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JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF IRRIGATION
MINISTRY OF WATER RESOURCES
THE KINGDOM OF NEPAL

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

FINAL REPORT

VOLUME III (8/9)

SUPPORTING REPORT

(A8: FMP/KHUTIYA RIVER)

MAY 1999

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

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FINAL REPORT

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VOLUME II : MAIN REPORT

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A8. FLOOD MITIGATION PLAN:

KHUTIYA RIVER BASIN

SUPPORTING REPORT
A8. FLOOD MITIGATION PLAN: KHUTIYA RIVER BASIN

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1. EXISTING CONDITIONS

1.1 Topography and Geology

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

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

The Khutiya 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) Khutiya River Basin

Khutiya river originates in western Siwalik hills. Overall longitudinal profile of the Khutiya river is shown in Fig. A1.2 in comparison with those of other rivers originating in the eastern Siwalik hills. In comparison with rivers originating in eastern Siwalik hills. The Khutiya river has higher ground elevation and steeper riverbed in the Bhabhar zone. The Khutiya river is surrounded by dense mixed forest, and less cultivated lands exist along the river.

As a sample, geological formation in the lower Khutiya river is shown below. The ground near the site is very soft and the slope is so gentle, so that the river channel suffers from changes by lateral erosion.

(Depth from surface)	(Lithology)
0 - 0.6 m	Surface soil-yellowish gray

0.6 - 4.5 m	Sand fine
4.5 - 9.0 m	Clay gray sticky
9.0 - 19.0 m	Gravel medium
19.0 - 43.8 m	Clay yellowish sticky
43.8 - 69.0 m	Clay sticky with medium gravel
69.0 - 72.0 m	Gravel pebble and sand, yellow

Geological map of the Khutiya 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 Far Western Development Region is shown in Table A1.1 and their locations in Fig. A1.4. No hydro-metric station exist in the Khutiya river system.

1.2.2 Meteo-Hydrological Features of Basin

Climate of the Khutiya 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 Khutiya river basin. Figure A1.5 shows the meteo-hydrological features of the basin based on the monthly average data at Dhangadhi (sta. code: 0209).

(1) Temperature

Altitude affects much the temperature. The annual average temperature is 24.0℃, ranging from 14.6℃ in the coldest month to 31.0℃ in the hottest month. The coldest month is in January and the hottest falls in between May and August. The temperature rises from March to June-July while it decreases from October to January.

(2) Relative Humidity

According to Fig. A1.5, annual average relative humidity is 79.2%, ranging from 51.7% in April to 94.7% in December.

(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 Dhangadhi is 1,661mm on average ranging from 1,269 to 2,303mm depending on the year. The maximum rainfall is 2,303 mm in 1990. The 86% 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 Khutiya is a class-III river of about 35 km and has a basin area of about 325 km^2, (32,500 ha.). It rises in the Siwalik hills and its length in the Terai plain is about 29 km with an area of some 150 km^2 (15,000 ha.). It is joined by the Shiva Ganga North river just below midway in the Terai.

There is a wetland in the vicinity of the river called the Khutiya river floodplain. It has an area of some 3,600 ha with a perennial stream. Because this area is still relatively undisturbed, more varieties and numbers of plants and animals are found in this wetland as compared to other wetlands. The sisoo tree *(Dalbergia sissoo)* and Khair *(Acacia catechu)* dominate the floodplain. Other important tree species found in the area include: *Trewia nudiflora*, (Bhelar), *Adina cordifolia*, (Haldu), *Syzigium cumini*, (Jamun) and Simal *(Bombax ceiba)*.

There are reports of many species of fish, amphibians, reptiles, birds and mammals, including the smooth coated otter, *Lutrogale perspicillata*. The river is a feeding ground for numerous resident and migratory bird species. The recorded species of importance include: *Ciconia episcopus, C. nigra, Ichthyophaga icthyaetus, Motacilla cinerea, M. citreola, M. madraspatensis, Pelagopsis capensis, Phalacrocorax niger, Pseudibis papillosa, Spilornis cheela, Tringa ochropus, T. hypoleucos, T. nebularia, T. totanus, Vanellus indicus, V. spinosus*, (IUCN/Nepal [1996] Wetland Database).

The existing land use and population of the Khutiya 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)	5,800	8,640	440	120	15,000	(29,200)*
Ratio (%)	38.7	57.6	2.9	0.8	100	(1.9)**

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

The area round the Khutiya is the least agriculturally developed area of all the eight rivers, but it is an area that is being settled rapidly. Therefore, it is important that flood mitigation measures be put in place quickly, so as to prevent people settling along the riverbanks and to protect flood prone and wetland areas. At present, agriculture only occupies an estimated 39% of the land, with forests 58%. Even so, sand, silt and/or floodwater on average cover about 1,200 hectares of which about 220 ha. are inundated with sand and soil. Some of this soil cover is a result of human activity, especially in the Siwalik hills. In addition, nearly 3% of the land is barren or covered with sand, principally due to flooding and inundation.

1.4 Socio Economy

(1) Economic Activities

Land Use: The Khutiya river flows in Kailali district. According to the district data, agricultural and forest land makes up 97.1% of the total plain area.

(unit: hectare)

District	Agriculture	Forest	Sand/Gravel /Boulder	Others
KAILALI	74,315 38.6%	112,805 58.5%	5,668 2.9%	0 0.0%
10 Districts (where M/P rivers flow)	800,591 64.1%	352,508 28.2%	43095 3.5%	52,449 4.2%

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

Economically Active Population (10 Years of Age and Over) by Major Occupation: 79.8% of the labor force is engaged in agriculture, as opposed to 3.8% in manufacturing and 9.9% in service sectors.

District	Agriculture Worker	Service Worker	Production Worker	Sales Worker and Others
KAILALI	135,490 79.8%	13,339 9.9%	5,164 3.8%	8868 6.5%
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: Kailali district produces a wide range of crops, with major crops of paddy, wheat, maize, and oilseed. These major crops but wheat and oilseed 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
KAILALI	51,000 (2.03)	12,017 (1.62)	19,000 (1.46)	---	15,000 (0.62)	300 (29.00)	---
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 Kailali district, the average land holding size has declined in recent years like other districts in the Terai plain. The average size is far below the 16.4-hectare ceiling imposed by the 1964 Lands Act. More than 90 % of the agricultural land is under owner-cultivation. With regard to the agricultural land under "formal" tenancy, the most dominant form is sharecropping.

District	Owner-Cultivated (%)		Average Holding Size (ha.)	
	1981/82	1991/92	1981/82	1991/92
KAILALI	97.6	94.4	1.70	1.35
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
KAILALI	8.8	74.7	15.0
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 Kailali district is 418,000 as of 1991 with population growth rate of 4.8% (1981-1991). The population growth ratio was markedly high during 1970s and, since then, it remains almost the same level, even when the growth rates of many other Teri districts subsided.

Demographic Records Of Flood-Prone VDCs: The following table shows the population trends of the VDCs affected by Khutiya floods. The 1981-91 population growth rate of the affected VDCs is 8.4%. This indicates that the population pressure is higher in the flood-risk VDCs, than other localities in Kailali district.

District	VDC	1971	1981	1991	1996
Kailali	Urma	2,948	4,558	7,997	10,124
	Phulwari	-	-	13,580	17,192
	Veladenipur	1,999	-	5,006	6,338
	Dhangadhi	-	27,274	44,753	56,657
Total		4,947	31,832	71,336	90,311

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 Kailali district is also ranked among the lowest strata (52th among all 75 districts).

1.5 River and Basin Conditions

1.5.1 Principal Basin Features

The Khutiya river basin extends from 28°40′N to 29°00′N and from 80°35′E to 80°45′E. The Khutiya river originates in western Siwalik hills and is classified as a

class III river. Administratively it is located in Kailali district of Far Western Development Region.

Basin area of the Khutiya river is 325 km^2 in total, consisting of 175 km^2 of mountainous basin and 150 km^2 of plain area. Boundaries of the river basin and sub-basins were drawn on the basin map. Basin boundary in the Terai plain was delineated in consideration of existing drainage channels, irrigation canals, road networks and other ground objects.

General basin maps of the Khutiya river is shown in Fig. A1.7. Topographic maps of 1/25,000 for the western part of Nepal are under preparation in Department of Survey and not yet available. Topographic maps of 1/50,000 were used to prepare overall basin maps of the Khutiya river. Aerial photos of approximately 1/50,000 were used for the lower Khutiya river, since a part of the topographic maps were not available even for the scales of 1/50,000.

Notable features of the Khutiya river basin are as follows:

1) River in the upstream from the E-W highway flows through thick forest lands forming wide and braided channel.
2) The Shiva Ganga river is the major tributary of the Khutiya river.
3) The riverine areas of the Khutiya are covered by a lot of forests, and the lands are not so developed.
4) The Khutiya river flows into the Mohana river that runs on the Indian border. The Mohana river flows side of Dhangadi town causing bank erosion problems.

1.5.2 Characteristics of River Channel

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

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

River	Class	Length(km)	Slope	Width(m)
Khutiya R.	III	35.0(28.6)	1/70~2130	50~650

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

1.5.3 River Course Shifting

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

In order to look into the actual shifting of river course in the past, topographic maps prepared in 1953 (scale: 1/50,000) and those in 1996 (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, the following features are considered:

1) Meander of river course in the upper reaches of E-W highway is not severe, while it is severe in the lower reaches of the bridge.
2) Shifting of river course remains 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 Khutiya river were sampled at 10 sites (Fig. A1.10) among which outdoor analyses were carried out at 6 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: Samples are from the main course of the Khutiya river except for Kh-1 from the Mohana river and Kh-5 from the Shiva Ganga river.
2) Grain size:
   - d_{60} 0.24 to 1.22 mm (medium to very coarse sand): Main river downstream Kh-4 site, and Kh-1 and Kh-5 sites
   - d_{60} = 5.24 to 29.28 mm (fine to coarse gravel): Main river downstream from Kh-9 site except Kh-8 site
   - d_{60} = 139(large cobbles): Main river at Kh-10 site.
3) Uniformity index: Riverbed materials are well-sorted and uniform in the downstream reaches from Kh-4
   - UI = 2.5 to 3.1: Main river downstream from Kh-4 site, and Kh-1 and Kh-5 sites
   - UI = 66 to 133: Main river upstream from Kh-6
4) Specific gravity:
   - SG = 2.63 g/cc on average ranging from 2.58 to 2.69 g/cc.
5) Longitudinal distribution: Significant changes in grain sizes are seen at two sections between Kh-4 and Kh-6 sites and Kh-9 and Kh-10 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

There is neither major irrigation project nor other water resources development project undertaken in the Khutiya river basin.

1.6 Vegetation and Sediment Yield in Watershed Area

(1) Climate and Vegetation Division

Watershed of the Khutiya 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 Khutiya river was worked out using the aerial photos taken in 1996 as follows:

(Land Use of Watersheds)

Land use	Area (ha)	Ratio (%)
Forest	16,471	94.1
Bush	-	-
Cultivation	613	3.5
Cliff	313	1.8
River	103	0.6
Urban	-	-
Total	17,500	100.0

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

Watershed of the Khutiya river is located on the southern slope of the Siwalik hills. Cultivated land is only 4% and forestland occupies 94%. The vegetation is Hill Sal forest. The cliff land ratio of 1.8% is relatively high. The size of each cliff is large and the cliff slope faces to the south. The cliff is a cuesta scarp and is formed by bare rock. In the southern part of the Siwalik hills, most of the ridges are bare or bush lands. The forests are rather devastated.

(3) Erosive Landform of Watershed Area

The drainage system and slope of watershed of the Khutiya river are shown in Fig.A1.13 and Fig.A1.14. The drainage system and slope maps allow the interpretation of erosive landform characteristics of the watershed area.

Although the drainage density of the Khutiya river watershed is low as a whole, the density is relatively high in the northern watershed. Small size cultivated lands are distributed sporadically in the central and northern watershed. The steep slope lands with relatively large scale are seen in the central to northern watershed.

(4) Estimation of Sediment Yield

The sediment yield of the Khutiya 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: Khutiya River)

Land use	Area (ha)	Erosion rate(mm/yr)	Yield(m^3/yr)
Forest	15,797	2	316,000
Bush	674	10	67,000
Cultivation	666	0.4	2,000
Cliff	260	20	73,000
River	103	0	0
Urban	-	0	0
Total/average	17,500	2.56	448,000

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 4 VDC/Municipality offices were selected for the investigation. Furthermore, a total of 65 residents in the flood prone areas were selected for the interview using questionnaire form.

Questionnaires to the residents are summarized and shown in Table A1.3. In recent 10 years, the basin experienced floods in 1997, 1986 and 1983. Among these, the 1997-flood is the biggest.

In the lower reaches, riverbed is said silted up and floodwater frequently flows over the riverbanks. Flood suffering areas distribute almost all the area of Beladehipur, Dhangadhi and Urma VDCs and Khutiyatale No. 7 of Phool Bari VDC. Bank erosion is active in the alluvial fan reaches.

After the 1997-flood, encephalitis was infectious over the Kailali district, and about 200 persons over the district were attached with the disease, half of which have lost their lives.

Flooding over the farmland, bank erosion and sedimentation are the major types of disasters. According to the data and information obtained from DDC and DIO of Kailali district, loss of life and damage to properties are shown in Table A1.4, mainly based on data during 1997-flood.

According to the field investigation and interviews with residents, flood-suffering areas during the 1997-flood are shown in Fig. A1.15.

1.8 Flood Mitigation Activities

1.8.1 Existing River Facilities

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

1) Embankment: none
2) Spur : 3 sites

3) Revetment : none
4) Head work : none
5) Bridge : none

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

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

1.8.2 Policy Framework

There are various laws and policies governing and orientating the flood mitigation activities as listed below.

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

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.

LIST OF METEOROLOGICAL STATIONS

Station No.	Station Name	Type of Station	Reg.	Latitude	Longitude	Elevation (m)	Start of Record	Remarks
				° ' "	° ' "			
0101	Kakerpakha	Precipitation	FW	29 39 00	80 30 00	842	05-1956	
0102	Baitadi	Precipitation	FW	29 33 00	80 25 00	1,635	02-1973	
0103	Patan (West)	Climatology	FW	29 28 00	80 32 00	1,266	05-1956	
0104	Dandeldhura	Synoptic	FW	29 18 00	80 35 00	1,865	05-1956	
0105	Mahendra Nagar	Agrometeology	FW	29 02 00	80 13 00	176	02-1971	
0106	Belauri Santipur	Precipitation	FW	28 41 00	80 21 00	159	02-1971	Khutiya+
0107	Darchula	Climatology	FW	29 51 00	80 34 00	1,097	02-1974	
0108	Satbanjh	Precipitation	FW	29 32 00	80 28 00	2,370	06-1976	
0201	Pipalkot	Precipitation	FW	29 37 00	80 52 00	1,456	06-1956	
0202	Chainpur (West)	Climatology	FW	29 33 00	81 13 00	1,304	06-1956	
0203	Silgadi Doti	Climatology	FW	29 16 00	80 59 00	1,360	06-1956	
0204	Pajura	Precipitation	FW	29 23 00	81 19 00	1,400	01-1976	
0205	Katai	Precipitation	FW	29 00 00	81 08 00	1,388	12-1957	
0206	Asara Ghat	Precipitation	FW	28 57 00	81 27 00	650	03-1963	
0207	Tikapur	Climatology	FW	28 30 00	80 57 00	140	03-1976	
0208	Sandepani	Precipitation	FW	28 45 00	80 55 00	195	12-1957	Khutiya+
0209	Dhangadhi	Climatology	FW	28 41 00	80 36 00	170	06-1956	Khutiya
0210	Bangga Camp	Climatology	FW	28 58 00	81 07 00	340	03-1963	
0211	Khaptad	Precipitation	FW	29 23 00	81 12 00	3,430	04-1976	
0212	Sitapur	Precipitation	FW	28 34 00	80 49 00	152	02-1971	Khutiya+
0214	Kola Gaun	Precipitation	FW	29 07 00	80 41 00	1,304	02-1975	Khutiya+
0215	Godavari (West)	Climatology	FW	28 52 00	80 38 00	288	06-1975	Khutiya
0217	Mangalsen	Precipitation	FW	29 09 00	81 17 00	1,345	01-1979	
0218	Dipayal (Doti)	Synoptic	FW	29 15 00	80 57 00	617	12-1981	
0219	Dhangadhi	Synoptic	FW	28 41 00	80 36 00	170	"	

(Note) Reg. FW: Far Western 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
Khutiya River															
Kh-1	1.3	3.7	50.1	95.3	99.6	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Kh-2	1.3	4.6	62.6	97.9	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Kh-3	0.2	0.7	1.3	4.7	30.8	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Kh-4	0.5	3.0	53.9	87.2	92.2	92.8	93.2	94.0	95.0	95.6	96.1	96.4	100.0	100.0	100.0
Kh-5	0.0	1.0	34.8	93.4	98.1	98.8	99.5	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Kh-6	1.3	2.0	8.1	20.8	36.8	44.1	50.1	55.7	71.7	79.7	87.8	93.7	100.0	100.0	100.0
Kh-7	0.7	1.5	10.2	28.7	46.5	53.9	59.3	64.4	72.4	77.6	83.1	89.4	100.0	100.0	100.0
Kh-8	0.6	1.1	10.3	35.3	59.7	69.5	73.9	77.8	84.0	87.4	90.9	94.0	100.0	100.0	100.0
Kh-9	0.4	0.6	1.7	4.8	12.9	25.8	31.9	39.6	49.8	57.1	67.2	76.8	94.5	100.0	100.0
Kh-10	0.3	0.6	3.0	5.3	8.1	13.0	17.1	20.3	26.9	30.1	34.4	40.0	48.2	72.7	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)
Khutiya River								
Kh-1	0.13	0.28	0.30	0.37	2.79	2.59	2.59	2.59
Kh-2	0.13	0.24	0.26	0.34	2.75	2.63	2.59	2.61
Kh-3	0.57	1.22	1.30	1.65	2.88	2.60	2.63	2.62
Kh-4	0.13	0.28	0.30	0.40	3.06	2.65	2.63	2.64
Kh-5	0.16	0.31	0.33	0.39	2.51	2.67	2.70	2.69
Kh-6	0.35	11.46	14.23	31.84	91.64	2.63	2.68	2.66
Kh-7	0.29	5.24	10.01	39.31	133.28	2.63	2.59	2.61
Kh-8	0.28	0.87	1.35	19.00	67.34	2.63	2.61	2.62
Kh-9	1.04	29.28	34.74	68.58	65.77	2.59	2.56	2.58
Kh-10	3.76	139.63	160.85	266.46	70.82	2.68	2.63	2.66
							Average	2.63

SUMMARY OF QUESTIONNAIRES BY RIVER

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

No.	Questions/items	Summary of answers
1. FLOOD EVENTS		
1.1	Year of most severe flood in past 10 years (nop)	1997(60)
1.2	Floods in a year (times)	Average(2) ranging(2 to 3)
1.3	Severe floods in past 10 years (times)	Average(2) ranging(2 to 3)
1.4	(Cancelled)	(Cancelled)
1.5	Cause of flood (nop)	• Too much rain(42) • Sediment flow(28) • Bank erosion(14) • Others(12)
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(4) • Buffalo(2) • Sheep/Goat(3) • Poultry(9)
2.3	Damage to farm land (ha)	• Irrigated land: Average(1.1) ranging(1.0 to 1.25) • Non-irrigated land: Average(5.6) ranging(0.6 to 6.0)
2.4	Extent of damage to farm land	• Simple inundation (nop): 0 • Loss of crops (nop): Paddy(38), Sugarcane(1), Maize(14), Others(2) • Total washout (ha): Average(0.68) ranging(0 to 1.25)
2.5	Extent of damage to dwelling and asset	• Flooding duration (days): Average(2) ranging(1 to 3) • Flooding depth in (m): Average(1.2) ranging(0.88 to 1.5) • Damage to house (nop): Severe(4), Moderate(19), Ordinary(4) • Loss of cash (Rs): Average(0.0) ranging(0.0) • Loss of food grains (kg): Paddy: Average(590) ranging(0 to 730) • Clothing (nos): Average(0) ranging(0) • Other valuables: Average(0) ranging(0)
2.6	Problems during flood (nop)	• Erosion of river bank(15) • Sediment in the river(15) • Sediment in irrigation canal(0) • Drinking water problem(3) • Sanitary problem(0) • Salinity(0) • Flooding over farm land(28) • Others(5)
2.7	Epidemic disease after flood? (nop)	• Yes(29) • No(1)
2.8	If yes, kind of epidemic disease (nop)	• Cholera(0) • Dysentery(19) • Typhoid(3) • Others(7)
2.9	Fatal causality? (nop)	• Yes(8) • No(8)
2.10	Reason of flood(nop)	• Too much rain(19) • Lack of flood protection works(24) • Weak river training works(0) • Sediment load in the flood water(5) • Flood from adjoining rivers(4)
2.11	Total amount of damage (Rs)	Average(36,500) ranging(0 to 118,700)

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

SUMMARY OF QUESTIONNAIRES BY RIVER

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

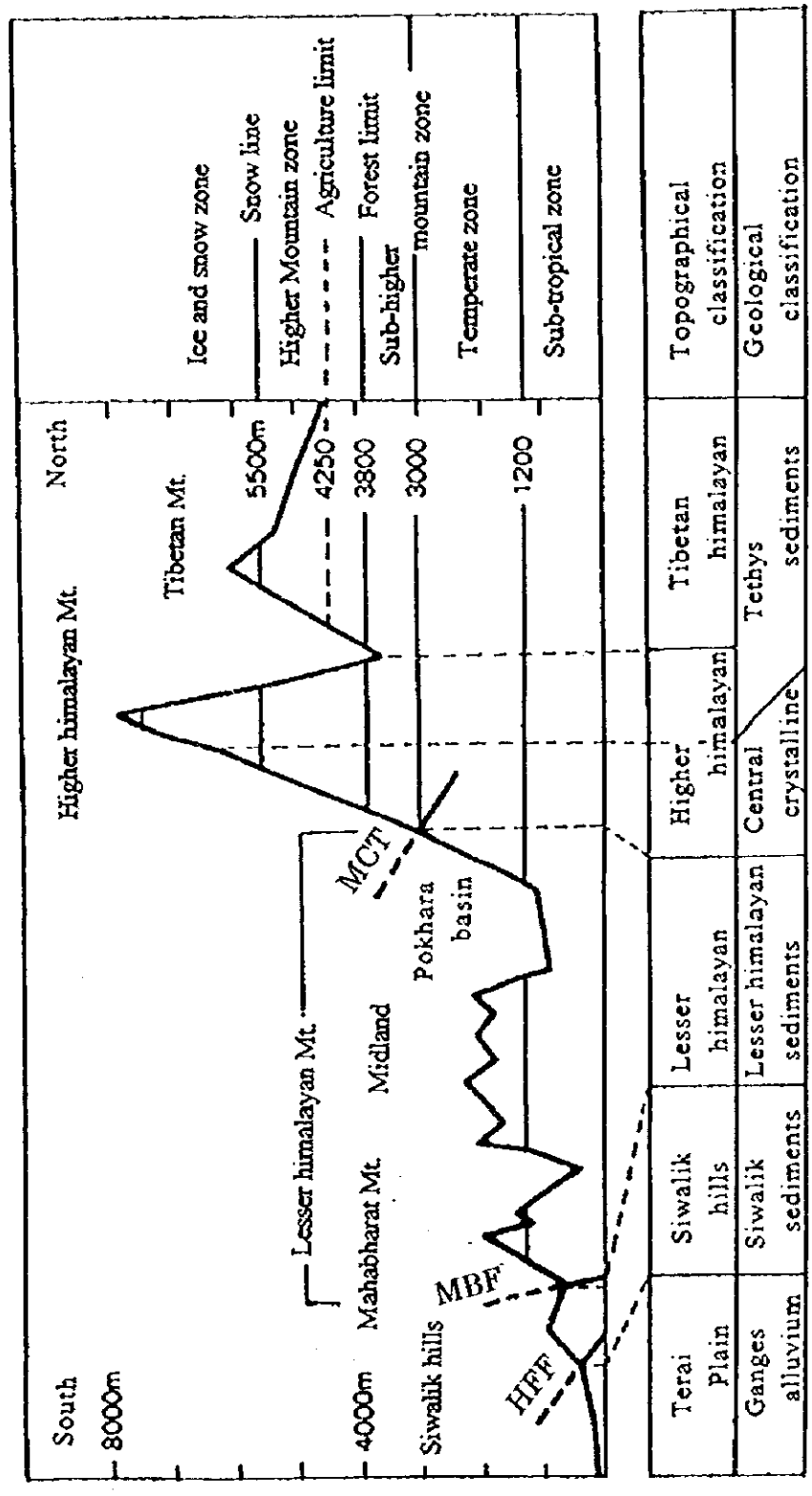
No.	Questions/items	Summary of answers
3. FLOOD WARNING SYSTEM		
3.1	(Cancelled)	(Cancelled)
3.2	Self warning (nop)	• Heavy rain/High flood level(5) • Bank erosion(0) • Smelled mud(1) • Unusual sound(4) • Others(0)
3.3	Warning by others (nop)	• Neighbors(0) • Institutions(0) • Others(0)
4. FLOOD RELIEF MEASURES		
4.1	Evacuation experience? (nop)	• Yes(10) • No(51)
4.2	If yes, place of evacuation (nop)	• High ground(3) • Public building(0) • Others houses(7) • Other sites(0)
4.3	Being relieved? (nop)	• Yes(4) • No(38)
4.4	If yes, how?(nop)	• In cash(3) • Kind(1)
4.5	Organization/individual giving relief (nop)	• Central government(1) • DDC(0) • VDC(3) • Other institutions(0) • NGO(0) • Individuals(0)
4.6	(Cancelled)	(Cancelled)
5. PREVENTIVE MEASURES AGAINST FLOOD		
5.1a	Current preparedness/ measures (nop)	• Warning(0) • Evacuation(0) • Settlement(0)
5.1b	Proposed preparedness/ measures (nop)	• Warning(4) • Evacuation(0) • Settlement(24)
5.2a	Current non-structural measures (nop)	• Seed storage(0) • Cash pools(0) • Informal insurance(0) • Others(0)
5.2b	Proposed non-structural measures (nop)	• Seed storage(2) • Cash pools(0) • Informal insurance(0) • Others(0)
5.3a	Current structural measures (nop)	• Embankment(0) • Spur(0) • Simple gabion(0) • Plantation(0) • Others(0)
5.3b	Proposed structural measures(nop)	• Embankment(58) • Spur(0) • Simple gabion(0) • Plantation(0) • Others(0)
6. PARTICIPATION ACTIVITIES		
6.1	Experience of Participation in activities? (nop)	• Yes(1) • No(59)
6.2	If yes, type (nop)	• Cash(0) • Labor(1) • Kind(0) • Care taker(1) • Others(0)
6.3	If no, reason (nop)	• Being affected badly(6) • Financially weak(0) • Being out of the area(3) • No willingness(3) • Others(49)
6.4	Willing to participate in future? (nop)	• Yes(53) • No(3)
6.5	If yes, type (nop)	• Cash(9) • Labor(45) • Kind(6) • Care taker(18) • Others(2)
6.6	If no, reasons (nop)	• No time(2) • No benefit(1) • No Willingness(0) • Not known how to participate(0) • Others(0)

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

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

VDC/Municipality	Loss of				Damage of						Remarks
	Human Life (nos.)	Cattle (nos.)	Land (ha)	House (nos.)	Crop (ton)	Land (ha)	House (nos.)	Public Facility			
								Road (m)	Channel (m)	Others	
Beladevipur	-	15	10	6	5	-	4	-	400	-	Kailali
Urma	2	21	-	4	3	-	8	-	-	-	District
Dhangadhi	-	4	15	-	2	35	-	-	-	-	
Phoolbari	5	15	2	-	-	-	-	-	-	-	
Total	7	55	27	10	10	35	12	0	400	0	

Remarks : 400m of gabion walls of head works of Khutiya Irrigation Project (UNCDF) 1977-1985,was damaged by 1997 flood.
Note : Severe damage to houses has been considered as loss of house and loss of human life here is due to Encephalitis.



TOPOGRAPHICAL AND GEOLOGICAL CLASSIFICATION(N-S PROFILE)

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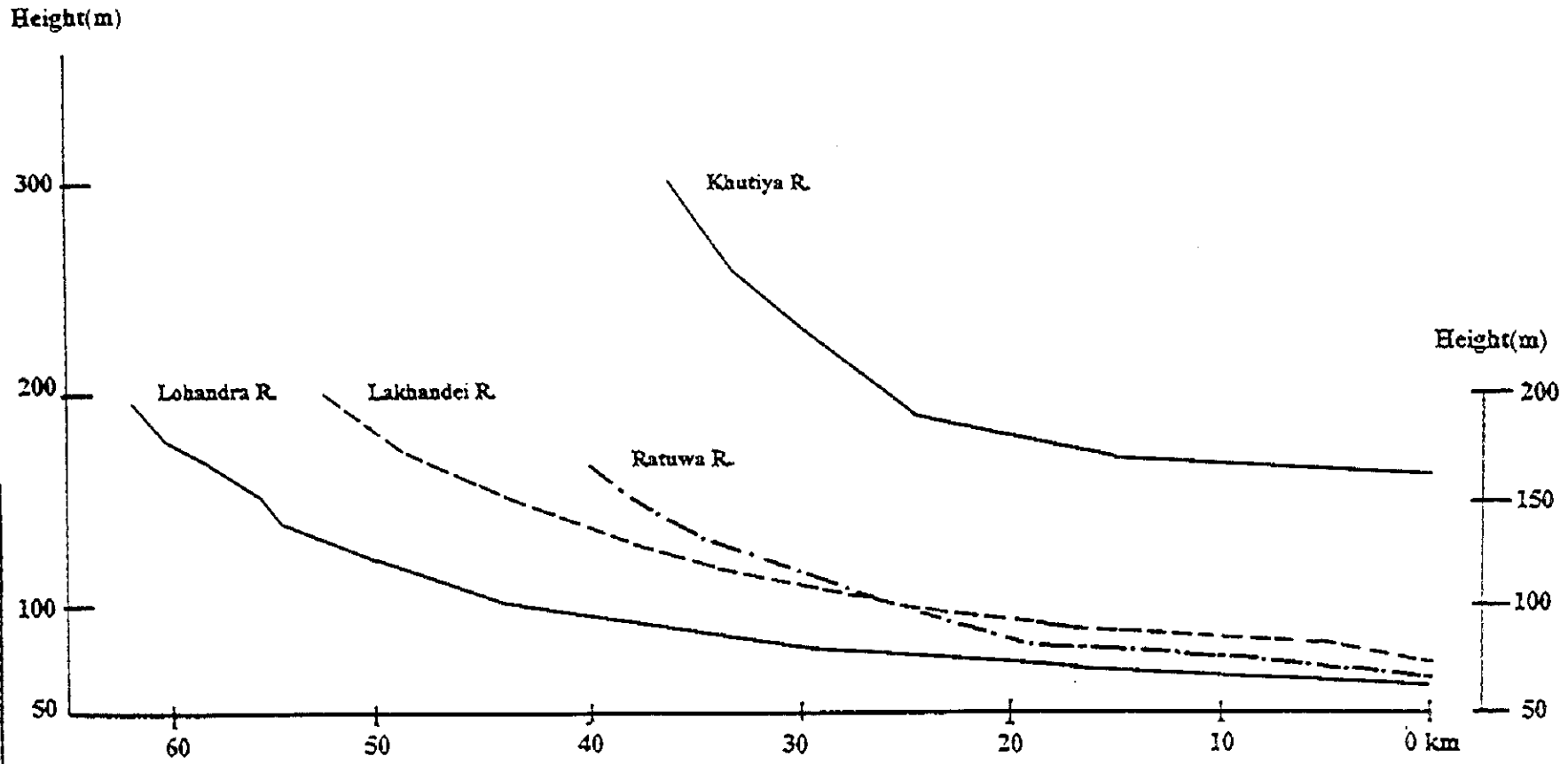

OVERALL LONGITUDINAL PLOFIELES
OF RIVERS ORIGINATED IN SIWALIK HILLS

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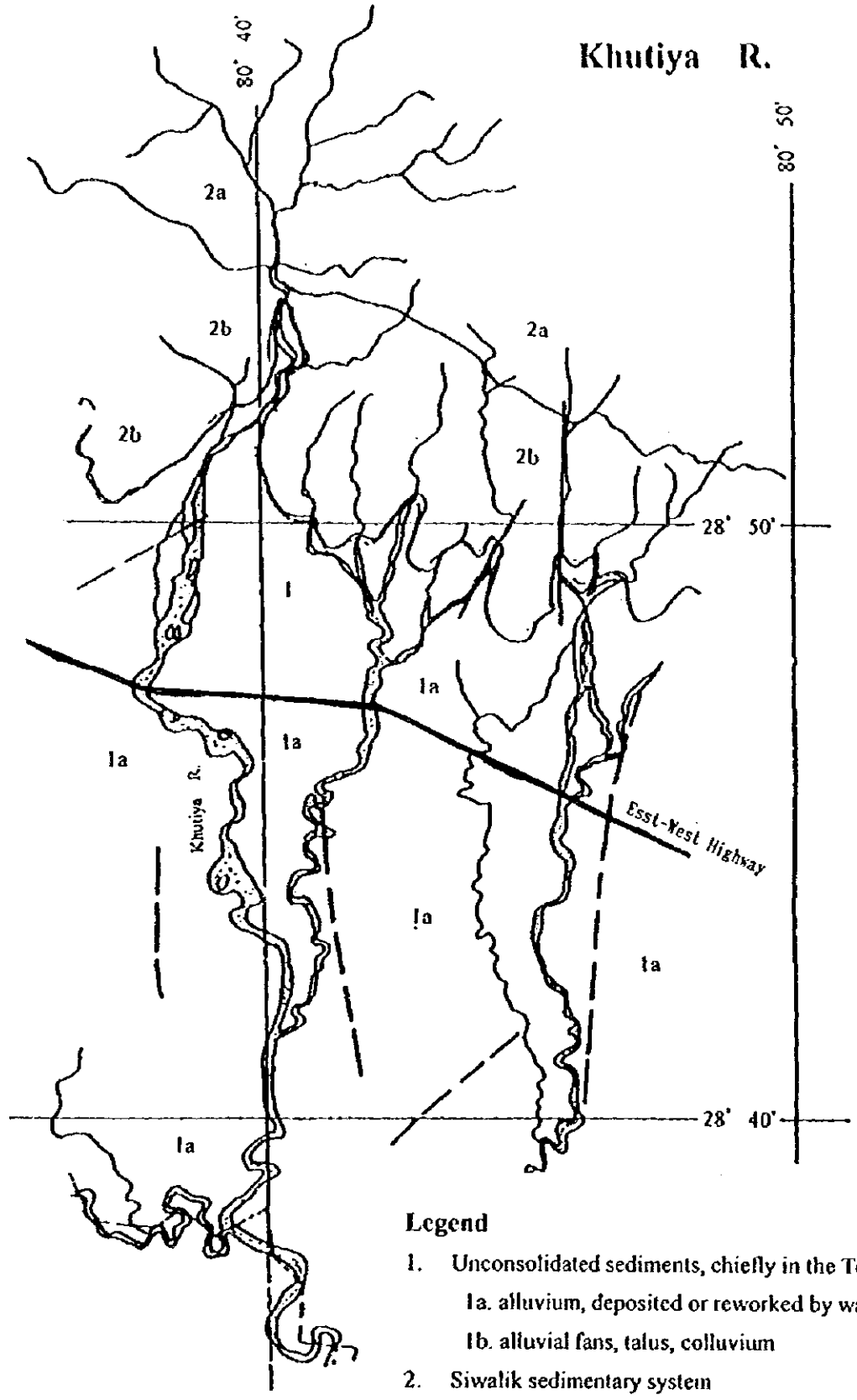
A8-1.24

Fig. A1.2



Legend

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

GEOLOGICAL MAP(KHUTIYA R.)

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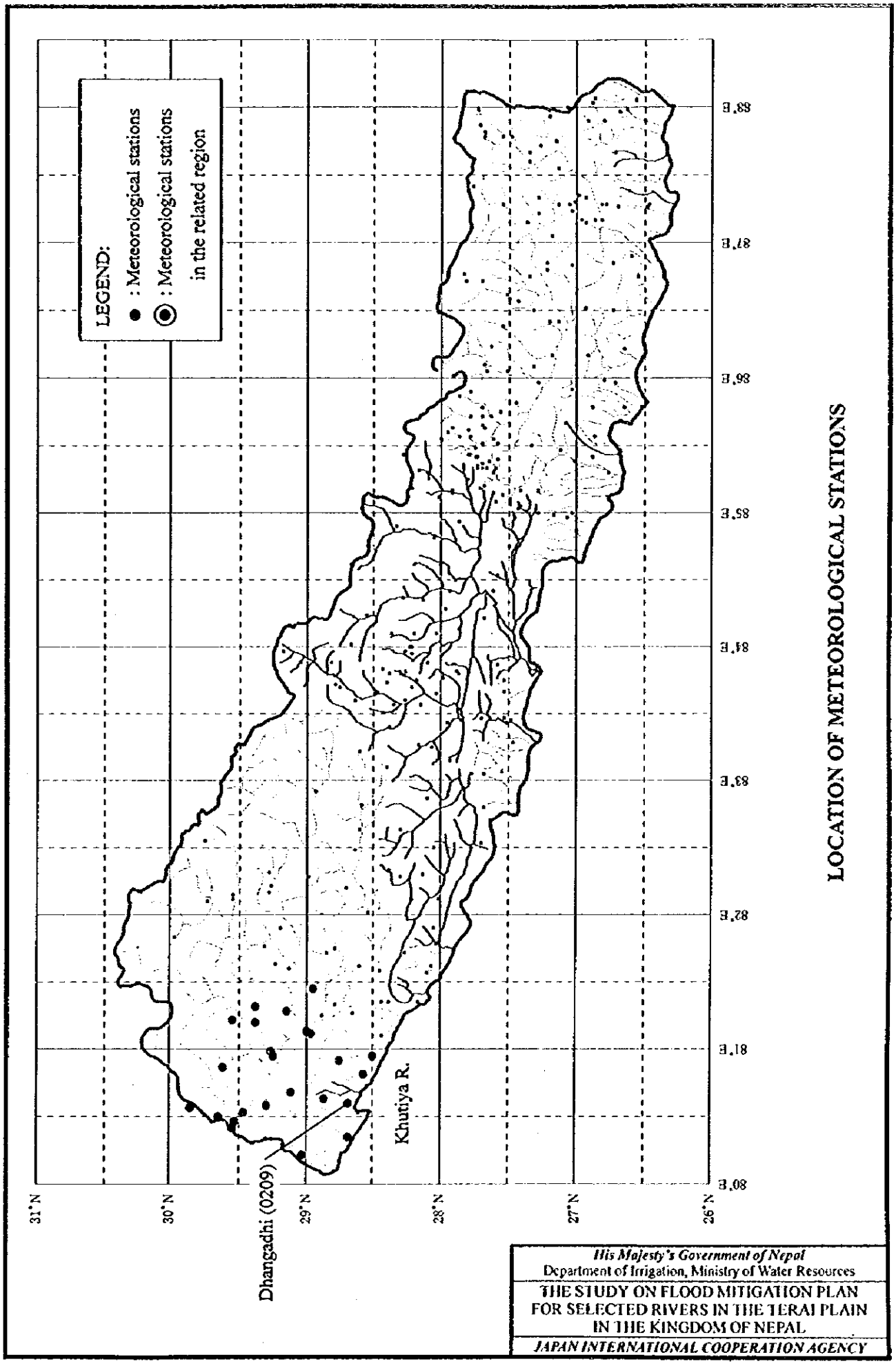
Fig. A1.4



LOCATION OF METEOROLOGICAL STATIONS

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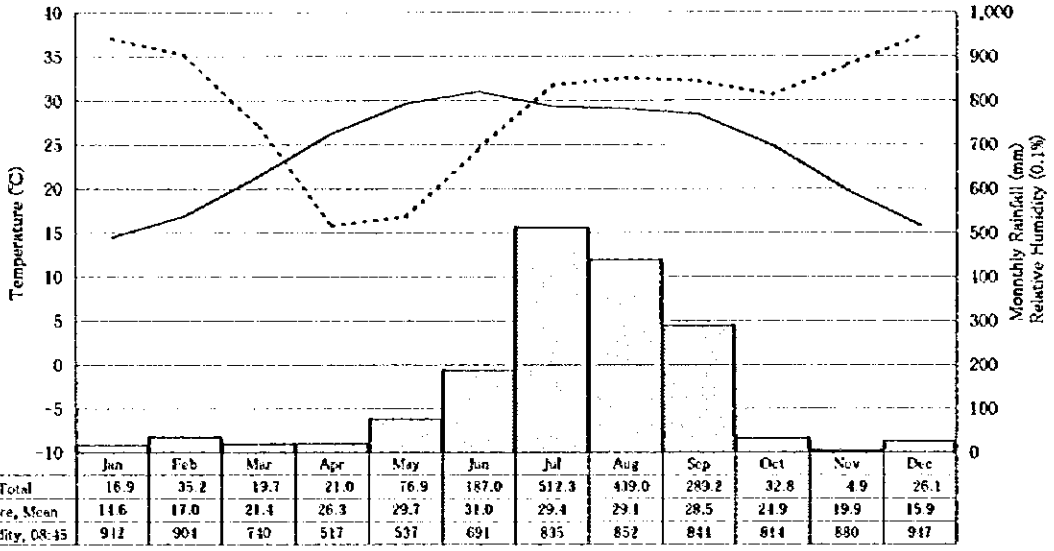
Code: 0209
Station: Dhangadhi

Latitude: 28°41'
Longitude: 80°36'
Elevation: 170 m

Dhangadhi (0209)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation, Total	16.9	35.2	19.7	21.0	76.9	187.0	512.3	439.0	289.2	32.8	4.9	26.1
Air Temperature, Mean	14.6	17.0	21.4	26.3	29.7	31.0	29.4	29.1	28.5	24.9	19.9	15.9
Relative Humidity, 08:45	912	904	740	517	537	691	835	852	841	814	880	947

Air Temperature, Mean (Unit: °C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	-	-	22.3	27.0	30.0	31.4	28.9	29.2	27.9	24.5	19.7	16.6	-
1986	15.2	16.9	21.8	26.1	27.8	30.3	28.8	28.7	28.7	24.8	20.6	16.2	23.8
1987	15.5	18.5	22.6	26.1	28.6	32.6	29.9	29.5	29.4	25.6	20.5	16.4	24.6
1988	15.6	18.3	21.5	27.4	30.4	30.6	29.4	29.3	29.5	25.5	20.7	17.4	24.6
1989	14.3	15.9	21.3	25.7	30.8	30.0	29.4	29.0	28.6	25.9	19.4	15.3	23.8
1990	14.7	16.4	19.9	26.2	28.1	31.0	28.6	29.3	28.6	24.4	20.2	15.7	23.6
1991	13.4	17.5	21.6	26.4	30.8	30.7	30.4	29.1	28.0	24.8	18.8	15.2	23.8
1992	14.4	15.3	21.6	27.2	29.1	31.0	29.5	29.1	28.3	24.5	19.8	15.2	23.7
1993	13.2	17.8	19.7	25.9	30.3	31.0	29.6	29.0	27.8	25.1	20.0	15.8	23.7
1994	15.0	16.1	22.2	25.6	31.4	31.8	30.1	29.1	28.5	24.6	19.2	15.4	24.1
Ave.	14.6	17.0	21.4	26.3	29.7	31.0	29.4	29.1	28.5	24.9	19.9	15.9	24.0

Relative Humidity, 08:45 (Unit: %)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	82	81	65	50	56	66	84	86	83	83	84	90	75.8
1986	96	94	76	55	59	71	85	85	85	76	93	95	80.8
1987	95	88	64	58	52	64	82	82	83	79	83	95	77.1
1988	95	86	74	56	55	69	86	86	81	81	87	94	79.2
1989	95	91	77	47	44	75	84	85	86	80	87	94	78.8
1990	96	95	81	48	72	76	88	82	83	82	87	97	82.3
1991	96	92	83	53	51	72	84	89	90	82	89	94	81.3
1992	96	93	67	42	47	61	78	82	85	86	90	97	77.0
1993	96	91	74	52	56	69	82	88	86	81	90	95	80.0
1994	95	93	79	56	45	68	82	87	82	84	90	96	79.8
Ave.	94.2	90.4	74.0	51.7	53.7	69.1	83.5	85.2	84.4	81.4	88.0	94.7	79.2

Precipitation, Total (Unit: mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	10	0	0	8	89	117	396	460	438	214	0	46	1,778
1986	4	40	2	63	77	232	498	197	227	37	15	52	1,444
1987	7	17	3	16	69	154	648	282	193	0	0	6	1,395
1988	8	3	36	25	65	206	729	350	207	1	0	30	1,660
1989	74	15	32	0	12	248	571	593	235	8	16	20	1,824
1990	0	130	28	1	265	203	860	410	330	0	0	76	2,303
1991	16	49	24	51	61	154	395	504	541	0	10	31	1,836
1992	18	18	0	9	70	127	293	547	279	68	8	0	1,437
1993	8	33	72	4	45	207	359	547	409	0	0	0	1,664
1994	24	67	0	33	16	222	374	500	33	0	0	0	1,269
Ave.	16.9	35.2	19.7	21.0	76.9	187.0	512.3	439.0	289.2	32.8	4.9	26.1	1,661

METEOROLOGICAL CONDITIONS

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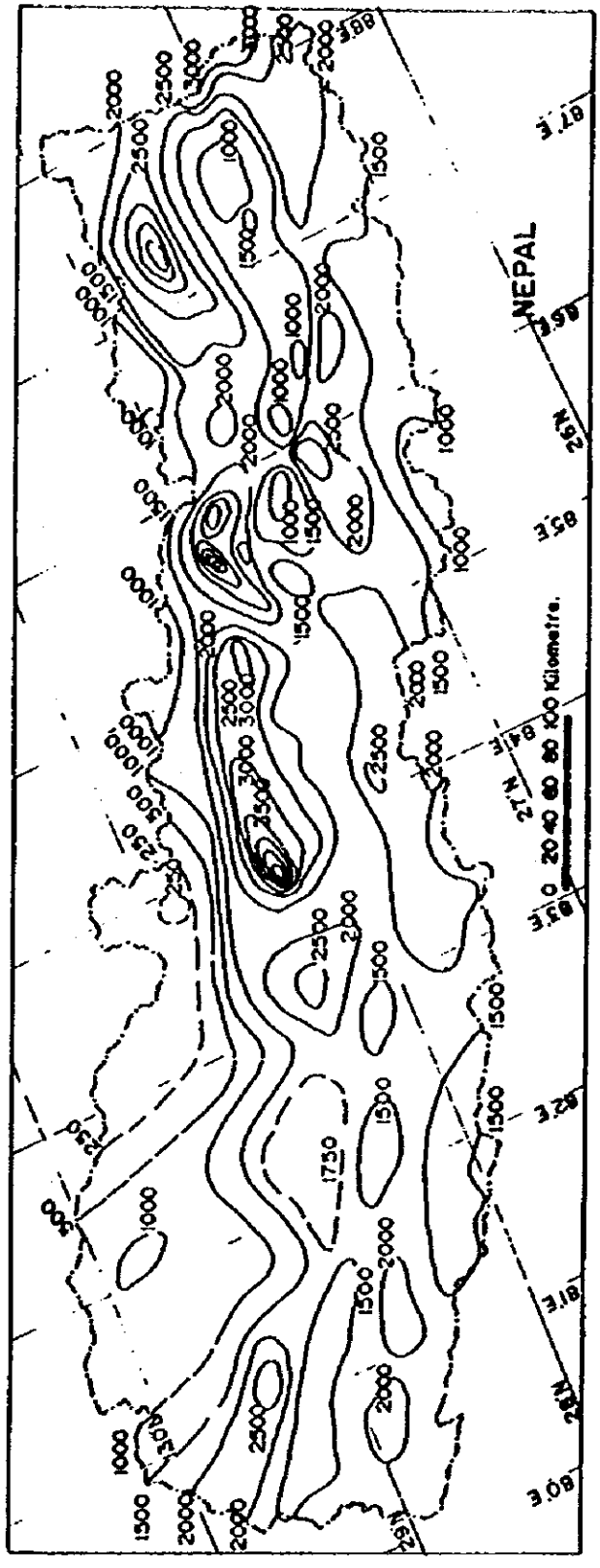
MEAN ANNUAL PRECIPITATION (mm) 1971-1985



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

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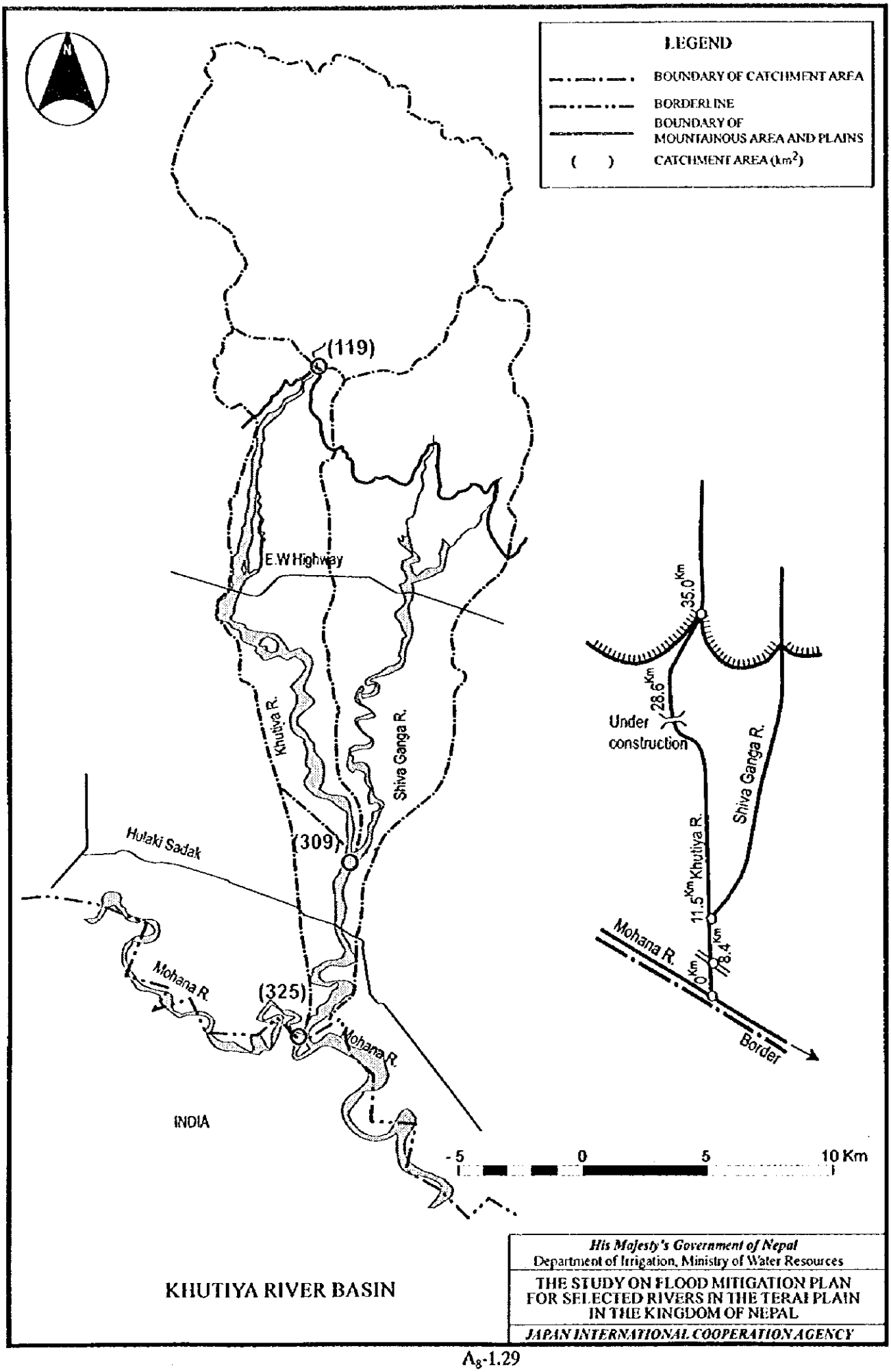
Fig. A1.7



KHUTIYA RIVER BASIN

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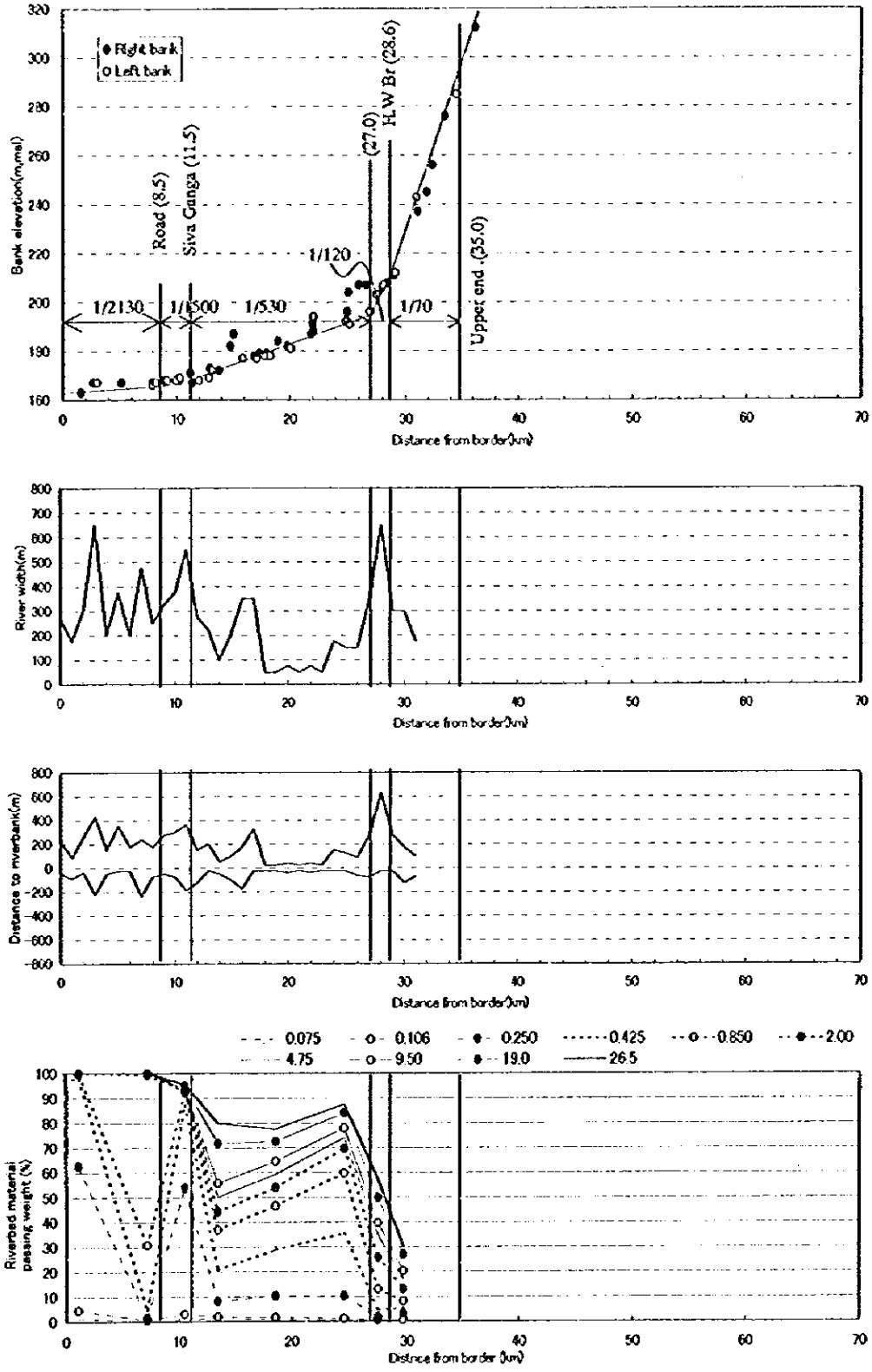
JAPAN INTERNATIONAL COOPERATION AGENCY

KHUTIYA RIVER



CHARACTERISTICS OF EXISTING CHANNEL

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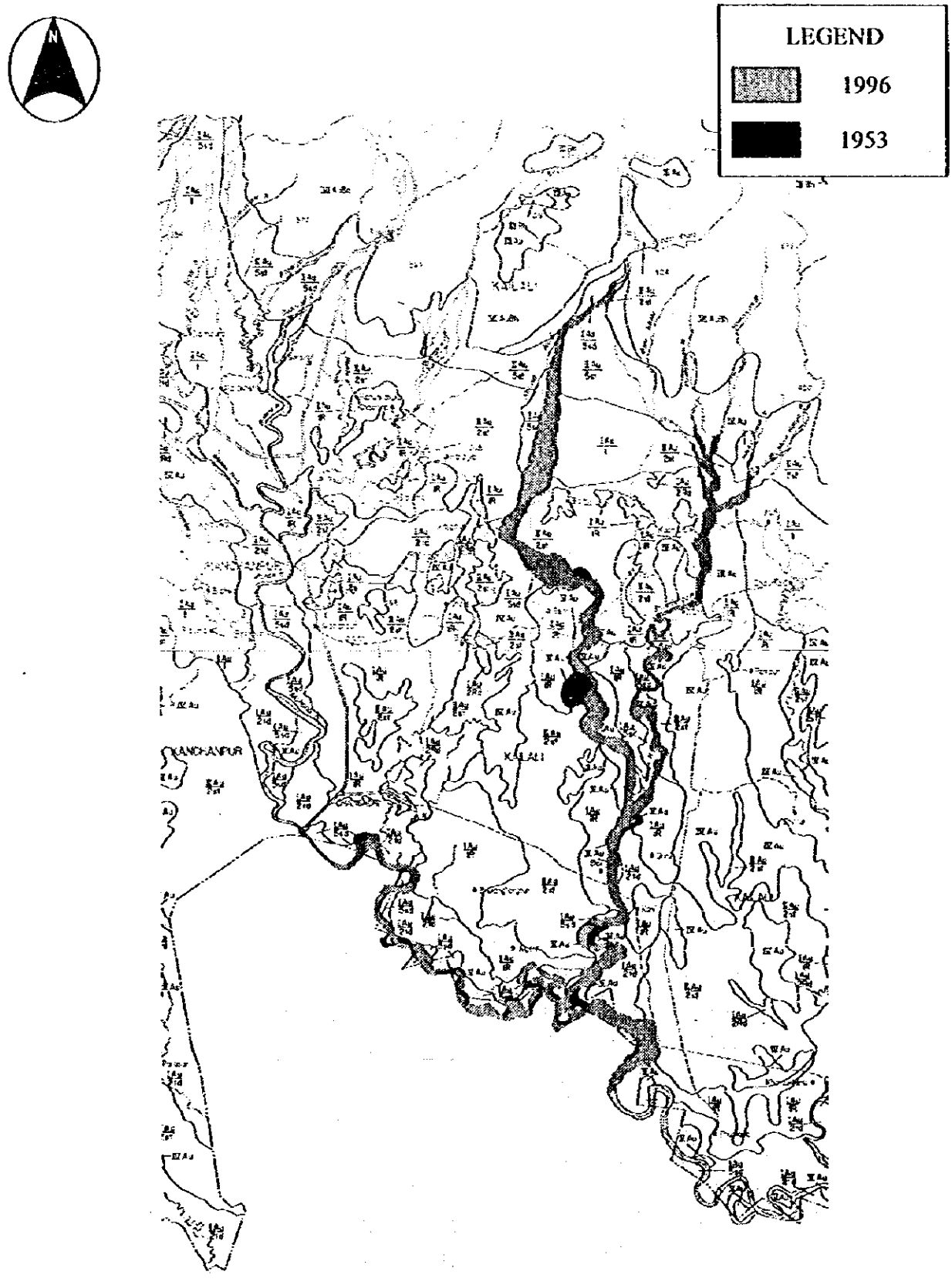

CHANGE OF KHUTIYA RIVER COURSE

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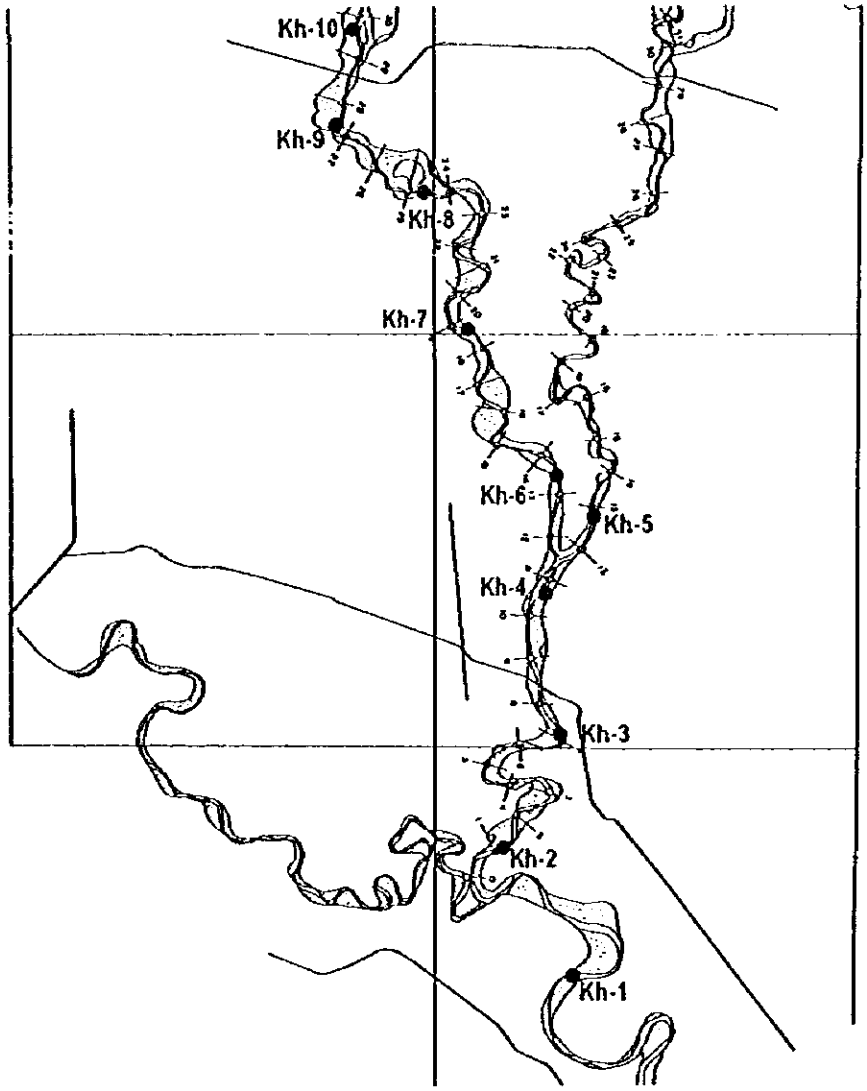

SN	Sample code	Soil classification by eye	Description of sampling place	GPS Reading		FGA (Y/N)
				N	E	
1	Kh-1	Fine sand		28°37.315'	80°41.015'	N
2	Kh-2	Very fine silt		28°38.669'	80°39.664'	N
3	Kh-3	Fine sand		28°40.239'	80°40.115'	N
4	Kh-4	Coarse sand with 2% gravel		28°41.002'	80°40.120'	Y
5	Kh-5	Silty sand		28°41.994'	80°40.780'	N
6	Kh-6	Mixed gravel		28°42.455'	80°40.536'	Y
7	Kh-7			28°44.349'	80°39.704'	Y
8	Kh-8			28°45.870'	80°39.717'	Y
9	Kh-9	Mixed gravel(Large size)		28°46.961'	80°38.144'	Y
10	Kh-10	Mixed gravel		28°48.267'	80°38.197'	Y

SAMPLING SITES OF RIVERBED MATERIALS (KHUTIYA RIVER)

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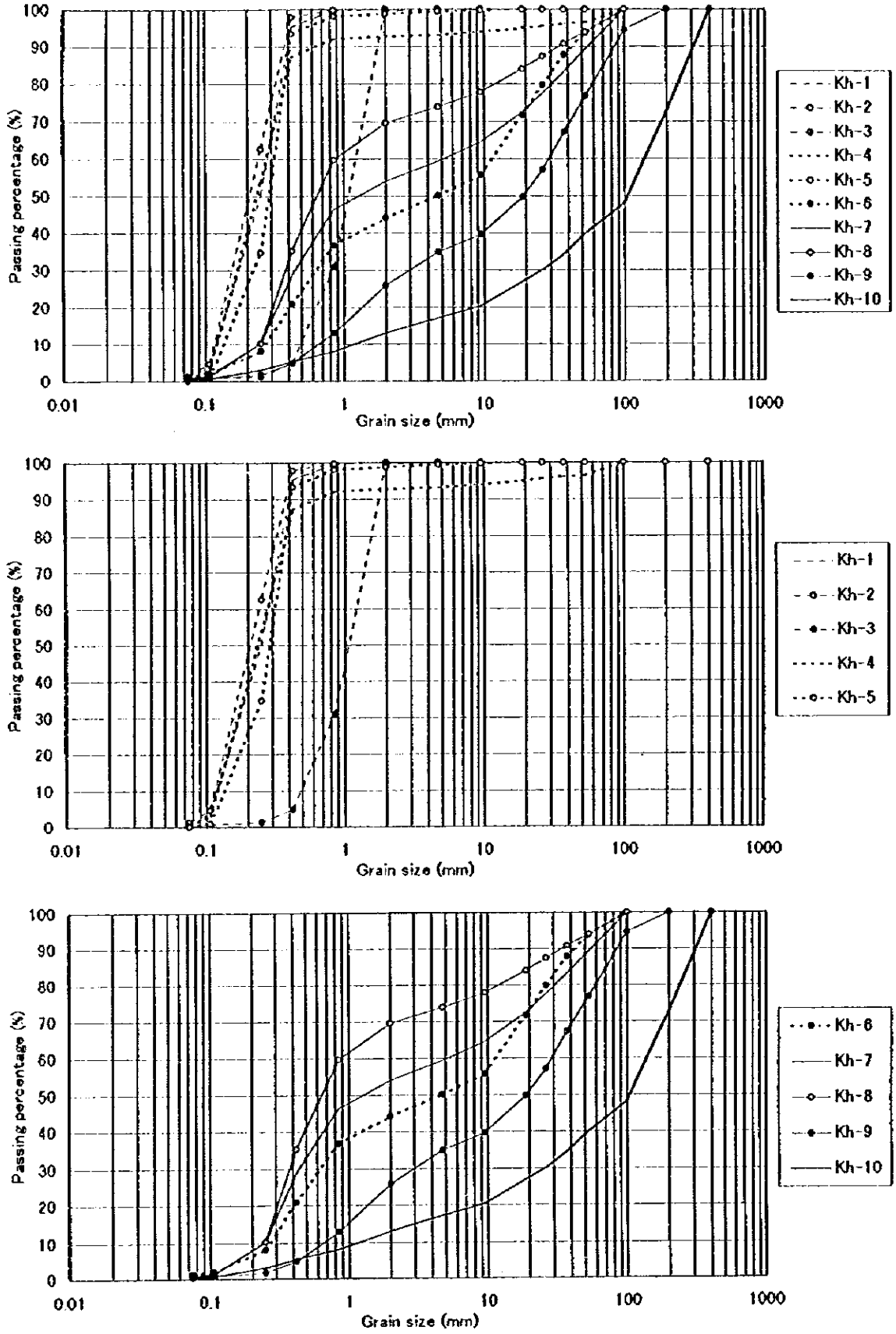

GRADING CURVES OF RIVERBED MATERIALS (KHUTIYA R.)

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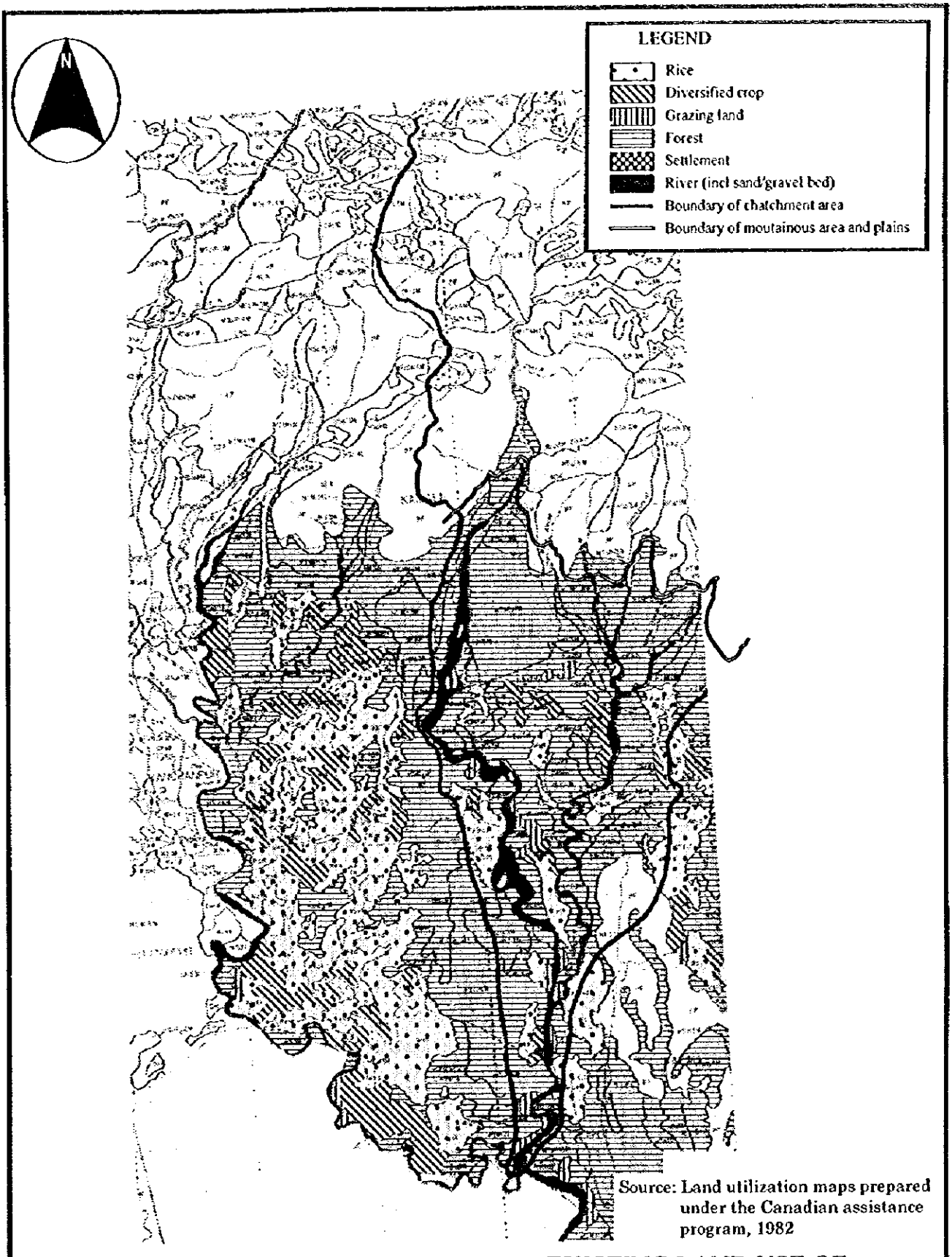
N
LEGEND
Rice
Diversified crop
Grazing land
Forest
Settlement
River (incl sand/gravel bed)
Boundary of chatchment area
Boundary of moutainous area and plains
Source: Land utilization maps prepared under the Canadian assistance program, 1982
EXISTING LAND USE OF KHUTIYA RIVER BASIN
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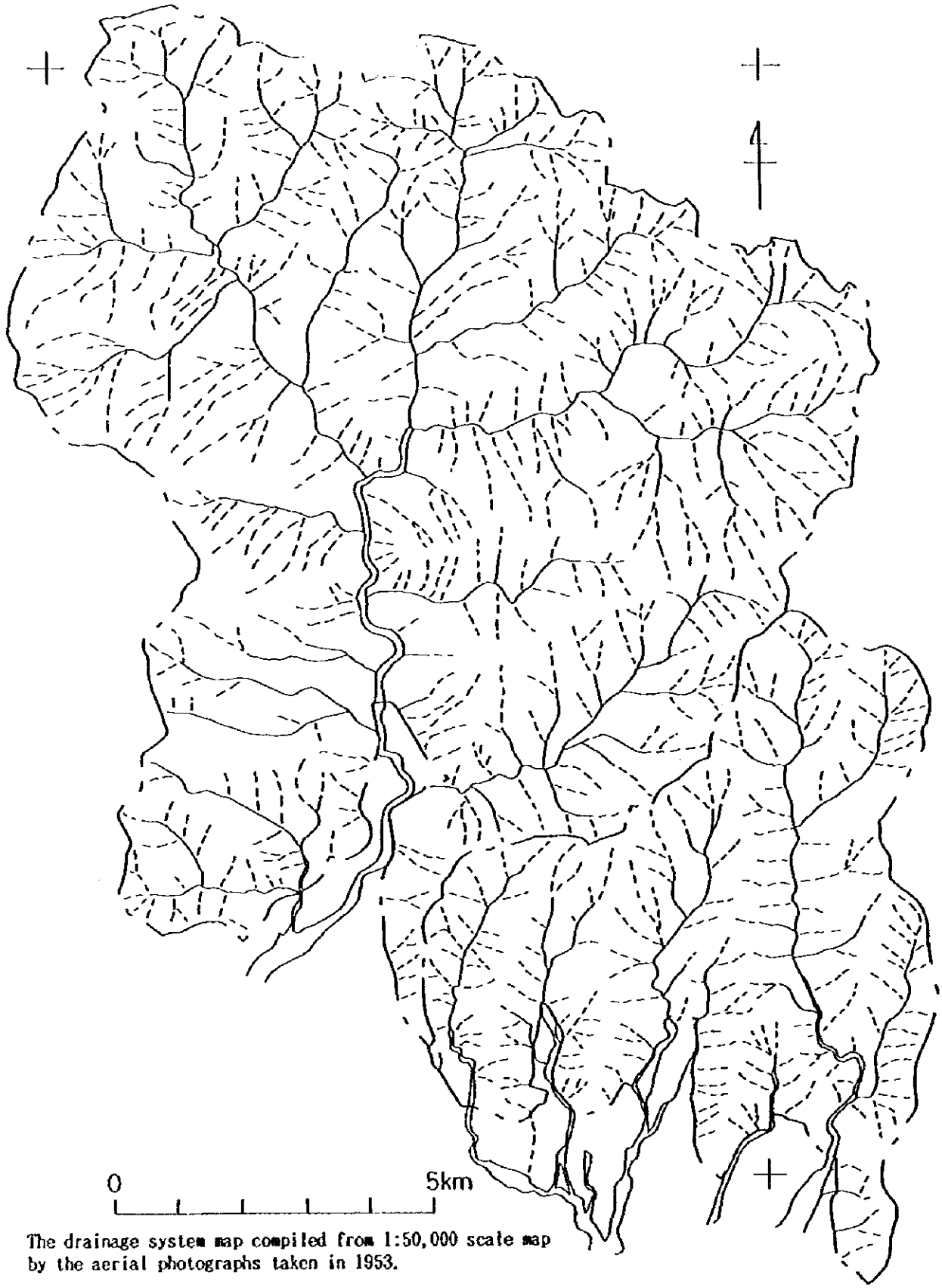
5
0
5
10 Km



The drainage system map compiled from 1:50,000 scale map by the aerial photographs taken in 1953.

DRAINAGE SYTEM OF THE KHUTIYA WATERSHED

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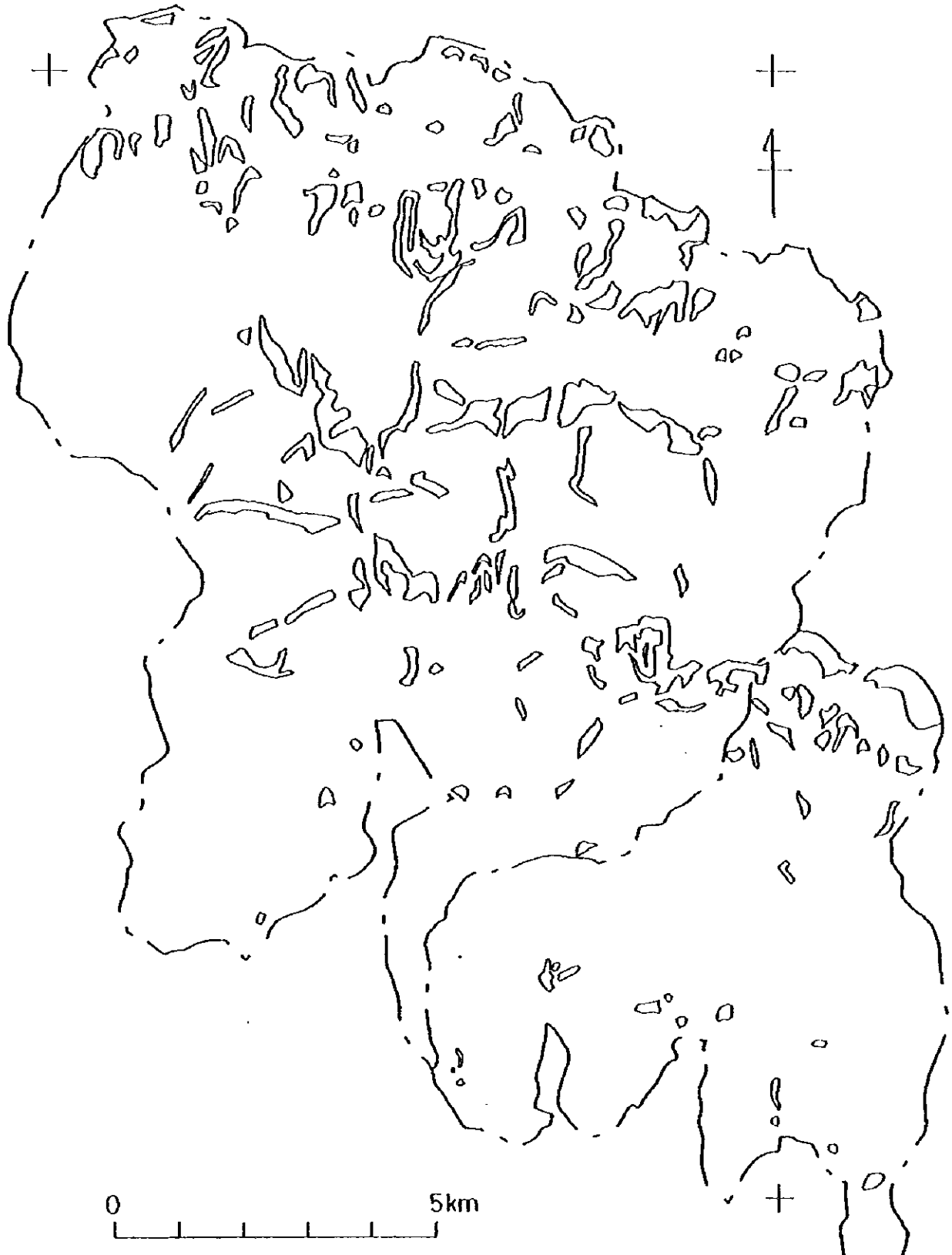

The slope map compiled from 1:50,000 scale map
by the aerial photographs taken in 1953.
Locations of slopes steeper than 40°are shown

SLOPE MAP MORE THAN 40° OF THE KHUTIYA RIVER

LOCATIONS OF STEEP SLOPE IN KHUTIYA WATERSHED

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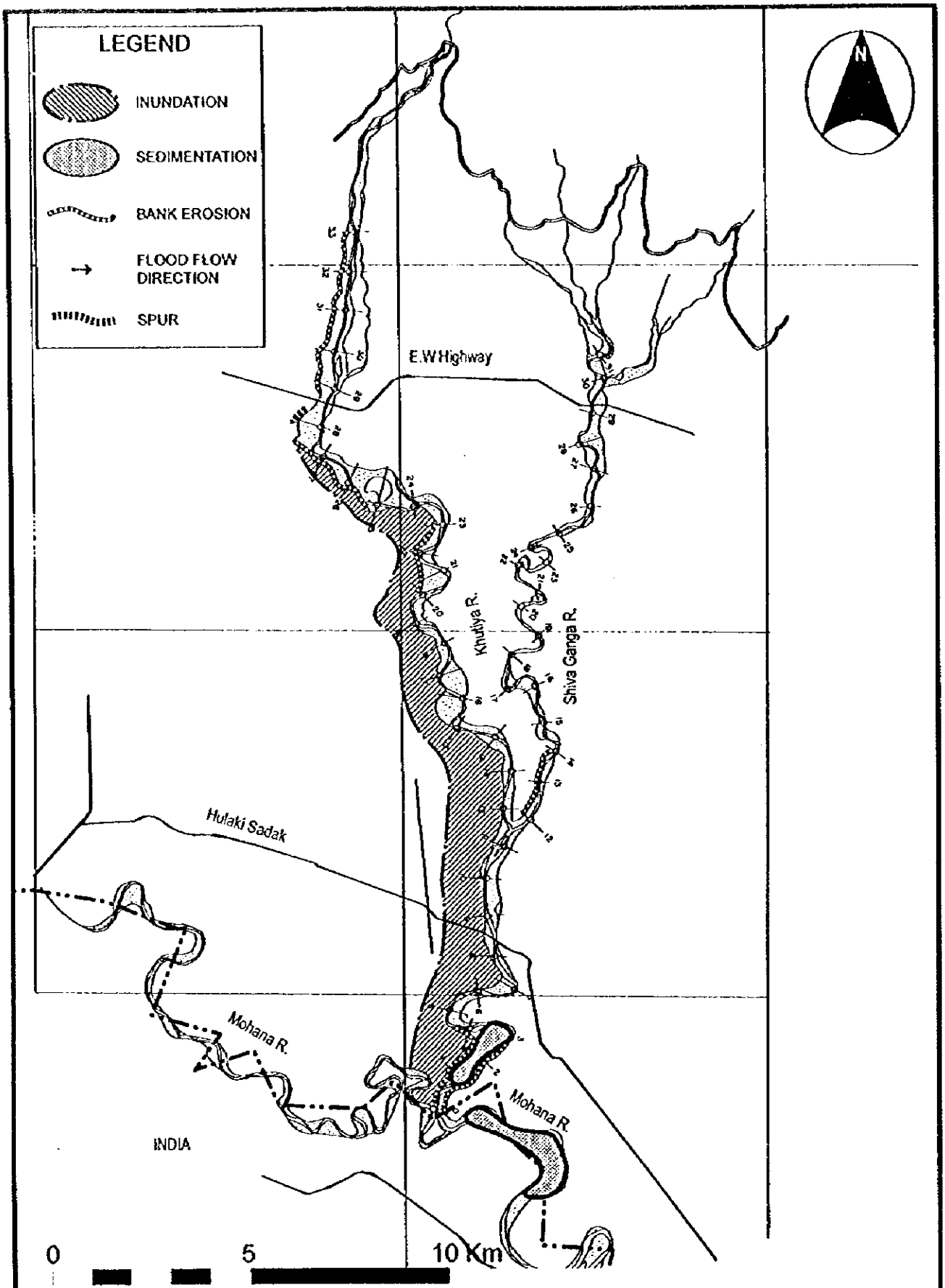
Fig. A1.15



FLOOD SUFFERING AREA
(KUTIYA RIVER,1995)

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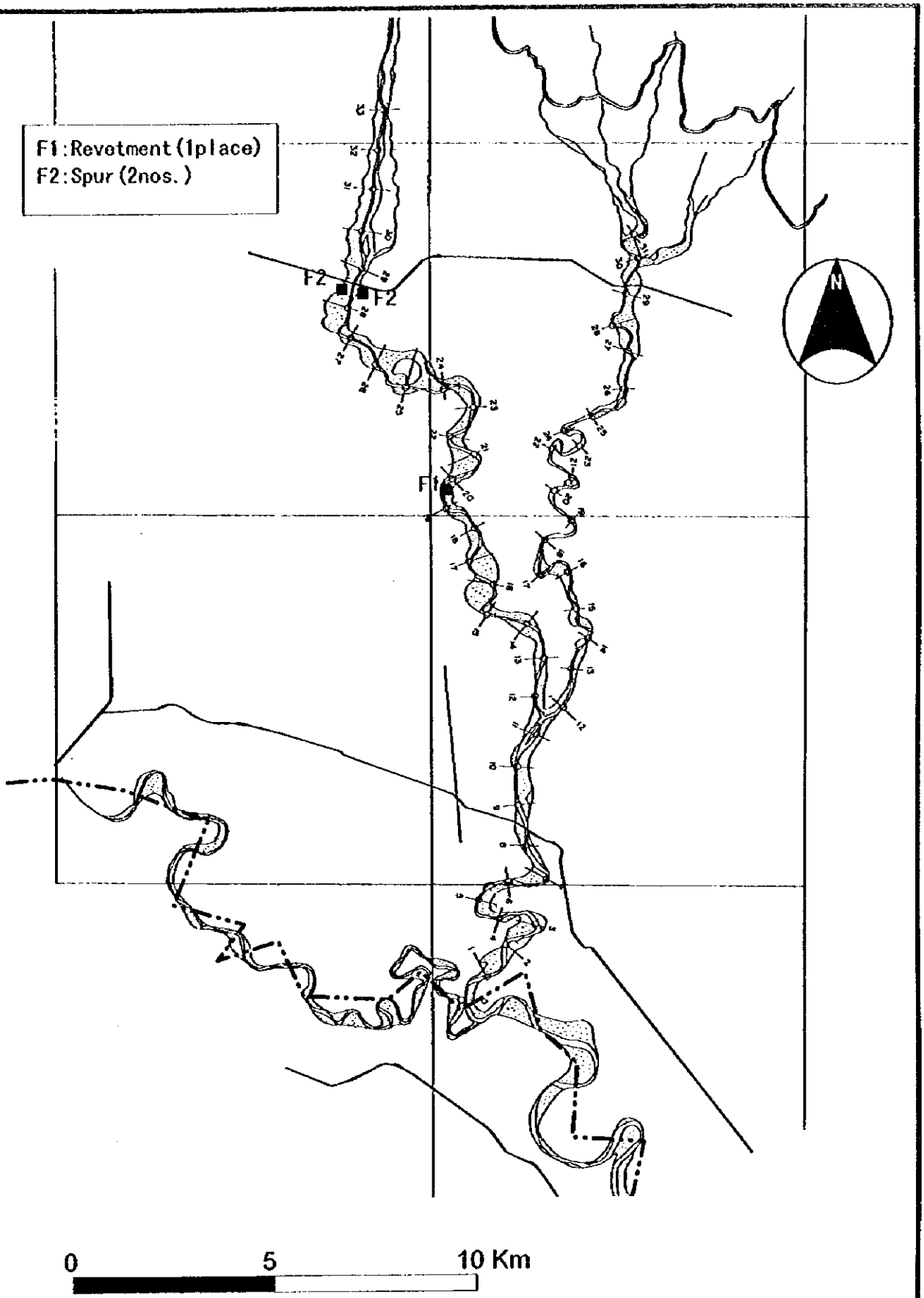

LOCATIONS OF RIVER FACILITIES

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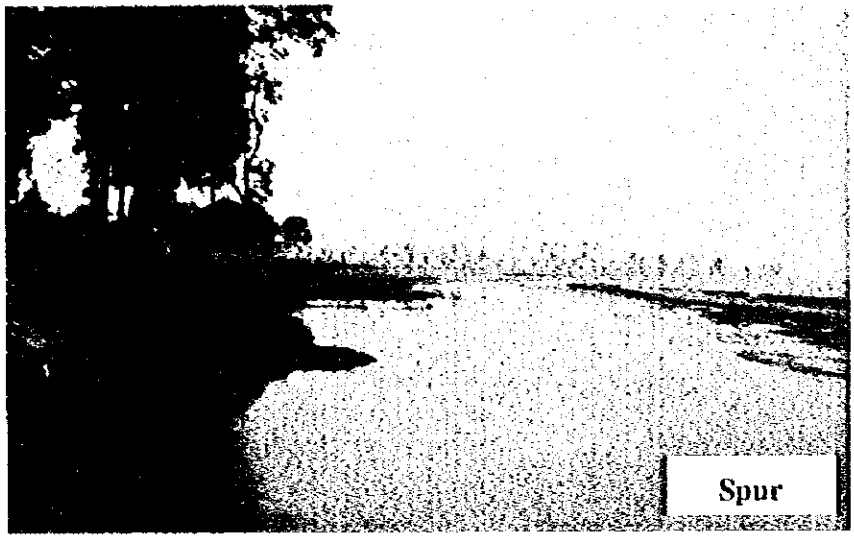

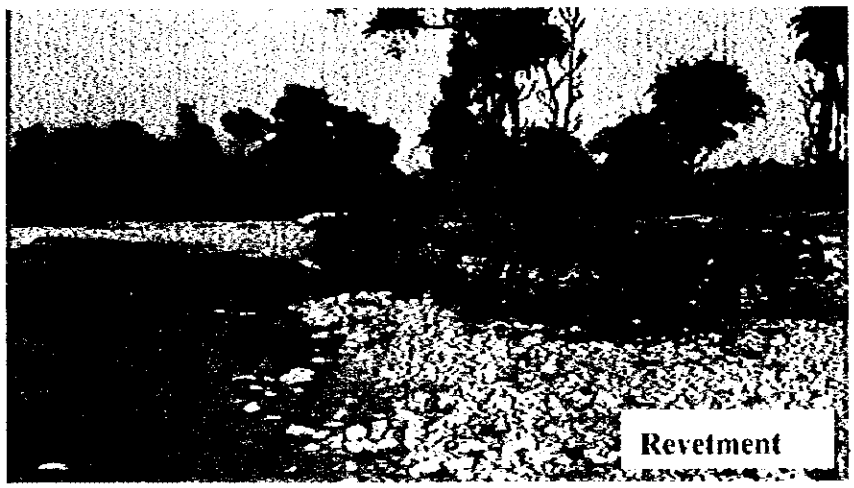

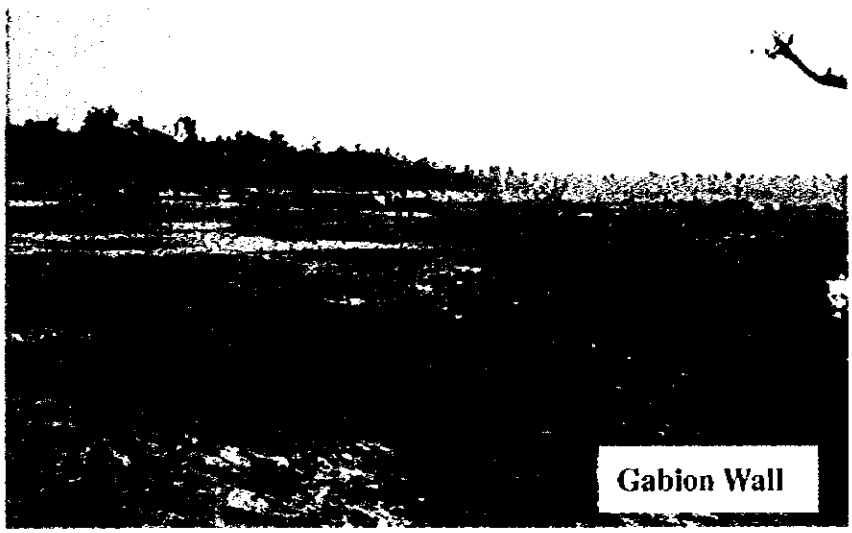

TYPICAL RIVER FACILITIES

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2. FLOOD MITIGATION MASTER PLAN

2.1 Principles for Formulation of Master Plan

(1) Objective of Master Plan

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

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

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

(2) Target Year

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

(3) Objects to be Protected

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

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

3) Flooding and inundation.

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

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

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

(4) Approach to Flood Mitigation

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

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

2.2 Flood Mitigation Measures and Project Components

(1) Conceivable Flood Mitigation Measures

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

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

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

(2) Project Components

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

2.3 Watershed Management Component

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

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

leading role in this regard.

(1) Erosion Control Facilities

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

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

(2) Afforestation/Reforestation and Land Use Regulation

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

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

(3) Publicity Activities

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

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

2.4 River Control Component

2.4.1 Design Discharge

The probable peak discharges at a specific section of the river were estimated by the following equation:

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

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

where

Q_n : Probable discharge of n-year return period (m^3/s)

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

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

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

The values of C_2 and Q_n/Q_2 for the Khutiya river basin were estimated commonly for the river 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 Khutiya 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 river basin are shown below:

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
Khutiya	325	460	740	920	1,100	1,330

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

- KH-1: Reaches from Indian border to Siva Ganga river junction (Sta. 11.5 km)
- KH-2: Reaches from Siva Ganga river junction to Sta. 27 km
- KH-3: Reaches from Sta. 27 km to upper end (Sta. 35.0 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)	
Khutiya R.							
KH-1	2-2	-	-	-	0.58	0.58	346(175-650)
KH-2	2-1	-	-	-	5.9	15	167(50-350)
KH-3	1	-	-	-	84	124	355(175-650)

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 flood water flow.
4) The initial RBLs are examined from the viewpoints of property protection and channel capacity. The RBL will be revised partially, if the result of examination demands.
5) The RBLs are fixed and authorized finally after getting consent of government authorities and local communities concerned.

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

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

2.4.4 Facility Plan

(1) Channel Treatment

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

(2) Bank Protection

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

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

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

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

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

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

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

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

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

(3) Dike Works

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

1) **Forest and grass belts:** Trees and grass planted along the river course are not strictly dikes. However, these grass and tree belts would alleviate flood damages in the flood prone areas, retarding the flood flows and promoting the formation of a natural levee along the belt (Fig. A2.3).
2) **Dike road:** Road embankment constructed along the river as rural road and flood dike as well. Even 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 is an effective measure for the prevention of flooding. However, a continuous dike was not proposed considering the present land use of the flood prone area, the anticipated difficulties in maintenance under the uncontrolled sediment yield in watershed area and the necessity of coordinating the plan with India.

These dikes are aligned, in principle except for the ring dike, on the river boundary line (RBL). The river zone between the RBLs on both banks is planed considering the water

and sediment transport capacity and existing river width. Various types of dike works are conceivable. Selection of these works should be made considering the channel characteristics, land use in flood prone areas, etc.

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

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

(4) Excavation of Low Water Channel

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

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

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

(5) Realignment of Channel

1) **Cut-off Channel (COC):** This will ensure smooth flood and sediment flows

by shortening and steepening the channel in meandering sections, and keep away the river course from the site to be protected. The COC may not be applicable to the channels in alluvial fan, since the river course is braided and unstable. The COC is planed considering the following:

- Cut-off channel was planned for the severe by meandering channel.
- Cut-off channel section was designed with the average width and depth of the existing river.
- Closing dike shall close the head of the existing channel.

2) **Diversion Channel:** The primary functions of a diversion channel are to divert all or a part of the river water to alleviate flood discharge in the lower reaches, or to keep the river course away from the objects and areas to be protected. However, appropriate sites for diversion channels are difficult to locate for the rivers in the Terai plain, since these rivers take routes in parallel to each other, in a south-east direction, and the trans-basin of the flood water may cause another problem in the receiving river.

(6) Storage or Detention of Flood Water

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

2.5 Community Development Component

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

local people to maintain and sustain the flood control structures.

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

2.5.1 Community Mobilization

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

(1) Workshops for Local Government Institutions (LGIs)

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

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

(2) Creation of Organizational Bases at the Community

Formation of Community Organizations (COs)

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

Promotion of Public Awareness, Knowledge & Skills

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

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

Generation of Financial Resources by COs

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

2.5.2 Local Coping Measures

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

(1) Flood Proofing

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

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

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

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

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

One modality of possible support is to introduce the above-mentioned practices to localities where they are feasible but 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; 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 Far Western Development Region
   - Basin area: 325 km^2 in total consisting of mountainous basin 175 km^2 and plain area 150 km^2.
   - Many forests cover the riverine areas of the Khutiya, and not many areas have been converted to agriculture.
2) River system: The Shiva Ganga river is the major tributary. The Khutiya river flow into the Mohana river which runs on the Indian border.
3) River channel: River in the upstream from the E-W highway flows through thick forest forming a wide and braided channel. In the lower reaches the river

meanders severely. Riverbed materials along the river changes from medium sand in the lower reaches to large cobbles in the upper reaches.

4) River segments:
   - Segment 2-2: From 0.0 km (Indian border) to 11.5 km (Shiva Ganga R. jct.)
   - Segment 2-1: From 11.5 km to 27.0 km
   - Segment 1 : From 27.0 km to 35.0 km (upper end)
5) Flood and sediment disasters:
   - Recent major floods: 1997, 1986 and 1983 floods in order of severity.
   - Kinds of damages: Flooding over farm lands, bank erosion, and sedimentation
   - Suffering areas: 4 VDCs in Kailali district
   - Condition and mechanism of flooding: In the lower reaches riverbed is said to silt up and floodwater frequently flows over the riverine areas. Bank erosion is active in the alluvial fan reaches. After the 1997-flood, encephalities was infectious over the Kailali district. About 200 people over the district were attached with the disease and half of them died.

(2) Principal Measures to be Taken

1) Branch channels will be closed securely with diversion facilities if necessary.
2) Forest belt will be provided for Segment 1 and grass belt in Segments 2-2 and 2-1.
3) An area at the confluence of the Khutiya and Shiva Ganga rivers will be preserved for retarding basin.
4) Bank protection works by a series of spurs will be implemented based on the monitoring result of riverbanks. Preventive measures for bank erosion will also be taken by adopting bioengineering approach.
5) Watershed management will be carried out for erosion and runoff control.
6) Flood plain management will be carried out for mitigation of damage due to flood and sediment disasters.

(3) Layout Plan

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

(4) Project Works and Cost

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

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

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

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

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

CANDIDATE SPECIES FOR BIOENGINEERING WORKS IN TERAI

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

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

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

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

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

PROJECT COST FOR MASTER PLAN

KHUTIYA RIVER (unit: 1000NRs)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				60,048
1. Preparatory Works	L.S.	1.00		5,459
2. Bank Protection Works				29,571
2-1 Pile Spur (Type-A)	km	0.60	5,301	3,181
2-2 Gabion Spur (Type-A)	km	3.20	8,247	26,390
3. Cannel Works				20,056
3-1 River Boundary Line	km	42.10	27	1,137
3-2 Tree Belt	ha	37.00	68	2,516
3-3 Grass Belt	ha	95.50	126	12,033
3-4 Closing Dike/structure	place	2.00	2,185	4,370
4. Miscellaneous Works	L.S.	1.00		4,963
II . Compensation Cost	L.S.	1.00		31,800
III. Administration Cost	L.S.	1.00		4,592
IV. Engineering Service	L.S.	1.00		9,007
V . Physical Contingency	L.S.	1.00		10,086
Poject Cost				115,534

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

ANNUAL DISBURSEMENT SCHEDULE OF KHUTIYA RIVER PROJECT FOR MASTER PLAN

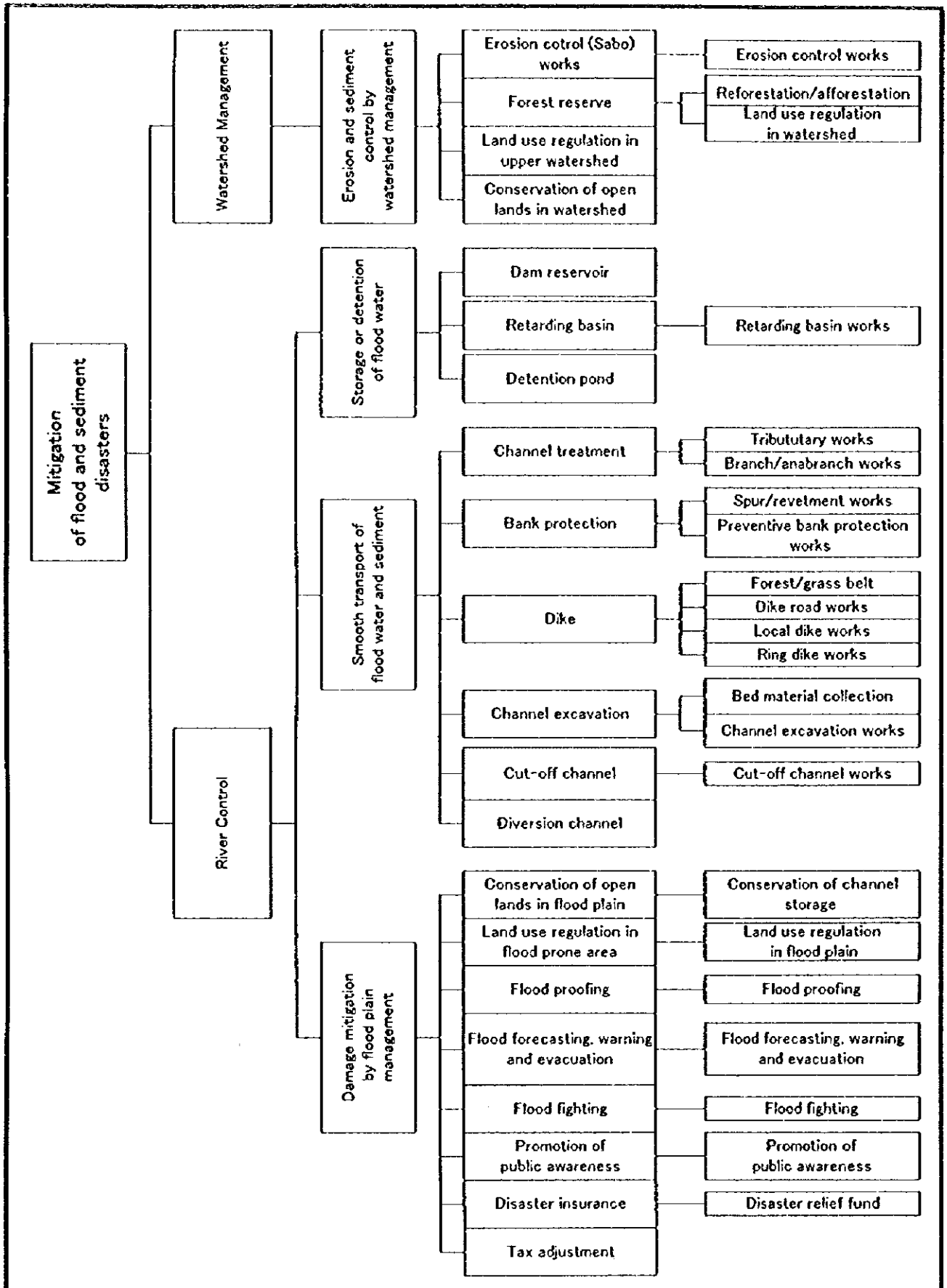
(Financial Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	60,048	0	0	0	5,231	5,231	5,231	3,412	3,412	3,412	3,412	3,412	3,412	3,412	3,412	3,412	3,412	3,412	3,412	3,412
1. Preparatory Works	5,459	0	0	0	1,820	1,820	1,820	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	29,571	0	0	0	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848	1,848
3. Channel Woks	20,056	0	0	0	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253	1,253
4. Miscellaneous Works	4,963	0	0	0	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310
II . Compensation Cost	31,800	0	0	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	1,988	0
III. Addministration Cost	4,592	0	0	99	361	361	361	270	270	270	270	270	270	270	270	270	270	270	270	171
IV. Engineering Cost	9,007	1,501	1,501	1,501	392	392	392	256	256	256	256	256	256	256	256	256	256	256	256	256
1. F/S, D/D etc.	4,504	1,501	1,501	1,501	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	4,504	0	0	0	392	392	392	256	256	256	256	256	256	256	256	256	256	256	256	256
V. Physical Contingency (10% of Items I , II &IV)	10,086	150	150	349	761	761	761	566	566	566	566	566	566	566	566	566	566	566	566	367
VI. Total	115,534	1,651	1,651	3,937	8,733	8,733	8,733	6,491	6,491	6,491	6,491	6,491	6,491	6,491	6,491	6,491	6,491	6,491	6,491	4,205

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

(Economic Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	54,043	0	0	0	4,708	4,708	4,708	3,071	3,071	3,071	3,071	3,071	3,071	3,071	3,071	3,071	3,071	3,071	3,071	3,071
1. Preparatory Works	4,913	0	0	0	1,638	1,638	1,638	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	26,614	0	0	0	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663	1,663
3. Channel Woks	18,050	0	0	0	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128
5. Miscellaneous Works	4,466	0	0	0	279	279	279	279	279	279	279	279	279	279	279	279	279	279	279	279
II . Compensation Cost	28,620	0	0	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	1,789	0
III. Addministration Cost	4,133	0	0	89	325	325	325	243	243	243	243	243	243	243	243	243	243	243	243	154
IV. Engineering Cost	8,107	1,351	1,351	1,351	353	353	353	230	230	230	230	230	230	230	230	230	230	230	230	230
1. F/S, D/D etc.	4,053	1,351	1,351	1,351	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	4,053	0	0	0	353	353	353	230	230	230	230	230	230	230	230	230	230	230	230	230
V. Physical Contingency (10% of Items I , II &IV)	9,077	135	135	314	685	685	685	509	509	509	509	509	509	509	509	509	509	509	509	330
VI. Total	103,980	1,486	1,486	3,543	7,860	7,860	7,860	5,842	5,842	5,842	5,842	5,842	5,842	5,842	5,842	5,842	5,842	5,842	5,842	3,785



FLOOD MITIGATION MEASURES

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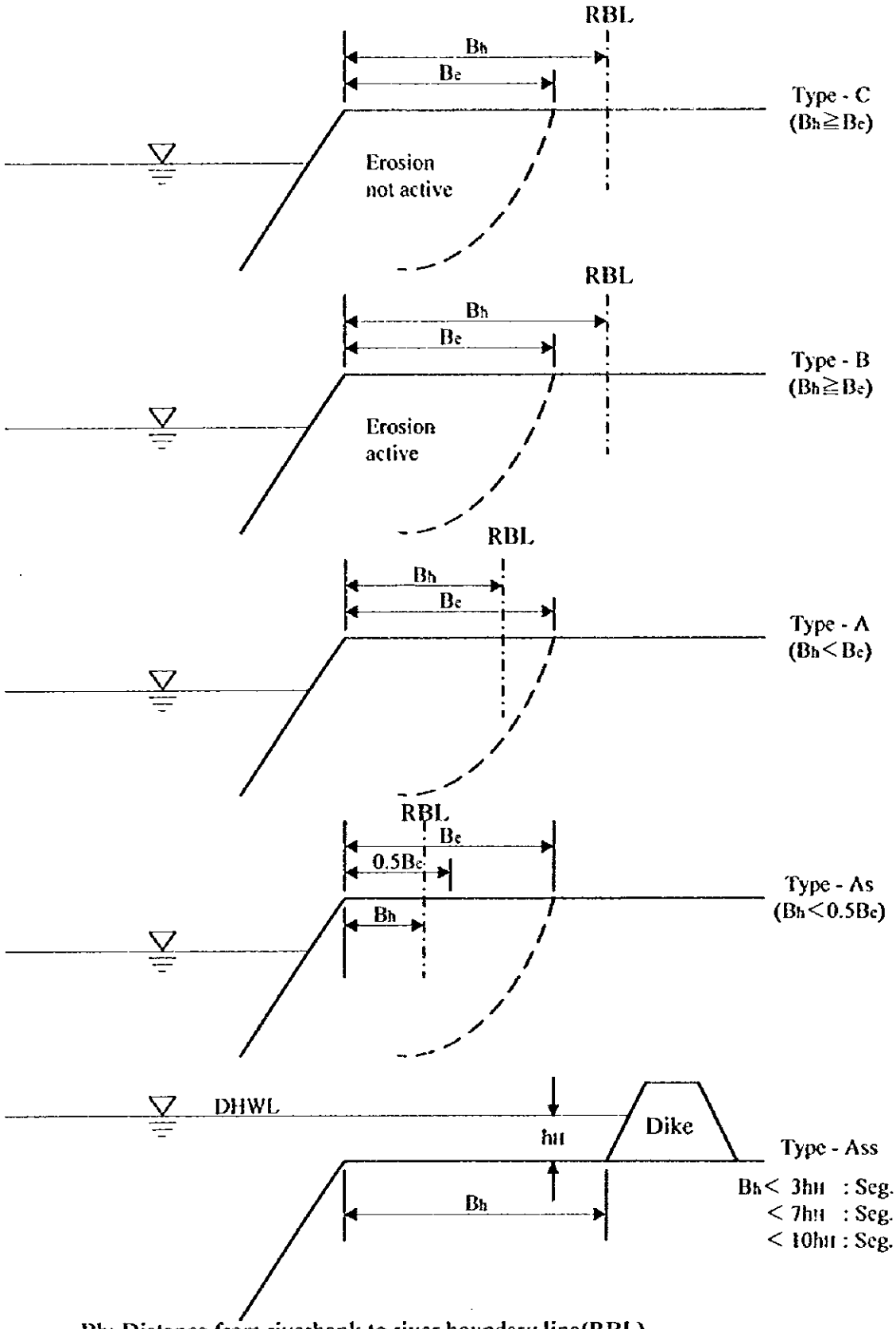
JAPAN INTERNATIONAL COOPERATION AGENCY



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

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

CLASSIFICATION OF TYPES OF RIVER BANK

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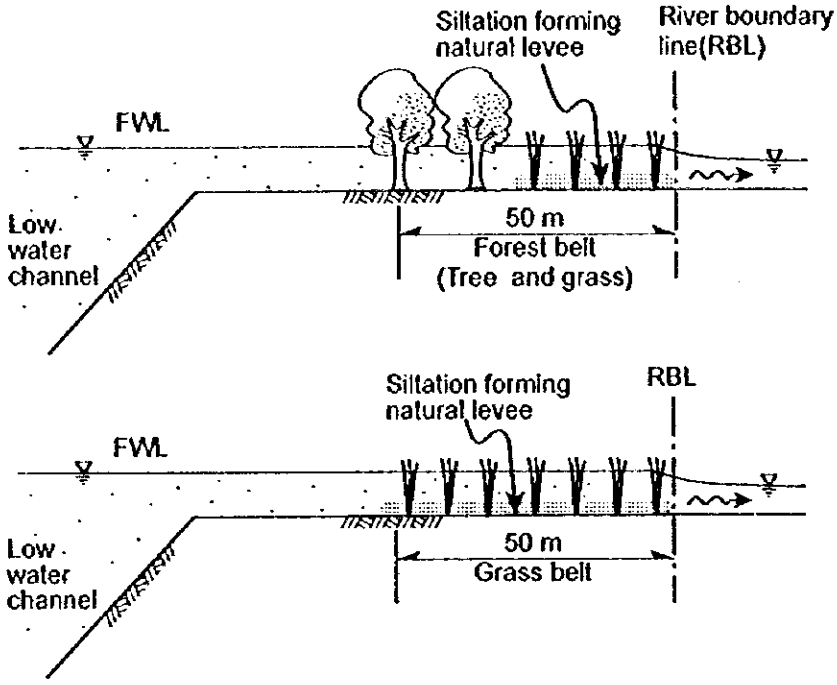
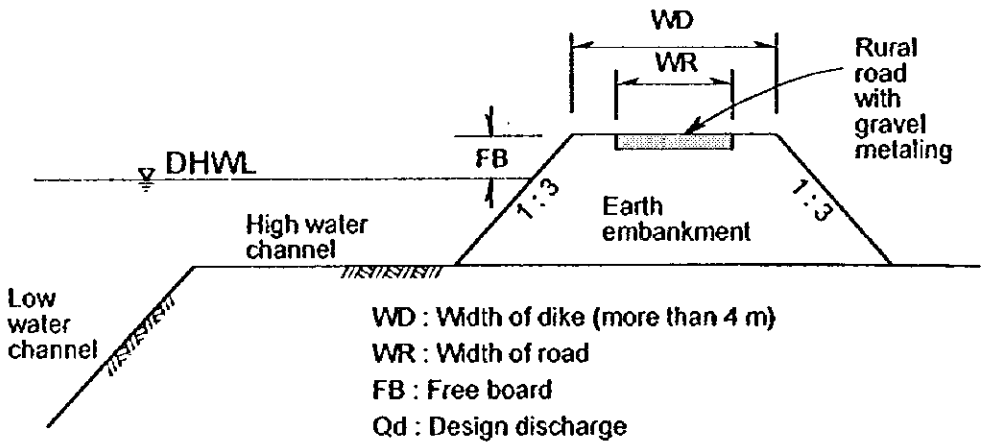
Forest and Grass Belt



Earth Dike / Road



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

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

DIKE WORKS

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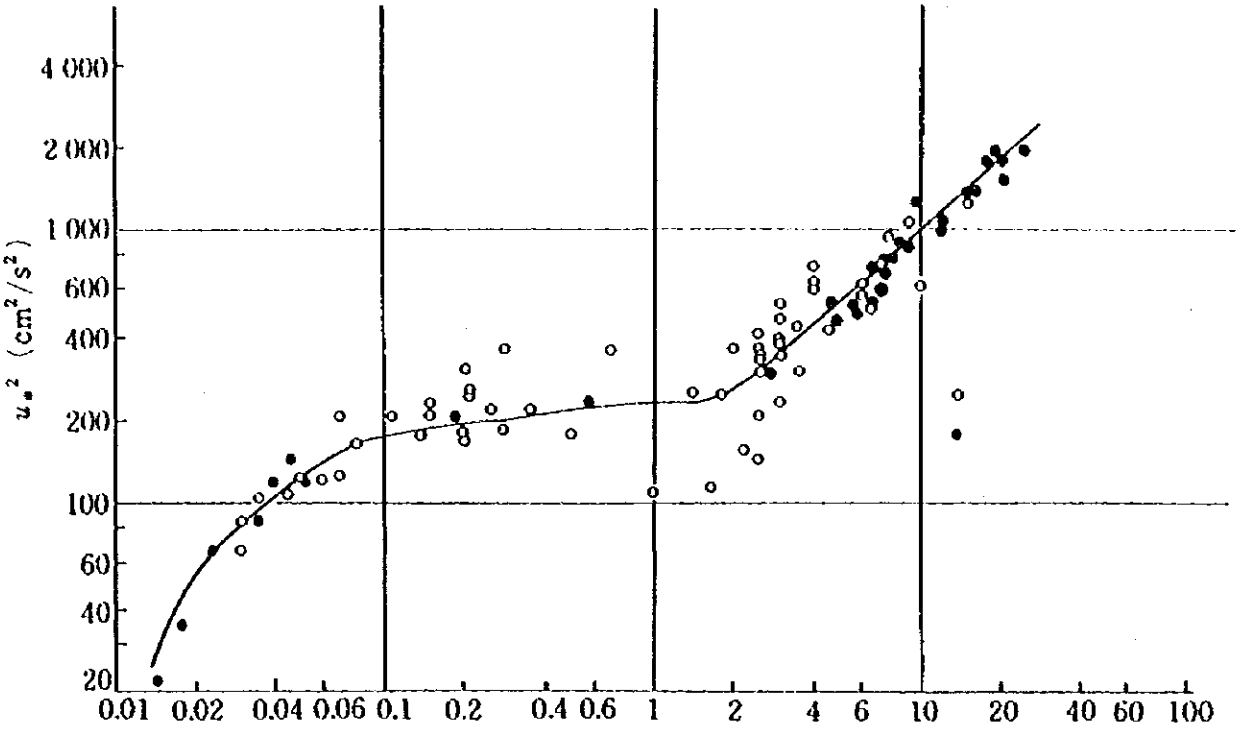

$$Q_2 = A \cdot V = \frac{B \cdot h_L^{5/3} \cdot I^{1/2}}{n} \quad \Rightarrow \quad h_L = \left\{ \frac{Q_2 \cdot n}{B \cdot I^{1/2}} \right\}^{3/5}$$

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

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

n : Manning's coefficient of roughness

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

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

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

h_L : Mean depth of low water channel (m)

B : Low water channel width

RELATIONSHIP BETWEEN BED MATERIAL SIZE AND FRICTION VELOCITY

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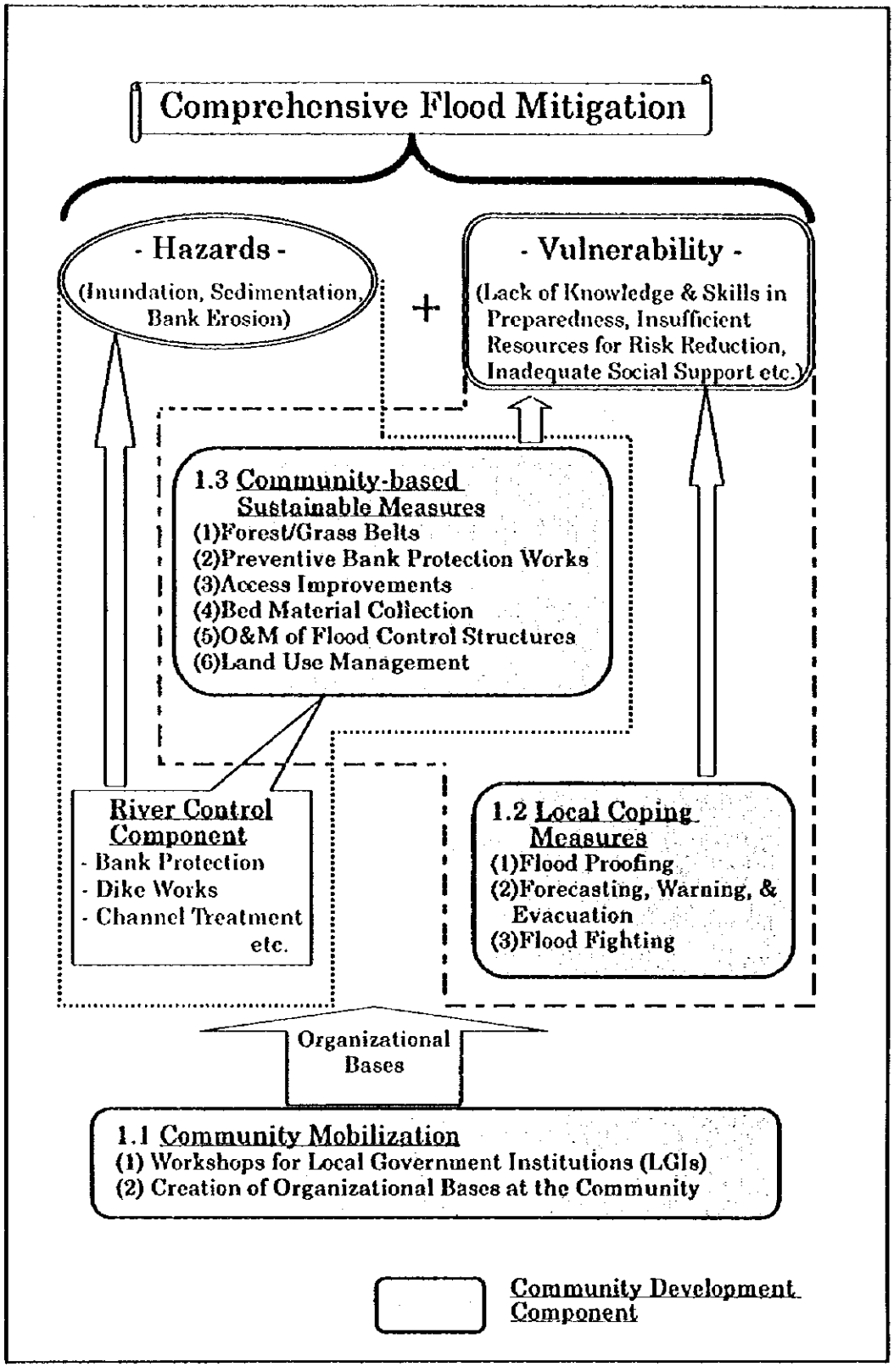

COMPREHENSIVE FLOOD MITIGATION

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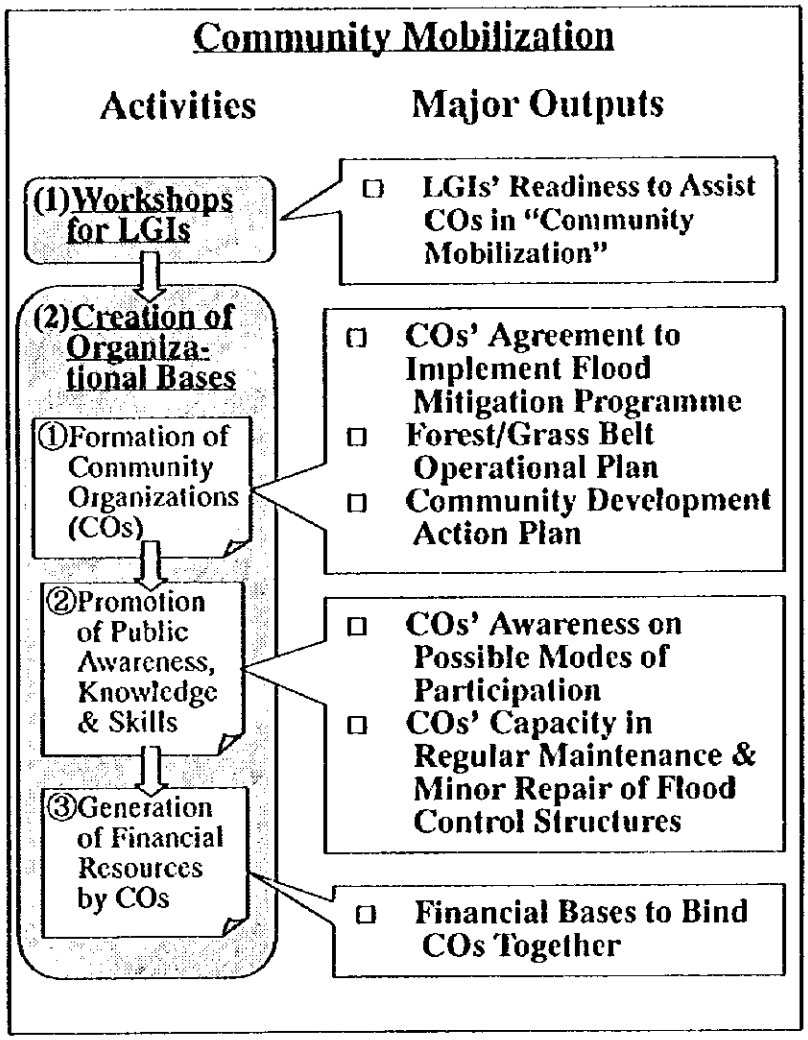

COMMUNITY MOBILIZATION

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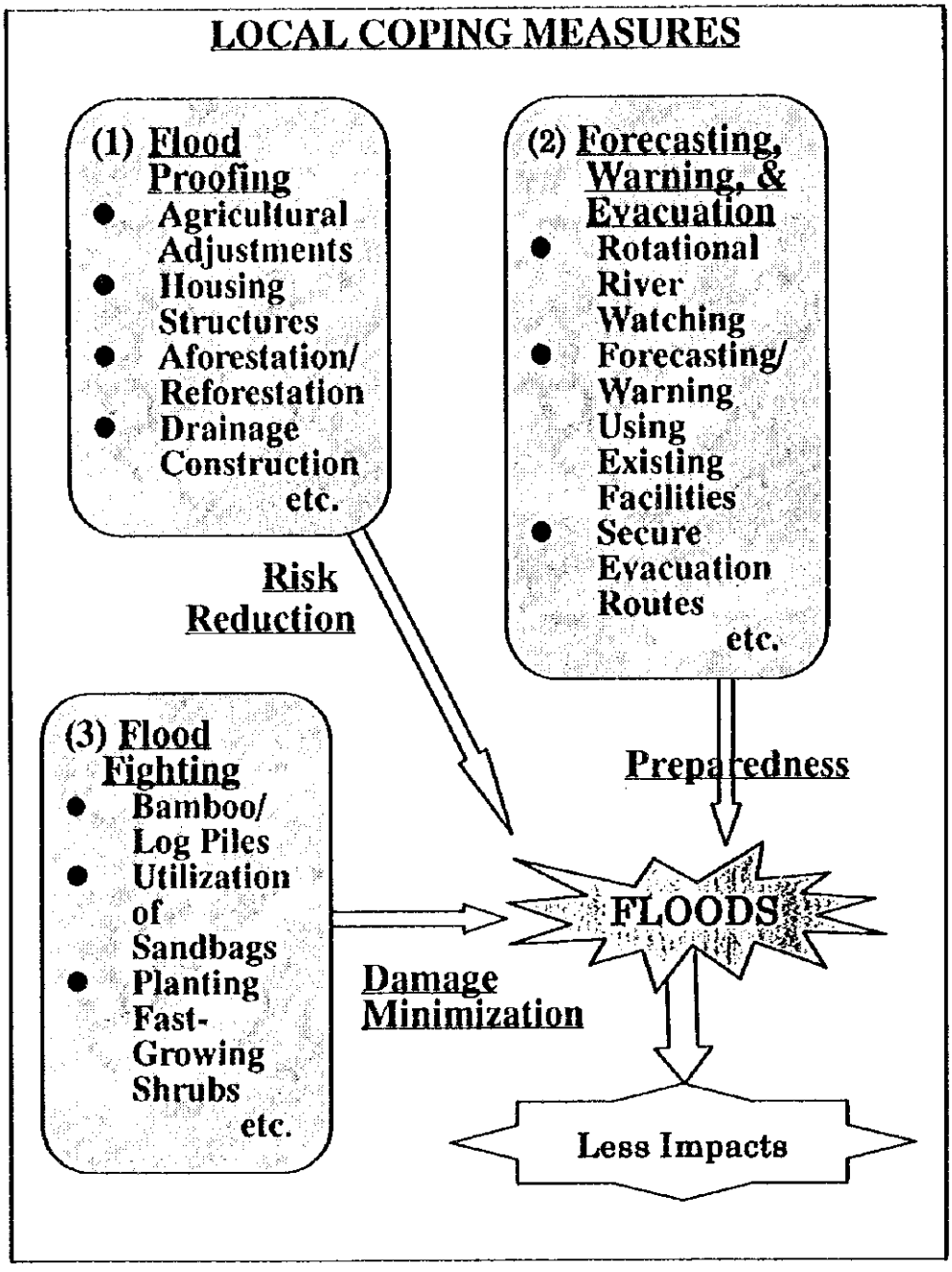

LOCAL COPING MEASURES

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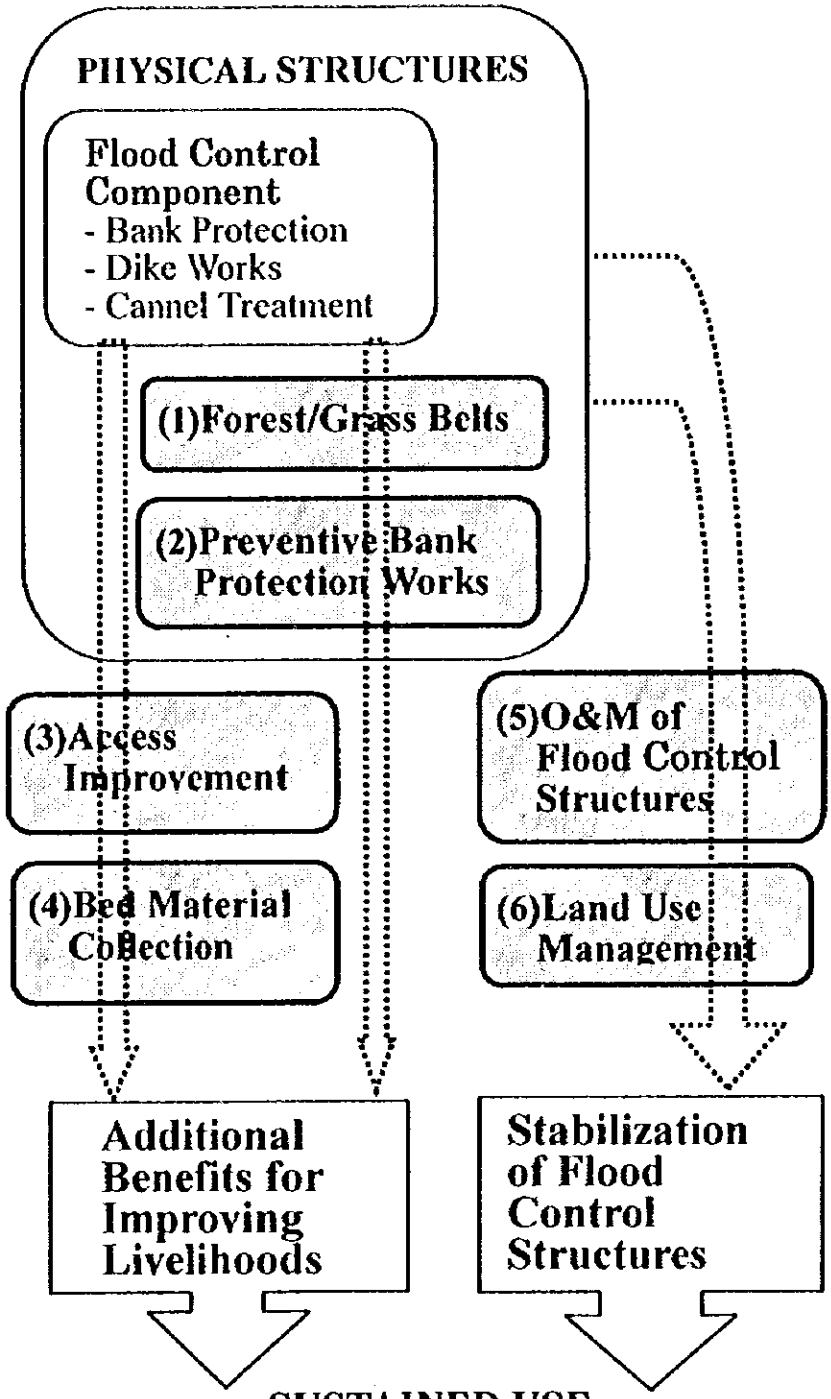
Community-based Sustainable Measures



COMMUNITY-BASED SUSTAINABLE MEASURES

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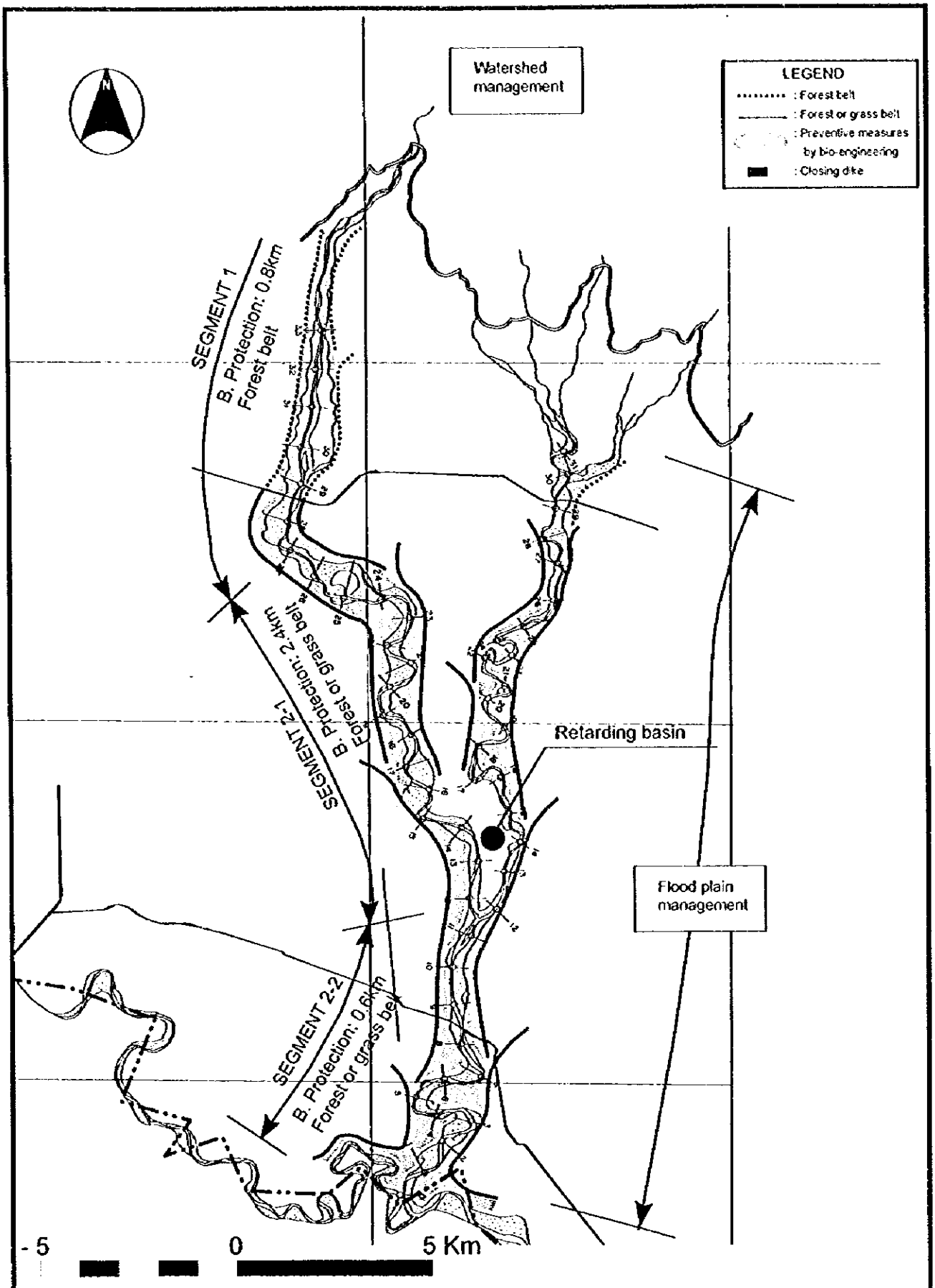

LAYOUT PLAN FOR FLOOD MITIGATION
(KHUTIYA RIVER)

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