,751	87.95
10	1,575 - 1,222	1,398	41.97
			1615.00

Basin 17

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,610 - 4,228	4,419	60.84
2	4,228 - 3,845	4,037	307.22
3	3,845 - 3,463	3,654	409.95
4	3,463 - 3,081	3,272	353.10
5	3,081 - 2,699	2,890	255.35
6	2,699 - 2,316	2,507	179.54
7	2,316 - 1,934	2,125	145.63
8	1,934 - 1,552	1,743	109.72
9	1,552 - 1,169	1,360	90.77
10	1,169 - 787	978	46.88
			1959.00

Basin 18

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	4,416 - 4,035	4,225	30.12
2	4,035 - 3,653	3,844	59.24
3	3,653 - 3,272	3,463	311.24
4	3,272 - 2,891	3,081	755.02
5	2,891 - 2,510	2,700	823.29
6	2,510 - 2,128	2,319	405.62
7	2,128 - 1,747	1,938	202.81
8	1,747 - 1,366	1,556	191.77
9	1,366 - 984	1,175	144.58
10	984 - 603	794	79.32
			3003.00

Basin 19

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	2,528 - 2,323	2,426	6.99
2	2,323 - 2,119	2,221	21.96
3	2,119 - 1,914	2,016	80.87
4	1,914 - 1,709	1,812	64.90
5	1,709 - 1,505	1,607	63.90
6	1,505 - 1,300	1,402	54.91
7	1,300 - 1,095	1,197	70.89
8	1,095 - 890	993	117.81
9	890 - 686	788	86.86
10	686 - 481	583	54.91
			624.00

Basin 20

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,843 - 5,464	5,654	8.90
2	5,464 - 5,085	5,275	65.25
3	5,085 - 4,706	4,896	351.47
4	4,706 - 4,327	4,517	990.64
5	4,327 - 3,949	4,138	1152.28
6	3,949 - 3,570	3,759	880.90
7	3,570 - 3,191	3,380	470.11
8	3,191 - 2,812	3,001	213.55
9	2,812 - 2,433	2,622	65.25
10	2,433 - 2,054	2,243	29.66
			4228.00

Basin 21

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,393 - 5,219	5,306	27.36
2	5,219 - 5,046	5,133	130.60
3	5,046 - 4,872	4,959	272.38
4	4,872 - 4,699	4,785	490.04
5	4,699 - 4,525	4,612	619.39
6	4,525 - 4,351	4,438	723.87
7	4,351 - 4,178	4,265	896.75
8	4,178 - 4,004	4,091	881.83
9	4,004 - 3,831	3,917	833.32
10	3,831 - 3,657	3,744	359.45
			5235.00

Basin 22

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,389 - 5,056	5,223	99.82
2	5,056 - 4,724	4,890	413.55
3	4,724 - 4,391	4,558	905.53
4	4,391 - 4,059	4,225	869.88
5	4,059 - 3,726	3,892	356.51
6	3,726 - 3,393	3,560	263.81
7	3,393 - 3,061	3,227	335.12
8	3,061 - 2,728	2,895	285.20
9	2,728 - 2,396	2,562	270.94
10	2,396 - 2,063	2,229	199.64
			4000.00

Basin 23

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	6,019 - 5,768	5,893	5.57
2	5,768 - 5,517	5,642	34.56
3	5,517 - 5,266	5,391	140.45
4	5,266 - 5,015	5,140	235.20
5	5,015 - 4,764	4,889	395.72
6	4,764 - 4,512	4,638	520.57
7	4,512 - 4,261	4,387	694.46
8	4,261 - 4,010	4,136	613.09
9	4,010 - 3,759	3,885	366.74
10	3,759 - 3,508	3,634	200.65
			3207.00

Basin 24 (estimated based on basin 23)

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	6,019 - 5,768	5,893	5.30
2	5,768 - 5,517	5,642	32.83
3	5,517 - 5,266	5,391	133.45
4	5,266 - 5,015	5,140	223.47
5	5,015 - 4,764	4,889	375.98
6	4,764 - 4,512	4,638	494.59
7	4,512 - 4,261	4,387	659.81
8	4,261 - 4,010	4,136	582.50
9	4,010 - 3,759	3,885	348.44
10	3,759 - 3,508	3,634	190.64
			3047.00

Basin 25

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,513 - 5,156	5,334	19.92
2	5,156 - 4,798	4,977	91.61
3	4,798 - 4,441	4,620	501.89
4	4,441 - 4,084	4,262	649.27
5	4,084 - 3,727	3,905	533.75
6	3,727 - 3,369	3,548	470.02
7	3,369 - 3,012	3,191	398.32
8	3,012 - 2,655	2,833	322.64
9	2,655 - 2,297	2,476	314.67
10	2,297 - 1,940	2,119	258.91
			3561.00

Basin 26

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,599 - 5,427	5,513	22.60
2	5,427 - 5,255	5,341	66.06
3	5,255 - 5,083	5,169	104.31
4	5,083 - 4,911	4,997	161.68
5	4,911 - 4,740	4,825	163.41
6	4,740 - 4,568	4,654	156.46
7	4,568 - 4,396	4,482	128.64
8	4,396 - 4,224	4,310	111.26
9	4,224 - 4,052	4,138	172.11
10	4,052 - 3,880	3,966	455.47
			1542.00

Basin 27

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,275 - 5,123	5,199	30.26
2	5,123 - 4,970	5,046	70.07
3	4,970 - 4,818	4,894	135.36
4	4,818 - 4,665	4,742	307.35
5	4,665 - 4,513	4,589	500.04
6	4,513 - 4,361	4,437	735.73
7	4,361 - 4,208	4,284	973.01
8	4,208 - 4,056	4,132	1073.33
9	4,056 - 3,903	3,980	484.11
10	3,903 - 3,751	3,827	391.75
			4701.00

Basin 28

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,549 - 5,354	5,451	11.15
2	5,354 - 5,159	5,256	52.05
3	5,159 - 4,964	5,061	167.31
4	4,964 - 4,769	4,866	449.88
5	4,769 - 4,574	4,671	777.06
6	4,574 - 4,378	4,476	1204.63
7	4,378 - 4,183	4,281	1442.59
8	4,183 - 3,988	4,086	1431.43
9	3,988 - 3,793	3,891	1138.95
10	3,793 - 3,598	3,696	993.95
			7669.00

Basin 29

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,775 - 5,522	5,649	23.13
2	5,522 - 5,269	5,396	153.41
3	5,269 - 5,017	5,143	427.36
4	5,017 - 4,764	4,890	683.04
5	4,764 - 4,511	4,637	742.70
6	4,511 - 4,258	4,385	686.69
7	4,258 - 4,005	4,132	540.59
8	4,005 - 3,753	3,879	368.91
9	3,753 - 3,500	3,626	237.42
10	3,500 - 3,247	3,373	37.74
			3901.00

Basin 30

	Range of Height (m)	Middle Height (m)	Basin Area (km^2)
1	5,498 - 5,270	5,384	51.79
2	5,270 - 5,042	5,156	187.74
3	5,042 - 4,814	4,928	349.59
4	4,814 - 4,586	4,700	507.12
5	4,586 - 4,358	4,472	429.43
6	4,358 - 4,129	4,243	284.85
7	4,129 - 3,901	4,015	164.00
8	3,901 - 3,673	3,787	140.27
9	3,673 - 3,445	3,559	79.84
10	3,445 - 3,217	3,331	114.37
			2309.00

Table 2.2.1 Annual Flood Peak Series

(Unit: m^3/s)

	Khirmanjo	Chubek
1967/7/25	2,670	3,001
1968	-	-
1969/7/24	4,370	4,912
1970/7/1	2,780	3,125
1971/7/30	2,710	3,046
1972/6/27	2,560	2,877
1973	-	-
1974	-	-
1975	-	-
1976	-	-
1977/6/26	3,160	3,552
1978/7/1	4,230	4,755
1979/7/12	3,140	3,529
1980/6/25	2,460	2,765
1981/7/16	2,630	2,956
1982/8/6	2,670	3,001
1983/8/3	3,540	3,979
1984/6/28	3,170	3,563
1985/7/13	2,960	3,327
1986/7/7	3,350	3,765
1987/7/6	3,200	3,597
1988/6/28	3,490	3,923
1989	-	-
1990/6/25	3,600	4,046
1991/7/11	2,510	2,821
1992/5/15	1,880	2,113
1993	-	-
1994/7/5	3,901	4,385
1995/7/22	2,793	3,140
1996/6/13	3,244	3,647
1997/7/21	2,301	2,587
1998/7/12	4,194	4,714
1999/7/19	2,628	2,953
2000/7/14	1,728	1,942
2001/6/16	1,949	2,190
2002/6/16	2,989	3,360
2003/6/28	2,989	3,360
2004	-	-
2005/6/26	4,149	4,664
2006/7/11	2,490	2,799
Average	3,014	3,387

*: Peak Discharges after 1994 arecalculated by using estimated rating curve.
Discharges of Chubek are estimated by peak discharge ratio.

Table 2.2.2 (1) Results of Riverbed Material Survey

No.1

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	817.0	33.0	150	4945.35
100	50～100	345.2	13.9	75	1044.75
50	10～50	714.9	28.8	30	865.47
10	4.75～10	466.0	18.8	7.375	138.69
4.75	2.36～4.75	12.1	0.5	3.555	1.74
2.36	1.4～2.36	1.0	0.0	1.88	0.08
1.4	0.6～1.4	1.9	0.1	1	0.08
0.6	0.3～0.6	4.0	0.2	0.45	0.07
0.3	0.075～0.3	21.1	0.9	0.188	0.16
0.075	0.001～0.075	94.8	3.8	0.038	0.15
				d_m	69.96

No2

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	202.4	17.9	150	2685.75
100	50～100	36.8	3.3	75	244.13
50	10～50	538.2	47.6	30	1428.33
10	4.75～10	220.0	19.5	7.375	143.53
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	0.0	0.0	1.88	0.00
1.4	0.6～1.4	0.8	0.1	1	0.07
0.6	0.3～0.6	7.7	0.7	0.45	0.31
0.3	0.075～0.3	75.6	6.7	0.188	1.26
0.075	0.001～0.075	49.0	4.3	0.038	0.17
				d_m	45.04

No3

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	221.0	6.3	150	945.15
100	50～100	296.0	8.4	75	632.93
50	10～50	1556.0	44.4	30	1330.89
10	4.75～10	26.3	0.8	7.375	5.53
4.75	2.36～4.75	50.2	1.4	3.555	5.08
2.36	1.4～2.36	182.0	5.2	1.88	9.75
1.4	0.6～1.4	554.9	15.8	1	15.82
0.6	0.3～0.6	406.1	11.6	0.45	5.21
0.3	0.075～0.3	207.8	5.9	0.188	1.11
0.075	0.001～0.075	7.1	0.2	0.038	0.01
				d_m	29.52

No4

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	1554.0	49.5	150	7425.90
100	50～100	309.2	9.9	75	738.75
50	10～50	664.8	21.2	30	635.37
10	4.75～10	466.0	14.8	7.375	109.48
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	5.2	0.2	1.88	0.31
1.4	0.6～1.4	15.2	0.5	1	0.49
0.6	0.3～0.6	35.6	1.1	0.45	0.51
0.3	0.075～0.3	54.5	1.7	0.188	0.33
0.075	0.001～0.075	34.4	1.1	0.038	0.04
				d_m	89.11

No5

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	149.2	7.9	150	1178.40
100	50～100	755.0	39.8	75	2981.55
50	10～50	524.0	27.6	30	827.73
10	4.75～10	310.0	16.3	7.375	120.38
4.75	2.36～4.75	1.4	0.1	3.555	0.26
2.36	1.4～2.36	3.9	0.2	1.88	0.39
1.4	0.6～1.4	10.9	0.6	1	0.57
0.6	0.3～0.6	26.0	1.4	0.45	0.62
0.3	0.075～0.3	87.4	4.6	0.188	0.87
0.075	0.001～0.075	31.4	1.7	0.038	0.06
				d_m	51.11

No6

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	290.8	17.3	150	2596.20
100	50～100	720.6	42.9	75	3216.75
50	10～50	322.0	19.2	30	574.98
10	4.75～10	232.1	13.8	7.375	101.89
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	0.0	0.0	1.88	0.00
1.4	0.6～1.4	0.1	0.0	1	0.00
0.6	0.3～0.6	0.6	0.0	0.45	0.02
0.3	0.075～0.3	9.5	0.6	0.188	0.11
0.075	0.001～0.075	104.4	6.2	0.038	0.24
				d_m	64.90

No7

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	589.9	29.5	150	4430.70
100	50～100	323.2	16.2	75	1213.73
50	10～50	728.0	36.5	30	1093.59
10	4.75～10	115.0	5.8	7.375	42.47
4.75	2.36～4.75	3.1	0.2	3.555	0.55
2.36	1.4～2.36	12.4	0.6	1.88	1.17
1.4	0.6～1.4	25.9	1.3	1	1.30
0.6	0.3～0.6	39.0	2.0	0.45	0.88
0.3	0.075～0.3	64.7	3.2	0.188	0.61
0.075	0.001～0.075	95.9	4.8	0.038	0.18
				d_m	67.85

No8

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	102.6	8.0	150	1207.20
100	50～100	256.8	20.1	75	1510.73
50	10～50	369.6	29.0	30	869.73
10	4.75～10	292.6	23.0	7.375	169.26
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	1.3	0.1	1.88	0.19
1.4	0.6～1.4	5.6	0.4	1	0.44
0.6	0.3～0.6	12.7	1.0	0.45	0.45
0.3	0.075～0.3	85.5	6.7	0.188	1.26
0.075	0.001～0.075	148.3	11.6	0.038	0.44
				d_m	37.60

No.9

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	0.0	0.0	150	0.00
100	50～100	157.4	21.5	75	1614.00
50	10～50	73.2	10.0	30	300.24
10	4.75～10	246.8	33.7	7.375	248.86
4.75	2.36～4.75	7.9	1.1	3.555	3.85
2.36	1.4～2.36	4.2	0.6	1.88	1.07
1.4	0.6～1.4	12.1	1.7	1	1.66
0.6	0.3～0.6	55.8	7.6	0.45	3.44
0.3	0.075～0.3	108.2	14.8	0.188	2.78
0.075	0.001～0.075	65.7	9.0	0.038	0.34
				d_m	21.76

No10

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	0.0	0.0	150	0.00
100	50～100	251.0	17.7	75	1326.90
50	10～50	720.6	50.8	30	1523.79
10	4.75～10	235.6	16.6	7.375	122.48
4.75	2.36～4.75	5.7	0.4	3.555	1.43
2.36	1.4～2.36	3.7	0.3	1.88	0.49
1.4	0.6～1.4	6.9	0.5	1	0.49
0.6	0.3～0.6	23.0	1.6	0.45	0.73
0.3	0.075～0.3	92.1	6.5	0.188	1.22
0.075	0.001～0.075	80.1	5.6	0.038	0.22
				d_m	29.78

No.11

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	124.4	8.8	150	1325.70
100	50～100	226.2	16.1	75	1205.33
50	10～50	699.2	49.7	30	1490.31
10	4.75～10	182.0	12.9	7.375	95.37
4.75	2.36～4.75	7.8	0.6	3.555	1.97
2.36	1.4～2.36	2.8	0.2	1.88	0.37
1.4	0.6～1.4	12.7	0.9	1	0.90
0.6	0.3～0.6	34.2	2.4	0.45	1.10
0.3	0.075～0.3	75.8	5.4	0.188	1.01
0.075	0.001～0.075	42.4	3.0	0.038	0.12
				d_m	41.22

No.12

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	0.0	0.0	150	0.00
100	50～100	222.4	16.0	75	1198.88
50	10～50	538.8	38.7	30	1161.78
10	4.75～10	384.0	27.6	7.375	203.55
4.75	2.36～4.75	0.7	0.1	3.555	0.18
2.36	1.4～2.36	2.9	0.2	1.88	0.40
1.4	0.6～1.4	6.9	0.5	1	0.50
0.6	0.3～0.6	30.4	2.2	0.45	0.99
0.3	0.075～0.3	133.0	9.6	0.188	1.80
0.075	0.001～0.075	72.1	5.2	0.038	0.20
				d_m	25.68

Table 2.2.2 (2) Results of Riverbed Material Survey

No.13

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	42.1	3.0	150	453.90
100	50～100	76.4	5.5	75	411.83
50	10～50	16.6	1.2	30	35.79
10	4.75～10	561.6	40.4	7.375	297.69
4.75	2.36～4.75	8.3	0.6	3.555	2.11
2.36	1.4～2.36	3.7	0.3	1.88	0.50
1.4	0.6～1.4	34.3	2.5	1	2.46
0.6	0.3～0.6	127.4	9.2	0.45	4.12
0.3	0.075～0.3	146.8	10.6	0.188	1.98
0.075	0.001～0.075	94.7	6.8	0.038	0.26
				d_m	15.15

No.14

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	202.4	14.5	150	2182.20
100	50～100	36.8	2.6	75	198.38
50	10～50	538.2	38.7	30	1160.49
10	4.75～10	220.0	15.8	7.375	116.62
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	0.0	0.0	1.88	0.00
1.4	0.6～1.4	0.0	0.0	1	0.00
0.6	0.3～0.6	2.9	0.2	0.45	0.09
0.3	0.075～0.3	44.1	3.2	0.188	0.60
0.075	0.001～0.075	96.0	6.9	0.038	0.26
				d_m	44.64

No.15

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	0.0	0.0	150	0.00
100	50～100	50.0	3.6	75	269.55
50	10～50	214.0	15.4	30	461.43
10	4.75～10	320.0	23.0	7.375	169.63
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	0.0	0.0	1.88	0.00
1.4	0.6～1.4	2.8	0.2	1	0.20
0.6	0.3～0.6	5.2	0.4	0.45	0.17
0.3	0.075～0.3	88.3	6.3	0.188	1.19
0.075	0.001～0.075	519.1	37.3	0.038	1.42
				d_m	10.48

No.16

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	0.0	0.0	150	0.00
100	50～100	206.6	14.8	75	1113.68
50	10～50	580.2	41.7	30	1251.06
10	4.75～10	0.0	0.0	7.375	0.00
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	1.9	0.1	1.88	0.25
1.4	0.6～1.4	14.8	1.1	1	1.07
0.6	0.3～0.6	46.5	3.3	0.45	1.50
0.3	0.075～0.3	161.3	11.6	0.188	2.18
0.075	0.001～0.075	102.8	7.4	0.038	0.28
				d_m	29.60

No.17

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	0.0	0.0	150	0.00
100	50～100	49.8	3.6	75	268.43
50	10～50	510.2	36.7	30	1100.13
10	4.75～10	98.4	7.1	7.375	52.16
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	8.9	0.6	1.88	1.20
1.4	0.6～1.4	24.9	1.8	1	1.79
0.6	0.3～0.6	71.4	5.1	0.45	2.31
0.3	0.075～0.3	205.2	14.7	0.188	2.77
0.075	0.001～0.075	149.7	10.8	0.038	0.41
				d_m	17.78

No.18

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	434.8	31.3	150	4687.65
100	50～100	563.8	40.5	75	3039.23
50	10～50	66.0	4.7	30	142.32
10	4.75～10	0.0	0.0	7.375	0.00
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	0.0	0.0	1.88	0.00
1.4	0.6～1.4	0.1	0.0	1	0.01
0.6	0.3～0.6	0.7	0.1	0.45	0.02
0.3	0.075～0.3	13.5	1.0	0.188	0.18
0.075	0.001～0.075	149.1	10.7	0.038	0.41
				d_m	89.16

No.19

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	182.6	13.1	150	1968.60
100	50～100	181.3	13.0	75	977.33
50	10～50	463.4	33.3	30	999.21
10	4.75～10	572.0	41.1	7.375	303.21
4.75	2.36～4.75	0.0	0.0	3.555	0.00
2.36	1.4～2.36	4.1	0.3	1.88	0.55
1.4	0.6～1.4	22.5	1.6	1	1.62
0.6	0.3～0.6	31.9	2.3	0.45	1.03
0.3	0.075～0.3	34.2	2.5	0.188	0.46
0.075	0.001～0.075	64.8	4.7	0.038	0.18
				d_m	38.00

No.20

Sieve Opening (mm)	①Size range a～b(mm)	②Passage Weight (g)	③F(di) (%)	④ di (mm)	④×⑤ F(di)×di
	200～∞				
200	100～200	235.1	16.9	150	2534.70
100	50～100	189.6	13.6	75	1022.10
50	10～50	508.8	36.6	30	1097.10
10	4.75～10	453.1	32.6	7.375	240.18
4.75	2.36～4.75	3.1	0.2	3.555	0.78
2.36	1.4～2.36	5.4	0.4	1.88	0.74
1.4	0.6～1.4	31.6	2.3	1	2.27
0.6	0.3～0.6	36.9	2.7	0.45	1.20
0.3	0.075～0.3	28.0	2.0	0.188	0.38
0.075	0.001～0.075	47.2	3.4	0.038	0.13
				d_m	44.30

Table 2.2.3 Comparison of the Interval of Spur Dike

Unit: flow velocity (m/s), depth (m)

<table>
<tr><th></th><th></th><th colspan="6">3L</th><th colspan="6">4L</th><th colspan="6">5L</th><th colspan="6">6L</th></tr>
<tr><td rowspan="9">Large Scale
2005 flood
(4,700 m^3/s)</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">3.77</td><td colspan="3">3.81</td><td colspan="3">3.77</td><td colspan="3">3.83</td><td colspan="3">3.79</td><td colspan="3">3.76</td><td colspan="3">3.78</td><td colspan="3">3.77</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.71</td><td colspan="3">-0.79</td><td colspan="3">-0.58</td><td colspan="3">-1.20</td><td colspan="3">-0.93</td><td colspan="3">0.16</td><td colspan="3">-1.14</td><td colspan="3">0.56</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.62</td><td colspan="3">-0.60</td><td colspan="3">-0.50</td><td colspan="3">-0.84</td><td colspan="3">-0.87</td><td colspan="3">0.53</td><td colspan="3">-0.80</td><td colspan="3">0.88</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">-0.37</td><td colspan="3">-0.25</td><td colspan="3">-0.30</td><td colspan="3">-0.01</td><td colspan="3">-0.50</td><td colspan="3">1.16</td><td colspan="3">-0.06</td><td colspan="3">1.45</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-4.96</td><td colspan="2">-2.57</td><td colspan="2">-4.38</td><td colspan="2">-4.79</td><td colspan="2">-3.06</td><td colspan="2">-5.57</td><td colspan="2">-5.27</td><td colspan="2">-5.21</td><td colspan="2">-6.89</td><td colspan="2">-5.55</td><td colspan="2">-5.15</td><td colspan="2">-6.60</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">4.36</td><td colspan="2">3.05</td><td colspan="2">3.40</td><td colspan="2">4.33</td><td colspan="2">3.24</td><td colspan="2">3.60</td><td colspan="2">4.38</td><td colspan="2">3.52</td><td colspan="2">3.86</td><td colspan="2">4.40</td><td colspan="2">3.53</td><td colspan="2">3.77</td></tr>
<tr><td rowspan="9">Annual Max Scale
(3,400 m^3/s)
Superelevational
Flow</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">4.02</td><td colspan="3">4.44</td><td colspan="3">4.14</td><td colspan="3">4.61</td><td colspan="3">4.33</td><td colspan="3">4.71</td><td colspan="3">4.33</td><td colspan="3">4.67</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.41</td><td colspan="3">-0.87</td><td colspan="3">-0.38</td><td colspan="3">-0.76</td><td colspan="3">0.16</td><td colspan="3">-0.67</td><td colspan="3">0.57</td><td colspan="3">-0.10</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.44</td><td colspan="3">-0.73</td><td colspan="3">-0.22</td><td colspan="3">-0.36</td><td colspan="3">0.38</td><td colspan="3">-0.07</td><td colspan="3">0.76</td><td colspan="3">0.42</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">-0.15</td><td colspan="3">-0.17</td><td colspan="3">0.14</td><td colspan="3">0.48</td><td colspan="3">0.66</td><td colspan="3">0.76</td><td colspan="3">1.03</td><td colspan="3">1.13</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">0.00</td><td colspan="2">-3.55</td><td colspan="2">-5.58</td><td colspan="2">0.00</td><td colspan="2">-4.66</td><td colspan="2">-6.45</td><td colspan="2">0.00</td><td colspan="2">-4.04</td><td colspan="2">-9.92</td><td colspan="2">0.17</td><td colspan="2">-5.91</td><td colspan="2">-9.42</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">0.37</td><td colspan="2">2.35</td><td colspan="2">3.52</td><td colspan="2">0.52</td><td colspan="2">3.00</td><td colspan="2">3.99</td><td colspan="2">0.31</td><td colspan="2">2.96</td><td colspan="2">4.53</td><td colspan="2">0.38</td><td colspan="2">3.24</td><td colspan="2">4.72</td></tr>
</table>

Note: The lengths of spur dike are the length of themselves. V: Flow Velocity, S.D: Spur Dike

Table 2.2.4 Comparison of the Angle of Spur Dike

Unit: flow velocity (m/s), depth (m)

<table>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="18">Angle</td></tr>
<tr><td colspan="6">90˚</td><td colspan="6">63˚</td><td colspan="6">45˚</td></tr>
<tr><td rowspan="11">Large Scale
2005 flood (4,700 m^3/s)</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">3.77</td><td colspan="3">3.83</td><td colspan="3">3.78</td><td colspan="3">3.83</td><td colspan="3">3.79</td><td colspan="3">3.87</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.58</td><td colspan="3">-1.20</td><td colspan="3">-0.48</td><td colspan="3">-0.74</td><td colspan="3">-0.67</td><td colspan="3">-0.63</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.50</td><td colspan="3">-0.84</td><td colspan="3">-0.44</td><td colspan="3">-0.42</td><td colspan="3">-0.67</td><td colspan="3">-0.18</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">-0.30</td><td colspan="3">-0.01</td><td colspan="3">-0.27</td><td colspan="3">0.33</td><td colspan="3">-0.49</td><td colspan="3">0.53</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-4.79</td><td colspan="2">-3.06</td><td colspan="2">-5.57</td><td colspan="2">-5.03</td><td colspan="2">-3.40</td><td colspan="2">-5.40</td><td colspan="2">-3.60</td><td colspan="2">-3.38</td><td colspan="2">-5.21</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">4.33</td><td colspan="2">3.24</td><td colspan="2">3.60</td><td colspan="2">4.37</td><td colspan="2">3.28</td><td colspan="2">3.60</td><td colspan="2">4.14</td><td colspan="2">3.30</td><td colspan="2">3.70</td></tr>
<tr><td rowspan="8">Annual Max Scale
(3,400 m^3/s)
Superelevational Flow</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">4.14</td><td colspan="3">4.61</td><td colspan="3">4.06</td><td colspan="3">4.57</td><td colspan="3">4.65</td><td colspan="3">4.35</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.38</td><td colspan="3">-0.76</td><td colspan="3">0.17</td><td colspan="3">-0.28</td><td colspan="3">0.27</td><td colspan="3">-0.41</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.22</td><td colspan="3">-0.36</td><td colspan="3">0.38</td><td colspan="3">0.21</td><td colspan="3">0.49</td><td colspan="3">0.13</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">0.14</td><td colspan="3">0.48</td><td colspan="3">0.69</td><td colspan="3">0.89</td><td colspan="3">0.80</td><td colspan="3">0.84</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-0.01</td><td colspan="2">-4.66</td><td colspan="2">-6.45</td><td colspan="2">-0.17</td><td colspan="2">-5.14</td><td colspan="2">-6.40</td><td colspan="2">-0.62</td><td colspan="2">-4.92</td><td colspan="2">-6.16</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">0.25</td><td colspan="2">2.70</td><td colspan="2">3.95</td><td colspan="2">0.84</td><td colspan="2">3.13</td><td colspan="2">4.01</td><td colspan="2">1.05</td><td colspan="2">3.11</td><td colspan="2">4.04</td></tr>
</table>

V: Flow Velocity, S.D: Spur Dike

NOTE:

Where, the length of spur dike is 30 m in the direction of the center of river.

Therefore, the lengths of spur dikes themselves are as follows.

90˚: 30.0 m

63˚: 33.7 m

45˚: 42.4 m

The angle is from the embankment line.

Table 2.2.5 Comparison of the Length of Spur Dike (Interval: 4L)

Unit: flow velocity (m/s), depth (m)

<table>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="12">Length: 30 m</td><td colspan="12">Length: 50 m</td></tr>
<tr><td colspan="6">90˚</td><td colspan="6">45˚</td><td colspan="6">90˚</td><td colspan="6">45˚</td></tr>
<tr><td rowspan="8">Large Scale
2005 flood
(4,700 m³/s)</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">3.77</td><td colspan="3">3.83</td><td colspan="3">3.75</td><td colspan="3">3.78</td><td colspan="3">3.89</td><td colspan="3">3.94</td><td colspan="3">3.79</td><td colspan="3">3.81</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.58</td><td colspan="3">-1.20</td><td colspan="3">-1.16</td><td colspan="3">0.12</td><td colspan="3">-0.69</td><td colspan="3">-0.84</td><td colspan="3">-1.18</td><td colspan="3">0.33</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.50</td><td colspan="3">-0.84</td><td colspan="3">-0.67</td><td colspan="3">0.62</td><td colspan="3">-0.76</td><td colspan="3">-0.55</td><td colspan="3">-0.93</td><td colspan="3">0.64</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">-0.30</td><td colspan="3">-0.01</td><td colspan="3">0.47</td><td colspan="3">1.43</td><td colspan="3">-0.67</td><td colspan="3">-0.06</td><td colspan="3">-0.37</td><td colspan="3">1.17</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-4.79</td><td colspan="2">-3.06</td><td colspan="2">-5.57</td><td colspan="2">-4.80</td><td colspan="2">-2.79</td><td colspan="2">-5.27</td><td colspan="2">-7.96</td><td colspan="2">-7.87</td><td colspan="2">-7.76</td><td colspan="2">-3.44</td><td colspan="2">-6.22</td><td colspan="2">-6.11</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">4.33</td><td colspan="2">3.24</td><td colspan="2">3.60</td><td colspan="2">3.84</td><td colspan="2">3.27</td><td colspan="2">3.14</td><td colspan="2">4.49</td><td colspan="2">3.69</td><td colspan="2">3.86</td><td colspan="2">3.52</td><td colspan="2">3.42</td><td colspan="2">3.14</td></tr>
<tr><td rowspan="8">Annual Max Scale
(3,400 m³/s)
Superelevational
Flow</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">4.14</td><td colspan="3">4.61</td><td colspan="3">4.26</td><td colspan="3">4.56</td><td colspan="3">4.22</td><td colspan="3">4.98</td><td colspan="3">4.35</td><td colspan="3">4.52</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.38</td><td colspan="3">-0.76</td><td colspan="3">0.43</td><td colspan="3">0.76</td><td colspan="3">0.73</td><td colspan="3">-1.32</td><td colspan="3">0.24</td><td colspan="3">1.13</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.22</td><td colspan="3">-0.36</td><td colspan="3">0.67</td><td colspan="3">1.24</td><td colspan="3">0.93</td><td colspan="3">-1.16</td><td colspan="3">0.38</td><td colspan="3">1.47</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">0.14</td><td colspan="3">0.48</td><td colspan="3">0.97</td><td colspan="3">1.99</td><td colspan="3">1.21</td><td colspan="3">-0.92</td><td colspan="3">0.62</td><td colspan="3">1.98</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-0.01</td><td colspan="2">-4.66</td><td colspan="2">-6.45</td><td colspan="2">-0.24</td><td colspan="2">-5.34</td><td colspan="2">-4.75</td><td colspan="2">-6.78</td><td colspan="2">-9.74</td><td colspan="2">-8.28</td><td colspan="2">-0.04</td><td colspan="2">-6.89</td><td colspan="2">-7.32</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">0.52</td><td colspan="2">3.00</td><td colspan="2">3.99</td><td colspan="2">0.34</td><td colspan="2">2.70</td><td colspan="2">3.59</td><td colspan="2">2.00</td><td colspan="2">4.44</td><td colspan="2">4.46</td><td colspan="2">0.65</td><td colspan="2">3.28</td><td colspan="2">4.35</td></tr>
</table>

Note: The lengths of spur dike are the length of themselves. V: Flow Velocity, S.D: Spur Dike

Table 2.2.6 Comparison of the Scale of Flow Discharge

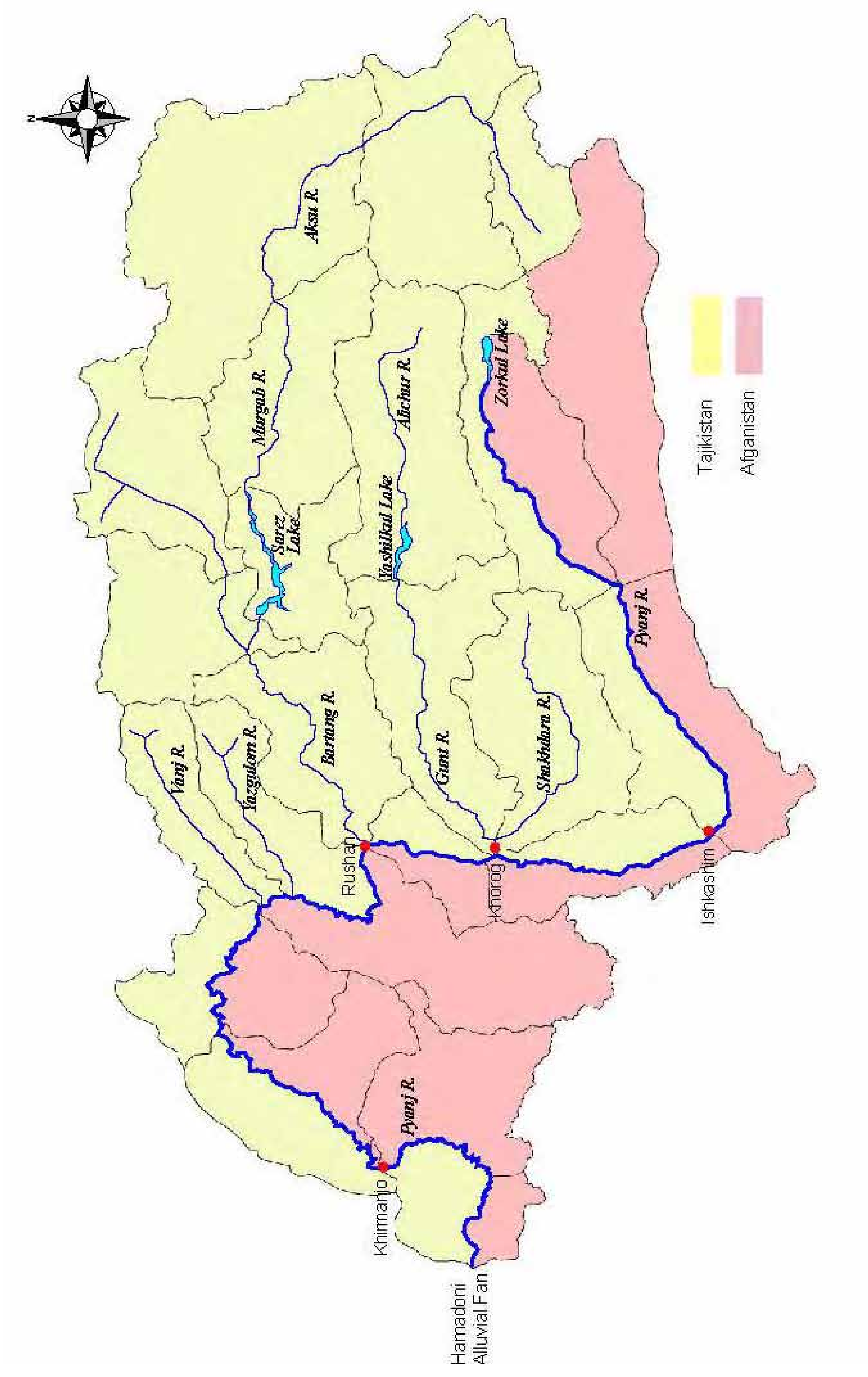
(Large scale channel with the perpendicular spur dike with length of 30 m and 4L Interval)

Unit: flow velocity (m/s), depth (m)

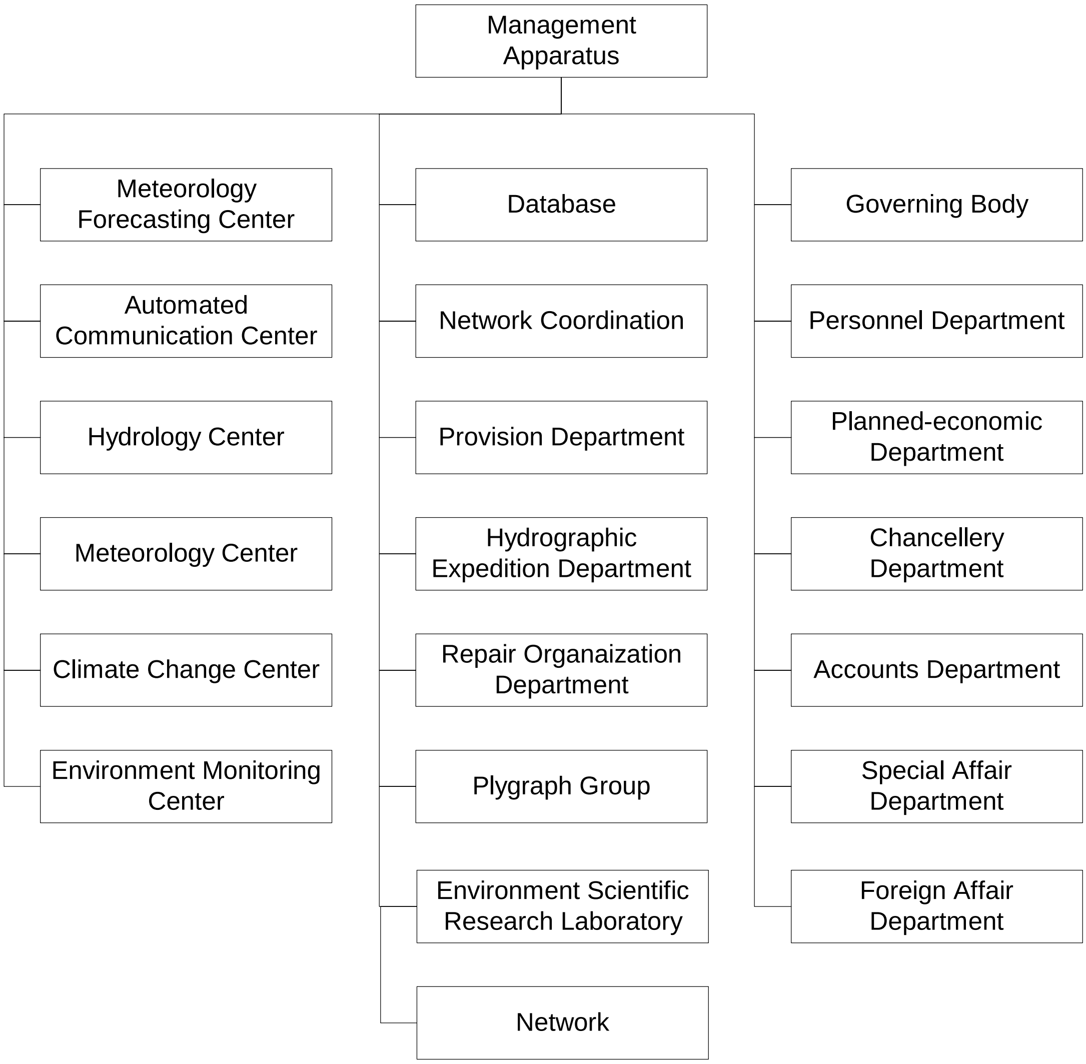
<table>
<tr><td rowspan="9">2005 Flood 4,700 m^3/s</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">3.77</td><td colspan="3">3.83</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.58</td><td colspan="3">-1.20</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.50</td><td colspan="3">-0.84</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">-0.30</td><td colspan="3">-0.01</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-4.79</td><td colspan="2">-3.06</td><td colspan="2">-5.57</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">4.33</td><td colspan="2">3.24</td><td colspan="2">3.60</td></tr>
<tr><td rowspan="9">Design Discharge (1/100)
5,900 m^3/s</td><td rowspan="2">V at the center of channel</td><td colspan="3">No.1–No.2</td><td colspan="3">No.2–No.3</td></tr>
<tr><td colspan="3">4.13</td><td colspan="3">4.19</td></tr>
<tr><td>V at 5m from dike</td><td colspan="3">-0.73</td><td colspan="3">-1.12</td></tr>
<tr><td>V at 10m from dike</td><td colspan="3">-0.56</td><td colspan="3">-0.63</td></tr>
<tr><td>V at 15m from dike</td><td colspan="3">-0.33</td><td colspan="3">0.26</td></tr>
<tr><td rowspan="2">Scouring depth around front edge of S.D</td><td colspan="2">1st</td><td colspan="2">2nd</td><td colspan="2">3rd</td></tr>
<tr><td colspan="2">-6.14</td><td colspan="2">-2.65</td><td colspan="2">-7.99</td></tr>
<tr><td>V at the front edge of S.D</td><td colspan="2">4.48</td><td colspan="2">3.37</td><td colspan="2">3.72</td></tr>
</table>

V: Flow Velocity, S.D: Spur Dike

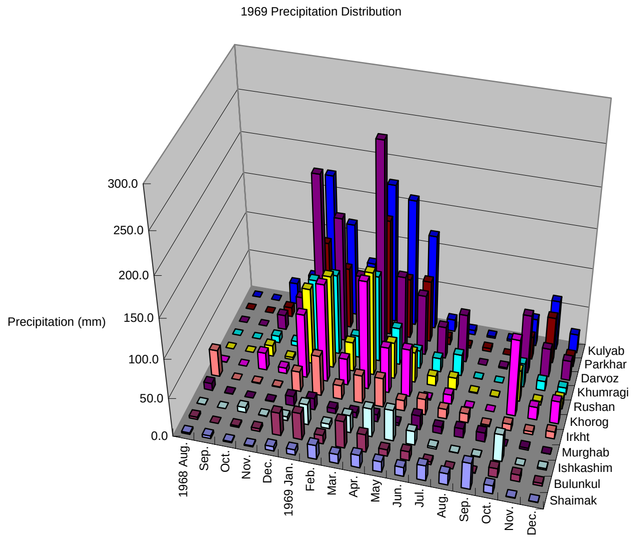
Figures

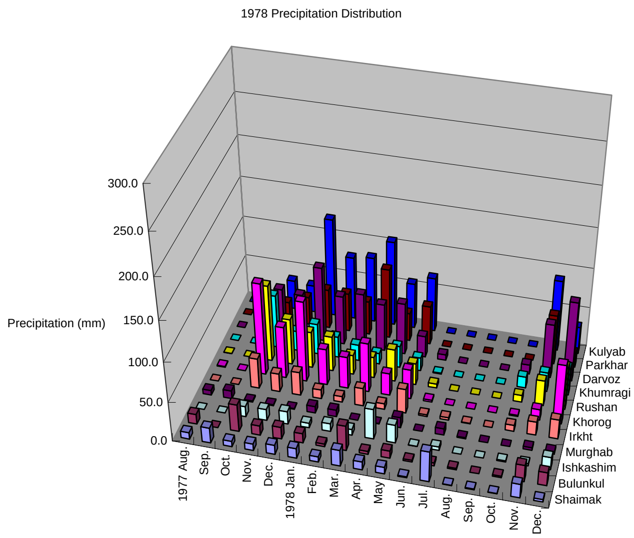


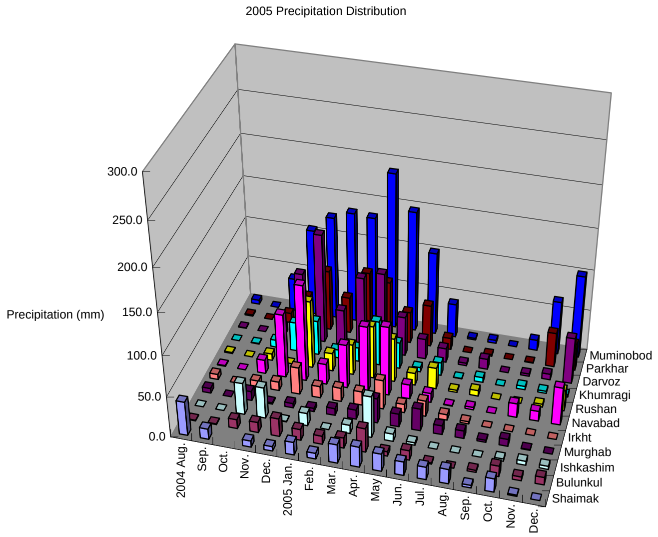
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.1 Pyanj River System
CTI INTERNATIONAL ENGINEERING CO., LTD	



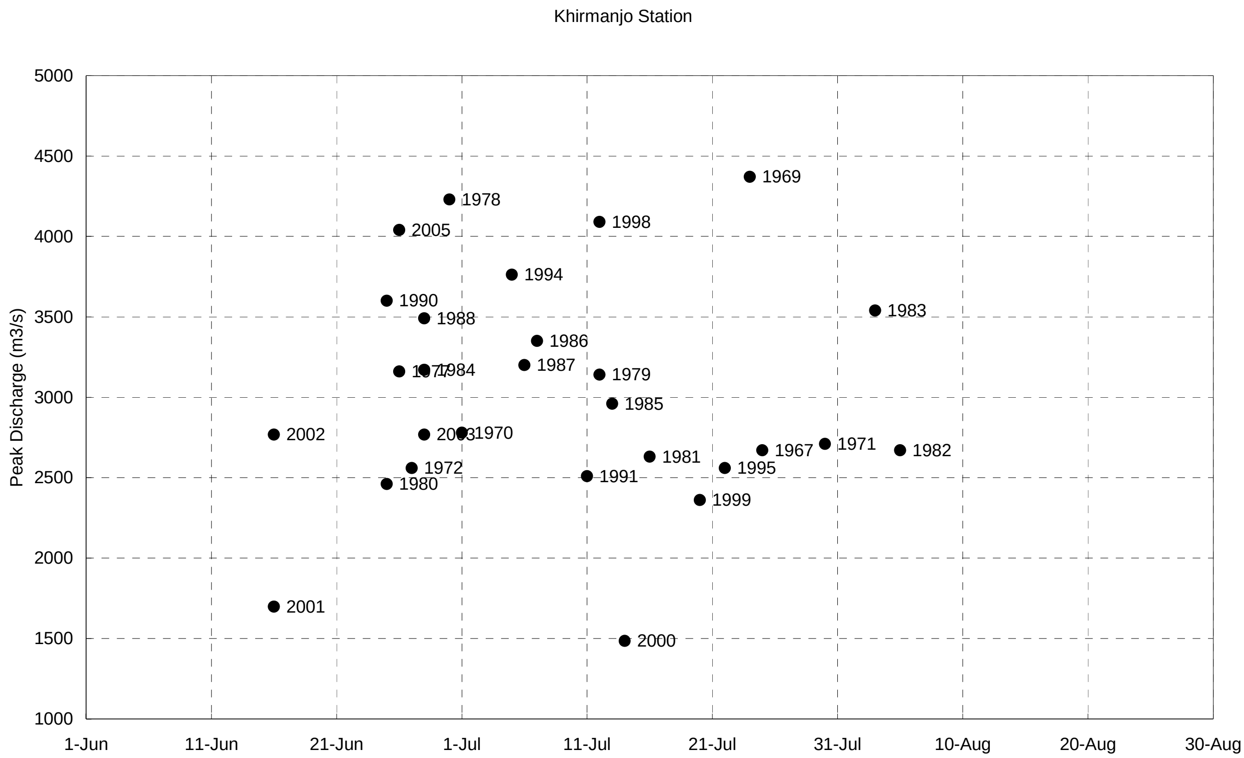
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig.2.1.2 Organization Chart of Tajikmeteorology
CTI INTERNATIONAL ENGINEERING CO., LTD	

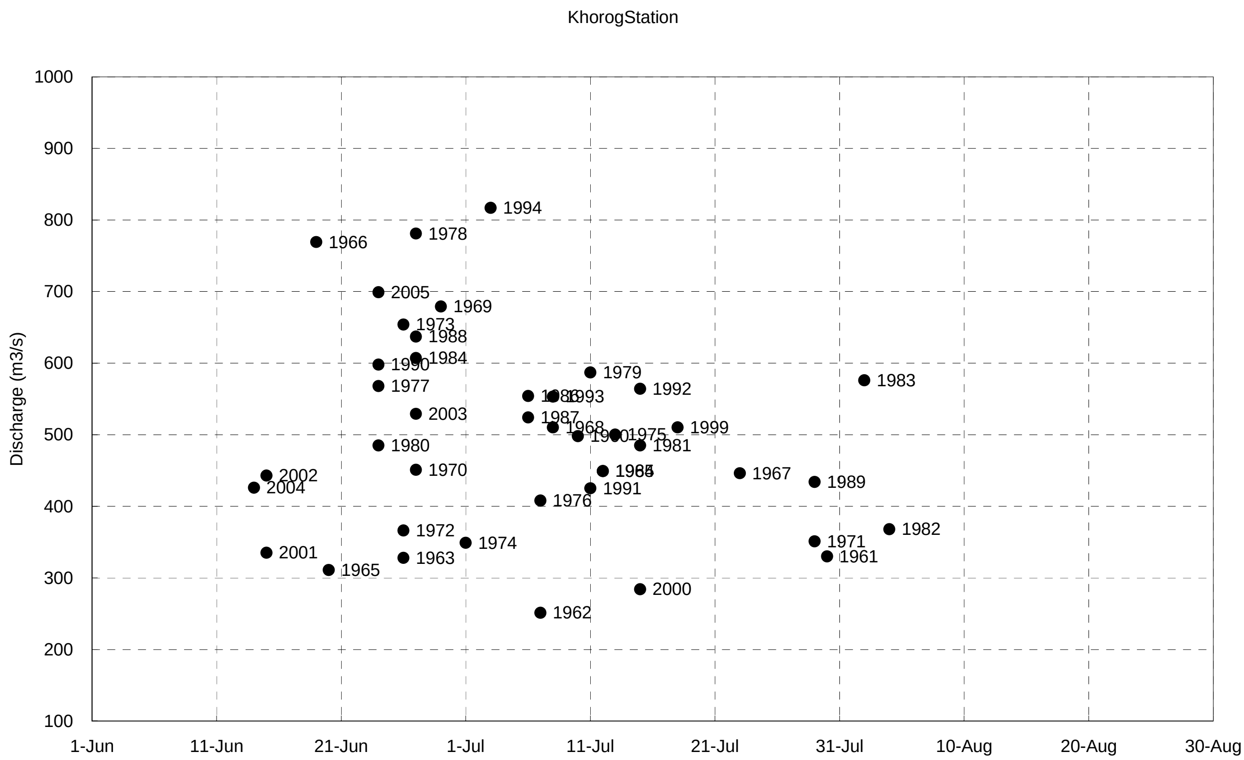




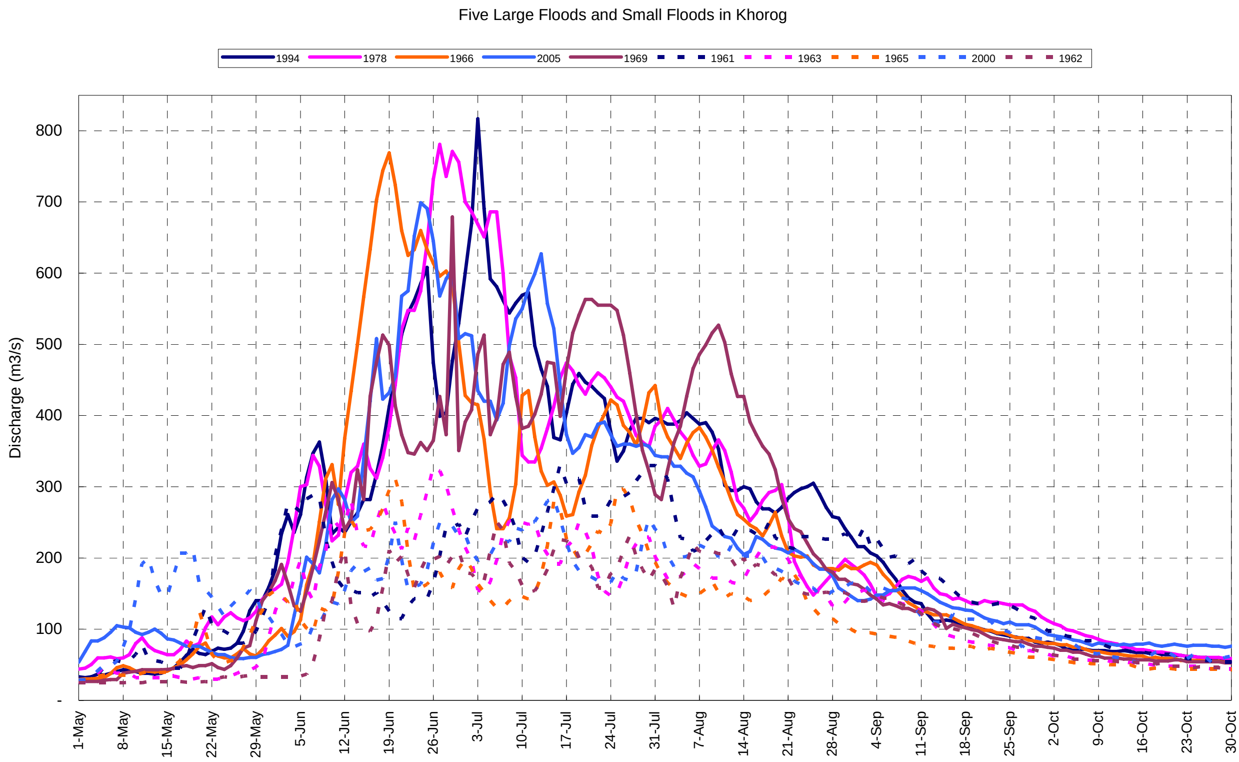


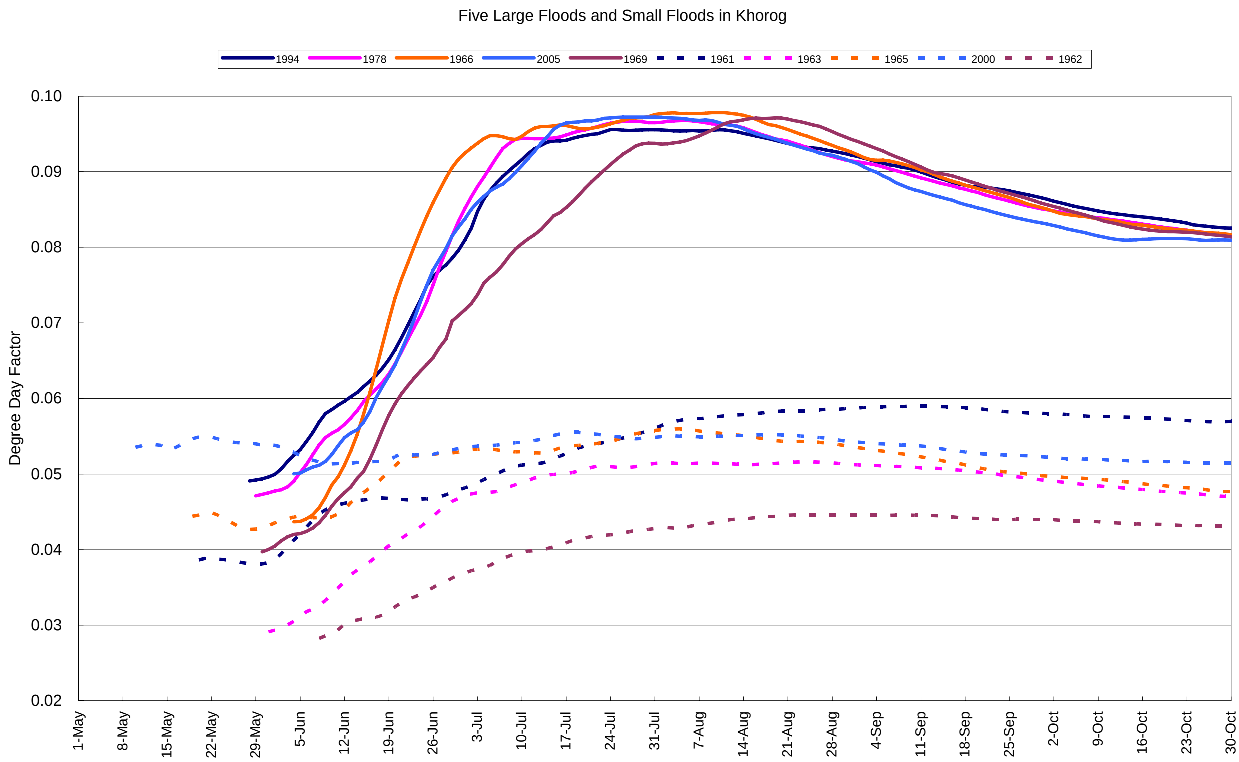
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.3 Precipitation Distribution
CTI INTERNATIONAL ENGINEERING CO., LTD	



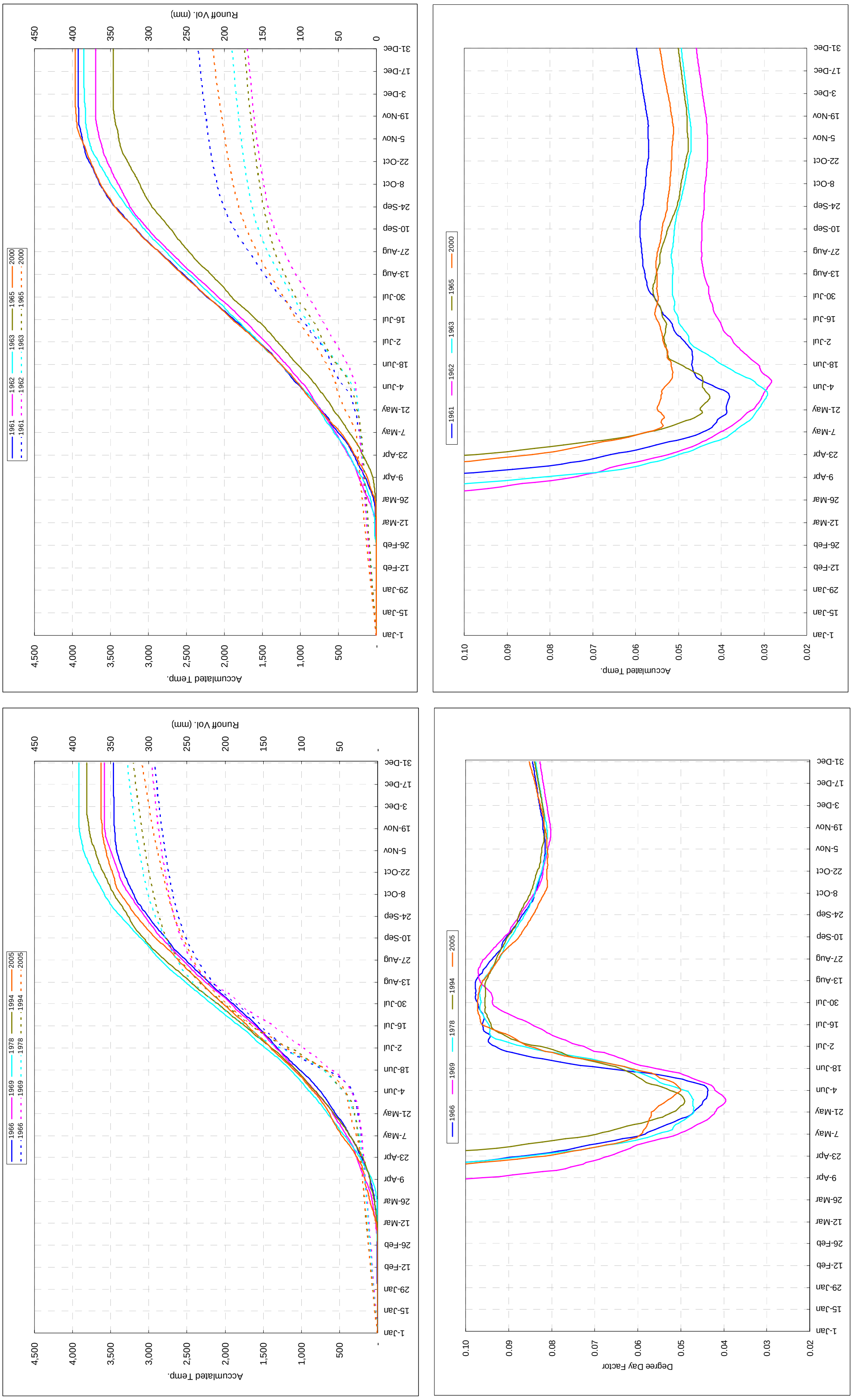


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.4 Timing of Peak Discharge Appearance
CTI INTERNATIONAL ENGINEERING CO., LTD	

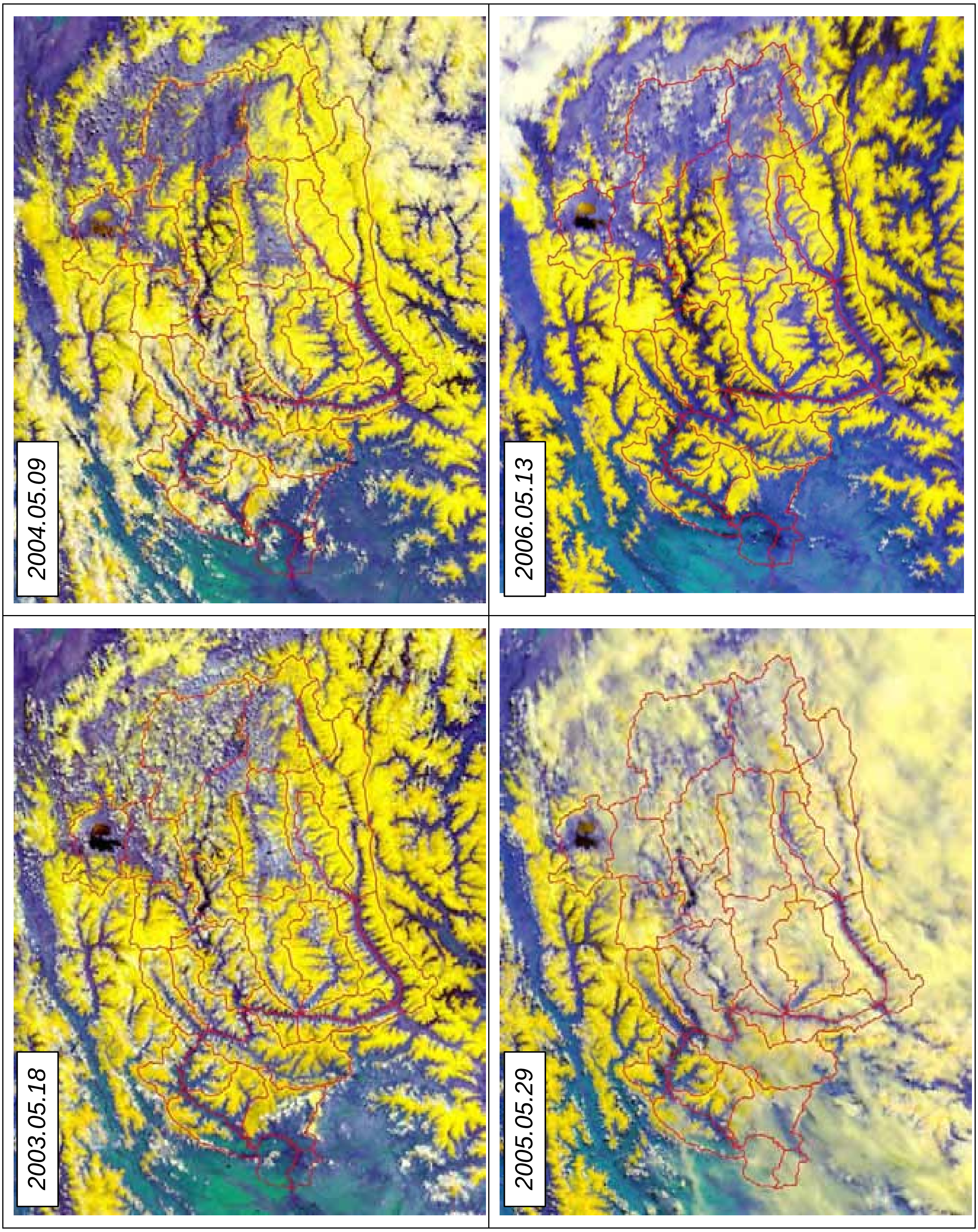




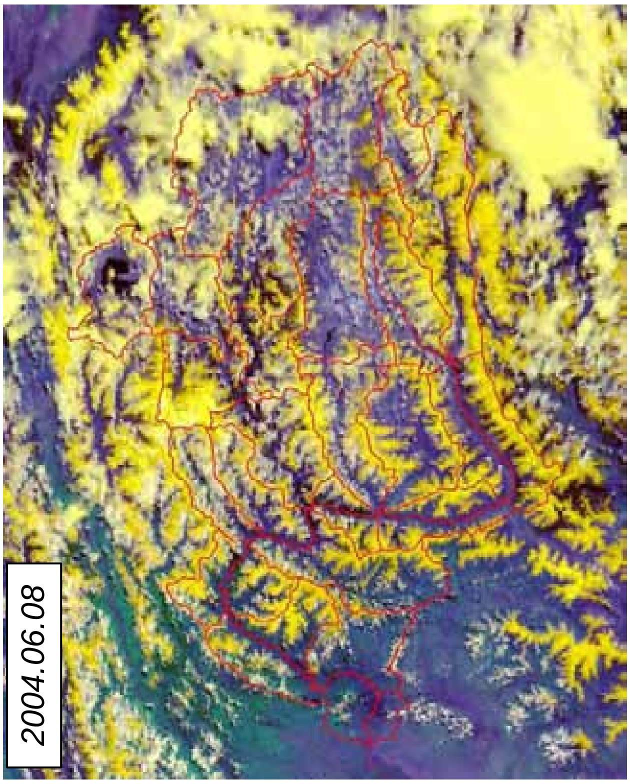
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.5 Degree Day Factor of Five Large Small Flood in Khorog
CTI INTERNATIONAL ENGINEERING CO., LTD	

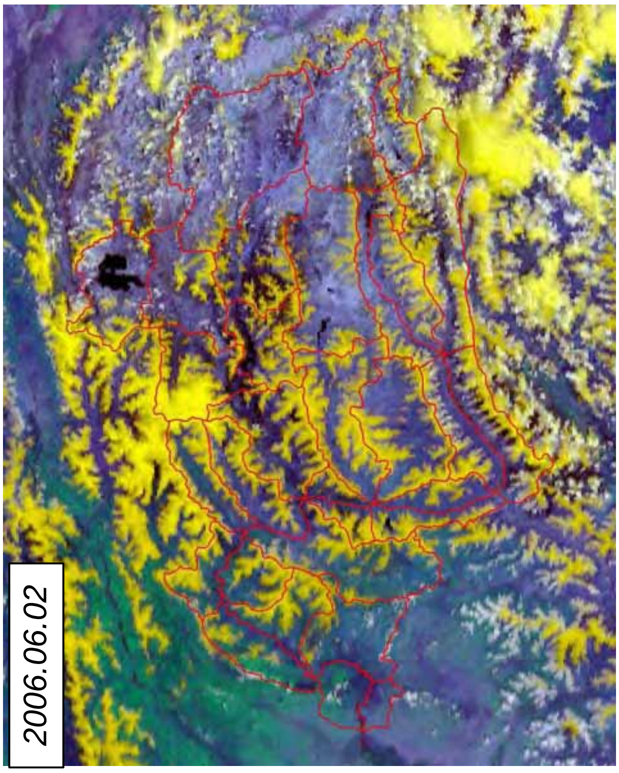


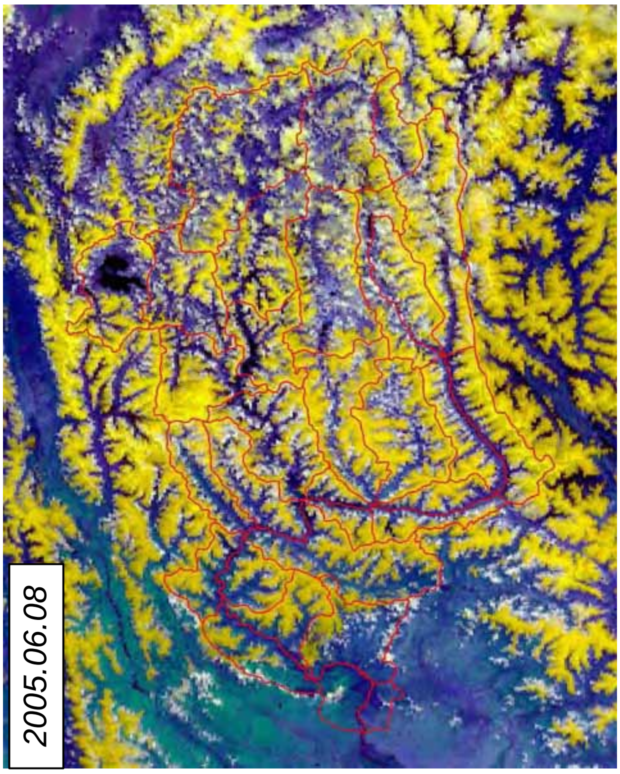
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.16	Comparison of Runoff Volume and Degree Day Factor in Khorog
CTI INTERNATIONAL ENGINEERING CO., LTD		



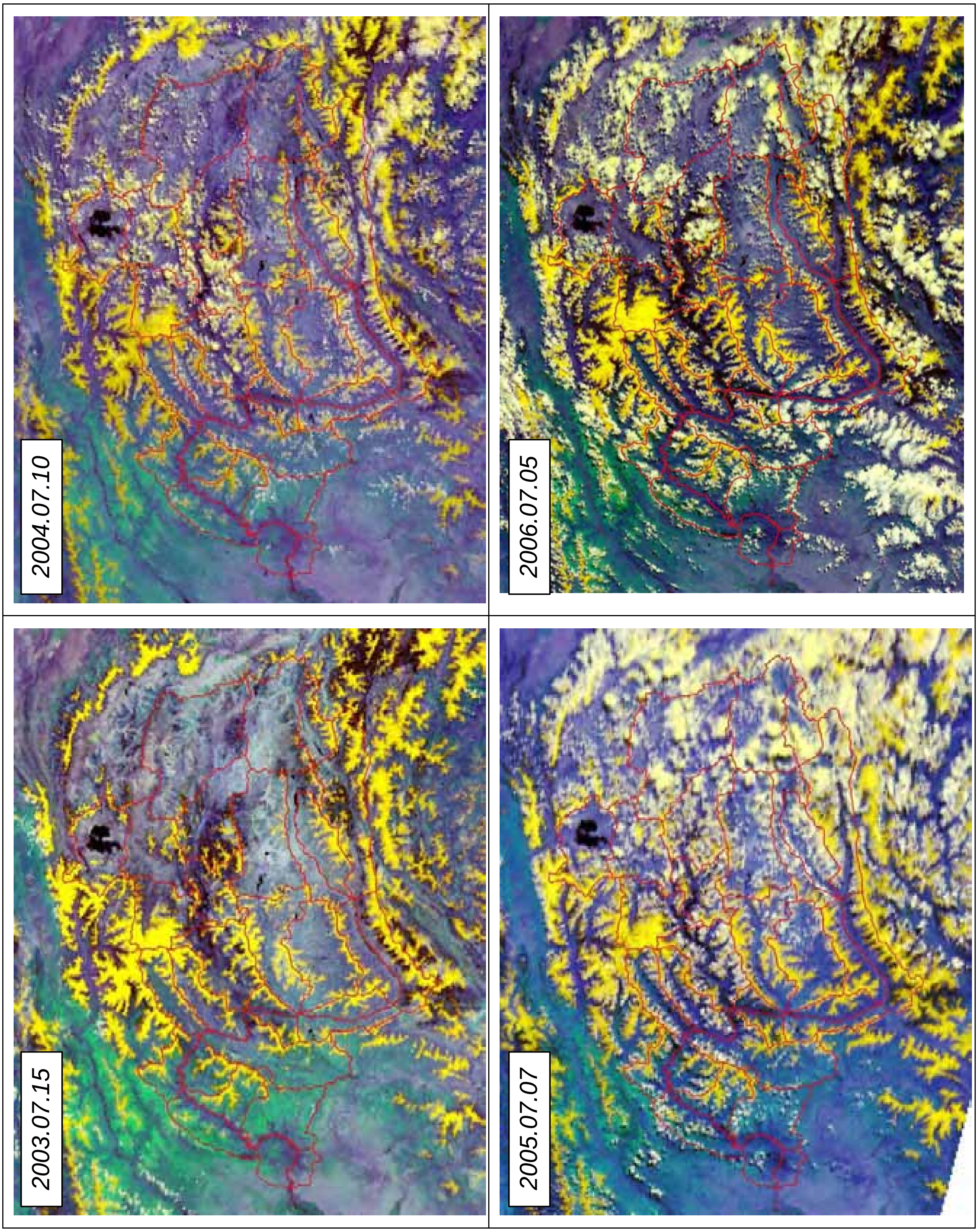
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.7 (1) Snow Coverage Area in May
CTI INTERNATIONAL ENGINEERING CO., LTD	



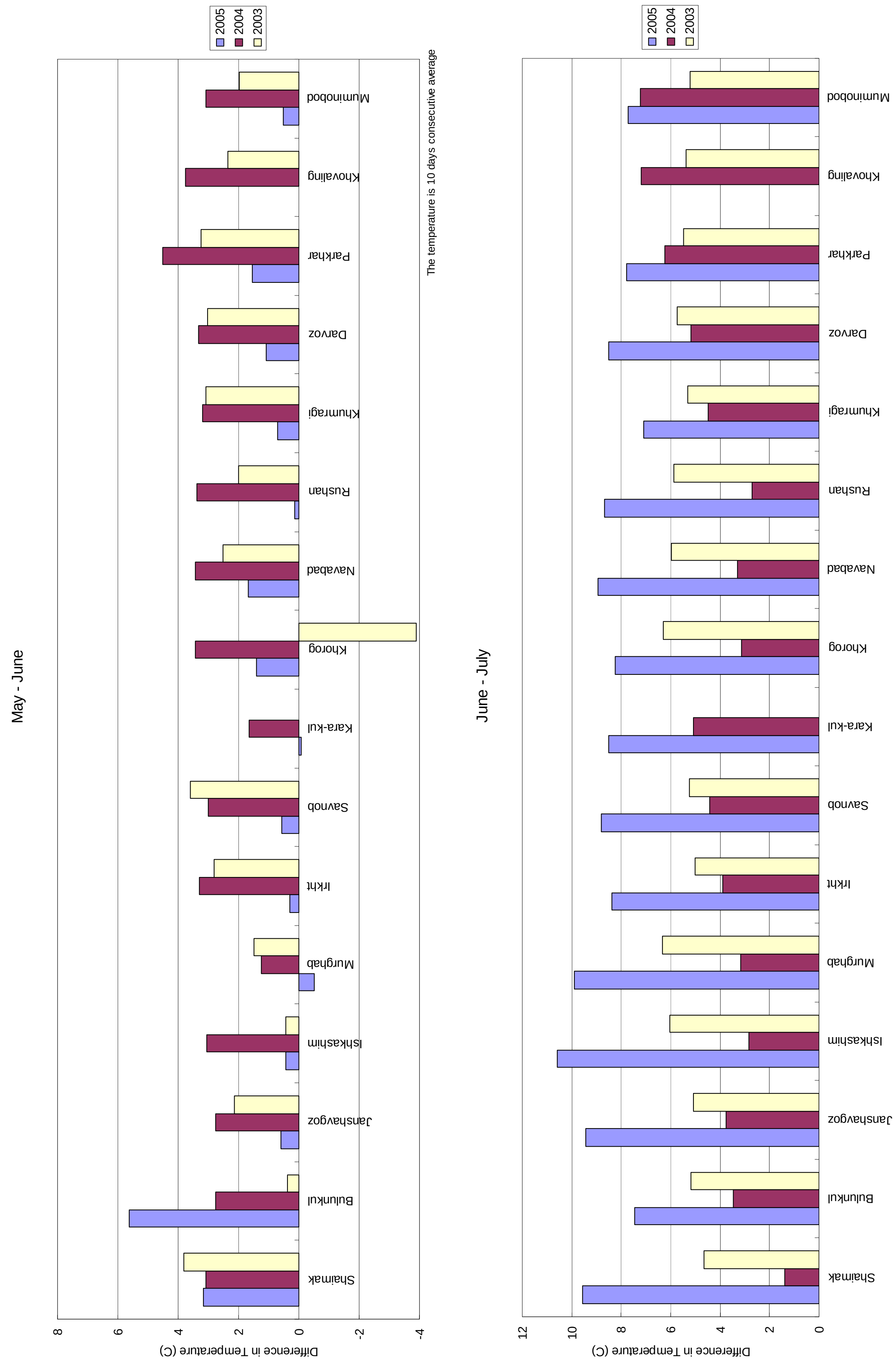




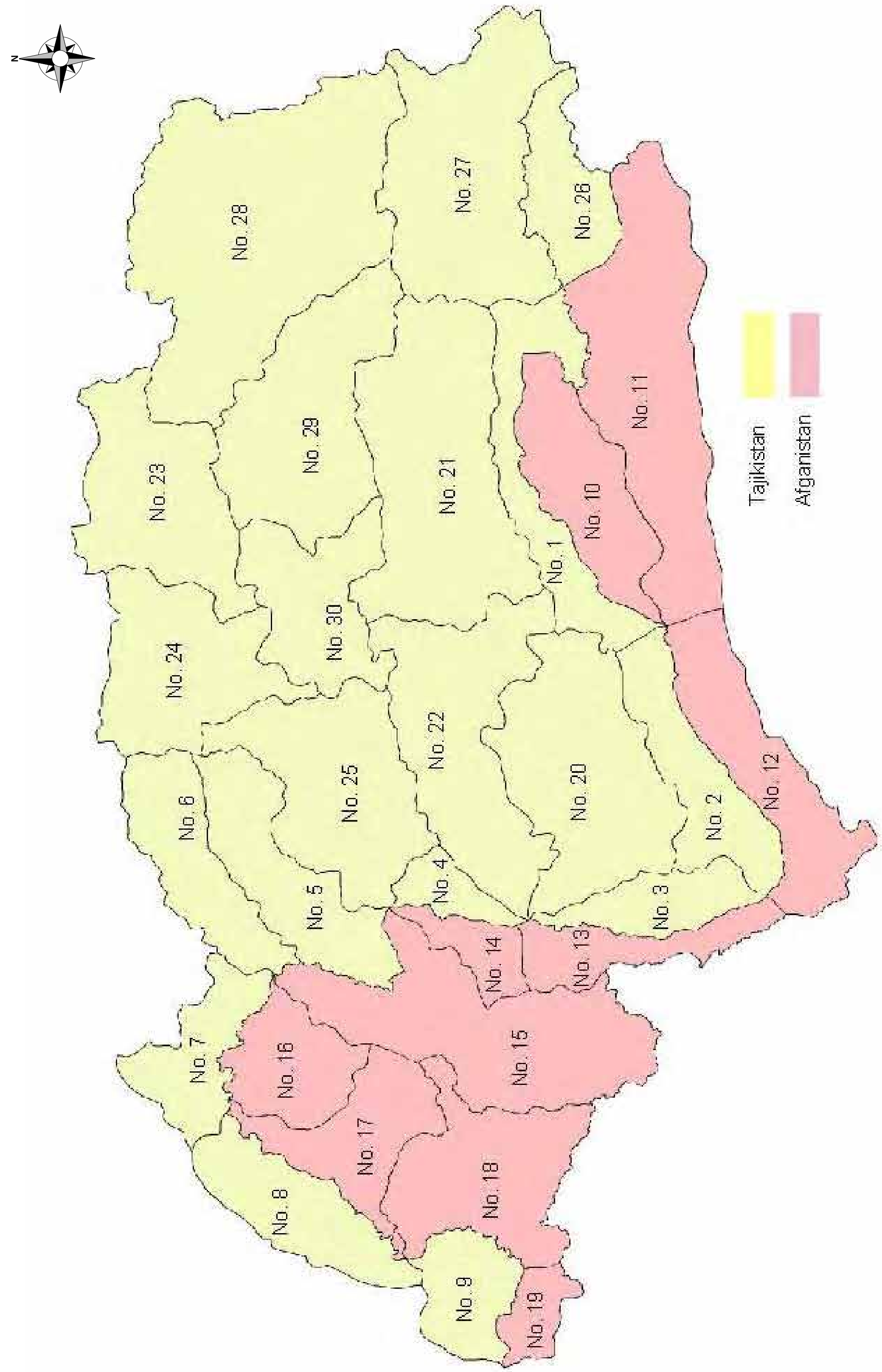
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig.2.1.7 (2) Snow Coverage Area in June
CTI INTERNATIONAL ENGINEERING CO., LTD	



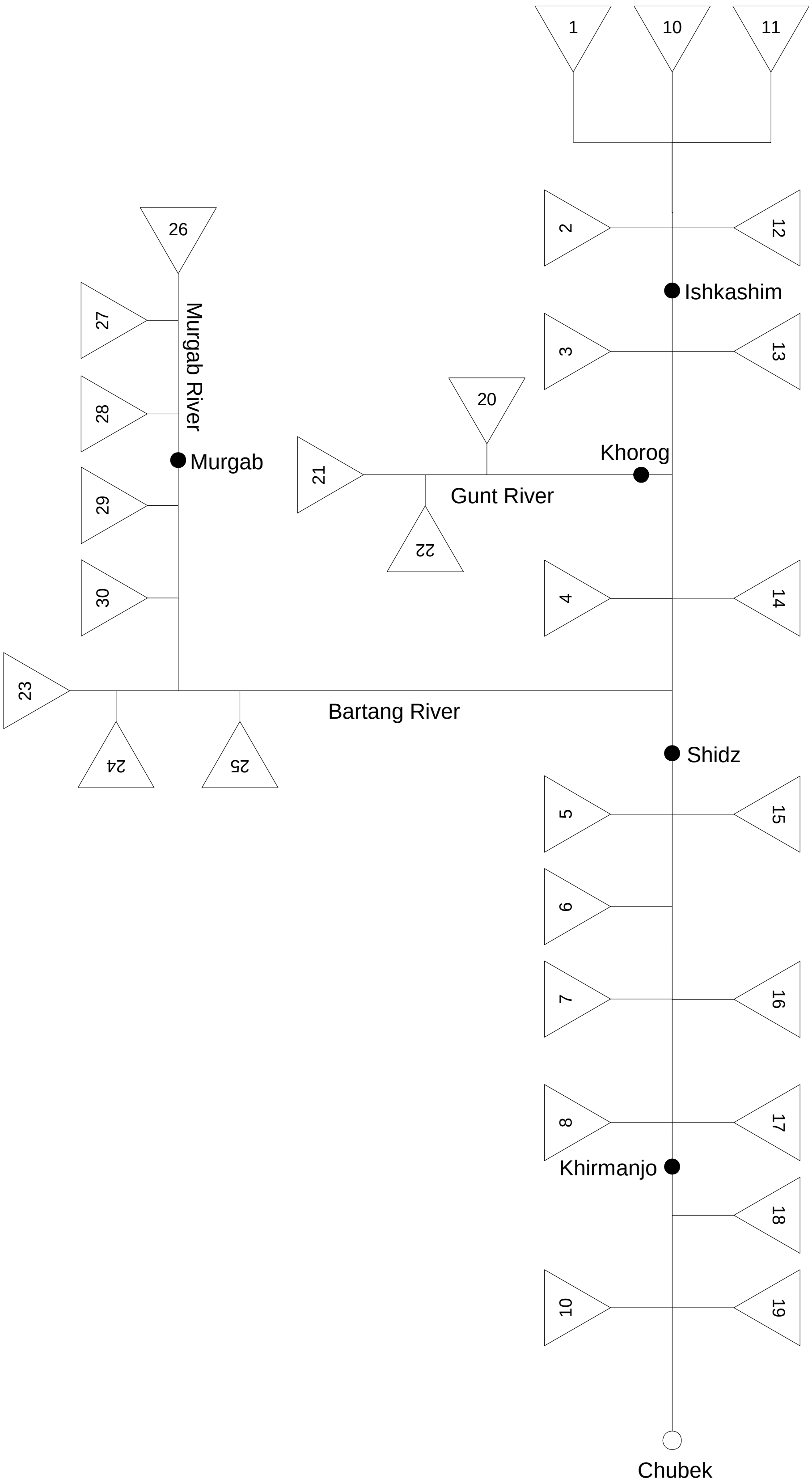
THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.7 (3) Snow Coverage Area in July
CTI INTERNATIONAL ENGINEERING CO., LTD	



THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.8 Difference in Temperature
CTI INTERNATIONAL ENGINEERING CO., LTD	



THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.9 Sub-Basin Map of Pyanj River
CTI INTERNATIONAL ENGINEERING CO., LTD	

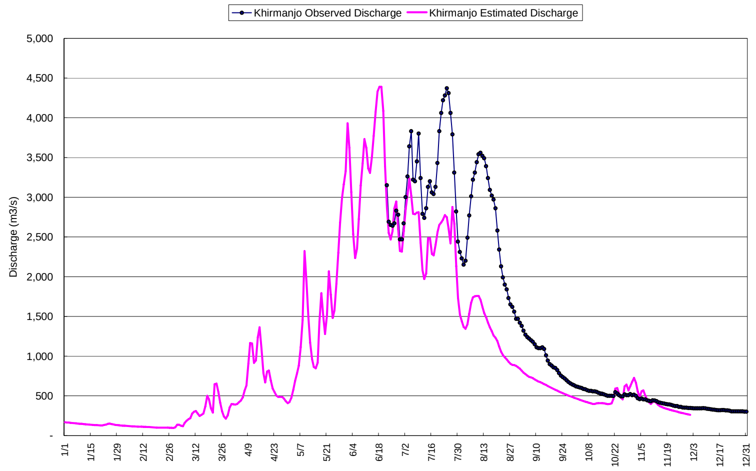


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER

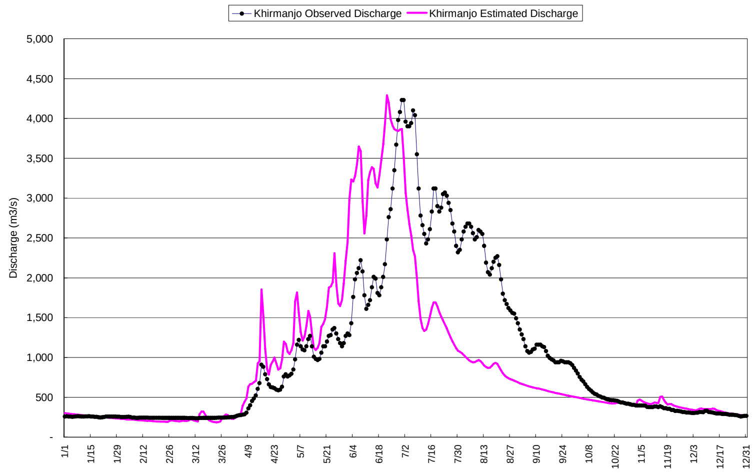
CTI INTERNATIONAL ENGINEERING CO., LTD

Fig. 2.1.10 Schematic Model for Pyanj River Basin

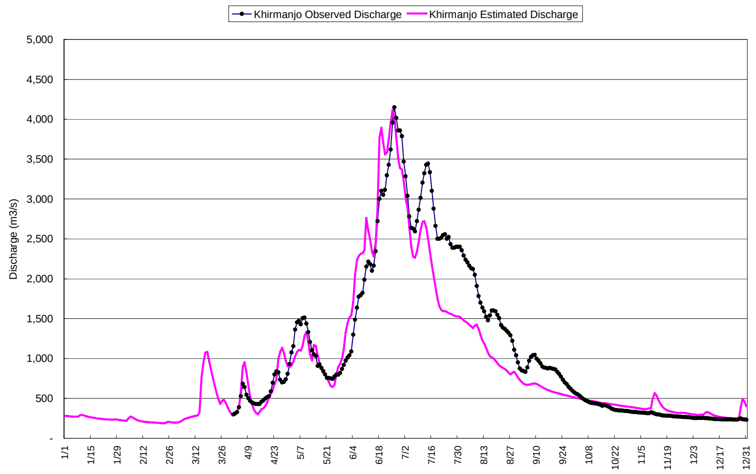
1969 Flood



1978 Flood

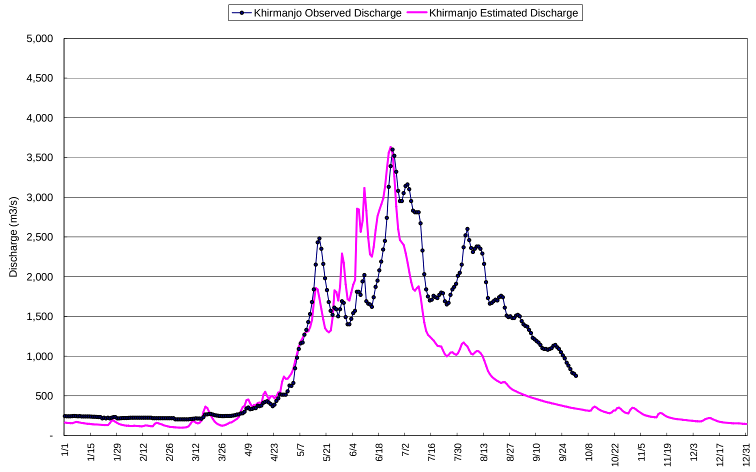


2005 Flood

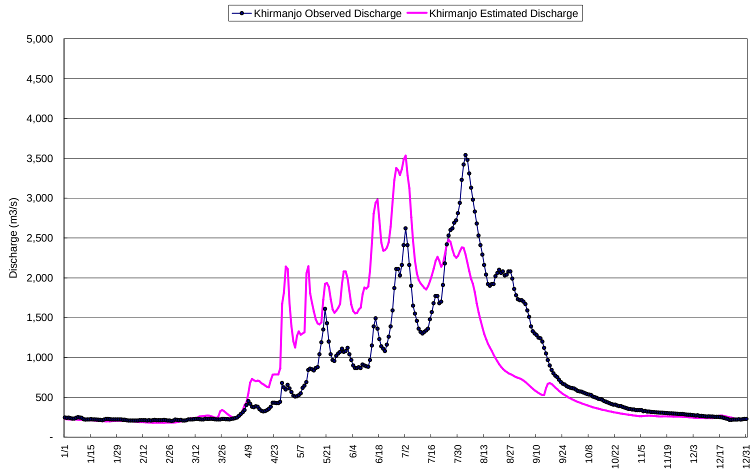


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.11(1) Result of Calibration at Khirmanjo
CTI INTERNATIONAL ENGINEERING CO., LTD	

1990 Flood

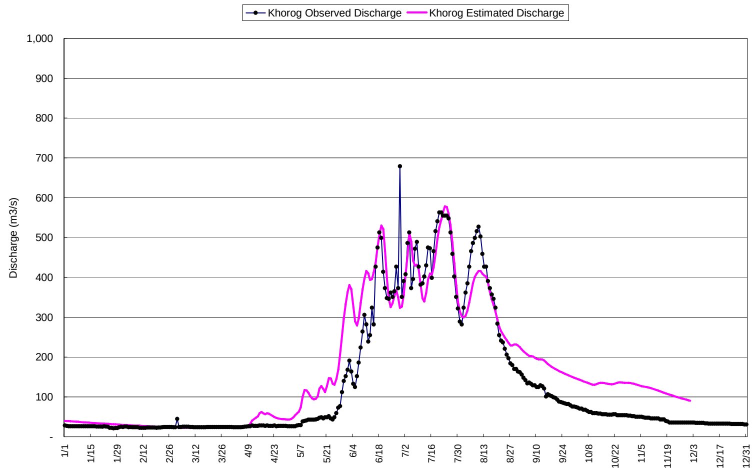


1983 Flood

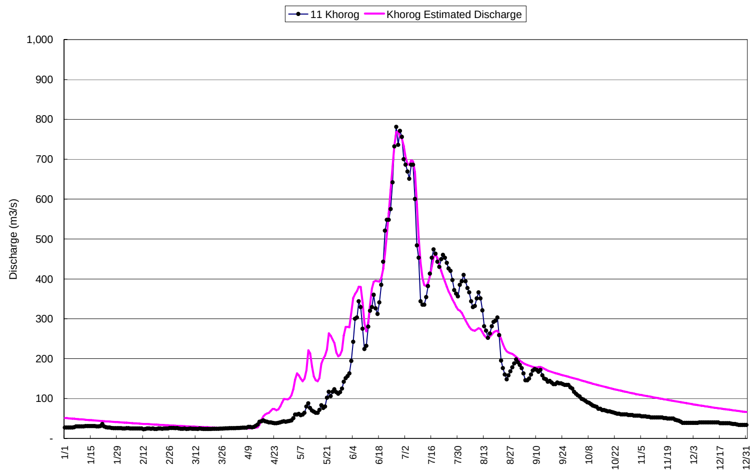


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.11(2) Result of Calibration at Khirmanjo
CTI INTERNATIONAL ENGINEERING CO., LTD	

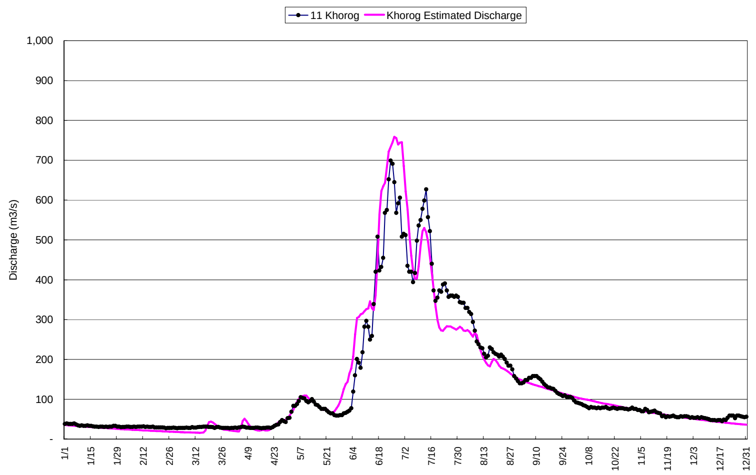
1969 Flood



1978 Flood

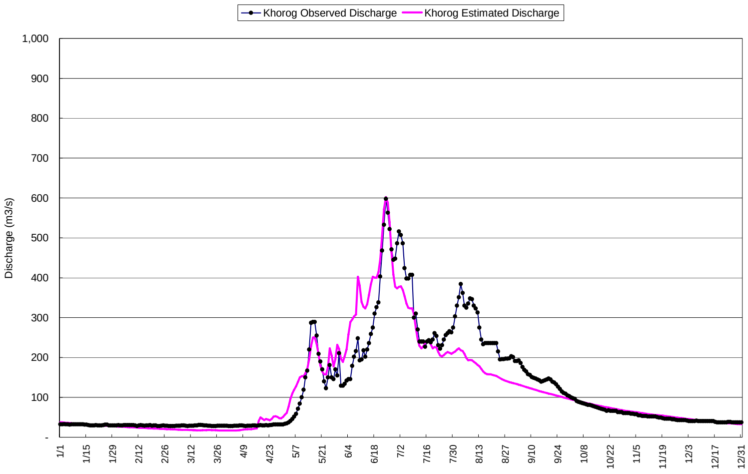


2005 Flood

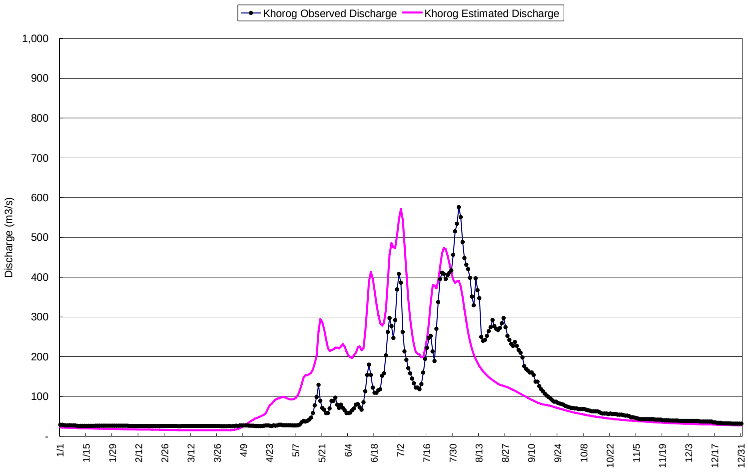


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.12(1) Result of Calibration at Khorog
CTI INTERNATIONAL ENGINEERING CO., LTD	

1990 Flood

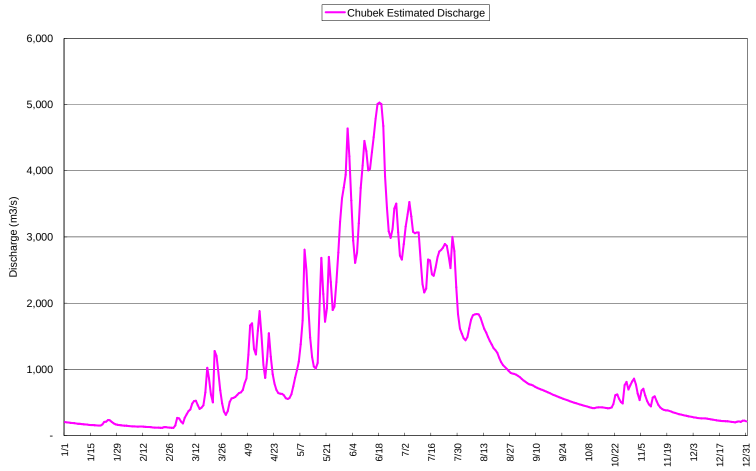


1983 Flood

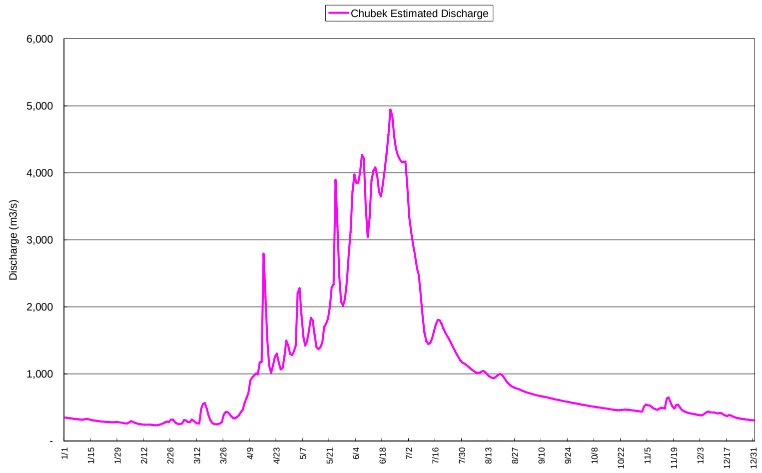


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.12(2) Result of Calibration at Khorog
CTI INTERNATIONAL ENGINEERING CO., LTD	

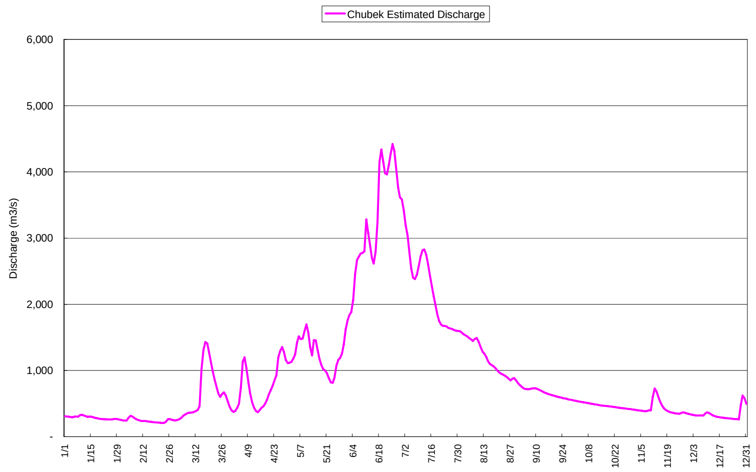
1969 Flood



1978 Flood

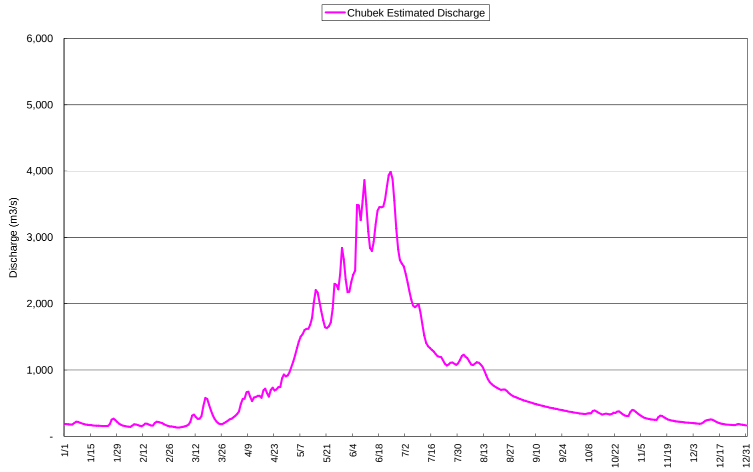


2005 Flood

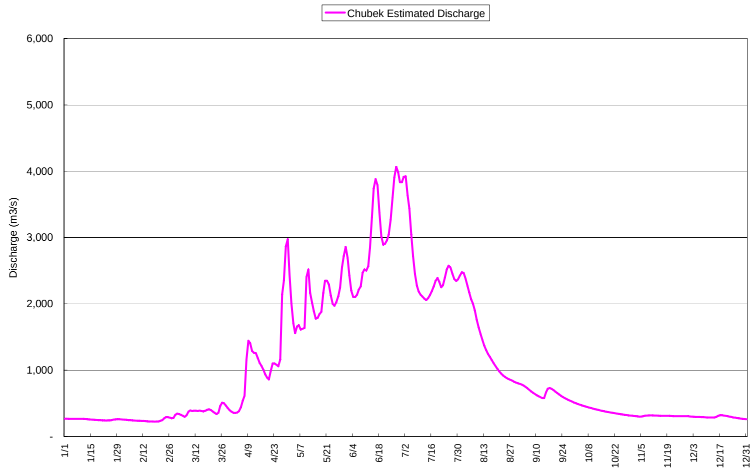


THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.13(1) Runoff Result at Chubek
CTI INTERNATIONAL ENGINEERING CO., LTD	

1990 Flood



1983 Flood



THE STUDY ON NATURAL DISASTER PREVENTION IN PYANJ RIVER	Fig. 2.1.13(2) Runoff Result at Chubek
CTI INTERNATIONAL ENGINEERING CO., LTD	