Table C1.1

QUESTION ITEMS FOR DIO, DDC AND VDC

MASTER PLAN STUDY FOR RIVER TRAINING WORKS IN TRAVEL PLANS

CHECK LISTS

1. Name of River :
2. Name of Institution :
3. Name of Position Responding :
   Position :
   Date :
4. Name of Surveyor :

1. Where is the flood prone area in the project area ?
   (Mark them in the topographic maps also note down name of same villages and VDCs)
2. Which VDCs of Municipalities are adjoining to the project river (get the ward nos also)
3. How often the area get flooded ?
4. Which are the severe flood year ? At least three data (Rank them)
5. Give the type of flood
   - Inundation
   - Flood flow
   - Sediment flow
   - Bank erosion
   - Breach of existing river training works or other structures
6. What was the extent of damage in terms of (quantify them)
   - Loss of human life
   - Loss of cattle
   - Damage of public facilities such road, irrigation etc.
   - Damage of crops (give name of crops and yield)
   - Damage or wash out of land (agriculture as well as barren)
   - Damage of household properties such as house, homestead, public properties.
7. In your feeling the river bed is aggrading or degrading ?
8. What is the reason of flood?

   Excess sediment
   Heavy rain followed by high water level
   Breach of river training works
   Damage if major structure
   Flood water entering from nearby river/s
9. How do you assess the extent of damage ? What are the sources ? Which institutions are responsible to collect the extent of damage ?
10. In case of past severe flood damage, were the people evacuated ? Where ?
11. What type of flood relief measures were under taken and when ? (timely)
12. Which institutions provided the relief measures ?
13. In general, what type of compensation is given to the flood affected people ?
14. Is there any flood warning system ?
15. In your opinion (respondent) what type of the flood protection measures are required and where ? Measures could be
    - Flood embankment
    - Groynes or Dykes
    - Fixing bed level
    - River channelizing
    - Afforeststion
16. What is the income from the river ? (Specially by letting or tendering the river bed materials such as boulders or sand) ? Please quantify the amount annual volume of these materials.
17. Was there any benefit from the flood ? Such as increase in crop yield etc.
18. Was there any epidemic of diseases after the flood ? What are they ?What was the extent ? Was there any causality ?
19. Are there any river training works in the river ? What type of structures ? (specify institutions)

    Flood embankments
    Spurs or groynes
    Weir
    Bridge etc.
20. Do you have any proposal implementing river training works or community based activities (budget allocation) ?

QUESTIONNAIRE FORM TO INDIVIDUAL RESIDENTS

Table C1.2

MASTER PLAN FOR RIVER TRAINING WORKS FOR TERAI PLAN CHECK LIST
FOR
HOUSEHOLD LEVEL SURVEY

Name of River : ____________
District : ____________
VDC/Municipality : ____________
Ward No. /Village : ____________
Date : ____________

Name : ____________
Caste ____________
Age (Years) ____ Sex M F
Family Member : ____ Occupation : ____
Length of Residence (Years) : ____

1 FLOOD

1.1 When was the most severe flood? (Give the year)
1.2 How many times did you suffer annually? (Give nos.)
1.3 How many times did you suffer from severe flood in past 10 years?
1.4 How often you are affected once in? (Give in months)
1.5 Cause of flood
- (a) Too much rain
- (b) Sediment flow
- (c) Bank erosion
- (d) Others

2 EFFECT DUE TO SEVERE FLOOD IN PAST

2.1 Loss of human life (Give in nos)
2.2 Loss of livestock/animal husbandry (Give in nos)
- (a) Cow
- (b) Buffalo
- (c) Sheep/Goat
- (d) Poultry

2.3 Damage to farm land (Give in ha)
- (a) Irrigated land
- (b) Unirrigated land

2.4 Extent of damage to farm land
- (a) Simple inundation
- (b) Loss of crops
  - (i) Paddy (ii) Sugarcane
  - (iii) Maize (iv) Others
- (c) Total washout

2.5 Extent of damage to dwelling and asset
- (a) Flooding days
- (b) Flooding depth in (m)
- (c) Damage to house (severe/moderate/ordinary)
- (d) Loss of cash (Rs)
- (e) Loss of food grains (Kg)
- (f) Clothing
- (g) Other valuables

2.6 What kind of problems did you observed in your surrounding during the flood?
- (a) Erosion of river bank
- (b) Sediment in the river
- (c) Sediment in the irrigation canal
- (d) Drinking water problem
- (e) Sanitary problem
- (f) Salinity
- (g) Flooding over farm land
- (h) Others

2.7 Did you have epidemic disease after the flood? (Y/N)
2.8 If yes what are they
- (a) Cholera
- (b) Dysentery
- (c) Typhoid
- (d) Other

2.9 Was there any fatal causality? (Y/N)
2.10 In your feeling, what is the reason of flood in your area?
- (a) Too much rain
- (b) Due to lack of flood protection works
- (c) Due to weak river training works
- (d) Sediment load in the flood water
- (e) Flood enter from adjoining rivers

2.11 Total damage in terms of money (Rs)

3 FLOOD WARNING SYSTEM

3.1 Caught by surprise
3.2 Self Warning
- (a) Heavy rain/High flood level
- (b) Bank erosion
- (c) Smelled mud
- (d) Unusual sound
- (e) Others

3.3 Warned by others
- (a) Neighbours
- (b) Institutions (Get the name)
- (c) Others

4 FLOOD RELIEF MEASURES

4.1 Were you evacuated during flood? (Y/N)
4.2 If yes where?
- (a) High ground
- (b) Public building
- (c) Others houses
- (d) Other sites

4.3 Did you get flood relief ? (Y/N)
4.4 If "yes"
- (a) In cash
- (b) Kind

4.5 Who gave?
- (a) Centre government
- (b) DDC
- (c) VDC
- (d) Other institutions
- (e) NGO
- (f) Individuals

4.6 If "No" why ?
- (a) Did not know where to evacuate?
- (b) Did not know flood was coming?
- (c) No necessary
- (d) Others

5 PREVENTIVE MEASURES AGAINST FLOOD — Current / Proposed

5.1 Preparedness/Response measures
- (a) Warning
- (b) Evacuation
- (c) Settlement

5.2 Non structural measures
- (a) Seed storage
- (b) Cash pools
- (c) Informal insurance
- (d) Others

5.3 Structure measures
- (a) Embankment
- (b) Spur
- (c) Simple gabion
- (d) Plantation
- (e) Others

6 PARTICIPATION ACTIVITIES

6.1 Did you participated in flood prevention activities? (Y/N)
6.2 If yes what are they?
- (a) Cash
- (b) Labour
- (c) Kind
- (d) Care taker
- (e) Others

6.3 If no what are the reasons?
- (a) Yourself were badly affected
- (b) Financial weak
- (c) Yourself out of the area
- (d) Did not feel like
- (e) Others

6.4 Are you interested in future flood protection works? (Y/N)
6.5 If "yes" what form?
- (a) Cash
- (b) Labour
- (c) Kind
- (d) Care taker
- (e) Other

6.6 If "no" what are the reasons?
- (a) No time
- (b) No benefit
- (c) Do not like to participate
- (d) Do not know how to participate
- (e) Others

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VDC/MUNICIPALITIES SUBJECT TO INVESTIGATION

River	District	VDC/Municipality
Ratuwa R.	Jhapa (Left)	(1)DamakMunicipality, (2)Lakhanpur, (3)Kohabra, (4) Khajurgachhi
	Morang (Right)	(1) Raj Ghat, (2) Itahara, (3) Sijuwa, (4) Jhurkiya, (5) Mahadeva
Lohandrra R	Morang (Left)	(1) Bel Bari, (2) Kaseni, (3) Babiya Birta, (4) Dadar Bairiya, (5) Kadamaha, (6) Sisbani Jahada, (7) Majahare
	Morang (Right)	(1) Kerabari, (2) Haraicha, (3) Banigama, (4) Motipur, (5) Thalaha, (6) Katahari
Lakhandei R.	Sarlahi (Left)	(1) Pipariya, (2) Pidari, (3) Haripur, (4) Shreepur, (5) Sundarpur, (6) Padariya, (7) Bhadsar
	Sarlahi (Right)	(1) Ghurkauli, (2) Janaki Nagar, (3) Belhi, (4) Laxmipur, (5) Phool Parasi, (6) Simara
Narayani R.	Chitwan (Left)	(1) Mangalpur, (2) Gunjnagar, (3) Divyanagar, (4) Meghauli
	Nawalparasi (Right)	(1) Mukundpur, (2) Rajahar, (3) Kumarbarti, (4) Kolhuwa, (5) Narayani, (6) Parsauni, (7) Naya Belhani
Tinau R.	Rupandehi (Left)	(1) Sankarnagar, (2) Anandban, (3) Roinihawa, (4) Hatti Bangai
	Rupandehi (Right)	(1) Motipur, (2) Sauraha Pharsatikar, (3) West Amawa, (4) Mainahiya, (5) Harnaiya, (6) Sipuwa, (7) Bhagwanpur
West Rapti R.	Dang (Left)	(1) Gobardiya, (2) Gadawa
	Dang (Right)	(1) Lalmatiya, (2) Sishaniya, (3) Sonpur, (4) Chailahi, (5) Satbariya
	Banke (Left)	(1) Baijapur, (2) Fatehpur
	Banke (Right)	(1) Kachnapur, (2) Kamdi, (3) Betahani, (4) Holiya, (5) Binauna
Babai R.	Bardiya (Left)	(1) Baniyabhar, (2) Padanaha, (3) Dhadhawar, (4) Muhamadpur
	Bardiya	(1) Baganaha, (2) Gulariya Municipality
Khutiya R.	Kailali (Left)	(1) Urma, (2) Phool Bari
	Kailali (Right)	(1) Beladehipur, (2) Dhangadhi (Municipality)

(Remarks) VDCs/Municipalities subject to investigation of flood and sediment disasters are 81 in total.

Table C1.4

SUMMARY OF QUESTIONNAIRES

No.	Items	Unit	1.Ratuwa R.	2.Lohandra R.	3.Lakhandei R.	4.Narayani R.	5.Tinau R.	6.W.Rapti R.	7.Babai R.	8.Khutiya R.
	Interviewee	persons	171	131	192	101	107	228	129	65
1.1	Most severe flood	year	'88, '95, '96	'87,'88,'95	'97,'93,'95	'88,'93,'95	'96,'95,'93	'97,'96,'93	'95,'87,'96	'97,'86,'83
1.2	Flood suffering: Average(Range)	times/yr.	7(3~22)	8(3~13)	10(10~20)	4(2~9)	14(14~15)	7(4~12)	3(2~8)	2(2~3)
2.5	Extent of damage:									
	Flooding duration: Average(Range)	days	3.7(1~28)	3.0(1~17)	7.0(3~28)	6.0(2~12)	3.3(1~5)	2.3(1~7)	3.9(2~7)	2(1~3)
	Flooding depth: Average(Range)	meter	1.5(0.1~3.0)	0.8(0.6~0.9)	1.6(0.3~3.0)	1.6(0.3~3.0)	1.1(0.2~1.6)	1.5(0.75~2.0)	1.6(0.8~1.7)	1.2(0.88~1.5)
2.6	Problems brought about:									
	Flooding over farm land	nos, %	125 23%	81 16%	51 5%	64 19%	27 5%	43 21%	109 26%	28 42%
	River bank erosion	nos, %	167 31%	118 23%	177 19%	79 24%	106 20%	82 40%	118 28%	15 23%
	Sedimentation(river, canal)	nos, %	137 26%	177 34%	315 34%	117 35%	167 31%	23 11%	85 20%	15 23%
	Drinking water problem	nos, %	63 12%	58 11%	186 20%	43 13%	97 18%	48 23%	55 13%	3 5%
	Sanitary problem	nos, %	28 5%	42 8%	166 18%	28 8%	57 10%	2 1%	41 10%	0 0%
	Others	nos, %	14 3%	40 8%	38 4%	1 0%	89 16%	9 4%	9 2%	5 8%
2.10	Reason of flooding:									
	Too much rain	nos, %	134 34%	97 37%	171 25%	37 24%	106 27%	31 26%	37 24%	19 37%
	Sediment load	nos, %	67 17%	37 14%	144 21%	20 13%	79 20%	3 2%	2 1%	5 10%
	Flooding	nos, %	18 5%	20 8%	30 4%	6 4%	9 2%	7 6%	4 3%	4 8%
	Lack of protection works	nos, %	130 33%	88 34%	190 28%	93 60%	105 26%	75 62%	93 60%	24 46%
	Insufficient works	nos, %	43 11%	19 7%	153 22%	0 0%	101 25%	5 4%	19 12%	0 0%
4.1	Experience of evacuation:									
	Yes/No	nos	83/88 Y49%	45/79 Y36%	120/72 Y63%	72/29 Y71%	72/29 Y71%	52/127 Y29%	61/68 Y47%	10/51 Y16%
6.1	Experience of paticipation to F.M. activities:									
	Yes/No	nos	114/57 Y67%	53/63 Y46%	180/12 Y94%	43/58 Y43%	106/1 Y99%	49/137 Y26%	51/78 Y40%	1/59 Y2%
6.2	Type of participation:									
	Labor	nos, %	102 59%	46 74%	172 87%	26 63%	102 98%	48 89%	37 60%	1 50%
	Cash	nos, %	24 14%	9 15%	5 3%	1 2%	2 2%	2 4%	3 5%	0 0%
	Kind and care-taking	nos, %	43 25%	7 11%	20 10%	6 15%	0 0%	2 4%	15 24%	1 50%
	Other	nos, %	3 2%	0 0%	0 0%	8 20%	0 0%	2 4%	7 11%	0 0%
6.4	Willing to paticipation to F.M. activities:									
	Yes/No	nos	161/6 Y96%	108/6 Y95%	182/3 Y98%	95/0 Y100%	105/0 Y100%	159/23 Y87%	99/29 Y77%	53/3 Y95%
6.5	Type of participation:									
	Labor	nos, %	159 59%	106 76%	182 78%	93 83%	104 83%	163 76%	93 83%	45 56%
	Cash	nos, %	51 19%	17 12%	32 14%	6 5%	21 17%	19 9%	8 7%	9 11%
	Kind and care-taking	nos, %	60 22%	17 12%	18 8%	13 12%	0 0%	31 14%	11 10%	24 30%
	Other	nos, %	1 0%	0 0%	0 0%	0 0%	0 0%	2 1%	0 0%	2 3%

(Remarks) Most severe flood: Most severe flood in past 10 years
nos: Number of answers

RIVER BED MATERIAL AND CHANNEL CHARACTERISTICS

River stretch			River	Ground elevation		Ground	Grain size		River width
Reaches	From (km)	To (km)	segment code	From (m)	To (m)	slope (1/I)	d_{60} (mm)	d_R (mm)	Bm (min-max) (m)
Ratuwa R.									
RA-1	0.0	13.0	2-2	69	80	1,180	0.30	0.30	356 (188-500)
RA-2	13.0	26.0	2-1	80	102	590	0.34	0.34	446 (275-638)
RA-3	26.0	36.2	1	102	134	320	0.43	0.43	516 (300-688)
RA-4	36.2	43.7	1	134	178	170	0.74	0.74	348 (225-425)
Lohandra R.									
LO-1	0.0	14.0	2-2	60	67	2,000	0.30	0.30	55 (25-100)
LO-2	14.0	33.1	2-2	67	87	970	0.27	0.27	89 (25-163)
LO-3	33.1	42.0	2-1	87	96	970	1.2	1.2	119 (75-238)
LO-4	42.0	49.6	2-1	96	120	320	2.4	2.4	200 (75-250)
LO-5	49.6	58.8	1	120	170	180	19	82	221 (138-350)
LO-6	58.8	67.5	1	170	285	80	23	81	178 (25-513)
Lakhandei R.									
LA-1	0.0	21.0	2-2	76	93	1,240	0.20	0.20	143 (38-375)
LA-2	21.0	37.0	2-1	93	124	520	0.31	0.31	326 (100-588)
LA-3	37.0	43.0	1	124	150	240	0.35	0.35	371 (200-588)
LA-4	43.0	51.4	1	150	185	240	4.3	4.3	547 (200-888)
Narayani R									
NA-1	(Narrow reaches)		-			-	-	-	226 (150-350)
NA-2	18.4	44.9	2-1	120	137	1,560	39	60	1,463 (400-2450)
NA-3	44.9	83.0	2-1	137	190	720	27	73	1,394 (300-2500)
Tinau R.									
TI-1	0.0	12.7	2-2	92	96	3,180	0.18	0.18	163 (88-325)
TI-2	12.7	31.0	2-2	96	105	2,030	0.39	0.39	79 (50-150)
TI-3	31.0	41.0	2-1	105	115	1,000	3.6	3.6	159 (63-325)
TI-4	41.0	53.0	1	115	143	430	17	42	557 (325-875)
TI-5	53.0	59.5	1	143	203	110	46	96	450 (88-925)
W.Rapti R.									
WR-1	0.0	23.0	2-2	130	142	1,920	0.29	0.29	417 (225-750)
WR-2	23.0	53.0	2-1	142	171	1,030	29	55	790 (238-1700)
WR-3	(Narrow reaches)		-			-	0.28	0.28	224 (75-950)
WR-4	115.0	132.0	2-2	225	240	1,130	0.31	0.31	760 (350-1400)
WR-5	132.0	163.5	2-1	240	298	540	24	47	827 (125-1400)
Babai R.									
BA-1	0.0	30.0	2-2	137	150	2,310	0.26	0.26	427 (88-724)
BA-2	30.0	38.0	2-1	150	159	890	43	63	592 (338-700)
BA-3	38.0	48.0	1	159	190	320	38	71	858 (325-1325)
Khutiya R.									
KH-1	0.0	11.5	2-2			-	0.58	0.58	346 (175-650)
KH-2	11.5	27.0	2-1			-	5.9	15	167 (50-350)
KH-3	27.0	35.0	1			-	84	124	355 (175-650)

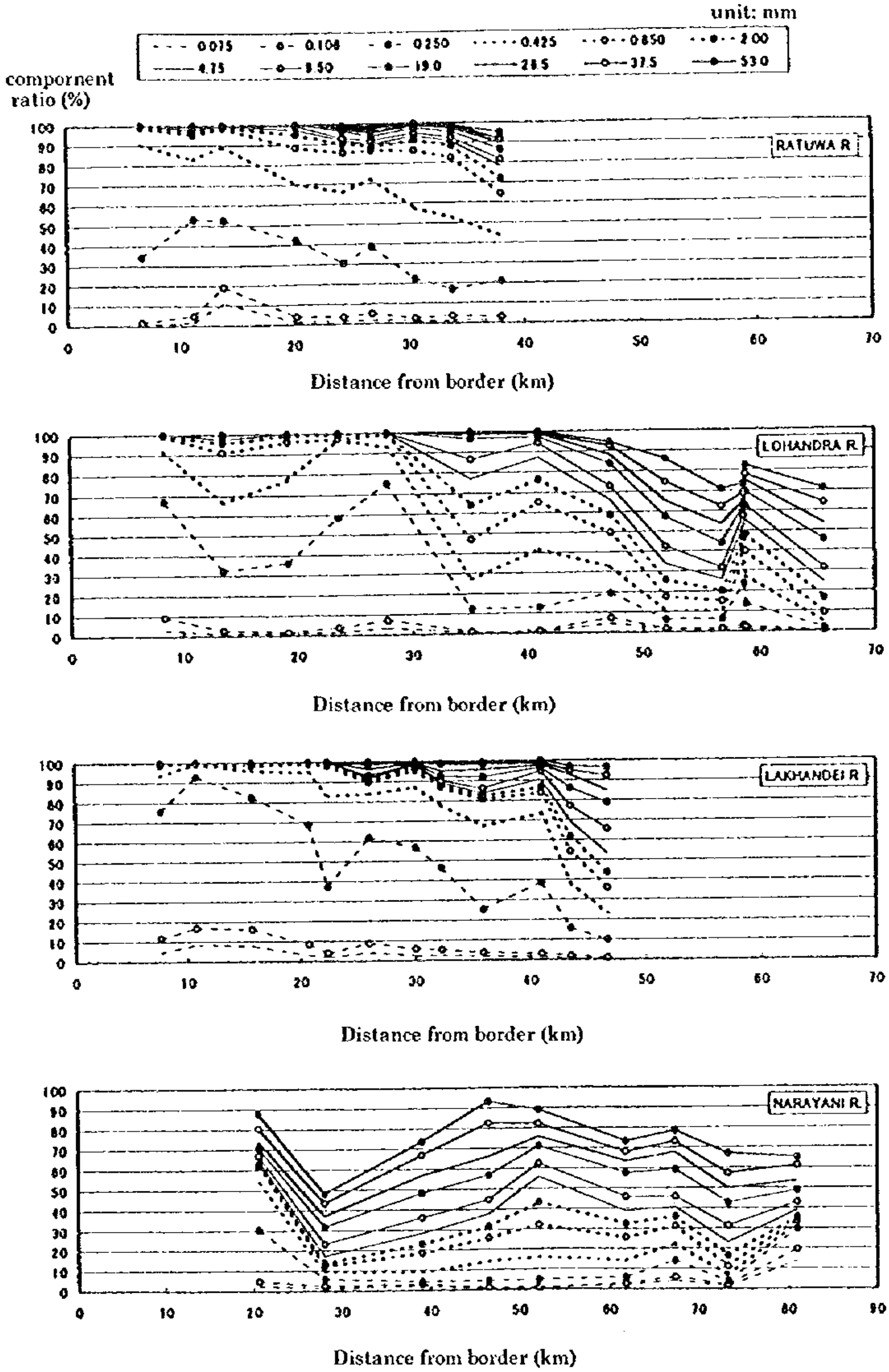
CLASSIFICATION OF RIVERBED MATERIALS

Classification by AGU		Range (mm)
Boulders	Very large boulders	4096～2048
	Large boulders	2048～1024
	Medium boulders	1024～ 512
	Small boulders	512～ 256
Cobbles	Large cobbles	256～128
	Small cobbles	128～64
Gravel	Very coarse gravel	64～32
	Coarse gravel	32～16
	Medium gavel	16～8
	Fine gravel	8～4
	Very fine gravel	4～2
Sand	Very coarse sand	2～1
	Coarse sand	1～0.5
	Medium sand	0.5 ～0.25
	Fine sand	0.25～0.125
	Very fine sand	0.125～0.062
Silt	Coarse silt	0.062～0.031
	Medium silt	0.031～0.016
	Fine silt	0.016～0.008
	Very fine silt	0.008～0.004
Clay	Coarse clay	0.004～0.002
	Medium clay	0.002～0.001
	Fine clay	0.001～0.0005
	Very fine clay	0.0005～0.00024

Table C1.7

EXISTING RIVER FACILITIES

Facility/structure		Ratuwa R.	Lohandra R.	Lakhandei R.	Narayani R.	Tinau R.	W.Rapti R.	Babai R.	Khutiya R.	Total
Embankment	(m)	2	1	2	-		-	2	-	7
Spur	(place)	26	51	48	65	77	81	54	3	405
Revetment	(place)	4	4	0	4	19	15	10	0	56
- Gabion wall		3	1	-	-	11	14	6	-	35
- Retaining wall		-	-	-	2	5	-	2	-	9
- Other wall		1	3	-	2	3	1	2	-	12
Head work	(place)	-	-	-	-	3	1	-	-	4
Bridge	(place)	1	1	2	1	2	3	2	-	12
Total		33	57	52	70	101	100	68	3	484



LONGITUDINAL DISTRIBUTION OF GRAIN SIZE

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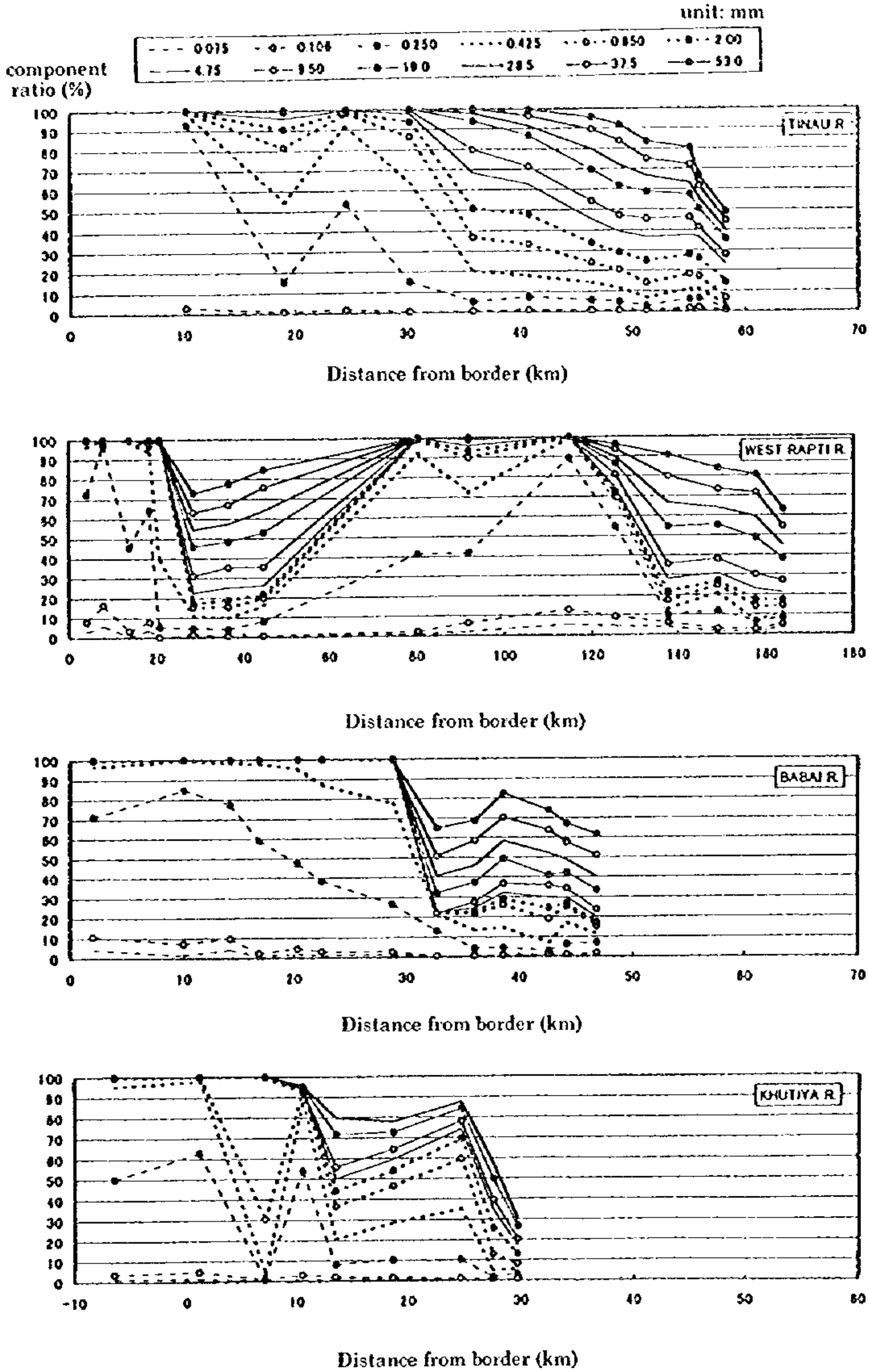

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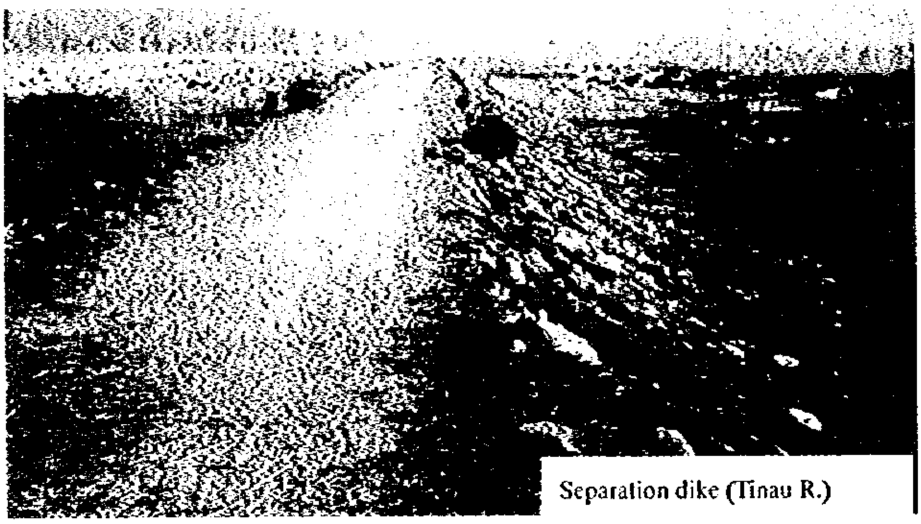
Earth dike (Lohandra R.)



Separation dike (Tinau R.)

Earth dike (Lokhander R.)

TYPICAL RIVER FACILITIES
(DIKE)

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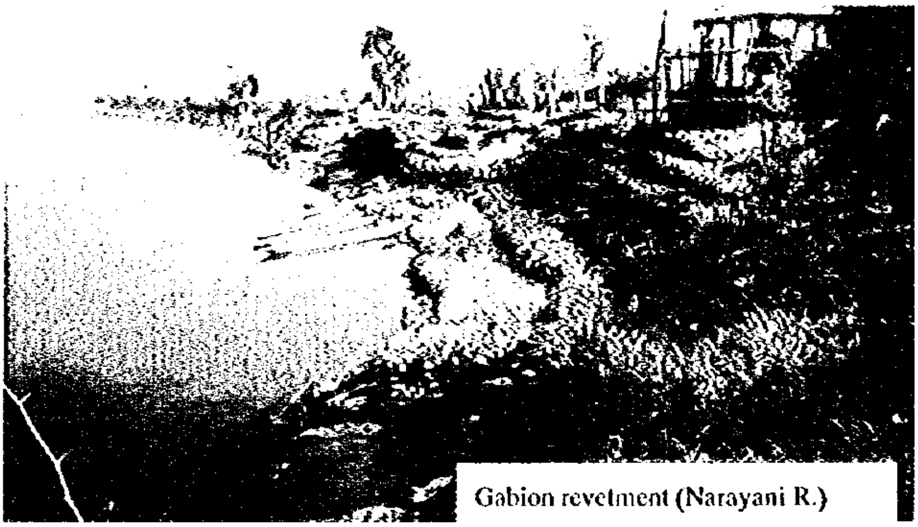
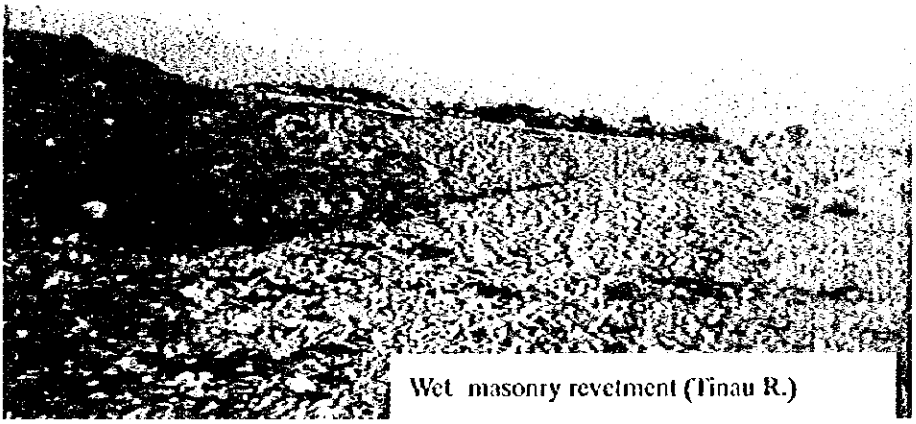
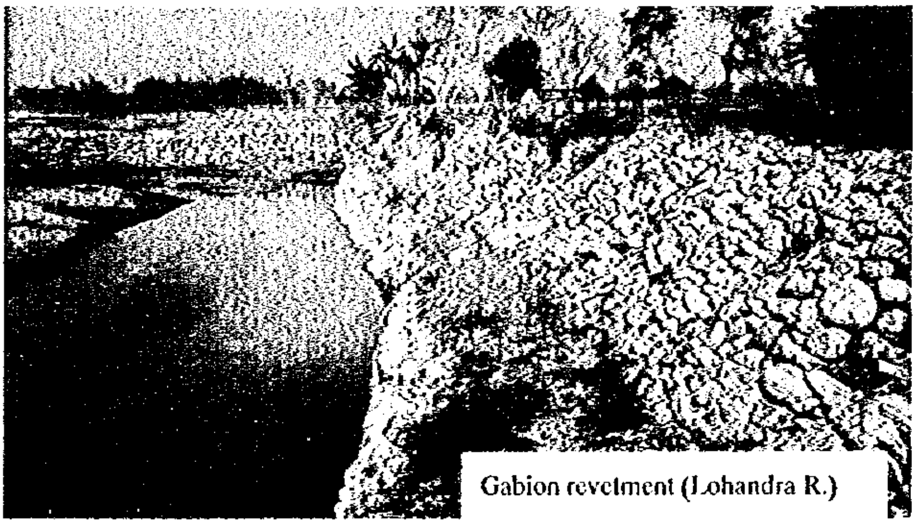


Gabion revetment (Narayani R.)



Wet masonry revetment (Tinau R.)



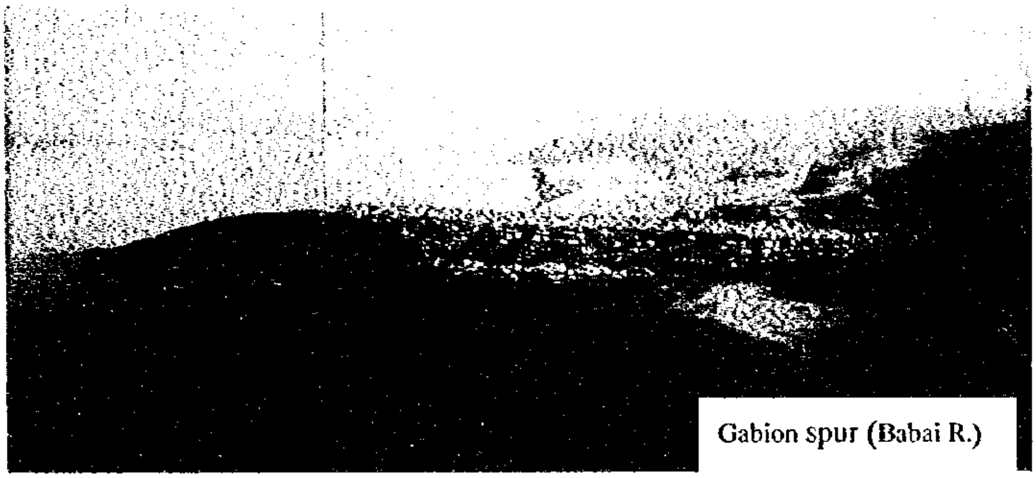
Gabion revetment (Lohandra R.)

TYPICAL RIVER FACILITIES
(REVETMENT)

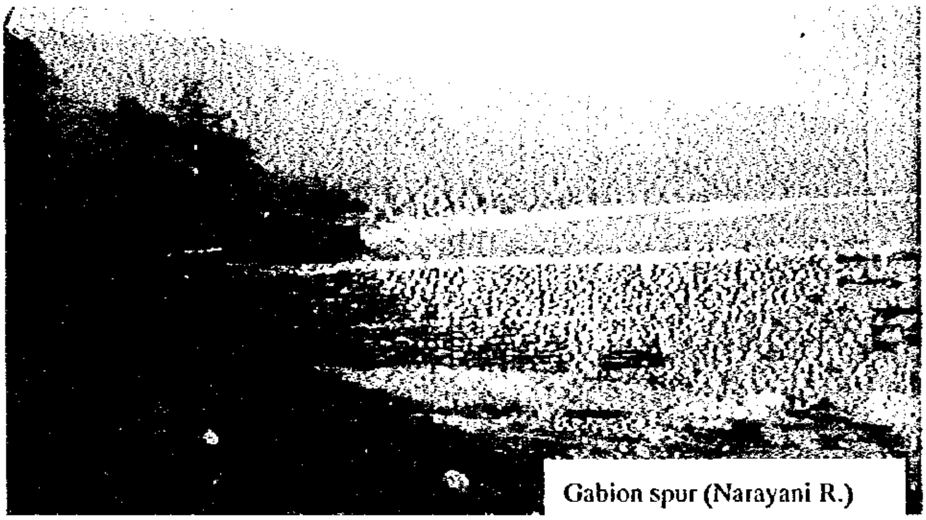
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

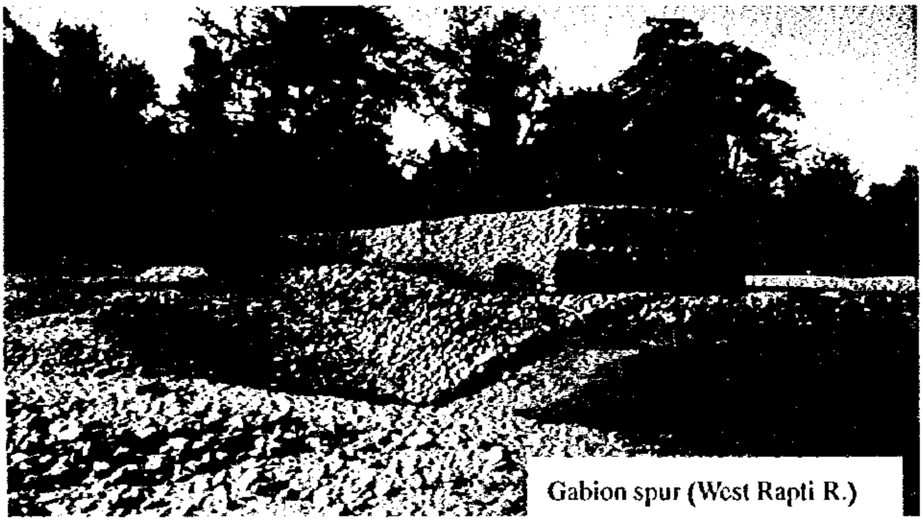
JAPAN INTERNATIONAL COOPERATION AGENCY



Gabion spur (Babai R.)



Gabion spur (Narayani R.)



Gabion spur (West Rapti R.)

TYPICAL RIVER FACILITES (SPUR)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

2. HYDROLOGICAL ANALYSIS

2.1 Rainfall Analysis

Rainfall records of 157 stations over the country were examined based on the annual maximum daily rainfall and annual rainfall for 10 years from 1985 to 1994. Daily rainfall (1-day rainfall) is observed in Nepal for 24 hours from 08:45am to 08:45am in next morning. The annual maximum daily rainfalls of these stations are summarized in Table C2.1. In consideration of location and data availability, 29 stations out of 157 stations were selected for further analysis. Figure C2.1 shows the location of the selected stations.

(1) Probable Daily Rainfall

The annual maximum records of daily rainfall were collected at the selected 29 stations for the probability analysis. Results of the probability analysis by Gumbel method are shown in Table C2.2 with the statistical parameters such as sample size, average, standard deviation and coefficient of variation of each station. The results and observed data for each station are also plotted in Fig. C2.2. In this analysis, two annual maximum records of 373.2 mm in 1993 at station code: 0905 and 453.2 mm in 1990 at station code: 0906 were discarded, since they were abnormally large comparing with other data.

There are numerous class-III rivers originating from the Siwalik hills and rainfall stations for these river basins are small in number. Probable daily rainfall of the class-III river basins were analyzed based on the records as available. The class-III river basins extend over the elevation from 50 to 500 m,MSL. Therefore for the analysis, selected are 17 stations located at elevation less than 500 m,MSL. Figure C2.3 shows a probable daily rainfall of the selected rainfall stations. Typical probable daily rainfall in the class-III river basin is shown below taking an average of 17 stations.

(Probable Daily Rainfall in Class-III River Basin)

Return period (year)	2	5	10	20	50	100
Probable daily rainfall (mm)	147	201	237	271	316	350

(2) 24-hour Rainfall

The relationship between 24-hour rainfall (P_{24}) and daily (P_{day}) rainfall is mentioned in "Design Manuals for Irrigation Projects in Nepal, M.3 Hydrology and Agro-meteorology Manual" as follows:

$$P_{24} = 1.13 \times P_{day} \quad \text{(Using the Herschfield factor)}$$

The relationship between P_{24} and P_{day} was also examined using monthly maximum daily data for 5 years from 1971 to 1975 at Kathmandu airport sta. Code: (1030), and the result is shown in Fig. C2.4. The 24-hour rainfall can be estimated from daily rainfall by the following formula which is applied for the further study in this report:

$$P_{24} = 1.16 \times P_{day} \quad \text{: Kathmandu airport}$$

Probable 24-hour rainfall in the class-III river basin was, thus, estimated using the above formula as follows:

(Probable 24-hour Rainfall in Class-III River Basin)

Return period (year)	2	5	10	20	50	100
Probable daily rainfall (P_{day} mm)	147	201	237	271	316	350
Probable 24-hour rainfall (P_{24} mm)	171	233	275	314	367	406

(3) Rainfall Depth for Short Duration

Records of monthly maximum rainfall for various short duration from 5 minutes to 24 hours are available only at Kathmandu airport sta. code: (1030) for 5 years from 1971 to 1975. Figure C2.5 shows the relations of cumulative rainfall or percentage to corresponding duration. Only the data whose 24-hour rainfall are more than 30mm are plotted. As a typical rainfall pattern in short duration, average of the cumulative percentage of rainfall was estimated as follows:

(Cumulative Rainfall Depth)

Duration (min)	5	10	15	30	60	120	360	720	1440
Cumulative percentage of rainfall (%)	7.8	14.6	20.0	31.4	41.3	54.9	78.2	92.7	100.0

The rainfall intensity in the class-III river basin can be estimated based on the assumption that the rainfall in the Class-III river basin has similar characteristics as those in the Kathmandu. Probable rainfall depth and rainfall intensity for several durations of each return period can be estimated using the relationship mentioned in the previous section. Probable rainfall depth and rainfall intensity is shown in Figs. C2.6 and C2.7.

2.2 Runoff Analysis

(1) Data Collection

Discharge records are available at 62 stations in 7 river basins, namely the Mahakali, Karnali, West Rapti, Narayani, Bagmati, Sapta Koshi and Kankai river basins. A total of 1,217 data were examined for runoff analysis. General conditions of 62 stations and data availability of each station are summarized in Tables C2.3 and C2.4. Figure C2.8 shows the location of these stations.

(2) Instantaneous Peak Discharge and Daily Discharge

Annual instantaneous peak discharge and maximum daily discharge are available in the "Hydrological Records of Nepal" published by Department of Hydrology and Meteorology (DHM). Relationship between the instantaneous peak discharge and the maximum daily discharge of corresponding month are examined and shown in Fig. C2.9 for all of the available data at 62 stations.

According to the result of examination, the relationship between instantaneous peak discharge (Q_p) and maximum daily discharge (Q_{dmax}) in Nepal can be expressed as follows:

$$Q_p = 1.21 \times Q_{dmax}$$

This relationship may change depending on the runoff hydrographs of the respective floods. However, for the planning purpose, this relationship can be applied to estimate the instantaneous peak discharge where only daily runoff data are available.

(3) Probability Analysis

Discharge probability was analyzed by Gumbel method based on the annual maximum (instantaneous) discharge records at 62 stations. The annual maximum discharge records of 5,210 m^3/s in 1968 at station code: 445 and 3,300 m^3/s in 1981 at station code: 610 were discarded, since they were abnormally large comparing with other data. The results of probability analysis at each station are given in Table C2.5 with the statistical parameters. And the result and observed data of each station are plotted in Fig. C2.10 extracting the stations which have records for more than 20 years

In consideration of accuracy and availability of data, results of probability analysis based on data more than 20 years are to be used for further study. There are 32 stations which has annual maximum discharge data more than 20 years.

(4) Relationship between Probable Discharge and Basin Area

Probable specific discharge was studied to grasp the relationship between discharge and catchment area under the same return period. Probable specific discharges of 2-year return period were examined and plotted in Fig. C2.11 with its catchment area using data at 28 stations located at elevation less than 1,000 m,MSL.

Creager's formula is also drawn in the figure to verify application of the formula to this study. Creager's formula is given by:

$$q = CA^{(A^{-0.05}-1)}$$

where q is the specific discharge ($m^3/s/km^2$), A is the catchment area (km^2), and C is the coefficient depending on basin characteristics. Three (3) curves in the figure show Creager's formula for various coefficients of C=25, 6 and 2.

For reference, a relationship is also shown in the figure with a dotted line cited from the "Design Manual for Irrigation Project in Nepal, M.3 Hydrology and Agro-meteorology Manual, February 1990". This relationship is expressed by:

$$Q_2 = 1.8762 \times A^{0.8783}$$

$$q_2 = \frac{1.8762 \times A^{0.8783}}{A} = 1.8762 \times A^{-0.1217}$$

where Q_2 (m^3/s)is the probable discharge of 2-year return period, q_2 ($m^3/s/km^2$) is the probable specific discharge of 2-year return period, and A (km^2) is the catchment area below 3,000 m,MSL.

Based on the distribution of probable specific discharges of 2-year return period shown in Fig. C2.11. It is judged that Creager's formula can be applied for the estimation of discharge with the coefficient (C) ranging form 2 to 25.

(5) Ratio of Probable Discharges

Using the results of probability analysis of the 32 stations, studies were made on the rate of probable discharge (Q_n/Q_2), namely a ratio of any probable discharge (Q_n) to 2-year discharge (Q_2). The ratio of probable discharge is shown in Fig. C2.12.

Thick solid lines in the figure are probable discharges of the stations in the Babai code: (290), West Rapti code: (360) and Narayani code: (450) river basins. Thin solid lines show probable discharge at the stations in the Siwalik basins.

The ratio of probable discharges Q_n/Q_2 for the above three river basins were determined base on the discharge records of their own basins. The ratios of class-III river basins were assumed taking the average ratio excluding Narayani (sta. code: 450) as shown in Fig. C2.12, since no discharge records are available for these basins.

Based on the results of above discussion, probable discharge at a specific point of respective rivers can be estimated by the following equation:

$$Q_n = (Q_n / Q_2) \cdot q_2 \cdot A$$

$$q_2 = C \cdot A^{(A^{-0.05} - 1)}$$

Where Q_n (m^3/s) is the probable discharge of n-year return period, (Q_n/Q_2) is the ratio of probable discharges, q_2 ($m^3/s/km^2$) is the probable specific discharge of 2-year return period, C is the Creager's coefficient depending on the basin characteristics, and A (km^2) is the catchment area. The values of C and Q_n/Q_2 for respective rivers are summarize below.

(Ratio of Probable Discharges to 2-year Discharge)

River	C	Return period (year)						Remarks
		2	5	10	20	50	100	
Ratuwa	6.0	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
Lohandra	6.0	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
Lakhandei	6.0	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
Narayani	25.8	1.00	1.34	1.57	1.79	2.07	2.28	Station 450
Tinau	6.0	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
West Rapti	8.1	1.00	1.57	1.95	2.31	2.78	3.13	Station 360
Babai	11.1	1.00	1.72	2.20	2.66	3.26	3.70	Station 290
Khutiya	6.0	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average

Coefficients C and Q_n for Narayani, West Rapti, Babai river basins were estimated based on records at the stations of Narayani (code: 450), West Rapti (code: 360) and Babai (code: 290), respectively. The Creager's coefficients of other river basins for the Study (Class-III rivers) were assumed commonly C = 6.0 taking the average (Fig. C2.11).

2.3 Flood flow Analysis

(1) Methodology

Flood flow analysis was made using a unsteady flow simulation model. The model mainly consists of channel and flood plain models.

<u>Channel Model</u>

1) Fundamental equations:

$$\frac{\eta}{g}\frac{\partial v}{\partial t}+\frac{a}{2g}\frac{\partial v^2}{\partial x}+\frac{\partial H}{\partial x}+\frac{n^2}{R^{4/3}}v|v|=0$$

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=-q$$

2) Boundary conditions:
   - Upper end: Discharge hydrograph
   - Lower end: Water level hydrograph or stage-discharge curve
3) Channel data: Channel sections surveyed

<u>Flood Plain Model</u>

1) Fundamental equations:

$$\frac{1}{g}\frac{\partial v_p}{\partial t}+\frac{\partial H_T}{\partial l}+f_p v_p|v_p|=0$$

$$F\frac{dH_p}{dt}=Q_{in}-Q_{out}$$

2) Boundary conditions: Various types of boundary conditions such culvert, canal, embankment, etc. can be incorporated at the boundary of plain block.
3) Flood plain data: Plain areas at various elevations for each plain block.

<u>Notations of Above Equations</u>

t : Time

x : Distance along river

v and Q : Channel discharge and velocity

H, A and R : Water level, flow area and hydraulic mean depth

n	: Manning's coefficient of roughness
g	: Acceleration of gravity
η , α	: Coefficients depending on velocity distribution
v_p	: Velocity at the joint of plain blocks
f_p	: Energy loss at the joint of plain blocks
$\delta H_T / \delta l$	: Surface slope in plain block
F, H_p	: Surface area and water level of in plain block
Q_{in} and Q_{out}	: Inflow and outflow of the plain block

The Manning's coefficient of roughness (n) for the Lakhandei and Babai rivers were assumed as follows:

River/Stretch	Perennial Channel	Sand riverbed	Flood plain
Lakhandei R.			
Seg.2-2 (0.0-21.0km)	0.030	0.050	0.1
Seg.2-1 (21.0-37.0km)	0.035	0.060	0.1
Seg.1 (37.0-51.4km)	0.040	0.070	0.1
Babai R.			
Seg.2-2 (0.0-30.0km)	0.030	0.050	0.1
Seg.2-1 (30.0-38.0km)	0.035	0.060	0.1
Seg.1 (38.48.0km)	0.040	0.070	0.1

(2) Runoff Hydrograph

Base-flow Discharge

Base-flow discharge that was the assumed channel flow before and after the flood runoff was studied based on the runoff records for 20 years at Babai river station (No.290). According to the study;

1) Average of annual maximum monthly discharge: 388 m^3/s
2) Average of monthly discharge when the annual maximum discharge occurred: 382 m^2/s

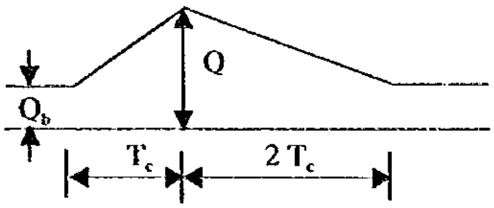
Based on the above, base-flow at Babai river station was assumed to be 390 m^3/sec. Base-flow discharge at respective river sections of interest of the Babai and Lakhandei rivers were assumed applying the same specific base-flow discharge assumed at Babai river station as follows:

$q_b = 390\ m^3/s\ /\ 3{,}002\ km^2 = 0.13\ m^3/s\ /km^2$

$Q_b \quad = 0.13\ m^3/s/\ km^2 \times A(km^2)$

Discharge Hydrograph

The triangular discharge hydrograph was assumed as shown below for the present study, since the actual runoff hydrograph was not available.



Q : Peak discharge
Q_b: Base-flow discharge
T_c : Time of concentration

Recession period of flood is assumed to be twice of time of concentration (T_c). The time of concentration (T_c) was estimated at the Chapani river junction for the Lakhandei river and at Babai barrage for the Babai river, by Kraven's empirical formula for natural mountainous basins as follows:

(Items)	(Lakhandei R.)	(Babai R.)
River length	20 km	154 km
Propagation velocity	3.5 m/s	3.5 m/s
Time of concentration (T_c)	2 hr	12 hr

Hourly discharges were estimated as shown in Tables C2.6 and C2.7 respectively for the Lakhandei and Babai rivers. Runoff from the residual basin is estimated as a balance of discharges at adjacent river sections for runoff calculation.

(3) Results of Simulation

The model was first adjusted for each basin condition using the latest flood data, 1997-flood for the Lakhandei river and 1995-flood for the Babai river. Then the model was run under the following cases for different magnitudes of runoff (1.05, 2, 5, 10, 20, 50 and 100 year probable floods):

1) Flood flow under the present channel conditions
2) Flood flow confined within the present river area.

Results are shown in Fig. C2.13 and Table C2.8 for the Lakhandei river, and Fig. C2.14 and Table C2.9 for the Babai river.

(4) Hydraulic Effects of Grass Belt

Equations

The grass belt placed along the riverbanks will resist against overflowing river water. The grass belt will also trap sediment in the belt and alleviate sedimentation damage in the flood prone area.

The water flow in the grass belt can be expressed by the drag formula as follows:

$$Ie = (\frac{Cd}{2g} \cdot \frac{D}{T^2}) \cdot V^2$$

where

- V: Flow velocity
- C_D: Drag coefficient (C_D=1.2 for cylinder)
- D: Diameter of grass
- T: Center to center distance of grass
- Ie: Energy gradient
- g: Acceleration of gravity (=9.8 m/sec^2)

If the conditions of grass belt are assumed as D=0.5 cm and T=2.5 cm, the following relations are derived from the above equations:

$$Ie = dH / W = 0.489v^2 \qquad \text{(m,sec)}$$

where (dH) is the loss of head through the grass belt width (W).

On the other hand, it is generally known that the sediment particle settles if the shear velocity (U_*) becomes smaller than the settling velocity (ω_o), i.e., $U_*/\omega_o < 1$. The velocity coefficients ($\phi = V/U_*$) of the Lakhandei and Babai rivers were estimated as approximately ϕ =20 for the depth-grain size ratio (H/d)>1000. Therefore, the sediment particles will settle under the following velocity:

$$V < \phi U_* = \phi\, \omega_o = 20\omega_o$$

Critical Grass Belt Width for Sedimentation

Assuming dH=1m, the grass belt width (W) necessary for the settlement of various grain size were estimated using the equations mentioned above as follows:

Items	Grain size (mm)				
	0.062	0.125	0.25	0.5	1.0
Classification	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand
Settling velocity (ωo: cm/s)	0.4	1.5	3.5	6.1	9.6
Critical velocity (Vc: m/s)	0.08	0.3	0.7	1.22	1.92
Critical belt width (Wc: m) for dH=1m	319	23	4.2	1.4	0.6

The above result shows that the fine sand and coarser bed materials will settle within the grass belt of about 25 m width.

Flow Resistance of Grass Belt

The following equation is derived applying Manning's uniform flow formula to the drag formula discussed above:

$$n = R^{2/3} Ie^{1/2} / V = 0.699 R^{2/3} \quad \text{(m, sec)}$$

Where n is Manning's coefficient of roughness and R is hydraulic mean depth.

By using the above equation, flow resistance of grass belt can be evaluated in the term of roughness (n) as a function of hydraulic mean depth (R) as follows.

R(m)	0.2	0.4	0.6	0.8	1.0
n	0.24	0.38	0.50	0.60	0.70

Based on the above, roughness of the grass belt was assumed to be n = 0.5 for the flood flow model.

ANNUAL MAXIMUM 1-DAY RAINFALL

(Unit: mm)

	Code	Station	Elevation	N	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0103	Patan (West)	1,266	10	79	100	75	88.6	81.1	137.5	79.8	90.9	94.6	88
2	0104	Dandeldhura	1,865	10	122	123	52.4	80	62	119.5	92	49.6	82.5	62.4
3	0105	Mahendra Nagar	176	5						297.5	136.4	153.7	141.6	112.4
4	0106	Belauri Santipur	159	8			120.5	84.1	225.3	230.5	115.4	222.1	145.3	98.3
5	0202	Chainpur (West)	1,304	9	107	100	71.5	70.5	67	88	71.5	70		80.2
6	0203	Silgadi Doti	1,360	9	106	101	113.2	78.3	135.3	91.4	65.5	54.5		67.2
7	0207	Tikapur	140	8	152	74	108.6	296	187.2	120.8	210.7	114.9		
8	0208	Sandepani	195	8			139.2	195.3	130.2	200.1	132.2	160.2	135.3	75
9	0209	Dhangadhi	170	10	144	99	135	188	97.5	203.4	144.2	190	119.6	100.4
10	0212	Sitapur	152	8			120	184	127	106.2	134.3	166	122	233.2
11	0214	Kola Gaun	1,304	8			85.6	120.6	121.2	125.1	98.2	83.7	160.5	74.5
12	0215	Godavari (West)	288	10	150	150	82.2	175.7	245.5	166.5	171.7	228	152.5	176.5
13	0218	Dipayal (Doti)	617	10	90	113	66	59.2	107.2	66.6	67.4	46.2	148.4	62.8
14	0303	Jumla	2,300	10	61	53	65.5	39.4	35.5	40.4	46	24.5	53.9	42.5
15	0307	Rara	3,048	8			80	93	41	37	99.6	28.8	68.6	31
16	0310	Dipayal Gaun	2,310	10	64	89	70.2	48.2	35.4	46.5	53.4	32.5	36.5	56
17	0401	Pusma Camp	950	10	101	82	66.5	124.7	144	93.5	91.8	95.8	98	93.5
18	0402	Dailekh	1,402	10	79	79	67.5	72.4	60.4	100.4	61.9	75.6	95.1	96.9
19	0405	Chisapani (Karnali)	225	9		180	98.8	158.6	141.7	200.3	88.7	127	115.3	119.5
20	0406	Surkhet (Birendra Nagar)	720	10	138	281	83.9	169	137.4	84.7	103.2	100.5	112	70.6
21	0407	Kusum	235	7			88.2	146.3	200.9	95.4	91.9		121.3	181.2
22	0408	Gulariya	215	8			124.3	236	105	130.2	95	123	169	94
23	0409	Khajura (Nepalgunj)	190	7		115	87.7	174	176.2	91.5	131.7	162		
24	0412	Naubasta	135	8			70.2	143.8	167	92.5	89.2	96.8	187.2	135.2
25	0413	Shyalo Shree	302	8			170	171.5	161.2	127	106.2	121.5	208.1	102
26	0414	Baijapur	226	8			111.1	82.2	84.9	84.3	40.5	80.3	85.4	120.5
27	0415	Bargadaha	200	8			155.1	218.5	237	118	73.5	71	101	92
28	0416	Nepalgunj (Reg.Off.)	144	10	114	116	155.1	218.5	237	118	100.5	182.5	119	90
29	0417	Rani Janwa Nursery	200	9		112	94.2	187.5	123.4	134.4	50.2	97	144.4	42
30	0419	Sikta	195	8		144		161	149	145	141.6	75.5	145.6	100
31	0504	Libang Gaun	1,270	8			104.7	92.4	100.4	74.2	86.3	60.2	62.3	128
32	0505	Bijuwar Tar	823	8			125.7	71	82.1	88.1	169	78.4	78.6	97.4
33	0507	Nayabasti (Dang)	698	8			146.4	192.1	132.3	82.5	75.7	115.2	76.7	90.3
34	0508	Tulsipur	725	10	161	89	96.9	101.2	120.6	85.3	68	131.5	107.5	60.4
35	0509	Ghorahi (Masina)	725	8			144.3	115.6	96.8	115.6	81.2	73.4	85.3	112.7
36	0510	Loilabas	320	8			159.2	109.5	170.3	91.7	80.4	82.5	192.4	165.3
37	0511	Salyan Bazar	1,457	10	113	94	63	88.6	95	80.5	58	81	70.6	52
38	0512	Luwamjula Bazar	885	8			95.5	83.4	93.3	59.2	81.2	51.2	123.4	41.5
39	0513	Chaur Jhari Tar	910	10	71	80	121	95	85.2	85	69.4	95	67	86
40	0514	Musikot (Rukumkot)	2,100	7		120	96			88.3	92.8	96.5	141	170
41	0601	Jomsom	2,744	10	87	24	43	12	18.4	27	20	16	31.2	18.5
42	0604	Thakmarpha	2,566	9	75	37	53.6	26.2	21	19	25	24	40.3	
43	0605	Baglung	984	9	93	100	98	76.8	104.4	97	85.2	94.4		121
44	0606	Tatopani	1,243	5				70	74	51			58.2	56.8
45	0607	Lete	2,384	7			112	80	73	68		44.4	49	68.5
46	0608	Ranipauwa (M.Nath)	3,609	7			16	15	16.3		14.5	11.3	10.4	13.5
47	0609	Beni Bazar	835	4				99.7	70.6	70.2			200	
48	0610	Ghami (Mustang)	3,465	5			43			27	18.5	11.3	26	
49	0612	Mustang (Lomanglang)	3,705	7	26	20	45.1	12.1	18	18.7				20
50	0613	Karki Neta	1,720	7			120	120.1	119	163.2		125.7	104.7	120
51	0614	Kushma	891	8			94.9	71.5	109	150	95	131	106.5	113
52	0615	Bobang	2,273	7			115.2	82.4	102	80.5		105.5	91.5	120
53	0616	Gurja Khani	2,530	8			85.4	71.1	68.2	60	62	60.2	72	65
54	0619	Ghorapani	2,742	8			93.7	110	130.5	140.5	100	95	101.5	110
55	0620	Tribeni	0	5						111.3	100.8	158.6	136	99.1
56	0701	Ridi Bazar	442	8			100.5	77.4	98.8	80.5	130.4	79.5	107	118
57	0702	Tansen	1,067	5	123	128	118.4	88						155.6
58	0703	Butwal	205	10	131	190	240.4	200.5	163.9	290.5	143	97.5	171	178
59	0704	Beluwa (Girwari)	150	8			166.4	204.3	203.4	270.3	171.8	117.6	182.4	269.2
60	0705	Bhairhawa Airport	109	10	102	146	115.8	166.1	171.6	154.1	140	111.3	130.6	176.5
61	0706	Dunkauli	154	10	156	128	101.8	117.2	115.5	269	140	119	289	220
62	0707	Bhairhawa (Agric)	120	10	96	175	140.8	177.1	193.4	182.2	88.4	94.5	193.4	174.2
63	0710	Dumkibas	164	3					50.3	329				173
64	0715	Khanchikot	1,760	9	155	123	166.3	131.7	258.3	79.8	104.7	82		110.8
65	0716	Taulihawa	94	9	142	299	117	112.2	171.6	138.5	186	109.2	167.2	
66	0721	Pattharkot (West)	200	8			296	128.5	116	88.5	175	178	178	180
67	0722	Musikot	1,280	8			130.2	128.2	95	80	127	80	200.2	120.2
68	0723	Bhagwanpur	80	8			154	224.5	195.2	113.8	104	112	206	126
69	0725	Tamghas	1,530	10	142	115	112	87.5	132.5	58.1	93.5	89.5	94	107
70	0726	Gagarkot	500	7			132.5	127.5	236.4		173.5	115.2	163.7	94.4
71	0727	Lumbini	95	8			85.3	144.7	170	200.9	85.4	123	162.3	80.9

ANNUAL MAXIMUM 1-DAY RAINFALL

(Unit: mm)

	Code	Station	Elevation	N	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
72	0728	Simari	154	9	199	166	212.5	129.8	144	140	84	84		134
73	0801	Jagat (Setibas)	1,334	5			130.5	41.9	42		12.4	19.8		
74	0802	Khudi Bazar	823	9	115	281	156	130	117	135.5	138	150		128
75	0803	Pokhara (Hospital)	866	0										
76	0804	Pokhara Airport	827	10	235	143	196.4	166.6	168.3	157.9	167.4	148.1	145.2	199.2
77	0805	Syangja	868	10	120	100	106.8	168.5	105.5	135.5	127.5	160.5	97.2	123
78	0806	Larke Sando	3,650	8			25.5	80.8	80.5	45.8	25.7	20.8	45.7	96
79	0807	Kunchha	855	8			138.5	168.5	163.2	276.4	145.2	165.2	141.3	135.6
80	0808	Bandipur	965	7			126	160	96.4	126.2		50.4	45	60.4
81	0809	Gorkha	1,097	9	89	95	134.3	100	75.9	105	90.2		78	117.2
82	0810	Chapkot	460	10	89	127	155	141	150.5	135	150	94	136.5	91.5
83	0811	Malepatan (Pokhara)	856	8	206	115	138.5	154.6	184.2	152			179.2	264.6
84	0813	Bhadaure Deurali	1,600	8			128	300	170.6	201	150	110	90.4	90
85	0814	Lumle	1,740	10	163	170	189.5	156	156	205.7	216	163.5	272	252.5
86	0815	Khairini Tar	500	10	91	108	166	168	140.7	120	90.9	142.5	162.2	173.3
87	0816	Chame	2,680	5						42.3	32	27	42	32
88	0817	Damauli	358	8			197	128	143	79	81	78	87.2	79
89	0818	Lamachaur	1,070	7				140	178.5	160.6	150.8	148.2	140.6	140.6
90	0821	Ghandruk	1,960	6				89.5		93	91.5	71.4	182.2	113.2
91	0823	Gharedhunga	1,120	8			181.3	131.3	128.5	128.3	145.3	102.6	65	143.6
92	0824	Sikesh	1,820	8			242.1	135.4	119.2	166.8	124.8	83.8	119.1	182
93	0902	Rampur	256	10	117	113	203.4	135	110	96.8	126.1	86.6	227.5	175.9
94	0903	Jhawani	270	8			71	62	55	162.4	90	84.7	74	208
95	0904	Chisapani Gadhi	1,706	8			126	106.8	84	137	106	58	295	96.4
96	0905	Daman	2,314	10	97	151	124.5	61.5	76	100.8	69	55	373.2	74.5
97	0906	Hetaunda N.F.I	474	10	159	190	223	103.5	152	453.2	94.4	115.2	257	124
98	0909	Simara Airport	130	10	240	267	300.3	199.8	77	151.7	205.7	118.8	228	137.8
99	0911	Parwanipur	115	10	210	227	320	257.7	88.3	118.7	149.5	120	182.3	117.5
100	0912	Ramoli Bairiya	152	8			140.5	127.5	65	172.5	165.4	92.5	195.5	170.5
101	0917	Hetaunda (Ind Dis)	466	4			155.7	89	166.8	438				
102	0919	Makwanpur Gadhi	1,030	7				58	129.3	247.5	200	55.4	205.3	105
103	0920	Beluwa	274	8			108.8	113.2	120	230.4	131.4	70.4	220	304.3
104	0922	Gaur	90	8			236.5	113.7	83	94.5	90	235	146	105.5
105	1001	Timure	1,900	7			156	84	31.4	191.2	40	40.5		42
106	1002	Aru Ghat D.Bazar	518	8			140	94.4	80.4	90	84.5	90.4	90	91.4
107	1003	Trishuli	595	1										134.8
108	1004	Nuwakot	1,003	8	128	132	138			60	62.4	55	55.5	45
109	1005	Dhading	1,420	8			115	74	75	95	62.4	55	55.5	45
110	1007	Kakani	2,064	8	100	116	88	83.2	132	97.6	85.5		85.2	
111	1016	Sarmathang	2,625	3	123	123					84			
112	1022	Godavari	1,400	10	120	96	172	63.5	68.2	110	92.8	84.2	113.3	117.6
113	1029	Khumaltar	1,350	9	72	73	118	78	51	62.6	44.2		88.2	66
114	1030	Kathmandu Airport	1,336	10	69	78	124.4	66	57	73.2	74.2	45.2	62.8	99
115	1036	Panchkhal	865	7	121			74.3	52	74	54.5	69.5	50.3	
116	1038	Dhunibesi	1,085	9	70	109	102.3	124.7	80.6	86.5		92.5	194	88.3
117	1039	Panipokari (Kathmandu)	1,335	5	66	103	147.6				92.2	48.4		
118	1043	Nagarkot	2,163	7		179	90.6	72.4		101.2	92.5	86.8		98
119	1054	Thamachit	1,847	8			21	21.4	21	16	12	9	9	8
120	1055	Dhunche	1,982	2			82	138						
121	1057	Pansayakhola	1,240	4		100					105	82		48
122	1062	Sangachok	1,327	6	73	78	95		75.2	62.4	80			
123	1103	Jiri	2,003	8	76	67		78.5	113.8	71	85		77.2	79.6
124	1107	Sindhuli Gadhi	1,463	4			172	110	89.5					111.8
125	1109	Pattharkot (East)	275	8			190.2	302.8	109.8	126.2	80.8	175.2	437	133.1
126	1110	Tulsi	457	8			233.8	182.3	118.2	123.5	164.2	69.4	145.3	114.3
127	1111	Janakpur Airport	90	10	132	126	302	128.6	113.5	73.8	110	100.8	192	151.4
128	1118	Manusmara	100	7			283		109.2	196	106.3	85	120	152
129	1119	Gausala	200	7			115.5	60	50.5		50.4	60	80	90.5
130	1120	Malangwa	150	8			363.9	128.2	107	156	252	104	128	106
131	1121	Karmaiya	131	4	123		183	121		123.4				
132	1122	Jalesore	0	4						86	82		128	86
133	1206	Okhaldhunga	1,720	10	81	73	140.3	123.1	98.7	105.5	150	111.4	75.4	65.4
134	1212	Phatepur	100	7	55	115	270	95	201		120			102
135	1215	Lahan	138	10	183	117	228	143.8	128	87	126	120	116	171.5
136	1220	Chialsa	2,770	9	74	110	96.7	69	84	57	68		76	66
137	1223	Rajbiraj	91	10	149	97	170	125	92	143	90	95.2	159	137
138	1303	Chainpur (East)	1,329	10	70	44	123.2	69.3	53.4	90.2	110.3	67.5	59.2	56.3
139	1304	Pakhribvas	1,680	8	114	113	137.3	73.7			97.3	112.2	84.2	108.7
140	1307	Dhankuta	1,445	10	77	66	164.2	57.6	81.4	104.7	51.6	53.2	59.2	84.8
141	1311	Dharan Bazar	444	7			302.5	235		180	129.2	96.2	87.4	246.3
142	1312	Haraincha	152	8			223.6	184.4	141.2	120.7	130.5	156.7	152.4	133.8

ANNUAL MAXIMUM 1-DAY RAINFALL

(Unit: mm)

	Code	Station	Elevation	N	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
143	1313	Biratnagar (City)	67	0										
144	1319	Biratnagar Airport	72	10	123	101	219.1	93.3	169	125.4	86.2	139.3	114	60.8
145	1320	Tarahara	200	9	93	160	377.6	98	240	131	125.9		182.1	114.8
146	1323	Dharan British Camp	400	5		86	345.6					97	104.5	285
147	1324	Bhojpur	1,595	8	108		106.7	54.7	103.2		53.5	54.2	45.5	59.7
148	1405	Taplejung	1,732	10	84	63	129.6	75.8	66.2	134.7	65.8	47.4	80.1	129.8
149	1407	Iam Tea Estate	1,300	10	127	177	178	82	124	123	108	84	77.8	131.2
150	1408	Damak	163	8			300.5	152.5	194.5	156	170.2	80.2	162.1	131.8
151	1409	Anarmani Birta	122	8			178	168	168	175	210	196.2	166.2	137.7
152	1410	Himali Gaun	1,654	8			201	159.5	170	152.9	125.5	90	87.5	81.4
153	1411	Soktim Tea Estate	530	4			186.5	144.5	185	258				
154	1412	Chandra Gadhi	120	7			155	100	200.1	222.3		93.4	211.3	120.6
155	1415	Sanischare	168	8			227	153	162	166	245	188.2	284	164
156	1416	Kanyam Tea Estate	1,678	10	352	222	258.2	188	315.3	146	184.7	131.8	128.4	112
157	1421	Gaida (Kankai)	143	10	207	150	243	147	191	215	198	151.5	150	188.4

PROBABILITY ANALYSIS FOR DAILY RAINFALL

No.	Code	Station	Elevation (m)	R max (mm)	Statistical Parameters				a	x_0	Return Period					
					N	x_{MEAN}	S_x	C_V			2	5	10	20	50	100
1	0209	Dhangadhi	170	267.	20	135	61.68	46%	0.01723	104.62	126	192	235	277	331	372
2	0215	Godavari (West)	288	245.5	15	170	39.69	23%	0.02571	150.03	164	208	238	266	302	329
3	0401	Pusma Camp	950	230.	24	110	42.00	38%	0.02587	89.72	104	148	177	205	241	268
4	0416	Nepalgunj (Reg.Off.)	144	310.	20	157	62.43	40%	0.01703	126.33	148	214	259	301	356	397
5	0508	Tulsipur	725	184.	25	106	32.36	31%	0.03373	90.14	101	135	157	178	206	227
6	0510	Loilabas	320	192.4	8	131	42.14	32%	0.02146	108.85	126	179	214	247	291	323
7	0703	Butwal	205	309.	24	193	55.70	29%	0.01951	165.75	185	243	281	318	366	402
8	0705	Bhairhawa Airport	109	252.	25	148	40.97	28%	0.02664	127.99	142	184	212	239	274	301
9	0706	Dunkauli	154	289.	23	158	51.55	33%	0.02097	132.96	150	204	240	275	319	352
10	0707	Bhairhawa (Agric)	120	292.	22	154	53.01	35%	0.02029	127.68	146	202	239	274	320	354
11	0725	Tamghas	1,530	142.	15	108	21.17	20%	0.04822	96.90	105	128	144	159	178	192
12	0804	Pokhara Airport	827	278.	25	179	34.11	19%	0.03200	162.13	174	209	232	255	284	306
13	0805	Syangja	868	241.	21	151	51.29	34%	0.02085	125.99	144	198	234	268	313	347
14	0810	Chapkot	460	342.	24	157	60.33	38%	0.01801	127.57	148	211	253	293	344	383
15	0814	Lumle	1,740	277.	25	196	39.30	20%	0.02777	176.71	190	231	258	284	317	342
16	0815	Khairini Tar	500	182.	21	136	27.02	20%	0.03958	122.71	132	161	180	198	221	239
17	0902	Rampur	256	227.5	25	147	46.67	32%	0.02339	124.02	140	188	220	251	291	321
18	0905	Daman	2,314	234.	23	116	47.07	41%	0.02297	93.06	109	158	191	222	263	293
19	0906	Hetaunda N.F.I	474	261.	23	162	51.20	32%	0.02112	136.77	154	208	243	277	322	355
20	0909	Simara Airport	130	300.3	24	166	66.22	40%	0.01641	133.72	156	225	271	315	372	414
21	0911	Parwanipur	115	320.	25	152	65.61	43%	0.01663	119.69	142	210	255	298	354	396
22	1022	Godavari	1,400	172.	25	107	27.77	26%	0.03930	93.82	103	132	151	169	193	211
23	1030	Kathmandu Airport	1,336	124.4	25	78	17.63	23%	0.06192	69.44	75	94	106	117	132	144
24	1111	Janakpur Airport	90	302.	25	128	58.36	45%	0.01870	99.98	120	180	220	259	309	346
25	1215	Lahan	138	228.	25	141	42.39	30%	0.02575	120.60	135	179	208	236	272	299
26	1319	Biratnagar Airport	72	219.1	25	139	37.22	27%	0.02932	121.30	134	172	198	223	254	278
27	1407	Ilam Tea Estate	1,300	180.	25	120	35.48	30%	0.03076	102.88	115	152	176	199	230	252
28	1416	Kanyam Tea Estate	1,678	352.	23	190	61.58	32%	0.01756	160.37	181	246	289	330	383	422
29	1421	Gaida (Kankai)	143	243.	11	179	33.68	19%	0.02873	161.93	175	214	240	265	298	322

LIST OF DISCHARGE OBSERVATION STATIONS

No.	Code	River	Catchment	Qmax	q=Qmax/A	N	N≧20	Remarks
1	120.	Chamelia	1,150	417.	0.36	25	O	Mahakali Basin
2	170.	Surnagad	118	373.	3.16	19		Mahakali Basin
3	220.	Tila Nala	1,870	420.	0.22	8		Karnali Basin
4	225.	Sinja Khola	824	320.	0.39	13		Karnali Basin
5	240.	Karnali	19,260	5,050.	0.26	32	O	Karnali Basin
6	250.	Karnali	21,240	9,600.	0.45	31	O	Karnali Basin
7	260.	Seit	7,460	7,030.	0.94	31	O	Karnali Basin
8	265.	Thulo Bheri	6,720	1,370.	0.20	5		Karnali Basin
9	270.	Bheri	12,290	5,610.	0.46	28	O	Karnali Basin
10	280.	Karnali	42,890	21,700.	0.51	32	O	Karnali Basin
11	290.	Babai	3,000	6,480.	2.16	20	O	Babai Basin
12	330.	Mari Khola	1,980	1,100.	0.56	27	O	West Rapti Basin
13	339.5	Jhimruk Khola	683	2,170.	3.18	20	O	West Rapti Basin
14	340.	Jhimruk Khola	696	263.	0.38	6		West Rapti Basin
15	350.	Rapti	3,380	3,000.	0.89	16		West Rapti Basin
16	360.	Rapri	5,150	5,730.	1.11	27	O	West Rapti Basin
17	404.7	Myagdi Khola	1,112	892.	0.80	7		Narayani Basin
18	410.	Kali Gandaki	6,630	3,300.	0.50	29	O	Narayani Basin
19	415.	Andhi Khola	476	1,590.	3.34	27	O	Narayani Basin
20	417.	Badigad Khola	1,990	1,370.	0.69	15		Narayani Basin
21	420.	Kali Gandaki	11,400	7,400.	0.65	25	O	Narayani Basin
22	428.	Mardi Khola	160	406.	2.54	16		Narayani Basin
23	430.	Seti Khola	582	900.	1.55	21	O	Narayani Basin
24	438.	Madi	858	2,570.	3.00	13		Narayani Basin
25	439.3	Khudi Khola	151	124.	0.82	10		Narayani Basin
26	439.7	Marsyangdi	4,088	2,560.	0.63	7		Narayani Basin
27	439.8	Marsyangdi	3,850	3,790.	0.98	13		Narayani Basin
28	440.	Chepe Khola	308	826.	2.68	30	O	Narayani Basin
29	445.	Burhi Gandaki	4,270	5,210.	1.22	27	O	Narayani Basin
30	446.8	Phalankhu Khola	162	510.	3.15	15		Narayani Basin
31	447.	Trisuli	4,110	2,280.	0.55	26	O	Narayani Basin
32	448.	Tadi Khola	653	1,700.	2.60	19		Narayani Basin
33	450.	Narayani	31,100	25,700.	0.83	30	O	Narayani Basin
34	460.	Rapti	579	1,290.	2.23	28	O	Narayani Basin
35	465.	Manahari Khola	427	1,450.	3.40	28	O	Narayani Basin
36	470.	Lothar Khola	169	650.	3.85	27	O	Narayani Basin
37	505.	Bagmati	17	53.2	3.13	29	O	Bagmati Basin
38	536.2	Bishnumati Khola	4	7.3	1.83	18		Bagmati Basin
39	540.	Nakhu Khola	43	181.	4.21	18		Bagmati Basin
40	550.	Bagmati River	585	876.	1.50	18		Bagmati Basin
41	565.	Kulekhani Khola	122	136.	1.11	3		Bagmati Basin
42	570.	Kulekhani Khola	126	571.	4.53	15		Bagmati Basin
43	589.	Bagmati	2,700	7,600.	2.81	12		Bagmati Basin
44	590.	Bagmati	2,720	9,000.	3.31	15		Bagmati Basin
45	604.5	Arun	28,200	4,190.	0.15	16		Koshi Basin
46	606.	Arun	30,380	5,550.	0.18	5		Koshi Basin
47	610.	Bhote Kosi	2,410	3,300.	1.37	25	O	Koshi Basin
48	620.	Balephi Khola	629	1,450.	2.31	29	O	Koshi Basin
49	627.5	Melamchi Khola		33.1		4		Koshi Basin
50	630.	Sunkosi	4,920	5,100.	1.04	27	O	Koshi Basin
51	640.	Rosi Khola	87	167.	1.92	22	O	Koshi Basin
52	647.	Tamakosi	2,753	960.	0.35	15		Koshi Basin
53	650.	Khimti Khola	313	2,420.	7.73	15		Koshi Basin
54	652.	Sunkosi	10,000	15,600.	1.56	21	O	Koshi Basin
55	660.	Likhu Khola	823	860.	1.04	26	O	Koshi Basin
56	668.4	Taktor Khola	87	35.6	0.41	5		Koshi Basin
57	670.	Dudh Kosi	4,100	11,600.	2.83	27	O	Koshi Basin
58	680.	Sun Kosi	17,600	9,390.	0.53	20	O	Koshi Basin
59	690.	Tamur	5,640	6,700.	1.19	26	O	Koshi Basin
60	695.	Sapta Koshi	54,100	23,600.	0.44	10		Koshi Basin
61	728.	Mai Khola	377	1,510.	4.01	8		Kankai Basin
62	795.	Kankai Mai	1,148	7,500.	6.53	20	O	Kankai Basin

AVAILABILITY OF DISCHARGE DATA

No.	Code	Basin	River	1960's								1970's										1980's										1990's				N
				2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	
1	120.	Mahakali Basin	Chamelia				=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		=	=	=	=	=	=	=				25
2	170.	Mahakali Basin	Surnagad					=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=										19
3	220.	Karnali Basin	Tila Nala																=	=		=	=	=	=		=	=								8
4	225.	Karnali Basin	Sinja Khola																	=	=	=	=	=	=	=	=	=	=	=	=	=				13
5	240.	Karnali Basin	Karnali	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	32
6	250.	Karnali Basin	Karnali		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	31
7	260.	Karnali Basin	Seti		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	31
8	265.	Karnali Basin	Thulo Bheri																									=	=	=	=	=				5
9	270.	Karnali Basin	Bheri		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				28
10	280.	Karnali Basin	Karnali	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	32
11	290.	Babai Basin	Babai						=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=								20
12	330.	West Rapti Basin	Mari Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
13	339.5	West Rapti Basin	Jhimruk Khola										=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				20
14	340.	West Rapti Basin	Jhimruk Khola				=	=	=	=	=	=																								6
15	350.	West Rapti Basin	Rapti														=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				16
16	360.	West Rapti Basin	Rapri			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
17	404.7	Narayani Basin	Myagdi Khola																									=	=	=	=	=	=	=		7
18	410.	Narayani Basin	Kali Gandaki			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		29
19	415.	Narayani Basin	Andhi Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
20	417.	Narayani Basin	Badigad Khola															=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				15
21	420.	Narayani Basin	Kali Gandaki			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		=	=	=		=	=	=	=				25
22	428.	Narayani Basin	Mardi Khola													=		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				16
23	430.	Narayani Basin	Seti Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=										21
24	438.	Narayani Basin	Madi																	=	=	=	=	=	=	=	=	=	=	=	=	=				13
25	439.3	Narayani Basin	Khudi Khola																						=	=	=	=	=		=	=	=	=	=	10
26	439.7	Narayani Basin	Marsyangdi																										=	=	=	=	=	=	=	7
27	439.8	Narayani Basin	Marsyangdi												=	=	=	=	=	=	=	=	=	=	=	=	=									13
28	440.	Narayani Basin	Chepe Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	30
29	445.	Narayani Basin	Burhi Gandaki			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
30	446.8	Narayani Basin	Phalankhu Khola										=	=	=	=	=	=	=	=	=	=	=	=	=	=	=									15
31	447.	Narayani Basin	Trisuli						=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		26
32	448.	Narayani Basin	Tadi Khola							=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=								19
33	450.	Narayani Basin	Narayani		=	=	=	=	=	=	=	=	=	=	=	=	=		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	30
34	460.	Narayani Basin	Rapti		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				28
35	465.	Narayani Basin	Manahari Khola		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				28
36	470.	Narayani Basin	Lothar Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
37	505.	Bagmati Basin	Bagmati		=	=	=	=	=	=	=	=	=	=		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		=	=	29
38	536.2	Bagmati Basin	Bishnumati Khola							=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=									18
39	540.	Bagmati Basin	Nakhu Khola		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=														18
40	550.	Bagmati Basin	Bagmati River		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=														18
41	565.	Bagmati Basin	Kulekhani Khola															=	=	=																3
42	570.	Bagmati Basin	Kulekhani Khola		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=																	15
43	589.	Bagmati Basin	Bagmati																		=	=	=	=	=	=	=	=	=	=	=	=				12
44	590.	Bagmati Basin	Bagmati				=	=	=	=	=	=	=	=	=	=	=	=	=	=	=															15
45	604.5	Koshi Basin	Arun														=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				16
46	606.	Koshi Basin	Arun																									=	=	=	=	=				5
47	610.	Koshi Basin	Bhote Kosi				=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		=	=	=	=				25
48	620.	Koshi Basin	Balephi Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=		=	=	=	=	=	=	29
49	627.5	Koshi Basin	Melamchi Khola																													=	=	=	=	4
50	630.	Koshi Basin	Sunkosi			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
51	640.	Koshi Basin	Rosi Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=									22
52	647.	Koshi Basin	Tamakosi										=	=	=	=	=	=	=	=	=	=	=	=	=	=	=									15
53	650.	Koshi Basin	Khimti Khola																		=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	15
54	652.	Koshi Basin	Sunkosi							=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=						21
55	660.	Koshi Basin	Likhu Khola			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=					26
56	668.4	Koshi Basin	Taktor Khola																									=	=	=	=	=				5
57	670.	Koshi Basin	Dudh Kosi			=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				27
58	680.	Koshi Basin	Sun Kosi					=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=									20
59	690.	Koshi Basin	Tamur				=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				26
60	695.	Koshi Basin	Sapta Koshi																=	=	=	=		=	=	=	=	=	=							10
61	728.	Kankai Basin	Mai Khola																						=	=	=	=	=	=	=	=				8
62	795.	Kankai Basin	Kankai Mai										=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=				20

(Note) N: Years of available data

ESTIMATED PROBABLE DISCHARGE

No.	Code	River	Catchment	Elevation	Statistical Parameters				Return Period					
					N	x_{MEAN}	S_x	C_V	2	5	10	20	50	100
1	120.	Chamelia	1,150	-	25	243	60.78	25%	234	297	339	379	430	469
2	170.	Surnagad	118	1,110	19	151	84.28	56%	138	229	289	346	420	476
3	220.	Tila Nala	1,870	-	8	321	81.39	25%	310	412	480	545	628	691
4	225.	Sinja Khola	824	-	13	185	57.08	31%	177	242	285	326	379	419
5	240.	Karnali	19,260	629	32	2,358	717.06	30%	2248	2974	3455	3916	4513	4960
6	250.	Karnali	21,240	320	31	3,613	1664.43	46%	3358	5049	6168	7242	8632	9673
7	260.	Seti	7,460	328	31	2,965	1494.50	50%	2736	4254	5259	6223	7471	8406
8	265.	Thulo Bheri	6,720	-	5	1,024	187.25	18%	1002	1270	1447	1617	1837	2002
9	270.	Bheri	12,290	246	28	3,439	1134.32	33%	3267	4431	5201	5941	6897	7614
10	280.	Karnali	42,890	191	32	9,600	3323.60	35%	9091	12456	14685	16822	19589	21662
11	290.	Babai	3,000	192	20	2,601	1604.55	62%	2364	4075	5208	6294	7701	8755
12	330.	Mari Khola	1,980	536	27	569	205.12	36%	538	749	889	1023	1197	1327
13	339.5	Jhimruk Khola	683	-	20	568	442.82	78%	503	975	1288	1588	1976	2267
14	340.	Jhimruk Khola	696	692	6	191	52.20	27%	184	255	302	346	404	448
15	350.	Rapti	3,380	381	16	1,473	527.02	36%	1397	1977	2361	2729	3205	3562
16	360.	Rapti	5,150	218	27	2,339	1193.39	51%	2157	3386	4200	4980	5991	6748
17	404.7	Myagdi Khola	1,112	-	7	585	160.98	28%	564	773	911	1043	1215	1343
18	410.	Kali Gandaki	6,630	546	29	1,823	473.99	26%	1751	2236	2556	2864	3262	3561
19	415.	Andhi Khola	476	543	27	590	279.77	47%	548	836	1027	1210	1446	1624
20	417.	Badigad Khola	1,990	-	15	860	234.43	27%	826	1087	1259	1424	1638	1799
21	420.	Kali Gandaki	11,400	198	25	4,341	1430.28	33%	4126	5611	6595	7538	8759	9674
22	428.	Mardi Khola	160	-	16	167	79.56	48%	155	243	300	356	428	482
23	430.	Seti Khola	582	830	21	411	210.92	51%	379	603	751	893	1077	1214
24	438.	Madi	858	-	13	871	567.11	65%	792	1436	1863	2272	2802	3199
25	439.3	Khudi Khola	151	-	10	50	27.15	55%	46	78	100	120	147	167
26	439.7	Marsyangdi	4,088	354	7	1,470	493.84	34%	1407	2047	2470	2877	3403	3797
27	439.8	Marsyangdi	3,850	320	13	1,648	695.21	42%	1551	2341	2864	3366	4015	4502
28	440.	Chepe Khola	308	442	30	277	144.72	52%	255	403	500	594	715	806
29	445.	Burhi Gandaki	4,270	485	26	765	188.88	25%	737	932	1061	1185	1346	1466
30	446.8	Phalankhu Khola	162	630	15	198	130.24	66%	180	324	420	512	631	720
31	447.	Trisuli	4,110	600	26	1,174	446.57	38%	1107	1569	1874	2168	2547	2832
32	448.	Tadi Khola	653	475	19	722	433.25	60%	659	1124	1432	1727	2109	2396
33	450.	Narayani	31,100	180	30	12,917	4142.16	32%	12285	16505	19300	21980	25450	28050
34	460.	Rapti	579	332	28	599	294.20	49%	555	856	1056	1248	1496	1682
35	465.	Manahari Khola	427	305	28	528	388.04	74%	469	867	1130	1383	1710	1956
36	470.	Lothar Khola	169	336	27	340	141.34	42%	319	464	561	653	773	862
37	505.	Bagmati	17	1,600	29	15	12.54	85%	13	26	34	42	53	61
38	536.2	Bishnumati Khola	4	1,454	18	3	1.23	40%	3	4	5	6	7	8
39	540.	Nakhu Khola	43	1,400	18	48	37.88	79%	42	83	110	137	170	195
40	550.	Bagmati River	585	1,280	18	448	177.57	40%	422	614	741	863	1021	1139
41	565.	Kulekhani Khola	122	1,514	3	90	40.28	45%	86	157	204	249	308	351
42	570.	Kulekhani Khola	126	1,480	15	194	136.92	71%	174	326	427	523	648	742
43	589.	Bagmati	2,700	180	12	4,496	1933.17	43%	4227	6455	7930	9346	11177	12550
44	590.	Bagmati	2,720	177	15	3,525	2479.63	70%	3170	5924	7747	9496	11760	13456
45	604.5	Arun	28,200	414	16	2,586	696.55	27%	2485	3251	3758	4245	4875	5346
46	606.	Arun	30,380	-	5	4,178	885.79	21%	4075	5341	6180	6984	8025	8805
47	610.	Bhote Kosi	2,410	840	24	507	245.52	48%	470	726	896	1059	1269	1427
48	620.	Balephi Khola	629	793	29	611	310.32	51%	564	881	1091	1293	1553	1749
49	627.5	Melamchi Khola	-	-	4	29	3.30	12%	28	33	37	40	44	47
50	630.	Sunkosi	4,920	589	27	2,276	1009.76	44%	2123	3163	3851	4512	5367	6007
51	640.	Rosi Khola	87	1,480	22	52	36.17	70%	46	85	110	134	165	189
52	647.	Tamakosi	2,753	849	15	814	75.26	9%	803	887	942	995	1064	1115
53	650.	Khimti Khola	313	1,520	15	1,275	650.40	51%	1182	1904	2383	2841	3435	3880
54	652.	Sunkosi	10,000	455	21	4,564	2937.09	64%	4128	7241	9302	11280	13839	15756
55	660.	Likhu Khola	823	543	26	379	125.99	33%	360	490	576	659	766	846
56	668.4	Taktor Khola	87	2,350	5	24	5.90	24%	24	32	38	43	50	55
57	670.	Dudh Kosi	4,100	460	27	2,645	2033.66	77%	2337	4432	5818	7148	8870	10160
58	680.	Sun Kosi	17,600	200	20	4,966	1404.28	28%	4758	6256	7247	8198	9429	10352
59	690.	Tamur	5,640	276	26	3,405	1144.76	34%	3232	4416	5200	5951	6924	7654
60	695.	Sapta Koshi	54,100	140	10	9,743	4964.46	51%	9070	14996	18919	22682	27553	31203
61	728.	Mai Khola	377	-	8	472	441.89	94%	415	968	1335	1687	2142	2483
62	795.	Kankai Mai	1,148	125	20	3,606	1721.73	48%	3352	5188	6403	7569	9079	10210

BASIN AREA AND RUNOFF HYDROGRAPHS: LAKHANDEI RIVER

Creager's C = 6.0 for 2-years flood

Section	#1	#2	#3	#4	#5	#6
Location	No.44 +950m	No.40 +200m	No.37 +600m	No.29 +250m	No.12 +700m	No.4 +300m
dA(km^2)	107	48	19	34	81	11
A(km^2)	107	155	174	208	289	300
C	6.0	6.0	6.0	6.0	6.0	6.0
Q(m^3/s)	242	302	323	357	428	437
Q_b(m^3/s)	14	20	23	27	38	39

DISCHARGE HYDROGRAPHS:

Time (hr)	Q#1 (m^3/s)	dQ (m^3/s)	Q#2 (m^3/s)	dQ (m^3/s)	Q#3 (m^3/s)	dQ (m^3/s)	Q#4 (m^3/s)	dQ (m^3/s)	Q#5 (m^3/s)	dQ (m^3/s)	Q#6 (m^3/s)
0	14	6	20	2	23	4	27	11	38	1	39
1	128	33	161	12	173	19	192	41	233	5	238
2	242	60	302	21	323	34	357	71	428	9	437
3	185	46	232	16	248	27	275	56	331	7	338
4	128	33	161	12	173	19	192	41	233	5	238
5	71	20	91	7	98	12	110	26	135	3	139
6	14	6	20	2	23	4	27	11	38	1	39

BASIN AREA AND RUNOFF HYDROGRAPHS: BABAI RIVER

Creager's C = 11.1 for 2-year flood

Section	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Location	No.46 +150m	No.44 +850m	No.36 +700m	No.28 +0m	No.25 +800m	No.23 +900m	No.18 +700m	No.15 +1050m	No.8 +400m	No.3 +400m
$dA(km^2)$	3002	6	12	36	15	38	83	132	92	9
$A(km^2)$	3002	3008	3020	3056	3071	3109	3192	3324	3416	3425
C	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
$Q(m^3/s)$	2374	2376	2380	2391	2396	2408	2433	2473	2499	2502
$Q_b(m^3/s)$	390	391	392	397	399	404	415	432	444	445

DISCHARGE HYDROGRAPHS

Time (hr)	Q#1 (m^3/s)	dQ (m^3/s)	Q#2 (m^3/s)	dQ (m^3/s)	Q#3 (m^3/s)	dQ (m^3/s)	Q#4 (m^3/s)	dQ (m^3/s)	Q#5 (m^3/s)	dQ (m^3/s)	Q#6 (m^3/s)	dQ (m^3/s)	Q#7 (m^3/s)	dQ (m^3/s)	Q#8 (m^3/s)	dQ (m^3/s)	Q#9 (m^3/s)	dQ (m^3/s)	Q#10 (m^3/s)
0	390	1	391	2	392	5	397	2	399	5	404	11	415	17	432	12	444	1	445
1	555	1	556	2	558	5	563	2	565	6	571	12	583	19	602	13	615	1	616
2	721	1	722	2	724	6	729	2	732	6	738	13	751	21	772	14	786	1	788
3	886	1	887	2	889	6	896	3	898	7	905	14	919	23	942	16	958	2	959
4	1051	1	1052	2	1055	7	1062	3	1065	7	1072	16	1087	25	1112	17	1129	2	1131
5	1217	1	1218	2	1220	7	1228	3	1231	8	1239	17	1256	26	1282	18	1300	2	1302
6	1382	1	1383	3	1386	8	1394	3	1397	8	1406	18	1424	28	1452	19	1472	2	1473
7	1547	1	1549	3	1552	9	1560	4	1564	9	1573	19	1592	30	1622	21	1643	2	1645
8	1713	2	1714	3	1717	9	1726	4	1730	10	1740	21	1760	32	1792	22	1814	2	1816
9	1878	2	1880	3	1883	10	1893	4	1897	10	1907	22	1928	34	1962	23	1985	2	1988
10	2043	2	2045	3	2048	10	2059	4	2063	11	2074	23	2097	36	2132	24	2157	2	2159
11	2209	2	2210	4	2214	11	2225	4	2229	11	2241	24	2265	38	2302	26	2328	2	2331
12	2374	2	2376	4	2380	11	2391	5	2396	12	2408	25	2433	40	2473	27	2499	3	2502
13	2291	2	2293	4	2297	11	2308	5	2313	12	2324	25	2349	39	2387	26	2414	3	2416
14	2209	2	2210	4	2214	11	2225	4	2229	11	2241	24	2265	38	2302	26	2328	2	2331
15	2126	2	2128	4	2131	11	2142	4	2146	11	2157	24	2181	37	2217	25	2242	2	2245
16	2043	2	2045	3	2048	10	2059	4	2063	11	2074	23	2097	36	2132	24	2157	2	2159
17	1961	2	1962	3	1966	10	1976	4	1980	10	1990	22	2013	35	2047	24	2071	2	2073
18	1878	2	1880	3	1883	10	1893	4	1897	10	1907	22	1928	34	1962	23	1985	2	1988
19	1795	2	1797	3	1800	9	1809	4	1813	10	1823	21	1844	33	1877	23	1900	2	1902
20	1713	2	1714	3	1717	9	1726	4	1730	10	1740	21	1760	32	1792	22	1814	2	1816
21	1630	1	1631	3	1634	9	1643	4	1647	9	1656	20	1676	31	1707	21	1729	2	1731
22	1547	1	1549	3	1552	9	1560	4	1564	9	1573	19	1592	30	1622	21	1643	2	1645
23	1465	1	1466	3	1469	8	1477	3	1481	9	1489	19	1508	29	1537	20	1557	2	1559
24	1382	1	1383	3	1386	8	1394	3	1397	8	1406	18	1424	28	1452	19	1472	2	1473
25	1299	1	1301	3	1303	8	1311	3	1314	8	1322	18	1340	27	1367	19	1386	2	1388
26	1217	1	1218	2	1220	7	1228	3	1231	8	1239	17	1256	26	1282	18	1300	2	1302
27	1134	1	1135	2	1138	7	1145	3	1148	8	1155	16	1172	26	1197	18	1215	2	1216
28	1051	1	1052	2	1055	7	1062	3	1065	7	1072	16	1087	25	1112	17	1129	2	1131
29	969	1	970	2	972	7	979	3	981	7	988	15	1003	24	1027	16	1043	2	1045
30	886	1	887	2	889	6	896	3	898	7	905	14	919	23	942	16	958	2	959
31	803	1	804	2	806	6	812	3	815	6	821	14	835	22	857	15	872	1	874
32	721	1	722	2	724	6	729	2	732	6	738	13	751	21	772	14	786	1	788
33	638	1	639	2	641	6	646	2	649	6	654	13	667	20	687	14	701	1	702
34	555	1	556	2	558	5	563	2	565	6	571	12	583	19	602	13	615	1	616
35	473	1	473	2	475	5	480	2	482	5	487	11	499	18	517	13	529	1	531
36	390	1	391	2	392	5	397	2	399	5	404	11	415	17	432	12	444	1	445

RESULT OF FLOOD FLOW ANALYSIS (LAKHANDEI RIVER WITHOUT PROJECT)

No.	Section	Distance	2 - year		5 - year		10 - year		20 - year		50 - year		100 - year	
		(m)	H (m, MSL)	Q (m³/s)	H (m, MSL)	Q (m³/s)	H (m, MSL)	Q (m³/s)	H (m, MSL)	Q (m³/s)	H (m, MSL)	Q (m³/s)	H (m, MSL)	Q (m³/s)
1	NO.0	0	75.949	45	75.949	31	75.949	33	75.949	32	75.870	151	75.870	109
2	NO.1	900	76.715	49	76.715	92	76.715	107	76.715	103	76.748	115	76.748	138
3	NO.2	1,600	77.798	53	77.800	108	77.803	126	77.804	125	77.825	145	77.838	171
4	NO.3	2,500	78.520	111	78.524	177	78.525	185	78.526	202	78.263	226	78.296	258
5	NO.6	4,550	80.412	31	80.536	63	80.561	83	80.580	109	80.628	139	80.669	164
6	NO.7	5,500	80.586	96	80.586	119	80.619	135	80.661	175	80.730	208	80.789	230
7	NO.8	6,500	80.638	83	80.653	108	80.722	117	80.773	147	80.849	170	80.909	173
8	NO.9	7,250	81.416	71	81.416	85	81.416	92	81.416	111	81.457	128	81.456	133
9	+360m	7,600	81.882	110	81.882	110	81.882	110	81.883	116	81.938	131	81.968	142
10	NO.10	8,200	82.944	143	82.944	143	82.956	143	83.047	143	83.180	159	83.284	159
11	NO.11	9,200	83.635	151	83.635	151	83.635	151	83.635	151	83.742	173	83.742	173
12	NO.12	10,100	84.172	152	84.172	166	84.172	191	84.172	208	84.276	233	84.276	259
13	NO.13	11,100	84.635	196	85.077	196	85.242	196	85.374	196	85.535	220	85.721	220
14	NO.14	11,950	85.021	106	85.271	106	85.385	106	85.491	107	85.626	119	85.796	119
15	NO.15	12,900	85.911	125	85.907	125	86.007	125	86.061	125	86.145	144	86.250	144
16	NO.16	13,950	86.784	108	86.784	108	86.784	108	86.903	108	86.894	122	86.885	122
17	NO.17	15,150	88.131	117	88.290	117	88.243	117	88.221	128	88.272	136	88.269	137
18	NO.18	15,950	89.002	124	89.064	148	89.098	159	89.117	166	89.154	173	89.267	187
19	NO.19	16,650	89.918	183	90.040	215	90.082	253	90.193	272	90.126	290	90.197	286
20	NO.20	17,700	91.355	208	91.174	264	91.276	303	91.339	312	91.416	348	91.536	354
21	NO.21	19,200	92.233	286	92.344	406	92.412	480	92.430	504	92.459	537	92.501	594
22	NO.22	20,100	93.621	286	93.802	407	93.894	481	93.921	505	93.992	538	94.101	606
23	NO.23	21,200	95.233	288	95.436	412	95.560	485	95.628	493	95.649	516	95.686	600
24	NO.24	22,200	96.998	289	97.312	416	97.415	486	97.406	480	97.455	513	97.580	587
25	NO.25	23,000	98.545	289	98.722	347	98.822	400	98.817	398	98.864	424	98.946	481
26	NO.26	24,000	100.234	292	100.344	404	100.447	462	100.442	458	100.486	482	100.614	528
27	NO.27	24,900	101.420	293	101.665	394	101.773	449	101.763	446	101.809	467	101.897	539
28	NO.28	26,150	103.605	298	103.760	453	103.828	575	103.827	573	103.861	573	103.961	589
29	NO.29	27,050	105.312	299	105.522	494	105.674	620	105.686	688	105.682	736	105.684	785
30	NO.30	27,850	107.017	295	107.273	472	107.395	579	107.473	661	107.527	729	107.570	790
31	NO.31	28,850	108.850	296	109.104	474	109.238	580	109.335	663	109.417	724	109.484	781
32	NO.32	30,050	111.121	297	111.382	476	111.519	584	111.617	666	111.683	820	111.739	916
33	NO.33	30,950	113.250	297	113.501	477	113.634	585	113.729	668	113.891	831	113.986	941
34	NO.34	31,900	115.239	299	115.506	479	115.645	587	115.744	671	115.926	835	116.040	945
35	NO.35	32,900	117.773	300	118.018	481	118.149	591	118.241	675	118.413	842	118.520	953
36	NO.36	33,950	120.424	301	120.680	483	120.812	595	120.905	678	121.080	843	121.190	957
37	NO.37	34,850	122.615	302	122.887	485	123.032	597	123.133	681	123.324	853	123.439	966
38	+480m	35,400	124.266	303	124.587	486	124.746	599	124.854	683	125.060	857	125.184	969
39	NO.38	35,930	125.536	288	125.837	459	126.001	566	126.114	646	126.361	743	126.501	836
40	NO.39	36,930	128.181	291	128.371	474	128.479	591	128.550	704	128.639	848	128.708	949
41	NO.40	37,930	130.925	293	131.125	477	131.235	595	131.333	708	131.449	852	131.527	957
42	NO.41	38,930	134.549	239	134.732	390	134.833	486	134.921	579	135.024	701	135.094	793
43	+870m	39,830	138.623	242	138.932	393	139.092	490	139.233	584	139.403	708	139.520	800

RESULT OF FLOOD FLOW ANALYSIS (LAKHANDEI RIVER WITH PROJECT)

No.	Section	Distance (m)	2 - year H (m, MSL)	2 - year Q (m^3/s)	5 - year H (m, MSL)	5 - year Q (m^3/s)	10 - year H (m, MSL)	10 - year Q (m^3/s)	20 - year H (m, MSL)	20 - year Q (m^3/s)	50 - year H (m, MSL)	50 - year Q (m^3/s)	100 - year H (m, MSL)	100 - year Q (m^3/s)
1	NO.0	0	75.955	168	75.959	117	75.958	121	75.962	122	75.959	124.65	75.961	125
2	NO.1	900	76.784	175	76.848	241	76.858	249	76.865	253	76.868	257.00	76.871	259
3	NO.2	1,600	77.926	181	77.993	242	78.003	250	78.011	254	78.015	257.32	78.018	259
4	NO.3	2,500	78.338	189	78.423	250	78.436	261	78.446	269	78.451	272.42	78.456	276
5	NO.6	4,550	80.574	198	80.651	249	80.666	260	80.678	270	80.684	274.20	80.689	273
6	NO.7	5,500	80.795	200	80.900	254	80.921	260	80.940	259	80.951	279.48	80.958	306
7	NO.8	6,500	80.883	202	81.003	254	81.033	294	81.069	341	81.092	315.47	81.102	220
8	NO.9	7,250	81.501	200	81.592	261	81.712	222	81.863	149	81.957	408.51	81.992	425
9	+360m	7,600	82.130	205	82.235	262	82.402	288	82.575	333	82.673	365.24	82.707	377
10	NO.10	8,200	83.790	143	84.195	143	84.313	143	84.438	143	84.575	159.42	84.631	159
11	NO.11	9,200	83.737	151	84.112	151	84.224	151	84.320	151	84.403	173.22	84.451	173
12	NO.12	10,100	84.172	136	84.256	166	84.383	174	84.494	175	84.565	178.50	84.616	190
13	NO.13	11,100	84.748	196	85.075	196	85.132	196	85.203	196	85.275	220.18	85.358	220
14	NO.14	11,950	85.077	106	85.350	113	85.393	121	85.439	124	85.501	127.71	85.570	129
15	NO.15	12,900	85.843	94	86.075	99	86.155	111	86.191	117	86.219	120.46	86.232	122
16	NO.16	13,950	86.784	99	86.917	103	87.022	117	87.063	125	87.093	131.58	87.104	134
17	NO.17	15,150	87.935	103	88.529	175	88.535	176	88.549	177	88.603	174.24	88.639	181
18	NO.18	15,950	89.073	160	89.792	258	89.784	257	89.764	254	89.791	258.39	89.797	271
19	NO.19	16,650	90.091	266	90.224	293	90.189	331	90.262	354	90.277	375.77	90.297	385
20	NO.20	17,700	91.331	199	91.406	311	91.520	370	91.587	410	91.650	451.06	91.674	467
21	NO.21	19,200	92.234	286	92.422	434	92.523	519	92.596	589	92.658	641.44	92.684	658
22	NO.22	20,100	93.622	287	93.837	435	93.940	522	94.100	606	94.156	657.97	94.175	684
23	NO.23	21,200	95.233	288	95.563	445	95.638	543	95.678	606	95.744	670.68	95.769	701
24	NO.24	22,200	96.998	289	97.353	448	97.477	531	97.579	594	97.614	634.85	97.628	661
25	NO.25	23,000	98.545	289	98.771	372	98.898	447	98.956	486	99.032	533.64	99.070	558
26	NO.26	24,000	100.234	292	100.396	433	100.524	497	100.623	529	100.700	566.01	100.740	591
27	NO.27	24,900	101.420	293	101.721	420	101.835	482	101.891	531	101.955	560.60	101.998	581
28	NO.28	26,150	103.605	298	103.808	453	103.887	520	103.942	596	103.990	676.51	104.013	721
29	NO.29	27,050	105.312	299	105.521	493	105.603	606	105.689	696	105.775	767.27	105.818	809
30	NO.30	27,850	107.017	295	107.271	471	107.399	585	107.489	689	107.551	773.76	107.580	818
31	NO.31	28,850	108.850	296	109.102	472	109.246	587	109.367	691	109.487	773.92	109.514	817
32	NO.32	30,050	111.121	297	111.380	476	111.527	591	111.650	695	111.738	818.00	111.786	876
33	NO.33	30,950	113.250	297	113.501	477	113.643	593	113.762	700	113.890	829.17	113.947	893
34	NO.34	31,900	115.239	299	115.506	479	115.655	596	115.780	702	115.923	831.69	115.990	898
35	NO.35	32,900	117.773	300	118.018	481	118.158	600	118.276	707	118.409	836.31	118.473	902
36	NO.36	33,950	120.424	301	120.680	483	120.822	604	120.941	712	121.073	839.66	121.139	904
37	NO.37	34,850	122.615	302	122.887	485	123.043	607	123.172	715	123.314	842.31	123.384	909
38	+480m	35,400	124.266	303	124.587	486	124.758	608	124.897	717	125.046	843.34	125.121	911
39	NO.38	35,930	125.536	288	125.837	459	126.016	576	126.163	683	126.325	803.91	126.405	867
40	NO.39	36,930	128.181	291	128.371	474	128.490	591	128.587	704	128.689	849.47	128.733	954
41	NO.40	37,930	130.925	293	131.125	477	131.235	595	131.333	708	131.450	853.70	131.530	960
42	NO.41	38,930	134.549	239	134.732	390	134.833	486	134.921	579	135.026	701.39	135.097	793
43	+870m	39,830	138.623	242	138.932	393	139.092	490	139.233	584	139.403	708.00	139.520	800

Table C2.9 (1/2)

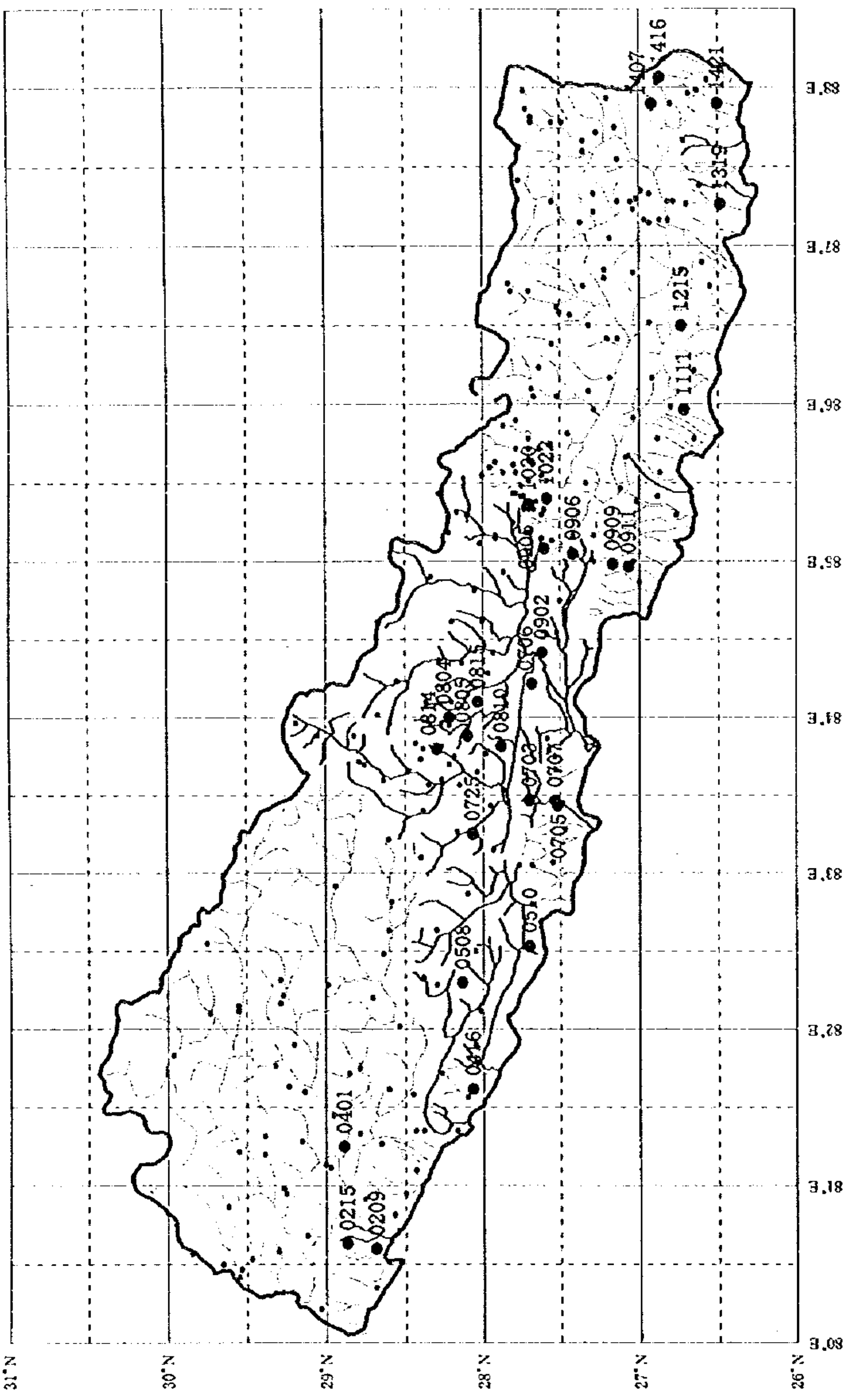
RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITHOUT PROJECT)

No.	Section	Distance (m)	2 - year H (m, MSL)	2 - year Q (m³/s)	5 - year H (m, MSL)	5 - year Q (m³/s)	10 - year H (m, MSL)	10 - year Q (m³/s)	20 - year H (m, MSL)	20 - year Q (m³/s)	50 - year H (m, MSL)	50 - year Q (m³/s)	100 - year H (m, MSL)	100 - year Q (m³/s)
1	NO.1	0	141.266	1681	141.814	2028	142.042	2175	142.221	2292	142.414	2417	142.531	2493
2	NO.2	690	141.496	1740	142.029	2342	142.244	2663	142.410	2945	142.535	3274	142.690	3489
3	NO.3	1,461	141.655	2059	142.130	3203	142.301	3822	142.415	4390	142.522	5020	142.574	5440
4	Bnd	1,891	141.835	2059	142.464	3203	142.737	3822	142.961	4390	143.205	5020	143.360	5440
5	NO.4	3,001	142.166	1576	143.030	2517	143.433	3300	143.777	4124	144.147	5165	144.384	5924
6	NO.6	4,548	142.247	1629	143.144	2288	143.587	2822	143.973	3367	144.397	4032	144.873	4504
7	NO.8	6,688	142.477	2041	143.354	2956	143.819	3415	144.229	3958	144.681	4597	144.977	5053
8	NO.9	7,708	142.755	1969	143.613	2630	144.083	2941	144.503	3244	144.970	3524	145.277	3700
9	NO.12	10,204	143.518	2076	144.415	2739	144.882	2876	145.284	3184	145.701	3573	145.971	3869
10	NO.13	11,344	143.942	2078	144.774	3264	145.209	3654	145.596	4258	146.009	4989	146.282	5519
11	NO.14	11,924	144.111	2081	144.994	3397	145.423	3963	145.826	4690	146.257	5559	146.542	6193
12	NO.15	12,836	144.254	2085	145.192	3302	145.627	3945	146.048	4729	146.503	5597	146.806	6224
13	NO.16	13,577	144.364	2043	145.336	3317	145.787	4064	146.232	4923	146.710	5862	147.029	6559
14	NO.17	14,457	144.474	1722	145.460	2789	145.917	3629	146.369	4642	146.852	5655	147.176	6418
15	NO.18	15,729	145.027	1730	145.379	2743	146.355	3289	146.847	3788	147.321	4399	147.653	4866
16	NO.19	16,809	145.749	2069	146.630	3177	147.027	3636	147.405	4290	147.846	5027	148.146	5581
17	NO.20	18,147	146.513	1817	147.375	3154	147.743	3734	148.156	4199	148.620	4768	148.942	5174
18	NO.21	19,059	146.950	1822	147.917	2715	148.308	3147	148.689	3392	149.119	3697	149.421	4003
19	NO.22	19,871	147.450	2034	148.338	3459	148.668	4196	148.986	4685	149.376	5465	149.651	6061
20	NO.23	20,291	147.683	2084	148.600	3505	148.946	4184	149.254	4716	149.657	5320	149.944	5779
21	NO.24	22,043	148.417	2076	149.500	3492	149.927	4189	150.242	4817	150.646	5467	150.936	5880
22	NO.25	23,043	148.845	2078	149.902	3503	150.356	4014	150.722	4408	151.116	4920	151.354	5392
23	NO.27	25,913	150.953	1862	152.350	2469	152.799	2860	153.125	3262	153.540	3577	153.880	3877
24	NO.28	26,865	151.293	2314	152.529	3390	152.961	4041	153.284	4666	153.667	5356	153.986	5928
25	NO.29	27,665	151.712	2303	152.869	3516	153.302	4276	153.635	5020	154.068	6001	154.398	6609
26	NO.30	28,225	152.141	2304	153.260	3520	153.724	4338	154.101	5144	154.487	6177	154.795	6884
27	NO.31	29,443	153.082	2333	154.098	3885	154.625	4828	155.085	5647	155.605	6533	155.971	7045
28	NO.32	30,593	154.393	2338	155.293	3896	155.763	4860	156.141	5783	156.531	6883	156.766	7619
29	NO.33	31,525	155.668	2339	156.652	3799	157.183	4693	157.641	5549	158.135	6676	158.439	7516
30	NO.34	32,695	157.018	2342	157.878	3949	158.355	4826	158.787	5577	159.299	6526	159.643	7213
31	NO.35	33,907	159.265	2343	160.236	3910	160.617	4712	160.936	5281	161.339	5907	161.625	6334
32	NO.36	34,759	160.824	2345	161.724	3976	162.096	4949	162.353	5712	162.635	6631	162.843	7124
33	NO.37	35,939	162.574	2349	163.427	3991	163.858	5010	164.156	5939	164.496	6978	164.664	7698
34	NO.38	36,819	164.448	2343	165.196	4003	165.608	5080	165.946	6060	166.287	7285	166.504	8197
35	NO.39	38,003	167.458	2341	168.089	3968	168.442	4988	168.744	5938	169.101	7060	169.358	7892
36	NO.40	39,267	170.889	2340	171.614	3967	171.973	4982	172.278	5950	172.604	7058	172.842	7788
37	NO.41	40,337	173.335	2332	174.168	3958	174.556	4976	174.897	6031	175.258	7267	175.480	8185
38	NO.42	40,962	174.901	2382	175.537	3927	175.881	4975	176.217	6142	176.554	7300	176.804	8252
39	NO.43	41,762	177.618	2299	178.165	3879	178.472	4917	178.904	6082	179.108	7087	179.351	7887
40	NO.44	42,791	181.925	2368	182.838	4075	183.194	5212	183.452	6302	183.682	7706	183.764	8615
41	NO.45	43,890	185.167	2370	186.278	4077	186.915	5215	187.477	6305	188.156	7728	188.567	8774
42	NO.46	44,790	187.661	2374	188.700	4083	189.263	5223	189.756	6315	190.353	7739	190.757	8784

RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITH PROJECT)

No.	Section	Distance (m)	2 - year H (m, MSL)	2 - year Q (m^3/s)	5 - year H (m, MSL)	5 - year Q (m^3/s)	10 - year H (m, MSL)	10 - year Q (m^3/s)	20 - year H (m, MSL)	20 - year Q (m^3/s)	50 - year H (m, MSL)	50 - year Q (m^3/s)	100 - year H (m, MSL)	100 - year Q (m^3/s)
1	NO.1	0	141.297	1699	141.790	2012	141.991	2143	142.184	2267	142.403	2410	142.540	2499
2	NO.2	690	141.527	1766	142.006	2309	142.197	2589	142.375	2883	142.575	3256	142.698	3506
3	NO.3	1,461	141.683	2108	142.110	3141	142.265	3679	142.391	4270	142.517	4982	142.582	5458
4	Bnd	1,891	141.869	2108	142.434	3141	142.676	3679	142.914	4270	143.191	4982	143.370	5458
5	NO.4	3,001	142.201	2107	142.979	3007	143.335	3527	143.701	4132	144.126	5070	144.399	5823
6	NO.6	4,548	142.342	2111	143.141	2938	143.513	3333	143.896	3818	144.357	4460	144.663	4973
7	NO.8	6,688	142.705	2051	143.503	2939	143.870	3349	144.258	3852	144.730	4450	145.053	4883
8	NO.9	7,708	142.935	1968	143.744	2665	144.110	2948	144.499	3281	144.972	3622	145.299	3817
9	NO.12	10,204	143.623	2107	144.510	2845	144.889	3064	145.290	3385	145.727	3767	146.013	4045
10	NO.13	11,344	144.033	2109	144.913	3307	145.267	3759	145.648	4413	146.065	5195	146.344	5743
11	NO.14	11,924	144.195	2112	145.131	3357	145.491	3940	145.892	4723	146.332	5614	146.623	6261
12	NO.15	12,836	144.332	2118	145.310	3284	145.685	3937	146.109	4784	146.572	5677	146.880	6329
13	NO.16	13,577	144.438	2123	145.445	3292	145.843	3944	146.296	4853	146.782	5805	147.107	6514
14	NO.17	14,457	144.543	2098	145.548	3267	145.955	3821	146.420	4734	146.913	5688	147.244	6428
15	NO.18	15,729	145.234	2106	146.048	3258	146.398	3681	146.881	4121	147.354	4632	147.689	5049
16	NO.19	16,809	146.097	2086	146.907	3403	147.176	4032	147.513	4673	147.904	5271	148.193	5872
17	NO.20	18,147	146.687	1802	147.631	3016	147.980	3675	148.350	4161	148.756	4831	149.053	5236
18	NO.21	19,059	147.047	1802	148.038	2649	148.418	3155	148.798	3549	149.216	3944	149.500	4182
19	NO.22	19,871	147.497	2041	148.410	3310	148.796	4062	149.126	4706	149.511	5430	149.771	5898
20	NO.23	20,291	147.718	2107	148.625	3476	149.027	4165	149.347	4813	149.729	5576	149.994	5971
21	NO.24	22,043	148.446	2099	149.492	3533	149.954	4257	150.332	4964	150.756	5728	150.997	6132
22	NO.25	23,043	148.871	2101	149.896	3568	150.352	4227	150.741	4832	151.145	5549	151.363	5922
23	NO.27	25,913	150.980	1869	152.410	2401	152.965	2730	153.443	3045	153.967	3357	154.234	3617
24	NO.28	26,865	151.315	2329	152.569	3317	153.091	3937	153.545	4509	154.040	5132	154.288	5685
25	NO.29	27,665	151.733	2317	152.879	3485	153.379	4204	153.804	4908	154.286	5683	154.548	6341
26	NO.30	28,225	152.152	2317	153.260	3488	153.759	4298	154.185	5104	154.650	6052	154.929	6804
27	NO.31	29,443	153.094	2348	154.092	3819	154.625	4789	155.110	5676	155.652	6507	156.015	7015
28	NO.32	30,593	154.403	2353	155.267	3923	155.750	4821	156.148	5735	156.542	6866	156.781	7600
29	NO.33	31,525	155.679	2354	156.612	3785	157.164	4645	157.647	5500	158.139	6560	158.445	7369
30	NO.34	32,695	157.028	2357	157.861	3938	158.328	4856	158.763	5702	159.252	6682	159.586	7426
31	NO.35	33,907	159.278	2359	160.230	3899	160.631	4691	160.992	5276	161.401	5884	161.702	6344
32	NO.36	34,759	160.835	2360	161.719	3964	162.092	4927	162.361	5724	162.645	6609	162.873	7131
33	NO.37	35,939	162.582	2363	163.421	3976	163.849	4979	164.161	5964	164.486	7003	164.673	7769
34	NO.38	36,819	164.454	2360	165.191	4016	165.597	5034	165.960	6057	166.298	7253	166.529	8156
35	NO.39	38,003	167.459	2362	168.094	4011	168.425	4991	168.738	5905	169.093	7063	169.346	7902
36	NO.40	39,267	170.903	2363	171.634	4021	171.973	4983	172.268	5917	172.607	7045	172.846	7781
37	NO.41	40,337	173.334	2364	174.201	4019	174.560	4979	174.886	6001	175.256	7210	175.481	8111
38	NO.42	40,962	174.837	2367	175.588	4093	175.892	5008	176.188	6058	176.538	7276	176.791	8151
39	NO.43	41,762	177.645	2368	178.201	3995	178.543	4969	178.893	6065	179.098	7125	179.322	7882
40	NO.44	42,791	181.997	2388	182.937	4113	183.259	5257	183.480	6358	183.748	7781	183.816	8698
41	NO.45	43,890	185.167	2370	186.279	4077	186.915	5215	187.479	6307	188.159	7736	188.571	8781
42	NO.46	44,790	187.661	2374	188.700	4083	189.263	5223	189.756	6315	190.353	7739	190.757	8784

Fig. C2.1

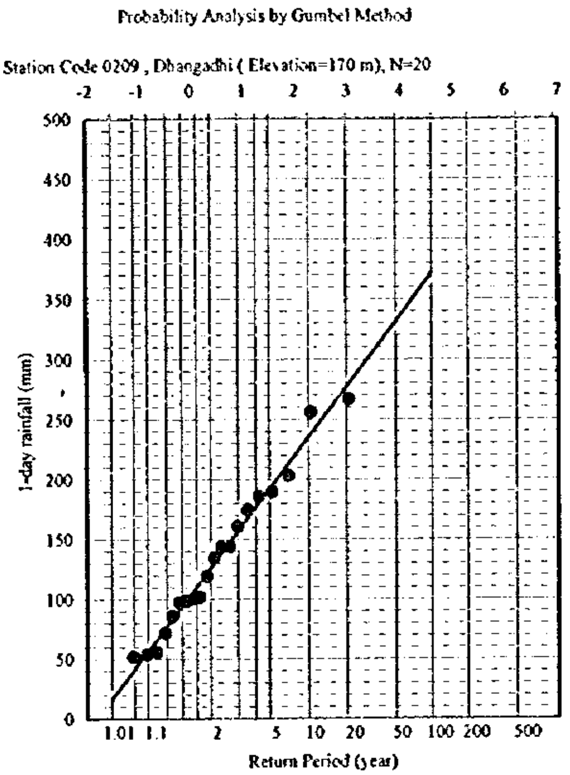


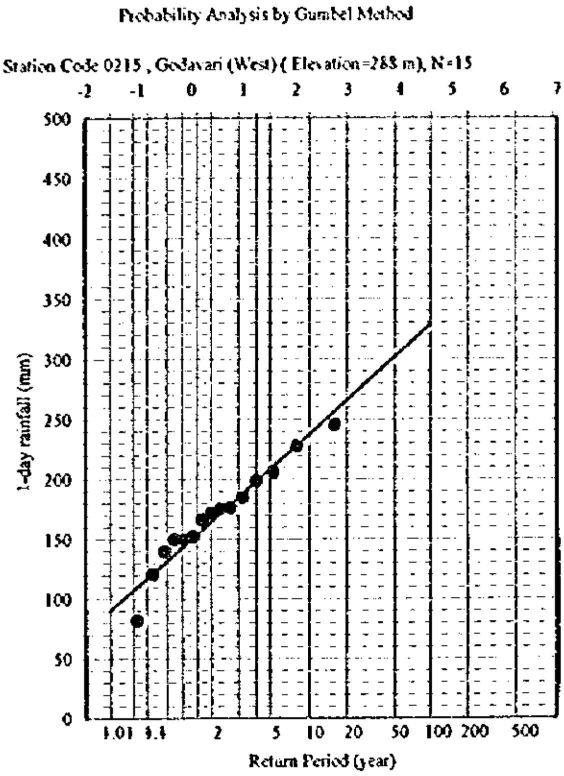
LOCATION OF RAINFALL STATIONS (SLECTED 29 STATIONS)

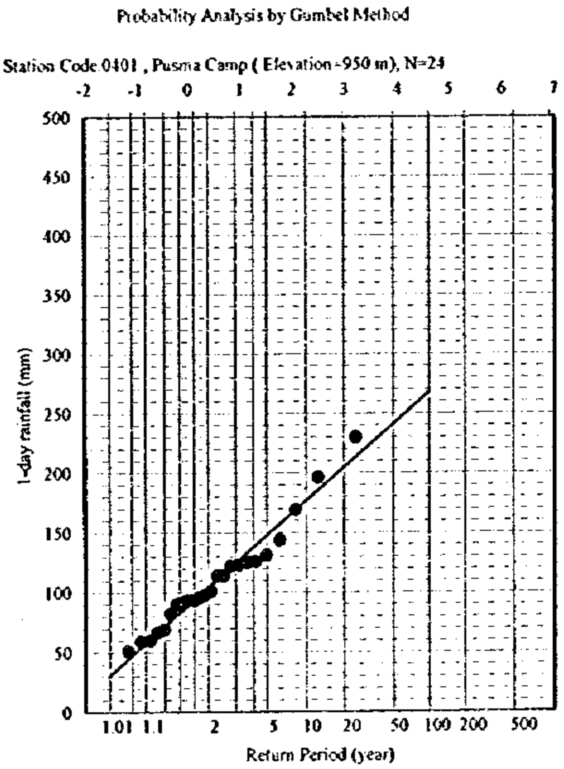
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

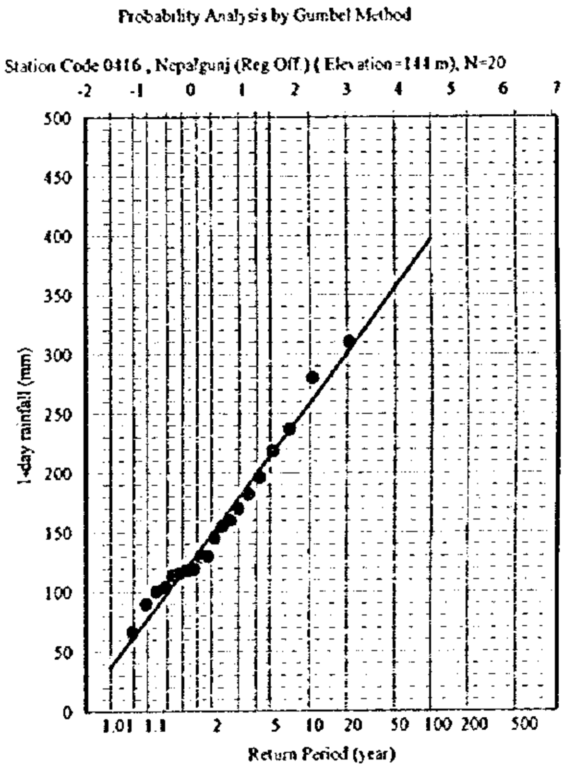
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY







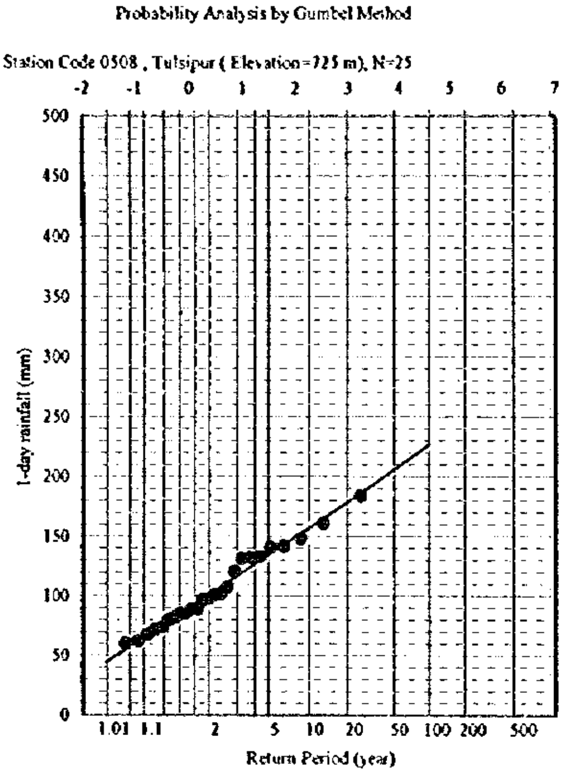


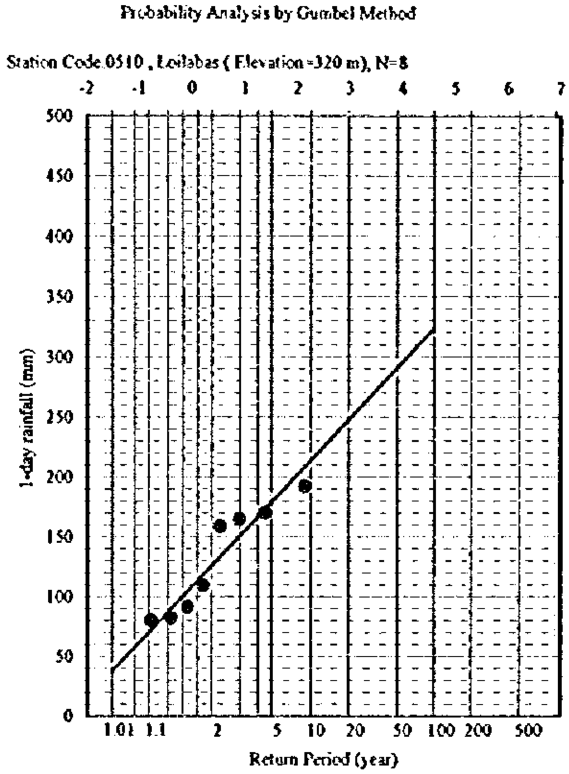
PROBABILITY ANALYSIS FOR DAILY RAINFALL

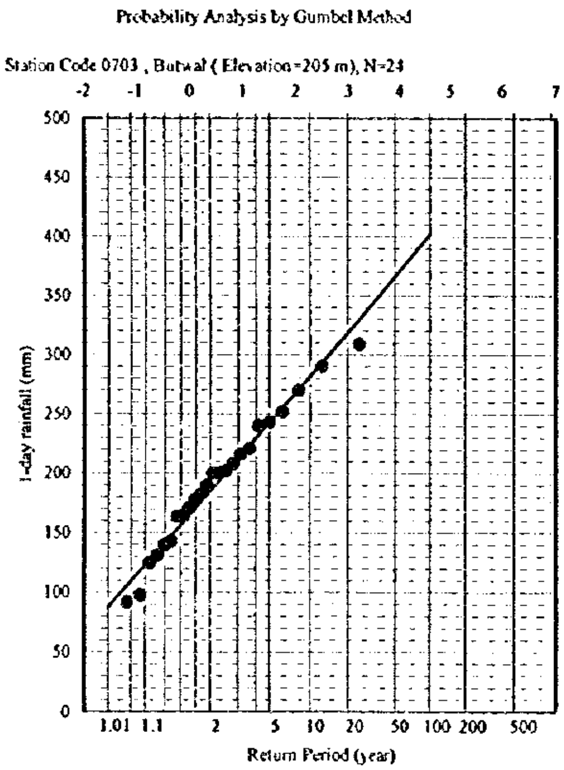
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

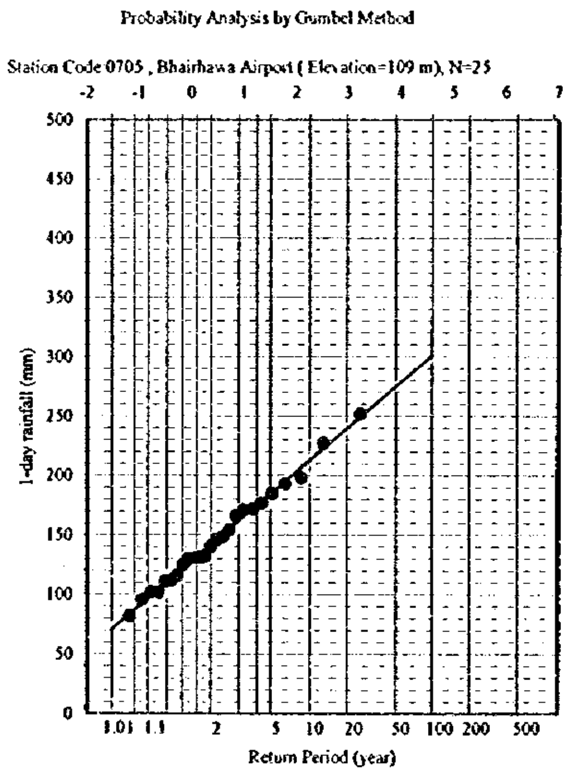
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY







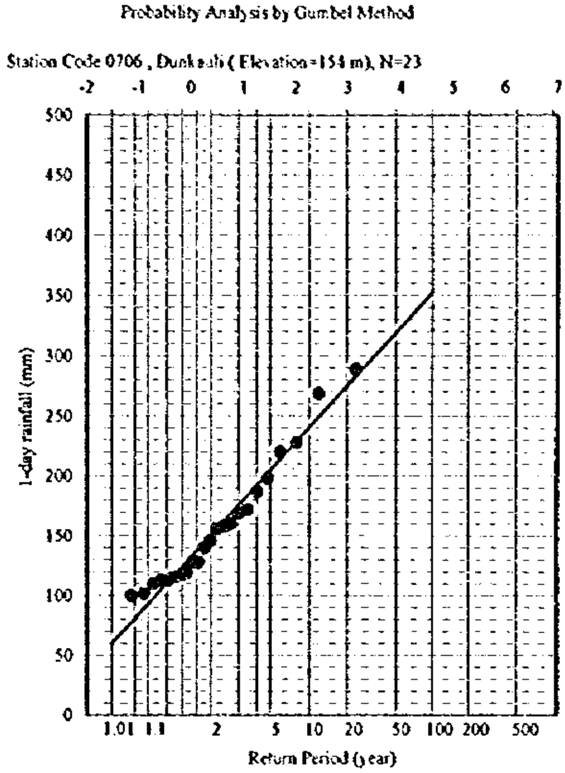


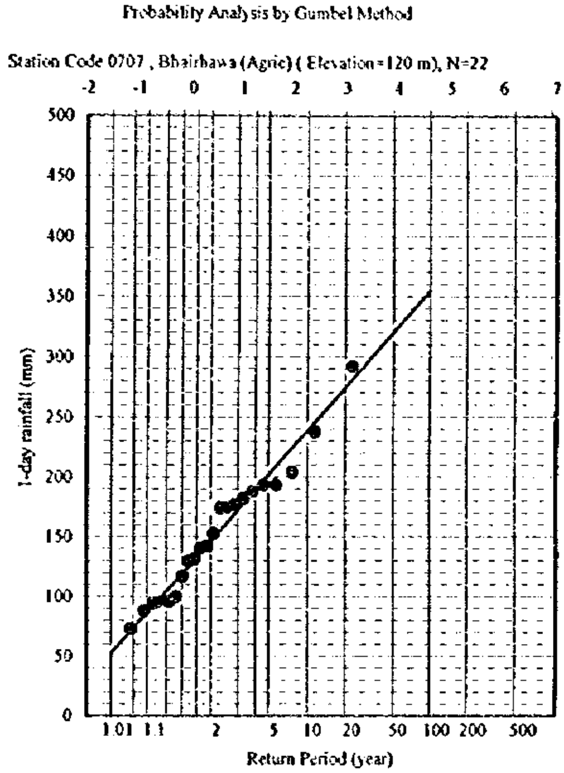
PROBABILITY ANALYSIS FOR DAILY RAINFALL

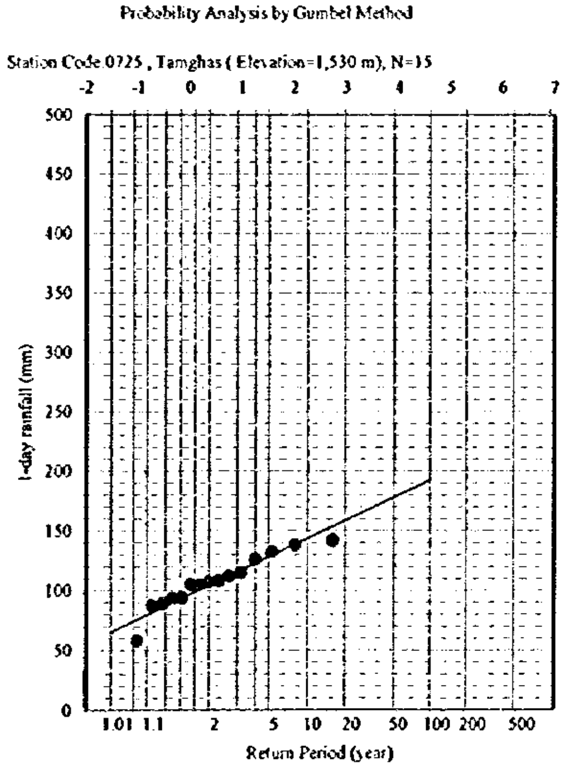
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

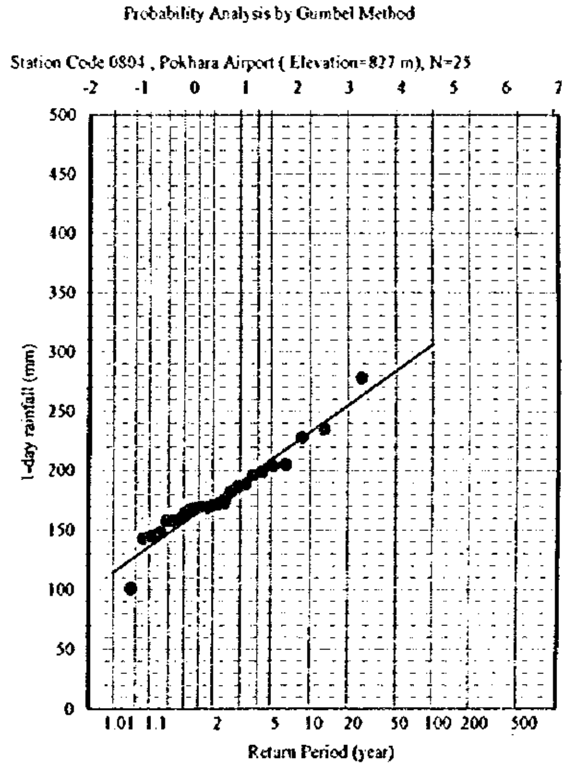
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY







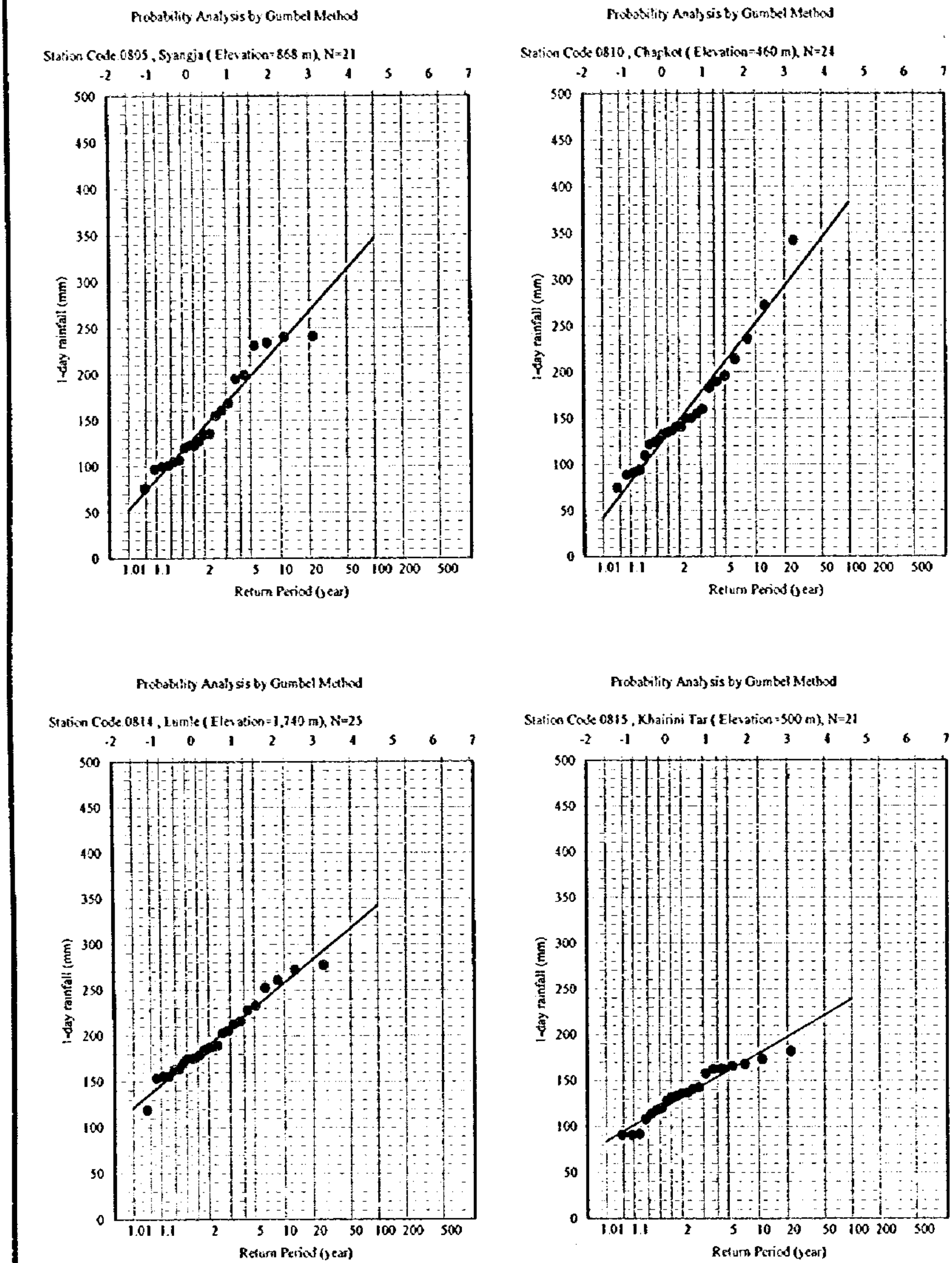


PROBABILITY ANALYSIS FOR DAILY RAINFALL

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

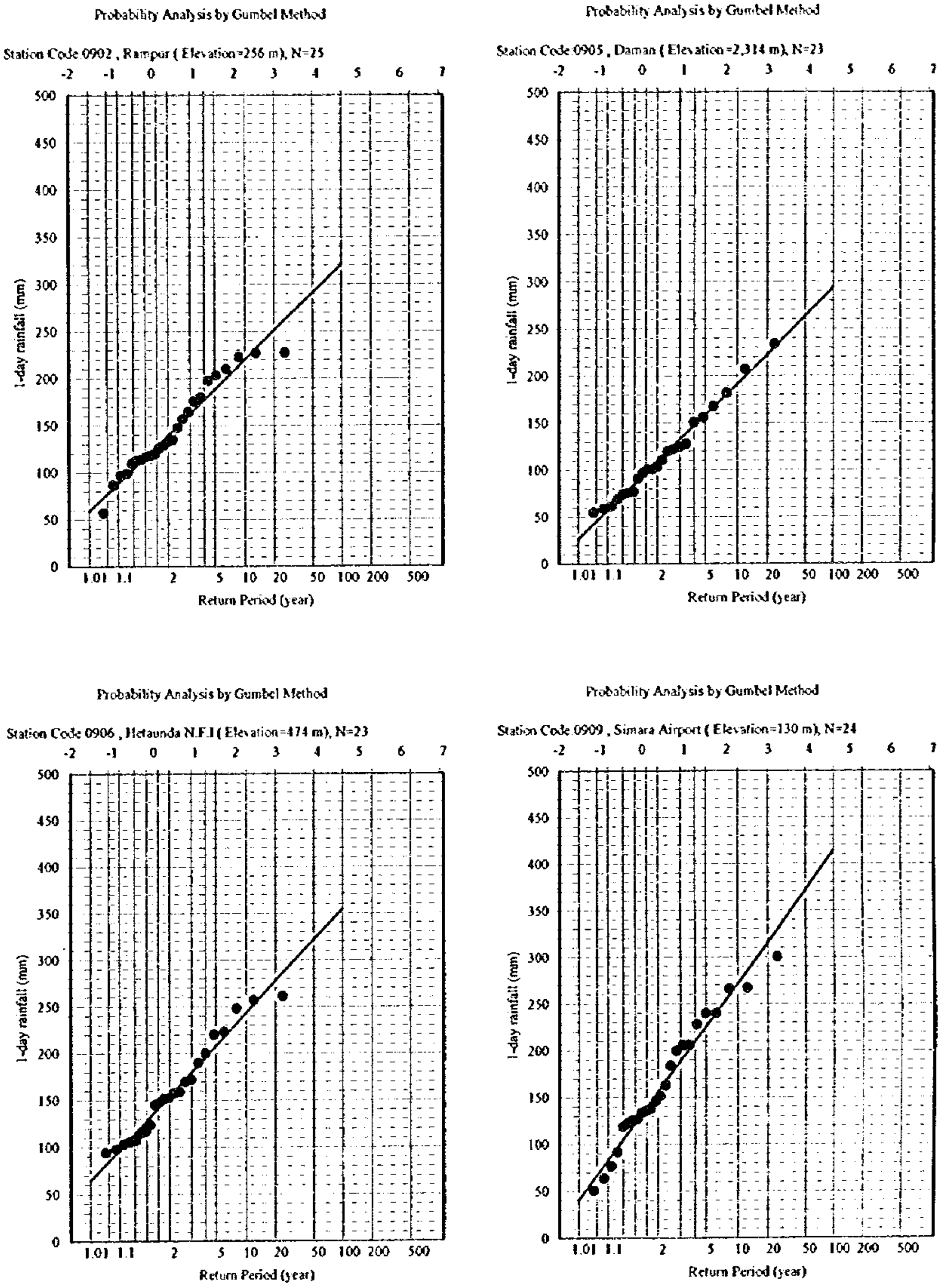
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



PROBABILITY ANALYSIS FOR DAILY RAINFALL

His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY

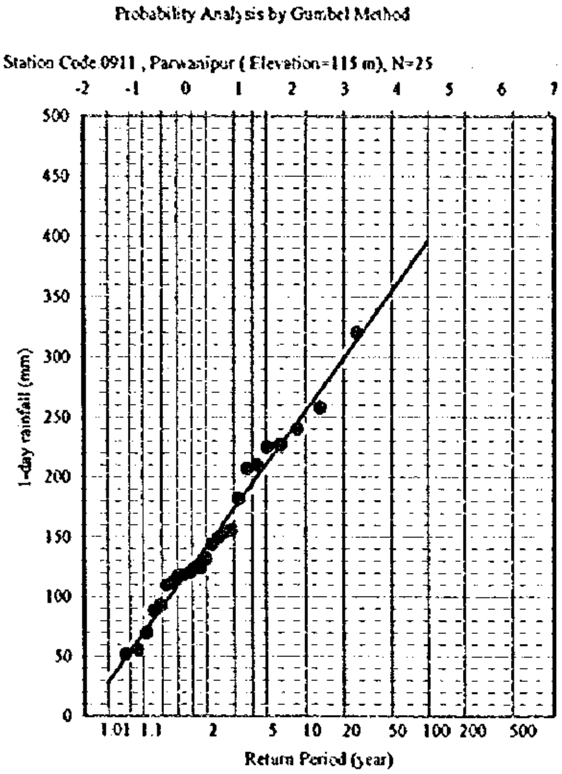


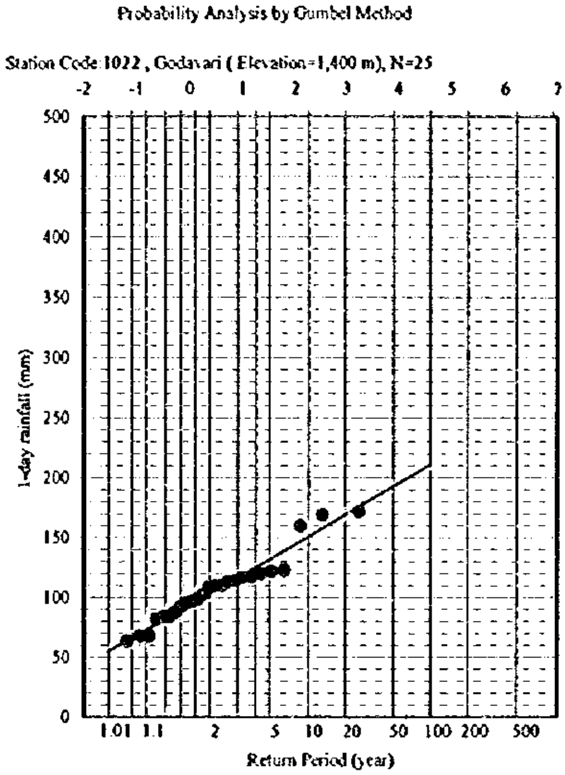
PROBABILITY ANALYSIS FOR DAILY RAINFALL

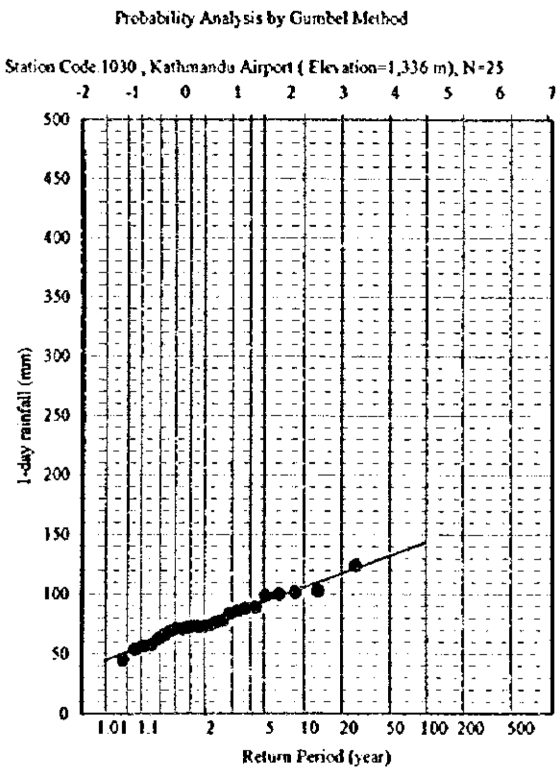
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

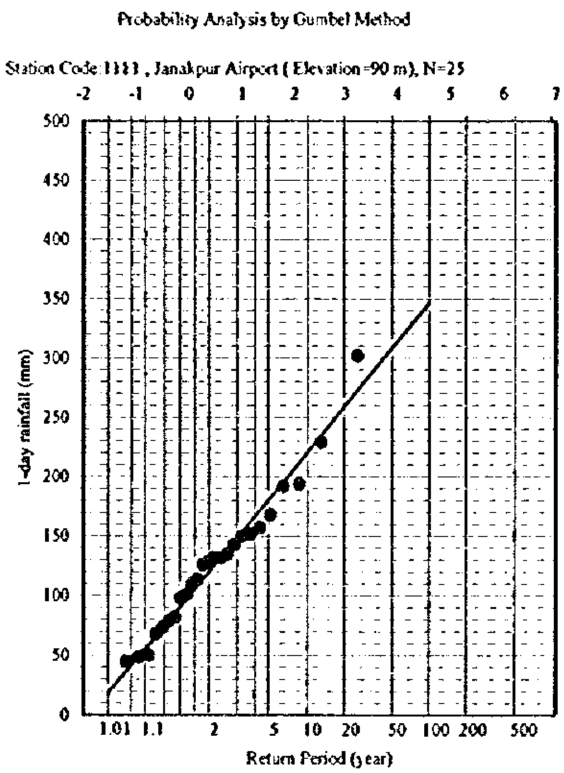
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY









PROBABILITY ANALYSIS FOR DAILY RAINFALL

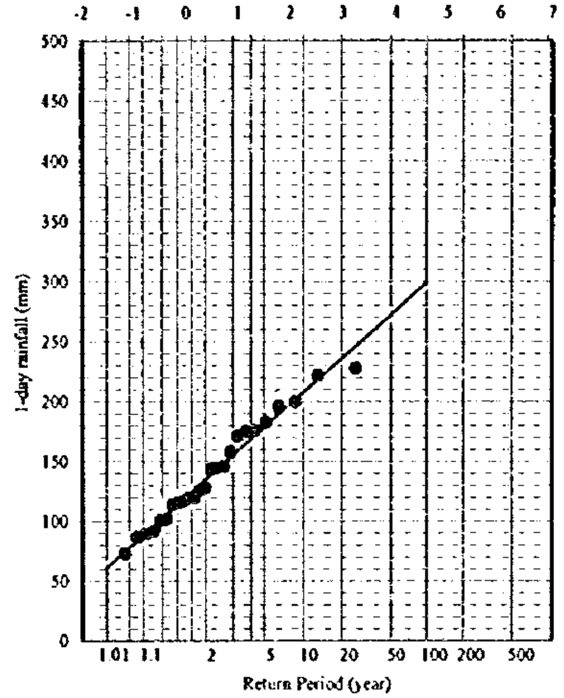
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

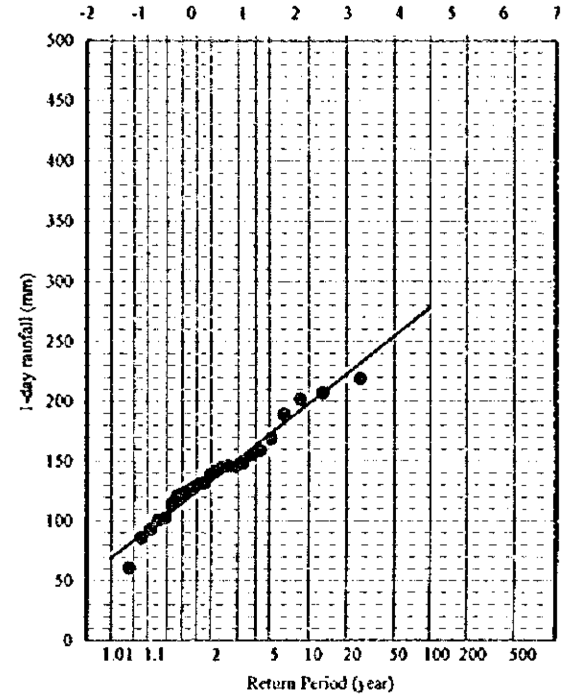
Probability Analysis by Gumbel Method

Station Code 1215 , Lahan (Elevation=138 m), N=25



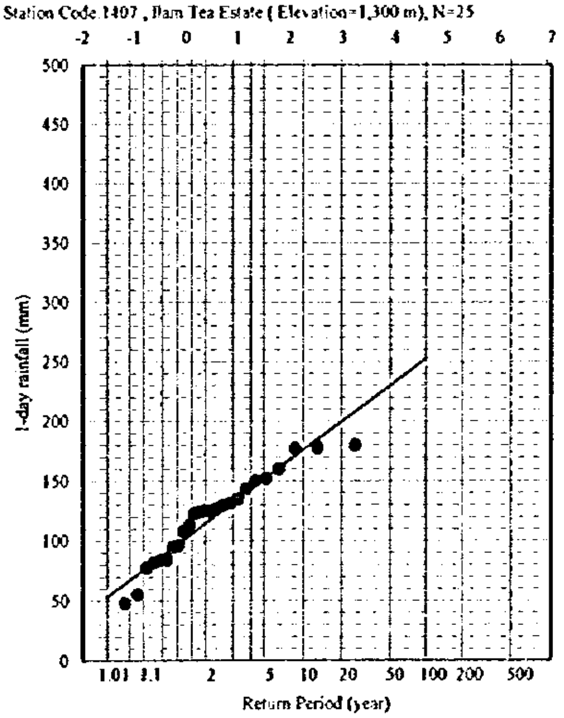
Probability Analysis by Gumbel Method

Station Code 1319 , Biratnagar Airport (Elevation=72 m), N=25



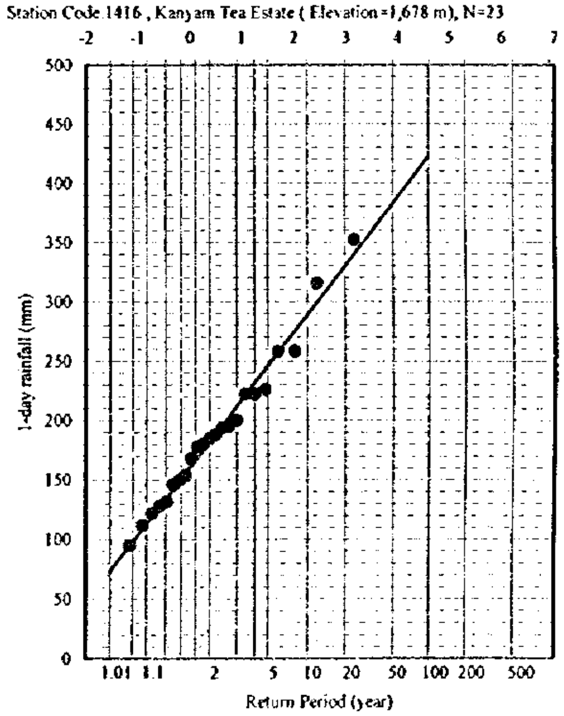
Probability Analysis by Gumbel Method

Station Code 1407 , Ilam Tea Estate (Elevation=1,300 m), N=25



Probability Analysis by Gumbel Method

Station Code 1416 , Kanyam Tea Estate (Elevation=1,678 m), N=23

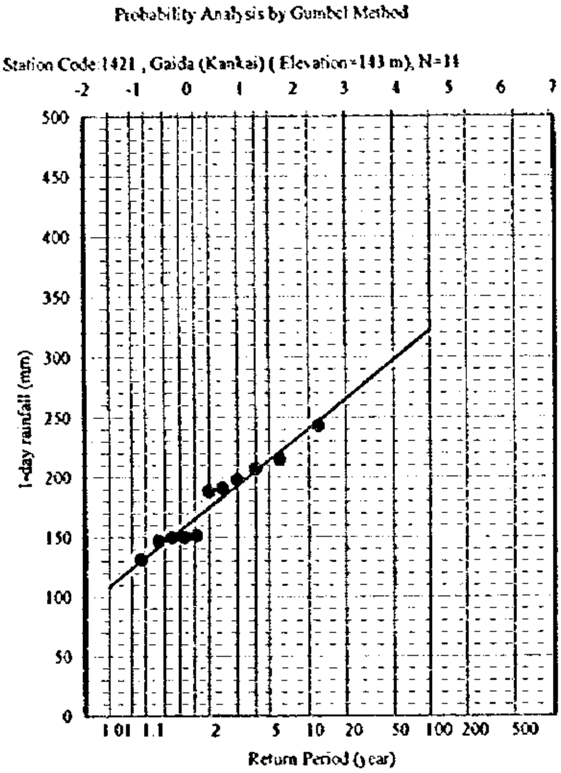


PROBABILITY ANALYSIS FOR DAILY RAINFALL

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

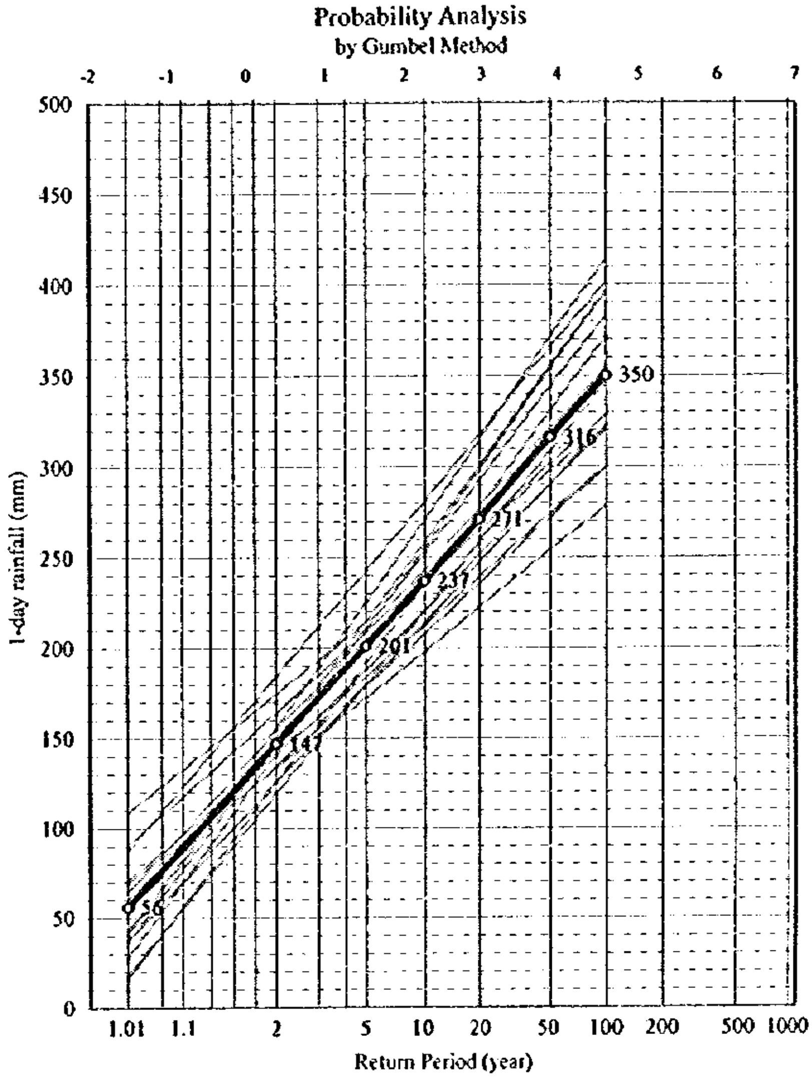
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



PROBABILITY ANALYSIS FOR DAILY RAINFALL

His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



No.	Code	Station	Elevation	Return Period						
				1.01	2	5	10	20	50	100
1	0209	Dhangadhi	170	16	126	192	235	277	331	372
2	0215	Godavari (West)	288	91	164	208	238	266	302	329
4	0416	Nepalgunj (Reg.Off.)	144	37	148	214	259	301	356	397
6	0510	Loilabas	320	38	126	179	214	247	291	323
7	0703	Butwal	205	87	185	243	281	318	366	402
8	0705	Bhairhawa Airport	109	71	142	184	212	239	274	301
9	0706	Dunkauli	154	60	150	204	240	275	319	352
10	0707	Bhairhawa (Agric)	120	52	146	202	239	274	320	354
14	0810	Chapkot	460	43	148	211	253	293	344	383
17	0902	Rampur	256	59	140	188	220	251	291	321
19	0906	Hetaunda N.F.I	474	64	154	208	243	277	322	355
20	0909	Simara Airport	130	41	156	225	271	315	372	414
21	0911	Parwanipur	115	28	142	210	255	298	354	396
24	1111	Janakpur Airport	90	18	120	180	220	259	309	346
25	1215	Lahan	138	61	135	179	208	236	272	299
26	1319	Biratnagar Airport	72	69	134	172	198	223	254	278
29	1421	Gaida (Kankai)	143	109	175	214	240	265	298	322
Average				56	147	201	237	271	316	350

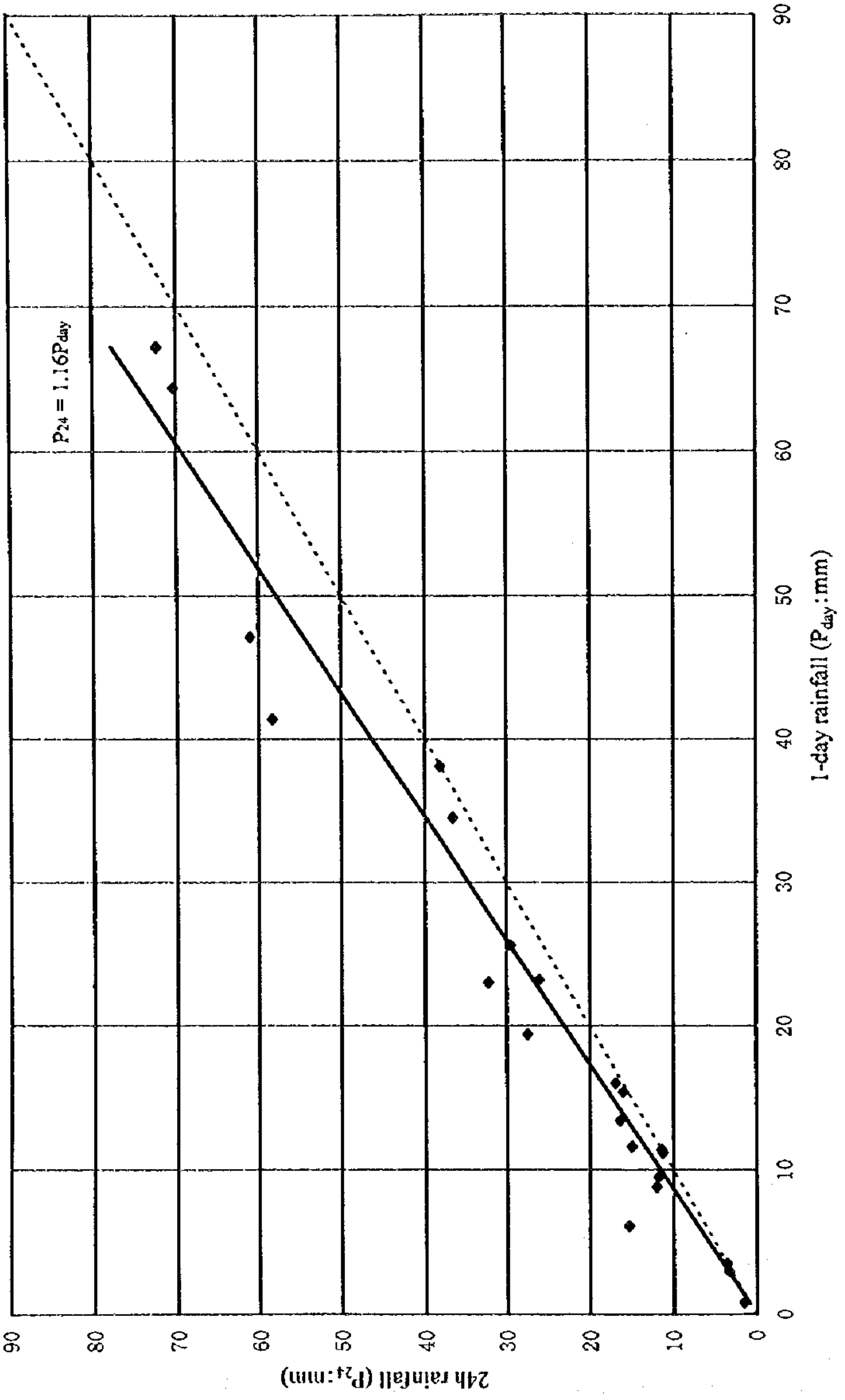
PROBABLE DAILY RAINFALL IN CLASS-III RIVER BASINS

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C2.4

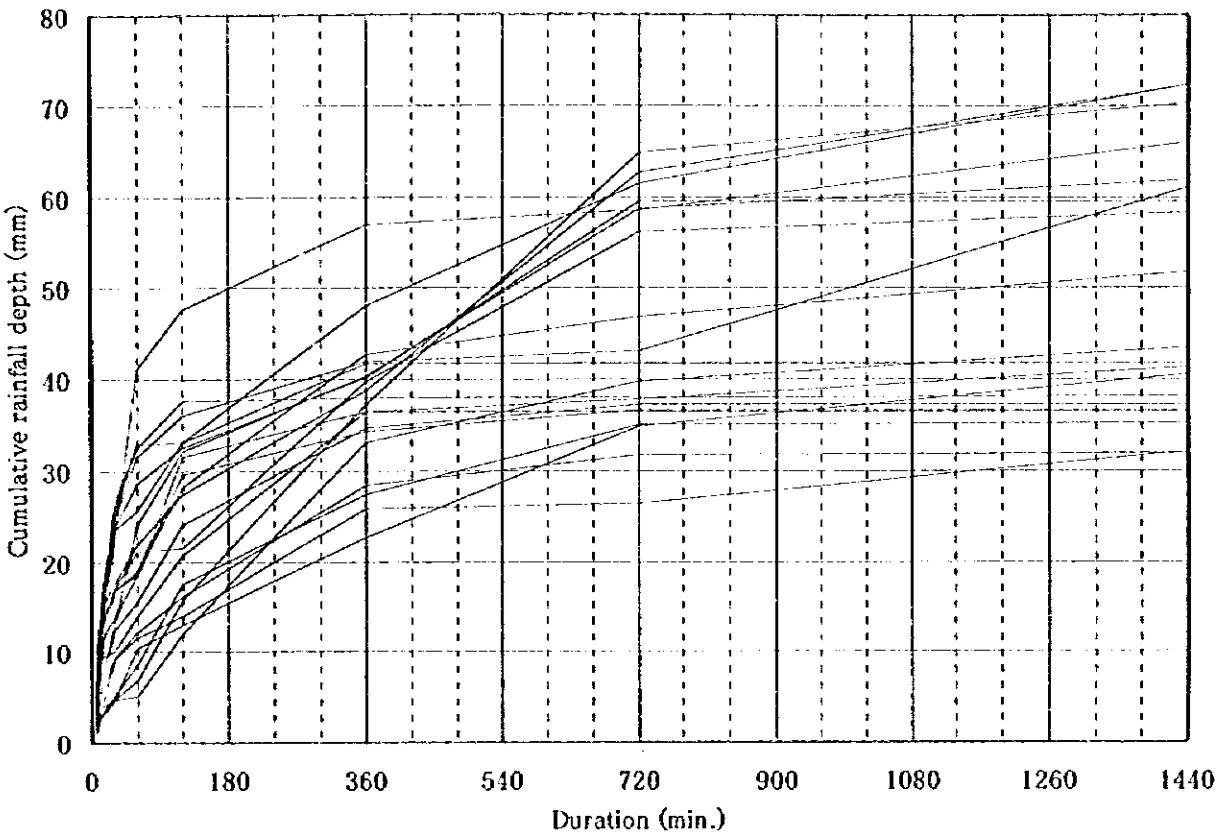


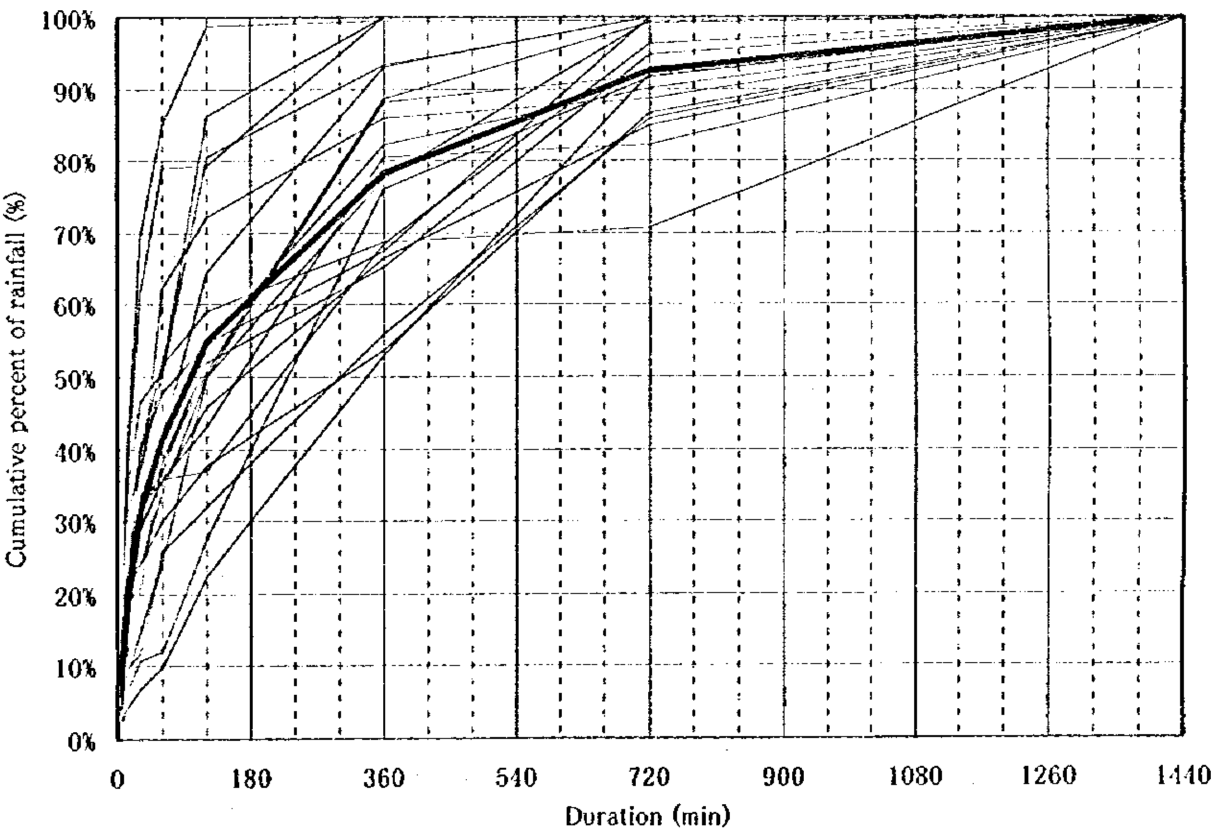
RELATIONSHIP BETWEEN DAIRY AND 24-HOUR RAINFALLS

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

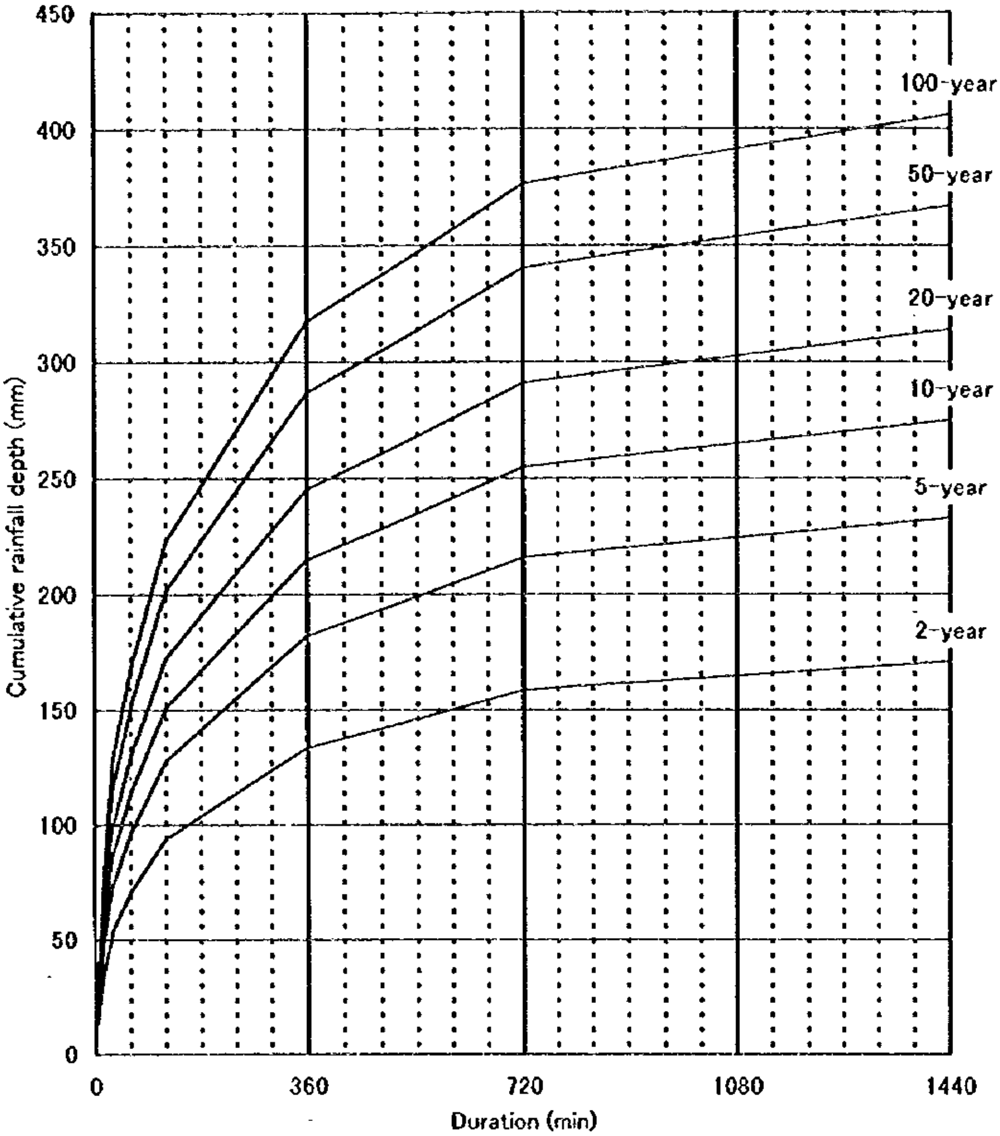
JAPAN INTERNATIONAL COOPERATION AGENCY





RAINFALL FOR SHORT DURATION

His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



PROBABLE RAINFALL DEPTH (mm)

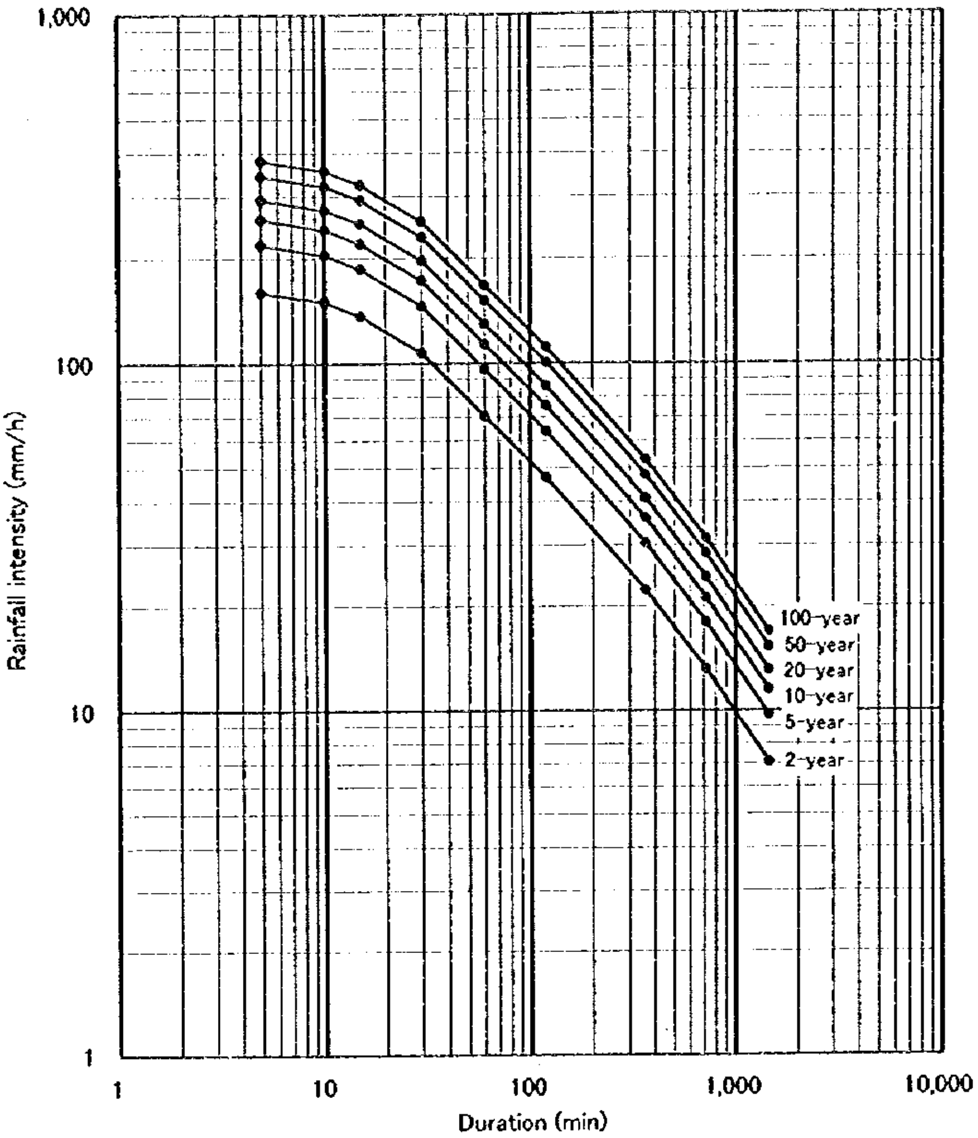
Return period (year)	Duration (min)								
	5	10	15	30	60	120	360	720	1440
	7.8%	14.6%	20.0%	31.4%	41.3%	54.9%	78.2%	92.7%	100.0%
2	13	25	34	54	71	94	134	159	171
5	18	34	47	73	96	128	182	216	233
10	22	40	55	86	114	151	215	255	275
20	25	46	63	99	130	172	246	291	314
50	29	54	73	115	152	202	287	340	367
100	32	59	81	128	168	223	318	376	406

PROBABLE RAINFALL DEPTH FOR SHORT DURATION

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



PROBABLE RAINFALL INTENSITY (mm/h)

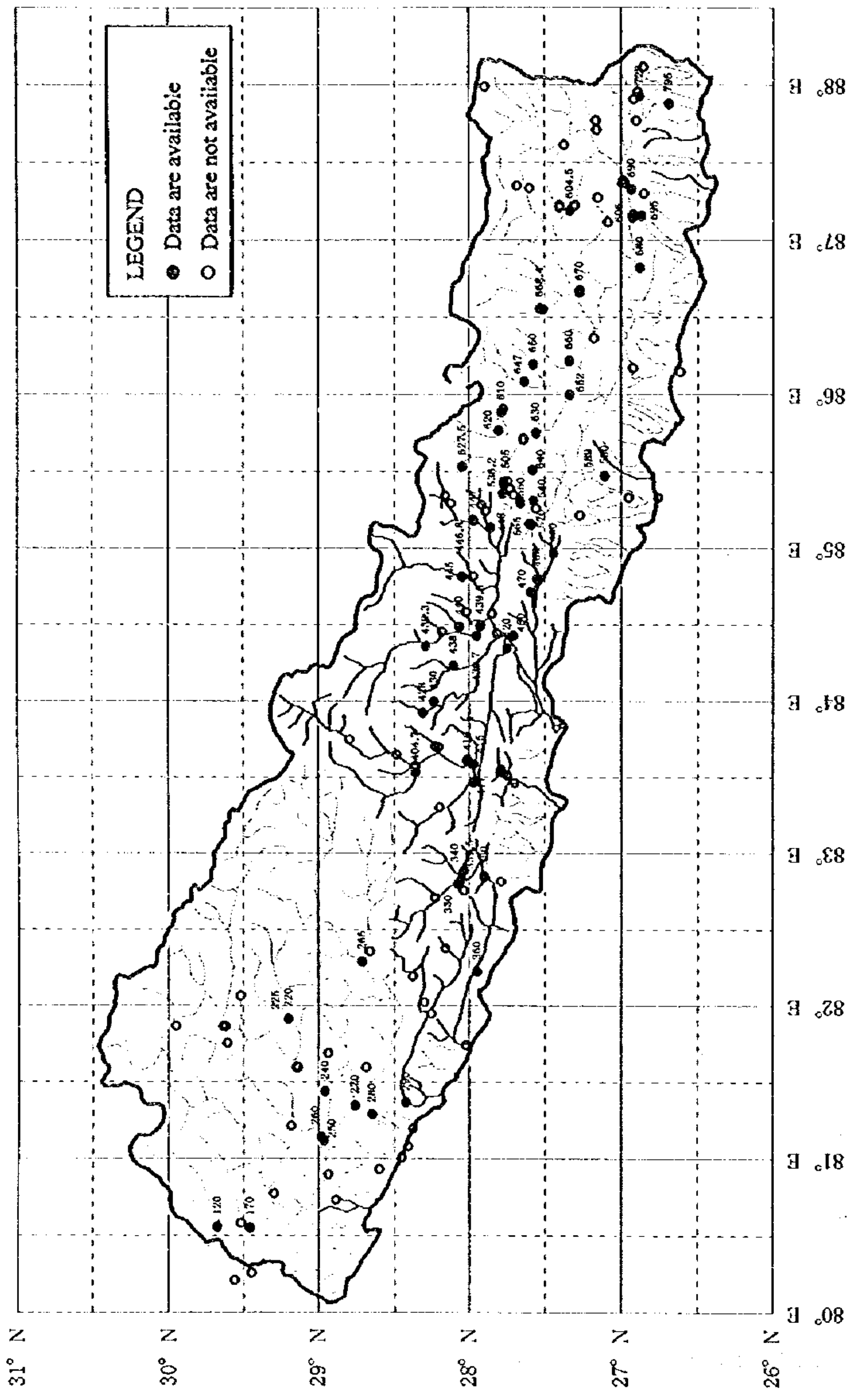
Return period (year)	Duration (min)								
	5	10	15	30	60	120	360	720	1440
2	160	150	137	107	71	47	22	13	7
5	218	204	186	146	96	64	30	18	10
10	258	241	220	173	114	76	36	21	12
20	294	275	251	197	130	86	41	24	13
50	343	322	294	230	152	101	48	28	15
100	380	356	325	255	168	112	53	31	17

PROBABLE RAINFALL INTENSITY FOR SHORT DURATION

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

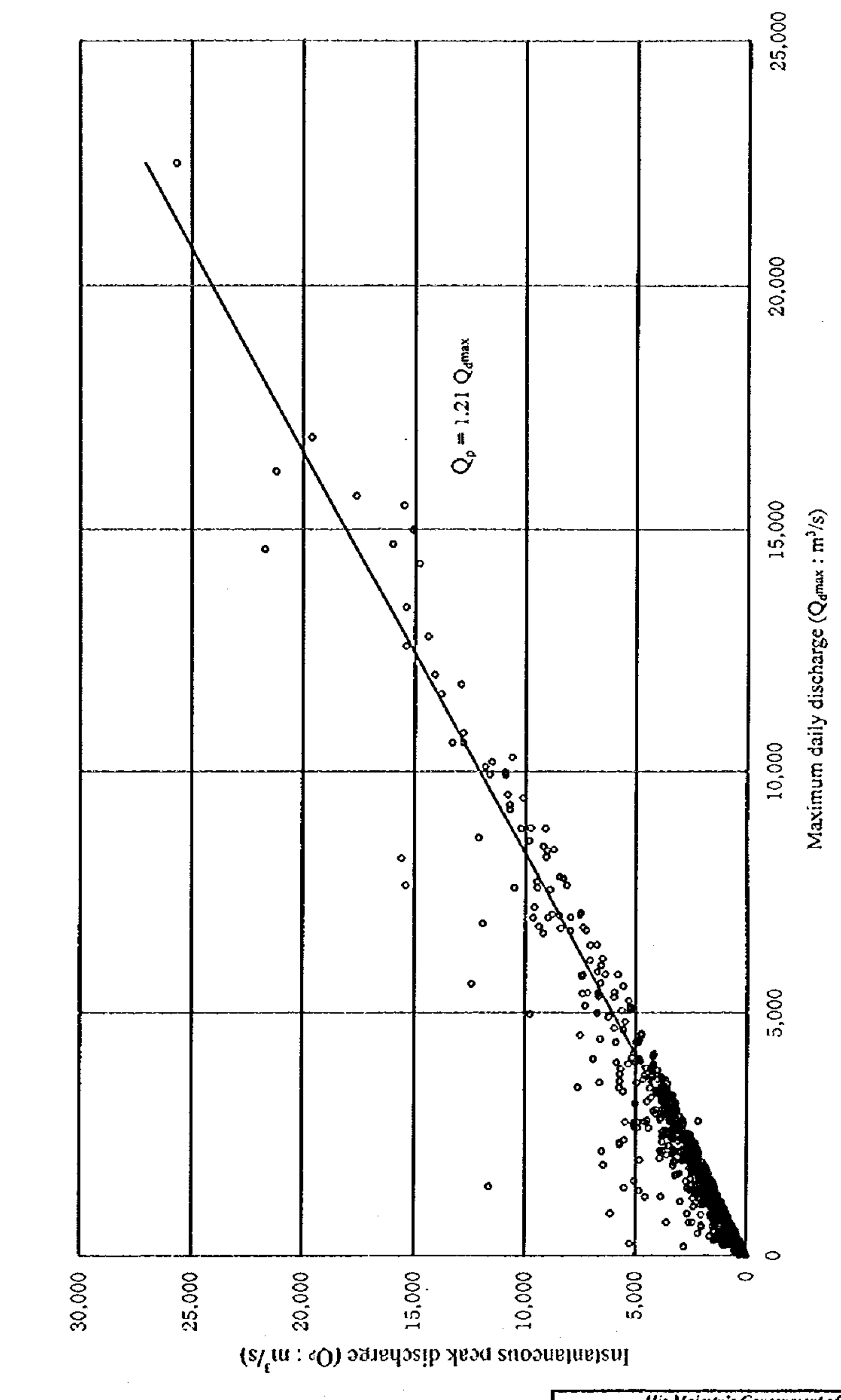


LOCATION OF DISCHARGE OBSERVATION STATIONS

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

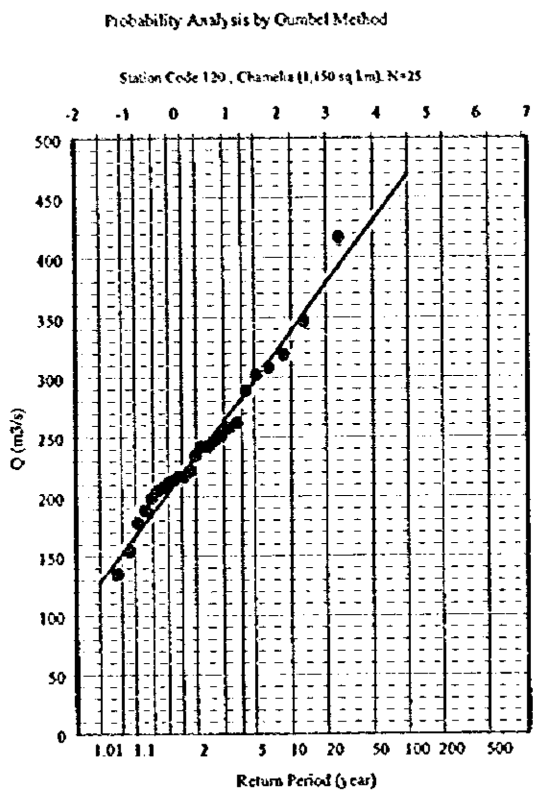


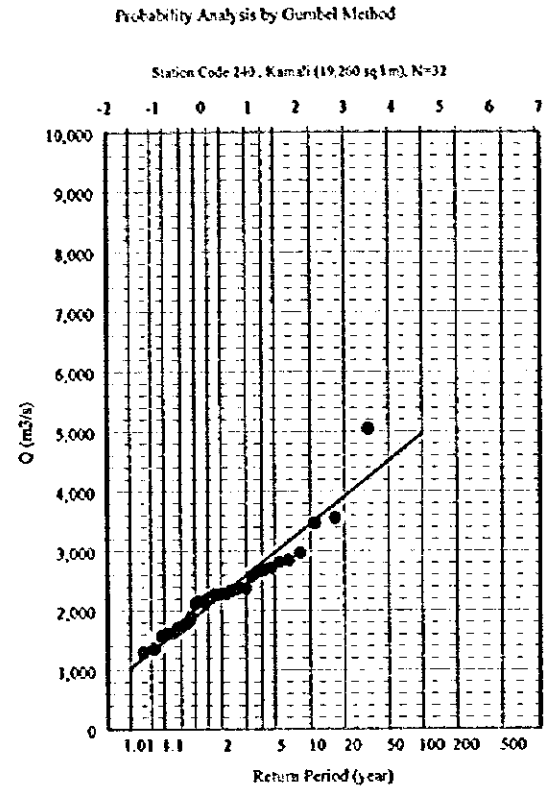
RELATIONSHIP BETWEEN PEAK DISCHARGE AND DAILY DISCHARGE

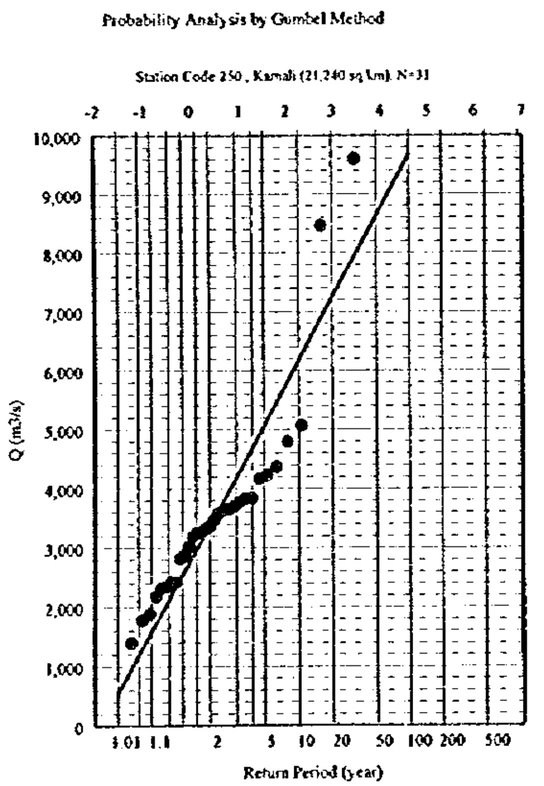
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

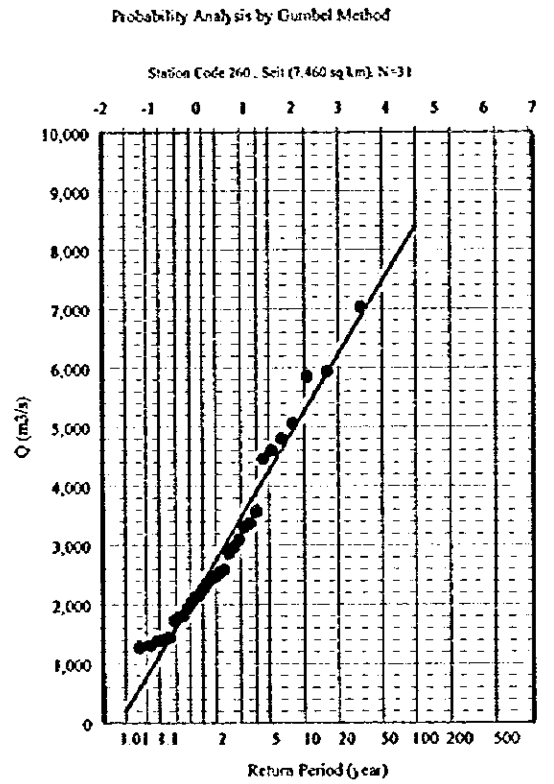
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY









PROBABILITY ANALYSIS OF DISCHARGE

His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
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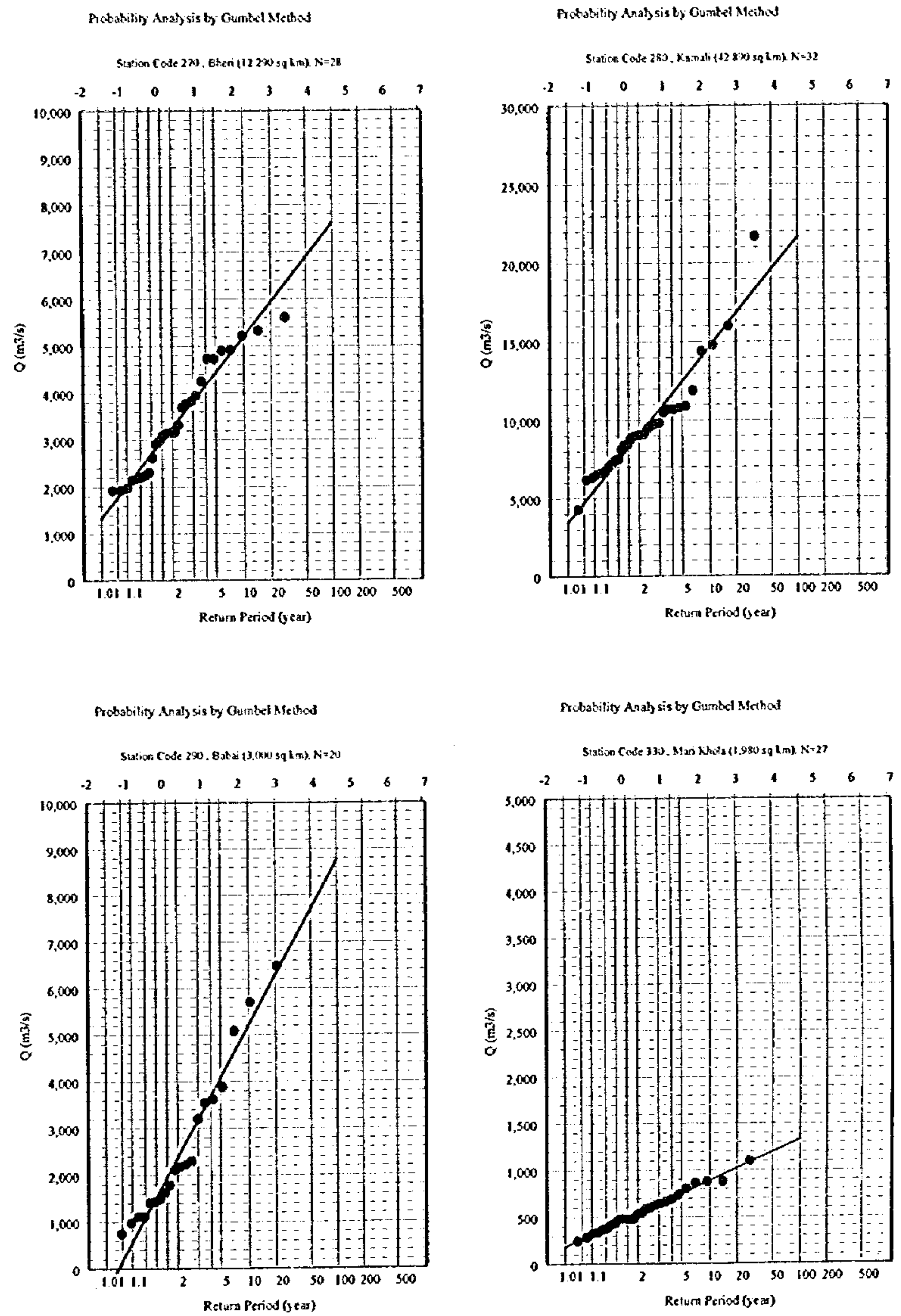

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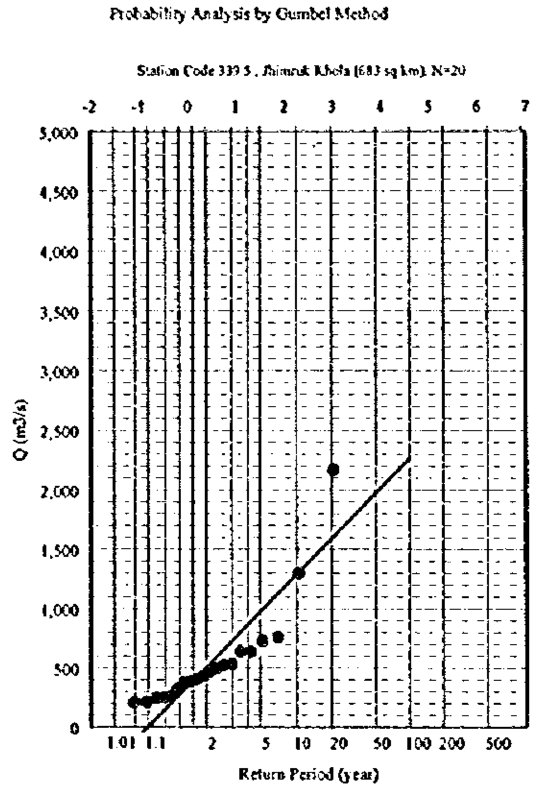

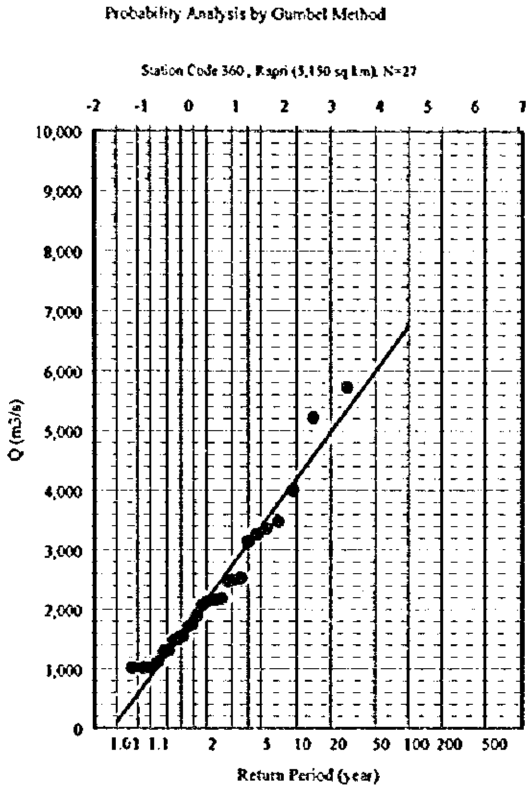

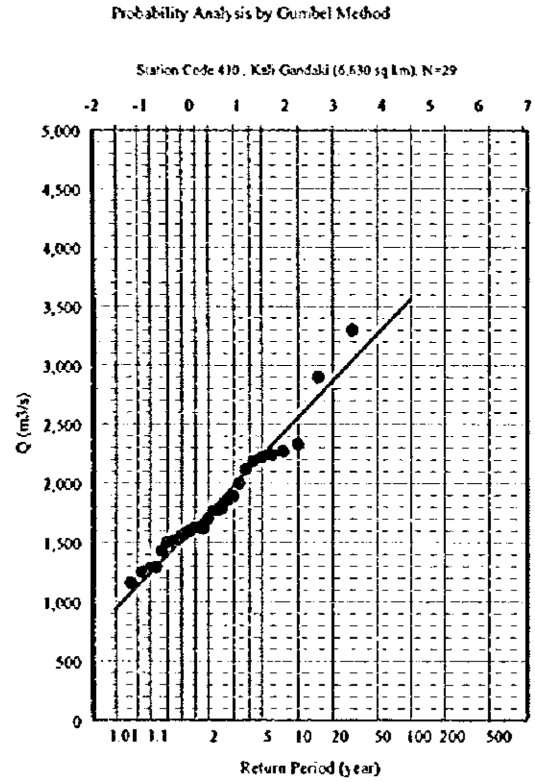

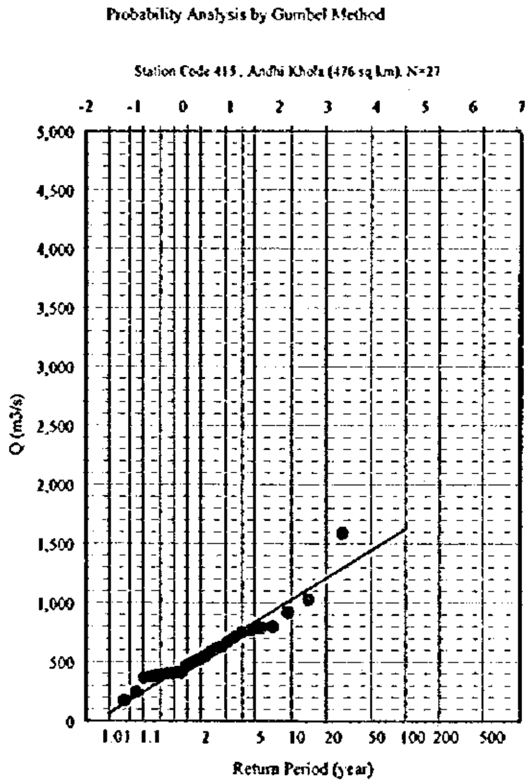

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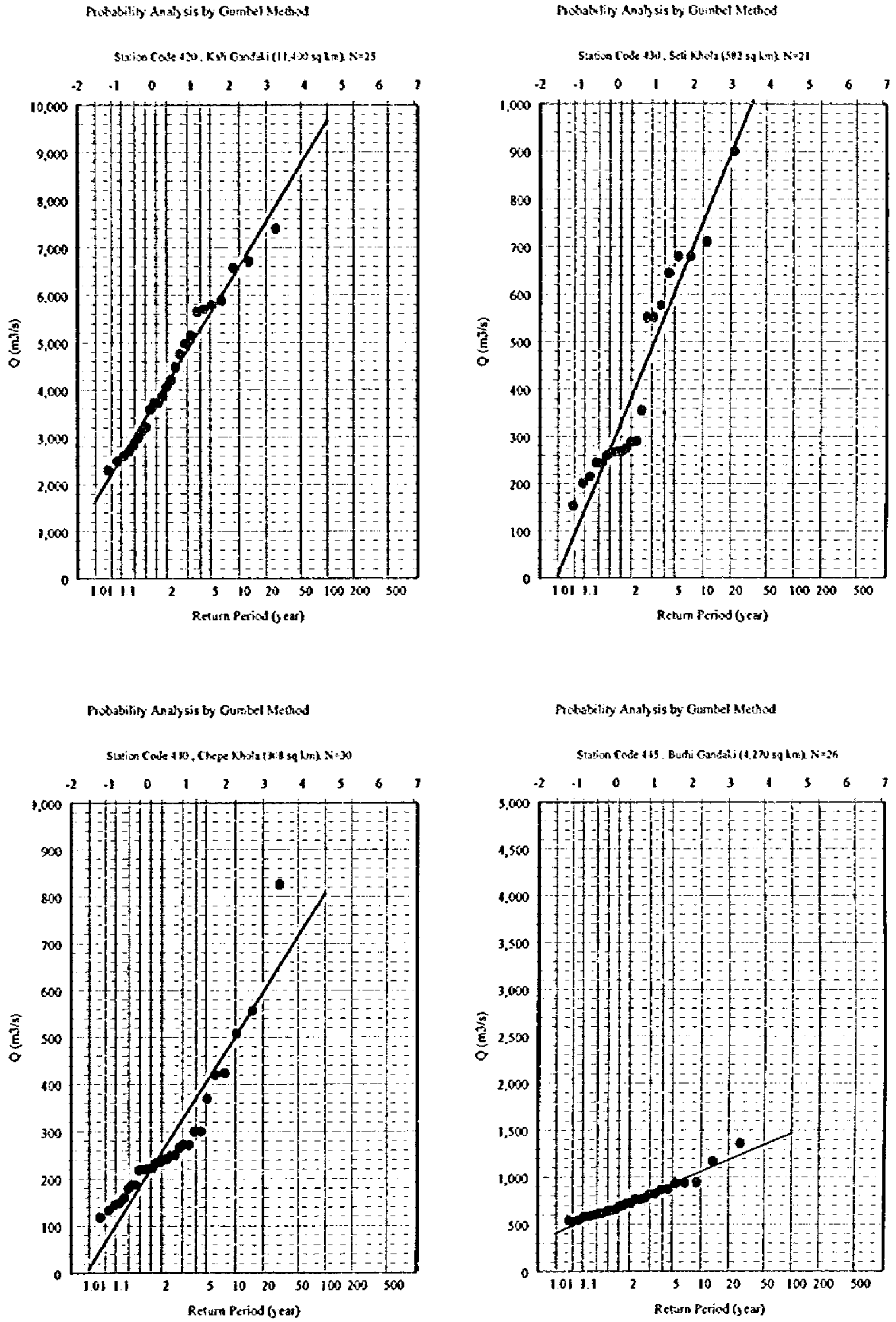

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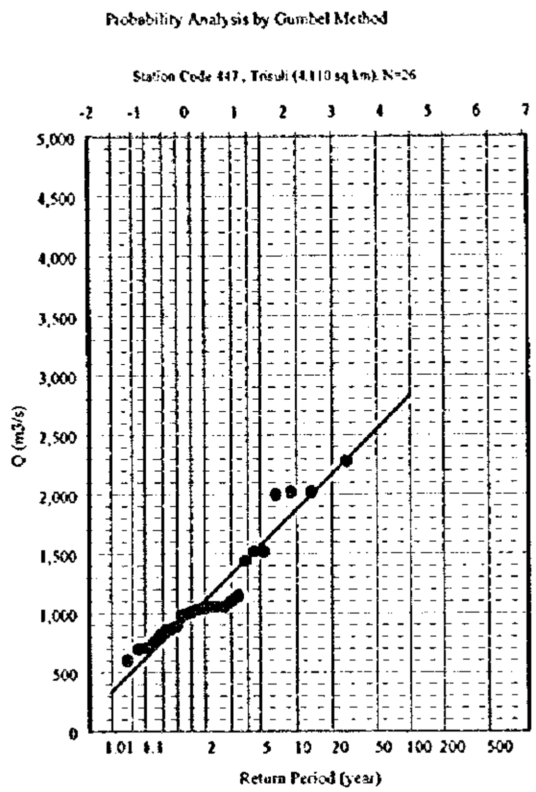

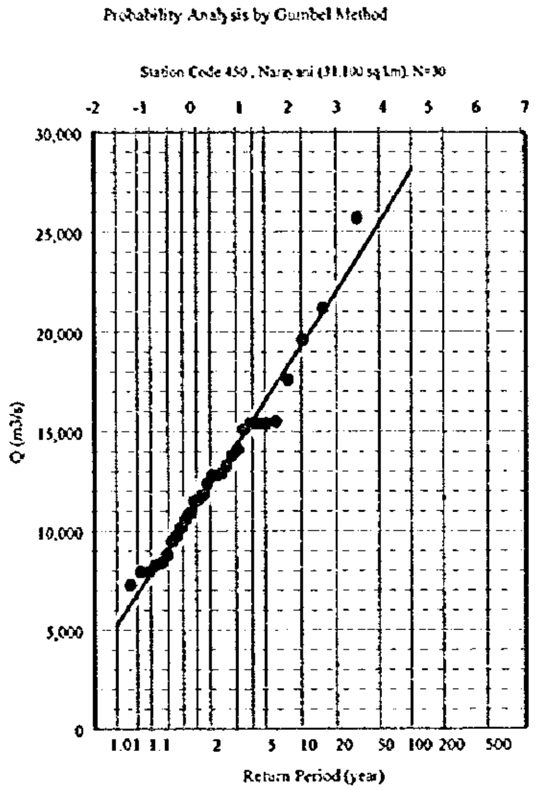

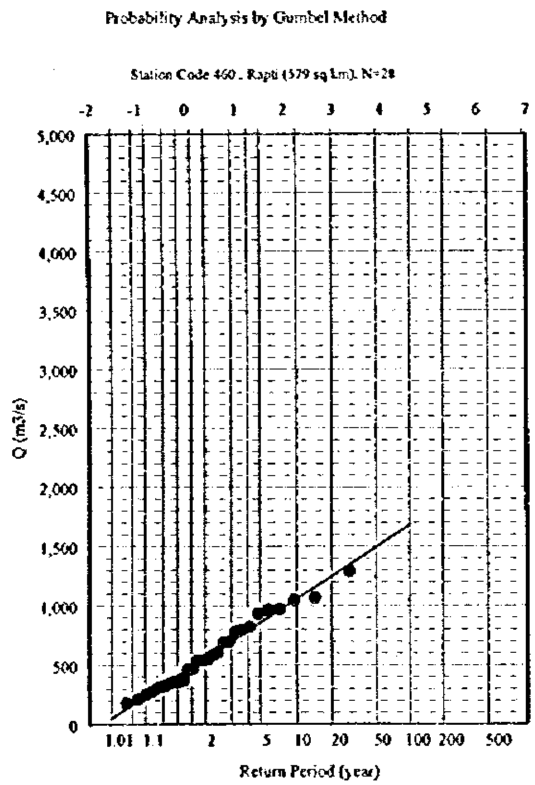

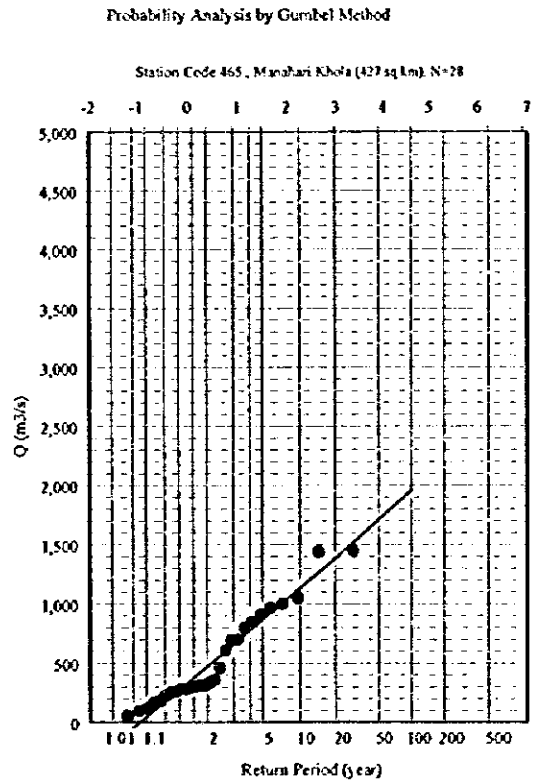

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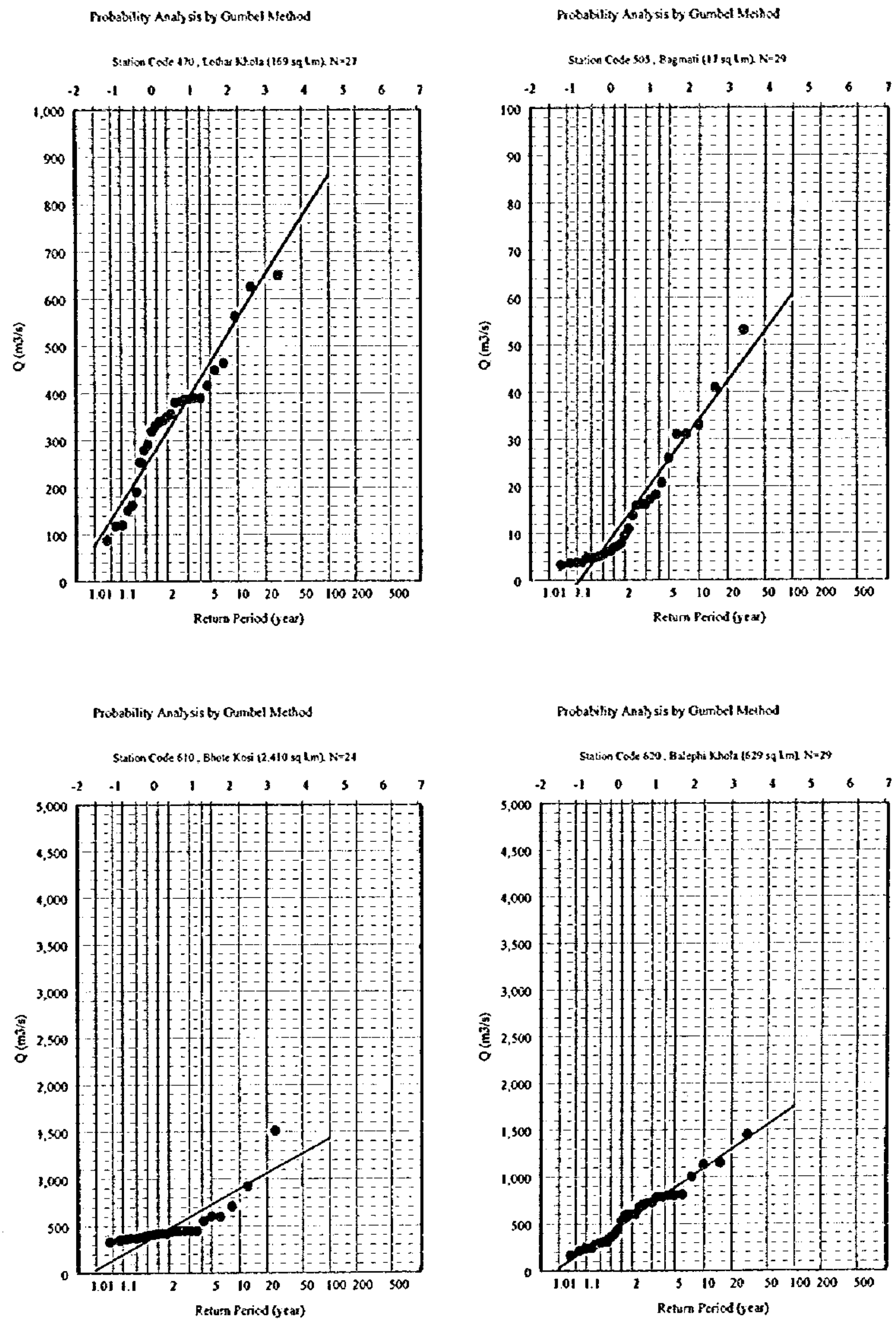

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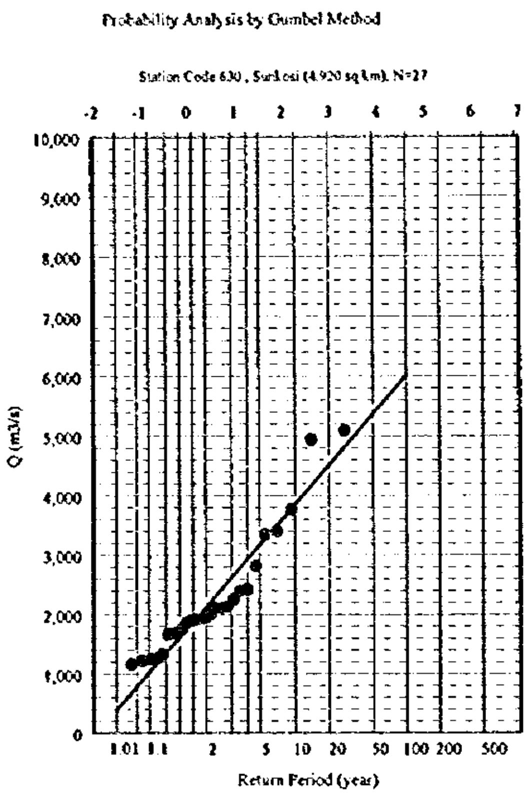

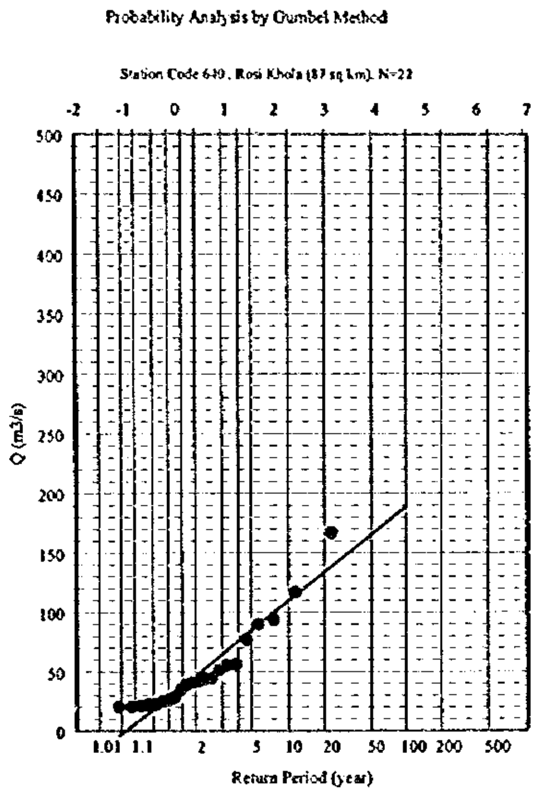

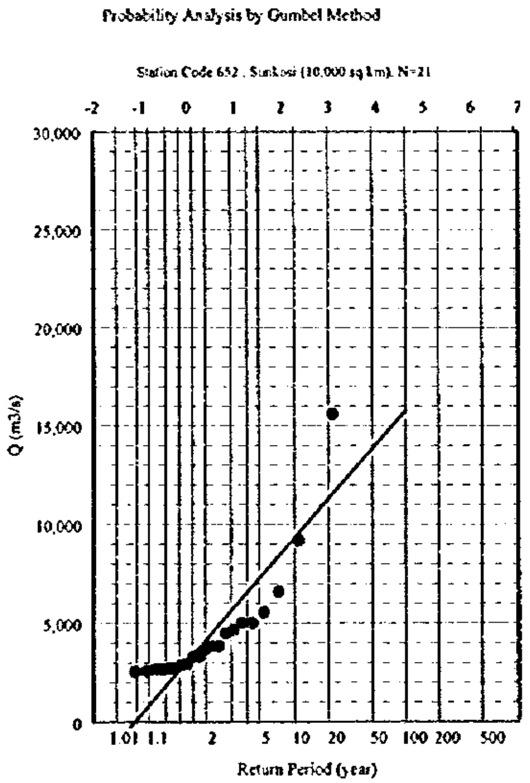

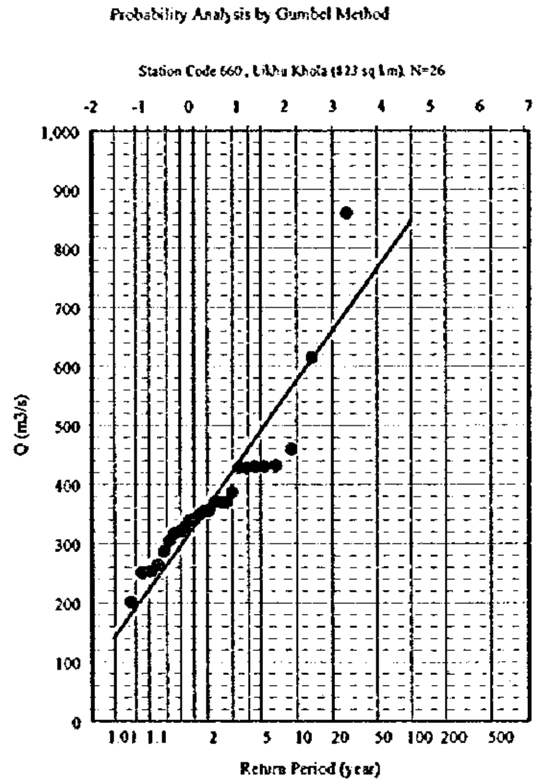

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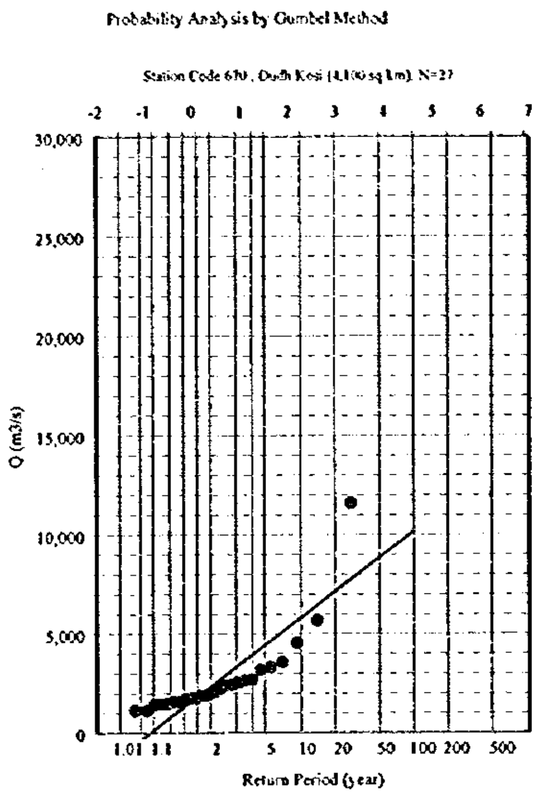

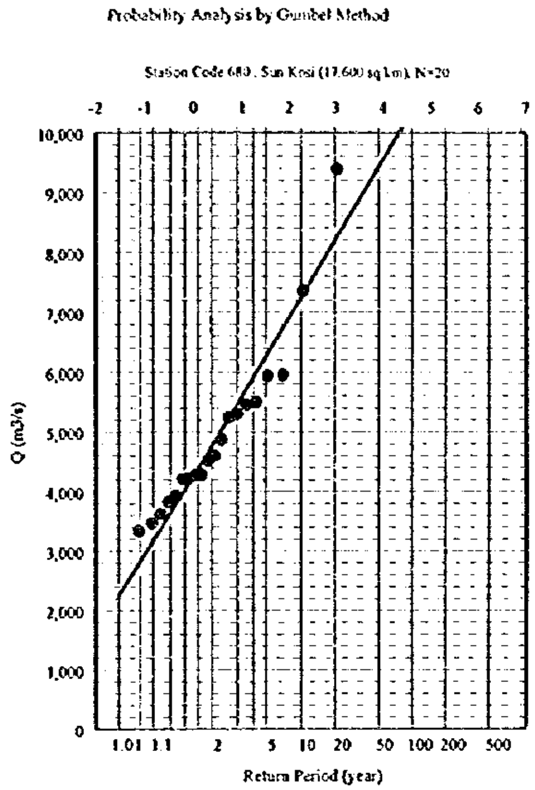

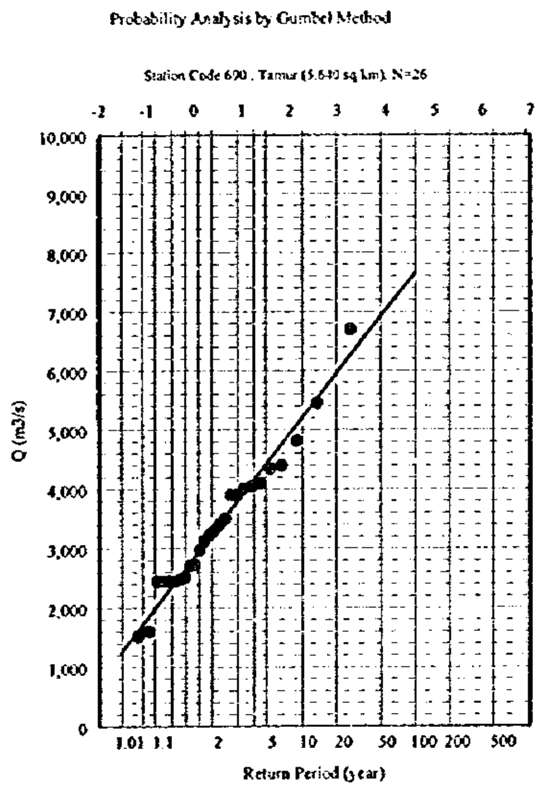

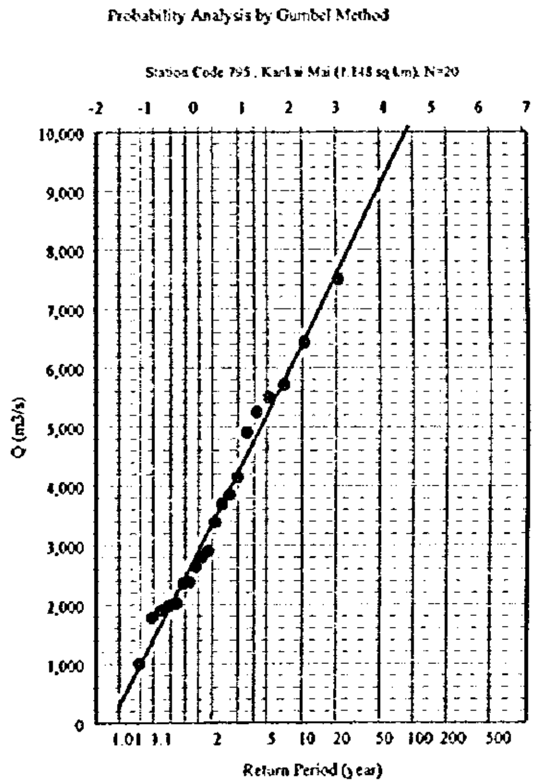

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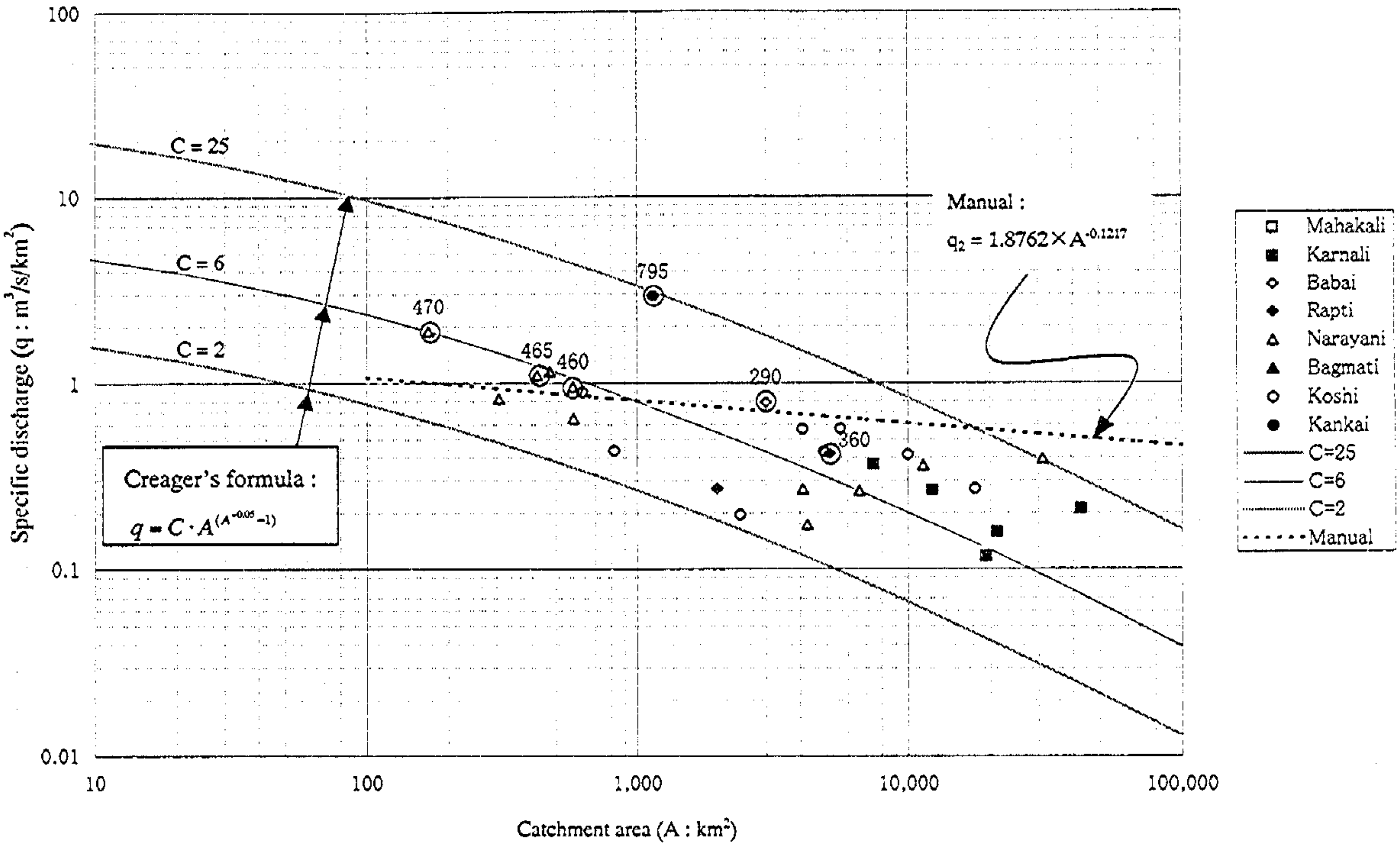

PROBABLE SPECIFIC DISCHARGE OF 2-YEAR RETURN PERIOD

His Majesty's Government of Nepal
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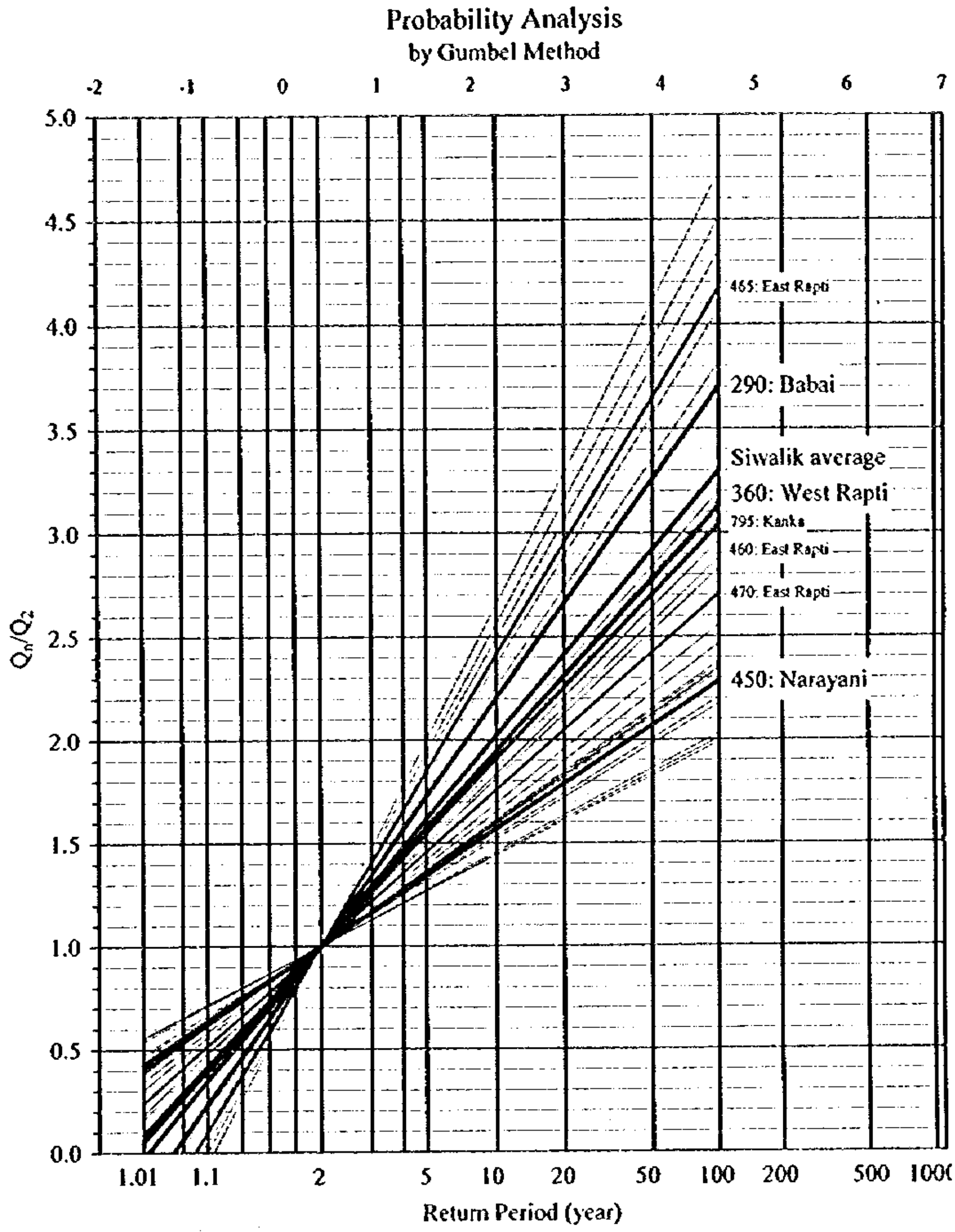

Code	River	Catchment (km2)	Elevation (m)	Return Period 2	5	10	20	50	100	Remarks
290.	Babai	3,000	192	1.00	1.72	2.20	2.66	3.26	3.70	
360.	West Rapti	5,150	218	1.00	1.57	1.95	2.31	2.78	3.13	
450.	Narayani	31,100	180	1.00	1.34	1.57	1.79	2.07	2.28	
460.	East Rapti	579	332	1.00	1.54	1.90	2.25	2.70	3.03	
465.	Manahari Khola	427	305	1.00	1.85	2.41	2.95	3.65	4.17	
470.	Lothar Khola	169	336	1.00	1.46	1.76	2.05	2.42	2.71	
795.	Kankai Mai	1,148	125	1.00	1.55	1.91	2.26	2.71	3.05	
	Average (excl. sta. Code: 450)			1.00	1.62	2.02	2.41	2.92	3.30	

RATIO OF PROBABLE DISCHARGE

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