

## CANDIDATE SPECIES FOR BIOENGINEERING WORKS IN TERAI

|                               | Naturally Grown Species   | Nursery Species  |
|-------------------------------|---|--|
| Grasses                       | <ul style="list-style-type: none"> <li>- Arundo donax (Narkato)</li> <li>- Cymbopogon microtheca (Khar)</li> <li>- Cymbopogon pendulus (Dangre Khar)</li> <li>- Cynodon dactylon (Dhubo)</li> <li>- Eulaliopsis ninanta (Babiyo, Sabai Grass)</li> <li>- Neyraudia arundinacea (Sito)</li> <li>- Neyraudia reynaudiana (Dhonde)</li> <li>- Pennisetum clandestinum (Kikuyu, Thulo Dhubo)</li> <li>- Pogonatherum paniceum (Musekharuki)</li> <li>- Saccharum spontaneus (Kans)</li> </ul> | <ul style="list-style-type: none"> <li>- Desmodium intortum</li> <li>- Pennisetum purpureum (Napier)</li> <li>- Setaria anceps</li> <li>- Thysanolaena maxima (Amliso) - also in forests -</li> <li>- Stylo</li> <li>- Molasses grass</li> </ul> |
| Shrubs & Non-Plantation Trees | <ul style="list-style-type: none"> <li>- Adhatoda vasica (Assuro)</li> <li>- Butea minor (Bhujetro)</li> <li>- Calatorpha giganteum (Aak)</li> <li>- Colebrookea oppositifolia (Chusun)</li> <li>- Ipomoea fistulata (Saruwa --- Behu)</li> <li>- Lantana camara (Phul Kanda)</li> <li>- Phoenix humilis (Thakal)</li> <li>- Trema orientalis (Kunyel)</li> <li>- Vitex negundo (Simali)</li> <li>- Wedlandia species (Tilka)</li> <li>- Woodfordia fruticosa (Dhanyero)</li> </ul>       |  |
| Trees                         | <ul style="list-style-type: none"> <li>- Acacia catechu (Khayer) --- also in nursery</li> <li>- Acacia auriculiformis</li> <li>- Albizia julibrissin</li> <li>- Ficus semicordata (Khasre Khayu, Khanayo)</li> <li>- Shorea robusta (Sal) -- also in nursery</li> </ul>   | <ul style="list-style-type: none"> <li>- Bauhinia purpurea (Tanki)</li> <li>- Delonix regia (Gulmohar)</li> <li>- Leucaena species (Ipil Ipil)</li> <li>- Bamboo species</li> </ul>  |

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

## INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

| From:                    | Species Used  | Income-generating Products   |
|--------------------------|---|--|
| Nursery                  | <p><b>Trees</b></p> <ul style="list-style-type: none"> <li>- Acacia catechu (Khayer)</li> <li>- Shorea robusta (Sal)</li> <li>- Bauhinia purpurea (Tanki)</li> <li>- Delonix regia (Gulmohar)</li> <li>- Leucaena species (Ipil Ipil)</li> <li>- Bamboo species</li> </ul> <p><b>Grasses</b></p> <ul style="list-style-type: none"> <li>- Desmodium intortu</li> <li>- Pennisetum purpureum (Napier)</li> <li>- Thysanofaena maxima (Amliso)</li> <li>- Stylo</li> <li>- Molasess grass</li> </ul>  | <ul style="list-style-type: none"> <li>- saplings</li> <li>- saplings</li> <li>- saplings</li> <li>- seeds/saplings</li> <li>- seeds/saplings</li> <li>- roots</li> <li>- seeds</li> <li>- cutting</li> <li>- seeds/cutting</li> <li>- seeds</li> <li>- seeds</li> </ul>   |
| Bio-Engineering Facility | <p><b>Grasses</b></p> <ul style="list-style-type: none"> <li>- Desmodium intortum</li> <li>- Pennisetum purpureum (Napier)</li> <li>- Thysanofaena maxima (Amliso)</li> <li>- Stylo</li> <li>- Molasess grass</li> <li>- Arundo donax (Narkato)</li> <li>- Cymbopogon microtheca (Khar)</li> <li>- Cymbopogon pendulus (Dangre Khar)</li> <li>- Cynodon dactylon (Dhubo)</li> <li>- Eulaliopsis ninanta (Babiyo)</li> <li>- Saccharum spontaneus (Kans)</li> </ul> <p><b>Shrubs</b></p> <ul style="list-style-type: none"> <li>- Adhatoda vasica (Assuro)</li> </ul> <p><b>Trees</b></p> <ul style="list-style-type: none"> <li>- Bamboo species</li> <li>- Bauhinia purpurea (Tanki)</li> <li>- Delonix regia (Gulmohar)</li> <li>- Leucaena species (Ipil Ipil)</li> <li>- Acacia catechu (Khayer)</li> <li>- Shorea robusta (Sal)</li> </ul> | <ul style="list-style-type: none"> <li>- fuel wood</li> <li>- fodder/mulching</li> <li>- fodder/broom</li> <li>- fodder/seed</li> <li>- fodder/seed</li> <li>- fencing</li> <li>- roof thatch</li> <li>- roof thatch</li> <li>- fodder</li> <li>- rope</li> <li>- roof thatch/rope</li> <li>- green manure/medicine</li> <li>- furniture/timber</li> <li>- fodder/fuel wood</li> <li>- fuel wood</li> <li>- fodder/fuel wood</li> <li>- timber/fuel wood/medicine</li> <li>- leaf plate</li> </ul> |

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

Table A2.3

## PROJECT COST FOR MASTER PLAN

| RATUWA RIVER                      |                    | (unit: NRs1000) |           |                |
|-----------------------------------|--------------------|-----------------|-----------|----------------|
| Item                              | Unit               | Quantity        | Unit Cost | Amount         |
| <b>I . Construction Base Cost</b> |                    |                 |           | <b>310,842</b> |
| 1. Preparatory Works              | L.S.               | 1.00            |           | 28,258         |
| 2. Bank Protection Works          |                    |                 |           | 69,627         |
| 2-1 Pile Spur (Type-A)            | km                 | 2.40            | 5,301     | 12,722         |
| 2-2 Gabion Spur (Type-A)          | km                 | 6.90            | 8,247     | 56,904         |
| 3. Cannel Works                   |                    |                 |           | 58,980         |
| 3-1 River Boundary Line           | km                 | 99.80           | 27        | 2,695          |
| 3-2 Tree Belt                     | ha                 | 191.75          | 68        | 13,039         |
| 3-3 Grass Belt                    | ha                 | 279.75          | 126       | 35,249         |
| 3-4 Cut-off Cannel                | 1000m <sup>3</sup> | 62.50           | 93        | 5,813          |
| 3-5 Closing Dike/structure        | place              | 1.00            | 2,185     | 2,185          |
| 4. Ring Dike Works                |                    |                 |           | 128,288        |
| 4-1 Dike Embankment               | km                 | 20.90           | 2,596     | 54,256         |
| 4-2 Drainage Sluice               | place              | 40.00           | 1,275     | 51,000         |
| 4-3 Gravel Metaling               | km                 | 20.90           | 1,102     | 23,032         |
| 5. Miscellaneous Works            | L.S.               | 1.00            |           | 25,689         |
| <b>II . Compensation Cost</b>     | L.S.               | 1.00            |           | <b>124,392</b> |
| <b>III . Administration Cost</b>  | L.S.               | 1.00            |           | <b>21,762</b>  |
| <b>IV . Engineering Service</b>   | L.S.               | 1.00            |           | <b>46,626</b>  |
| <b>V . Physical Contingency</b>   | L.S.               | 1.00            |           | <b>48,156</b>  |
| <b>Project Cost</b>               |                    |                 |           | <b>551,808</b> |

Note: \*1 Price Level in October 1998

\*2 Conversion 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 RATUWA RIVER PROJECT FOR MASTER PLAN

| Description                 | (1,000NRs) |       |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
|-----------------------------|------------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                             | Total      | 1999  | 2000  | 2001   | 2002   | 2003   | 2004   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   |        |
| I. Construction Base Cost   | 310,842    | 0     | 0     | 0      | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 | 27,081 |
| 1. Preparatory Works        | 28,258     | 0     | 0     | 0      | 9,419  | 9,419  | 9,419  | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| 2. Bank Protection Works    | 69,627     | 0     | 0     | 0      | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  | 4,352  |
| 3. Channel Works            | 58,980     | 0     | 0     | 0      | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  | 3,686  |
| 4. Ring Dike Works          | 128,288    | 0     | 0     | 0      | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  | 8,018  |
| 5. Miscellaneous Works      | 25,689     | 0     | 0     | 0      | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  | 1,606  |
| II. Compensation Cost       | 124,392    | 0     | 0     | 0      | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  | 7,775  |
| III. Administration Cost    | 21,762     | 0     | 0     | 389    | 1,743  | 1,743  | 1,743  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  | 1,272  |
| IV. Engineering Cost        | 46,626     | 7,771 | 7,771 | 7,771  | 2,031  | 2,031  | 2,031  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  |
| 1. F/S, D/D etc.            | 23,313     | 7,771 | 7,771 | 7,771  | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| 2. Construction Supervision | 23,313     | 0     | 0     | 0      | 2,031  | 2,031  | 2,031  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  | 1,325  |
| V. Physical Contingency     | 48,186     | 777   | 777   | 1,555  | 3,689  | 3,689  | 3,689  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  | 2,676  |
| (10% of Items I, II & IV)   |            |       |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| VI. Total                   | 551,808    | 8,548 | 8,548 | 17,489 | 42,318 | 42,318 | 42,318 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 | 30,708 |

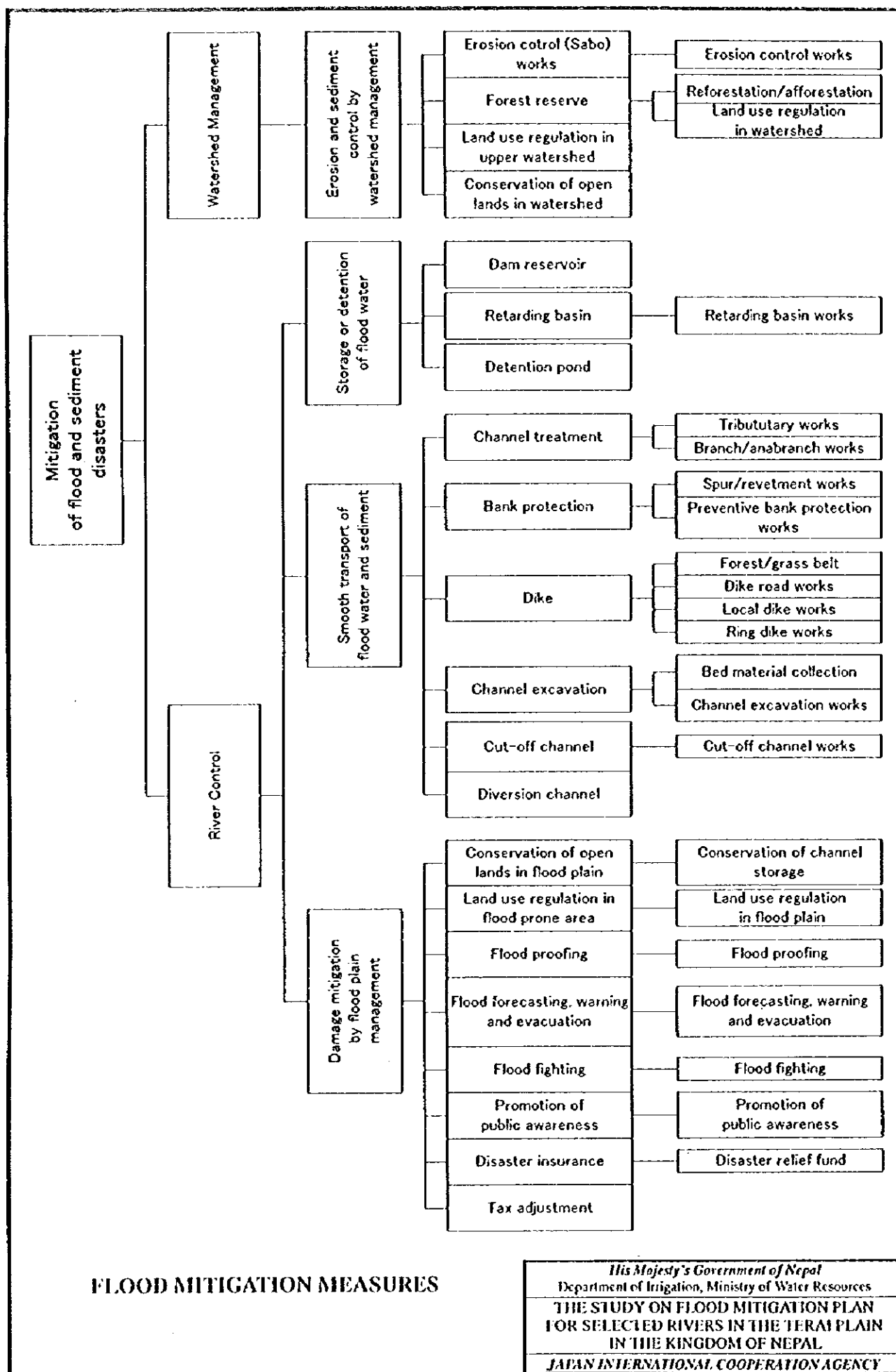
| Description                 | (1,000NRs) |       |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
|-----------------------------|------------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                             | Total      | 1999  | 2000  | 2001   | 2002   | 2003   | 2004   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   |
| I. Construction Base Cost   | 279,758    | 0     | 0     | 0      | 24,373 | 24,373 | 24,373 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 | 15,895 |
| 1. Preparatory Works        | 25,433     | 0     | 0     | 0      | 8,478  | 8,478  | 8,478  | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| 2. Bank Protection Works    | 62,664     | 0     | 0     | 0      | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  | 3,917  |
| 3. Channel Works            | 53,082     | 0     | 0     | 0      | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  | 3,318  |
| 4. Ring Dike Works          | 115,459    | 0     | 0     | 0      | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  | 7,216  |
| 5. Miscellaneous Works      | 23,121     | 0     | 0     | 0      | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  | 1,445  |
| II. Compensation Cost       | 111,953    | 0     | 0     | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  | 6,997  |
| III. Administration Cost    | 19,586     | 0     | 0     | 350    | 1,568  | 1,568  | 1,568  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  | 1,145  |
| IV. Engineering Cost        | 41,964     | 6,994 | 6,994 | 6,994  | 1,828  | 1,828  | 1,828  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  |
| 1. F/S, D/D etc.            | 20,982     | 6,994 | 6,994 | 6,994  | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| 2. Construction Supervision | 20,982     | 0     | 0     | 0      | 1,828  | 1,828  | 1,828  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  | 1,192  |
| V. Physical Contingency     | 43,367     | 699   | 699   | 1,399  | 3,320  | 3,320  | 3,320  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  | 2,408  |
| (10% of Items I, II & IV)   |            |       |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| VI. Total                   | 496,628    | 7,693 | 7,693 | 15,740 | 38,086 | 38,086 | 38,086 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 | 27,638 |

Note: \*1 Price Level in October 1998

\*2 Conversion Rate US\$ 1.00 = NRs 67.95, 1.00 Yen = NRs 0.59

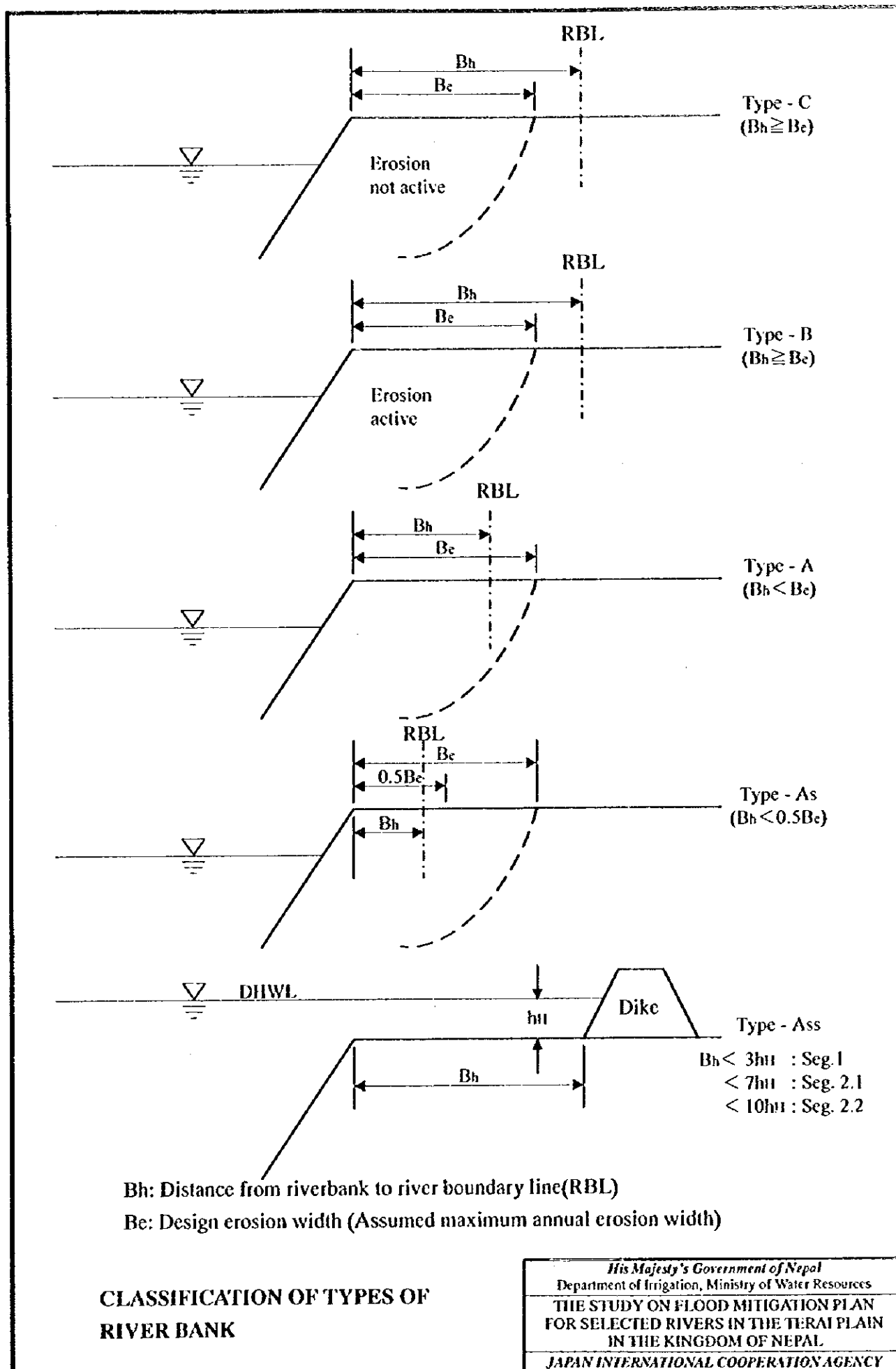
\*3 Cost do not include Price Contingency and Value Added Tax

\*4 Figures may not add up to totals due to rounding

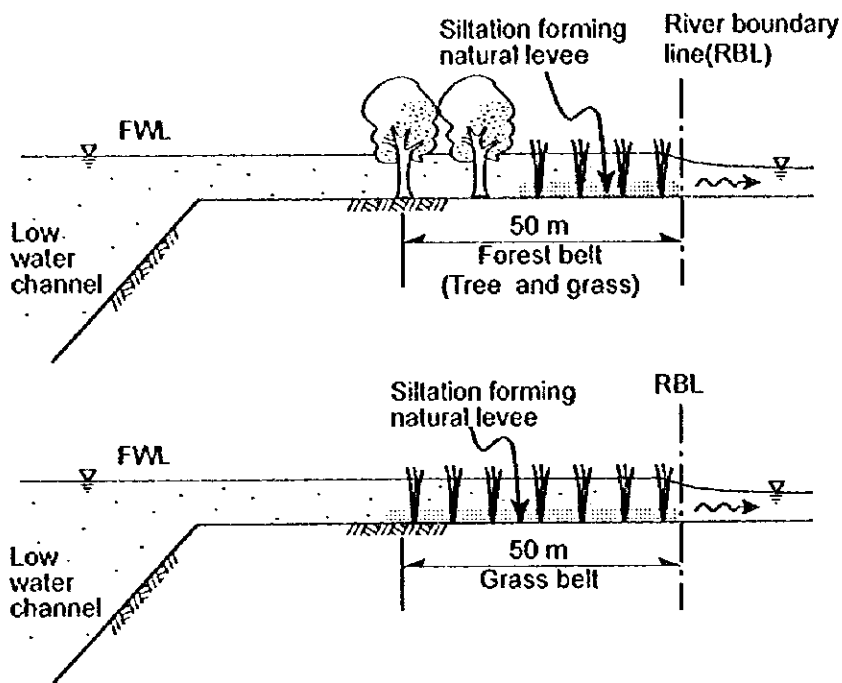


**FLOOD MITIGATION MEASURES**

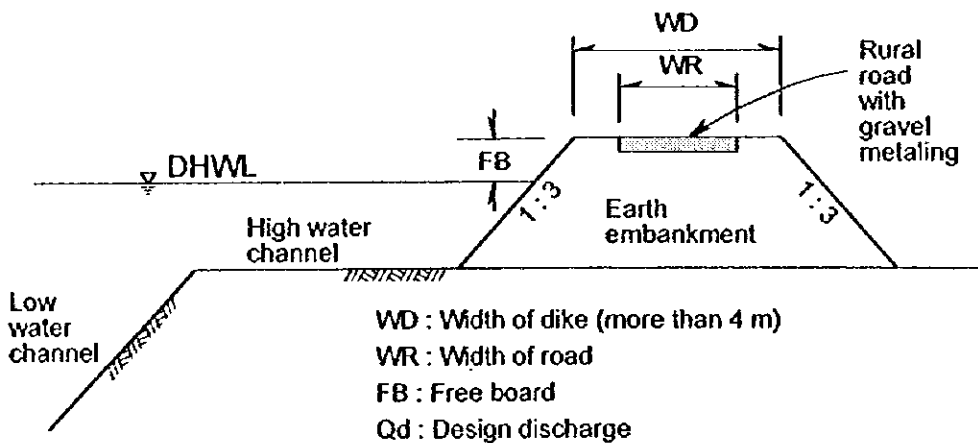
*His Majesty's Government of Nepal*  
 Department of Irrigation, Ministry of Water Resources  
**THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL**  
 JAPAN INTERNATIONAL COOPERATION AGENCY



### Forest and Grass Belt



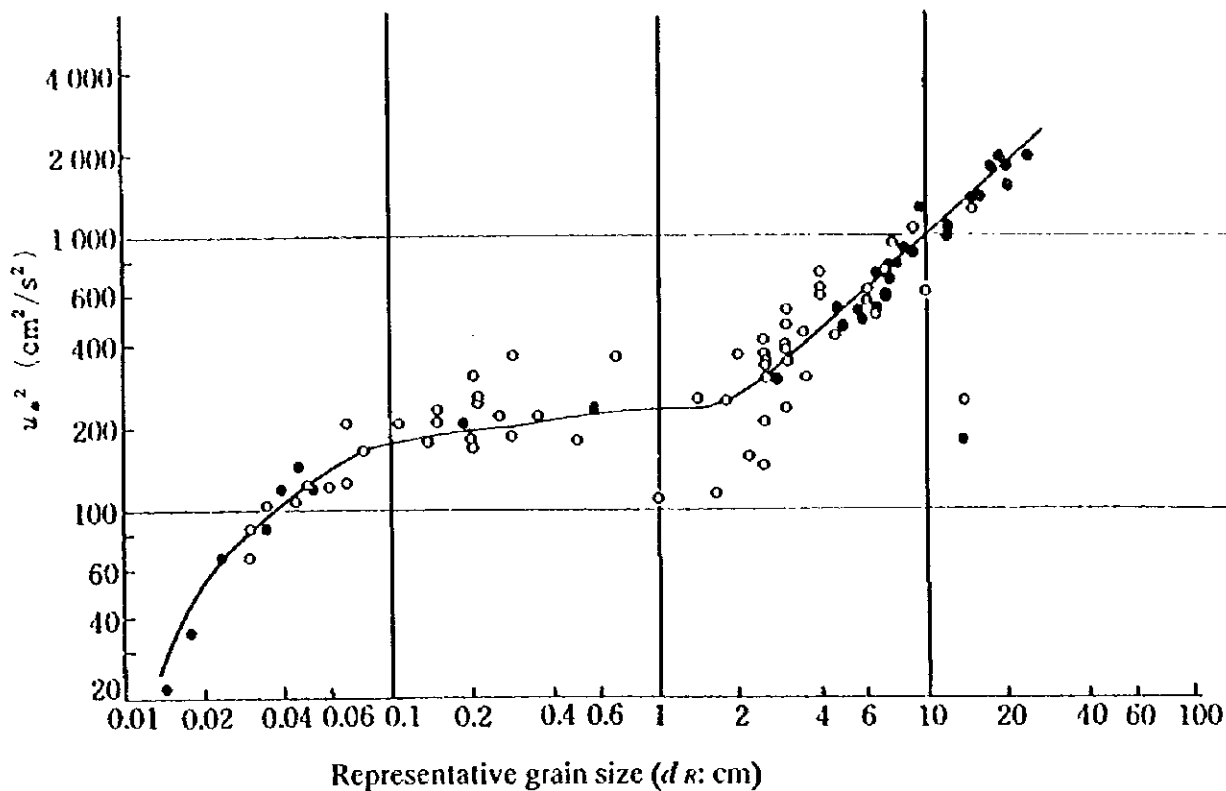
### Earth Dike / Road



| Qd (m <sup>3</sup> /s) | FB (m)<br>(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

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



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

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

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

$n$  : Manning's coefficient of roughness

$g$  : Acceleration of gravity ( $\text{m/sec}^2$ )

$Q_2$  : Two-year probable discharge ( $\text{m}^3/\text{s}$ )

$u_*$  :  $u_*$ -value obtained from  $d_r$ - $u_*$  diagram for a given representative grain size ( $d_r$ ) ( $\text{m/s}$ )

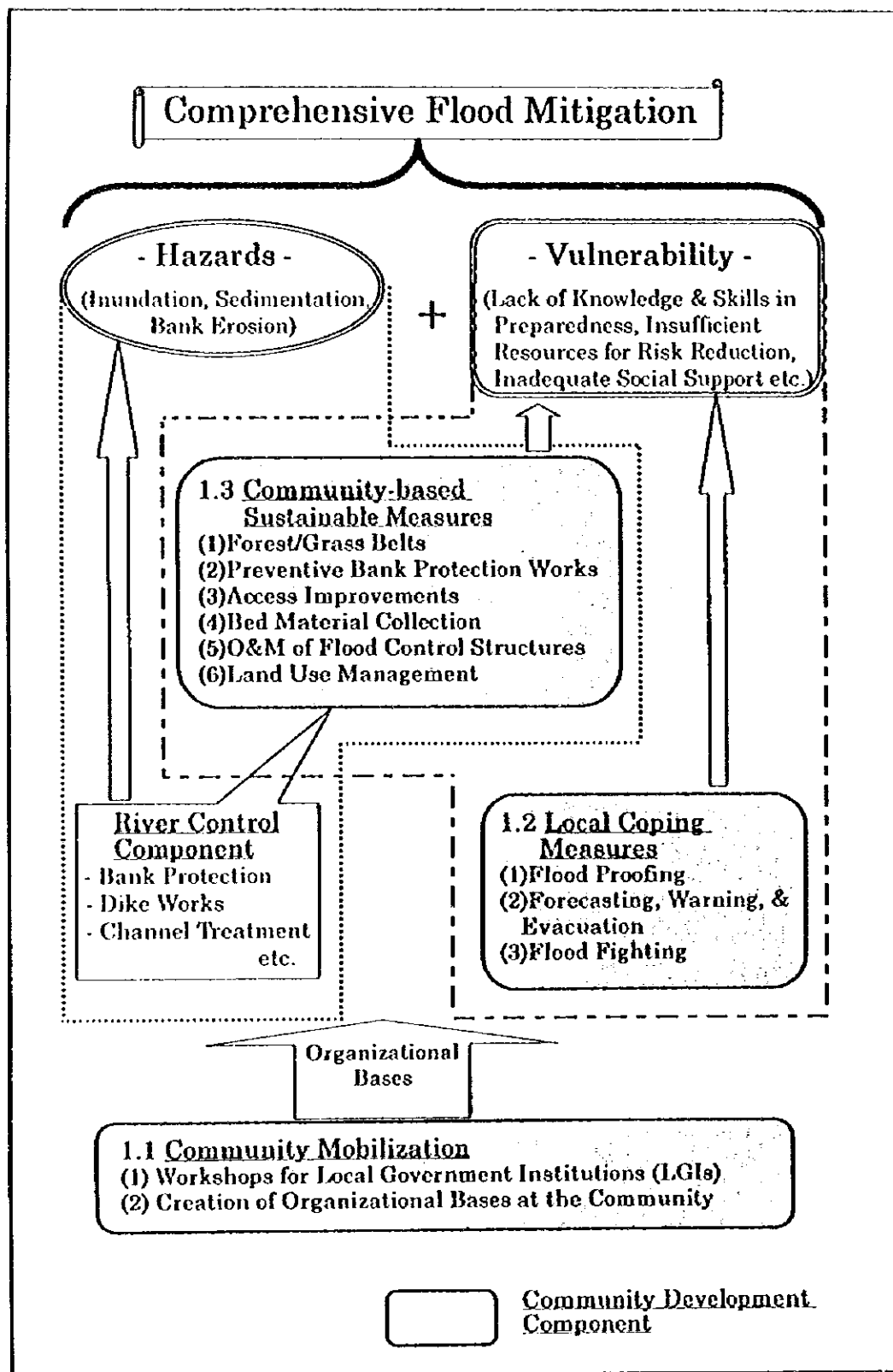
$h_L$  : Mean depth of low water channel ( $\text{m}$ )

$B$  : Low water channel width

#### RELATIONSHIP BETWEEN BED MATERIAL SIZE AND FRICTION VELOCITY

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

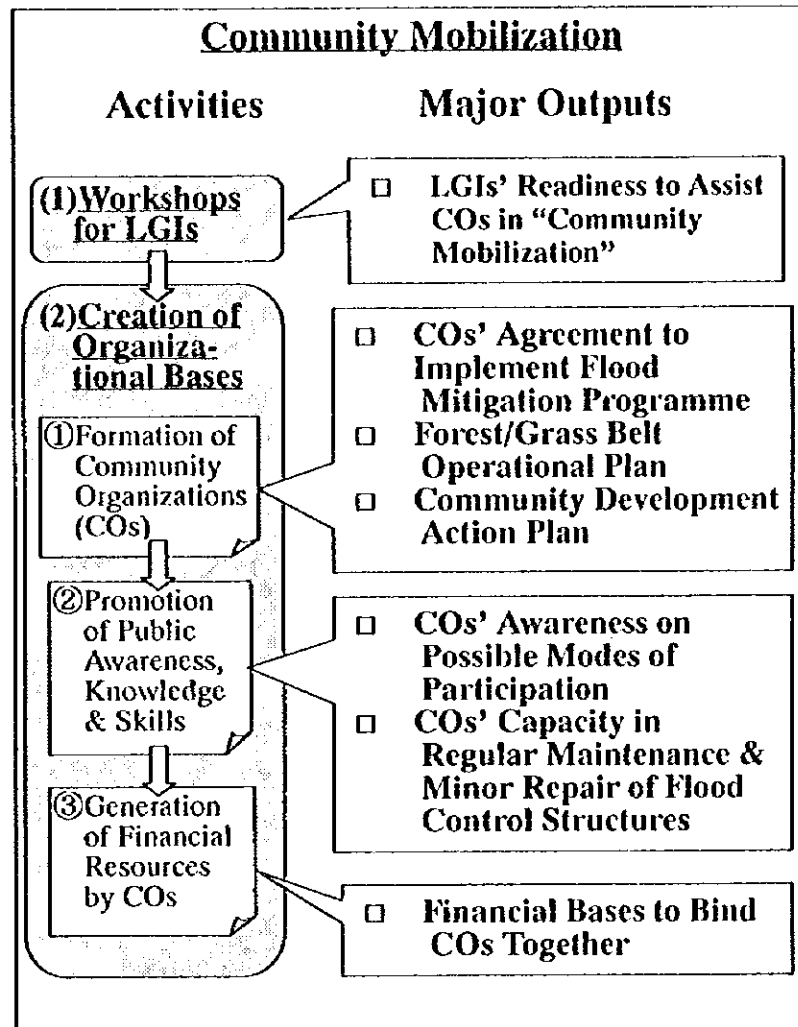




**COMPREHENSIVE FLOOD MITIGATION**

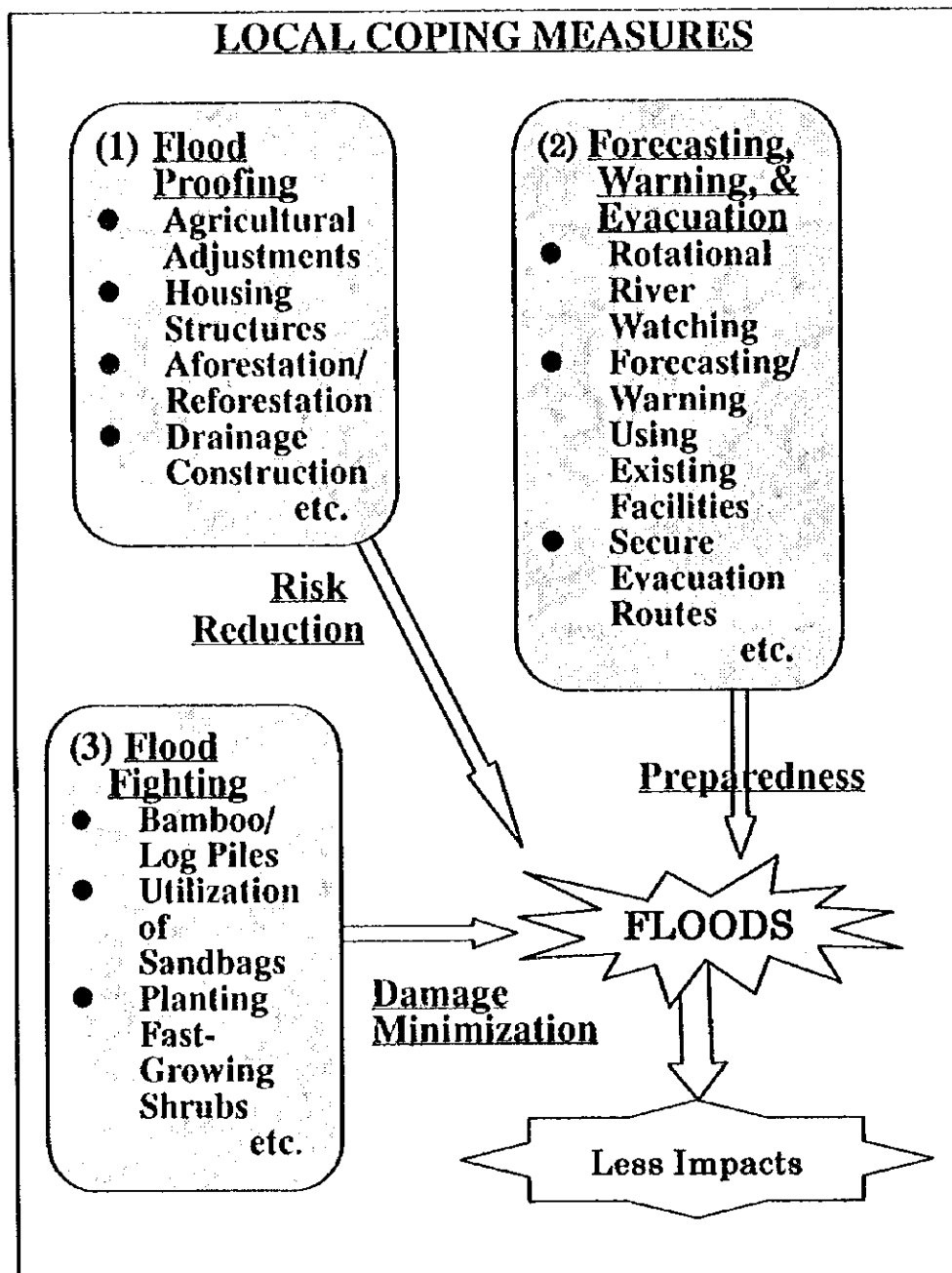
*His Majesty's Government of Nepal*  
 Department of Irrigation, Ministry of Water Resources  
**THE STUDY ON FLOOD MITIGATION PLAN  
 FOR SELECTED RIVERS IN THE TERAI PLAIN  
 IN THE KINGDOM OF NEPAL**

**JAPAN INTERNATIONAL COOPERATION AGENCY**



**COMMUNITY MOBILIZATION**

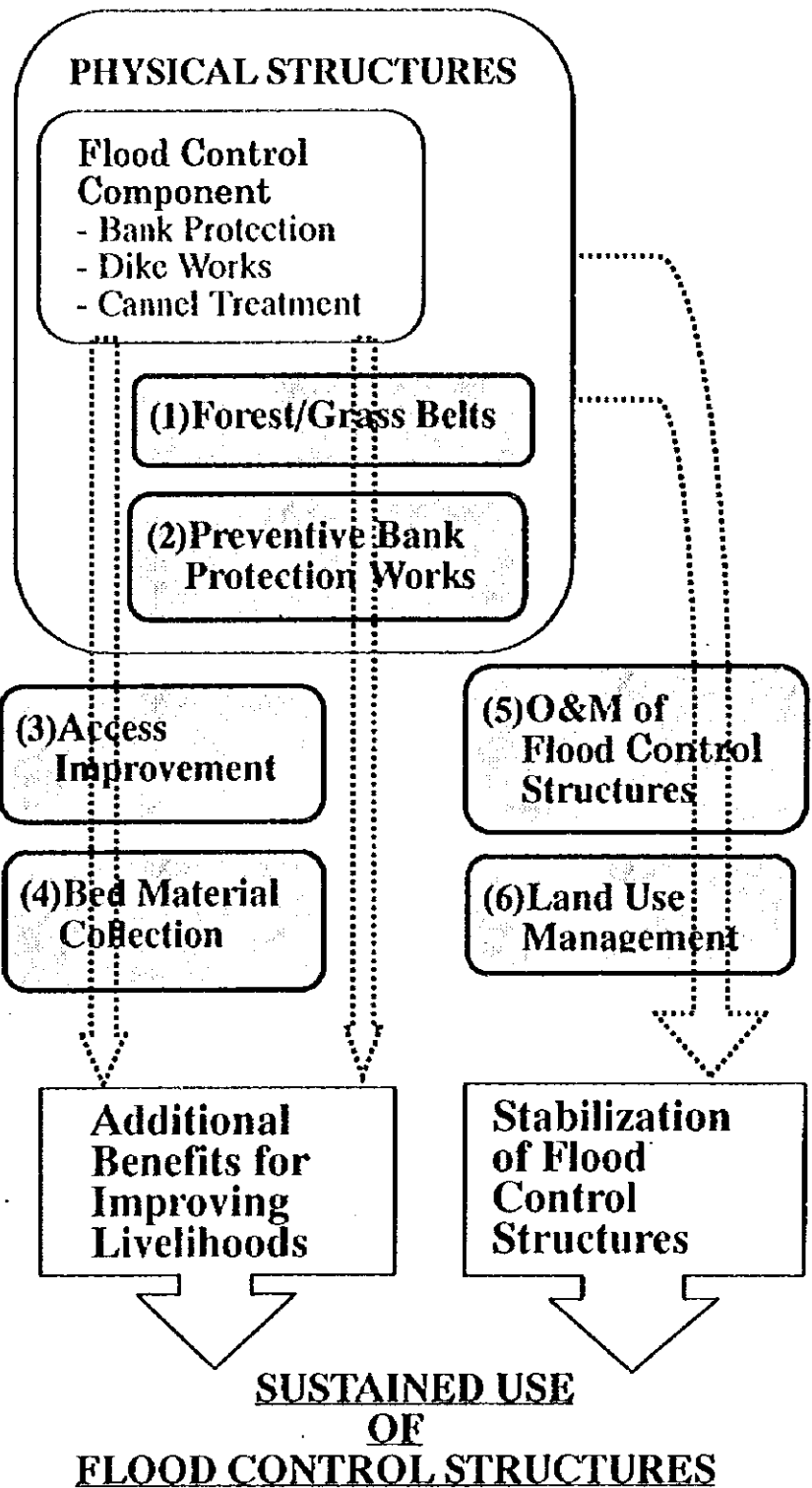
*His Majesty's Government of Nepal*  
 Department of Irrigation, Ministry of Water Resources  
 THE STUDY ON FLOOD MITIGATION PLAN  
 FOR SELECTED RIVERS IN THE TERAI PLAIN  
 IN THE KINGDOM OF NEPAL  
 JAPAN INTERNATIONAL COOPERATION AGENCY



LOCAL COPING MEASURES

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

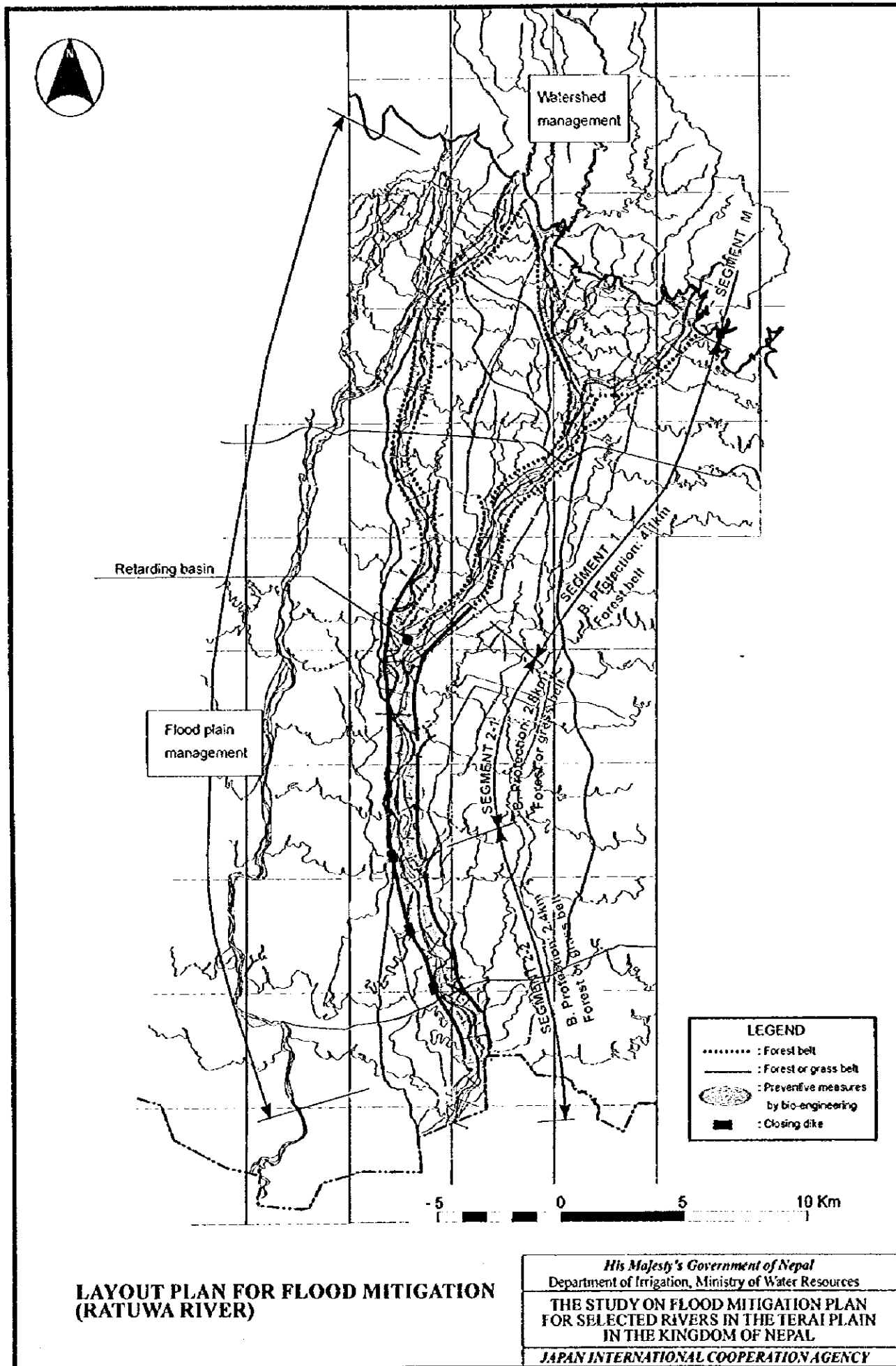
### Community-based Sustainable Measures



**COMMUNITY-BASED  
SUSTAINABLE MEASURES**

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

Fig. A2.9



**LAYOUT PLAN FOR FLOOD MITIGATION (RATUWA RIVER)**

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

### 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, based 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 bioengineering 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, and 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 DOSCW 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. If and when need arises, other line agencies and/or NGOs may be included as DCC members.

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

- 1) All the flood-prone villages will be directly represented in DCC, to provide

an open and transparent forum for interactions between the district and the villages (whereas DRTCC is composed only of district-level representatives, which often is the cause of irrational allocation of funding).

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

## **(2) Cooperating Agencies**

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

### **Technical Line Agencies**

#### **DOSCWM:**

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

#### **DOF:**

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

#### **DOA:**

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

**CDO:**

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

**Local Government Institutions (LGIs)**

**DDC:**

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

**VDC / Municipality:**

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

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

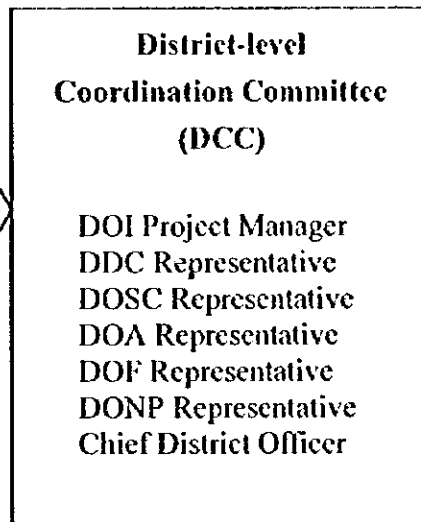
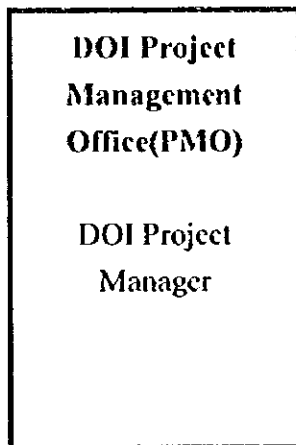
## ACTION PROGRAM TOWARD TARGET YEAR

River: **RATUWA RIVER**

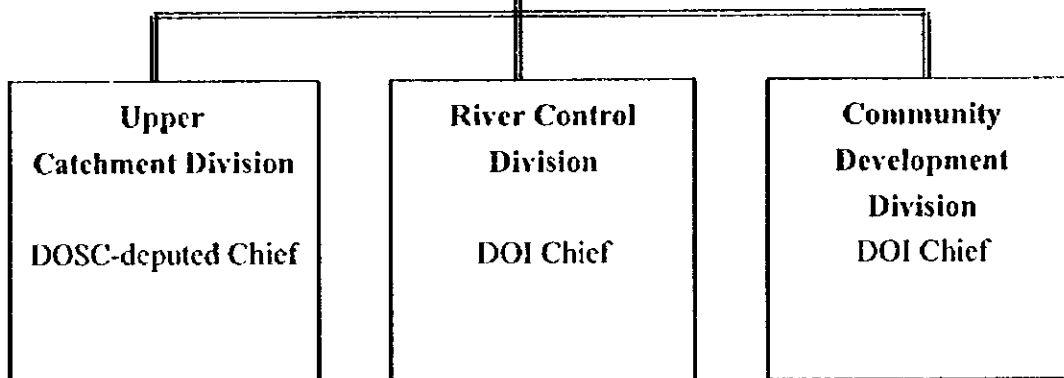
| Activities<br>Master Plan<br>National Plan<br>(year)         | Phasing            |                     |                     |                     |
|--|--------------------|---------------------|---------------------|---------------------|
|  | 1st.               | 2nd.                | 3rd.                |                     |
|  | 9th<br>(1997-2002) | 10th<br>(2002-2007) | 11th<br>(2007-2012) | 12th<br>(2012-2017) |
| <b>(1) Preparatory Works</b>                                 |                    |                     |                     |                     |
| 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) Research/ investigation                                   |                    | ████████            |                     |                     |
| <b>(2) Coordination for Flood Mitigation</b>                 |                    |                     |                     |                     |
| 1) Community development                                     | ████████           |                     |                     |                     |
| 2) Watershed management                                      | ████████           |                     |                     |                     |
| 3) Flood Plain Management                                    | ████████           |                     |                     |                     |
| <b>(3) River Works in Segment-1</b>                          |                    |                     |                     |                     |
| Channel treatment works:                                     |                    |                     |                     |                     |
| • Tributary works  |                    | ████████            |                     |                     |
| • Branch/ anabranch works                                    |                    | ████████            |                     |                     |
| Bank protection works:                                       |                    |                     |                     |                     |
| • Spur/ revetment  |                    | ████████            |                     |                     |
| • Preventive bank protection measurs<br>(by bio-engineering) |                    | ████████            |                     |                     |
| Dike works:  |                    |                     |                     |                     |
| • Forest belt  |                    | ████████            |                     |                     |
| • Ring dike  |                    | ████████            |                     |                     |
| Channel excavation works:                                    |                    |                     |                     |                     |
| • Bed material exploitation                                  |                    | ████████            |                     |                     |
| Retarding basin  |                    | ████████            |                     |                     |
| <b>(4) River Works in Segment-2</b>                          |                    |                     |                     |                     |
| Channel treatment works:                                     |                    |                     |                     |                     |
| • Tributary works  |                    | ████████            |                     |                     |
| • Branch/ anabranch works                                    |                    | ████████            |                     |                     |
| Bank protection works:                                       |                    |                     |                     |                     |
| • Spur/ revetment  |                    | ████████            |                     |                     |
| • Preventive bank protection measurs<br>(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**

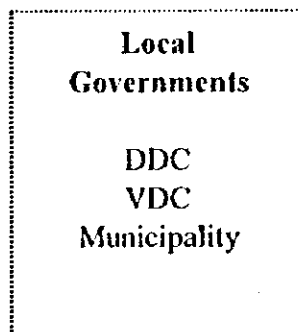
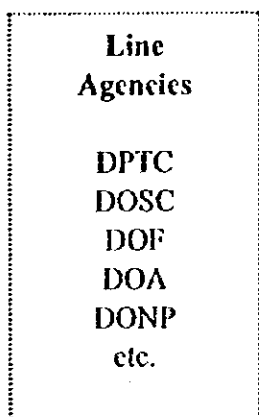
*Coordinating Agency*



*Implementing Division*



*Cooperating Agency*



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

## 4. EVALUATION

### 4.1 Economic Evaluation

#### (1) Basin Overview

Starting from Damak municipality, the flood plain of Ratuwa river travels inside both Jhapa and Morang districts. The area of the whole plains is 25,000 hectares with the estimated population of 135,000. About 80% of the land is used for agriculture. The largest portion of agricultural land is used for paddy (with the estimated 96/97 production of 51,300 metric tons), followed by maize (5,600 metric tons) and wheat (2,560 metric tons). The retail value of 96/97-paddy production was Rs.770 million, and in the case of maize, it was Rs.45 million.

In the flood-prone areas there exist 8 manufacturing establishments - those with more than 1 employees (4 -timber/furniture, 1-cotton cloth, 1-oil seed, 1-tea, 1-brick), all of which are located in the outer parts of Damak municipality. The Master Plan will prevent the extension of flood-risk areas to other parts of the municipality, which serve as an important commercial junction on Mahendra highway.

#### (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 ensures the social and economic activities in the flood prone area which enable further investments for the development of the flood prone area and the surrounding areas.
- 5) **Land reclamation:** Existing low-lying barren lands along the river turn to

arable ones. Channel excavation and normalization at severely meandering section may create lands for agriculture and settlement.

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

### (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 <sup>6</sup> Rs) | EIRR (%)     | B/C  | NPV (10 <sup>6</sup> Rs) |
| Ratuwa | 3.8            | 0.41 | -122.8                   | 9.6          | 0.81 | -39.9                    |

*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 at Master Plan Study Stage

An environmental screening was 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 (ES)".

### (2) Results of Environmental Screening

The flood mitigation plan for the Ratuwa 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, riverbanks will be reinforced and perhaps one or two bends straightened. There are 7,125 hectares of listed wetlands along this river. These wetlands will be mapped, their use tabulated and a plan formulated to protect them where feasible.

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

### **(3) Overall Evaluation**

The flood mitigation interventions on the Ratuwa river basin in the Terai are overwhelmingly environmentally positive. Flood mitigation interventions will occur along the whole length of the river in the Terai. In particular, the two riverbanks will be realigned and demarcated so as to minimize flood damage. These new alignments 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.

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

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

### **(4) Environmental Study in Future**

According to the new Environmental Conservation Rules (ECR) issued in June 1997, if

a watershed management plan for the upland areas (Segment M) is included as part of the flood prevention measures, then an Initial Environmental Evaluation (IEE) is required at the planning stage. 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 (EIA) may be necessary at the project proposal stage. The determining factor is whether the proposed planting is in a continuous block of a single indigenous species of more than 25 hectares, or for a single exotic species, is in a continuous block of more than 5 hectares.

There are many 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 new RBL 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 system. If these proposed interventions are more than 1 km in length, an IEE will be necessary along each of these river stretches at the project proposal stage. Similarly, there may be ring dike work, of more than 1 km. in circumference, round some groups of houses. If so, an IEE is necessary.

There may be the Ratuwa floodplain (wetland) in the vicinity of the river. If it is determined that the flood mitigation measures will affect this wetland, then an EIA is

necessary 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.

Table 4.1(1/2)

**COST BENEFIT FLOW FOR MASTER PLAN**  
(Existing Basin)

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

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

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

**COST BENEFIT FLOW FOR MASTER PLAN**  
(Future Basin)

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

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

EIRR: 9.6%  
 B/C: 0.97  
 NPV(B-C): -8.168 (NRs.1,000)

## SOCIAL ENVIRONMENT ASSESSMENT: RATUWA 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 entitled "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: RATUWA 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: RATUWA 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 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-existent.   |
| G   | Other (specify)     |  |            |   |

**Note.** The column entitled "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









JICA