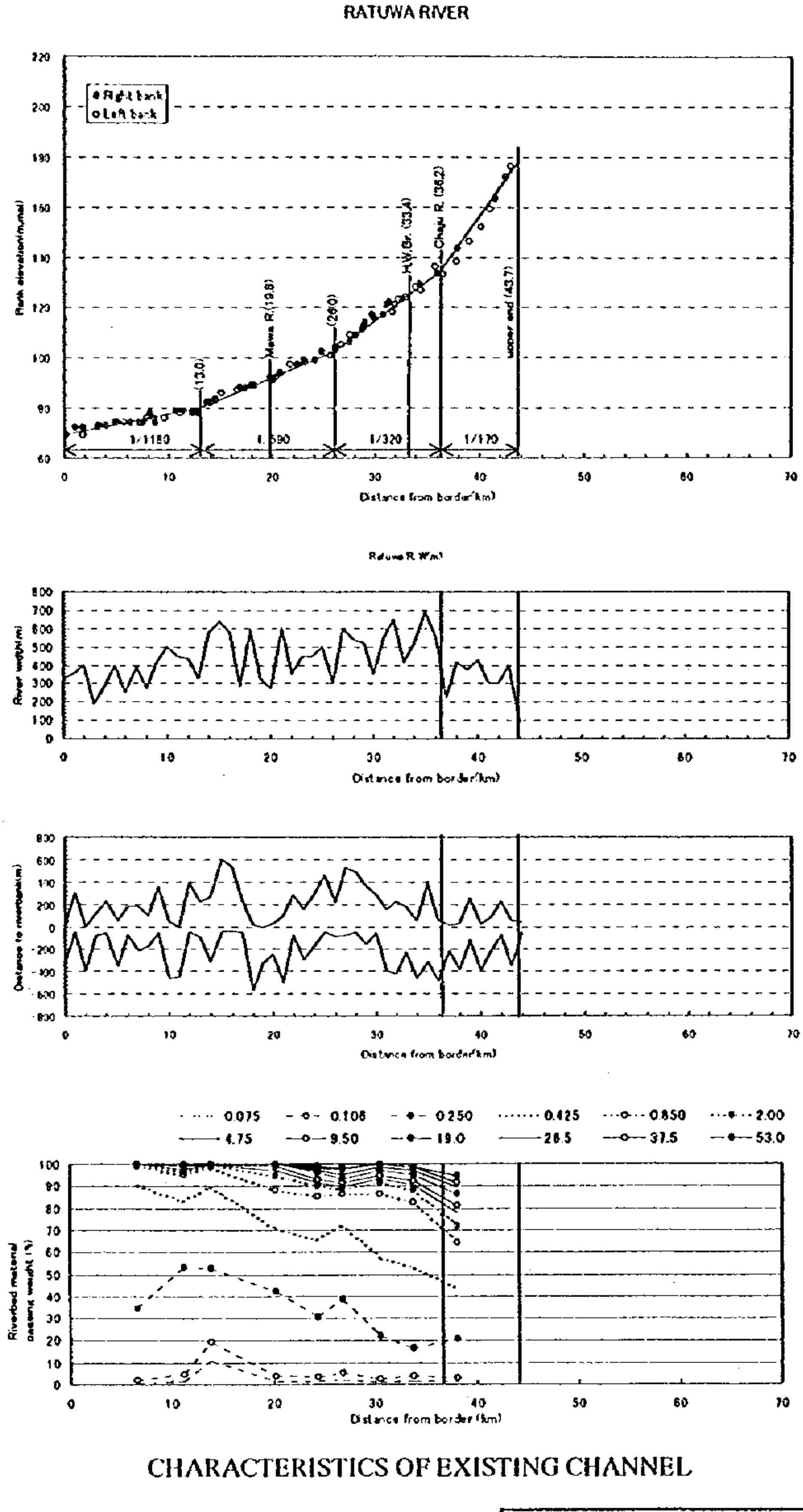
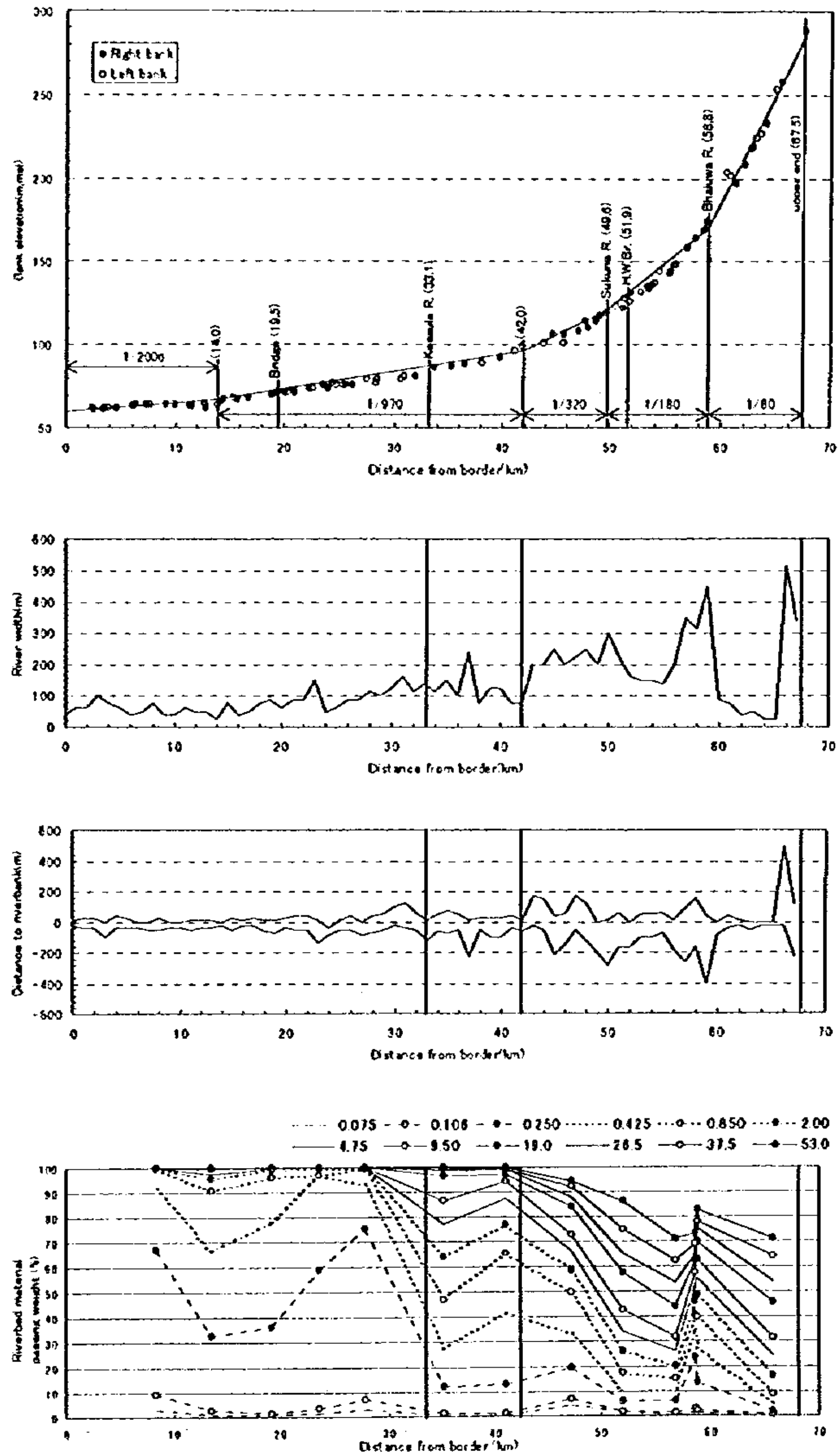


CHARACTERISTICS OF EXISTING CHANNEL

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

LOHANDRA RIVER



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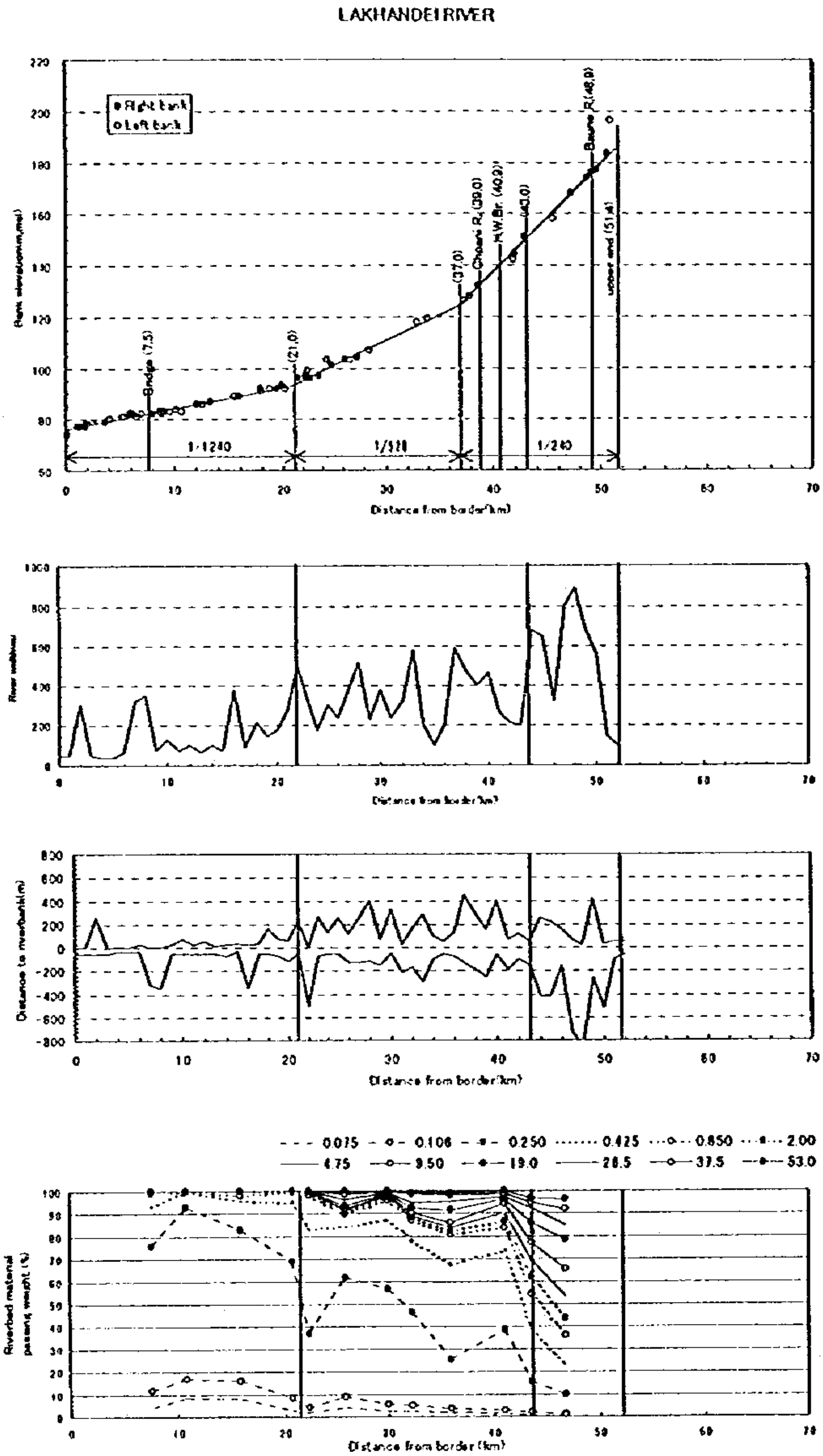

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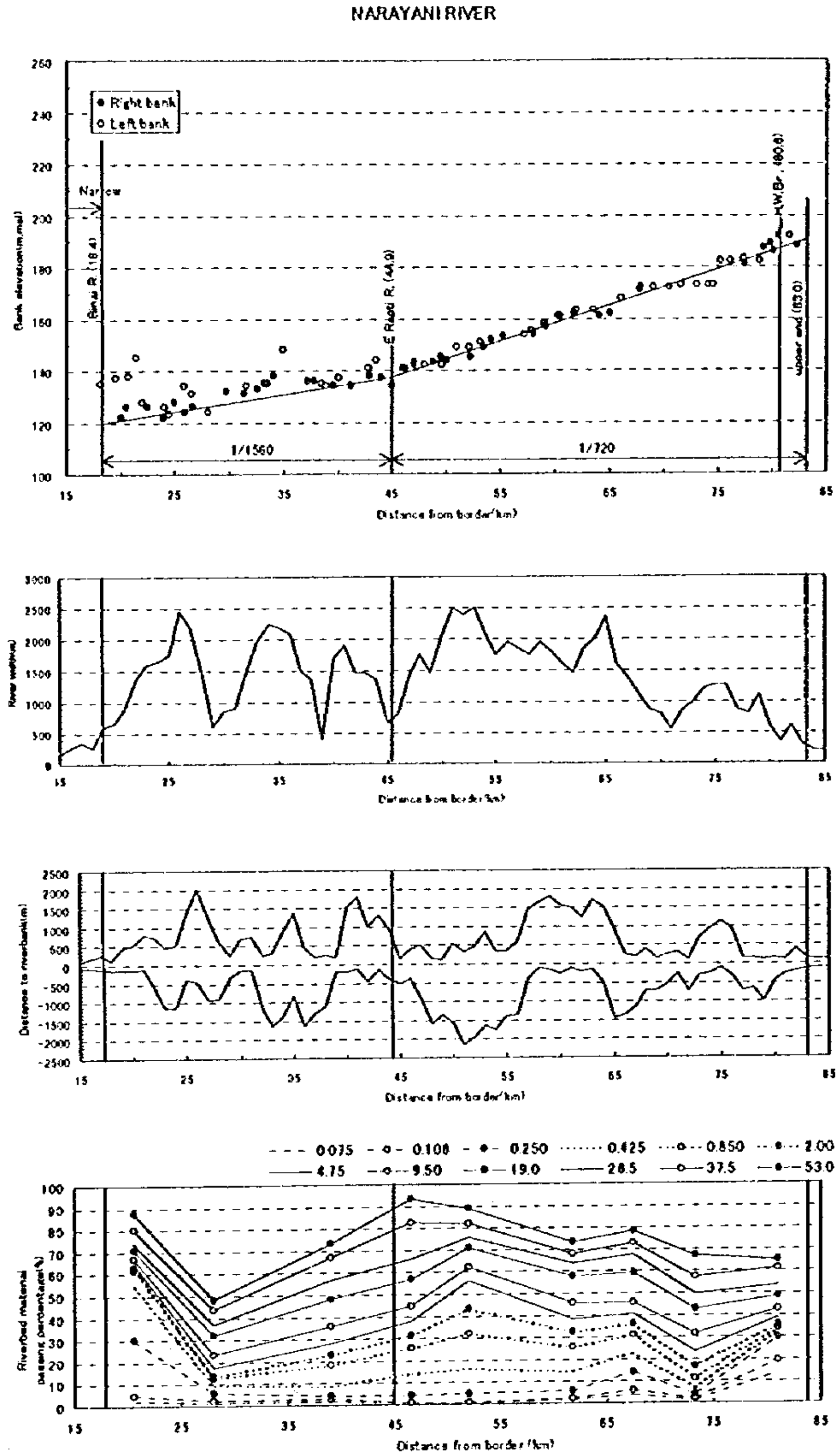

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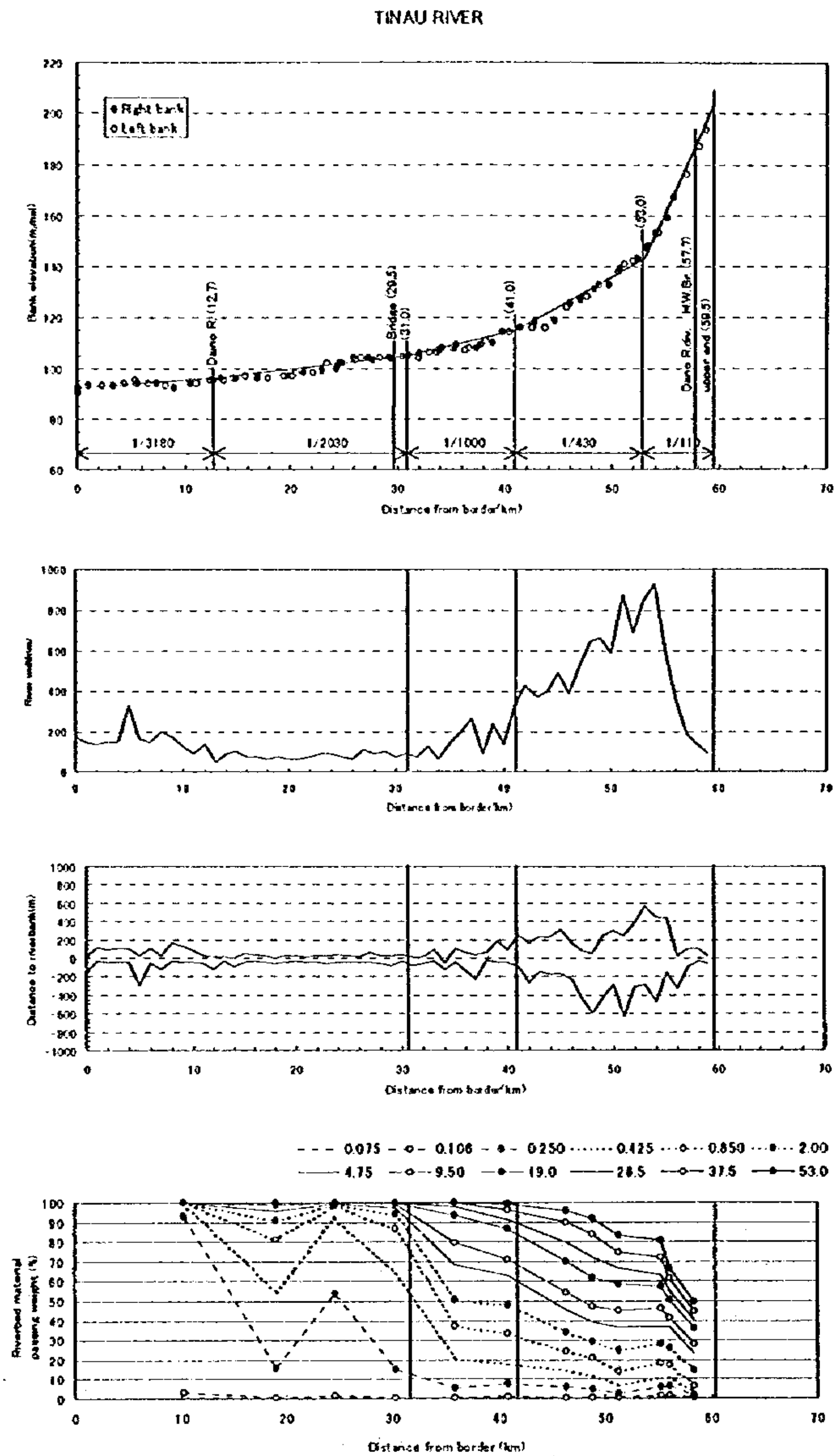

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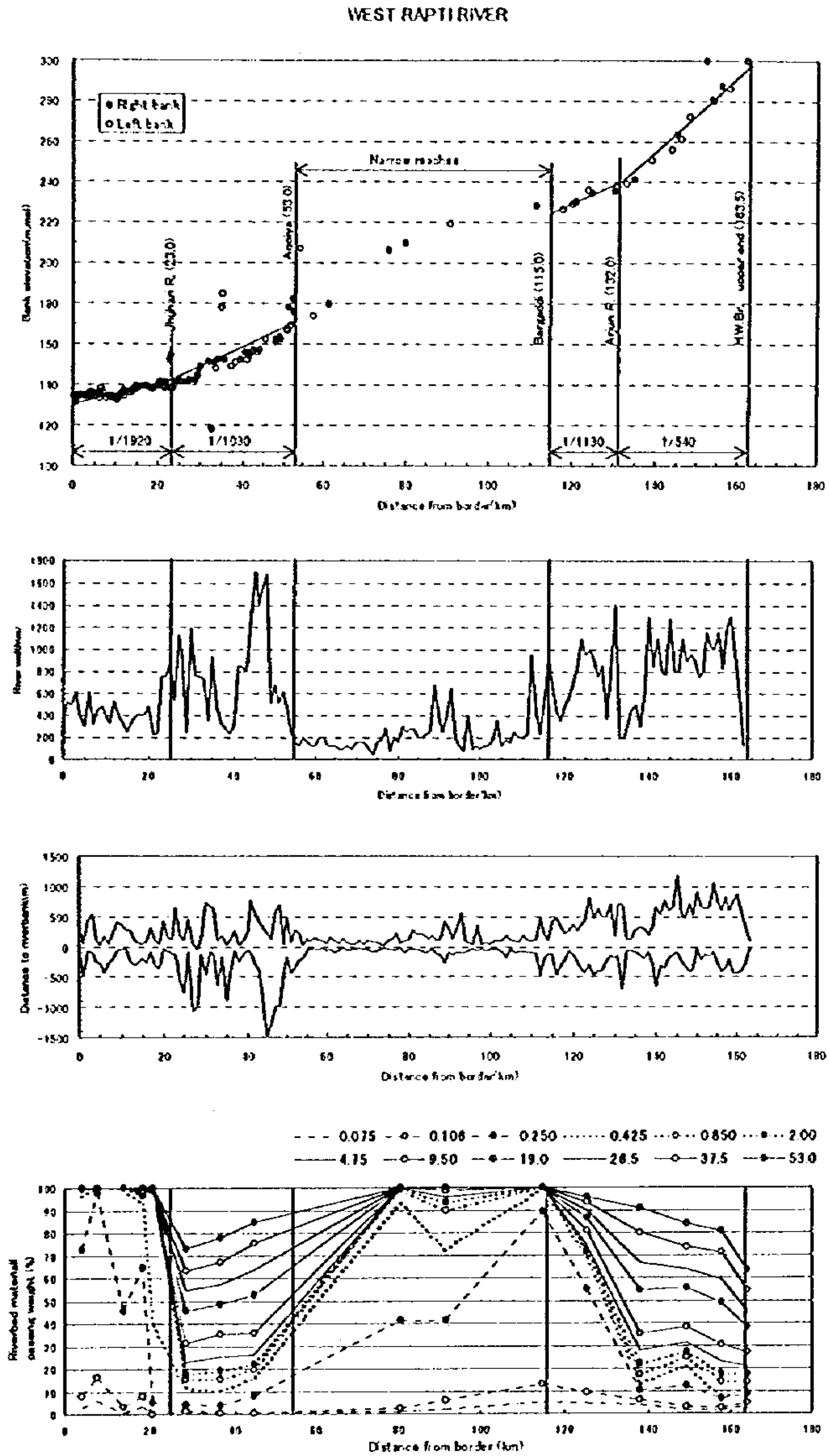

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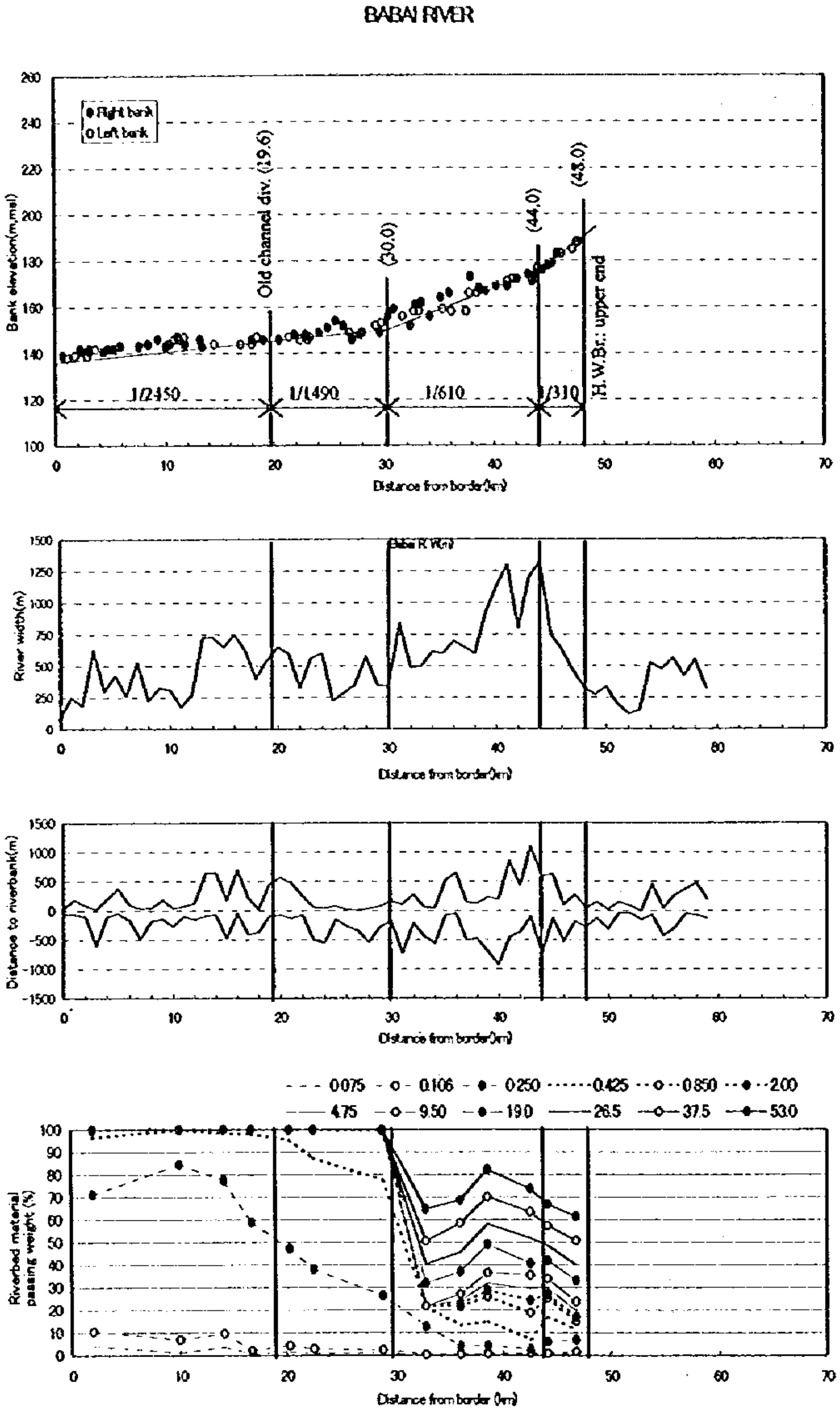

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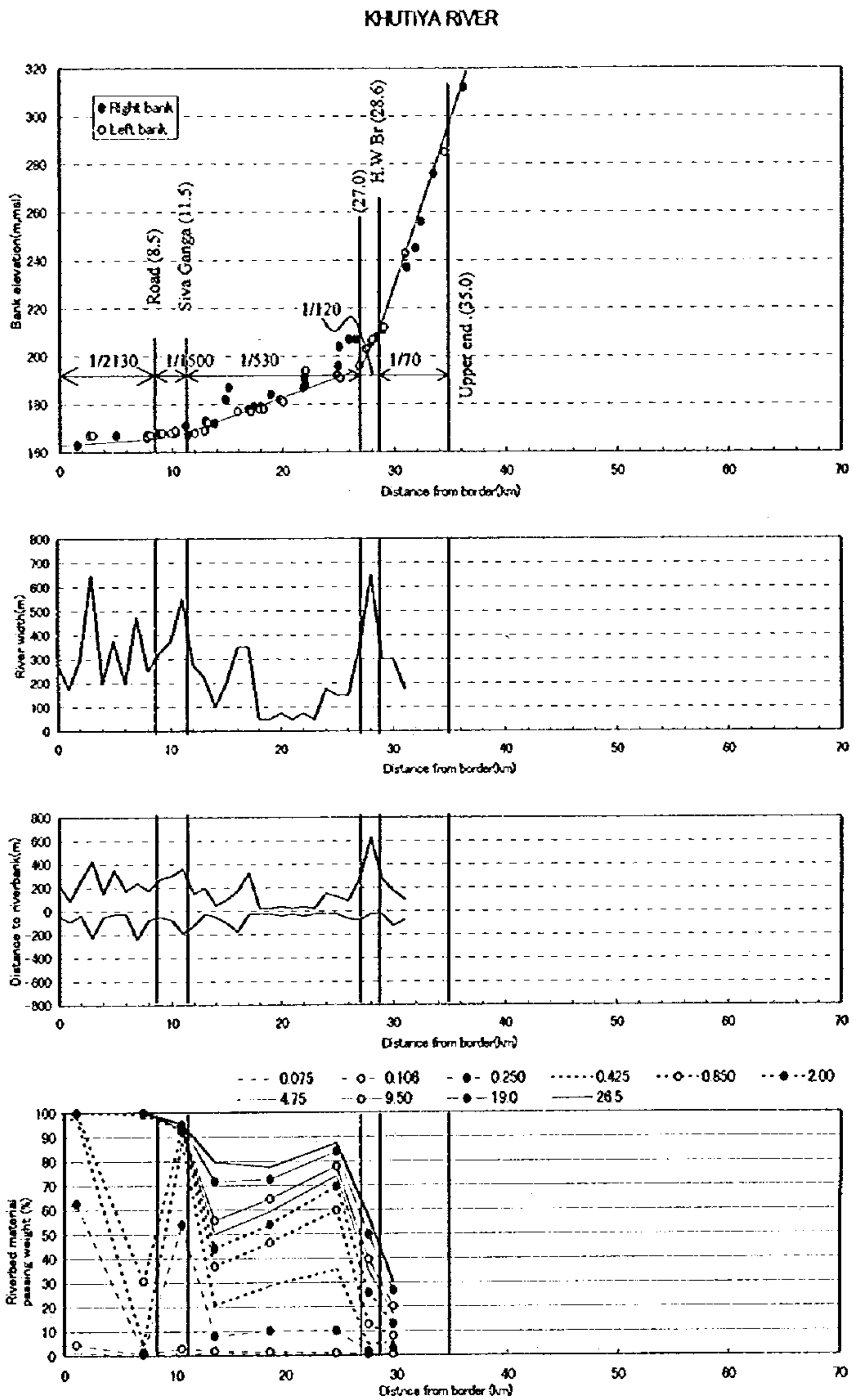

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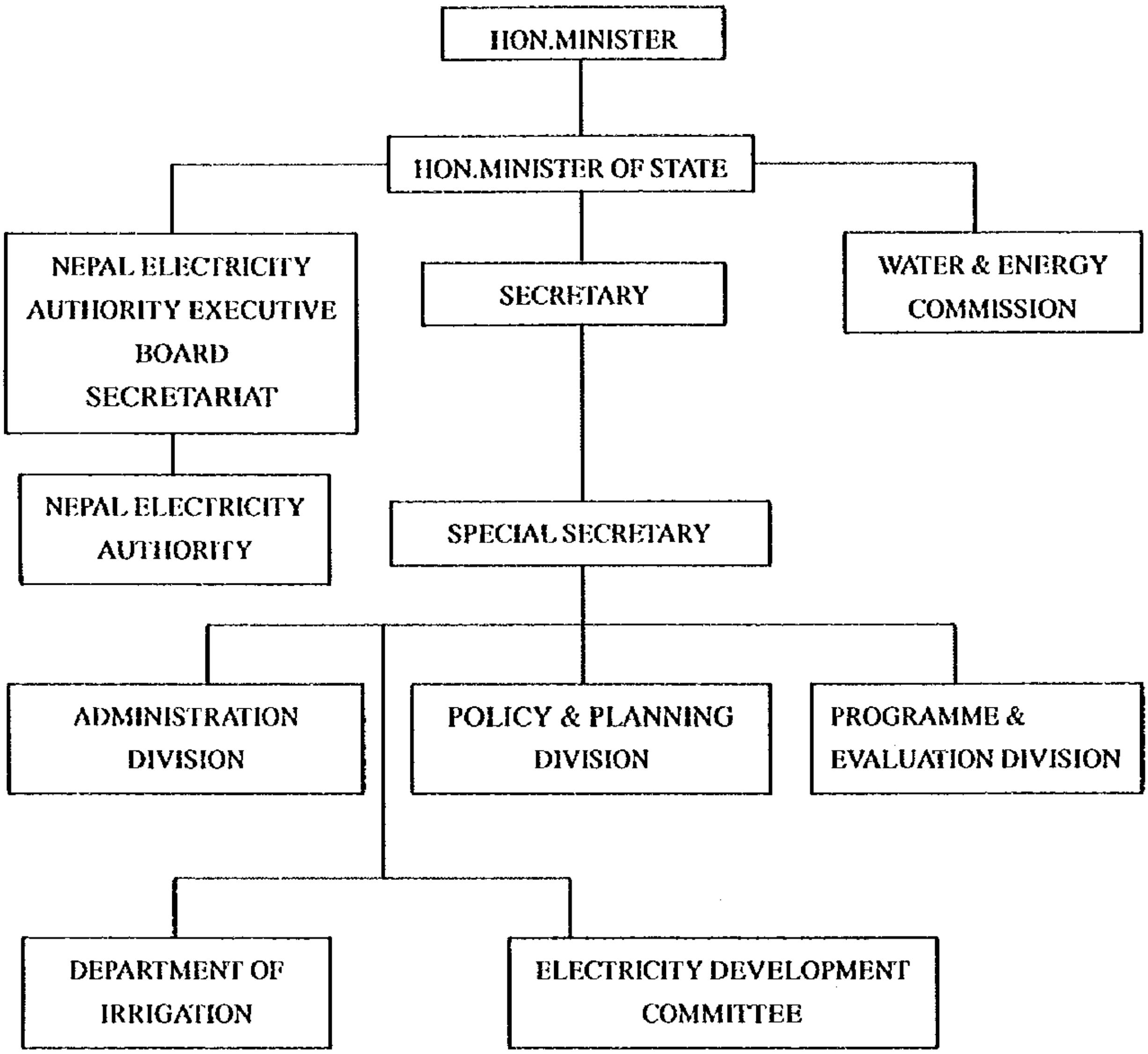
HIS MAJESTY'S GOVERNMENT
MINISTRY OF WATER RESOURCES
ORGANIZATION CHART

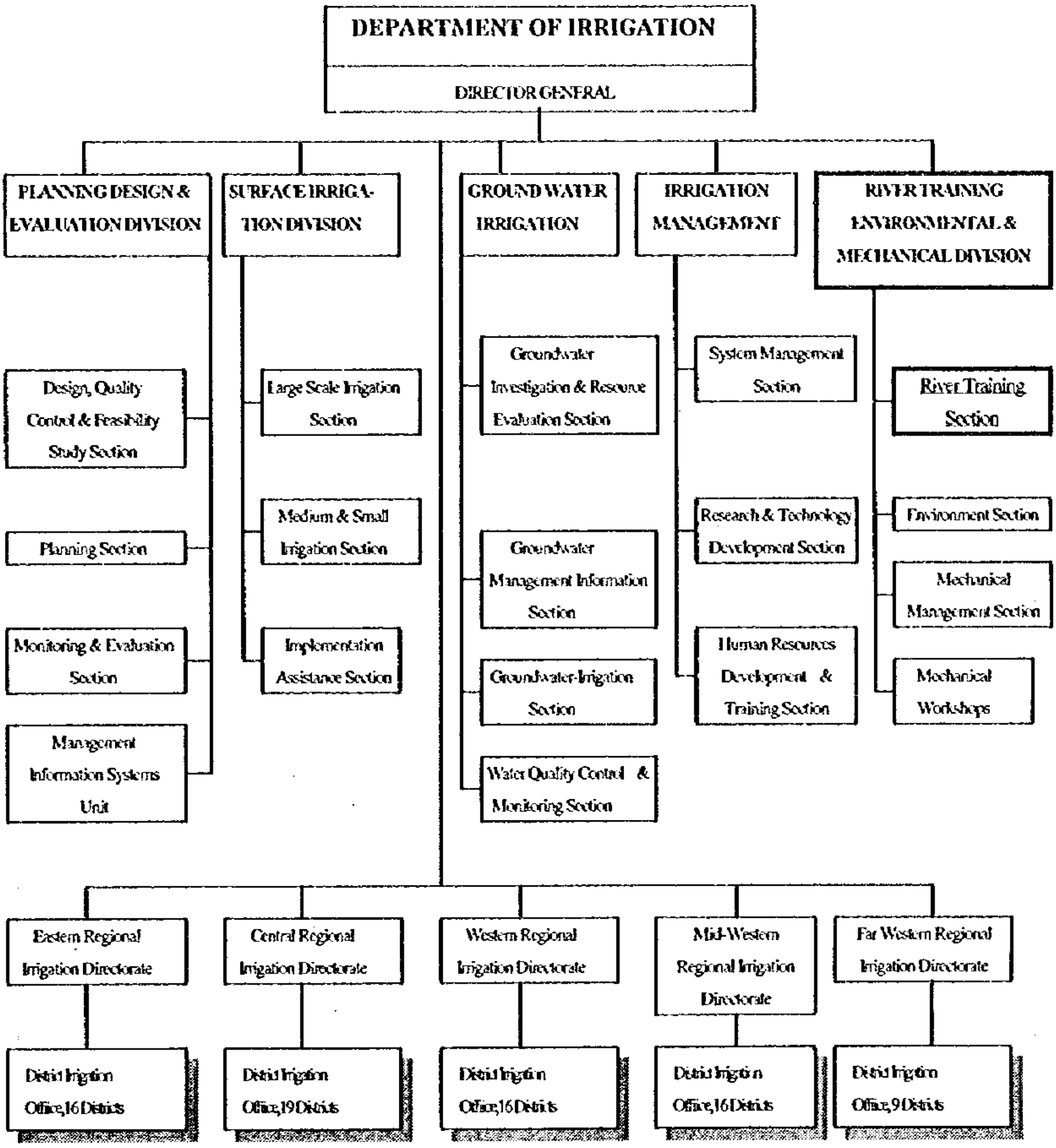


source: Dept. of Irrigation (as of March 1998)

ORGANIZATION CHART:
MINISTRY OF WATER RESOURCES

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. 2.14



source: Dept. of Irrigation (as of March 1998)

ORGANIZATION CHART:
DEPARTMENT OF IRRIGATION

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THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
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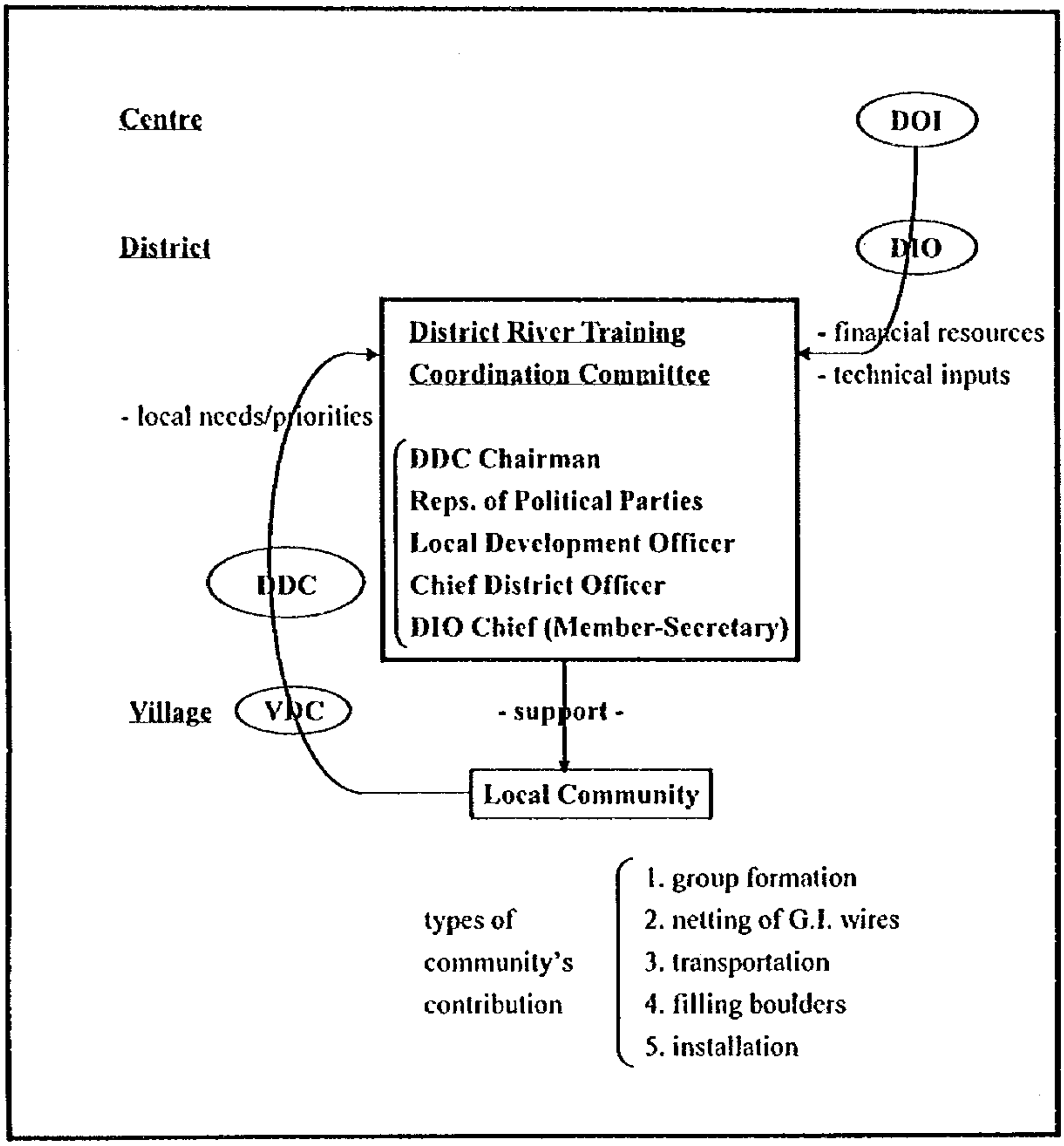
Fig. 2.15

PARTICIPATORY ARRANGEMENT
FOR DOI'S LOCAL-LEVEL FLOOD MITIGATION PROJECTS



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Department of Irrigation, Ministry of Water Resources
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FOR SELECTED RIVERS IN THE TERAI PLAIN
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CHAPTER 3 BASIC INVESTIGATION AND STUDY

3.1 Investigation of River Facilities

It is helpful to learn from the existing river facilities. Conditions of existing river facilities were investigated in the field for about one month from the middle of January 1998. The investigation aims to clarify location, function, structure, and extent of damage, if any, of the existing river facilities such as dikes, bank protection works, drainage sluices, weir/barrages, intake gates, bridges, and other flood mitigation and water use facilities.

The investigation was carried out according to the following procedures:

1) To collect data and information on the river facilities from the related district offices.
2) To plot location of facilities (by using GPS) on a topographic map (1/25,000).
3) To sketch the general layout of facilities and structural details (plan and section) by measuring major dimensions.
4) To take photos of:
   - The general views of each river at structure sites,
   - The upstream and downstream views of each structure, and
   - Other spot views which best show the structures and damaged sites.

The investigation covered a total of 484 facility sites for the eight rivers in the Study Area. The kind of major river facilities are shown in Table 3.1 for the respective rivers. As seen in the table, spur works constitutes by far the majority of facilities in the rivers subject to the study. Almost all the spur and revetment works are made of gabions consisting of boulders and galvanized iron (G.I.) wire nets.

These facilities are located sporadically along the river course. Some of these spur and revetment works are damaged already probably due to insufficient foot protection works. Although stability and function of spur works can be attained when they are installed as a series, single spur was seen in some sites probably due to the lack of fund for river works.

The types of existing spur or bank protection works are uniform. A variety of bank protection and flood mitigation measures should be introduced considering the river condition and availability of materials.

3.2 Investigation of Flood and Sediment Disasters

(1) Method of Investigation

Conditions of past flood and sediment disasters were investigated for all of the eight rivers in the Study Area. Data and information were collected from the following:

1) District irrigation offices (DIO) and district development committee (DDC) offices.
2) Selected village development committee (VDC) and municipality offices.
3) Selected individual residents more than 1,000 persons in total.

(2) Implementation of Investigation

The investigation was carried out over a period of one month from the middle of January 1998 by four teams consisting of two Nepali consultants employed by the Study Team:

Group 1: Ratuwa and Lohandra rivers
Group 2: Lakhandei and Tinau rivers
Group 3: Narayani and Babai rivers
Group 4: West Rapti and Khutiya rivers.

On the basis of the information obtained from the district irrigation offices and district development offices, 78 Village Development Committee offices and 3 Municipality offices were selected for the investigation. Furthermore, 1,124 residents in the flood prone areas were selected for individual interviews using questionnaire form.

The VDC/Municipalities and individual residents subject to the interviews are shown in Table 3.2 and summarized below.

(VDC/Municipalities and Individuals Subject to Investigation)

River	Related districts	VDC/Municipality (number)	Interviewees (persons)
1. Ratuwa R.	Jhapa, Morang	9	171
2. Lohandra R.	Morang	13	131
3. Lakhandei R.	Sarlahi	13	192
4. Narayani R.	Chitwan, Nawalparasi	11	101
5. Tinau R.	Rupandehi	11	107
6. West Rapti R.	Banke, Dang	14	228
7. Babai R.	Bardiya	6	129
8. Khutiya R.	Kailali	4	65
Total	10 districts	81	1,124

(3) Result of Investigation

According to field investigations and interviews with the residents, flood prone areas were delineated as shown in Fig. 3.1.

Flood and sediment disasters in the Study Area are summarized in Table 3.3. These are mainly based on the questionnaire responses of the residents in the flood prone areas.

Incorporating the information and data obtained from the District Development Committee (DDC), District Irrigation Office (DIO) and Village Development Committee (VDC) as well, conditions of the disasters and people's response to them are summarized as follows:

1) **Recent major flood:** All river basins in the Study Area experienced large flood events in the last three years. The flood in 1993 was memorized as a big flood only in the Narayani and West Rapti river basins.
2) **Frequency of flooding in a year:** Frequency of flooding is high in the Ratuwa, Lakhandei and Tinau river basins, though it depends on the reaches even in a river.
3) **Types of disasters:** Riverbank erosion, flooding over farmland, and sedimentation are the major types of disasters in the Study Area. In the Ratuwa and Babai river basins, these three problems are of equal importance, though the bank erosion problem was uppermost. In the Lohandra, Lakhandei, Narayani and Tinau river basins, the most residents pointed out sedimentation problem followed by bank erosion problem. Riverbank erosion is the principal problems in the West Rapti river basin and flooding

over the farmland in the Khutiya river basin.

4) **Experience of evacuation:** More than 50 % of interviewees have experienced evacuation in the Lakhandei, Narayani and Tinau river basins.

5) **Experience of participation in flood mitigation activities:** More than 50 % of residents have participated in flood mitigation activities in the Ratuwa, Lakhandei and Tinau river basins. Especially in the latter two basins, almost all the interviewees have had the experience. Participation is mostly in the form of labor service.

6) **Willingness to participation in flood mitigation activities:** Most of the interviewees expressed their willingness to participate in flood mitigation activities mainly with labor service, which suggests that under pressure the residents will take action for their own protection.

3.3 Investigation of Riverbed Materials

Riverbed materials were investigated for plain reaches of the eight rivers in the Study Area by a Nepali consultant under a contract in accordance with the program and specification prepared by the JICA Study Team. The investigation includes the following outdoor and indoor works:

1) Sampling of river bed materials at the site
2) Grain size analysis at the site and in the laboratory
3) Specific gravity test in the laboratory

(1) Sampling of Riverbed Materials

Riverbed materials were sampled near the shore where the river bed materials are exposed. The sampling sites were selected so that the sampled material is representative of the typical river section. The riverbed material was sampled according to the following sequence and specifications:

1) Take a photo of river channel for its upstream and downstream views from the sampling site.
2) Remove surface materials about 30 cm in depth and take a photo of sampling spot with scale to show the grain sizes.
3) Take out bed materials, an additional 50 cm in depth, making the total removal of 80 cm in depth from original surface.

- The quantity of material to be taken out depends on the maximum grain size of the sample as follows:

(Quantity of Bed Material Sampling)

Max. grain size (mm)	Materials taken (kg)	Sample (kg)	Remarks
less than 10	4	1	For indoor analysis
10 to 20	20	5	For outdoor analysis
20 to 40	60	15	For outdoor analysis
40 to 60	80	20	For outdoor analysis
60 to 80	120	30	For outdoor analysis
more than 80	140	35	For outdoor analysis

- The removed material is put on a clean vinyl sheet and mixed well. Then, a quarter of the material is sampled.
- If the maximum grain size is less than 10 mm, the sample is kept in a clean container with the site name clearly specified. This sample is for the indoor grain size analysis.
- If the maximum grain size exceeds 10 mm, the sample is put on a vinyl sheet and dried in the air. The sample is for grain size analysis at the site (outdoor analysis).

(2) Grain Size Analysis

Grain size analysis was carried out to determine the grain size distribution of the riverbed material. The analysis was undertaken at the site (outdoor analysis) for the bigger grain size portion and indoor for the smaller grain size portion.

Outdoor Analysis: The outdoor grain size analysis was carried out using the following procedures:

1) Weigh the whole sample.
2) Screen the sample with a standard sieve set and to record the weight of the material remaining on each sieve and the material passing through the smallest sieve. The total weight should be more or less equal to the total weight of sample.
3) The standard sieve set consists of sieve holes of 53.0 mm, 37.5 mm, 26.5 mm, 19.1 mm and 9.50 mm or those approved by the JICA Engineer.
4) The balance used for weighing the material should be of sensitivity higher than 1.0 g.
5) Each of grains remaining on 53.0-mm sieve should be measured for its grain

size and weight. The grain size should be measured for length, width and thickness.

6) The material remaining on the sieves less than 37.5 mm should be mixed after the sieve analysis and about 1 kg of sample should be removed for a specific gravity test. The sample should be put in a clean container with its site name clearly written.

Indoor Analysis: The indoor grain size analysis was carried out as follows:

1) The sieve set used for indoor analysis consists of 9.50 mm, 4.75 mm, 2.00 mm, 0.85 mm, 0.425 mm, 0.250 mm, 0.106 mm and 0.075 mm or those approved by the JICA Engineer.
2) The balance of sensitivity higher than 0.1 g should be used for weighing the material remaining on each sieve.

(3) Specific Gravity Test

Specific gravity tests for fine aggregate was carried out indoors with about 1 kg of the sample used for the indoor grain size analysis. The specific gravity is determined as the ratio of the material weight to the weight of displaced water.

(4) Quantity of Work

1) Sampling:

(Sampling Sites)

River	For indoor test	For outdoor test
1. Ratuwa R.	13 sites	8 sites
2. Lohandra R.	13 sites	8 sites
3. Lakhandei R.	13 sites	8 sites
4. Narayani R.	23 sites	20 sites
5. Tinau R.	13 sites	8 sites
6. West Rapti R.	23 sites	12 sites
7. Babai R.	13 sites	6 sites
8. Khutiya R.	10 sites	6 sites

2) Grain size analysis
   - Outdoor grain size analysis : 76 samples
   - Indoor grain size analysis : 121 samples

3) Specific gravity test : 121 samples

(5) Result of Investigation

According to the results of grain size analyses, grading curves are shown in Fig. 3.2 for the respective rivers. Representative grain sizes of the riverbed materials are shown in Table 3.4 along with the specific gravity of the material.

Based on the investigation result, grain size distribution along the river is shown in Fig. 2.12. In the upper reaches grain size of the bed materials is distributed in a wide range, and gradually it becomes more uniform in the lower reaches. It is noteworthy that the changes in grain size distribution occur abruptly for the West Rapti and Babai rivers.

3.4 Hydrological Study

3.4.1 Meteo-hydrological Observatory

In Nepal the responsibility for meteo-hydrological data collection and analysis have been born mainly by the Department of Hydrology and Meteorology (DHM), the Ministry of Science and Technology. Meteo-hydrological observations are also conducted by other authorities such as Department of Irrigation (DOI), Nepal Electricity Authority (NEA), and International Center for Integrated Mountain Development (ICIMOD). In principle, all observed meteo-hydrological data are sent to the DHM. The DHM publishes the data as a yearbook after basic checking has been completed.

Meteorological Data: The Meteorology Section of the DHM is responsible for compilation and analysis of meteorological observation records such as precipitation, temperature, humidity, vapor pressure, sunshine, wind, evaporation and soil temperature. These observed data are processed at their computer center. Monthly meteorological data are compiled in the yearbook of "Climatological Records" and "Precipitation Records" published by the DHM. Unpublished data such as daily and hourly precipitation are also available through official channels.

Hydrological Data: The Hydrology Section of the DHM is responsible for the compilation and analysis of hydrological observation records such as water level and sediment. These observed data are processed at their computer center. Discharge data, on a monthly basis, are compiled in the yearbook of "Hydrological Records" published by the DHM. Unpublished daily and hourly discharge data are also available through official channels except those reliable stage-discharge relationships have not been established yet. Sediment sample data are not published because their compilation is not yet completed.

3.4.2 Rainfall Analysis

Rainfall records at 157 stations were first examined based on data for 10 years from 1985 to 1994. Daily rainfall (1-day rainfall) in Nepal is defined as a total rainfall for 24 hours from 08:45am to 08:45am in next morning. After considering location and data availability, 29 stations out of 157 stations were selected for further data collection and analysis. Figure 3.3 shows the location of the selected 29 stations.

(1) Probable Daily Rainfall

The annual maximum records of daily rainfall were collected for the 29 stations from 1971 to 1995, and the probability analysis of the annual maximum daily rainfall was executed for these stations. The results of the probability analysis are given in Table 3.5 with the statistical parameters such as sample size, average, standard deviation and coefficient of variation at each station using Gumbel method.

In order to figure out the typical value of probable daily rainfall in the Terai plain, 17 stations located at elevation below 500 m,MSL were selected out of the 29 stations. Figure 3.4 shows a probable daily rainfall of these stations.

(2) 24-hour Rainfall

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

$P_{24} = 1.13 \times P_{day}$: Using the Herschfield factor

The relationship was also examined using data at Kathmandu airport station (1030), and the result is shown in Fig. 3.5. The 24-hour rainfall can be estimated from daily rainfall by the following formula:

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

(3) Rainfall Depth for Short Duration

Records of monthly maximum rainfall for various duration from 5 minutes to 24 hours are available only at Kathmandu airport station (1030) for 5 years from 1971 to 1975.

Figure 3.5 shows the relations of cumulative rainfall or percentage to corresponding duration. Only the data of which the 24-hour rainfall exceeds 30 mm were plotted on the Figure. On an average, the short duration rainfall can be estimated using the following percentage from the 24-hour rainfall.

(Cumulative Percentage of Rainfall)

Duration (min) (hr)	5 -	10 -	15 -	30 -	60 1	120 2	360 6	720 12	1440 24
Cumulative percentage of rainfall (%)	7.8	14.6	20.0	31.4	41.3	54.9	78.2	92.7	100.0

3.4.3 Runoff Analysis

All the available runoff data such as annual maximum discharge and annual maximum daily discharge were collected from the DHM 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. A list of the 62 stations is given in Tables 3.6. Figure 3.6 shows the location of these stations.

(1) Peak Discharge and Daily Discharge

Instantaneous peak discharge and maximum daily discharge rates are available in the "Hydrological Records of Nepal" published by the DHM. The relationship between the instantaneous peak discharge and the maximum daily discharge of corresponding months are examined for all of the available data at 62 stations. These are shown in Fig. 3.7. The relationship between instantaneous peak discharge (Q_p) and maximum daily discharge (Q_{dmax}) in Nepal can be expressed as follows:

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

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

(2) Relationship between Discharge and Basin Area

Specific discharge rate was studied to grasp the relationship between discharge and catchment area based on the specific discharges for 2-year return period, which were estimated as an average of annual maximum discharges. The 2-year discharges are plotted in Fig. 3.8 with their catchment areas using data at 28 stations with records for more than 20 years located at elevation lower than 1,000 m,MSL.

Creager's formula is also used to verify the applicability of the formula to this area. The 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. The upper, mean and lower enveloping curves in the Figure show Creager's formula for coefficients of C=25, 6 and 2.

For reference, dotted line in the Figure shows the relationship described in the "Design Manual for Irrigation Project in Nepal, M.3: Hydrology and Agro-meteorology Manual", which are expressed as:

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

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

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

Based on the distribution in Fig. 3.8, Creager's formula is judged to be applicable.

(3) Ratio of Probable Discharges

Probability analysis was made by Gumbel method based on annual maximum (instantaneous) discharges at 62 stations. In consideration of the 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 have annual maximum data for more than 20 years.

Using the results of probability analysis at the 32 stations, studies were made on the dimensionless probable discharge (Q_n/Q_2) which is defined as a ratio of any probable discharge (Q_n) to 2-year discharge (Q_2). The dimensionless probable discharge is shown in Fig. 3.9. The ratio of probable discharges Q_n/Q_2 for river basins in the Study Area are summarized below.

(Q_n/Q_2 for Various Return Period)

River	Q_n/Q_2 for various return period						Remarks
	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	
Ratuwa	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
Lohandra	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
Lakhandei	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
Narayani	1.00	1.34	1.57	1.79	2.07	2.28	Station 450
Tinau	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average
West Rapti	1.00	1.57	1.95	2.31	2.78	3.13	Station 360
Babai	1.00	1.72	2.20	2.66	3.26	3.70	Station 290
Khutiya	1.00	1.62	2.02	2.41	2.92	3.30	Siwalik Average

(4) Estimation of Probable Discharge

The probable discharge at the base point of each river 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) : Probable discharge of n-year return period,

(Q_n/Q_2) : Ratio of probable discharges,

q_2 (m^3/s/km^2) : Probable specific discharge of 2-year return period,

C : Coefficient depending on basin characteristics and return period, and

A (km^2) : Catchment area.

The values of C are assumed as follows for respective rivers.

1) C = 25.8, 8.1 and 11.1, respectively, for the Narayani, West Rapti, Babai river basins estimated using records of their own basin.
2) C = 6.0 for other river basins commonly estimated using records in Siwalik basin.

The probable discharges of 2, 5, 10, 20, 50 and 100-year return periods were estimated using the above formula and shown in Table 3.7.

3.5 Sediment Yield

Of the eight river basins for the Study, watershed areas of five river basins which originate in the Siwalik hills are studied from sediment yield viewpoint. They are the

Ratuwa, Lohandra, Lakhandei, Tinau and Khutiya river basins.

Other river basins, i.e., the Narayani, West Rapti and Babai river basins originate in the Higher and Lesser Himalayan zones. The sediment yield in these zone does not directly influence the sediment problems in the Terai plain, since the sediment yielded in these zones deposits first in the valleys and is transported to the plain by river flows.

3.5.1 Forest Vegetation

(1) Climate and Vegetation Distribution

The watersheds of the eight rivers are distributed widely from eastern to western borders of Nepal. Therefore, it is necessary to consider the vegetation for the whole country of Nepal.

The annual monsoon is one of the most dominant factors determining the vegetation of this area. Since the Mahabharat and Himalayan ranges intercept the wet monsoon, the rainy zone is formed on the southern side of these ranges (Fig. 3.10) and arid zone on the northern side.

The climatic and vegetation divisions of Nepal are shown in Fig. 3.11 after *A. Stainton.* Nepal is classified into five divisions as follows:

Div. I	Terai and Outer Himalaya
Div. II	Middle mountain (Eastern-Central-Western)
Div. III	Humla Jumla
Div. IV	Himalayan Inner Valley
Div. V	Alpine Desert

Out of the five divisions mentioned above, Divisions I and II have a close relationship with the five rivers for the sediment yield study.

Terai and Outer Himalaya (Siwalik Hill): The Terai plain is composed of an alluvial fan and alluvial plain, of elevation ranging from 50 to 300 m,MSL extending from the foot of Siwalik hills to the Indian border. The climate of this area belongs to Monsoon Sub-tropical zone, and the rainy season is from June to September with the dry season from October to May. Terai plain was covered widely by Sal forests (*Shorea robusta*). But, recently farmers from Middle Mountains cleared the forests for agricultural land

and villages.

Sal is a species of the *Dipterocarpaceae* family commonly distribute in the southeast Asian tropical forest. Tree reaches a height of 40 m in the Terai. Forests of Acacia and Sisoo (*Dalbergia sissoo*) are also seen along the riverbanks in the Terai plain.

Sal forests are classified into three physiognomic-vegetation types according to the location, i.e., Bhabar and Terai Sal forests, Dun Sal forests, and hill Sal forests.

Forests have been left in the Siwalik hills, because these hills are unsuitable for settlement due to steep slopes and the difficulty of getting water. However, tree felling has recently accelerated in Siwalik hills. The Siwalik hills with an elevation ranging from 500 to 1,000 m,MSL, located in eastern to central part of the country, are covered with hill Sal forest.

In the western Siwalik hills up to 1500 m,MSL, it is distinctive that the dry north slope is covered with sub-tropical deciduous forest whose dominant species is *Anogeissus latifolia,* while the humid south slope is covered with hill Sal forest. *Pinus roxburghii* forest are also sound in the hills higher than 900 m,MSL along the ridge.

Middle Mountain: The Middle Mountain is the area of 1000 to 2500 m,MSL in elevation between the Mahabharat and High Himalayas ranges. The Middle Mountain is the central place of Himalayan mountain residents. Although large forest areas still remain in the western part of the country where population is sparse, the forest in the eastern and central parts, where the population is large, has been converted to farmland and residential area.

Forests are left only in such places as steep slope, areas hard to access, community forests managed by village, forests of native shrine, and on the north slopes unsuitable for agriculture. Forests in the Middle Mountain are divided into the following seven vegetation zones primarily depending on the elevation:

1) Sal forest (Upper limit is 1000 to 1200 m,MSL) which is a continuation from the Terai
2) Laurel forest (1000 to 2500 m,MSL) which consists of Genus *castanopsis*, Subgenus *cyclobalanopsis*, Genus *schima* – *Castanopsis* forest, Family *Lauraceae*, Family *Symplocaceae* and so on.

3) *Quercus semecarpifolia* forest and *Tsuga dumosa forest* (2500 to 3000 m,MSL)
4) *Abies spectabilis* forest (3000 to 3800 m,MSL)
5) *Betula utilis* forest (3700 to 3800 m,MSL)
6) Alpine shrub (3800 to 3900 m,MSL)
7) Alpine meadow (3800 to 5000 m,MSL)
8) No vegetation above 5,000 m,MSL due to permanent ice and snow.

(2) Agriculture and Forest

The forest is important for farmers, for it produces fodder, bedding, compost, firewood and timber. The firewood is collected from the nearby forest. Lack of wood fuel is serious in the Middle Mountain where population is large and forest is scarce. Women and children collect firewood mainly by cutting down small trees in the neighborhood of village. This makes the succession of forest difficult and reforestation hard.

Livestock is kept by using straw and leaf litter from forest as fodder. The livestock culture also influences the natural vegetation adversely due to selective and over grazing by livestock. Because of these practices (firewood collection and topping trees for fodder), many areas are becoming denuded and waste lands are increasing, resulting in severe soil erosion.

(3) Forest Vegetation in Study Area

Sediment problems in the Terai plain are more serious in the watershed located in the Siwalik hills, because the hill material is geologically weak and the resultant sediment from the watershed is deposited directly on the plain. In view of this, the vegetation conditions are discussed here for the Siwalik river basins (the Ratuwa, Lohandra, Lakhandei and Khutiya rivers) and the Tinau river basin.

Ratuwa River Watershed: The Ratuwa river watershed is located on the south side of eastern Siwalik hills. Therefore, hilly area of the watershed is covered with hill Sal forest. According to the interpretation of aerial photograph, there are more bare slopes than those shown on the topographic maps. Almost all slopes are steep and their patterns look like fish scale, facing south without vegetation cover. These are conspicuous in the middle of Ratuwa river watershed and the Chaju river watershed.

The Geographical features of these bare rocks are cuesta scarps. Restoration of vegetation on these cliffs is difficult. Such areas are inappropriate for afforestation.

Bush land is the area where soil erosion can be reduced effectively by afforestation, because the slope is gentle.

Lohandra River Watershed: The Lohandra river is on the western side of the Ratuwa river, and it is located on the south side of eastern Siwalik hills. The vegetation of the watershed is hill Sal forest. The center of the watershed is dotted with wide cliffs. The cliffs are also found on the slope facing south, but they are not so remarkable as the Ratuwa river. Bush land is the area where soil erosion can be reduced effectively by afforestation, because the slope is gentle. Moreover, afforestation around the cultivated lands is also important.

Lakhandei River Watershed: The vegetation of Siwalik hills facing south is hill Sal forest and upper north watershed is of Dun Sal forests. Some small landslides are found in the branch watershed of Siwalik hills facing south according to the interpretation of aerial photograph. It is important to preserve the forests on the steep slope of Siwalik hills.

Tinau River Watershed: The Tinau river watershed is located in central Siwalik hills. The vegetation of the watershed is hill Sal forest and Dun Sal forest. Bush land spreads out on moderate slopes on the circumference of cultivated land, pasture land, fallow field or abandoned fields. Many cliffs are on the southern slope. Cuesta on the watershed areas is very frequent. Both the bush land and cliffs are common in the watersheds. Soil erosion can be reduced by afforestation.

Khutiya River Watershed: The Khutiya river watershed is located in western Siwalik hills, and the vegetation of the watershed is hill Sal forest. All the ridges are bare or sparse bush land in the southern part of Siwalik hills. Most of the forests are degraded such that soil erosion is very possible. Special consideration is necessary for the afforestation, because annual precipitation is little in this region.

3.5.2 Sediment Yield

(1) Estimation Method of Sediment Yield

Sediment yield from the watershed area was estimated based on the assumed soil erosion rates depending on the land use conditions. The soil erosion rates were assumed mainly in reference to those of the Ratu river as follows:

(Soil Erosion Rate for Estimation of Sediment Yield)

Land use	Soil erosion Rate(mm/year)	Remarks
Forest	2	Degraded forest, gullied land
Bush, grass, bamboo	10	Severely degrated, heavily grazed forest, gullied land
Cultivated land	0.4	Farm land (Dr. Akiya) & dense forest lands with good ground cover in Ratu watershed
Bare land, soil cliff, rock cliff and rock	20	Same as in Ratu Watershed
River bed	0	
Urban	0	

The soil erosion rates of forest and bare land were assumed at 2 mm/year and 20 mm/year taking same rates as the Ratu river. The rate of bush land was assumed 10 mm/year at taking same value as grazing land. For the cultivated land the rate was assumed at 0.4 mm/year referring to the values in Japan and the Ratu river. The rate of riverbed and urban area was assumed to be zero. Then the annual sediment yield is calculated by the following equation:

$$V = \Sigma(Ai \times Ei)$$

where

V: Sediment yield of watershed area

Ai: Area by land use

Ei: Soil erosion rate by land use

The areas by land use (Ai) were measured using the topographic maps of scale 1/25,000 except the Khutiya river for which the 1/50,000 topographic map was used with photo-interpretation. The results of land use measurement are as follows:

(Land Use Area: 1990-1996)

Items	River				
	Ratuwa	Lohandra	Lakhandei	Tinau	Khutiya
Forest (ha)	7006	8292	7855	33831	15797
Bush (ha)	346	1805	75	2481	674
Cultivation(ha)	1924	3731	2236	17683	666
Cliff (ha)	55	128	22	565	260
River (ha)	279	347	508	329	103
Urban (ha)	0	0	0	109	0
Total (ha)	9610	14303	10696	54998	17500
Year	1992	1992	1992	1990	1996

(Remarks) 1) Cliff represents soil cliff, rock cliff and outcrop of rock.
2) Land use survey was implemented for the Ratuwa, Lohandra, Lakhandei and Tinau rivers in 1992, and the Khutiya river in 1996.

(2) Annual Sediment Yield

The sediment yield estimated for the assumed soil erosion rates are shown in the table below. The maximum overall soil erosion rate is 2.70 mm/year for the Lohandra river area, followed by 2.56 mm/year for the Khutiya river basin. The minimum soil erosion rate is 1.66 mm/year for the Lakhandei river basin.

(Annual Sediment Yield)

Items	River				
	Ratuwa	Lohandra	Lakhandei	Tinau	Khutiya
Forest (m^3/year)	140,120	165,840	157,100	676,620	315,940
Bush (m^3/year)	34,600	180,500	7,500	248,100	67,400
Cultivation(m^3/year)	7,696	14,924	8,944	70,732	2,452
Cliff (m^3/year)	11,000	25,600	4,400	113,000	72,600
Total (m^3/year)	193,416	386,864	177,944	1,108,452	448,392
Erosion rate(mm/year)	2.01	2.70	1.66	2.02	2.56

(Remarks) Average soil erosion rate = Sediment yield/Watershed area

(3) Sediment Yield during Extraordinary Disaster

According to "The Research Report on the Investigation of Landslide and Soil Erosion in Nepal Using Remote Sensing Technology", the soil erosion rates of ordinary year and 1993 disaster are reported as follows:

1) Ordinary year (1) : 3.55 mm/yr.
2) 1993-disaster (2) : 24.00 to 27.79 mm/yr.
3) Ratio = (2)/(1) : 6.8 to 7.8

From the above, soil erosion rate or sediment yield during an extraordinary disaster like 1993-flood may reach at some 10 times of the sediment yield of ordinary (average) year.

(Further in-depth descriptions on the topics of this chapter are compiled in SUPPORTING REPORT C: BASIC INVESTIGATIONS AND STUDIES.)

Table 3.1

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

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 3.3

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

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size 16 (%)	50 (%)	60 (%)	65 (%)	84 (%)	d84/d16	Specific gravity(g/cc) S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
Ratuwa River									
Ra-1	0.15	0.29	0.32	0.33	0.40	2.59	2.59	2.59	2.59
Ra-2	0.13	0.24	0.28	0.31	0.45	3.48	2.65	2.68	2.67
Ra-3	0.09	0.23	0.28	0.30	0.39	4.23	2.67	2.66	2.67
Ra-4	0.14	0.29	0.35	0.38	0.72	5.15	2.68	2.66	2.67
Ra-5	0.16	0.33	0.39	0.42	0.80	5.08	2.63	2.67	2.65
Ra-6	0.14	0.30	0.35	0.38	0.75	5.35	2.59	2.60	2.60
Ra-8	0.19	0.38	0.45	0.51	0.81	4.20	2.63	2.63	2.63
Ra-9	0.24	0.41	0.50	0.56	1.05	4.38	2.63	2.65	2.64
Ra-11	0.20	0.52	0.74	0.92	13.95	70.04	2.65	2.68	2.67
Ra-7	0.25	0.35	0.39	0.41	0.65	2.59	2.65	2.63	2.64
Ra-10	0.17	0.41	0.55	0.65	1.73	10.07	2.66	2.68	2.67
Ra-12	0.19	0.40	0.48	0.54	0.83	4.37	2.66	2.65	2.66
Ra-13	0.18	0.37	0.43	0.48	0.74	4.14	2.60	2.59	2.60
								Average	2.64
Lohandra River									
Lo-1	0.12	0.19	0.23	0.24	0.36	3.07	2.59	2.60	2.60
Lo-2	0.16	0.33	0.38	0.42	0.70	4.48	2.63	2.65	2.64
Lo-3	0.15	0.30	0.34	0.36	0.54	3.53	2.68	2.65	2.67
Lo-4	0.13	0.22	0.25	0.27	0.36	2.76	2.70	2.68	2.69
Lo-5	0.12	0.18	0.21	0.22	0.33	2.74	2.64	2.63	2.64
Lo-6	0.29	0.98	1.63	2.13	7.97	27.93	2.68	2.67	2.68
Lo-7	0.26	0.54	0.73	0.84	3.68	13.89	2.65	2.61	2.63
Lo-8	0.20	0.88	2.43	4.23	19.43	98.61	2.60	2.65	2.63
Lo-9	0.75	13.46	21.35	26.29	50.03	67.09	2.67	2.67	2.67
Lo-10	0.98	23.42	34.21	41.68	87.64	89.69	2.63	2.60	2.62
Lo-11	0.27	2.53	7.50	12.19	79.17	287.92	2.68	2.63	2.66
Lo-12	0.18	3.41	13.95	26.98	92.11	505.89	2.63	2.59	2.61
Lo-13	1.96	22.76	32.90	39.77	77.09	39.26	2.63	2.68	2.66
								Average	2.64
Lakhandei River									
La-1	0.11	0.18	0.20	0.22	0.32	2.85	2.65	2.63	2.64
La-2	0.10	0.15	0.17	0.18	0.23	2.20	2.63	2.66	2.65
La-3	0.11	0.16	0.19	0.20	0.27	2.50	2.63	2.67	2.65
La-4	0.12	0.19	0.22	0.24	0.34	2.89	2.67	2.63	2.65
La-5	0.14	0.29	0.33	0.35	0.44	3.06	2.69	2.65	2.67
La-6	0.12	0.21	0.24	0.27	0.43	3.58	2.61	2.58	2.60
La-7	0.13	0.22	0.27	0.29	0.40	3.19	2.59	2.63	2.61
La-8	0.13	0.27	0.31	0.34	0.68	5.13	2.63	2.60	2.62
La-9	0.17	0.34	0.39	0.41	5.31	30.66	2.68	2.70	2.69
La-10	0.15	0.30	0.35	0.37	0.91	6.24	2.63	2.68	2.66
La-12	0.25	0.71	1.63	2.90	16.26	64.27	2.66	2.69	2.68
La-13	0.32	3.61	7.01	9.27	25.32	78.32	2.59	2.63	2.61
La-11	0.14	0.31	0.37	0.41	2.17	15.05	2.63	2.65	2.64
								Average	2.64

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size 16 (%)	50 (%)	60 (%)	65 (%)	84 (%)	d84/d16	Specific gravity(g/cc) S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
Narayani River									
Na-1	0.70	26.87	39.70	48.10	119.69	170.48	2.61	2.65	2.63
Na-2	0.15	0.39	0.73	4.87	44.68	289.44	2.68	2.63	2.66
Na-5	3.49	56.19	77.96	91.84	142.03	40.65	2.66	2.65	2.66
Na-6	1.10	14.27	20.41	23.52	41.71	37.94	2.69	2.70	2.70
Na-7	0.61	34.16	55.35	63.90	112.92	185.79	2.59	2.63	2.61
Na-10	0.47	12.79	21.26	25.51	39.29	83.06	2.68	2.65	2.67
Na-12	0.42	3.20	7.39	11.79	41.44	98.55	2.63	2.65	2.64
Na-15	0.47	12.18	21.63	29.75	108.37	230.41	2.68	2.65	2.67
Na-18	0.22	10.99	16.74	20.27	42.08	195.34	2.68	2.63	2.66
Na-19	0.39	13.31	23.88	39.99	137.50	356.02	2.68	2.70	2.69
Na-20	0.97	9.84	14.74	18.04	40.24	41.47	2.65	2.68	2.67
Na-21	12.87	60.06	75.19	84.12	133.23	10.35	2.63	2.58	2.61
Na-22	0.09	20.95	35.82	52.37	86.30	1000.3	2.58	2.61	2.60
Na-3	0.46	12.14	21.82	27.25	57.01	122.71	2.68	2.68	2.68
Na-4	0.89	17.97	29.15	35.46	64.84	72.75	2.68	2.70	2.69
Na-8	1.24	13.09	20.27	24.30	47.63	38.26	2.68	2.63	2.66
Na-9	#N/A	0.09	0.10	0.12	0.19	#N/A	2.65	2.63	2.64
Na-9A	#N/A	0.10	0.14	0.17	0.40	#N/A	2.68	2.63	2.66
Na-11	0.72	35.08	47.71	56.10	108.37	151.46	2.64	2.61	2.63
Na-13	0.21	0.98	5.93	11.00	42.80	206.73	2.65	2.68	2.67
Na-14	0.14	0.29	0.34	0.36	0.63	4.57	2.59	2.63	2.61
Na-16	0.55	19.68	24.36	27.17	43.80	79.14	2.59	2.61	2.60
Na-17	0.38	30.67	40.12	43.95	66.30	176.58	2.63	2.59	2.61
								Average	2.65
Tinau River									
Ti-1	0.12	0.17	0.18	0.19	0.23	1.92	2.59	2.63	2.61
Ti-2	0.25	0.40	0.49	0.56	1.08	4.29	2.68	2.63	2.66
Ti-4	0.13	0.24	0.27	0.29	0.38	2.83	2.63	2.63	2.63
Ti-5	0.25	0.37	0.41	0.45	0.79	3.13	2.59	2.63	2.61
Ti-6	0.36	1.90	3.17	4.07	11.77	32.28	2.68	2.63	2.66
Ti-7	0.39	2.24	4.04	5.72	16.88	43.65	2.63	2.65	2.64
Ti-8	0.48	6.76	12.25	15.33	30.73	64.09	2.67	2.65	2.66
Ti-9	0.59	10.81	17.43	21.13	37.99	64.66	2.68	2.66	2.67
Ti-10	0.99	12.08	19.96	24.76	54.66	55.46	2.68	2.65	2.67
Ti-11	0.68	11.95	21.99	28.34	59.51	87.39	2.59	2.63	2.61
Ti-12	0.73	18.29	34.35	47.70	125.01	170.64	2.68	2.67	2.68
Ti-13	2.34	54.64	80.50	97.70	144.88	61.96	2.65	2.67	2.66
Ti-3	0.31	0.57	0.63	0.67	0.82	2.60	2.68	2.63	2.66
								Average	2.65

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size 16 (%)	50 (%)	60 (%)	65 (%)	84 (%)	d84/d16	Specific gravity (g/cc) S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
West Rapti River									
WR-1	0.12	0.19	0.21	0.23	0.32	2.73	2.67	2.69	2.68
WR-2	0.11	0.15	0.17	0.18	0.22	2.06	2.56	2.60	2.58
WR-3	0.14	0.26	0.29	0.30	0.37	2.65	2.66	2.60	2.63
WR-4	0.12	0.20	0.23	0.25	0.36	2.99	2.59	2.60	2.60
WR-5	0.30	0.48	0.54	0.57	0.72	2.42	2.56	2.60	2.58
WR-7	1.17	22.38	33.09	39.99	77.97	66.38	2.65	2.68	2.67
WR-10	0.99	20.10	29.15	34.94	63.62	64.16	2.68	2.70	2.69
WR-12	0.45	16.98	23.56	27.35	51.89	116.57	2.66	2.68	2.67
WR-14	0.14	0.27	0.30	0.32	0.39	2.71	2.67	2.68	2.68
WR-15	0.13	0.29	0.34	0.38	0.68	5.03	2.63	2.67	2.65
WR-16	0.11	0.16	0.18	0.19	0.24	2.15	2.65	2.63	2.64
WR-17	0.12	0.23	0.31	0.38	13.95	115.59	2.65	2.67	2.66
WR-19	0.69	16.18	22.17	25.42	42.90	61.82	2.60	2.59	2.60
WR-20	0.32	15.37	22.82	27.64	53.59	168.32	2.66	2.69	2.68
WR-21	1.47	19.83	27.09	31.25	59.10	40.29	2.67	2.70	2.69
WR-22	1.49	31.77	46.69	56.91	115.82	77.62	2.60	2.63	2.62
WR-6	0.11	0.17	0.18	0.19	0.24	2.08	2.66	2.63	2.65
WR-8	0.33	0.53	0.59	0.62	0.74	2.27	2.63	2.66	2.65
WR-9	0.16	0.30	0.33	0.34	0.40	2.47	2.59	2.60	2.60
WR-11	1.84	39.10	56.53	65.43	116.43	63.32	2.59	2.63	2.61
WR-13	2.43	45.94	62.10	71.00	121.36	49.86	2.64	2.61	2.63
WR-18	6.50	39.22	52.86	59.06	89.77	13.80	2.67	2.63	2.65
WR-23	3.58	45.45	65.48	75.93	129.90	36.26	2.63	2.67	2.65
								Average	2.64
Babai River									
Ba-1	0.11	0.19	0.21	0.23	0.33	2.86	2.65	2.68	2.67
Ba-2	0.12	0.17	0.19	0.20	0.25	2.12	2.66	2.69	2.68
Ba-3	0.11	0.18	0.20	0.21	0.30	2.58	2.60	2.65	2.63
Ba-4	0.13	0.22	0.25	0.27	0.35	2.69	2.63	2.67	2.65
Ba-5	0.13	0.26	0.29	0.30	0.37	2.80	2.68	2.65	2.67
Ba-6	0.15	0.28	0.32	0.33	0.41	2.81	2.67	2.63	2.65
Ba-7	0.17	0.32	0.35	0.37	0.52	3.03	2.67	2.65	2.66
Ba-8	0.30	36.68	47.13	53.24	83.52	275.52	2.69	2.63	2.66
Ba-9	0.53	29.81	39.45	46.77	78.68	147.97	2.69	2.66	2.68
Ba-10	0.45	19.66	28.01	32.36	58.86	129.43	2.58	2.60	2.59
Ba-11	0.72	25.02	33.75	39.44	67.98	94.91	2.60	2.65	2.63
Ba-12	0.40	27.97	41.24	49.39	120.81	299.79	2.59	2.61	2.60
Ba-13	1.22	36.56	50.47	60.71	121.36	99.43	2.65	2.67	2.66
								Average	2.65

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size 16 (%)	50 (%)	60 (%)	65 (%)	84 (%)	d84/d16	Specific gravity(g/cc) S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
Khutiya River									
Kh-2	0.13	0.21	0.24	0.26	0.34	2.75	2.63	2.59	2.61
Kh-3	0.57	1.08	1.22	1.30	1.65	2.88	2.60	2.63	2.62
Kh-4	0.13	0.23	0.28	0.30	0.40	3.06	2.65	2.63	2.64
Kh-6	0.35	4.69	11.46	14.23	31.84	91.64	2.63	2.68	2.66
Kh-7	0.29	1.27	5.24	10.01	39.31	133.28	2.63	2.59	2.61
Kh-8	0.28	0.64	0.87	1.35	19.00	67.34	2.63	2.61	2.62
Kh-9	1.04	19.19	29.28	34.74	68.58	65.77	2.59	2.56	2.58
Kh-10	3.76	105.22	139.63	160.85	266.46	70.82	2.68	2.63	2.66
Kh-1	0.13	0.25	0.28	0.30	0.37	2.79	2.59	2.59	2.59
Kh-5	0.16	0.29	0.31	0.33	0.39	2.51	2.67	2.70	2.69
								Average	2.63

Table 3.5

PROBABILITY ANALYSIS FOR DAILY RAINFALL

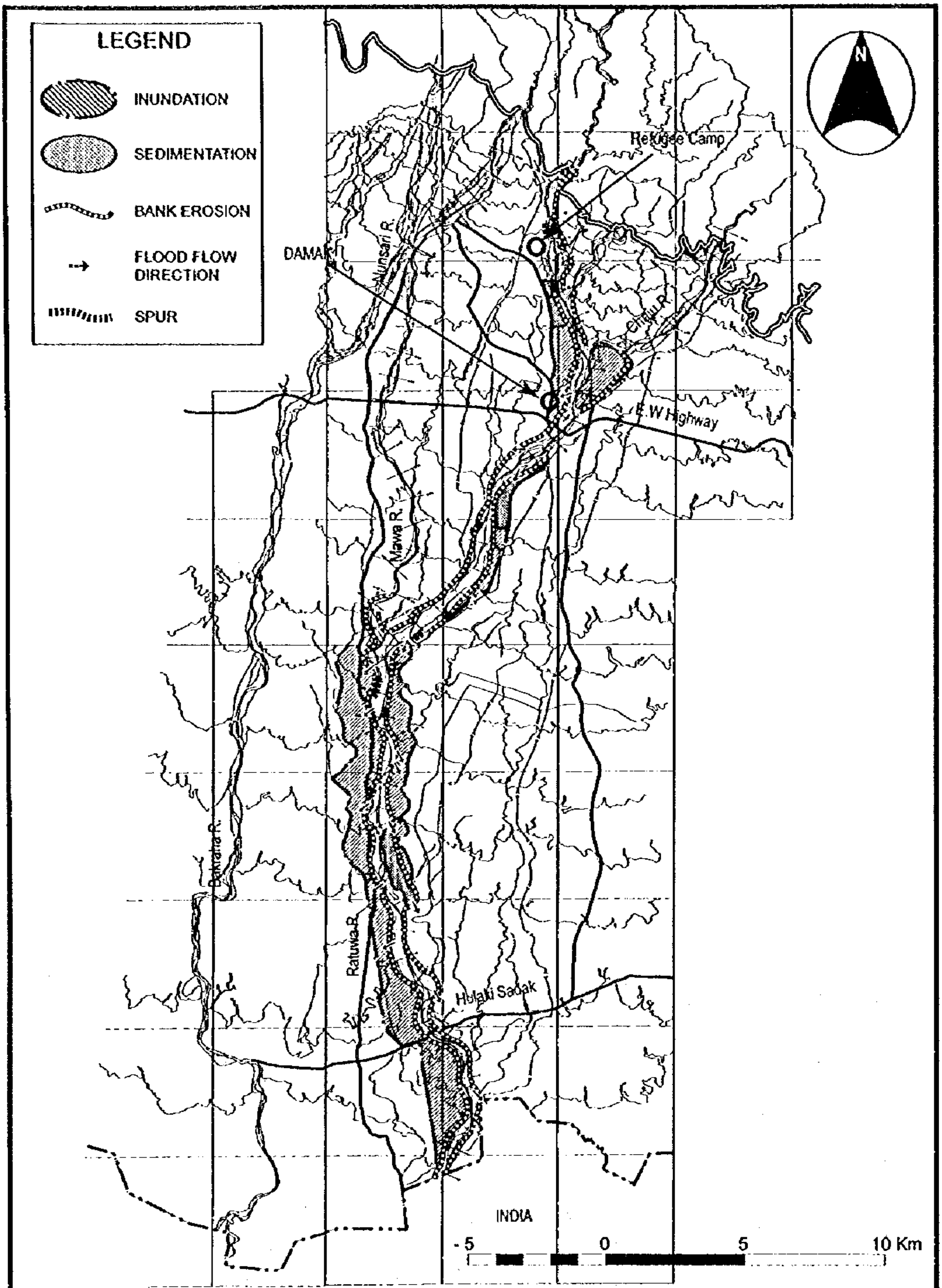
No.	Code	Station	Elevation (m)	R max (mm)	Statistical Parameters N	x_{MEAN}	S_x	C_V	a	x_0	Return Period 2	5	10	20	50	100
1	0209	Dhangadhi	170	267.	20	135	61.68	46%	0.01723	104.62	126	192	235	277	331	372
2	0215	Godavari (West)	288	245.5	15	170	39.69	23%	0.02571	150.03	164	208	238	266	302	329
3	0401	Pusma 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.	Seti	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.	Rapti	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	Taklor 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

PROBABLE DISCHARGE

Section		Catchment	Probable discharge (m^3/s)						Remarks
Point	km	(km^2)	Q2	Q5	Q10	Q20	Q50	Q100	
Ratuwa R.									
1	43.7	68	183	296	369	441	534	603	Upper end
2	19.8	262	406	658	821	979	1,186	1,341	Mawa R.
3	12.2	301	438	709	885	1,055	1,279	1,445	
4	0.0	383	498	806	1,005	1,199	1,453	1,642	Border
Lohandra R.									
1	67.5	0	-	-	-	-	-	-	Upper end (Chisan R.)
2	49.6	88	215	348	434	518	628	710	Sukuna R.
3	33.1	193	343	555	692	826	1,001	1,131	Kesaula R.
4	0.0	310	445	721	899	1,072	1,299	1,468	Border
Lohandra R.									
1	67.5	109	245	397	495	591	716	809	Upper end (Chisan R.)
2	49.6	197	347	562	700	836	1,012	1,144	Sukuna R.
3	33.1	302	439	711	886	1,057	1,281	1,448	Kesaula R.
4	0.0	419	521	844	1,053	1,256	1,522	1,720	Border
Lakhandei R.									
1	51.4	65	178	288	359	428	519	586	Upper end
2	39.0	155	302	490	610	728	882	997	Chapani R.
3	0.0	300	437	708	883	1,054	1,276	1,443	Border
Narayani R.									
450	-	31,100	12,285	16,505	19,300	21,980	25,450	28,050	Water-level station
1	-	16,481	10,156	13,609	15,945	18,179	21,022	23,155	Marsyandi R.
2	-	19,560	10,714	14,357	16,822	19,179	22,179	24,429	Seti R.
3	83.0	31,100	12,303	16,486	19,316	22,023	25,468	28,051	Upper end (Gandaki R.)
4	44.9	34,089	12,630	16,924	19,829	22,608	26,144	28,797	East Rapti R.
5	18.4	35,780	12,804	17,158	20,103	22,919	26,505	29,194	Narrow
Tinau R.									
1	59.5	550	598	970	1,209	1,442	1,748	1,975	Upper end
2	12.7	625	638	1,033	1,288	1,537	1,862	2,104	Dano R.
3	12.7	1,065	822	1,331	1,659	1,980	2,399	2,711	Dano R. (aft. jct.)
4	0.0	1,081	827	1,340	1,671	1,993	2,415	2,730	Border
West Rapti R.									
360	-	5,150	2,125	3,386	4,200	4,980	5,991	6,748	Water-level station
1	161.5	3,934	1,927	3,065	3,816	4,510	5,435	6,129	Rangsing R.
2	132.0	4,647	2,054	3,267	4,068	4,807	5,794	6,533	Arjun R.
3	53.0	5,464	2,183	3,471	4,322	5,108	6,156	6,942	Narrow
4	23.0	6,125	2,277	3,620	4,508	5,327	6,420	7,239	Jhijhari R.
5	0.0	6,418	2,316	3,682	4,585	5,418	6,530	7,363	Border
Babai R.									
290	-	3,000	2,364	4,075	5,208	6,294	7,701	8,755	Water-level station
1	48.0	3,002	2,374	4,083	5,223	6,315	7,739	8,784	Barrage
2	0.0	3,425	2,502	4,303	5,504	6,655	8,156	9,257	Border
Khutiya R.									
1	35.0	119	259	419	522	623	755	853	Upper end
2	11.5	209	358	581	724	864	1,047	1,183	Shiva Ganga R.
2	11.5	309	444	720	897	1,070	1,297	1,466	Shiva Ganga R. (aft. Jct.)
3	0.0	325	456	739	922	1,100	1,332	1,506	Border

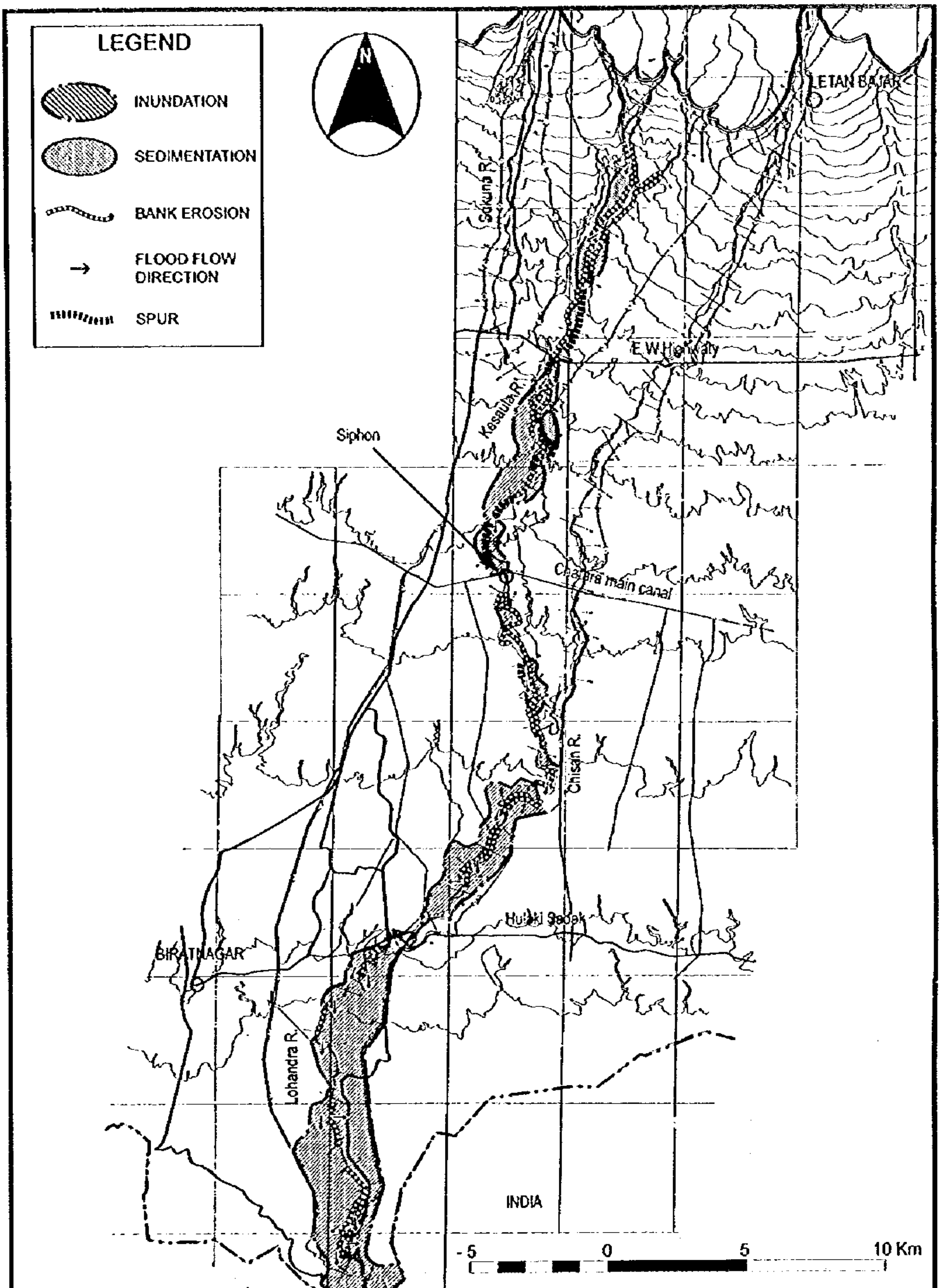


FLOOD SUFFRING AREA (RATUWA RIVER,1995)

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

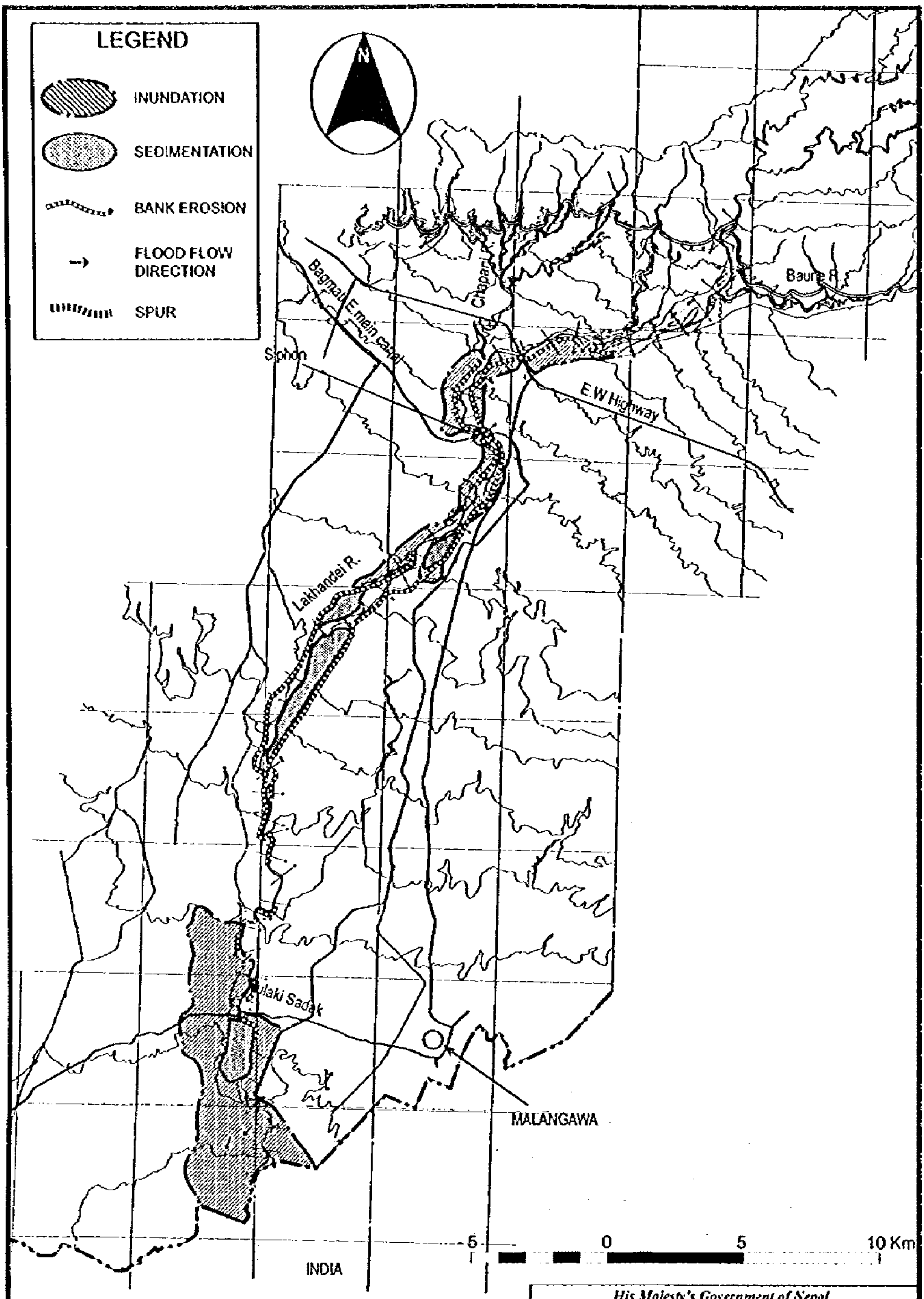


FLOOD SUFFERING AREA (LOHANDRA RIVER,1995)

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

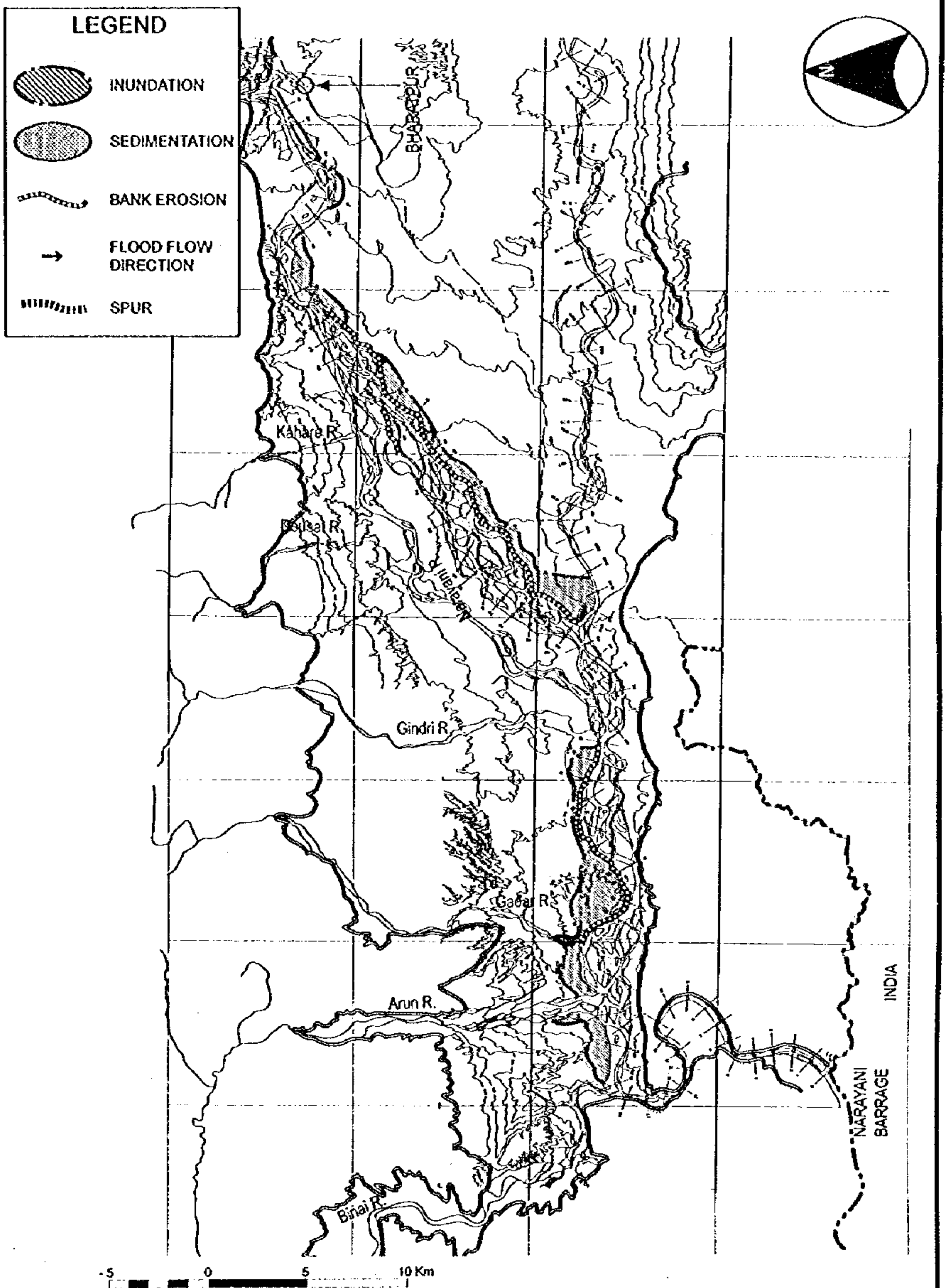


FLOOD SUFFERING AREA (LAKHANDEI RIVER,1995)

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



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

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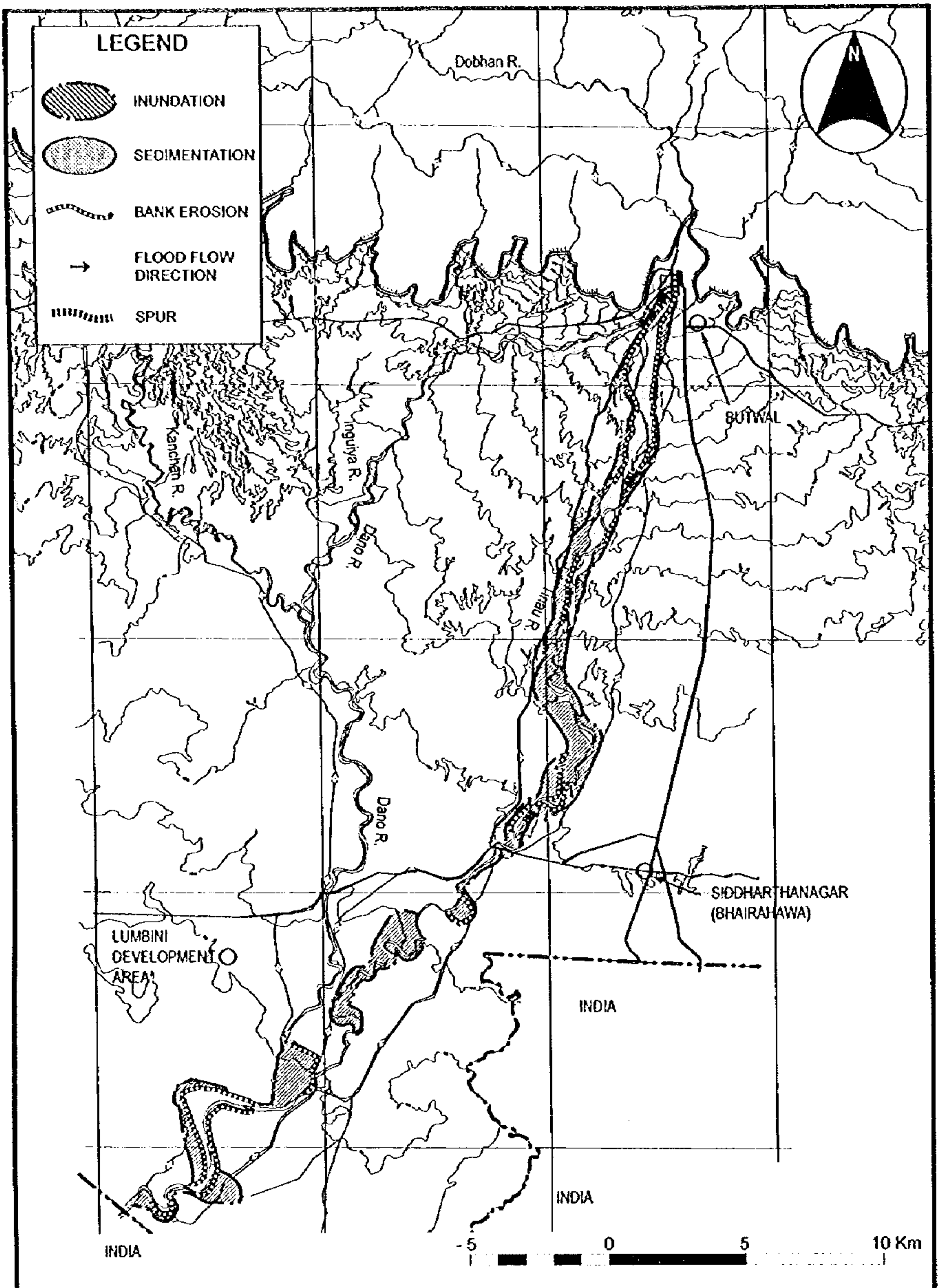
FLOOD SUFFERING AREA (NARAYANI RIVER, 1995)



FLOOD SUFFERING AREA (TINAU RIVER,1995)

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

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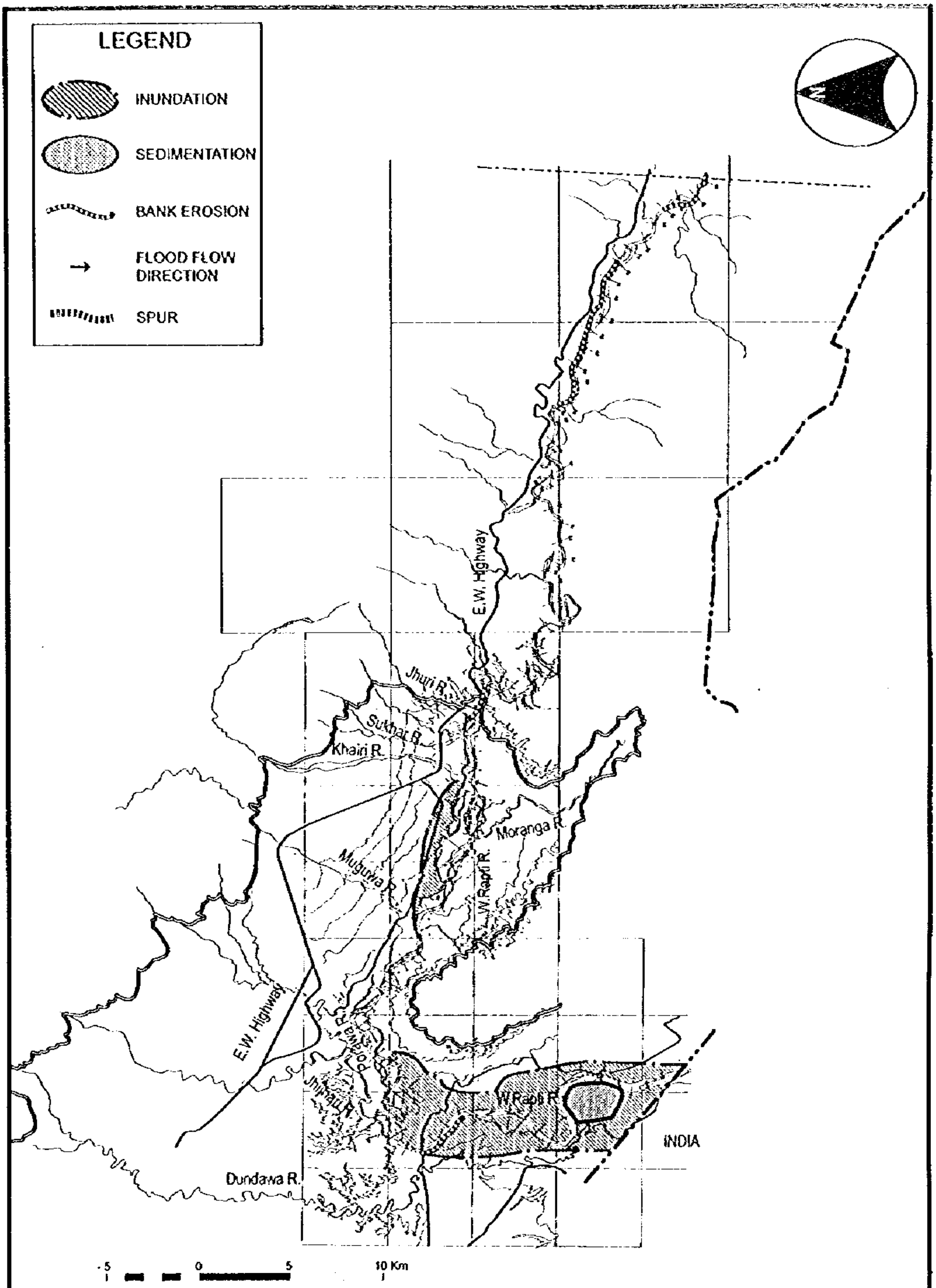
Fig. 3.1 (6/9)



FLOOD SUFFERING AREA
(WEST RAPTI RIVER 1/2,1995)

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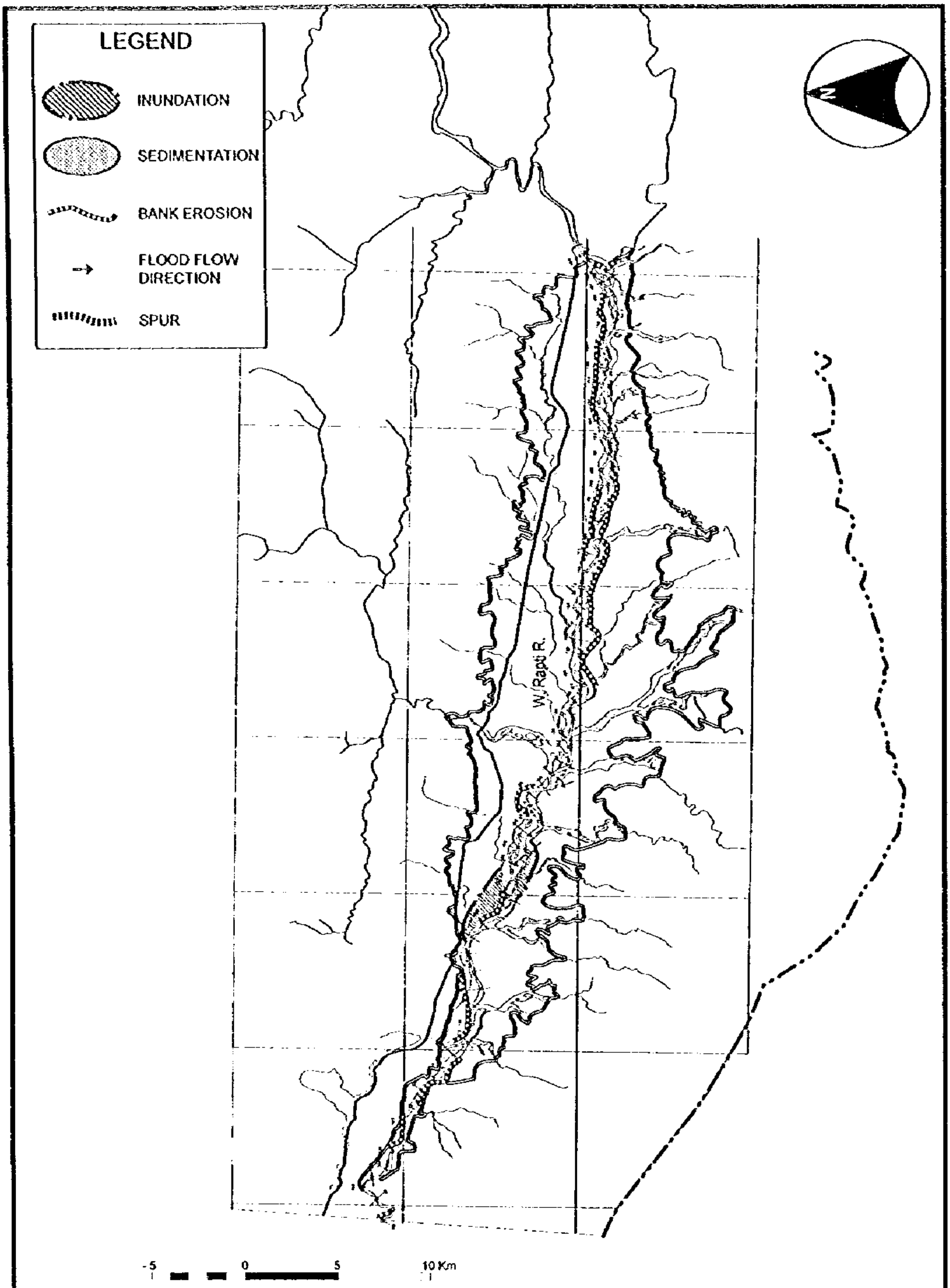

FLOOD SUFFERING AREA
(WEST RAPTI RIVER 2/2,1995)

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

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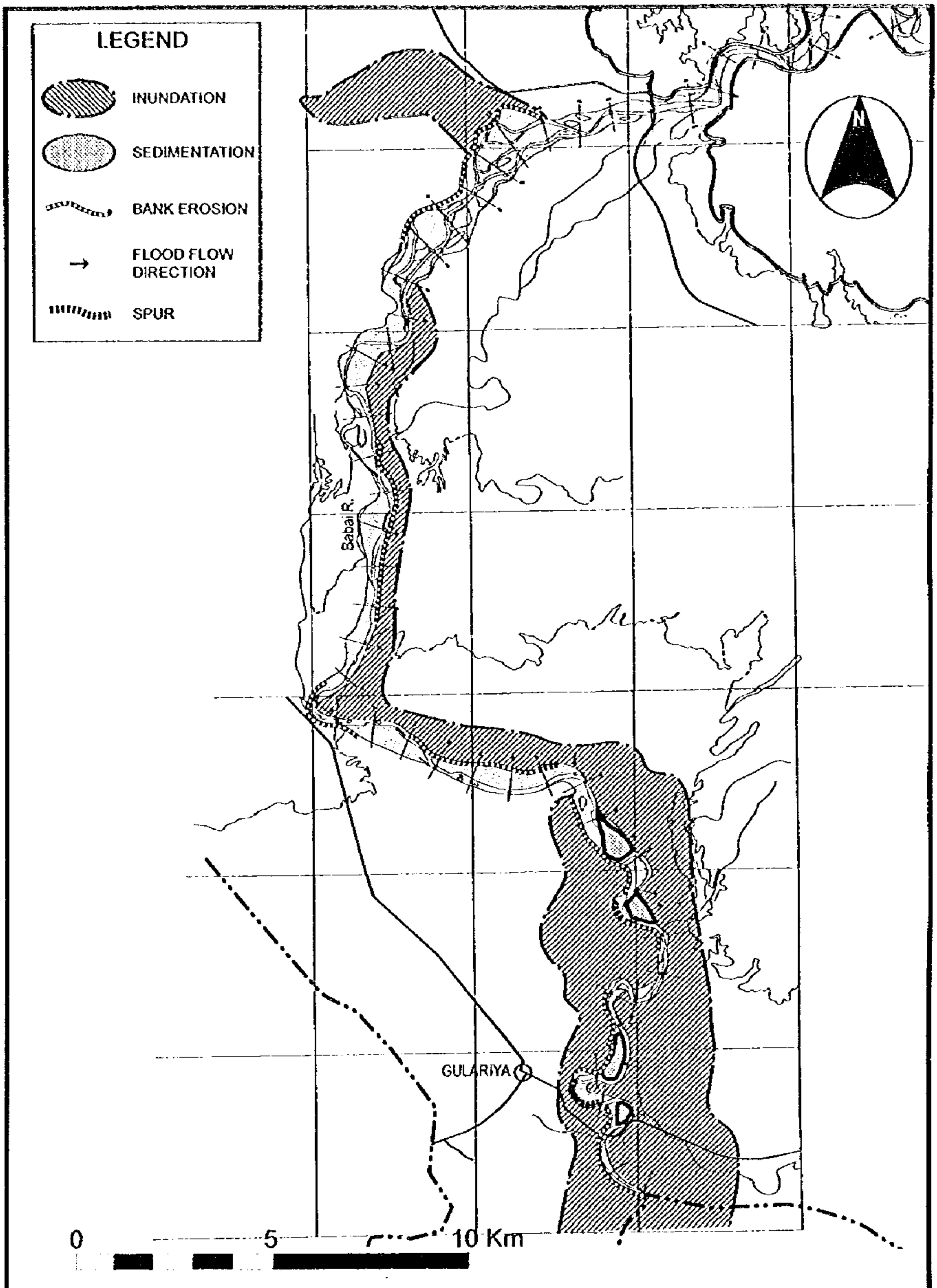

FLOOD SUFFERING AREA
(BABAI RIVER,1995)

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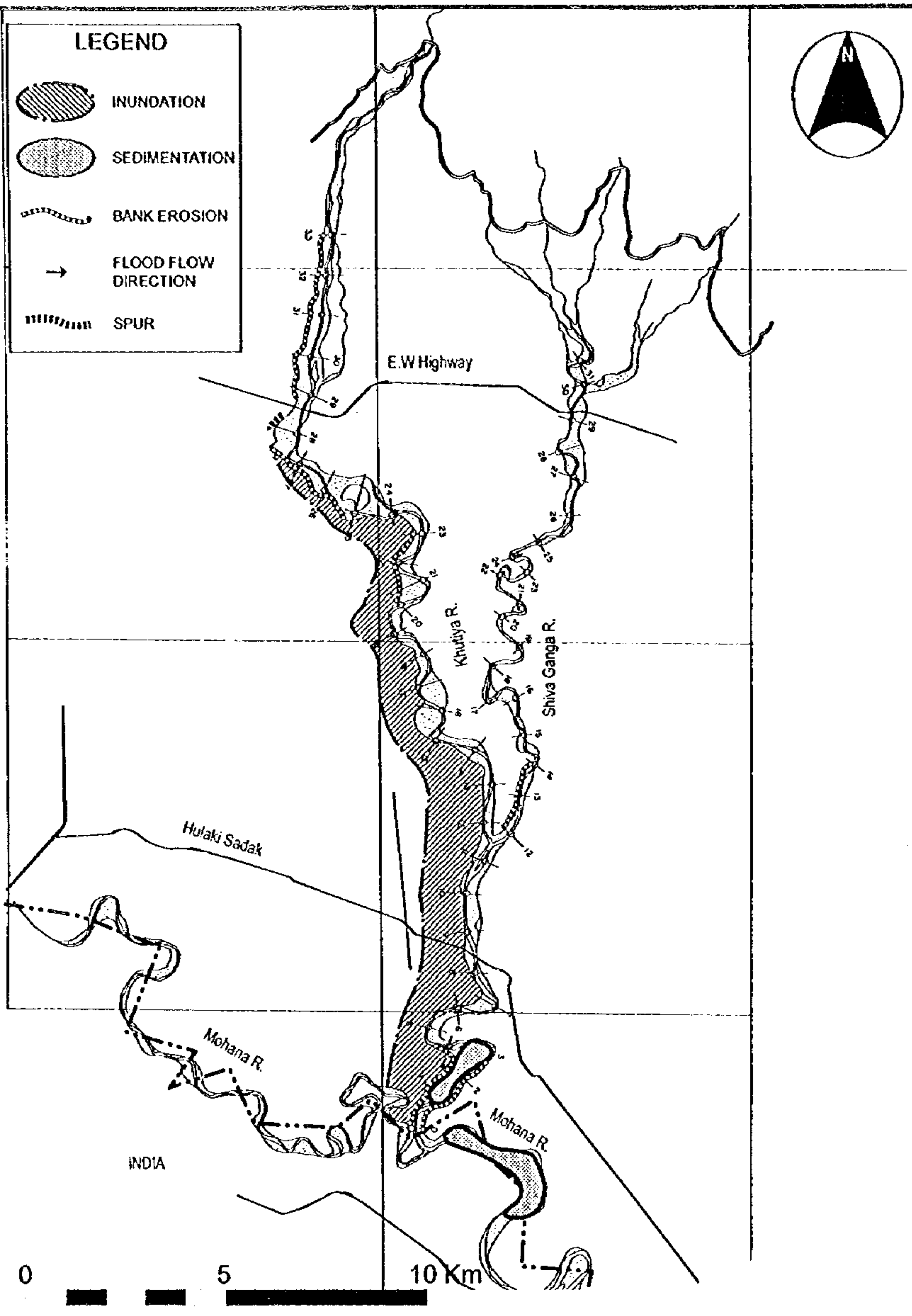
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



FLOOD SUFFERING AREA (KUTIYA RIVER,1995)

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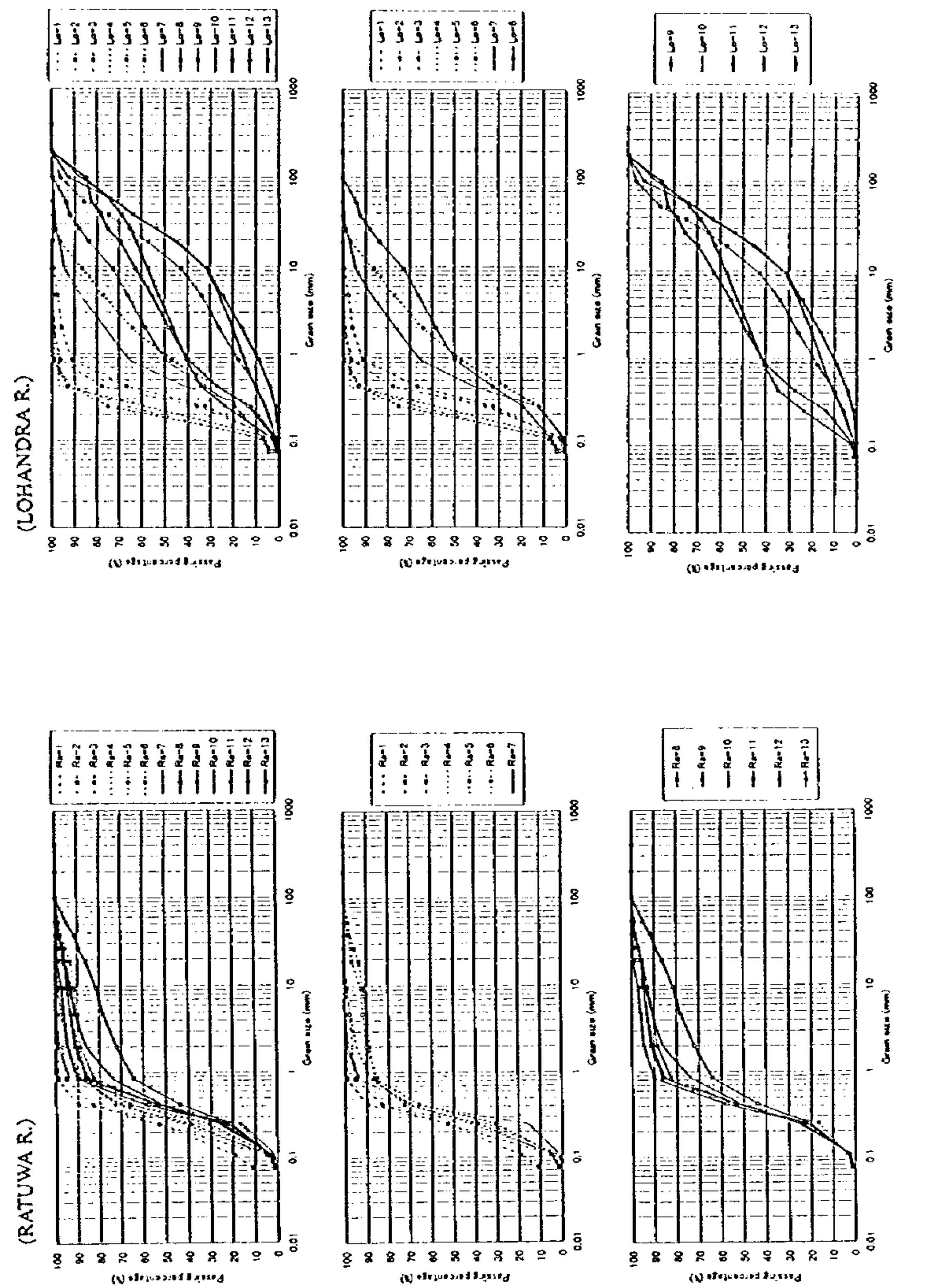
JAPAN INTERNATIONAL COOPERATION AGENCY



GRADING CURVES OF RIVERBED MATERIALS

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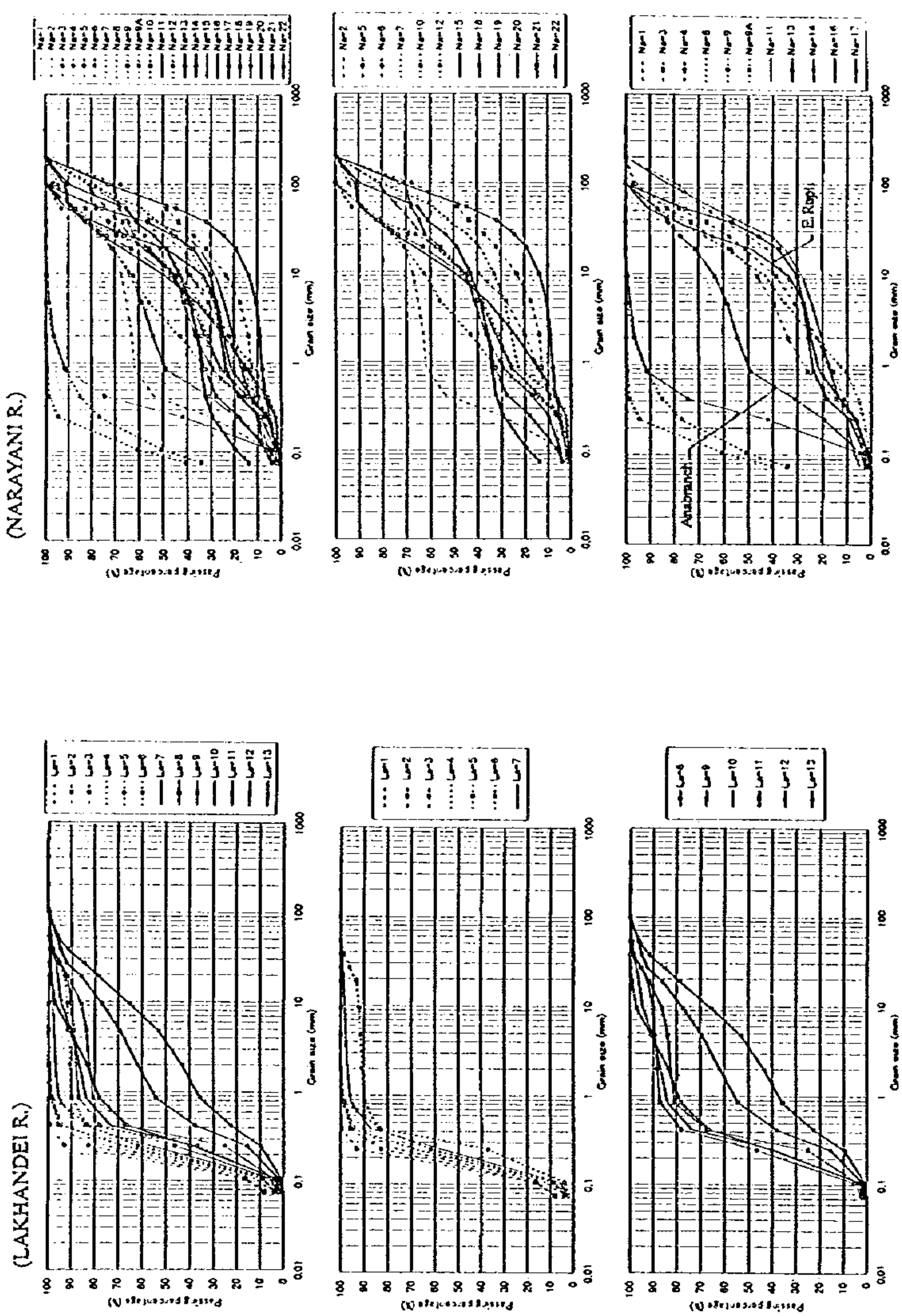
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERRA PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



GRADING CURVES OF RIVERBED MATERIALS

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THE STUDY ON FLOOD MITIGATION PLAN
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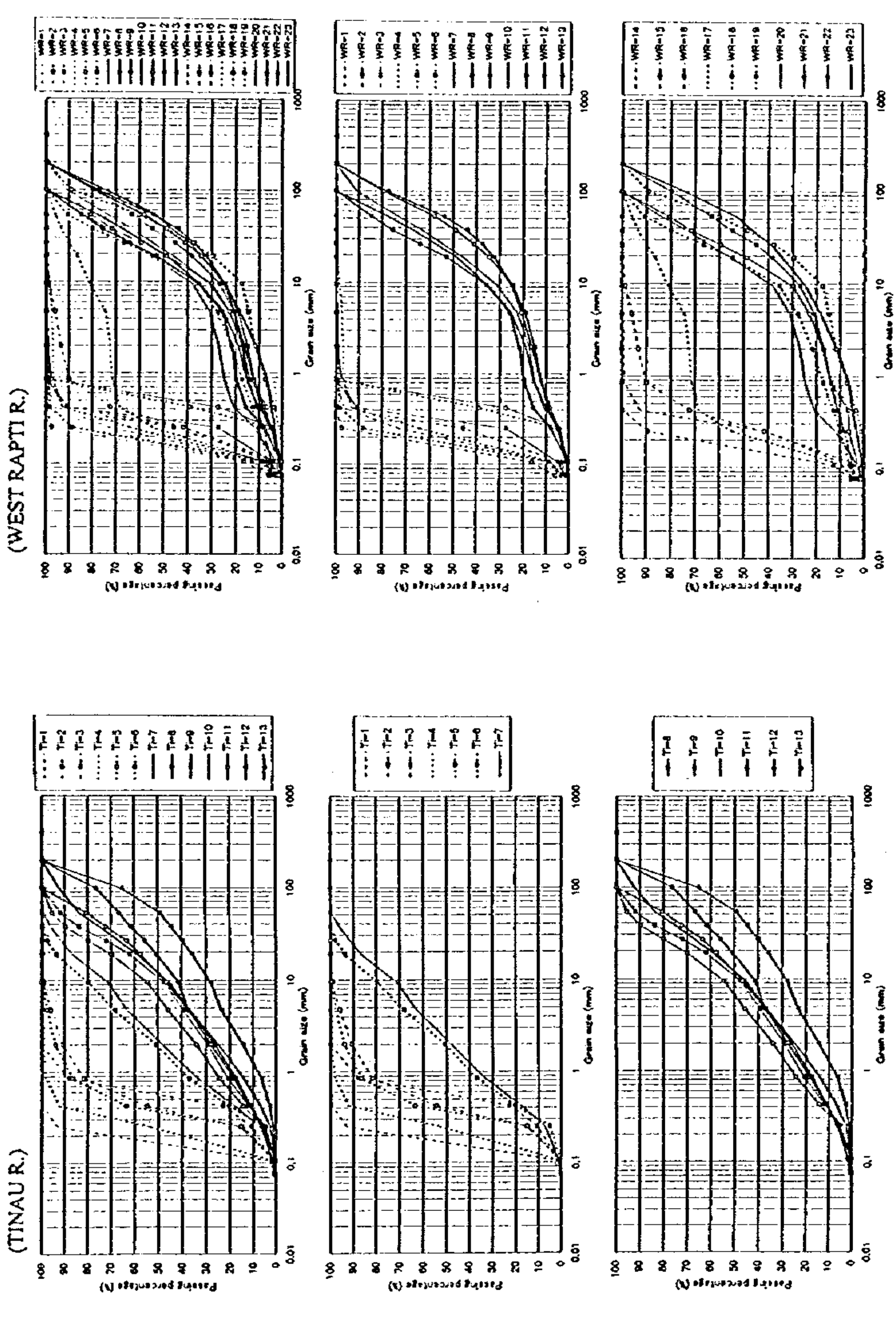
JAPAN INTERNATIONAL COOPERATION AGENCY



GRADING CURVES OF RIVERBED MATERIALS

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THE STUDY ON FLOOD MITIGATION PLAN
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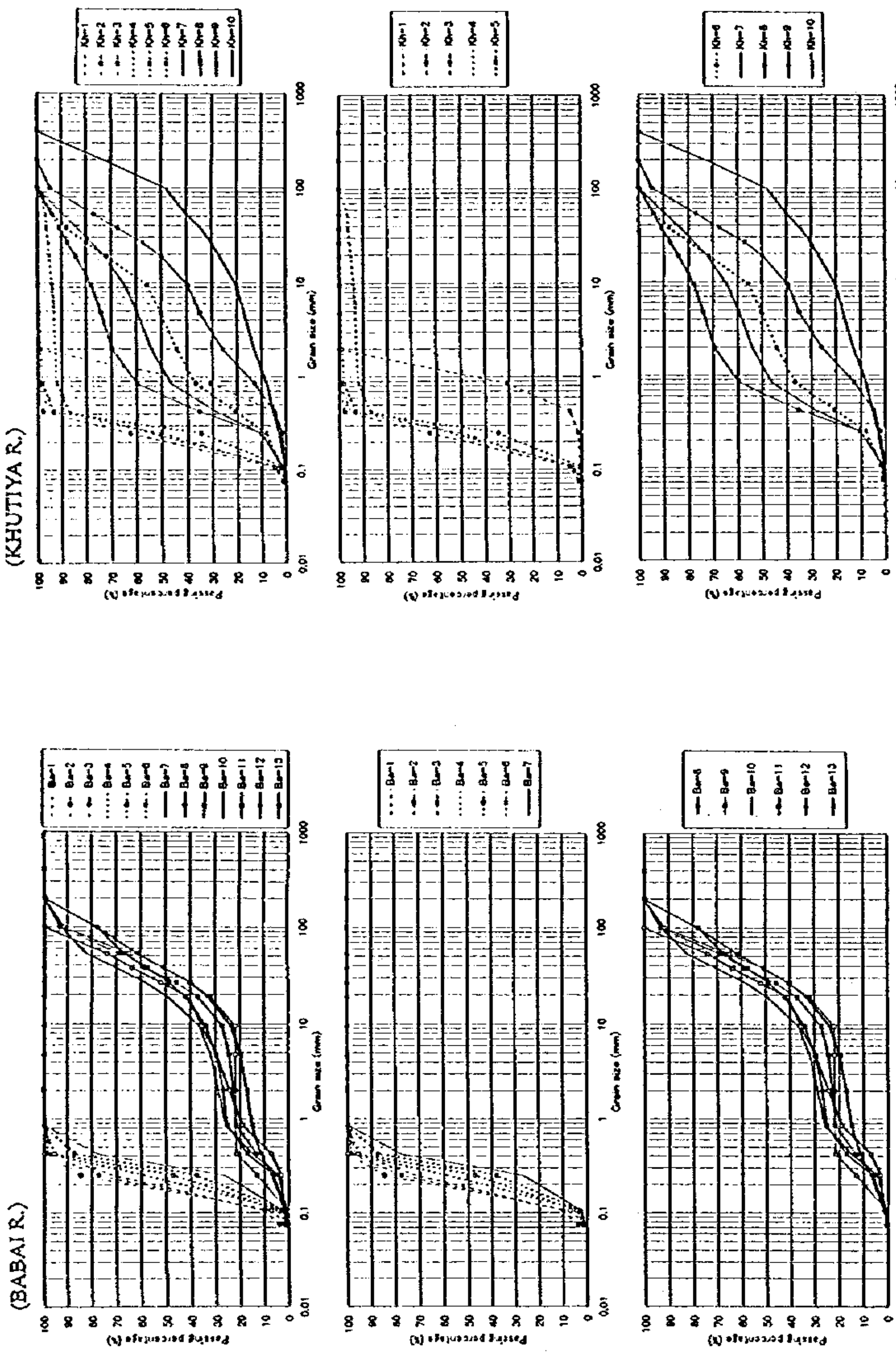


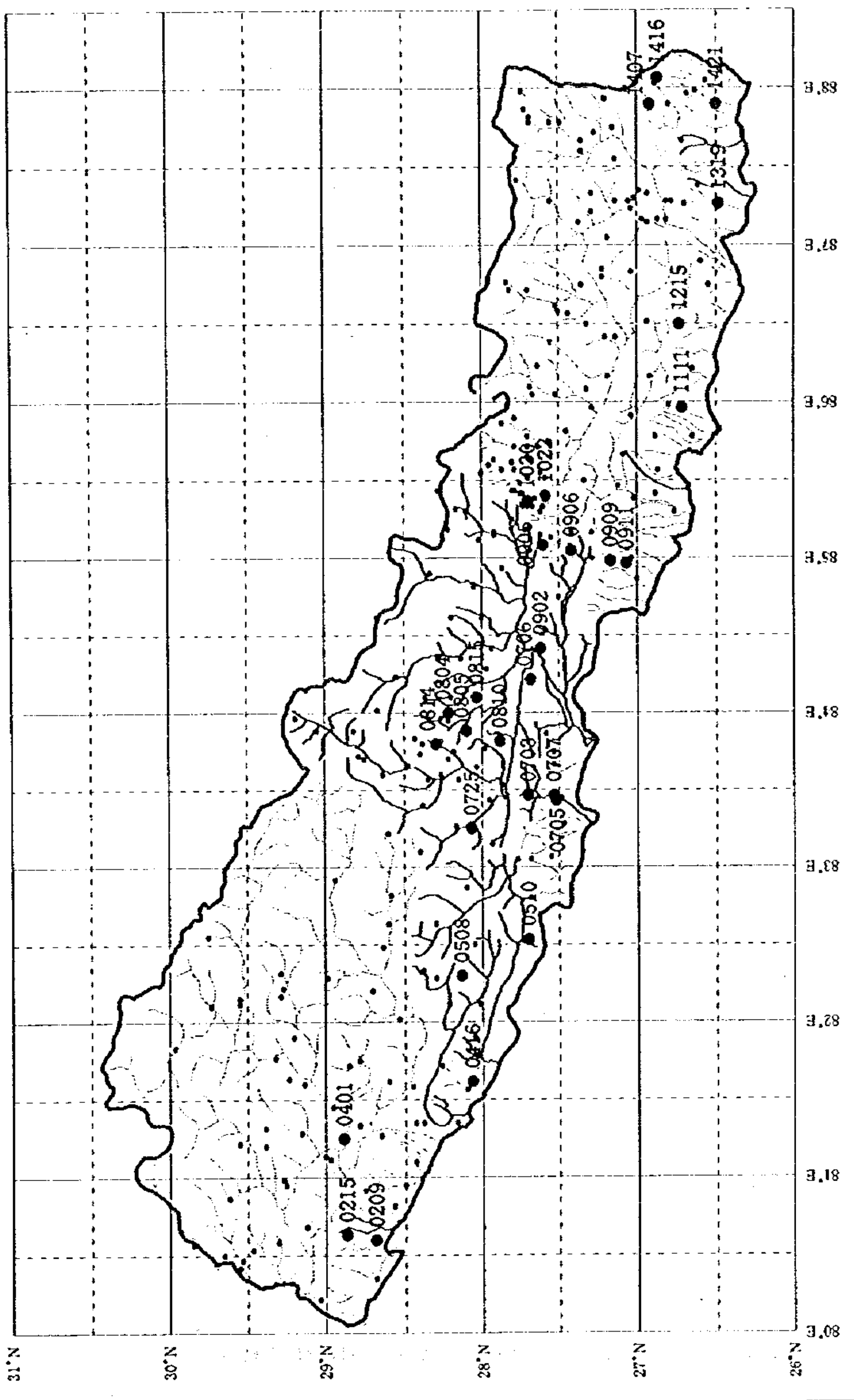
GRADING CURVES OF RIVERBED MATERIALS

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3.3



LOCATION OF RAINFALL STATIONS (SLECTED 29 STATIONS)

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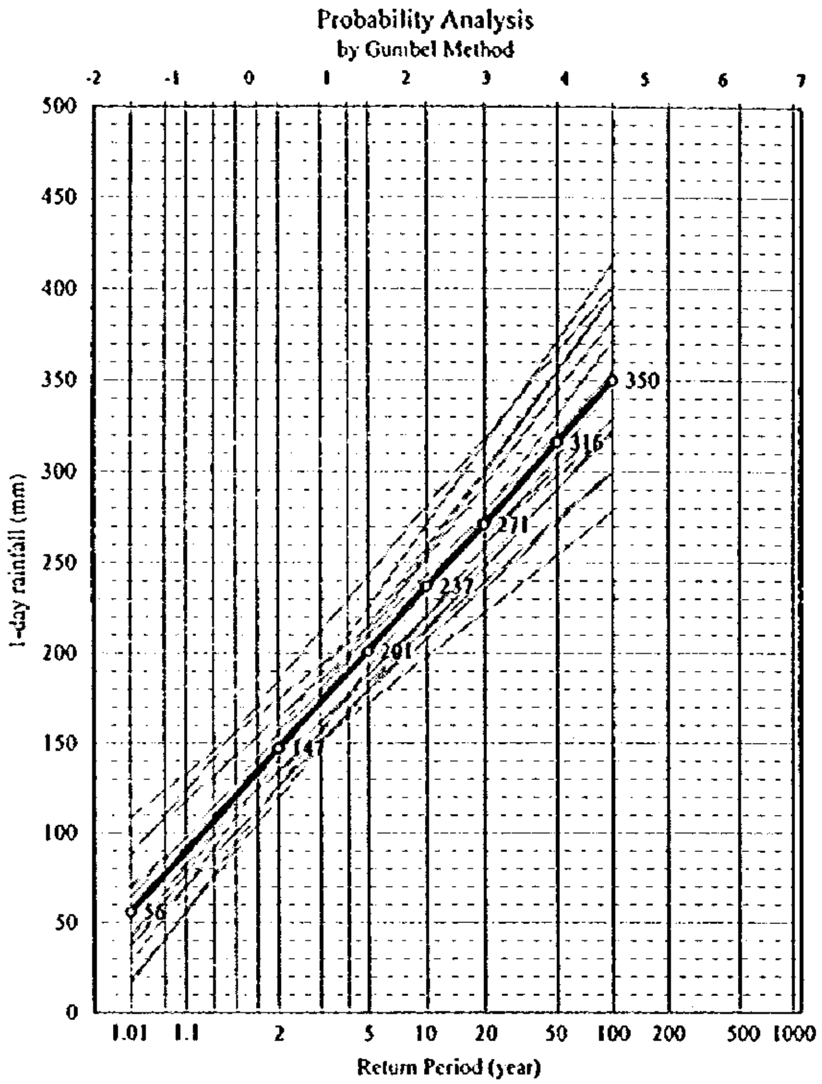
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



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

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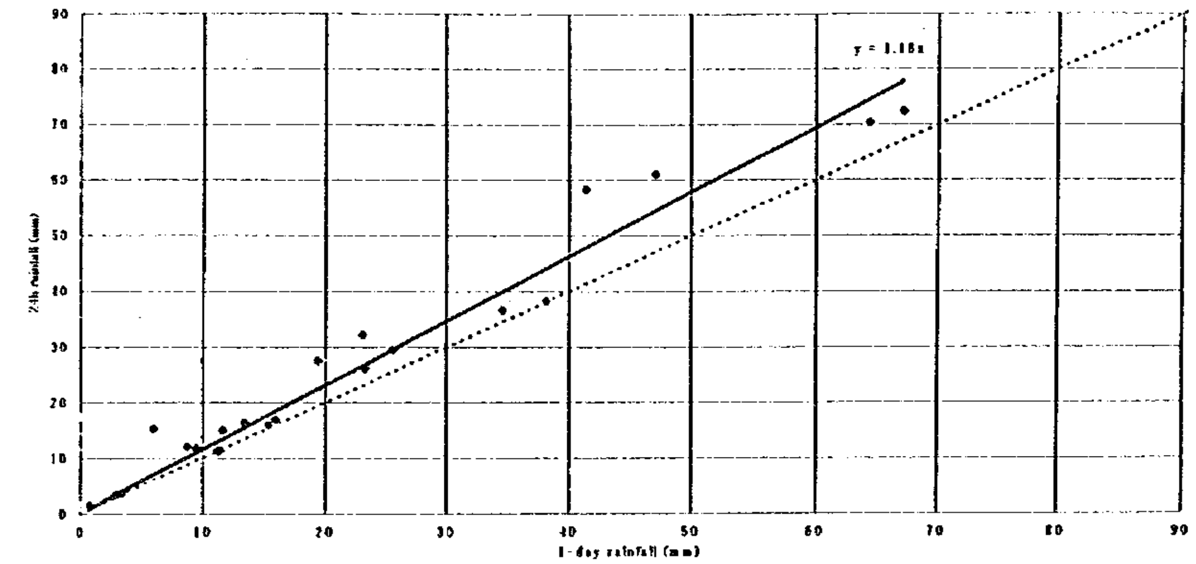
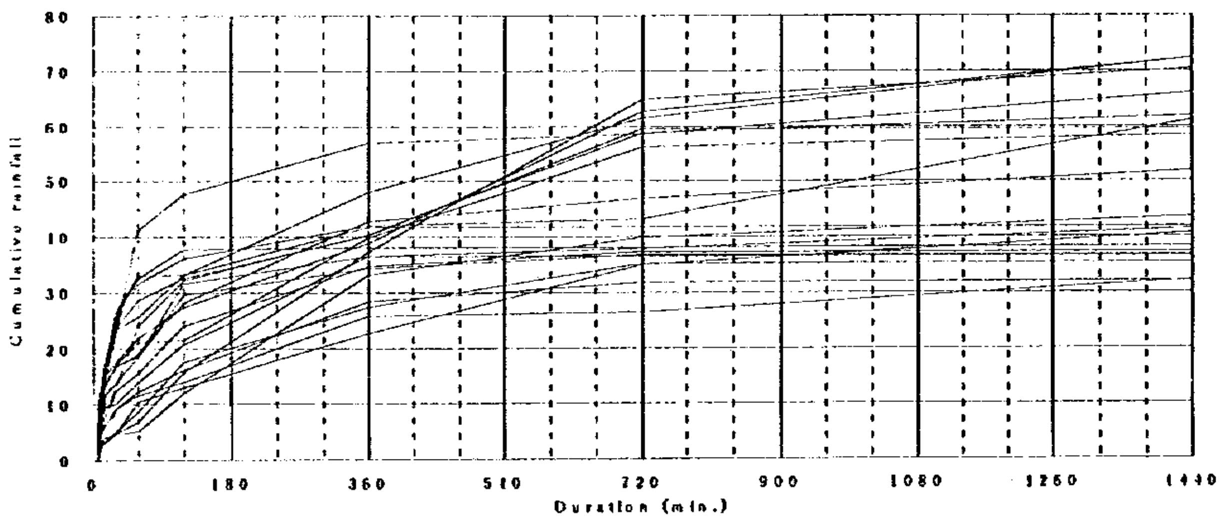
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

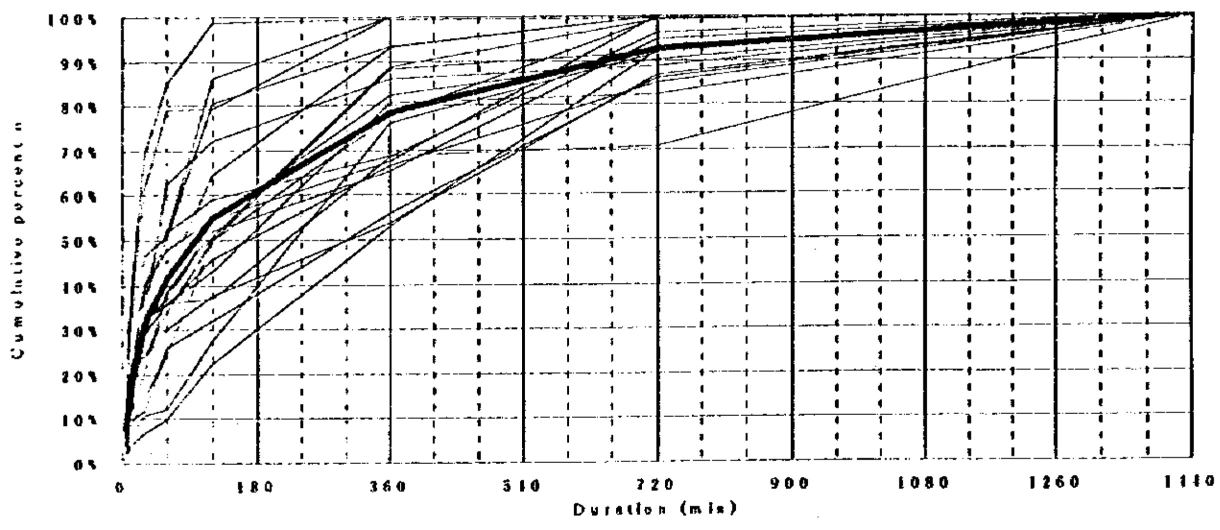
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3.5



RELATIONSHIPS BETWEEN 24-HOUR RAINFALL AND DAILY RAINFALL





RAINFALL FOR SHORT DURATION

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

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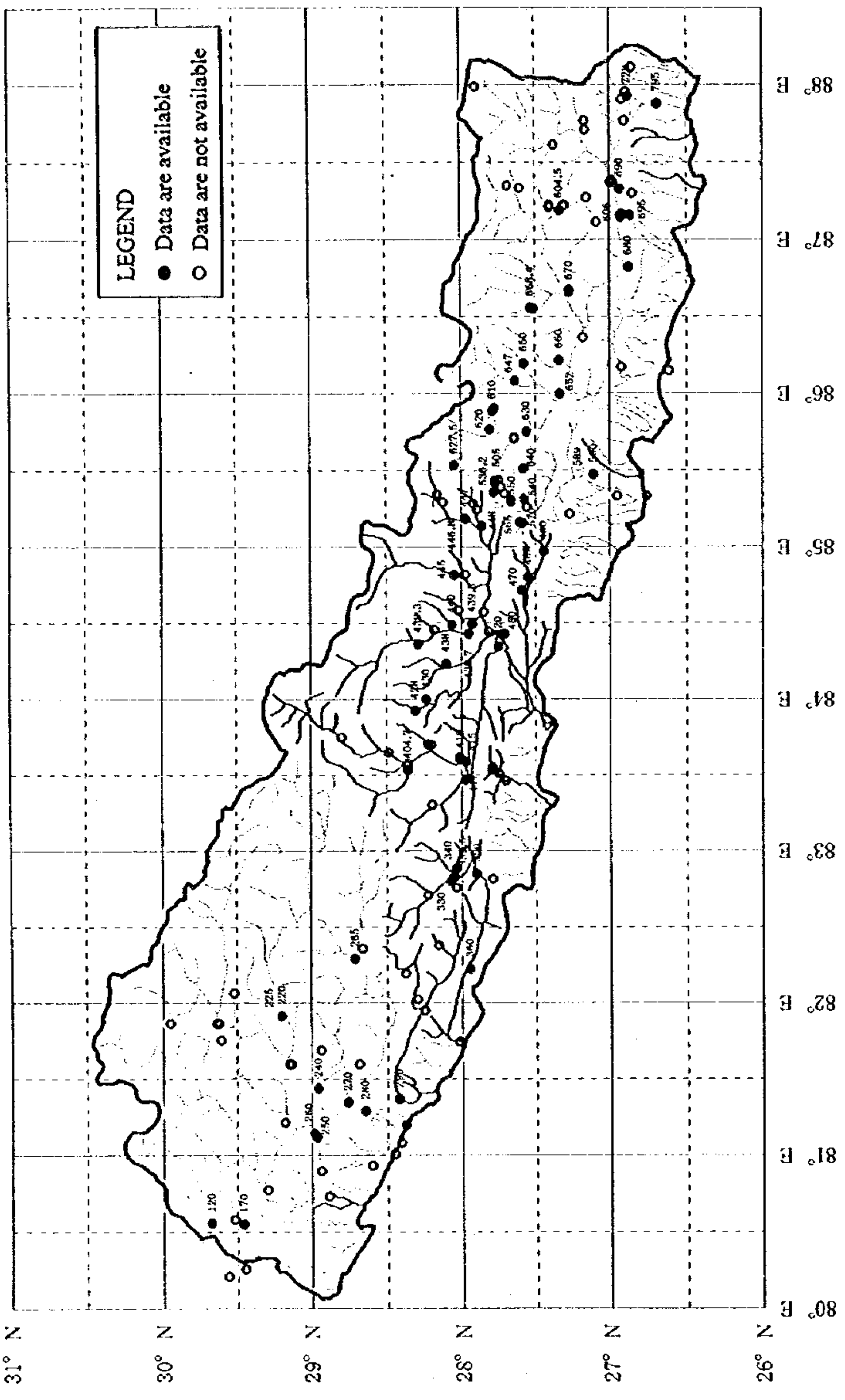
Fig. 3.6



LOCATION OF DISCHARGE OBSERVATION STATIONS

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

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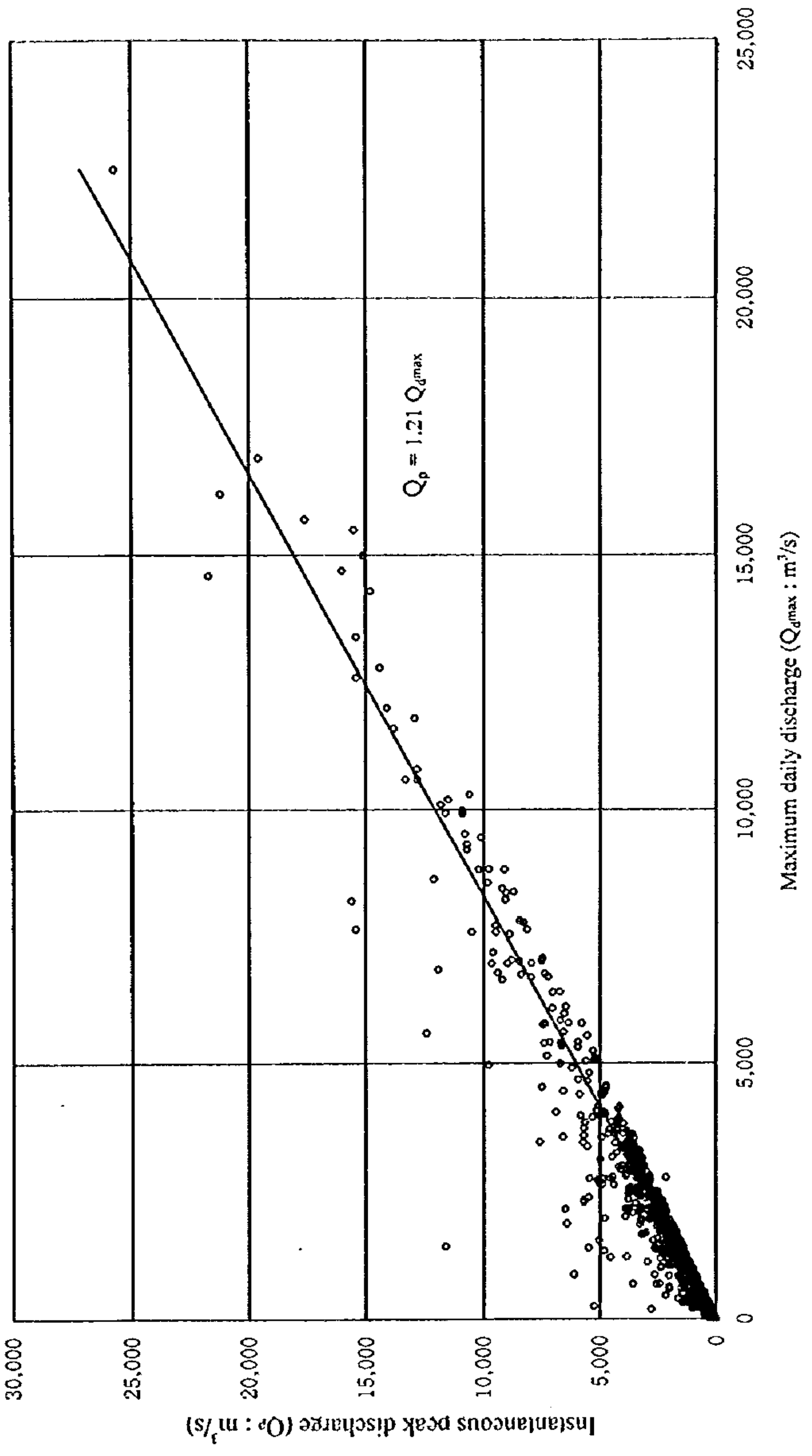

RELATIONSHIP BETWEEN PEAK DISCHARGE AND DAILY DISCHARGE

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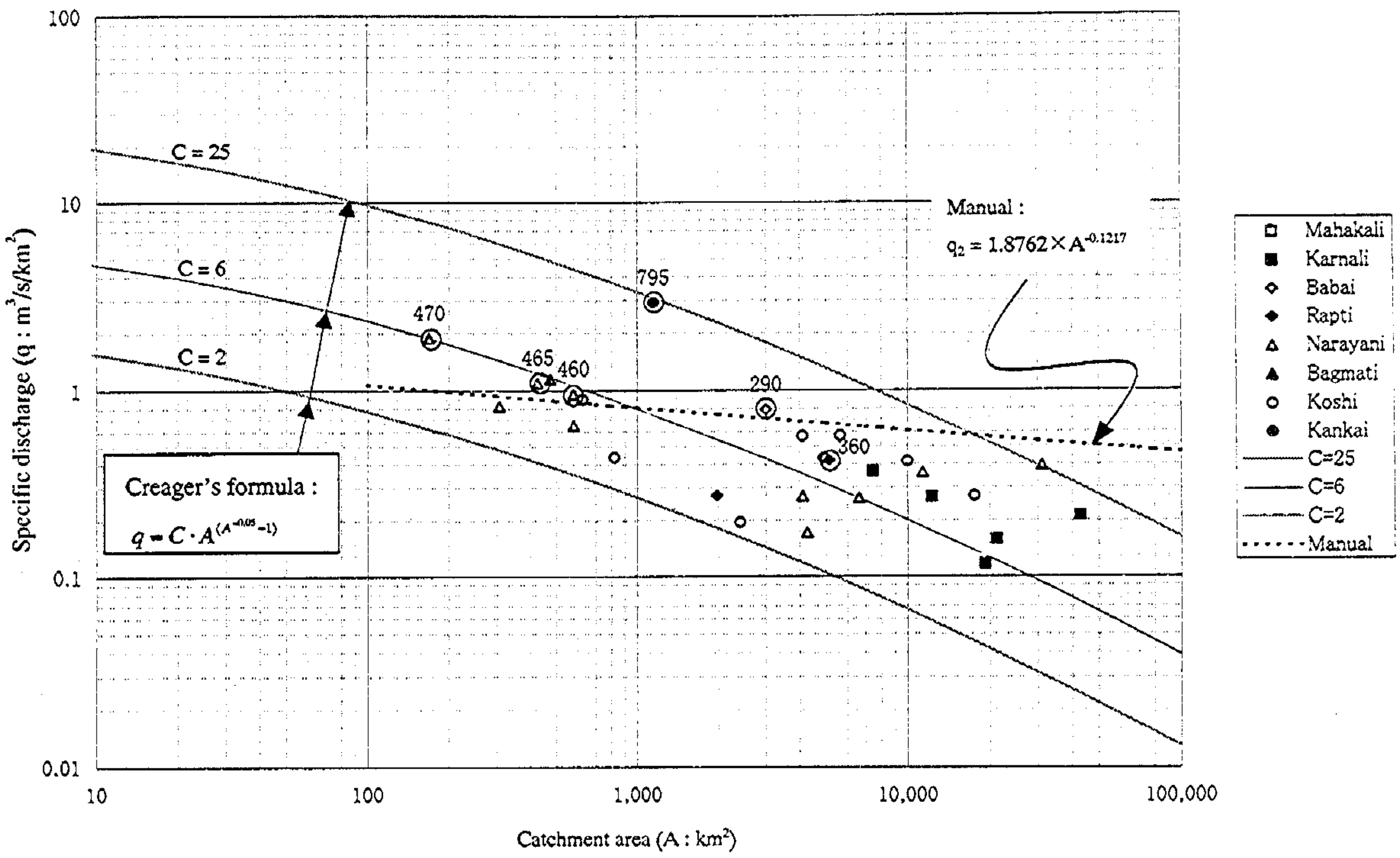
JAPAN INTERNATIONAL COOPERATION AGENCY



PROBABLE SPECIFIC DISCHARGE OF 2-YEAR RETURN PERIOD

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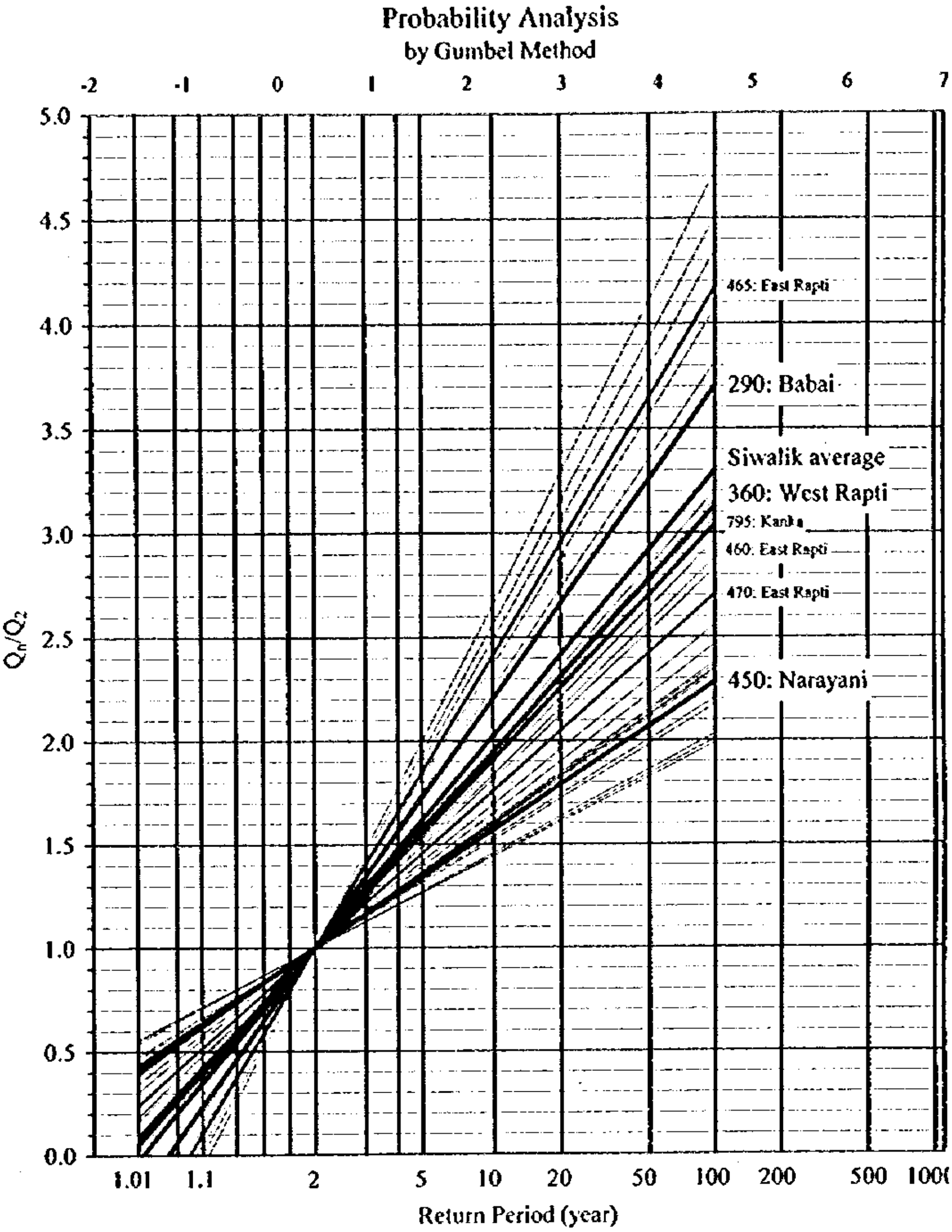

Code	River	Catchment (km2)	Elevation (m)	Return Period 2	5	10	20	50	100	Remarks
290.	Babai	3,000	192	1.00	1.72	2.20	2.66	3.26	3.70	
360.	West Rapti	5,150	218	1.00	1.57	1.95	2.31	2.78	3.12	
450.	Narayani	31,100	180	1.00	1.34	1.57	1.79	2.07	2.28	
460.	East Rapti	579	332	1.00	1.54	1.90	2.25	2.70	3.03	
465.	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

His Majesty's Government of Nepal
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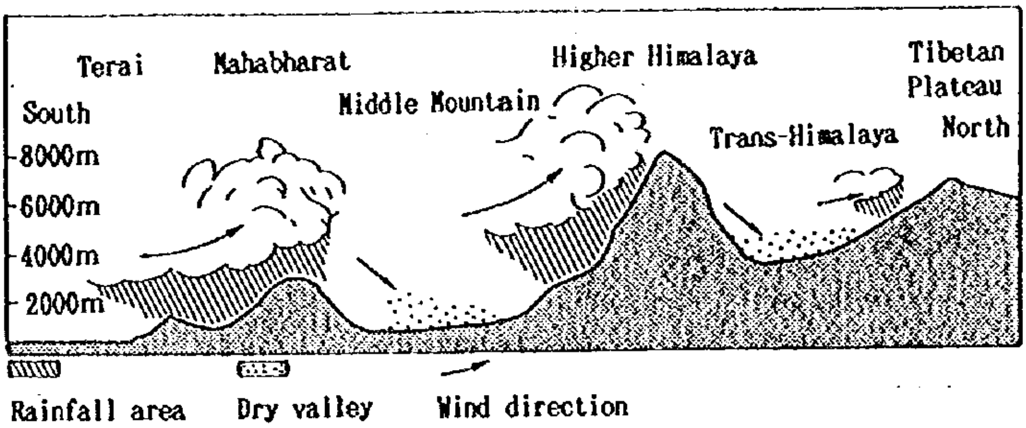

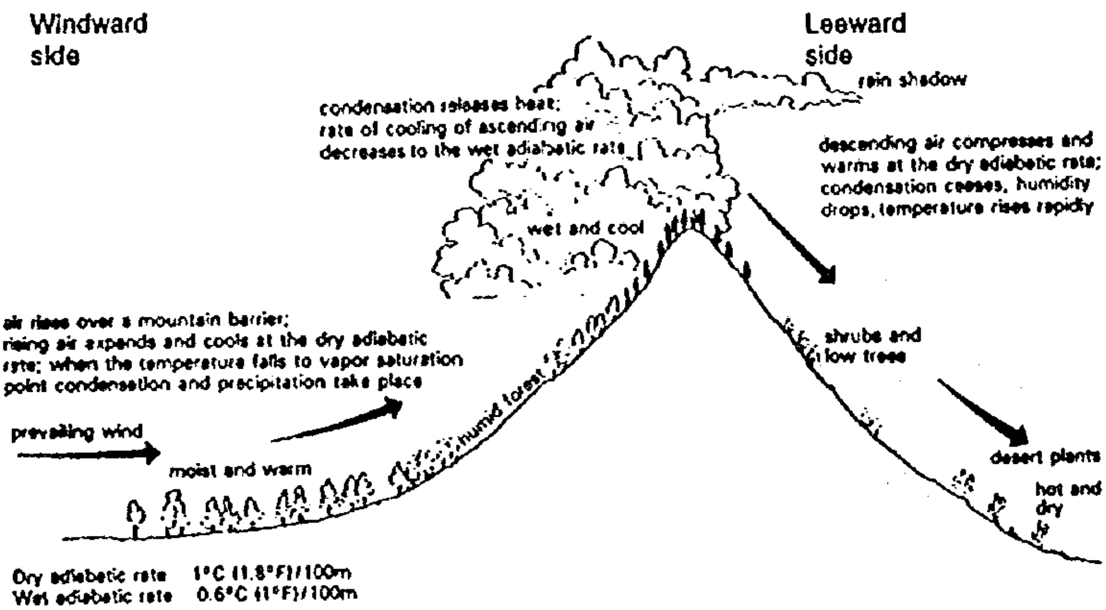

WET MONSOON AND HIMALAYA

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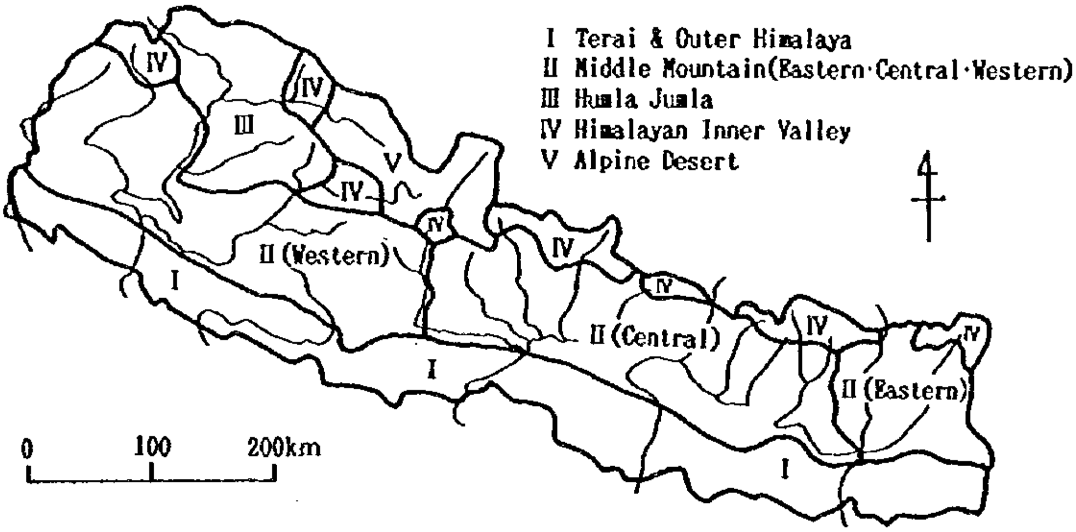
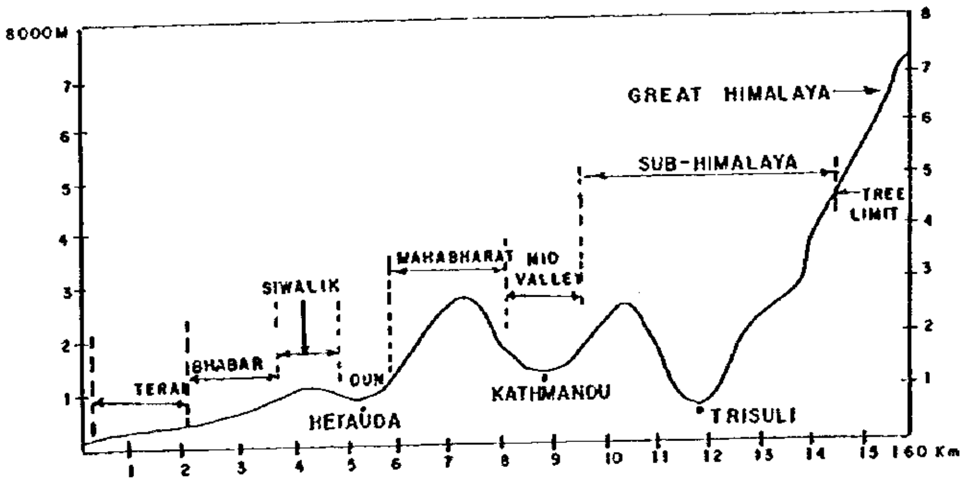


(a) Climatic and Vegetational Divisions of Nepal
(Stainton, 1972)



(b) Topographic Profile
(The Cross-Section of The Nepal Through Kathmandu Valley: Shrestha,B.P.,1989)

VEGETATIONAL DIVISION AND TOPOGRAPHIC PROFILE

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