CHAPTER 4 FLOOD MITIGATION MASTER PLAN

4.1 Principles for Formulation of Master Plan

(1) Basic Frame of Flood Mitigation

The Ninth Plan: The Ninth Plan (1997-2002) focuses on poverty alleviation as the main objective of the plan. "The Access to Ninth Plan" prospects, as a long-term target, to bring the poverty level down to 10 % by the end of Twelfth Plan (2012 – 2017) from the present 45 %. This is to be achieved by keeping annual economic growth rate at 7.2 % for GDP and 5.1 % for per capita income over the 20 year period, though the targets are not final and are still under examination. The Ninth Plan states, in its policy sector of irrigation, the river control program as follows:

> "The river control program shall be coordinated with agricultural, forest and soil conservation programs to make it more effective and its scope of work shall gradually be expanded."

Population Flow: The major pattern of the population flow in Nepal is from the mountain/hill regions to the Terai. As a result, the Terai saw a population growth rate nearly three times as rapid as that of the hills and mountains, and the percentage of the Terai's population increased from 37% of the whole country in 1971 to 46 % in 1991. The 1998-population of the Terai is about 11.0 million, (9.7 mill. in rural and 1.3 mill. in urban areas) sharing about 50 % of the country total. Because of migration into the area, the population of the Terai is anticipated to double in 20 years time. Thus by 2020, the Terai may contain 67% of Nepal's population.

Economic Activities: The GDP growth rate has been between 4 to 5% per annum during the past 10 years. Nepal is a predominantly agrarian economy. The share of the agriculture sector in Nepal's GDP has been between 40 and 50 %. In addition, more than 80 % of the labor force is dependent upon agriculture. Therefore, the development of agriculture is a key to enhance GDP and, accordingly, to alleviate poverty. The development of the agricultural sector impacts on non-agricultural sector and also promotes growth in opportunities for employment.

Terai Plain: The Terai plain is called the "granary of Nepal", because of the significant contributions the Terai makes to the overall agricultural production. Almost a half of the country's cultivated land is in the Terai and farmers in the Terai produce nearly

60 % of the country's food grain. A wide range of crops is produced, with major crops of paddy, maize, wheat, pulses, and oilseeds. Most of these major crops are grown during monsoon.

Flood Mitigation in Basic Frame: In order to meet the growing demand for food, agricultural productivity has to increase. This should be done by increasing unit production, rather than converting more forest land to agriculture as has been done previously and to a small extent is occurring today. Flood mitigation measures play an important role in this regard to support people's livelihood and the development of agriculture, reducing damages due to flood and sediment, reclaiming some of the sterile land, and enabling intensified cropping in the Terai plain.

(2) Concept of Flood Mitigation 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 proposed 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 of their implementation are also discussed.

(3) Target Year

In line with the national development plan, target year was set at the end of Twelfth Plan in 2017 which is 20 years from now.

(4) Objects to be Protected

The flood mitigation will be discussed mainly for the Terai plain. As to the watershed area, recommendation will be made from watershed conservation viewpoint.

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; and
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.

(5) 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, and low cost for both construction and maintenance. In this regard, consideration is given to the use of local materials in parallel with the participation of local residents as much as possible.
2) **Provision of Safe Lands:** Expansion of rural towns and isolated farm house is taking place due to migration and population increase in the Terai plain.

Some of the new residents live on the land which are flood prone. Provision of safe and productive land is one of the important tasks of the flood mitigation projects in the Terai plain. 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.

4.2 Strategy for Flood Mitigation

(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 (Watershed area);
2) Storage or detention of flood water (Upper basin);
3) Smooth transport of floodwater and sediment (Flood prone area); and
4) Damage mitigation by flood plain management (Flood prone area).

These flood mitigation measures are shown in Fig. 4.1. Measures applicable to the rivers in the Terai plain are discussed in the following subsections considering the characteristics of the river and the existing situation of the basin and the country.

(2) Erosion and Sediment Control by Watershed Management

Forest Reserve and Land Use Regulation: The forest reserve and land use regulation will be the main activities in the watershed area to sustain and enhance the natural erosion control function of the forest, since the geological conditions in the Siwalik hills are very poor and intensive erosion control works in such areas are difficult technically and financially. The flood mitigation Master Plan is, therefore, formulated under the existing watershed conditions. The forest reserve includes reforestation and afforestation.

Local Erosion Control Works: Local erosion control works are also needed to protect the settlements as remedial measures.

(3) Storage or Detention of Floodwater

Dam Reservoir: Dam reservoir to control flood and sediment flows is not proposed mainly for the following reasons:

1) Dam is not recommended in the class-III river watersheds, because of poor geological conditions in the Siwalik hills. Furthermore, the dam reservoir will not be so effective, since the watershed of the class-III river shares only one third of the total basin area.
2) As to class-I and class-II rivers in the Study Area, any multipurpose dam which can serves for flood mitigation as well has not been proposed. Considering the cost performance, single purpose dam for flood mitigation is not proposed.

Retarding Basin: In order to reduce flood peak in the downstream reaches, natural flood storage function should be conserved as a retarding basin.

(4) Smooth Transport of Floodwater and Sediment

Conventional Measure: In order to ensure the smooth transport of floodwater and sediment, conventional measures such as channel treatment, bank protection, dike, channel excavation and cut-off channel works should be employed. Among these works, river dike is a primary facility to ensure the smooth flood flow, but at the same time it changes markedly flow conditions of floodwater and sediment in river channel. Adoption of diking system needs careful consideration to make the project economical and sustainable.

Continuous Dike: Continuous dike constructed along the river course is an effective measure to protect flood prone areas from floodwater and sediment, confining them within the river area. However, the continuous dike also induces some difficulties and problems as described below, especially in the river basin with much sediment yield from the watershed:

1) **Concentration of Floodwater and Sediment:** The continuous dike induces concentration of floodwater and sediment in the lower reaches (see Fig. 4.2). Therefore, the continuous dike should be designed giving careful consideration on the continuation of floodwater and sediment flows.

Otherwise the continuous dike may cause a remarkable rise of riverbed and, in consequence, a breach of the dike. For the sediment study, rivers in the Terai plain have two major problems. They are uncontrollable sediment yields in watershed and necessity of plan coordination with India.

2) **Uncontrollable Sediment Yields in Watershed:** Sediment control in the watershed is difficult owing to the poor geological conditions and budgetary constrains. Moreover, the mechanism of the sediment yield in the Siwalik hills is not known and has to be investigated after this. Under such a situation, reliable sediment study for the plain river reaches is difficult, since the sediment supply from the upper watershed is uncertain.
3) **Coordination of Plan with India:** All the rivers in the Terai plain flow into the Ganges river in India. The river channel in India should have equivalent capacity for flood water and sediment transport so as not to cause flooding and sediment problems around the border. Therefore, the continuous dike will not be realized unless the plan is coordinated and agreed with India.
4) **Difficulty in Maintenance:** A continuous dike generally needs a sustainable maintenance and repair in order to keep the function properly for the whole length of the dike. Such maintenance activities require a large amount of budget. The damaged dike should be repaired immediately for coming floods. If the dike is left broken, the floodwater may breach the dike and bring about more serious damages than ever, since the continuous dike concentrates the floodwater in the lower reaches and the dike would induce the increase of houses and other properties near the dike. Considering the present financial constrain of the government, such a timely response is deemed difficult.

Low Dike Allowing Controlled Flooding: Instead of the continuous dike, low dike allowing controlled flooding can be considered, since the sheet flood flows in farmlands would not be so disastrous. If the flooding are allowed in some reaches, concentration of floodwater in the lower reaches would also be alleviated. However, it is difficult, in practice, to designate lands for flooding in an emergency. It is more practical to protect villages and other important properties locally by local dikes or ring dikes.

Forest and Grass Belt as River Dike: Considering the present tight budgetary situation, priority of flood mitigation should be given to bank protection and damage mitigation of villages. As for the protection against flooding and inundation, forest and grass belt should be proposed as river dike. The trees and grass planted along the riverbank will

trap the sediment and reduce the overflow of floodwater. The trapped sediment will form a natural dike along the belt. Moreover, the tree and grass will bring in income for the community, which make the flood mitigation activities sustainable.

Proposed Dike: Based on the above studies and consideration, the following types of dikes are proposed for the rivers in the Terai plain to make the project practical, low-cost and sustainable:

1) **Local dike:** Dike to protect properties locally. Ring dike around the settlement and dike road to be used as road and dike also fall in this category.
2) **Forest and grass belt as river dike:** Owing to the function of the belt, the flood prone area will be substantially protected from sedimentation, and the inundation will be reduced, though the area still suffers from controlled flooding. Owing to there, it is expected that a river channel of about 2-year return period will be formed.

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 not found 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.

(5) Damage Mitigation by Flood Plain Management

The flood plain management should be incorporated with other flood mitigation measures, so as to accomplish the mitigation of substantial flood damages in the flood plain. Measures for the flood plain management include the following:

1) Conservation of channel storage;
2) Land use regulation in flood plain;
3) Flood proofing;
4) Flood forecasting, warning and evacuation;
5) Flood fighting;
6) Promotion of public awareness; and
7) Disaster relief fund.

(6) Project Components

In order to undertake the flood mitigation project in a practical and sustainable manner, it is important to implement the measures in combination with community development activities. Therefore, the flood mitigation efforts should be divided into three components, i.e., (1) watershed management, (2) river control, and (3) community development components.

4.3 Watershed Management Component

Enhancement of 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 organizations 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, can be applied considering topographical, geological and social situation of the site:

1) Construction of check dam.
2) Revetment works along riverbanks.
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) Promote afforestation and reforestation, and foster natural regeneration of trees.
2) Promote planting farm tree and shrub as commercial crops such as fruit trees, medicinal herbs, aromatic plants and natural dyes. Well-managed commercial crops prevent land erosion in watershed 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) Plant fodder grasses on slopes and fodder trees on terraces, and restrict the number of livestock within permissible limits for sustaining the pasture and forest.
4) Conserve of wild medical herbs, by protecting from over-collect, thus allowing a sustained yield.
5) Reduce energy use through the improving stoves.
6) Train local leaders in land use and woodland management, and exchange 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) Establish a specific date or dates for tree planting activities as a national and/or local level event, and conduct tree-planting campaign for afforestation, reforestation, farm tree planting and forest conservation.
2) Hold commemorative tree planting for any ceremonies and memorial events by residents, and local and national leaders.
3) Promote environmental education, tree nursery and small arboretums in school.
4) Enact a system of commendation for excellent tree planting projects, including agro-forestry, riverside plantings and other community activities.
5) Combine natural regeneration and/or afforestation project with tourism and

local development project.

6) Conduct a campaign by mass media for planting trees.
7) Establish foundations and solicit funds to encourage tree planting.
8) Organize tree-planting volunteer groups, and facilitate volunteers from the overseas countries to participate as well.
9) Conduct study tours to on-going projects to learn from past initiatives.

4.4 River Control Component

4.4.1 Design Discharge

According to the result of study in runoff analysis of the previous chapter, probable flood discharge has been estimated at the major points of rivers in the Terai plain. Probable discharges at the lower end (Indian border) of respective river basins are shown below:

(Estimated Probable Discharge)

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
1.Ratuwa	383	500	810	1,010	1,200	1,450
2.Lohandra	310	450	720	900	1,070	1,300
3.Lakhandei	300	440	710	880	1,050	1,280
4.Narayani	31,645	12,400	16,600	19,400	22,100	25,600
5.Tinau	1,081	830	1,340	1,670	1,990	2,420
6.West Rapti	6,418	2,320	3,680	4,590	5,420	6,530
7.Babai	3,425	2,500	4,300	5,500	6,660	8,160
8.Khutiya	325	460	740	920	1,100	1,330

4.4.2 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.

Criteria of these segments are shown in Table 4.1. Segment 3 does not exist in the Terai plain rivers. The Segment 2 is divided further into Segments 2-1 and 2-2.

River channel can be divided into several reaches depending on the riverbed material, channel slope, river width and surrounding topography. River slope, representative grain size and average river width are worked out for respective reaches and shown in Table 4.2. River control measures should be discussed based on the channel

characteristics of respective segments.

4.4.3 River Boundary Line (RBL)

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 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 a plan.

Setting 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) Study river width necessary to transport design floodwater and sediment.
2) Investigate erosion width along the both riverbanks. The erosion width discussed here is a 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) Draw initial RBL on both banks keeping distance more than B_e from river bank. The RBL should be set on a smooth alignment for floodwater flow.
4) The initial RBL is examined from the viewpoints of property protection and channel capacity. The RBL will be revised partially, if the result of

examination demands.

5) The RBL is 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.

4.4.4 Facility Plan

(1) Channel Treatment

Two types of channel treatment works are considered, namely, tributary works and branch/anabranch works.

1) **Tributary works:** Treatment of tributaries (or incoming water), unifying tributary systems and controlling flows from other river systems, 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 (or outgoing water) by closing dike works with diversion structure, if necessary, to prevent river course shifting and flood water spilling.

(2) Bank Protection

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

1) **Spur (or groin) works:** A series of spurs prevents bank erosion primarily by two functions of spur, namely, to retard flow velocity near the bank and to change the flow direction away from the bank.
2) **Revetment works:** Revetment works prevent bank erosion by covering bank slopes and protecting their foundations. Spur and revetment works are the primary bank protection measures. These measures can be planed

independently or jointly.

3) **Preventive bank protection works:** Grass and trees planted on the riverbanks resist and retard the erosion. These bioengineering technologies can be used as preventive measures against bank erosion, not as direct bank protection works.

Design of Spur Works: 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

Types of Riverbank: Conditions of riverbank shall be monitored every year after the flood season and the necessity of protection works shall be examined depending on the conditions of riverbank. In order to identify the sites in critical conditions and prioritize the work sites for bank protection, riverbanks should be classified into several types (Fig. 4.3) based on the relationship between the distance from river bank to the river boundary line (B_b) and design erosion width (B_e). Types of riverbank and necessary measures to be taken are summarized below:

1) **Type-A bank:** $B_b < B_e$ and bank erosion is active; Bank protection works are desirable as far as the fund is available. Preventive measures for bank erosion are needed immediately.
2) **Type-A_s bank:** $B_b < 0.5\ B_e$ and bank erosion is active; Bank protection works are needed immediately.

3) **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; Protection works of dike slope are needed.
4) **Type-B bank:** $B_h \geqq B_c$ and bank erosion is active; Preventive measures for bank erosion are needed.
5) **Type-C bank:** $B_h \geqq B_c$ and bank erosion is not active due to topographical and geological reasons; No bank protection works are needed.

(3) Dike Works

Proposed Dike Works: Dike works aim to prevent floodwater and sediment from spilling over the land. As was discussed in the Section: Strategy for Flood Mitigation, continuous dike will not be proposed for the rivers in the Terai.

Forest and Grass Belts: Tree 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. 4.4). The forest belt consists of trees to cope with floating logs and other course materials and grasses to trap sediment. The grass belt is made of grass only to trap sediment. The forest belt can replace the grass belt as far as it is aligned on the RBL. These tree and grass will bring in income to the community. Generally speaking, grass yields products soon, while tree need long years to grow.

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.

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.

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.

Dike Alignment: These dikes are aligned in principle on the river boundary line (RBL), except for the ring dike.

(4) Excavation of Low Water Channel

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

Channel excavation: Intensive channel excavation is not recommended for the rivers in the Terai plain, since the maintenance of the excavated channel would be difficult under the conditions that 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 earth dike materials.

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 design width of low water channel should be examined in relation with friction velocity and representative bed material size. An empirical relationship developed by Dr. Koichi Yamamoto is shown in Fig. 4.5. This Figure indicates that, if the designed section satisfy the emperical relation, the section would be stable. This relationship was derived based on the river data in Japan. It is recommended to reproduce the relationship using data from Terai rivers in future.

(5) Realignment of Channel

Cut-off Channel (COC): This will ensure smooth flood/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 was planed at the severely meandering section considering the following:

1) Cut-off channel section shall be designed with the average width and depth of the existing river.
2) The head of the existing channel shall be closed by closing dike.

(6) Storage or Detention of Flood Water

Retarding Basin: In order to reduce flood peaks in the downstream reaches, a retarding basin can be considered by conserving natural flood storage function. The retarding basin can be planned at the confluence of tributaries to reduce runoff peak by spilling floodwater into the retarding basin. The conservation of channel storage also function markedly for this purpose.

4.5 Community Development Component

The community development component for flood mitigation will consist of three sets of activities (Fig. 4.6). 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 flood mitigation 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. 4.6. 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).

4.5.1 Community Mobilization

The community development will start with the community mobilization, to strengthen the organizational bases for local flood mitigation initiatives (Fig. 4.7). 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 and 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 (1) forest/grass belt products, (2) nursery products (in case the communities run nurseries), and (3) group savings. Savings will primarily be used as capital 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 the COs in establishing a record keeping system, and in acquiring skills in running it in a transparent manner.

4.5.2 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. 4.8). The following is a menu of support, in assisting local communities to enhance their local coping measures.

(1) 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 leads to the instability of riverbank.

3) **Deforestation:** Not all the forests along the rivers are not 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) Flood Proofing

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

Agricultural Adjustments:

1) 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;
2) Grow sweet potatoes, if as a result of floods their farming lands are covered by thick sand, thus preventing them from cultivating other crops;
3) Where feasible, change from maize growing to rice cultivation which is less vulnerable to inundation, and in other words, more flood-resistant; and
4) Set aside rice seedlings, in order that they can re-plant paddies, even in case rice fields are destroyed due to flooding.

Housing Structures:

1) Construct houses on plinths, so that flood water flows underneath;
2) Raise grain stores on stilts, while build escape areas under roofs for family members and other valuables; and,
3) Concentrate houses on higher grounds of the communities, to prevent residential shelters from being inundated during floods.

Other Possible Flood Proofing Measures:

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

Introduction to Other Localities: 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.

(3) 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.

(4) Flood Fighting

The following are examples of local flood fighting measures:

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

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

4.5.3 Community-based Sustainable Measures

The "community-based sustainable measures" is to derive additional benefits from the physical facilities, and to motivate the beneficiaries to sustain the structures (Fig. 4.9). Forest/grass belts, and preventive bank protection works will derive tree/grass products out of the flood control measures, while access improvements and bed material collection will produce other additional benefits. These additional values will motivate the COs to sustain the physical structures, through operation and maintenance (O&M) of flood control structures, and land use management.

(1) Bank Protection Works

Local 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. 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.

Preventive Bank Protection Works: 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 4.3 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).

(2) Forest/Grass Belts as Dike Works

The flood mitigation plan envisages the development of forest/grass belts. Table 4.4 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 4.3, 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.

(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 be 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 graveling roadways.

(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 that bed material collection is not feasible in all the areas along the rivers. Certain localities face the constraints of (1) unavailability of sand/gravel, (2) low quality of sand /gravel, (3) lack of roadways from outside to excavation sites, (4) distance to transport to markets, (5) lack of flexible/clear-cut rules and regulations, and (6) objections from community members. However, efforts can be made to redress the above-mentioned constraints except (1) and (2).

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 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 be 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.

4.6 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 for the respective river basins elected for the Study.

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 flood mitigation concept described here.

4.6.1 Present Conditions and Principal Measures to be Taken

(1) Ratuwa River

Present Conditions and Problems of Ratuwa River:

1) **River basin:**
   - Class-III river in Eastern Development Region
   - Basin area: 383 km^2 in total consisting of mountainous basin 133 km^2 and plain area 250 km^2.
   - There exist Damak city and refugee camps by UNHCR in the riverine area.
2) **River system:** The Mawa river, a right tributary, is about to join the Nunsari/Bakra river near Madhumalla Bajar.
3) **River channel:** River is wide and braided for the whole stretch. Changes in riverbed material along the river are small ranging from medium to coarse sand. Gravel and other coarse materials are not found even in Segment 1.
4) **River segments:**
   - Segment 2-2: From 0.0 km (Indian border) to 13.0 km
   - Segment 2-1: From 13.0 km to 26.0 km
   - Segment 1 : From 26.0 km to 43.7 km (upper end of plain)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1988, 1995 and 1996 floods in the order of severity.
   - Kinds of damages: Bank erosion, sedimentation and flooding over farm lands.
   - Suffering areas: 7 villages in 3 VDCs and 4 wards of Damak municipality in Jhapa district, and 4 villages in 3 VDCs in Morang district.
   - Conditions and mechanism of flooding: Riverbed of the Ratuwa river is said to be agrading and widening. The Ratuwa river floods the riverine areas every year from June to August. In the lower reaches the floodwater spills and spreads over the old river courses and trails.

Principal Measures to be Taken for Ratuwa River:

1) The Mawa river and the Nunsari river will be separated completely by a closing dike.
2) Branch and anabranch in Segments 2-2 and 2-1 will be closed securely with closing dike or controlled with diversion facilities if necessary.
3) Forest belt will be provided for Segment 1 and forest or grass belt in Segments

2-2 and 2-1.

4) Cut-off channel will be constructed at the severe bends.
5) An area at the confluence of the Ratuwa and Mawa rivers will be preserved as a retarding basin.
6) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
7) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
8) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(2) Lohandra River

Present Conditions and Problems of Lohandra River:

1) **River basin:**
   - Class-III river in Eastern Development Region
   - Basin area: 419(310) km^2 in total consisting of mountainous basin 140(31) km^2 and plain area 279 km^2. Areas in ( ) indicate those excluding mountainous basin of the Chisan river.
   - Middle and lower portions of the flood prone areas are the service areas of the Sunsari Morang (Kosi river) Irrigation Project.
2) **River system:** The Lohandra river is located between alluvial fans of the Chisan and Khadam rivers. The Lohandra river which itself is a branch river of the Chisan joins the Kesaula river from the Chisan and the Sukuna river from the Khadam.
3) **River channel:** River is wide and braided in the upper reaches and becomes narrow gradually toward lower reaches. Riverbed materials range from very coarse gravel in the upper reaches to fine sand in the lower reaches.
4) **River segments:**
   - Segment 2-2: From 0.0 km (Indian border) to 33.1 km (Kesaula R. jct.)
   - Segment 2-2: From 33.1 km to 49.6 km (Sukuna R. jct.)
   - Segment 1 : From 29.6 km to 67.5 km (upper end of plain)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1987, 1988, 1995 and 1996 floods in the order of severity.

- Kinds of damage: Sedimentation, bank erosion and flooding over farm lands.
- Suffering areas: 28 villages in 14 VDCs in Morang district
- Conditions and mechanism of flooding: Settlements and lands along the Lohandra river suffer from flood and sediment disasters almost every year. The riverbed is said to be aggrading markedly especially in the upstream reaches from Chatara canal. Bank erosion is active on the both sides of the river. Since the river channel is small in the lower reaches, flood water from the upstream areas frequently floods over the riverine farmlands.

Principal Measures to be Taken for Lohandra River:

1) The main Lohandra and the Kesaula rivers will be separated completely from the Chisan river by a closing dike or diversion facilities.
2) The Sukuna river will be separated from the Chisan river completely by closing dike.
3) An anabranch at 46.7 km on the left bank will be closed securely with closing dike or controlled with diversion facility if necessary.
4) Forest belt will be provided for Segment 1 and forest or grass belt in Segments 2-2 and 2-1.
5) Cut-off channels will be constructed at severe bends. Cut-off channel from 27.8 km to 31.4 km aims to bypass dense settlement areas.
6) An area at the confluence of the Lohandra and Sukuna rivers will be preserved as a retarding basin.
7) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
8) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
9) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(3) Lakhandei River

Present Conditions and Problems of Lakhandei River:

1) **River basin:**
   - Class-III river in Central Development Region
   - Basin area: 300 km^2 in total consisting of mountainous basin 106 km^2 and plain area 194 km^2.
   - Middle and lower portions of the flood prone areas are the service areas of the Bagmati Irrigation Project.
2) **River system:** Major tributaries are the Baune and Chapani rivers.
3) **River channel:** River is wide and braided in the upper reaches and becomes narrow gradually toward lower reaches. Riverbed materials ranges from very coarse gravel in the upper reaches to fine sand in the lower reaches.
4) **River segments:**
   - Segment 2-2: From 0.0 km (Indian border) to 21.0 km
   - Segment 2-1: From 21.0 km to 37.0 km
   - Segment 1 : From 37.0 km to 51.4 km (upper end of plain)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1997, 1993 and 1995 floods in the order of severity
   - Kinds of damages: Sedimentation, bank erosion and flooding over farm lands
   - Suffering areas: 27 villages in 11 VDCs in Sarlahi district
   - Conditions and mechanism of flooding: The Lakhandei river floods over the riverine area almost every year. The flood and sediment disasters are caused not only by the runoff from its own basin, but floodwater from the Bagmati river as well. The 1997-August flood inundated the lands as deep as 1.5 m for 3 to 7 days, causing extensive damages due to sedimentation and inundation over the farm lands. The 1997-flood also brought about diseases such as malaria, dysentery and typhoid, resulting in loss of 91 human lives in the whole Sarlahi district.

Principal Measures to be Taken for Lakhandei River:

1) A branch and anabranches at 26.1 km, 16.3 km and 31.9 km will be closed securely with closing dike or controlled with diversion facilities if necessary.
2) Forest belt will be provided along the river boundary line (RBL) for Segment 1 and forest or grass belt for Segments 2-2 and 2-1.

3) Cut-off channel will be constructed at severe bends.
4) An area at the confluence of the Lakhandei and Chapani rivers will be preserved for retarding basin.
5) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
6) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
7) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(4) Narayani River

Present Conditions and Problems of Narayani River:

1) **River basin:**
   - Class-I river in Central and Western Development Regions
   - Basin area: 35,780 km^2 in total consisting of mountainous basin 35,075 km^2 and plain area 705 km^2.
   - The plain area is called as Inner Terai having a narrow gorge in the lower end near Indian border.
   - At the gorge section, the Narayani barrage is located and providing water for the Nepal Gandak Western Canal Project.
   - Bharatpur city is located in the riverine area near the upper end of the plain area.
2) **River system:** Major tributaries in the inner Terai are the East Rapti and Rewa rivers. Numerous tributaries from the Siwalik hills also join to the Narayani in the plain.
3) **River channel:** River is braided in the plain area and has anabranches and islands in the river area. Grain size of the riverbed materials is coarse being distributed in a wide range from fine gravel to small cobbles. Changes in grain size along the river are not significant.
4) **River segments:**
   - Segment 2-1: From 18.4 km (Binai R. jct.) to 83.0 km (upper end of plain)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1988, 1993 and 1995 floods in the order of

severity.

- Kinds of damage: Bank erosion and flooding over farm lands.
- Suffering areas: 23 villages in 4 VDCs in Chitwan district, and 22 villages in 8 VDCs in Nawalparasi district.
- Conditions and mechanism of flooding: Bank erosion is the most serious problem in the basin. Frequent flooding occurs in the low-lying lands on the right bank in the lower reaches down from the East Rapti river junction

Principal Measures to be Taken for Narayani River:

1) Forest or grass belts will be provided on one side of the river, i.e., right dike of the Narayani downstream from the confluence of the East Rapti river, left dike upstream from the confluence, and right dike for the East Rapti river.
2) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
3) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
4) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(5) Tinau River

Present Conditions and Problems of Tinau River:

1) **River basin:**
   - Class-II river in Western Development Region
   - Basin area: 1,081 km^2 in total consisting of mountainous basin 669 km^2 and plain area 412 km^2.
   - Butwal city is located in the riverine area near the upper end of the plain.
   - The flood prone area of the Tinau river is partly covered by the service areas of the Bhairahawa Lumbini Groundwater Project.
2) **River system:** The Dano river diverts from the Tinau river near Butwal city and joins again at about 13 km upstream from the Indian border. The main Tinau river convey flood water and sediment from the Mahabharat ranges, and the Dano river those from the Siwalik hills and the Tinau river.
3) **River channel:** River is wide and braided in the upper reaches and becomes

narrow gradually toward lower reaches. Riverbed materials along the river changes from small cobbles in the upper reaches to fine sand in the lower reaches.

4) **River segments:**
   - Segment 2-2: From 0.0 km (Indian border) to 31.0 km
   - Segment 2-1: From 31.0 km to 41.0 km
   - Segment 1 : From 41.0 km to 59.5 km (upper end of plain)

5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1996, 1995 and 1993 floods in the order of severity.
   - Kinds of damages: Bank erosion and sedimentation over farm lands
   - Suffering areas: 51 villages in 12 VDCs in Rupandehi district.
   - Conditions and mechanism of flooding: Almost every year the Tinau river floods over and causes damages in riverine villages and farmlands. 1996-flood is the biggest in recent years and brought about epidemic disease such as cholera, dysentery, typhoid, etc., resulting in loss of 26 human lives in the whole Rupandehi district.

Principal Measures to be Taken for Tinau River:

1) A hydraulic control structure will be constructed for the Dano river at the diversion from the Tinau river.
2) Some drainage channels will be unified before joining the Dano river.
3) A branch of the Dano river will be closed securely with closing dike or controlled with diversion facility if necessary.
4) Forest belt will be provided for Segment 1 and forest or grass belt for Segments 2-2 and 2-1.
5) Cut-off channels will be constructed at the severe bends.
6) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
7) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
8) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(6) West Rapti River

Present Conditions and Problems of West Rapti River:

1) **River basin:**
   - Class-II river in Mid-Western Development Region
   - Basin area: 6,418 km^2 in total consisting of mountainous basin 5,800 km^2 and plain area 618 km^2.
   - Sikta Irrigation Project was proposed in 1980. However, the project was not implemented due to failure of coordination with India. India was constructing a barrage across the West Rapti near the border. The works are said to be suspended now.
2) **River system:** The West Rapti river can be divided into upper and lower basins by the narrow section upstream from Agaiya. The upper basin of the West Rapti is called as Dang valley surrounded by the northern slope of the Siwalik hills, southern slope of the Mahabharat ranges, and narrow gorge in the lower end. The lower basin of the West Rapti is a free meandering zone. The river course is changeable in the lower reaches near the Indian border.
3) **River channel:** River is wide and braided in the upper basin of the West Rapti river. In the lower basin of the West Rapti, river is wide and braided in the upper reaches and meandering in the lower reaches. Grain size of the riverbed materials changes clearly from gravel to sand. The gravel (coarse to very coarse) presents in the upper reaches of the both basins and the sand (fine to coarse) is found in the lower reaches of the both upper and lower basins.
4) **River segments:**

   Lower basin
   - Segment 2-2: From 0.0 km (Indian border) to 23.0 km (Jhijhari R. jct.)
   - Segment 2-1: From 23.0 km to 53.0 km (Agaiya at upper end of plain)

   Upper basin (Dang valley)
   - Segment 2-2: From 115.0 km (Bargaddi) to 132.0 km (Arjun R. jct.)
   - Segment 2-1: From 132.0 km to 163.5 (upper end of valley)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1997, 1996 and 1993 floods in the order of severity.
   - Kinds of damages: Bank erosion, flooding over farmlands and sedimentation.
   - Suffering areas: 23 wards in 8 VDCs in Banke district, and 33 villages in 9 VDCs in Dang district.

- Conditions and mechanism of flooding: In the upper basin (Dang valley), bank erosion and flooding over the farm lands are limited in the areas along the edge of the braided riverbed and confluence of the tributaries. In the lower basin, riverbed is said to be rising especially in the lower reaches and flood water flows over the riverine areas frequently. The river course also changes actively near the Indian border. After the 1997-flood, epidemic disease attacked the flood suffering areas in Dang and Banke districts, though detailed data are not available.

Principal Measures to be Taken for West Rapti River:

1) Confluence of the Dundawa river will be stabilized by river training works.
2) Anabranches will be closed securely with closing dike or controlled with diversion facilities if necessary.
3) Forest or grass belts will be formed in Segments 2-2 on both banks and in Segment 2-1 on left bank.
4) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
5) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
6) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(7) Babai River

Present Conditions and Problems of Babai River:

1) **River basin:**
   - Class-II river in Mid-Western Development Region
   - Basin area: 3,425 km^2 in total consisting of mountainous basin 3,054 km^2 and plain area 371 km^2.
   - Babai barrage exists at the upper end of the plain area and supply water to the left bank (east side) areas including flood prone areas of the Babai.
   - There is a scheme to convey irrigation water from the east canal to west side area across the Babai by siphon. This scheme will be implemented soon upon funding.
   - A study is being carried out by JICA to divert a part of water from the

Bheli river to the Babai river for power generation and irrigation purposes. This scheme will not affect significantly the flood flows of the Babai river.

2) **River system:** There is no major right tributaries joining in the downstream reaches of the barrage, though there are some small tributaries joining from the left. It is said that the Babai river shifted to the present course about 40 years ago.
3) **River channel:** At downstream of the barrage the Babai river expands its width abruptly and forms a braided channel. In the lower reaches, river course meanders severely. Grain size of the riverbed materials changes clearly from gravel (coarse to very coarse) in the upper reaches to sand (fine to medium) in the lower reaches.
4) **River segments:**
   - Segment 2-2: From 0.0 km (Indian border) to 30.0 km
   - Segment 2-1: From 30.0 km to 38.0 km
   - Segment 1 : From 38.0 km to 48.0 (Barrage at the upper end of plain)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1995, 1987 and 1996 floods in the order of severity.
   - Kinds of damages: Bank erosion, flooding over farm lands and sedimentation
   - Suffering areas: 7 wards in Gulariya municipality and 4 VDCs in Bardiya district.
   - Conditions and mechanism of flooding: Gulariya municipality and Mahamadpur VDC suffer from inundation almost every year. During the 1995-flood, about 470 families of Gulariya municipality were evacuated to the public facilities such as schools. After the flood, epidemic disease attacked the Gulariya municipality and two VDCs, 12 human lives were lost.

Principal Measures to be Taken for Babai River:

1) Right bank from 42.5 km to 45 km will be protected securely to protect farmer's irrigation canal and further to prevent river course shifting toward the Karnali river.
2) Old Babai river at 19.5 km will be closed securely with closing dike.
3) Anabranches will be closed securely at 12.3 km, 22.0 km and 29.8 km with closing dike or controlled with diversion facilities if necessary.

4) Forest belt will be provided in Segment 1 and forest or grass belt in Segments 2-2 and 2-1.
5) Alternative study should be carried out for the meander reaches near Kusumba Bazar and Indrapur bridge.
6) Bank protection works will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
7) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
8) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

(8) Khutiya River

Present Conditions and Problems of Khutiya River:

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 flows 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 large cobbles in the upper reaches to medium sand in the lower 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 of plain)
5) **Flood and sediment disasters:**
   - Major floods in past 10 years: 1997, 1986 and 1983 floods in the 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, encephalitis was infectious over the Kailali district. About 200 people over the district were attacked with the disease and half of them died.

Principal Measures to be Taken for Khutiya River:

1) Branch channels will be closed securely with closing dike or controlled with diversion facilities if necessary.
2) Forest belt will be provided for Segment 1 and forest or 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 will be implemented at the critical riverbanks based on the monitoring. Preventive measures for bank erosion will also be undertaken adopting bioengineering measures.
5) Watershed management will be carried out for erosion and runoff control by means of erosion control facilities, afforestation/reforestation, land use regulation, and publicity activities.
6) Flood plain management will be carried out adopting all the possible measures for mitigation of damage due to flood and sediment disasters.

4.6.2 Layout Plan

Layout of the flood mitigation Master Plan is shown in Fig. 4.10 for the eight river basins. The Figures show the general layout of watershed, river control and community development components for the flood mitigation plan, whose details were presented in the previous sections of this chapter.

4.6.3 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 implementation of the Master Plan project was estimated under the following conditions:

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

Exchange Rate of Currencies: Exchange rate of currencies are assumed as follows:

US$1.00 = NRs.67.93 = ¥115.14 (NRs.1.00 = ¥1.69)

Constitution of Project Cost: Project cost is composed of the following cost items;

1) Construction base cost: Unit cost basis
2) Compensation cost: Unit cost basis
3) Administration cost: 5% of [(1) + (2)]
4) Engineering service cost: Lump sum basis
5) Physical contingency: 10% of [(1) + (2) + (3) + (4)]
6) Price contingency (Financial cost only): At annual escalation rate of 3 % for foreign currency, and 10 % for local currency portions

Quantity of work, standard unit work cost and amount of project cost are shown in Table 4.5.

4.7 Action Plan toward Target Years

4.7.1 Sequence of Works

The Master Plan is proposed for implementation by the target year of 2017. The project works must be carried out effectively in orderly manner toward the target year. It is also important to realize the flood mitigation effects, even in the course of implementation, corresponding to the progress of work.

(1) Preparatory Works

Feasibility Study: A Feasibility Study will be conducted immediately after this, mainly covering the following:

1) River Survey: To obtain topographic maps along the river with smaller contour intervals, longitudinal river profiles and cross sections.
2) Restudy of Master Plan: Based on the river survey result.
3) Feasibility Study: The study will cover discrete environmental studies as well in order to obtain approval for project implementation from MOPE.

Fund Arrangement: The project cost estimated in the Feasibility Study is allocated

among the central/local governments and local communities, taking into consideration the nature of work and the capability of funding.

Definite Plan/Detail Design: A definite plan of the flood mitigation works, including river boundary line (RBL), will be drawn up after getting consent of the concerned central/local government agencies and local communities. A detailed design will be prepared of the project facilities.

Preservation of Lands: Population in the Terai is growing rapidly. Because of this, more and more people are living in flood prone areas close to the rivers. Therefore it is essential to preserve the lands for flood mitigation facilities. This should start immediately after the preparation of definite flood mitigation plan. Appropriate land use should also be encouraged as stated in the definite plan and detail design.

Research and Investigation: In parallel with implementation of the specific flood mitigation projects, research and investigation activities are needed to support the projects. The following are included among these, but not limited to:

1) **Flood and Sediment Runoff:** Study and analysis on flood runoff and sediment yield especially for class III rivers originating at Siwalik hills are necessary. Observations on a designated model basin would serve this purpose.
2) **Investigation of Bank Erosion characteristics:** Characteristics of bank erosion in the Terai have yet to be investigated. Mechanisms of bank erosion, erosion speed and width, etc. should be investigated in relation with the river segment, riverbed and bank materials, river flow condition, etc.
3) **Development of Bank Protection Works:** Various types of bank protection works should be introduced in each of the river segment, considering the effectiveness, materials available, and cost-performance. Recommended bank protection work for rivers in the Terai should be made through hydraulic model tests in the laboratory and prototype models in field.
4) **Research on Application of Bioengineering Technology:** In order to introduce bioengineering technology as a component of flood mitigation, research works and accumulation of experience are necessary, among others on the selection of plant species, type and function of work applicable, growing techniques, and contribution to income generation.

(2) Coordination For Flood Mitigation

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

(3) River Works

Channel Treatment Works:

1) Tributary Works: Tributary work to stop or control inflow/outflow from/to adjacent river basins will be implemented soon after the preparation of the definite plan.
2) Branch/Anabranch Work: Closing or control works of branches and anabranches will be carried out soon after the preparation of definite plan.

Bank Protection Works:

1) Spur/Revetment Work: River bank classified as Type-As bank needs protection works immediately and works are desirable for Type-A bank as well. The bank protection works will be executed continuously, primarily for Type-As banks, identified by periodic monitoring after every flood seasons.
2) Preventive Bank Protection Measures: Preventive bank protection measures by bioengineering is required immediately for Type-A bank and are desirable for all the river bank between river course and the river boundary line (RBL).

Dike Works:

1) Forest/Grass Belt: Forest belt will be provided on the RBL for Segment 1 (alluvial fan) in principle, while the forest or grass belt for Segments 2-1 and 2-2. The work can be carried out at any place and at any time after the preparation of definite plan, but for the purpose of marking the boundary, it is best to do it quickly.
2) Local dike, Dike Road and Ring Dike: These works for local dike, dike road and ring dike can be started after the preparation of definite plan from the places where the work is ready so as to realize the flood mitigation.
3) Retarding Basin: It is important to preserve the lands for the retarding basin, confining by forest belt, grass belt or earth dike.

Channel Excavation and COC Works:

1) Channel normalization: Channel normalization and cut-off channel works will be executed after the preparation of definite plan.

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

4.7.2 Action Plan

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

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

1) Preparatory works such as feasibility study, fund arrangement, definite plan/detail design, and preservation of lands.
2) Research and investigation, and coordination for watershed management and flood plain management in combination with community development activities.
3) Bank protection works at the critical sites.
4) Preventive bank protection works by bioengineering.
5) Bed material collection.

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

1) Channel treatment works.
2) Forest and grass belts work in field.
3) Dike works such as local dike, dike roads and ring dike in critical sites.
4) Channel excavation works and cut-off channel.

3rd Phase (Eleventh and Twelfth Plans: 2007-2017):

1) Continuation of activities for research/investigation and coordination, and works for bank protection, dike, channel excavation.
2) All the works and activities targeted for the Master Plan will be completed.

General action program for the implementation of the Master Plan project is shown in Fig. 4.11.

4.7.3 Implementation Arrangement

Principles: In principle, beneficiaries should undertake the flood mitigation measures for their own protection. However, the following should be implemented by the central government:

1) Large scale works that local government and community cannot afford;
2) Basic flood mitigation facilities;
3) Works requiring urgent implementation; and
4) Technical guidance, coordination and political arrangements to be taken from nation-wide viewpoint.

Watershed Management Component: Works and activities in the watershed areas are implemented by the central government. The watershed management component includes erosion control work, afforestation/reforestation and land use regulation, and publicity activities.

River control component: Works and activities in the plain area are implemented by the central government. The river control component includes channel treatment works, bank protection works, dike works, channel excavation works, and land use regulation.

Community development component: The community development activities for flood mitigation are carried out by the local community and VDC/DDC as well, for their own protection in the near-by area. The community development component includes activities for community mobilization, local coping measures, and community-based sustainable flood mitigation measures.

Associate activities: Aside from the above components project works, associate activities such as research/investigation and technical guidance regarding the project works are expected from the central government and other authorities concerned.

4.8 Economic Evaluation

(1) Effects of Flood Mitigation

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

1) **Reduction of damage due to flood and sediment:** Inundation and sedimentation will be alleviated and reduce damages of village houses, crop production, public facilities, etc.

2) **Protection of riverbank from erosion:** Loss of lands due to riverbank erosion are averted, and villages and farmlands will be protected.
3) **Indirect effects:** Owing to the reduction in damages in flood prone area, social and economic activities in the surrounding areas will not be interfered.
4) **Land enhancement:** Flood mitigation project ensures the social and economic activities in the flood prone area which enable further investments for the development of the flood prone area and the surrounding areas.
5) **Land reclamation:** Existing low-lying barren lands along the river turn to arable ones. Channel excavation and normalization at severely meandering section may create lands for agriculture and settlement.
6) **Flood-free embankment:** The earth embankment constructed as local dike and ring dike can be used as rural roads and flood-free areas in the flood prone area. The area will also serve for evacuation and flood fighting activities.
7) **Income generation:** The forest belt and grass belt for flood mitigation will generate community's income. The trees from the forest belt could be used for flood mitigation as well.
8) **Stabilization of residents' livelihood:** Flood free land is the basis of the residents' livelihood in the flood prone areas. Only under such conditions, residents are encouraged to accumulate their immovable and other properties, and accordingly can stabilize their livelihood.
9) **Community development:** The Master Plan places emphasis on flood mitigation through community development. The community-based approaches will forge links among the resident people and may enable other community development activities.

(2) Economic Evaluation for Master Plan Projects

Economic viability of the flood mitigation Master Plan was examined preliminarily. Out of the various effects listed in the previous section, (1) flood damage reduction benefit, (2) bank protection benefit, and (3) indirect benefit were considered as tangible benefit for the evaluation.

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

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

Conditions and Result of Evaluation: Evaluation was made for the existing basin conditions and future basin conditions in target year (2017). The benefit in the target year was assumed in proportional to the population projected. Cash flows of the project cost, maintenance cost and benefit are shown in Table 4.6. With these cash flows, the economic internal rate of return (EIRR), cost-benefit ratio (B/C), and net present value (NPV or B-C) were worked out. The results are summarized below.

(Result of Economic Evaluation)

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^6Rs)
Ratuwa	3.8	0.49	-121.3	9.6	0.97	-8.2
Lohandra	0.0	0.27	-204.6	2.8	0.42	-161.7
Lakhandei	3.6	0.47	-135.7	10.2	1.02	4.6
Narayani	4.0	0.50	-122.8	10.9	1.09	21.2
Tinau	2.8	0.42	-199.8	9.2	0.93	-24.5
W. Rapti	4.2	0.52	-47.9	11.8	1.18	17.7
Babai	9.3	0.94	-11.3	14.8	1.48	89.0
Khutiya	0.0	0.27	-36.2	4.8	0.56	-21.9

(Note) B/C and NPV were calculated under the discount rate of 10%.

Focusing on the future basin, the Babai river yields high EIRR value, while the value is low for the Lohandra and Khutiya river. Economic viability of the remaining 5 rivers is of same level ranging from 9.2 to 11.8. However, these evaluation results should be handled only as a rule of thumb, since the costs and benefits for the evaluation are estimated without topographic and river survey data.

(Further in-depth descriptions on the studies and analyses made in this chapter are compiled in SUPPORTING REPORT-C: BASIC INVESTIGATIONS AND STUDIES, and detailed discussions on the plan formulation for respective river basins are compiled in SUPPORTING REPORT-A (A1 through A8): FLOOD MITIGATION PLAN.)

Table 4.1

CRITERIA OF RIVER SEGMENT

	Segment M	Segment 1	Segment 2		Segment 3
			2-1	2-2	
Geomorphologic type	← Mountain →	← Alluvial fan →	← Natural levee zone →		← Delta →
Representative bed materials size (d_R)	Various	> 2 cm	3cm to 1cm	1cm to 0.3 mm	< 0.3 mm
Riverbank materials	Exposed rocks are often seen	Same materials as those of river bed, occasionally covered with thin silt layer	Mixture of fine sand, silt and clay with same materials as those of river bed at the bottom		Silt and clay
Gradient of channel	Various	1/60 to 1/400	1/400 to 1/5,000		1/5,000 to level
Meandering	Various	Little meander	Severe meandering, S-shaped meander and island are seen in the channel with large width-depth ratio		There are some large meanders and some others small meanders
Bank erosion	Very active	Very active	Medium; more active in the channel with larger bed materials		Not active and little river course change
Average channel depth	Various	0.5 to 3 m	2 to 8 m		3 to 8 m

(Remark) These criteria show general features of the segment which may vary depending the specific conditions of the rivers

CHARACTERISTICS OF RIVER CHANNEL

River stretch			River segment code	Ground slope (1/l)	Grain size		River width Bm (min-max) (m)
Reaches	From (km)	To (km)			d_{60} (mm)	d_R (mm)	
Ratuwa R.							
RA-1	0.0	13.0	2-2	1,180	0.30	0.30	356 (188-500)
RA-2	13.0	26.0	2-1	590	0.34	0.34	446 (275-638)
RA-3	26.0	36.2	1	320	0.43	0.43	516 (300-688)
RA-4	36.2	43.7	1	170	0.74	0.74	348 (225-425)
Lohandra R.							
LO-1	0.0	14.0	2-2	2,000	0.30	0.30	55 (25-100)
LO-2	14.0	33.1	2-2	970	0.27	0.27	89 (25-163)
LO-3	33.1	42.0	2-1	970	1.2	1.2	119 (75-238)
LO-4	42.0	49.6	2-1	320	2.4	2.4	200 (75-250)
LO-5	49.6	58.8	1	180	19	82	221 (138-350)
LO-6	58.8	67.5	1	80	23	81	178 (25-513)
Lakhandei R.							
LA-1	0.0	21.0	2-2	1,240	0.20	0.20	143 (38-375)
LA-2	21.0	37.0	2-1	520	0.31	0.31	326 (100-588)
LA-3	37.0	43.0	1	240	0.35	0.35	371 (200-588)
LA-4	43.0	51.4	1	240	4.3	4.3	547 (200-888)
Narayani R							
NA-1	(Narrow reaches)		-	-	-	-	226 (150-350)
NA-2	18.4	44.9	2-1	1,560	39	60	1,463 (400-2450)
NA-3	44.9	83.0	2-1	720	27	73	1,394 (300-2500)
Tinau R.							
TI-1	0.0	12.7	2-2	3,180	0.18	0.18	163 (88-325)
TI-2	12.7	31.0	2-2	2,030	0.39	0.39	79 (50-150)
TI-3	31.0	41.0	2-1	1,000	3.6	3.6	159 (63-325)
TI-4	41.0	53.0	1	430	17	42	557 (325-875)
TI-5	53.0	59.5	1	110	46	96	450 (88-925)
W.Rapti R.							
WR-1	0.0	23.0	2-2	1,920	0.29	0.29	417 (225-750)
WR-2	23.0	53.0	2-1	1,030	29	55	790 (238-1700)
WR-3	(Narrow reaches)		-	-	0.28	0.28	224 (75-950)
WR-4	115.0	132.0	2-2	1,130	0.31	0.31	760 (350-1400)
WR-5	132.0	163.5	2-1	540	24	47	827 (125-1400)
Babai R.							
BA-1	0.0	30.0	2-2	2,310	0.26	0.26	427 (88-724)
BA-2	30.0	38.0	2-1	890	43	63	592 (338-700)
BA-3	38.0	48.0	1	320	38	71	858 (325-1325)
Khutiya R.							
KH-1	0.0	11.5	2-2	-	0.58	0.58	346 (175-650)
KH-2	11.5	27.0	2-1	-	5.9	15	167 (50-350)
KH-3	27.0	35.0	1	-	84	124	355 (175-650)

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

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

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

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 --- Behcu) - 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

RATUWA RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				310,842
1. Preparatory Works	L.S.	1.00		28,258
2. Bank Protection Works				69,627
2-1 Pile Spur (Type-A)	km	2.40	5,301	12,722
2-2 Gabion Spur (Type-A)	km	6.90	8,247	56,904
3. Cannel Works				58,980
3-1 River Boundary Line	km	99.80	27	2,695
3-2 Tree Belt	ha	191.75	68	13,039
3-3 Grass Belt	ha	279.75	126	35,249
3-4 Cut-off Cannel	1000m3	62.50	93	5,813
3-5 Closing Dike/structure	place	1.00	2,185	2,185
4. Ring Dike Works				128,288
4-1 Dike Embankment	km	20.90	2,596	54,256
4-2 Drainage Sluice	place	40.00	1,275	51,000
4-3 Gravel Metaling	km	20.90	1,102	23,032
5. Miscellaneous Works	L.S.	1.00		25,689
II . Compensation Cost	L.S.	1.00		124,392
III. Administration Cost	L.S.	1.00		21,762
IV. Engineering Service	L.S.	1.00		46,626
V . Physical Contingency	L.S.	1.00		48,186
Poject Cost				551,808

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

PROJECT COST FOR MASTER PLAN

LOHANDRA RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				376,545
1. Preparatory Works	L.S.	1.00		34,231
2. Bank Protection Works				39,878
2-1 Pile Spur (Type-A)	km	4.10	5,301	21,734
2-2 Gabion Spur (Type-A)	km	2.20	8,247	18,143
3. Cannel Works				95,644
3-1 River Boundary Line	km	105.00	27	2,835
3-2 Tree Belt	ha	55.50	68	3,774
3-3 Grass Belt	ha	436.50	126	54,999
3-4 Cut-off Cannel	1000m3	272.00	93	25,296
3-5 Closing Dike/structure	place	4.00	2,185	8,740
4. Ring Dike Works				175,672
4-1 Dike Embankment	km	31.30	2,596	81,255
4-2 Drainage Sluice	place	47.00	1,275	59,925
4-3 Gravel Metaling	km	31.30	1,102	34,493
5. Miscellaneous Works	L.S.	1.00		31,119
II . Compensation Cost	L.S.	1.00		135,792
III. Administration Cost	L.S.	1.00		25,617
IV. Engineering Service	L.S.	1.00		56,482
V . Physical Contingency	L.S.	1.00		56,882
Poject Cost				651,317

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

Table 4.5 (1/4)

LAKHANDEI RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				348,680
1. Preparatory Works	L.S.	1.00		31,698
2. Bank Protection Works				131,417
2-1 Pile Spur (Type-A)	km	6.90	5,301	36,577
2-2 Gabion Spur (Type-A)	km	11.50	8,247	94,841
3. Cannel Works				108,416
3-1 River Boundary Line	km	75.50	27	2,039
3-2 Tree Belt	ha	27.50	68	1,870
3-3 Grass Belt	ha	350.00	126	44,100
3-4 Channel Excavation	1000m3	461.59	93	42,928
3-5 Closing Dike/structure	place	8.00	2,185	17,480
4. Ring Dike Works				24,699
4-1 Dike Embankment	km	5.30	2,596	13,759
4-2 Drainage Sluice	place	4.00	1,275	5,100
4-3 Gravel Metaling	km	5.30	1,102	5,841
5. Dike Road Works				23,632
5-1 Dike Embankment	km	6.55	2,506	16,414
5-2 Gravel Metaling	km	6.55	1,102	7,218
6. Miscellaneous Works	L.S.	1.00		28,817
II . Compensation Cost	L.S.	1.00		120,771
III. Administration Cost	L.S.	1.00		23,473
IV. Engineering Service	L.S.	1.00		52,302
V . Physical Contingency	L.S.	1.00		52,175
Poject Cost				597,401

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

PROJECT COST FOR MASTER PLAN

NARAYANI RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				333,927
1. Preparatory Works	L.S.	1.00		30,357
2. Bank Protection Works				138,278
2-1 Gabion Spur (Type-A)	km	1.80	8,247	14,845
2-2 Gabion Spur (Type-B)	km	1.40	10,296	14,414
2-3 Gabion Spur (Type-C)	km	10.10	10,794	109,019
3. Cannel Works				50,692
3-1 River Boundary Line	km	88.60	27	2,392
3-2 Tree Belt	ha	199.75	68	13,583
3-3 Grass Belt	ha	199.75	126	25,169
3-4 Closing Dike/structure	place	4.00	2,387	9,548
4. Ring Dike Works				87,003
4-1 Dike Embankment	km	18.70	2,596	48,545
4-2 Drainage Sluice	place	14.00	1,275	17,850
4-3 Gravel Metaling	km	18.70	1,102	20,607
5. Miscellaneous Works	L.S.	1.00		27,597
II . Compensation Cost	L.S.	1.00		117,963
III. Administration Cost	L.S.	1.00		22,594
IV. Engineering Service	L.S.	1.00		50,089
V . Physical Contingency	L.S.	1.00		50,198
Poject Cost				574,771

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

Table 4.5 (2/4)

TINAUI RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				408,143
1. Preparatory Works	L.S.	1.00		37,104
2. Bank Protection Works				117,336
2-1 Pile Spur (Type-B)	km	9.60	7,289	69,974
2-2 Gabion Spur (Type-B)	km	4.60	10,296	47,362
3. Cannel Works				122,808
3-1 River Boundary Line	km	156.60	27	4,228
3-2 Tree Belt	ha	91.75	68	6,239
3-3 Grass Belt	ha	691.25	126	87,098
3-4 Cut-off Cannel	1000m3	143.10	93	13,308
3-5 Closing Dike/structure	place	5.00	2,387	11,935
4. Ring Dike Works				97,164
4-1 Dike Embankment	km	18.00	2,596	46,728
4-2 Drainage Sluice	place	24.00	1,275	30,600
4-3 Gravel Metaling	km	18.00	1,102	19,836
5. Miscellaneous Works	L.S.	1.00		33,731
II . Compensation Cost	L.S.	1.00		231,255
III. Administration Cost	L.S.	1.00		31,970
IV. Engineering Service	L.S.	1.00		61,221
V. Physical Contingency	L.S.	1.00		70,062
Poject Cost				802,651

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

PROJECT COST FOR MASTER PLAN

WEST RAPTI RIVER (unit: NRs1000)

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

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

Table 4.5 (3/4)

BABAI RIVER (unit: NRs1000)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				265,885
1. Preparatory Works	L.S.	1.00		24,171
2. Bank Protection Works				167,558
2-1 Pile Spur (Type-B)	km	13.10	7,289	95,486
2-2 Gabion Spur (Type-B)	km	7.00	10,296	72,072
3. Cannel Works				52,182
3-1 River Boundary Line	km	76.00	27	2,052
3-2 Tree Belt	ha	40.75	68	2,771
3-3 Grass Belt	ha	243.25	126	30,650
3-4 Closing Dike/structure	place	7.00	2,387	16,709
4. Dike Road				0
4-1 Dike Embankment	km	0.00	2,506	0
4-2 Gravel Metaling	km	0.00	1,102	0
5. Miscellaneous Works	L.S.	1.00		21,974
II . Compensation Cost	L.S.	1.00		68,160
III . Administration Cost	L.S.	1.00		16,702
IV . Engineering Service	L.S.	1.00		39,883
V . Physical Contingency	L.S.	1.00		37,393
Poject Cost				428,022

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

PROJECT COST FOR MASTER PLAN

KHUTIYA RIVER (unit: NRs1000)

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

Table 4.5 (4/4)

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Ratuwa (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	7,693	0	7,693	0	7,693	0
2 2000	7,693	0	7,693	0	6,994	0
3 2001	15,740	0	15,740	0	13,008	0
4 2002	38,086	0	38,086	0	28,615	0
5 2003	38,086	203	38,289	2,263	26,152	1,545
6 2004	38,086	406	38,492	4,525	23,901	2,810
7 2005	27,638	609	28,247	6,788	15,945	3,832
8 2006	27,638	757	28,395	8,430	14,571	4,326
9 2007	27,638	904	28,542	10,071	13,315	4,698
10 2008	27,638	1,052	28,690	11,713	12,167	4,968
11 2009	27,638	1,199	28,837	13,355	11,118	5,149
12 2010	27,638	1,347	28,985	14,997	10,159	5,256
13 2011	27,638	1,494	29,132	16,639	9,282	5,302
14 2012	27,638	1,642	29,280	18,281	8,481	5,295
15 2013	27,638	1,789	29,427	19,923	7,749	5,246
16 2014	27,638	1,936	29,574	21,565	7,080	5,162
17 2015	27,638	2,084	29,722	23,206	6,468	5,050
18 2016	27,638	2,231	29,869	24,848	5,909	4,916
19 2017	19,591	2,379	21,970	26,490	3,951	4,764
20 2018		2,483	2,483	27,654	406	4,522
21 2019		2,483	2,483	27,654	369	4,111
22 2020		2,483	2,483	27,654	336	3,737
23 2021		2,483	2,483	27,654	305	3,397
24 2022		2,483	2,483	27,654	277	3,088
25 2023		2,483	2,483	27,654	252	2,808
26 2024		2,483	2,483	27,654	229	2,552
27 2025		2,483	2,483	27,654	208	2,320
28 2026		2,483	2,483	27,654	189	2,109
29 2027		2,483	2,483	27,654	172	1,918
30 2028		2,483	2,483	27,654	157	1,743
31 2029		2,483	2,483	27,654	142	1,585
32 2030		2,483	2,483	27,654	129	1,441
33 2031		2,483	2,483	27,654	118	1,310
34 2032		2,483	2,483	27,654	107	1,191
35 2033		2,483	2,483	27,654	97	1,082
36 2034		2,483	2,483	27,654	88	984
37 2035		2,483	2,483	27,654	80	895
38 2036		2,483	2,483	27,654	73	813
39 2037		2,483	2,483	27,654	66	739
40 2038		2,483	2,483	27,654	60	672
41 2039		2,483	2,483	27,654	55	611
42 2040		2,483	2,483	27,654	50	555
43 2041		2,483	2,483	27,654	45	505
44 2042		2,483	2,483	27,654	41	459
45 2043		2,483	2,483	27,654	37	417
46 2044		2,483	2,483	27,654	34	379
47 2045		2,483	2,483	27,654	31	345
48 2046		2,483	2,483	27,654	28	314
49 2047		2,483	2,483	27,654	26	285
50 2048		2,483	2,483	27,654	23	259
Total	496,631	97,010	593,641	1,080,368	236,793	115,467

EIRR: 3.8%
B/C: 0.49
NPV(B-C): -121,326 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

River: Ratuwa (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	7,693	0	7,693	0	7,693	0
2 2000	7,693	0	7,693	0	6,994	0
3 2001	15,740	0	15,740	0	13,008	0
4 2002	38,086	0	38,086	0	28,615	0
5 2003	38,086	203	38,289	4,480	26,152	3,060
6 2004	38,086	406	38,492	8,960	23,901	5,563
7 2005	27,638	609	28,247	13,440	15,945	7,586
8 2006	27,638	757	28,395	16,691	14,571	8,565
9 2007	27,638	904	28,542	19,942	13,315	9,303
10 2008	27,638	1,052	28,690	23,192	12,167	9,836
11 2009	27,638	1,199	28,837	26,443	11,118	10,195
12 2010	27,638	1,347	28,985	29,694	10,159	10,408
13 2011	27,638	1,494	29,132	32,945	9,282	10,497
14 2012	27,638	1,642	29,280	36,196	8,481	10,485
15 2013	27,638	1,789	29,427	39,447	7,749	10,388
16 2014	27,638	1,936	29,574	42,698	7,080	10,222
17 2015	27,638	2,084	29,722	45,949	6,468	10,000
18 2016	27,638	2,231	29,869	49,200	5,909	9,734
19 2017	19,591	2,379	21,970	52,451	3,951	9,434
20 2018		2,483	2,483	54,755	406	8,953
21 2019		2,483	2,483	54,755	369	8,139
22 2020		2,483	2,483	54,755	336	7,399
23 2021		2,483	2,483	54,755	305	6,726
24 2022		2,483	2,483	54,755	277	6,115
25 2023		2,483	2,483	54,755	252	5,559
26 2024		2,483	2,483	54,755	229	5,054
27 2025		2,483	2,483	54,755	208	4,594
28 2026		2,483	2,483	54,755	189	4,177
29 2027		2,483	2,483	54,755	172	3,797
30 2028		2,483	2,483	54,755	157	3,452
31 2029		2,483	2,483	54,755	142	3,138
32 2030		2,483	2,483	54,755	129	2,853
33 2031		2,483	2,483	54,755	118	2,593
34 2032		2,483	2,483	54,755	107	2,358
35 2033		2,483	2,483	54,755	97	2,143
36 2034		2,483	2,483	54,755	88	1,948
37 2035		2,483	2,483	54,755	80	1,771
38 2036		2,483	2,483	54,755	73	1,610
39 2037		2,483	2,483	54,755	66	1,464
40 2038		2,483	2,483	54,755	60	1,331
41 2039		2,483	2,483	54,755	55	1,210
42 2040		2,483	2,483	54,755	50	1,100
43 2041		2,483	2,483	54,755	45	1,000
44 2042		2,483	2,483	54,755	41	909
45 2043		2,483	2,483	54,755	37	826
46 2044		2,483	2,483	54,755	34	751
47 2045		2,483	2,483	54,755	31	683
48 2046		2,483	2,483	54,755	28	621
49 2047		2,483	2,483	54,755	26	564
50 2048		2,483	2,483	54,755	23	513
Total	496,631	97,010	593,641	2,139,129	236,793	228,625

EIRR: 9.6%
B/C: 0.97
NPV(B-C): -8,168 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Lohadra (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	9,319	0	9,319	0	9,319	0
2 2000	9,319	0	9,319	0	8,472	0
3 2001	18,104	0	18,104	0	14,962	0
4 2002	45,173	0	45,173	0	33,939	0
5 2003	45,173	241	45,414	1,478	31,018	1,010
6 2004	45,173	482	45,655	2,957	28,348	1,836
7 2005	32,516	723	33,239	4,435	18,762	2,503
8 2006	32,516	896	33,412	5,499	17,146	2,822
9 2007	32,516	1,070	33,586	6,563	15,668	3,062
10 2008	32,516	1,243	33,759	7,627	14,317	3,235
11 2009	32,516	1,417	33,933	8,691	13,083	3,351
12 2010	32,516	1,590	34,106	9,756	11,954	3,419
13 2011	32,516	1,764	34,280	10,820	10,923	3,447
14 2012	32,516	1,937	34,453	11,884	9,980	3,442
15 2013	32,516	2,111	34,627	12,948	9,118	3,410
16 2014	32,516	2,284	34,800	14,012	8,331	3,354
17 2015	32,516	2,457	34,973	15,076	7,611	3,281
18 2016	32,516	2,631	35,147	16,140	6,954	3,193
19 2017	23,732	2,804	26,536	17,204	4,773	3,094
20 2018		2,931	2,931	17,981	479	2,940
21 2019		2,931	2,931	17,981	436	2,673
22 2020		2,931	2,931	17,981	396	2,430
23 2021		2,931	2,931	17,981	360	2,209
24 2022		2,931	2,931	17,981	327	2,008
25 2023		2,931	2,931	17,981	298	1,826
26 2024		2,931	2,931	17,981	271	1,660
27 2025		2,931	2,931	17,981	246	1,509
28 2026		2,931	2,931	17,981	224	1,372
29 2027		2,931	2,931	17,981	203	1,247
30 2028		2,931	2,931	17,981	185	1,134
31 2029		2,931	2,931	17,981	168	1,030
32 2030		2,931	2,931	17,981	153	937
33 2031		2,931	2,931	17,981	139	852
34 2032		2,931	2,931	17,981	126	774
35 2033		2,931	2,931	17,981	115	704
36 2034		2,931	2,931	17,981	104	640
37 2035		2,931	2,931	17,981	95	582
38 2036		2,931	2,931	17,981	86	529
39 2037		2,931	2,931	17,981	78	481
40 2038		2,931	2,931	17,981	71	437
41 2039		2,931	2,931	17,981	65	397
42 2040		2,931	2,931	17,981	59	361
43 2041		2,931	2,931	17,981	54	328
44 2042		2,931	2,931	17,981	49	298
45 2043		2,931	2,931	17,981	44	271
46 2044		2,931	2,931	17,981	40	247
47 2045		2,931	2,931	17,981	37	224
48 2046		2,931	2,931	17,981	33	204
49 2047		2,931	2,931	17,981	30	185
50 2048		2,931	2,931	17,981	27	168
Total	586,185	114,509	700,694	702,502	279,675	75,113

EIRR: 0.0%
B/C: 0.27
NPV(B-C): -204,559 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

River: Lohadra (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	9,319	0	9,319	0	9,319	0
2 2000	9,319	0	9,319	0	8,472	0
3 2001	18,104	0	18,104	0	14,962	0
4 2002	45,173	0	45,173	0	33,939	0
5 2003	45,173	241	45,414	2,321	31,018	1,585
6 2004	45,173	482	45,655	4,642	28,348	2,882
7 2005	32,516	723	33,239	6 963	18,762	3,930
8 2006	32,516	896	33,412	8,634	17,146	4,430
9 2007	32,516	1,070	33,586	10,304	15,668	4,807
10 2008	32,516	1,243	33,759	11,975	14,317	5,079
11 2009	32,516	1,417	33,933	13,646	13,083	5,261
12 2010	32,516	1,590	34,106	15,316	11,954	5,368
13 2011	32,516	1,764	34,280	16,987	10,923	5,413
14 2012	32,516	1,937	34,453	18,658	9,980	5,404
15 2013	32,516	2,111	34,627	20,328	9,118	5,353
16 2014	32,516	2,284	34,800	21,999	8,331	5,266
17 2015	32,516	2,457	34,973	23,670	7,611	5,151
18 2016	32,516	2,631	35,147	25,340	6,954	5,013
19 2017	23,732	2,804	26,536	27,011	4,773	4,858
20 2018		2,931	2,931	28,230	479	4,616
21 2019		2,931	2,931	28,230	436	4,196
22 2020		2,931	2,931	28,230	396	3,815
23 2021		2,931	2,931	28,230	360	3,468
24 2022		2,931	2,931	28,230	327	3,153
25 2023		2,931	2,931	28,230	298	2,866
26 2024		2,931	2,931	28,230	271	2,606
27 2025		2,931	2,931	28,230	246	2,369
28 2026		2,931	2,931	28,230	224	2,153
29 2027		2,931	2,931	28,230	203	1,958
30 2028		2,931	2,931	28,230	185	1,780
31 2029		2,931	2,931	28,230	168	1,618
32 2030		2,931	2,931	28,230	153	1,471
33 2031		2,931	2,931	28,230	139	1,337
34 2032		2,931	2,931	28,230	126	1,215
35 2033		2,931	2,931	28,230	115	1,105
36 2034		2,931	2,931	28,230	104	1,005
37 2035		2,931	2,931	28,230	95	913
38 2036		2,931	2,931	28,230	86	830
39 2037		2,931	2,931	28,230	78	755
40 2038		2,931	2,931	28,230	71	686
41 2039		2,931	2,931	28,230	65	624
42 2040		2,931	2,931	28,230	59	567
43 2041		2,931	2,931	28,230	54	515
44 2042		2,931	2,931	28,230	49	469
45 2043		2,931	2,931	28,230	44	426
46 2044		2,931	2,931	28,230	40	387
47 2045		2,931	2,931	28,230	37	352
48 2046		2,931	2,931	28,230	33	320
49 2047		2,931	2,931	28,230	30	291
50 2048		2,931	2,931	28,230	27	265
Total	586,185	114,509	700,694	1,102,928	279,675	117,931

EIRR: 2.8%
B/C: 0.42
NPV(B-C): -161,743 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN

(Existing Basin)

River: Lakhandei

(Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	8,630	0	8,630	0	8,630	0
2 2000	8,630	0	8,630	0	7,845	0
3 2001	16,442	0	16,442	0	13,588	0
4 2002	41,509	0	41,509	0	31,186	0
5 2003	41,509	221	41,730	2,384	28,502	1,628
6 2004	41,509	443	41,952	4,767	26,049	2,960
7 2005	29,788	664	30,452	7,151	17,190	4,036
8 2006	29,788	823	30,611	8,861	15,708	4,547
9 2007	29,788	982	30,770	10,572	14,354	4,932
10 2008	29,788	1,141	30,929	12,282	13,117	5,209
11 2009	29,788	1,300	31,088	13,993	11,986	5,395
12 2010	29,788	1,459	31,247	15,703	10,952	5,504
13 2011	29,788	1,618	31,406	17,414	10,007	5,549
14 2012	29,788	1,777	31,565	19,124	9,143	5,540
15 2013	29,788	1,935	31,723	20,835	8,354	5,486
16 2014	29,788	2,094	31,882	22,545	7,632	5,397
17 2015	29,788	2,253	32,041	24,256	6,973	5,279
18 2016	29,788	2,412	32,200	25,967	6,371	5,137
19 2017	21,976	2,571	24,547	27,677	4,415	4,978
20 2018		2,688	2,688	28,939	440	4,732
21 2019		2,688	2,688	28,939	400	4,302
22 2020		2,688	2,688	28,939	363	3,911
23 2021		2,688	2,688	28,939	330	3,555
24 2022		2,688	2,688	28,939	300	3,232
25 2023		2,688	2,688	28,939	273	2,938
26 2024		2,688	2,688	28,939	248	2,671
27 2025		2,688	2,688	28,939	226	2,428
28 2026		2,688	2,688	28,939	205	2,207
29 2027		2,688	2,688	28,939	186	2,007
30 2028		2,688	2,688	28,939	169	1,824
31 2029		2,688	2,688	28,939	154	1,658
32 2030		2,688	2,688	28,939	140	1,508
33 2031		2,688	2,688	28,939	127	1,371
34 2032		2,688	2,688	28,939	116	1,246
35 2033		2,688	2,688	28,939	105	1,133
36 2034		2,688	2,688	28,939	96	1,030
37 2035		2,688	2,688	28,939	87	936
38 2036		2,688	2,688	28,939	79	851
39 2037		2,688	2,688	28,939	72	774
40 2038		2,688	2,688	28,939	65	703
41 2039		2,688	2,688	28,939	59	639
42 2040		2,688	2,688	28,939	54	581
43 2041		2,688	2,688	28,939	49	528
44 2042		2,688	2,688	28,939	45	480
45 2043		2,688	2,688	28,939	41	437
46 2044		2,688	2,688	28,939	37	397
47 2045		2,688	2,688	28,939	34	361
48 2046		2,688	2,688	28,939	30	328
49 2047		2,688	2,688	28,939	28	298
50 2048		2,688	2,688	28,939	25	271
Total	537,661	105,031	642,692	1,130,640	256,586	120,915

EIRR: 3.6%
B/C: 0.47
NPV(B-C): -135,672 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN

(Future Basin)

River: Lakhandei

(Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	8,630	0	8,630	0	8,630	0
2 2000	8,630	0	8,630	0	7,845	0
3 2001	16,442	0	16,442	0	13,588	0
4 2002	41,509	0	41,509	0	31,186	0
5 2003	41,509	221	41,730	5,148	28,502	3,516
6 2004	41,509	443	41,952	10,297	26,049	6,394
7 2005	29,788	664	30,452	15,445	17,190	8,719
8 2006	29,788	823	30,611	19,140	15,708	9,822
9 2007	29,788	982	30,770	22,835	14,354	10,653
10 2008	29,788	1,141	30,929	26,530	13,117	11,251
11 2009	29,788	1,300	31,088	30,224	11,986	11,653
12 2010	29,788	1,459	31,247	33,919	10,952	11,888
13 2011	29,788	1,618	31,406	37,614	10,007	11,985
14 2012	29,788	1,777	31,565	41,309	9,143	11,966
15 2013	29,788	1,935	31,723	45,003	8,354	11,851
16 2014	29,788	2,094	31,882	48,698	7,632	11,658
17 2015	29,788	2,253	32,041	52,393	6,973	11,402
18 2016	29,788	2,412	32,200	56,088	6,371	11,097
19 2017	21,976	2,571	24,547	59,782	4,415	10,752
20 2018		2,688	2,688	62,508	440	10,221
21 2019		2,688	2,688	62,508	400	9,291
22 2020		2,688	2,688	62,508	363	8,447
23 2021		2,688	2,688	62,508	330	7,679
24 2022		2,688	2,688	62,508	300	6,981
25 2023		2,688	2,688	62,508	273	6,346
26 2024		2,688	2,688	62,508	248	5,769
27 2025		2,688	2,688	62,508	226	5,245
28 2026		2,688	2,688	62,508	205	4,768
29 2027		2,688	2,688	62,508	186	4,335
30 2028		2,688	2,688	62,508	169	3,940
31 2029		2,688	2,688	62,508	154	3,582
32 2030		2,688	2,688	62,508	140	3,257
33 2031		2,688	2,688	62,508	127	2,961
34 2032		2,688	2,688	62,508	116	2,691
35 2033		2,688	2,688	62,508	105	2,447
36 2034		2,688	2,688	62,508	96	2,224
37 2035		2,688	2,688	62,508	87	2,022
38 2036		2,688	2,688	62,508	79	1,838
39 2037		2,688	2,688	62,508	72	1,671
40 2038		2,688	2,688	62,508	65	1,519
41 2039		2,688	2,688	62,508	59	1,381
42 2040		2,688	2,688	62,508	54	1,256
43 2041		2,688	2,688	62,508	49	1,141
44 2042		2,688	2,688	62,508	45	1,038
45 2043		2,688	2,688	62,508	41	943
46 2044		2,688	2,688	62,508	37	858
47 2045		2,688	2,688	62,508	34	780
48 2046		2,688	2,688	62,508	30	709
49 2047		2,688	2,688	62,508	28	644
50 2048		2,688	2,688	62,508	25	586
Total	537,661	105,031	642,692	2,442,183	256,586	261,176

EIRR: 10.2%
B/C: 1.02
NPV(B-C): 4,589 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Narayani (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	8,265	0	8,265	0	8,265	0
2 2000	8,265	0	8,265	0	7,514	0
3 2001	15,895	0	15,895	0	13,136	0
4 2002	39,901	0	39,901	0	29,978	0
5 2003	39,901	213	40,114	2,444	27,398	1,669
6 2004	39,901	426	40,327	4,888	25,040	3,035
7 2005	28,677	639	29,316	7,332	16,548	4,138
8 2006	28,677	792	29,469	9,088	15,122	4,664
9 2007	28,677	944	29,621	10,844	13,819	5,059
10 2008	28,677	1,097	29,774	12,601	12,627	5,344
11 2009	28,677	1,250	29,927	14,357	11,538	5,535
12 2010	28,677	1,403	30,080	16,113	10,543	5,648
13 2011	28,677	1,556	30,233	17,870	9,633	5,694
14 2012	28,677	1,709	30,386	19,626	8,802	5,685
15 2013	28,677	1,862	30,539	21,383	8,042	5,631
16 2014	28,677	2,015	30,692	23,139	7,347	5,539
17 2015	28,677	2,168	30,845	24,895	6,713	5,418
18 2016	28,677	2,321	30,998	26,652	6,133	5,273
19 2017	21,046	2,474	23,520	28,408	4,230	5,109
20 2018		2,586	2,586	29,697	423	4,856
21 2019		2,586	2,586	29,697	384	4,414
22 2020		2,586	2,586	29,697	350	4,013
23 2021		2,586	2,586	29,697	318	3,648
24 2022		2,586	2,586	29,697	289	3,317
25 2023		2,586	2,586	29,697	263	3,015
26 2024		2,586	2,586	29,697	239	2,741
27 2025		2,586	2,586	29,697	217	2,492
28 2026		2,586	2,586	29,697	197	2,265
29 2027		2,586	2,586	29,697	179	2,059
30 2028		2,586	2,586	29,697	163	1,872
31 2029		2,586	2,586	29,697	148	1,702
32 2030		2,586	2,586	29,697	135	1,547
33 2031		2,586	2,586	29,697	123	1,407
34 2032		2,586	2,586	29,697	111	1,279
35 2033		2,586	2,586	29,697	101	1,162
36 2034		2,586	2,586	29,697	92	1,057
37 2035		2,586	2,586	29,697	84	961
38 2036		2,586	2,586	29,697	76	873
39 2037		2,586	2,586	29,697	69	794
40 2038		2,586	2,586	29,697	63	722
41 2039		2,586	2,586	29,697	57	656
42 2040		2,586	2,586	29,697	52	597
43 2041		2,586	2,586	29,697	47	542
44 2042		2,586	2,586	29,697	43	493
45 2043		2,586	2,586	29,697	39	448
46 2044		2,586	2,586	29,697	35	407
47 2045		2,586	2,586	29,697	32	370
48 2046		2,586	2,586	29,697	29	337
49 2047		2,586	2,586	29,697	27	306
50 2048		2,586	2,586	29,697	24	278
Total	517,298	101,053	618,351	1,160,245	246,839	124,071

EIRR: 4.0%
B/C: 0.50
NPV(B-C): -122,768 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

River: Narayani (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	8,265	0	8,265	0	8,265	0
2 2000	8,265	0	8,265	0	7,514	0
3 2001	15,895	0	15,895	0	13,136	0
4 2002	39,901	0	39,901	0	29,978	0
5 2003	39,901	213	40,114	5,279	27,398	3,605
6 2004	39,901	426	40,327	10,557	25,040	6,555
7 2005	28,677	639	29,316	15,836	16,548	8,939
8 2006	28,677	792	29,469	19,630	15,122	10,073
9 2007	28,677	944	29,621	23,424	13,819	10,927
10 2008	28,677	1,097	29,774	27,217	12,627	11,543
11 2009	28,677	1,250	29,927	31,011	11,538	11,956
12 2010	28,677	1,403	30,080	34,805	10,543	12,199
13 2011	28,677	1,556	30,233	38,599	9,633	12,299
14 2012	28,677	1,709	30,386	42,392	8,802	12,280
15 2013	28,677	1,862	30,539	46,186	8,042	12,162
16 2014	28,677	2,015	30,692	49,980	7,347	11,965
17 2015	28,677	2,168	30,845	53,774	6,713	11,703
18 2016	28,677	2,321	30,998	57,567	6,133	11,389
19 2017	21,046	2,474	23,520	61,361	4,230	11,036
20 2018		2,586	2,586	64,146	423	10,488
21 2019		2,586	2,586	64,146	384	9,535
22 2020		2,586	2,586	64,146	350	8,668
23 2021		2,586	2,586	64,146	318	7,880
24 2022		2,586	2,586	64,146	289	7,164
25 2023		2,586	2,586	64,146	263	6,512
26 2024		2,586	2,586	64,146	239	5,920
27 2025		2,586	2,586	64,146	217	5,382
28 2026		2,586	2,586	64,146	197	4,893
29 2027		2,586	2,586	64,146	179	4,448
30 2028		2,586	2,586	64,146	163	4,044
31 2029		2,586	2,586	64,146	148	3,676
32 2030		2,586	2,586	64,146	135	3,342
33 2031		2,586	2,586	64,146	123	3,038
34 2032		2,586	2,586	64,146	111	2,762
35 2033		2,586	2,586	64,146	101	2,511
36 2034		2,586	2,586	64,146	92	2,283
37 2035		2,586	2,586	64,146	84	2,075
38 2036		2,586	2,586	64,146	76	1,886
39 2037		2,586	2,586	64,146	69	1,715
40 2038		2,586	2,586	64,146	63	1,559
41 2039		2,586	2,586	64,146	57	1,417
42 2040		2,586	2,586	64,146	52	1,288
43 2041		2,586	2,586	64,146	47	1,171
44 2042		2,586	2,586	64,146	43	1,065
45 2043		2,586	2,586	64,146	39	968
46 2044		2,586	2,586	64,146	35	880
47 2045		2,586	2,586	64,146	32	800
48 2046		2,586	2,586	64,146	29	727
49 2047		2,586	2,586	64,146	27	661
50 2048		2,586	2,586	64,146	24	601
Total	517,298	101,053	618,351	2,506,130	246,839	267,993

EIRR: 10.9%
B/C: 1.09
NPV(B-C): 21,154 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Tinau (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	10,102	0	10,102	0	10,102	0
2 2000	10,102	0	10,102	0	9,184	0
3 2001	25,061	0	25,061	0	20,712	0
4 2002	54,402	0	54,402	0	40,873	0
5 2003	54,402	290	54,692	2,771	37,356	1,893
6 2004	54,402	580	54,982	5,543	34,140	3,442
7 2005	40,683	871	41,554	8,314	23,456	4,693
8 2006	40,683	1,088	41,771	10,387	21,435	5,330
9 2007	40,683	1,305	41,988	12,459	19,588	5,812
10 2008	40,683	1,522	42,205	14,531	17,899	6,163
11 2009	40,683	1,739	42,422	16,604	16,355	6,402
12 2010	40,683	1,956	42,639	18,676	14,945	6,546
13 2011	40,683	2,173	42,856	20,749	13,655	6,611
14 2012	40,683	2,390	43,073	22,821	12,477	6,611
15 2013	40,683	2,607	43,290	24,894	11,400	6,555
16 2014	40,683	2,824	43,507	26,966	10,415	6,455
17 2015	40,683	3,041	43,724	29,039	9,516	6,320
18 2016	40,683	3,258	43,941	31,111	8,693	6,155
19 2017	25,723	3,475	29,198	33,184	5,251	5,968
20 2018		3,612	3,612	34,494	591	5,640
21 2019		3,612	3,612	34,494	537	5,127
22 2020		3,612	3,612	34,494	488	4,661
23 2021		3,612	3,612	34,494	444	4,237
24 2022		3,612	3,612	34,494	403	3,852
25 2023		3,612	3,612	34,494	367	3,502
26 2024		3,612	3,612	34,494	333	3,184
27 2025		3,612	3,612	34,494	303	2,894
28 2026		3,612	3,612	34,494	276	2,631
29 2027		3,612	3,612	34,494	250	2,392
30 2028		3,612	3,612	34,494	228	2,174
31 2029		3,612	3,612	34,494	207	1,977
32 2030		3,612	3,612	34,494	188	1,797
33 2031		3,612	3,612	34,494	171	1,634
34 2032		3,612	3,612	34,494	156	1,485
35 2033		3,612	3,612	34,494	141	1,350
36 2034		3,612	3,612	34,494	129	1,227
37 2035		3,612	3,612	34,494	117	1,116
38 2036		3,612	3,612	34,494	106	1,014
39 2037		3,612	3,612	34,494	97	922
40 2038		3,612	3,612	34,494	88	838
41 2039		3,612	3,612	34,494	80	762
42 2040		3,612	3,612	34,494	73	693
43 2041		3,612	3,612	34,494	66	630
44 2042		3,612	3,612	34,494	60	573
45 2043		3,612	3,612	34,494	55	521
46 2044		3,612	3,612	34,494	50	473
47 2045		3,612	3,612	34,494	45	430
48 2046		3,612	3,612	34,494	41	391
49 2047		3,612	3,612	34,494	37	356
50 2048		3,612	3,612	34,494	34	323
Total	722,390	141,086	863,476	1,347,363	343,608	143,764

EIRR: 2.8%
B/C: 0.42
NPV(B-C): -199,844 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

River: Tinau (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	10,102	0	10,102	0	10,102	0
2 2000	10,102	0	10,102	0	9,184	0
3 2001	25,061	0	25,061	0	20,712	0
4 2002	54,402	0	54,402	0	40,873	0
5 2003	54,402	290	54,692	6,152	37,356	4,202
6 2004	54,402	580	54,982	12,305	34,140	7,640
7 2005	40,683	871	41,554	18,457	23,456	10,419
8 2006	40,683	1,088	41,771	23,058	21,435	11,832
9 2007	40,683	1,305	41,988	27,659	19,588	12,903
10 2008	40,683	1,522	42,205	32,260	17,899	13,681
11 2009	40,683	1,739	42,422	36,861	16,355	14,211
12 2010	40,683	1,956	42,639	41,462	14,945	14,532
13 2011	40,683	2,173	42,856	46,062	13,655	14,677
14 2012	40,683	2,390	43,073	50,663	12,477	14,675
15 2013	40,683	2,607	43,290	55,264	11,400	14,553
16 2014	40,683	2,824	43,507	59,865	10,415	14,331
17 2015	40,683	3,041	43,724	64,466	9,516	14,030
18 2016	40,683	3,258	43,941	69,067	8,693	13,664
19 2017	25,723	3,475	29,198	73,668	5,251	13,250
20 2018		3,612	3,612	76,577	591	12,521
21 2019		3,612	3,612	76,577	537	11,383
22 2020		3,612	3,612	76,577	488	10,348
23 2021		3,612	3,612	76,577	444	9,407
24 2022		3,612	3,612	76,577	403	8,552
25 2023		3,612	3,612	76,577	367	7,774
26 2024		3,612	3,612	76,577	333	7,068
27 2025		3,612	3,612	76,577	303	6,425
28 2026		3,612	3,612	76,577	276	5,841
29 2027		3,612	3,612	76,577	250	5,310
30 2028		3,612	3,612	76,577	228	4,827
31 2029		3,612	3,612	76,577	207	4,388
32 2030		3,612	3,612	76,577	188	3,990
33 2031		3,612	3,612	76,577	171	3,627
34 2032		3,612	3,612	76,577	156	3,297
35 2033		3,612	3,612	76,577	141	2,997
36 2034		3,612	3,612	76,577	129	2,725
37 2035		3,612	3,612	76,577	117	2,477
38 2036		3,612	3,612	76,577	106	2,252
39 2037		3,612	3,612	76,577	97	2,047
40 2038		3,612	3,612	76,577	88	1,861
41 2039		3,612	3,612	76,577	80	1,692
42 2040		3,612	3,612	76,577	73	1,538
43 2041		3,612	3,612	76,577	66	1,398
44 2042		3,612	3,612	76,577	60	1,271
45 2043		3,612	3,612	76,577	55	1,156
46 2044		3,612	3,612	76,577	50	1,051
47 2045		3,612	3,612	76,577	45	955
48 2046		3,612	3,612	76,577	41	868
49 2047		3,612	3,612	76,577	37	789
50 2048		3,612	3,612	76,577	34	718
Total	722,390	141,086	863,476	2,991,145	343,608	319,156

EIRR: 9.2%
B/C: 0.93
NPV(B-C): -24,452 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

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

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

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

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

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

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

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

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Babai (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	6,581	0	6,581	0	6,581	0
2 2000	6,581	0	6,581	0	5,983	0
3 2001	10,990	0	10,990	0	9,083	0
4 2002	30,104	0	30,104	0	22,618	0
5 2003	30,104	161	30,265	3,445	20,671	2,353
6 2004	30,104	321	30,425	6,891	18,892	4,279
7 2005	21,167	482	21,649	10,336	12,220	5,834
8 2006	21,167	595	21,762	12,758	11,167	6,547
9 2007	21,167	708	21,875	15,181	10,205	7,082
10 2008	21,167	821	21,988	17,603	9,325	7,465
11 2009	21,167	933	22,100	20,026	8,521	7,721
12 2010	21,167	1,046	22,213	22,448	7,786	7,868
13 2011	21,167	1,159	22,326	24,871	7,114	7,925
14 2012	21,167	1,272	22,439	27,293	6,500	7,906
15 2013	21,167	1,385	22,552	29,715	5,939	7,825
16 2014	21,167	1,498	22,665	32,138	5,426	7,694
17 2015	21,167	1,611	22,778	34,560	4,957	7,521
18 2016	21,167	1,724	22,891	36,983	4,529	7,317
19 2017	16,758	1,837	18,595	39,405	3,344	7,087
20 2018		1,926	1,926	41,323	315	6,757
21 2019		1,926	1,926	41,323	286	6,142
22 2020		1,926	1,926	41,323	260	5,584
23 2021		1,926	1,926	41,323	237	5,076
24 2022		1,926	1,926	41,323	215	4,615
25 2023		1,926	1,926	41,323	196	4,195
26 2024		1,926	1,926	41,323	178	3,814
27 2025		1,926	1,926	41,323	162	3,467
28 2026		1,926	1,926	41,323	147	3,152
29 2027		1,926	1,926	41,323	134	2,865
30 2028		1,926	1,926	41,323	121	2,605
31 2029		1,926	1,926	41,323	110	2,368
32 2030		1,926	1,926	41,323	100	2,153
33 2031		1,926	1,926	41,323	91	1,957
34 2032		1,926	1,926	41,323	83	1,779
35 2033		1,926	1,926	41,323	75	1,617
36 2034		1,926	1,926	41,323	69	1,470
37 2035		1,926	1,926	41,323	62	1,337
38 2036		1,926	1,926	41,323	57	1,215
39 2037		1,926	1,926	41,323	51	1,105
40 2038		1,926	1,926	41,323	47	1,004
41 2039		1,926	1,926	41,323	43	913
42 2040		1,926	1,926	41,323	39	830
43 2041		1,926	1,926	41,323	35	755
44 2042		1,926	1,926	41,323	32	686
45 2043		1,926	1,926	41,323	29	624
46 2044		1,926	1,926	41,323	26	567
47 2045		1,926	1,926	41,323	24	515
48 2046		1,926	1,926	41,323	22	469
49 2047		1,926	1,926	41,323	20	426
50 2048		1,926	1,926	41,323	18	387
Total	385,226	75,262	460,488	1,614,666	184,142	172,874

EIRR: 9.3%
B/C: 0.94
NPV(B-C): -11,268 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

River: Babai (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	6,581	0	6,581	0	6,581	0
2 2000	6,581	0	6,581	0	5,983	0
3 2001	10,990	0	10,990	0	9,083	0
4 2002	30,104	0	30,104	0	22,618	0
5 2003	30,104	161	30,265	5,444	20,671	3,718
6 2004	30,104	321	30,425	10,887	18,892	6,760
7 2005	21,167	482	21,649	16,331	12,220	9,218
8 2006	21,167	595	21,762	20,158	11,167	10,344
9 2007	21,167	708	21,875	23,986	10,205	11,189
10 2008	21,167	821	21,988	27,813	9,325	11,795
11 2009	21,167	933	22,100	31,640	8,521	12,199
12 2010	21,167	1,046	22,213	35,468	7,786	12,431
13 2011	21,167	1,159	22,326	39,295	7,114	12,521
14 2012	21,167	1,272	22,439	43,123	6,500	12,491
15 2013	21,167	1,385	22,552	46,950	5,939	12,363
16 2014	21,167	1,498	22,665	50,778	5,426	12,156
17 2015	21,167	1,611	22,778	54,605	4,957	11,884
18 2016	21,167	1,724	22,891	58,433	4,529	11,561
19 2017	16,758	1,837	18,595	62,260	3,344	11,198
20 2018		1,926	1,926	65,290	315	10,675
21 2019		1,926	1,926	65,290	286	9,705
22 2020		1,926	1,926	65,290	260	8,823
23 2021		1,926	1,926	65,290	237	8,021
24 2022		1,926	1,926	65,290	215	7,292
25 2023		1,926	1,926	65,290	196	6,629
26 2024		1,926	1,926	65,290	178	6,026
27 2025		1,926	1,926	65,290	162	5,478
28 2026		1,926	1,926	65,290	147	4,980
29 2027		1,926	1,926	65,290	134	4,527
30 2028		1,926	1,926	65,290	121	4,116
31 2029		1,926	1,926	65,290	110	3,742
32 2030		1,926	1,926	65,290	100	3,402
33 2031		1,926	1,926	65,290	91	3,092
34 2032		1,926	1,926	65,290	83	2,811
35 2033		1,926	1,926	65,290	75	2,556
36 2034		1,926	1,926	65,290	69	2,323
37 2035		1,926	1,926	65,290	62	2,112
38 2036		1,926	1,926	65,290	57	1,920
39 2037		1,926	1,926	65,290	51	1,746
40 2038		1,926	1,926	65,290	47	1,587
41 2039		1,926	1,926	65,290	43	1,443
42 2040		1,926	1,926	65,290	39	1,311
43 2041		1,926	1,926	65,290	35	1,192
44 2042		1,926	1,926	65,290	32	1,084
45 2043		1,926	1,926	65,290	29	985
46 2044		1,926	1,926	65,290	26	896
47 2045		1,926	1,926	65,290	24	814
48 2046		1,926	1,926	65,290	22	740
49 2047		1,926	1,926	65,290	20	673
50 2048		1,926	1,926	65,290	18	612
Total	385,226	75,262	460,488	2,551,172	184,142	273,142

EIRR: 14.8%
B/C: 1.48
NPV(B-C): 88,999 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Khutiya (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	1,486	0	1,486	0	1,486	0
2 2000	1,486	0	1,486	0	1,351	0
3 2001	3,543	0	3,543	0	2,928	0
4 2002	7,860	0	7,860	0	5,905	0
5 2003	7,860	42	7,902	257	5,397	175
6 2004	7,860	84	7,944	514	4,933	319
7 2005	5,842	126	5,968	770	3,369	435
8 2006	5,842	157	5,999	961	3,078	493
9 2007	5,842	188	6,030	1,152	2,813	537
10 2008	5,842	219	6,061	1,343	2,571	569
11 2009	5,842	250	6,092	1,534	2,349	591
12 2010	5,842	282	6,124	1,725	2,146	604
13 2011	5,842	313	6,155	1,915	1,961	610
14 2012	5,842	344	6,186	2,106	1,792	610
15 2013	5,842	375	6,217	2,297	1,637	605
16 2014	5,842	406	6,248	2,488	1,496	596
17 2015	5,842	437	6,279	2,679	1,367	583
18 2016	5,842	469	6,311	2,870	1,249	568
19 2017	3,785	500	4,285	3,060	771	550
20 2018		520	520	3,184	85	521
21 2019		520	520	3,184	77	473
22 2020		520	520	3,184	70	430
23 2021		520	520	3,184	64	391
24 2022		520	520	3,184	58	356
25 2023		520	520	3,184	53	323
26 2024		520	520	3,184	48	294
27 2025		520	520	3,184	44	267
28 2026		520	520	3,184	40	243
29 2027		520	520	3,184	36	221
30 2028		520	520	3,184	33	201
31 2029		520	520	3,184	30	182
32 2030		520	520	3,184	27	166
33 2031		520	520	3,184	25	151
34 2032		520	520	3,184	22	137
35 2033		520	520	3,184	20	125
36 2034		520	520	3,184	19	113
37 2035		520	520	3,184	17	103
38 2036		520	520	3,184	15	94
39 2037		520	520	3,184	14	85
40 2038		520	520	3,184	13	77
41 2039		520	520	3,184	11	70
42 2040		520	520	3,184	10	64
43 2041		520	520	3,184	9	58
44 2042		520	520	3,184	9	53
45 2043		520	520	3,184	8	48
46 2044		520	520	3,184	7	44
47 2045		520	520	3,184	6	40
48 2046		520	520	3,184	6	36
49 2047		520	520	3,184	5	33
50 2048		520	520	3,184	5	30
Total	103,984	20,309	124,293	124,374	49,484	13,275

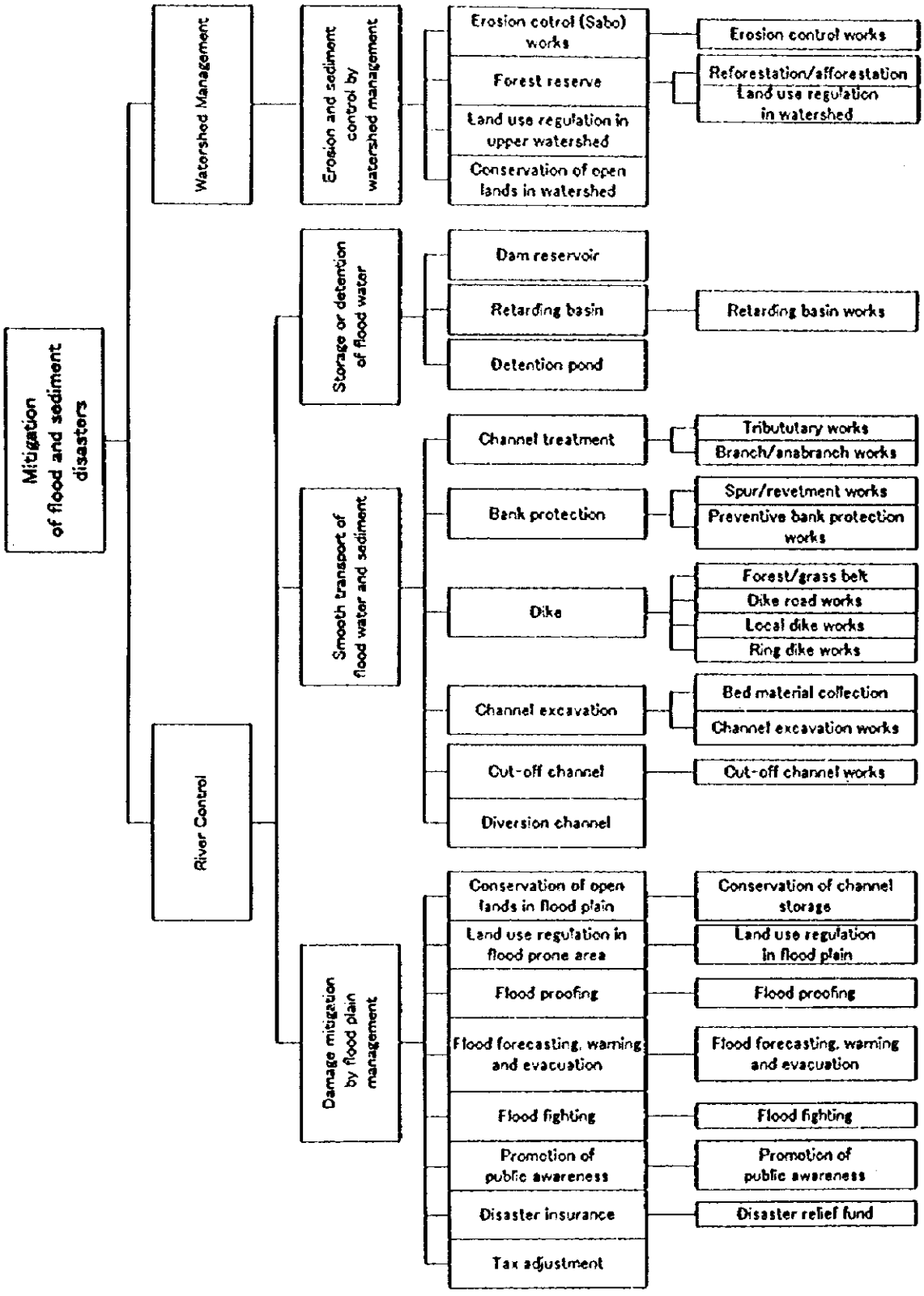
EIRR: 0.0%
B/C: 0.27
NPV(B-C): -36,209 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN
(Future Basin)

River: Khutiya (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	1,486	0	1,486	0	1,486	0
2 2000	1,486	0	1,486	0	1,351	0
3 2001	3,543	0	3,543	0	2,928	0
4 2002	7,860	0	7,860	0	5,905	0
5 2003	7,860	42	7,902	534	5,397	365
6 2004	7,860	84	7,944	1,068	4,933	663
7 2005	5,842	126	5,968	1,602	3,369	904
8 2006	5,842	157	5,999	1,999	3,078	1,026
9 2007	5,842	188	6,030	2,396	2,813	1,118
10 2008	5,842	219	6,061	2,793	2,571	1,185
11 2009	5,842	250	6,092	3,190	2,349	1,230
12 2010	5,842	282	6,124	3,587	2,146	1,257
13 2011	5,842	313	6,155	3,984	1,961	1,269
14 2012	5,842	344	6,186	4,381	1,792	1,269
15 2013	5,842	375	6,217	4,778	1,637	1,258
16 2014	5,842	406	6,248	5,175	1,496	1,239
17 2015	5,842	437	6,279	5,572	1,367	1,213
18 2016	5,842	469	6,311	5,969	1,249	1,181
19 2017	3,785	500	4,285	6,366	771	1,145
20 2018		520	520	6,623	85	1,083
21 2019		520	520	6,623	77	984
22 2020		520	520	6,623	70	895
23 2021		520	520	6,623	64	814
24 2022		520	520	6,623	58	740
25 2023		520	520	6,623	53	672
26 2024		520	520	6,623	48	611
27 2025		520	520	6,623	44	556
28 2026		520	520	6,623	40	505
29 2027		520	520	6,623	36	459
30 2028		520	520	6,623	33	417
31 2029		520	520	6,623	30	380
32 2030		520	520	6,623	27	345
33 2031		520	520	6,623	25	314
34 2032		520	520	6,623	22	285
35 2033		520	520	6,623	20	259
36 2034		520	520	6,623	19	236
37 2035		520	520	6,623	17	214
38 2036		520	520	6,623	15	195
39 2037		520	520	6,623	14	177
40 2038		520	520	6,623	13	161
41 2039		520	520	6,623	11	146
42 2040		520	520	6,623	10	133
43 2041		520	520	6,623	9	121
44 2042		520	520	6,623	9	110
45 2043		520	520	6,623	8	100
46 2044		520	520	6,623	7	91
47 2045		520	520	6,623	6	83
48 2046		520	520	6,623	6	75
49 2047		520	520	6,623	5	68
50 2048		520	520	6,623	5	62
Total	103,984	20,309	124,293	258,698	49,484	27,612

EIRR: 4.8%
B/C: 0.56
NPV(B-C): -21,871 (NRs.1,000)



FLOOD MITIGATION MEASURES

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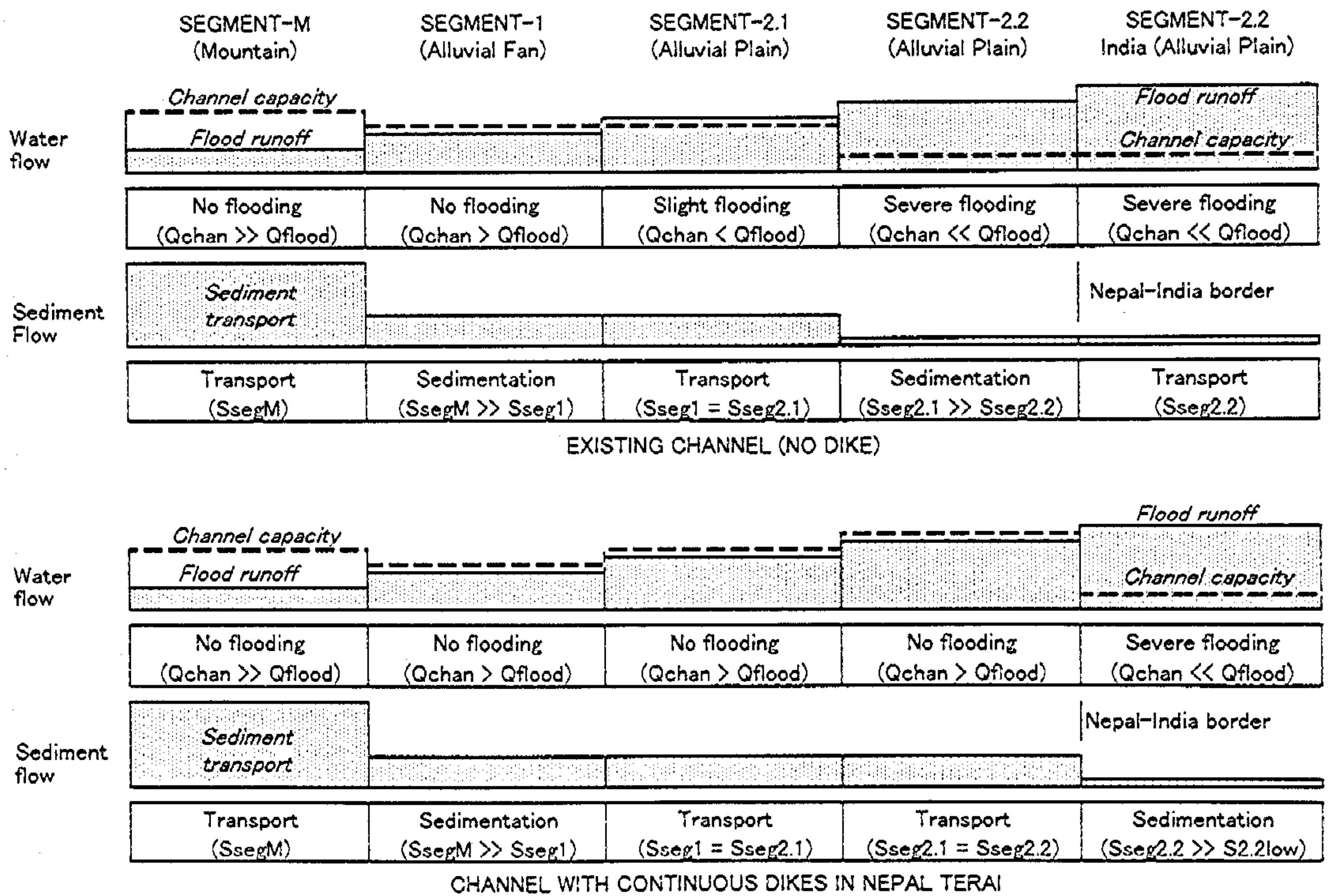
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



CONCEPTUAL FLOOD WATER AND SEDIMENT FLOW IN TERAI

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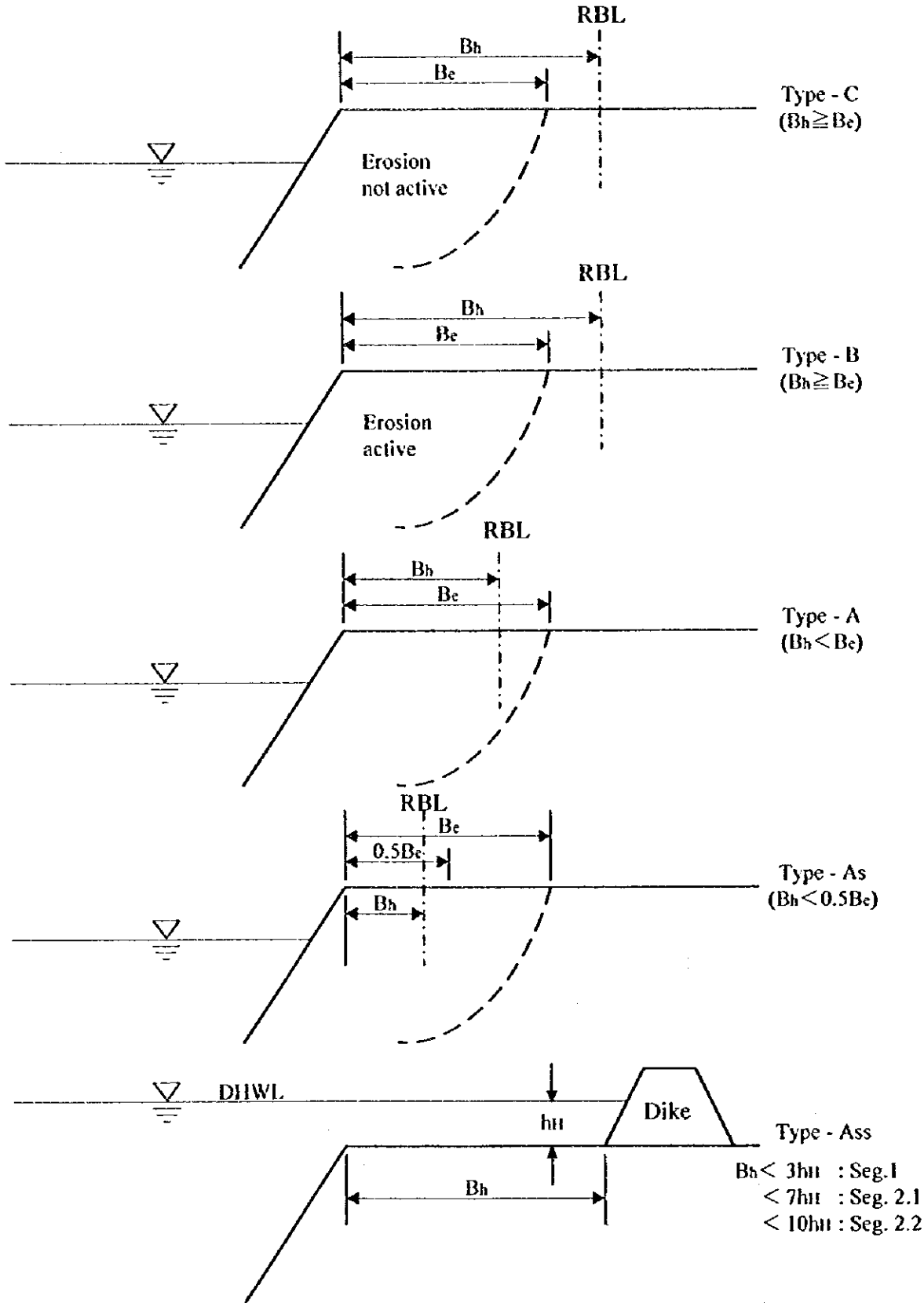

Bh: Distance from riverbank to river boundary line(RBL)

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

CLASSIFICATION OF TYPES OF RIVER BANK

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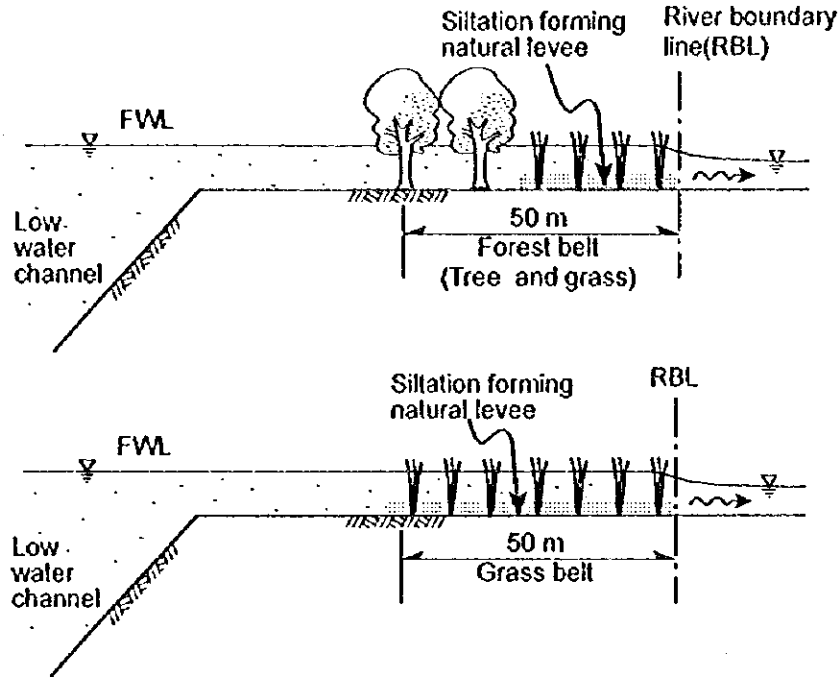
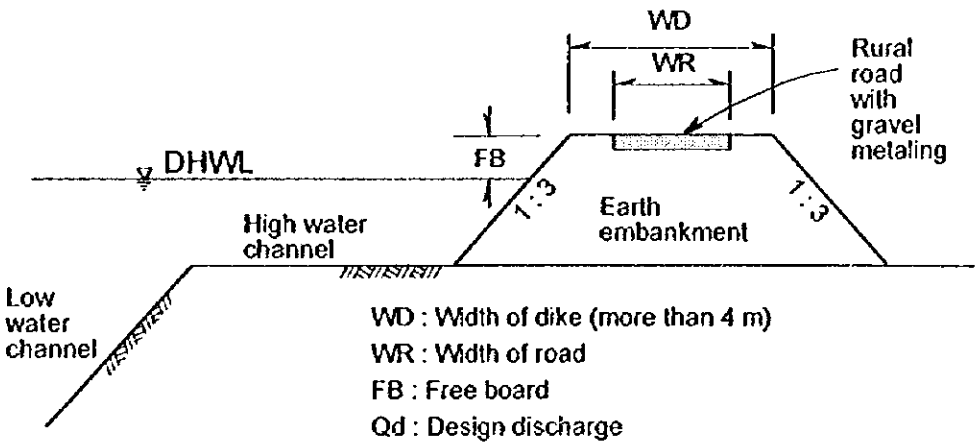
Forest and Grass Belt



Earth Dike / Road



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

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

DIKE WORKS

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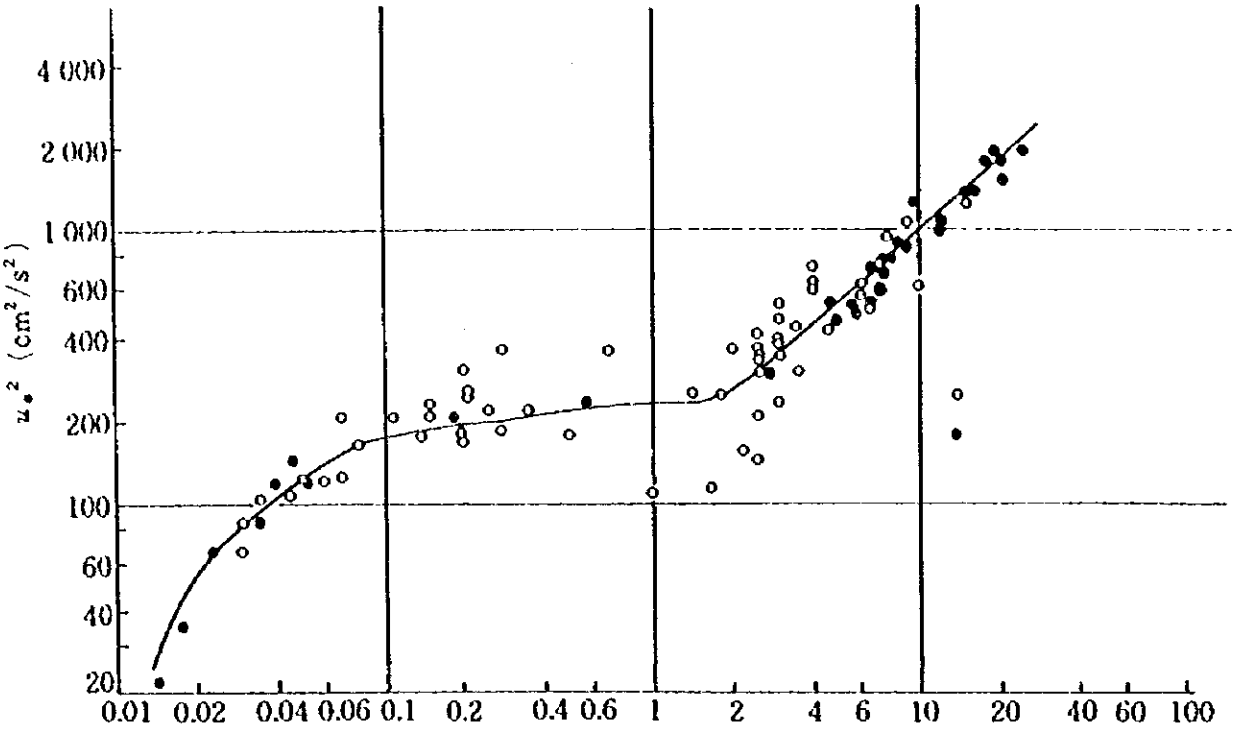


$$Q_2 = A \cdot V = \frac{B \cdot h_L^{5/3} \cdot I^{1/2}}{n} \quad \Rightarrow \quad h_L = \left\{ \frac{Q_2 \cdot n}{B \cdot I^{1/2}} \right\}^{3/5}$$

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

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

n : Manning's coefficient of roughness

g : Acceleration of gravity (m/sec²)

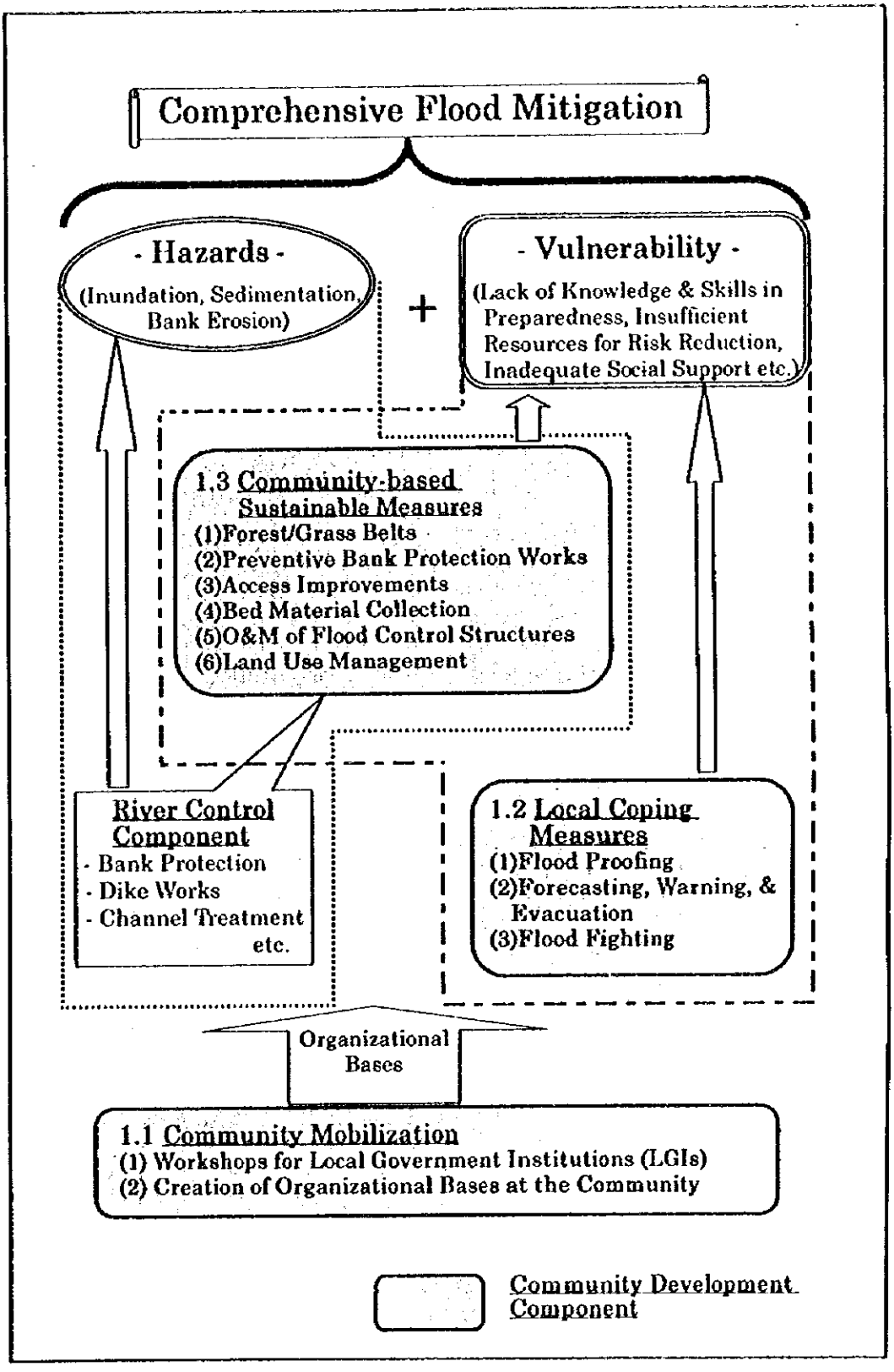
Q_2 : Two-year probable discharge (m3/s)

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

h_L : Mean depth of low water channel (m)

B : Low water channel width

RELATIONSHIP BETWEEN BED MATERIAL SIZE AND FRICTION VELOCITY



COMPREHENSIVE FLOOD MITIGATION

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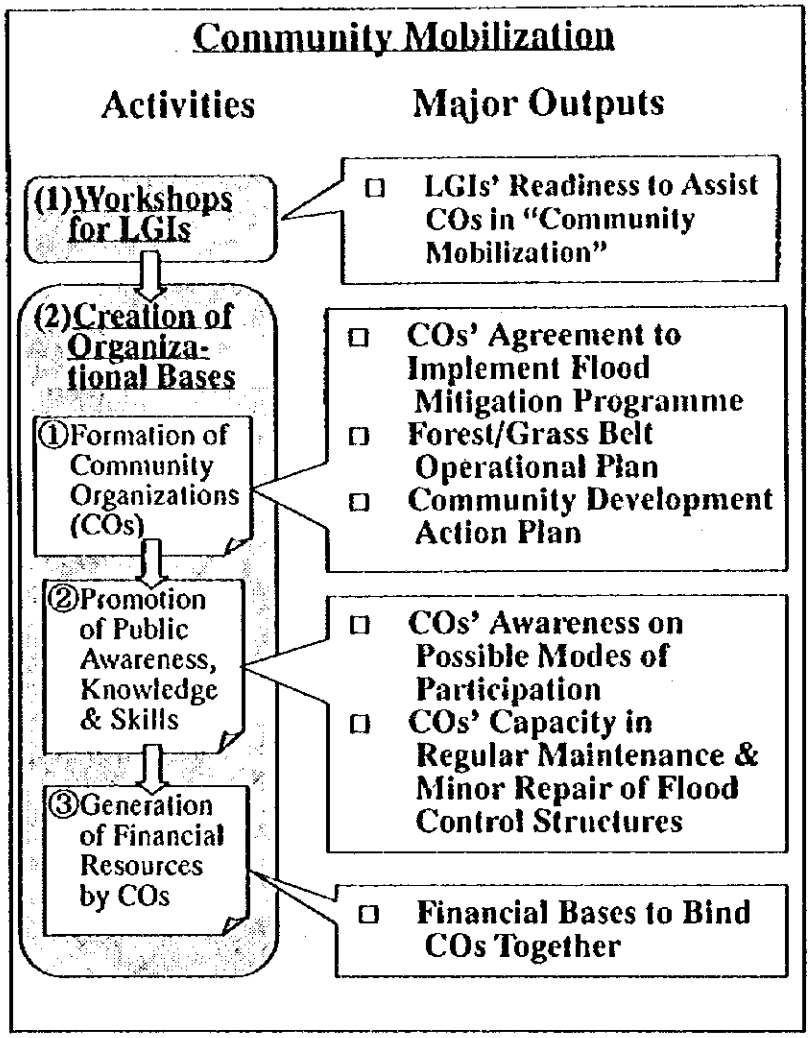

COMMUNITY MOBILIZATION

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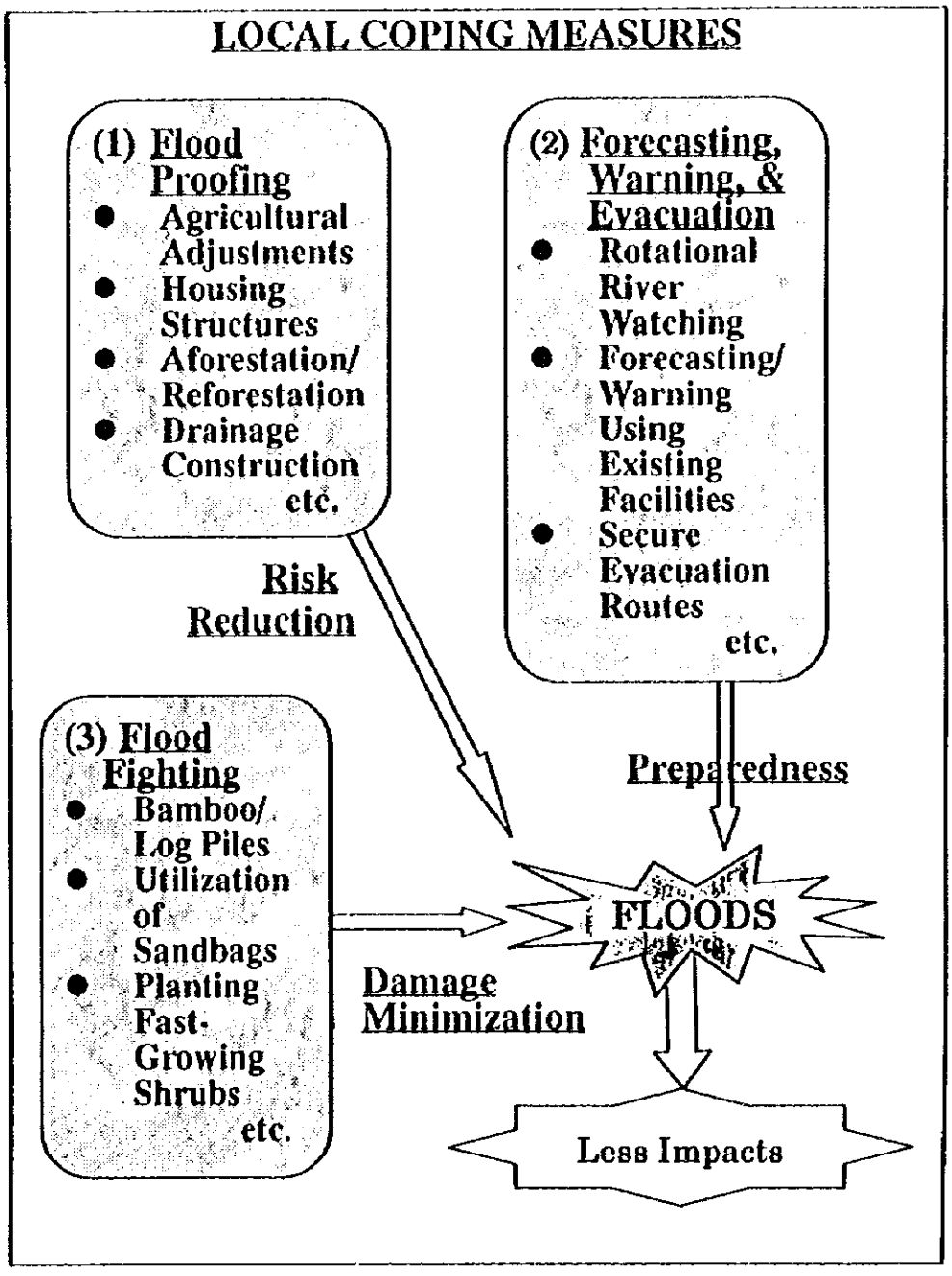

LOCAL COPING MEASURES

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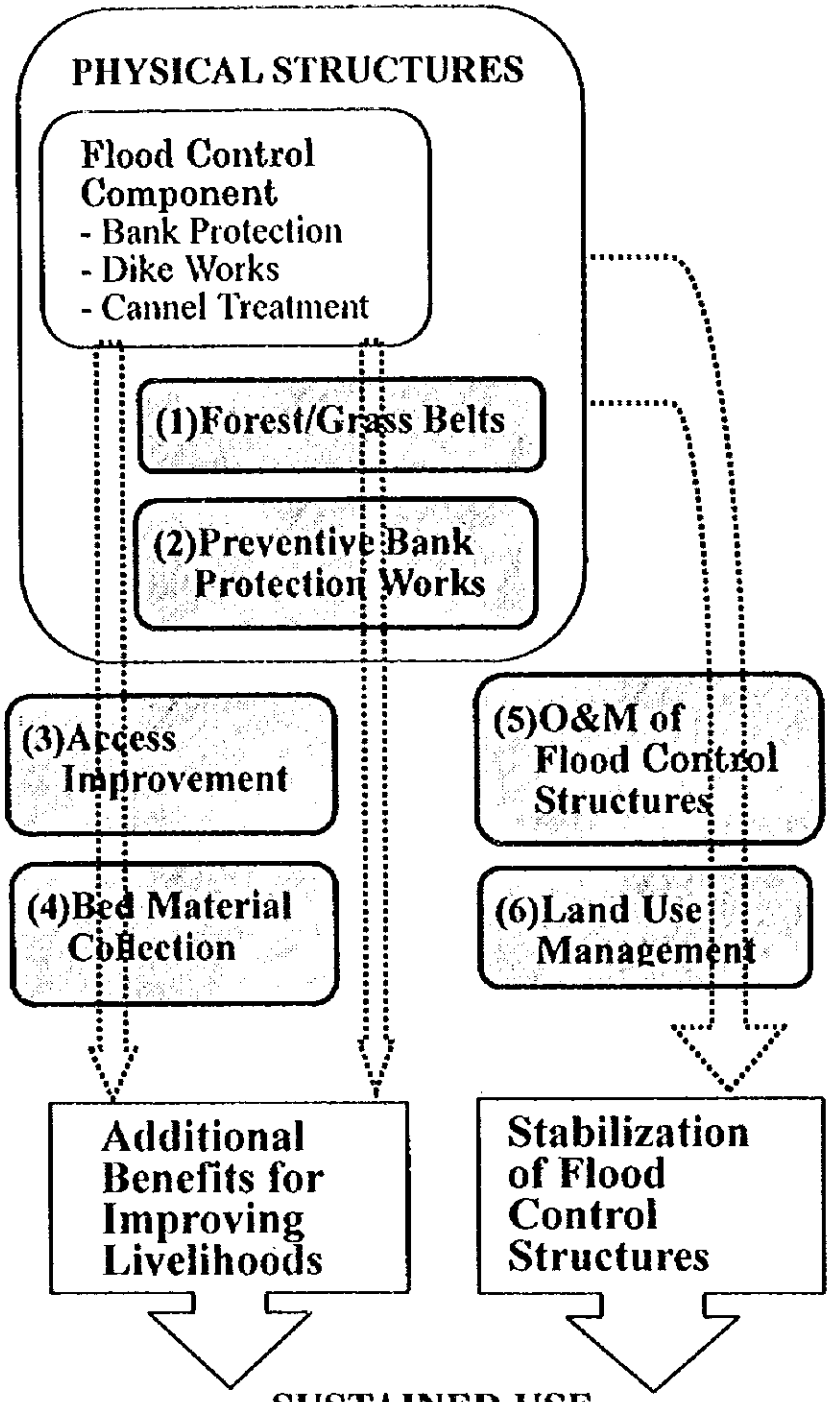
Community-based Sustainable Measures



COMMUNITY-BASED SUSTAINABLE MEASURES

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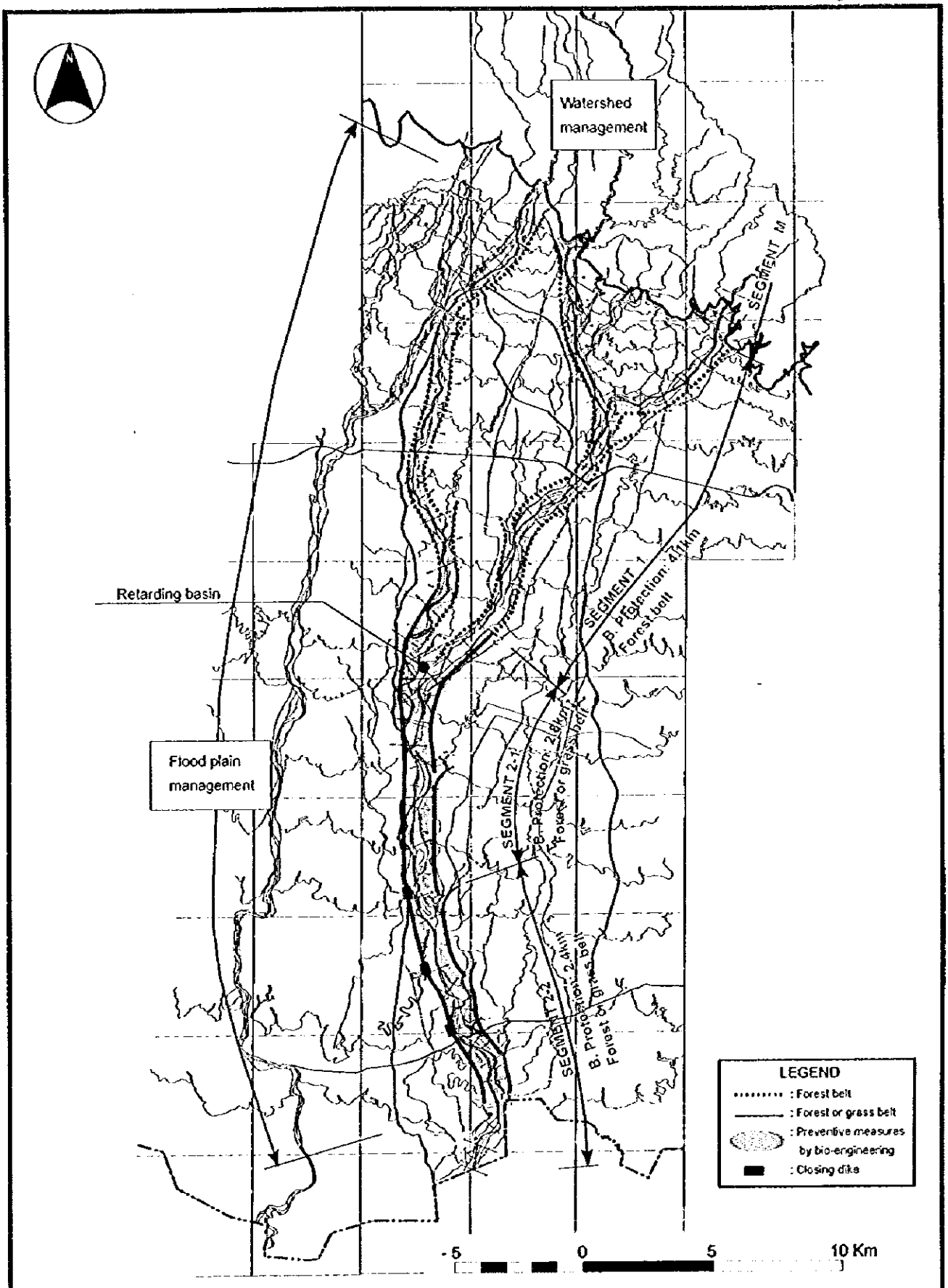


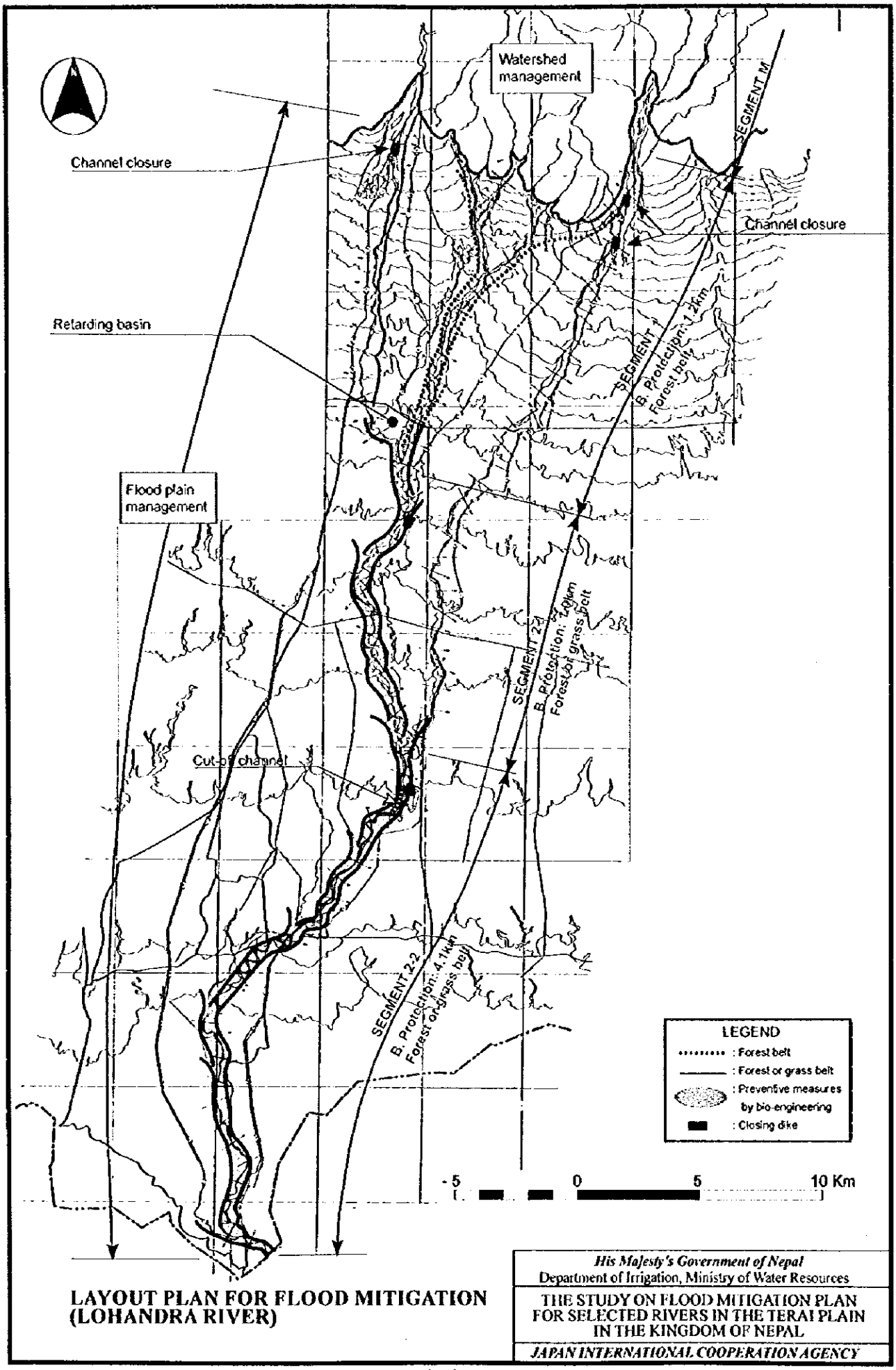
LAYOUT PLAN FOR FLOOD MITIGATION (RATUWA RIVER)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 4.10 (2/8)



LAYOUT PLAN FOR FLOOD MITIGATION (LOHANDRA RIVER)

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

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

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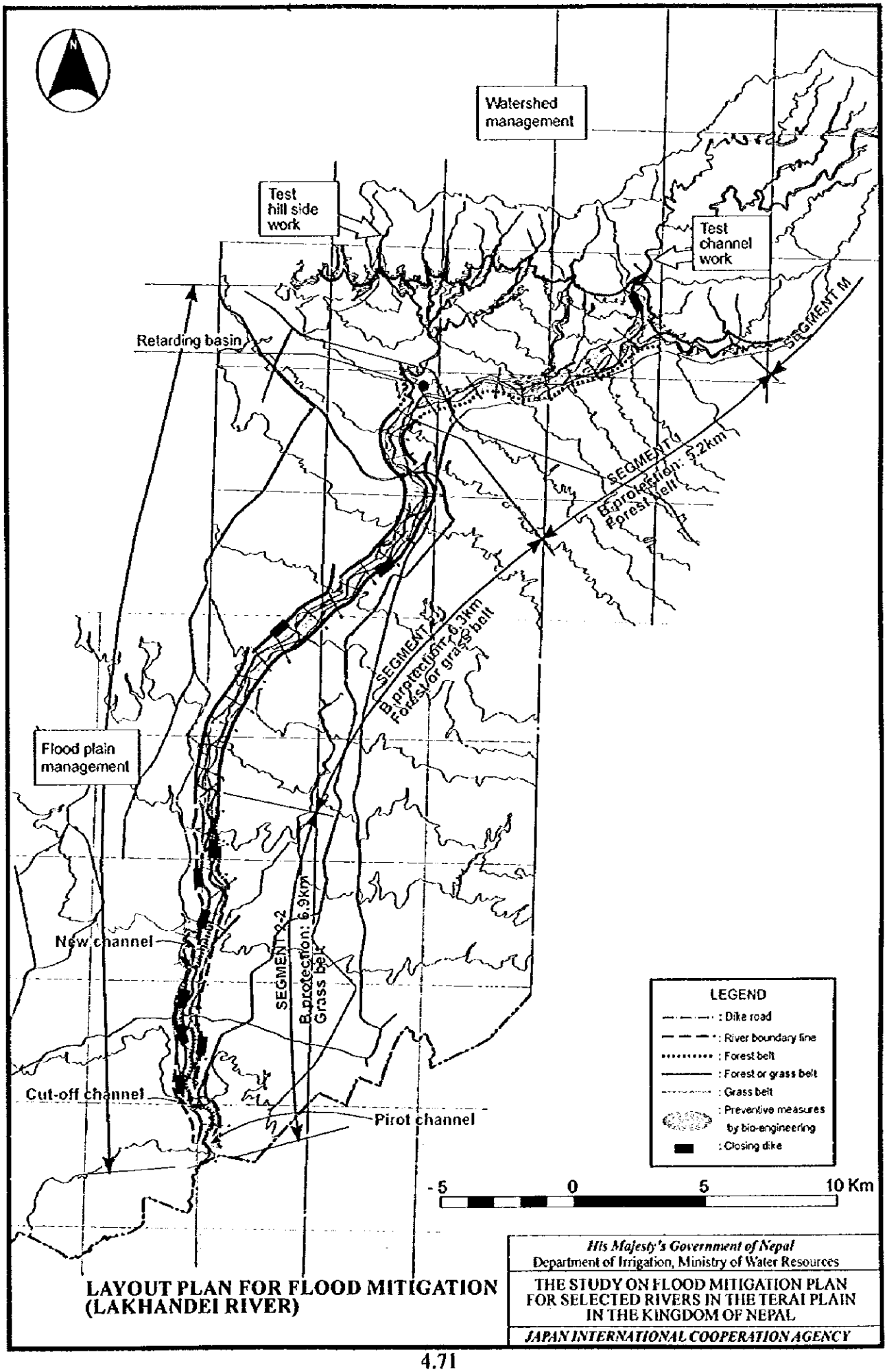

LAYOUT PLAN FOR FLOOD MITIGATION (LAKHANDEI RIVER)

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

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

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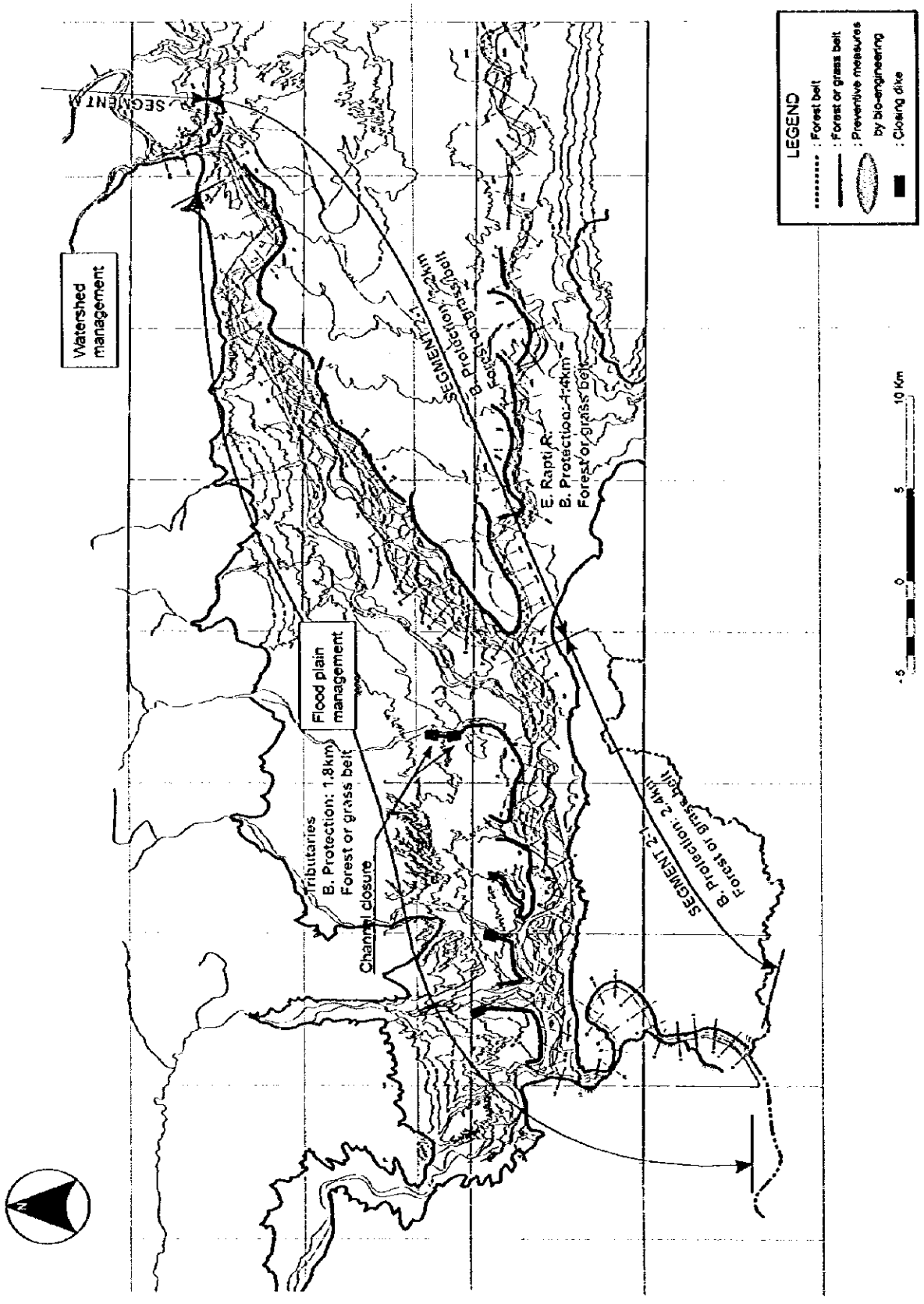
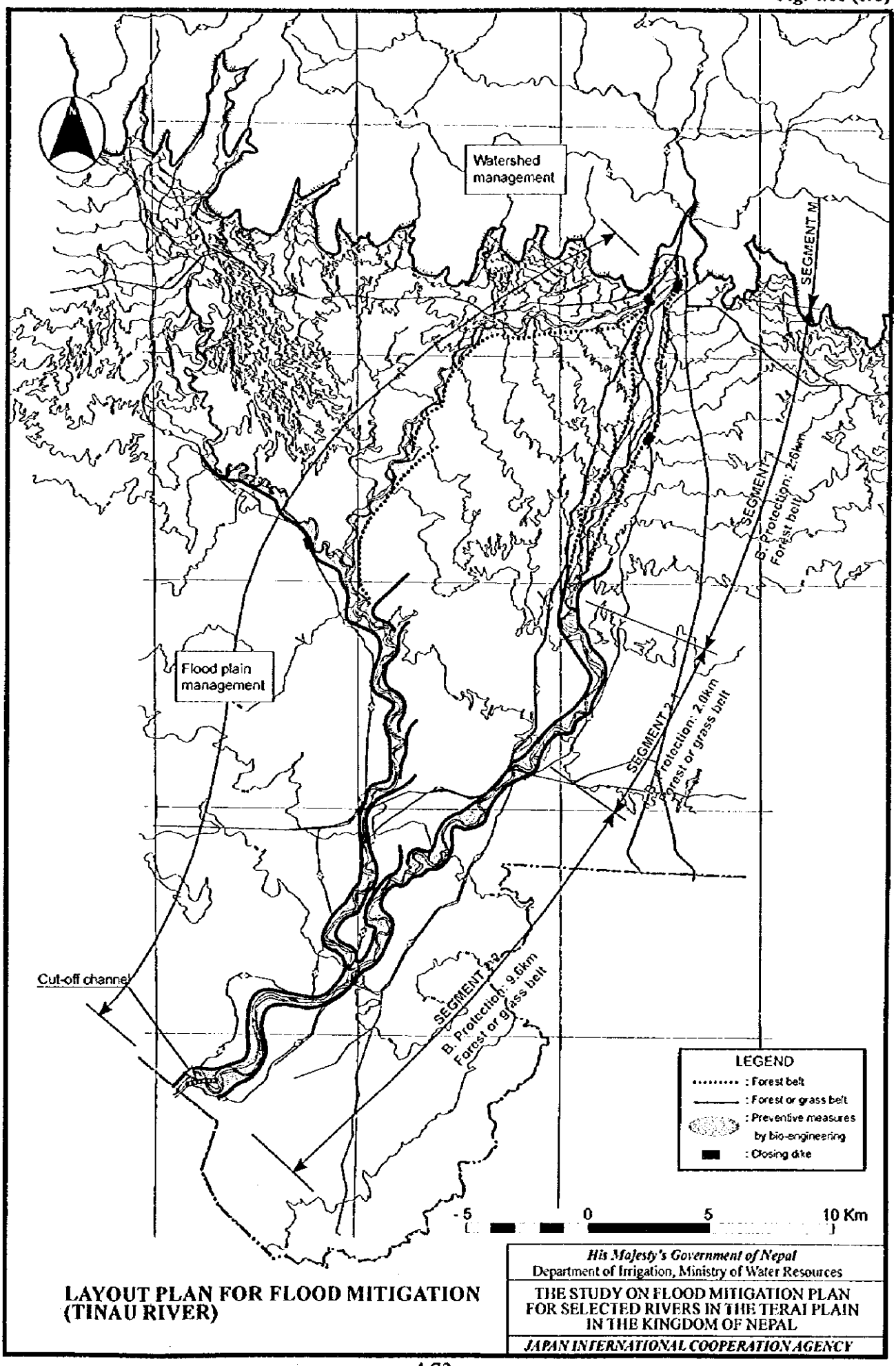


LAYOUT PLAN FOR FLOOD MITIGATION
(NARAYANI RIVER)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY



LAYOUT PLAN FOR FLOOD MITIGATION (TINAU RIVER)

His Majesty's Government of Nepal
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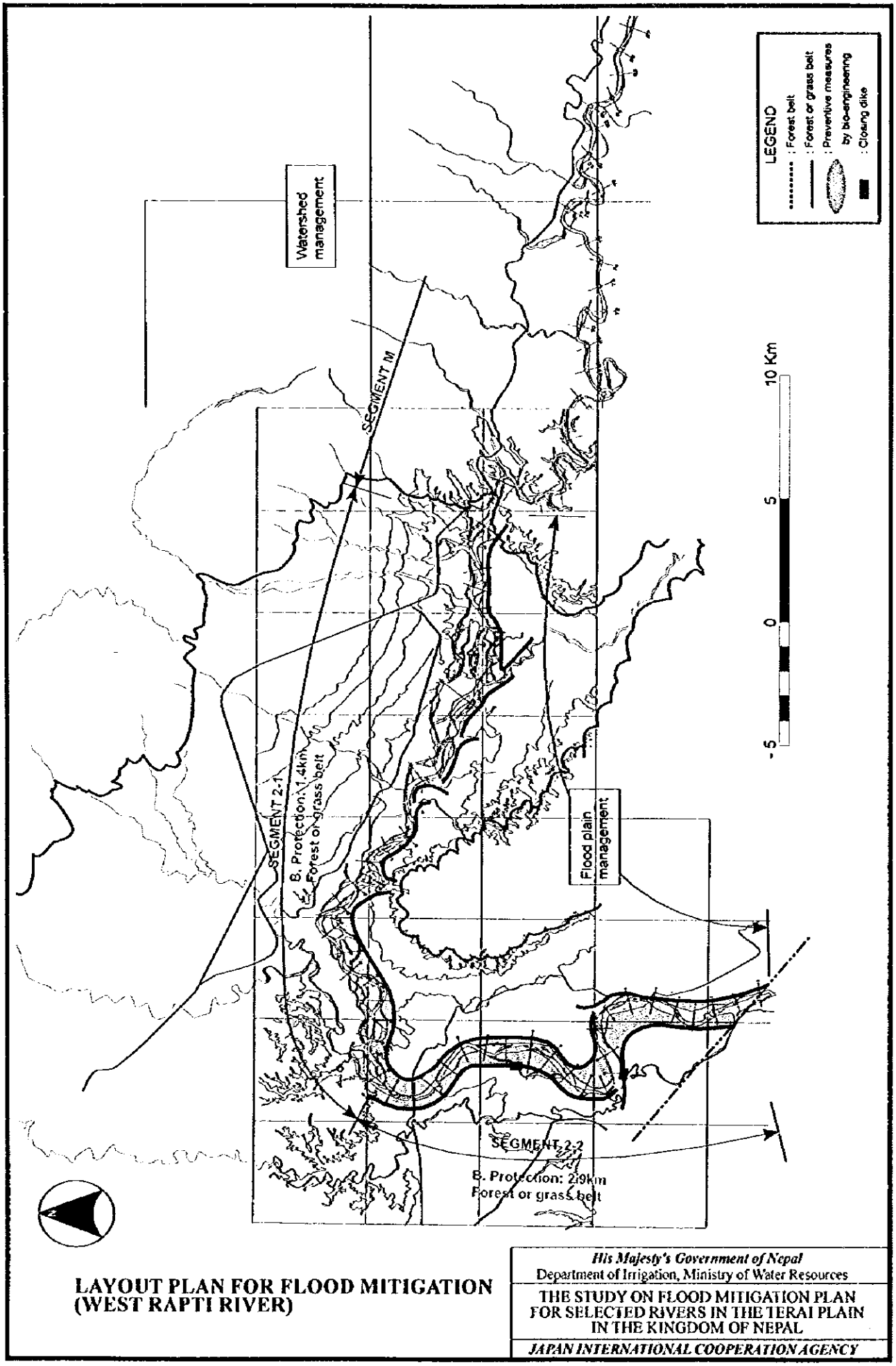

LAYOUT PLAN FOR FLOOD MITIGATION (WEST RAPTI RIVER)

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

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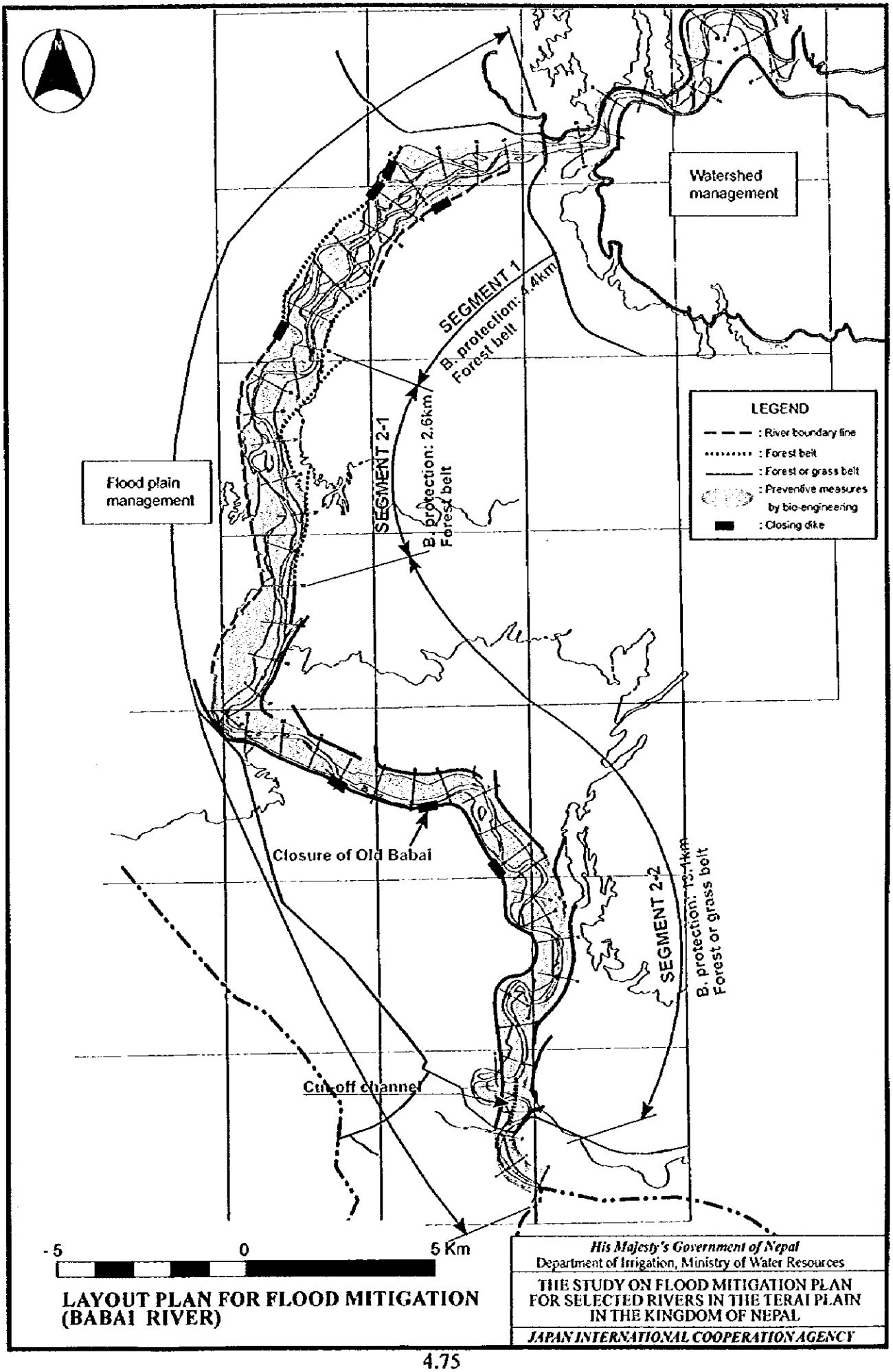
JAPAN INTERNATIONAL COOPERATION AGENCY

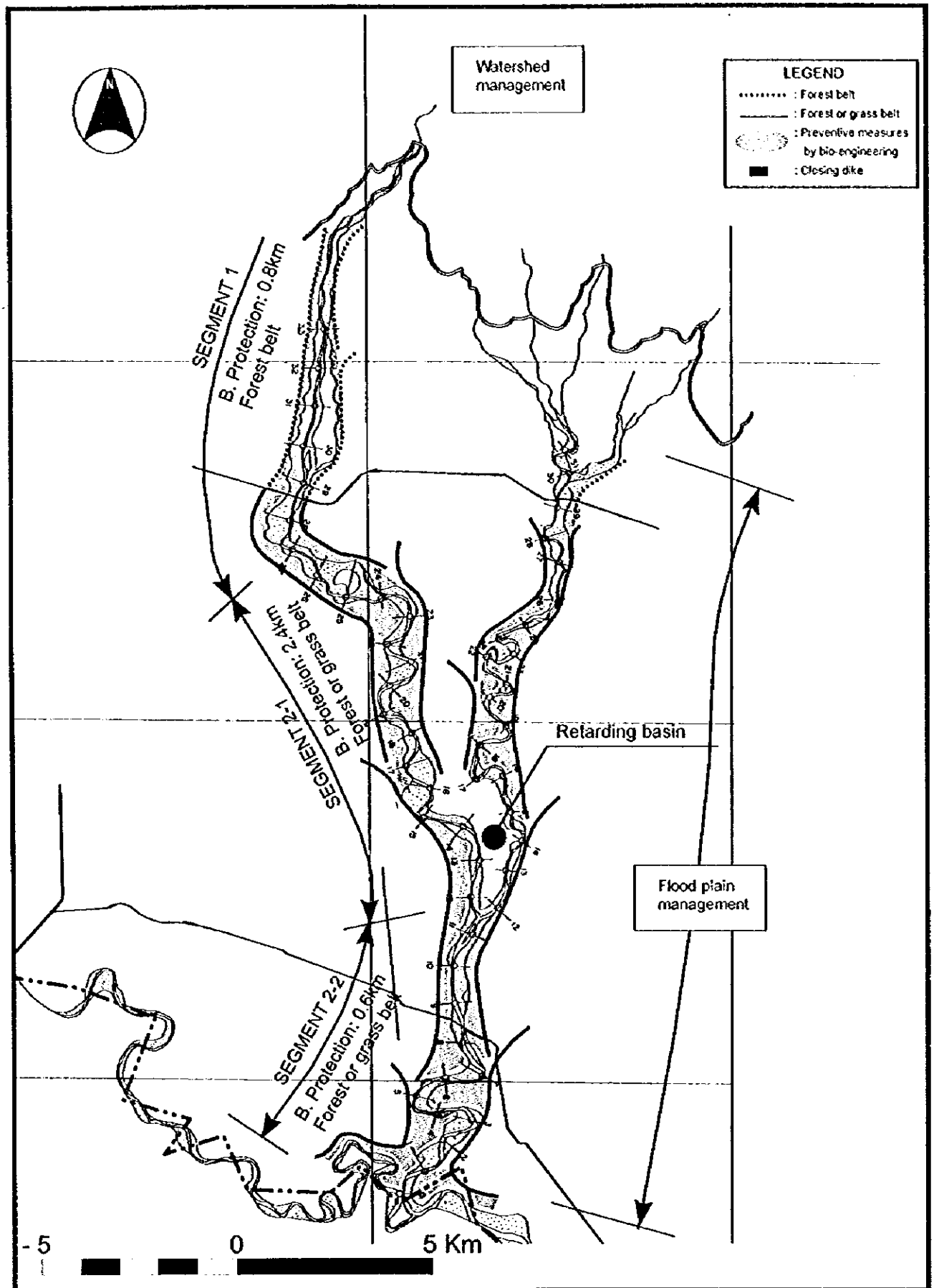


LAYOUT PLAN FOR FLOOD MITIGATION (BABAI RIVER)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY



LAYOUT PLAN FOR FLOOD MITIGATION
(KHUTIYA RIVER)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

ACTION PROGRAM TOWARD TARGET YEAR

River: **RATUWA RIVER**

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

CHAPTER 5 SELECTION OF PRIORITY PROJECT

5.1 General

Since a river channel conveys water and sediment continuously from upstream to downstream reaches, flood mitigation measures introduced in the upper reaches affect, to a certain extent, the incidence of flooding in the lower reaches. Therefore, it is common approach to discuss flood mitigation measures from basin-wide viewpoint. Feasibility Study for the flood mitigation is also conducted, in general, from a basin-wide viewpoint, not for individual component structures or facilities. The total costs invested in a plan and the total benefits accruing from the investment shall be compared for evaluation, not by component.

Any of the eight river basins studied in the formulation of the Master Plan could be selected for the Feasibility Study, since these rivers have been selected out of the numerous river basins in the Terai plain as model basins. After studying the model river basins, the choice of rivers for the Feasibility Study are narrowed down further based on the following criteria.

1) **Selection from different rives classes and development regions:** The river basin shall be selected from different river classes of I, II and III and from different development regions of the country, since the results of studies would be a technical guideline for planning flood mitigation of other similar river basins in the Terai plain.
2) **Selection based on priority of implementation:** The river basin shall be selected based on the priority of implementation. The priority is evaluated from the following aspects.
   - High economic viability
   - Urgency of flood mitigation
   - More favorable social impacts
   - Less adverse social and environmental impacts
   - Sustainability flood mitigation activities
   - Availability of basic data

5.2 River Class and Development Region

Rivers in the Terai plain are generally classified into three as follows:

1) Class-I rivers which originate in the High Mountains and have large catchment areas,
2) Class-II rivers which originate in the Middle Mountains and have medium size catchment areas, and
3) Class-III rivers which originate in the Siwalik hills and have small catchment areas.

On the other hand, the country of Nepal is administratively divided into five development regions, i.e., Eastern, Central, Western, Mid-Western and Far-Western development regions from east to west.

The eight (8) river basins for the Master Plan study fall under the following river class and development region (D.R.):

	(River)	(River class)	(Development region)
1)	Ratuwa R.	Class-III	Eastern D. R.
2)	Lohandra R.	Class-III	Eastern D. R.
3)	Lakhandei R.	Class-III	Central D. R.
4)	Narayani R.	Class-I	Central D. R./Western D. R.
5)	Tinau R.	Class-II	Western D. R.
6)	West Rapti R.	Class-II	Mid-Western D. R.
7)	Babai R.	Class-II	Mid-Western D. R.
8)	Khutiya R.	Class-III	Far-Western D. R.

5.3 Priority of Implementation

(1) Criteria for Priority Classification

Priority classification of eight river basins is given according to the evaluations of the following criteria:

1) **Higher Economic Viability:**
   (1-1) Present basin development: Land use and settlements in flood-prone areas
   (1-2) Existing public facilities: Road network, irrigation canal systems, etc.

2) **Urgency of Flood Mitigation:**
   (2-1) Recent severe flood damage
   (2-2) Progress of flood mitigation works

3) **More Favorable Social Impacts:**

(3-1) Extent of protected areas, population and its trend

(3-2) Existence of municipalities of economic and political importance

4) **Less Adverse Social and Environment Impacts:**

(4-1) Relocation of houses

(4-2) National park and wetlands

5) **Sustainability of Flood Mitigation Activities:**

(5-1) Desire of local government and DIO

(5-2) Availability of local materials for works

6) **Availability of Basic Data:**

(6-1) Availability of topographic maps

(6-2) Availability of hydrological data

(2) Method of Evaluation and Result

Based on the study results made so far, the eight river basins included in the Master Plan study were evaluated using the above criteria.

The evaluation was made giving marks of three levels, i.e., 1, 2 and 3 where the priority level 1 indicates highest priority. Therefore, the river basin with the lowest total points has the highest priority.

The evaluation for the respective rivers and items is shown in Table 5.1. According to the evaluation, the five top priority rivers are as follows:

(Rank)	(River)	(River class)	(Development region)
1st.	Babai river	II	Mid Western
2nd.	Lakhandei river	III	Central
3rd.	Tinau river	II	Western
4th	Ratuwa river	III	Eastern
4th	Narayani river	I	Central/Western

5.4 Selection of River Basins

(1) River Basins for Further Study

According to the result of evaluation shown in Table 5.1, the following two river basins with ranking as 1st and 2nd are selected for further study. They also represent different river class and development regions:

1) **Babai river basin** : Class-II river in Mid-Western Development Region
2) **Lakhandei river basin** : Class-III river in Central Development Region

Discussions were made whether the Narayani river should be included for further study or not. The Narayani river is 4th ranked in priority and class-I river located in both Central and Western Development Regions. Finally the Narayani river was not selected for the following reasons:

1) The Narayani river flows in Inner Terai and has a narrow channel section in its the lower reaches near Indian boundary. The Narayani river has different nature from other Class-I rivers such as the Kosi and Karnali rivers which flow in Terai plain without narrow sections in the lower reaches. Therefore, the Narayani river is not a representative basin of the Class-I river type.
2) The Narayani river is a large river joined by many tributaries of a similar scale to the other river basins in the master plan study. A feasibility study for such a large river has many study items, which form a whole project in itself. It should form a separate study, divorced from the present study. Otherwise an in-depth study for the selected two river would be difficult.
3) On the other hand, the further study result obtained from the chosen class-II and class-III rivers could be applicable to the flood and sediment problems for the tributaries of the Narayani river.

(2) River Basin for Comprehensive Flood Mitigation Plan

Out of two river basins selected for further study, one river is to be selected for the study on comprehensive flood mitigation plan including watershed. **The Lakhandei river** was specified for the study which includes the sabo (erosion control) and soil conservation measures in the mountainous regions or watershed area as well. The Lakhandei river originates in the Siwalik hills. These hills yield much sediment, some of which could be controlled through watershed management techniques.

SELECTION OF RIVERS FOR PRIORITY PROJECT

Items for Evaluation	1.Ratuwa R.		2.Lohandra R.		3.Lakhandei R.		4.Narayani N.		5.Tinau R.		5.W.Rapti R.		7.Babai R.		8.Khutiya R.	
	Evaluation	Mk.	Evaluation	Mk.	Evaluation	Mk.	Evaluation	Mk.	Evaluation	Mk.	Evaluation	Mk.	Evaluation	Mk.	Evaluation	Mk.
(A) Classification of River Basin																
Class of river	III		III		III		I		II		II		II		III	
Development region	Eastern		Eastern		Central		Central/Western		Western		Mid-Western		Mid-Western		Far-Western	
(B) Priority of Immediate Implementation																
(1) Higher Economic Viability		4		2		3		4		4		5		3		6
(1-1) Present basin development	Medium	2	High	1	Medium	2	Medium	2	Medium	2	Medium	2	Medium	2	Low	3
(1-2) Existing public facilities	Medium	2	High	1	High	1	Medium	2	Medium	2	Low	3	High	1	Low	3
(2) Urgency of Flood Mitigation		5		5		3		6		5		2		3		2
(2-1) Recent severe floods	'88, '95, '96	3	'87, '88, '96	3	'97, '93, '95	1	'88, '93, '95	3	'96, '95, '93	2	'97, '96, '93	1	'95, '87, '96	2	'97, '86, '83	1
(2-2) Progress of flood mitigation works	Medium	2	Medium	2	Medium	2	Higher	3	Higher	3	Lower	1	Lower	1	Lower	1
(3) Favorable Social Impacts		3		5		5		2		2		5		2		4
(3-1) Protected area and population	Medium	2	Medium	2	Medium	2	More	1	More	1	Medium	2	More	1	Less	3
(3-2) Existence of municipalities	Damak	1	-	3	-	3	Narayangat	1	Butwal	1	-	3	Gulariya	1	Dhangadhi	1
(4) Adverse Social/Environment Impacts		3		3		3		4		4		4		3		3
(4-1) Relocation of houses	Few	1	Some	2	Some	2	Few	1	Some	2	Few	1	Few	1	Few	1
(4-2) National park and wet lands	Small	2	None	1	None	1	Large	3	Small	2	Large	3	Small	2	Small	2
(5) Sustainability of Flood Mitigation		2		3		2		3		3		2		2		3
(5-1) Desire of local government/DIO	Very active	1	Active	2	Very active	1	Active	2	Active	2	Very active	1	Very active	1	Active	2
(5-2) Availability of local materials	Available	1	Available	1	Available	1	Available	1	Available	1	Available	1	Available	1	Available	1
(6) Availability of Basic Data		4		4		3		2		2		4		3		6
(6-1) Topographic maps	Available	1	Available	1	Available	1	Available	1	Available	1	Available	1	Available	1	Not avail.	3
(6-2) Hydrological data	Not avail.	3	Not avail.	3	WL avail.	2	Available	1	Available	1	Not avail.	3	WL avail.	2	Not avail.	3
Total point	21		22		19		21		20		22		16		24	
(C) Overall Evaluation																
Priority order	4		6		2		4		3		6		1		8	
RiverClass/DevelopmentRegion	III/ Eastern		III/ Eastern		III/ Central (Selected)		I/ Central-West.		II/ Western		II/ MidWestern		II/ MidWestern (Selected)		III/ FarWestern	

Table 5.1