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JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF IRRIGATION
MINISTRY OF WATER RESOURCES
THE KINGDOM OF NEPAL

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

FINAL REPORT

VOLUME III (1/9)

SUPPORTING REPORT

(A1: FMP/RATUWA RIVER)

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FINAL REPORT

VOLUME I : EXECUTIVE SUMMARY

VOLUME II : MAIN REPORT

VOLUME III : SUPPORTING REPORT

- A1: FLOOD MITIGATION PLAN/RATUWA RIVER
- A2: FLOOD MITIGATION PLAN/LOHANDRA RIVER
- A3: FLOOD MITIGATION PLAN/LAKHANDEI RIVER
- A4: FLOOD MITIGATION PLAN/NARAYANI RIVER
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VOLUME IV : DATA BOOK

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A1. FLOOD MITIGATION PLAN:

RATUWA RIVER BASIN

SUPPORTING REPORT
A1. FLOOD MITIGATION PLAN: RATUWA RIVER BASIN

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1. EXISTING CONDITIONS

1.1 Topography and Geology

The topography and geology of Nepal can be divided into the following zones (Fig. A1.1):

1) Inner Himalayan valleys
2) Higher Himalayan zone
3) Lesser Himalayan zone
   - Midland range
   - Mahabharat range
4) Siwalik (Churia) hills
5) Dun valleys
6) Terai plain

The Ratuwa river basin falls under the topographical and geological zones of Siwalik hills and Terai plain. Principal features of these zones are presented below.

(1) Siwalik (Churia) Hills

The Siwalik (Churia) hills are the lowest hills bordering the Indo-Gangetic plain in the north. Mostly it consists of rocks of alternating beds of clay, sandstone, sand and pebble. The rocks generally dip northwards. Alternately loose and hard rock beds have produced the escarpment feature. In many places rugged land with numerous gullies and mound of talus are found. The topographic slope varies from 200 to 400 m/km on the average. The Siwalik hills are divided into three layers, i.e., upper, middle and lower Siwaliks.

Upper Siwalik

The upper Siwalik is mainly conglomerate with pebbles and boulders of pale schistose quartzite, purple and white quartzite; dark phyllites; purple and dark pebbly quartzite and silt brown sandstone. The depth of upper Siwalik is about 2000 to 3000 meters.

Middle Siwalik

The layer of middle Siwalik is found in the form of thick deposits of sandstone. These

are characterized by their feldspar and mica content. Apparently the sandstone has been derived from granite rocks. Calcerous concretions and seams of coal are found in the basal part. In many sections, the sandstone forms vertical cliffs. The depth of middle Siwalik is about 2000 to 2500 meters.

Lower Siwalik

The lower Siwalik is alteration of brown, weathered sandstone and chocolate coloured clays. The alternation of beds are not thick as the sandstone. Beds of impure limestone also occur within the lower Siwalik. The depth of lower Siwalik is about 1200 to 1500 meters. All pebbles except those found in the brown sandstone are derived from rocks of Pre-tertiary age.

(2) Terai Plain

The Terai plain is the continuation of Indo-Gangetic plain having an elevation from 50 to 300 m,MSL. Its width varies between 10 to 30 km with one exception at Koilabash narrow, and extends from east to west Nepal for about 900 km.

The Terai slopes toward south with steeper slope at the foot hill region and nearly flat at the southern end.

In the Terai plain the changes of river stream are often seen in places by the lateral erosion incorporated by much sediment from the mountainous area. On such rivers, artificial structure works such as bridge, roads and irrigation facilities have to be given careful consideration.

The Terai plain is divided into three zones, i.e., (1) Bhabhar zone (foot of hill), (2) Marshy area (spring line), and (3) Southern Terai (Indian border).

Bhabhar Zone

The Bhabhar zone lies at the foot of Siwalik hills and is about 12 km wide (Charkose Jhadi). It is composed of boulder, pebble, cobble and sand of Siwalik hills or Mahabharat range deposited by the present rivers. In most cases the rocks are sandstone, quartz or charty dolomite. The foot of hills is covered with evergreen forest.

Soils are mainly alluvium consisting of sand, silt, clay looms and silty clay. In the dry

season almost all rivers in this zone have no flow on the surface and water flow underground only.

Marshy Area

The marshy area is found in the south of Bhabhar zone where two lithological units having different porosity and permeability meet or inter finger along with the change of elevation mainly resulting in spring lines, ponds, lakes, etc. The lithology is mostly composed of pebbles and sandy bed with a few clay partings. The lithology of the pebbles is similar to the boulder zone and sand beds are loose, brownish to greenish with black and red shale fragments. The clay is mostly blackish grey where a thick sequence is found, but yellow one is also observed at some places where there was a temporary hiatus in its deposition or because of a flood at that time. This is particularly true in Lumbini zone.

Southern Terai

This nearly flat and not well-drained area is found between middle Terai and the Indo-Nepal border. The area is composed of sand, clay and silt with less pebble.

(3) Ratuwa River Basin

The Ratuwa river basin is located in the eastern part of Nepal. The river originates in the eastern Siwalik hills. These hills are composed of loose stratums, especially clastic sediments such as sand, gravel and clay. During the monsoon period, heavy rainfall drops on the soft rocks or clay, sand and loose pebble layers, causing serious erosion and landslide.

During rainy season, the Siwalik hills yield much sediment and discharge them to the Terai plain. Rainfall in the eastern part of Nepal is heavier than the western part. Large flood carries and deposits these sediment in the hill valleys or Bhabhar zone in the Terai plain. Marshy areas of the Terai are composed of sand and clay, and southern zones of the Terai are of fine sand, silt and clay. In the marsh and southern zones, the river sometime shifts to new route. Overall longitudinal profile of the Ratuwa river is shown in Fig. A1.2 in comparison with those of other rivers originating in the Siwalik hills.

Geological map of the Ratuwa river basin is shown in Fig. A1.3

1.2 Meteorology and Hydrology

1.2.1 Meteo-Hydrological Observation

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

The Meteorology Section of DHM is responsible for compilation and analysis of meteorological observation records such as precipitation, temperature, humidity, vapor pressure, sunshine, wind, evaporation and soil temperature. And the Hydrology Section of DHM is responsible for compilation and analysis of hydrological observation records such as water level and sediment.

Based on the DHM's data, a list of meteorological stations in the Eastern Development Region is shown in Table A1.1 and their locations in Fig. A1.4. No hydro-metric station exists in the Ratuwa river system.

In order to supplement the existing observatory, the Study Team installed two water level gauges (staff gauges) for the Ratuwa river at Damak on the left and right side bank piers of the East-West Highway bridge.

River	Caretaker	Remarks
Ratuwa	Jhapa District Irrigation Office (Chandragadhi)	Left bank bridge pier: 5 m Right bank bridge pier: 5 m

1.2.2 Meteo-Hydrological Features of Basin

Climate of the Ratuwa river basin falls under monsoon subtropical zone, and the dry season (from October to May) and rainy season (from June to September) are clear. The dry and rainy seasons due to monsoon are the major cause of climatic contrasts in the Ratuwa river basin. Figure A1.5 shows the meteo-hydrological features of the basin based on the monthly average data at Biratnagar airport (sta. code: 1319).

(1) Temperature

Altitude affects much the temperature. The annual average temperature is 24.3℃, ranging from 16.1℃ in the coldest month to 28.8℃ in the hottest month. The coldest month is in January and the hottest falls in between June and August. The temperature rises from March to June-July while it decreases from October to January.

(2) Relative Humidity

According to Fig. A1.5, annual average relative humidity is 80.4%, ranging from 59.1% in April to 93.8% in January.

(3) Rainfall

The study area receives the southeast monsoon during the months from June to September. The monsoon air-stream is forced to rise as it meets the Himalayas and causes heavy rainfall on the south facing slopes (Fig. A1.6).

According to Fig. A1.5, annual rainfall at Biratnagar airport is 1,877mm on average ranging from 829 to 2,666mm depending on the year. The maximum rainfall is 2,666mm in 1989. The 79% of annual rainfall is concentrated in rainy season from June to September.

(4) Runoff

Although the hydro-metric records such as water level and discharge are not available for the class-III river basins originating at the Siwalik hills, the following runoff characteristics are presumed from the rainfall and geological features of the basin:

1) Runoff concentrates in monsoon season and that in driest months is very low because of small basin size and porous geological condition.
2) Flood hydrograph would be very sharp with high peak discharge and short runoff duration less than 1 day.
3) The flood runoff is accompanied with heavy sediment runoff from the Siwalik hills.

1.3 Environment

1.3.1 Environmental Organizations and Institutions

The Environmental Division of the Ministry of Population and Environment has overall responsibility for environmental matters in Nepal. In June of 1997, Environmental Conservation Rules were issued under section 24 of the 1997 Environmental Conservation Act. These rules lay down procedure to be followed when new projects are proposed or existing projects extended.

1.3.2 Environmental Overview

The Ratuwa river is a class-III river rising in the Siwalik hills. In the Terai plains, its length is about 35 km., with a basin area of some 383 km^2 (38,300 hectares) of which 250 km^2 are in the Terai. Two tributaries join the Ratuwa river in the Terai, the Chaju and the Mawa. Another river, the Mawa may flow into the Nuansari tributary during the monsoons. Thus, it is proposed to reinforce the Mawa riverbank along this stretch to prevent this from happening. The distance from the base of Siwalik hills to the Indian border is nearly 64 km. During the monsoons, riverbank erosion occurs. Additionally, many areas are inundated with coarse sand and/or floodwater.

Before malaria was eradicated from the Terai about 40 years ago, much of the area was covered with forests and wetlands. There was an abundance of plant species and wildlife. Now, only a few of these areas remain, mainly in National Parks and Forest Reserves. Most of the Terai has been colonized, especially in the east, and much of the land has been converted to agriculture. The existing land use and population of the Ratuwa river basin in the Terai is shown below.

(Land Area, Land Use and Population: 1998)

Items	Agri-culture	Forest	Barren/ sand	Other	Total	Population
Area (ha)	20,600	2,250	1,540	610	25,000	(138,300)*
Ratio (%)	82.4	9.0	6.2	2.4	100	(5.5)**

(Note)*: population (persons), **: population density (per/ha)

Over 80% of the Ratuwa basin area in the Terai are now farmed. However, according to the Inventory of Wetlands in the Terai, (IUCN 1996), there may be a wetland in the vicinity of the Ratuwa river. This is the Ratuwa floodplain (No. 157 in the IUCN book).

The Ratuwa floodplain is a small wetland of some 7,000 ha. situated near Damak Municipality. It has a permanent inflow and outflow of water. It contains indigenous trees such *as Terminalia tomentosa, Dalbergia sissoo* and *Acacia catechu,* and grasses such as *Saccharum spontaneum* and *Imperata cylindrica.* There is only one wild fish, *Amphipnous cuchia*, but there are several indigenous and migratory birds recorded in this wetland. These include *Ciconia episcopus, Leptoptilos dubius, Platalea leucorodia, Egretta alba, Ceryle lugubris* and *Ketupa zeylonensis.*

Thus, from an environmental viewpoint, protecting this wetland is important. Also, with such a high population density, the protection of the farmland and property is important. Every year, sand, silt and/or floodwater on average covers on average about 2,500 hectares of which nearly 600 ha are covered with sand and soil. Some of this soil cover is a result of human activity, especially in the Siwalik hills. In addition, an estimated 6% of the land is barren or covered with sand, principally due to flooding.

This is why flood mitigation measures, including watershed activities are essential to protect the environment. With appropriate flood mitigation measures, such land could be reclaimed and soil/sand inundation reduced. Also, farmers knowing their land are safe from flooding and inundation could invest in irrigation and increase their productivity. This may relieve the pressure on the remaining wetlands, curtail deforestation and boost grain production.

1.4 Socio Economy

(1) Economic Activities

Land Use: The Ratuwa river flows in Jhapa and Morang districts. According to the district data, agricultural and forestland makes up most of the total plain area in the two districts (91.4%/95.6% respectively).

(unit: hectare)

District	Agriculture	Forest	Sand/Gravel /Boulder	Others
JHAPA	120,153 82.0%	13,849 9.4%	9,023 6.2%	3,555 2.4%
MORANG	113,231 75.8%	29,615 19.8%	5,250 3.5%	1,231 0.8%
10 Districts (where M/P rivers flow)	800,591 64.1%	352,508 28.2%	43095 3.5%	52,449 4.2%

Source: Land Resources Mapping Project 1986, Department of Survey
Forest Survey 1993, Department of Forest

Economically Active Population (10 Years of Age and Over) by Major Occupation: A ratio of 84.9%/82.6% of the labor force is engaged in agriculture, as opposed to 5.6%/6.3% in manufacturing and 18.9%/23.4% in service sectors.

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
JHAPA	129,397 66.0%	37,016 18.9%	11,044 5.6%	17,952 9.5%
MORANG	138,017 59.2%	54,649 23.4%	14,796 6.3%	25855 10.9%
10 Districts (where M/P rivers flow)	1,123,328 73.9%	215,393 14.2%	73,937 4.9%	107522 7%

Source: Population Census 1991, Central Bureau of Statistics

Crop Area and Productively of Agriculture Crop: Jhapa and Morang districts produce a wide range of crops, with major crops of paddy, maize, and wheat. These major crops but wheat are grown during the monsoon. Although there are also winter paddy and maize, most of the paddy and maize are grown in summer.

unit: hectare. (metric ton/ha.)

District	Paddy	Maize	Wheat	Pulses	Oilseeds	Sugarcane	Vegetables
JHAPA	104,45 (2.71)	33,625 (1.4)	15,250 (2.05)	3,516 (0.79)	3,012 (0.79)	76 (3.00)	1,515 (7.16)
MORANG	97,200 (2.57)	14,000 (1.82)	17,940 (1.70)	6,930 (0.50)	7,900 (1.40)	1,260 (40.0)	2,250 (12.58)
10 Districts (where M/P rivers flow)	537671 (27.79)	145489 (18.14)	174589 (19)	98536 (4.9)	102720 (7.92)	17331 (233.06)	11930 (52.58)

Source: Annual Agricultural Development Programme 1995/96, District

(2) Land Holding

Land Ownership & Holding: In Jhapa/Morang districts, the average land holding size has declined in recent years like other districts in the Terai plain. The average size is far below the 16.4 hectare ceiling imposed by the 1964 Lands Act. About 80% of the agricultural land is under owner-cultivation. With regard to the agricultural land under "formal" tenancy, the most dominant form is sharecropping.

District	Owner-Cultivated (%)		Average Holding Size (ha.)	
	1981/82	1991/92	1981/82	1991/92
JHAPA	89.2	83.6	1.53	1.41
MORANG	93.0	79.4	1.34	1.42
Terai	91.8	87.6	1.47	1.22

Tenure Arrangements: However, that since informal arrangements of land tenancy are not recorded in the official census, the above figure of owner-cultivation should be

treated with caution. Underlying the sharecropping category is a commonly known phenomenon of "dual ownership". To undertake flood mitigation works for land under "dual ownership", it will be imperative to involve both land owners and tenants, both of whom are entitled to certain shares of the proceeds of the land.

District	Tenure Arrangement – 1991/92 (%)		
	Fixed Rent	Share Crop	Others
JHAPA	20.9	59.4	19.1
MORANG	22.9	73.1	4.0
Terai	30.6	62.7	6.7

Source: Nepal Sample Census of Agriculture 1991/92, Department of Agriculture

(3) Population

From nation-wide viewpoint, in-migration in the east is approaching to zero, as new lands available for cultivation are being closed. On the other hand, the western districts continue to exhibit high population growth, since the land frontiers are relatively open. In a similar vein, the original inhabitants of the Terai constitute nearly or more than half the population towards the west, while the proportion of indigenous groups makes up less than half in most of the eastern districts.

Population of Jhapa and Morang districts is 594,000 and 675,000 as of 1991 with population growth rates of 2.3% and 2.1% (1981-1991) respectively. The population growth ratios have gradually been declining since 1970s, just as the national average. The population growth rates of the two districts have always been slightly lower, over the last few decade, than the national average, i.e., 2.3% (1981-1991).

Demographic Records of Flood-Prone VDCs/Municipality: The following table shows the population trends of the VDCs affected by Ratuwa floods. The 1981-91 population growth rate of the affected VDCs is 1.9%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Jhapa/Morang districts.

District	VDC/Municipality	1971	1981	1991	1996
Jhapa	Damak	13,993	23,319	41,321	45,913
	Khajurgachhi	3,727	6,813	7,471	8,301
	Kohaura	4,657	12,616	10,619	-
	Lakhanpur	-	17,010	17,081	18,979
Morang	Itahari	-	15,053	14,931	18,224
	Sijuwa	4,359	9,972	10,999	13,425
	Rajghat	10,049	10,161	12,577	15,351
	Jhurkiya	4,324	10,230	8,452	10,316
	Mahadewa	-	-	3,713	4,532
Total		41,109	105,174	127,164	135,041

Source: Population Census 1991, Central Bureau of Statistics
Nepal District Profile 1997, National search Associates

(4) Human Development Index (HDI)

In terms of the Human Development Index (which is a development indicator based on life expectancy, adult literacy, and GDP), the districts in eastern areas of the country receive, in general, higher performance, and become lower toward the west. Accordingly, the HDI of Jhapa and Morang districts are among the highest (5th and 4th of all 75 districts).

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The Ratuwa river basin extends from 26°15′N to 26°45′N and from 87°30′E to 87°45′E. The Ratuwa river originates in Siwalik hills and is classified as a class III river. Administratively it is located in Jhapa district (left bank basin) and Morang district (right bank basin) both in Eastern Development Region.

Basin area of the Ratuwa river is 383 km^2 in total, consisting of 133 km^2 of mountainous area and 250 km^2 of plain area. Boundaries of the river basin and sub-basins were drawn on the basin map. Basin boundary in the Terai plain was delineated in consideration of existing drainage channels, irrigation canals, road networks and other ground objects. General basin maps of the Ratuwa river is shown in Fig. A1.7 The basin map was prepared based on the topographic maps of scale 1/25,000.

Notable features of the Ratuwa river basin are as follows:

1) River channel is wide and braided for the whole reaches.
2) The Chaju and Mawa rivers are the major tributaries.
3) The Mawa river contacts to the Nunsari/Bakra river near Madhumalla Bajar town. A separation dike has been constructed at the contact point to prevent the Mawa floodwater from flowing into the Nunsari/Bakra river basin.
4) Damak city and Bhutanese refugee camps by UNHCR exist in the riverine areas

1.5.2 Characteristics of River Channel

Channel slope and width of the existing river are shown in Fig. A1.8 for the plain reaches. These were prepared based on the topographic map of scale 1/25,000, since river survey results were not available. In order to obtain the river profile, spot elevation data on the topographic map were used and the river width was measured on the map at the intervals of 1 km along the river. The river width includes perennial river sections and sand bars of the meandering and braided river section.

According to the figure, principal features of the existing river in the Terai plain are summarized below.

River	Class	Length(km)	Slope	Width(m)
Ratuwa R.	III	43.7(33.4)	1/170～1180	200～690

Note: River length in ( ) indicates that downstream from E-W Highway

1.5.3 River Course Shifting

It is generally said that rivers in the Terai plain have tendency to shift westwards. If it is true the existing talweg might take closer to west or right side bank as a whole. To confirm this hypothesis, the location of talweg in the river section was measured at every 1 km and shown in the Fig. A1.8. The clear tendency of westward shifting was not seen.

In order to look into the actual shifting of river course in the past, topographic maps prepared in 1953/54 (scale: 1/50,000) and those in 1992 (scale: 1/25,000) were superimposed and shown in Fig. A1.9.

According to the figure showing river course change during the past 38 years, meander of the both river channels is not severe, and the shifting of river course seems to remain within the meandering belt.

1.5.4 Riverbed Materials

The Study Team investigated riverbed materials along the plain reaches of the river. The investigation includes the following outdoor and indoor works:

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

Bed materials of the Ratuwa river were sampled at 13 sites (Fig. A1.10) among which outdoor analyses were carried out at 8 sites. Results of riverbed material tests are shown in Table A1.2 and the grading curves in Fig. A1.11.

Principal features of the riverbed materials are summarized below. In the descriptions below, UI denotes uniformity index defined as a ratio of d_{84} to d_{16}, SG stands for specific gravity, and classification of grain size is principally based on classification by AGU.

1) Samples: Riverbed materials were sampled from the main course of the Ratuwa river except for the following:
   - Ra-7 and Ra-10: Mawa R.
   - Ra-12 and Ra-13: Chaju R.
2) Grain size:
   - d_{60} = 0.28 to 0.74: Medium to coarse sand
3) Uniformity index ($UI = d_{84}/d_{16}$): Riverbed materials are well-sorted and uniform except for Ra-10 and Ra-11.
   - UI = 2.6～5.4 except Ra-10 and Ra-11
   - UI = 10 for Ra-10, and 70 for Ra-11
4) Specific gravity (SG):
   - SG = 2.64 g/cc on average ranging from 2.59 to 2.67 g/cc
5) Longitudinal distribution: Change in grain size is seen in the upstream and downstream reaches of Chaju river junction.

Based on the investigation result, grain size distribution along the river is shown in the Fig. A1.8.

1.5.5 Land Use

Land utilization map and land capability map (scale: 1/50,000) are available. These maps have been prepared by Topographic Survey Section of Survey Department under the Canadian assistance program.

Mapping details are based on aerial photos taken in 1978 and 1979 and extensive field truthing and sampling during the year 1980 and 1981. The maps were published in 1982.

Existing land use of the plain area is shown in Fig. A1.12 based on the land utilization map. These maps were prepared rearranging the classifications into five categories, i.e., (1) rice field, (2) diversified cropland, (3) grazing land, (4) forest, and (5) settlement.

Land capability map is also available, which shows the land capability for agricultural development mainly based on the land system such as topography, land slope, soil and drainage conditions. Future land use would be prospected from the land capability.

1.5.6 Existing Basin Development Projects and Plans

Intensive irrigation projects and other water resources development projects are not yet implemented in the basin. At the upper riverine areas of the Ratuwa river basin, Bhutanese refugee camps by UNHCR exist.

1.6 Vegetation and Sediment Yield in Watershed Area

(1) Climate and Vegetation Division

Watershed of the Ratuwa river is classified as the Terai and Outer Himalaya division from the climate and vegetation viewpoint.

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

The Siwalik hills were formed by upheaval of sediment bed carried from Himalaya. Forests are left in the Siwalik hills, because of too steep inclination for settlement and farming. But, clearing forest takes place recently even in the Siwalik hills.

(2) Land Use in Watershed Area

The land use of the watershed area of the Ratuwa river are worked out using the aerial photos taken 1992 and topographic maps of 1/25,000 as follows:

(Land Use of Watersheds)

Land use	Area (ha)	Ratio (%)
Forest	7,006	72.9
Bush	346	3.6
Cultivation	1,924	20.0
Cliff	55	0.6
River	279	2.9
Urban	-	-
Total	9,610	100.0

(Remarks) 1) Bush: Scrub, Bush, Grass & Bamboo

2) Cliff: Soil cliff , Rock cliff & Out crop of rock

Ratuwa River Watershed is located in the eastern Siwalik hills. Therefore, hilly area of the watershed is covered with Hill Sal forest. About 20% of the watershed areas are used as cultivated land with gentle slope. Bush lands are seen around the cultivated land. They seem to be pasture, fallow field or abandoned cultivated land.

Though a size of cliff land is wide and it is scattered over the watershed on the topographical map, ratio of cliff land is only 0.6%. These cliff lands are distributed in forest land. Steep slopes facing south without vegetation cover are seen on the aerial photo. In the middle of the Ratuwa and Chaju river watershed almost all slopes are steep, and without vegetation cover facing south with pattern like scale of fish.

Geographically these bare rocks are cuesta scarps. Restoration of vegetation in these cliff lands is difficult and inappropriate for afforestation. Bush land is the area where soil erosion can be reduced effectively by afforestation, because ground slope is gentle.

(3) Erosive Landform of Watershed Area

The drainage system and slope of watershed of the Ratuwa river are shown in Fig.A1.13

and Fig. A1.14. The drainage system and slope maps allow the interpretation of erosive landform characteristics of the watershed area.

The drainage density of the central and southern watershed of the Ratuwa river is high, while the density is extremely low in the north. The cultivated lands extend on the gentle slope lands in the northern watershed, and the forest areas are concentrated on the steep slopes of the southern watershed.

(4) Estimation of Sediment Yield

The sediment yield of the Ratuwa river is estimated by the soil erosion rate depending on the land use. The soil erosion rate was assumed mainly referring to the data of soil erosion rates of the Ratu river.

(Estimation of Sediment Yield: Ratuwa River)

Land use	Area (ha)	Erosion rate(mm/yr)	Yield(m^3/yr)
Forest	7,006	2	140,000
Bush	346	10	35,000
Cultivation	1,924	0.4	8,000
Cliff	55	20	11,000
River	279	0	0
Urban	0	0	0
Total/average	9,610	2.01	193,000

According to an investigation for the soil erosion rate, sediment yield in the disaster of 1993 has been estimated at about seven (7) times of that in an ordinary year. From this, it is anticipated that the sediment yield in disastrous year may amount to some ten times of the above value estimated for the ordinary year.

1.7 Past Flood and Sediment Disasters

The Study Team investigated conditions of past flood and sediment disasters in January 1998. On the basis of the information obtained from the District Irrigation offices and District Development Committee offices, a total of 9 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 171 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are summarized in Table A1.3. Flood in 1988 is the biggest in recent 10 years followed by those in 1995 and 1996. Riverbed of the Ratuwa

river is said aggrading and widening. The Ratuwa river floods over the riverbanks every year from June to August. Bank erosion, sedimentation and flooding over farmlands are the major types of disasters.

According to the data and information obtained from DDC and DIO of Jhapa and Morang districts, bank erosion takes place along the whole riverbanks and the flooding in the following areas:

(Areas Suffering from Bank Erosion and Flooding)

VDC/Municipality	Village/Ward
Lakhanpur	Khayarbari
Kohabara	Dimmautha, Khadigaun, Magar Khaigaun, Telliyadangi
Khajurgachhi	Shyam Toli
Damak Municipality	Beldangi, Bhangbari, Hatkhola, Srijana Tole
Rajghat	Marajasthan
Itahara	Gaighat, Bhulkadubba
Mahadeva	Merchhadangi

Loss of life and damage to properties are shown in Table A1.4, mainly based on data during 1995-flood. According to the field investigation and interviews of residents, flood-suffering areas during the 1995-flood are shown in Fig. A1.15.

1.8 Flood Mitigation Activities

1.8.1 Existing River Facilities

According to the result of investigation conducted by the Study Team in January 1998, major river facilities of the Lakhandei river are as follows:

1) Embankment: 2 sites
2) Spur : 26 sites
3) Revetment : 4 sites
4) Head work : none
5) Bridge : 1 site

Location of these facilities is shown in Fig. A1.16. As seen in the above, spur (groin) works share by far the majority of the facilities followed by revetment works. Almost all the spur and revetment works are made of gabion by boulder and galvanized iron (G.I.) wire net.

The existing facilities are located sporadically along the river course. Some of these spur and revetment works are damaged already probably due to inappropriate foot protection. In some sites single spur was seen, though the spur works can function effectively, in general, when they are installed as a series. The types of existing spur or bank protection works are monotonous. Variety of works should be introduced taking account the river condition and availability of materials. Photos of typical river facilities are shown in Fig. A1.17.

1.8.2 Policy Framework

There are various laws and policies governing and orientating the flood mitigation activities. The followings are the major ones, among others:

1) Approach to the Ninth Plan (1997-2002)
2) National Action Plan on Disaster Management
3) Draft Flood Mitigation Policy
4) Watershed Development Policy

1.8.3 Organizations Involved in Flood Mitigation

The Department of Irrigation (DOI) is responsible for flood mitigation in the downstream areas. At the same time, there are other agencies that can make significant contributions to the implementation of flood mitigation project, both within and outside the central Government.

The Water-induced Disaster Prevention Technical Center (DPTC) has developed technologies and methodologies which can be applied to the project.

The Department of Soil Conservation and Watershed Management (DOCSWM), with an increasing number of branch offices in the Terai plain, also contributes to the project implementation through soil conservation which is also a crucial factor in promoting flood mitigation in the target areas.

As indicated by the experience of the efforts for small-scale infrastructure development by the Ministry of Local Development (MLD), the local governing institutions (LGIs) can play a significant role in facilitating community mobilization and also in coordinating different organizations operating in their own jurisdictions. There exists an NGO-led disaster preparedness network (DPNET), an association of organizations

concerned with community-based disaster management can participate in implementing community development components of the flood mitigation project.

Table A1.1

LIST OF METEOROLOGICAL STATIONS

Station No.	Station Name	Type of Station	Reg	Latitude			Longitude			Elevation (m)	Start of Record	Remarks
				°	'	"	°	'	"			
1201	Namche Bazar	Precipitation	E	27	49	00	86	43	00	3,450	04-1971	
1202	Chaurikhark	Precipitation	E	27	42	00	86	43	00	2,619	04-1948	
1203	Pakarnas	Precipitation	E	27	26	00	86	34	00	1,982	12-1947	
1204	Aisealukharh	Precipitation	E	27	21	00	86	45	00	2,143	05-1948	
1206	Okhaldhunga	Synoptic	E	27	19	00	86	30	00	1,720	12-1947	
1207	Name Bhanjyang	Precipitation	E	27	12	00	86	25	00	1,576	11-1947	
1208	Dwarpa	Precipitation	E	27	13	00	86	51	00	1,829	05-1959	
1210	Kurule Ghat	Precipitation	E	27	08	00	86	25	00	497	12-1947	
1211	Khotang Bazar	Precipitation	E	27	02	00	86	50	00	1,295	05-1959	
1212	Phatepur	Climatology	E	26	44	00	86	51	00	100	07-1976	
1213	Udayapur Gadhi	Climatology	E	26	56	00	86	31	00	1,175	07-1947	
1215	Lahan	Climatology	E	26	44	00	86	30	00	138	11-1955	
1216	Siraha	Precipitation	E	26	39	00	86	13	00	102	06-1947	
1217	Khumjung	Precipitation	E	27	49	00	86	43	00	3,750	05-1966	
1218	Tengboche	Precipitation	E	27	50	00	86	46	00	3,857	05-1966	
1219	Salleri	Precipitation	E	27	30	00	86	35	00	2,378	12-1947	
1220	Chiafsa	Agrometeology	E	27	31	00	86	37	00	2,770	05-1966	
1222	Diktel	Precipitation	E	27	13	00	86	48	00	1,623	06-1973	
1223	Rajbiraj	Climatology	E	26	33	00	86	45	00	91	12-1971	
1224	Sirwa	Precipitation	E	27	33	00	86	23	00	1,662	05-1959	
1225	Syangboche	Precipitation	E	27	49	00	86	43	00	3,700	05-1973	
1226	Barmajhiya	Precipitation	E	26	36	00	86	54	00	85	09-1975	
1301	Num	Precipitation	E	27	33	00	87	17	00	1,497	06-1959	
1303	Chainpur (East)	Climatology	E	27	17	00	87	20	00	1,329	07-1947	
1304	Pakhribas	Agrometeology	E	27	03	00	87	17	00	1,680	01-1976	
1305	Leguwa Ghat	Precipitation	E	27	08	00	87	17	00	410	07-1947	
1306	Munga	Precipitation	E	27	02	00	87	14	00	1,317	07-1947	
1307	Dhankuta	Synoptic	E	26	59	00	87	21	00	1,445	06-1947	
1308	Mulghat	Precipitation	E	26	56	00	87	20	00	365	06-1947	
1309	Tribeni	Precipitation	E	26	56	00	87	09	00	143	05-1948	
1310	Barahkshetra	Precipitation	E	26	52	00	87	10	00	146	03-1947	
1311	Dharan Bazar	Precipitation	E	26	49	00	87	17	00	444	06-1947	Ratua / Lohendra
1312	Haraincha	Precipitation	E	26	37	00	87	23	00	152	04-1956	Ratua / Lohendra
1313	Biratnagar (City)	Precipitation	E	26	28	00	87	17	00	67	05-1948	Ratua / Lohendra
1314	Terathum	Climatology	E	27	08	00	87	33	00	1,633	04-1966	
1316	Chatara	Precipitation	E	26	49	00	87	10	00	183	06-1948	
1317	Chepuwa	Precipitation	E	27	46	00	87	25	00	2,590	06-1959	
1318	Paripatle (Horti)	Precipitation	E	27	01	00	87	18	00	1,364	11-1966	
1319	Biratnagar Airport	Agrometeology	E	26	29	00	87	16	00	72	07-1968	Ratua / Lohendra
1320	Tarahara	Agrometeology	E	26	42	00	87	16	00	200	07-1968	
1321	Tumlingtar	Precipitation	E	27	17	00	87	13	00	303	05-1977	
1322	Machuwaghat	Precipitation	E	26	58	00	87	10	00	158	05-1948	
1323	Dharan British Camp	Climatology	E	26	47	00	87	17	00	400	08-1969	Ratua / Lohendra
1324	Bhojpur	Agrometeology	E	27	11	00	87	03	00	1,595	06-1954	
1325	Dingla	Precipitation	E	27	22	00	87	09	00	1,190	05-1948	
1401	Olangchung Gola	Precipitation	E	27	41	00	87	47	00	3,119	07-1947	
1402	Pangthung Dema	Precipitation	E	27	41	00	87	49	00	2,818	12-1947	
1403	Lungtang	Precipitation	E	27	33	00	87	47	00	1,780	07-1947	
1404	Taplethok	Precipitation	E	27	29	00	87	47	00	1,383	07-1947	
1405	Taplejung	Synoptic	E	27	21	00	87	40	00	1,732	07-1947	
1406	Memeng Jagat	Precipitation	E	27	12	00	87	56	00	1,830	07-1947	
1407	Ilam Tea Estate	Agrometeology	E	26	55	00	87	54	00	1,300	03-1956	
1408	Damak	Precipitation	E	26	43	00	87	40	00	163	03-1956	Ratua / Lohendra
1409	Anarmani Birta	Precipitation	E	26	38	00	87	59	00	122	03-1956	
1410	Himali Gaun	Precipitation	E	26	53	00	88	02	00	1,654	02-1968	
1411	Soktim Tea Estate	Climatology	E	26	48	00	87	54	00	530	06-1966	
1412	Chandra Gadhi	Precipitation	E	26	34	00	88	03	00	120	02-1971	
1413	Khamachin	Precipitation	E	27	44	00	87	59	00	4,242	12-1948	
1414	Nup	Precipitation	E	27	43	00	87	52	00	4,000	06-1948	
1415	Sanischare	Precipitation	E	26	41	00	87	58	00	168	01-1972	
1416	Kanyam Tea Estate	Climatology	E	26	52	00	88	04	00	1,678	04-1972	
1417	Jaubari	Precipitation	E	27	04	00	88	00	00	3,050	06-1973	
1418	Angbung	Precipitation	E	27	16	00	87	43	00	1,219	07-1947	
1419	Phidim (Panchther)	Climatology	E	27	09	00	87	45	00	1,205	07-1978	
1420	Dovan	Precipitation	E	27	21	00	87	36	00	763	07-1947	
1421	Gaida (Kankai)	Climatology	E	26	30	00	87	54	00	143	02-1984	

(Note) Reg E: Eastern Region (All the stations of this region are listed)

GRAIDING OF RIVERBED MATERIALS

Sample code	Cumulative percentage of passing materials (%)														
	<0.075 (mm)	<0.106 (mm)	<0.25 (mm)	<0.425 (mm)	<0.85 (mm)	<2 (mm)	<4.75 (mm)	<9.5 (mm)	<19 (mm)	<26.5 (mm)	<37.5 (mm)	<53 (mm)	<100 (mm)	<200 (mm)	<400 (mm)
	0.075	0.106	0.250	0.425	0.850	2.00	4.75	9.50	19.0	26.5	37.5	53.0	100.0	200.0	400.0
Ratuwa River															
Ra-1	0.3	1.7	34.3	90.4	99.2	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ra-2	1.5	4.9	53.0	83.0	95.1	96.7	97.5	98.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ra-3	11.0	19.1	52.5	89.5	98.7	99.3	99.4	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ra-4	1.2	3.7	42.2	70.5	88.3	94.7	97.3	99.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ra-5	1.4	3.5	30.5	65.9	85.6	89.9	91.7	92.7	96.3	97.3	98.1	99.3	100.0	100.0	100.0
Ra-6	1.7	5.1	38.7	72.5	86.6	88.7	89.9	91.4	93.4	95.4	97.4	98.1	100.0	100.0	100.0
Ra-7	0.3	1.1	15.7	68.7	93.6	98.6	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ra-8	1.1	2.4	22.1	57.5	86.2	91.4	93.4	95.0	97.3	98.7	100.0	100.0	100.0	100.0	100.0
Ra-9	1.2	3.6	16.7	52.9	82.6	88.4	90.6	92.5	95.3	97.3	98.7	98.7	100.0	100.0	100.0
Ra-10	0.8	2.5	26.4	51.6	73.8	86.0	91.0	93.5	95.6	96.6	98.6	99.3	100.0	100.0	100.0
Ra-11	1.3	2.8	20.7	43.8	64.3	72.0	78.1	81.3	86.2	89.4	91.4	95.0	100.0	100.0	100.0
Ra-12	1.7	3.3	22.1	54.1	85.3	90.7	92.8	94.5	95.8	96.8	98.3	100.0	100.0	100.0	100.0
Ra-13	1.1	2.5	24.6	59.1	90.2	94.5	96.0	97.1	99.3	99.4	99.4	100.0	100.0	100.0	100.0

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size					Specific gravity (g/cc)		
	16 (%)	60 (%)	65 (%)	84 (%)	d84 / d16	S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
Ratuwa River								
Ra-1	0.15	0.32	0.33	0.40	2.59	2.59	2.59	2.59
Ra-2	0.13	0.28	0.31	0.45	3.48	2.65	2.68	2.67
Ra-3	0.09	0.28	0.30	0.39	4.23	2.67	2.66	2.67
Ra-4	0.14	0.35	0.38	0.72	5.15	2.68	2.66	2.67
Ra-5	0.16	0.39	0.42	0.80	5.08	2.63	2.67	2.65
Ra-6	0.14	0.35	0.38	0.75	5.35	2.59	2.60	2.60
Ra-7	0.25	0.39	0.41	0.65	2.59	2.65	2.63	2.64
Ra-8	0.19	0.45	0.51	0.81	4.20	2.63	2.63	2.63
Ra-9	0.24	0.50	0.56	1.05	4.38	2.63	2.65	2.64
Ra-10	0.17	0.55	0.65	1.73	10.07	2.66	2.68	2.67
Ra-11	0.20	0.71	0.92	13.95	70.04	2.65	2.68	2.67
Ra-12	0.19	0.48	0.54	0.83	4.37	2.66	2.65	2.66
Ra-13	0.18	0.43	0.48	0.74	4.14	2.60	2.59	2.60
							Average	2.64

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: RATUWA RIVER(1/2)

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1988(44), 1995(43), 1996(20), 1993(17), 1989(11), 1997(11), 1994(9), 1987(5)
1.2	Floods in a year (times)	Average(7) ranging(3 to 22)
1.3	Severe floods in past 10 years (times)	Average(7) ranging(4 to 10)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(135) • Sediment flow(77) • Bank erosion(142) • Others(0)
2. EFFECT DUE TO SEVERE FLOOD IN PAST		
2.1	Loss of human life (nop)	0 (excluding those due to epidemic disease)
2.2	Loss of livestock/husbandry (nos)	• Cow(11) • Buffalo(6) • Sheep/Goat(13) • Poultry(246)
2.3	Damage to farm land (ha)	• Irrigated land: Average(1.6) ranging(1.2 to 2.2) • Non-irrigated land: Average(17.6) ranging(1.0 to 142.0)
2.4	Extent of damage to farm land	• Simple inundation (nop): 38 • Loss of crops (nop): Paddy(28), Sugarcane(0), Maize(0), Others(0) • Total washout (ha): Average(2.1) ranging(1.3 to 10.8)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(3.7) ranging(1 to 28) • Flooding depth in (m): Average(1.5) ranging(0.1 to 3.0) • Damage to house (nop): Severe(61), Moderate(23), Ordinary(23) • Loss of cash (Rs): Average(1,620) ranging(0 to 2,500) • Loss of food grains (kg): Paddy: Average(1,483) ranging(0 to 28,000) • Clothing (nos): Average(1) ranging(0 to 1) • Other valuables: Average(2) ranging(0 to 2)
2.6	Problems during flood (nop)	• Erosion of river bank(167) • Sediment in the river(103) • Sediment in irrigation canal(34) • Drinking water problem(63) • Sanitary problem(28) • Salinity(10) • Flooding over farm land(125) • Others(4)
2.7	Epidemic disease after flood? (nop)	• Yes(38) • No(133)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(5) • Dysentery(18) • Typhoid(12) • Others(3)
2.9	Fatal causality? (nop)	• Yes(2) • No(147)
2.10	Reason of flood(nop)	• Too much rain(134) • Lack of flood protection works(130) • Weak river training works(43) • Sediment load in the flood water(67) • Flood from adjoining rivers(18)
2.11	Total amount of damage (Rs)	Average(343,800) ranging(0 to 719,600)

(Remarks) nop: Number of persons who answer to the item.

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: **RATUWA RIVER(2/2)**

No.	Questions/items	Summary of answers
3. FLOOD WARNING SYSTEM		
3.1	(Cancelled)	(Cancelled)
3.2	Self warning (nop)	• Heavy rain/High flood level(166) • Bank erosion(5) • Smelled mud(0) • Unusual sound(1) • Others(0)
3.3	Warning by others (nop)	• Neighbors(1) • Institutions(0) • Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	• Yes(83) • No(88)
4.2	If yes, place of evacuation (nop)	• High ground(26) • Public building(12) • Others houses(35) • Other sites(9)
4.3	Being relieved? (nop)	• Yes(58) • No(113)
4.4	If yes, how?(nop)	• In cash(19) • Kind(39)
4.5	Organization/individual giving relief (nop)	• Central government(8) • DDC(6) • VDC(28) • Other institutions(7) • NGO(15) • Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	• Warning(0) • Evacuation(71) • Settlement(64)
5.1b	Proposed preparedness/ measures (nop)	• Warning(0) • Evacuation(5) • Settlement(102)
5.2a	Current non-structural measures (nop)	• Seed storage(4) • Cash pools(0) • Informal insurance(0) • Others(0)
5.2b	Proposed non-structural measures (nop)	• Seed storage(161) • Cash pools(164) • Informal insurance(79) • Others(1)
5.3a	Current structural measures (nop)	• Embankment(0) • Spur(50) • Simple gabion(1) • Plantation(3) • Others(0)
5.3b	Proposed structural measures(nop)	• Embankment(147) • Spur(129) • Simple gabion(26) • Plantation(31) • Others(1)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	• Yes(114) • No(57)
6.2	If yes, type (nop)	• Cash(24) • Labor(102) • Kind(18) • Care taker(25) • Others(3)
6.3	If no, reason (nop)	• Being affected badly(14) • Financially weak(7) • Being out of the area(5) • No willingness(18) • Others(11)
6.4	Willing to participate in future? (nop)	• Yes(161) • No(6)
6.5	If yes, type (nop)	• Cash(51) • Labor(159) • Kind(31) • Care taker(29) • Others(1)
6.6	If no, reasons (nop)	• No time(0) • No benefit(0) • No Willingness(0) • Not known how to participate(0) • Others(6)

(Remarks) nop: Number of persons who answer to the item.

LOSS OF LIFE AND DAMAGE TO PROPERTIES (RATUWA RIVER) (1995-FLOOD)

DAMAGE OF PUBLIC FACILITIES

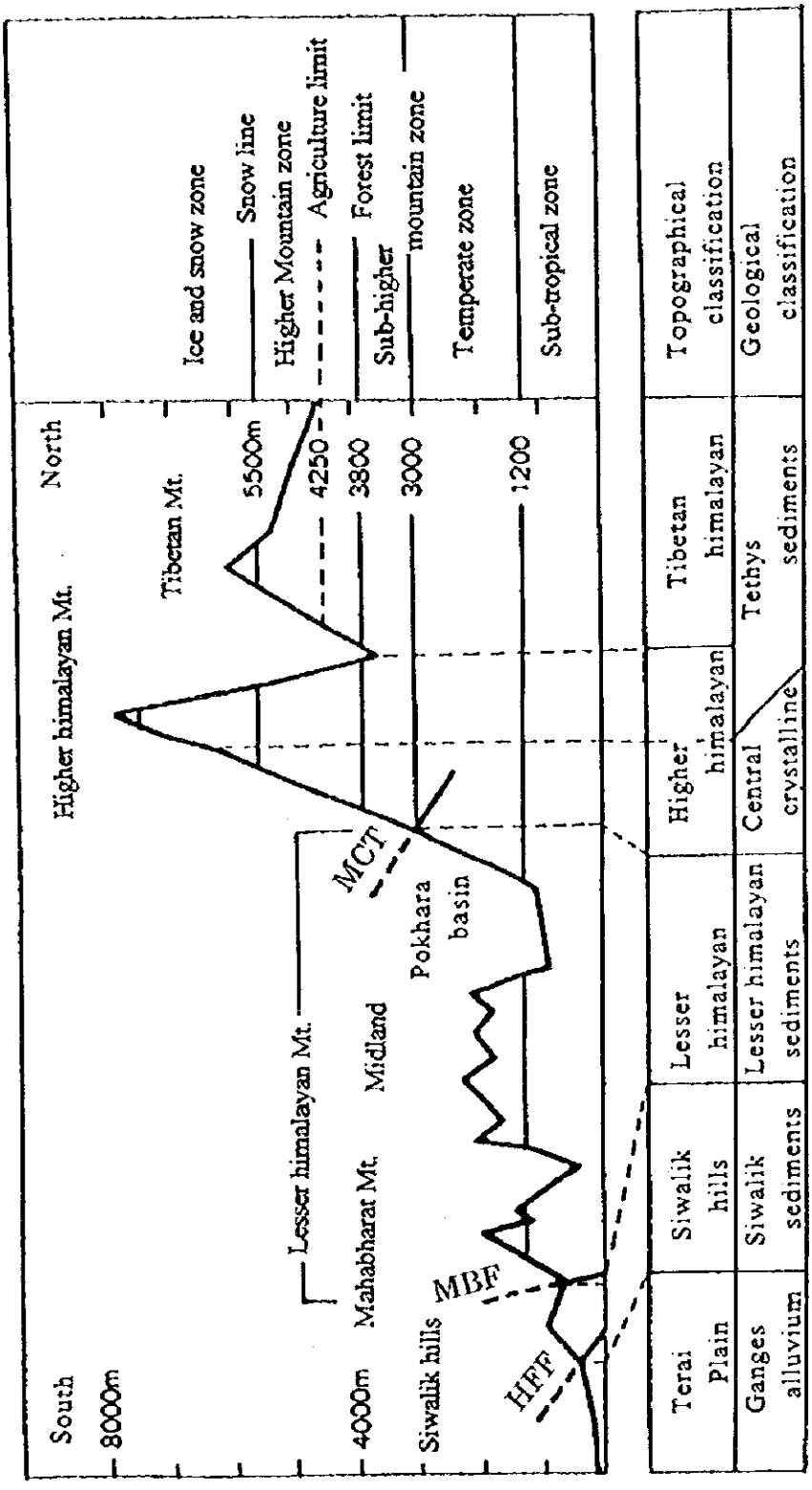
VDC/Municipality	Road (km)	Irrigation Channel (km)	Culvert (nos.)	Remarks
Khajurgachhi	1.50	-	-	
Sijuwa	1.00	1.00	-	
Kohabara	-	4.50	-	
Mahadeva	1.50	-	-	
Damak	0.50	0.03	-	
Lakhanpur	21.00	12.00	-	
Itahara	4.00	1.00	6	
Rajghat	1.00	1.00	-	
Total	30.50	18.03	6	

DAMAGE OF LAND, CROPS AND THEIR YIELD AND HOUSEHOLD PROPERTIES

VDC/Municipality	Damage of Land (hac)		Damage of Crop (kg)		Name of Crop	Damage of HH (nos.)	Remarks
	Inundation	Washout	By inundation	By washout			
Damak	1,150	620	862,500	1,860,000	Paddy	900	3.50 hac
Lakhanpur	500	200	375,000	600,000	Paddy	219	nursury
Khobara	400	215	300,000	645,000	Paddy	98	
Khajurgachhi	150	20	112,500	60,000	Paddy	40	
Rajghat	60	200	45,000	600,000	Paddy	35	
Itahara	300	200	225,000	600,000	Paddy	50	school-1
Sijuwa	200	170	150,000	510,000	Paddy	130	
Jhurkiya	185	15	138,750	45,000	Paddy	-	
Mahadeva	200	120	150,000	360,000	Paddy	67	
Total	3,145	1,760	2,358,750	5,280,000		1,539	

LOSS OF LIFE

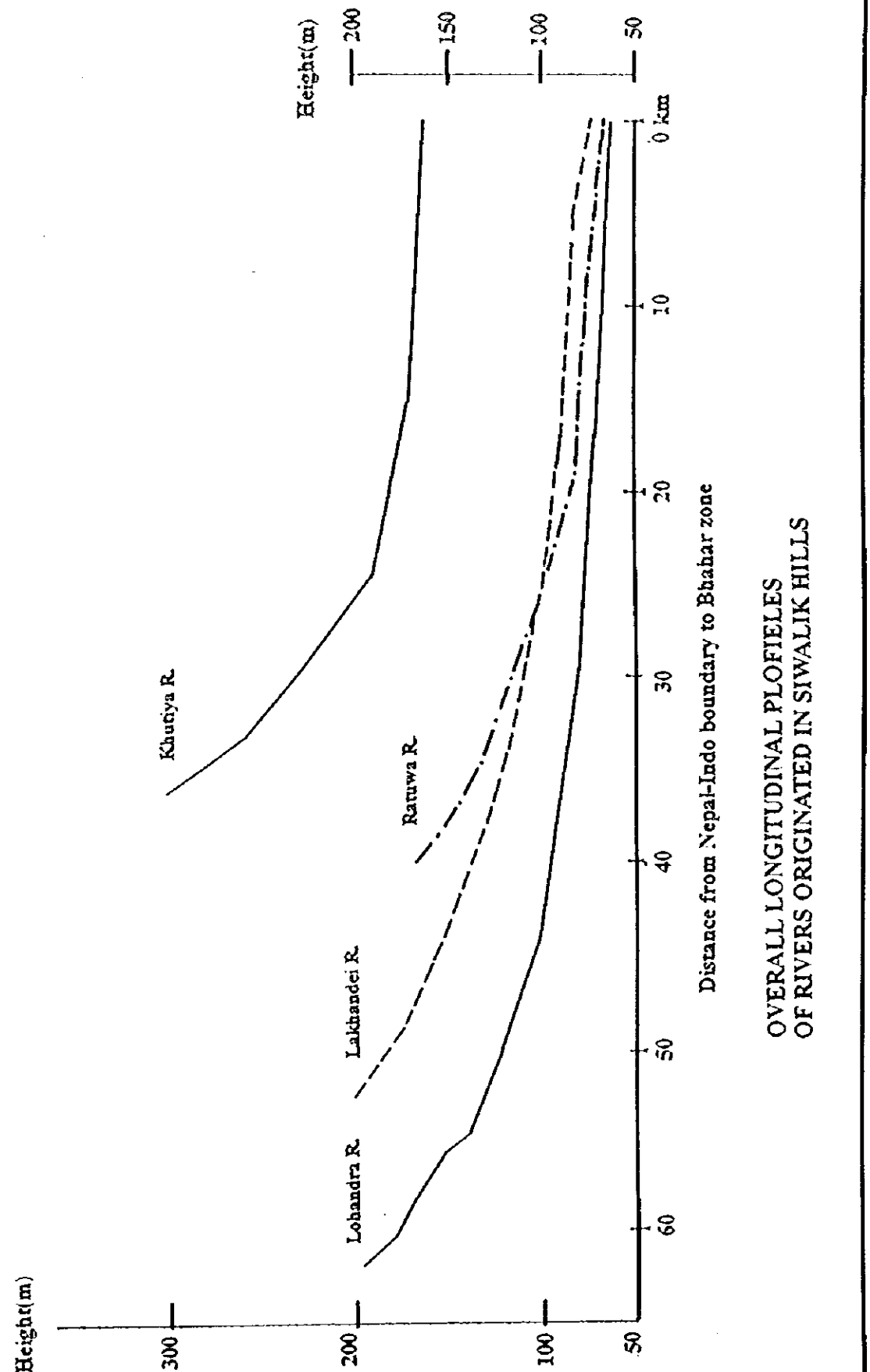
VDC/Municipality	Human Life (nos.)	Loss of Cattle (nos.)			Poultry (nos.)	Remarks
		Cow/Buffalo	Goat	Pig		
Lakhanpur	2	17	-	-	-	
Kohabara	4	-	-	-	-	
Rajghat	-	20	47	25	298	
Itahara	-	95	-	-	-	
Sijuwa	1	-	-	-	-	
Total	7	132	47	25	298	

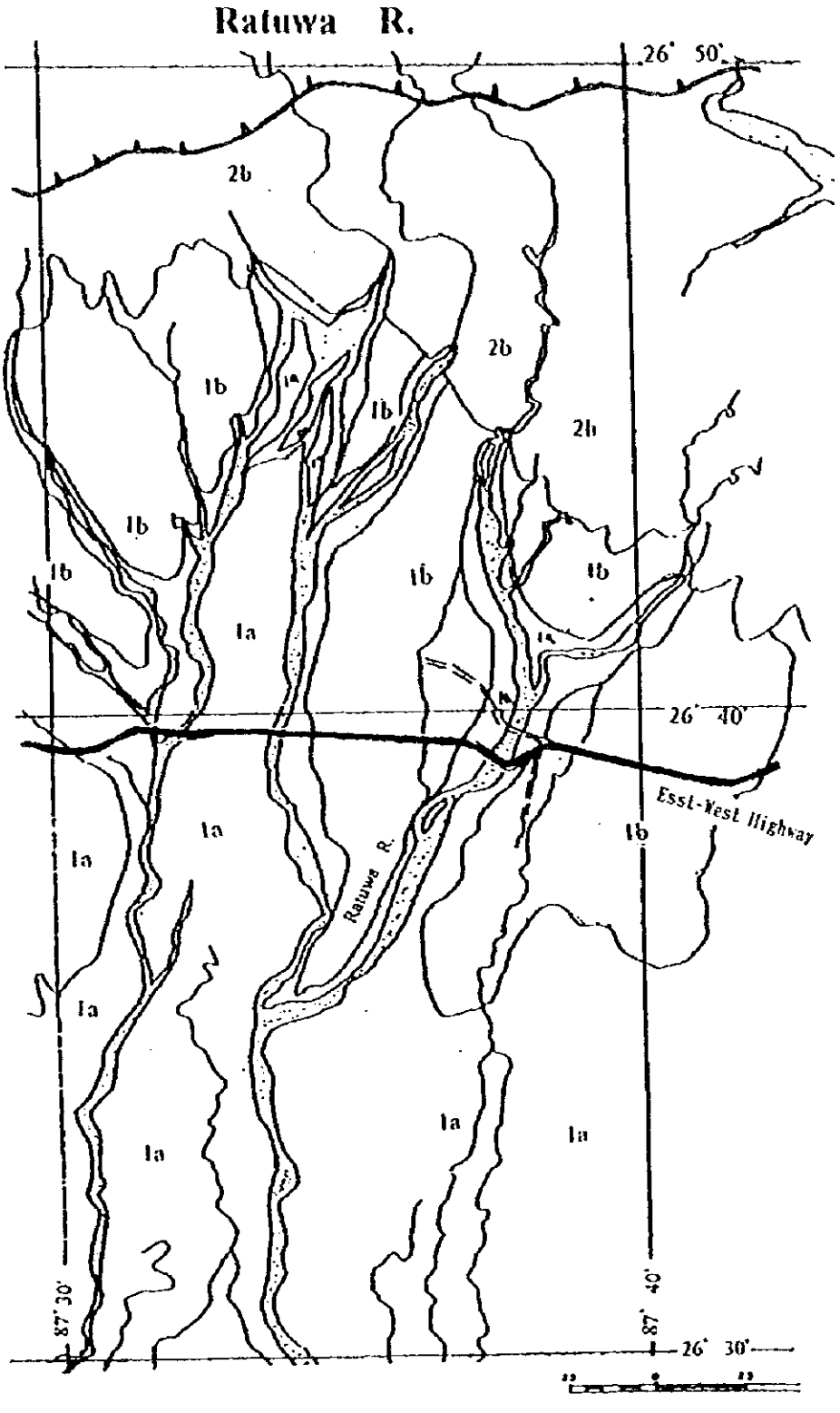


TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

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. A1.2


Height(m)
200
150
100
50
0 km
10
20
30
40
50
60
Khutiya R.
Ratuwa R.
Lakhandei R.
Lohandra R.
Height(m)
300
200
100
50
Distance from Nepal-Indo boundary to Bhabar zone
OVERALL LONGITUDINAL PLOFIELES
OF RIVERS ORIGINATED IN SIWALIK HILLS
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



Legend

1. Unconsolidated sediments, chiefly in the Terai plain
   - 1a. alluvium, deposited or reworked by water
   - 1b. alluvial fans, talus, colluvium
2. Siwalik sedimentary system
   - 2a Upper formation-generally coarser clastics
   - 2b. Lower formation-generally finer clastics

GEOLOGICAL MAP(RATUWA R.)

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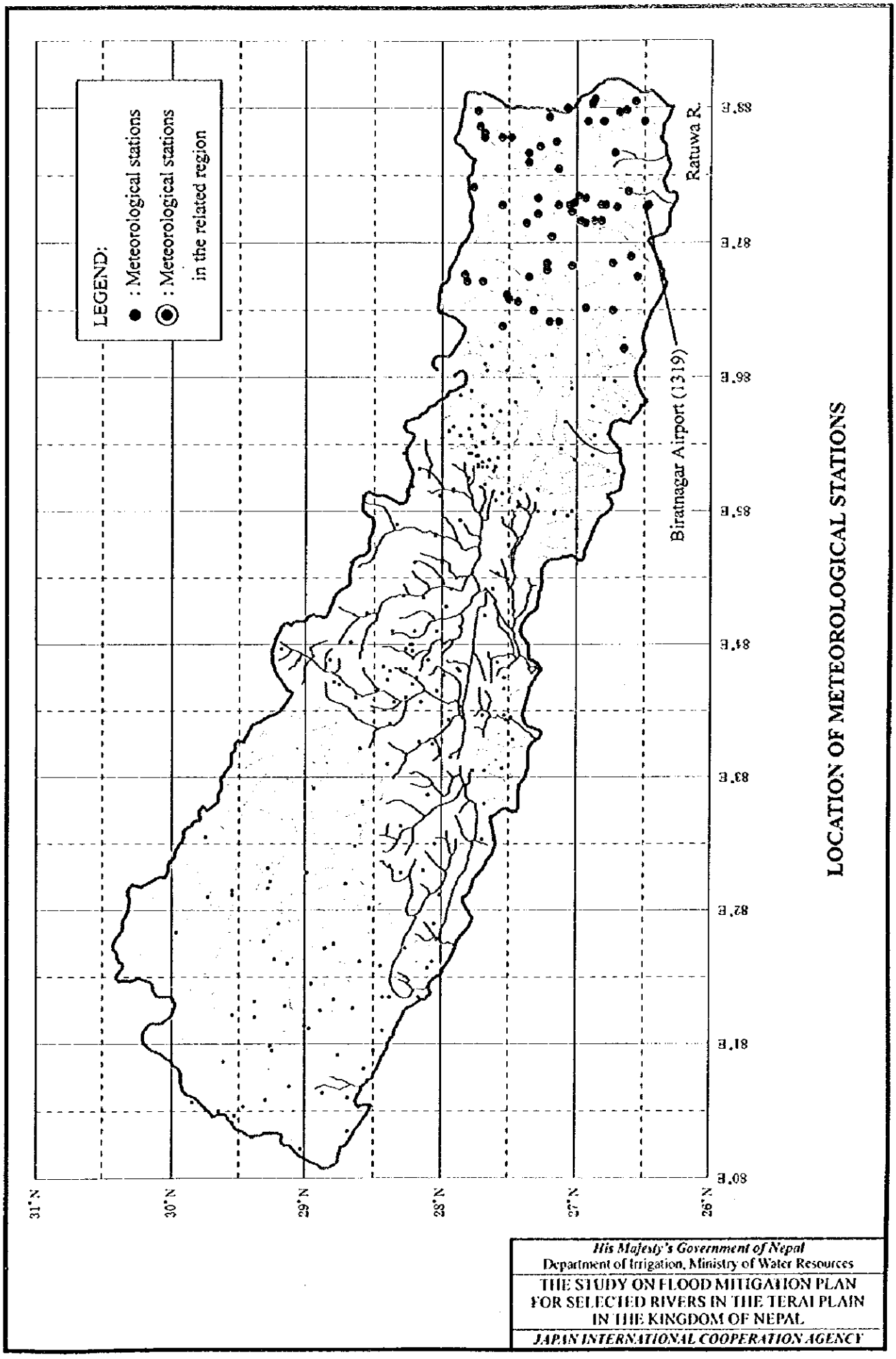

LOCATION OF METEOROLOGICAL STATIONS

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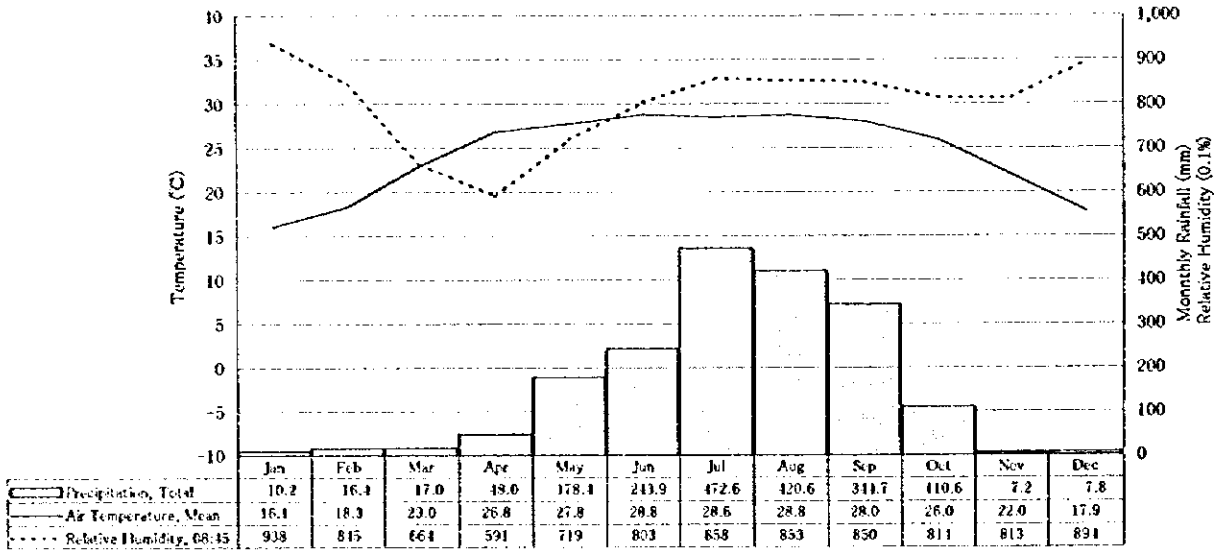
Code 1319
Station: Biratnagar Airport

Latitude: 26°29'
Longitude: 87°16'
Elevation: 72 m

Biratnagar Airport (1319)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, Total	10.2	16.4	17.0	48.0	178.4	243.9	472.6	420.6	344.7	110.6	7.2	7.8
Air Temperature, Mean	16.1	18.3	23.0	26.8	27.8	28.8	28.6	28.8	28.0	26.0	22.0	17.9
Relative Humidity, 08:45	938	815	664	591	719	803	858	853	850	811	813	891

Air Temperature, Mean (Unit: °C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	16.1	18.2	24.7	28.8	27.8	29.0	27.7	29.5	28.1	26.0	21.3	18.0	24.6
1986	16.6	18.4	23.6	26.6	26.4	29.3	28.7	29.4	27.4	24.8	22.5	17.9	24.3
1987	17.0	19.4	23.1	26.2	28.2	29.1	27.7	27.8	27.7	25.8	22.6	18.9	24.4
1988	17.1	19.6	22.4	26.1	27.8	28.6	28.9	28.3	29.2	27.1	22.5	19.3	24.7
1989	15.4	17.0	22.4	27.0	27.6	28.1	27.7	28.1	26.4	26.3	21.5	16.9	23.7
1990	16.5	18.6	21.6	25.6	27.3	28.7	28.5	29.2	28.3	25.4	22.5	17.9	24.1
1991	15.5	19.1	23.5	26.8	27.9	28.0	28.4	28.6	27.9	26.2	20.8	17.1	24.1
1992	15.9	16.4	23.6	28.4	27.6	29.6	28.8	29.1	28.9	26.0	21.7	16.8	24.4
1993	14.4	19.2	21.4	25.4	27.5	28.4	29.4	28.5	28.0	26.5	22.8	18.8	24.2
1994	17.0	17.7	23.6	27.6	30.2	29.4	30.1	29.6	28.8	25.8	21.8	17.5	24.9
Ave.	16.1	18.3	23.0	26.8	27.8	28.8	28.6	28.8	28.0	26.0	22.0	17.9	24.3

Relative Humidity, 08:45 (Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	89	79	62	61	74	83	88	85	86	82	83	90	80.2
1986	96	86	59	58	71	77	85	83	84	81	81	86	78.9
1987	92	84	72	56	64	79	87	83	85	79	78	87	78.8
1988	93	84	63	63	70	74	87	87	79	75	71	87	77.8
1989	91	76	65	50	68	81	85	85	88	81	85	89	78.7
1990	95	85	72	66	80	85	89	84	85	80	79	91	82.7
1991	94	87	70	62	74	83	84	85	87	83	85	90	82.0
1992	95	86	59	52	74	77	85	87	86	84	81	94	80.0
1993	96	87	69	64	75	82	86	89	85	84	88	90	82.9
1994	97	90	73	59	69	82	82	85	85	85	82	90	81.6
Ave.	93.8	84.5	66.4	59.1	71.9	80.3	85.8	85.3	85.0	81.4	81.3	89.4	80.4

Precipitation, Total (Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	1	2	24	0	184	179	632	189	286	217	9	16	1,739
1986	0	2	1	39	216	210	487	218	362	151	1	25	1,712
1987	0	6	36	58	120	325	617	749	480	138	12	1	2,572
1988	0	67	23	127	118	129	512	724	121	107	38	4	1,970
1989	15	32	5	0	327	316	685	401	791	59	0	5	2,666
1990	0	16	15	109	313	457	602	510	301	23	0	0	2,356
1991	35	4	22	51	108	163	285	290	411	70	0	26	1,465
1992	2	3	0	2	187	147	396	201	189	291	0	1	1,419
1993	21	1	35	91	130	308	357	699	346	49	9	0	2,046
1994	28	31	9	3	81	165	123	225	160	1	3	0	829
Ave.	10.2	16.4	17.0	48.0	178.4	243.9	472.6	420.6	344.7	110.6	7.2	7.8	1,877

METEOROLOGICAL CONDITIONS

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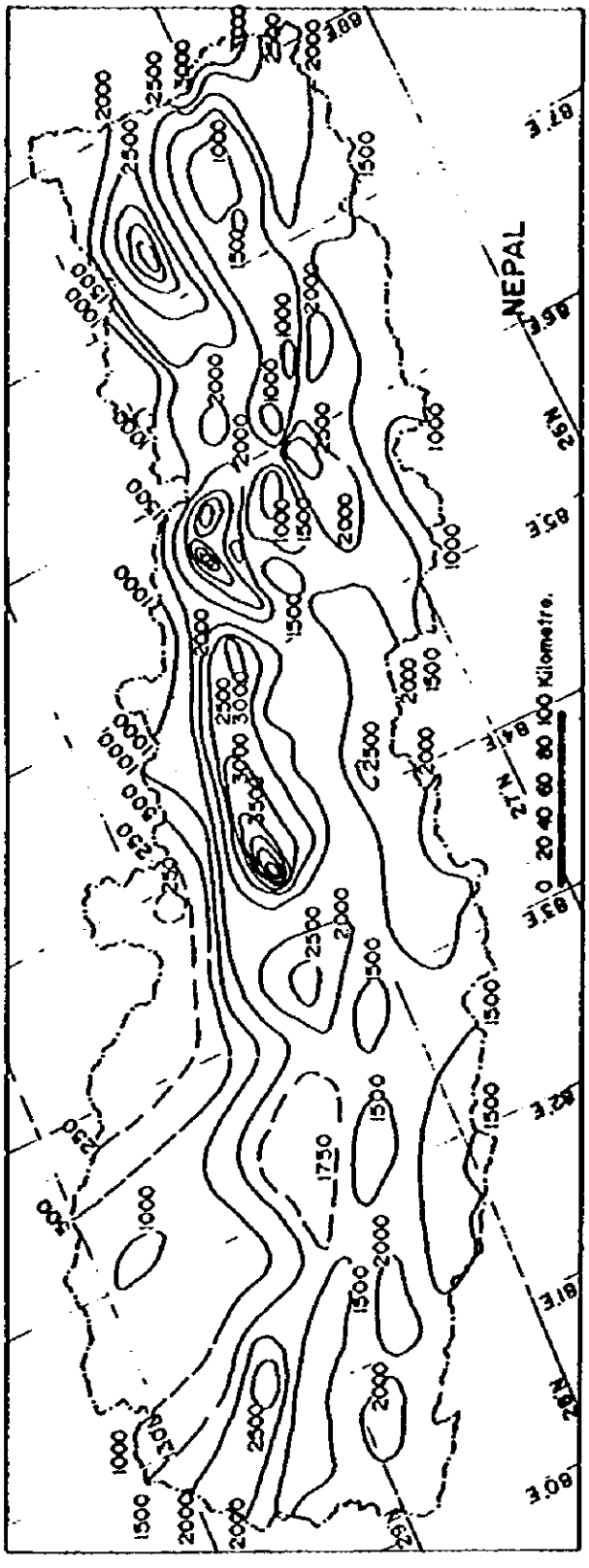
MEAN ANNUAL PRECIPITATION (mm) 1971-1985



Source: Natural Hazards and Man Made Impacts in The Nepal Himalaya, C.K.Sharman, 1988

ANNUAL RAINFALL
DISTRIBUTION OF NEPAL

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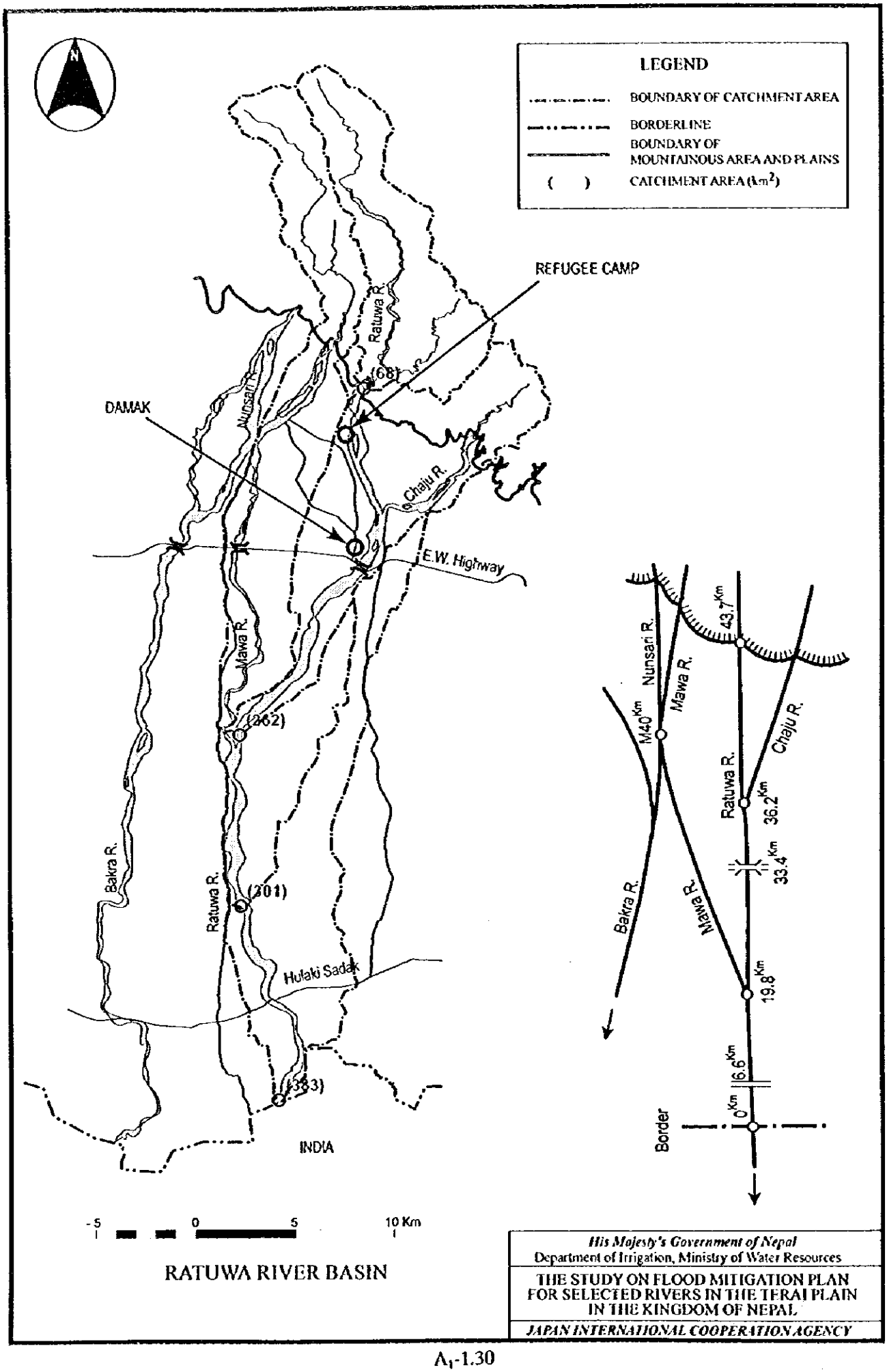
LEGEND
BOUNDARY OF CATCHMENT AREA
BORDERLINE
BOUNDARY OF MOUNTAINOUS AREA AND PLAINS
( ) CATCHMENT AREA (km²)
REFUGEE CAMP
DAMAK
Ratuwa R.
Nunsari R.
Chaiju R.
E.W. Highway
Mawa R.
Bakra R.
Hulaki Sadak
INDIA
(68)
(262)
(301)
(383)
Nunsari R.
Mawa R.
Chaiju R.
Ratuwa R.
Bakra R.
Mawa R.
Border
43.7Km
M40Km
36.2Km
33.4Km
19.8Km
16.6Km
0Km
-5
0
5
10 Km
RATUWA RIVER BASIN
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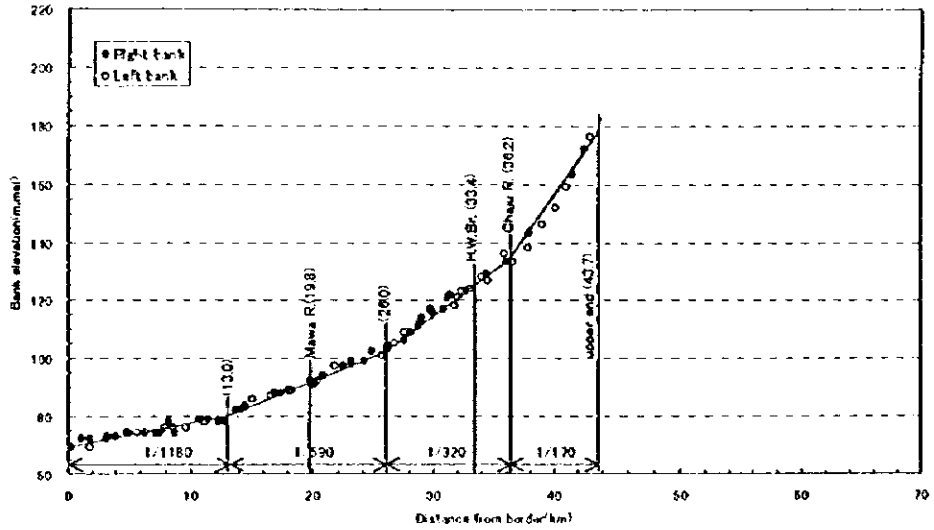
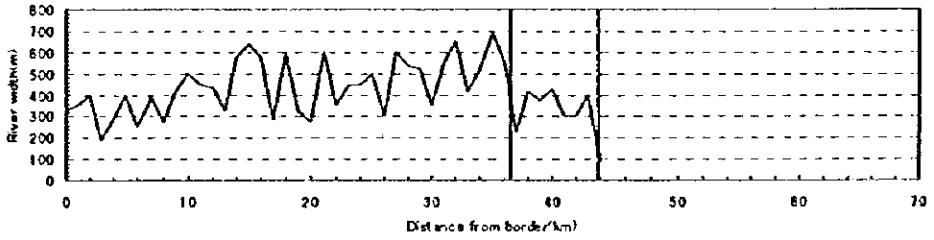
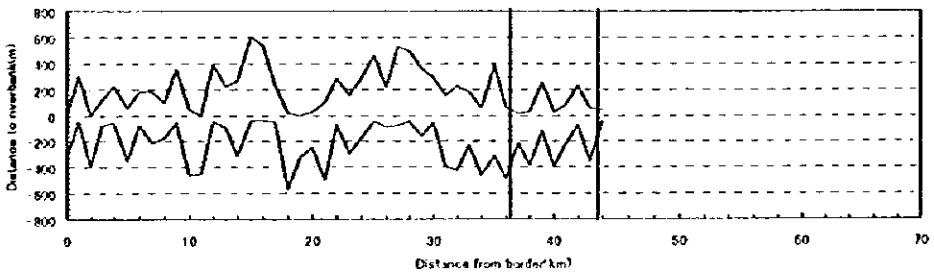
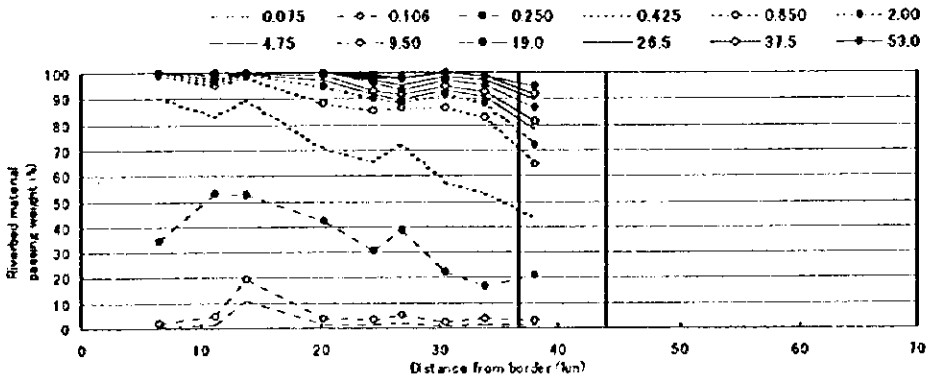
RATUWA RIVER









CHARACTERISTICS OF EXISTING CHANNEL

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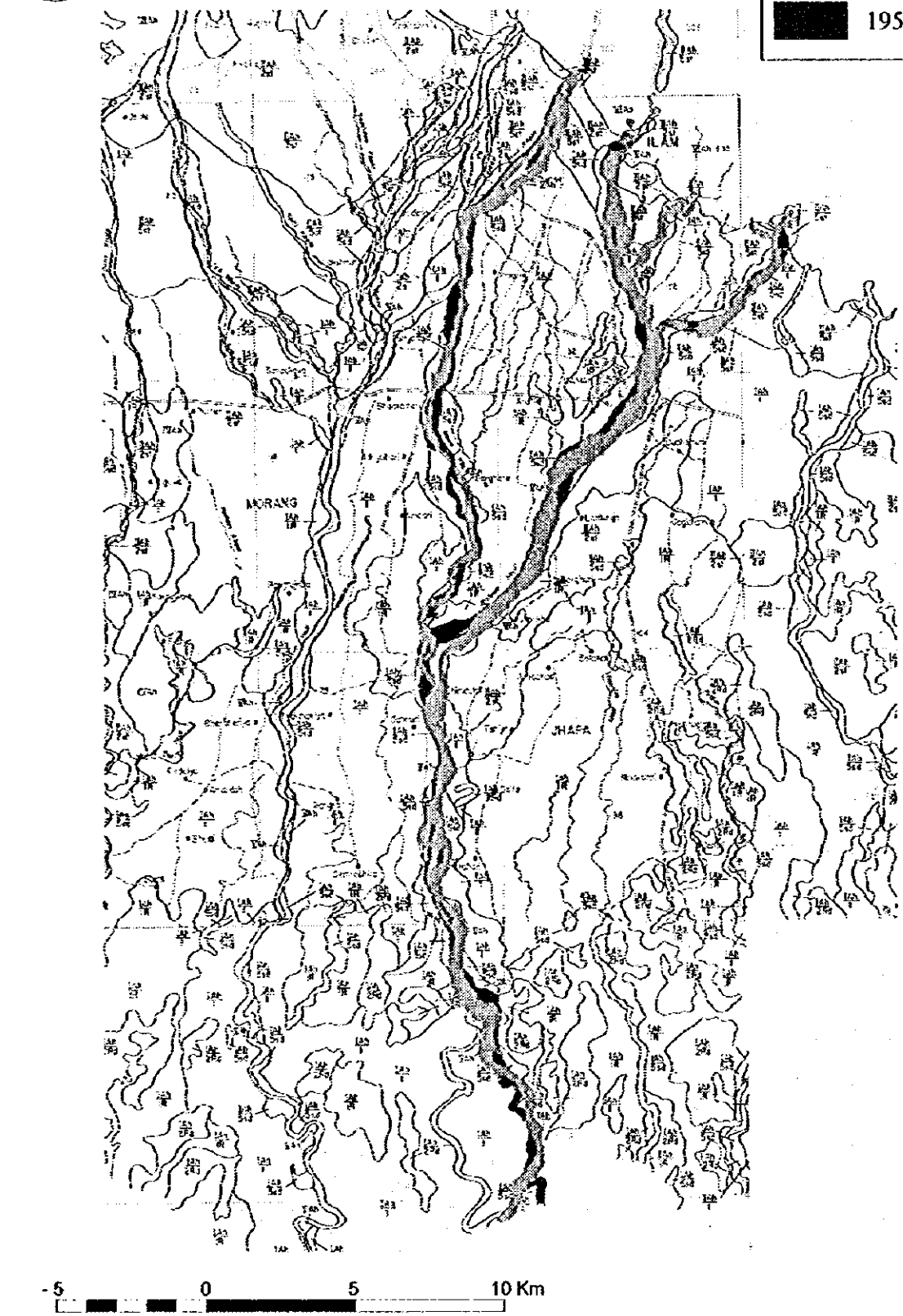

CHANGE OF RATUWA RIVER COURSE

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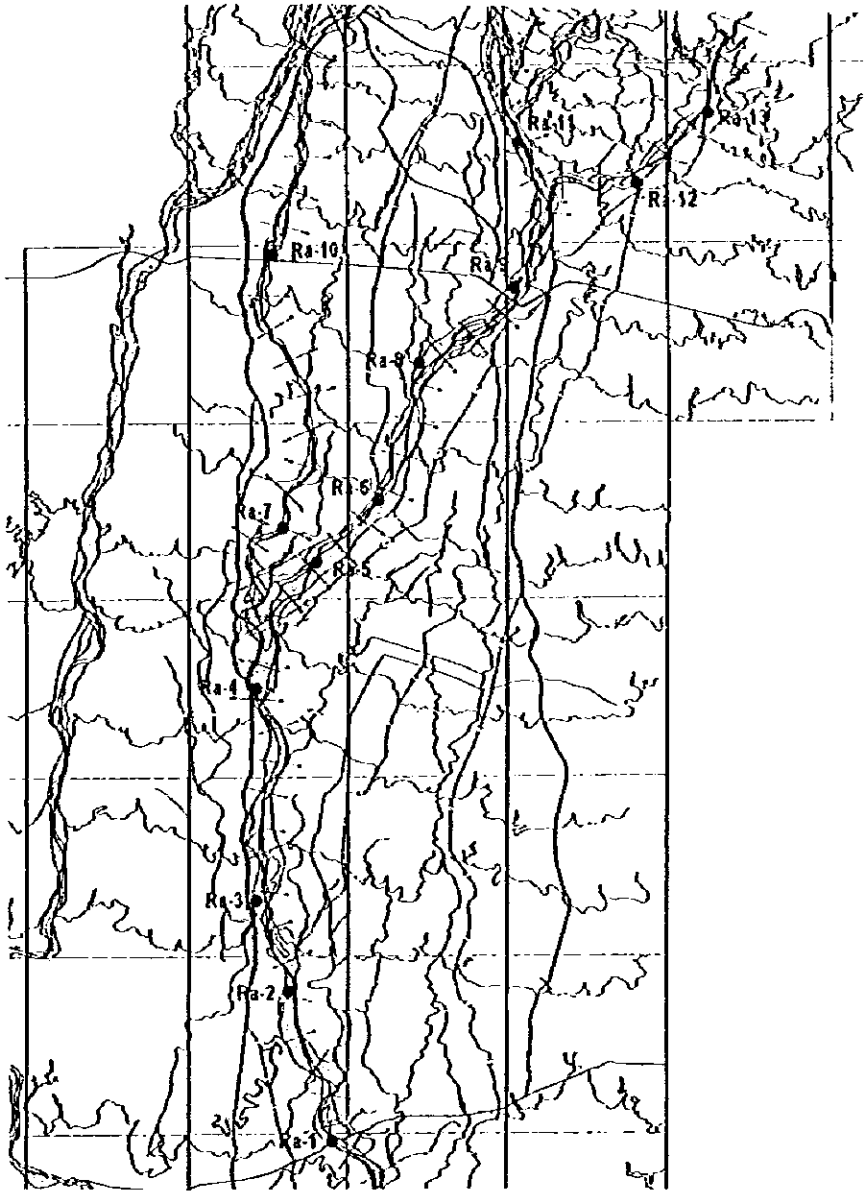
JAPAN INTERNATIONAL COOPERATION AGENCY



SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading		FGA (Y/N)
				N	E	
1	La-1	Silty sand	Near bridge on Hulaki road	26°51.776'	85°29.636'	N
2	La-2	Silty sand	Sundarpur WN 9	26°53.259'	85°29.641'	N
3	La-3	Silty sand	Padari WN 5	26°55.009'	85°30.026'	N
4	La-4	Silty sand	Shreepur WN 1	26°57.020'	85°30.081'	N
5	La-5	Silty sand	Hempur WN 5	26°58.005'	85°30.454'	N
6	La-6	Gravel mixed sand	Pipariya WN 3	26°59.349'	85°31.589'	Y
7	La-7	Gravel mixed sand		27°00.644'	85°33.094'	Y
8	La-8	Gravel mixed sand	Haripur WN 8	27°01.377'	85°34.124'	Y
9	La-9	Boulder mixed sand	Netragunj WN 4	27°02.953'	85°34.472'	Y
10	La-10	Gravel mixed sand	Nawalpur WN 6	27°04.466'	85°34.240'	Y
11	La-11	Gravel mixed sand	Sashapur WN 1	27°05.203'	85°34.558'	Y
12	La-12	Boulder mixed sand	Nawalpur WN 9	27°04.683'	85°36.642'	Y
13	La-13	Boulder mixed sand	Patharkot WN 5	27°05.069'	85°38.406'	Y

SAMPLING SITES OF RIVERBED MATERIALS (RATUWA RIVER)

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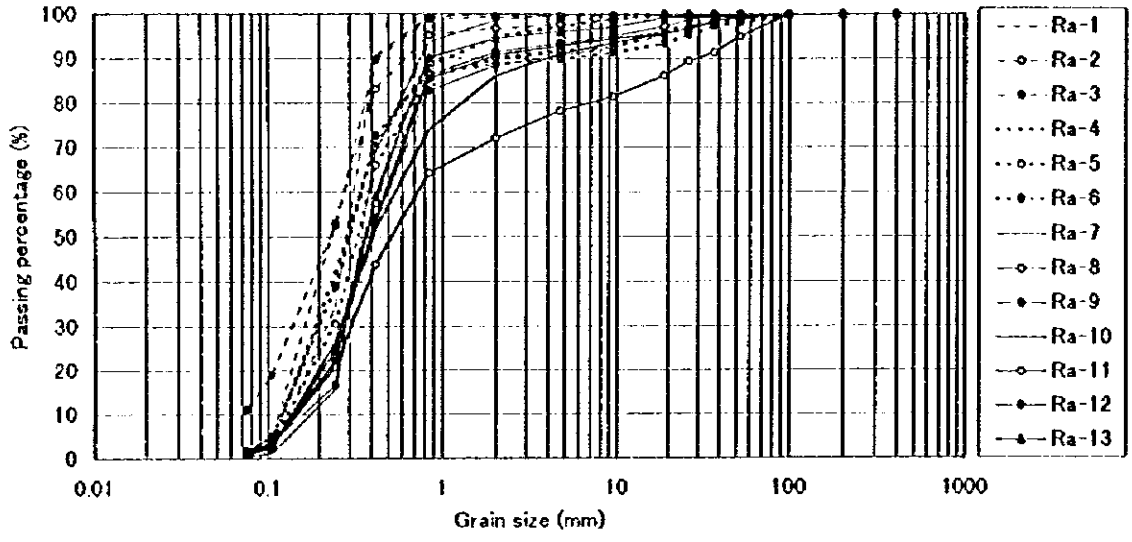

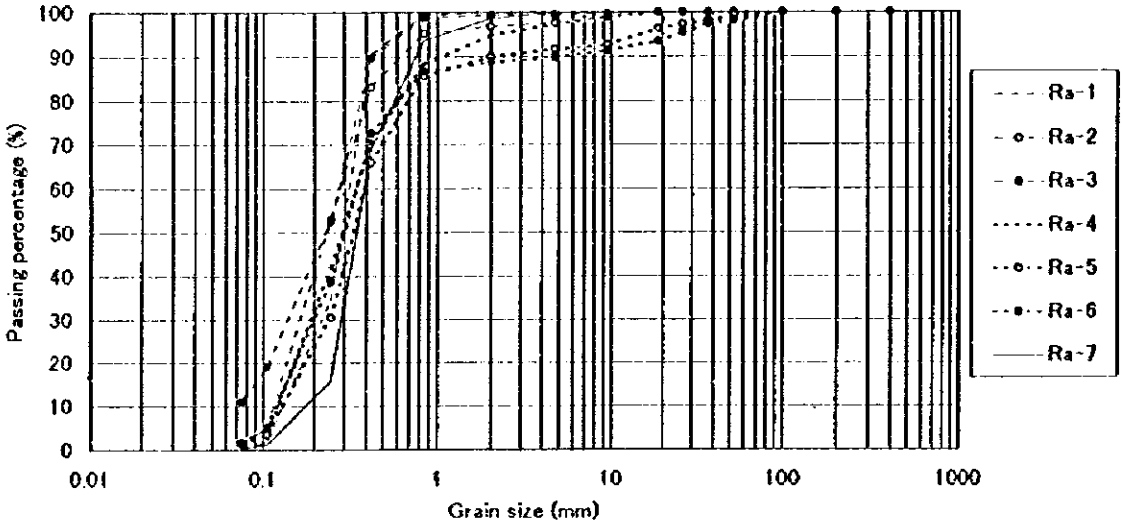

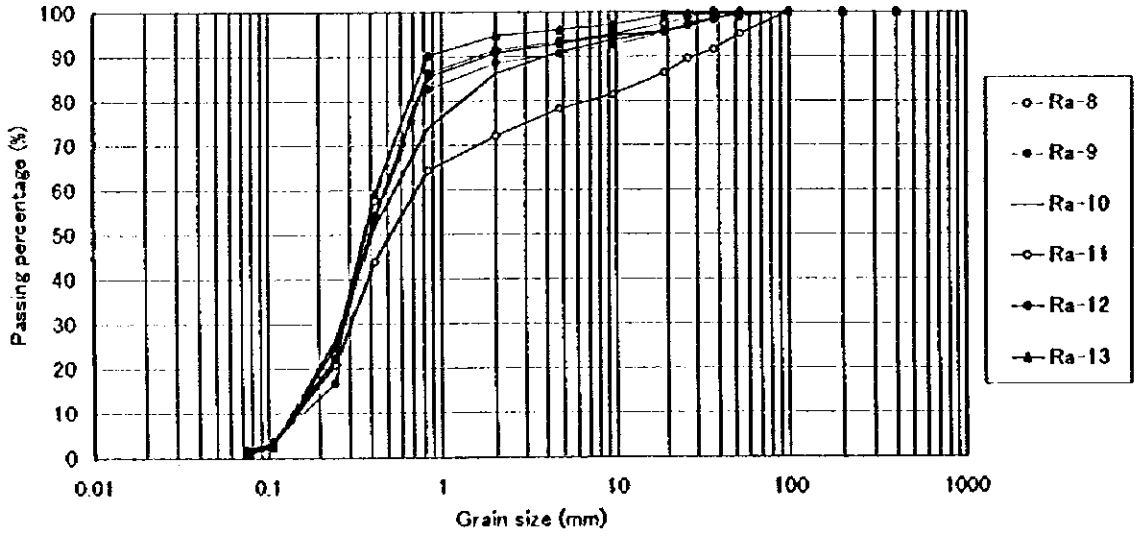

GRADING CURVES OF RIVERBED MATERIALS (RATUWA R.)

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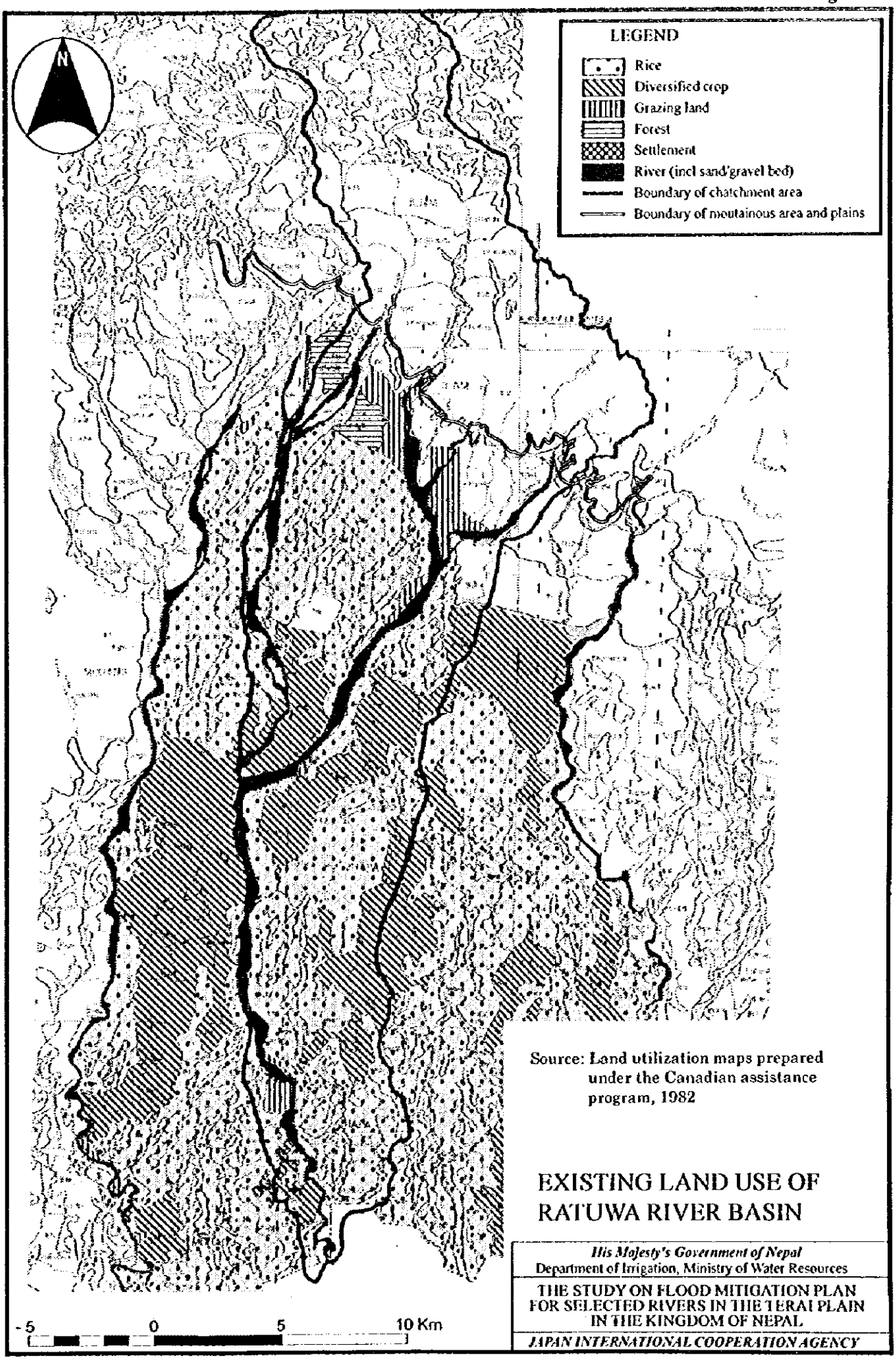
Fig. A1.12



Source: Land utilization maps prepared under the Canadian assistance program, 1982

EXISTING LAND USE OF RATUWA RIVER BASIN

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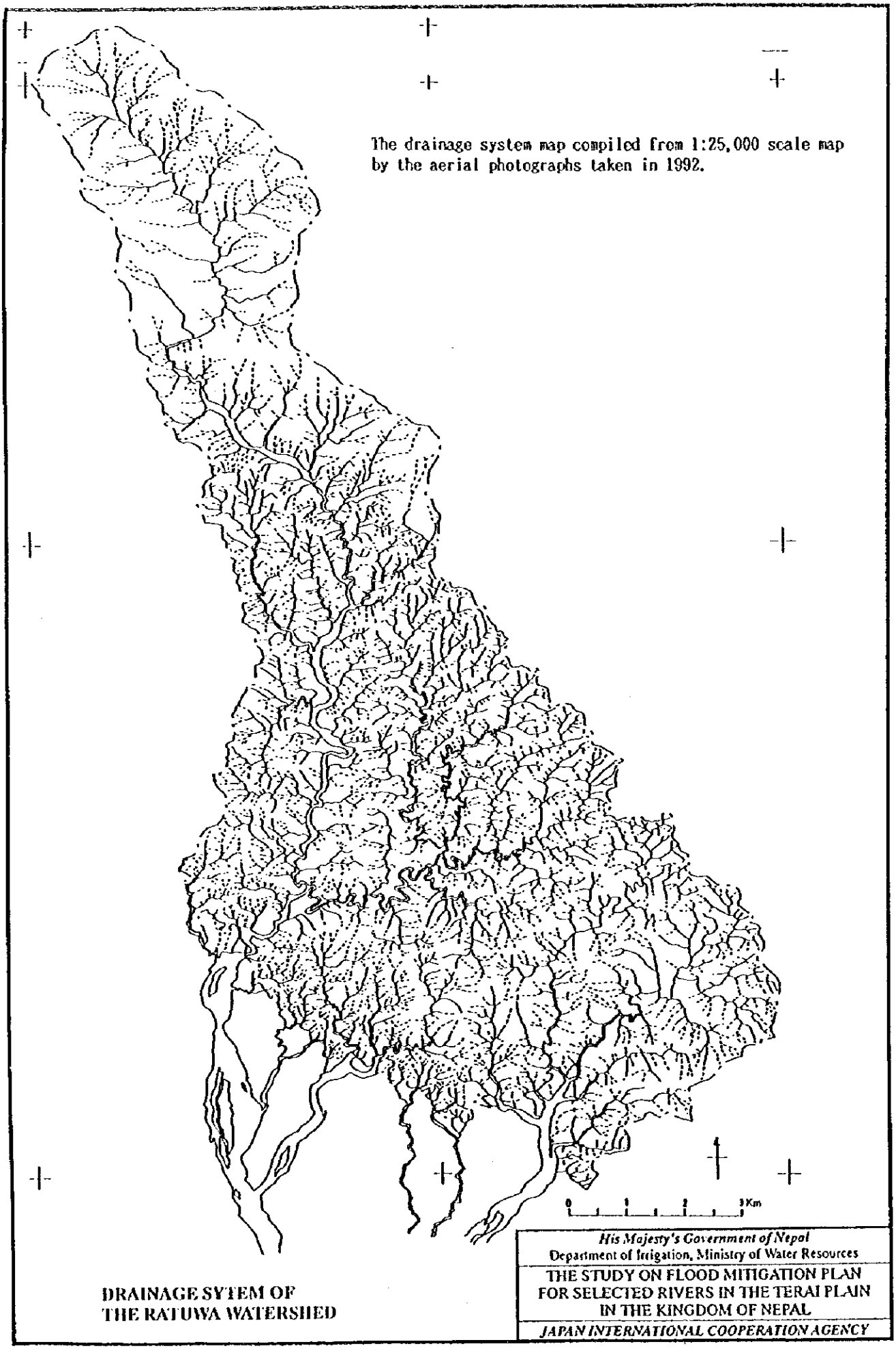
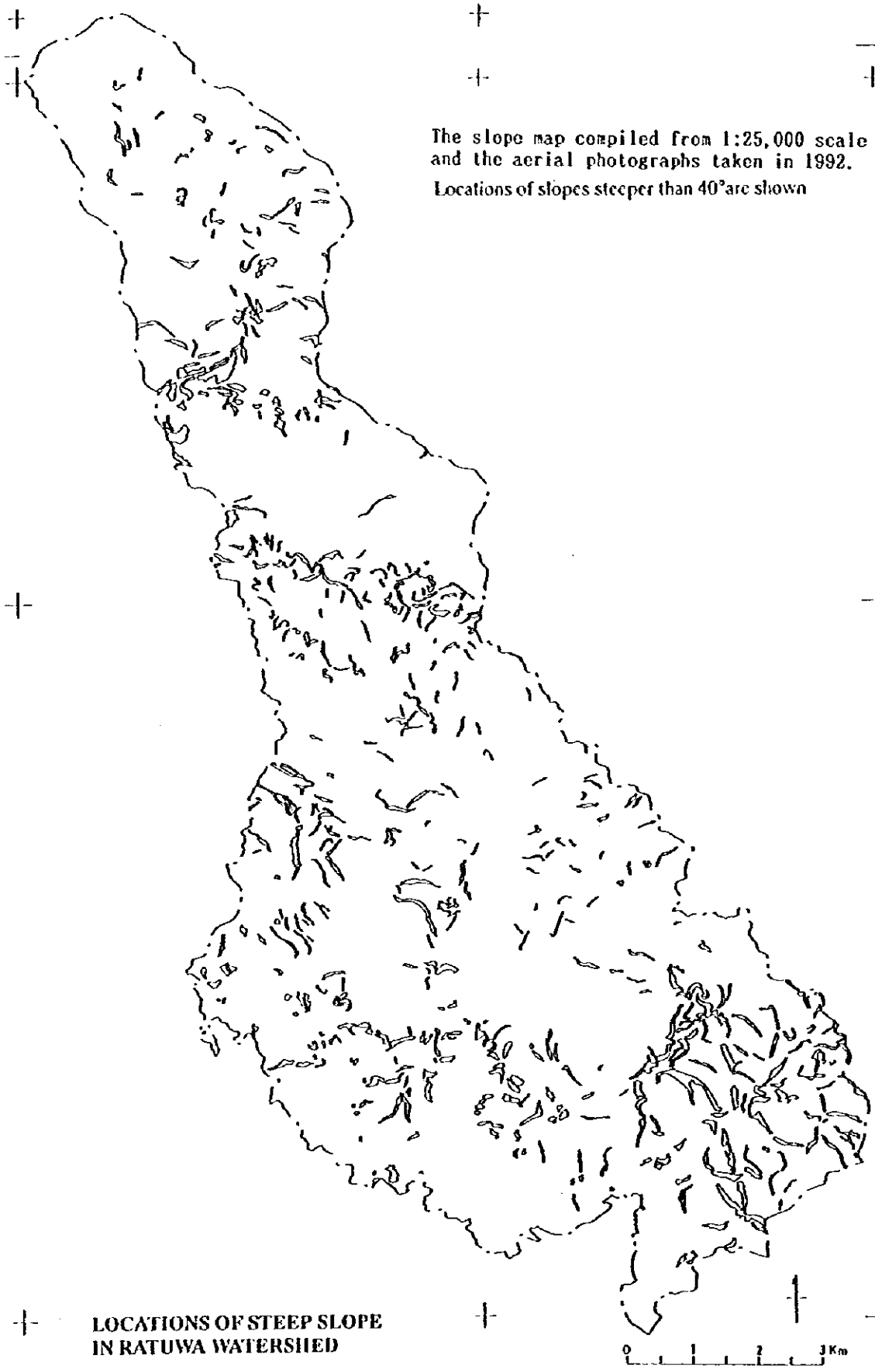


DRAINAGE SYTEM OF
THE RATUWA WATERSHED



LOCATIONS OF STEEP SLOPE
IN RATUWA WATERSHED

SLOPE MAP MORE THAN 40° OF THE RATUWA RIVER

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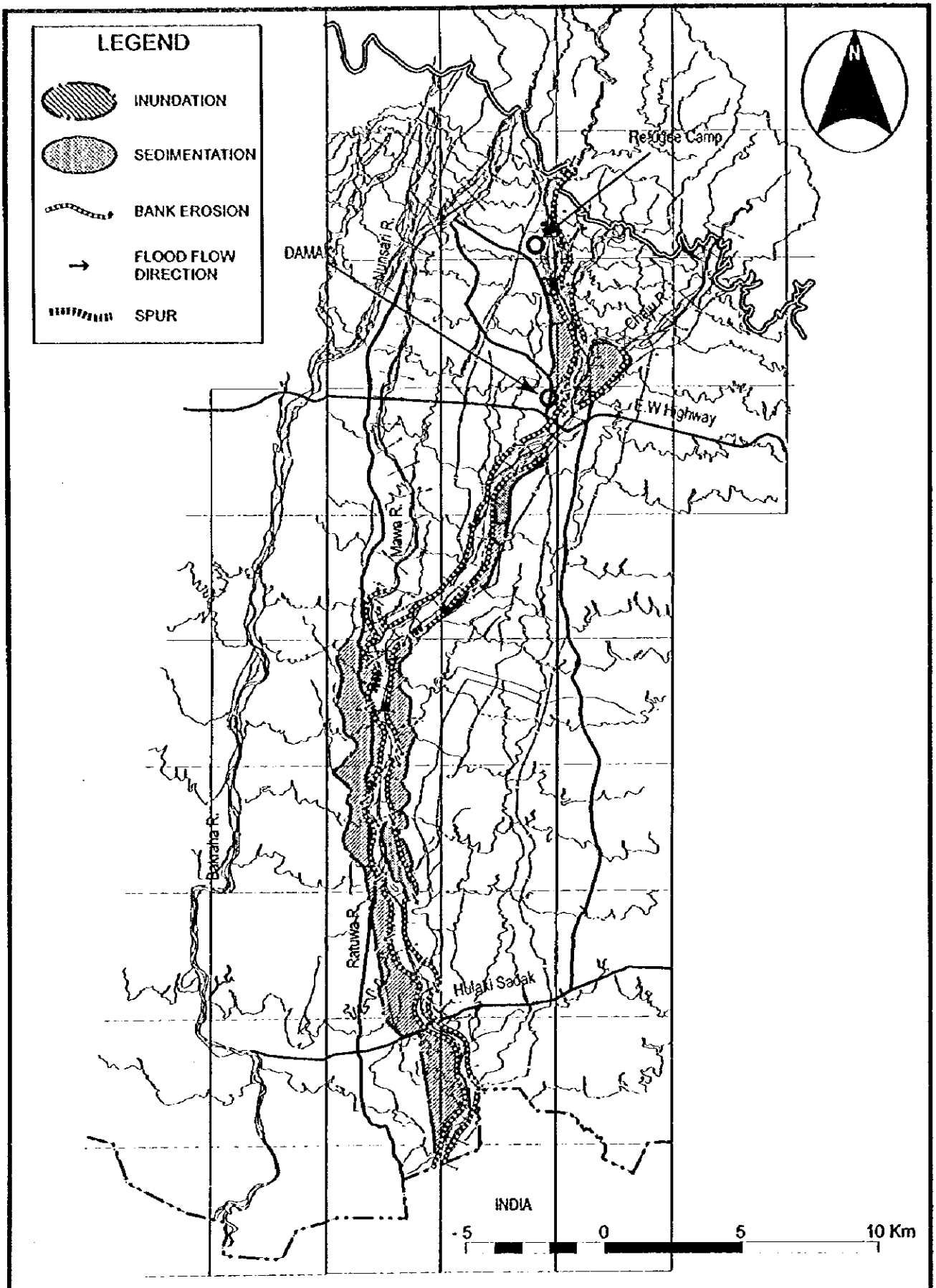
Fig. A1.15



FLOOD SUFFRING AREA (RATUWA RIVER,1995)

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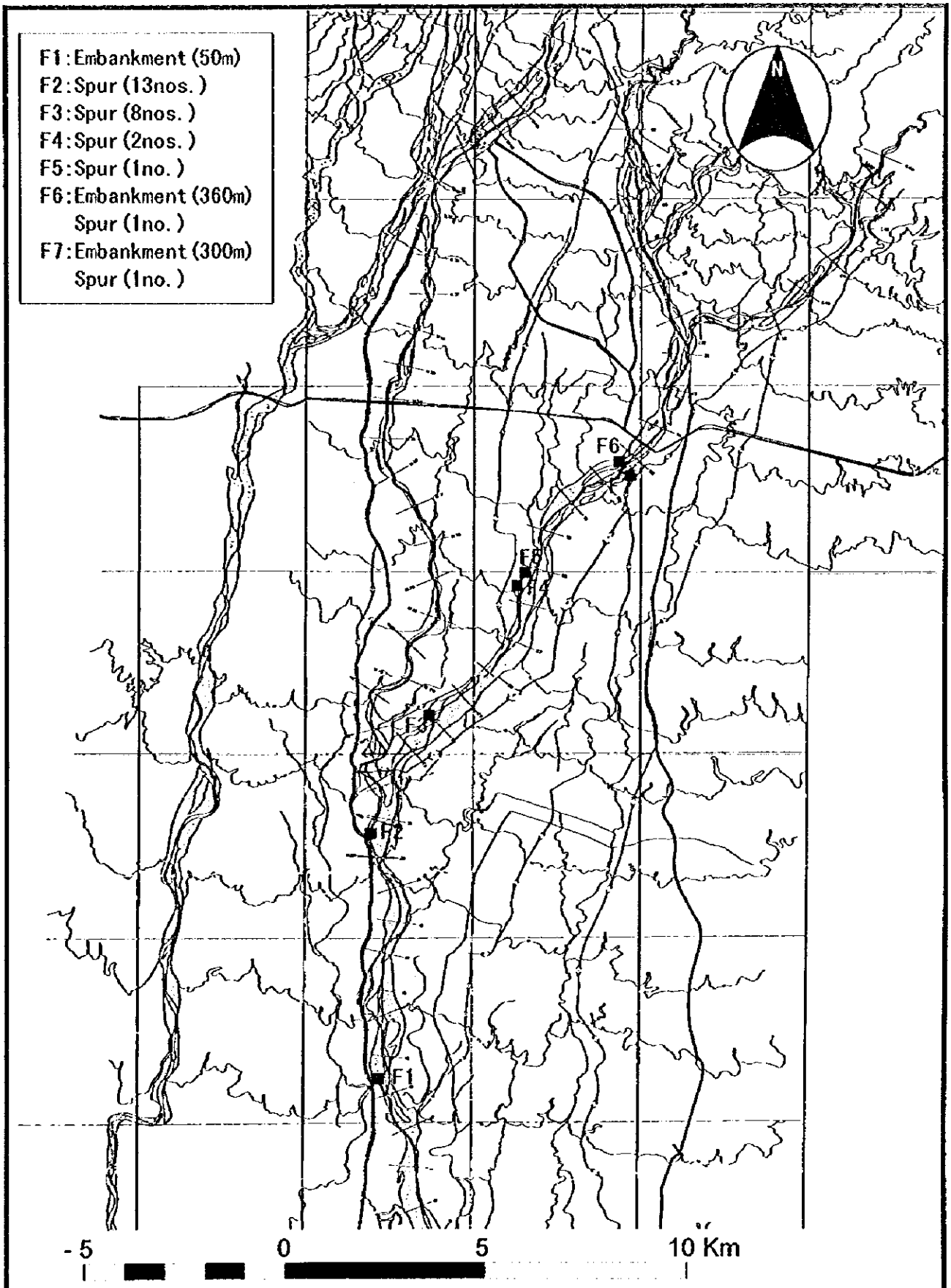

LOCATIONS OF RIVER FACILITIES

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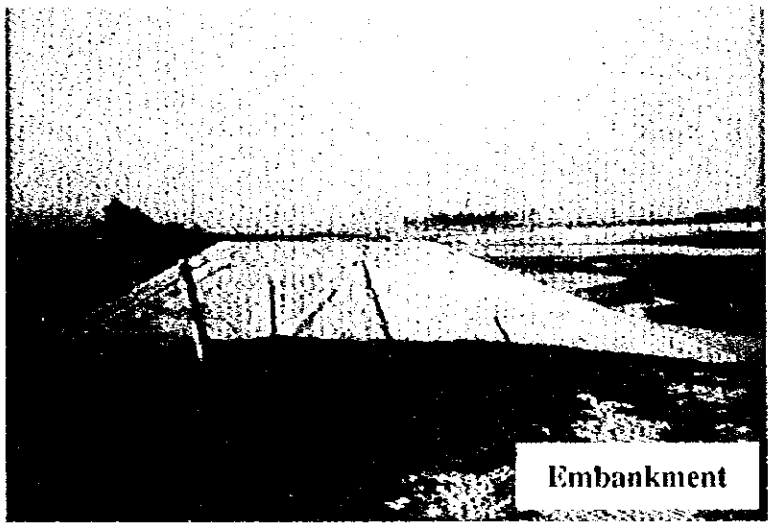

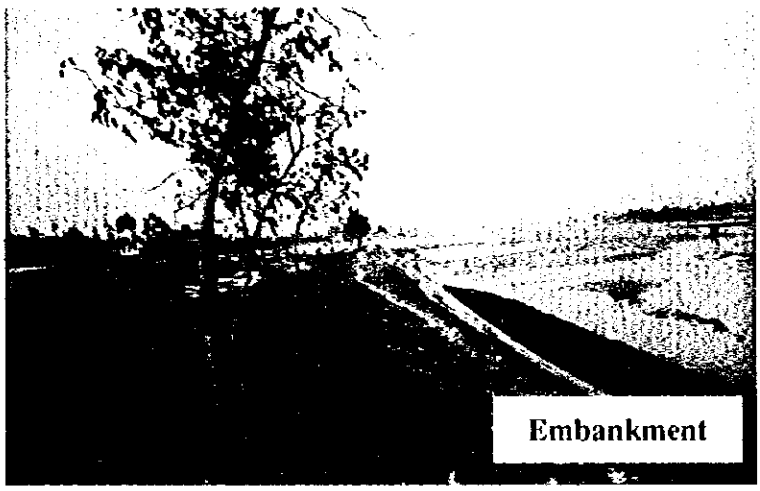

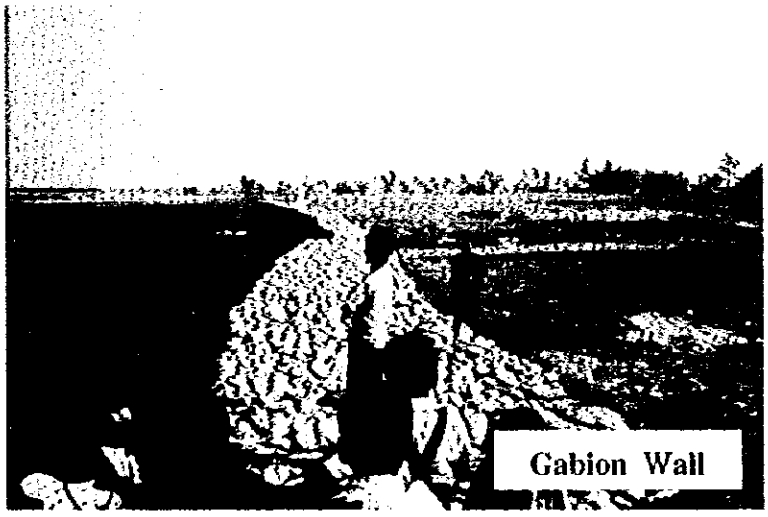

TYPICAL RIVER FACILITIES

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2. FLOOD MITIGATION MASTER PLAN

2.1 Principles for Formulation of Master Plan

(1) Objective of Master Plan

Objective: The Master Plan aims to direct or guide the flood mitigation activities that will be conducted by various agencies and organizations concerned. In the present study, flood mitigation always means the mitigation of damages due to flood and sediment induced disasters.

Master Plan: Flood mitigation measures generally needs long and continuos periods of efforts to accomplish. Therefore, all of these efforts must be directed in an orderly manner toward flood mitigation targets described in the Master Plan. The Master Plan includes the following contents:

1) Present conditions and problems
2) Flood mitigation measures: The measures consist of watershed management, river control and community development components.
3) Master Plan: A conceptual plan for flood mitigation is prepared to cope with basin's flood and sediment disasters. Discussions on the technical details are left for future studies.
4) Action program: Activities to be performed by the target year are clarified and actions toward the target year are detailed. Execution methods and procedures for the implementation are also discussed.

(2) Target Year

In line with the national development plan, target year was set at the end of Twelfth Plan in 2017.

(3) Objects to be Protected

According to the investigation of flood and sediment disasters, the major causes of damage in the Terai plain are:

1) Bank erosion,
2) Sedimentation in the riverine areas, and

3) Flooding and inundation.

Owing to these, the following objects in the flood prone area have been affected by damage:

1) Human being: Injury and loss of life
2) Settlements: Houses and household effects, public buildings such as school and hospital, etc.
3) Public facilities: Highway and roads, bridges, electric cables, irrigation canals, river training works, etc.
4) Farm lands and livestock: Paddy and other crops, livestock, etc.

Such people, land and facilities in flood prone areas located along the rivers shall be protected from flood and sediment disasters.

(4) Approach to Flood Mitigation

Considering the natural and social conditions of the Study Area and the financial situation of HMG/N, the following matters are taken into consideration in planning the flood mitigation of the rivers in Terai plain:

1) **Maximum use of local materials and human resources:** The proposed plan should fit in with the financial situation of the country. The proposed project must be practical and sustainable, low cost for both construction and in the maintenance. In this regard, consideration is given to the use of local materials in parallel with the participation of local residents as much as possible.
2) **Provision of safe lands:** Expansion of rural towns and isolated farm house is taking place due to migration and population increase in the Terai plain. Some of the new residents live on the land which are flood prone. Provision of safe and productive land is one of the important tasks of the flood mitigation projects in the Terai plain, and the prevention of loss of human life is a top priority.
3) **Comprehensive measures:** Flood mitigation measures should be inclusive adopting non-structural measures as well as structural measures..
4) **Technical Model:** The proposed flood mitigation plan should be a technical model for other river basins of similar nature.

2.2 Flood Mitigation Measures and Project Components

(1) Conceivable Flood Mitigation Measures

In order to mitigate damage due to flood and sediment disaster, it is necessary to employ all the possible measures. The flood mitigation measures are broadly classified into four, according to their functions, as follows:

1) Erosion and sediment control by watershed management
2) Storage or detention of flood water
3) Smooth transport of flood water and sediment
4) Damage mitigation by flood plain management

These flood mitigation measures are shown in Fig. A2.1. Considering the characteristics of the river and the existing situation of the basin, measures applicable to the rivers in the Terai plain are also shown in the Figure.

(2) Project Components

In order to undertake the project in a practical and sustainable manner, it is important to implement the watershed management and river control measures in combination with community development activities. Therefore, the flood mitigation is composed of three components, i.e., watershed management, river control and community development components.

2.3 Watershed Management Component

Enhancement of the living standard of the resident is the premise for preventing soil erosion and the watershed management. Therefore, it is preferable to adopt countermeasures for promotion of watershed conservation together with community development activities.

For the conservation of watershed, construction of erosion control facilities, encouragement of afforestation and land use control are recommended as primary measures. In order to materialize the measures, publicity activities mobilizing local community, and governmental and non-governmental organization are also essential. The Department of Soil Conservation and Watershed Management (DOSCWM) and Water-induced Disaster Prevention Technical Center(DPTC) are expected to take the

leading role in this regard.

(1) Erosion Control Facilities

As remedial measures, the following erosion control facilities, solely or in combination with bioengineering technology, could be applied considering topographical, geographical and social situation of the site:

1) Construction of check dam
2) Revetment works along river banks
3) Protection of hillside slope by revetment work and small terracing with vegetation
4) Protection of small-scale channel with gully plugging and surrounding slopes by planting shrubs and grasses.

(2) Afforestation/Reforestation and Land Use Regulation

Afforestation/reforestation and land use regulation aim to foster physical strength of the watershed area against land erosion. The followings are the recommended measures for the watersheds under study:

1) Afforestation and reforestation artificially and fostering natural regeneration of trees.
2) Promoting farm tree and shrub planting by growing commercial crops such as fruit trees, medicinal herbs, aromatic plants and natural dyes. Well-managed commercial crops prevents land erosion in watersheds and promotes sustainable watershed management activities through income generation. The cultivation of medicinal and aromatic plants has been one of the main programs of Nepali forestry policy. Root crops should not be chosen.
3) Planting of fodder grasses on slopes, fodder trees on terraces, and restricting the number of livestock within permissible limits for sustaining the pasture and forest.
4) Conservation of wild medical herbs, by protecting from over-collect, thus allowing a sustained yield.
5) Reducing energy use through the promotion of improved stoves.
6) Training the local leaders in land use and woodland management, and exchanging know-how among other communities.

(3) Publicity Activities

Afforestation and reforestation have already been carried out in Nepal. However, public people have little knowledge on this matter. In order to promote watershed management, the understanding and cooperation of communities, local and central governments and other organizations are indispensable. In this regard, publicity activities should be extended employing all possible means as follows:

1) Establishing a specific date or dates for tree planting activities as a national and/or local level events and conducting tree planting campaign for afforestation, reforestation, form tree planting and forest conservation.
2) Commemorative tree planting for any ceremonies and memorial events by residents, and local and national leaders.
3) Environmental education, tree nursery and small arboretums in school.
4) Enactment of a system of commendation for excellent tree planting projects, including agroforestry, riverside plantings and other community activities.
5) Combination of natural regeneration and/or afforestation project with tourism and local development project.
6) Campaign by mass media for planting trees.
7) Establishment of foundations and solicitation of funds to encourage tree planting.
8) Organizing tree-planting volunteer groups and facilitating volunteers from the overseas countries to participate as well.
9) Conducting of study tours to on-going projects to learn from past initiatives.

2.4 River Control Component

2.4.1 Design Discharge

The probable peak discharges at a specific section of the river were 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 : Probable discharge of n-year return period (m^3/s)

(Q_n/Q_2) : Ratio of n-year probable discharge to 2-year discharge

q_2 : Probable specific discharge on 2-year return period ($m^3/s/km^2$).

C_2 : Coefficient of Creager's formula for 2-year return period

The values of C_2 and Q_n/Q_2 for the Ratuwa river basin are estimated commonly for rivers originating at Siwalik hills as shown in the following table, based on the probable discharges of the upper East Rapti (460), Manahari (465) and Lothar rivers:

(Q_n/Q_2-values for Ratuwa River)

C	Q_2/Q_2	Q_5/Q_2	Q_{10}/Q_2	Q_{20}/Q_2	Q_{50}/Q_2	Q_{100}/Q_2
6.0	1.00	1.62	2.02	2.41	2.92	3.30

Probable discharges of 2, 5, 10, 20 and 50-year return periods at the lower end (Indian border) is as follows:

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
Ratuwa	383	500	810	1,010	1,200	1,450

2.4.2 River Segments and Channel Characteristics

The river is generally divided into four segments with similar characteristics mainly based on river slope and bed materials, i.e., Segment M for mountain reaches, Segment 1 for alluvial fan, Segment 2 for natural levee zone, and Segment 3 for delta.

Segment-3 does not exist in the Terai plain rivers. The Segment 2 is divided further into Segments 2-1 and 2-2. River control measures should be discussed based on the channel characteristics of respective segments.

River channel of the Ratuwa was divided into four stretches depending on the channel slope, grain size distribution, river width, surrounding topography, etc. as follows:

1) RA-1: Reaches from Indian border to Sta. 13.0 km
2) RA-2: Reaches from Sta. 13.0 km to Sta. 26.0 km
3) RA-3: Reaches from Sta. 26.0 km to Chaju river junction (Sta. 36.2 km)
4) RA-4: Reaches from Chaju river junction to upper end (Sta. 43.7 km)

Grain size and other channel factors are worked out for respective stretches as follows:

River stretch	River segment code	Ground elevation		Ground slope (1/1)	Grain size		River width Bm (min-max) (m)
		From (m)	To (m)		d_{60} (mm)	d_R (mm)	
Ratuwa R.							
RA-1	2-2	69	80	1,180	0.30	0.30	356 (188-500)
RA-2	2-1	80	102	590	0.34	0.34	446 (275-638)
RA-3	1	102	134	320	0.43	0.43	516 (300-688)
RA-4	1	134	178	170	0.74	0.74	348 (225-425)

2.4.3 River Boundary Line (RBL)

Necessity of River Boundary Line: Stabilization of river course is a fundamental task to achieve river control. As a reference datum for the river course stabilization, the river boundary line (RBL) should be first designated and authorized for the flood mitigation activities, identifying the lands and objects to be protected. The RBL must be fixed and protected from movements of the river courses.

Use of the RBL: All the river-related facilities for flood mitigation and water use should be planned and designed in consideration of the authorized RBL. By so doing the efforts for flood mitigation to be carried out when the occasion demands would be accumulated and the safety level of the river would be enhanced gradually in line with the plan.

Setting the RBL: The RBL should be set satisfying the following requirements:

1) Protection of properties: The RBL should be placed to protect important lands and objects from flood and sediment disasters.
2) Enough channel capacity: The river width between the right and left RBLs should be more than average width of the existing river and enough to transport of flood water and sediment.
3) Free from erosion: The RBL itself should be free from erosion keeping enough distance from river bank or providing appropriate bank protection measures.

Procedure of Setting RBL: Therefore, the RBL is designed and authorized through the following procedures:

1) To study river width necessary to transport design flood water and sediment
2) To investigate erosion width along the both river banks. The erosion width

discussed here is total erosion width of riverbank throughout a flood season. Design erosion width (B_e) is determined as the maximum value for respective river reaches based on the investigated data.

3) To draw initial RBLs on both banks keeping distance more than B_e from river bank. The RBL should be set on a smooth alignment for flood water flow.
4) The initial RBLs are examined from the viewpoints of property protection and channel capacity. The RBL will be revised partially, if the result of examination demands.
5) The RBLs are fixed and authorized finally after getting consent of government authorities and local communities concerned.

The RBL should be clearly marked in the field by permanent objects such as stakes, planted trees, dike road or dike embankment.

The design erosion width (B_e) was assumed, tentatively for the present study, to be B_e = 50 m based on the information obtained in the field.

2.4.4 Facility Plan

(1) Channel Treatment

1) **Tributary works:** Treatment of tributaries by diversion structure, closing dike, and connecting channel works, to fix the river system and catchment boundary.
2) **Branch/anabranch works:** Treatment of branches and anabranches by closing dike works with diversion structure, if necessary, to prevent river course shifting and flood water spreading.

(2) Bank Protection

Bank protection aims to protect the banks from erosion and accordingly to stabilize the river course.

1) **Spur (or groin) works:** A series of spurs to prevents bank erosion, primarily by two functions, namely to retard flow velocity near the bank and to change the flow direction away from the bank. Spur and revetment works are the primary bank protection measures. These measures can be planed independently or jointly. Various types of bank protection works have been developed empirically over the world, and the works should be selected

considering the channel characteristics of the river.

2) **Revetment works:** Revetment works prevent bank erosion by covering bank slopes and protecting their foundations.
3) **Preventive bank protection works:** Grass and trees planted on the riverbanks to resist and retard erosion. These bioengineering technologies can be used as preventive measures against bank erosion, not as direct bank protection works.

Design of Spur: For the purpose of Master Plan study, spur works were tentatively selected for bank protection, since river section data were not available. The following assumptions were also introduced mostly based on the data in Japan:

1) Total length of a series of spurs (L):
   L = X/4.0 for Segment 1
   L = X/3.0 for Segment 2-1
   L = X/2.0 for Segment 2-2
   where X : Bank length to be protected
2) Crown height of spur (h_{sp}) from bank level:
   h_{sp} = 0.0 h_L for Segment 1
   h_{sp} = 0.3 h_L for Segment 2-1
   h_{sp} = 0.5 h_L for Segment 2-2
   where h_L: Mean depth of low water channel
3) Type of spur:
   Gabion spur for Segments 1 and 2-1
   Pile groin for Segment 2-2

Classification of riverbank: In order to identify the sites in critical conditions and prioritize the work sites for protection, riverbanks should be classified in the following types (Fig. A2.2) based on the relationship between the distance from river bank to the river boundary line (B_h) and design erosion width (B_e):

1) Type-C bank: $B_h \geqq B_e$ and bank erosion is not active due to topographical and geological reasons.
2) Type-B bank: $B_h \geqq B_e$ and bank erosion is active.
3) Type-A bank: $B_h < B_e$ and bank erosion is active.
4) Type-A_s bank: $B_h < 0.5\ B_e$ and bank erosion is active.
5) Type-A_{ss} bank: $B_h < 3h_{H}$, $7h_{H}$ and $10h_{H}$ for Segment 1, Segment 2-1 and Segment 2-2, respectively, where h_H: design water depth in high water channel.

Periodic monitoring: Conditions of riverbank shall be monitored every year after the flood season and the necessity of protection works shall be examined based on the following criteria depending on the types of river bank:

1) Type-C bank: No bank protection works are needed.
2) Type-B bank: Preventive measures for bank erosion are needed.
3) Type-A bank: Bank protection works are desirable as far as the fund is available. Preventive measures for bank erosion are needed immediately.
4) Type-A_s bank: Bank protection works are needed immediately.
5) Type-A_{ss} bank: Protection works of dike slope are needed.

(3) Dike Works

Dike works aim to prevent floodwater and sediment from spreading over the land.

1) **Forest and grass belts:** Trees and grass planted along the river course are not strictly dikes. However, these grass and tree belts would alleviate flood damages in the flood prone areas, retarding the flood flows and promoting the formation of a natural levee along the belt (Fig. A2.3).
2) **Dike road:** Road embankment constructed along the river as rural road and flood dike as well. Even tough the embankment is lower than the design level, the road embankment would protect nearby lands from flooding and sedimentation most of the time.
3) **Local dike:** A local dike is applicable to protect a specific area from flooding in such places as the confluence of tributaries, the bifurcation site of an old river course and other local sites of low elevation.
4) **Ring dike:** A ring dike is applicable to protect sporadic important objects like settlements in flood prone areas. A facility for interior drainage is also required.
5) **Continuous dike:** A continuous dike along the river course is an effective measure for the prevention of flooding. However, a continuous dike was not proposed considering the present land use of the flood prone area, the anticipated difficulties in maintenance under the uncontrolled sediment yield in watershed area and the necessity of coordinating the plan with India.

These dikes are aligned, in principle except for the ring dike, on the river boundary line

(RBL). The river zone between the RBLs on both banks is planed considering the water and sediment transport capacity and existing river width. Various types of dike works are conceivable. Selection of these works should be made considering the channel characteristics, land use in flood prone areas, etc.

For the purpose of the Master Plan study, following dike works are tentatively selected:

1) Forest belt for Segment 1
2) Grass belt for Segments 2-1 and 2-2
3) Local dike
4) Ring dike

(4) Excavation of Low Water Channel

Channel excavation works primarily aims to increase channel capacity and to normalize the river courses.

1) **Channel excavation:** Intensive channel excavation is not recommended for the rivers in the Terai plain, since the sediment in the upper watershed is not controlled yet. Therefore, channel excavation may be executed only for channel normalization in extremely narrow sections and for collecting materials for earth dikes.
2) **Collection of bed material:** Collection of riverbed material also contributes to the increase of the channel capacity, as far as the amount and places of collection are planned appropriately from a river control viewpoint. The collection can be undertaken on the coarse material bed such as in the alluvial fan.

Channel section: Wide channel has large capacity for floodwater transport but small capacity for sediment transport, which may result in silting up of channel sections. The designed width of the low water channel should be checked with the empirical relationship developed by Dr. Koichi Yamamoto (Fig. A2.4). Since this relationship was prepared based on the data of rivers in Japan, it is recommended to reproduce the relationship using data from Terai rivers in future.

(5) Realignment of Channel

1) **Cut-off Channel (COC):** This will ensure smooth flood and sediment flows by shortening and steepening the channel in meandering sections, and keep away the river course from the site to be protected. The COC may not be applicable to the channels in alluvial fan, since the river course is braided and unstable. The COC is planed considering the following:
   - Cut-off channel was planned for the severe by meandering channel.
   - Cut-off channel section was designed with the average width and depth of the existing river.
   - Closing dike shall close the head of the existing channel.
2) **Diversion Channel:** The primary functions of a diversion channel are to divert all or a part of the river water to alleviate flood discharge in the lower reaches, or to keep the river course away from the objects and areas to be protected. However, appropriate sites for diversion channels are difficult to locate for the rivers in the Terai plain, since these rivers take routes in parallel to each other, in a south-east direction, and the trans-basin of the flood water may cause another problem in the receiving river.

(6) Storage or Detention of Flood Water

1) **Dam Reservoir:** Dam reservoir to control flood and sediment flows are not applicable in class-III river basins, because of the poor geological conditions in the Siwalik hills. Single purpose dam for flood mitigation would not be economically feasible. As to multi-purpose dams, promising projects are not proposed at present for the river basins in the Study Area. Therefore, the dam schemes were not incorporated at present.
2) **Retarding Basin:** In order to reduce flood peaks in the downstream reaches, a retarding basin by conserving natural flood storage function can be considered. The retarding basin can be planned at the confluence of tributaries. It will (1) reduce runoff peak by spilling floodwater into the retarding basin; (2) collect flood water from the upper reaches; and (3) join tributaries without a drainage sluice, thereby as a back-water levee.

2.5 Community Development Component

The "Community Development Component" will consist of three sets of activities (Fig. A2.5). The "Community Mobilization" intends to build up organizational bases for the

Plan implementation. The "Local Coping Measures" will enable the communities to "live with flooding". The "Community-based Sustainable Measures" will motivate the local people to maintain and sustain the flood control structures.

This Master Plan will address both hazards (e.g., inundation, sedimentation, and bank erosion) and people's vulnerability (e.g., lack of awareness and motivation for flood mitigation, inadequate resources to adjust to flooding, lack of access to alternative sources of livelihoods) as shown in Fig. A2.5. The hazard control will be addressed by the "River Control" component (and partly by "Community-based Sustainable Measures" with some structural measures). The "Community Development" will promote vulnerability reduction in itself (by enhancing the people's capabilities to adjust to hazards, through "Local Coping Measures"), and also will bring the "River Control" component to impact on vulnerability (by linking the physical structures with community development, through "Community-based Sustainable Measures"). In this way, the "Community Development" component will contribute towards Comprehensive Flood Mitigation (tackling both hazards and vulnerability).

2.5.1 Community Mobilization

The "Community Development" will start with the "Community Mobilization" component, to strengthen the organizational bases for local flood mitigation initiatives (Fig. A2.6). Unlike the past practices in which the people are hastily "organized" primarily for the construction of physical facilities, more focus will be placed on awareness-raising and capacity-building of the communities themselves.

(1) Workshops for Local Government Institutions (LGIs)

There are specific set of "Community Development" activities that will be entrusted to the LGIs. Although the DIO even presently seeks the LGIs' cooperation in mobilizing the communities in flood control projects, the LGIs contribute only to labor hiring, with little regard to awareness-raising of the local people. In order to upgrade the LGIs' capacities to perform the full-fledged "Community Mobilization" tasks, a series of training workshop will be undertaken at the inception of the "Community Development" activities. The subjects to be taken up in the workshops are as follows:

1) Technicalities of Flood Control Measures (functioning of various measures)
2) Local Initiatives for Flood Mitigation (actions expected of communities)

3) Community Mobilization Processes (procedures for community mobilization)
4) Facilitative Roles by LGIs (roles and responsibilities of LGIs)

(2) Creation of Organizational Bases at the Community

Formation of Community Organizations (COs)

1) **Step 1: Organize Settlement-wise Meetings:** An initial meeting will be held in each settlement, inviting all the households.
2) **Step 2: Dialogues with Communities:** This step is to enable the communities to understand the potential benefits of the Plan through a) Presentation of "Flood Control" Component, and b) Relating "Flood Control" with Other Local Needs
3) **Step 3: Establishment of COs for Forest/Grass Belts:** To develop and maintain the forest/grass belts, settlement-wise COs will be established, through a) Formalization of COs, b) Preparation of Forest/Grass Belt Operational Plan, and c) Registration of CO with the District Authority.
4) **Step 4: Strengthening of COs for Other Flood Control Works:** Where additional structures (other than forest/grass belts) are proposed, the CO will be strengthened, through a) Formation of Inter-CO Groups, *where necessary* , and b) Formulation of "Community Development" Action Plans.
5) **Step 5: Enter into Agreement with CO Groups:** Finally, a formal agreement is signed with COs, which stipulates project activities, time frames and budgets, as well as responsibilities of both sides.

Promotion of Public Awareness, Knowledge & Skills

Once the COs are formalized, formal training will be conducted on the following topics:

1) **Technicalities of Flood Control Measures:** to understand how various measures are to function and are to be maintained, and also why continuous dikes are not opted.
2) **Skills in Masonry and Gabion-netting:** to gain employment during the construction stage, and also to obtain skill necessary for the maintenance activities.
3) **Community Participation in Flood Mitigation:** to understand modalities of "participation", e.g., labor/in-kind/cash contributions, as well as local practice.

Generation of Financial Resources by COs

The COs can generate financial resources through a) Forest/Grass Belt Products, b) Nursery Products (in case the communities run nurseries), and c) Group Savings. Savings will primarily be used as capital to for regular maintenance and minor repair of flood control structures, and/or for undertaking community-based flood mitigation activities. At the same time, it is important to assist COs in establishing a record keeping system, and in acquiring skills in running it in a transparent manner.

2.5.2 Local Coping Measures

Since it is not possible to contain all flooding through river control facilities alone, it is important for people also to take coping measures on their own, to complement the physical structures. The Plan component for "Local Coping Measures" will be undertaken on a community-by-community basis (Fig. A2.7). The following are a menu of support, in assisting local communities to enhance their local coping measures.

(1) Flood Proofing

The following are examples of flood proofing measures observed in the Terai plain:

1) **Agricultural Adjustments:**
   - Immediately after the summer crops are damaged, cultivate fast-growing crops (e.g., certain types of vegetables, Arun maize) which can even harvested in a few months' time - even in time for farmers to start winter crops;
   - Grow sweet potatoes if as a result of floods their farming lands are covered by thick sand, thus preventing them from cultivating other crops;
   - Where feasible, change from maize growing to rice cultivation which is less vulnerable to inundation, and in other words, more flood-resistant; and
   - Set aside rice seedlings, in order that they can re-plant paddies, even in case rice fields are destroyed due to flooding.

2) **Housing Structures:**
   - Construct houses on plinths, so that flood water flows underneath;
   - Raise grain stores on stilts, while build escape areas under roofs for family members and other valuables; and,

- Concentrate houses on higher grounds of the communities, to prevent residential shelters from being inundated during floods.

3) **Other Possible Flood Proofing Measures:**
   - Afforestation/reforestation on the riverbanks will serve to curtail the speed of overflow water in case of emergencies;
   - In low-lying areas, drainage will serve to reduce the level of inundation as well as to improve hygienic conditions during the monsoon; and,
   - Small-scale reservoirs (e.g., creation/expansion of new/existing ponds) on community-owned barren land.

One modality of possible support is to introduce the above-mentioned practices to localities where they are feasible but still unknown. Some communities may be facing the resource constraints, which can be supported with the supply of those lacking materials. Moreover, support will also be provided even to existing flood proofing efforts, when there is scope for further improvements.

(2) Forecasting, Warning, & Evacuation

The following are some of such examples of local measures:

1) **Forecasting and Warning:** Some people anticipate floods when they observe;
   - Changes in the water flow (e.g., rising levels of water, river water mixed with mud, leaves floating on the water, increasing number of fish);
   - Unusual sound/smell of rivers (e.g. rumbling sounds coming from the river, muddy smells of the stream); and,
   - Continued rainfall in surrounding areas, or in the upper watersheds.

2) **Evacuation:**
   - Stay in under-roof areas/ on rooftops, until floodwater subsides;
   - Stay on trees (e.g., bananas, and mangoes) planted around houses;
   - Evacuate to neighbors' second-story houses, or to others' houses in surrounding areas on higher grounds; and,
   - Shift valuables (e.g., money, grain, and livestock) to safer areas, before the monsoon season starts.

For both "forecasting/warning" and "evacuation", a possible strategy is to improve upon

local measures (e.g., it is fairly common that warning and evacuation are undertaken individually, which can be organized as joint efforts). More systematic approaches to forecasting/warning simply by utilizing existing facilities, such as P.C.O. (Public Call Office). In localities that find it difficult to secure suitable evacuation sites, support will be provided, e.g., in developing accessible roads to safer areas.

(3) Flood Fighting

The following are examples of local flood fighting measures:

1) Install bamboo piles as bank protection works;
2) Grow indigenous shrubs on the land-cutting sites;
3) Plant bamboo on river banks as protective works;
4) Construct temporary spurs made of logs;
5) Use sandbags with bamboo piles; and
6) Place boulders and tree trunks, where embankments are being breached.

However, such village-level measures often lack technical soundness. In such cases, the faults will be corrected with the provision of technical advice. Where certain materials are not available locally, support will be extended for the local communities themselves to procure or produce those materials locally. Only for those materials beyond the reach of the local populations will be donated to the local communities.

2.5.3 Community-based Sustainable Measures

The "Community-based Sustainable Measures" component is to derive additional benefits from the physical facilities, and to motivate the beneficiaries to sustain the structures (Fig. A2.8). (1) forest/grass belts, (2) preventive bank protection works will derive tree/grass products out of the flood control measures, while (3) access improvements, (4) bed material collection will produce other additional benefits. These additional values will motivate the COs to sustain the physical structures, through (5) operation and maintenance (O&M) of flood control structures, and (6) land use management.

(1) Forest/Grass Belts as Dike Works

The flood mitigation plan envisages the development of forest/grass belts. Table A2.1 shows a list of potential candidate trees/shrubs/grass that can be used as part of the Belts. The belts will also serve various necessities of the local residents. As illustrated in

Table A2.2, there are various local trees, shrubs, and grass that are of multi-purpose (e.g., fuel, timber, roofing, etc). The COs can sell surpluses of forest products in the market. Moreover, in case the local communities choose those species that require nurseries, the COs can sell extra seeds/seedlings that are produced in their nurseries.

In addition to these direct opportunities, there are also multitude of indirect benefits that farmers can tap into. Certain trees/grasses can be used to promote livestock farming, i.e., as fodder for domestic animals (e.g., buffaloes, goats, and cows). In places where bioengineering strategies include forestry development, bee keeping, ginger/turmeric farming, and coffee growing could also be initiated near/in the forests.

(2) Preventive Bank Protection Works

There are broadly two types of bank protection works that the local communities can undertake using their own resources. One is the construction of flood control works entirely relying upon local materials (e.g., bamboo and sandbags). In some cases, the communities attempt to contain bank erosion and/or flooding by installing revetments/spurs using local materials such as bamboo and sandbags. These will be disseminated where the velocities are not high. Local communities will also be assisted to generate their own resources, e.g., the plantation of bamboo, group savings to purchase sandbags themselves. The government agencies will also be encouraged to refrain from handing out those materials, to the extent possible.

Another modality of local bank protection works is the plantation of trees/shrubs/grass, usually to supplement engineering structures. Bioengineering will help derive at long-term stability of the river control measures, by stabilizing the land that adjacent to the engineering structures. It will be used to derive tree/grass products. As Table A2.2 shows, there exist two categories of income-earning opportunities, i.e., one emanates from sales of extra seeds and seedlings produced in nurseries, and the other from the supply of tree products, e.g., fuel wood, fodder, and timber. In addition to extension activities, support will also be extended to those localities that already practice bioengineering, but still have room for improvements (e.g., introduction of higher-value species).

(3) Access Improvements using Flood Control Structures

Flood mitigation projects, when dikes are constructed, provide opportunities to

simultaneously develop rural road networks. In some places, the dikes alone will be designed as access roads. In other areas, short-distance unpaved roads (gravel, or earthen) will be constructed, to link embankments with outside road networks. Where revetments will be constructed, it is expected that the riverbanks are also stabilized. Therefore in places where access improvements are required, gravel and/or earthen roads will be developed along those banks.

In doing so, it is important to take into consideration a variety of expectation people may have concerning accessibility improvements, e.g., to transport agricultural products, to send children to school, to go to health clinics, or to attend village meetings. One critical issue, in the context of flood mitigation, is the damages to roads during flooding which prevent the people for evacuating to safer sites. In such places, support will be extended to link road development with the evacuation requirements.

Community-based approaches have been extensively tested for rural road construction at various locations in Nepal. Such approaches can encourage people to contribute their own resources to the rural road projects (e.g., land, labor, construction materials, and cash). This way, local road projects contain unit costs of road construction, usually ranging from 50,000 to 80,000 Rs/km for gravelling earthen roads.

(4) Bed Material Collection as Channel Excavation Works

Many rivers in the Terai are being mined for sand, gravel and boulder, which serve as one important source of revenues for many District Development Committees (DDCs). More importantly, sand/gravel/boulder collection from a riverbed can be part of a river training scheme, which serves to increase the transport capacity of a river. It can also provide employment opportunities for rural people in the Terai plain.

It is to be noted bed material collection is not feasible in all the areas along the rivers. Certain localities face the constraints of (a) unavailability of sand/gravel, (b) low quality of sand /gravel, (c) lack of roadways from outside to excavation sites, (d) distance to transport to markets, (e) lack of flexible/clear-cut rules and regulations, and (f) objections from community members. However, efforts can be made to redress the above-mentioned constraints except (a) and (b).

Despite the high demands for sand/gravel/boulder, riverbed extraction should not be promoted *laissez-faire*. On the contrary, tighter control should be exercised over

contractors, to minimize the extraction of sand/gravel/boulder in accessible locations (near riverbanks or bridges). Generally speaking, it is necessary to dig in the middle part of the river where the sediments are deposited and which generally causes the diversion of river flow towards the banks.

(5) Operation and Maintenance of Flood Control Structures

The local communities will be responsible to constantly monitor the sites, and when necessary, seek external support for rehabilitation. For revetment works made of galvanized iron (G.I.) wire boxes, community will be instructed to monitor the river bed, and when it is scoured, to place stones and rubbles on the river bed. When the gabion wire is cut, the local residents will request the DIO, through the DDC/VDC, for additional nets. It is also necessary, on a regular basis, to remove objects which may be hooked to the G.I. wire boxes.

Gabion spurs and permeable types of pile spurs, similarly, require monitoring of the riverbeds. When the surface of the riverbeds are washed off, it is crucial to stabilize the foundation of the spurs by placing stones and rubbles on the riverbeds. Moreover, the local residents need to ensure that any objects hooked to the piles or the gabion should be removed. In case of gabion spurs, it is also desirable to plant grass or shrubs on the sand-deposit areas, to stabilize the land adjacent to the structures.

Dike works are subject to scouring of their slopes, given its objective to counteract the flood forces. It is therefore critical to ensure that the local communities undertake timely repairs of slope failures. Moreover, it is expected that the dikes are also used as rural roads throughout the year. In this respect, another maintenance task required is to watch the conditions, and whenever necessary to flatten the bumps of the dike roads.

(6) Land Use Management

The purpose of land use management is to ensure flood risks are not worsened by ill-conceived land uses, by conserving the land adjacent to the rivers. Along the target rivers, the following types of poor land use are observed.

1) **Over cultivation:** Farmers with land adjacent to the rivers cultivate right on the riverside. This exacerbates soil compaction, thus accelerating bank erosion.
2) **Over grazing:** Pastureland along the target rivers is usually used freely by

herdsmen, which cause overgrazing problems. This leads to the reduction of vegetation cover, which also stability of the riverbank.

3) **Deforestation:** Not all the forests along the rivers are properly managed. Some are being deforested, while others are maintained but not in a manner conducive to soil conservation.

Against this background, it is crucial for the local communities to agree on local rules and practices that will stop the above-mentioned poor land use management. Those with landholdings on the riverside will be encouraged to stop over cultivation. This can be promoted, through the introduction of high yield crops, or other income-generating activities, e.g., livestock raising. It is important for the farmers to gain alternative sources of income to compensate for the loss of cultivated land. To curb over grazing, more organized systems of pasture land management will be initiated, e.g., rotational grazing, and fodder plantation. Planting of trees near the rivers will be also promoted, both on community land as well as on private farmlands.

2.6 Flood Mitigation Plan

Based on the discussions and analyses made so far, Master Plan for flood mitigation activities by the target year 2017 was worked out. The Master Plan still remains at the concept level, since the planning was made on the topographic map basis (scale 1/25,000 and partly 1/50,000) and the river survey data were not available. In future the Master Plan should be upgraded based on a river survey to be conducted, in line with the concept of flood mitigation described here.

(1) Present Conditions and Problems

1) River basin:
   - Class-III river in Eastern Development Region
   - Basin area: 383 km^2 in total consisting of mountainous basin 133 km^2 and plain area 250 km^2.
   - Damak city and refugee camps by UNHCR exist in the riverine area.
2) River system: The Mawa river, a right tributary, is about to join the Nunsari/Bakra river near Madhumalla Bajar town.
3) River channel: River is wide and braided for the whole stretch. Changes in riverbed material along the river are small ranging from medium to coarse sand. Gravel and other coarse materials are not found even in Segment 1.

4) River segments:
   - Segment 2-2: From 0.0 km (Indian border) to 13.0 km
   - Segment 2-1: From 13.0 km to 26.0 km
   - Segment 1 : From 26.0 km to 43.7 km (upper end)
5) Flood and sediment disasters:
   - Recent major floods: 1988, 1995 and 1996 floods in order of severity.
   - Kinds of damages: Bank erosion, sedimentation and flooding over farm lands.
   - Suffering areas: 7 villages in 3 VDCs and 4 wards of Damak municipality in Jhapa district, and 4 villages in 3 VDCs in Morang district.
   - Conditions and mechanism of flooding: Riverbed of the Ratuwa river is said to be agrading and widening. The Ratuwa river floods the riverine areas every year from June to August. In the lower reaches the floodwater spreads along the old river courses and trails.

(2) Principal Measures to be Taken

1) The Mawa river and the Nunsari river will be separated completely by a closing dike.
2) Branch and anabranch in Segments 2-2 and 2-1 will be closed securely with diversion facilities if necessary.
3) Forest belt will be provided for Segment 1 and grass belt in Segments 2-2 and 2-1.
4) Cut-off channel will be constructed at the severe bends.
5) An area at the confluence of the Ratuwa and Mawa rivers will be preserved as a retarding basin.
6) Bank protection works by a series of spurs will be implemented based on the monitoring result of riverbanks. Preventive measures for bank erosion will also be taken by adopting bioengineering approach.
7) Watershed management will be carried out for erosion and runoff control.
8) Flood plain management will be carried out for mitigation of damage due to flood and sediment disasters.

(3) Layout Plan

Layout of the flood mitigation Master Plan is shown in Fig. A2.9.

(4) Project Works and Cost

Quantities of works for the Master Plan were estimated based on the standards and assumptions discussed in the previous sections, and preliminary cost required for the project implementation was estimated under the following conditions:

1) Price Level: The project cost and other related unit costs are expressed under the economic conditions prevailing in October 1998.

2) Exchange Rate of Currencies: Exchange rate of currencies are assumed as follows:
   US$1.00 = Rs.67.93 = ¥115.14 (Rs.1.00 = ¥1.69)

3) Constitution of Project Cost: Project cost is the sum of construction base cost, land and compensation cost, administration cost, engineering, physical contingency and value added tax. Calculation is carried out based on the following:
   (1) Construction base cost = (Work volume) x (Unit work cost)
   (2) Land and compensation cost = (Area of land to be acquired and number of houses to be relocated) x (Unit cost)
   (3) Administration cost = 5% of (1)
   (4) Engineering service cost = 10% of (1)
   (5) Sub-total = (1) + (2) + (3) + (4)
   (6) Physical contingency = 10% of (5)
   (7) Price contingency =Assumed annual escalation rate at 3% for foreign currency portion, and 10% for local currency portion
   (8) Value added tax = 10% of (5) + (6) + (7)

Quantity of work, unit work cost and amount of project cost are shown in Table A2.3. Annual disbursement of investment cost was estimated on the basis of the implementation schedule. The annual disbursement schedule of financial and economic costs for Ratuwa river are shown in Table A2.4.