2. FLOOD MITIGATION MASTER PLAN

2.1 Principles for Formulation of Master Plan

(1) Objective of Master Plan

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

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

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

(2) Target Year

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

(3) Objects to be Protected

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

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

3) Flooding and inundation.

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

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

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

(4) Approach to Flood Mitigation

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

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

2.2 Flood Mitigation Measures and Project Components

(1) Conceivable Flood Mitigation Measures

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

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

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

(2) Project Components

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

2.3 Watershed Management Component

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

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

leading role in this regard.

(1) Erosion Control Facilities

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

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

(2) Afforestation/Reforestation and Land Use Regulation

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

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

(3) Publicity Activities

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

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

2.4 River Control Component

2.4.1 Design Discharge

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

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

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

where

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

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

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

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

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

(Q_n/Q_2-values for Tinau River)

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

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

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
Tinau	1,081	830	1,340	1,670	1,990	2,420

2.4.2 River Segments and Channel Characteristics

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

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

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

- TI-1: Reaches from Indian border to Dano river junction (Sta. 12.7 km)
- TI-2: Reaches from Dano river junction to Sta. 31 km (near Belahari)
- TI-3: Reaches from Sta. 31 km to Sta. 41 km
- TI-4: Reaches from Sta. 41 km to Sta. 53.0 km
- TI-5: Reaches from Sta. 53.0 km to upper end (Sta. 59.5 km)

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

River stretch	River segment code	Ground elevation		Ground slope (1/l)	Grain size		River width Bm (min-max) (m)
		From (m)	To (m)		d_{60} (mm)	d_R (mm)	
Tinau R.							
TI-1	2-2	92	96	3,180	0.18	0.18	163(88-325)
TI-2	2-2	96	105	2,030	0.39	0.39	79(50-150)
TI-3	2-1	105	115	1,000	3.6	3.6	159(63-325)
TI-4	1	115	143	430	17	42	557(325-875)
TI-5	1	143	203	110	46	96	450(88-925)

2.4.3 River Boundary Line (RBL)

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

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

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

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

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

1) To study river width necessary to transport design flood water and sediment
2) To investigate erosion width along the both river banks. The erosion width discussed here is total erosion width of riverbank throughout a flood season. Design erosion width (B_e) is determined as the maximum value for respective river reaches based on the investigated data.
3) To draw initial RBLs on both banks keeping distance more than B_e from river bank. The RBL should be set on a smooth alignment for floodwater flow.
4) The initial RBLs are examined from the viewpoints of property protection and channel capacity. The RBL will be revised partially, if the result of examination demands.
5) The RBLs are fixed and authorized finally after getting consent of government authorities and local communities concerned.

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

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

2.4.4 Facility Plan

(1) Channel Treatment

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

(2) Bank Protection

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

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

independently or jointly. Various types of bank protection works have been developed empirically over the world, and the works should be selected considering the channel characteristics of the river.

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

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

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

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

1) Type-C bank: $B_h \geqq B_e$ and bank erosion is not active due to topographical and geological reasons.
2) Type-B bank: $B_h \geqq B_e$ and bank erosion is active.
3) Type-A bank: $B_h < B_e$ and bank erosion is active.
4) Type-A_s bank: $B_h < 0.5\ B_e$ and bank erosion is active.

5) Type-A_{ss} bank: $B_h < 3h_H$, $7h_H$ and $10h_H$ for Segment 1, Segment 2-1 and Segment 2-2, respectively, where h_H: design water depth in high water channel.

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

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

(3) Dike Works

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

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

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

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

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

(4) Excavation of Low Water Channel

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

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

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

(5) Realignment of Channel

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

(6) Storage or Detention of Flood Water

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

2.5 Community Development Component

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

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

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

2.5.1 Community Mobilization

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

(1) Workshops for Local Government Institutions (LGIs)

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

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

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

(2) Creation of Organizational Bases at the Community

Formation of Community Organizations (COs)

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

Promotion of Public Awareness, Knowledge & Skills

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

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

Generation of Financial Resources by COs

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

2.5.2 Local Coping Measures

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

(1) Flood Proofing

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

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

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

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

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

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

(2) Forecasting, Warning, & Evacuation

The following are some of such examples of local measures:

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

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

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

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

(3) Flood Fighting

The following are examples of local flood fighting measures:

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

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

2.5.3 Community-based Sustainable Measures

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

(1) Forest/Grass Belts as Dike Works

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

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

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

(2) Preventive Bank Protection Works

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

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

(3) Access Improvements using Flood Control Structures

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

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

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

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

(4) Bed Material Collection as Channel Excavation Works

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

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

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

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

(5) Operation and Maintenance of Flood Control Structures

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

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

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

(6) Land Use Management

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

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

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

3) **Deforestation:** Not all the forests along the rivers are 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.

2.6 Flood Mitigation Plan

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

(1) Present Conditions and Problems

1) River basin:
   - Class-II river in 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 area.
   - 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 near Butwal city and joins again at about 13 km upstream from the Indian border. The main Tinau

convey floodwater and sediment from the Mahabharat ranges, and the Dano river those from the Siwalik hill and the Tinau river.

3) River channel: River is wide and braided in the upper reaches and becomes narrower gradually toward lower reaches. Riverbed materials along the river changes from fine sand in the lower reaches to small cobbles in the upper 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)
5) Flood and sediment disasters:
   - Recent major floods: 1996, 1995 and 1993 floods in 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 and brought about epidemic disease such as chorela, dysentery, typhoid, etc., resulting in loss of 26 human lives in the whole Rupandei district.

(2) Principal Measures to be Taken

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 diversion facility if necessary.
4) Forest belt will be provided for Segment 1 and grass belt for Segments 2-2 and 2-1.
5) Cut-off channels will be constructed at the severe bends.
6) Bank protection works by a series of spurs will be implemented based on the monitoring result of riverbanks. Preventive measures for bank erosion will also be taken by adopting bioengineering approach.
7) Watershed management will be carried out for erosion and runoff control.
8) Flood plain management will be carried out for mitigation of damage due to flood and sediment disasters.

(3) Layout Plan

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

(4) Project Works and Cost

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

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

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

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

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

CANDIDATE SPECIES FOR BIOENGINEERING WORKS IN TERAI

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

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

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

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

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

PROJECT COST FOR MASTER PLAN

TINAU RIVER (unit: 1000NRs)

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	$1000m^3$	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

ANNUAL DISBURSEMENT SCHEDULE OF TINAU RIVER PROJECT FOR MASTER PLAN

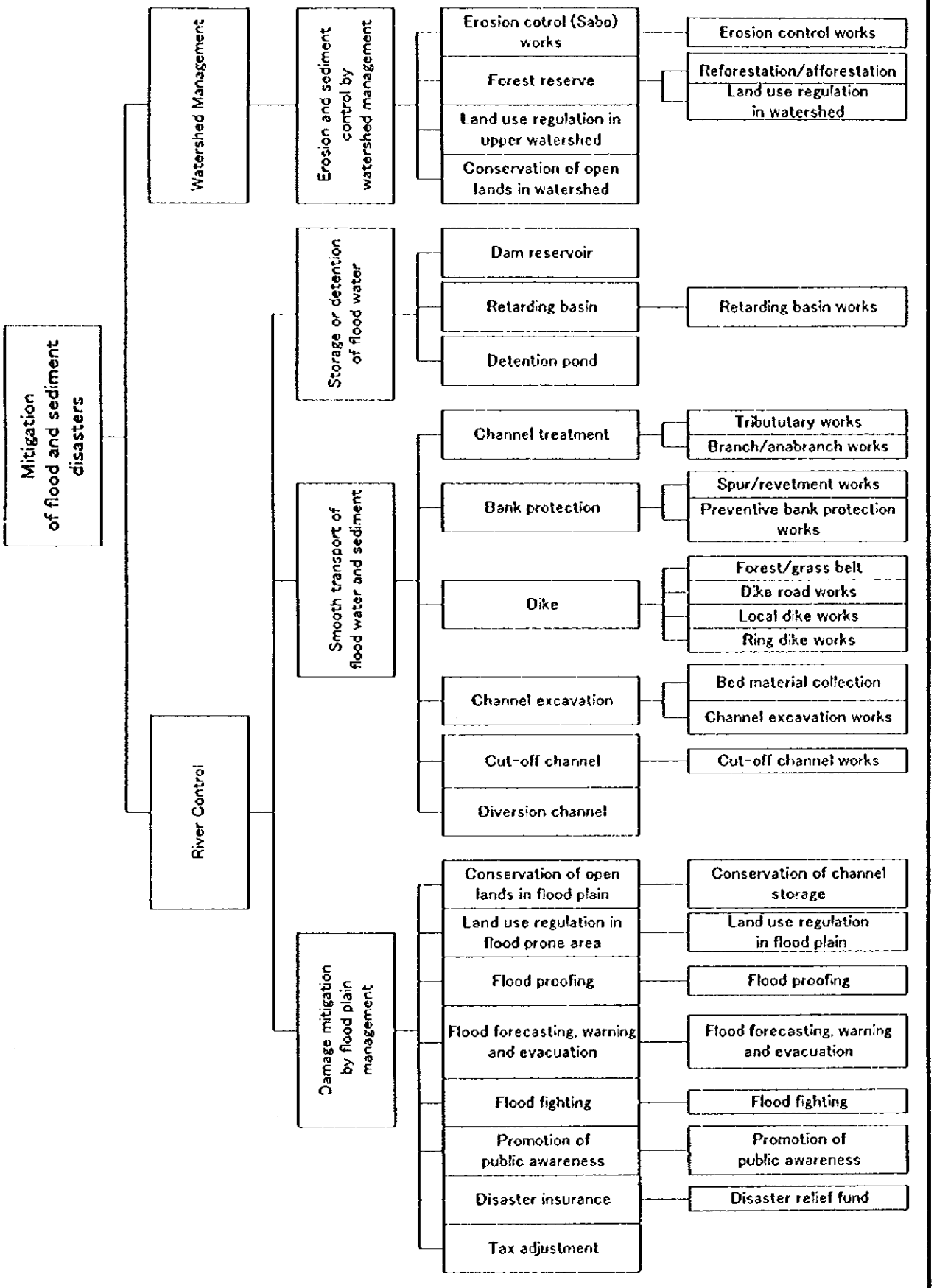
(Financial Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	408,143	0	0	0	35,558	35,558	35,558	23,190	23,190	23,190	23,190	23,190	23,190	23,190	23,190	23,190	23,190	23,190	23,190	23,190
1. Preparatory Works	37,104	0	0	0	12,368	12,368	12,368	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	117,336	0	0	0	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334	7,334
3. Channel Woks	122,808	0	0	0	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676	7,676
4. Ring Dike Works	97,164	0	0	0	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073	6,073
5. Miscellaneous Works	33,731	0	0	0	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108
II . Compensation Cost	231,255	0	0	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	14,453	0
III. Addministration Cost	31,970	0	0	725	2,501	2,501	2,501	1,882	1,882	1,882	1,882	1,882	1,882	1,882	1,882	1,882	1,882	1,882	1,882	1,159
IV. Engineering Cost	61,221	0	30,611	0	2,667	2,667	2,667	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739
1. F/S, D/D etc.	30,611	0	30,611	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	30,611	0	0	0	2,667	2,667	2,667	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739	1,739
V. Physical Contingency (10% of Items I , II &IV)	70,062	0	3,061	1,445	5,268	5,268	5,268	3,938	3,938	3,938	3,938	3,938	3,938	3,938	3,938	3,938	3,938	3,938	3,938	2,493
VI. Total	802,651	0	33,672	16,621	60,447	60,447	60,447	45,203	45,203	45,203	45,203	45,203	45,203	45,203	45,203	45,203	45,203	45,203	45,203	28,582

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

(Economic Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I . Construction Base Cost	367,328	0	0	0	32,002	32,002	32,002	20,871	20,871	20,871	20,871	20,871	20,871	20,871	20,871	20,871	20,871	20,871	20,871	20,871
1. Preparatory Works	33,393	0	0	0	11,131	11,131	11,131	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	105,602	0	0	0	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600	6,600
3. Channel Woks	110,527	0	0	0	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908	6,908
4. Ring Dike Works	87,448	0	0	0	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465	5,465
5. Miscellaneous Works	30,358	0	0	0	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897	1,897
II . Compensation Cost	208,130	0	0	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	13,008	0
III. Addministration Cost	28,773	0	0	650	2,251	2,251	2,251	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,694	1,044
IV. Engineering Cost	55,099	9,183	9,183	9,183	2,400	2,400	2,400	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565
1. F/S, D/D etc.	27,550	9,183	9,183	9,183	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	27,550	0	0	0	2,400	2,400	2,400	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565	1,565
V. Physical Contingency (10% of Items I , II &IV)	63,056	918	918	2,219	4,741	4,741	4,741	3,544	3,544	3,544	3,544	3,544	3,544	3,544	3,544	3,544	3,544	3,544	3,544	2,244
VI. Total	722,386	10,102	10,102	25,061	54,402	54,402	54,402	40,683	40,683	40,683	40,683	40,683	40,683	40,683	40,683	40,683	40,683	40,683	40,683	25,725



FLOOD MITIGATION MEASURES

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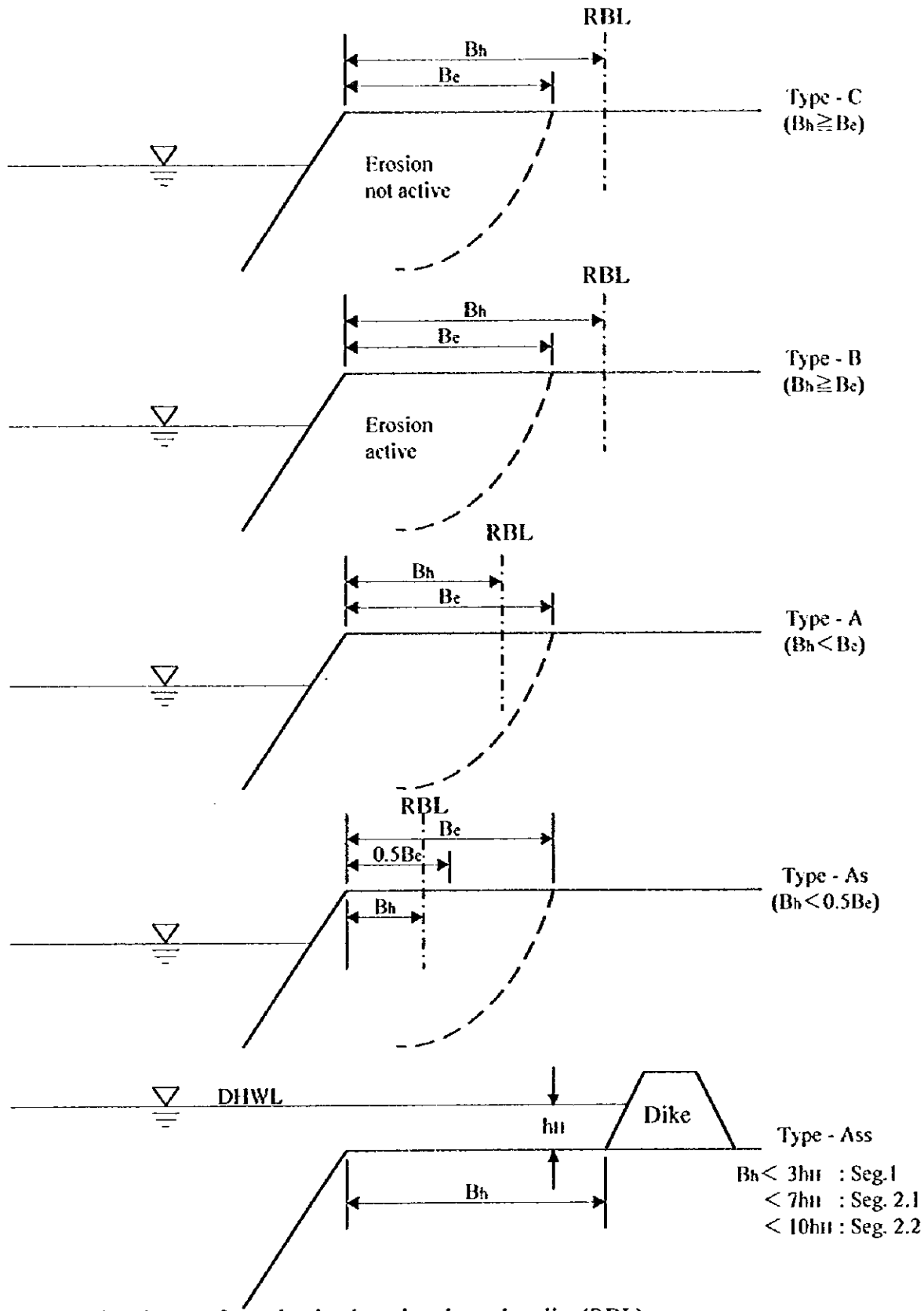
Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



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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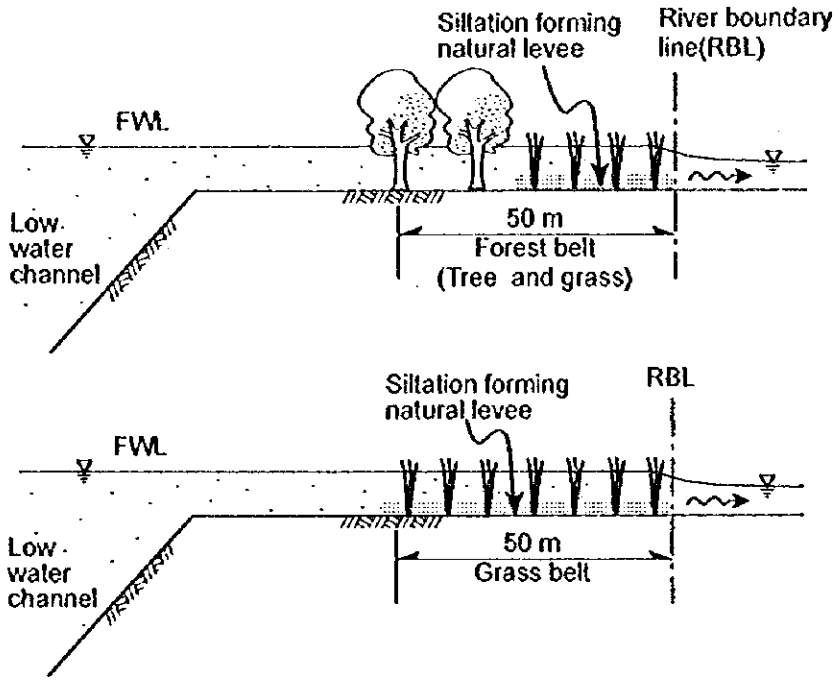
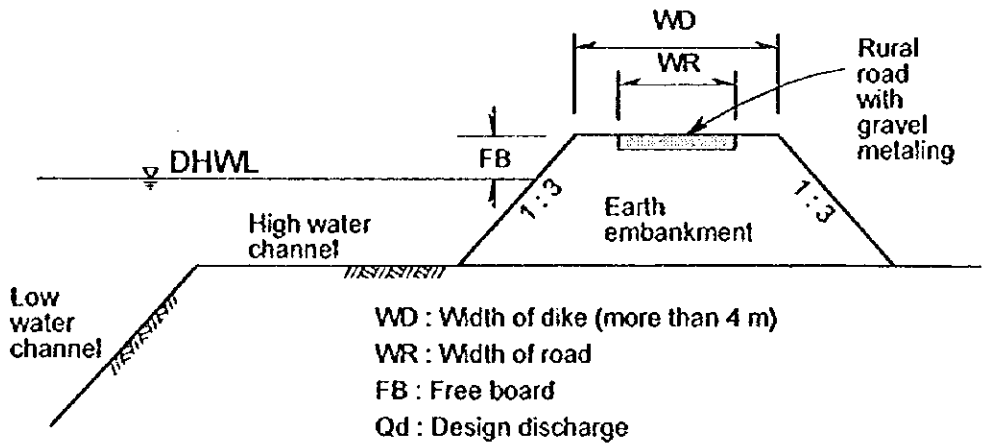
JAPAN INTERNATIONAL COOPERATION AGENCY

Forest and Grass Belt



Earth Dike / Road



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

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

DIKE WORKS

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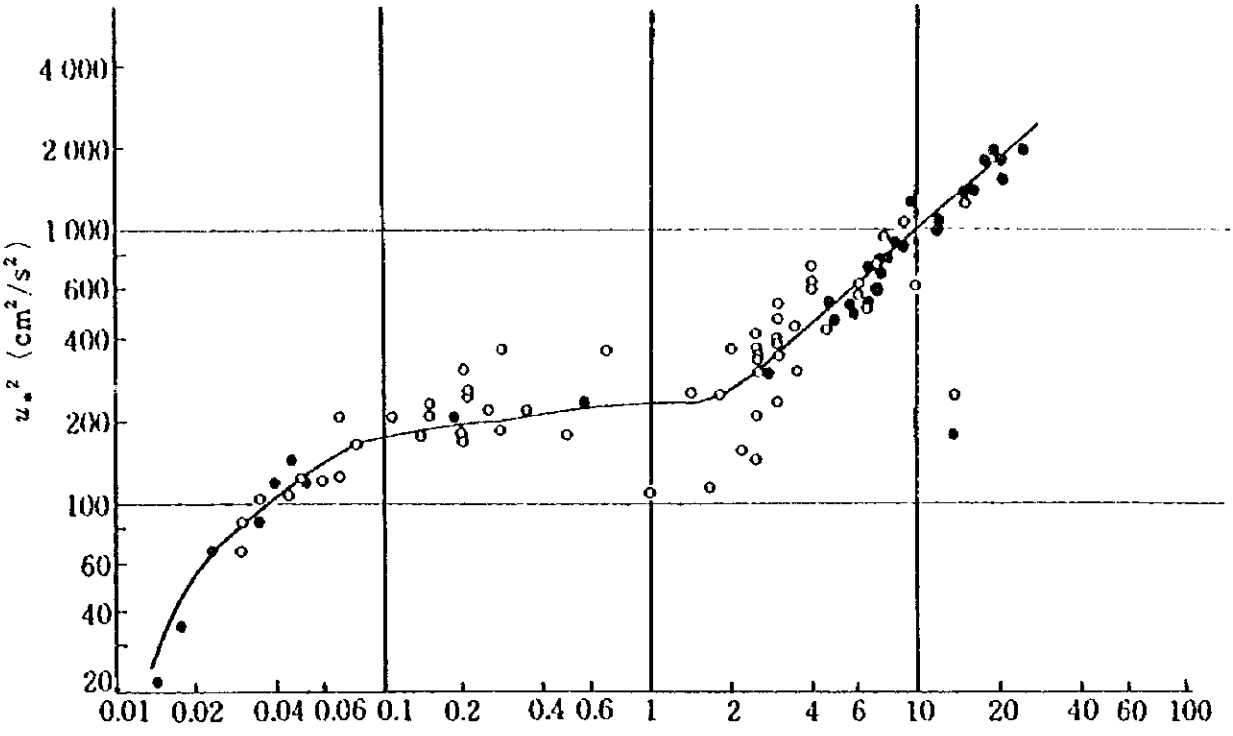


$$Q_2 = A \cdot V = \frac{B \cdot h_L^{5/3} \cdot I^{1/2}}{n} \quad \Rightarrow \quad h_L = \left\{ \frac{Q_2 \cdot n}{B \cdot I^{1/2}} \right\}^{3/5}$$

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

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

n : Manning's coefficient of roughness

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

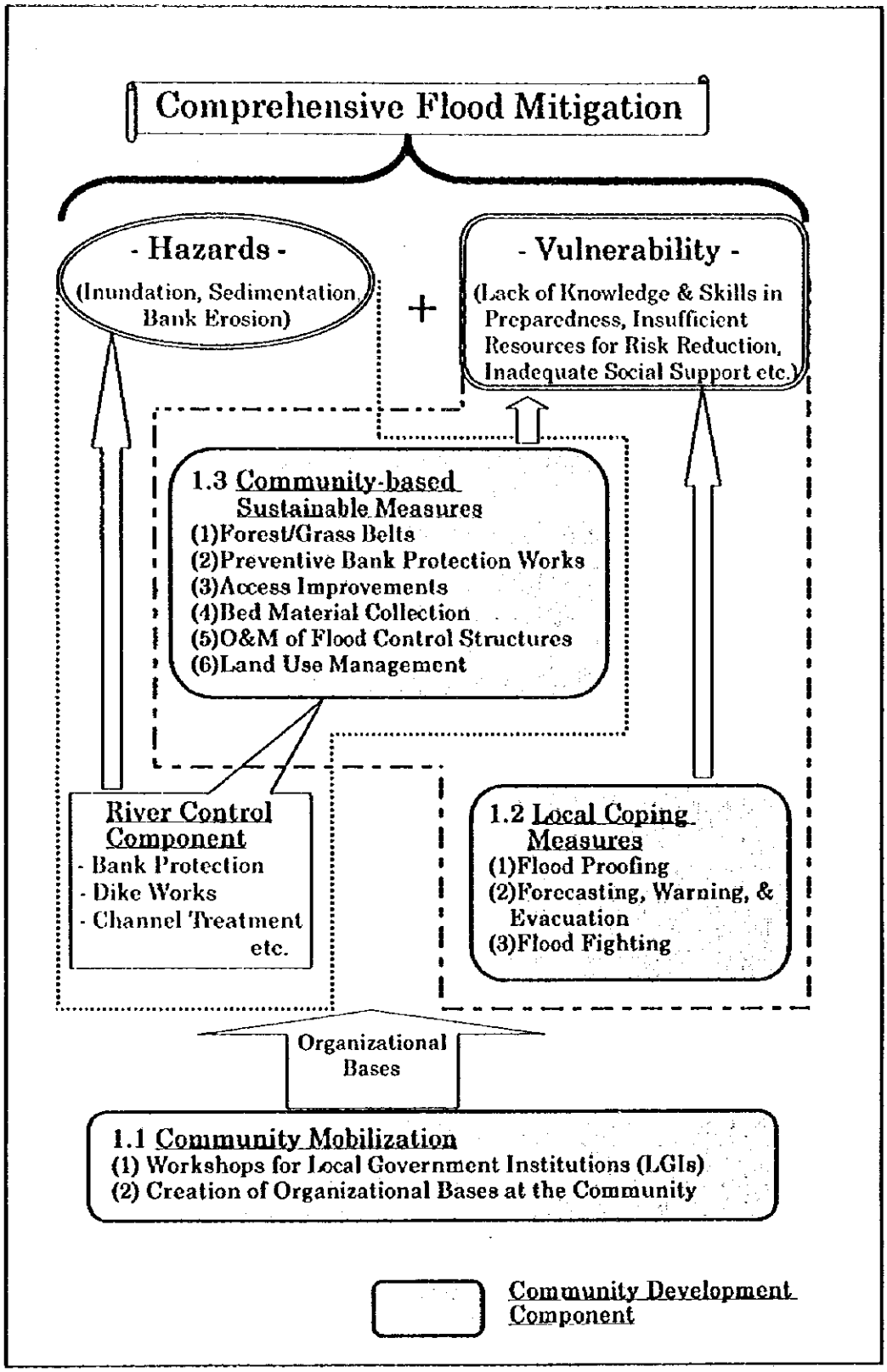
Q_2 : Two-year probable discharge (m3/s)

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

h_L : Mean depth of low water channel (m)

B : Low water channel width

RELATIONSHIP BETWEEN BED MATERIAL SIZE AND FRICTION VELOCITY



COMPREHENSIVE FLOOD MITIGATION

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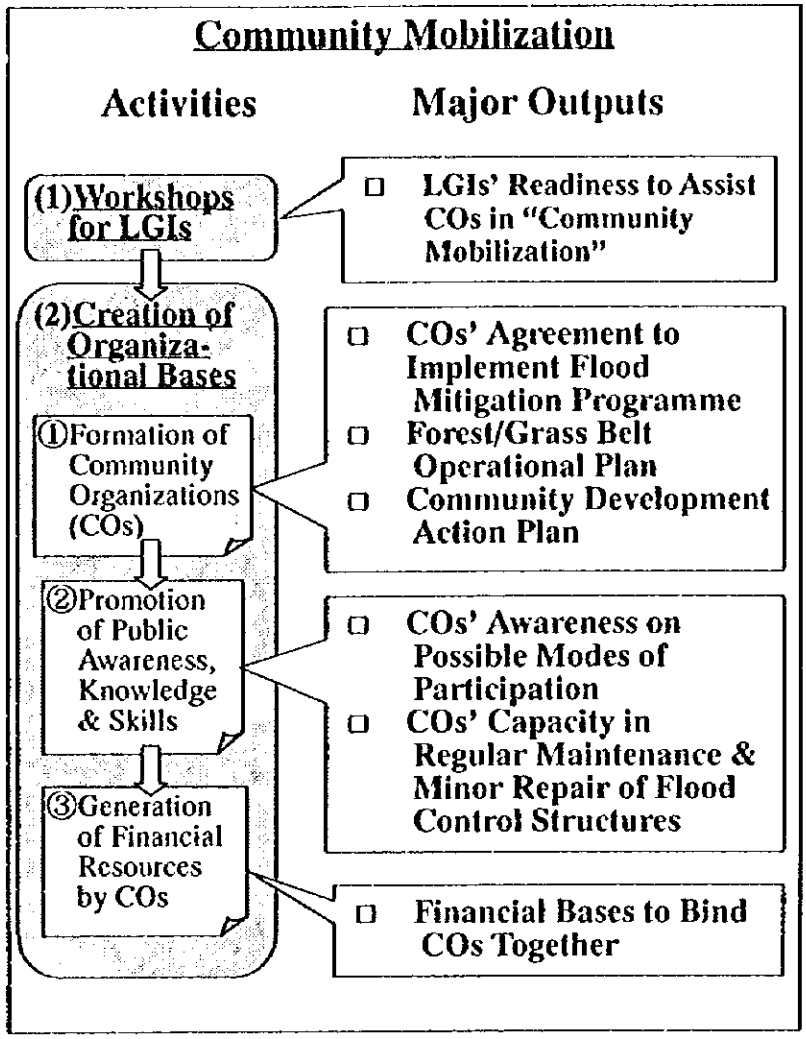

COMMUNITY MOBILIZATION

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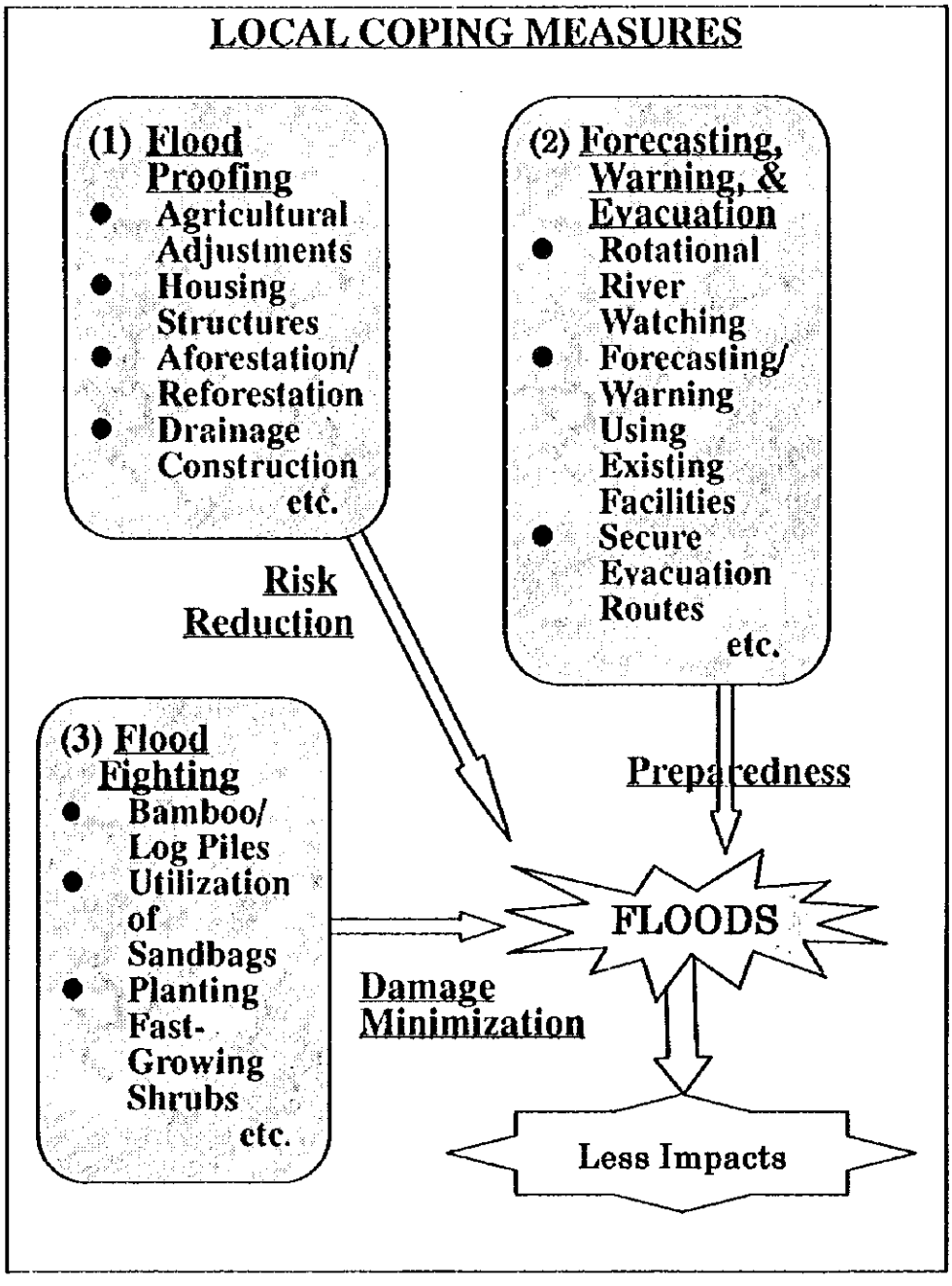

LOCAL COPING MEASURES

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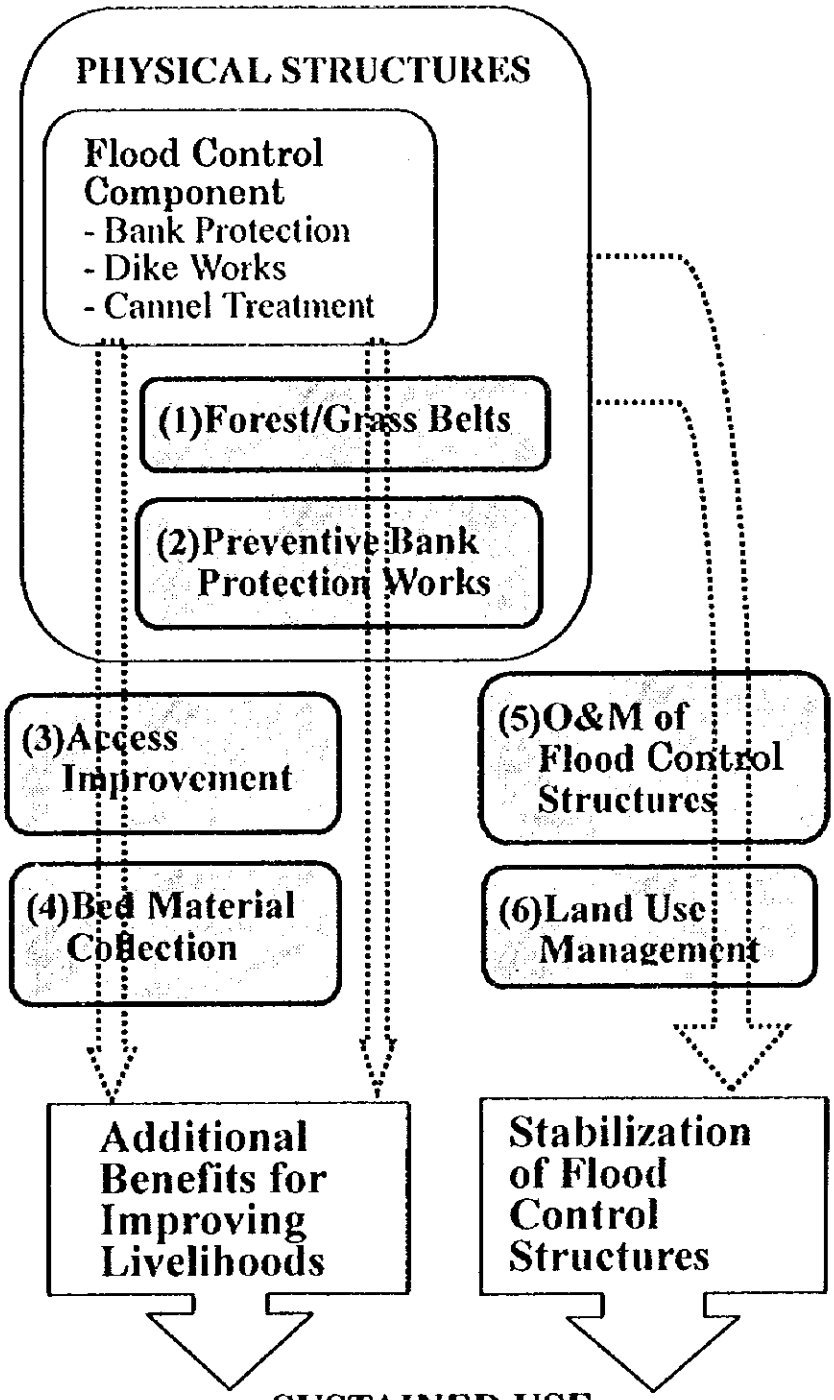
Community-based Sustainable Measures



COMMUNITY-BASED SUSTAINABLE MEASURES

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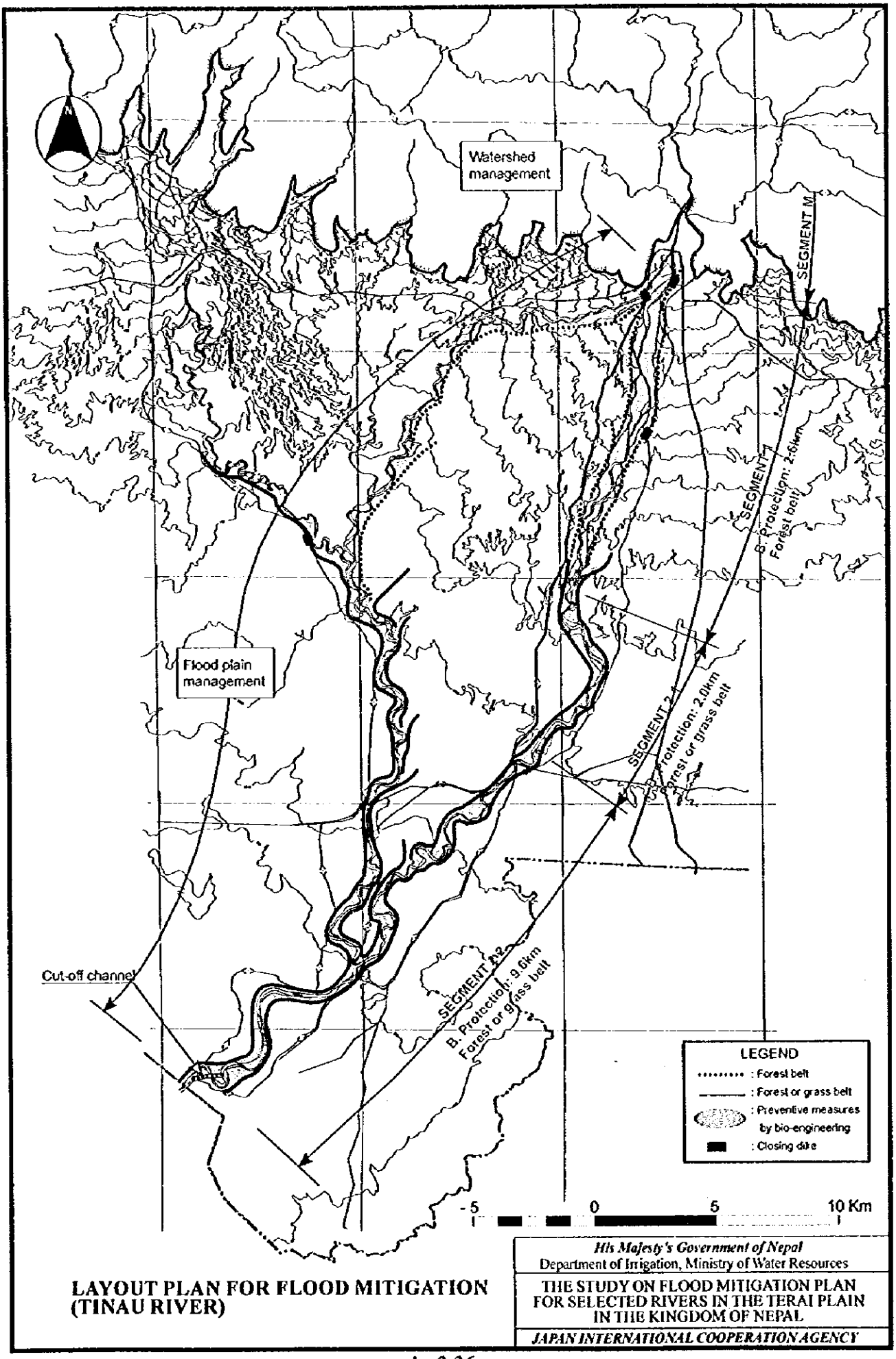
Fig. A2.9



LAYOUT PLAN FOR FLOOD MITIGATION (TINAU RIVER)

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3. ACTION PROGRAM TOWARD TARGET YEAR

3.1 Sequence of Works

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

(1) Preparatory Works

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

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

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

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

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

(2) Coordination For Flood Mitigation

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

(3) River Works

1) **Channel Treatment Works:**

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

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

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

2) **Bank Protection Works:**

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

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

3) **Dike Works:**

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

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

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

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

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

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

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

3.2 Action Plan

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

1) **1st Phase (Ninth plan: 1997-2002):**
   (a) Preparatory works such as feasibility study, fund arrangement, definite plan/detail design, preservation of lands will be performed.
   (b) Research and investigation, and coordination for watershed management and flood plain management will be started in combination with community development activities.
   (c) Bank protection and ring dike works will be executed at the critical sites.
   (d) Preventive bank protection works by bioengineering, and bed material collection is also started in this phase.

2) **2nd Phase (Tenth plan: 2002-2007):**
   (a) Channel treatment works which are the key to stabilize the river system will be executed.
   (b) Forest belt will start for its work in field. Grass belt will be completed for Segment 2-1 and 2-2.
   (c) Local dikes and dike roads will be constructed where they are required.

3) **3rd Phase (Eleventh and twelfth plan: 2007-2017):**
   (a) All the works and activities targeted for the Master Plan will be completed.

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

3.3 Implementation Arrangements

(1) Coordinating/Implementing Agencies

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

The River Control Division will take the lead in the design and construction management of the River Control Component. At the same time, the local government institutions (LGIs) also play an important role to match the DOI's resources with local

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

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

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

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

1) **All the flood-prone villages will be directly represented in DCC**, to provide an open and transparent forum for interactions between the district and the

villages (whereas DRTCC is composed only of district-level representatives, which often is the cause of irrational allocation of funding).

2) **DCC will draw members from pertinent line agencies**, i.e., DOSCWM, DOF, and DOA for a more comprehensive approaches to river training (whereas DRTCC does not include any line agencies, which makes it difficult to coordinate river training, with other related developmental activities).

(2) Cooperating Agencies

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

<u>Technical Line Agencies</u>

DOSCWM :

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

DOF:

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

DOA:

1) Provide technical advice on safe cultivation on the riverside.
2) Offer awareness building and seedlings to support in crop production that would minimize river cutting and flood damage.

CDO:

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

Local Government Institutions (LGIs)

DDC:

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

VDC / Municipality:

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

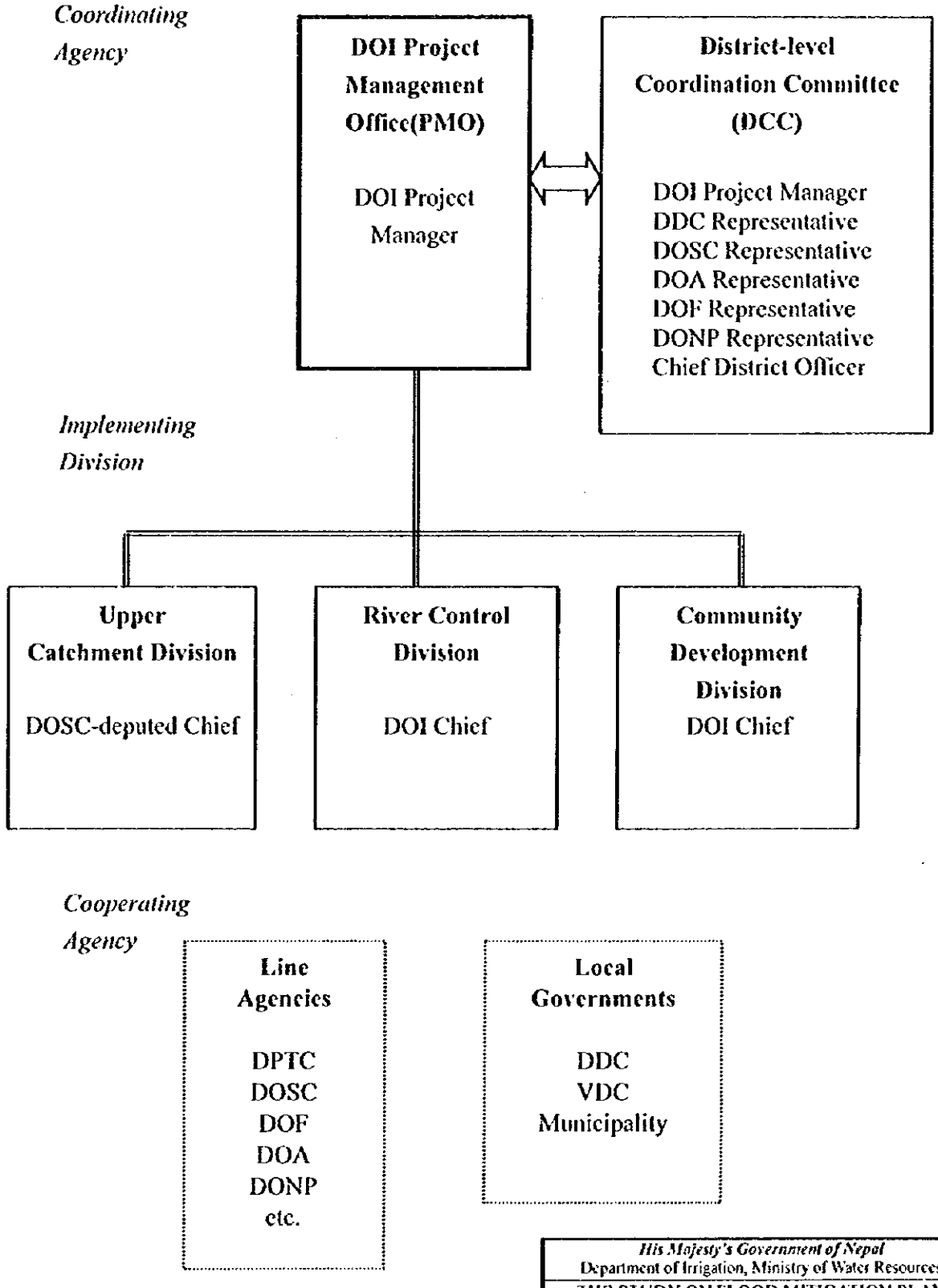
In view of upgrading the LGIs' capabilities to undertake these crucial roles for "community development", a series of training workshops will be undertaken at the inception of "community development" activities, as mentioned in the section on "Community Development" component/

ACTION PROGRAM TOWARD TARGET YEAR

River: TINAU 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 exploitation				
Retarding basin				
(4) River Works in Segment-2				
Channel treatment works:				
•Tributary works				
•Branch/ anabranch works				
Bank protection works:				
• Spur/ revetment				
• Preventive bank protection measurs (by bio-engineering)				
Dike works:				
• Grass belt				
• Low dike road w/ drainage sluice				
• Continuous dike w/ drainage sluice				
• Ring dike				
Channel excavation works:				
• Bed material exploitation				
• Widening channel				
Cut-off channel works				
Retarding basin				

IMPLEMENTATION ARRANGEMENT FOR FLOOD MITIGATION IN TERAI



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4. EVALUATION

4.1 Economic Evaluation

(1) Basin Overview

Starting from the narrow gorge near Butwal municipality, the Tinau plain area lies on 41,200 hectares of land, about 80% of which is used for agriculture. Paddy production occupies the largest portion of agricultural land (with the estimated 1996/97 production of 21,200 metric tons), followed by wheat (4,600 metric tons) and pulses (480 metric tons). In 1996/97 the retail value of paddy production was Rs.318 million, and pulses was Rs.18 million. There exist only one manufacturing establishment (1-leather factory) in the flood-prone villages in the Terai.

Amongst the eight target basins the Tinau basin areas recorded seconded highest population growth during 1991-96. The Master Plan implementation calls for the Tinau basin, to accommodate an ever-increasing in-migration of people onto flood-risk areas along Tinau river.

(2) Effects of Flood Mitigation

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

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

section may create lands for agriculture and settlement.

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

(3) Preliminary Economic Evaluation for Master Plan Projects

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

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

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

Conditions for Economic Evaluation: Evaluation was made for the existing basin conditions and future basin conditions in target year (2017). The benefit in the target year was assumed in proportional to the population projected. Cash flows of the project cost, maintenance cost and benefit are shown in Table A4.1. With these cash flows, the economic internal rate of return (EIRR), cost-benefit ratio (B/C) and net present value

(NPV, or B-C) were worked out. The results are summarized below, though these should be restudied in future based on river survey data.

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^6Rs)
Tinau	2.8	0.35	-195.4	9.2	0.78	-67.0

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

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

4.2 Environmental Screening

(1) Environmental Screening of Rivers Covered by Master Plan

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

(2) Results of Environmental Screening

The flood mitigation plan for the Tinau river is to align and demarcate the two river banks along the length of the river in the Terai, so as to minimize flood damage. These banks will then be stabilized by vegetative means (forest and grass belts). Occasionally, some riverbanks will be reinforced and perhaps one or two bends straightened. There are 3 listed wetlands in the vicinity of this river. These wetlands will be mapped, their use tabulated, and a plan formulated to protect them.

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

(3) Overall Evaluation

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

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

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

(4) Environmental Study in Future

According to new Environmental Conservation Rules (ECR) issued in June 1997, an Initial Environmental Examination (IEE) is necessary when compiling a watershed

management plan. If any of the planned interventions, such as riverbank protection, are more than 1 km in length, then an IEE is needed at the project proposal stage. Similarly, if tree planting is planned then an IEE or an Environmental Impact Assessment may be necessary at the project proposal stage. The determining factor is whether the proposed planting is in a continuous block of a single indigenous species of more than 25 hectares, or for a single exotic species, is in a continuous block of more than 5 hectares.

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

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

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

If any of the 3 wetlands will be affected by flood mitigation measures, an EIA is necessary for each affected wetland at the project proposal stage.

4.3 Technical Evaluation

The flood mitigation activities must be undertaken in a sustainable way. Therefore, the

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

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

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

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

4.4 Conclusion and Recommendation

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

COST BENEFIT FLOW FOR MASTER PLAN

(Existing Basin)

River: 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	1,317,363	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)

SOCIAL ENVIRONMENT ASSESSMENT: TINAU RIVER.

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

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

NATURAL ENVIRONMENT ASSESSMENT: TINAU RIVER.

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

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

POLLUTION ASSESSMENT: TINAU RIVER.

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

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