社会開発調査部報告書

No. 62

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 (2/9)

SUPPORTING REPORT

(A2: FMP/LOHANDRA RIVER)

MAY 1999

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

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 (2/9)

SUPPORTING REPORT

(A2: FMP/LOHANDRA RIVER)

MAY 1999

NIKKEN Consultants, Inc.

NIPPON KOEI CO., LTD.

THE STUDY

ON

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

FINAL REPORT

VOLUME I : EXECUTIVE SUMMARY

VOLUME II : MAIN REPORT

VOLUME III : SUPPORTING REPORT

- A1: FLOOD MITIGATION PLAN/RATUWA RIVER
- A2: FLOOD MITIGATION PLAN/LOHANDRA RIVER
- A3: FLOOD MITIGATION PLAN/LAKHANDEI RIVER
- A4: FLOOD MITIGATION PLAN/NARAYANI RIVER
- A5: FLOOD MITIGATION PLAN/TINAU RIVER
- A6: FLOOD MITIGATION PLAN/WEST RAPTI RIVER
- A7: FLOOD MITIGATION PLAN/BABAI RIVER
- A8: FLOOD MITIGATION PLAN/KHUTIYA RIVER
- B : OVERALL DESCRIPTION OF STUDY AREA
- C : BASIC INVESTIGATIONS AND STUDIES
- D : OTHER DOCUMENTS

VOLUME IV : DATA BOOK

The costs are estimated based on the price and average exchange rate in October 1998.

The average exchange rate is as follows:

US$ 1.00=NRs.67.93

¥ 1.00 =NRs.0.59

A2. FLOOD MITIGATION PLAN:

LOHANDRA RIVER BASIN

SUPPORTING REPORT
A2. FLOOD MITIGATION PLAN: LOHANDRA RIVER BASIN

TABLE OF CONTENTS

(page)

LIST OF TABLES

(page)

LIST OF FIGURES

(page)

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

(1) Siwalik (Churia) Hills

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

Upper Siwalik

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

Middle Siwalik

The layer of middle Siwalik is found in the form of thick deposits of sandstone. These are characterized by their feldspar and mica content. Apparently the sandstone has been derived from granite rocks. 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 is not thick as the sandstone. Beds of impure limestone also occur within the lower Siwalik. The depth of lower Siwalik is about 1200 to 1500 meters. All pebbles except those found in the brown sandstone are derived from rocks of Pre-tertiary age.

(2) Terai Plain

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

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

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

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

Bhabhar Zone

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

Soils are mainly alluvium consisting of sand, silt, clay looms and silty clay. In the dry season almost all rivers in this zone have no flow on the surface and water flow underground only.

Marshy Area

The marshy area is found in the south of Bhabhar zone where two lithological units having different porosity and permeability meet or inter finger along with the change of elevation mainly resulting in spring lines, ponds, lakes, etc. The lithology is mostly composed of pebbles and sandy bed with a few clay partings. The lithology of the pebbles is similar to the boulder zone and sand beds are loose, brownish to greenish with black and red shale fragments. The clay is mostly blackish 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.

(3) Lohandra River Basin

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

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

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

1.2 Meteorology and Hydrology

1.2.1 Meteo-Hydrological Observation

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

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

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

In order to supplement the existing observatory, the Study Team installed new water level gauge (staff gauge) at Lalbhitti for the Lohandra river (1 site) on the left side pier of the East-West Highway bridge:

River	Caretaker	Remarks
Lohandra	Morang District Irrigation Office (Biratnagar)	Left bank bridge pier: 5 m

1.2.2 Meteo-Hydrological Features of Basin

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

(1) Temperature

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

(2) Relative Humidity

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

(3) Rainfall

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

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

(4) Runoff

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

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

1.3 Environment

1.3.1 Environmental Organizations and Institutions

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

1.3.2 Environmental Overview

The Lohandra river is a class-III river rising in the Siwalik hills. In the Terai plains, its length is about 67 km. (52 km. below the E-W highway), with a basin area of some 310 km^2 (31,000 hectares) of which 279 km^2 (27,900 ha.) are in the Terai. Two large tributaries join the Lohandra river in the Terai, the Sukuna and the Kesaula. Another two small rivers join where the Lohandra meets the plain. During the monsoons, riverbank erosion occurs. Additionally, many areas are inundated with coarse sand and/or floodwater.

Before malaria was eradicated from the Terai about 40 years ago, much of the area was covered with forests and wetlands. There was an abundance of plant species and wildlife. Now, only a few of these areas remain, mainly in National Parks and Forest Reserves. Most of the Terai has been colonized, especially in the east, and much of the land has been converted to agriculture. In the Lohandra area, a forest reserve of sal, *Shorea robusta,* is on the border between the Siwalik hills and the plain, but agriculture dominates. The existing land use and population of the Lohandra river basin in the Terai is shown below.

(Land Area, Land Use and Population: 1998)

Items	Agri-culture	Forest	Barren/ Sand	Other	Total	Population
Area (ha)	23,490	2,230	1,480	700	27,900	(143,000)*
Ratio (%)	84.2	8.0	5.3	2.5	100	(5.1)**

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

Over 80% of the Lohandra basin area in the Terai are now farmed and according to the Inventory of Wetlands (IUCN 1996), there are no remaining registered wetlands in the vicinity of this river. However, with such a high population density, the protection of the farmland and property is important. Every year, sand, silt and/or floodwater on average covers on average about 2,800 hectares of which about 650 ha. are covered with sand and soil. Some of this soil cover is a result of human activity, especially in the Siwalik hills. In addition, over 5% of the land is barren or covered with sand, principally due to flooding and inundation. .

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

1.4 Socio Economy

(1) Economic Activities

Land Use: The Lohandra river flows in Morang district. According to the district data, agricultural and forestland makes up 95.6% of the total plain area.

unit: hectare

District	Agriculture	Forest	Sand/Gravel /Boulder	Others	Total
MORANG	113,231 75.8%	29,615 19.8%	5,250 3.5%	1,231 0.8%	149327 90%
10 Districts (where M/P rivers flow)	800,591 64.1%	352,508 28.2%	43095 3.5%	52,449 4.2%	1,248,643 90%

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: Compared to other Terai districts a smaller portion (59.2%) of the labor force is engaged in agriculture, while larger segments are engaged in manufacturing (6.3%) and in service sector (23.4%).

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
MORANG	138,017 59.2%	54,649 23.4%	14,796 6.3%	25855 10.9%
10 Districts (where M/P rivers flow)	1,123,328 73.9%	215,393 14.2%	73,937 4.9%	107522 7%

Source: Population Census 1991, Central Bureau of Statistics

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

unit: hectare. (metric ton/ha.)

District	Paddy	Maize	Wheat	Pulses	Oilseeds	Sugarcane	Vegetables
MORANG	97,200 (2.57)	14,000 (1.82)	17,940 (1.70)	6,930 (0.50)	7,900 (1.40)	1,260 (40.0)	2,250 (12.58)
10 Districts (where M/P rivers flow)	537671 (27.79)	145489 (18.14)	174589 (19)	98536 (4.9)	102720 (7.92)	17331 (233.06)	11930 (52.58)

Source: Annual Agricultural Development Programme 1995/96, District

(2) Land Holding

Land Ownership & Holding: In Morang district, the average land holding size has not declined in recent years unlike other districts in the Terai plain. The average size is far below the 16.4 hectare ceiling imposed by the 1964 Lands Act. Nearly 80% of the agricultural land is under owner-cultivation. With regard to the agricultural land under "formal" tenancy, the most dominant form is sharecropping.

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

Tenure Arrangements: However, that since informal arrangements of land tenancy are not recorded in the official census, the above figure of owner-cultivation should be treated with caution. Underlying the sharecropping category is a commonly known phenomenon of "dual ownership". To undertake flood mitigation works for land under "dual ownership", it will be imperative to involve both land owners and tenants, both of whom are entitled to certain shares of the proceeds of the land.

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

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

(3) Population

From nation-wide viewpoint, in-migration in the east is approaching to zero, as new lands available for cultivation are being closed. On the other hand, the western districts continue to exhibit high population growth, since the land frontiers are relatively open.

In a similar vein, the original inhabitants of the Terai constitute nearly or more than half the population towards the west, while the proportion of indigenous groups makes up less than half in most of the eastern districts.

Population of Morang district is 675,000 as of 1991 with population growth rate of 2.3% (1981-1991). The population growth ratio was equal to that of the national average during 1970s, but it is currently far less than the national average.

The following table shows the population trends of the VDCs affected by Lohandra floods. The 1981-91 population growth rate of the affected VDCs is 3.3%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Morang district.

Demographic Records of Flood-Prone VDCs:

District	VDC	1971	1981	1991	1996
Morang	Belbari	-	-	15,154	18,497
	Babbiya Birta	7,997	9,400	12,979	15,842
	Majhare	4,520	5,965	7,230	8,825
	Kathari	6,093	10,763	12,655	15,446
	Motipur	2,622	-	4,611	5,628
	Thalaha	3,488	-	5,201	6,348
	Dadar Bairiya	3,470	6,598	6,280	7,665
	Kadmaha	3,167	6,598	5,182	6,325
	Sisbanijahada	3,305	6,647	5,722	6,984
	Kerabari	3,705	7,620	12,031	14,685
	Haraicha	7,294	12,241	5,067	6,185
	Banigama	4,412	5,086	6,748	8,236
	Bhatigach	4,381	-	-	-
	Budhanagar	-	7,337	9,310	11,363
Total		54,454	78,255	108,170	132,029

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

(4) Human Development Index (HDI)

In terms of the Human Development Index (which is a development indicator based on life expectancy, adult literacy, and GDP), the districts in eastern areas of the country receive, in general, higher performance, and become lower toward the west. Accordingly, the HDI of Morang district (located towards the Eastern Development Region) is highest (4th among all 75 districts) among the M/P target districts.

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The Lohandra river basin extends from 26°15′N to 26°45′N and from 87°15′E to 87°30′E.

The Lohandra river originates in Siwalik hills and is classified as a class III river. Administratively it is located in Morang district of Western Development Region.

Basin area of the Lohandra river is 310 km^2 (419 km^2) in total, consisting of 31 km^2 (140 km^2) of mountainous area and 279 km^2 of plain area. Areas in ( ) indicate those including mountainous basin of the Chisan river. 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 Lohandra river is shown in Fig. A1.7. The basin map was prepared based on the topographic maps of scale 1/25,000.

Notable features of the Lohandra river basin are as follows:

1) River channel is wide and braided in the upper reaches and becomes narrow gradually toward lower reaches.
2) The Lohandra river is located between large alluvial fans of the Chisan and Khadam rivers. A branch river of the Chisan river forms the main Lohandra river joining the Kesaula river from the Chisan and the Sukuna river from the Khadam.
3) Flood prone areas along the middle and lower reaches are the service areas of Sunsari Morang (Kosi river) Irrigation Project.

1.5.2 Characteristics of River Channel

Channel slope and width of the existing river are shown in Fig. A1.8 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 sand bars of the meandering and braided river section.

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

River	Class	Length(km)	Slope	Width(m)
Lohandra R.	III	67.5(51.9)	1/80～2000	50～520

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

1.5.3 River Course Shifting

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

In order to look into the actual shifting of river course in the past, topographic maps prepared in 1948/49 (scale: 1/50,000) and those in 1992 (scale: 1/25,000) were superimposed and shown in Fig.A1.9.

According to the figure showing river course change during the past 43 years, meander of the both river channels is not severe, and shifting of river course seems to remain within the meandering belt.

1.5.4 Riverbed Materials

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

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

Bed materials of the Lohandra river were sampled at 13 sites (Fig. A1.10) among which outdoor analyses were carried out at 8 sites.

Results of riverbed material tests are shown in Table A1.2 and the grading curves in Fig. A1.11.

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

1) Samples: All samples are from the main course of the Lohandra river except for Lo-13 from the Chisan river.
2) Grain size:
   - d_{60} = 0.21 to 0.38 mm (fine to medium sand): downstream from Lo-5
   - d_{60} = 0.73 to 1.63 mm (very coarse to coarse sand): downstream from E-W Highway
   - d_{60} = 2.43 to 34.2 mm (very fine to very coarse gravel): upstream from E-W Highway
3) Uniformity index: Riverbed materials are well-sorted and uniform in the downstream reaches from Lo-5 site.
   - UI = 2.7 to 4.5: downstream from Lo-5 site
   - UI = 14 to 28: downstream from E-W Highway
   - UI = 67 to 506: downstream from E-W Highway except Lo-13
4) Specific gravity:
   - SG = 2.64 g/cc on average ranging from 2.60 to 2.69 g/cc
5) Longitudinal distribution: Significant changes in grain sizes are seen at two sections between (1) Lo-5 and Lo-6 sites, and (2) Lo-7 and Lo-8 sites.

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

1.5.5 Land Use

Land utilization map and land capability map (scale: 1/50,000) are available. These maps have been prepared by Topographic Survey Section of Survey Department under the Canadian assistance program. Mapping details are based on aerial photos taken in 1978 and 1979 and extensive field truthing and sampling during the year 1980 and 1981. The maps were published in 1982.

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

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

1.5.6 Existing Basin Development Projects and Plans

Sunsari Morang Irrigation Project

Background: The Sunsari Morang Irrigation Project (SMIP) was originally implemented as Chatra Canal Project (CCP) under the Grant Aid from the Government of India (1964 – 1975). The SMIP has been rehabilitated since 1978 by the financial assistance of International Development Association (IDA).

Rehabilitation: The rehabilitation is divided into three stages of command area development and mitigation of sedimentation problem, namely Sunsari Morang Headwork Project (SMHP), as follow (Fig. A1.13):

1) Stage-I: Development of the Shankarpur Distributary and its adjacent area (9,750 ha) including the Kosi river control and sediment control device. (April 1978 – June 1986).
2) Stage-II: Development of the Sitagunj and Ramgunj Distributaries area (16,600 ha) including improvement of Chatra Main Canal (CMC) and related structures (November 1988 – July 1994).
3) Stage-III: Development of the remaining command area (46,000 ha) under a phased implementation program including improvement of CMC, related structures, and other required improvement works for the Stage-I & II areas. Feasibility Study was completed in June, 1995.
4) SMHP: Construction of a new intake, a de-silting basin, electrically operated dredgers, and a micro-hydro power station in the head reach of the main canal. (March 1993 planned to complete by November 1995).

Advantages of the SMIP are rich water resource of the Kosi, good soils and competent farmers. The water management problems have been greatly reduced by the adoption of a simply structured irrigation system under the Stage-II Project and the participation of farmers from project design to system's operation and maintenance (O&M).
(Source: Sunsari Morang Irrigation Development Board)

1.6 Vegetation and Sediment Yield in Watershed Area

(1) Climate and Vegetation Division

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

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

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

(2) Land Use in Watershed Area

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

(Land Use of Watersheds)

Land use	Area (ha)	Ratio (%)
Forest	8,292	58.0
Bush	1,805	12.6
Cultivation	3,731	26.1
Cliff	128	0.9
River	347	2.4
Urban	-	-
Total	14,303	100.0

(Remarks) Bush:Scrub, Bush, Grass & Bamboo, Cliff:Soil cliff, Rock cliff & Out crop of rock

Watershed of the Lohandra river is located in the eastern Siwalik hills. Vegetation of the watershed is Hill Sal forest.

The ratio of cultivated land is high with the percentage of 26%. The ratio of forest land (58%) is relatively low and the bush land ratio (12%) is high. Cultivated lands distribute widely in the central and northern part of the watershed. Bush lands are seen around the cultivated lands, and they seem to be pasture, fallow lands or abandoned fields. The cliff lands share 0.9%. Bush land is the area where soil erosion can be reduced effectively by afforestation because of gentle ground slope.

(3) Erosive Landform of Watershed Area

The drainage system and slope of watershed of the Lohandra river are shown in Fig.A1.14 and Fig.A1.15. The drainage system and slope maps allow the interpretation of erosive landform characteristics of the watershed area.

The drainage density of the southern watershed of the Lohandra river is high comparing to that of central and northern watershed. Less cultivated land is found in the southern watershed, while more cultivated land in the northern watershed.

(4) Estimation of Sediment Yield

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

(Estimation of Sediment Yield: Lohandra River)

Land use	Area (ha)	Erosion rate(mm/yr)	Yield(m^3/yr)
Forest	8,292	2	166,000
Bush	1,805	10	181,000
Cultivation	3,731	0.4	15,000
Cliff	128	20	26,000
River	347	0	0
Urban	-	0	0
Total/average	14,303	2.70	387,000

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

1.7 Past Flood and Sediment Disasters

The Study Team investigated conditions of past flood and sediment disasters in January

1998. On the basis of the information obtained from the District Irrigation offices and District Development Committee offices, a total of 13 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 131 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are summarized in Table A1.3. Settlements and lands along the Lohandra river are suffering from flood and sediment disasters almost every years. Among these, a flood in 1987 is the biggest in recent 10 years followed by floods in 1988, 1995 and 1996.

Agradation of riverbed is said remarkable especially upstream reaches from Chatara canal and bank erosion is active on the both riverbanks. Since river channel is small in the lower reaches, floodwater from the upstream reaches frequently floods over the riverine farmland. Sedimentation, bank erosion and flooding over farmlands are the major types of disasters. According to the data and information obtained from DDC and DIO of Morang district, areas suffering from bank erosion and flooding are summarized as follows:

(Areas Suffering from Bank Erosion and Flooding)

VDC	Village/Ward
Belbari	Bagartol, Kramda, Phokland, Dharahara Chowk(north)
Kaseni	Bagarbasti
Babiya Birta	Behalwa, Babiya
Dadar Bairiya	Kadmaha(north)
Kadmaha	Lohandraghat
Sisbani Jahada	Chetampur(north), Sohal
Majhare	Sirsiya, Bhimpur, Chhotki Mahadevtol, Tarigama
Kerabari	Kusmegauda
Haricha	Kumargau
Motipur	Bintol
Thalaha	Thalaha(east), Hurhuriya, Satartol
Katahari	Nayabazar, Bathantol
Bhattigachh	Jayarampur, Chhotki Bairiya, Jatrutol
Budhanagar	Laxmipur, Kalabanjar

Loss of life and damage to properties are shown in Table A1.4, mainly based on data during 1995-flood. According to the field investigation and interviews of residents, flood-suffering areas during the 1995-flood are shown in Fig. A1.16.

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: 1 site
2) Spur : 51 sites
3) Revetment : 4 sites
4) Head work : none
5) Bridge : 1 site

Location of these facilities is shown in Fig. A1.17. 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. A1.18.

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 °	Latitude '	Latitude "	Longitude °	Longitude '	Longitude "	Elevation (m)	Start of Record	Remarks
1201	Namche Bazar	Precipitation	E	27	49	00	86	43	00	3,450	04-1971	
1202	Chaurikhark	Precipitation	E	27	42	00	86	43	00	2,619	04-1948	
1203	Pakarnas	Precipitation	E	27	26	00	86	34	00	1,982	12-1947	
1204	Aisealukharh	Precipitation	E	27	21	00	86	45	00	2,143	05-1948	
1206	Okhaldhunga	Synoptic	E	27	19	00	86	30	00	1,720	12-1947	
1207	Name Bhanjyang	Precipitation	E	27	12	00	86	25	00	1,576	11-1947	
1208	Dwarpa	Precipitation	E	27	13	00	86	51	00	1,829	05-1959	
1210	Kurule Ghat	Precipitation	E	27	08	00	86	25	00	497	12-1947	
1211	Khotang Bazar	Precipitation	E	27	02	00	86	50	00	1,295	05-1959	
1212	Phatepur	Climatology	E	26	44	00	86	51	00	100	07-1976	
1213	Udayapur Gadhi	Climatology	E	26	56	00	86	31	00	1,175	07-1947	
1215	Lahan	Climatology	E	26	44	00	86	30	00	138	11-1955	
1216	Siraha	Precipitation	E	26	39	00	86	13	00	102	06-1947	
1217	Khumjung	Precipitation	E	27	49	00	86	43	00	3,750	05-1966	
1218	Tengboche	Precipitation	E	27	50	00	86	46	00	3,857	05-1966	
1219	Salleri	Precipitation	E	27	30	00	86	35	00	2,378	12-1947	
1220	Chialsa	Agrometeology	E	27	31	00	86	37	00	2,770	05-1966	
1222	Diktel	Precipitation	E	27	13	00	86	48	00	1,623	06-1973	
1223	Rajbiraj	Climatology	E	26	33	00	86	45	00	91	12-1971	
1224	Sirwa	Precipitation	E	27	33	00	86	23	00	1,662	05-1959	
1225	Syangboche	Precipitation	E	27	49	00	86	43	00	3,700	05-1973	
1226	Barmajhiya	Precipitation	E	26	36	00	86	54	00	85	09-1975	
1301	Num	Precipitation	E	27	33	00	87	17	00	1,497	06-1959	
1303	Chainpur (East)	Climatology	E	27	17	00	87	20	00	1,329	07-1947	
1304	Pakhribvas	Agrometeology	E	27	03	00	87	17	00	1,680	01-1976	
1305	Leguwa Ghat	Precipitation	E	27	08	00	87	17	00	410	07-1947	
1306	Munga	Precipitation	E	27	02	00	87	14	00	1,317	07-1947	
1307	Dhankuta	Synoptic	E	26	59	00	87	21	00	1,445	06-1947	
1308	Mulghat	Precipitation	E	26	56	00	87	20	00	365	06-1947	
1309	Tribeni	Precipitation	E	26	56	00	87	09	00	143	05-1948	
1310	Barahkshetra	Precipitation	E	26	52	00	87	10	00	146	03-1947	
1311	Dharan Bazar	Precipitation	E	26	49	00	87	17	00	444	06-1947	Ratua / Lohendra
1312	Haraincha	Precipitation	E	26	37	00	87	23	00	152	04-1956	Ratua / Lohendra
1313	Biratnagar (City)	Precipitation	E	26	28	00	87	17	00	67	05-1948	Ratua / Lohendra
1314	Termathum	Climatology	E	27	08	00	87	33	00	1,633	04-1966	
1316	Chatara	Precipitation	E	26	49	00	87	10	00	183	06-1948	
1317	Chepuwa	Precipitation	E	27	46	00	87	25	00	2,590	06-1959	
1318	Paripatle (Horti)	Precipitation	E	27	01	00	87	18	00	1,364	11-1966	
1319	Biratnagar Airport	Agrometeology	E	26	29	00	87	16	00	72	07-1968	Ratua / Lohendra
1320	Tarahara	Agrometeology	E	26	42	00	87	16	00	200	07-1968	
1321	Tumlingtar	Precipitation	E	27	17	00	87	13	00	303	05-1977	
1322	Machuwaghat	Precipitation	E	26	58	00	87	10	00	158	05-1948	
1323	Dharan British Camp	Climatology	E	26	47	00	87	17	00	400	08-1969	Ratua / Lohendra
1324	Bhojpur	Agrometeology	E	27	11	00	87	03	00	1,595	06-1954	
1325	Dingla	Precipitation	E	27	22	00	87	09	00	1,190	05-1948	
1401	Olangchung Gola	Precipitation	E	27	41	00	87	47	00	3,119	07-1947	
1402	Pangthung Doma	Precipitation	E	27	41	00	87	49	00	2,818	12-1947	
1403	Lungtang	Precipitation	E	27	33	00	87	47	00	1,780	07-1947	
1404	Taplethok	Precipitation	E	27	29	00	87	47	00	1,383	07-1947	
1405	Taplejung	Synoptic	E	27	21	00	87	40	00	1,732	07-1947	
1406	Memeng Jagat	Precipitation	E	27	12	00	87	56	00	1,830	07-1947	
1407	Ilam Tea Estate	Agrometeology	E	26	55	00	87	54	00	1,300	03-1956	
1408	Damak	Precipitation	E	26	43	00	87	40	00	163	03-1956	Ratua / Lohendra
1409	Anarmani Birta	Precipitation	E	26	38	00	87	59	00	122	03-1956	
1410	Himali Gaun	Precipitation	E	26	53	00	88	02	00	1,654	02-1968	
1411	Soktim Tea Estate	Climatology	E	26	48	00	87	54	00	530	06-1966	
1412	Chandra Gadhi	Precipitation	E	26	34	00	88	03	00	120	02-1971	
1413	Khamachin	Precipitation	E	27	44	00	87	59	00	4,242	12-1948	
1414	Nup	Precipitation	E	27	43	00	87	52	00	4,000	06-1948	
1415	Sanischare	Precipitation	E	26	41	00	87	58	00	168	01-1972	
1416	Kanyam Tea Estate	Climatology	E	26	52	00	88	04	00	1,678	04-1972	
1417	Jaubari	Precipitation	E	27	04	00	88	00	00	3,050	06-1973	
1418	Angbung	Precipitation	E	27	16	00	87	43	00	1,219	07-1947	
1419	Phidim (Panchther)	Climatology	E	27	09	00	87	45	00	1,205	07-1978	
1420	Dovan	Precipitation	E	27	21	00	87	36	00	763	07-1947	
1421	Gaida (Kankai)	Climatology	E	26	30	00	87	54	00	143	02-1984	

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

GRAIDING OF RIVERBED MATERIALS

Sample code	Cumulative percentage of passing materials (%)														
	<0.075 (mm)	<0.106 (mm)	<0.25 (mm)	<0.425 (mm)	<0.85 (mm)	<2 (mm)	<4.75 (mm)	<9.5 (mm)	<19 (mm)	<26.5 (mm)	<37.5 (mm)	<53 (mm)	<100 (mm)	<200 (mm)	<400 (mm)
	0.075	0.106	0.250	0.425	0.850	2.00	4.75	9.50	19.0	26.5	37.5	53.0	100.0	200.0	400.0
Lohandra River															
Lo-1	3.0	9.3	67.0	91.8	99.5	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lo-2	0.8	2.6	32.6	66.5	91.1	95.8	97.6	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lo-3	0.9	1.5	36.0	77.8	96.2	99.0	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lo-4	1.2	3.6	58.7	97.0	97.1	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lo-5	3.1	7.2	75.0	93.1	99.2	99.8	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lo-6	0.6	1.2	12.3	27.2	47.1	64.1	77.0	86.4	96.7	98.7	100.0	100.0	100.0	100.0	100.0
Lo-7	0.6	1.1	12.9	41.6	65.3	76.4	87.2	94.3	97.0	99.0	99.0	100.0	100.0	100.0	100.0
Lo-8	4.3	7.1	19.4	32.8	49.7	58.3	66.0	72.7	83.7	88.0	92.3	94.1	100.0	100.0	100.0
Lo-9	1.5	1.5	6.0	9.9	17.4	26.0	33.8	42.7	57.2	65.2	74.6	85.9	96.3	100.0	100.0
Lo-10	0.6	1.3	6.2	10.6	15.2	20.0	25.9	31.7	44.1	53.5	62.3	71.0	87.4	100.0	100.0
Lo-11	1.1	2.2	13.5	27.3	39.7	48.1	55.2	62.5	69.5	75.2	78.0	82.5	84.9	100.0	100.0
Lo-12	1.2	3.0	23.6	34.4	40.6	46.2	52.3	57.2	62.2	64.8	68.5	73.2	85.6	100.0	100.0
Lo-13	0.2	0.3	1.6	4.1	8.9	16.2	24.3	31.4	45.5	53.8	63.8	71.0	93.0	100.0	100.0

REPRESENTATIVE GRAIN SIZES AND SPECIFIC GRAVITY

Sample code	Representative grain size					Specific gravity(g/cc)		
	16 (%)	60 (%)	65 (%)	84 (%)	d84/d16	S.G.1 (g/cc)	S.G.2 (g/cc)	S.Gave (g/cc)
Lohandra River								
Lo-1	0.12	0.23	0.24	0.36	3.07	2.59	2.60	2.60
Lo-2	0.16	0.38	0.42	0.70	4.48	2.63	2.65	2.64
Lo-3	0.15	0.34	0.36	0.54	3.53	2.68	2.65	2.67
Lo-4	0.13	0.25	0.27	0.36	2.76	2.70	2.68	2.69
Lo-5	0.12	0.21	0.22	0.33	2.74	2.64	2.63	2.64
Lo-6	0.29	1.63	2.13	7.97	27.93	2.68	2.67	2.68
Lo-7	0.26	0.73	0.84	3.68	13.89	2.65	2.61	2.63
Lo-8	0.20	2.43	4.23	19.43	98.61	2.60	2.65	2.63
Lo-9	0.75	21.35	26.29	50.03	67.09	2.67	2.67	2.67
Lo-10	0.98	34.21	41.68	87.64	89.69	2.63	2.60	2.62
Lo-11	0.27	7.50	12.19	79.17	287.92	2.68	2.63	2.66
Lo-12	0.18	13.95	26.98	92.11	505.89	2.63	2.59	2.61
Lo-13	1.96	32.90	39.77	77.09	39.26	2.63	2.68	2.66
							Average	2.64

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: **LOHANDRA RIVER(1/2)**

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1987(59), 1988(57), 1995(9), 1996(1), 1997(1)
1.2	Floods in a year (times)	Average(8) ranging(3 to 13)
1.3	Severe floods in past 10 years (times)	Average(4) ranging(3 to 10)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(96) • Sediment flow(41) • Bank erosion(112) • Others(0)
2. EFFECT DUE TO SEVERE FLOOD IN PAST		
2.1	Loss of human life (nop)	0 (excluding those due to epidemic disease)
2.2	Loss of livestock/husbandry (nos)	• Cow(10) • Buffalo(0) • Sheep/Goat(6) • Poultry(171)
2.3	Damage to farm land (ha)	• Irrigated land: Average(0.1) ranging(0.6 to 1.34) • Non-irrigated land: Average(1.5) ranging(0.6 to 3.0)
2.4	Extent of damage to farm land	• Simple inundation (nop):39 • Loss of crops (nop): Paddy(39), Sugarcane(0), Maize(1), Others(18) • Total washout (ha): Average(0.9) ranging(0.3 to 3.0)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(3.0) ranging(1 to 17) • Flooding depth in (m): Average(0.8) ranging(0.6 to 0.9) • Damage to house (nop): Severe(37), Moderate(16), Ordinary(27) • Loss of cash (Rs): Average(0) ranging(0) • Loss of food grains (kg): Paddy: Average(800) ranging(0 to 2,100) • Clothing (nos): Average(3) ranging(2 to4) • Other valuables: Average(6) ranging(3 to10)
2.6	Problems during flood (nop)	• Erosion of river bank(118) • Sediment in the river(106) • Sediment in irrigation canal(71) • Drinking water problem(58) • Sanitary problem(42) • Salinity(38) • Flooding over farm land(81) • Others(2)
2.7	Epidemic disease after flood? (nop)	• Yes(74) • No(57)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(5) • Dysentery(46) • Typhoid(19) • Others(4)
2.9	Fatal causality? (nop)	• Yes(4) • No(105)
2.10	Reason of flood(nop)	• Too much rain(97) • Lack of flood protection works(88) • Weak river training works(19) • Sediment load in the flood water(37) • Flood from adjoining rivers(20)
2.11	Total amount of damage (Rs)	Average(440,000) ranging(0 to 620,000)

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

SUMMARY OF QUESTIONNAIRES BY RIVER

Name of river: LOHANDRA 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(108) • Bank erosion(0) • Smelled mud(0) • Unusual sound(0) • Others(0)
3.3	Warning by others (nop)	• Neighbors(0) • Institutions(0) • Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	• Yes(45) • No(79)
4.2	If yes, place of evacuation (nop)	• High ground(11) • Public building(2) • Others houses(22) • Other sites(4)
4.3	Being relieved? (nop)	• Yes(34) • No(91)
4.4	If yes, how?(nop)	• In cash(7) • Kind(27)
4.5	Organization/individual giving relief (nop)	• Central government(18) • DDC(1) • VDC(7) • Other institutions(4) • NGO(6) • Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	• Warning(0) • Evacuation(44) • Settlement(87)
5.1b	Proposed preparedness/ measures (nop)	• Warning(0) • Evacuation(0) • Settlement(43)
5.2a	Current non-structural measures (nop)	• Seed storage(8) • Cash pools(1) • Informal insurance(0) • Others(0)
5.2b	Proposed non-structural measures (nop)	• Seed storage(110) • Cash pools(120) • Informal insurance(66) • Others(2)
5.3a	Current structural measures (nop)	• Embankment(13) • Spur(38) • Simple gabion(10 • Plantation(1) • Others(0)
5.3b	Proposed structural measures(nop)	• Embankment(48) • Spur(95) • Simple gabion(48) • Plantation(27) • Others(8)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	• Yes(53) • No(63)
6.2	If yes, type (nop)	• Cash(9) • Labor(46) • Kind(4) • Care taker(3) • Others(0)
6.3	If no, reason (nop)	• Being affected badly8) • Financially weak(19) • Being out of the area(1) • No willingness(34) • Others(5)
6.4	Willing to participate in future? (nop)	• Yes(108) • No(6)
6.5	If yes, type (nop)	• Cash(17) • Labor(106) • Kind(9) • Care taker(8) • Others(0)
6.6	If no, reasons (nop)	• No time(0) • No benefit(1) • No Willingness(0) • Not known how to participate(1) • Others(0)

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

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

DAMAGE OF PUBLIC FACILITIES

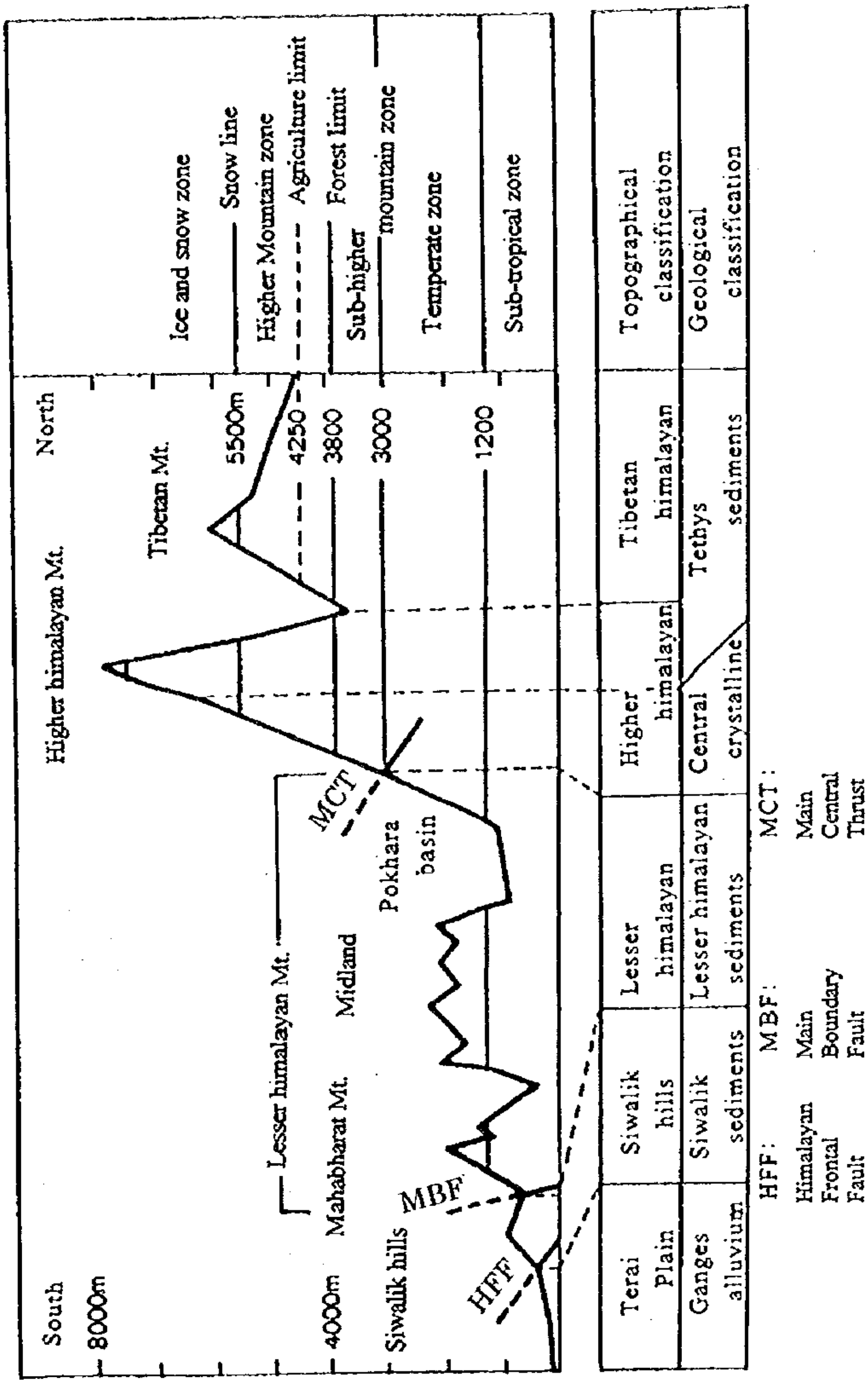
VDC/Municipality	Road (km)	Irrigation Channel (km)	Culvert (nos.)	Remarks
Belbari	8.00 (6 nos)	4.00 (42 nos)	-	School-1
Kaseni	-	2.00 (1 no)	-	-
Babiya Birta	1.80 (3 nos)	0.30 (2 nos)	-	-
Dadar Bairiya	2.50 (1 no)	-	-	School-1
Kadmaha	0.25 (1 no)	0.05 (1 no)	-	-
Sisbani Jahada	0.05 (1 no)	-	1	-
Majhare	2.00 (2 nos)		3	-
Kerabari	0.20 (1 no)	0.70 (7 nos)	-	-
Haraicha	2.00 (2 nos)	2.00 (2 nos)	-	-
Banigama	1.50 (3 nos)	0.10 (2 nos)	-	School-1
Motipur	-	0.50 (1 no)	-	-
Thalaha	4.00 (4 nos)	1.00 (1 no)	-	-
Katahari	0.50 (3 nos)	-	-	Temple-1
Bhattigachh	2.00 (2 nos)	-	-	-
Budhnagar	0.30 (1 no)	-	-	-
Total	25.10	10.19	5	

DAMAGE OF LAND, CROPS AND THEIR YIELD AND HOUSEHOLD PROPERTIES

VDC/Municipality	Damage of Land (hac)		Damage of Crop (kg)		Name of Crop	Damage of HH (nos.)	Remarks
	Inundation	Washout	By inundation	By washout			
Belbari	30	240	22,500	724,000	Paddy	135	
Kaseni	90	60	67,500	18,000	Paddy	40	
Babiya Birta	50	50	37,500	150,000	Paddy	51	
Dadar Bairiya	200	50	150,000	150,000	Paddy	125	
Kadmaha	50	20	37,500	60,000	Paddy	50	
Sisbani Jahada	200	30	150,000	90,000	Paddy	50	
Majhare	300	50	225,000	150,000	Paddy	85	
Kerabari	100	75	75,000	225,000	Paddy	45	
Haraicha	200	40	15,000	120,000	Paddy	14	
Banigama	65	40	48,750	120,000	Paddy	9	
Motipur	100	70	75,000	210,000	Paddy	75	
Thalaha	300	35	225,000	105,000	Paddy	70	
Katahari	200	30	150,000	90,000	Paddy	70	
Bhattigachh	300	15	225,000	45,000	Paddy	15	
Budhnagar	50	10	37,500	30,000	Paddy	80	
Total	2,235	815	1,676,250	8,965,000		914	

LOSS OF LIFE

VDC/Municipality	Human Life (nos.)	Loss of Cattle (nos.)			Poultry (nos.)	Remarks
		Cow/Buffalo	Goat	Pig		
Belbari	-	130	-	-	-	
Kaseni	1	-	-	10	100	
Majhare	-	50	-	-	-	
Kerabari	1	-	-	-	-	
Thaloha	3	5	-	-	45	
Motipur	1	-	-	-	-	
Banigama	-	2	-	-	-	
Katahari	-	20	-	-	-	
Budhanagar	-	2	8	-	-	
Total	5	209	8	10	145	

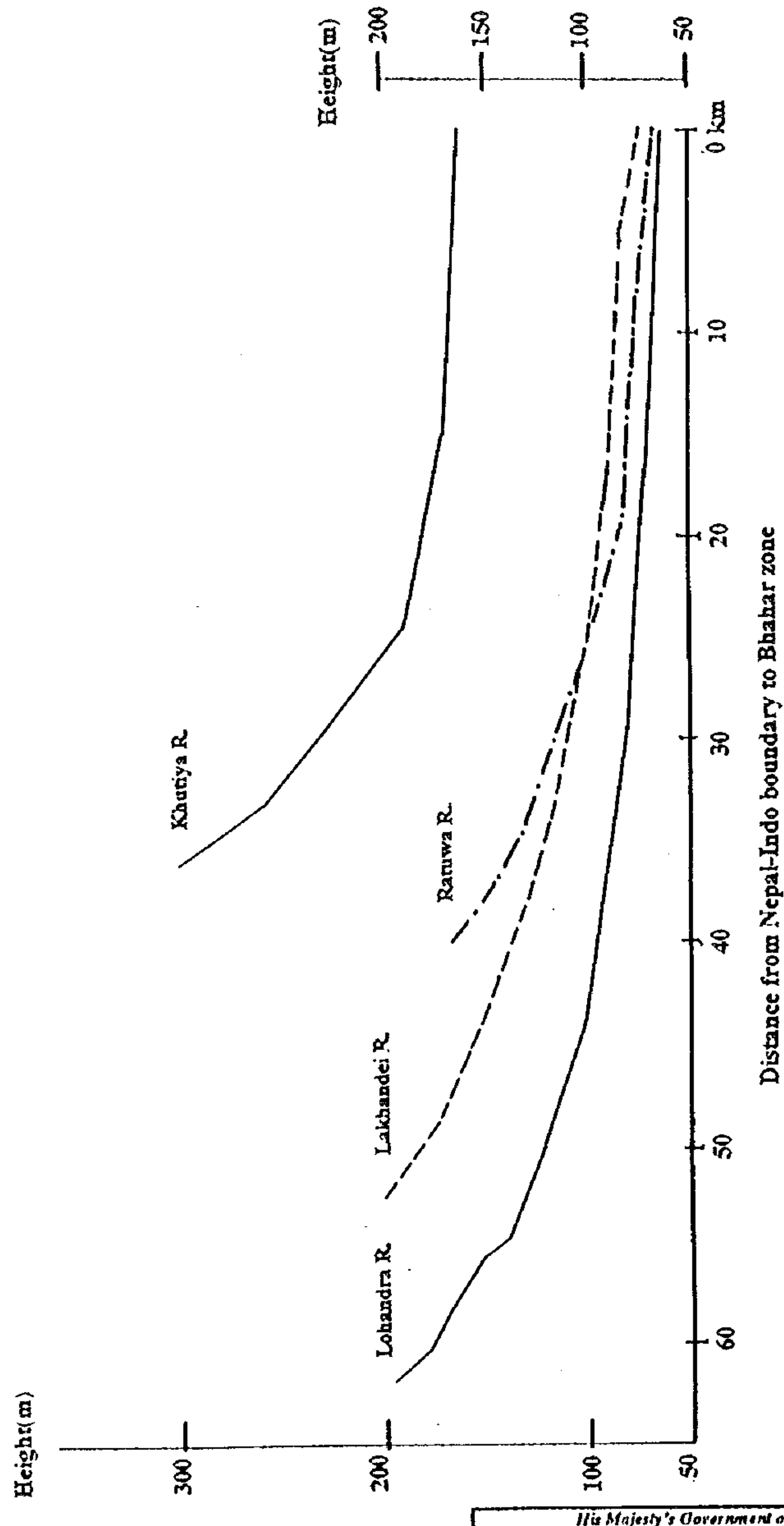


TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

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

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

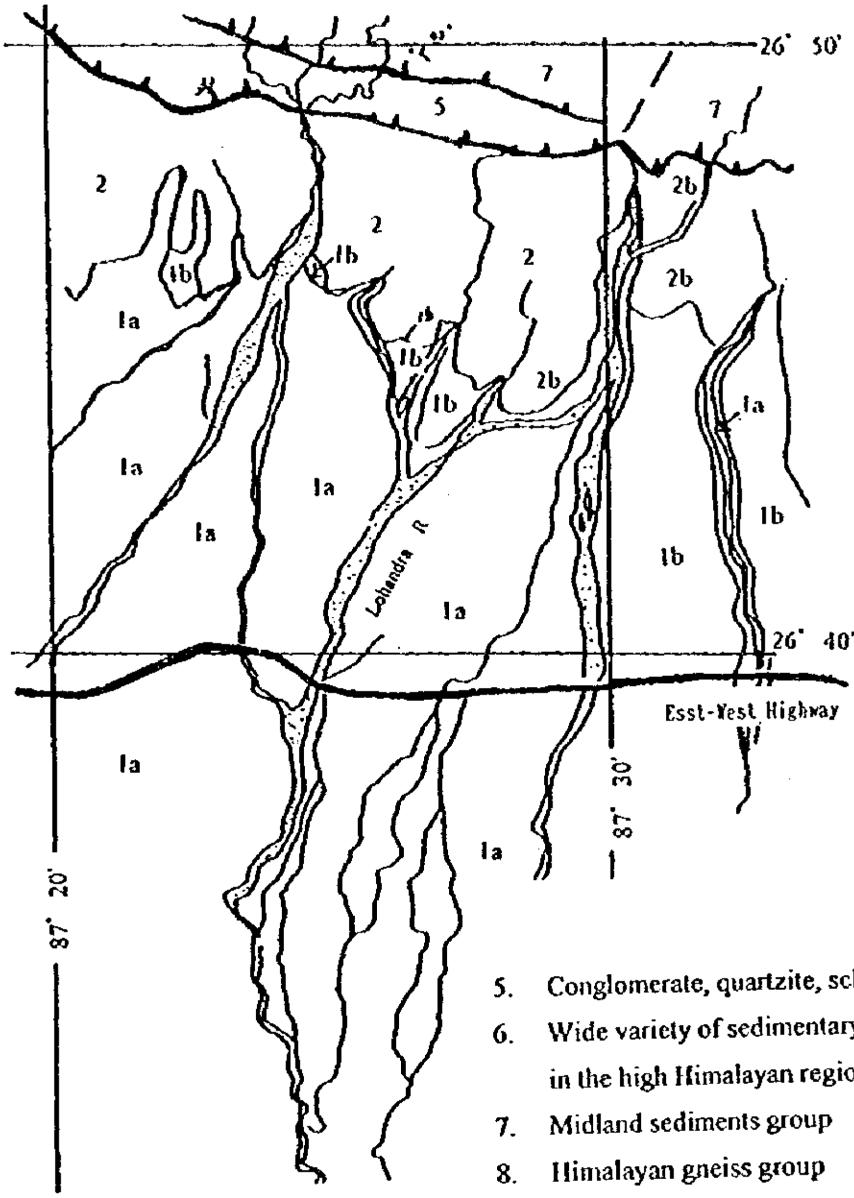
JAPAN INTERNATIONAL COOPERATION AGENCY



OVERALL LONGITUDINAL PLOFIELES
OF RIVERS ORIGINATED IN SIWALIK HILLS

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

Lohandra R.



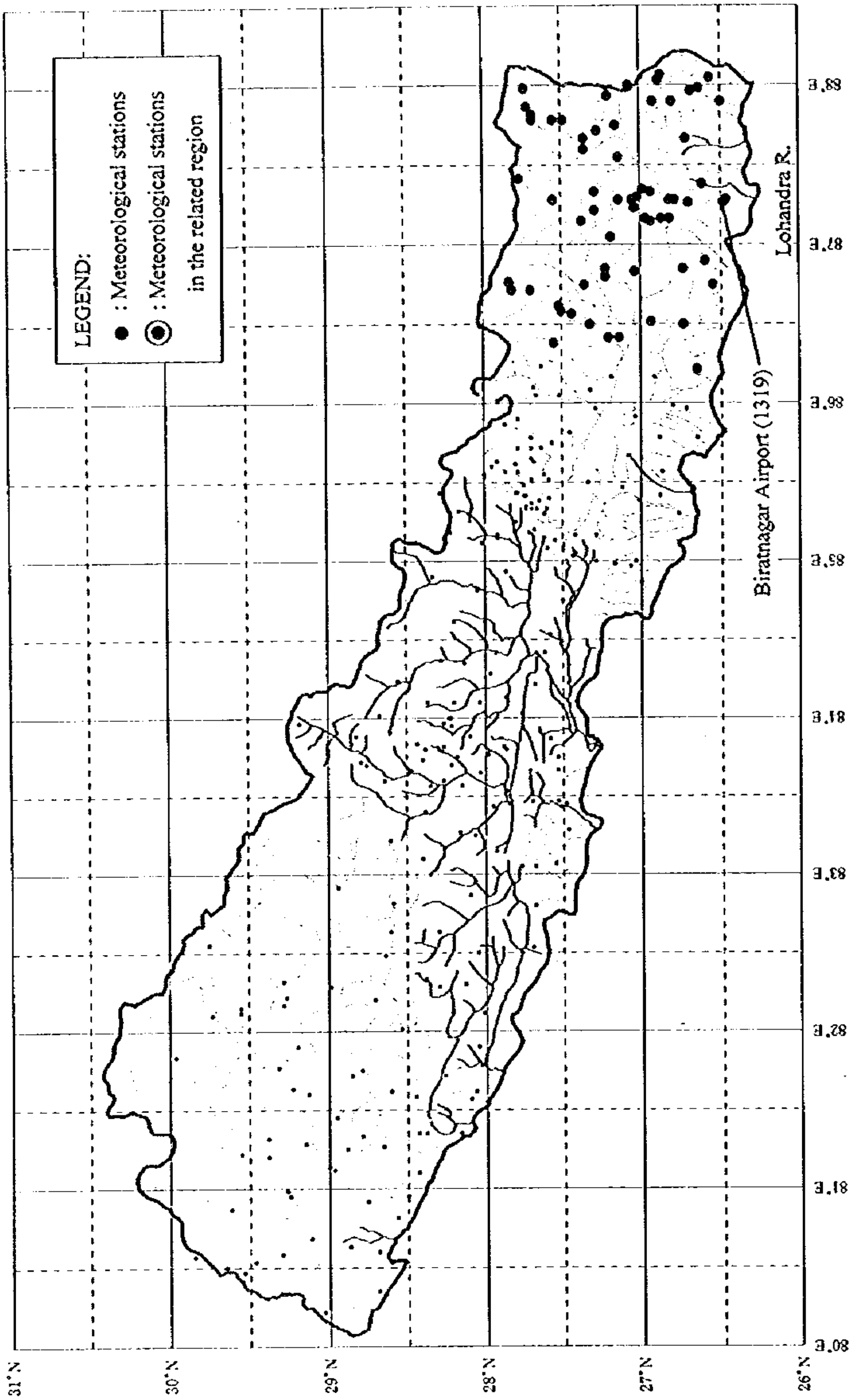
5. Conglomerate, quartzite, schist
6. Wide variety of sedimentary /metamorphic strata, in the high Himalayan region
7. Midland sediments group
8. Himalayan gneiss group

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
3. Sandstone, siltstone, shale and limestone(Lower Shiwalik)
4. Shale and limestone (Eocene)

GEOLOGICAL MAP(LOHANDRA R.)

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



LOCATION OF METEOROLOGICAL STATIONS

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

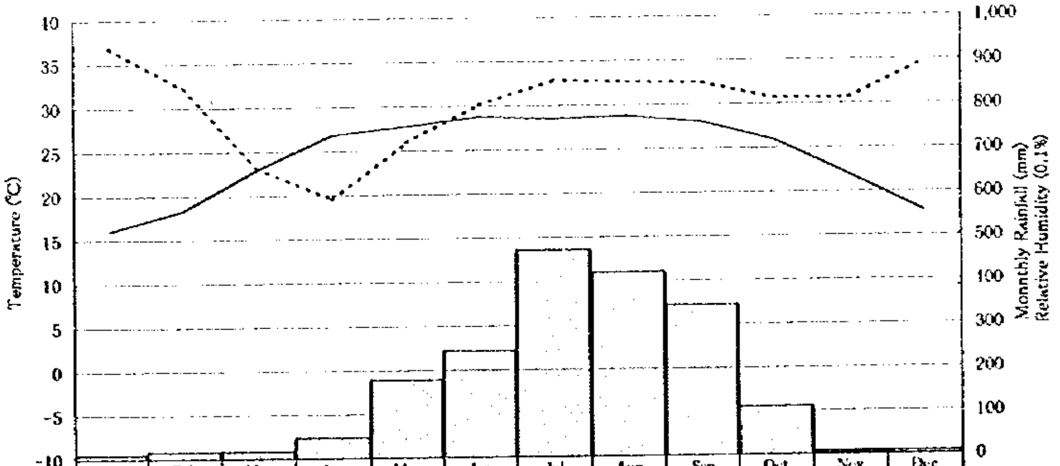
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

Code: 1319
Station: Biratnagar Airport

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

Biratnagar Airport (1319)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, Total	10.2	16.4	17.0	48.0	178.4	243.9	472.6	420.6	314.7	110.6	7.2	7.8
Air Temperature, Mean	16.1	18.3	23.0	26.8	27.8	28.8	28.6	28.8	28.0	26.0	22.0	17.9
Relative Humidity, 08:45	938	845	664	591	719	803	858	853	850	814	813	894

Air Temperature, Mean (Unit. °C)

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

Relative Humidity, 08:45 (Unit. %)

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

Precipitation, Total (Unit. mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	1	2	24	0	184	179	632	189	286	217	9	16	1,739
1986	0	2	1	39	216	210	487	218	362	151	1	25	1,712
1987	0	6	36	58	120	325	647	749	480	138	12	1	2,572
1988	0	67	23	127	118	129	512	724	121	107	38	4	1,970
1989	15	32	5	0	327	346	685	401	791	59	0	5	2,666
1990	0	16	15	109	313	467	602	510	301	23	0	0	2,356
1991	35	4	22	51	108	163	285	290	411	70	0	26	1,465
1992	2	3	0	2	187	147	396	201	189	291	0	1	1,419
1993	21	1	35	91	130	308	357	699	346	49	9	0	2,046
1994	28	31	9	3	81	165	123	225	160	1	3	0	829
Ave.	10.2	16.4	17.0	48.0	178.4	243.9	472.6	420.6	314.7	110.6	7.2	7.8	1,877

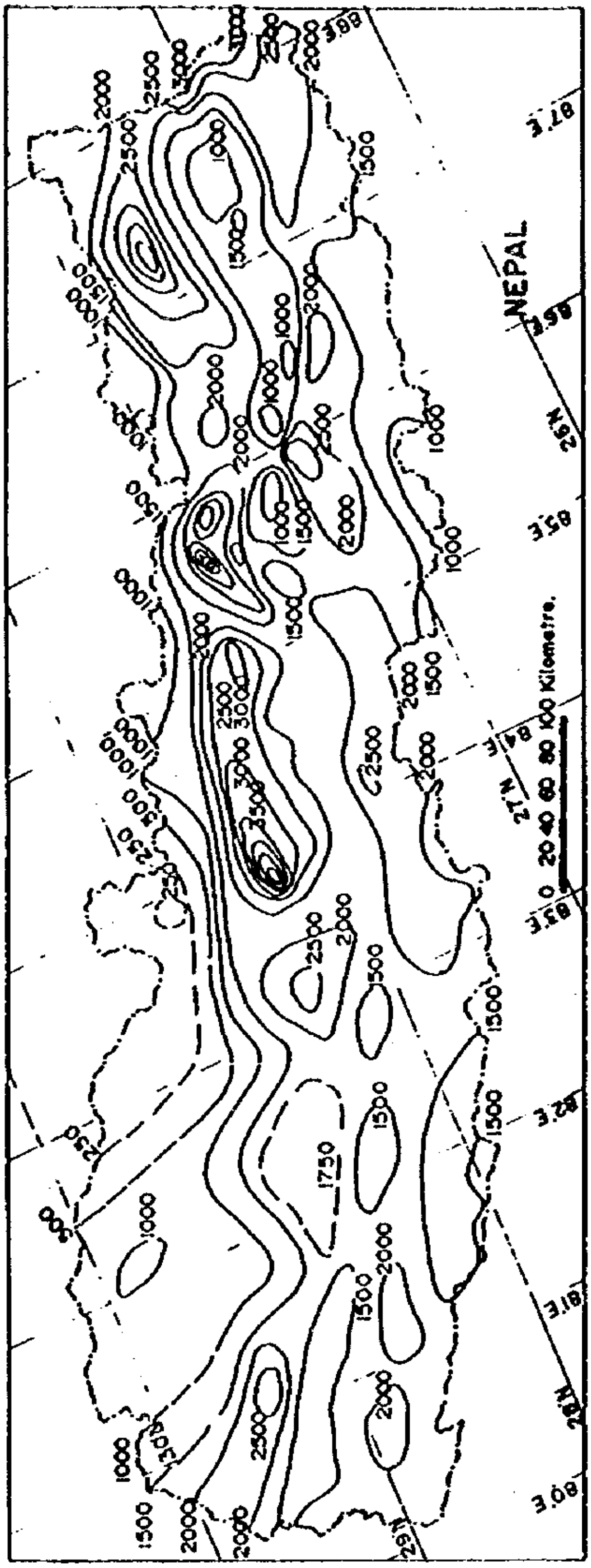
METEOROLOGICAL CONDITIONS

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

MEAN ANNUAL PRECIPITATION (mm) 1971-1985



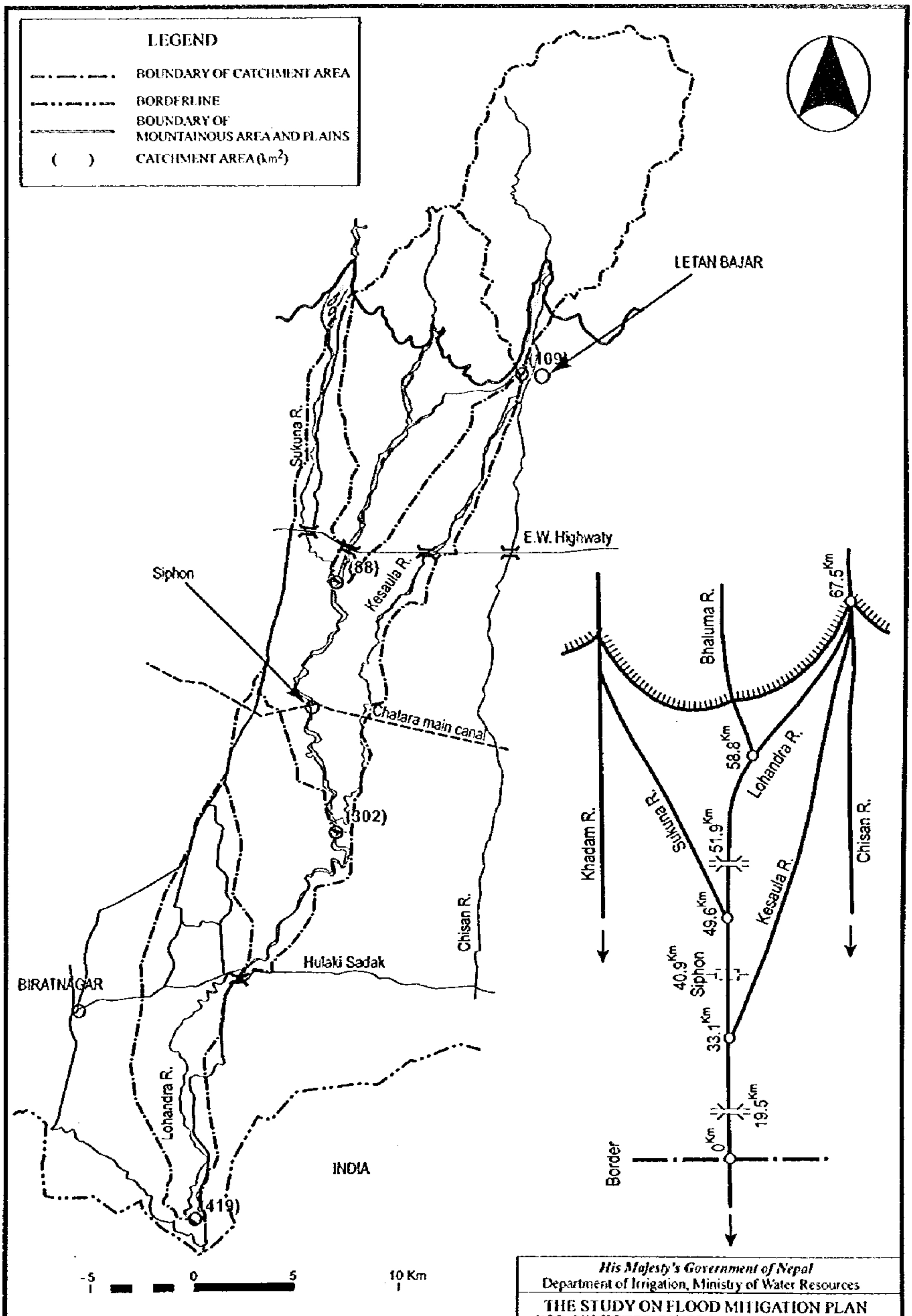
Source: Natural Hazards and Man Made Impacts in The Nepal Himalaya, C.K.Sharman, 1988

ANNUAL RAINFALL DISTRIBUTION OF NEPAL

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY



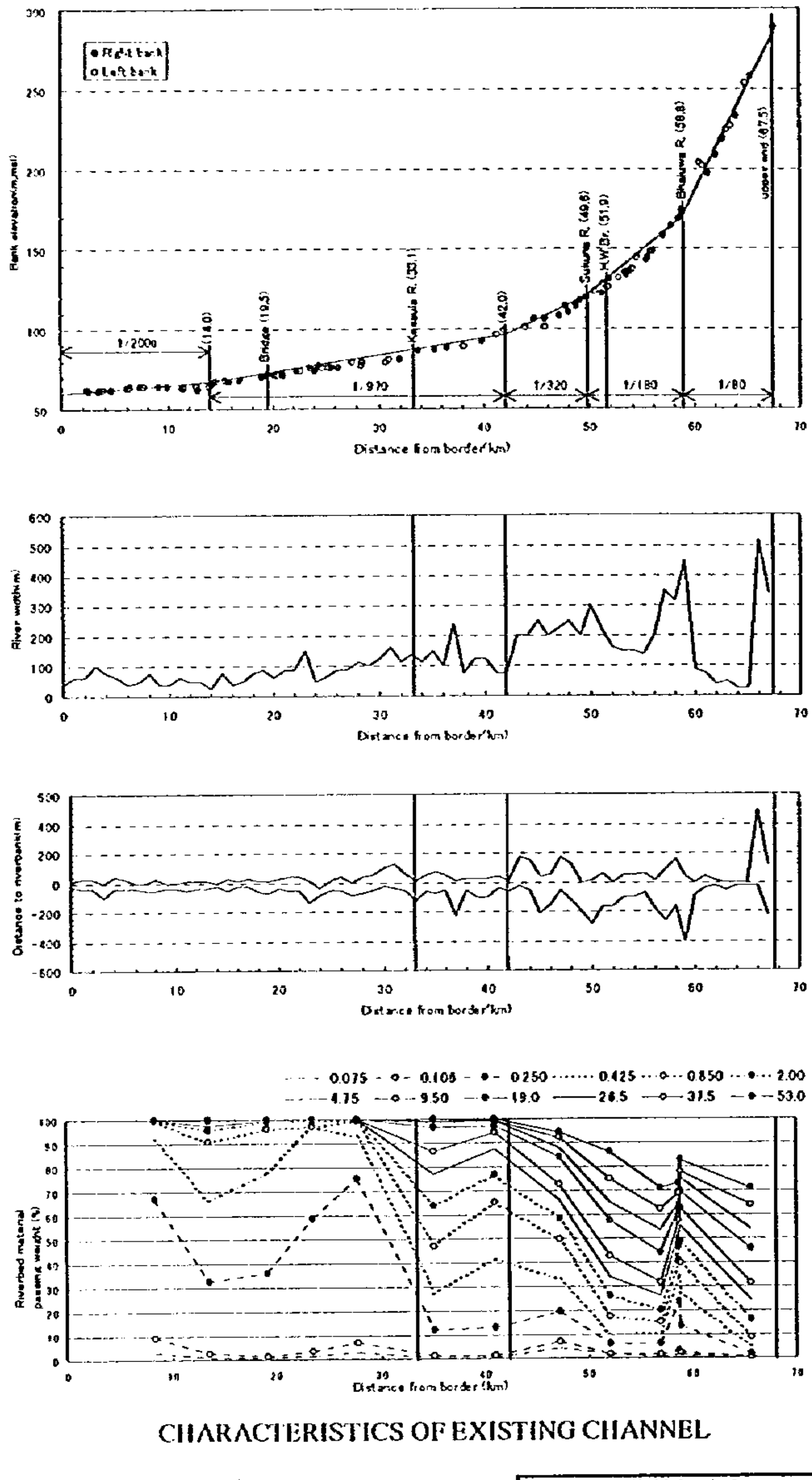
LOHANDRA RIVER BASIN

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

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

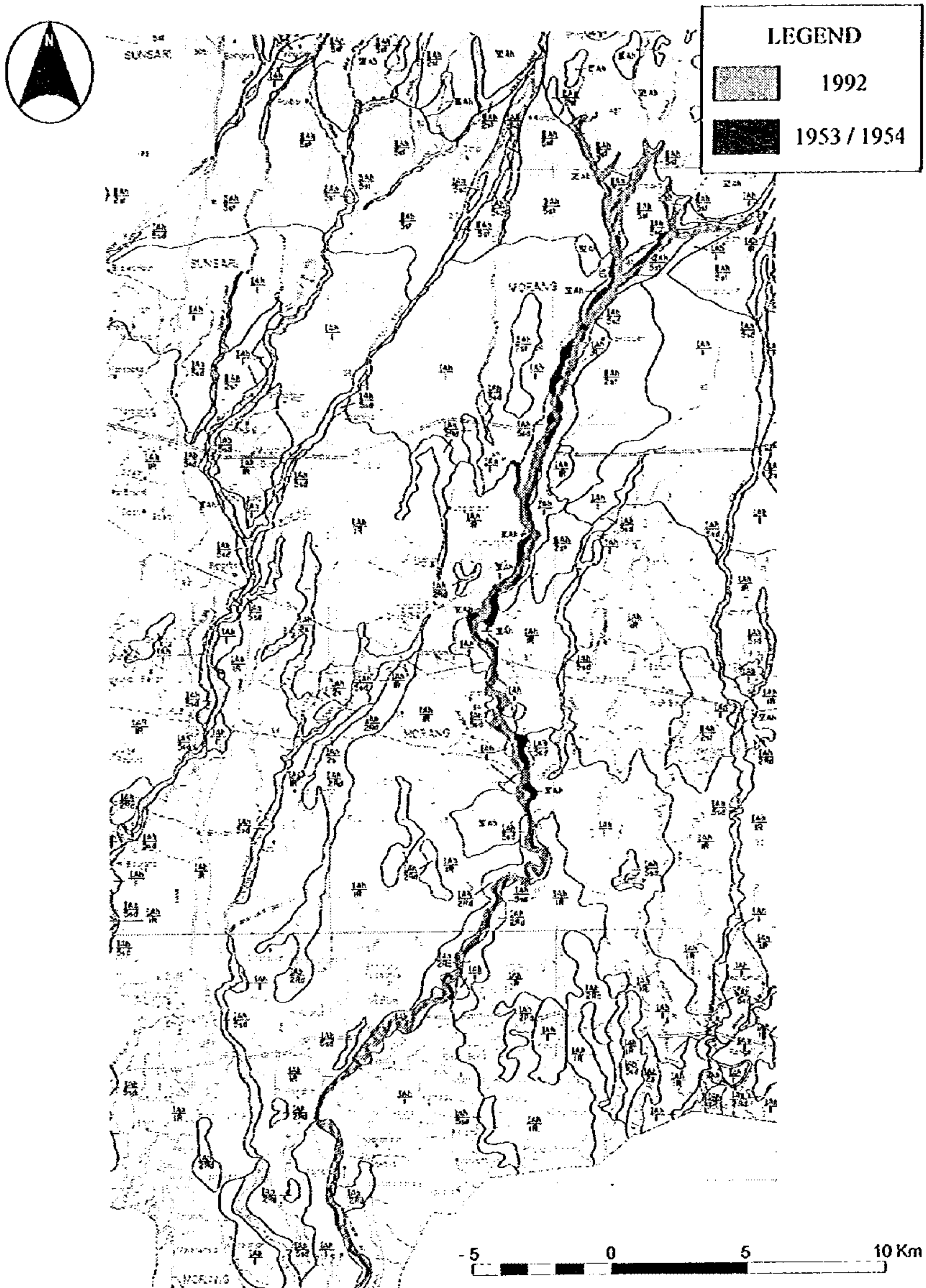
JAPAN INTERNATIONAL COOPERATION AGENCY

LOHANDRA RIVER



CHARACTERISTICS OF EXISTING CHANNEL

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

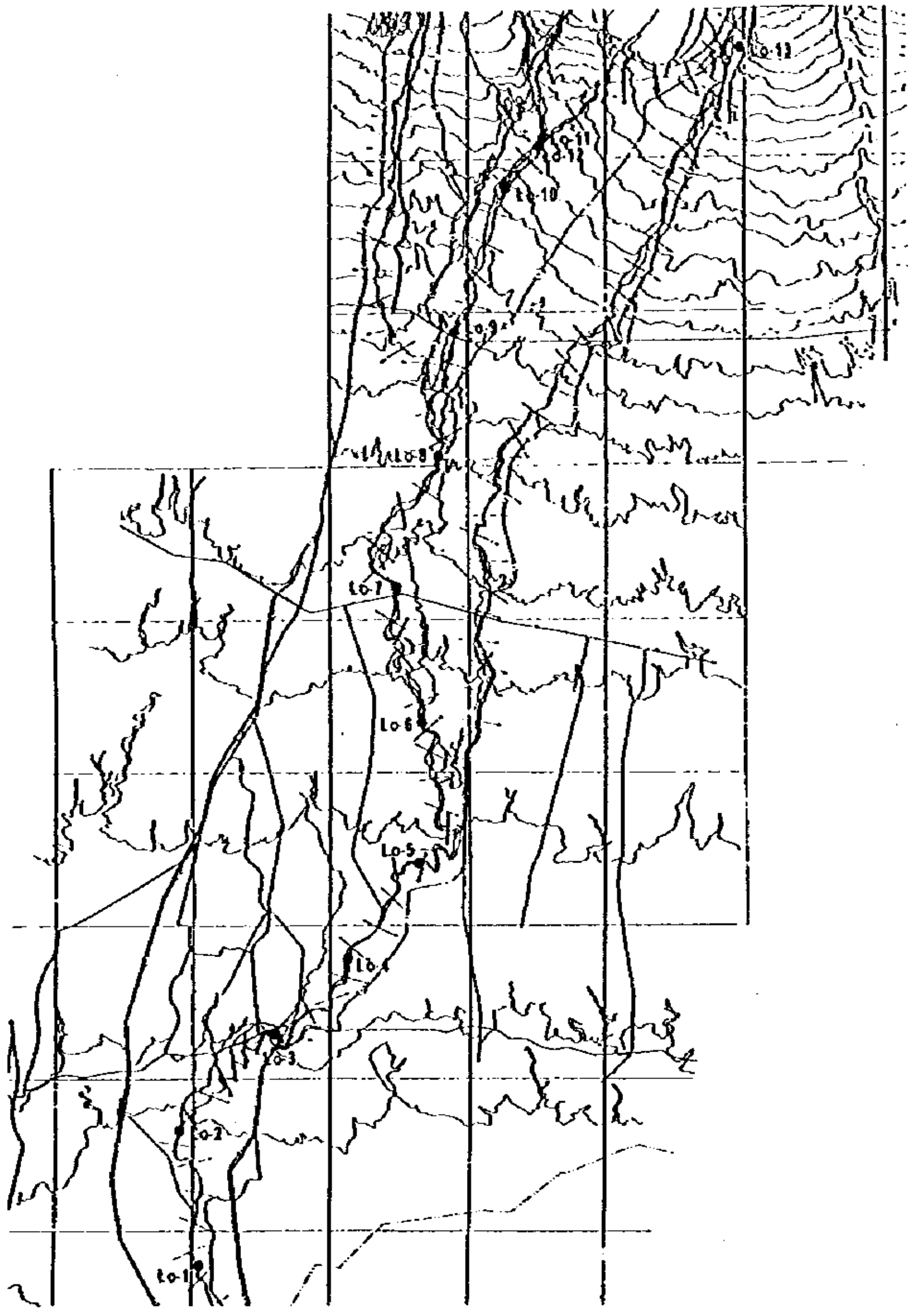


CHANGE OF LOHANDRA RIVER COURSE

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY



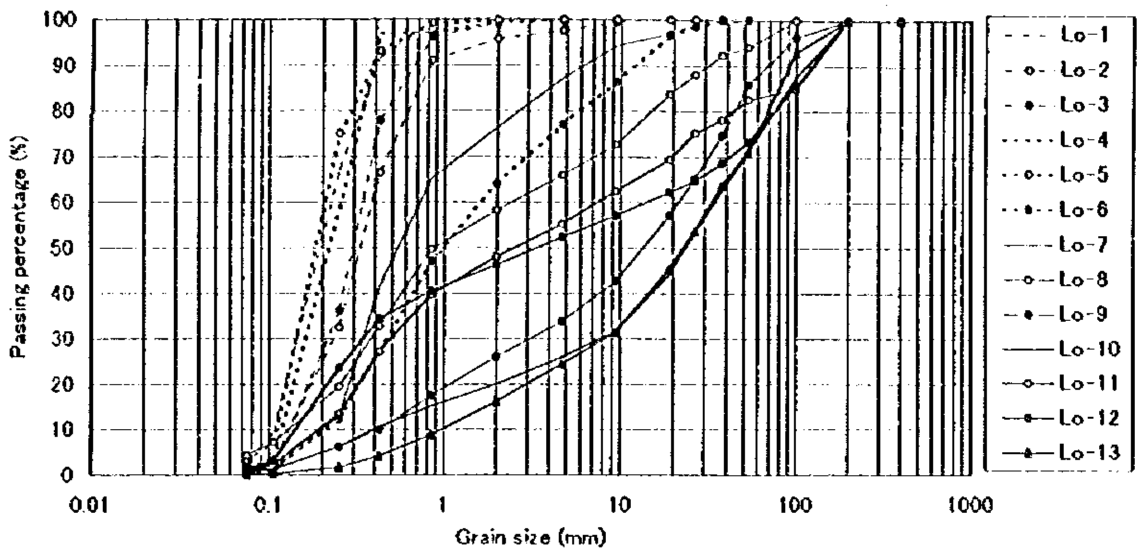
SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading		FGA (Y/N)
				N	E	
1	Lo-1	Silty sand	Majhare WN 7	26°24.467'	87°20.190'	N
2	Lo-2	Silty sand	Siswani WN 8	26°26.669'	87°19.745'	N
3	Lo-3	Silty sand	Lohendra WN 9, Naya Bazar	26°28.247'	87°21.416'	N
4	Lo-4	Silty sand	Thalaha WN 8	26°29.465'	87°22.830'	N
5	Lo-5	Silty sand	Thalaha WN 7, Hurhuriya	26°31.019'	87°23.999'	N
6	Lo-6	Aggregate mixed sand	Motipur WN 2	26°33.274'	87°24.158'	Y
7	Lo-7	Aggregate mixed sand	Near Chhata Main Canal Syphon	26°35.478'	87°23.704'	Y
8	Lo-8	Boulder mixed sand	Belbari WN 3, WN 5	26°37.753'	87°24.674'	Y
9	Lo-9	Boulder mixed sand	Belbari	26°39.707'	87°24.739'	Y
10	Lo-10	Boulder mixed sand	Kerabari WN 9	26°41.829'	87°25.586'	Y
11	Lo-11	Boulder mixed sand	Bhaluwa WN 9	26°43.048'	87°26.462'	Y
12	Lo-12	Boulder mixed sand		26°42.958'	87°26.401'	Y
13	Lo-13	Boulder mixed sand	Letang WN 2	26°44.342'	87°29.953'	Y

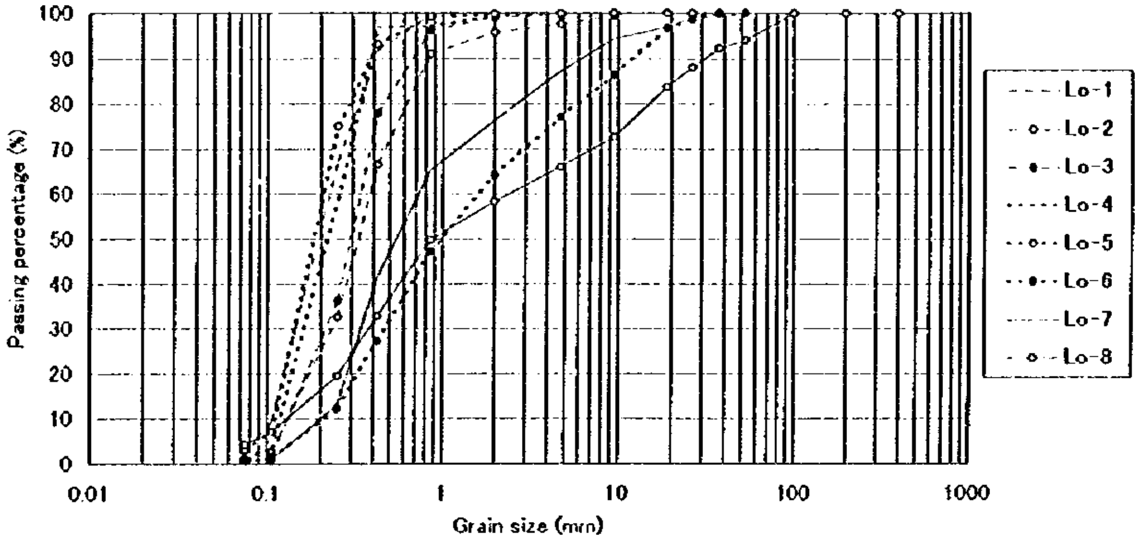
SAMPLING SITES OF RIVERBED MATERIALS (LOHANDRA RIVER)

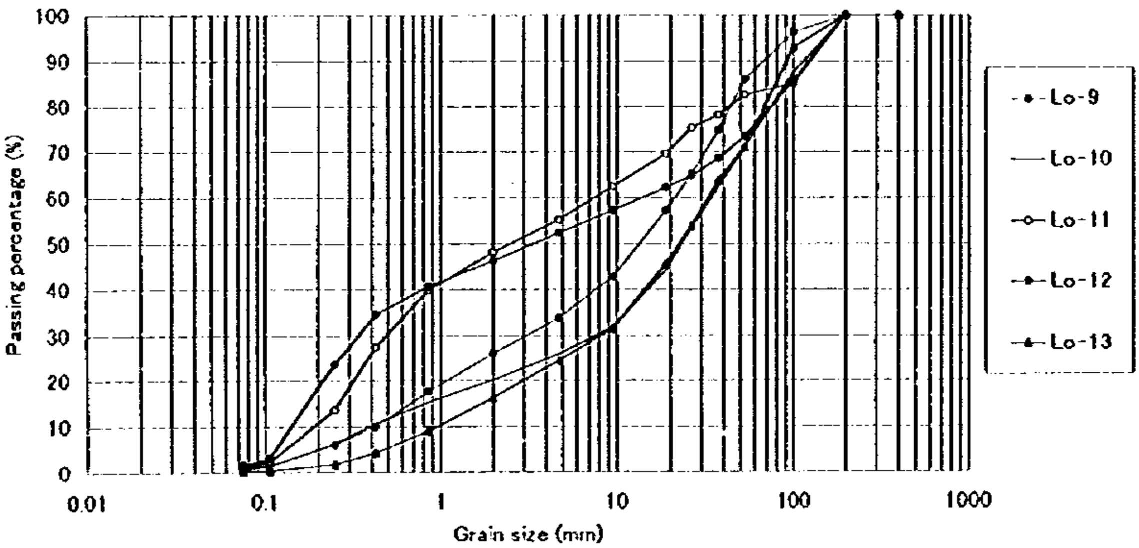
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

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

JAPAN INTERNATIONAL COOPERATION AGENCY





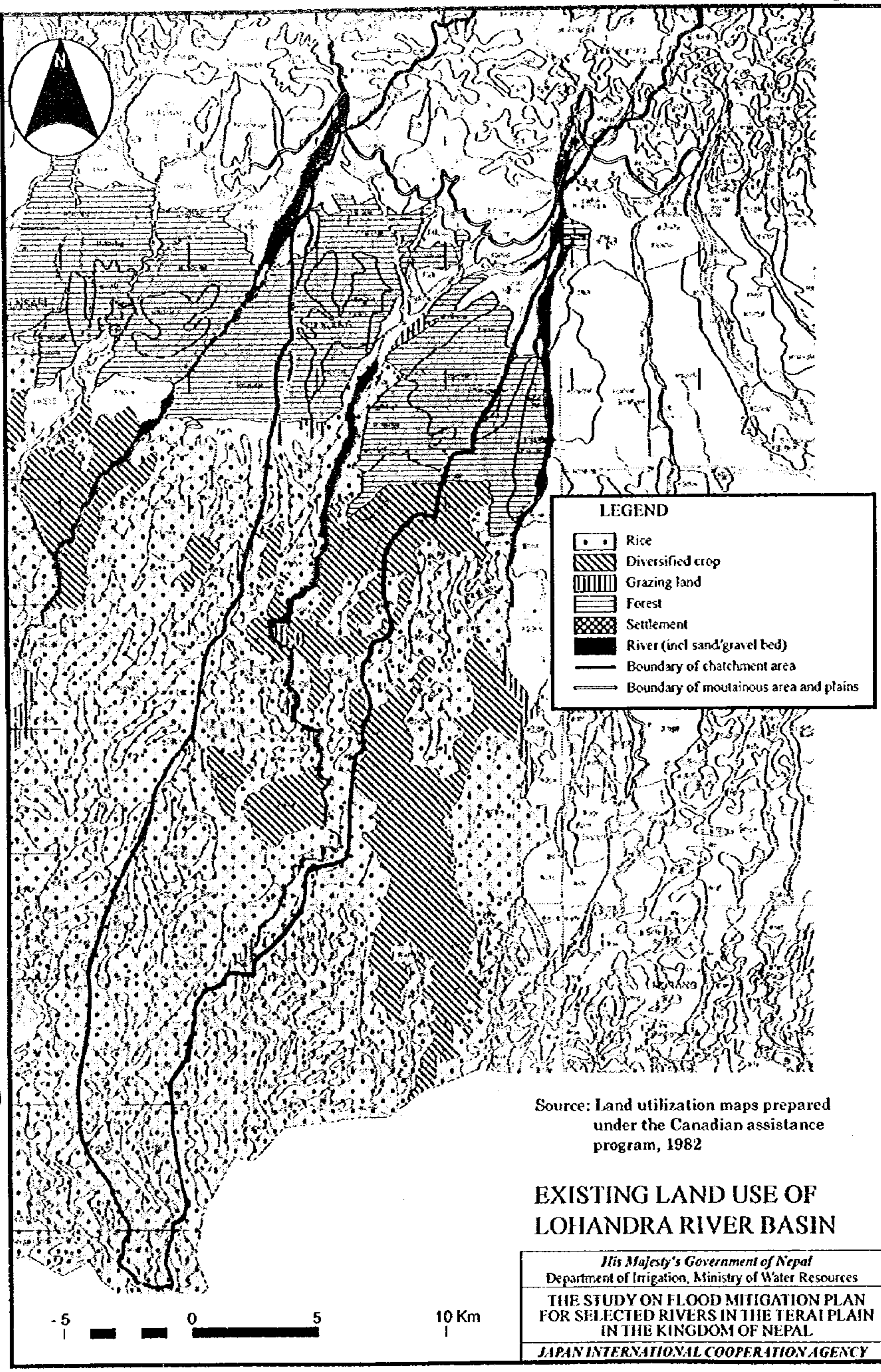


GRADING CURVES OF RIVERBED MATERIALS (LOHANDRA R.)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY



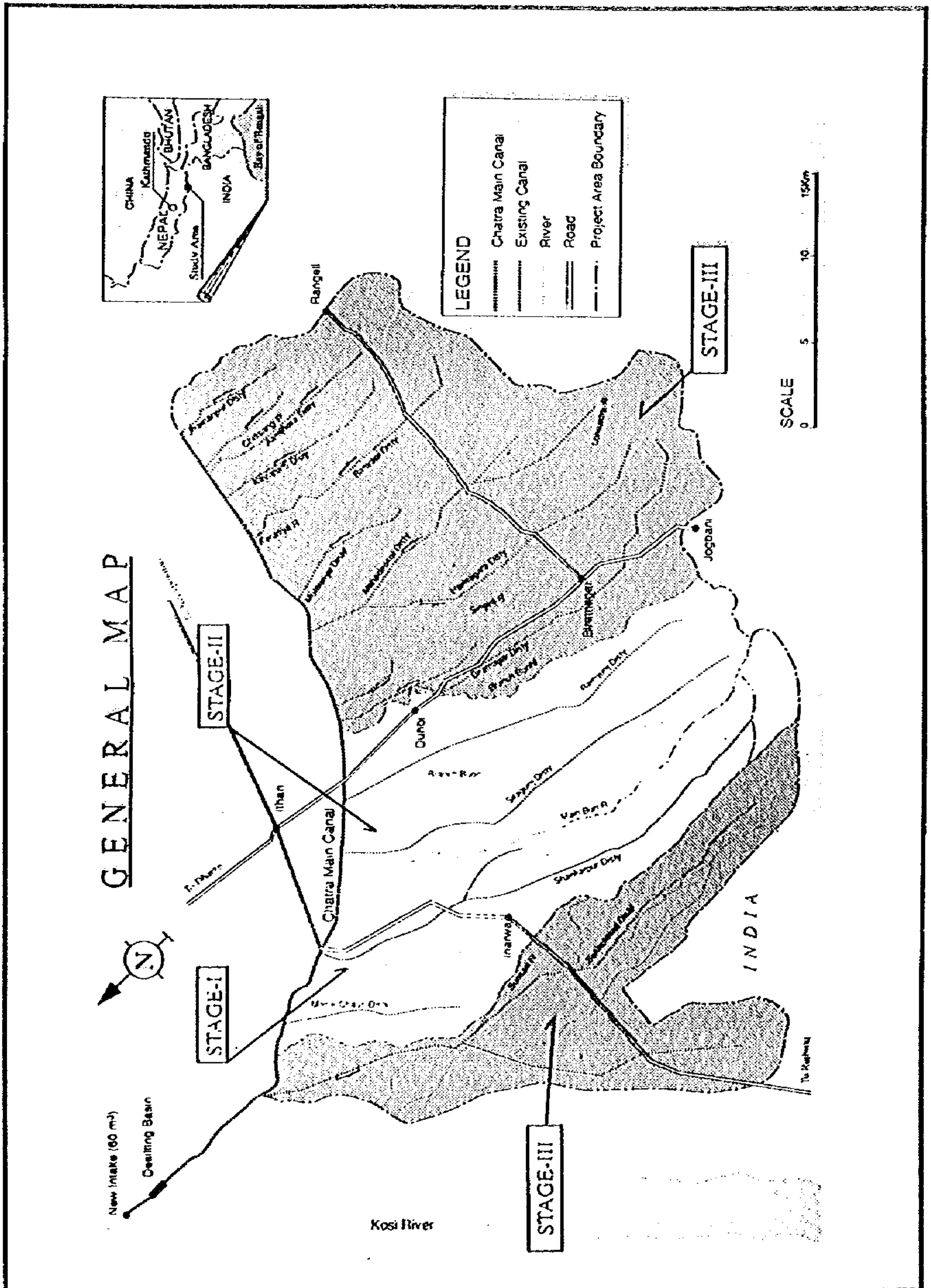
Source: Land utilization maps prepared under the Canadian assistance program, 1982

EXISTING LAND USE OF LOHANDRA RIVER BASIN

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

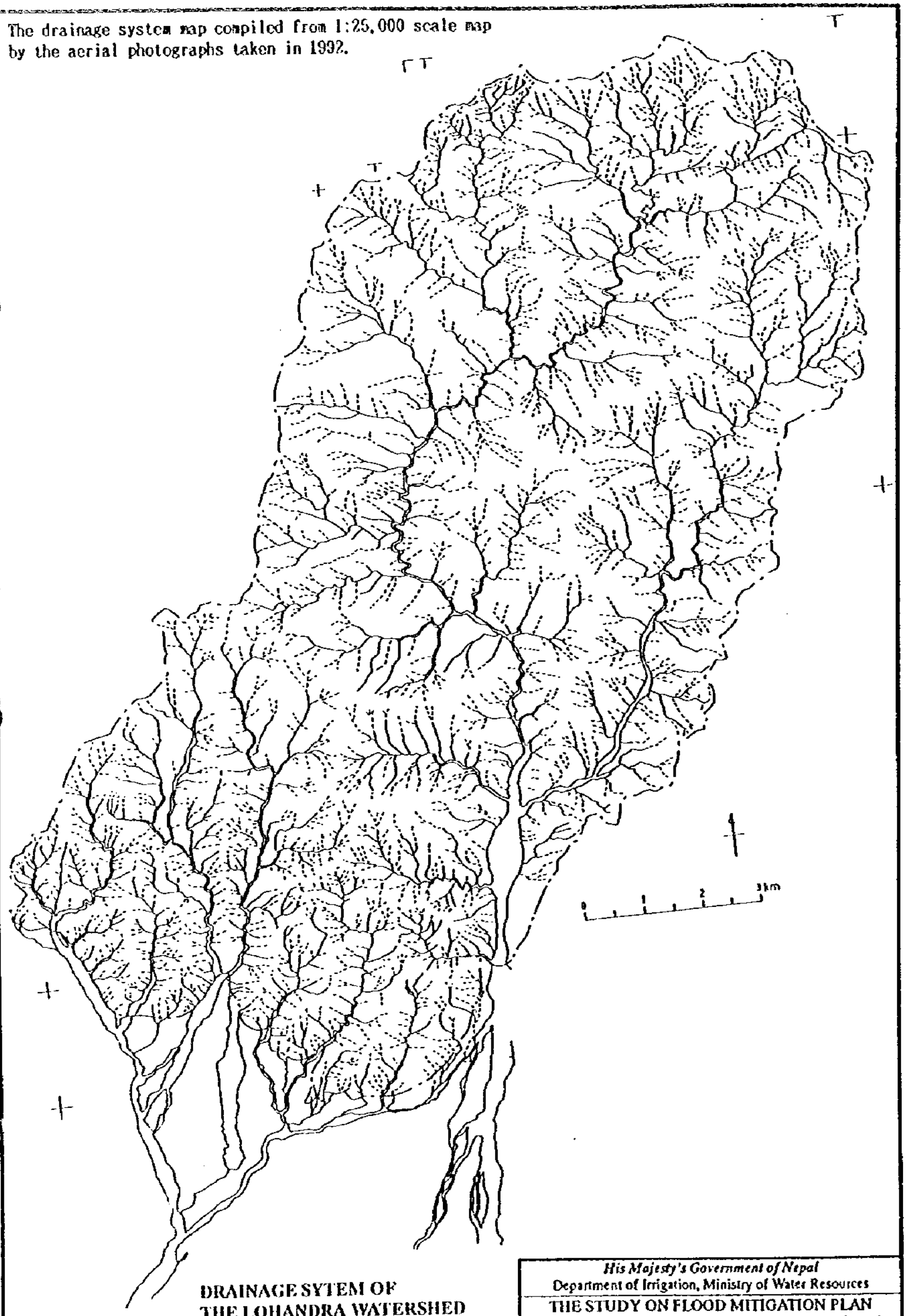


SUNSARI MORANG IRRIGATION PROJECT

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY



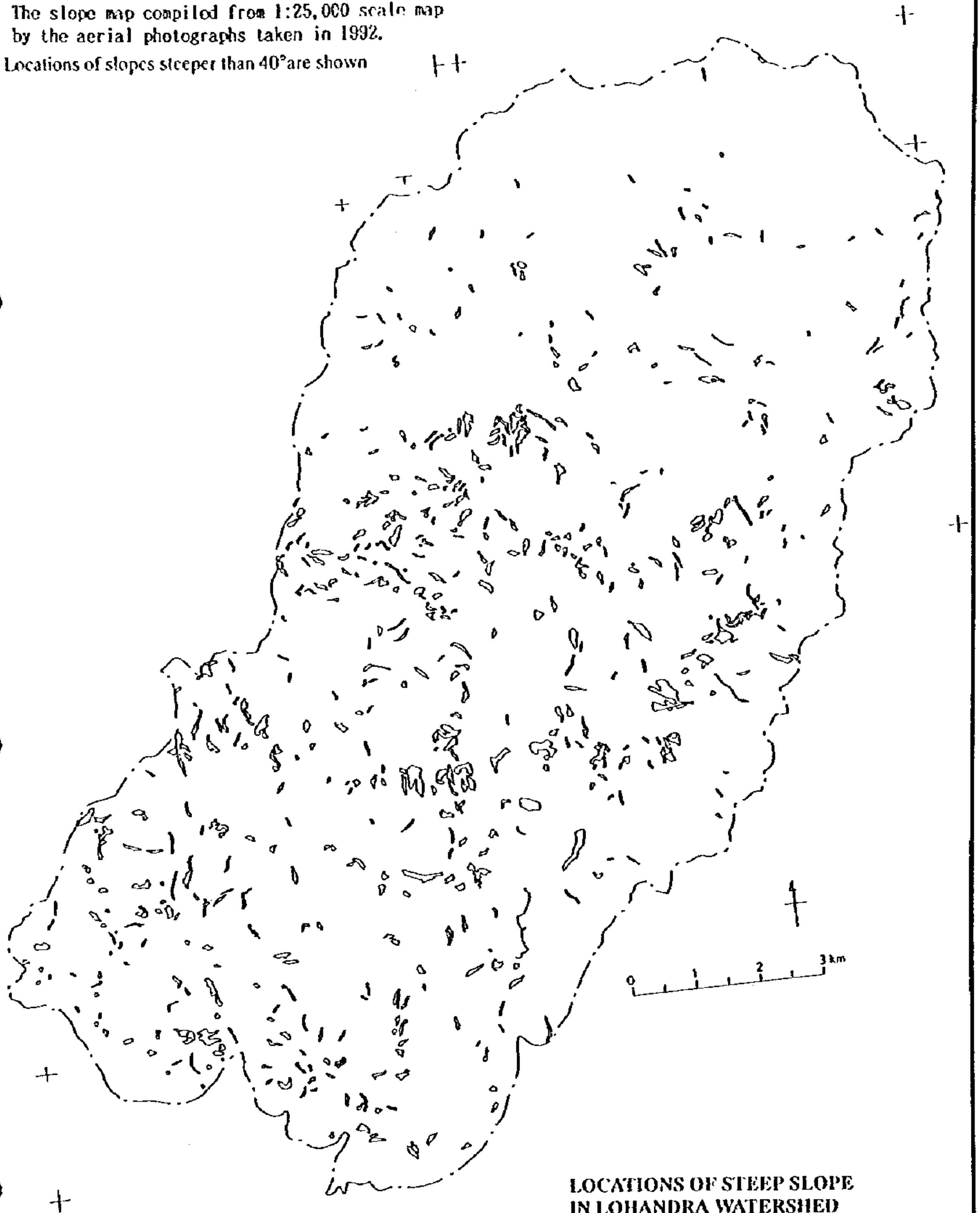
DRAINAGE SYTEM OF
THE LOHANDRA WATERSHED

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

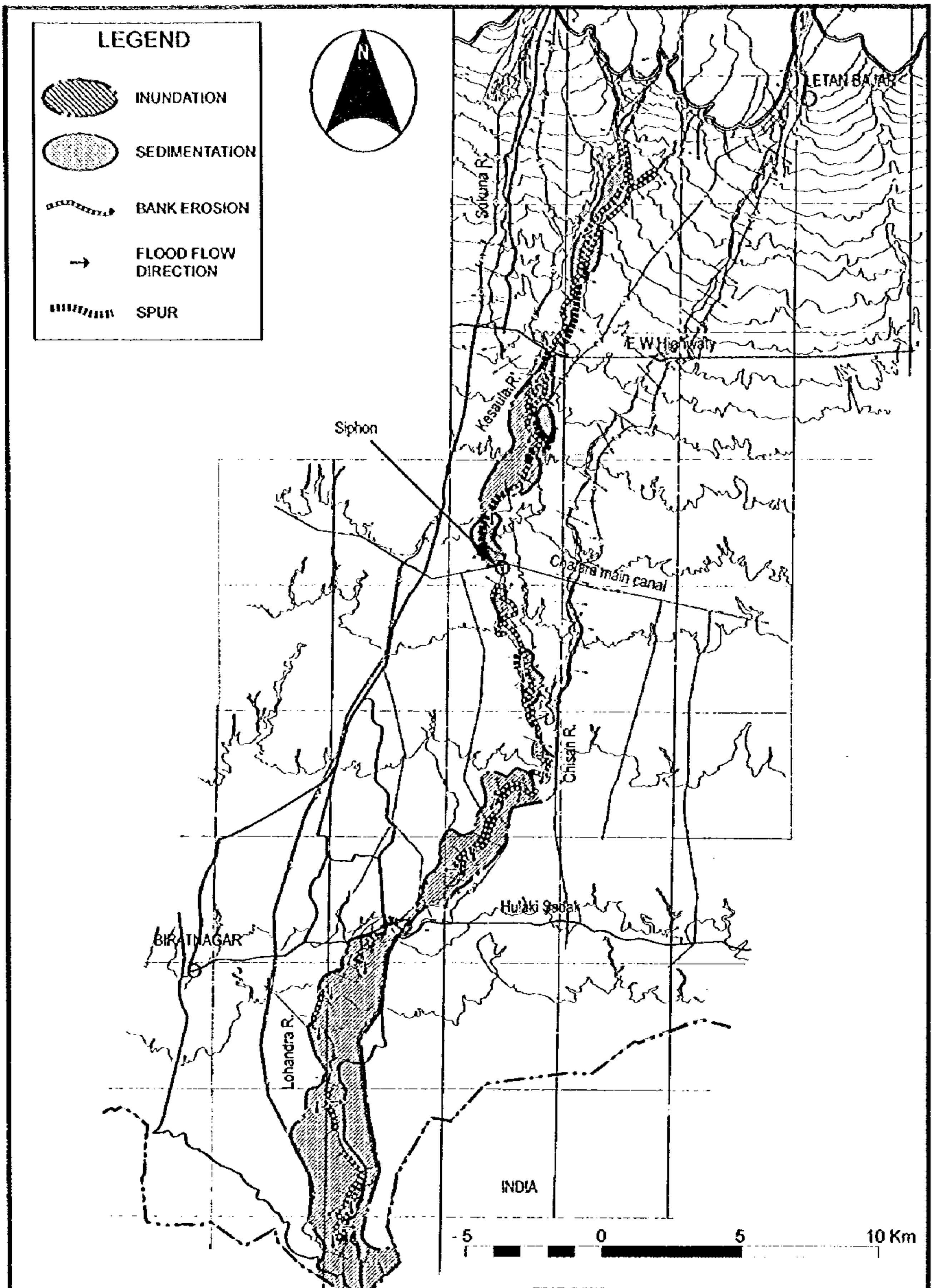
The slope map compiled from 1:25,000 scale map
by the aerial photographs taken in 1992.
Locations of slopes steeper than 40°are shown



LOCATIONS OF STEEP SLOPE
IN LOHANDRA WATERSHED

SLOPE MAP MORE THAN 40° OF THE LOHANDRA 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
JAPAN INTERNATIONAL COOPERATION AGENCY

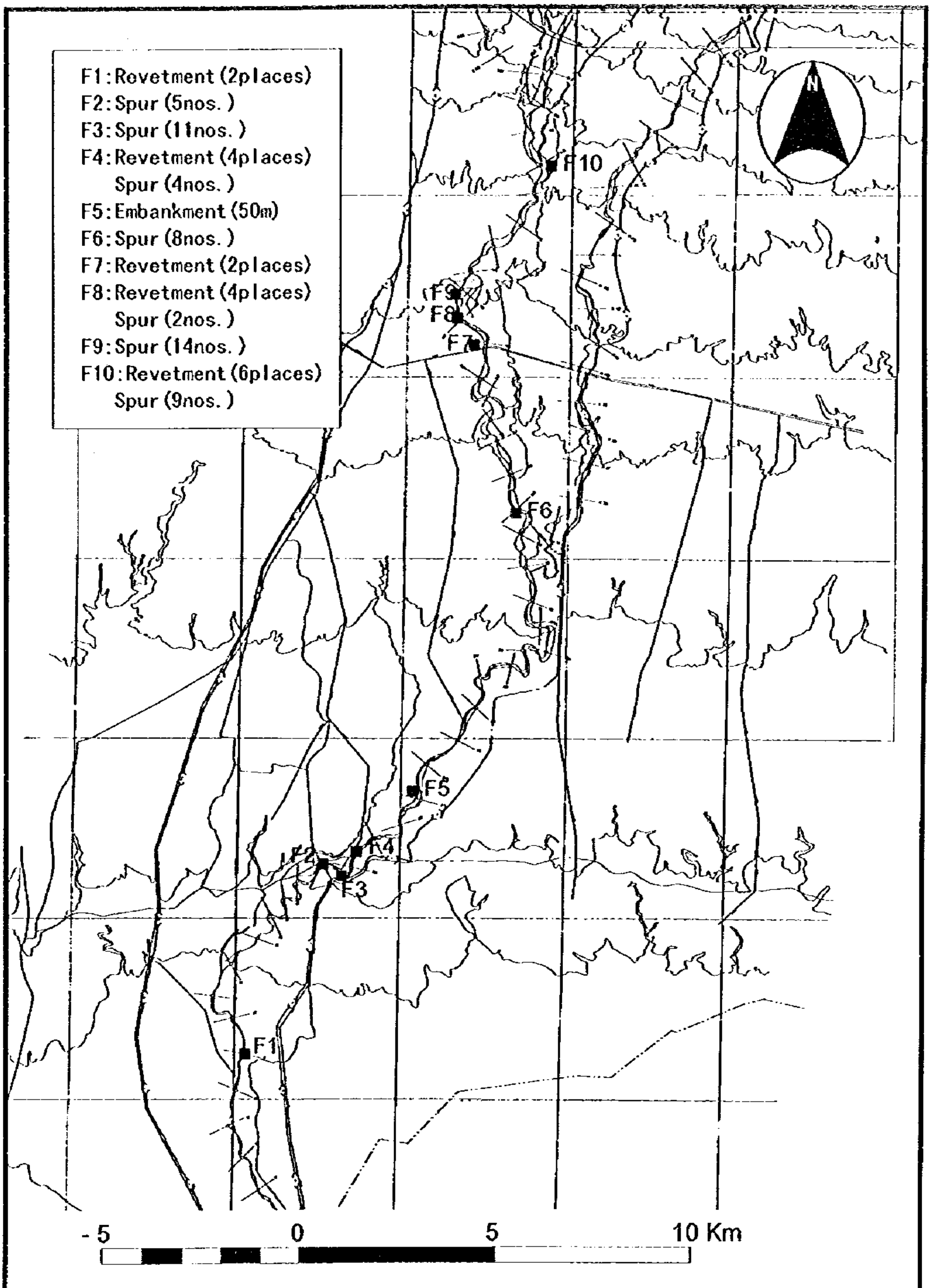


FLOOD SUFFERING AREA (LOHANDRA RIVER,1995)

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

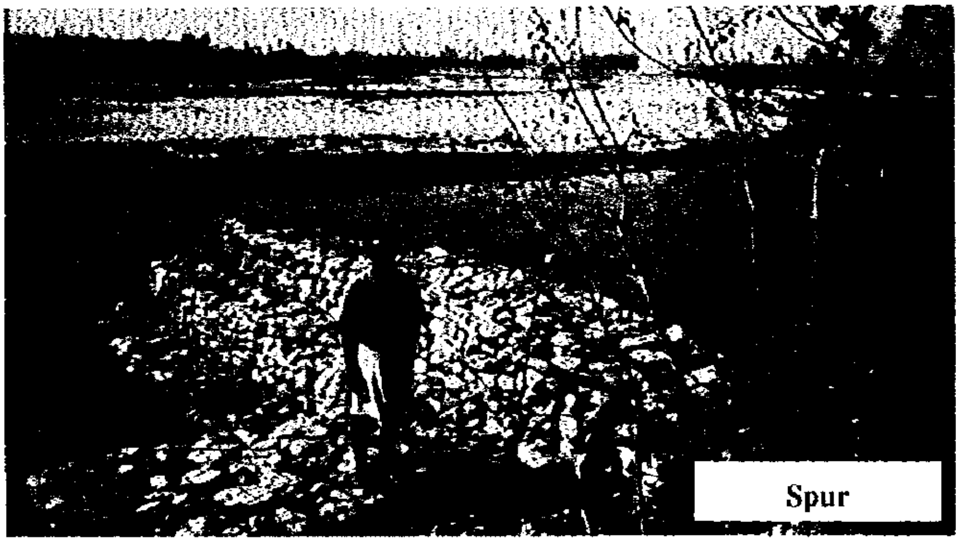
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



LOCATIONS OF RIVER FACILITIES

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



TYPICAL RIVER FACILITIES

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

2. 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 lands 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

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

(Q_n/Q_2-values for Lohandra River)

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

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

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
Lohandra	310	450	720	900	1,070	1,300

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

- LO-1: Reaches from Indian border to Sta. 14.0 km
- LO-2: Reaches from Sta. 14.0 km to Kesaula river junction (Sta. 33.1 km)
- LO-3: Reaches from Kesaula river junction to Sta. 42 km (just upstream of Chatara Main Canal Siphon)
- LO-4: Reaches from Sta. 42.0 km to Sukuna river junction
- LO-5: Reaches from Sukuna river junction to Bhaluwa river junction

- LO-6: Reaches from Bhaluwa river junction to upper end (Sta. 67.5 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)	
Lohandra R.							
LO-1	2-2	60	67	2,000	0.30	0.30	55(25-100)
LO-2	2-2	67	87	970	0.27	0.27	89(25-163)
LO-3	2-1	87	96	970	1.2	1.2	119(75-238)
LO-4	2-1	96	120	320	2.4	2.4	200(75-250)
LO-5	1	120	170	180	19	82	221(138-350)
LO-6	1	170	285	80	23	81	178(25-513)

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: $B_b < 3h_H$, $7h_H$ 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 are not applicable in class-III river basins, because of the poor geological conditions in the Siwalik hills. Single purpose dam for flood mitigation would not be economically feasible. As to multi-purpose dams, promising projects are not proposed at present for the river basins in the Study Area. Therefore, the dam schemes were not incorporated at present.
2) **Retarding Basin:** In order to reduce flood peaks in the downstream reaches, a retarding basin by conserving natural flood storage function can be considered. The retarding basin can be planned at the confluence of tributaries. It will (1) reduce runoff peak by spilling floodwater into the retarding basin; (2) collect flood water from the upper reaches; and (3) join tributaries without a drainage sluice, thereby as a back-water levee.

2.5 Community Development Component

The "Community Development Component" will consist of three sets of activities (Fig. A2.5). The "Community Mobilization" intends to build up organizational bases for the Plan implementation. The "Local Coping Measures" will enable the communities to "live with flooding". The "Community-based Sustainable Measures" will motivate the local people to maintain and sustain the flood control structures.

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

2.5.1 Community Mobilization

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

(1) Workshops for Local Government Institutions (LGIs)

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

1) Technicalities of Flood Control Measures (functioning of various measures)
2) Local Initiatives for Flood Mitigation (actions expected of communities)
3) Community Mobilization Processes (procedures for community mobilization)
4) Facilitative Roles by LGIs (roles and responsibilities of LGIs)

(2) Creation of Organizational Bases at the Community

Formation of Community Organizations (COs)

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

Promotion of Public Awareness, Knowledge & Skills

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

1) **Technicalities of Flood Control Measures:** to understand how various measures are to function and are to be maintained, and also why continuous dikes are not opted.
2) **Skills in Masonry and Gabion-netting:** to gain employment during the construction stage, and also to obtain skill necessary for the maintenance activities.

3) **Community Participation in Flood Mitigation:** to understand modalities of "participation", e.g., labor/in-kind/cash contributions, as well as local practice.

<u>**Generation of Financial Resources by COs**</u>

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:** Pastureland along the target rivers is usually used freely by herdsmen, which cause overgrazing problems. This leads to the reduction of vegetation cover, which also stability of the riverbank.
3) **Deforestation:** Not all the forests along the rivers are properly managed. Some are being deforested, while others are maintained but not in a manner conducive to soil conservation.

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

2.6 Flood Mitigation Plan

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

(1) Present Conditions and Problems

1) River basin:
   - Class-III river in Eastern Development Region
   - Basin area: 419(310) km^2 in total consisting of mountainous basin 140(31) km^2 and plain area 279 km^2. Areas in ( ) indicate those excluding mountainous basin of the Chisan river.

- Middle and lower portions of the flood prone areas are the service areas of the Sunsari Morang (Kosi river) Irrigation Project.

2) River system: The Lohandra river is located between alluvial fans of the Chisan and Kadan rivers. The Lohandra river which is a branch river of the Chisan joins the Kesaula river from the Chisan and the Sukuna river from the Kadam.
3) River channel: River is wide and braided in the upper reaches and becomes narrower gradually toward lower reaches. Riverbed materials range fine sand in the lower reaches to very coarse gravel in the upper reaches.
4) River segments:
   - Segment 2-2: From 0.0 km (Indian border) to 33.1 km (Kesaula R. jct.)
   - Segment 2-2: From 33.1 km to 49.6 km (Sukuna R. jct.)
   - Segment 1 : From 29.6 km to 67.5 km (upper end)
5) Flood and sediment disasters:
   - Recent major floods: 1987,1988,1995 and 1996 floods in order of severity.
   - Kinds of damage: Sedimentation, bank erosion and flooding over farm lands.
   - Suffering areas: 28 villages in 14 VDCs in Morang district
   - Conditions and mechanism of flooding: Settlements and lands along the Lohandra river suffer from flood and sediment disasters almost every year. The riverbed is said to be aggrading markedly especially in the upstream reaches from Chatara canal. Bank erosion is active on the both sides of the river. Since the river channel is small in the lower reaches, flood water from the upstream areas frequently floods over the riverine farmlands.

(2) Principal Measures to be Taken

1) The main Lohandra and the Kesaula rivers will be separated from the Chisan river completely by a closing dike with diversion facilities if necessary.
2) The Sukuna river will be separated from the Chisan river completely by closing dike.
3) An anabranch at 46.7 km on the left bank will be closed securely with diversion facility if necessary.
4) Forest belt will be provided for Segment 1 and grass belt in Segments 2-2 and 2-1.

5) Cut-off channels will be constructed at severe bends. Cut-off channel from 27.8 km to 31.4 km aims to bypass dense settlement areas.
6) An area at the confluence of the Lohandra and Sukuna rivers will be preserved as a retarding basin.
7) 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 adapting bioengineering approach.
8) Watershed management will be carried out for erosion and runoff control.
9) 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. 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 Lohandra river are shown in Table A2.4.