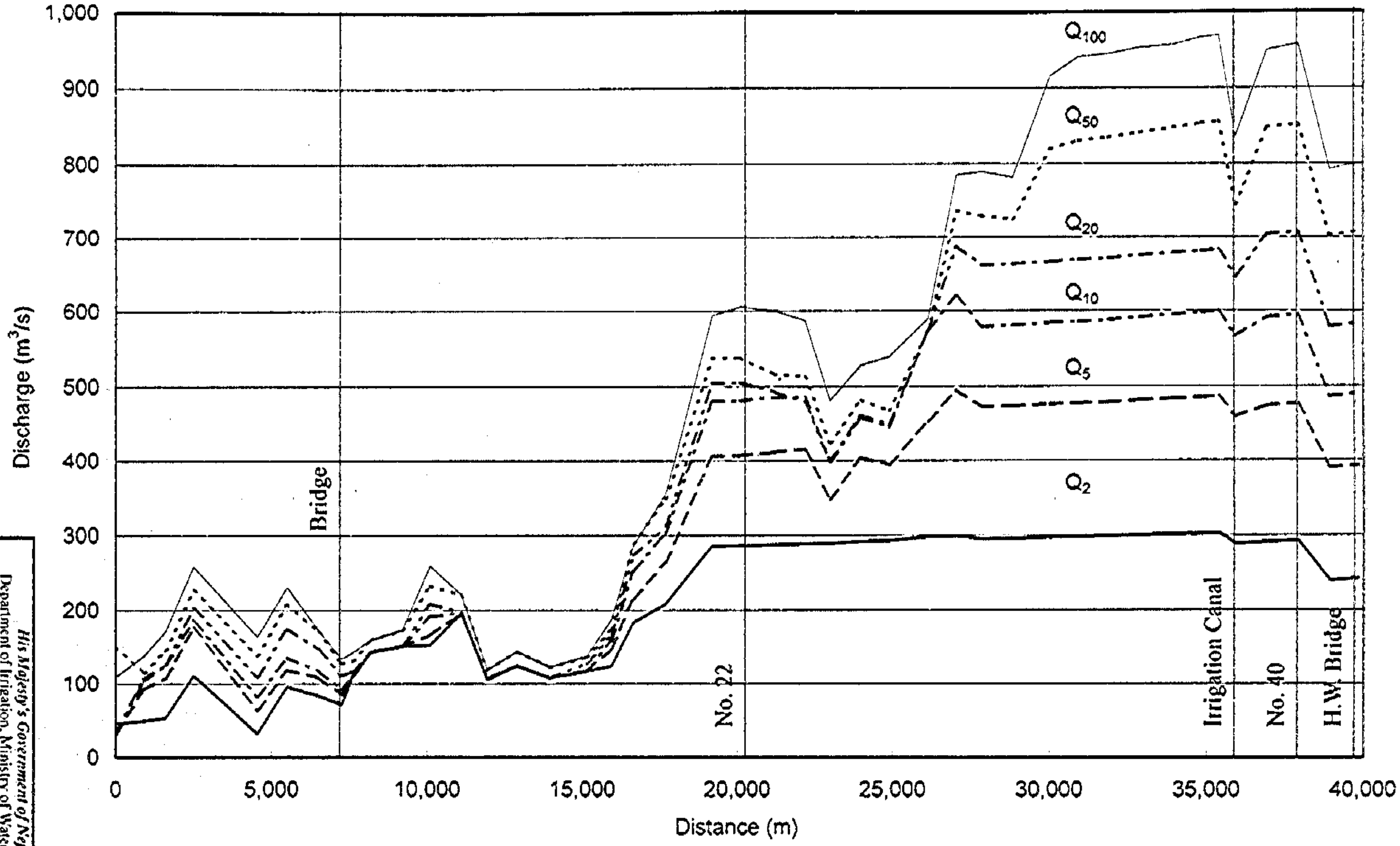

RESULT OF FLOOD FLOW ANALYSIS (LAKHANDEI RIVER WITHOUT PROJECT)

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FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL
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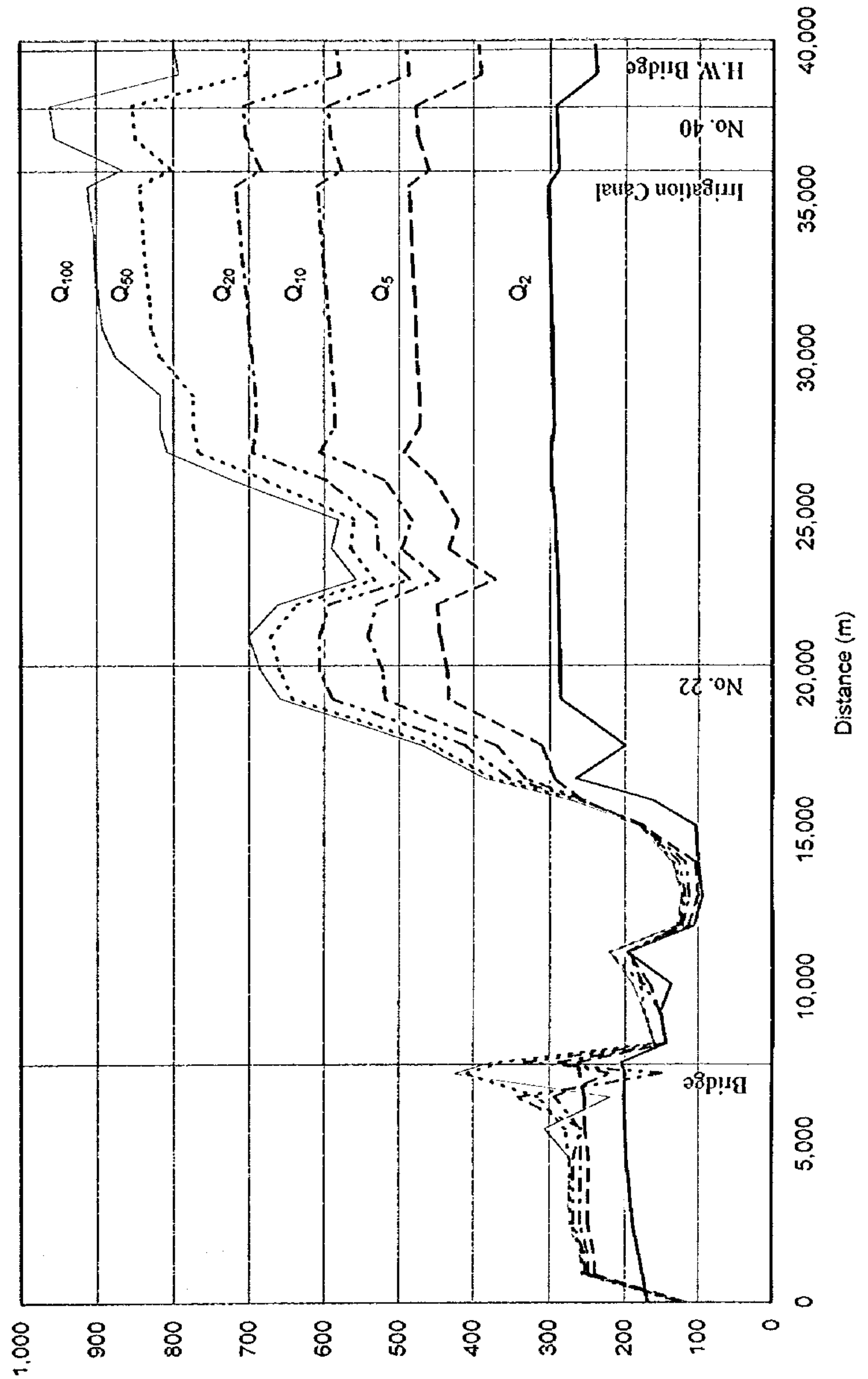
Fig. C2.13(2/2)



RESULT OF FLOOD FLOW ANALYSIS (LAKHANDEI RIVER WITH PROJECT)

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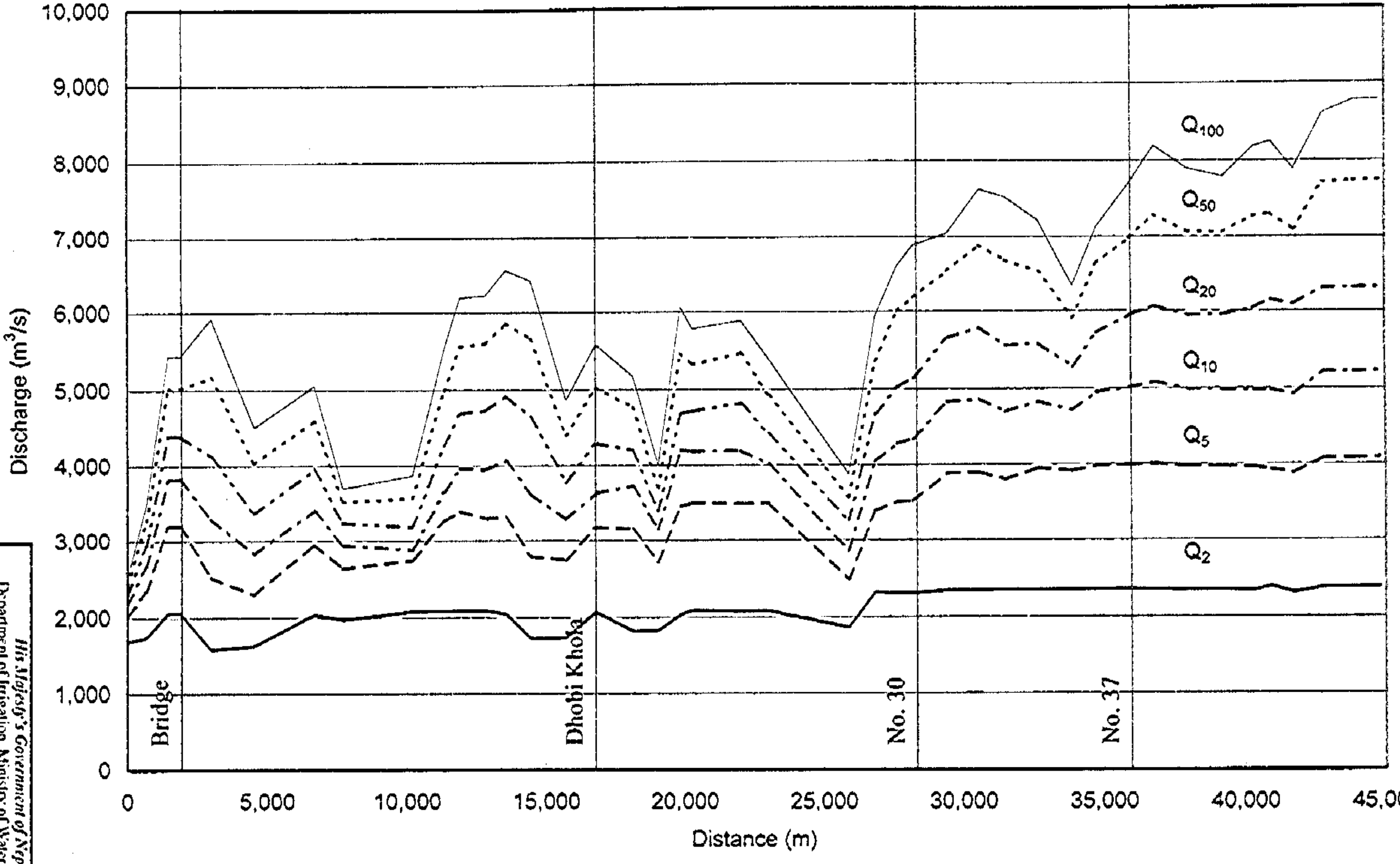

RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITHOUT PROJECT)

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

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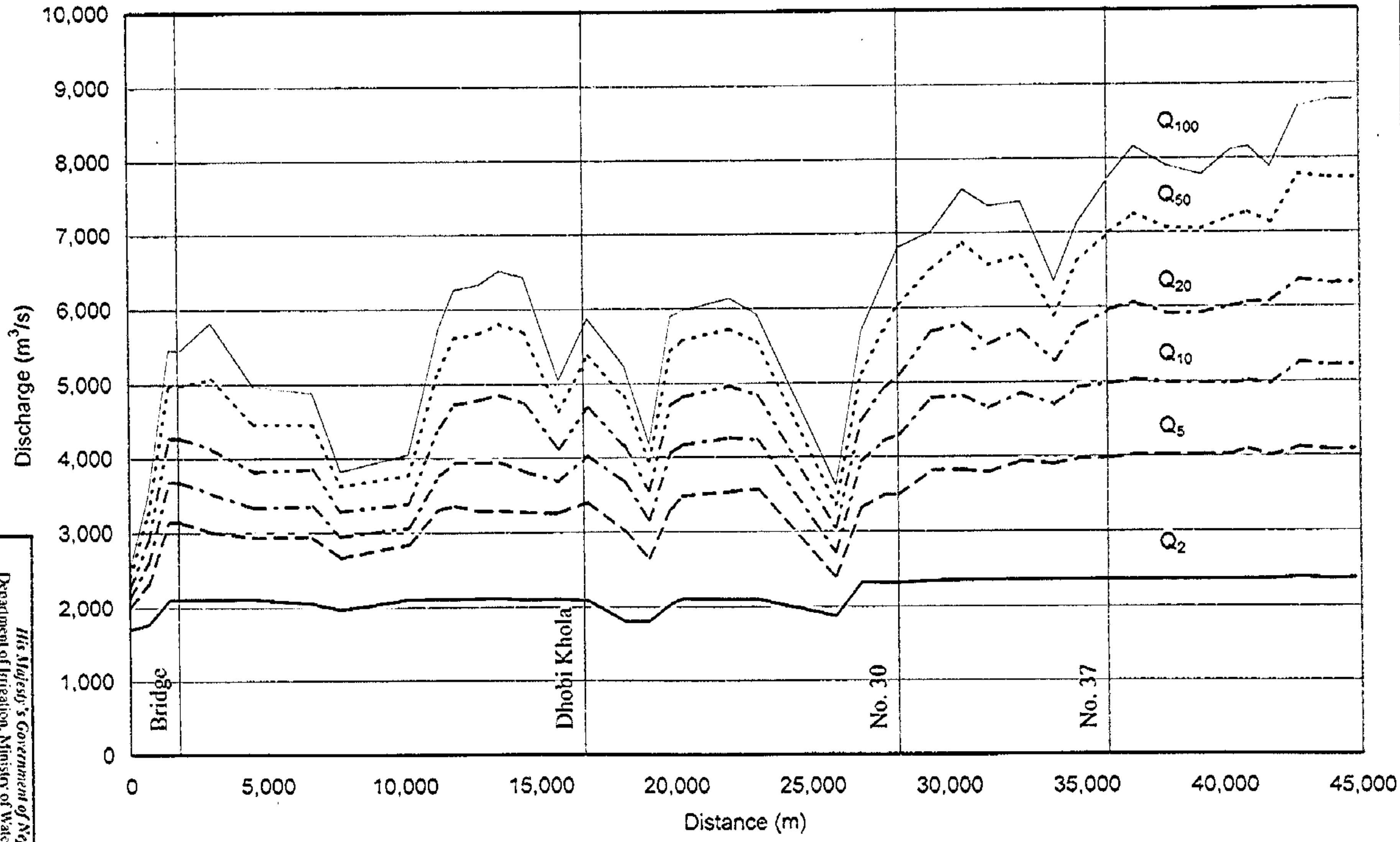
Fig. C2.14(2/2)



RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITH PROJECT)

His Majesty's Government of Nepal
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THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

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3. STUDY ON SEDIMENT YIELD

3.1 Geological Background of Sediment Yield

The Himalayan uplift started 100~150km north of the Himalayan main ridges where the Indus and the Brahmaputra rivers originate in Miocene, Neogene, and moved toward south with passage of time.

The estimation of denudation rates in Central Nepal was made by measuring fission-track ages of the granites group rocks of the Higher Himalaya and the Main Central Thrust zones along the Kali Gandaki and Modi river valleys (*Arita, Ganzawa*, 1997). The results show a linear increase with an average denudation rate of 0.8 mm/year during the period from Early Pleistocene (1.2 million years ago: Ma) to Late Pliocene (2.3Ma) with increasing elevations. The average denudation rate after the Late Pliocene is high exceeding 3 mm/year. The rate continues to increase and reaches to an average rate of 6.2 mm/year from Early Pleistocene (1.2Ma) to present. The average denudation rate of the Lesser Himalaya ranges from 1.7 to 2.8 mm/year.

The rapid uplift of the Himalaya was also confirmed by the leveling survey data. The Survey Department of Nepal undertook leveling survey in 1977 through 1990, along the north-south routes from Birganj to Kathmandu and from Kodari to Kathmandu. According to the survey results, the uplift rate of the Terai plain and Siwalik hills is 2 mm/year, and the Mahabharat mountain area more than 2 mm/year. The rate of the Higher Himalaya shows 8 mm/year at maximum and the area near Tibetan boundary approximately 6 mm/year.

The study of Landsat images of the Middle Himalaya shows the active erosion on the southern mountain slopes. Clear differences in erosion activity are observed between the Higher Himalaya and Lesser Himalaya. This is a front of the valley-head erosion. The drainage density gradually increases from the Hi-Himalaya to Lesser Himalaya and Siwalik hills, and the Siwalik hills are in the most active erosional process.

The Siwalik hills as the latest erosion front consists of fluvial mud and sand (Siwalik group) from the Himalayan mountain area formed since Pleistocene (approximately 16 million years ago). This Siwalik group slightly declines to north and consists of the lower, middle and upper groups, with different sizes of materials gradually changing from mudstone, sandstone to conglomerate from lower to upper groups. The Siwalik hills formed the cuesta landform which run in parallel from east to west. And the dip slope of cuesta is used as cultivated land. The south slope facing the Terai plain consists of steep outcrop-origin cliffs where mudflows take place.

3.2 Erosive Landform Characteristics of Watershed Area

Watershed areas of five river basins which originate in the Siwalik hills are studied for sediment yield. They are the Ratuwa, Lohandra, Lakhandei, Tinau (main river in Mahabharat range) and Khutiya river basins.

Other river basins, i.e., the Narayani, West Rapti and Babai river basins originate in the Higher and Lesser Himalayan zones. The sediment yield in these zone does not directly influence the sediment problems in the Terai plain, since the sediment yielded in these zones deposits first in the valleys and is transported to the plain by river flows.

(1) Drainage System and Slope of Watershed

The watersheds of the Ratuwa, Lohandra, Lakhandei, Tinau and Khutiya rivers are all small in size and are located in the Siwalik hills except for the Tinau river. Watershed of the Tinau river is partly situated in Mahabharat mountains. Since the erosion largely depends on the ground slope and river flow, the Drainage system and slope represent the erosive landform characteristics of the watershed.

The drainage density is relatively higher in the Ratuwa and Tinau river watersheds, and lower in the Lohandara and Lakhandei river watersheds. As to the density of slopes steeper than 40°, the Tinau river watershed is high, while the Ratuwa, Lohandra and Khutiya river watersheds show intermediate levels and the Lakhandei river watershed slightly low level.

(2) Vegetation and Land Use of Watersheds for Study

The land use of the five watersheds was studied based on the topographic maps and shown below.

Land Use of Study River Watersheds Area (unit:ha, Ratio:%)

Land use	Ratuwa		Lohandra		Lakhandei		Tinau		Khutiya	
	Area	Ratio	Area	Ratio	Area	Ratio	Area	Ratio	Area	Ratio
Forest	7006	72.9	8292	58.0	7855	73.4	33831	61.5	16471	94.1
Bush	346	3.6	1805	12.6	75	0.7	2481	4.5	0	0
Cultivation	1924	20.0	3731	26.1	2236	20.9	17683	32.2	613	3.5
Cliff	55	0.6	128	0.9	22	0.2	565	1.0	313	1.8
River	279	2.9	347	2.4	508	4.7	329	0.6	103	0.6
Urban	0	0	0	0	0	0	109	0.2	0	0
Total	9610	100.0	14303	100.0	10696	100.0	54998	100.0	17500	100.0

(Remarks)

1) Bush: Scrub, Bush, Grass & Bamboo
2) Cliff: Soil cliff, Rock cliff & Out crop of rock
3) River: River bed & Water body
4) Aerial photography for the mapping were taken in Ratuwa, Lohandra and Lakhandei, 1992. in Tinau, 1990 and in Khutiya, 1996.

The forest area shares majority of watershed ranging from 58% of the Lohandra watershed to 94% of the Khutiya. The cultivated land occupies more than 20% except for 3.5% of the Khutiya watershed. Cultivated land is wide in the Tinau watershed occupying about 1/3 of the watershed.

3.3 Previous Studies on Sediment Yield

In this section, previous study results made on the sediment yield are introduced.

(1) Land Denudation Study of Nepal and Japan

Table C3.1 shows the soil erosion rates estimated for different land uses in Nepal and Japan. The maximum soil erosion rate of 21 mm/year is estimated in the gullied land of metamorphic and sedimentary rock. On the other hand, sheet erosion rate in Japan ranges as shown below.

(Sheet Erosion and Landuse in Japan)

Land Use Condition	Range of Sheet Erosion(mm/year)
Devastated land	100 - 10
Vegitated land	10 - 1
Farm land	1 - 0.1
Forest	0.1 - 0.01

(Source) Akiya, K (1978): Sediment Yield, Sinsabo No.107.

(2) Sediment Yield Study of Ratu River

Standard Annual Soil Erosion Rate

A sediment yield study was made for of the Ratu river in the "Research Report on the Investigation of Landslide and Soil Erosion in Nepal Using Remote Sensing Technology: 1996". The Ratu river is situated at the Siwalik hills at Janakpur in central Nepal. The watershed of the Ratu river has a stream length of approximately 35 km, basin area of 91 km^2 with maximum elevation of 708 m,MSL, and average river bed slope of 1/100.

In this study, standard rates of annual soil erosion were set as shown below, referring to the past study results of erosion rate for different land use.

(Standard Annual Soil Erosion Rates)

Land use	Soil erosion rate	
	mm/year	$ton/km^2/year$
Degraded forest, gullied land	2	4,000
Bear land	20	40,000
Sound forest area with less sediment yield	0.4	800

Annual Sediment Yield in Ordinary Year

Annual sediment yield was estimated for the Ratu river in ordinary years 1973, 1993 and 1995 based on the soil erosion rates set above and Landsat data. The estimated result is shown below. According to the result, average soil erosion rate is 3.6 mm/year ranging from 3.29 to 3.89 mm/year.

(Annual Sediment Yield of Ratu Watershed: Ordinary Year)

Year	1973	1993	1995
Sediment yield(m^3/year)	271,000	321,000	293,000
Average erosion rate (mm/year)	3.29	3.89	3.55

Sediment Yields during Flood in 1993

An estimate was made for the Sediment yield of the Ratu river during 1993 July flood. According to the estimate, approximately 2,000,000 m^3 of sediment was yielded during the flood in the Ratu river watershed area, which is equivalent to a soil erosion rate of 24 mm/year.

3.4 Estimation of Sediment Yield

(1) Method of Estimation

The sediment yields of the Ratuwa, Lohandra, Lakhandei, Tinau and Khutiya rivers were estimated based on the land use and corresponding annual soil erosion rates. The soil erosion rate was assumed mainly referring to the data of the Ratu river as follows.

(Soil Erosion Rate Set for Estimation of Sediment Yield)

Land use	Soil erosion rate(mm/year)	Remarks
Forest	2	Degraded forest, gullied land
Bush, Grass, Bamboo	10	Severely degrated, heavily grazed forest, gullied land
Cultivation	0.4	Farm land(Dr. Akiya) & dense forest lands with good ground cover in Ratu watershed
Bear land: Soil cliff, rock cliff & rock	20	same as in Ratu Watershed
River bed	0	
Urban	0	

The Sediment Yield is estimated by the following equation:

$$V = \Sigma(Ai \times Ei)$$

where,

V : Sediment yield of watershed area

Ai: Area of land use

Ei: Soil erosion rate by land use

(2) Estimated Annual Sediment Yield in Ordinary Year

The sediment yield estimated based on the land use and soil erosion rate is shown in the table below. The maximum average soil erosion rate is 2.70 mm/year in the Lohandra river watershed followed by 2.56 mm/year in the Khutiya river watershed. The minimum soil erosion rate is 1.66 mm/year in the Lakhandei river watershed.

(Presumed Annual Sediment Yield on Ordinary Year)

River	Forest (m^3/year)	Bush (m^3/year)	Cultiva-tion (m^3/year)	Cliff (m^3/year)	Total (m^3/year)	Erosion rate (mm/year)
Ratuwa	140120	34600	7696	11000	193416	2.01
Lohandra	165840	180500	14924	25600	386864	2.70
Lakhandei	157100	7500	8944	4400	177944	1.66
Tinau	676620	248100	70732	113000	1108452	2.02
Khutiya	315940	67400	2452	72600	448392	2.56

(Remarks) Average soil erosion rate = Sediment yield / Watershed area

(3) Estimated Sediment Yield in Disaster Year

The annual sediment yield of the ordinary year and the sediment yield during the flood in 1993 have been estimated in "The Research Report on the Investigation of Landslide and Soil Erosion in Nepal Using Remote Sensing Technology". According to this report, the soil erosion rate in an ordinary year is 3.6 mm/year and 24.0 mm/year in the disaster 1993. This data shows that the soil erosion rate in the disaster year could increase up to about seven (7) times of that of ordinary year. Applying this rate, the sediment yield in the disaster year was estimated as follows:

(Estimated Sediment Yield in Disaster Year)

River	Watershed area (ha)	Soil erosion rate(mm/year)		Sediment yield (m^3/year)	
		Ordinary year	In disaster	Ordinary year	In disaster
Ratuwa	9,610	2.01	14.07	193,000	1,354,000
Lohandra	14,303	2.70	18.90	387, 000	2,708,000
Lakhandei	10,696	1.66	11.62	178, 000	1,246,000
Tinau	54,998	2.02	14.14	1,108,000	7,759,000
Khutiya	17,500	2.56	17.92	448,000	3,139,000

LAND DENUDATION FOR SOME AREAS IN NEPAL

Description of the site	Rate		Reference
	Tons/km²/year	mm/year	
Siwalik: East Nepal, Chatra; S-aspect, Sandstone foothills; different land use Ranging from forest to grazing	780 - 3,680	0.4 - 2	Chatra, 1974
- degraded forest	2,000	1	Laban, 1978
- degraded forest, gullied land	4,000	2	Laban, 1978
- severely degraded heavily grazed forest, gullied land	20,000	10	Sakya
- degraded forest (+agriculture fields)	3,150 - 14,000	1.58 - 7	Laban, 1978
- gullied land	6,300 - 42,000	3.15 - 21	Laban, 1978
Middle Mountains, Kathmandu Valley; Steep slopes, south of valley, near Godawari;75% dense forest lands with Good ground cover on shales, hard Limestone and quartzite	800	0.4	Kandel, 1978 Laban, 1978

(Remarks) Soil erosion rates: Soil deposits density is assumed as $2g/cm^3$.

(Source) Sharma C.K.(1988): Natural hazards and man made impacts in the Nepal Himalaya.

4. STUDY ON WATERSHED MANAGEMENT

4.1 Devastation and Control of Forest

(1) Agriculture and Devastation of Forest

Agriculture, a main industry of Nepal, greatly depends on the forest and grass land, and forests are so closely related with agriculture. The population density is especially high in the Terai and the Middle Mountain. Therefore, forests in this area have changed widely into cultivated lands. As a results, the forest have been reduced and deteriorated.

Active gathering of firewood and fodder tree leaf is also a cause of the deterioration. The rate of the firewood in all the energy sources of Nepal is 93% in coal equivalent. The 95% of the population live in rural areas, and most of them are using firewood as a fuel, consuming 95% of the lumber as a firewood.

The number of livestock are too much in Nepal compared with land capability. In addition to the wild grass and agricultural by-products such as straw, stem and leaves of corn, large quantity of tree leaves are used as fodder of livestock especially in dry season. Too much cutting of bush and lopping of trees resulted in poor vegetation on the ground and accelerated the surface erosion.

Collection of firewood and fodder is the work of women and children. They mow small trees at hand and they don't give careful consideration to the regeneration of forests.

The farm lands which are used to be on the gentle hill slope are being extended to the forest on the steeper slopes, too. Such a devastation of forests causes soil erosion, depletion of water resources and floods.

(2) Forest Policy of HMG/N

The forestry policy of the HMG/N is based on the "Master Plan for the Forestry Sector (1989-2010)". The Master Plan is composed of six main programs and six support programs as follows:

<u>Main programs</u>

1) Community and private forestry

2) National and leasehold forestry
3) Wood based industries
4) Medicinal and aromatic plants and other forest products .
5) Soil conservation and watershed management
6) Conservation of ecosystem and genetic resources

Support programs

1) Policy and legal reform
2) Institutional reform
3) Human resources
4) Research and extension
5) Resources information and planning assistance
6) Monitoring and evaluation

The Master Plan also pointed out that there are some problems in the implementation of the forestry diffusion projects, and suggests that it is most important to enhance livelihood of local residents based on their needs for the protection of the environment and the forest conservation.

4.2 Development and Watershed Conservation

Various projects have been undertaken for the forest restoration in Nepal. A study was made on for the decrease of forests and livelihood of local residents for 3 years from 1991. Main problems and strategy identified are as follows. On the basis of the study Community Development and Forest Watershed Conservation Project in the suburbs of Pokhara has been conducted since July 1994.

Main problems

1) Local inhabitants (especially women, child) are destroying the natural environment and forests which are the base of their own life (Vicious circle of Poverty and the destruction of the environment). They are the wrongdoers, and on the other hand they are the victims. The conservation of environment and forest can not be achieved without their awareness and action on these matters. However, their poverty obstructs their awareness and action. They can not stand up only for the environmental and forest conservation unless they overcome their poverty and arising problems with it.

2) The sectoral development policy does not always meet the needs of the community and the inhabitants
3) There is no participation of local people and local official staffs in project preparation.
4) Policy makers of the implementing body are poorly motivated.
5) Authority is concentrated in the central government and the procedures are intricated, so that the necessary input is not made in a timely manner.
6) There are many cases that the project size is too large to incorporate farmers' efforts for self-reliance.
7) Monitoring in the field is insufficient, therefore the project stagnates and stops.

Strategy for solution

1) It is important not only to complain about the environmental and forest conservation, but to satisfy local people's daily needs.
2) A ward should be reorganized with a development unit so that the effort for self-reliance of the local people are fully satisfied.
3) Development projects should be prepared and implemented for respective wards.
4) Planning and execution bodies of the project should be the respective wards.
5) The monitoring system is critical to carry out the project in a timely and proper.

Procedures taken in the Community Development and Forest Watershed Conservation Project are introduced some more here. The inhabitants first decided the development projects which they wanted to carry out, and "user groups" were organized for each works, then a representative committee was established in the ward. The inhabitants offered labor and material available at the spot without charge. As a rule of thumb, it was targeted that local people and the project could share the costs equally. The user groups made their own rules including disciplinary regulations. The project includes repair work of water pipes and service tank, construction of suspension bridge, construction of check dams and revetment, installation of public lavatories, construction of nurseries, afforestation, and improvement of cooking stoves to reduce the consumption of firewood.

And the income enhancement campaign was also executed to support women and occupation castes with their economical independence.

4.3 Recommendation for Watershed Management

The enhancement of the living standard of the local 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 communities, and government and non-governmental organization are 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

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 and Land Use Control

1) Afforestation and reforestation artificially and fostering natural regeneration of trees.
2) Promoting form 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 generation income. The cultivation of medicinal and aromatic plants has been one of the main programs of Nepali 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 for forest conservation and fodder production has 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 non-governmental organizations are essential. 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 misery 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.

5. STUDY ON FLOOD MITIGATION MEASURES

5.1 Flood Mitigation Measures

In order to mitigate damages due to flood and sediment disasters, it should be considered to employ all the possible measures by structural and non-structural ones. The flood mitigation measures are broadly classified into four from their functions as follows:

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

These flood mitigation measures are generally shown in Fig. C5.1. Discussions are made below on primary functions of these measures and applicability to the rivers in the Terai plain.

5.2 Smooth Transport of Flood Water and Sediment

1) **Channel treatment:** To fix river system and basin boundary.
   - **Tributary works:** Treatment works of tributaries to stabilize channel discharge such as diversion structure, closing dike, and connecting channel works.
   - **Branch/anabranch works:** Closing dike works of branches and anabranches, with diversion facility if necessary, to prevent river course shifting:
2) **Bank protection:** To stabilize river course, and to protect settlement and farmland from erosion.
   - **Spur (or groin):** A series of spurs prevents bank erosion primarily by two functions to retard flow velocity near bank and to change flow direction far away from bank.
   - **Revetment works:** Revetment works prevent bank erosion by covering bank slope and protecting its foundation.
   - **Grass covering and riverine forest:** The grass and trees planted on the riverbank resist to the bank erosion retarding its speed. This bioengineering technology can be used as preventive measures against bank erosion rather than direct bank protection works.

3) **Channel excavation works:** To provide enough channel capacity to transport floodwater and sediment.

- **Channel excavation:** Since sediment in the watershed is not controlled yet, the channel excavation should be limited to normalization of local channel section and river course.
- **Bed material collection:** Exploitation of riverbed materials also contributes to the increase of channel capacity, as far as the amount and places of exploitations are planned appropriately from river control viewpoint. The exploitation can be undertaken on the course material bed such as in alluvial fan.

4) **Dike embankment works:** To confine flood water and sediment within river area

- **Local dike:** Continuous dike is not proposed considering the difficulty in maintenance, economic viability and necessity of plan coordination with India. Instead, proposed are local dikes to protect frequently inundated areas and sites of important objects like villages.
- **Open dike:** Open dike is a preferable measures for the alluvial fan reaches. However, these measures are not recommended unless the sediment yield in the watershed is controlled. The primary functions of the open dike are; (1) To reduce runoff peak spilling flood water to the retarding basin at the open levee, (2) To collect flooded water in the upper reaches, and (3) To join tributaries without drainage sluice functioning as back-water levee.
- **Ring dike:** Ring dike is applicable to protect sporadic important objects like settlements in flood prone area.
- **Dike road:** Rural road constructed along design dike alignment can function as flood dike. Even if the embankment height is not enough to the design level, the road embankment would protect the lands from flooding and sedimentation of high frequency. The height of road should be decided considering the flood water level. The road embankment may be constructed where it is necessary and raised stage-wise corresponding to the requirement for flood mitigation.
- **Grass and forest belts:** Grass and tree planted along the river boundary line are not dike embankment correctly. However, these grass and tree belts would alleviate sedimentation and flooding damages in the flood prone areas, resisting to the flood flows and promoting sedimentation along the belt.

- **Back-water dike or drainage sluice:** At the crossing of tributaries, back-water dike or drainage sluice are needed to allow free inflows from tributary and to prevent river water from spilling. Back-water dike is to be applied to the large scale or steep slope tributaries.

5) **Cut-off channel (COC):** To ensure smooth flood and sediment flows by shortening and steeping the channel at the meandering sections, and to keep away from river course from the objects to be protected.
   - COC works may not be applicable to the river in alluvial fan, since the river course is braided and unstable.
6) **Diversion channel:** To divert a part or all of river water to alleviate flood discharge in the lower reaches, or to keep away from river course from the objects and areas to be protected.
   - Appropriate site for diversion channel would hardly be found for the rivers in Terai plain, since the river courses in the plain take routes in parallel with each other towards south-east direction and trans-basin of the flood water may cause another problem in the receiving river.

5.3 Storage or Detention of Flood Water and Sediment

1) **Sabo work:** To check and control sediment flow in the watershed
   - Sabo works should be implemented in the watershed areas. However, the sabo works are not taken up for the master plan under discussion, since intensive sabo works in the watershed require a lot of fund and time for implementation, and immediate effects are not expected. Flood mitigation in Terai plain is, therefore, discussed under the premise that the watershed conditions would remain as it is.
2) **Dam reservoir:** To control flood and sediment flows
   - Dam reservoir in class-III river basin would not be applicable because of poor geological conditions of the Siwalik.
   - Single purpose dam reservoir for flood mitigation would not be economically feasible. As to multi-purpose dam reservoir, promising dam project is not proposed at present for the river basins in the Study Area. Therefor the dam reservoir schemes are not incorporated in the present master plan.
3) **Retarding basin/detention pond:** To reduce flood peak in the downstream reaches.

5.4 Erosion and Runoff Control by Watershed Management

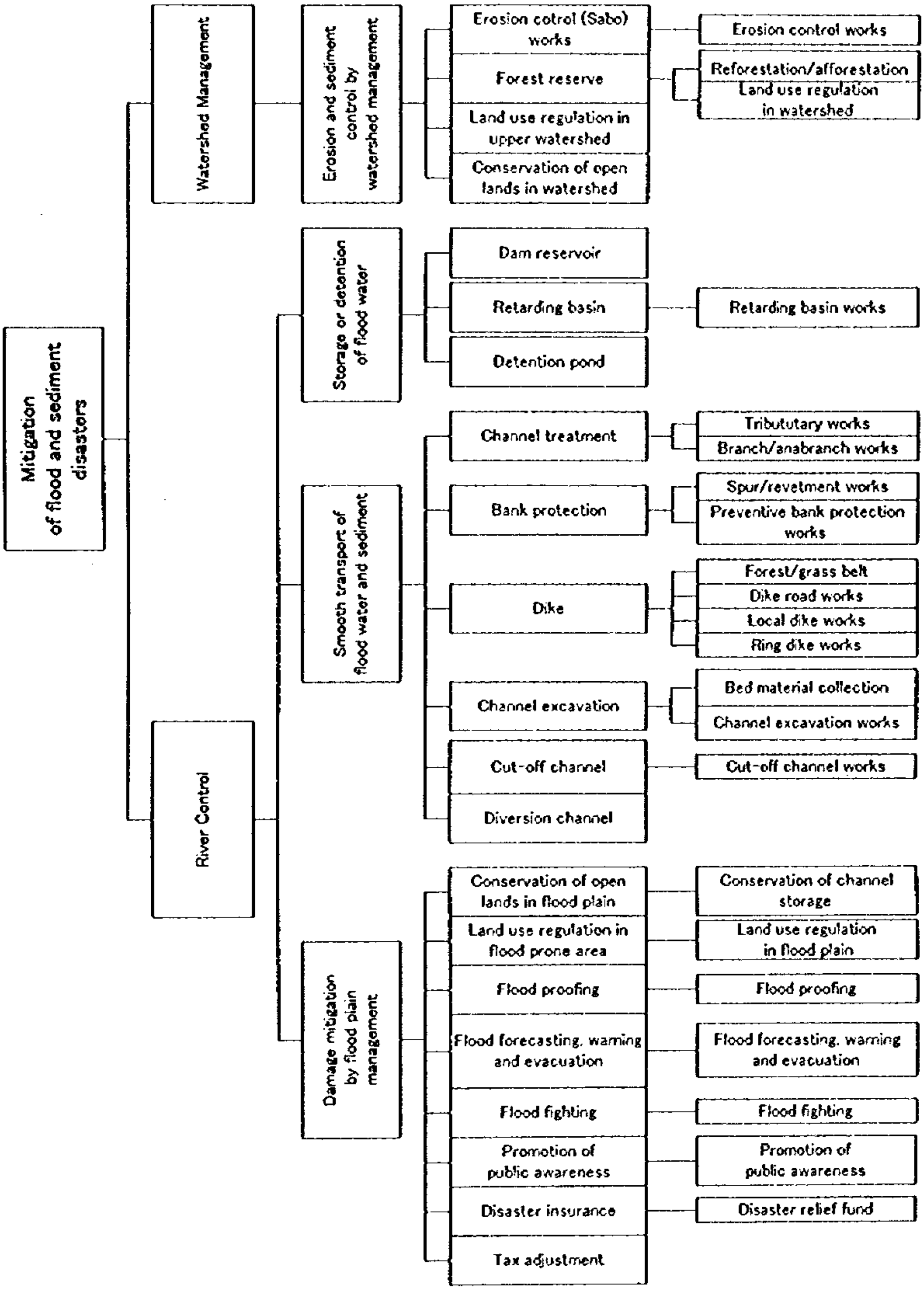
The following measures for watershed management can be considered:

1) Forest reserve,
2) Land use regulation, and
3) Conservation of open land for flooding and sedimentation.

5.5 Damage Mitigation by Flood Plain Management

The following measures are conceivable to cope with floods, reducing flood damages by non-structural approaches:

1) Conservation of open land;
2) Land use regulation;
3) Flood proofing;
4) Flood forecasting, warning, and evaluation;
5) Flood fighting;
6) Promotion of public awareness;
7) Disaster insurance; and
8) Tax adjusting.



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

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6. STUDY ON BANK PROTECTION MEASURES

6.1 Types of Riverbank for Protection

Bank protection works primarily aim to protect riverbank from erosion and to stabilize river course. As a target line for the bank protection, river boundary line (RBL) is set and maintained so as to be safe from erosion. The type of river bank is classified depending on the safety level against erosion. The safety of riverbank is evaluated according to the relationship between the distance from river bank to river boundary line (B_h) and design erosion width (B_e) as follows (Fig. C6.1):

1) Type-C bank: $B_h \geqq B_e$ and bank erosion is not active due to topographical and geological reasons.
    - B_e: Design erosion width
    - B_h: Distance from river bank to river boundary line(RBL)
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.

Conditions of bank 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 riverbank:

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.

6.2 Bank Protection Works

Spur and revetment works are the primary bank protection measures. These measures are executed independently or jointly. Various types of bank protection works are developed empirically over the world. Some of them are introduced in Fig. C6.2, citing from "River Training and Bank Protection, United Nations". These will be referred to develop bank protection works for rivers in the Terai plain.

As to the type of spurs, there also be variety of works, namely, high and low spurs, and permeable and impermeable spurs. Application of these spurs depends on the channel characteristics. For the Master Plan study, the following bank protection measures were considered:

1) **Spur (or groin):** A series of spurs prevents bank erosion primarily by two functions to retard flow velocity near bank and to change flow direction far away from bank.
2) **Revetment works:** Revetment works prevent bank erosion by covering bank slope and protecting its foundation.
3) **Grass covering and riverine forest:** The grass and trees planted on the riverbank resist to the bank erosion retarding its speed. This bioengineering technology can be used as preventive measures against bank erosion rather than direct bank protection works.

Since river section data are not available at present, the following assumptions were also introduced for Master Plan study mainly 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

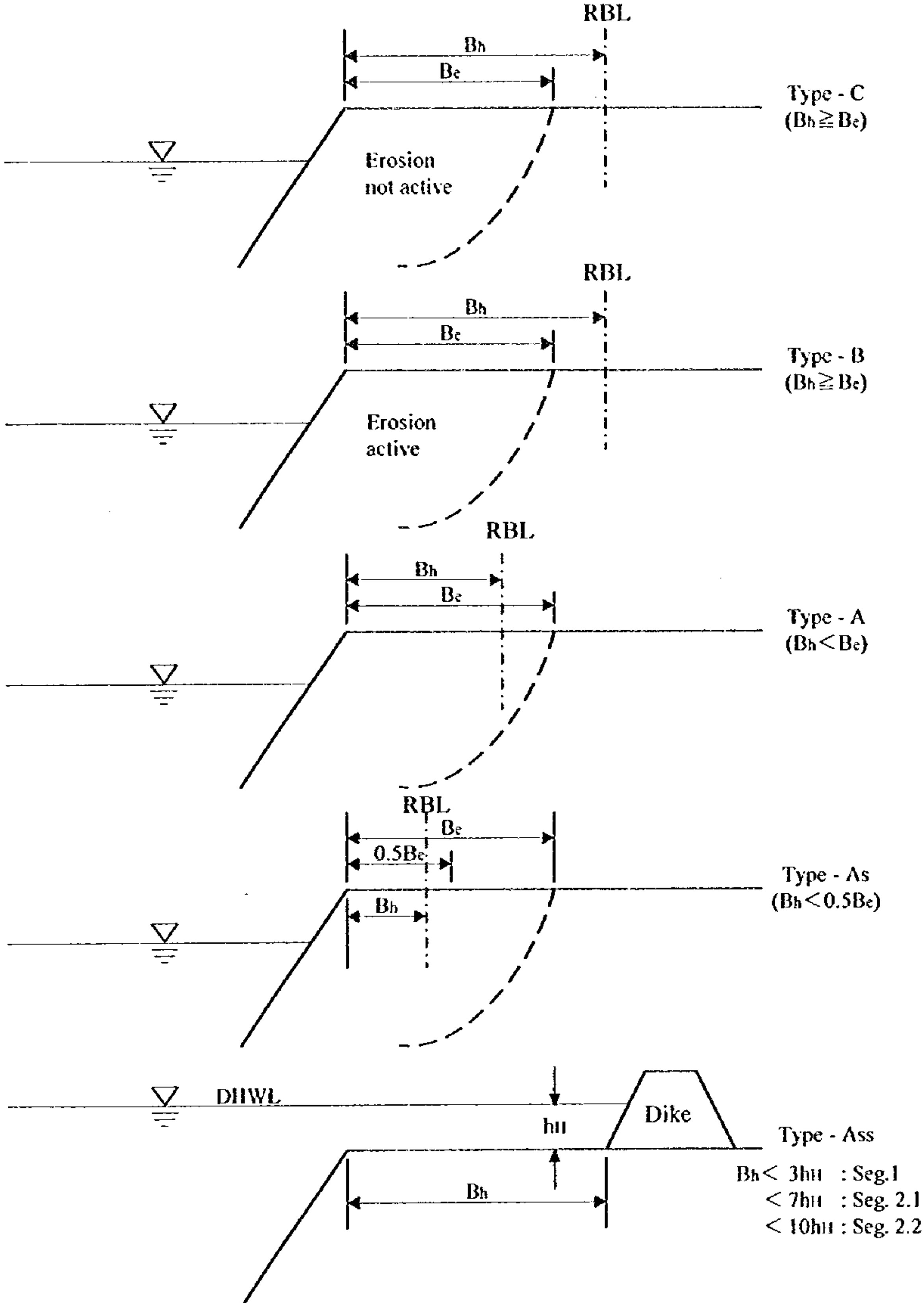
   $h_{sp} = 0.5\ h_L$ for Segment 2-2

   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



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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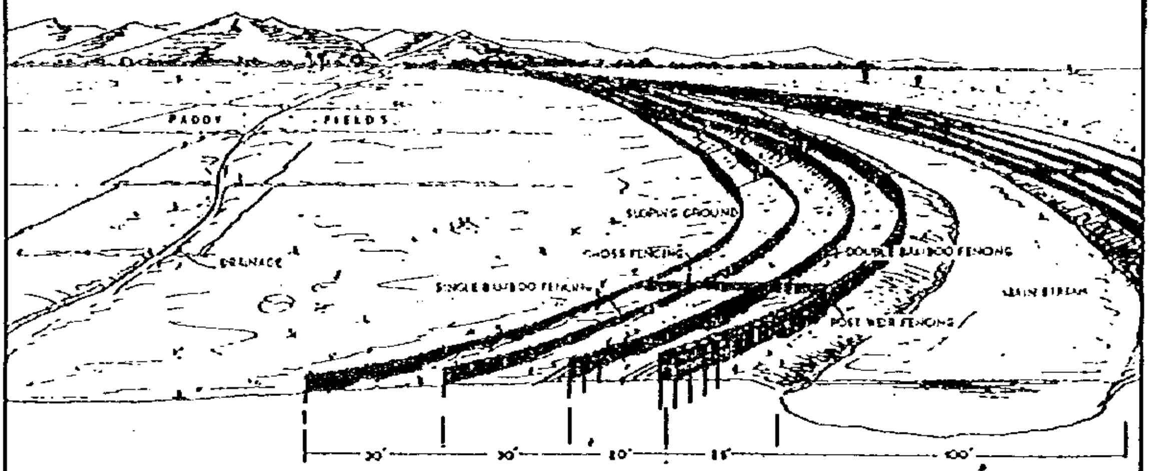

FIGURE 18 RIVER TRAINING WITHOUT EMBANKMENT IN BURMA
(AMELIORATION DU LIT SANS ENDIGUEMENT EN BIRMANIE)

Source : River Training
and Bank Protection,
United Nations

BANK PROTECTION WORKS

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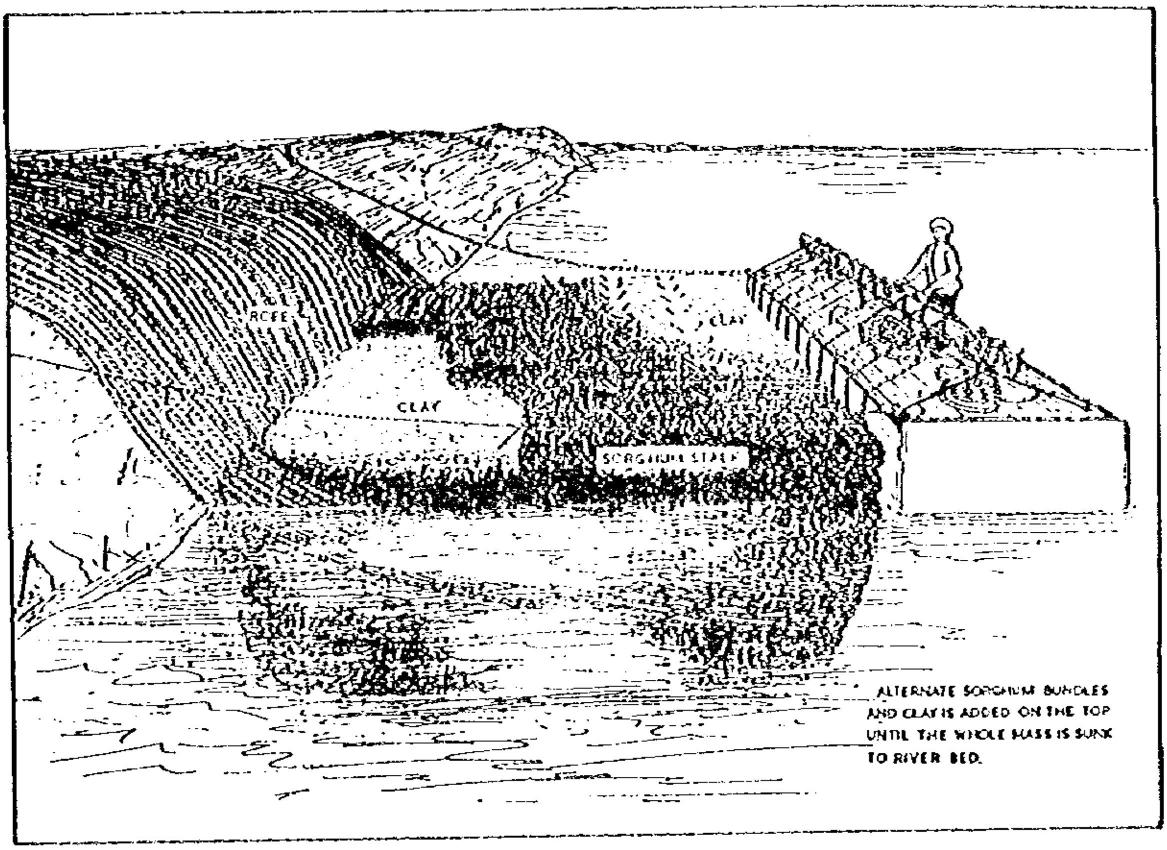
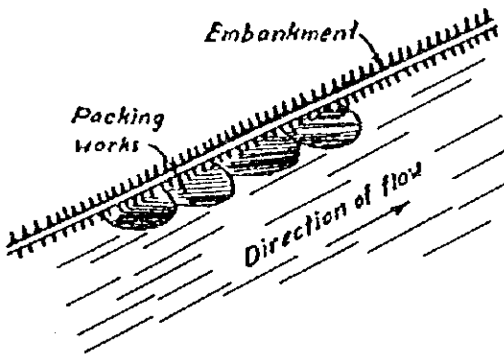


FIGURE 22 CONSTRUCTION OF SORGHUM REVETMENT IN YELLOW RIVER.



THE ARRANGEMENT OF FISH SCALE PACKING

Source : River Training and Bank Protection, United Nations

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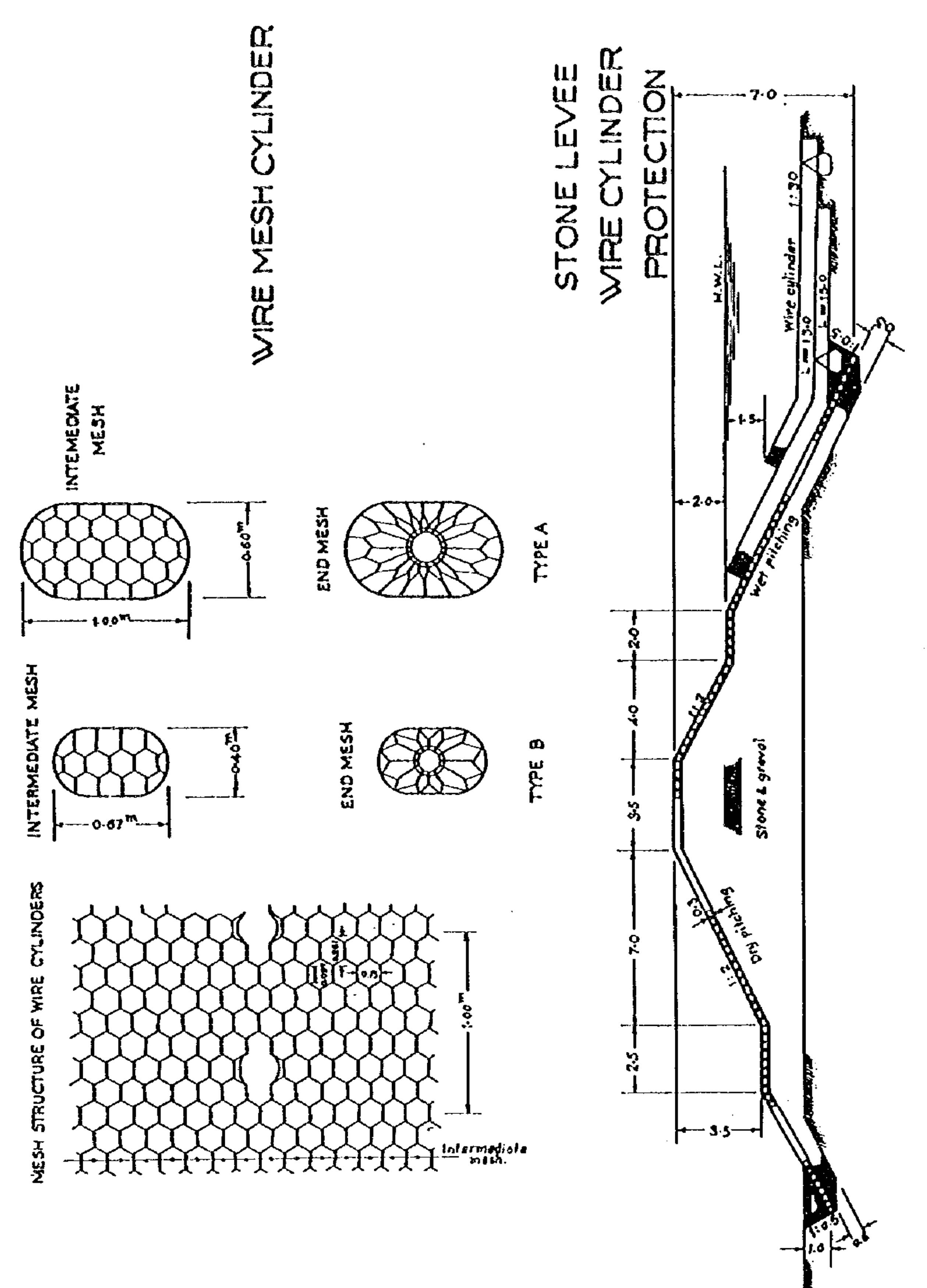

Source : River Training
and Bank Protection,
United Nations

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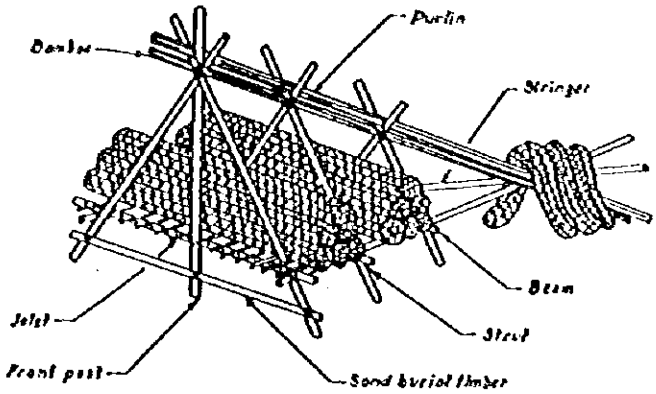
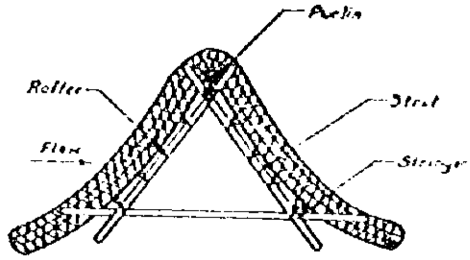
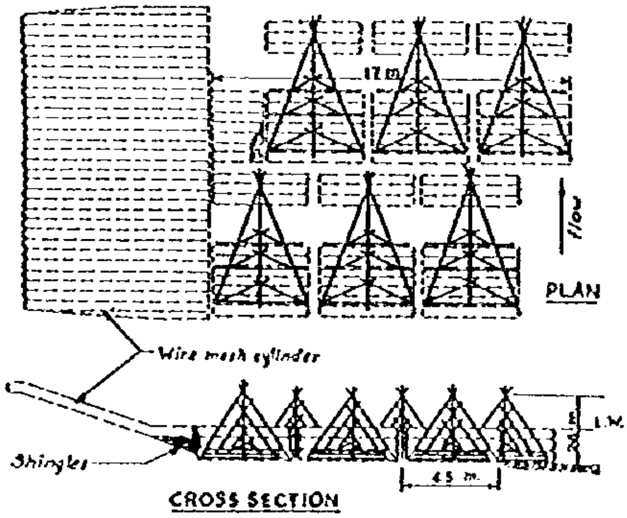


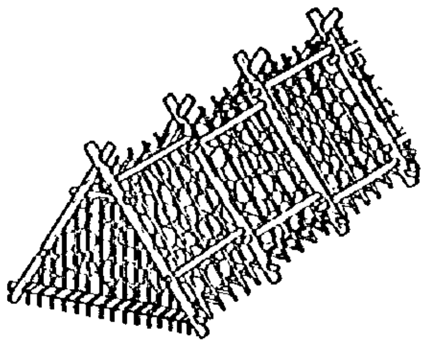
SACRED COW



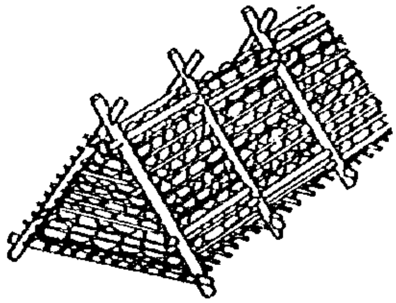
STABLED COW



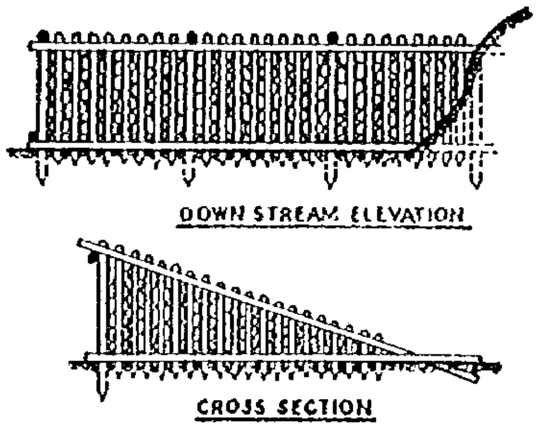
ARRANGEMENT OF SACRED COW



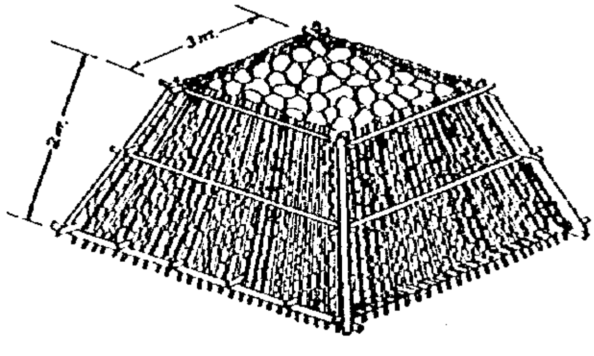
TRIANGULAR PRISM CRIB



TRIANGULAR PRISM CRIB



WEDGE SHAPED CRIB



FRUSTUM CRIB

Source : River Training and Bank Protection, United Nations

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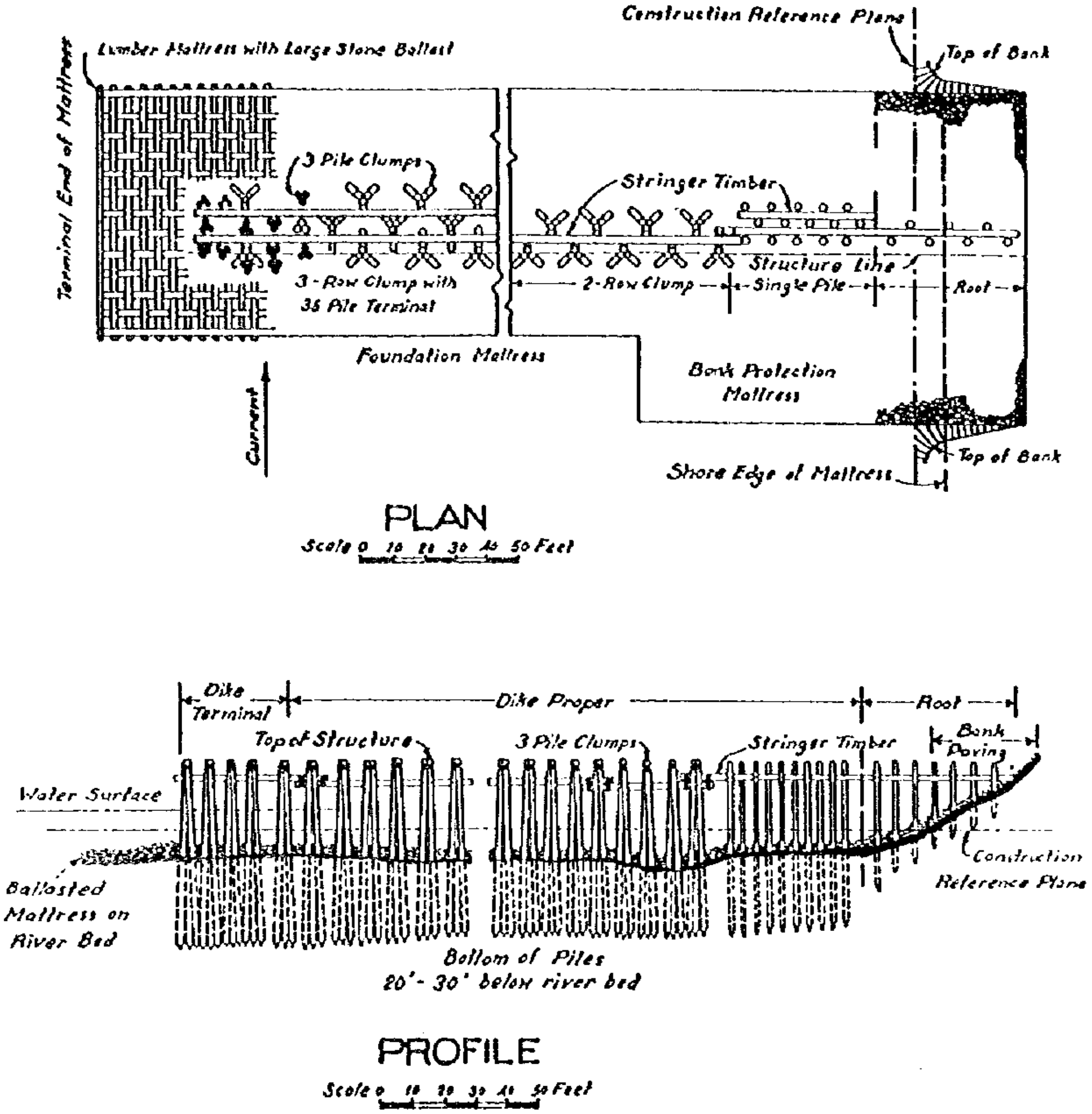

STANDARD PILE CLUMP GROYNE

Source : River Training and Bank Protection, United Nations

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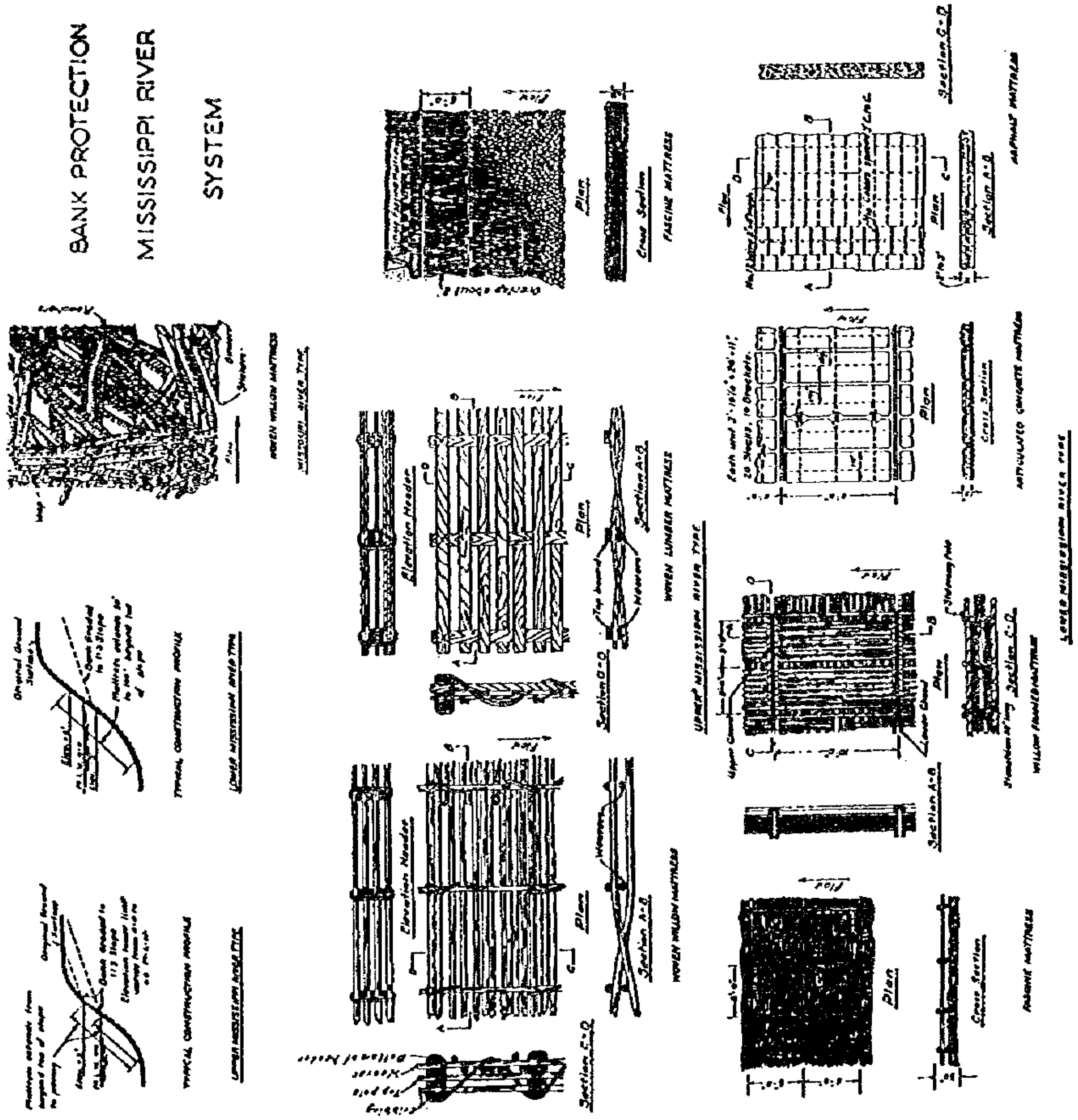
Source : River Training and Bank Protection, United Nations



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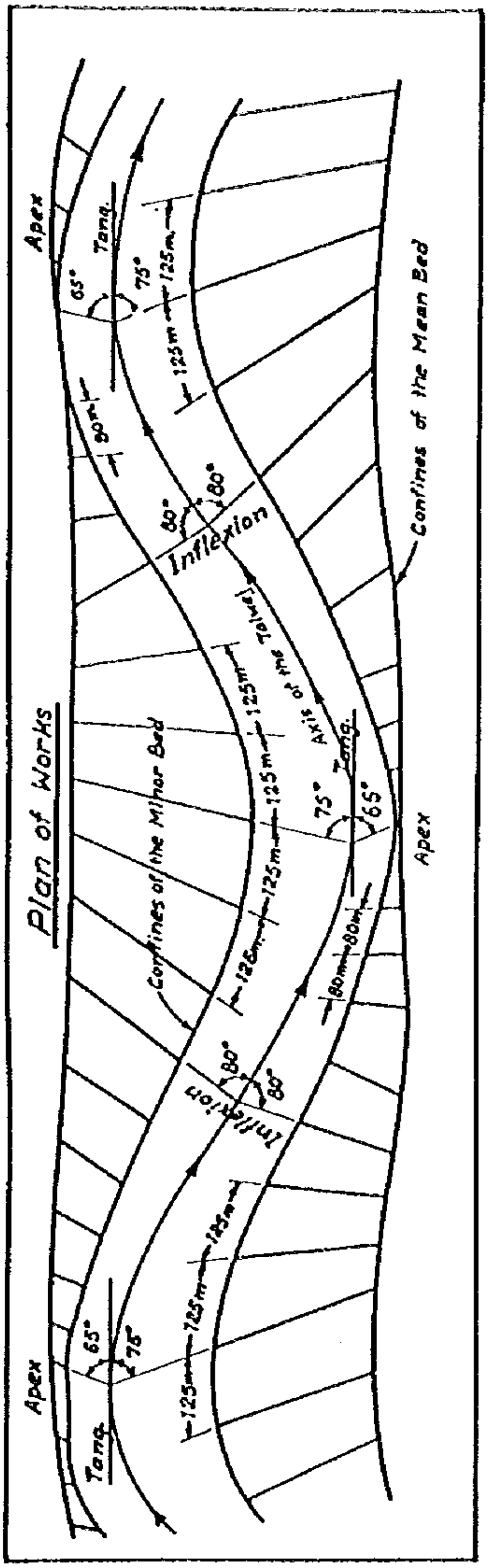
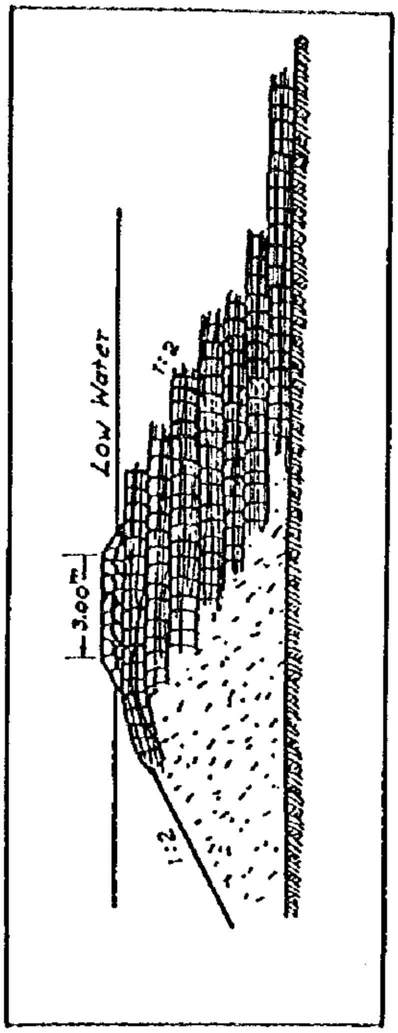


REGULATION OF THE LOIRE BETWEEN ANGERS AND NANTES



METHODS OF GROYNE CONSTRUCTION ON THE RHINE

Source : River Training and Bank Protection, United Nations

BANK PROTECTION WORKS

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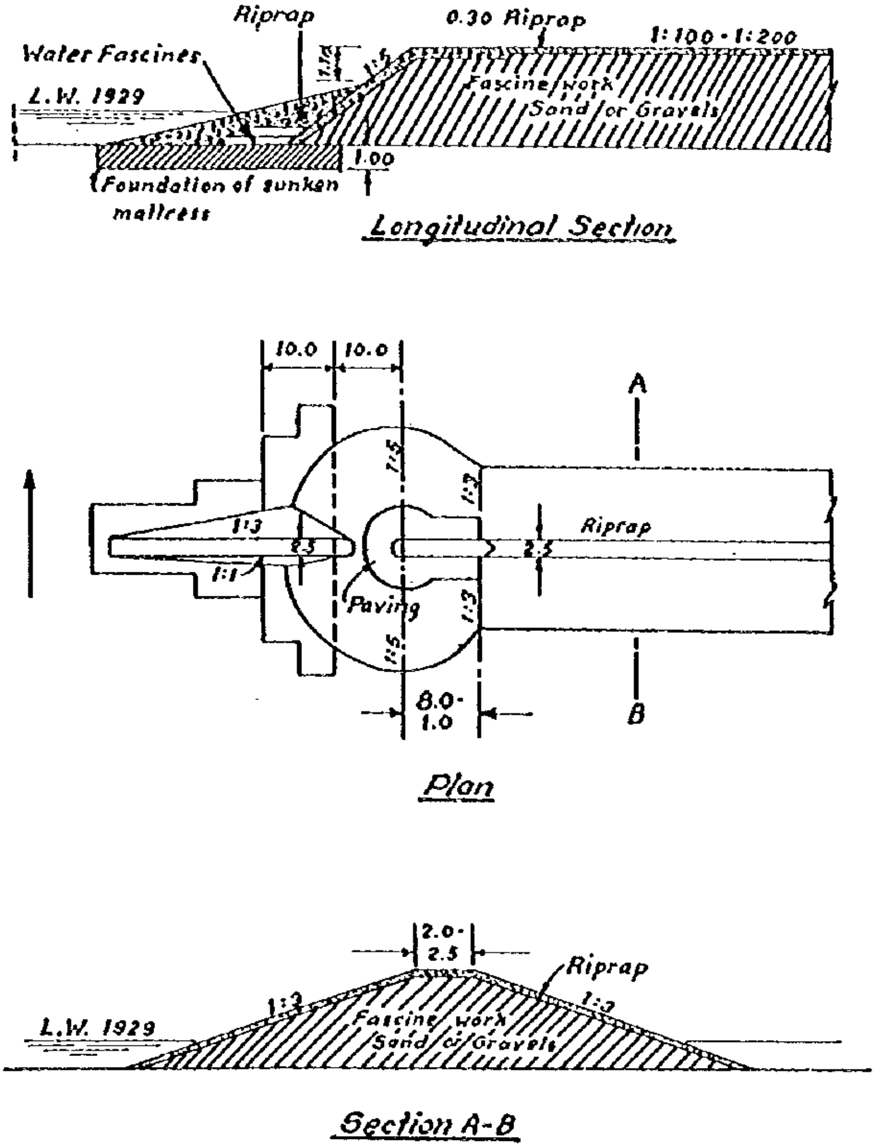

GROYNE ON THE ELBE WITH HEAD SILL

Source : River Training
and Bank Protection,
United Nations

BANK PROTECTION WORKS

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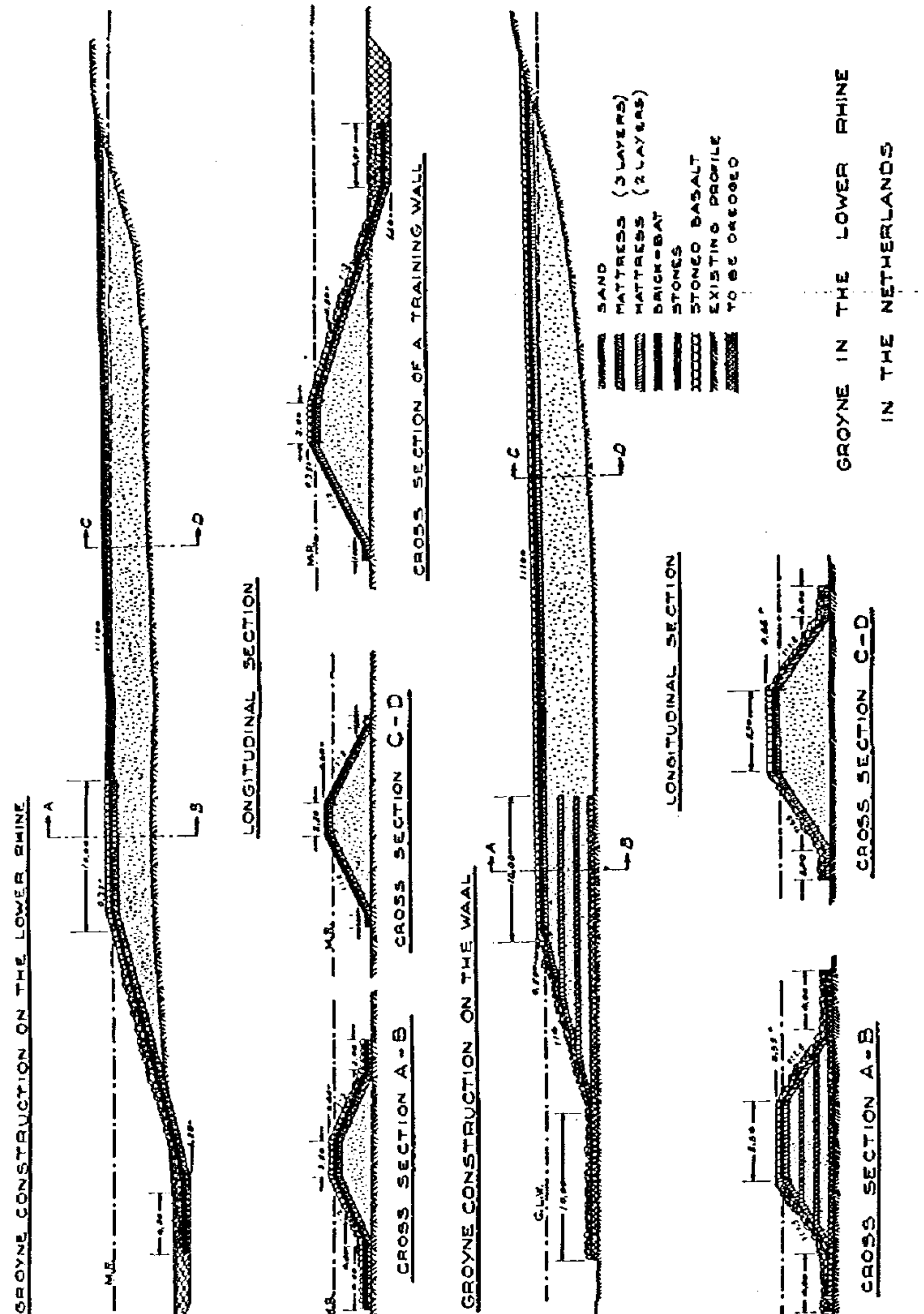

Source : River Training and Bank Protection, United Nations

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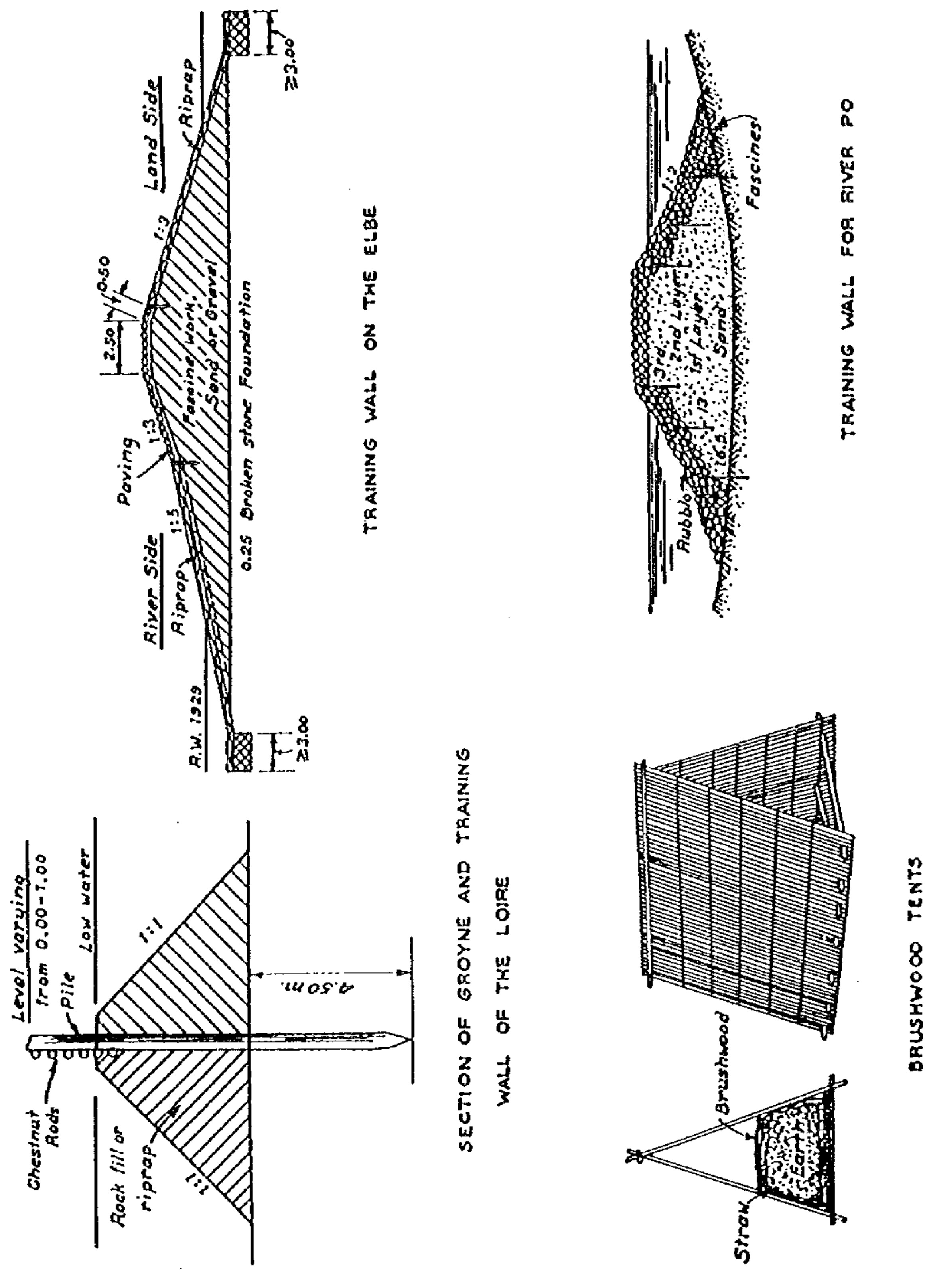

Source : River Training
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United Nations

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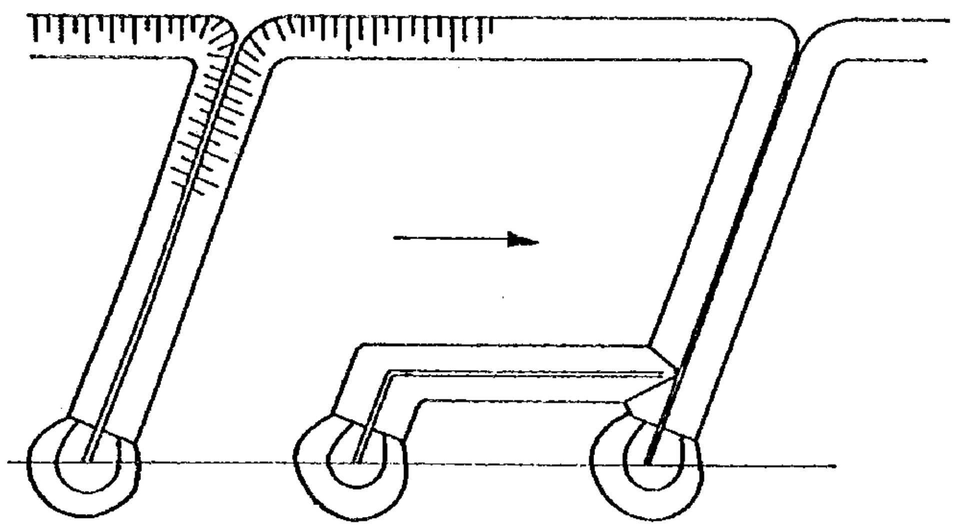

HOOKED GROYNES

Source : River Training
and Bank Protection,
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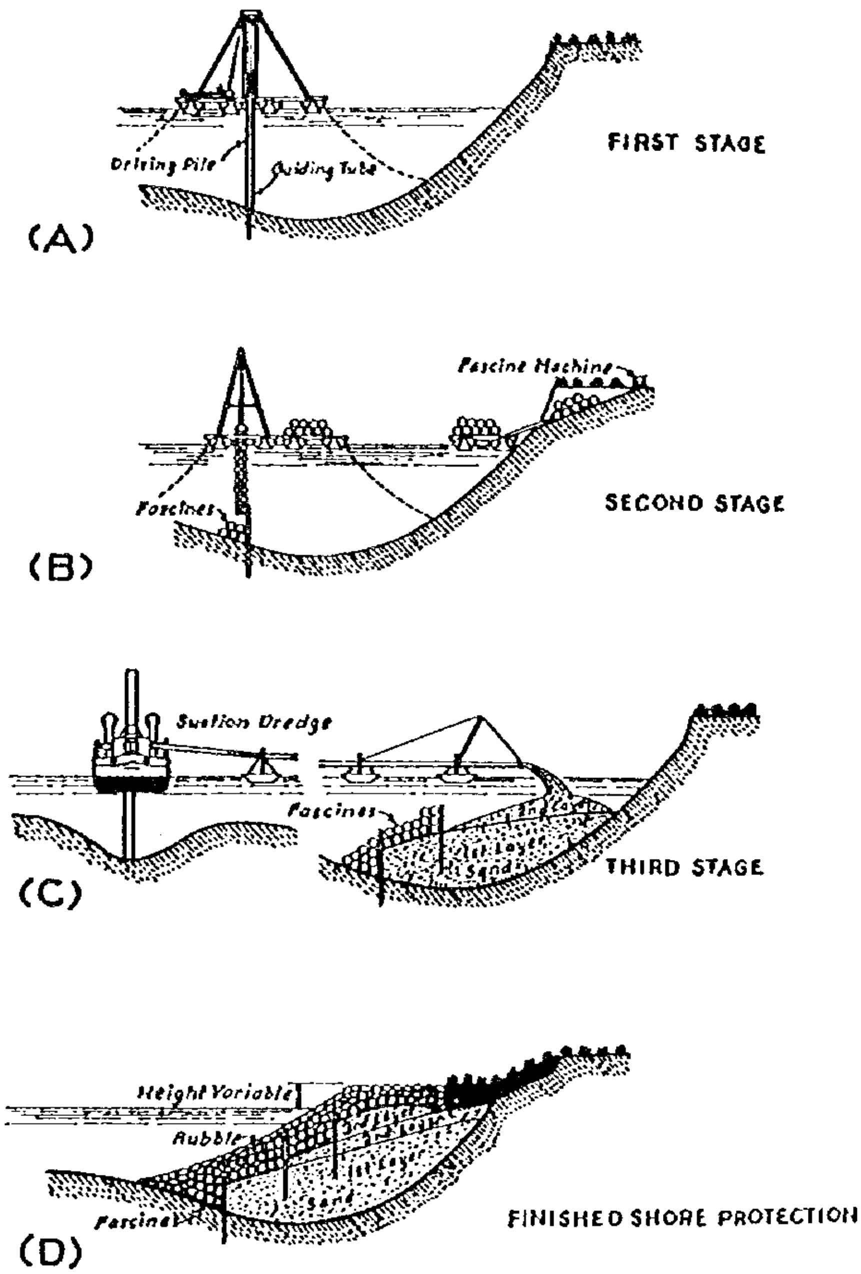

CONSTRUCTION OF SHORE PROTECTION ON THE RIVER PO

Source : River Training
and Bank Protection,
United Nations

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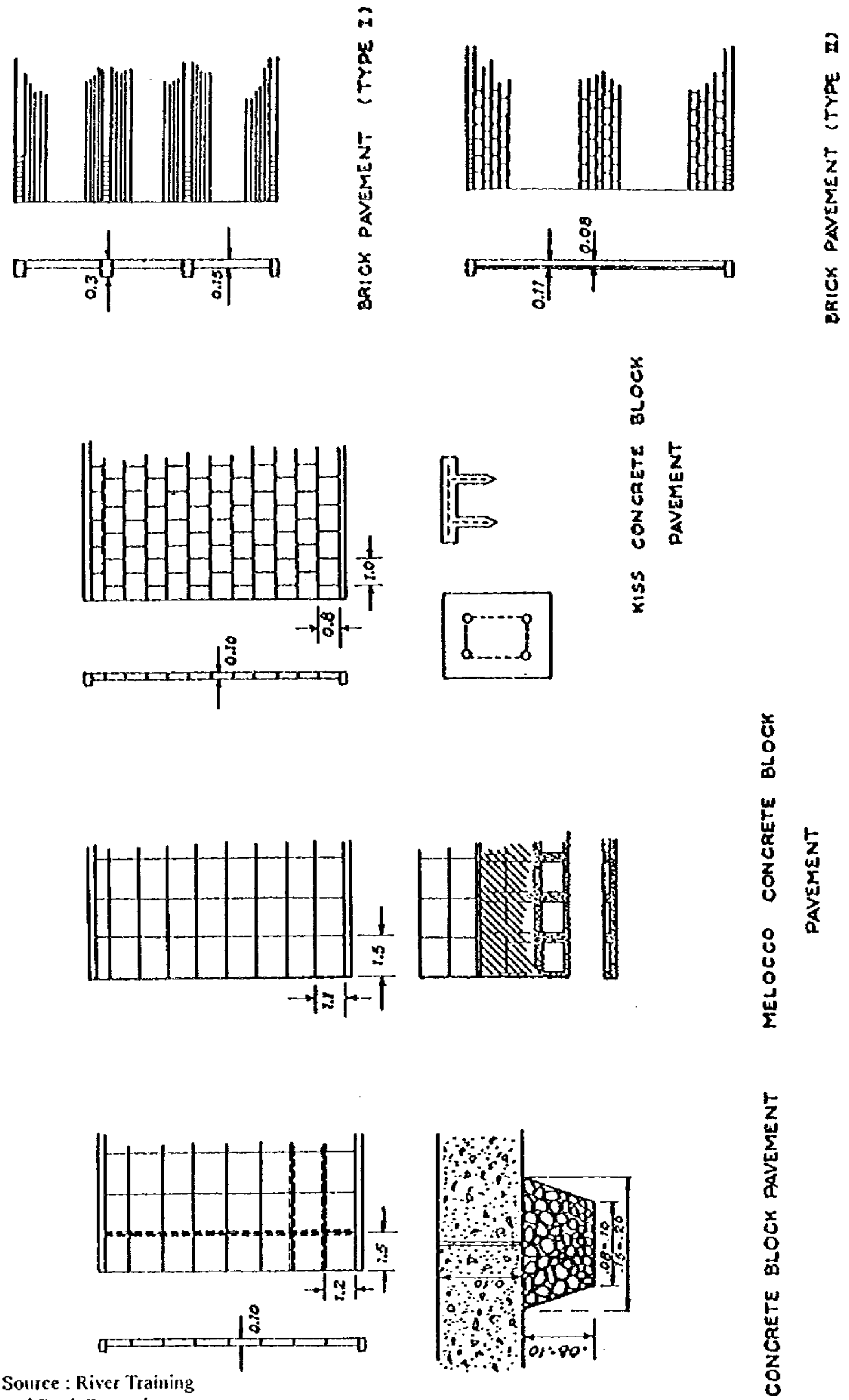

Source : River Training and Bank Protection, United Nations

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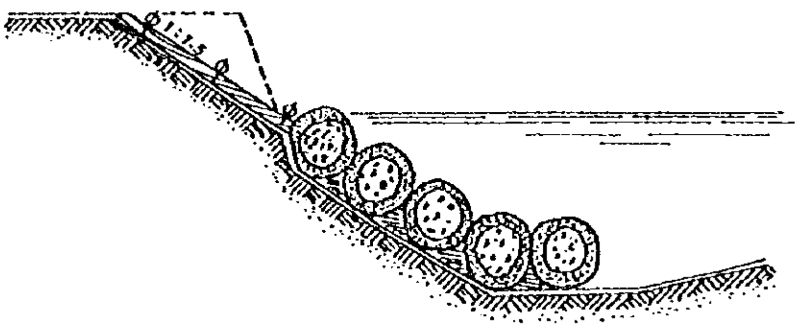
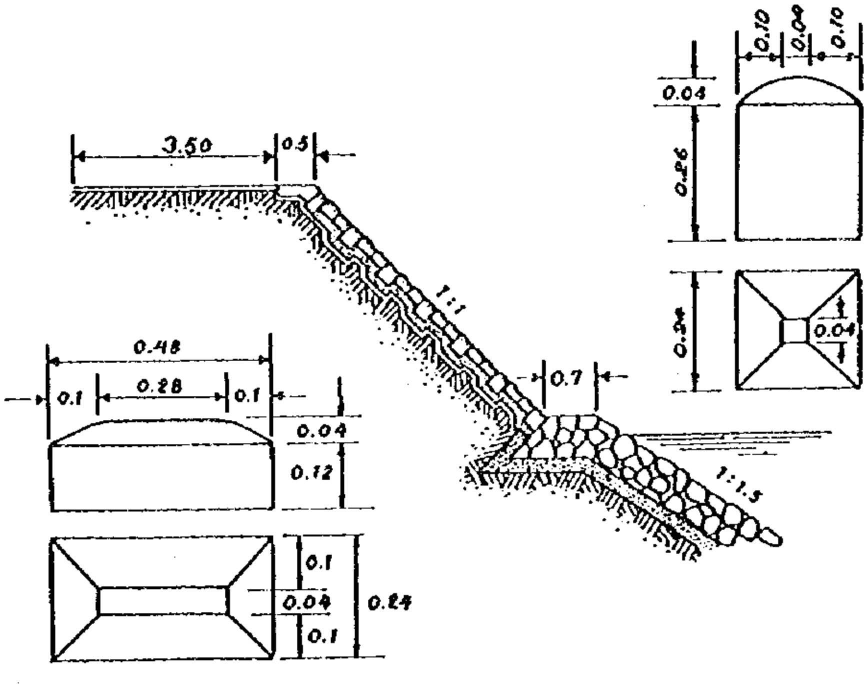


BRUSH ROLLERS



SQUARE AND RECTANGULAR BLOCKS

Source : River Training
and Bank Protection,
United Nations

BANK PROTECTION WORKS

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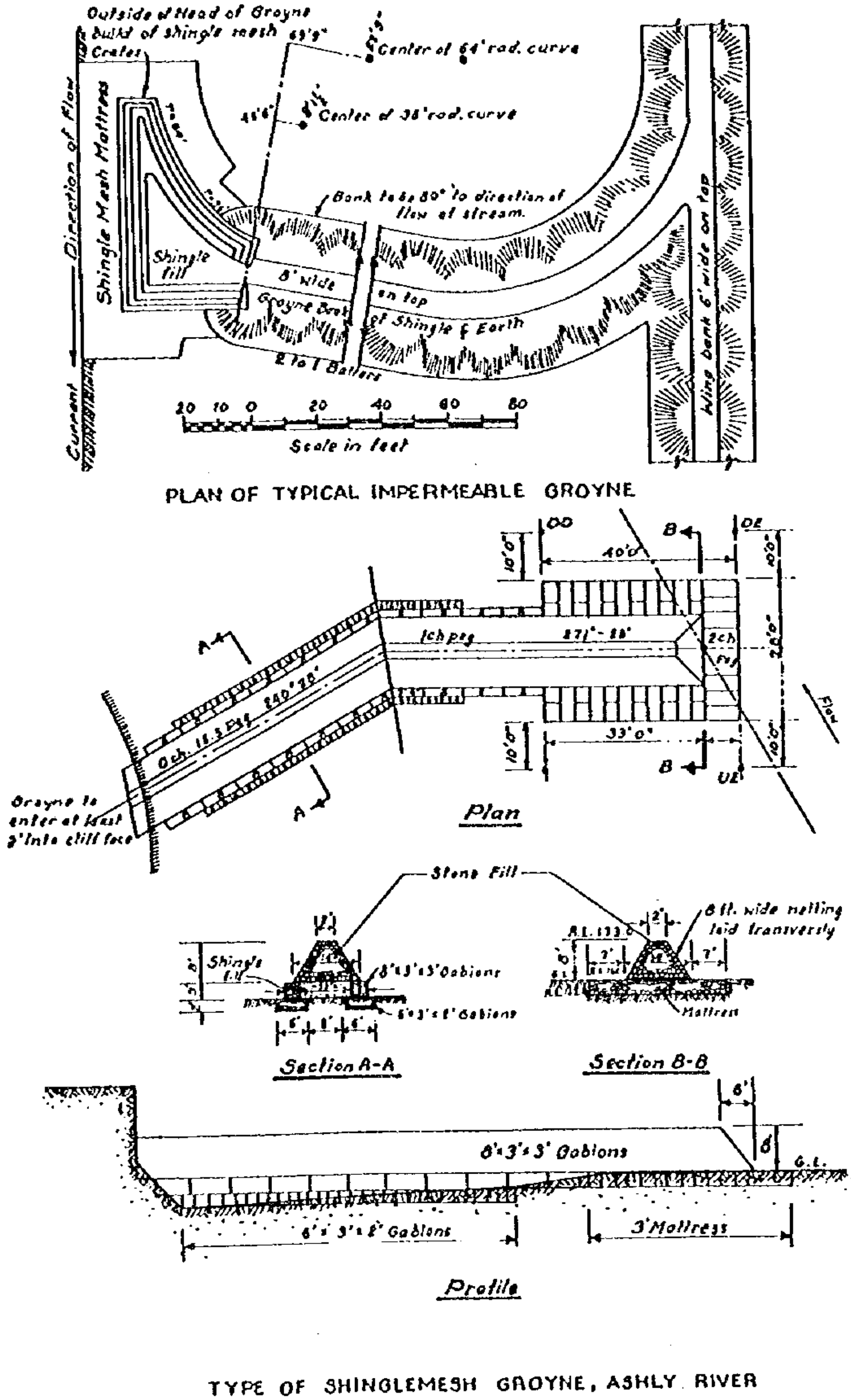

Source : River Training and Bank Protection, United Nations

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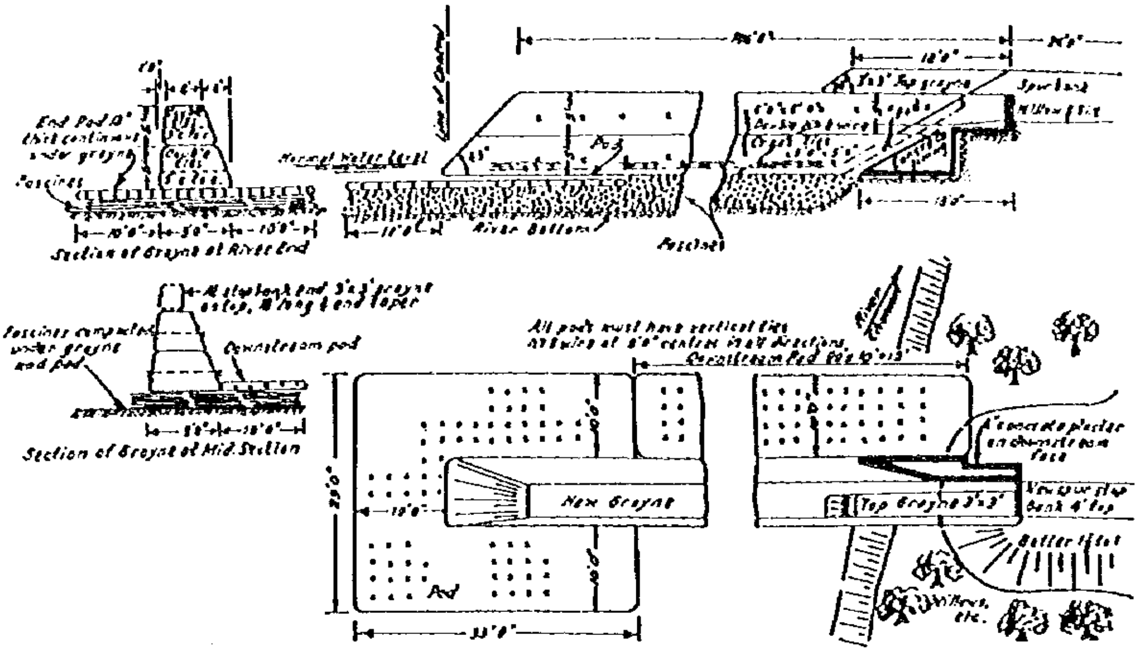
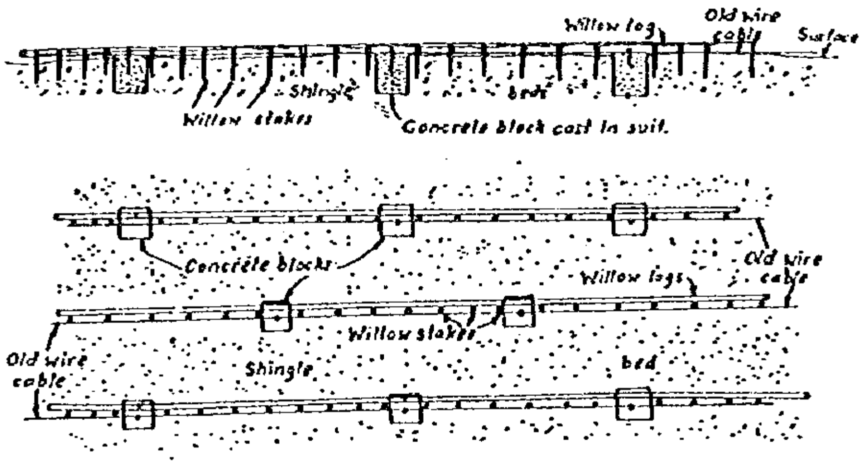
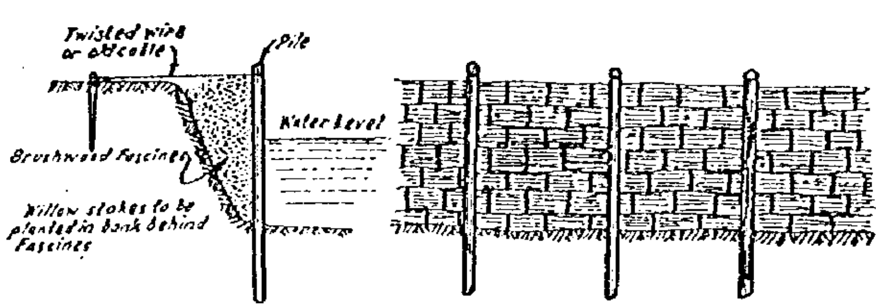


TYPE OF SHINGLEMESH GROYNE WITH MATTRESS ON DOWNSTREAM SIDE



TYPE OF WILLOW GROYNE



SECTION FRONT ELEVATION

PILE AND FASCINE REVETMENT

Source : River Training
and Bank Protection,
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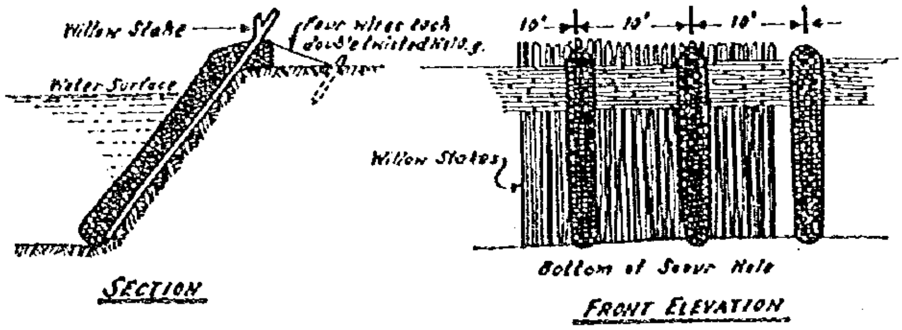
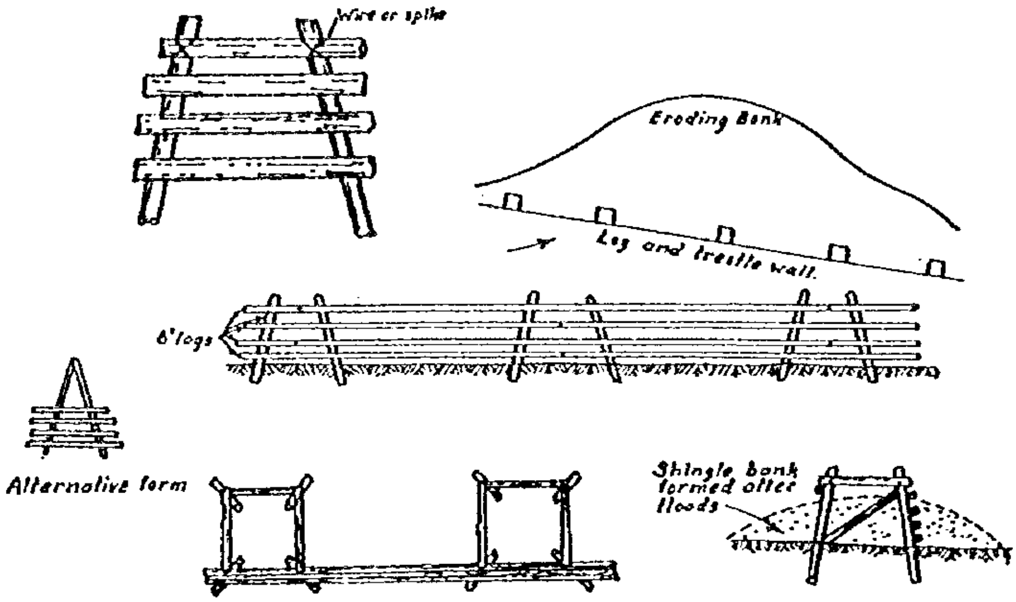


STONE SAUSAGE AND WILLOW STAKE PROTECTION



TYPE OF ROUGH LOG TRAINING WALL FOR PROTECTING ERODING BANK

Source : River Training and Bank Protection, United Nations

BANK PROTECTION WORKS

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7. COMMUNITY DEVELOPMENT COMPONENT

7.1 General

The "Community Development Component" will be categorized into three groups of activities, i.e., "Community Mobilization", "Local Coping Measures, and "Community-based Sustainable Measures". The "Community Mobilization", by assisting to form community organizations (COs), intends to build up organizational bases for the implementation of the Flood Mitigation Program. The "Local Coping Measures" will enable the COs to better cope with flooding at the times of its occurrence. The "Community-based Sustainable Measures" will motivate the COs to contribute their shares in maintaining and sustaining the flood control structures, by deriving additional benefits for improving their livelihoods.

Flooding occurs because of the coincidence of natural hazards (e.g., inundation, sedimentation, and bank erosion) and people's vulnerability (e.g., lack of awareness and motivation for preparedness, inadequate resources for risk reduction, lack of access to alternative sources of livelihoods). This Flood Mitigation Program will address both hazards and vulnerability. As shown in Fig. C7.1, the hazard control will principally addressed by the "River Control" component (and partly by "Community-based Sustainable Measures" that include several structural measures). On the other hand, vulnerability reduction will be promoted principally by the "Community Development" component. While "Local Coping Measures" will enhance the people's capabilities to adjust to hazards, thus directly reducing the people's vulnerability, "Community-based Sustainable Measures" will mainly serve to bring the "River Control" component to impact on vulnerability. In this way, the "Community Development" component will make crucial contributions toward the attainment of Comprehensive Flood Mitigation (tackling both the two sources of flood disasters, i.e., hazards and vulnerability).

7.2 Community Mobilization

The "Community Development" will start with the "Community Mobilization" component (Fig. C7.2), to strengthen the organizational bases for local flood mitigation initiatives. However, 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. Such alternative "Community Mobilization" approaches are likely to be time-consuming processes. However, it will be ensured that none of the following important steps will be skipped, in order that genuine "Community Mobilization" will be attained.

(1) Workshops for Local Government Institutions (LGIs)

The Local Government Institutions (LGIs) will play crucial roles in the "Community Development" component. The LGIs' main responsibilities will be to encourage and mobilize local resident to organize themselves. LGIs will also contribute some funds for the implementation of small-scale, community-based flood mitigation activities. In addition, there are specific sets of activities that will be entrusted to the LGIs, since they are costly or formidable for outsiders to take on. They include soil conservation in the river basins, establishment and maintenance of forest and grass belts, and regular monitoring and minor repair of flood control structures.

Even at present, the DIO seeks the LGIs' cooperation in mobilizing the communities in local flood control projects. In reality, however, the LGIs' contributions are usually confined only to labor hiring, with little regard to the training and education of the local people. The past experiences indicate that, when the people are mobilized only to labor on the construction works, they are rarely motivated to utilize and maintain the flood control works. In order to enable the LGIs to perform the alternative "Community Mobilization" tasks, a series of training workshop will be undertaken for the LGIs 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:** How various flood control measures (e.g., channel treatment, bank protection, dike works) function and are to be maintained.
2) **Local Initiatives for Flood Mitigation:** What actions are demanded of local communities (e.g., regular monitoring of physical structures, soil conservation) to sustain flood control facilities.
3) **Community Mobilization Processes:** How local communities are mobilized for development, through dialogues, and identification of needs and agreement.
4) **Facilitative Roles by LGIs:** What are roles and responsibilities of LGIs (e.g., coordination, conflict resolution, financing) in community mobilization.

Many of the LGI leaders believe only in continuous dikes from the foot of the mountain down to the border. They consider them to be indispensable in enhancing the security of their areas. Since continuous dikes are not proposed under this Program, the LGI leaders will be trained to fully understand the hydraulic situation under the conditions without continuous dike but with local dikes and forest/grass belts.

(2) Creation of Organizational Bases at the Community

The Flood Mitigation Program will then mobilize the LGIs, to create organizational bases at the community level. This will be achieved with three sets of activities, i.e., (a) Formation of Community Organizations (COs), (b) Promotion of Public Awareness, Knowledge, & Skills, and (c) Generation of Financial Resources by COs.

<u>Formation of Community Organizations (COs)</u>

Step 1 (Organize Settlement-wise Meetings): An initial meeting will be held in each ward of a VDC/Municipality, inviting all the households, with the following topics. (*note:* A VDC/Municipality ward usually corresponds to a natural settlement. However when a natural settlement contains several wards, or one ward is scattered, the above meetings will be held with a group of several wards, or at sub-ward levels)

1) Overall developmental problems facing the communities;
2) Types/causes of floods that strike the localities;
3) Possible countermeasures that can be taken;
4) Importance of group approaches to flood mitigation; and,
5) Potentialities/limitations of flood mitigation utilizing local resources and knowledge.

Step 2 (Dialogues with Communities): Following the initial meeting, dialogues will be maintained with the local communities. The main purpose of this stage is to enable the communities to understand the potential benefits of the Flood Mitigation Programs.

1) Presentation of "Flood Control" Component: Presentation of the forest/grass belt concepts, & where additional structures are proposed, other proposed flood control works. (e.g., bank protection, dike works, channel treatment)
2) Relating "Flood Control" with Other Local Needs: Assistance to identify what the community wants from the proposed flood control works. (e.g., the use of the forest/grass belt products as fuel, fodder, timber, the utilization of dikes as rural roads, or of ring dikes as refuge areas)

Step 3 (Establishment of COs for Forest/Grass Belts): To develop and maintain the forest/grass belts, settlement-wise COs will be established. (*note:* According to the size of a natural settlement, a CO will be formed at the ward / the sub-ward / the inter-ward level)

1) Formalization of COs: By agreeing on basic rules of CO management (e.g., composition & regular activities of the CO, decision-making mechanisms, and account-keeping), and by selecting chairperson, vice-chairperson, and treasurer.
2) Preparation of Forest/Grass Belt Operational Plan: By stipulating species selection, forest protection arrangement, use of forest/ grass products, penal regulations, and utilization of group funds, etc.
3) Registration of Forest/Grass CO with the District Authority: To enable the COs to officially receive support from the public sector organizations.

Step 4 (Strengthening of COs for Other Flood Control Works): As the next step, where additional structures (other than forest/grass belts) are proposed, the CO will be strengthened to take on other flood control works. (e.g., bank protection, dike works, channel treatment)

1) Formation of Inter-CO Groups: In case the proposed flood control work will benefit more than one CO, to agree on basic rules of inter-CO management, e.g., composition, basic activities, decision-making, and accounts-keeping. (*note*: When flood control facilities affect a multiple number of settlements, it is important to involve all of the beneficiary COs, to avoid "free-rider" problems; CO members would be discouraged to cooperate, when they know the benefits will be extended to those who do not contribute)
2) Formulation of "Community Development" Action Plans: Discussions to consider how local initiatives could be taken within the overall framework of the "Community Development" component.

Step 5 (Enter into Agreement with CO Groups): Finally, a formal agreement is signed with COs, which stipulates project activities (reflecting the local needs identified in the preceding step), time-frames and budgets, as well as responsibilities of both the external agencies and COs. The agreement will also include penalty clauses, in case either party fail to abide by the agreements.

Promotion of Public Awareness, Knowledge & Skills

Once the organizational bases are created with the above procedures, formal training of the COs will be undertaken, concerning the following topics:

Technicalities of Flood Control Measures: It is crucial for CO members to understand how various flood control measures are to function and are to be maintained, so that they can take on the tasks of regular monitoring and minor repair of bank protection, dike works etc. Just like the LGI leaders, the people tend to consider continuous dikes as the only solution to protecting their areas. The CO members should learn about the hydraulic situation under the conditions without continuous dike but with local dikes and forest/grass belts

Skills in Masonry and Gabion-netting: Training will also be provided to some representatives from each CO to gain skills in masonry and gabion-netting. Such skills training will be provided before the construction of the river control works, in order that CO members will gain not only employment, but also receive hands-on experience that can be applied later for the maintenance activities.

Community Participation in Flood Mitigation: It is also important for the COs to realize there are a range modalities of "participation", as attested to by numerous cases existing in Nepal.

1) **Labor Contributions:** Rural residents usually associate "participation" with voluntary labor contributions. However, there is also an alternative strategy, i.e., for the CO members to provide labor at reduced wage rates. The difference can be deposited in the CO funds.
2) **In-kind Contributions:** The COs can also make in-kind contributions, e.g., land donation and supply of materials. When there exist well-off members, in-kind contributions can be made in lieu of labor participation.
3) **Cash Contributions:** Funds generated through group savings can be used as cash contributions. What is important is not the sheer amount of money, but the fact that the communities themselves make investments to enhance their sense of ownership.
4) **Local Practice:** There are certain important practices that only the community groups can manage. These include riverbank conservation, appropriate land use, flood fighting. This type of activities are further delineated in the

following sections on "Local Coping Measures", and "Sustainable Measures".

Generation of Financial Resources by COs

The above-mentioned CO formation process will be accompanied by the mobilization of financial resources by the CO members themselves. There are several possible sources of generating funds by the local communities themselves:

1) **Forest/Grass Belt Products:** There are a range of local trees, shrubs, and grass that can be used as fuel, timber, roofing, etc. Having met the local needs for forest products, the COs can sell surpluses in the market.
2) **Nursery Products:** In case the local communities choose those species that require new nurseries, the COs can sell extra seeds and seedlings that are produced in their community nurseries.
3) **Group Savings:** Another source, which has been extensively tried in many other sectors, is group savings. In COs' regular meetings, also, each member deposits a certain amount of money (usually ranging from Rs.5 to Rs.50), according to his/her families' financial capacities.

Savings thus accumulated by CO members 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 under the "Community Development" component.

Rural people in the Terai plain may not be accustomed to systematic process of record keeping. When a systematic accounting of the group funds is lacking, CO members may feel they are not well informed of the use of the money, thus often leading to an environment of mistrust and confusion. In order to avoid such pitfalls, the project should assist in establishing a record keeping system, and provide them with skills training to run the system in a transparent manner.

7.3 Local Coping Measures

River control facilities often foster unrealistic expectations that all flooding can be controlled, thus prompting the people to be less cautious. It is therefore important for people to be aware of the importance of taking community-based coping measures on their own, to complement the physical facilities. Moreover, they are instrumental in heightening the people's awareness of their vulnerabilities to floods.

Rural people in the Terai are mostly aware of measures to lessen the impacts of floods, and in some cases, attempt their own coping measures, utilizing resources and knowledge they have. However, not all their coping measures are effective, and on the contrary, in some instances, they could be counterproductive. In such cases, external agencies can enable them to learn better ways of coping with floods, by providing proper know-how for flood mitigation. Moreover, in places where people are not aware of coping measures, external agencies can guide local communities to initiate small-scale measures to minimize the impacts of floods.

Each local area has a particular set of needs for "Local Coping Measures". For example, an organized river patrol system could fit well only with a locality where individual household spend sleepless nights watching rivers during monsoon. Agricultural adjustments would be needed only in a community where crops are often damaged by floods. The program component for "Local Coping Measures" will therefore be undertaken on a community-by-community basis.

The following are a menu of support, which the Program will draw upon in assisting local communities to enhance their local coping measures (Fig. C7.3).

(1) Flood Proofing

One common method that rural communities in the Terai take is to reduce the risks of damage by adjusting agriculture, and by strengthening building. There are also other ways of promoting flood proofing. The following are examples of such flood proofing measures that can be observed in the Terai plain:

Agricultural Adjustments:

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

rice fields are destroyed due to flooding.

Housing Structures:

1) Construct houses on plinths, so that flood water flows underneath;
2) Build walls of mud which will let water pass through in times of flooding, to prevent houses from collapsing;
3) Raise grain stores on stilts, while building escape areas under roofs for family members and other valuables; and
4) Concentrate houses on higher grounds of the communities, to prevent residential shelters from being inundated during floods.

Other Possible Flood Proofing Measures:

1) Aforestation/reforestation on the riverbanks will serve to curtail the speed of overflow water in case of emergencies;
2) In low-lying areas, drainage construction to reduce the level of inundation as well as to improve hygienic conditions during the monsoon; and,
3) Small-scale reservoirs development (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 if and where feasible. For example, extension work will be undertaken to disseminate housing techniques in settlements of new migrants who are not familiar with the flood-proof techniques. In other cases, some local communities may not be capable of implementing their ideas, due to the lack of resources. In such instances, those localities will be assisted to remove the resource constraints, e.g., supply of seedlings for the production of durable housing poles.

Moreover, even in places where the above measures are taken, there may be scope for further improvements with external support. One example is to assist local communities to pursue an organized approach (instead of individual approaches), for example, by forming cooperatives in which a farmers' group collectively store seeds to be draw upon during emergency periods.

(2) Forecasting, Warning, & Evacuation

Many farmers in the flood plains have their own ways of "forecasting and warning", in an attempt to give themselves enough lead time for evacuation. Usually, those who have experienced floods periodically have their own ways of evacuation in times of disasters. The following are some of such examples of local measures:

Forecasting and Warning: Some people predict coming floods from the following signs:

1) 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);
2) Unusual sound/smell of rivers (e.g. rumbling sounds coming from the river, muddy smells of the stream);
3) Abnormal behaviors of animals (e.g., wild animals coming out of the jungle, livestock animals start barking); and
4) Continued rainfall in surrounding areas, or in the upper watersheds.

Evacuation:

1) Stay in under-roof areas/ on rooftops, until floodwater subsides;
2) Stay on trees (e.g., bananas, and mangoes) planted around houses;
3) Evacuate to neighbors' second-story houses, or to others' houses located in surrounding areas on higher grounds;
4) Shift valuables (e.g., money, grain, and livestock) to safer areas, before the monsoon season starts; and,
5) Utilize fishing boats for evacuation purposes.

For both "forecasting/warning" and "evacuation", a possible strategy is to help local communities to improve upon and maintain those local measures, and to disseminate to other areas where there are hardly such traditions of local efforts. In the Terai plain where it is likely to take years before a sophisticated flood forecasting, warning and evacuation mechanism will be in place, it is crucial for the communities to continue/ adopt such local systems to cope with flooding.

One drawback commonly found in local forecasting, warning and evacuation is that such efforts are undertaken individually. In such cases, local communities will be supported to convert their practice into more collective efforts. For example, as the monsoon is drawing near, people residing in flood-prone areas start watching rivers day and night individually by each household. In those places, support will be extended to organize community groups to undertake river patrols on a rotational basis.

Similarly, it is possible to incorporate more systematic approaches in local "forecasting and warning" simply by utilizing existing facilities and resources. For example, there is one P.C.O. (Public Call Office) almost in each VDC in the Terai, which can be used to pass flood notices from the upstream areas. Where there is an irrigation barrage along the river, the irrigation office can possibly inform of the rising of the water level to other areas, in addition to the task of closing the water intake.

For "evacuation" purposes, people find refuges in their own localities, and if that is not possible, seek to safer areas in neighboring areas. At the same time, there exist certain localities that find it difficult to secure suitable evacuation sites, for various reasons, e.g., lack of accessible roads to safer areas. External support for "evacuation" will focus on such most needy areas. In such places, the construction of new community shelters will be avoided, since in the contexts of Nepal, they rarely accommodate many people with adequate food and sanitation. Instead, given the budgetary constraints, the above community-based approaches will be applied to the extent possible.

(3) Flood Fighting

Some local communities, when they notice the comings of flooding, install temporary flood fighting structures using local resources and materials. The structures serve either to contain the extent of bank erosion, or to deter the velocity of overflow. The following are examples of such 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, those village-level measures, albeit commendable for their self-help approaches, often lack technical soundness. For example, the people plant bamboo, but too late for bamboo to become resilient enough to flooding, or grow shrubs with densities insufficient to deter bank erosion. This type of cases warrants advice from outside experts to correct those technical faults. Such technical advise will be easily absorbed and to be put to practice, given the fact that those communities are already motivated and at least are aware of potentiality of collective efforts.

In addition to the sheer lack of local awareness, another issue at stake is the lack of materials. Flood fighting structures cannot achieve the technical optimum, in some cases, because of the unavailability of local materials. For example, bamboo/log piles could be augmented with boulders which are available only in certain localities. In such cases, support will be extended to augment their flood fighting efforts, through the supply of materials not available locally.

In some of the cases, those local-level flood fighting is elicited with a small amount of support from the DIO, the VDCs, and/or the DDCs. However, most of the materials provided by the external agencies, e.g., sandbags, and bamboo, are often readily available. Once the COs will start generating financial resources, as outlined in the above section "Community Mobilization", the communities will be encouraged to purchase flood fighting materials themselves, to the extent possible.

7.4 Community-based Sustainable Measures

Not only a flood control structure in itself does not produce direct economic returns, but its benefits are slow to accrue, and cannot always be accurately accounted for. Efforts should therefore be made to link flood control with other developmental activities, which will accrue more tangible and direct benefits. This way, flood mitigation projects will enhance their economic viability, and will also motivate people to help maintain the flood control structures.

The program component for "Community-based Sustainable Measures" is intended to derive additional benefits from the physical facilities, and to motivate the beneficiaries to help sustain the structures (Fig.C7.4). First, with (1) forest/grass belts, (2) preventive bank protection works, the program will use trees/shrubs/grass as part of flood control measures. This will enable the COs to derive tree/grass products, out of the flood control measures. Second, (3) access improvements, (4) bed material collection will enable the COs to gain additional benefits, mainly in facilitating local economic and social activities, and employment opportunities during the dry season.

Finally, these additional values will motivate the COs to maintain the physical structures. To enable the communities to act upon their willingness to sustain the measures, the "Community-based Sustainable Measures" will include (5) O&M of Flood Control Structures, and (6) Land Use Management. While (5) is concerned with the flood control structures themselves, (6) is intended to assist the COs to stabilize the soil and land adjacent to the flood control structures.

Naturally, the contents of a support package must be determined based on particular needs of each community (e.g., what income-generation potentials exist, or what types of access improvements are required). In this respect, just like "Local Coping Measures", it is important to identify local needs and priorities during the "Community Mobilization" stage.

(1) Forest/grass Belts as Dike Works

As explained in the above section "River Control Component", this Flood Mitigation Program envisages the development of Forest/Grass Belts along the target river basins. Table C7.1 shows a list of potential candidate trees/shrubs/grass that can be used as part of the Belts, with their relative functional strengths (i.e., river bank control, fully erosion, and landslide rehabilitation).

The Belts will serve not only as dike works, but also to serve various necessities of the local residents. As illustrated in Table C7.2, there are various local trees, shrubs, and grass that are of multi-purpose (e.g., fuel, timber, roofing, etc). Having met the local needs for forest products, the COs can sell surpluses in the market. Moreover, in case the local communities choose those species that require nurseries, the COs can sell extra seeds and seedlings that are produced in their community nurseries.

According to the projections made by the Department of Forest, the demands for tree products will continue to rise for the future to come. For example, during the period between 1995/96 and 2005/06, in the Terai, household consumption for fuel wood/fodder/timber will increase by 25.5 %. There continue to be ample opportunities for income-generation through the supply of plant products.

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 bio-engineering strategies include forestry development, bee-keeping, ginger/turmeric farming, and coffee growing could also be initiated near/in the forests.

As Table C7.3 shows, most of them are local species. Since sources of the seeds can usually be identified near the target areas, the collection of local seeds as part of flood mitigation projects are usually the best way to obtain seeds. Seeds are also available from the Department of Forest, and the Department of Livestock. For some species, a nursery is required as a source of seeds and/or seedlings. The use of small-scale nurseries are common in Nepal. Moreover, the experience shows that it is easy to staff and run good nurseries throughout the Terai, as long as the technical aspects are properly looked after by extension agencies.

(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, and the other is the plantation of trees/shrubs/grass, usually to supplement engineering structures for flood control.

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. While they may not be feasible where the velocities are high, they will be disseminated in places where the bank erosion and/or overflow can possibly be contained through locally initiated structures. In order to achieve this, the local communities will 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 locally initiated bank protection works is to apply vegetative structures to augment engineering solutions. Bio-engineering will help derive at long-term stability and sustainability of the flood control activities, since they a) rely on locally available resources, b) cost less than sole technological solutions, c) increase strengths over time, if managed properly, and d) stabilize the land that adjacent to the engineering structures.

The bio-engineering, in addition to the flood control functions, will be used to derive forest products. Table C7.1 provide a list of trees, shrubs, and grasses that can potentially be used for bio-engineering in the Terai. As Table C7.2 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.

Aside from introducing bioengineering techniques to wider areas, support will also be extended to those localities that already practice bioengineering. Often the residents who implement bioengineering may not always aware of the whole range of possible species, and often use the species that do not yield the types of products the communities want the most. It will therefore be useful to enable the communities to widen their choices, so that they can select the species that best matches.

(3) Access Improvements Using Flood Control Structures

There is a special need for roads in the Terai, although the Terai has comparatively a well-developed road network in Nepal (the Terai's road length per unit area more than triples that of the Hills and Mountains). Internationally speaking, the road length is 65% of that of Uttar Pradesh, which is considered to be a backward state of India, and in comparison with Bangladesh, the figure even drops to 12%.

Accordingly, there is a great deal of demand for road construction/maintenance in the Terai. The district-level annual planning exercise revealed that, for example, of all the request (280) that Chitwan district collected from its residents in 1995/96, about 30% (84) were concerned with roads. In the case of Banke, the figure was 18% (63 out of 347 requests). In view of the high demand for road development, the Government earmarks more than half of its district development grants, for road/bridge construction/maintenance.

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.

It is to be noted people hope for access improvements for a variety of reasons, e.g., to transport agricultural products, to purchase daily necessities, to send children to school, to go to health clinics, or to attend village meetings. It is therefore important to reflect particular needs of each local community. One critical issue, in the context of flood mitigation, is the damages to road networks during the monsoon which prevent the people from moving to potential evacuation sites. In such places, support will be extended to link access improvements with the local evacuation requirements.

In access improvement purposes, emphasis will be placed on labor-intensive methods which are locally suitable and affordable. 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 even cash). Local road projects, therefore, are likely to contain unit costs of road construction, usually ranging from 50,000 to 80,000 Rs/km for gravelling earthen roads. (For example, in Nawalparasi district, gravelling of 650 m road costed at Rs.52,538; in Rupandehi, Rs.81,250 for 1.5 km road; and in Baglung, Rs.370,272 for 5.5 km road).

This Flood Mitigation Program will mobilize District Development Committees' financial resources, which comes from the central Government as grants for road/ bridge construction/maintenance (with the average grant per district amounting to Rs.2.5 million in 1996/97). The district grant will be able to well cover several dozen km. of gravel roads, if community-based approaches are to be applied.

(4) Bed Material Collection as Channel Excavation Works

Many rivers in the Terai are being mined for sand, gravel and boulder, which serve as one important source of revenues for many District Development Committees (DDCs). For example, the DDC's revenue from sand/gravel/boulder collection constituted 17.9% of the 1996/97 total revenues (excluding grants from the central government) of Banke district. Even in Chitwan endowed with a broader range of tax bases, it is estimated to make up 11.0 % of the DDC's revenue in 1997/98.

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.

Except for Kathmandu (sand consumption in Kathmandu grew at the annual rate of 11.3 %, on average in 1984/85-94/95), there is little data on the demand of gravel/sand/boulder. However, it is known that the demand is always high in most urban areas of Nepal, since bed materials are among primary construction materials for highways and roads, dams and canals, buildings, and also river training facilities. Nepal also exports sand/gravel to India and Bangladesh. The newly constructed Kakarvitta -

Phulbari (Bangladesh) road, a 44 km narrow stretch southeast of Jhapa district, has the potentiality of boosting Nepal's sand/gravel exports to Bangladesh.

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.

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 motorable roads 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).

For example, the above (f) emanates form the misconception of the residents that riverbed extraction would cause of sever flooding. In such cases, extension activities can be conducted to raise awareness of the local communities.

The constraint (e) derives from the fact that the Department of Mines has delegated the authorities for riverbed extraction to the local governments (both DDC and VDC can handle which also causes confusion). At the same time, the river basins inside national forest/national parks come under the jurisdictions of the Departments of Forest (DOF) and of National Park (DONP), according to the Forest and National Park Acts. Because of this lack of clarity, neither party initiates bed material collection even where it is desirable from the viewpoint of river control. In such places, it is important to clarify the responsible party and to encourage the agency to promote riverbed collection-cum-river training.

Even the constraint (c) could be mitigated, once the master plan gets implemented. to boost the demands for boulders used for the plan itself. Under the master plan, the COs will be mobilized to make in-kind contributions to the construction works. Therefore, even in places where there are no motorable roads, the beneficiaries are expected to contribute transporting boulders without using automobiles.

(5) Operation and Maintenance of Flood Control Structures

Even for sophisticated engineering structures, a system of regular monitoring is necessary to ensure their continued stability. For this purpose, local communities will be given the responsibilities to constantly monitor the sites, and when necessary, seek external support for rehabilitation.

For revetment works made of G.I. 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. boxes.

For both gabion spurs and permeable types of pile spurs, similarly, it is important to monitor the level of the river beds. In case the surface of the river beds are washed off, it is crucial to stabilize the foundation of the spurs by placing stones and rubbles on the river beds. Moreover, the local residents will be required to see to it 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, which will serve to stabilize the land adjacent to the structures.

Dike works are subject to scouring of their slopes, given its objective to counteract the forces of floodwater. 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. In this Flood Mitigation Program, the major focus will be placed on the conservation of 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: Pasture land 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.

Stabilization of the riverbanks is a critical factor in sustaining the flood control works (e.g., bank protection, dike work). Otherwise, the land around the flood control structures will be scoured, which nullifies the physical facilities. Moreover, tree plantation will also serve to break the velocities of flood water. 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.

SELECTED SPECIES AND THEIR APPLICATION IN CONSERVATION MEASURES IN TERAI AND SIWALIK (CHURE) REGION

TREE SPECIES

Nepali/Local Name	Botanical Name	Applications		
		River Bank Control	Gully Erosion	Landslide Rehabilitation
1. Seto siris	Albizia procera	++		
2. Seto koiralo	Bauhinia variegate			+
3. Kalki phul	Callistemon cirinus	+		
4. Sissoo	Dalbergia sissoo	++		
5. Kabro	Fichus lacor			+
6. Khanyu	Fichus semicoroata			+
7. Dabdabe	Garuga pinnata	+	+	++
8. Kangiyo	Grevillea robusta		+	
9. Ibil Ibil	Leucena leucocephala		+	+
10. Bakaino	Melia azedarach		++	+
11. Kimbu	Morus alba		+	+
12. Amla	Phyllan thus emblica		+	+
13. Khirro	Sapium insigne		+	++
14. Tooni	Toona ciliata	+		
15. Mashala	Eucalyptus sp.	+		+

Source: B..D. Shrestha, Senior Geologist, Department of Soil Conservation

BRUSH AND SHRUB SPECIES

Local Name	Botanical Name	Applications		
		River Bank Control	Gully Erosion	Landslide Rehabilitation
1. Assuro	Adhatoda vasica	+	++	++
2. Hasua	Castrum nocturnum	+		
3. Nilkanda	Duranta repens		+	++
4. Bihaya	Ipomea fistulosa	++	++	++
5. Sajiwan	Jatropha curcas		+	+
6. Pate siuli	Opuntia ficus indica			+
7. Rato chulsi	Osbeikia stellata		+	+
8. Simali	Ultex negundo		+	++
9. Dhainyaro	Wood fordia fructicosa		+	+

GRASS SPECIES

Local Name	Botanical Name	Applications		
		River Bank Control	Gully Erosion	Landslide Rehabilitation
1. Dubo	Cynodon ductylon	++	+	+
2. Babiyo khar	Ehlaliopsis binata	+		
3. Molasses	Melinus minutiflora		+	++
4. Napier	Pennisetum purpureum	++	+++	+++
5. Kansh	Saccharum spontaneum	++	++	
6. Amlisso	Thysanolaena maxima	+	++	++
7. Khus	Veltiveri zizanioides	++		

Source: B..D. Shrestha, Senior Geologist, Department of Soil Conservation

BAMBOO SPECIES

Local Name	Botanical Name	Applications		
		River Bank Control	Gully Erosion	Landslide Rehabilitation
1. Tharu bans	Bambusa spp.	+	+	+
2. Tama bans	Dendro calamus hamiltoni	+	+	+

LEGUMES AND HERBS

Local Name	Botanical Name	Applications		
		River Bank Control	Gully Erosion	Landslide Rehabilitation
1. Kettuke	Agava americana		+	++
2. Bhuikatahar	Anahas, comosus		+	+
3. Rahar	Cajanus cajan		+	+
4. Aparajita	Clitoria ternatea		+	+
5. Desmodium	Desmodium intortum		++	++
6. Kera	Musa paradiscia		+	+
7. Stylo	Stylosanthes		+	+

Source: B..D. Shrestha, Senior Geologist, Department of Soil Conservation

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

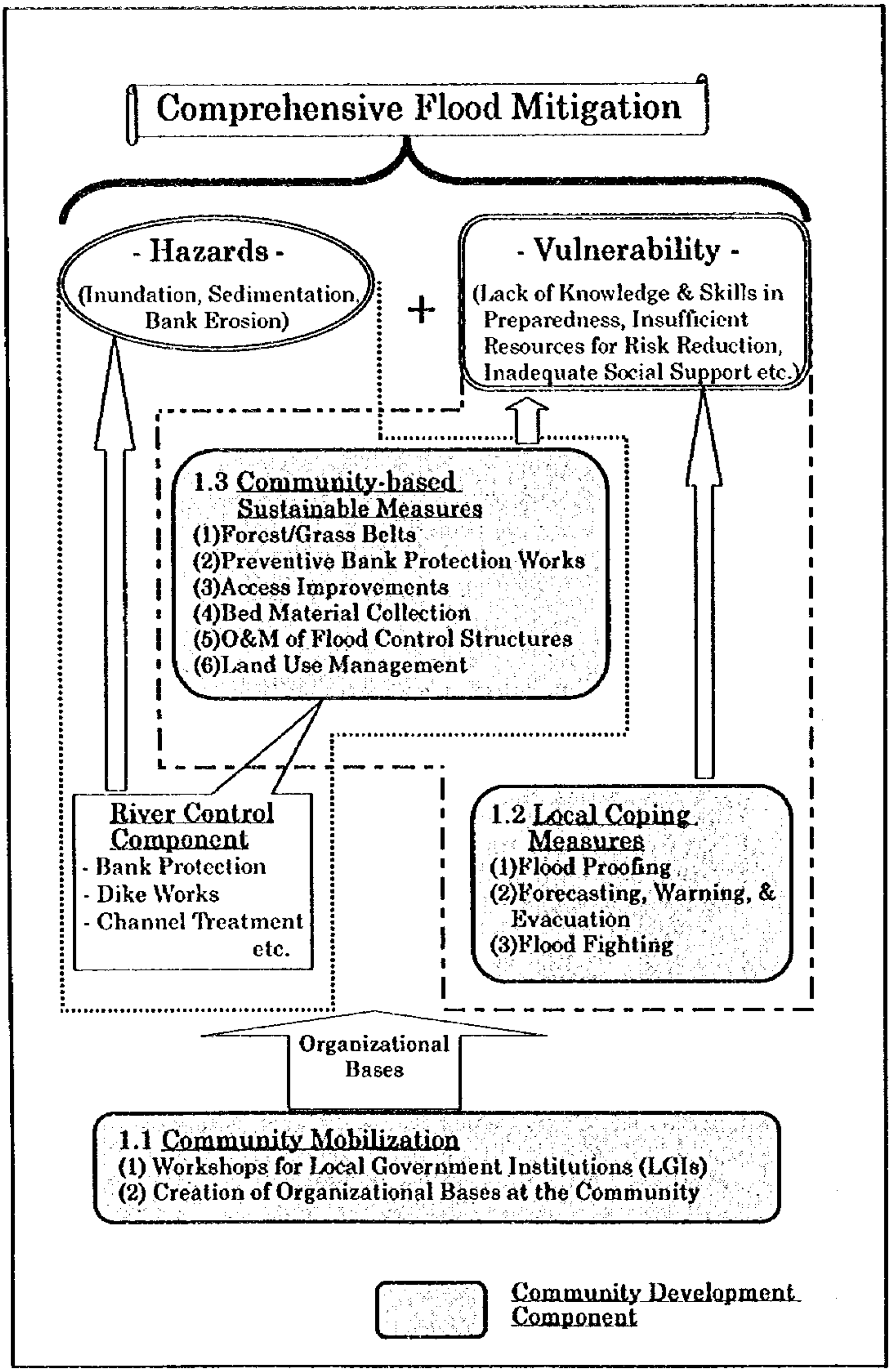
From:	Species Used	Income-generating Products
Nursery	<u>Trees</u>	
	- Acacia catechu (Khayer)	- saplings
	- Shorea robusta (Sal)	- saplings
	- Bauhinia purpurea (Tanki)	- saplings
	- Delonix regia (Gulmohar)	- seeds/saplings
	- Leucaena species (Ipil Ipil)	- seeds/saplings
	- Bamboo species	- roots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

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

CANDIDATE SPECIES FOR BIO-ENGINEERING WORKS IN TERAI

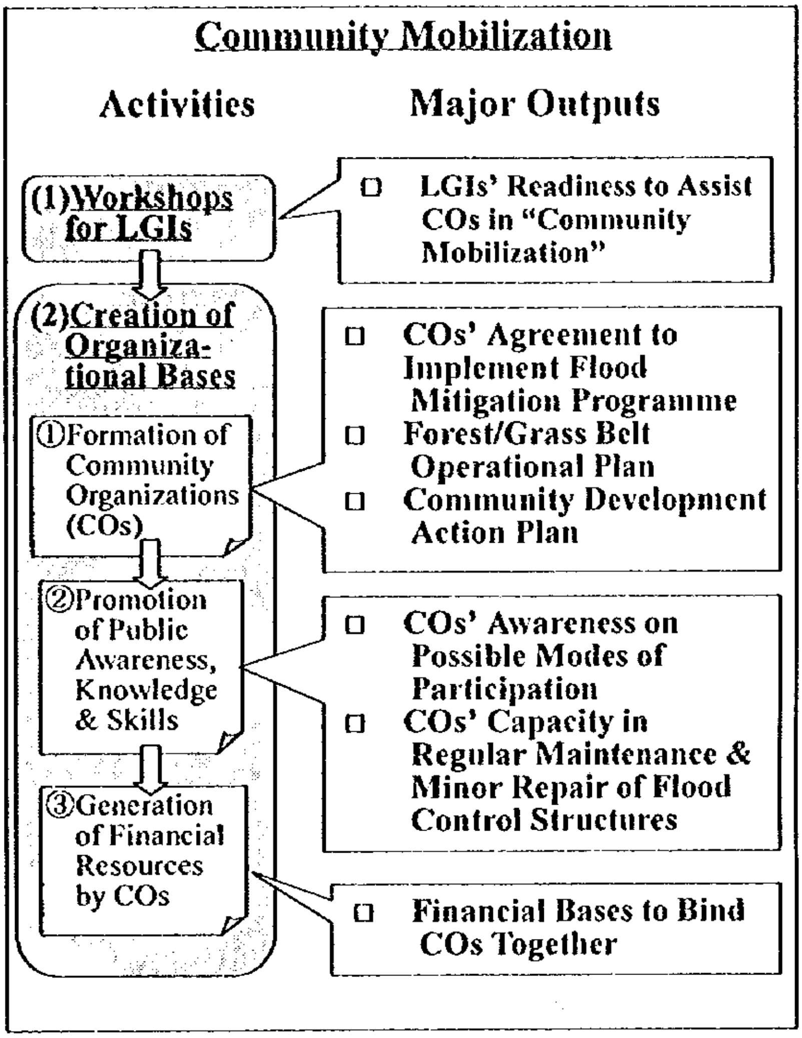
	Naturally Grown Species	Nursery Species
Grasses	- Arundo elonax (Narkato) - Cymbopogon microtheca (Khar) - Cymbopogon pendulus (Dangre Khar) - Cynodon dactylon (Dhubo) - Eulaliopsis ninanta (Babiyo, Sabai Grass) - Neyraudia arundinacea (Sito) - Neyraudia reynaudiana (Dhonde) - Pennisetum clandestinum (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



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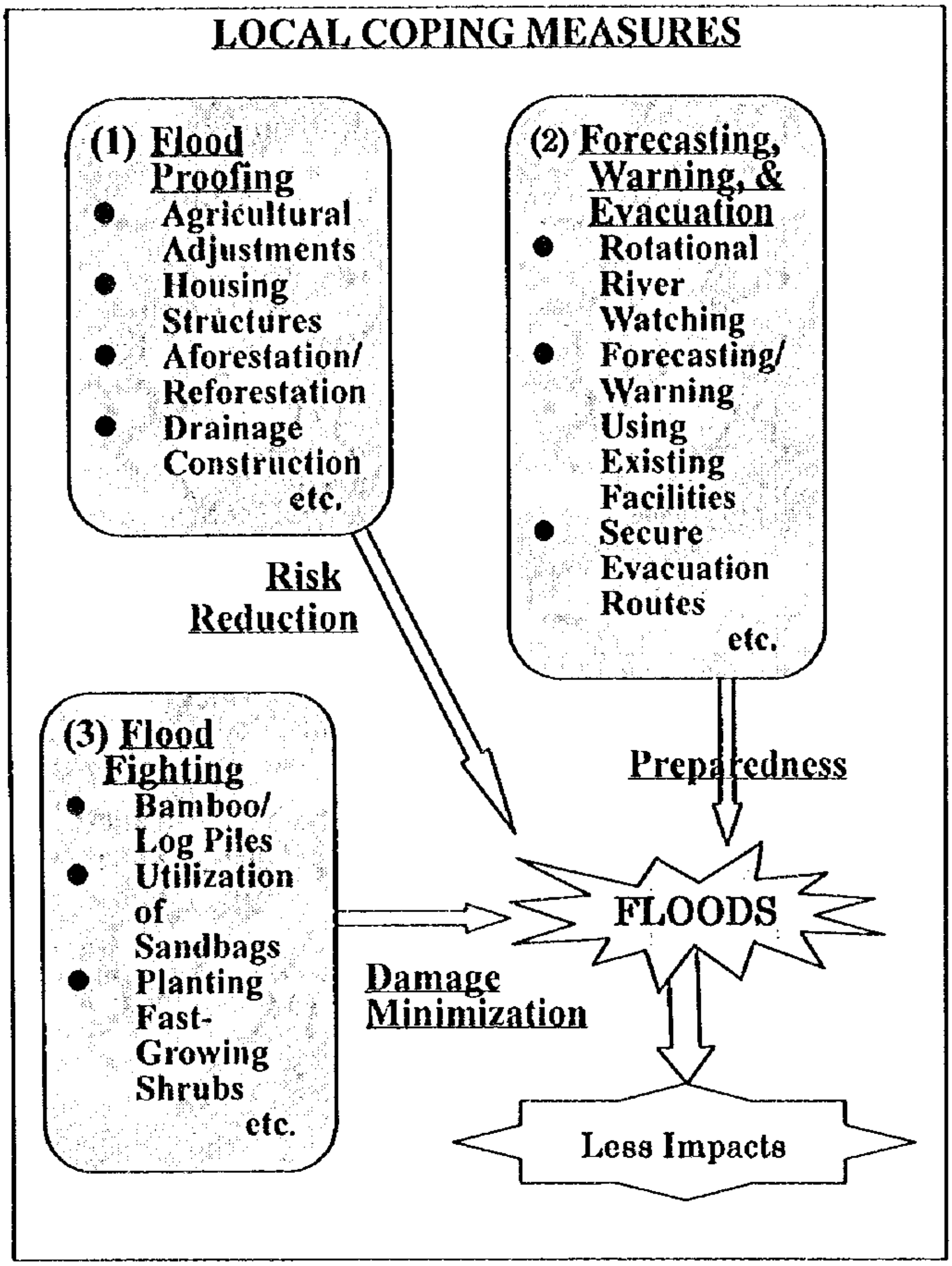
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



LOCAL COPING MEASURES

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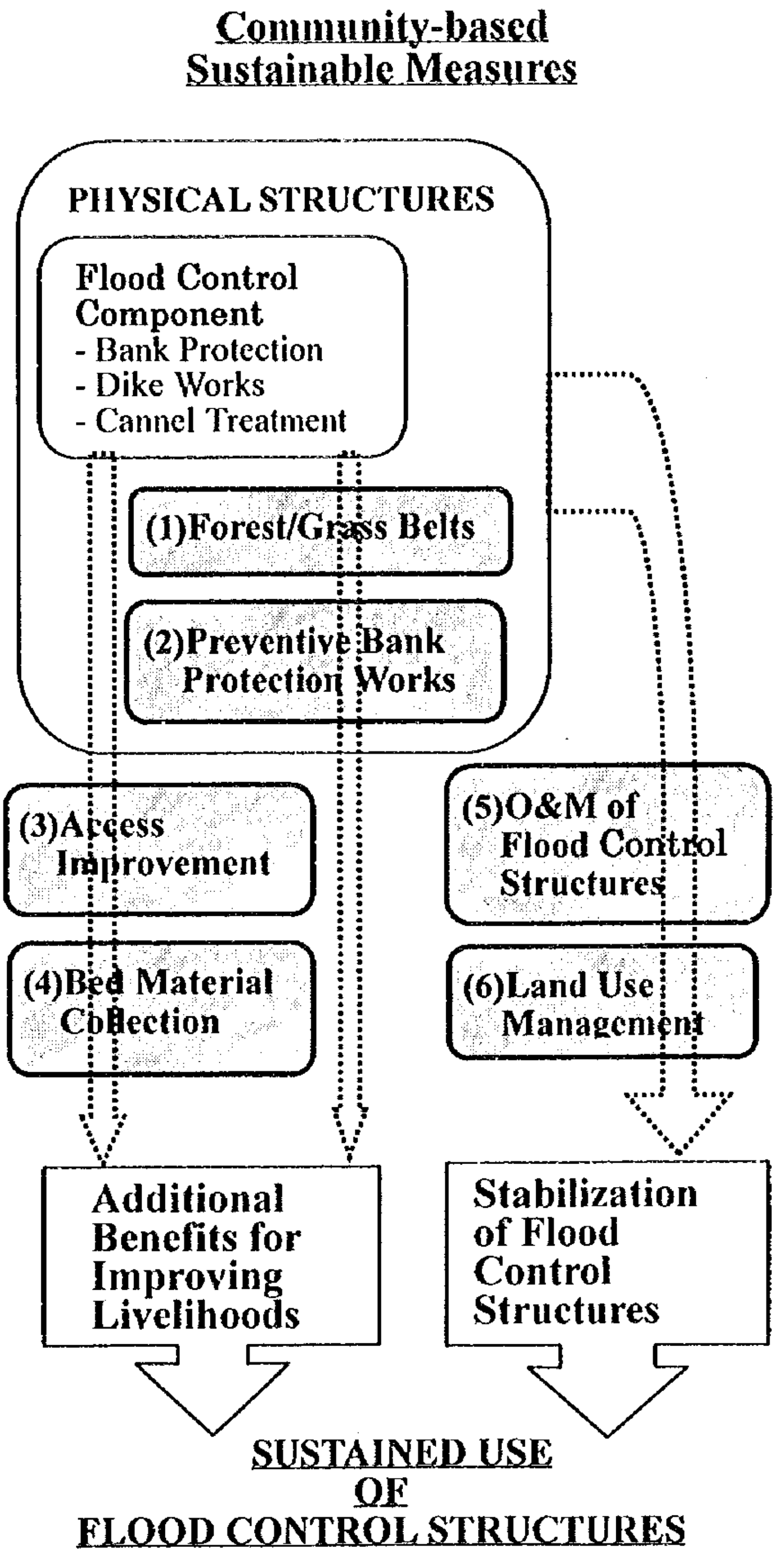
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



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

8. STUDY ON CONSTRUCTION MATERIALS AND COST

8.1 Construction Materials

(1) General

Major construction materials for the flood mitigation structures such as spur dike, embankment and revetment are described here in detail. Construction materials should be provided in local basically, though it is unavoidable that some of them shall be supplied from other districts or abroad.

Cobble stone, gravel, sand and the like will be collected from riverbed. According to the investigation result of riverbed material, cobble stone, gravel and sand are available, in general, in the upper, middle and lower reaches, respectively.

Generally speaking, collection of bed material is preferable from the viewpoint of expanding flow section and fixing river course. But the collection site, depth and volume, should be well-coordinated with flood mitigation plan and river maintenance activities.

(2) Embankment Materials

The earth materials along the river stretch are mostly usable for construction of earth dike. Humus, grass and wood should be removed carefully from the materials to complete the firm dike. The excavated soil from other flood mitigation works should also be utilized as embankment material.

(3) Cobble Stone

A large quantity of cobblestone will be required for gabion and masonry works. According to the result of riverbed material investigation, the cobble stone is available at sections listed in Table C8.1 (a).

Since it is difficult to find suitable material along the whole stretch of the Ratuwa and Lakhandei rivers, cobble stone must be supplied from other sources.

(4) Coarse Aggregate

The screened gravel as specified by the standard will be required as coarse aggregate for concrete works. From the result of investigation, sufficient quantity of coarse aggregate is obtainable in each river. The locations of candidate borrow areas are listed in Table C8.1 (b). The cobblestone will also be possible to use as coarse aggregate after crushing and screening.

(5) Fine Aggregate

The screened natural sand of specified quality will be required as fine aggregate for concrete works. From the result of investigation, sufficient quantity of fine aggregate is obtainable in each river. The location of prospective borrow areas are listed in Table C8.1 (c).

(6) Wooden and Bamboo Materials

Wooden and bamboo materials will be provided locally for construction of flood mitigation works. Although these materials can be procured from the vicinity, it is recommended to establish a methodical procurement system including reforestation for sustainable maintenance activity.

(7) Other Construction Materials

Other materials required for the construction of flood mitigation structures such as cement, reinforcing bars, gabion wire, etc. have to be brought from local markets near the work site or from other districts.

8.2 Cost Estimate

(1) General

The Project cost is estimated on the basis of design and construction plan. The current prices of construction materials, equipment and labor wages prevailing in the study area were obtained from both government agencies and private sector. The collected data was compared and evaluated to establish the cost data which are applicable to the Project.

(2) Basic Conditions of Cost Estimate

Project cost was estimated on the basis of 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 (NRs.1.00 = ¥1.69)

3) **Constitution of Project Cost:** Project cost is composed of construction base cost, compensation cost, administration cost, engineering service cost, price contingency, physical contingency and value added tax. Calculation is carried out based on the following:

   (1) Construction base cost: Unit cost basis
   (2) Compensation cost: Lump sum basis
   (3) Administration cost: 5% of (1) + (2)
   (4) Engineering service cost: Lump sum basis
   (5) Sub-total = (1) + (2) + (3) + (4)
   (6) Price contingency: Annual escalation rate of 3% for foreign currency portion and 10% for local currency portion
   (7) Physical contingency = 10% of (5)
   (8) Value added tax = 10% of (5) + (6) + (7)

(3) Unit Cost Analysis

Unit costs by work items are calculated from the material cost, labor cost and equipment cost by analyzing the data of similar works implemented in recent years as well as by taking into consideration of the local conditions in study areas. The unit costs of construction works are listed in Table C8.2 (a).

1) **Labor Wage:** Basic labor wages obtained from government agencies and private sectors were carefully examined and determined as shown in Table C8.2 (b).
2) **Unit Prices of Materials:** Unit prices of construction materials available at the site and those that have to be delivered from other districts through suppliers or dealers are determined under the current market prices. The list of construction material costs is shown in Table C8.2 (c).
3) **Work Unit Cost of Heavy Equipment:** The work unit costs of heavy

equipment are composed of owning cost, operation cost and maintenance cost. The work unit cost of heavy equipment are shown in Table C8.2 (d).

AVAILABILITY OF COBBLE STONE, AND COARSE AND FINE AGGREGATES

(a) Cobble Stone

River	Available sections (km from border)
Ratuwa	(Not available)
Lohandra	Upper from 61.0
Lakhandei	Upper from 41.5
Narayani	2.81, 67.5, upper from 81.0
Tinau	Upper from 56.0
West Rapti	40.0(T), 50.0(T), 164.0(T)
Babai	Upper from 44.0
Khutiya	Upper from 29.7

※ (T) : located in tributary

(b) Coarse Aggregate

River	Available sections (km from border)
Ratuwa	Upper from 38.0
Lohandra	52.0~59.0
Lakhandei	43.6~46.8
Narayani	28.1~39.0, 46.5~52.0, 61.7~81.0
Tinau	46.5~58.0
West Rapti	28.0, 37.0~44.5, 137.0~164.0
Babai	33.0~47.0
Khutiya	13.5~29.7

(c) Fine Aggregate

River	Available sections (km from border)
Ratuwa	30.5~38.0
Lohandra	35.0~47.0
Lakhandei	22.3~26.0, 36.0~41.0
Narayani	20.7, 53.0~59.0
Tinau	19.0~41.0
West Rapti	92.0~124.5
Babai	22.5~29.0
Khutiya	10.5~24.5

LIST OF UNIT COST AND PRICES

(a) UNIT COST OF CONSTRUCTION WORKS

(NRs)

Work Item	Unit	F.C.	L.C.	Cost
Stripping of Top Soil	m^2	0	5	5
Excavation(soft soil)	m^3	0	45	45
Excavation(boulder mixed soil)	m^3	0	90	90
Excavation(weathered rock)	m^3	252	28	280
Excavation(rock)	m^3	324	36	360
Embankment	m^3	51	34	85
Back Filling	m^3	24	16	40
Plain Concrete(1:3), inc.formwork	m^3	1,972	2,958	4,930
Reinforced Con.(1:3.), inc.form&ste	m^3	4,565	4,565	9,130
Wet Masonry	m^3	862	1,293	2,155
Rubble Concrete	m^3	1,262	1,893	3,155
Boulder Pitching	m^3	542	813	1,355
Gabion	m^3	742	1,113	1,855
Boulder Riprap	m^3	302	453	755
Gravel Work	m^3	392	588	980
Turfing	m^2	3	12	15
Log Pile Piling (ϕ 0.15m)	m	42	398	440
RC Pile Piling (□ 0.2m x 0.2m)	m	219	283	502
Tree Planting	ha	17,420	50,700	68,120
Grass Planting	ha	24,900	101,000	125,900

(b) BASIC LABOUR WEGES

(NRs)

Item	Unit	F.C.	L.C.	Wege
Foreman	md	0	150	150
Welder	md	0	140	140
Operator	md	0	120	120
Electrician	md	0	140	140
Mechanic	md	0	120	120
Mason	md	0	140	140
Painter	md	0	140	140
Driver	md	0	100	100
Concrete Worker	md	0	140	140
Steel Worker	md	0	140	140
Carpenter	md	0	140	140
Skilled Labour	md	0	100	100
As.Operator	md	0	100	100
As.Driver	md	0	80	80
Common Labour	md	0	60	60

LIST OF UNIT COST AND PRICES

(c) UNIT PRICES OF CONSTRUCTION MATERIALS

(NRs)

Item	Unit	F.C.	L.C.	Total
Portland Cement	ton	3,100	3,100	6,200
Concrete Aggregate; Coarse	m^3	399	266	665
Concrete Aggregate; Fine	m^3	240	160	400
Boulder Stone	m^3	369	246	615
Crushed Stone	m^3	399	266	665
Formwork Timber	m^3	2,000	18,000	20,000
Plywood (t=1.2 cm)	m^2	168	112	280
Bamboo; (L=5m)	pc	10	90	100
Deformed Bar	t	25,520	6,380	31,900
Gabion Wire	kg	36	9	45
Asphalt	kg	13	13	25
Gasoline	ltr	15	15	30
Light Oil	ltr	5	5	10
Hydraulic Oil	ltr	40	40	80
Grease	kg	35	35	70
Drain Pipe; PVC(D=40mm)	m	36	144	180
Hume Pipe (D=0.9m)	m	700	2,800	3,500
Hume Pipe (D=1.2m)	m	1,080	4,320	5,400
Water Stop; t=250mm	m	200	200	400
Log Pile (ϕ 0.15m)	m	35	318	353
RC Pile (☐ 0.2m x 0.2m)	m	183	183	366

(d) UNIT COST OF MAJOR CONSTRUCTION EQUIPMENT

(NRs)

Item	Capacity	Unit	F.C.	L.C.	Cost
Backhoe	0.7 m^3	hour	1,440	360	1,800
Backhoe	1.2 m^3	hour	2,560	640	3,200
Bulldozer	21 ton	hour	3,200	800	4,000
Bulldozer	11 ton	hour	1,440	360	1,800
Tractor Shavel	2 m^3	hour	1,440	360	1,800
Dump Truck	8 ton	hour	640	160	800
Air Compressor	11 m^3/min	day	3,360	840	4,200
Leg Hammer		day	800	200	1,000
Tire Roller	8 ton	hour	960	240	1,200
Vibratory Roller	3 ton	hour	560	140	700
Vibratory Roller	8 ton	hour	1,120	280	1,400
Truck Crane		hour	2,080	520	2,600
Aggregate Plant		hour	7,200	1,800	9,000
Batcher Plant	25 m^3/h	hour	4,320	1,080	5,400
Concrete Mixer		day	240	60	300
Crawle Crane	30 t	hour	3,200	800	4,000
Concrete Vibrator		day	400	100	500

9. ECONOMIC EVALUATION

9.1 Effects of Flood Mitigation

Implementation of the flood mitigation Master Plan will primarily safeguard the land and properties in the flood prone areas and also bring about other tangible and intangible effects to the Study Area as 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 is 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.

9.2 Economic Evaluation for Master Plan Projects

Economic viability of the flood mitigation Master Plan was examined preliminarily. Out of the various effects listed in the previous section, the following terms were considered as tangible benefit for the evaluation:

1) Flood damage reduction benefit
2) Bank protection benefit
3) Indirect benefit

9.2.1 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. An attempt was made to estimate the benefit based on damage data of the recent large flood.

(1) Annual Flood Damage

Based on the result of flood damage investigation conducted by the Study Team, annual average flood damage was estimated as follows:

1) Recent Flood Event: The recent large floods in respective river basins are shown in Table C9.1.
2) Flood Damage: Damage amounts of houses, agricultural crops and livestock are shown in Table C9.2. Damages of public facilities such as road, irrigation system, etc. were added at assumed 40% of the house damages. Indirect damage was also estimated at 10% of the total direct damage worked out in the above.
3) Annual Average Flood Damage: Ratio to convert the damage amount of recent large flood into the annual average damage was estimated as shown in Table C9.3. For the estimation, following assumptions were introduced:
   - Flood damage is zero for 1.05 year probable flood.
   - Probable flood damages are proportional to the corresponding probable flood discharges.

(2) Annual Average Flood Reduction Benefit

It is generally known that the bank-full discharge is dominant to form river section in the alluvial plain and the bank-full discharge is approximately of 2-year return period (or average of annual maximum discharge. The river channel sections to be formed with proposed forest/grass belts are, therefore, assumed to have capacity of 2-year probable discharge.

The existing flood prone area will be, therefore, protected by the levees and channel formed by the forest and grass belts up to 2-year probable floods. Furthermore, the forest and grass belts will alleviate flood damages against floods larger than two year return period. For this, it is assumed that the 50 percent of flood damages caused by 2 to 5-year return period will be reduced by the project. The annual average flood-reduction benefit was thus estimated as shown Table C9.4.

9.2.2 Bank Protection Benefit

As to the estimation of benefit accruing from bank protection works, benefit was estimated according to the following procedures:

1) Annual bank protection benefit (Bb) was estimated as a product of the land area (Ae) to be protected from erosion and the property amount (Pt) on the unit land area to be protected, i.e.,

   $$Bb = Ae \times Pt + Bi$$

2) Indirect benefit (Bi) was assumed at 10% of direct benefit.
3) The land area (Ae) to be saved from erosion was estimated by the annual average bank erosion width (Be), proposed bank protection length (Le) and number (n) of bank protection sites as follows:

   $$Ae = \sum_{i=1}^{n} Be \times (Le_i + 5 \times Be) = Be \times (\sum_{i=1}^{n} Le_i + 5 \times n \times Be)$$

   The Be-value was assumed to be 20 m for the Ratuwa, Lohandra, Lakhandei, Tinau and Khutiya rivers and tributaries of the Narayani river. For the main stream of the Narayani, West Rapti and Babai rivers, the Be-value was assumed to be 50 m. These assumptions are based upon the information obtained in the field.
4) The amount of properties (Pt) on the protected area should include all the existing properties on and future profit from the area to be saved from erosion. For the evaluation of Master Plan projects, the Pt-values were assumed based on the land prices of respective rivers.

The annual average bank-protection benefit was estimated as shown in Table C9.5.

9.2.3 Evaluation

(1) Conditions for Economic Evaluation

1) **Project life** was assumed 50 years starting from 1999 including the project implementation period.
2) **Project implementation period** was assumed up to year 2017, consisting of three years' preparatory period from 1999 for the feasibility study, definite plan/detailed design, etc., and construction period from 2002 to 2017.
3) **Economic cost** for project evaluation was estimated from financial project cost deducting 10% as transfer cost such as tax and duty. Annual disbursement schedule was prepared based on the implementation schedule.
4) **Annual maintenance cost** of the structures and facilities constructed under the project was assumed at 0.5% of the total project cost. The maintenance cost during the construction period was also considered at the same rate of the total cost disbursed by the previous year.
5) **Annual benefit** estimated in the previous section is expected to accrue after the completion of the whole project works. The annual benefit during the implementation period was assumed in proportional to the disbursement ratio of project cost by the previous year.
6) **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 projected population. The population of the respective river basin was projected as shown in Table C9.6.

(2) Result of Evaluation

Cash flows of the project cost, maintenance cost and benefit are shown in Table C9.7. 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.

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^5Rs)
Ratuwa	3.8	0.49	-121.3	9.6	0.97	-8.2
Lohandra	0.0	0.27	-204.6	2.8	0.42	-161.7
Lakhandei	3.6	0.47	-135.7	10.2	1.02	4.6
Narayani	4.0	0.50	-122.8	10.9	1.09	21.2
Tinau	2.8	0.42	-199.8	9.2	0.93	-24.5
W. Rapti	4.2	0.52	-47.9	11.8	1.18	17.7
Babai	9.3	0.94	-11.3	14.8	1.48	89.0
Khutiya	0.0	0.27	-36.2	4.8	0.56	-21.9

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

The Babai river gives relatively high economic return, and the Lohandra and Khutiya rivers low returns. The others are almost same values ranging around 10. However, these evaluation results should be handled only as a rule of thumb, since the costs and benefits for the evaluation are estimated without topographic and river survey data.

9.3 Economic Evaluation for Feasibility Study Stage

Economic viability was examined for the flood mitigation projects proposed in the Feasibility Study for the Lakhandei and Babai river basins. Flood damage reduction, bank protection and indirect benefits were considered for the evaluation.

The method of evaluation is basically the same with that adopted for the Master Plan project set forth in the previous section. In this section, special procedures taken and consideration given for the Feasibility Study are mainly described.

9.3.1 Flood Damage Reduction Benefit

At the beginning of the Feasibility Study stage, topographic mapping and river survey were conducted for the Lakhandei and Babai rivers. Therefore, the flood damage reduction benefit was estimated based on the simulation results of flood flows in these rivers.

The flood reduction benefit is defined as a balance of flood damages under the conditions without and with project.

(1) Flood Damages

Amounts of flood damages were estimated under the various magnitudes of flood events and with-and without-project conditions. The flood damages were estimated as follows:

1) Flood damage (Df) is a sum of damages to general assets (Dg), agricultural crops (Da), livestock (De), public facilities (Dp) and indirect damages (Di) as follows:

$$Df = Dg + Da + De + Dp + Di$$

2) Damage to general asset (Dg) includes building and movables of houses, shops, factories, and public buildings. The Dg was estimated as follows:

- Inundated area by depth: Based on the results of flood flow analysis
- Number of houses in the inundated area: Based on "General Environmental Inventory" conducted by the Study Team within the frame of Environmental Study
- Damage of general asset was assumed as follows by range of inundation depth:

Type of house	Damages (Rs)				
	< 0.5m	0.5-1m	1-2m	2-3m	> 3m
Thatched	4,000	5,000	6,000	8,000	15,000
Common	4,000	6,000	7,500	11,000	19,000

3) Damage to agricultural crops (Da) includes damages due to inundation (Dai) and sediment cover (Das). The damage due to sediment cover (Das) was estimated as follows:

- Area of sediment cover: According to the results of flood flow investigation conducted by the Study Team.
- Amount of damage: Whole of the production (Rs 1,620,000/km^2) was assumed to be lost in the area suffering sediment cover.

The damage due to inundation (Dai) was estimated as follows:

- Area of agricultural land: Depending on the percentage of agricultural land (78.1% for the Lakhandei river and 44.5% for the Babai river), according to Land Resources Mapping Project 1986, Department of Survey; and Forest.
- Damage ratio: Following damage ratio was assumed considering the probability of flood occurrence at respective growing stage of rice:

River	Damage ratio		
	< 0.5m	0.5-1m	> 1m
Lakhandei	0.11	0.27	0.76
Babai	0.12	0.30	0.87

(2) Annual Average Flood Reduction Benefit

Amounts of flood damages were estimated under the various inundation conditions obtained through flood flow analysis. The flood flow analysis was carried out for the following cases.

1) River condition: With and without Project
2) Return Period: 1.05, 2, 5, 10, 20, 50 and 100 years of return periods.

Under the river conditions with Projects, the river channel is assumed to have capacity of 2-year probable discharge associated with levees formed by forest and grass belts. The forest and grass belt also function to trap sediment and alleviate flooding in the flood prone area even for the probable floods more than 2 years.

Damages to public facilities and indirect damages were also incorporated in the total damage. The public facility damage was assumed at 40% of general asset damages and indirect damage at 10% of total direct damage amount.

The flood damages under the different conditions and calculation of annual average food-reduction benefit are shown in Table C9.8 and C9.9.

9.3.2 Bank Protection Benefit

The bank protection benefit was estimated, in principle, in the same procedures as evaluation of Master Plan project. But some detailed data were incorporated.

$$Bb = Ae \times (Ve + Pt) + Bi$$

$$Ae = \sum_{i=1}^{n} Be \times (Lei + 5 \times Be)$$

$$Pt = Pb + Pa + Pp$$

where

Bb:	Annual bank protection benefit
Ae:	Land area to be protected from erosion
Ve:	Value of land to be protected
Pt:	Property on the unit land area to be protected
Be:	Annual bank erosion width
Le:	Length of proposed bank protection

Pb:	Amount of buildings in unit area
Pa:	Annual profit of farmer in unit area
Pp:	Amount of public facilities
Bi:	Indirect benefit assumed at 10% of direct benefit

Calculation of bank protection benefit is shown in Table C9.10. The annual bank erosion width (Bc) was assumed at 19 m for the Lakhandei river and 52 m for the Babai river based on the field investigation results.

9.3.3 Evaluation

Cash flows of the project cost, maintenance cost and benefit were prepared according to the proposed implementation schedule.

The assumptions and conditions adopted for the evaluation of the Lakhandei and Babai rivers are basically the same as those for Master Plan Project except for the project implementation schedule.

According to the implementation schedule proposed for the Lakhandei and Babai rivers, annual disbursement schedules were prepared as follows:

- Lakhandei river: Detail design in 2001 and construction works 3 years from 2002 to 2005.
- Babai river: Detail design in 2000 and construction works 4 years from 2001 to 2005.

Cash flows of the project cost, maintenance cost and benefit are shown in Table C9.11. As indexes of the economic viability, the EIRR, B/C and NPV-values were worked out in the table. The results are summarized below.

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^6Rs)
Lakhandei	9.5	0.95	-14.6	20.8	2.05	308.0
Babai	9.7	0.98	-8.7	15.2	1.54	188.7

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

ESTIMATION OF RETURN PERIOD OF PAST MAJOR FLOODS

Items	Ratuwa R.	Lohandra R.	Lakhandei R.	Narayani R.	Tinau R.	W.Rapti R.	Babai R.	Khutiya R.
Year of object flood	1995	1995	1997	1993	1996	1997	1995	1997
Return period by Qmax								
Station #	-	-	-	450	-	-	-	-
Qmax (m3/s)	-	-	-	15,400	-	-	-	-
Return period (yr.)	**NR**	**NR**	**NR**	**6**	**NR**	**NR**	**NR**	**NR**
Return period by Weibull								
Year of major floods								
1st	1988	1987	1997	1988	1996	1997	1995	1997
2nd	1995	1988	1993	1993	1995	1996	1987	1986
3rd	1996	1995	1995	1995	1993	1993	1996	1983
Period (yr.)	10	10	10	10	10	10	11	12
Rank in above period	2	3	1	2	1	1	1	1
Return period (yr.)	**5.5**	**3.7**	**11.0**	**5.5**	**11.0**	**11.0**	**12.0**	**13.0**
Result of evaluation (yr.)	**6**	**4**	**11**	**6**	**11**	**11**	**12**	**13**

(Note) Return period by Weibull = i/(N+1), where i = Rank of annual max. events during N year period.
NR: No record available

INUNDATION DAMAGE OF RECENT FLOOD

Total Damage:

River (year)	House (1000Rs)	Agricultural crop (1000Rs)	Livestock (1000Rs)	Total (1000Rs)	Public facilities (1000Rs)	Indirect damage (1000Rs)	Grand total (1000Rs)
Ratuwa (1995)	23,085	55,869	1,511	80,465	9,234	8,970	98,669
Lohandra (1995)	13,710	27,938	2,393	44,041	5,484	4,952	54,477
Lakhandei (1997)	3,540	80,777	3,980	88,297	1,416	8,971	98,684
Narayani (1993)	7,050	34,160	2,225	43,435	2,820	4,626	50,881
Tinau (1996)	6,915	56,358	744	64,017	2,766	6,678	73,461
W. Rapti (1997)	5,535	23,397	2,174	31,106	2,214	3,332	36,652
Babai (1995)	31,350	27,094	2,896	61,341	12,540	7,388	81,269
Khutya (1997)	330	7,818	481	8,629	132	876	9,638

House Damage:

River	Daamaged house (house)	Unit damage (Rs/house)	Damage (1000Rs)
Ratuwa	1,539	15,000	23,085
Lohandra	914	15,000	13,710
Lakhandei	236	15,000	3,540
Narayani	470	15,000	7,050
Tinau	461	15,000	6,915
W.Rapti	369	15,000	5,535
Babai	2,090	15,000	31,350
Khutya	22	15,000	330

Agricultural Crops:

River	Crop loss (ton)	Unit production (Rs)	Damaged area (ha)	Expence (Rs/ha)	Profit (Rs/ha)	Damage (1000Rs)
Ratuwa	7,639	2.71	2,819	13,872	5,948	55,869
Lohandra	4,121	2.67	1,543	14,512	3,589	27,938
Lakhandei	11,727	2.35	4,990	12,847	3,340	80,777
Narayani	4,232	2.70	1,567	15,517	6,277	34,160
Tinau	4,979	1.72	2,895	15,561	3,908	56,358
W.Rapti	3,900	2.87	1,359	14,265	2,953	23,397
Babai	7,554	4.91	1,538	12,088	5,523	27,094
Khutya	1,000	2.03	493	13,032	2,839	7,818

Livestock:

River	Loss of livestock (kg)	Unit price (Rs/kg)	Damage (1000Rs)
Ratuwa	33,000	45.80	1,511
Lohandra	52,250	45.80	2,393
Lakhandei	99,500	40.00	3,980
Narayani	46,750	47.60	2,225
Tinau	17,000	43.75	744
W.Rapti	50,000	43.47	2,174
Babai	82,750	35.00	2,896
Khutya	13,750	35.00	481

CALCULATION OF ANNUAL AVERAGE DAMAGE

Assumptions:

1. Damage(D) = 0 at retun-period(T) = 1.05 yr.
2. Damage(D) is propotional to discharge(Q).

Notes:

T: Return period (yr)
Q: Ratio of probable discharge to 2-year flood
D: Ratio of damages to that of recent flood.

RATUWA R. 1995- flood

T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	6 yr.
Q	0.21	1.00	1.62	2.02	2.41	2.92	3.30	1.70
Q-Q1.05	0.00	0.79	1.41	1.81	2.20	2.71	3.09	1.49
D	0.00	0.53	0.95	1.21	1.48	1.82	2.07	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.530	0.265	0.120	0.120
5	0.200	0.300	0.946	0.738	0.221	0.341
10	0.100	0.100	1.215	1.081	0.108	0.449
20	0.050	0.050	1.477	1.346	0.067	0.517
50	0.020	0.030	1.819	1.648	0.049	0.566
100	0.010	0.010	2.074	1.946	0.019	0.586

LOHANDRA R. 1995- flood

T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	4 yr.
Q	0.21	1.00	1.62	2.02	2.41	2.92	3.30	1.49
Q-Q1.05	0.00	0.79	1.41	1.81	2.20	2.71	3.09	1.28
D	0.00	0.62	1.10	1.41	1.72	2.12	2.41	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.617	0.309	0.140	0.140
5	0.200	0.300	1.102	0.859	0.258	0.397
10	0.100	0.100	1.414	1.258	0.126	0.523
20	0.050	0.050	1.719	1.566	0.078	0.602
50	0.020	0.030	2.117	1.918	0.058	0.659
100	0.010	0.010	2.414	2.266	0.023	0.682

LAKHANDEI R. 1997- flood

T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	11 yr.
Q	0.21	1.00	1.62	2.02	2.41	2.92	3.30	2.10
Q-Q1.05	0.00	0.79	1.41	1.81	2.20	2.71	3.09	1.89
D	0.00	0.42	0.75	0.96	1.16	1.43	1.63	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.418	0.209	0.095	0.095
5	0.200	0.300	0.746	0.582	0.175	0.269
10	0.100	0.100	0.958	0.852	0.085	0.354
20	0.050	0.050	1.164	1.061	0.053	0.407
50	0.020	0.030	1.434	1.299	0.039	0.446
100	0.010	0.010	1.635	1.534	0.015	0.462

CALCULATION OF ANNUAL AVERAGE DAMAGE

Assumptions:

1. Damage(D) = 0 at retun-period(T) = 1.05 yr.
2. Damage(D) is propotional to discharge(Q).

Notes:

T: Return period (yr)

Q: Ratio of probable discharge to 2-year flood

D: Ratio of damages to that of recent flood.

NARAYANI R. 1993-flood

T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	6 yr.
Q	0.56	1.00	1.34	1.57	1.79	2.07	2.28	1.40
Q-Q1.05	0.00	0.44	0.78	1.01	1.23	1.51	1.72	0.84
D	0.00	0.52	0.93	1.20	1.46	1.80	2.05	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.524	0.262	0.118	0.118
5	0.200	0.300	0.929	0.726	0.218	0.336
10	0.100	0.100	1.202	1.065	0.107	0.443
20	0.050	0.050	1.464	1.333	0.067	0.510
50	0.020	0.030	1.798	1.631	0.049	0.558
100	0.010	0.010	2.048	1.923	0.019	0.578

TINAU R. 1996-flood

T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	11 yr.
Q	0.21	1.00	1.62	2.02	2.41	2.92	3.30	2.10
Q-Q1.05	0.00	0.79	1.41	1.81	2.20	2.71	3.09	1.89
D	0.00	0.42	0.75	0.96	1.16	1.43	1.63	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.418	0.209	0.095	0.095
5	0.200	0.300	0.746	0.582	0.175	0.269
10	0.100	0.100	0.958	0.852	0.085	0.354
20	0.050	0.050	1.164	1.061	0.053	0.407
50	0.020	0.030	1.434	1.299	0.039	0.446
100	0.010	0.010	1.635	1.534	0.015	0.462

W. RAPTI R. 1997-flood

T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	11 yr.
Q	0.27	1.00	1.57	1.95	2.31	2.78	3.13	2.02
Q-Q1.05	0.00	0.73	1.30	1.68	2.04	2.51	2.86	1.75
D	0.00	0.42	0.74	0.96	1.17	1.43	1.63	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.417	0.209	0.094	0.094
5	0.200	0.300	0.743	0.580	0.174	0.268
10	0.100	0.100	0.960	0.851	0.085	0.353
20	0.050	0.050	1.166	1.063	0.053	0.407
50	0.020	0.030	1.434	1.300	0.039	0.446
100	0.010	0.010	1.634	1.534	0.015	0.461

CALCULATION OF ANNUAL AVERAGE DAMAGE

Assumptions:

1. Damage(D) = 0 at retun-period(T) = 1.05 yr.
2. Damage(D) is propotional to discharge(Q).

Notes:

T: Return period (yr)
Q: Ratio of probable discharge to 2-year flood
D: Ratio of damages to that of recent flood.

BABAI R.

								1995-flood
T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	12 yr.
Q	0.06	1.00	1.72	2.20	2.66	3.26	3.70	2.30
Q-Q1.05	0.00	0.94	1.66	2.14	2.60	3.20	3.64	2.24
D	0.00	0.42	0.74	0.96	1.16	1.43	1.63	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.420	0.210	0.095	0.095
5	0.200	0.300	0.741	0.580	0.174	0.269
10	0.100	0.100	0.955	0.848	0.085	0.354
20	0.050	0.050	1.161	1.058	0.053	0.407
50	0.020	0.030	1.429	1.295	0.039	0.446
100	0.010	0.010	1.625	1.527	0.015	0.461

KHUTIYA R.

								1997-flood
T	1.05 yr.	2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.	13 yr.
Q	0.21	1.00	1.62	2.02	2.41	2.92	3.30	2.15
Q-Q1.05	0.00	0.79	1.41	1.81	2.20	2.71	3.09	1.94
D	0.00	0.41	0.73	0.93	1.13	1.40	1.59	1.00

T(yr.)	1/T	Toccur	D	Dave	Doccur	Dtotal
1	1.000		0.000			0.000
1.05	0.952	0.048	0.000	0.000	0.000	0.000
2	0.500	0.452	0.407	0.204	0.092	0.092
5	0.200	0.300	0.727	0.567	0.170	0.262
10	0.100	0.100	0.933	0.830	0.083	0.345
20	0.050	0.050	1.134	1.034	0.052	0.397
50	0.020	0.030	1.397	1.265	0.038	0.435
100	0.010	0.010	1.593	1.495	0.015	0.450

Table C9.4

ANNUAL AVERAGE BENEFIT

	Ratuwa	Lohandra	Lakhandei	Narayani	Tinau	W.Rapti	Babai	Khutiya
Probability of Damage Occurrence among Return Periods								
1.05 yr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 yr.	0.120	0.140	0.095	0.118	0.095	0.094	0.095	0.092
5 yr.	0.221	0.258	0.175	0.218	0.175	0.174	0.174	0.170
10 yr.	0.108	0.126	0.085	0.107	0.085	0.085	0.085	0.083
20 yr.	0.067	0.078	0.053	0.067	0.053	0.053	0.053	0.052
50 yr.	0.049	0.058	0.039	0.049	0.039	0.039	0.039	0.038
100 yr.	0.019	0.023	0.015	0.019	0.015	0.015	0.015	0.015
Probability of Damage Occurrence Accounted as Benefit								
1.05 yr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 yr.	0.120	0.140	0.095	0.118	0.095	0.094	0.095	0.092
5 yr.	0.111	0.129	0.088	0.109	0.088	0.087	0.087	0.085
10 yr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20 yr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50 yr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100 yr.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Conv.Ratio	0.231	0.269	0.183	0.227	0.183	0.181	0.182	0.177
Damage Amount of Recent Flood								
(1000Rs)	98,669	54,477	98,684	50,881	73,461	36,652	81,269	9,638
Annual Average Damage Reduction Benefit								
(1000Rs)	22,743	14,654	18,010	11,550	13,407	6,634	14,791	1,706
Annual Average Bank Protection Benefit								
(1000Rs)	4,910	3,326	10,930	18,147	21,087	5,676	26,532	1,478
Annual Average Total Benefit								
(1000Rs)	27,654	17,981	28,939	29,697	34,494	12,310	41,323	3,184

ANNUAL AVERAGE BANK PROTECTION BENEFIT

ANNUAL AVERAGE BANK EROSION BENEFIT

River	Total protected area (ha)	Unit area property (Rs/ha)	Direct benefit (1000Rs/yr)	IIndirect benefit (1000Rs/yr)	Annual benefit (1000Rs/yr)
Ratuwa	18.6	240,000	4,464	446	4,910
Lohandra	12.6	240,000	3,024	302	3,326
Lakhandei	36.8	270,000	9,936	994	10,930
Narayani	61.1	270,000	16,497	1650	18,147
Tinau	71.0	270,000	19,170	1917	21,087
W.Rapti	21.5	240,000	5,160	516	5,676
Babai	100.5	240,000	24,120	2412	26,532
Khutya	5.6	240,000	1,344	134	1,478
Total	327.7		83,715	8,372	92,087

PROTECTED AREA FROM BANK EROSION

River	Protection length (km)		Erosion width (m)		Protected area (ha)		
	Type-A	Type-B/C	Type-A	Type-B/C	Type-A	Type-B/C	Total
Ratuwa	9.3	0.0	20	50	18.6	0.0	18.6
Lohandra	6.3	0.0	20	50	12.6	0.0	12.6
Lakhandei	18.4	0.0	20	50	36.8	0.0	36.8
Narayani	1.8	11.5	20	50	3.6	57.5	61.1
Tinau	0.0	14.2	20	50	0.0	71.0	71.0
W.Rapti	0.0	4.3	20	50	0.0	21.5	21.5
Babai	0.0	20.1	20	50	0.0	100.5	100.5
Khutya	2.8	0.0	20	50	5.6	0.0	5.6
Total	39	50			77.2	250.5	327.7

PROJECTION OF POPULATION

River	A	B	C	1999 X=28:(1)	2017 X=46:(2)	(2)/(1)
Ratuwa River	41,109	8510.25	210.375	444,330	877,734	1.975
Lohandra River	54,454	2074.40	30.570	136,504	214,563	1.572
Lakhandei River	35,582	869.70	127.870	160,184	346,161	2.161
Narayani River	28,641	803.45	107.565	135,469	293,207	2.164
Tinau River	27,185	1623.55	159.835	197,955	440,079	2.223
West Rapti River	58,906	736.95	273.950	294,317	672,484	2.285
Babai River	27,066	2670.60	13.100	112,113	177,633	1.584
Khutiya River	4,947	2057.55	63.095	112,025	233,103	2.081

Notes: Population = A + B*X +C*X^2, X = (western calender year) - 1971