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 (6/9)

SUPPORTING REPORT

(A6: FMP/WEST RAPTI RIVER)

MAY 1999

NIKKEN Consultants, Inc.
NIPPON KOEI CO., LTD.

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A6. FLOOD MITIGATION PLAN:

WEST RAPTI RIVER BASIN

SUPPORTING REPORT
A6. FLOOD MITIGATION PLAN: WEST RAPTI 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 West Rapti river basin falls under the topographical and geological zones of Midland and Mahabharat ranges, Siwalik hills, Dun Valleys and Terai plain. Principal features of these zones are presented below.

(1) Lesser Himalayan Zone

Lesser Himalayan zone occupies the central part of the Himalayan Mountains. It consists of a series of mountain ranges rising abruptly above its low rolling hills.

The Lesser Himalayan zone is divided into two sub-ranges, namely the Midland and Mahabharat ranges from north.

Midland Range

The Midland range consists of low hills, river and tectonic valleys. The slope ranges from 100 to 400 m/km. In this range, generally the rocks consist of fissile phyllite and schist. The dip of the bed in this part is generally towards the north. In the areas where rivers have east-west course, landslides are seen on the southern bank of the river. Since the phyllite is a soft rock, the exposed bed in the bottom section of hill is found to be crushed in most places, indicating that the load is beyond its bearing capacity.

The Midland range is composed of soft rocks (phyllite, slate and dolomite) and thick

soil covers this area, hence it is heavily populated. Because soft rocks weather easily, the Midland range forms low and mild slope hills. Nearly all the hill slopes are found to be formed from the talus of landslide and rock fall. Generally the hill slope appears to be stable for a period of 8 to 10 years after the slide till the talus is washed away by under-cutting of the river, and at the same time, this causes the development of gullies and erosion throughout valleys. Slowly the topography changes from flat to steeper terrain and sliding occurs again.

Mahabharat Range

The Mahabharat range consists of comparatively harder rock than the midland range. The number of slides is found to be less even though the topography is steep. The topography is steeper on the southern slope comparing to the northern one of about 100 to 200 m/km. Slides take place on the northern slope and rock falls on the southern slope. The steep of the topography can be attributed to the Main Boundary Fault (MBF) which lies mostly at the southern foot of the ranges.

The Mahabharat range is the first set of high mountains facing the Terai plain, and affects much to the climate of Nepal during the monsoon.

(2) 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. Calcareous 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 colored 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.

(3) Dun Valleys

The Siwalik hills make separate ranges from east to west except in some places where it merges with Mahabharat range. The separate ranges form Dun Valleys as seen in Trijunga, East Rapti-Nawalpur, Deokhuri (West Rapti), Dang Valley, Surkhet Valley, etc. The Dun Valleys are fertile and are similar to the Terai plain in nature. Hence they are sometimes classified as a part of the Terai plain.

(4) 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 gray 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.

(5) West Rapti River Basin

The West Rapti river basin originates in the Mahabharat ranges. In the upper basin, the river is forced to bend its course by Main Boundary Thrust (MBT) and other faults. The channel is forced to flow to the northwest direction due to the Siwalik hills before it reaches to the Terai plain. Geological map of the West Rapti river basin is shown in Fig. A1.2.

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), 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 and hydro-metric stations in the Mid Western Development Region is shown in Tables A1.1 and A1.2, and their locations in Figs. A1.3 and A1.4.

In order to supplement the existing observatory, new recording rain gauge was installed by the Study Team at Banke District Irrigation Office in Nepalganj (1 site) for the lower West Rapti and Babai river basins. This office is under the direct control of DOI. An ordinary rain gauge (sta. No.0416 under DHM) is installed here.

River basin	Caretaker	Serial Number
West Rapti/Babai	Banke District Irrigation Office (Nepalganj)	Gauge: 232717 Recorder: 244189

1.2.2 Meteo-Hydrological Features of Basin

Climate of the West Rapti river basin falls under monsoon subtropical zone (Terai plain and Siwalik hills) and temperate zone (lesser Himalayan zone). 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 West Rapti river basin. Figure A1.5 shows the meteo-hydrological features of the basin based

on the monthly average data at Nepalganj (sta. code: 0416).

(1) Temperature

Altitude affects much the temperature. The annual average temperature is 25.0℃, ranging from 15.4℃ in the coldest month to 31.6℃ in the hottest month. The coldest month is in January and the hottest falls in between May 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 82.3%, ranging from 62.0% in May to 93.3% 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 Nepalganj is 1,370mm on average ranging from 869 to 1,911mm depending on the year. The maximum rainfall is 1911mm in 1988. The 85% of annual rainfall is concentrated in rainy season from June to September.

(4) Runoff

Figure A1.7 shows the monthly average flow of the West Rapti river at Jalkundi station (No.360).

According to Fig. A1.7, The runoff increases from May to August while it decreases from August to November and the most of runoff is concentrated in rainy season from June to September. The annual average runoff at Jalkundi station is approximately 130m^3/s. The maximum monthly average flow is approximately 420m^3/s in August. The monthly average flow exceeds the annual average during the period from July to October.

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 West Rapti river is a class-II river of about 230 km. rising in the lesser Mahabharat ranges. Once it reaches the Terai plains it first travels west about 110 km. before turning south to the Indian border. From this point, its length to the border with India is about 53 km.. Its total basin area is 6,418 km^2 (641,800 ha.) of which 618 km^2 (61,800 ha.) are in the Terai.

According to the Inventory of Wetlands in the Terai, (IUCN 1996), the wetlands along the West Rapti river have still to be fully determined. However, the West Rapti river floodplain occupies an area of 37,500 ha and crosses three districts, - Arghakhanchi, Dang and Banke. An estimated 40% of the land is farmed and 10% is classified as settlements, thus half of this floodplain has been modified already by human activity.

Dalbergia sissoo, Acacia catechu, Ficus glomerata, Engenia jambolana, Bombax ceiba, Terminalia tomentosa and *Shorea robusta* characterize the floodplain. It is a staging and foraging ground for migratory waterfowl such as *Egretta alba, Alcedo atthis, Pavo cristatus, Bubo nipalensis* and *Dendrocygna javanica.* The marsh crocodile *(Crocodilus palustris*) and the smooth otter *(Lutrogale perspicillata)* occur here.

While the wetlands and accompanying forest areas are important in the West Rapti basin of the Terai, over half the land has been converted to agriculture and with people migrating from other parts of Nepal, the forests and wetlands in this basin and the surrounding watershed are under threat. This can only be mitigated by increasing agricultural productivity and flood prevention measures are a key component of this. The existing land use and population of the West Rapti river basin is shown below.

(Land Area, Land Use and Population: 1998)

Items	Agri-culture	Forest	Barren/ sand	Other	Total	Population
Area (ha)	35,140	25,130	1,290	240	61,800	(173,400)*
Ratio (%)	56.8	40.7	2.1	0.4	100	(2.8)**

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

Every year, sand, silt and/or floodwater on average covers on average about 2,700 hectares of which about 500 ha. are covered with sand and soil. Some of this soil cover is a result of human activity, especially in the Chure hills. In addition, nearly 2% of the land is barren or covered with sand, principally due to flooding and inundation.

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

1.4 Socio Economy

(1) Economic Activities

Land Use: The West Rapti river flows in Banke and Dang districts. According to the district data, agricultural and forestland makes up most of the total plain area in the two districts (85.7%/nearly 100% respectively).

unit: hectare

District	Agriculture	Forest	Sand/Gravel /Boulder	Others
BANKE	55,785 48.0%	55,430 47.7%	4,670 4.0%	331 0.3%
DANG	71,871 66.4%	36,400 33.6%	0 0.0%	0 0.0%
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 67.3%/80.0% of the labor force is engaged in agriculture, as opposed to 7.1%/5.0% in manufacturing and 17.2%/10.4% in service sectors.

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
BANKE	62,613 67.3%	16,030 17.2%	6,599 7.1%	7810 8.4%
DANG	101,353 80.0%	13,246 10.4%	6,320 5.0%	5752 4.6%
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: Banke and Dang districts produce a wide range of crops, with major crops of paddy, maize, wheat, and pulse. These major crops but wheat and pulse 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
BANKE	32,350 (2.48)	7,500 (1.17)	12,899 (1.58)	9,450 ()1.09	8,488 (0.97)	---	3,535 (12.55)
DANG	33,500 (3.20)	23,200 2.09	14,100 (2.50)	24,150 (1.03)	18,450 (0.72)	---	1,323 (12.27)
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 Banke/Dang 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. Nearly 90 % 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
BANKE	88.5	86.2	1.47	1.37
DANG	80.4	80.9	1.57	1.17
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
BANKE	2.7	94.9	2.4
DANG	7.5	89.8	1.7
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 Banke and Dang districts is 286,000 and 354,000 as of 1991 with population growth rates of 3.3% and 2.8% (1981-1991) respectively. The population growth ratios were lower than the national average during 1970s, but the current pace of population growth rates are slightly higher than the national average, i.e., 2.3% (1981-1991).

Demographic Records Of Flood-Prone VDCs: The following table shows the population trends of the VDCs affected by West Rapti floods. The 1981-91 population growth rate of the affected VDCs is 6.7%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Banke/Dang districts.

District	VDC	1971	1981	1991	1996
Dang	**Gobardiya**	4,183	8,075	19,755	12,377
	Gangaparaspur	3,106	6,969	8,042	9,255
	Gadawa	-	8,181	7,877	9,065
	Rajpur	-	-	8,811	10,140
	Lalmetiya	7,196	8,619	12,048	13,866
	Sisahaniya	6,736	11,289	11,972	13,778
	Sonpur	4,775	6,376	8,650	9,955
	Chaulahi	5,585	7,333	10,800	12,429
	Satbariya	3,323	6,415	8,829	10,161

Banke	Bejapur	2,954	-	7,745	9,110
	Betahani	3,396	-	5,195	6,111
	Binavna	2,959	-	4,839	5,692
	Holiya	3,071	-	4,588	5,361
	Kamdi	2,465	3,783	6,391	7,517
	Kanchanpur	-	-	5,470	6,434
	Khaskusma	2,347	4,232	3,839	4,516
	Phatepur	4,713	6,593	10,793	12,695
	Gangapur	2,097	-	3,837	4,513
Total		58,906	77,865	149,481	162,975

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 HDIs of Banke and Dang districts are ranked among the lower strata (46th and 53th among all 75 districts).

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The West Rapti river basin extends from 27°45´N to 28°30´N and from 81°45´E to 83°15´E. The West Rapti river originates in Midland range and is classified as a class II river. Administratively it is located in Dang district (watershed basin) and Banke district (plain basin) both in Mid-Western Development Region.

Basin area of the West Rapti river is 6,418 km^2 in total, consisting of 5,800 km^2 of mountainous basin and 618 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 West Rapti river is shown in Fig. A1.8. Topographic maps of 1/25,000 for the western part of Nepal are under preparation in Department of Survey and not yet available. Topographic maps of 1/50,000 were used to prepare overall basin maps of the West Rapti river. Lower basin of the West Rapti river was prepared based

on the draft topographic maps of 1/25,000. Aerial photos of approximately 1/50,000 also were used to supplement the topographic maps.

Notable features of the West Rapti river basin are as follows:

1) The West Rapti river can be divided into upper and lower reaches by the narrow reaches upstream from Sikta.
2) The upper reaches of the West Rapti river forms a valley surrounded by the northern slope of the Siwalik hill, southern slope of the Mahabharat ranges, and narrow gorge in the lower end.
3) The lower reaches of the West Rapti river have wide channel of mild slope. Bank erosion and river course shifting are active.
4) Any works in the gorge sections to improve drainage in the upper basin would affect the flood flow conditions in the lower reaches.
5) Sikta Irrigation Project was studied in 1980. The project, however, was not put into implementation due to failure of coordination with India.
6) A barrage was being constructed by India crossing the West Rapti river near the border. The works are said suspended now.

1.5.2 Characteristics of River Channel

Channel slope and width of the existing river are shown in Fig. A1.9 for the plain stretch. 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 sandbars 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)
W. Rapti R.	II	53.0(163.5)	1/540～1920	200～1700

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. A1.9. 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 1996 (scale: 1/25,000) were superimposed and shown in Fig. A1.10.

As for the West Rapti river, only the lower reaches from Sikta was studied, since the shifting of river course upstream were considered to be limited within the meander belt of the existing river being sandwiched by the Mahabharat ranges and the Siwalik hill.

According to the figure showing river course change during the past 42 years, the following features are considered:

1) Meander of the West Rapti river in the upper reaches of the Jhijhari river junction is not severe and the shifting of river course remains within the meandering belt.
2) In the lower reaches of the junction, scale of the meandering gets larger and shifting of river courses is remarkable.

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 West Rapti river were sampled at 23 sites (Fig. A1.11) among which outdoor analyses were carried out at 12 sites.

Results of riverbed material tests are shown in Table A1.3 and the grading curves in Fig.A1.12.

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: Samples are from the main course of the West Rapti river except for the following:
   - Tributaries from Mahabharat: WR-8. WR-9, WR-11, WR-13 WR-18
   - Other tributaries: WR-6, WR-23
2) Grain size: It is note worthy that the grading curves of the West Rapti river are clearly classified into two types.
   - d_{60} = 0.17 to 0.54 mm (fine to coarse sand):Main river downstream from WR-5 site
   - d_{60} = 23.56 to 33.09 mm (coarse grovel): Main river downstream from WR-12 site
   - d_{60} = 0.18 to 0.34 mm (fine to medium sand): Main river downstream from WR-17 site
   - d_{60} = 22.17 to 46.69 mm (coarse to very coarse gravel): Main river upstream from WR-19 site
   - d_{60} = 0.18 to 0.59 mm (fine to coarse sand): Tributary samples of WR-6 ,WR-8, WR-9
   - d_{60} = 52.86 to 65.48 mm (very coarse gravel): Tributary samples of WR-11, WR-13, WR-18, WR-23
3) Uniformity index: Riverbed materials are well sorted and uniform in the reaches from WR-1 to WR-5 and WR-14 to WR-16
   - UI = 2.1 to 3.0: Main river downstream from WR-5 site
   - UI = 64 to 117: Main river downstream from WR-12 site
   - UI = 2.2 to 5.0 Main river downstream from WR-16 site
   - UI = 40 to 168: Main river upstream from WR-17 site
   - UI = 2.1 to 2.5: Tributary samples of WR-6, WR-8, WR-9
   - UI = 14 to 63: Tributary samples of WR-11, WR-13, WR-18, WR-23
4) Specific gravity
   - SG = 2.64 g/cc on average ranging from 2.58 to 2.69 g/cc
5) Longitudinal distribution: Significant changes in grain sizes are seen at three sections between (1) WR-5 and WR-7 sites, (2) WR-12 and WR-14 sites, and (3) WR-17 and WR-19 sites.

Based on the investigation result, grain size distribution along the river is shown in the Fig. A1.9.

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. A1.13 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

Sikta Irrigation Project

Introduction: The project area proposed to be irrigated under this scheme lies in the Banke District of the Mid Western Development Region of Nepal. In the west project area extends right down to the India border. In the project area Nepalganj is the main town that is the district as well as zonal headquarter of Bheri Zone.

Scheme: In this project (Fig. A1.14), a Head-works (Barrage) shall be constructed on Rapti river near village Agaiya to irrigate net 36070 ha. of land by constructing canals on both the banks. The Head-works site is nearby 60 km east of Nepalganj and is easily approachable by an all weather road (Mahendra Raj Marg). Before reaching the main irrigable area, 36 km of the right bank main canal will have to pass through a forest. The area to be irrigated by the right canal system is 34,270 ha between Mand and Dundwa rivers. The right main canal shall be lined for 36 km and its design capacity is 34 m^3/s. Irrigation area on the left and is 1,800 ha (net). The left bank canal will be 12.4 km in length with design capacity of in 2 m^3/s.

Back Ground: The pre-feasibility study of the project was conducted from January 1975 to June 1978. German Consultant Lahmeyer International (Gmbh) conducted its feasibility study from November 1978 to August 1980 and feasibility of this project with run-of-river diversion alone was established. On the basis of these studies, Department of Irrigation, Hydrology and Meteorology of HMGN (DIHM) established its full-fledged office in Nepalganj in November 1981 for a detailed investigation, planning, design, and execution of the project.

Construction Schedule: The construction schedule of this project has been shown in Appendix II. This schedule has been prepared on the assumption that construction work will start in full fledged way from the fiscal year 2040-41 (1983-84). In this condition, the project would be completed in 10 years i.e. in fiscal year 1992-93.
(Source: Sikta Irrigation Project, Brief Report; Mid-Western Development Region)

1.6 Vegetation in Watershed Area

General features of vegetation in the watershed area are presented here. Sediment yield from the watershed was not estimated for the West Rapti river, since the watershed area is large and the sediment yield in the watershed does not directly affect the sediment flows in the plain area. Most of the sediments in the plain area are secondary or tertiary sediment deposit transported by river flows.

Watershed of the West Rapti river is classified as the climate and vegetation divisions of Middle Mountain and Terai and Outer Himalaya.

(1) Terai and Outer Himalaya

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) Middle Mountain

The Middle Mountain is the area of 1000 to 2500 m,MSL between the Mahabharat and High Himalaya mountain. The Middle Mountain is the central place of Himalayan mountain residents. In the eastern and central part of the Middle Mountain, population is large and forest changed to cultivated lands and residential areas.

Large forest area shall remain in the western part of the country where population is sparse. Generally the forests are left in the areas such as (1) steep slope area which is hard to approach, (2) community forest managed by village, (3) forest with small shrine of native belief, and (4) north slope which is not suitable for agriculture.

Vegetation changes according to the changes of elevation. Sal forest continues from the Terai plain up to 1000 to 1200 m,MSL, followed by laurel forest from 1000 to 2500 m,MSL. These vegetation zones are recognized throughout the Middle Mountain, and forest species changes from humid type in eastern part to dry type in western part.

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 14 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 228 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are summarized and shown in Table A1.4. In recent ten years, the biggest flood occurred in 1997, followed by 1996 and 1993. Floods in 1961 and 1969 were more destructive than the above.

Bank erosion, flooding over farmland and sedimentation are the major types of disasters. According to the data and information obtained from DDC and DIO of Dang and Banke districts, areas suffering from bank erosion and flooding are summarized as shown below.

(Areas Suffering from Bank Erosion and Flooding)

VDC	Bank	Ward No.
Khaskusma	Right and left	No.9
Kachanapur	Right	No.1, 8
Baijapur	Left	No.2, 6
Binauna	Left	No.3, 8
Kamdi	Right	No.1
Fatehpur	Left	No.1, 2, 8, 9
Betahani	Right and left	No.4, 5, 6, 7, 8
Holiya	Right	No.2, 3, 4, 5, 6, 7
Lalmatiya	Right	No.1, 2, 3, 4
Sishaniya	Right	No. 2, 3, 9
Sonpur	Right	No. 2, 4,7
Chailahi	Right	No. 2, 4, 5, 6, 7
Satbariya	Right	No. 2, 3, 4
Gobardiya	Left	No. 1, 8, 9
Gangaparaspur	Left	No. 2, 3, 4, 7, 9
Gadwa	Left	No.6, 7, 8, 9
Rajpur	Left	No.1, 8, 9

Loss of life and damage to properties are shown in Table A1.5, mainly based on data during 1997-flood. According to the field investigation and interviews of residents in the flood-suffering areas during the 1997-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: none
2) Spur : 81 sites
3) Revetment : 15 sites
4) Head work : 1 site
5) Bridge : 3 sites

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 (DOSCWM), 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
				°	'	"	°	'	"			
0301	Mugu	Precipitation	MW	29	45	00	82	33	00	3,803	06-1958	
0302	Thirpu	Precipitation	MW	29	19	00	81	46	00	1,006	12-1956	
0303	Jumla	Synoptic	MW	29	17	00	82	10	00	2,300	12-1956	
0304	Guti Chaur	Precipitation	MW	29	17	00	82	19	00	3,080	06-1976	
0305	Sheri Ghat	Precipitation	MW	29	08	00	81	36	00	1,210	02-1966	
0306	Gam Shree Nagar	Precipitation	MW	29	33	00	82	09	00	2,133	10-1970	
0307	Rara	Climatology	MW	29	33	00	82	07	00	3,048	10-1970	
0308	Nagma	Precipitation	MW	29	12	00	81	54	00	1,905	10-1970	
0309	Bijayapur (Raskot)	Precipitation	MW	29	14	00	81	38	00	1,814	12-1956	
0310	Dipayal Gaun	Climatology	MW	29	16	00	82	13	00	2,310	06-1974	
0311	Simikot	Climatology	MW	29	58	00	81	50	00	2,800	05-1976	
0312	Dunai	Climatology	MW	28	56	00	82	55	00	2,058	06-1958	
0313	Darma	Precipitation	MW	29	44	00	82	06	00	1,950	09-1979	
0401	Pusma Camp	Climatology	MW	28	53	00	81	15	00	950	03-1963	
0402	Dailekh	Climatology	MW	28	51	00	81	43	00	1,402	01-1957	
0403	Jamu (Tikuwa Kuna)	Precipitation	MW	28	47	00	81	20	00	260	05-1963	
0404	Jajarkot	Precipitation	MW	28	42	00	82	12	00	1,231	12-1956	
0405	Chisapani (Karnali)	Climatology	MW	28	39	00	81	16	00	225	01-1963	
0406	Surkhet (Birendra Nagar)	Synoptic	MW	28	36	00	81	37	00	720	01-1957	
0407	Kusum	Precipitation	MW	28	01	00	82	07	00	235	11-1956	West Rapti
0408	Gulariya	Precipitation	MW	28	10	00	81	21	00	215	01-1957	Babai
0409	Khajura (Nepalgunj)	Agrometeology	MW	28	06	00	81	34	00	190	01-1968	West Rapti
0410	Bale Budha	Precipitation	MW	28	47	00	81	45	00	610	05-1965	
0411	Rajapur	Precipitation	MW	28	26	00	81	06	00	129	02-1971	
0412	Naubasta	Precipitation	MW	28	16	00	81	43	00	135	02-1971	West Rapti
0413	Shyalo Shree	Precipitation	MW	28	27	00	81	35	00	302	02-1971	Babai
0414	Baijapur	Precipitation	MW	28	03	00	81	54	00	226	02-1971	West Rapti
0415	Bargadaha	Precipitation	MW	28	26	00	81	21	00	200	11-1967	Babai
0416	Nepalgunj (Reg.Off.)	Climatology	MW	28	04	00	81	37	00	144	02-1973	West Rapti
0417	Rani Jaruwa Nursery	Climatology	MW	28	23	00	81	21	00	200	12-1975	Babai
0418	Maina Gaun (D.bas)	Precipitation	MW	28	59	00	82	17	00	2,000	05-1975	
0419	Sikta	Agrometeology	MW	28	02	00	81	47	00	195	05-1978	West Rapti
0501	Rukumkot	Precipitation	MW	28	36	00	82	38	00	1,560	07-1957	
0502	Shera Gaun	Precipitation	MW	28	35	00	82	49	00	2,150	07-1957	
0504	Libang Gaun	Precipitation	MW	28	18	00	82	38	00	1,270	07-1957	West Rapti
0505	Bijuwar Tar	Precipitation	MW	28	06	00	82	52	00	823	08-1957	West Rapti
0507	Nayabasti (Dang)	Precipitation	MW	28	13	00	82	07	00	698	12-1970	Babai
0508	Tulsipur	Climatology	MW	28	08	00	82	18	00	725	12-1970	Babai
0509	Ghorahi (Masina)	Precipitation	MW	28	03	00	82	30	00	725	12-1970	Babai
0510	Loilabas	Precipitation	MW	27	42	00	82	32	00	320	02-1971	
0511	Salyan Bazar	Climatology	MW	28	23	00	82	20	00	1,457	11-1956	Babai
0512	Luwamjula Bazar	Precipitation	MW	28	18	00	82	17	00	885	11-1971	Babai
0513	Chaur Jhari Tar	Climatology	MW	28	32	00	82	01	00	910	06-1975	
0514	Musikot (Rukumkot)	Climatology	MW	28	38	00	82	29	00	2,100	07-1973	
0515	Ghorai	Synoptic	MW	28	03	00	82	30	00	725	*	

(Note) Reg. MW: Mid Western Region (All the stations of this region are listed.)

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude			Longitude			Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			°	'	"	°	'	"								
120.	Chamelia	Karkale Gaon	29	40	20	80	33	30	-	1,150				01/01/65		
150.	Mahakali	Pancheshwor	29	26	45	80	15	30	-	12,236	C	R		01/01/62		
169.8	Surnagad	Gujar Gaon	29	31	00	80	35	00	-	(66)	C			-		
170.	Surnagad	Patan near Baitadi	29	27	30	80	33	10	1,110	118	C			01/01/66	01/04/88	
190.5	Kandr Khola	Amsara	28	36	00	80	56	00	-	(313)				-		
190.8	Khutiya Khola	Boladevi Gaon	28	53	00	80	44	00	-	-				-		Khutiya
205.	Kharpu Khola	Kharpu	29	57	00	81	52	00	-	1,310				14/05/78		
206.	Humla Karnali	Bihi Chhara	29	38	00	81	52	00	-	(8,447)				17/06/79		
208.	Mugu Karnali	Surkhet	29	37	00	81	52	00	-	5,300	C			13/06/79		
209.	Kawadi Khola	Kawadi Ghat	29	36	16	81	45	28	-	795				17/01/89		
210.	Rara Daha	Nizal	29	31	00	82	04	00	-	1,150				08/11/65		
215.	Humla Karnali	Thuldada	29	09	00	81	36	00	-	15,200	C			06/02/66		
220.	Tila Nala	Nagina	29	12	00	81	55	00	-	1,870	C			19/03/64		
225.	Sinja Khola	Diware	29	12	00	81	55	00	-	824	C			17/03/64		
230.	Tila Nadi	Seti Ghat	29	08	00	81	36	00	-	3,470	C			08/03/64		
240.	Karnali	Asara Ghat	28	57	10	81	26	30	629	19,260	C	R	S	01/01/61		
241.	Lohare Khola	Tallo Dungeswat	28	41	00	81	36	00	-	1,060	C			24/05/65		
245.	Chhamghat Khola	Gitachaur	28	56	00	81	41	30	-	(108)	C			20/03/78		
250.	Karnali	Benighat	28	57	40	81	07	10	320	21,240	C	R		01/02/63		
251.	Seit	Chainpur	29	33	30	80	12	40	-	2,040	C			-		
255.	Bhdhi Ganga	Kakarsant	29	11	00	81	13	00	-	1,340	C			28/04/78		
259.2	Seit	Gopaghat Gaon	29	18	00	80	46	30	-	4,420	C			-		
260.	Seit	Banga near Belgaon	28	58	40	81	08	40	328	7,460	C	R	S	06/02/63		
262.	Tuli Gad	Khanayatal	28	56	00	80	54	00	314	896	C	R		17/06/65		
265.	Thulo Bheri	Rimna	28	42	30	82	17	30	-	6,720	C			18/06/72		
267.	Sano Bheri	Simli Ghat	28	39	30	82	21	30	-	2,620	C			18/06/76		
269.5	Bheri Nadi	Samaiji Ghar							-	-	C	PR		16/12/89		
270.	Bheri	Jamu	28	45	20	81	21	00	246	12,290	C	R	S	23/01/63		
280.	Karnali	Chisapani	28	38	40	81	17	30	191	42,890	C	R	S	01/01/62		

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude			Longitude			Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			°	'	"	°	'	"								
284.	Sarda Khola	Shyalpani-Sita Pall	28	22	30	82	11	45	-	295				17/06/77		Babai
285.	Mohana	Kalakunta	28	27	00	81	00	30	-	(623)				22/04/76		
286.	Sarada Khola	Daradhunga	28	17	58	82	01	30	-	816	C	R	S	01/01/72		Babai
287.	Kauriala Karnali	Sattar Farm	28	24	30	81	05	00	-	-				17/03/80		
288.	Geruwa Karnali	Kothiya Ghat	28	22	30	81	12	00	-	(14,853)				18/03/80		
289.	Babai River	Gangate Gaon	28	15	00	81	57	00						06/01/72		
289.5	Gohar Khola	Sirchaur Gaon	28	09	15	82	22	45	-	-	C			21/06/77		Babai
289.9	Babai Nadi	Gangata							-	-				-		Babai
289.95	Babai Nadi	Chepang							-	-	C	R		01/10/89		Babai
290.	Babai	Bargadha	28	25	20	81	22	10	192	3,000	C	R		16/07/66	13/04/89	Babai
291.	Babai Nadi	Bhada							-	-				-		Babai
327.	Lungri Khola	Khungree Gaon	28	13	30	82	42	30	-	467	C			26/12/76		West Rapti
330.	Mari Khola	Nayagaon	28	04	20	82	48	00	536	1,980	C			01/01/64		West Rapti
333.	Arun Khola	Devistan	28	02	00	82	45	30	-	136	C			--/--/68		West Rapti
339.5	Jhimruk Khola	Tigra Gaon	28	03	00	82	49	40	-	683	C			22/05/71		West Rapti
340.	Jhimruk Khola	Kalimati Ghat	28	02	10	82	53	00	692	696	C			01/01/65	21/05/71	
350.	Rapti	Bagasoti Gaon	27	54	00	82	51	00	381	3,380	C	R	S	08/05/75		West Rapti
350.5	Rangsing Khola	Tinkhanne Gaon	27	47	30	82	49	00	-	(92)	C			03/01/83		West Rapti
360.	Rapri	Jalkundi	27	56	50	82	13	30	218	5,150	C	R	S	08/04/64		West Rapti
380.	Rapti River	Sindhania	28	01	00	81	44	45						06/03/83		
385.2	Rapti River	Farinda							-	-				-		West Rapti
387.4	Dumre Khola	Kalimati	27	47	47	83	32	09	595	90	C			18/06/80		Tinau
387.5	Madi Tinau	Charchare	27	47	29	83	33	08	570	103	C	R		17/06/80		Tinau
387.8	Jhumsa Khola	Dumahi Bari	27	45	00	83	30	46	335	99	C			15/02/85		Tinau
390.	Tinau Khola	Butwal	27	42	10	83	27	50	184	554	C			09/12/63		Tinau
403.	Kali Gandaki	Jomsom	28	47	30	83	45	00	-	(3,060)				07/06/69		Narayani
403.5	Kali Gandaki	Tatopani	28	29	00	83	39	00	1,239	-		R		--/03/92		
404.6	Kali Gandaki	Kalipul Beni	28	21	30	83	34	30	-	(4,581)				05/04/71		Narayani
404.7	Myagdi Khola	Mangla Ghat	28	21	30	83	32	00	-	(1,112)	C			19/05/75		Narayani

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude			Longitude			Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			°	'	"	°	'	"								
406.	Kali Gandaki	Modi Beni	28	12	00	83	42	00	667	-		R		--/03/92		
406.5	Modi Khola	Nayapul	28	13	30	83	42	15	-	(635)	C			25/05/75		Narayani
409.5	Seti Khola	Seti Beni	28	00	40	83	37	10	-	(138)				22/02/76		Narayani
410.	Kali Gandaki	Seti Beni	28	00	30	83	36	10	546	6,630	C	R	S	21/02/64		Narayani
413.2	Danab Khola								-	-	C			27/05/90		
414.1	Dararun Khola	Arjun Chaupari							-	-				01/01/90		
415.	Andhi Khola	Dumrichaur Andhimuhan	27	58	20	83	35	20	543	476	C			06/04/89		Narayani
416.2	Daram Khola	Wamitaksar	28	11	45	83	18	15	-	(239)	C			18/12/78		Narayani
417.	Badigad Khola	Rudrabeni Gulmi	27	58	20	83	28	10	-	1,990	C			24/05/67		Narayani
419.1	Kali Gandaki	Ansigh-AndhiGhat							-	-	C			13/04/89		Narayani
420.	Kali Gandaki	Kotagaon Shringe	27	45	00	84	20	50	198	11,400	C	R		15/04/64		Narayani
428.	Mardi Khola	Lahachok	28	18	30	83	55	30	-	160	C			07/06/70		Narayani
430.	Seti Khola	Phoolbari	28	14	00	84	00	00	830	582	C			01/01/89		Narayani
438.	Madi	Shisa Ghat	28	06	00	84	14	00	-	858	C			08/02/73		Narayani
439.3	Khudi Khola	Khudi Bazar	28	17	15	84	21	45	-	(151)	C			04/07/81		Narayani
439.4	Dordi Khola	Amote Bazar-Sera Besi	28	10	45	84	27	30	-	(341)	C			09/02/76		Narayani
439.7	Marsyangdi	Bimal Nagar	27	57	00	84	25	48	354	(4,088)	C	R	S	31/03/87		Narayani
439.8	Marsyangdi	Gopling Ghat	27	55	35	84	29	42	320	3,850	C	R	S	01/06/73	21/05/88	
440.	Chepe Khola	Garam Besi	28	03	41	84	29	23	442	308	C	PR		20/11/63		Narayani
441.	Daraundi Khola	Nayasanghu Gorkha	28	01	00	84	35	15	-	386	C			13/10/67		Narayani
441.5	Daraundi Khola	Ramdi												26/12/86		
445.	Burhi Gandaki	Arughat	28	02	37	84	48	59	485	4,270	C	R	S	28/11/63		Narayani
445.3	Ankhu Khola	Ankhu Bridge	27	58	20	84	49	10	-	768	C			--/--/67		Narayani
446.15	Lirung Khola	Kyangjin												-		
446.2	Langtang Khola	Shyaprubesi	28	09	30	85	20	45	-	(540)	C			-		Narayani
446.25	Bhote Kosi	Syaprubesi							-	-				-		
446.3	Trisuli Khola	Dhunche	28	07	10	85	17	40	-	49	C	R		--/--/63		Narayani
446.8	Phalankhu Khola	Betrawati	27	58	25	85	11	15	630	162				24/04/69		Narayani
447.	Trisuli	Betrawati	27	58	08	85	11	00	600	4,110	C	R	S	01/04/67		Narayani

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude			Longitude			Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			°	'	"	°	'	"								
447.4	Tadi Khola	Rautar Nuwakot	27	55	00	85	17	10	-	254				-		Narayani
447.9	Likhu Khola	Pattawari Nuwakot	27	53	30	85	14	45	-	(145)				-		Narayani
448.	Tadi Khola	Tadipul Belkot	27	51	35	85	08	18	475	653				14/06/68		Narayani
449.9	Trisuli	Mugling	27	51	00	84	34	30	-	-				-		Narayani
449.91	Trishuli	-							-	-				-		
449.95	Trisuli	Bhorletar	27	49	00	84	26	45	-	(14,500)	C			26/02/82		Narayani
450.	Narayani	Narayan Ghat	27	42	30	84	25	50	180	31,100	C	R	S	10/02/62		Narayani
460.	Rapti	Rajaiya	27	26	30	84	58	15	332	579	C			01/01/63		Narayani
465.	Manahari Khola	Manahari	27	33	00	84	48	10	305	427	C	R		13/06/63		Narayani
470.	Lothar Khola	Lothar	27	35	40	84	43	00	336	169	C			30/11/63		Narayani
505.	Bagmati	Sundarijal	27	46	30	85	25	40	1,600	17	C	R		07/12/62		
507.	Nagmati	Sundarijal	27	46	20	85	26	10	1,660	13				00/11/63		
510.	Sialmati	Syamdado	27	46	10	85	25	10	1,660	3				00/11/63		
511.	Dhakal Khola	Gagalgau	27	44	45	85	26	15	-	-				-		
520.	Bagmati River	Gokarna	27	43	45	85	23	30		56				-		
525.5	Manahara River	Shakyu Salmutar							-	-				04/03/00		
530.	Bagmati	Gauri Ghat	27	42	30	85	21	00	1,300	68				15/11/64		
536.2	Bishnumati Khola	Budhanilkantha	27	46	49	85	21	32	1,454	4				27/05/68	27/08/98	
540.	Nakhu Khola	Tika Bhairab	27	34	30	85	18	50	1,400	43				23/11/62		
548.	Nakhu Khola	Nakhu Jail Near Patan	27	39	40	85	18	30	-	56				01/01/87		
550.	Bagmati River	Chovar	27	39	40	85	17	50	1,280	585	C	R	S	01/07/62	--/--/80	
550.05	Bagmati	Khokana	27	16	00	85	13	00	1,255	607		PR		01/06/91		
550.1	Bagmati River	Sampkhel	27	33	30	85	15	45	-	-	C	R	S	15/06/85		
565.	Kulekhani Khola	Lamichaur	27	36	13	85	09	39	1,514	122	C	R		01/07/75	09/12/78	
570.	Kulekhani Khola	Kulekhani	27	35	10	85	09	30	1,480	126	C	R	S	01/12/62	15/11/77	
586.	Bagmati	Rai Gaon							-	-				01/02/88		
589.	Bagmati	Pandhera Dobhan	27	06	20	85	28	30	180	2,700	C	R	S	28/01/79		
590.	Bagmati	Karmaiya - Mangalpur	27	06	20	85	28	30	177	2,720		R	S	21/06/64	17/10/84	
592.	Bagmati	Bramhapuri	26	45	30	85	20	00	-	(13,790)				-		

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude	Longitude	Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			° ' "	° ' "								
595.	Jamuni	Chyutaha	26 57 00	85 20 00	-	-				19/03/92		
598.	Kamala	Chisapani	26 55 15	86 10 30	-	(1,595)				-		
599.	Kamala	Inarawa	26 36 45	86 09 00	-	-				-		
600.05	Barun Khola	Seksila Hatiya	27 41 00	87 21 00	1,500	352				22/12/86		
600.1	Arun	Uwa Gaon	27 36 00	87 20 06	1,294	26,750	C	R	S	11/05/72		
601.8	Pangtha Khola	Kurle Besi	27 24 00	87 13 30	-	(26)				01/09/98		
601.9	Pangma Khola	Kurle Besi	27 24 00	87 12 45	-	(38)				01/09/98		
602.	Sabhaya Khola	Tumlingtar	27 18 20	87 13 15	-	375	C	R		02/01/74		
602.5	Hinwa Khola	Pipletar	27 17 45	87 13 30	-	110	C			-		
604.	Arun	Leguwa Ghat	27 09 00	87 16 30	-	(4,183)				01/06/68		
604.5	Arun	Turkeghat	27 20 00	87 11 30	414	28,200	C	R		23/05/75		
605.	Pikhuwa Khola	Parapani Phedi	27 05 00	87 07 00		337				0/0/64		
606.	Arun	Simle	26 55 30	87 09 30	-	30,380	Br			-		
610.	Bhote Kosi	Barabise	27 47 10	85 53 20	840	2,410				17/02/65		
612.	Sun Kosi	Barabise	27 46 30	85 54 30	-	(84)				-		
620.	Balephi Khola	Jalbire	27 48 20	85 46 10	793	629	C			25/12/63		
625.	Sun Kosi	Dolalghat	27 38 30	85 43 00	-	(1,375)	C			-		
627.5	Melamchi Khola	Helambu	28 02 30	85 32 00	-	-				-		
627.55	Melamchi Khola	Sajhaya			-	-				-		
629.1	Indrawati	Dolalghat	27 38 20	85 42 30	-	1,225	C			17/09/72		
630.	Sunkosi	Pachuwar Ghat	27 33 30	85 45 10	589	4,920	C			26/03/64		
640.	Rosi Khola	Panauti	27 34 50	85 30 50	1,480	87				17/10/63		
641.	Rosi Khola	Lold Khola			-	-				-		
647.	Tamakosi	Busti	27 38 05	86 05 12	849	2,753	C	R		14/01/70		
650.	Khimti Khola	Rasnalu Village	27 34 30	86 11 50	1,520	313	C			06/04/64		
652.	Sunkosi	Khurkot	27 20 00	86 00 00	455	10,000	C			01/07/67		
660.	Likhu Khola	Sanghu Khola	27 20 10	86 13 10	543	823	C			24/03/64		
665.	Sun Kosi	Ahrkapur (Tokselghat)	27 10 30	86 22 00	-	(8,736)	C			20/02/86		
668.4	Taktor Khola	Beni	27 31 45	86 33 30	2,350	(87)	Br			-		

LIST OF HYDROMETRIC STATIONS

Station No.	Name of River	Name of Site	Latitude			Longitude			Elevation (m)	Drainage Area (km^2)	Instrument			Start of Record	End of Record	Remarks
			°	'	"	°	'	"								
668.5	Solua Khola	Salme	27	30	30	86	33	15	1,800	(324)	Br			-		
669.5	Rawa Khola	Gaikhure	27	16	00	86	40	30						-		
670.	Dudh Kosi	Rabuwa Bazar	27	16	00	86	39	50	460	4,100	C	R	S	10/03/64		
680.	Sun Kosi	Kampughat	26	52	30	86	49	20	200	17,600				28/06/65		
681.	Sun Kosi	Hampuachuwar	26	55	15	87	08	45	-	-	C			-		
684.	Tamur	Majhitar	27	09	30	87	42	45	-	-	C			-		
685.3	Maiwa Khola	Maiwa Dovan	27	22	10	87	36	50		194				-		
685.9	Hima Khola	Thapatar (Phidim)	27	09	45	87	46	15						0/0/74		
688.5	Madhu Khola	Dhankuta	26	59	30	87	22	15						-		
688.6	Banchare Khola	Dhankuta	26	59	00	87	22	30		13				-		
688.7	Nibuwa Khola	Dhankuta	26	59	00	87	23	15	-	(28)				-		
689.	Tankhuwa Khola	Biretar Near Dhankuta	26	58	30	87	22	15	-	51				--/--/64		
690.	Tamur	Mulghat	26	55	50	87	19	45	276	5,640	Br	PR	S	11/03/65		
691.	Tamur	Tribeni	26	55	00	87	10	00	-	(6,146)	C			-		
695.	Sapta Koshi	Chatara-Kothu	26	52	00	87	09	30	140	54,100	C		S	01/01/77		
698.	Sardu Khola	Mathilo Sardu-Dharan	26	51	00	87	18	05		7				0/0/71		
715.	Mai Khola	Mai Beni	26	53	25	87	57	20		210				0/0/71		
720.	Jog Mai Khola	Mai Beni	27	53	40	87	59	20		140				0/0/67		
728.	Mai Khola	Rajdwail	26	52	45	87	55	45	-	377	C		S	01/01/83		
730.	Puwa Khola	Sajbote (Ilam)	26	55	00	87	54	40	802	107	C			18/01/65		
738.	Deo Mai Khola	Angdang	26	54	00	87	46	15	-	(199)	C			-		Ratuwa ?
795.	Kankai Mai	Mainachuli	26	41	12	87	52	44	125	1,148	C	R		01/05/71		
799.	Kankai	Kumarkhod-Jhapa							-	-				30/10/87		
848.4	Siddhi Khola	Kajeni	26	51	15	88	07	00	-	-				-		

Note:

C: Cable way for discharge measurement
Br: Bridge available for discharge measurement
R: Recording gauge for water level observation
PR: Pressure type gauge for water level observation

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
West Rapti River															
WR-1	2.7	7.9	72.6	96.5	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-2	5.9	16.2	97.5	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-3	0.6	3.1	45.5	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-4	3.3	7.8	64.4	93.1	96.8	97.1	97.6	98.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-5	0.0	0.1	5.2	39.0	98.7	99.3	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-6	3.3	8.6	88.1	98.2	98.9	99.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-7	0.7	1.2	4.3	11.0	15.2	17.4	22.6	31.2	45.7	54.4	63.1	73.1	91.0	100.0	100.0
WR-8	0.0	0.1	4.0	27.4	97.5	99.3	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-9	1.3	4.9	27.2	90.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-10	0.1	0.4	3.8	10.1	15.4	18.9	25.1	35.3	48.5	57.4	67.0	77.5	100.0	100.0	100.0
WR-11	0.5	1.0	4.4	8.1	12.3	16.4	20.7	24.8	34.5	40.9	48.9	57.8	79.5	100.0	100.0
WR-12	0.3	0.6	7.8	15.7	19.7	21.7	25.8	35.6	52.8	63.9	75.5	84.5	100.0	100.0	100.0
WR-13	0.4	0.9	5.1	9.3	12.4	15.1	19.2	24.7	32.5	37.5	44.2	54.1	77.8	100.0	100.0
WR-14	0.8	2.2	41.3	92.4	99.0	99.3	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-15	1.9	6.2	41.5	72.0	89.9	93.3	95.9	98.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-16	5.3	12.8	89.3	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WR-17	4.4	9.1	54.7	68.2	71.5	72.3	74.3	81.0	86.4	89.8	93.4	96.0	100.0	100.0	100.0
WR-18	0.1	0.2	1.1	3.3	7.3	11.7	14.7	17.5	29.6	37.6	48.5	60.1	88.9	100.0	100.0
WR-19	3.7	6.1	10.1	12.9	17.3	21.6	27.9	35.5	54.4	66.5	79.8	90.6	100.0	100.0	100.0
WR-20	1.3	2.7	11.9	20.9	24.8	27.1	31.0	38.0	55.3	63.9	73.3	83.7	100.0	100.0	100.0
WR-21	1.3	2.4	6.4	6.4	13.9	17.2	22.8	30.0	48.6	59.2	71.4	80.7	100.0	100.0	100.0
WR-22	3.1	4.7	8.2	11.0	14.0	17.0	20.8	26.9	38.3	45.0	54.6	63.1	79.7	100.0	100.0
WR-23	0.4	0.8	3.1	4.8	6.4	11.4	18.2	24.7	34.4	39.0	46.4	52.9	74.3	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)
West Rapti River								
WR-1	0.12	0.21	0.23	0.32	2.73	2.67	2.69	2.68
WR-2	0.11	0.17	0.18	0.22	2.06	2.56	2.60	2.58
WR-3	0.14	0.29	0.30	0.37	2.65	2.66	2.60	2.63
WR-4	0.12	0.23	0.25	0.36	2.99	2.59	2.60	2.60
WR-5	0.30	0.54	0.57	0.72	2.42	2.56	2.60	2.58
WR-6	0.11	0.18	0.19	0.24	2.08	2.66	2.63	2.65
WR-7	1.17	33.09	39.99	77.97	66.38	2.65	2.68	2.67
WR-8	0.33	0.59	0.62	0.74	2.27	2.63	2.66	2.65
WR-9	0.16	0.33	0.34	0.40	2.47	2.59	2.60	2.60
WR-10	0.99	29.15	34.94	63.62	64.16	2.68	2.70	2.69
WR-11	1.84	56.53	65.43	116.43	63.32	2.59	2.63	2.61
WR-12	0.45	23.56	27.35	51.89	116.57	2.66	2.68	2.67
WR-13	2.43	62.10	71.00	121.36	49.86	2.64	2.61	2.63
WR-14	0.14	0.30	0.32	0.39	2.71	2.67	2.68	2.68
WR-15	0.13	0.34	0.38	0.68	5.03	2.63	2.67	2.65
WR-16	0.11	0.18	0.19	0.24	2.15	2.65	2.63	2.64
WR-17	0.12	0.31	0.38	13.95	115.59	2.65	2.67	2.66
WR-18	6.50	52.86	59.06	89.77	13.80	2.67	2.63	2.65
WR-19	0.69	22.17	25.42	42.90	61.82	2.60	2.59	2.60
WR-20	0.32	22.82	27.64	53.59	168.32	2.66	2.69	2.68
WR-21	1.47	27.09	31.25	59.10	40.29	2.67	2.70	2.69
WR-22	1.49	46.69	56.91	115.82	77.62	2.60	2.63	2.62
WR-23	3.58	65.48	75.93	129.90	36.26	2.63	2.67	2.65
							Average	2.64

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: **WEST RAPTI RIVER(1/2)**

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1997(144), 1993(12), 1996(12), 1995(3)
1.2	Floods in a year (times)	Average(7) ranging(4 to 12)
1.3	Severe floods in past 10 years (times)	Average(5) ranging(2 to 12)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(150) • Sediment flow(37) • Bank erosion(69) • Others(13)
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(88) • Buffalo(30) • Sheep/Goat(15) • Poultry(0)
2.3	Damage to farm land (ha)	• Irrigated land: Average(0.0) ranging(0) • Non-irrigated land: Average(1.7) ranging(0.7 to 2.7)
2.4	Extent of damage to farm land	• Simple inundation (nop): 0 • Loss of crops (nop): Paddy(79), Sugarcane(0), Maize(4), Others(1) • Total washout (ha): Average(1.6) ranging(0 to 16.0)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(2.3) ranging(1 to 7) • Flooding depth in (m): Average(1.5) ranging(0.75 to 2.0) • Damage to house (nop): Severe(32), Moderate(6), Ordinary(22) • Loss of cash (Rs): (No answer) • Loss of food grains (kg): Paddy: Average(250) ranging(0 to 460) • Clothing (nos): Average(0) ranging(0) • Other valuables: Average(0) ranging(0)
2.6	Problems during flood (nop)	• Erosion of river bank(82) • Sediment in the river(15) • Sediment in irrigation canal(8) • Drinking water problem(48) • Sanitary problem(2) • Salinity(0) • Flooding over farm land(43) • Others(9)
2.7	Epidemic disease after flood? (nop)	• Yes(28) • No(13)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(11) • Dysentery(10) • Typhoid(0) • Others(7)
2.9	Fatal causality? (nop)	• Yes(0) • No(43)
2.10	Reason of flood(nop)	• Too much rain(31) • Lack of flood protection works(75) • Weak river training works(5) • Sediment load in the flood water(3) • Flood from adjoining rivers(7)
2.11	Total amount of damage (Rs)	Average(211,000) ranging(0 to 1,500,000)

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

SUMMARY OF QUESTIONNAIRES BY RIVER

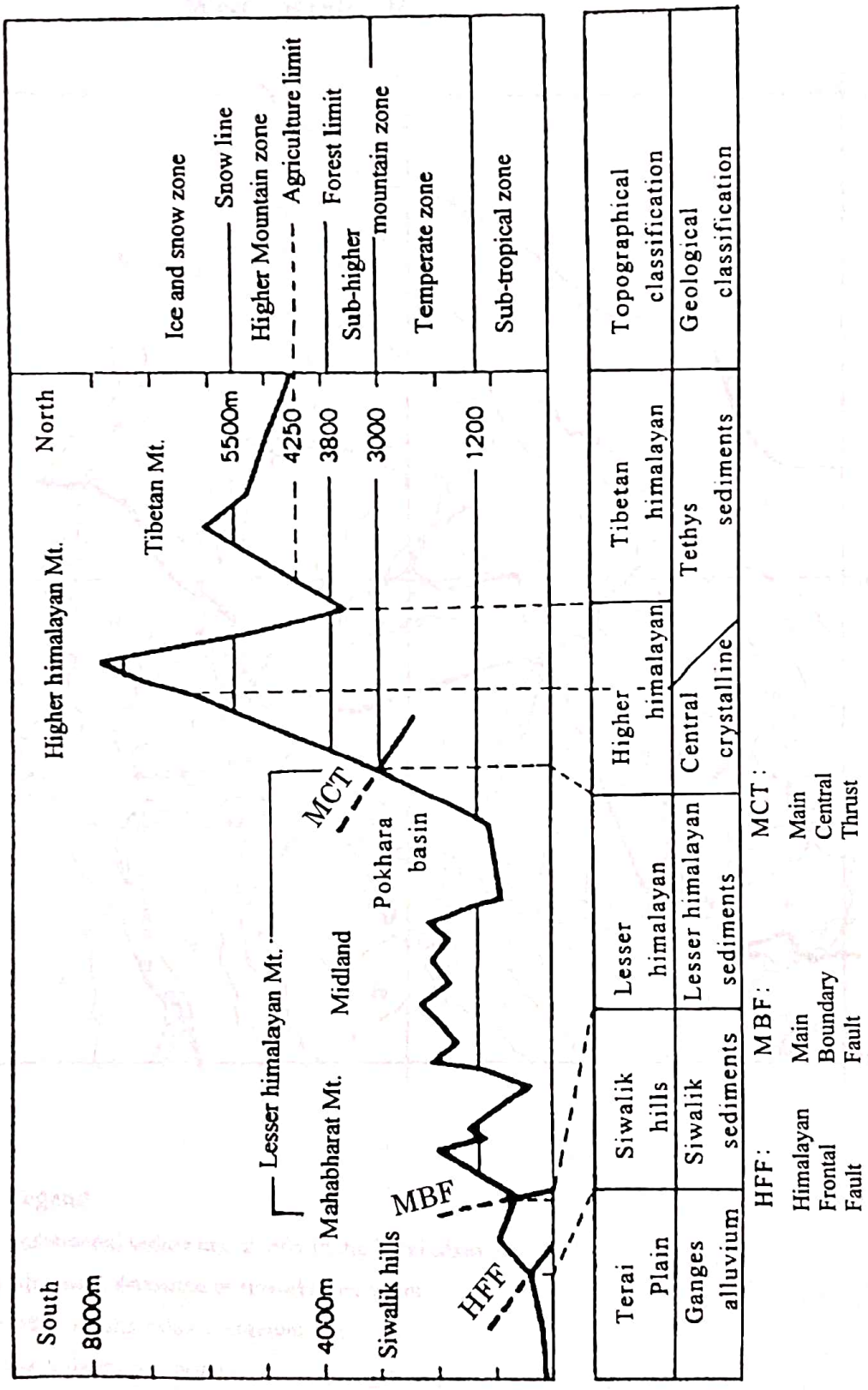
Name of river: **WEST RAPTI RIVER(2/2)**

No.	Questions/items	Summary of answers
3. FLOOD WARNING SYSTEM		
3.1	(Cancelled)	(Cancelled)
3.2	Self warning (nop)	· Heavy rain/High flood level(100) · Bank erosion(4) · Smelled mud(0) · Unusual sound(16) · Others(2)
3.3	Warning by others (nop)	· Neighbors(0) · Institutions(0) · Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	· Yes(52) · No(127)
4.2	If yes, place of evacuation (nop)	· High ground(10) · Public building(0) · Others houses(5) · Other sites(33)
4.3	Being relieved? (nop)	· Yes(4) · No(169)
4.4	If yes, how?(nop)	· In cash(3) · Kind(1)
4.5	Organization/individual giving relief (nop)	· Central government(3) · DDC(0) · VDC(4) · Other institutions(0) · NGO(0) · Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	· Warning(0) · Evacuation(12) · Settlement(21)
5.1b	Proposed preparedness/ measures (nop)	· Warning(5) · Evacuation(3) · Settlement(26)
5.2a	Current non-structural measures (nop)	· Seed storage(0) · Cash pools(0) · Informal insurance(0) · Others(0)
5.2b	Proposed non-structural measures (nop)	· Seed storage(4) · Cash pools(5) · Informal insurance(4) · Others(1)
5.3a	Current structural measures (nop)	· Embankment(0) · Spur(0) · Simple gabion(0) · Plantation(0) · Others(1)
5.3b	Proposed structural measures(nop)	· Embankment(125) · Spur(63) · Simple gabion(30) · Plantation(16) · Others(2)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	· Yes(49) · No(137)
6.2	If yes, type (nop)	· Cash(2) · Labor(48) · Kind(0) · Care taker(2) · Others(2)
6.3	If no, reason (nop)	· Being affected badly(4) · Financially weak(0) · Being out of the area(1) · No willingness(1) · Others(135)
6.4	Willing to participate in future? (nop)	· Yes(159) · No(23)
6.5	If yes, type (nop)	· Cash(19) · Labor(163) · Kind(5) · Care taker(26) · Others(2)
6.6	If no, reasons (nop)	· No time(4) · No benefit(21) · No Willingness(0) · Not known how to participate(0) · Others(0)

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

LOSS OF LIFE AND DAMAGE TO PROPERTIES (WEST RAPTI RIVER)
(1997-FLOOD)

VDC/Municipality	Loss of				Damage of						Remarks
	Human Life (nos.)	Cattle (nos.)	Land (hac)	House (nos.)	Crop (ton)	Land (hac)	House (nos.)	Public Facility			
								Road (m)	Channel (m)	Others	
Kanchapur	8	3	17	-	-	-	-	-	-	-	at Agahiya
Khaskusum	-	-	-	-	-	30	-	-	-	-	near Rapti
Barijapur	-	5	10	-	-	30	-	-	-	-	Bridge
Bihauna	-	-	15	25	8	-	-	-	-	-	BANKEY
Kamdi	3	13	67	25	92	-	30	-	-	-	DISTRICT
Fatehpur	-	35	157	5	-	-	-	-	-	-	
Betahani	2	45	50	5	210	-	30	-	-	-	
Holiya	22	37	242	25	81	95	160	-	-	-	Ferry
Gangapur	-	40	75	25	-	-	-	-	-	-	Accident
Lalmatiya	-	-	121	-	-	-	-	-	-	-	
Sonpur	-	-	28	-	-	4	22	-	-	-	DANG
Sishaniya	-	22	6	-	-	-	4	33	-	-	DISTRICT
Chailahi	-	-	29	-	-	3	-	-	-	-	
Satbariya	-	-	85	-	-	13	-	-	-	-	
Gobardiha	-	-	9	13	-	-	-	-	-	-	
Gangaparaspur	-	-	78	-	-	-	-	-	-	-	
Gadwa	-	-	22	-	-	-	-	38	-	-	
Rajpur	-	-	21	-	-	-	-	-	-	-	
Total	35	200	1,032	123	391	175	246	71	0	0	



TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

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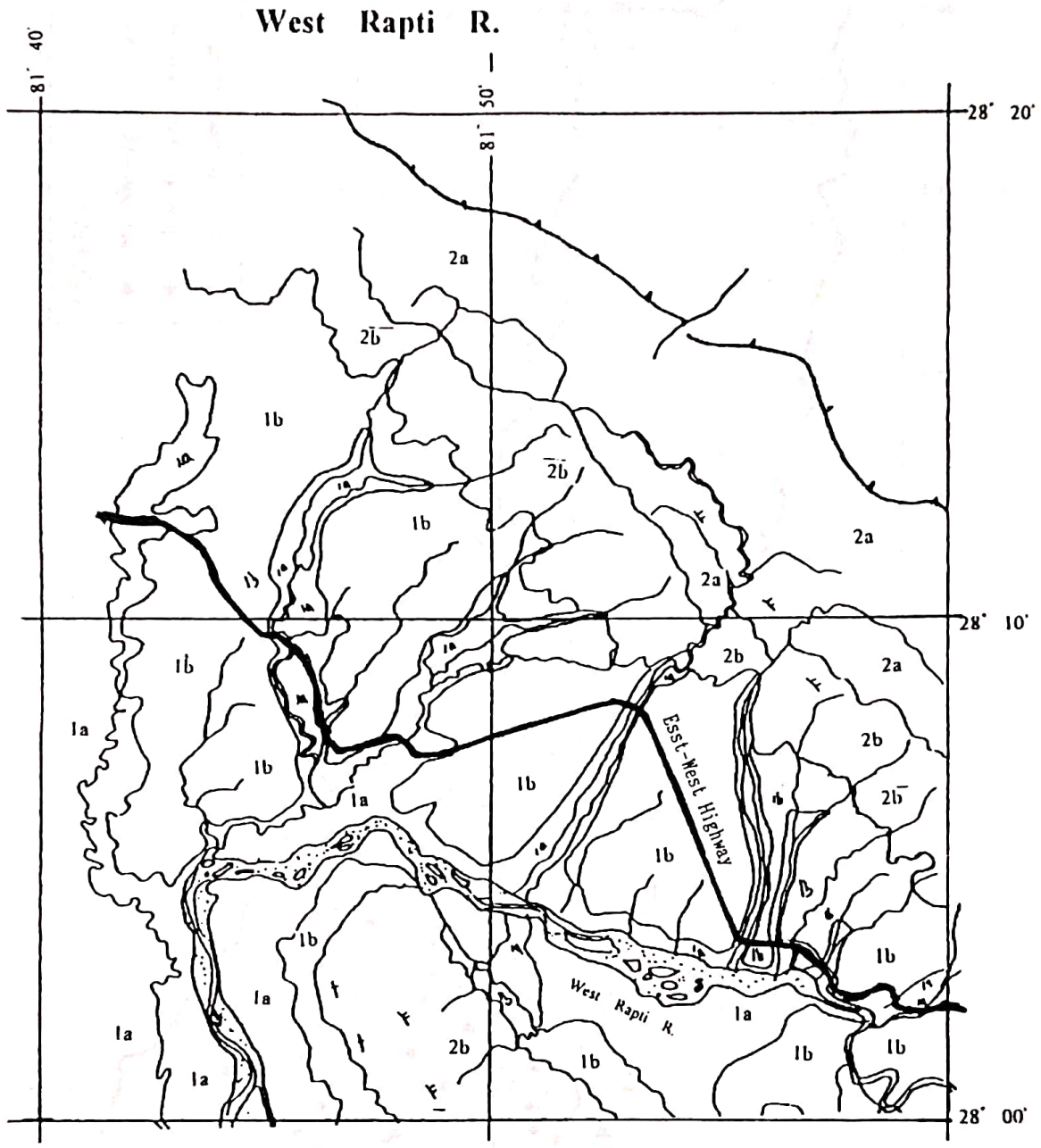
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



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(WEST RAPTI R.)

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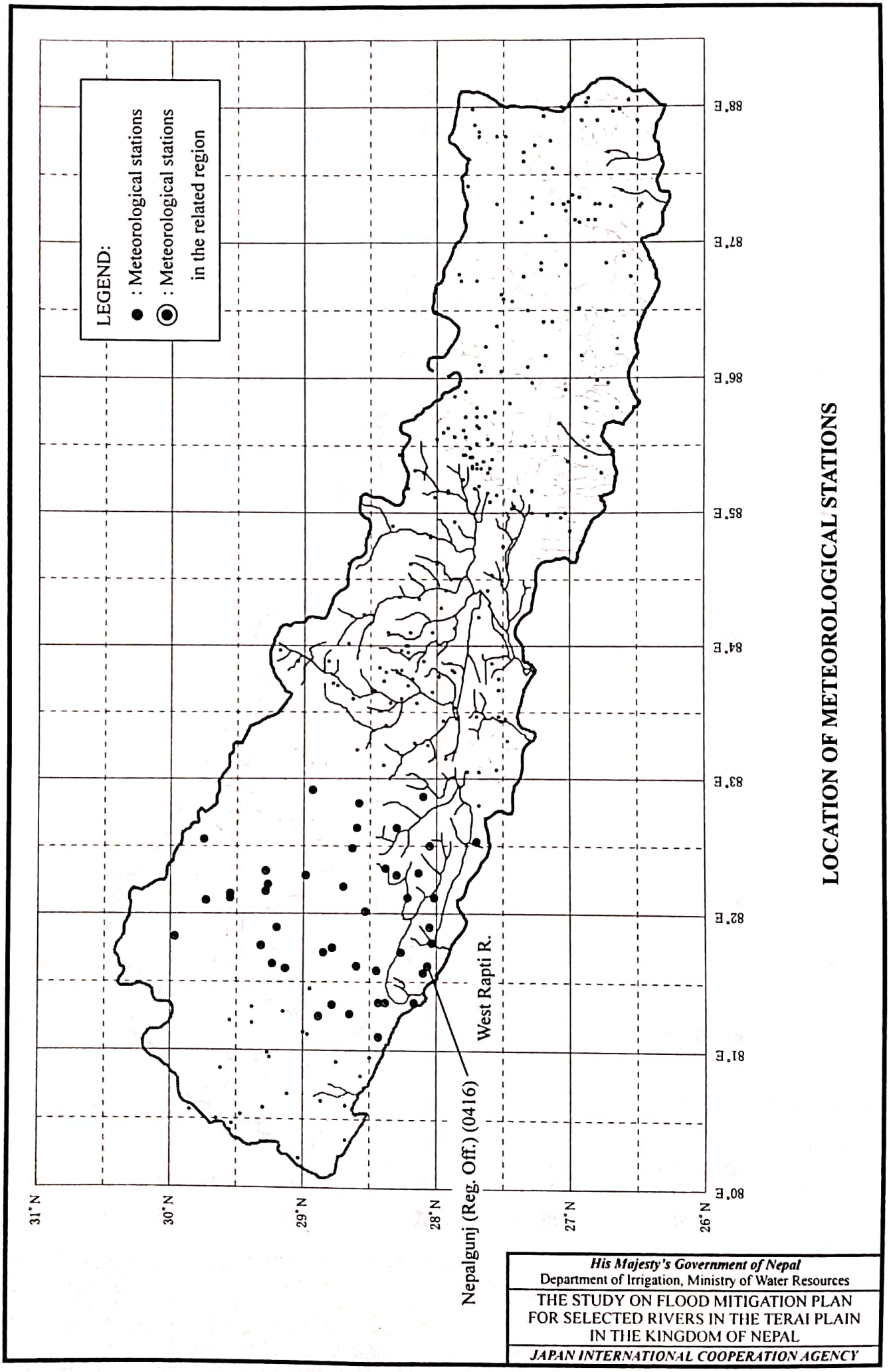

LOCATION OF METEOROLOGICAL STATIONS

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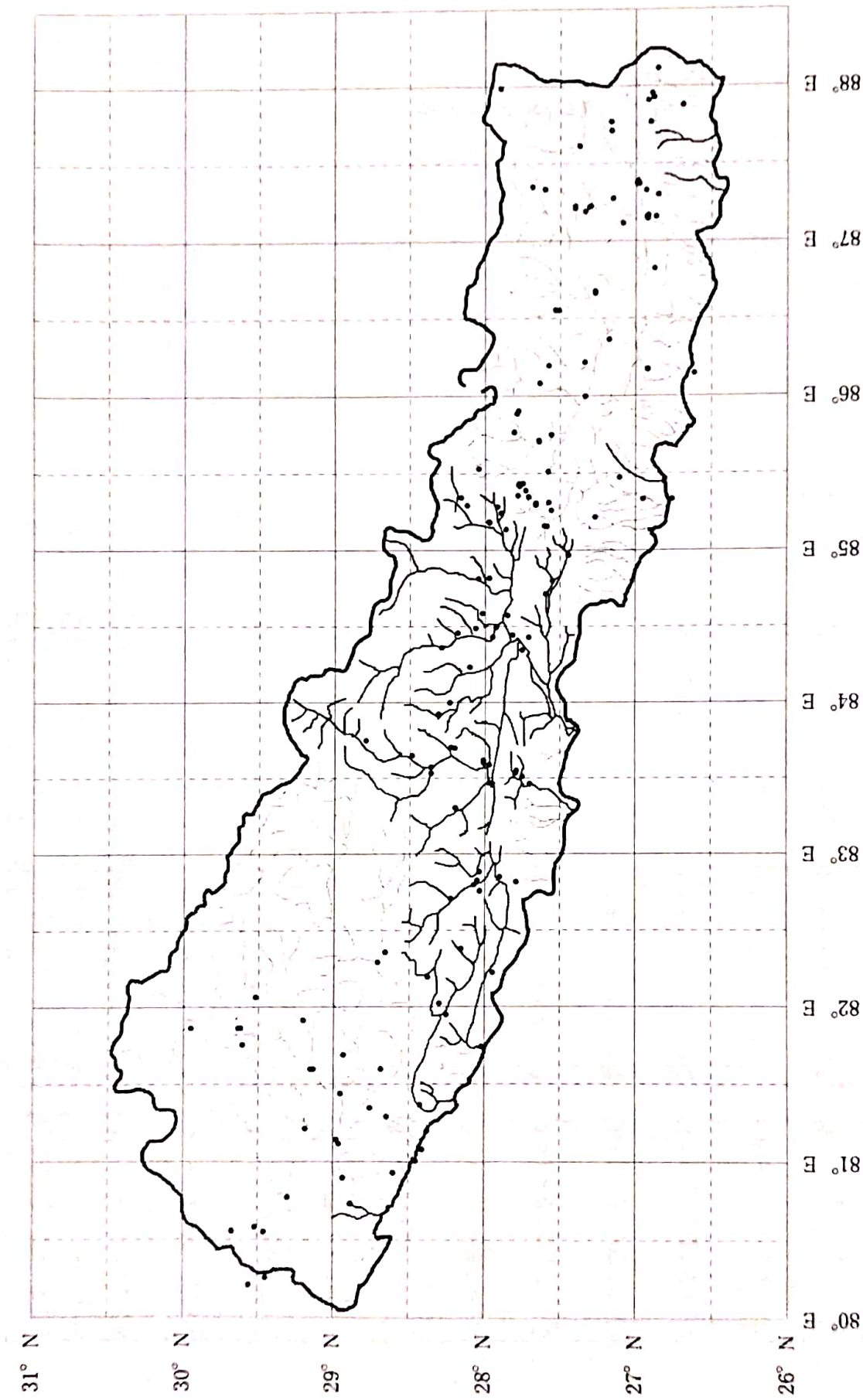

LOCATION OF HYDROMETRIC STATIONS

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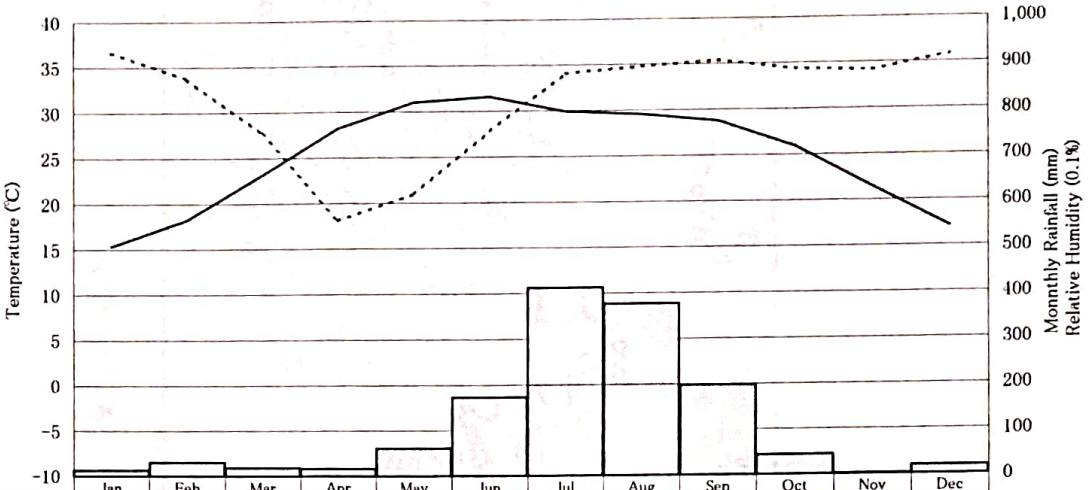
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

Code: 0416
Station: Nepalgunj (Reg.Off.)

Latitude: 28°04'
Longitude: 81°37'
Elevation: 144 m

Nepalgunj (Reg.Off.) (0416)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, Total	13.5	30.9	18.9	17.0	61.7	173.4	412.7	377.0	198.1	44.6	2.1	19.6
Air Temperature, Mean	15.4	18.2	23.1	28.2	31.0	31.6	29.9	29.6	28.8	26.0	21.5	17.1
Relative Humidity, 08:45	933	875	754	562	620	757	882	896	908	888	883	917

Air Temperature, Mean (Unit: °C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	15.8	17.9	24.6	29.5	32.0	31.6	29.1	29.7	28.1	25.3	21.1	17.3	25.2
1986	15.8	18.2	23.5	28.0	29.6	31.6	29.5	29.9	28.7	25.5	22.1	17.5	25.0
1987	16.5	20.8	24.3	28.4	30.0	33.7	29.6	29.6	29.3	26.2	21.2	17.1	25.5
1988	16.0	19.2	22.8	29.0	31.7	31.1	29.5	29.0	29.2	26.1	22.0	-	-
1989	14.4	16.6	22.5	27.5	31.6	29.9	29.4	29.4	28.6	26.4	21.2	17.1	24.5
1990	15.4	17.7	21.7	27.4	29.3	31.2	29.0	29.9	29.0	25.4	21.6	17.3	24.5
1991	14.8	19.0	23.6	28.0	32.5	31.6	30.8	29.5	28.8	26.1	19.8	16.3	25.0
1992	15.0	16.1	23.2	29.1	30.8	32.1	32.0	29.7	28.9	26.2	21.7	16.5	25.1
1993	14.0	19.4	21.4	27.5	30.5	31.1	30.1	29.6	28.5	26.8	22.7	18.0	25.0
1994	16.3	17.8	23.9	28.1	32.5	32.4	30.6	29.5	29.1	25.9	21.5	17.1	25.4
Ave.	15.4	18.2	23.1	28.2	31.0	31.6	29.9	29.6	28.8	26.0	21.5	17.1	25.0

Relative Humidity, 08:45 (Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	92	84	65	49	54	72	87	87	90	89	87	92	79.0
1986	91	91	73	52	53	69	86	86	86	87	87	94	79.6
1987	92	86	72	55	57	65	89	87	87	88	88	91	79.8
1988	94	83	70	52	63	75	89	91	91	89	85	92	81.2
1989	93	84	78	48	55	82	89	90	94	93	91	92	82.4
1990	96	93	82	60	77	84	91	89	93	88	88	90	85.9
1991	93	84	78	60	62	77	85	91	92	86	90	92	82.5
1992	94	92	77	62	63	71	88	90	94	91	91	94	83.9
1993	95	89	77	67	77	84	92	94	92	90	92	91	86.7
1994	93	89	82	57	59	78	86	91	89	87	84	89	82.0
Ave.	93.3	87.5	75.4	56.2	62.0	75.7	88.2	89.6	90.8	88.8	88.3	91.7	82.3

Precipitation, Total (Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	5	2	0	4	37	218	295	481	447	157	0	11	1,657
1986	3	46	6	24	46	96	212	274	190	53	3	56	1,009
1987	4	24	0	31	102	58	684	139	196	48	0	8	1,294
1988	15	10	20	22	63	157	834	629	106	23	0	32	1,911
1989	45	20	27	0	47	133	613	269	268	58	12	19	1,511
1990	0	100	95	0	146	293	510	210	158	19	0	34	1,565
1991	13	26	10	25	29	112	174	453	132	0	0	36	1,010
1992	9	12	0	8	20	125	201	432	230	88	6	0	1,131
1993	8	4	31	56	90	427	369	557	196	0	0	0	1,738
1994	33	65	0	0	37	115	235	326	58	0	0	0	869
Ave.	13.5	30.9	18.9	17.0	61.7	173.4	412.7	377.0	198.1	44.6	2.1	19.6	1,370

METEOROLOGICAL CONDITIONS

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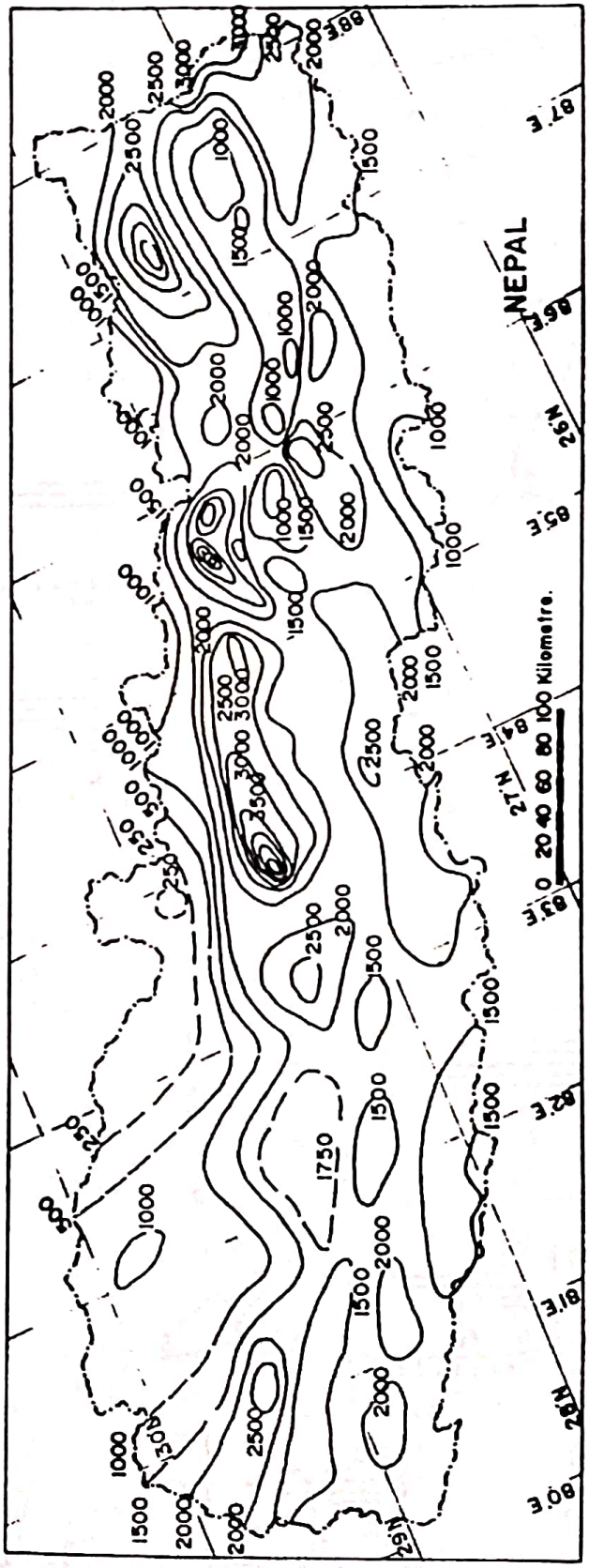
MEAN ANNUAL PRECIPITATION (mm) 1971-1985



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

ANNUAL RAINFALL DISTRIBUTION OF NEPAL

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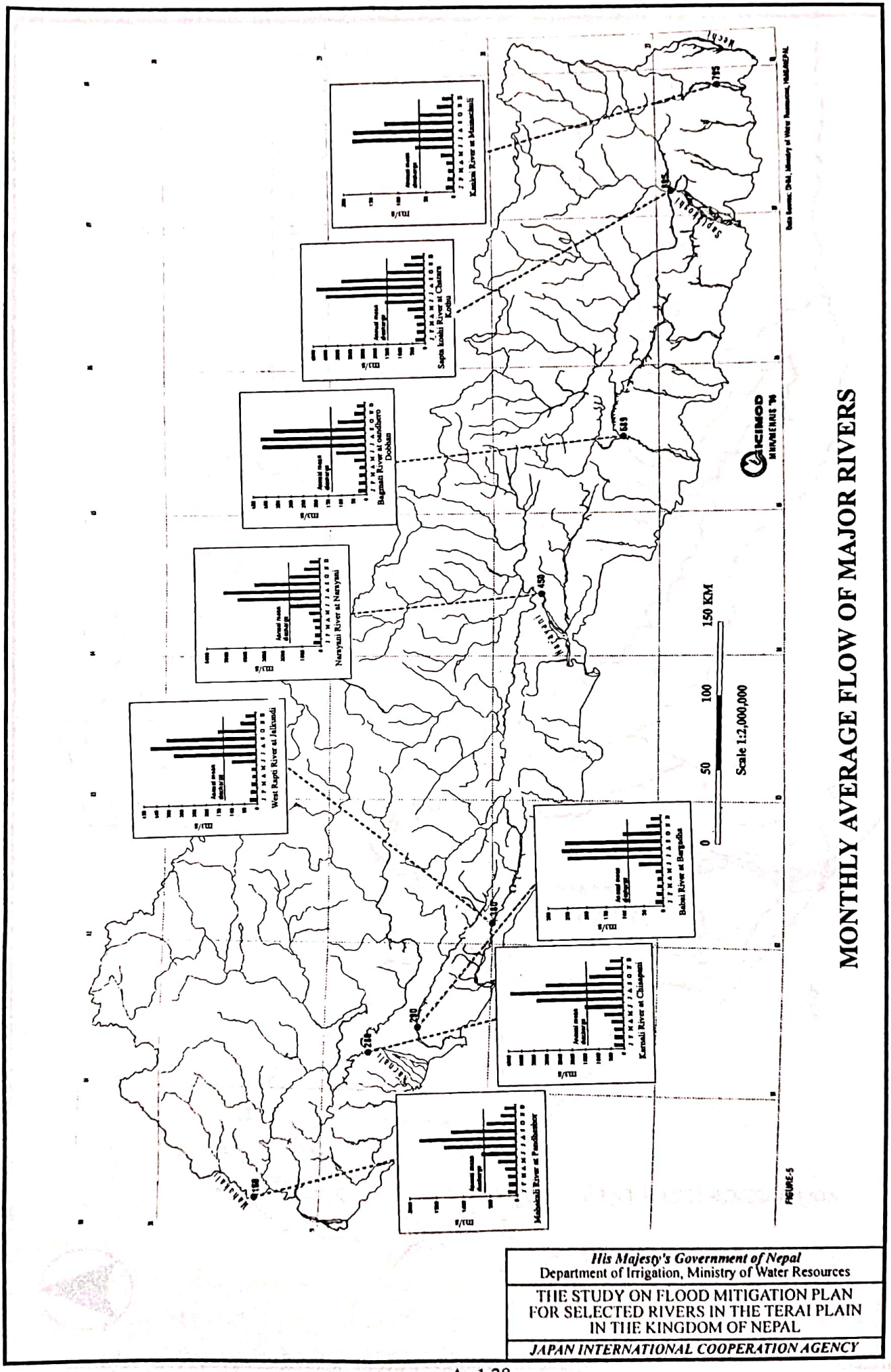

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JAPAN INTERNATIONAL COOPERATION AGENCY

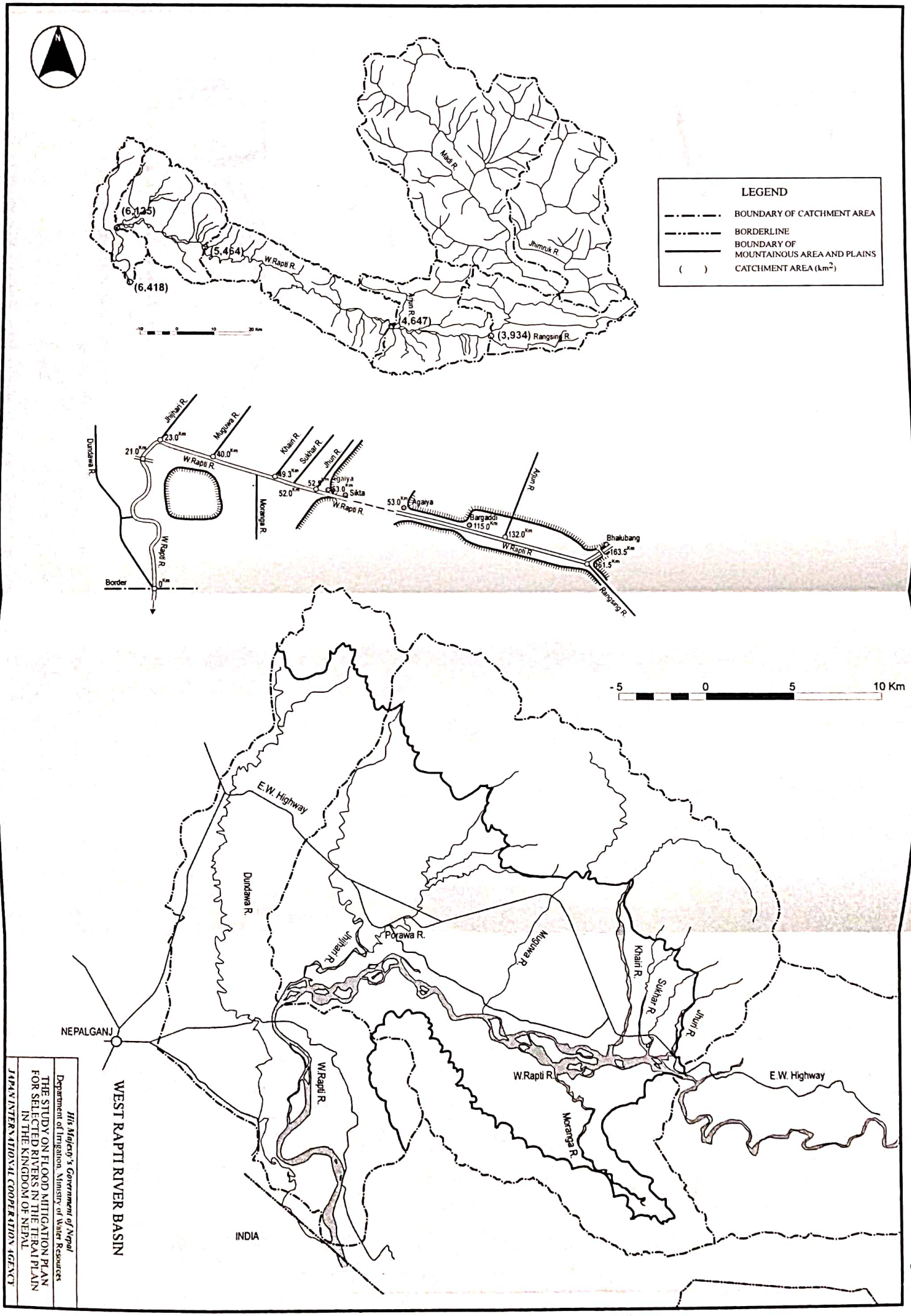

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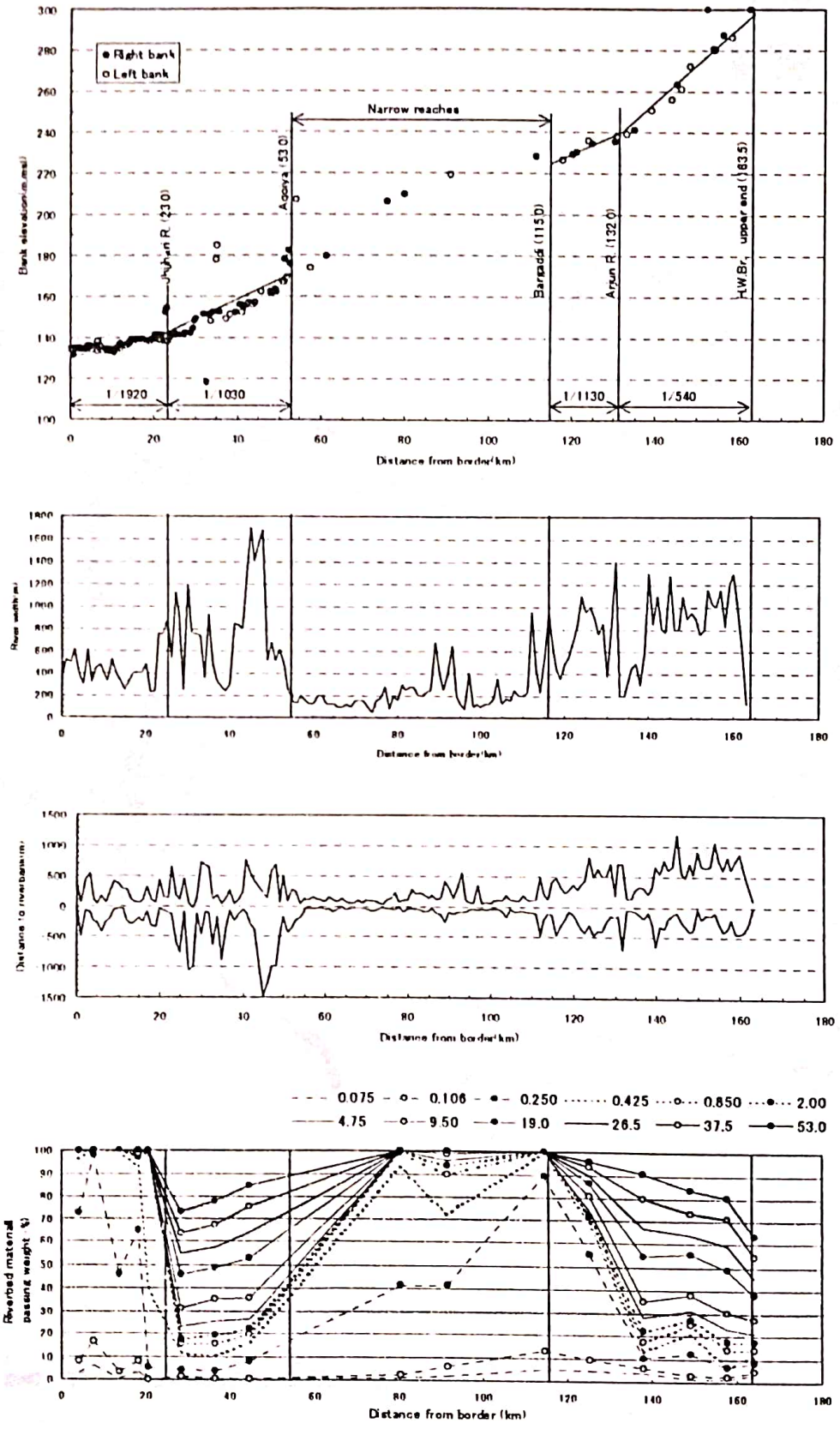
Fig. A1.8

WEST RAPTI RIVER



CHARACTERISTICS OF EXISTING CHANNEL

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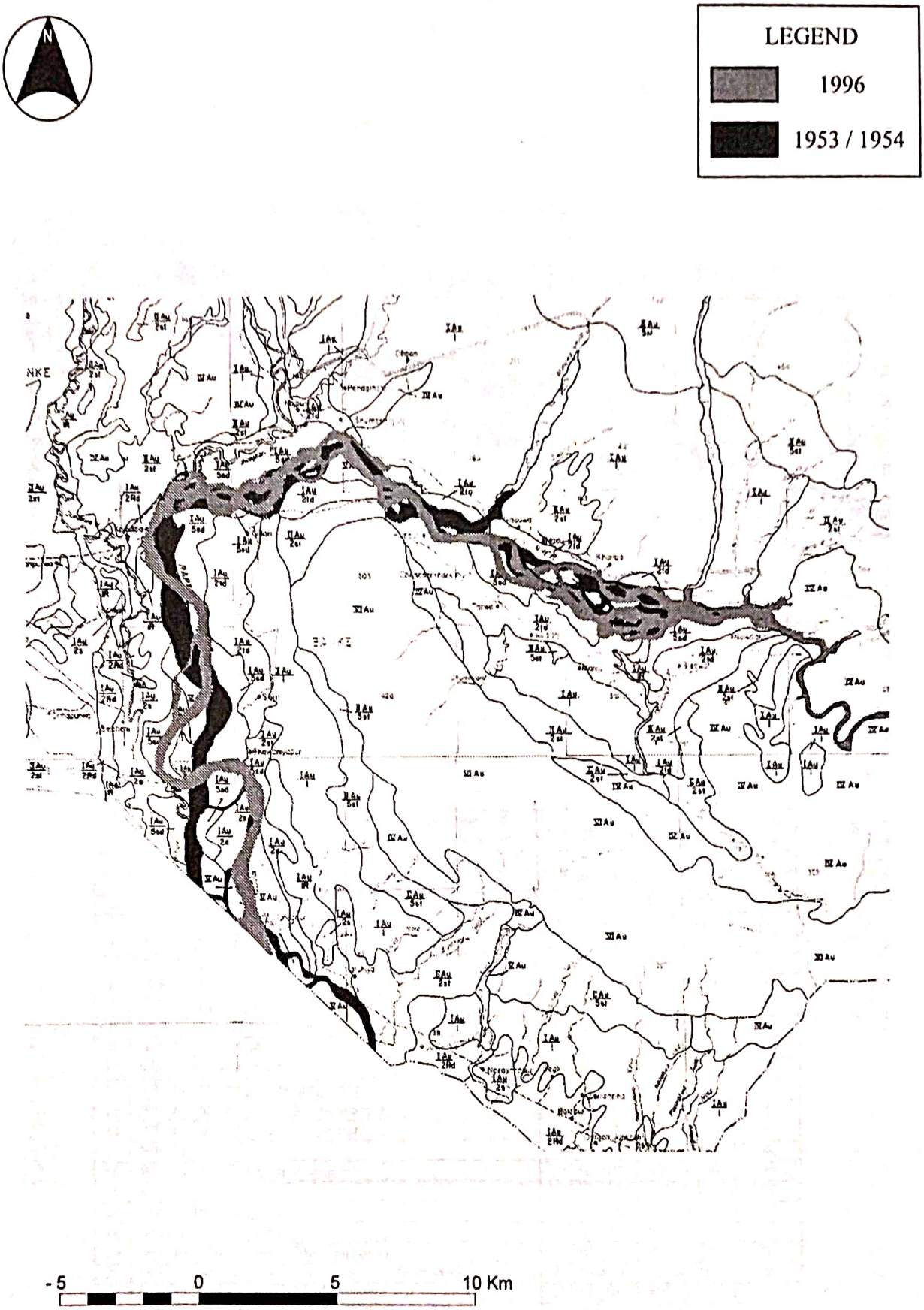
JAPAN INTERNATIONAL COOPERATION AGENCY



CHANGE OF WEST RAPTI RIVER COURSE

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FOR SELECTED RIVERS IN THE TERAI PLAIN
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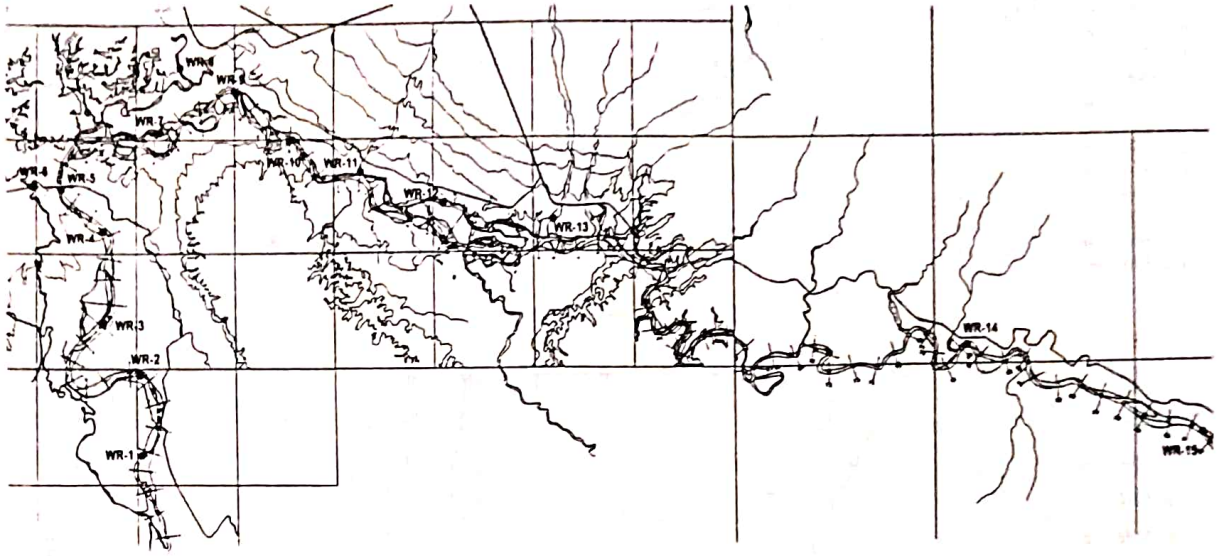

SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading N	GPS Reading E	FGA (Y/N)
1	WR-1	Fine sand		27°58.593′	81°43.786′	N
2	WR-2	Fine sand with silt		28°00.278′	81°43.284′	N
3	WR-3	Fine sand with silt		28°01.125′	81°43.548′	N
4	WR-4	Fine sand with silt		28°02.974′	81°44.172′	N
5	WR-5	Fine Silt		28°03.777′	81°43.171′	N
6	WR-6	Silty sand		28°04.019′	81°42.329′	N
7	WR-7	Mixed gravel		28°05.269′	81°45.811	Y
8	WR-8	Fine to medium sand		28°06.711′	81°46.023′	N
9	WR-9	Fine sand		28°06.175′	81°47.510′	N
10	WR-10	Mixed gravel		28°04.947′	81°49.110′	Y
11	WR-11	Mixed gravel(Large size)		28°04.733′	81°51.026′	Y
12	WR-12	Mixed gravel(Medium size)		28°03.496′	81°52.900′	Y
13	WR-13	Mixed gravel(Large size)		28°03.328′	81°55.593′	Y
14	WR-14	Fine sand		28°00.480′	82°05.914′	N
15	WR-15	Medium to fine sand		27°58.510′	82°11.866′	N
16	WR-16	Fine sand and silt		27°53.537′	82°21.447′	N
17	WR-17	Mixed gravel		27°51.824′	82°26.679′	Y
18	WR-18	Mixed gravel		27°53.041′	82°30.540′	Y
19	WR-19	Mixed gravel(Medium sand)		27°50.501′	82°32.105′	Y
20	WR-20	Mixed gravel with loosed medium sand		27°49.440′	82°38.256′	Y
21	WR_21	Mixed gravel(Medium)size		27°49.506′	82°43.059′	Y
22	WR-22	Mixed gravel with sand (Large size)		27°50.420′	82°46.157′	Y
23	WR-23			27°48.657′	82°45.881′	Y

SAMPLING SITES OF RIVERBED MATERIALS (WEST RAPTI RIVER)

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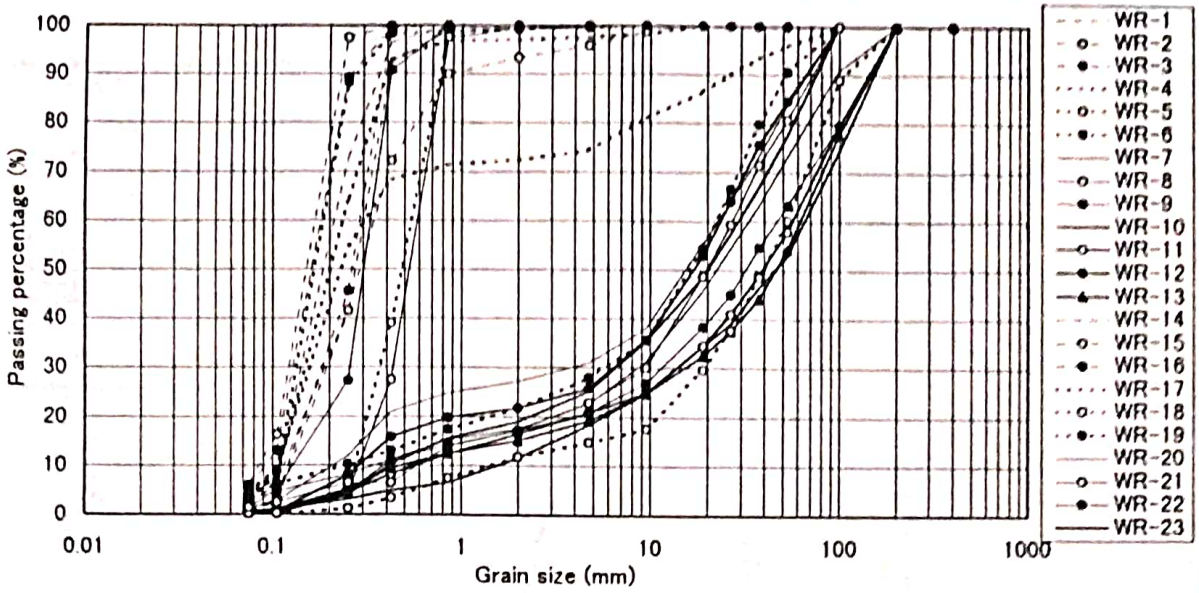

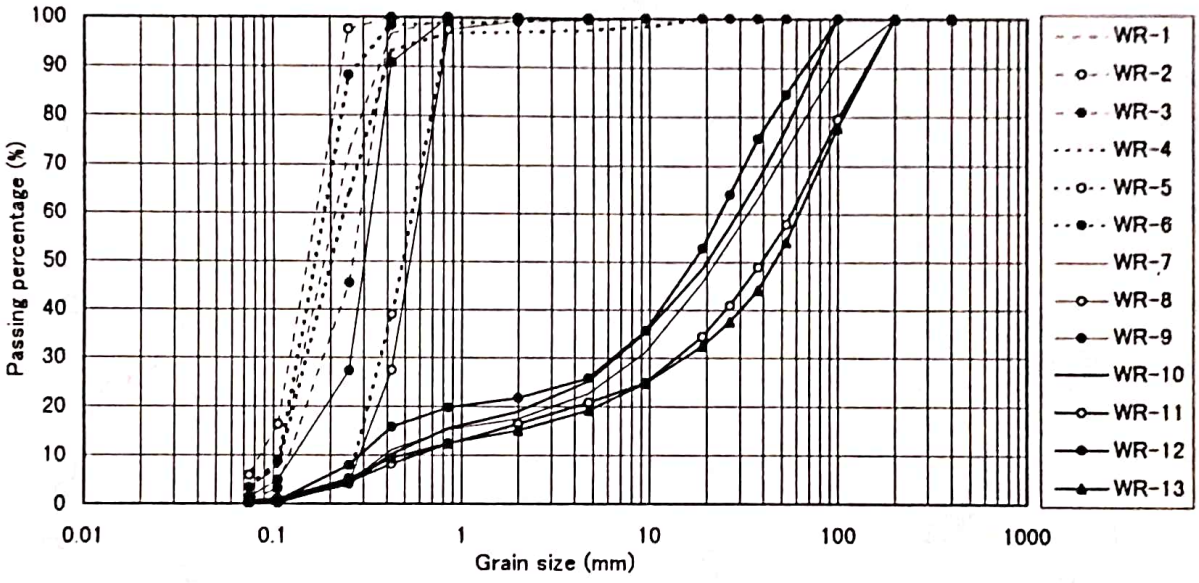

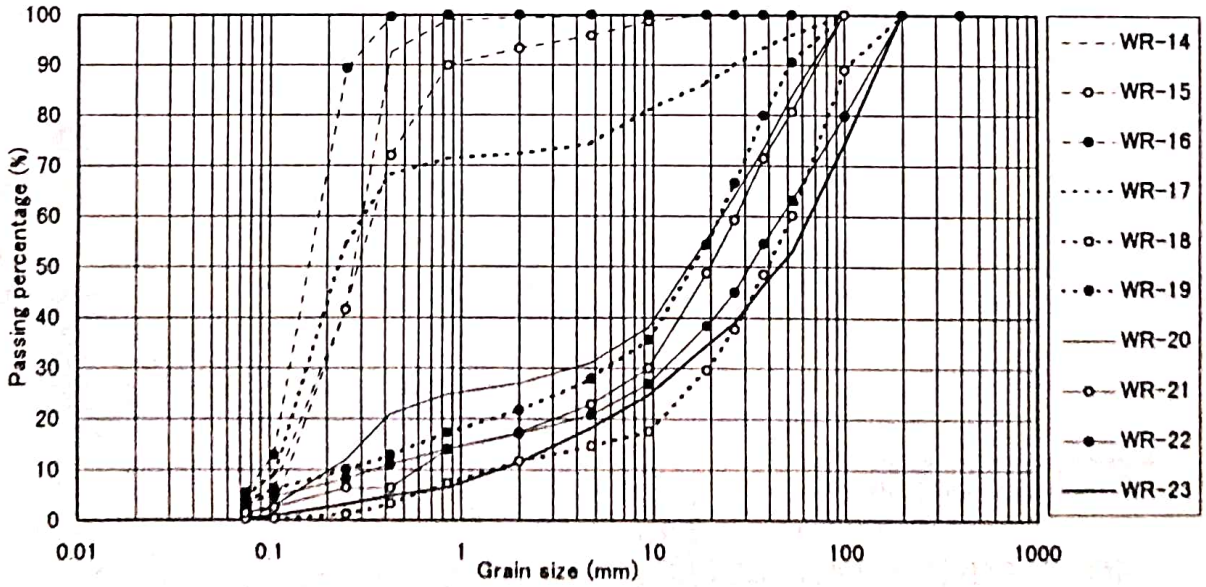

GRADING CURVES OF RIVERBED MATERIALS (WEST RAPTI R.)

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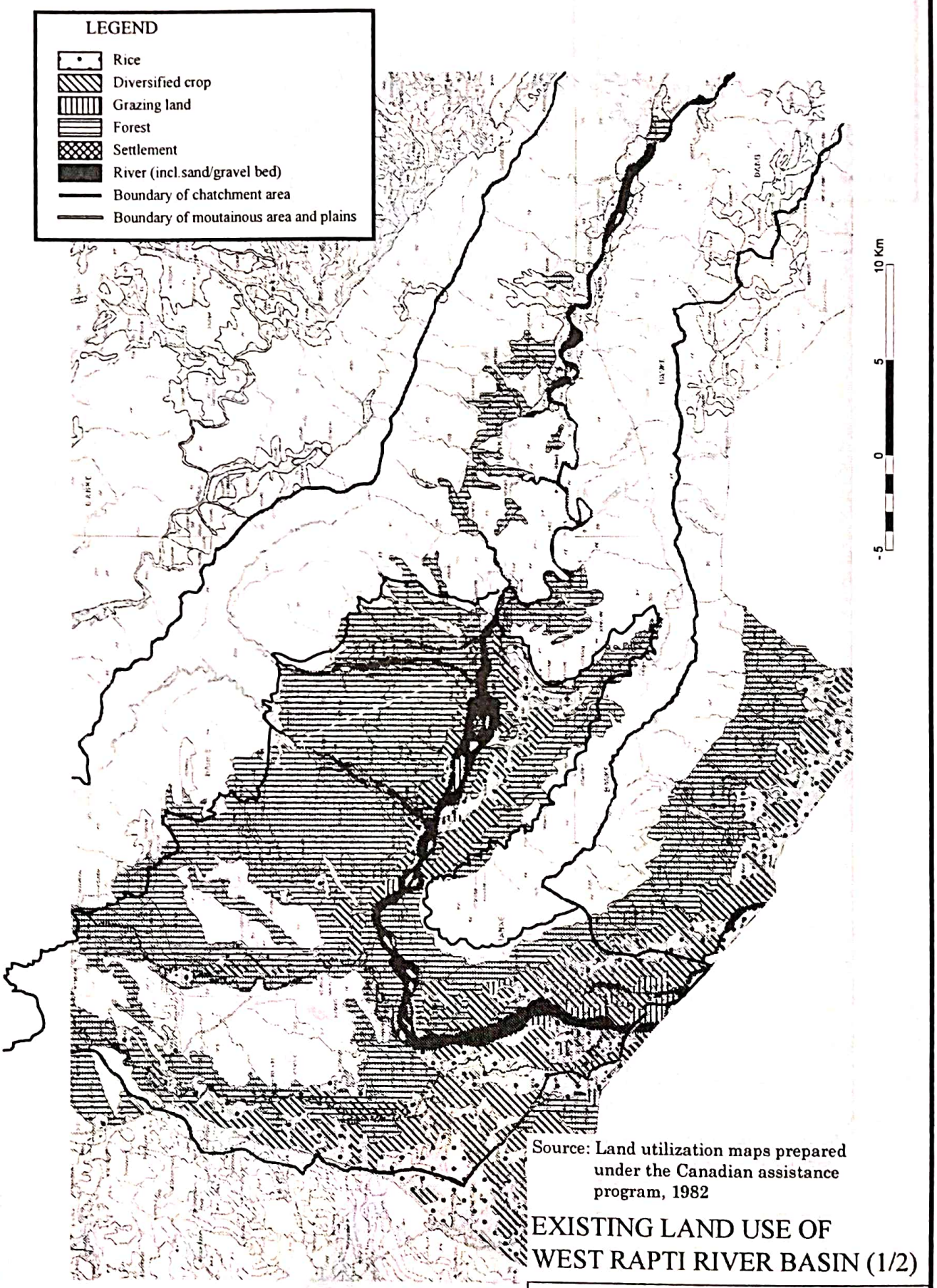

Source: Land utilization maps prepared under the Canadian assistance program, 1982

EXISTING LAND USE OF WEST RAPTI RIVER BASIN (1/2)

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

JAPAN INTERNATIONAL COOPERATION AGENCY

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

EXISTING LAND USE OF WEST RAPTI RIVER BASIN (2/2)

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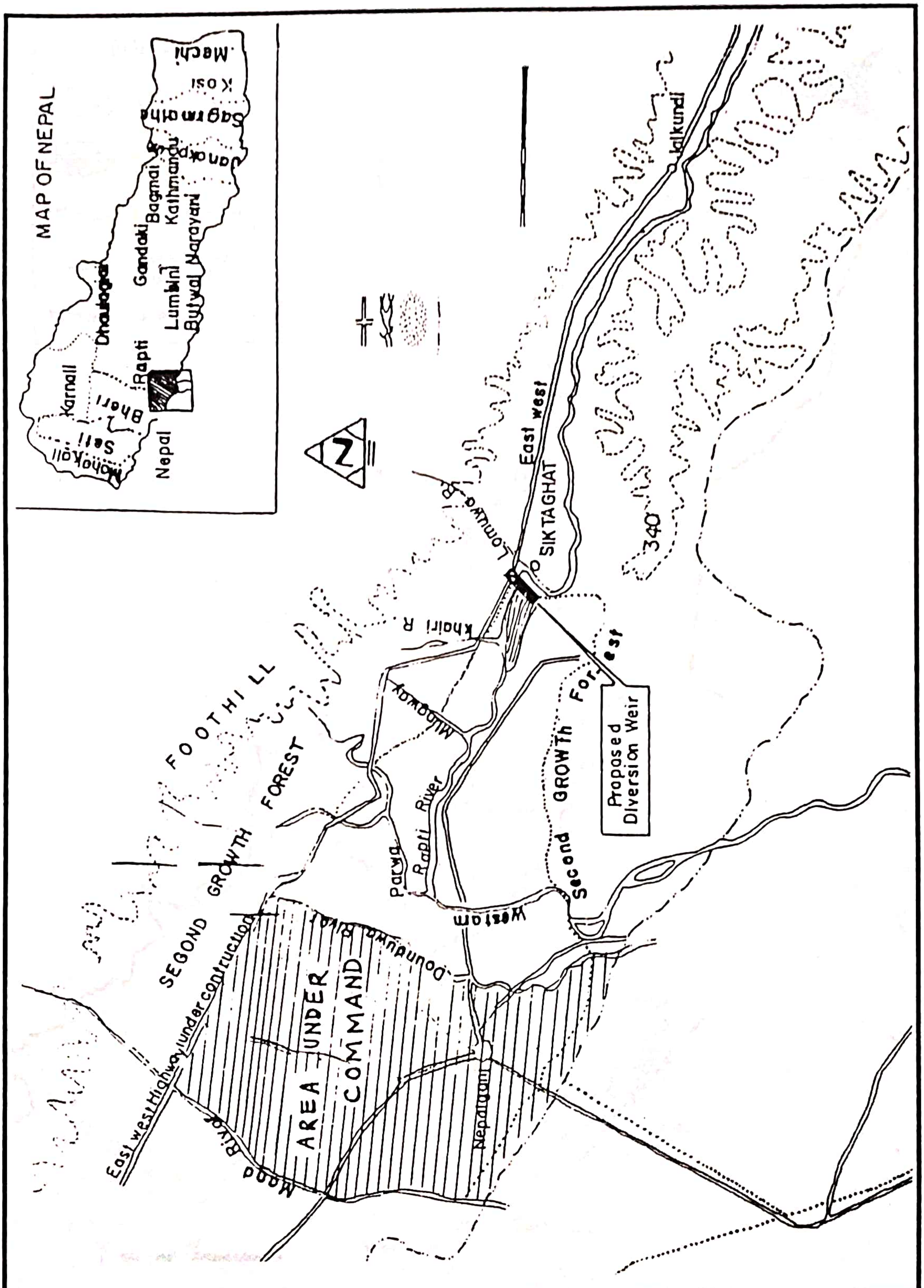

SIKTA IRRIGATION PROJECT

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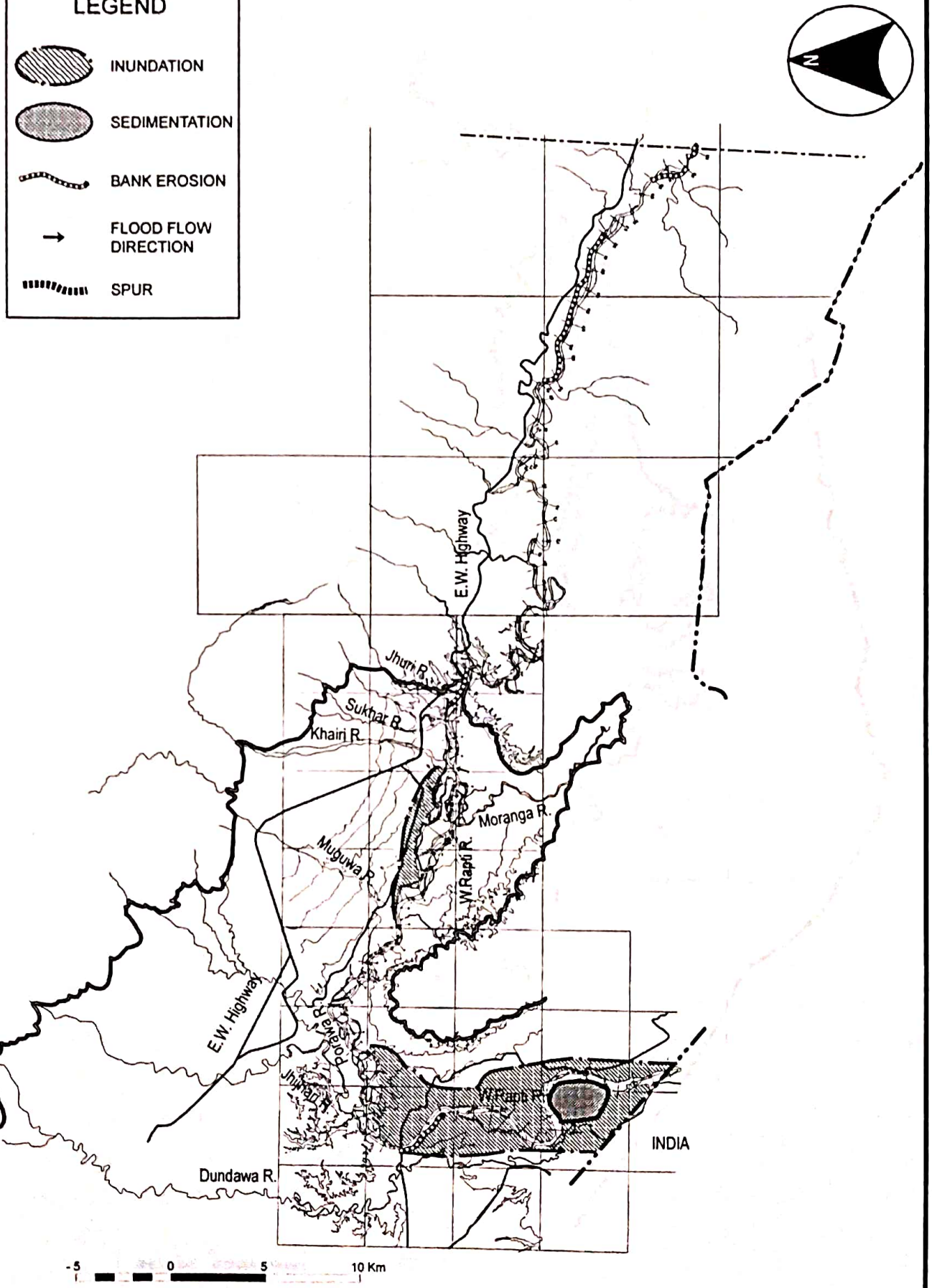

FLOOD SUFFERING AREA
(WEST RAPTI RIVER 1/2,1995)

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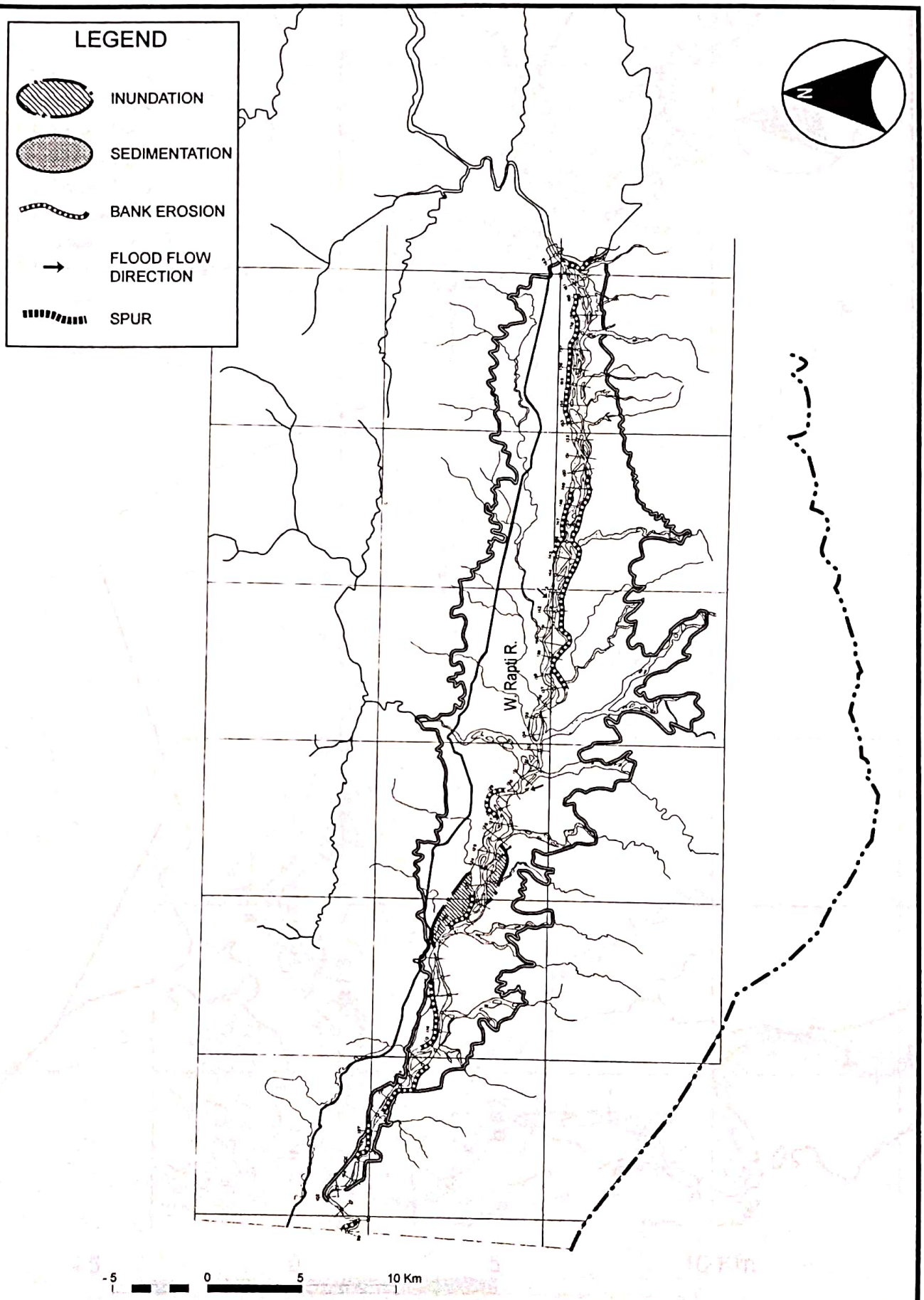

FLOOD SUFFERING AREA
(WEST RAPTI RIVER 2/2,1995)

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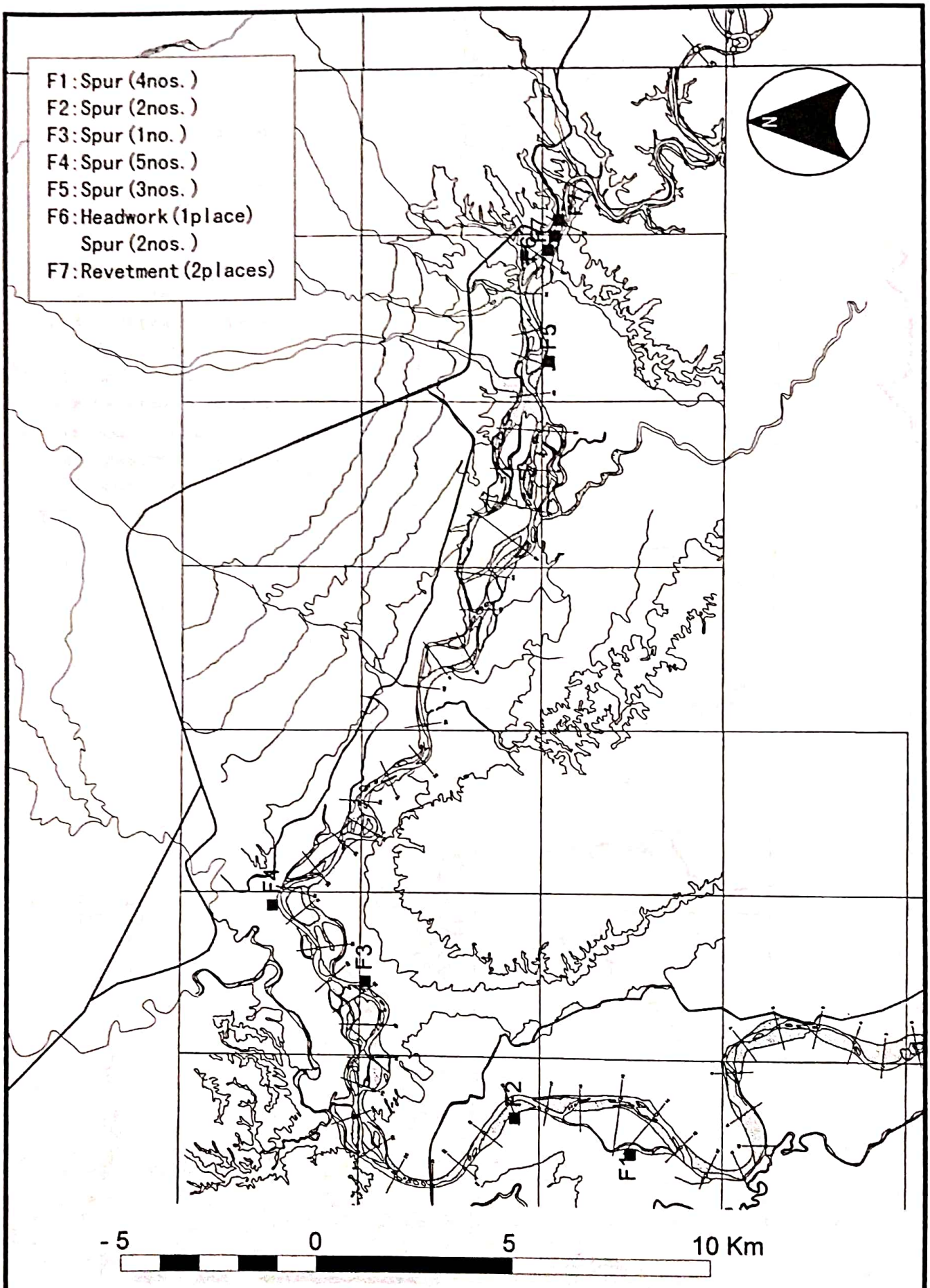

LOCATIONS OF RIVER FACILITIES

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THE STUDY ON FLOOD MITIGATION PLAN
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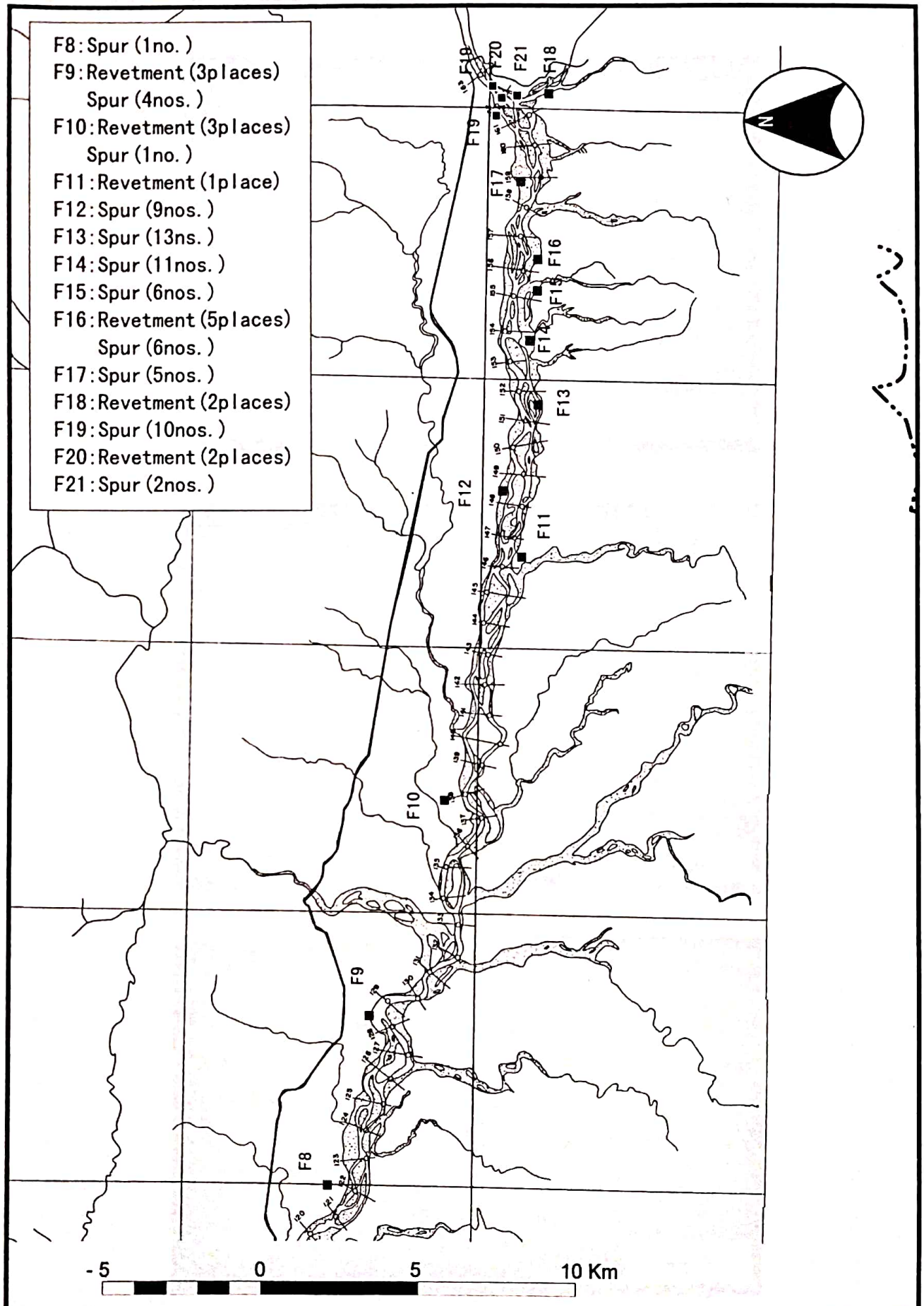
JAPAN INTERNATIONAL COOPERATION AGENCY



LOCATIONS OF RIVER FACILITIES

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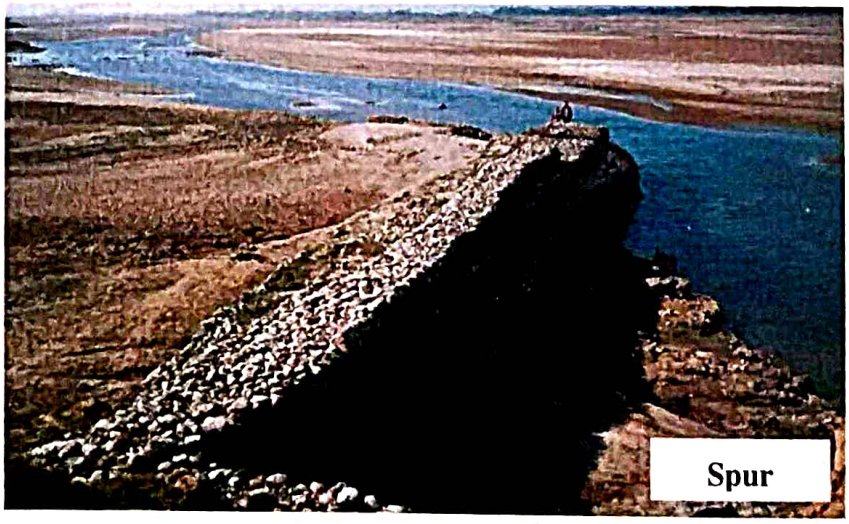

TYPICAL RIVER FACILITIES

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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 farmhouse 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 prevent land erosion in watersheds and promote sustainable watershed management activities through income generation. The cultivation of medicinal and aromatic plants has been one of the main programs of Nepalese 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 agro-forestry, 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

C_2-value for the West Rapti river basin was assumed to be C_2 = 8.1 based on the result of probability analysis of the West Rapti river data (sta. Code: 360). The values of Q_n/Q_2 for the West Rapti river were estimated, based on the same results of analysis as shown in the following table:

(Q_n/Q_2-values for West Rapti River)

C_2	Q_2/Q_2	Q_5/Q_2	Q_{10}/Q_2	Q_{20}/Q_2	Q_{50}/Q_2	Q_{100}/Q_2
8.1	1.00	1.57	1.95	2.31	2.78	3.13

Probable discharges of 2, 5, 10, 20 and 50-year return periods at the lower end (Indian border) of the river basin are shown below:

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
West Rapti	6,418	2,320	3,680	4,590	5,420	6,530

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 West Rapti was divided into five stretches depending on the channel slope, grain size distribution, river width, surrounding topography, etc. as follows:

1) WR-1: Reaches from Indian boarder to Jhijhari river junction (Sta. 23 km)
2) WR-2: Reaches from Jhijhari river junction to Agaiya (Sta. 53 km)
3) WR-3: Reaches from Agaiya to Bargaddi (Sta. 115 km)
4) WR-4: Reaches from Agaiya to Bargaddi
5) WR-5: Reaches from Bargaddi to E.W. highway bridge (Sta. 163.5 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/I)	Grain size		River width Bm (min-max) (m)
		From (m)	To (m)		d_{60} (mm)	d_R (mm)	
W.Rapti R.							
WR-1	2-2	130	142	1,920	0.29	0.29	417(225-750)
WR-2	2-1	142	171	1,030	29	55	790(238-1700)
WR-3	-	-	-	-	0.28	0.28	224(75-950)
WR-4	2-2	225	240	1,130	0.31	0.31	760(350-1400)
WR-5	2-1	240	298	540	24	47	827(125-1400)

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 riverbank 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 floodwater 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 if the embankment height 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 was an effective measure for the prevention of flooding. However, a continuous dike is 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 is 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 sill 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 as guide bunds; 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 serves 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:** Pasture land 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-II river in Mid-western Development Region
   - Basin area: 6,418 km^2 in total consisting of mountainous basin 5,800 km^2 and plain area 618 km^2.
   - Sikta Irrigation Project was proposed in 1980. However, the project was

not implemented due to failure of coordination with India. A barrage across the West Rapti was being constructed by India near the border. The works are said to be suspended now.

2) River system: The West Rapti river can be divided into upper and lower basins by the narrow section upstream from Agaiya. The upper basin of the West Rapti forms a round valley surrounded by the northern slope of the Siwalik hill, southern slope of the Mahabharat ranges, and narrow gorge in the lower end. The lower basin of the West Rapti is a free meandering zone. The river course is changeable in the lower reaches near the Indian border.

3) River channel: River is wide and braided in the upper basin of the West Rapti river. In the lower basin of the West Rapti, river is wide and braided in the upper reaches and meandering in the lower reaches. Grain size of the riverbed materials changes clearly from sand to gravel. The sand (fine to coarse) is found in the lower reaches of the both upper and lower basins and the gravel (coarse to very coarse) presents in the upper reaches of the both basins.

4) River segments:

Lower basin

- Segment 2-2: From 0.0 km (Indian border) to 23.0 km (Jhijhari R. jct.)
- Segment 2-1: From 23.0 km to 53.0 km (Agaiya)

Upper basin

- Segment 2-2: From 115.0 km (Bargaddi) to 132.0 km (Arjun R. jct.)
- Segment 2-1: From 132.0 km to 163.5 (upper end)

5) Flood and sediment disasters:

- Recent major floods: 1997, 1996 and 1993 floods in order of severity.
- Kinds of damages: Bank erosion, flooding over farmlands and sedimentation.
- Suffering areas: 23 wards in 8 VDCs in Banke district, and 33 villages in 9 VDCs in Dang district.
- Conditions and mechanism of flooding: In the upper basin, bank erosion and flooding over the farmlands are limited in the areas along the edge of the braided riverbed and confluence of the tributaries. In the lower basin, riverbed is said to be rising especially in the lower reaches and flood water flows over the riverine areas frequently. The river course also changes actively near the Indian border. After 1997-flood, epidemic disease attacked the flood suffering areas in Dang and Banke districts, though detailed data are not available.

(2) Principal Measures to be Taken

1) Junction of the Dundawa river will be stabilized by river training works.
2) Anabranches will be closed securely with diversion facilities if necessary.
3) Forest and grass belts will be formed in Segments 2-2 on both banks and in Segment 2-1 on left bank.
4) 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.
5) Watershed management will be carried out for erosion and runoff control.
6) Flood plain management will be carried out for mitigation of damages 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 West Rapti river are shown in Table A2.4.

CANDIDATE SPECIES FOR BIOENGINEERING WORKS IN TERAI

	Naturally Grown Species	Nursery Species
Grasses	- Arundo clonax (Narkato) - Cymbopogon microtheca (Khar) - Cymbopogon pendulus (Dangre Khar) - Cynodon dactylon (Dhubo) - Eulaliopsis ninanta (Babiyo, Sabai Grass) - Neyraudia arundinacea (Sito) - Neyraudia reynaudiana (Dhonde) - Pennisetum clandestinum (Kikuyu, Thulo Dhubo) - Pogonatherum paniceum (Musekharuki) - Saccharum spontaneus (Kans)	- Desmodium intortum - Pennisetum purpureum (Napier) - Setaria anceps - Thysanolaena maxima (Amliso) - also in forests - - Stylo - Molasess grass
Shrubs & Non-Plantation Trees	- Adhatoda vasica (Assuro) - Butea minor (Bhujetro) - Calatorpha giganteum (Aak) - Colebrookea oppositifolia (Chusun) - Ipomoea fistulata (Saruwa --- Beheu) - Lantana camara (Phul Kanda) - Phoenix humilis (Thakal) - Trema orientalis (Kunyelo) - Vitex negundo (Simali) - Wedlandia species (Tilka) - Woodfordia fruticosa (Dhanyero)	
Trees	- Acacia catechu (Khayer) --- also in nursery - Acacia auriculiformis - Albizia julibrissin - Ficus semicordata (Khasre Khayu, Khanayo) - Shorea robusta (Sal) -- also in nursery	- Bauhinia purpurea (Tanki) - Delonix regia (Gulmohar) - Leucaena species (Ipil Ipil) - Bamboo species

source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

From:	Species Used	Income-generating Products
Nursery	<u>Trees</u>	
	- Acacia catechu (Khayer)	- saplings
	- Shorea robusta (Sal)	- saplings
	- Bauhinia purpurea (Tanki)	- saplings
	- Delonix regia (Gulmohar)	- seeds/saplings
	- Leucaena species (Ipil Ipil)	- seeds/saplings
	- Bamboo species	- roots
	<u>Grasses</u>	
	- Desmodium intortu	
	- Pennisetum purpureum (Napier)	- seeds
	- Thysanolaena maxima (Amliso)	- cutting
	- Stylo	- seeds/cutting
	- Molasess grass	- seeds
		- seeds
Bio-Engineering Facility	<u>Grasses</u>	
	- Desmodium intortum	- fuel wood
	- Pennisetum purpureum (Napier)	- fodder/mulching
	- Thysanolaena maxima (Amliso)	- fodder/broom
	- Stylo	- fodder/seed
	- Molasess grass	- fodder/seed
	- Arundo clonax (Narkato)	- fencing
	- Cymbopogon microtheca (Khar)	- roof thatch
	- Cymbopogon pendulus (Dangre Khar)	- roof thatch
	- Cynodon dactylon (Dhubo)	- fodder
	- Eulaliopsis ninanta (Babiyo)	- rope
	- Saccharum spontaneus (Kans)	- roof thatch/rope
	<u>Shrubs</u>	
	- Adhatoda vasica (Assuro)	- green manure/medicine
	<u>Trees</u>	
	- Bamboo species	- furniture/timber
	- Bauhinia purpurea (Tanki)	- fodder/fuel wood
	- Delonix regia (Gulmohar)	- fuel wood
	- Leucaena species (Ipil Ipil)	- fodder/fuel wood
	- Acacia catechu (Khayer)	- timber/fuel wood/medicine
	- Shorea robusta (Sal)	- leaf plate

source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991

PROJECT COST FOR MASTER PLAN

WEST RAPTI RIVER (unit: 1000NRs)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				105,853
1. Preparatory Works	L.S.	1.00		9,623
2. Bank Protection Works				35,553
2-1 Pile Spur (Type-B)	km	2.90	7,289	21,138
2-2 Gabion Spur (Type-B)	km	1.40	10,296	14,414
3. Cannel Works				35,697
3-1 River Boundary Line	km	64.70	27	1,747
3-2 Tree Belt	ha	63.00	68	4,284
3-3 Grass Belt	ha	216.50	126	27,279
3-4 Closing Dike/structure	place	1.00	2,387	2,387
4. Ring Dike Works				16,233
4-1 Dike Embankment	km	3.70	2,596	9,605
4-2 Drainage Sluice	place	2.00	1,275	2,550
4-3 Gravel Metaling	km	3.70	1,102	4,077
5. Miscellaneous Works	L.S.	1.00		8,748
II . Compensation Cost	L.S.	1.00		80,712
III. Administration Cost	L.S.	1.00		9,328
IV. Engineering Service	L.S.	1.00		15,878
V . Physical Contingency	L.S.	1.00		20,244
Poject Cost				232,016

Note: *1 Price Level in October 1998
*2 Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
*3 Cost do not include Price Contingency and Value Added Tax
*4 Figures may not add up to totals due to rounding

ANNUAL DISBURSEMENT SCHEDULE OF WEST RAPTI RIVER PROJECT FOR MASTER PLAN

(Financial Cost)

(1,000NRs)

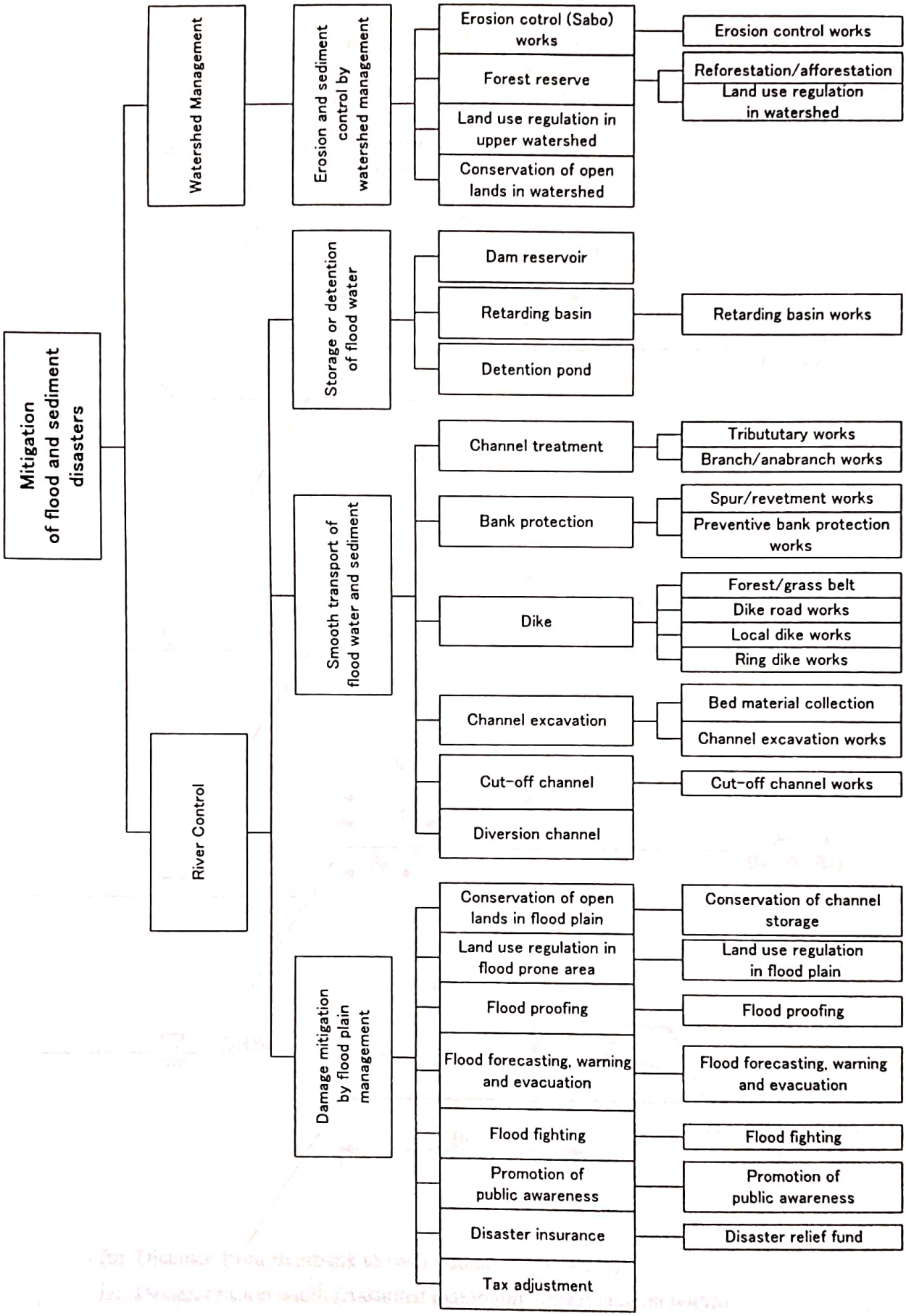
Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	105,853	0	0	0	9,222	9,222	9,222	6,014	6,014	6,014	6,014	6,014	6,014	6,014	6,014	6,014	6,014	6,014	6,014	6,014
1. Preparatory Works	9,623	0	0	0	3,208	3,208	3,208	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	35,553	0	0	0	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222	2,222
3. Channel Woks	35,697	0	0	0	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231	2,231
4. Ring Dike Works	16,233	0	0	0	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015	1,015
5. Miscellaneous Works	8,748	0	0	0	547	547	547	547	547	547	547	547	547	547	547	547	547	547	547	547
II . Compensation Cost	80,712	0	0	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	5,045	0
III. Addministration Cost	9,328	0	0	252	713	713	713	553	553	553	553	553	553	553	553	553	553	553	553	301
IV. Engineering Cost	15,878	2,646	2,646	2,646	692	692	692	451	451	451	451	451	451	451	451	451	451	451	451	451
1. F/S, D/D etc.	7,939	2,646	2,646	2,646	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	7,939	0	0	0	692	692	692	451	451	451	451	451	451	451	451	451	451	451	451	451
V . Physical Contingency (10% of Items I , II &IV)	20,244	265	265	769	1,496	1,496	1,496	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	647
VI. Total	232,016	2,911	2,911	8,712	17,167	17,167	17,167	13,214	13,214	13,214	13,214	13,214	13,214	13,214	13,214	13,214	13,214	13,214	13,214	7,413

Note: *1 Price Level in October 1998
*2 Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
*3 Cost do not include Price Contingency and Value Added Tax
*4 Figures may not add up to totals due to rounding

(Economic Cost)

(1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	95,268	0	0	0	8,300	8,300	8,300	5,413	5,413	5,413	5,413	5,413	5,413	5,413	5,413	5,413	5,413	5,413	5,413	5,413
1. Preparatory Works	8,661	0	0	0	2,887	2,887	2,887	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	31,997	0	0	0	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
3. Channel Woks	32,127	0	0	0	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008	2,008
4. Ring Dike Works	14,609	0	0	0	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913
5. Miscellaneous Works	7,873	0	0	0	492	492	492	492	492	492	492	492	492	492	492	492	492	492	492	492
II . Compensation Cost	72,641	0	0	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	0
III. Addministration Cost	8,395	0	0	227	642	642	642	498	498	498	498	498	498	498	498	498	498	498	498	271
IV. Engineering Cost	14,290	2,382	2,382	2,382	622	622	622	406	406	406	406	406	406	406	406	406	406	406	406	406
1. F/S, D/D etc.	7,145	2,382	2,382	2,382	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	7,145	0	0	0	622	622	622	406	406	406	406	406	406	406	406	406	406	406	406	406
V . Physical Contingency (10% of Items I , II &IV)	18,220	238	238	692	1,346	1,346	1,346	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	582
VI. Total	208,814	2,620	2,620	7,841	15,451	15,451	15,451	11,893	11,893	11,893	11,893	11,893	11,893	11,893	11,893	11,893	11,893	11,893	11,893	6,671



FLOOD MITIGATION MEASURES

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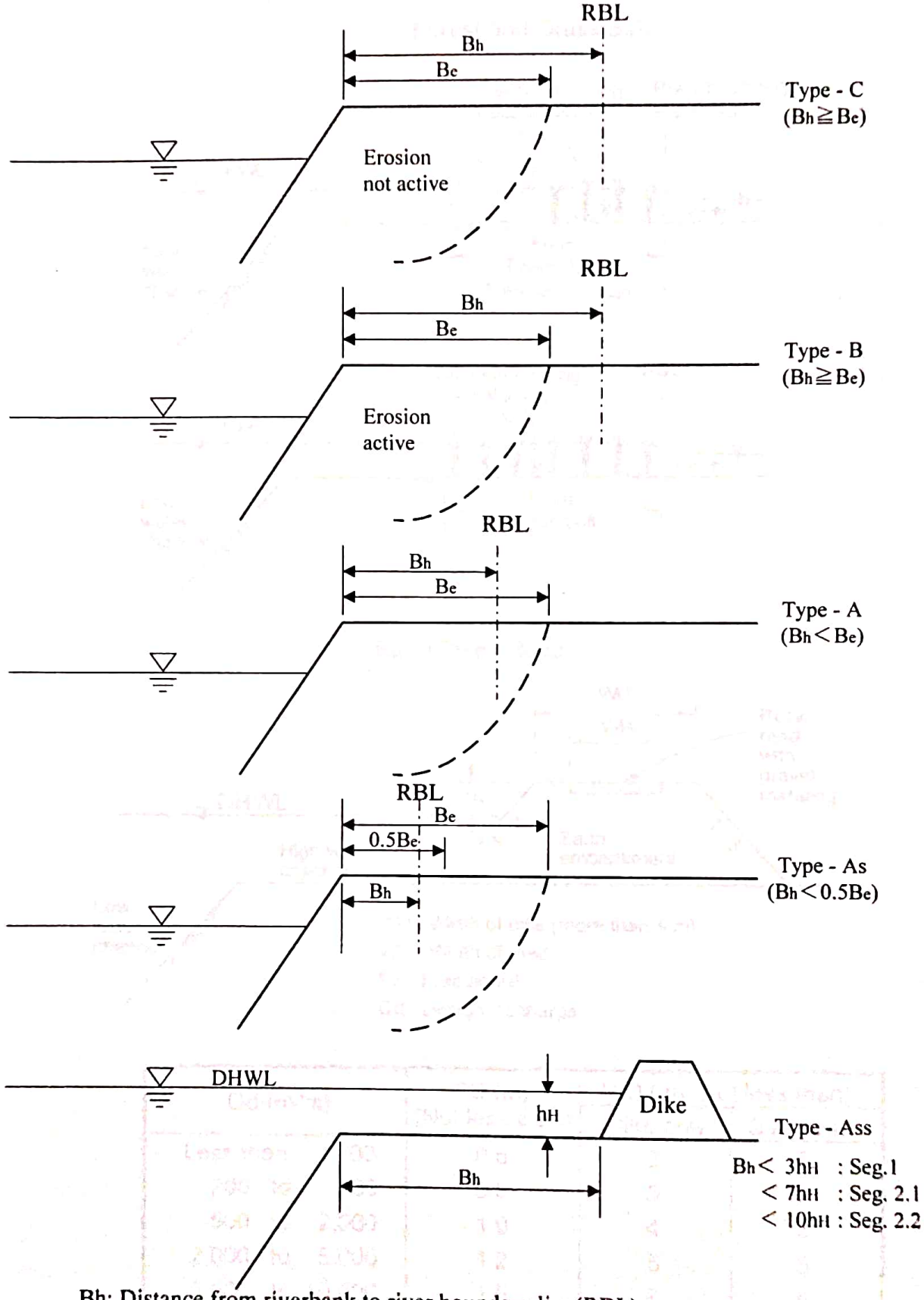

Bh: Distance from riverbank to river boundary line(RBL)

Be: Design erosion width (Assumed maximum annual erosion width)

CLASSIFICATION OF TYPES OF RIVER BANK

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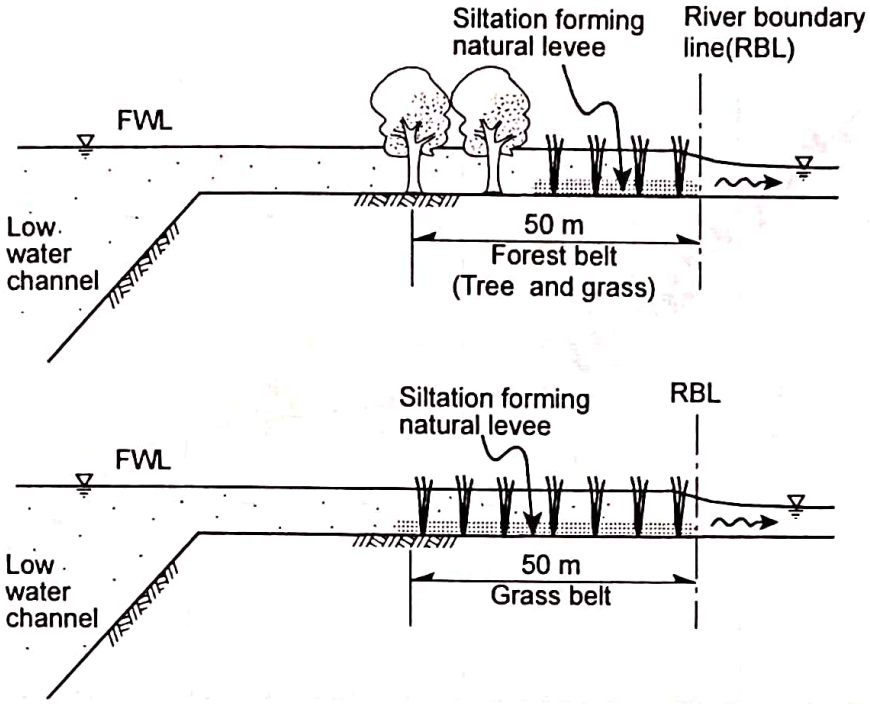
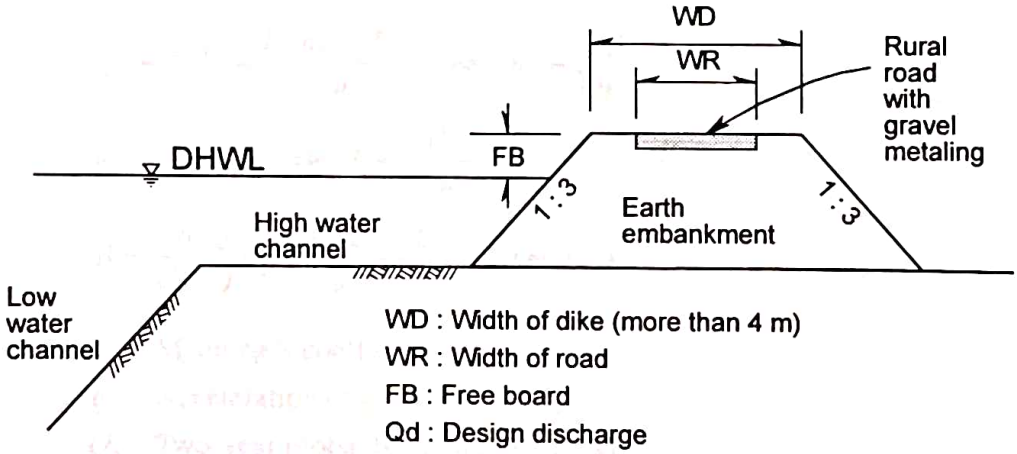
Forest and Grass Belt



Earth Dike / Road



WD : Width of dike (more than 4 m)
WR : Width of road
FB : Free board
Qd : Design discharge

Qd (m^3/s)	FB (m) (Not less than)	WD (m, Not less than)	
		Dike only	Dike road
Less than 200	0.6	3	5
200 to 500	0.8	3	5
500 to 2,000	1.0	4	5
2,000 to 5,000	1.2	5	5
5,000 to 10,000	1.5	6	6
More than 10,000	2.0	7	7

DIKE WORKS

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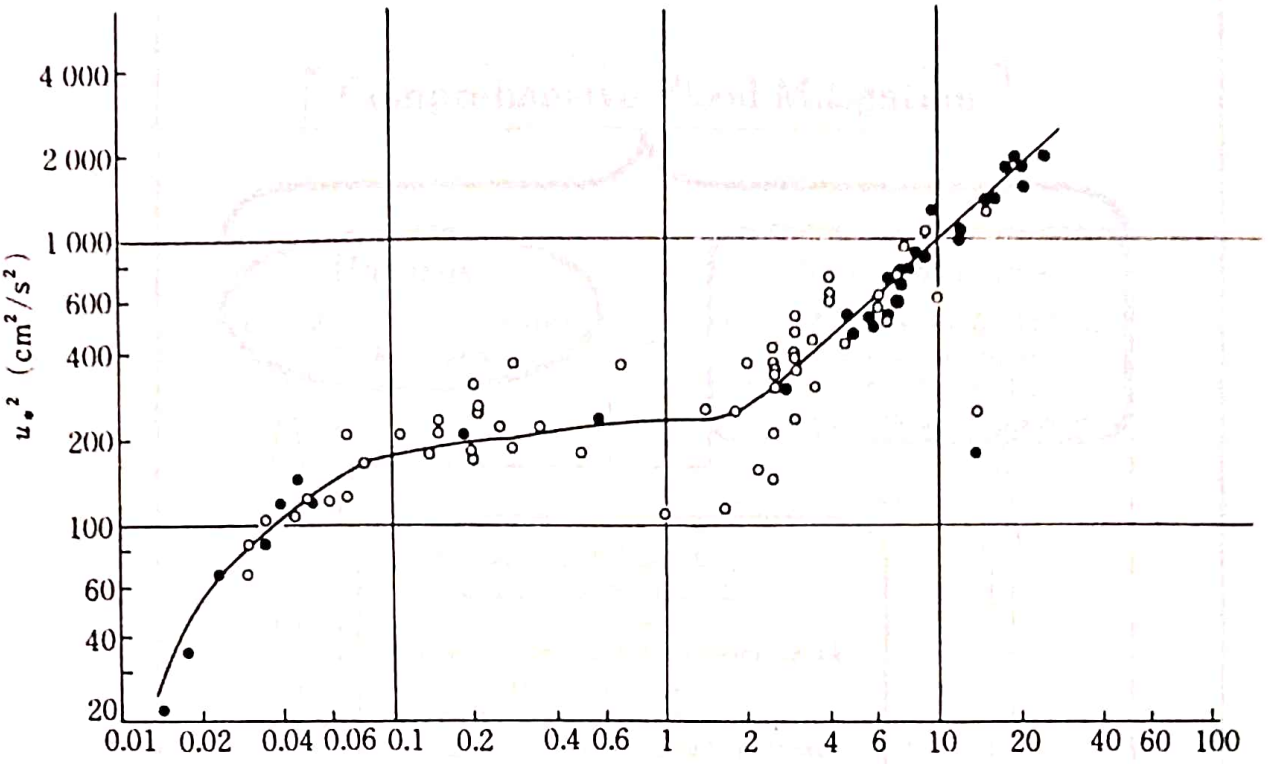


$$Q_2 = A \cdot V = \frac{B \cdot h_L^{5/3} \cdot I^{1/2}}{n} \quad \Rightarrow \quad h_L = \left\{ \frac{Q_2 \cdot n}{B \cdot I^{1/2}} \right\}^{3/5}$$

$$u_*^2 = g \cdot h_L \cdot I \quad \Rightarrow \quad I = \frac{u_*^2}{g \cdot h_L}$$

$$B = \frac{n \cdot Q_2}{h_L^{5/3} \cdot I^{1/2}} = \frac{n \cdot g^{1/2} \cdot Q_2}{u_* \cdot h_L^{7/6}} \qquad (m, \text{sec})$$

n : Manning's coefficient of roughness

g : Acceleration of gravity (m/sec^2)

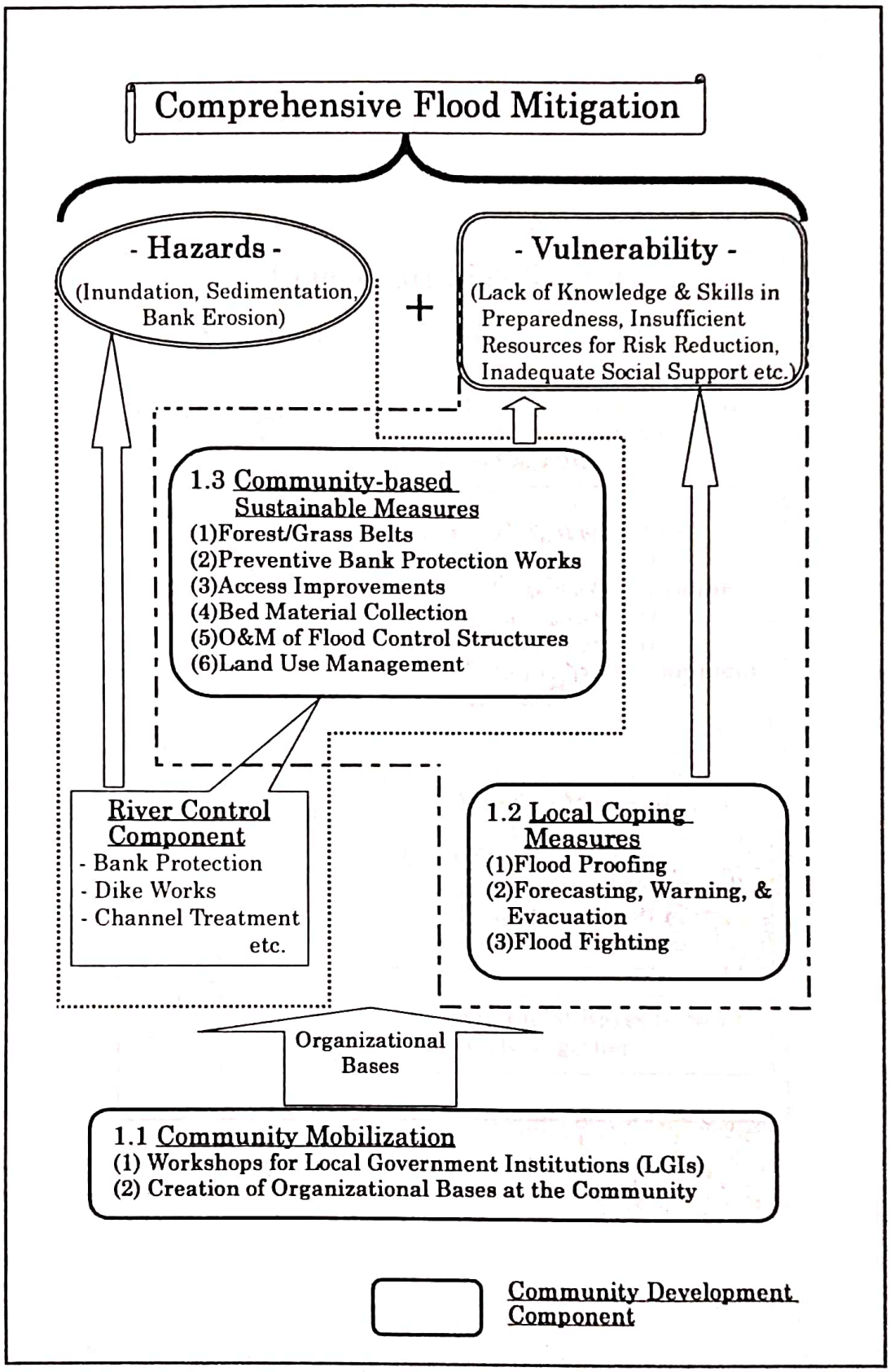
Q_2 : Two-year probable discharge (m3/s)

u_* : u_*-value obtained from d_R-u_* diagram for a given representative grain size (d_R) (m/s)

h_L : Mean depth of low water channel (m)

B : Low water channel width

RELATIONSHIP BETWEEN BED MATERIAL SIZE AND FRICTION VELOCITY



COMPREHENSIVE FLOOD MITIGATION

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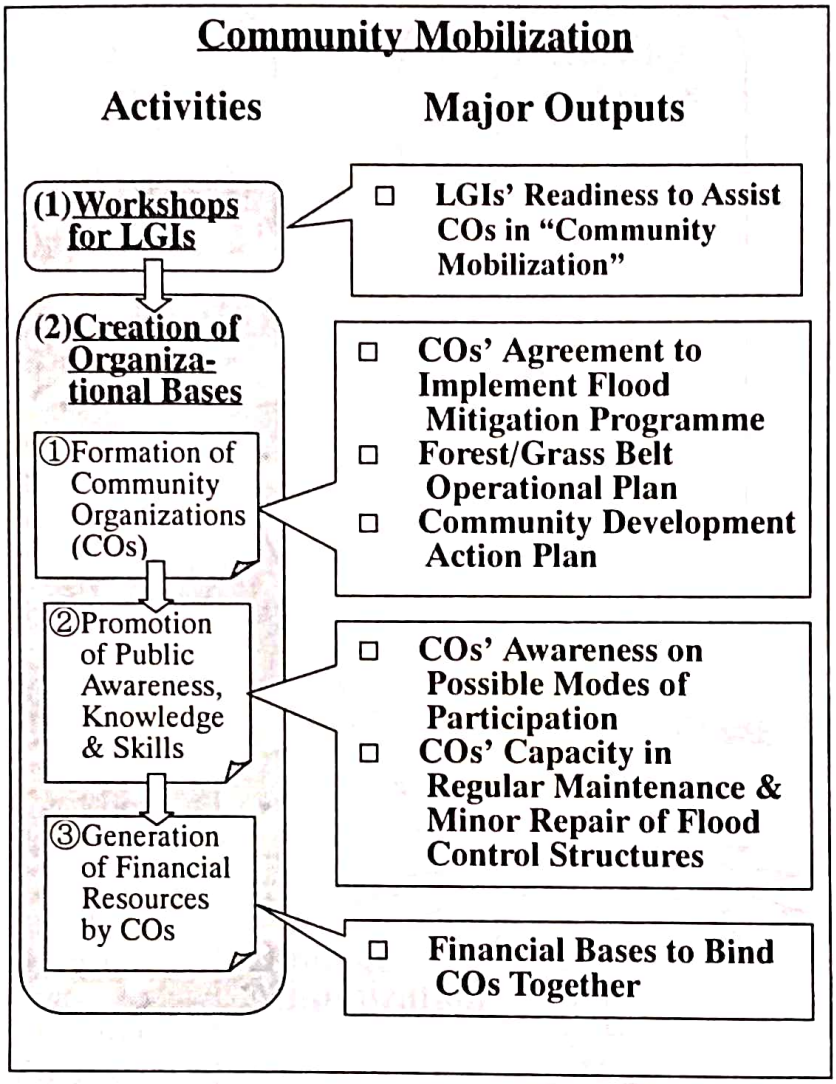

COMMUNITY MOBILIZATION

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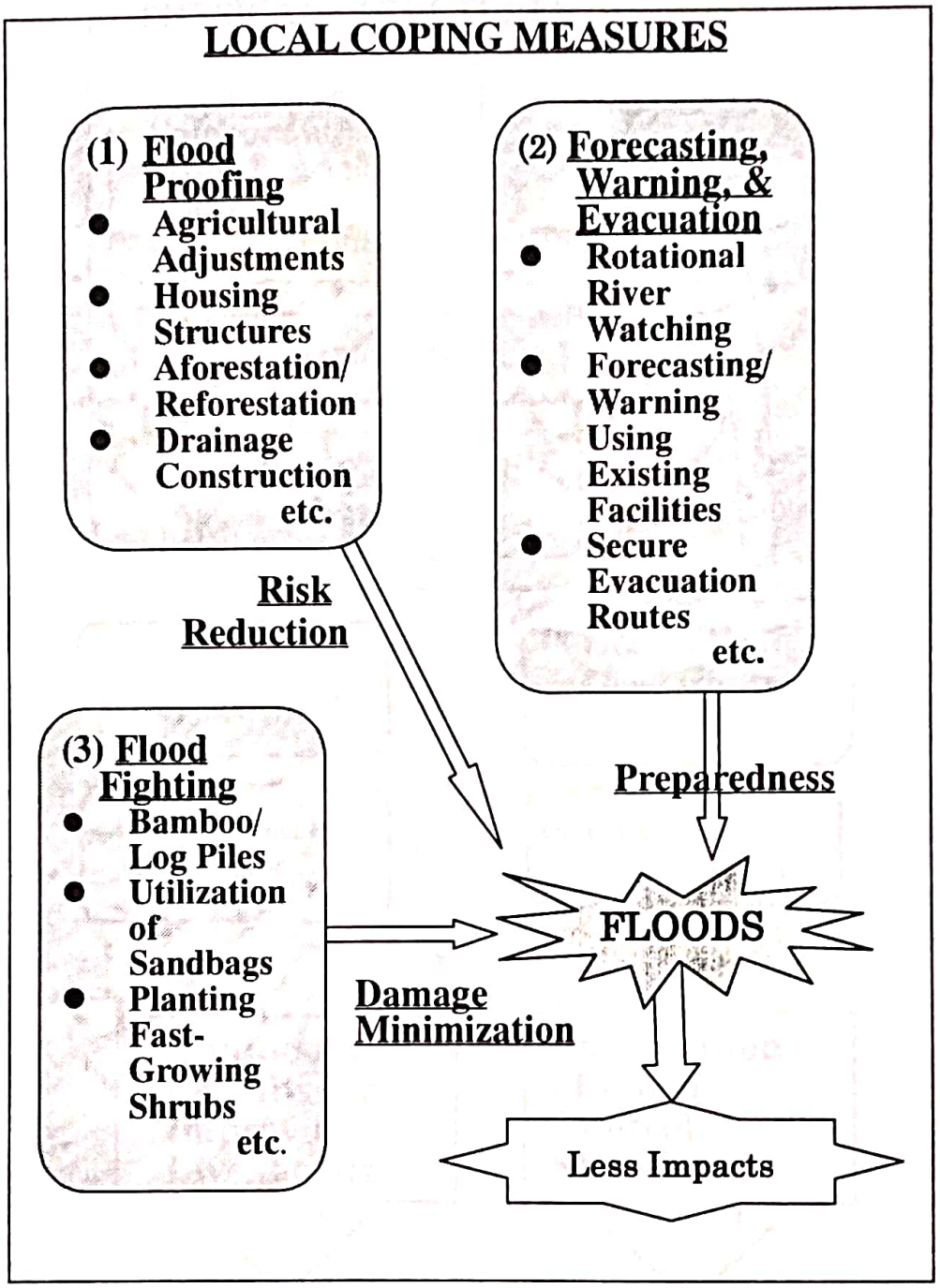

LOCAL COPING MEASURES

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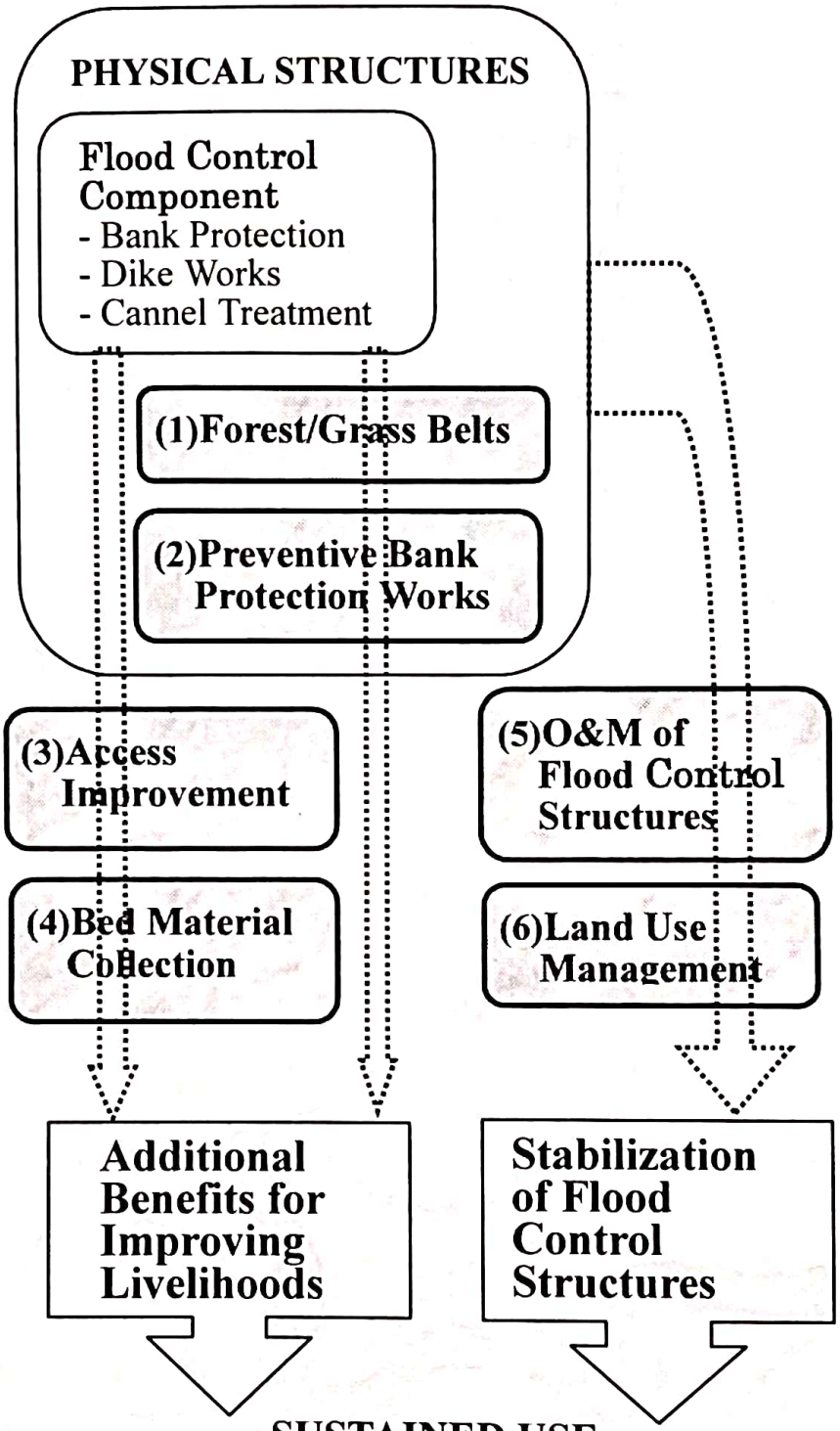
Community-based Sustainable Measures



COMMUNITY-BASED SUSTAINABLE MEASURES

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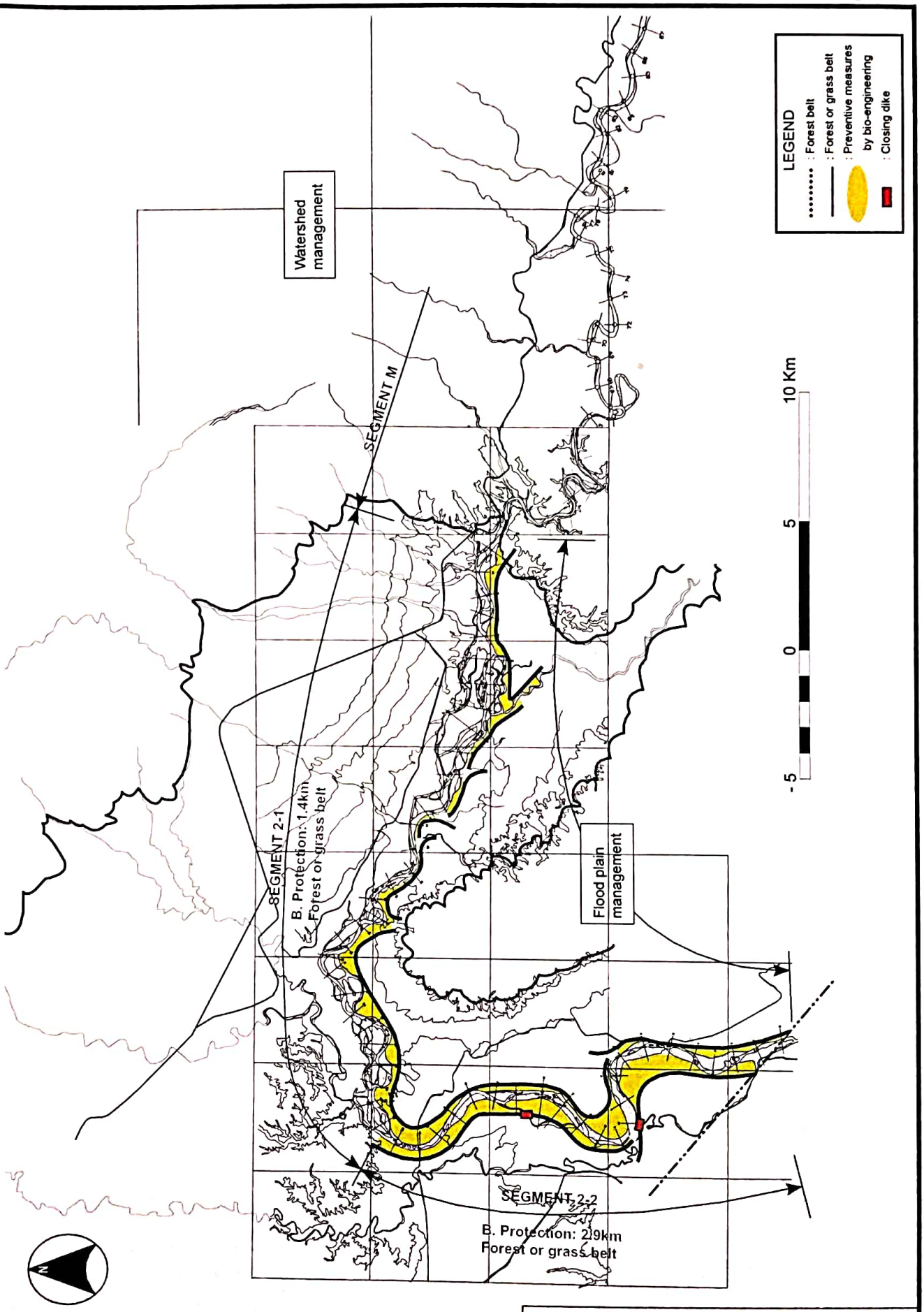

LAYOUT PLAN FOR FLOOD MITIGATION (WEST RAPTI RIVER)

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
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3. ACTION PROGRAM TOWARD TARGET YEAR

3.1 Sequence of Works

The Master Plan is proposed for the implementation by the target year of 2017. The project works must be carried out effectively in orderly manner toward the target year. It is also important to realize the flood mitigation effects, in the course of implementation, corresponding to the progress of work. In view of the above, consideration was given to the sequence of work as presented below.

(1) Preparatory Works

1) **Feasibility Study:** A Feasibility Study will be conducted immediately, mainly covering the following:
   (a) **River Survey:** To obtain topographic maps along the river with smaller contour intervals, longitudinal river profiles and cross sections.
   (b) **Restudy of Master Plan:** Based on the river survey result, the Master Plan proposed at the present stage should be subject to in-depth study.
   (c) **Feasibility Study:** The study will cover discrete environmental studies as well, in order to obtain approval for project implementation from MOPE.
2) **Fund Arrangement:** The project cost estimated in the Feasibility Study is allocated between the central and local governments, and local communities, taking into consideration the nature of work and the capability of funding.
3) **Definite Plan/Detail Design:** A definite plan of the flood mitigation works, including the river boundary line (RBL), will be drawn up after getting consent of the central and local government agencies and local communities concerned. A detailed design will be prepared of the project facilities.
4) **Preservation of Lands:** Population in the Terai is growing rapidly. Because of this, more and more people live in the flood prone areas close to the rivers. Therefore, it is essential to preserve the lands for flood mitigation facilities, and this should start immediately after the preparation of definite flood mitigation plan. Appropriate land use should also be encouraged as outlined in the definite plan and detail design.
5) **Research and Investigation:** In parallel with implementation of the specific flood mitigation projects, research and investigation activities are needed to support the projects. Among these following are included, but not limited to:
   (a) **Hydrological Study for Class-III Rivers:** Flood runoff and sediment

yield to be studied and analyzed especially for class III rivers originating at Siwalik hills. Observations on a designated model basin would serve this purpose.

(b) **Investigation of Bank Erosion Characteristics:** Characteristics of bank erosion in the Terai have yet to be investigated. Mechanisms of bank erosion, erosion speed/width, etc. should be investigated in relation with the river segment, riverbed and bank materials, river flow condition, etc.

(c) **Development of Bank Protection Works:** Various types of bank protection works should be introduced in each of the river segment, hared on effectiveness, materials available and cost-performance. Recommended bank protection work for rivers in the Terai should be made through hydraulic model tests in the laboratory and prototype models in field.

(d) **Research on Application of Bio-engineering Technology:** In order to introduce bio-engineering technology as a component of flood mitigation, research works and accumulation of experience are necessary, mainly for the selection of plant species, type and function of work applicable, cultivation techniques, and contribution to income generation.

(2) Coordination For Flood Mitigation

Coordination to mobilize watershed management and flood plain management should be taken as soon as possible in combination with the community development activities.

(3) River Works

1) **Channel Treatment Works:**

(a) **Tributary Works:** Tributary work to stop inflow/outflow from/to adjacent river basins will be implemented soon after the preparation of the definite plan.

(b) **Branch/Anabranch Work:** Closing works of branches and anabranches, with diversion structure if necessary, will be carried out soon after the preparation of definite plan.

(c) **Channel Connection Works:** Unification and normalization by connecting tributaries and drainage can be executed at any time before dike work commences.

2) **Bank Protection Works:**

(a) **Spur/Revetment Work:** Riverbank classified as Type-As bank needs protection works immediately and works are desirable for Type-A bank as well. The bank protection works will be executed continuously, primarily for Type-As banks identified by the periodic monitoring after every flood seasons.

(b) **Preventive Bank Protection Measures:** Preventive bank erosion measures by bio-engineering is required immediately for Type-A bank and are desirable for all the river bank between river course and boundary line of river zone.

3) **Dike Works:**

(a) **Forest and Grass Belts:** Forest belt will be formed inside of the river boundary line (RBL) in Segment 1 (alluvial fan) and grass belt in Segments 2-1 and 2-2 (natural levee zone). The work can be carried out at any time and any place, but for the purpose of marking the RBL it is best to do it quickly.

(b) **Local Dike and Dike Road:** The local dike and the dike road will be constructed inside along the RBL to protect the land locally and serves as rural road as well. These works should be started soon from the places where possible so as to realize the flood mitigation.

(c) **Ring Dike:** Ring dike work will be executed at the critical site.

(d) **Retarding Basin:** It is important to preserve the lands for the retarding basin, confining by forest belt, grass belt or earth dike.

4) **Channel Excavation and COC Works:**

(a) **Channel Excavation:** Channel excavation will be executed for channel normalization in extremely narrow sections.

(b) **Bed Material Collection:** Bed materials can be collected for construction materials soon after the preparation of definite plan according to a regulation to be prepared for bed material exploitation.

3.2 Action Plan

Implementation of the Master Plan project is programmed, in principle, by the phases of the national development plan from the ninth through twelfth plans as follows:

1) 1st Phase (Ninth plan: 1997-2002):

(a) Preparatory works such as feasibility study, fund arrangement, definite plan/detail design, preservation of lands will be performed.
(b) Research and investigation, and coordination for watershed management and flood plain management will be started in combination with community development activities.
(c) Bank protection and ring dike works will be executed at the critical sites.
(d) Preventive bank protection works by bioengineering, and bed material collection are also started in this phase.

2) 2nd Phase (Tenth plan: 2002-2007):

(a) Channel treatment work which is the key to stabilize the river system will be executed.
(b) Forest belt will start for its work in field. Grass belt will be completed for Segment 2-1 and 2-2.
(c) Local dikes and dike roads will be constructed where they are required.

3) 3rd Phase (Eleventh and twelfth plan: 2007-2017):

(a) All the works and activities targeted for the Master Plan will be completed.

General Action plan for the implementation of the Master Plan project is shown in Fig. A3.1.

3.3 Implementation Arrangements

(1) Coordinating/Implementing Agencies

The flood mitigation program will be managed by the DOI Project Management Office (PMO) to be set up at the district level. The PMO will comprise three divisions, i.e., an Upper Catchment Conservation Division, Flood Control Division, and Community Development Division. As shown in Fig. A3.2, it is expected that DOSCWM will depute its staff to work as the Chief of the Upper Catchment Division, while all the other key posts will be filled by DOI staff.

The River Control Division will take the lead in the design and construction management of the River Control Component. At the same time, the local government institutions (LGIs) also play an important role to match the DOI's resources with local communities. The LGIs will assist DOI in aggregating local information required for the design of the physical facilities, and also will encourage community organizations (COs) to make in-kind (labor, land, and material)/cash contributions to the construction of the flood control facilities. During the maintenance phase, also, LGIs will assist COs, when necessary, to liaise with DOI and other agencies to provide external skills and resources for the rehabilitation of flood control facilities. The River Control Component will draw largely upon bioengineering measures. The River Control Division will therefore seek, as and when necessary, technical as well as material inputs (e.g., seedlings and samplings) from technical line agencies such as the DOF and DOSCWM .

The Community Development Division will implement the Community Development Component. The Division will maintain close coordination with the LGIs. Under the overall coordination and supervision of the PMO Division, the LGIs will undertake community mobilization to assist communities to organize themselves, and will assist their community organizations (COs) to implement community-based flood mitigation measures. The community development activities envisage a range of activities which no single agencies can handle on its own. Accordingly, the Community Development Division will mobilize technical line agencies, e.g., DOSCWM, and DOA to provide technical and material inputs for community development activities.

A District-level Coordination Committee (DCC) will also be established, to provide coordination between the PMO and other relevant agencies which will participate as Cooperating Agencies (the details of the Cooperating Agencies' roles are provided in the following section). As shown in the figure on the implementation arrangement, the DCC will draw membership from the District Development Committee (DDC) as well as other line agencies. The latter include the Departments of Soil Conservation and Watershed Management (DOSCWM), Forest (DOF), and Agriculture (DOA). The Chief District Officer (CDO) will also serve as a DCC member. If and when need arises, other line agencies and/or NGOs may be included as DCC members.

At present, all the district-level DOI's resources for flood control are channeled through the District River Training Coordination Committee (DRTCC). On the other hand, the master plan will replace DRTCC with DCC, since the latter has the following

advantages over DRTCC:

1) **All the flood-prone villages will be directly represented in DCC,** to provide an open and transparent forum for interactions between the district and the villages (whereas DRTCC is composed only of district-level representatives, which often is the cause of irrational allocation of funding).
2) **DCC will draw members from pertinent line agencies,** i.e., DOSCWM, DOF, and DOA for a more comprehensive approaches to river training (whereas DRTCC does not include any line agencies, which makes it difficult to coordinate river training, with other related developmental activities).

(2) Cooperating Agencies

The DCC member institutions will participate in the program implementation, as the cooperating agencies. The flood mitigation program is a multi-sectored undertaking which no single agencies can handle on its own. Accordingly, DOI will mobilize technical line agencies as well as local government institutions, who will take on the tasks and responsibilities explained below.

Technical Line Agencies

DOSCWM :

1) Initiate programs aimed at soil conservation in the Chure range.
2) Provide seed and seedlings, as well as technical support for soil conservation.
3) Offer technical advice and also provide seedlings to protect infrastructure, soil erosion and flooding.

DOF:

1) Assist in establishing green belts along riverbanks.
2) Provide seed and saplings, as well as technical support.
3) Hand over forest /riverbed management to local communities wherever feasible.
4) In the watershed – hand over management of the forests to the local communities wherever feasible, and assist in their management.

DOA:

1) Provide technical advice on safe cultivation on the riverside.

2) Offer awareness building and seedlings to support in crop production that would minimize river cutting and flood damage.

CDO:

1) Resolve conflicts when DDC/VDCs alone cannot handle.
2) Make available district-level Natural Calamity Fund for community-level flood management.
3) Coordinate relief activities with the overall Flood Mitigation Plan.

Local Government Institutions (LGIs)

DDC:

1) Undertake the "Community Development" component, in collaboration with the VDCs, and communities.
2) Contribute some funding/other resources for "Community Development", in accordance with financial capacity.
3) Promote inter-VDC coordination, and/or coordination between DIO/other line agencies and the VDCs.
4) Shoulder the responsibility of regular monitoring and minor repair in partnership with the VDC/municipality.
5) Resolve conflict among different VDCs.
6) Include the program as a priority sector in district planning.

VDC / Municipality:

1) Collaborate with the DDC and local communities to conduct the "Community Development" component.
2) Contribute some funding/other resources for "Community Development", in accordance with financial capacity.
3) Undertake regular maintenance and minor repair.
4) Mobilize community participation.
5) Set criteria of community/individual contribution on the basis of equity.
6) Control encroachments/inappropriate practices along riverbanks.
7) Take the main role to minimize and resolve conflicts, if any.

In view of upgrading the LGIs' capabilities to undertake these crucial roles for "community development", a series of training workshops will be undertaken at the inception of "community development" activities, as mentioned in the section on

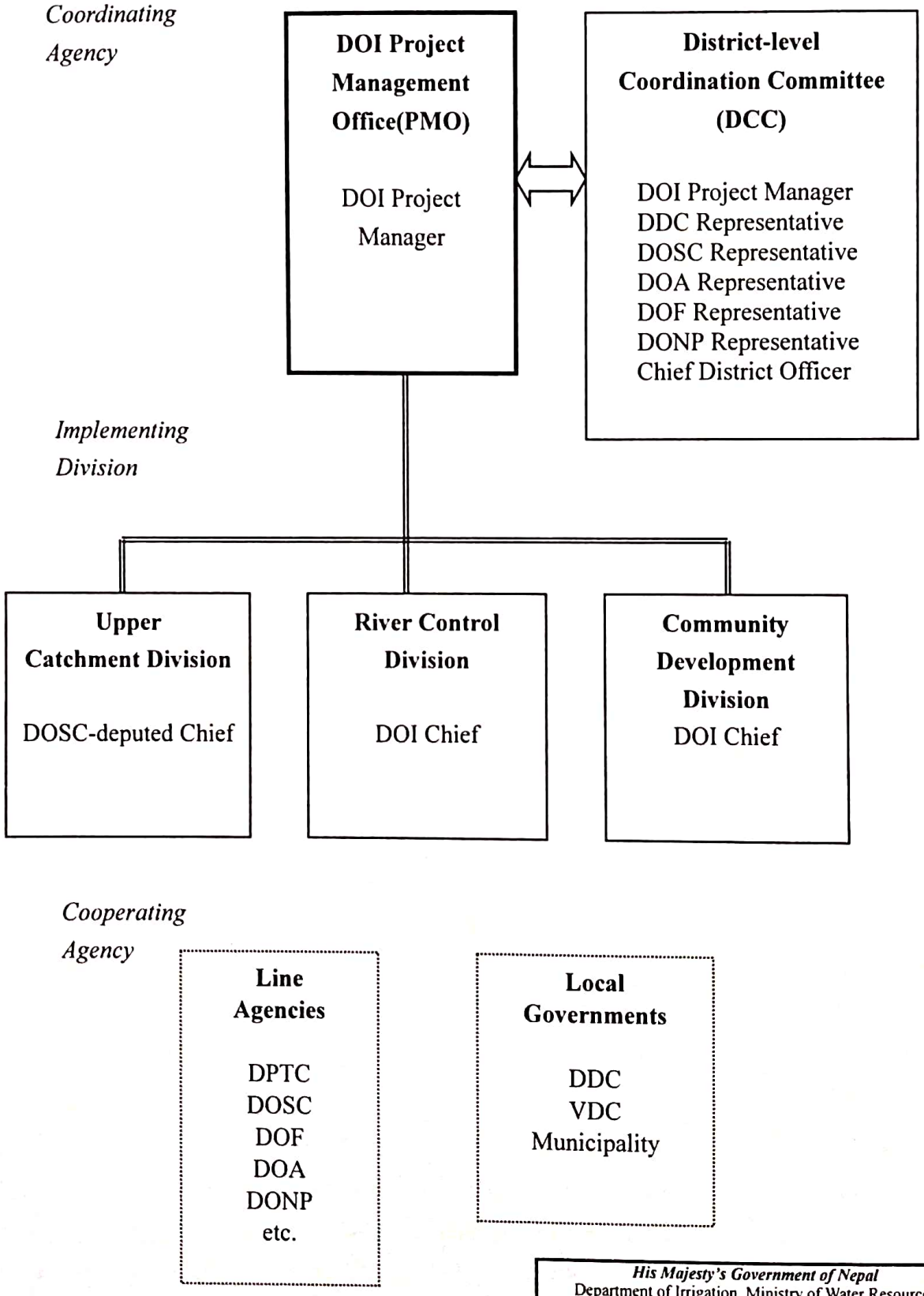
"Community Development" component.

ACTION PROGRAM TOWARD TARGET YEAR

River: **WEST RAPTI RIVER**

Activities / Master Plan / National Plan (year)	Phasing			
	1st.	2nd.	3rd.	
	9th (1997-2002)	10th (2002-2007)	11th (2007-2012)	12th (2012-2017)
(1) Preparatory Works				
1) Feasibility study:				
·River survey				
·Restudy of master plan				
·Feasibility study				
·Environmental study				
2) Fund arrangement				
3) Definite plan/ detail design				
4) Preservation of lands				
5) Rsearch/ investigation				
(2) Coordination for Flood Mitigation				
1) Community development				
2) Watershed management				
3) Flood Plain Management				
(3) River Works in Segment-1				
Channel treatment works:				
·Tributary works				
·Branch/ anabranch works				
Bank protection works:				
· Spur/ rvetment				
· Preventive bank protection measurs (by bio-engineering)				
Dike works:				
· Forest belt				
· Ring dike				
Channel excavation works:				
· Bed material exploitation				
Retarding basin				
(4) River Works in Segment-2				
Channel treatment works:				
·Tributary works				
·Branch/ anabranch works				
Bank protection works:				
· Spur/ revetment				
· Preventive bank protection measurs (by bio-engineering)				
Dike works:				
· Grass belt				
· Low dike road w/ drainage sluice				
· Continuous dike w/ drainage sluice				
· Ring dike				
Channel excavation works:				
· Bed material exploitation				
· Widening channel				
Cut-off channel works				
Retarding basin				

IMPLEMENTATION ARRANGEMENT FOR FLOOD MITIGATION IN TERAI



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4. EVALUATION

4.1 Economic Evaluation

(1) Basin Overview

West Rapti river flows in Dang district, and the river flows through Banke district before entering India. The total basin in the plain is 61,800 hectares in size, 55 % of the land is for agriculture, while forests cover 40%. There are no manufacturing establishments in the affected villages along West Rapti river.

Paddy production occupies the largest area of agricultural land (with the estimated 1996/97 production of 38,100 metric tons), followed by wheat (9,300 metric tons) and pulse (6,300 metric tons). Based upon the retail value of 96/97, paddy production amounted to Rs.647 million, and in the case of pulses, Rs.252 million.

(2) Effects of Flood Mitigation

Implementation of the flood mitigation Master Plan will primarily safeguard the land and properties in the flood prone areas and also bring about other favorable effects to the Study Area. The potential benefits and effects expected to accrue from the Master Plan, including tangible and intangible ones, are listed below.

1) **Reduction of damage due to flood and sediment:** Inundation and sedimentation will be alleviated and reduce damages of village houses, crop production, public facilities, etc.
2) **Protection of riverbank from erosion:** Loss of lands due to riverbank erosion are averted, and villages and farmlands will be protected.
3) **Indirect effects:** Owing to the reduction in damages in flood prone area, social and economic activities in the surrounding areas will not be interfered.
4) **Land enhancement:** Flood mitigation project ensure the social and economic activities in the flood prone area which enable further investments for the development of the flood prone area and the surrounding areas.
5) **Land reclamation:** Existing low-lying barren lands along the river turn to arable ones. Channel excavation and normalization at severely meandering section may create lands for agriculture and settlement.
6) **Flood-free embankment:** The earth embankment constructed as local dike and ring dike can be used as rural roads and flood-free areas in the flood prone

area. The area will also serve for evacuation and flood fighting activities.

7) **Income generation:** The forest belt and grass belt for flood mitigation will generate community's income. The trees from the forest belt could be used for flood mitigation as well.
8) **Stabilization of residents' livelihood:** Flood free land is the basis of the residents' livelihood in the flood prone areas. Only under such conditions, residents are encouraged to accumulate their immovable and other properties, and accordingly can stabilize their livelihood.
9) **Community development:** The Master Plan places emphasis on flood mitigation through community development. The community-based approaches will forge links among the resident people and may enable other community development activities.

(3) Preliminary Economic Evaluation for Master Plan Projects

Economic viability of the flood mitigation Master Plan was examined preliminarily. Out of the various effects listed in the previous section, (a) flood damage reduction benefit, (b) bank protection benefit, and (c) indirect benefit were considered as tangible benefit for the evaluation.

Flood Damage Reduction Benefit: Flood damage study by hydraulic analysis is difficult at this stage, since the river section data are not available and available topographic and hydrological data are limited. The flood damage reduction benefit was estimated preliminarily based on the damage data of recent large flood.

Bank Protection Benefit: Benefit accruing from bank protection works was estimated as a product of the land area to be protected from erosion and the amount of property on the unit land area to be protected.

Conditions for Economic Evaluation: Evaluation was made for the existing basin conditions and future basin conditions in target year (2017). The benefit in the target year was assumed in proportional to the population projected. Cash flows of the project cost, maintenance cost and benefit are shown in Table A4.1. With these cash flows, the economic internal rate of return (EIRR), cost-benefit ratio (B/C) and net present value (NPV, or B-C) were worked out. The results are summarized below, though these should be restudied in future based on river survey data.

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^6Rs)
W.Rapti	4.2	0.43	-49.2	11.8	0.99	-1.2

Note *: B/C and NPV were calculated under the discount rate of 12%.

Methodology and procedures of economic evaluation of the project are compiled in SUPPORTING REPORT-C.

4.2 Environmental Screening

(1) Environmental Screening of Rivers Covered by Master Plan

An environmental screening has been undertaken following the JICA environmental screening process, since there is no statement for environmental screening in Environmental Conservation Rules (ECR) of Nepal. The screening is termed an "initial environmental examination" by JICA. However, it should not be confused with the IEE as specified in Environmental Conservation Rules of Nepal. This latter is a detailed and prolonged environmental assessment, where as the former is an environmental screening to determine which specific projects or areas within a project require detailed environmental studies. Thus in order to avoid confusion the JICA "initial environmental examination" will be termed as "environmental screening" or ES.

(2) Results of Environmental Screening

The flood mitigation plan for the West Rapti river is to align and demarcate the two river banks along the length of the river in the Terai, so as to minimize flood damage. These banks will then be stabilized by vegetative means (forest and grass belts). Occasionally, some riverbanks will be reinforced. There are 37,500 ha of listed wetlands along this river, much of which are in the "inner Terai". Those wetlands in the plan area will be mapped, their use tabulated, and a plan formulated to protect them, where feasible.

Screening forms filled as a result of environmental screening are shown in Tables A4.2 through A4.4 for social environment assessment, natural environment assessment and pollution assessment, respectively.

(3) Overall Evaluation

The flood mitigation interventions on the West Rapti river basin in the Terai are overwhelmingly environmentally positive. Flood mitigation interventions will occur along the whole length of the river in the Terai. In particular, the two riverbanks will be realigned and demarcated by the river boundary line (RBL) so as to minimize flood damage. The RBL will be reinforced by physical and/or vegetative means, namely dikes, river training, and the planting of trees and grasses. These interventions will minimize flooding, decrease soil erosion from river banks and farmer's fields, minimize river course changes, reduce the deposition of coarse gravel, sand and soil particles on farmland and curtail house flooding and subsidence. It should also decrease the incidence of raw human sewage spilling into rivers, thus reducing infection from disease such as cholera.

Some houses may have to be relocated and some farmland taken if they are on the river boundary line (RBL) or on the riverside of the RBL. These measures cannot be undertaken without the consent of and compensation for the affected people. However, by stabilizing the river course and minimizing flood damage, the existing land (and houses) near to the river will be protected from degradation and previously degraded land can be reclaimed. So there should be a considerable net benefit. Also, the land on the riverside of the RBL may still be farmed during the "dry" season.

These interventions cannot be successful without the approval and active participation of the people living along or in the vicinity of the rivers. Flood mitigation measures, including repair and maintenance of the existing and proposed structure are ongoing activities. If the people are not involved in and approve of these activities from the outset, then the chances of successful flood mitigation measures will be minimal. Village Development Committees, Municipalities and District Development Committees must be a party to the plans and play an active role in their formulation, amendment and approval. The plans should also be dynamic and subject to alteration, addition and improvement as a result of learning from interventions in this and other river systems. However, the overall plan should not be subject to a rigorous environmental examination. This should be reserved for "fragile" areas that may be affected adversely as a result of the interventions.

(4) Environmental Study in Future

According to new Environmental Conservation Rules (ECR) issued in June 1997, an Initial Environmental Examination (IEE) is necessary when compiling a watershed management plan. If any of the planned interventions, such as riverbank protection, are more than 1 km in length, an IEE is needed at the project proposal stage. Similarly, if tree planting is planned then an IEE or an EIA may be necessary at the project proposal stage. The determining factor is whether the proposed planting is in a continuous block of a single indigenous species of more than 25 hectares, or for a single exotic species, is in a continuous block of more than 5 hectares.

There may be several houses and some fields within the RBL. A survey should be undertaken along the whole stretch of the river system, within the Terai, to determine the number of houses falling between the proposed RBLs and the ownership and land use of the land between the boundaries. Some of these houses may have to be relocated and others protected by a ring dike. Depending upon the number of houses to be relocated, either an IEE or an EIA will have to be undertaken at the project proposal stage. This survey should record possible relocation sites by location and area as well as degraded land that could be rehabilitated. At the same time, a note could be made of any religious, historic or archeological sites or building along or near the river. If there are any, then measures must be taken to protect them.

The agreement on the interventions of the people living along the river is not only necessary, but also critical to the success of the plan. This is why it is important to explain the proposals to all the concerned individuals and local authorities so that a consensus can be arrived at. Without agreement and support of the local people some of the proposed flood mitigation measures, particularly dike work and bioengineering measures, may not be implemented. If so, lasting flood prevention will be impossible to achieve.

Several bank protection measures are proposed along the river. If these are more than 1 km in length, an IEE will be required for each site at the project proposal stage. There may be ring dike protection work, of more than 1 km in circumference, round some groups of houses. If so, an IEE is necessary.

According to the Inventory of Wetlands in the Terai, (IUCN 1996), all the wetlands along the West Rapti river have still to be determined. A new inventory of wetlands is

due to be published in the next six months. This inventory may contain information about wetlands in the vicinity of this river, especially the Rapti Flood plain. Otherwise, a special survey may have to be mounted to determine, if there are any wetlands that may be affected by the flood mitigation measures.

4.3 Technical Evaluation

The flood mitigation activities must be undertaken in a sustainable way. Therefore, the plan must fit well with the local situation, the technical capability and financial solvency of the central and local government agencies, non-governmental organizations and local communities concerned. In planning the flood mitigation plan of the rivers in the Terai plain, efforts were made for the plan to meet these requirements as presented below.

1) **Consideration on Local Situation:**
   - Bottom-up procedures by community development activities are proposed for planning and implementation of the project.
   - Maximum use of local materials is proposed, and the works proposed are labor intensive.
   - Considering the potential disastrous situation of the Study Area, stage-wise approaches are proposed so that the residents could enjoy the benefits soon after they have been finished the component works invested.
   - The proposed works are selective for their sizes and able to enhance their function depending on the requirements and solvency of the local communities.

2) **Consideration on Technical Capability:**
   - The proposed works are mostly simple for their construction and maintenance as far as the appropriate instructions are given timely by the DOI/DIO engineer.
   - Participation of local communities in flood mitigation work is proposed. Through the experience of participation, local community will also learn the technique for flood mitigation and improve their awareness. This would contribute much to the sustainability of the project operation.
   - The proposed river control measures will be improved through on-site experience so that the measures will be more effective, practical and economic.

3) **Consideration on Financial Solvency:**
   - Taking into consideration the financial strictures of the country, low cost and labor intensive project is proposed with full use of local materials.
   - In addition to the procurement of fund from central and local government, in-come generation measures are proposed as a part of community development activities.

4.4 Conclusion and Recommendation

1) Implementation of the Master Plan will bring about various tangible and intangible benefits, to the communities in the Study Area. The project works can be implemented from those of higher cost-performance, keeping pace with basin's development.
2) From environmental conservation viewpoint, the proposed project will exert favorable effects on social and natural environment and no pollution problems are envisaged. Only problems found so far are conservation of wetlands most of which have already been developed as farmlands or are in protected areas of national parks and wildlife reserves.
3) The technology proposed for the Master Plan is appropriate, since the plan took due consideration of the local situation, the technical capability of the people and financial solvency of the country, etc.
4) The proposed Master Plan is economically and technically sound and exerts little adverse effect to the environment. Immediate implementation of the Feasibility Study is recommended in order to promote and support people's livelihood and the sound development of the Terai plain.

COST BENEFIT FLOW FOR MASTER PLAN

(Existing Basin)

River: West Rapti (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	2,620	0	2,620	0	2,620	0
2 2000	2,620	0	2,620	0	2,382	0
3 2001	7,841	0	7,841	0	6,480	0
4 2002	15,451	0	15,451	0	11,609	0
5 2003	15,451	82	15,533	972	10,610	664
6 2004	15,451	165	15,616	1,943	9,696	1,207
7 2005	11,893	247	12,140	2,915	6,853	1,646
8 2006	11,893	311	12,204	3,663	6,262	1,880
9 2007	11,893	374	12,267	4,411	5,723	2,058
10 2008	11,893	438	12,331	5,159	5,229	2,188
11 2009	11,893	501	12,394	5,907	4,778	2,277
12 2010	11,893	564	12,457	6,655	4,366	2,332
13 2011	11,893	628	12,521	7,403	3,990	2,359
14 2012	11,893	691	12,584	8,151	3,645	2,361
15 2013	11,893	755	12,648	8,899	3,331	2,343
16 2014	11,893	818	12,711	9,647	3,043	2,309
17 2015	11,893	882	12,775	10,395	2,780	2,262
18 2016	11,893	945	12,838	11,142	2,540	2,204
19 2017	6,671	1,009	7,680	11,890	1,381	2,139
20 2018		1,044	1,044	12,310	171	2,013
21 2019		1,044	1,044	12,310	155	1,830
22 2020		1,044	1,044	12,310	141	1,663
23 2021		1,044	1,044	12,310	128	1,512
24 2022		1,044	1,044	12,310	117	1,375
25 2023		1,044	1,044	12,310	106	1,250
26 2024		1,044	1,044	12,310	96	1,136
27 2025		1,044	1,044	12,310	88	1,033
28 2026		1,044	1,044	12,310	80	939
29 2027		1,044	1,044	12,310	72	854
30 2028		1,044	1,044	12,310	66	776
31 2029		1,044	1,044	12,310	60	705
32 2030		1,044	1,044	12,310	54	641
33 2031		1,044	1,044	12,310	49	583
34 2032		1,044	1,044	12,310	45	530
35 2033		1,044	1,044	12,310	41	482
36 2034		1,044	1,044	12,310	37	438
37 2035		1,044	1,044	12,310	34	398
38 2036		1,044	1,044	12,310	31	362
39 2037		1,044	1,044	12,310	28	329
40 2038		1,044	1,044	12,310	25	299
41 2039		1,044	1,044	12,310	23	272
42 2040		1,044	1,044	12,310	21	247
43 2041		1,044	1,044	12,310	19	225
44 2042		1,044	1,044	12,310	17	204
45 2043		1,044	1,044	12,310	16	186
46 2044		1,044	1,044	12,310	14	169
47 2045		1,044	1,044	12,310	13	154
48 2046		1,044	1,044	12,310	12	140
49 2047		1,044	1,044	12,310	11	127
50 2048		1,044	1,044	12,310	10	115
Total	208,821	40,777	249,598	480,761	99,098	51,216

EIRR: 4.2%
B/C: 0.52
NPV(B-C): -47,882 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN

(Future Basin)

River: West Rapti (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	2,620	0	2,620	0	2,620	0
2 2000	2,620	0	2,620	0	2,382	0
3 2001	7,841	0	7,841	0	6,480	0
4 2002	15,451	0	15,451	0	11,609	0
5 2003	15,451	82	15,533	2,216	10,610	1,513
6 2004	15,451	165	15,616	4,431	9,696	2,751
7 2005	11,893	247	12,140	6,647	6,853	3,752
8 2006	11,893	311	12,204	8,352	6,262	4,286
9 2007	11,893	374	12,267	10,057	5,723	4,692
10 2008	11,893	438	12,331	11,762	5,229	4,988
11 2009	11,893	501	12,394	13,468	4,778	5,192
12 2010	11,893	564	12,457	15,173	4,366	5,318
13 2011	11,893	628	12,521	16,878	3,990	5,378
14 2012	11,893	691	12,584	18,584	3,645	5,383
15 2013	11,893	755	12,648	20,289	3,331	5,343
16 2014	11,893	818	12,711	21,994	3,043	5,265
17 2015	11,893	882	12,775	23,700	2,780	5,158
18 2016	11,893	945	12,838	25,405	2,540	5,026
19 2017	6,671	1,009	7,680	27,110	1,381	4,876
20 2018		1,044	1,044	28,067	171	4,589
21 2019		1,044	1,044	28,067	155	4,172
22 2020		1,044	1,044	28,067	141	3,793
23 2021		1,044	1,044	28,067	128	3,448
24 2022		1,044	1,044	28,067	117	3,134
25 2023		1,044	1,044	28,067	106	2,849
26 2024		1,044	1,044	28,067	96	2,590
27 2025		1,044	1,044	28,067	88	2,355
28 2026		1,044	1,044	28,067	80	2,141
29 2027		1,044	1,044	28,067	72	1,946
30 2028		1,044	1,044	28,067	66	1,769
31 2029		1,044	1,044	28,067	60	1,608
32 2030		1,044	1,044	28,067	54	1,462
33 2031		1,044	1,044	28,067	49	1,329
34 2032		1,044	1,044	28,067	45	1,208
35 2033		1,044	1,044	28,067	41	1,099
36 2034		1,044	1,044	28,067	37	999
37 2035		1,044	1,044	28,067	34	908
38 2036		1,044	1,044	28,067	31	825
39 2037		1,044	1,044	28,067	28	750
40 2038		1,044	1,044	28,067	25	682
41 2039		1,044	1,044	28,067	23	620
42 2040		1,044	1,044	28,067	21	564
43 2041		1,044	1,044	28,067	19	513
44 2042		1,044	1,044	28,067	17	466
45 2043		1,044	1,044	28,067	16	424
46 2044		1,044	1,044	28,067	14	385
47 2045		1,044	1,044	28,067	13	350
48 2046		1,044	1,044	28,067	12	318
49 2047		1,044	1,044	28,067	11	289
50 2048		1,044	1,044	28,067	10	263
Total	208,821	40,777	249,598	1,096,136	99,098	116,772

EIRR: 11.8%
B/C: 1.18
NPV(B-C): 17,674 (NRs.1,000)

SOCIAL ENVIRONMENT ASSESSMENT: WEST RAPTI RIVER.

No.	Environmental Item	Type of Impact	Evaluation	Remarks
a	Resettlement	Resettlement by land occupation (Transfer of residence/land ownership rights)	B	Some people along the river will have to be resettled
b	Economic Activities	GAIN in production base (land etc.) and change of economic structure.	A	Stabilization of river banks and prevention of erosion and land degradation should lead to increase of productive land base
c	Traffic and Public Facilities	Positive impact on existing traffic, schools, hospital etc. (e.g., Traffic congestion, accident rate)	A	New roads should improve access to facilities and markets
d	Split of Communities	Separation of communities by interference of regional traffic.	D	No regional traffic
e	Cultural Property	Loss or deterioration of cultural properties such as temples, shrines, historic assets.	D	No loss envisaged. List to be made of historic assets, if any.
f	Water Rights and Rights of Common	IMPROVED access to water, irrigation or fishing rights.	B	By stabilizing river, there should be improved access to irrigation water and well water will have less chance of contamination.
g	Public Health Condition	IMPROVEMENT of health or sanitary conditions due to more secure latrines. There may be increased risk of pollution due additional use of agricultural chemicals.	B	Improved sanitary conditions may reduce the risk of water born diseases such as cholera. Over time farmers will use more fertilizers; these may contaminate the water supply
h	Waste	Eroded gravel, sand and soil trapped by the vegetation planted along the river banks. Domestic waste secured from polluting the river.	A	Vegetation used to build up river banks. Houses moved to prevent subsidence and thus effluent pollution
i	Hazards (Risks)	DECREASED risk of subsidence, building collapse and accidents.	A	By stabilizing the river banks, it will reduce risk of subsidence to buildings near the river.
j	Other (specify)			

Note. The column entitle "Type of Impact" describes the possible outcomes as a result of the project.
The marking system under "Evaluation" refers to the degree of environmental impact.
It is as follows: **A**, Important; **B**, Some; **C**, Unknown; **D**, No.
The "Remarks" column lists major environmental costs and benefits.

NATURAL ENVIRONMENT ASSESSMENT: WEST RAPTI RIVER.

No.	Environmental Item	Type of Impact	Evaluation	Remarks
a	Topography And Geology	Change of important topography and geology DECREASED due to REDUCTION of natural excavation and earth-fill.	B	Flood mitigation measures help prevent natural excavation and earth-fill.
b	Soil And Land	DECREASE of topsoil erosion by flood mitigation initiatives including reforestation. IMPROVEMENT to soil fertility, through decrease deposition of coarse gravel etc.	A	Flood mitigation measures will decrease topsoil erosion and the deposition of coarse sand and gravel onto fields close to the river.
c	Groundwater	Lowering of groundwater table due to overdraft and turbid water caused by construction work.	D	Flood mitigation measures will not affect water table during construction work.
d	Hydrological Situation	Change of discharge and water quality due to reclamation and/or drainage.	B	Successful flood mitigation interventions will lead to land reclamation of land previously degraded by past flooding.
e	River Basin	River basin erosion DECREASED and POSITIVE vegetation changes due to land reclamation and river training.	A	As a result of flood mitigation measures, soil erosion should decrease in the river basin, and land reclamation will increase due to river training. These measures should have a positive impact on the flora and fauna.
f	Fauna And Flora	Interruption of reproduction or extinction of species due to habitat changes.	D	There should be no effect on species due to habitat changes. But see Wetlands under (i) below.
g	Meteorology	Changes in microclimate, such as temperature, wind etc. due to large-scale reclamation and construction.	D	No large-scale construction or reclamation considered. However, the proposed planting of a belt of trees along both river banks may improve the local microclimate.
h	Landscape	IMPROVEMENT of aesthetic beauty by structural and topographical changes due to reclamation.	B	Flood mitigation measures, especially the planting of trees and grasses should improve the habitat and encourage an increased fauna.
i	Other (specify)	Wetland stability, (in the Terai).	A	The listed wetlands in the river basin will be identified and measures taken to stabilize or improve their habitat.

Note. The column entitle "Type of Impact" describes the possible outcomes as a result of the project.
The marking system under "Evaluation" refers to the degree of environmental impact.
It is as follows: **A**, Important; **B**, Some; **C**, Unknown; **D**, No.
The "Remarks" column lists major environmental costs and benefits.

POLLUTION ASSESSMENT: WEST RAPTI RIVER.

No.	Environmental Item	Type of Impact	Evaluation	Remarks
a	Air Pollution	Change in air quality caused by exhaust gases or toxic gases from vehicles and/or factories.	D	Not applicable
b	Water Pollution	Water pollution of rivers and groundwater caused by drilling mud and oil.	D	Not applicable
c	Soil Contamination	Contamination caused by discharge or diffusion of sewage or toxic substances.	D	Sewage from houses contaminating the soil should be negligible.
d	Noise and Vibration	Generation of noise and vibrations due to drilling and operation of pumping machines.	D	Not applicable
e	Land Subsidence	Deformation of the land and land subsidence due to lowering of groundwater table.	D	Increased population may use more groundwater, but the flood mitigation project should have no negative effect on the groundwater table.
f	Offensive Odour	Generation of offensive odours and exhaust gases.	D	These will be negligible or non-existant.
g	Other (specify)			

Note. The column entitle "Type of Impact" describes the possible outcomes as a result of the project.
The marking system under "Evaluation" refers to the degree of environmental impact.
It is as follows: **A**, Important; **B**, Some; **C**, Unknown; **D**, No.
The "Remarks" column lists major environmental costs and benefits