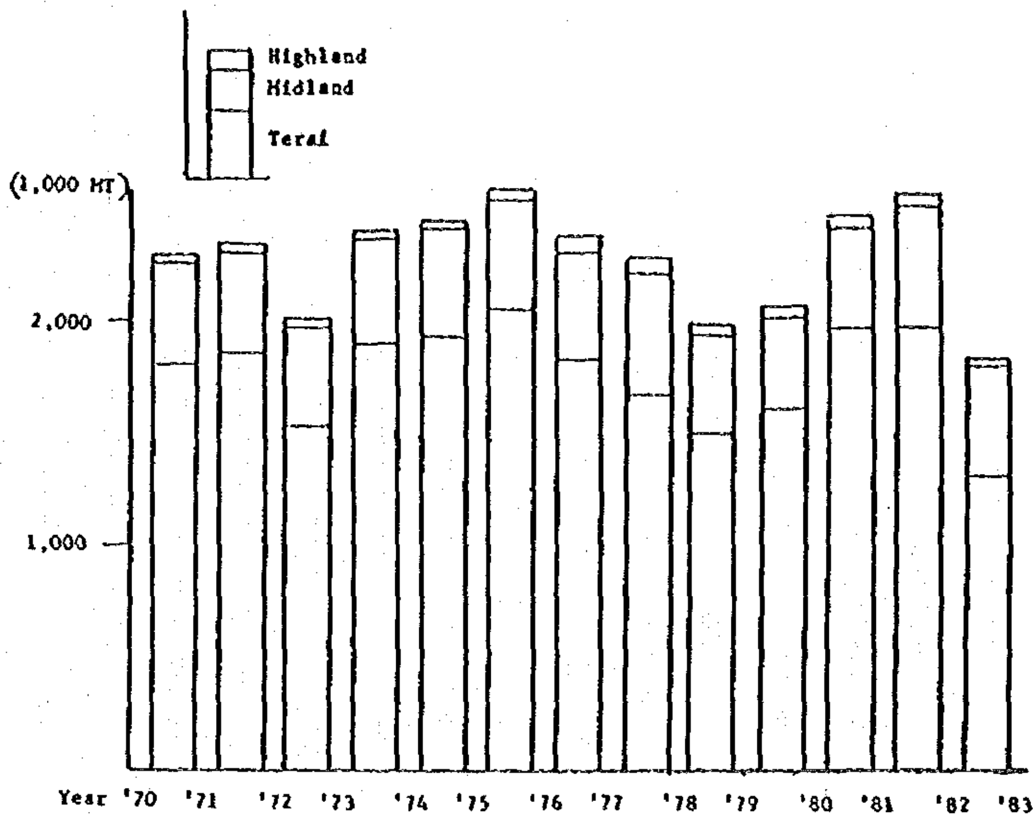


FIG. 5-2-6 PADDY PRODUCTION FOR EACH ZONE

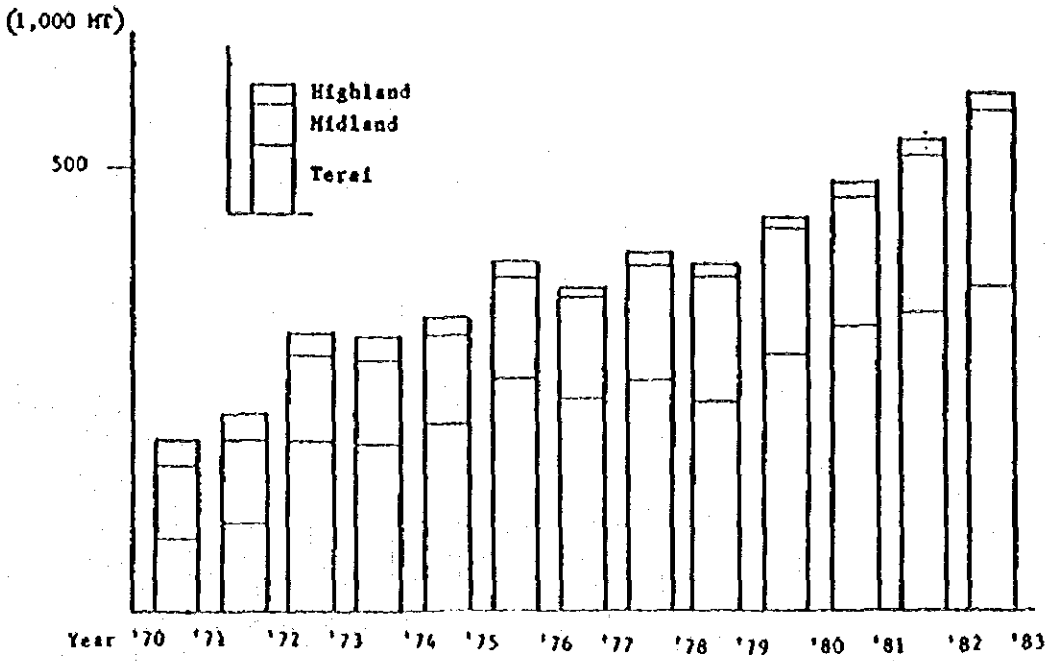


FIG. 5-2-7 WHEAT PRODUCTION FOR EACH ZONE

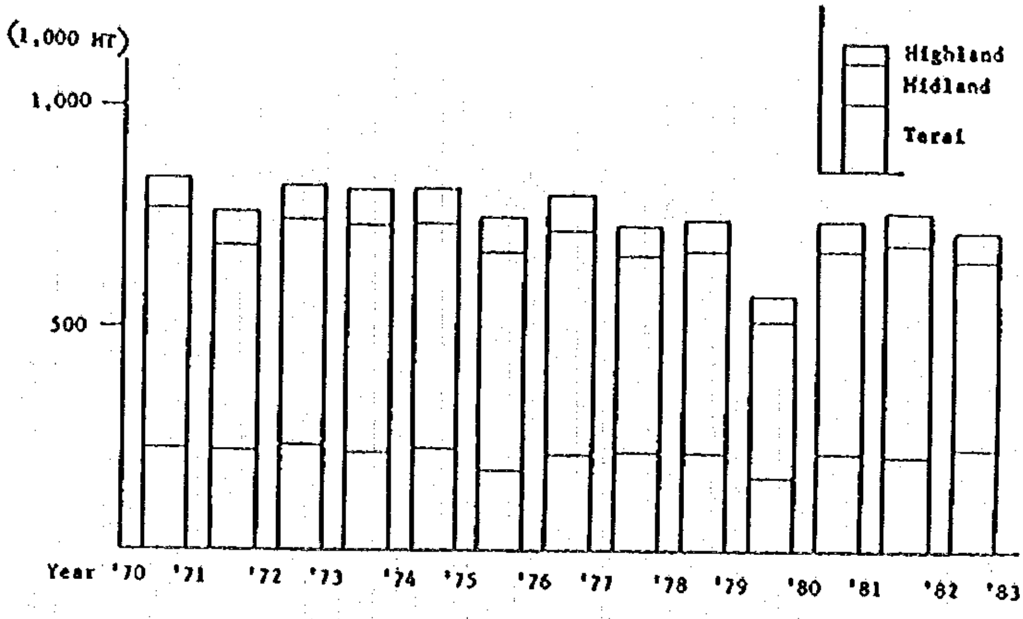


FIG. 5-2-8 MAIZE PRODUCTION FOR EACH ZONE

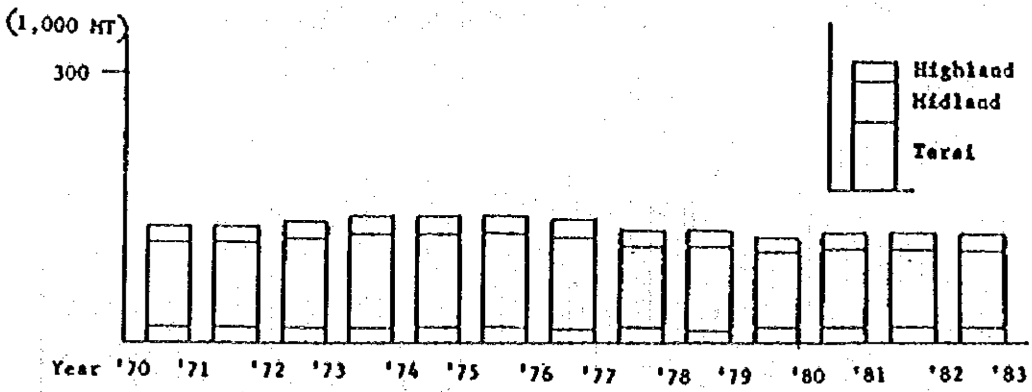


FIG. 5-2-9 MILLET PRODUCTION FOR EACH ZONE

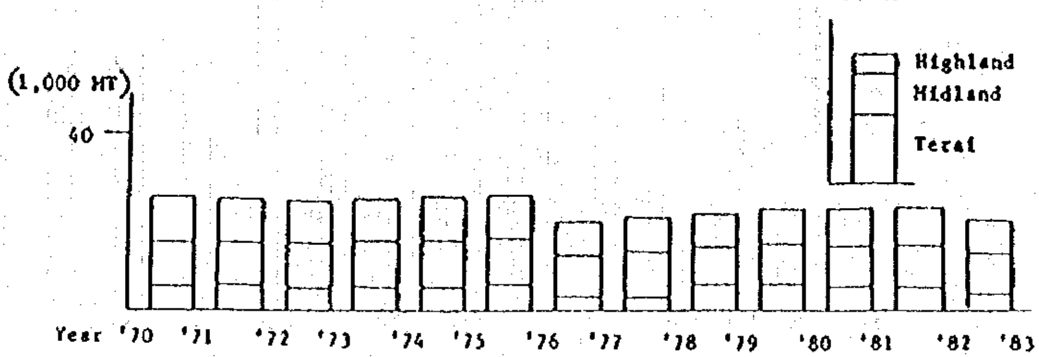


FIG. 5-2-10 BARLEY PRODUCTION FOR EACH ZONE

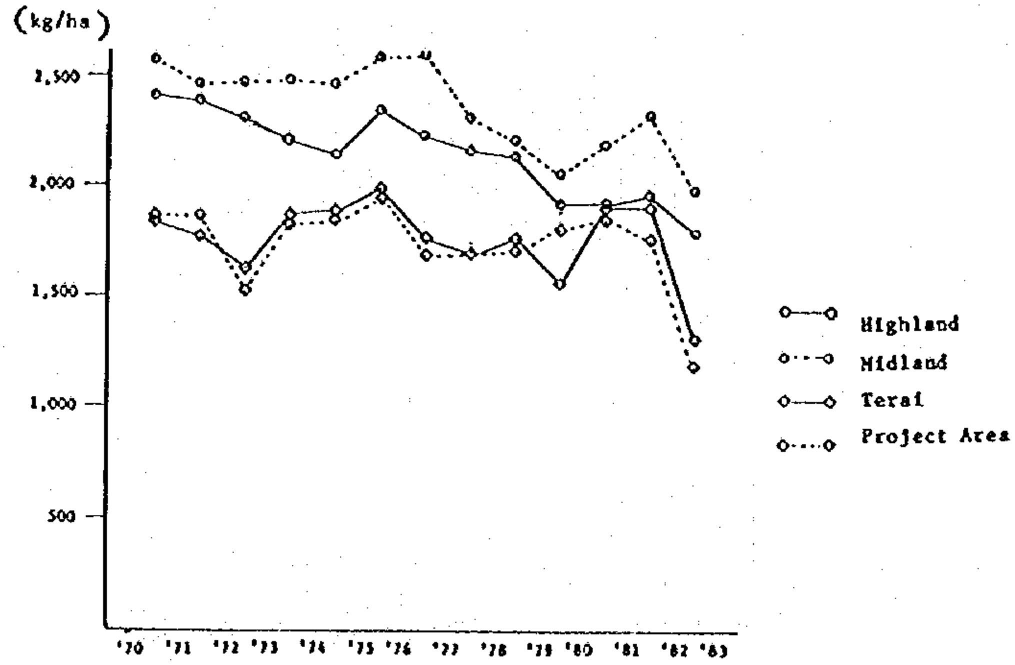


FIG. 5-2-11 FLUCTUATION IN PADDY YIELD FOR EACH ZONE

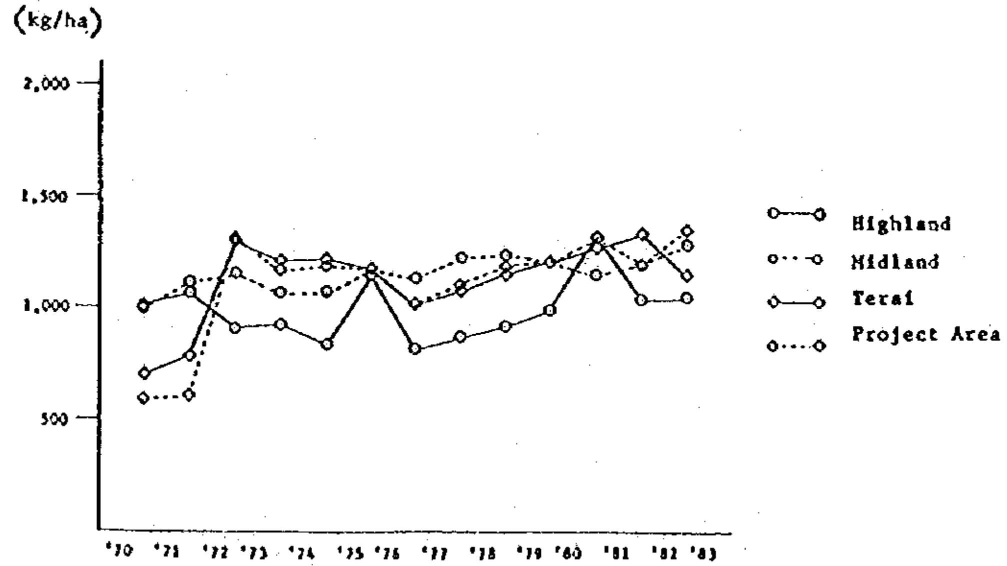


FIG. 5-2-12 FLUCTUATION IN WHEAT YIELD FOR EACH ZONE

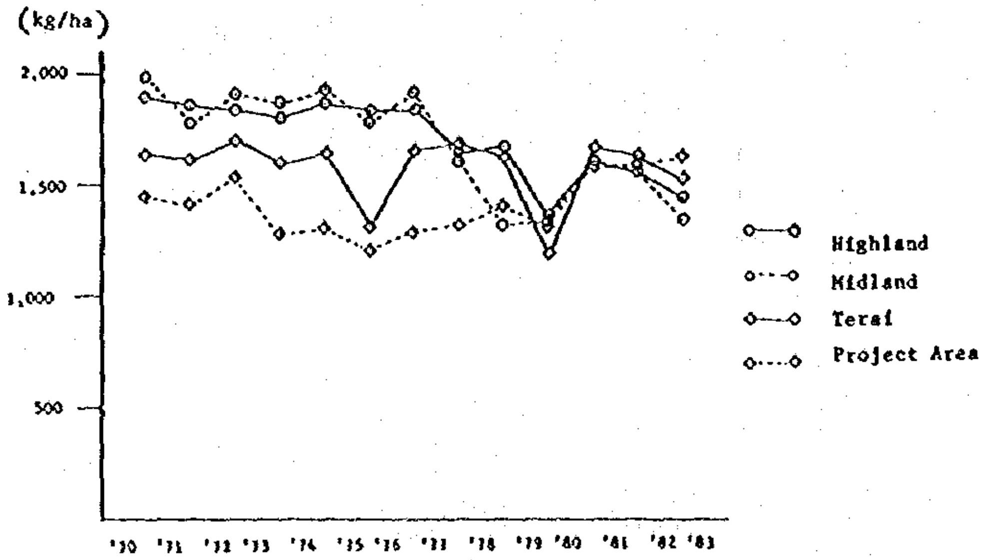


FIG. 5-2-13 FLUCTUATION IN MAIZE YIELD FOR EACH ZONE

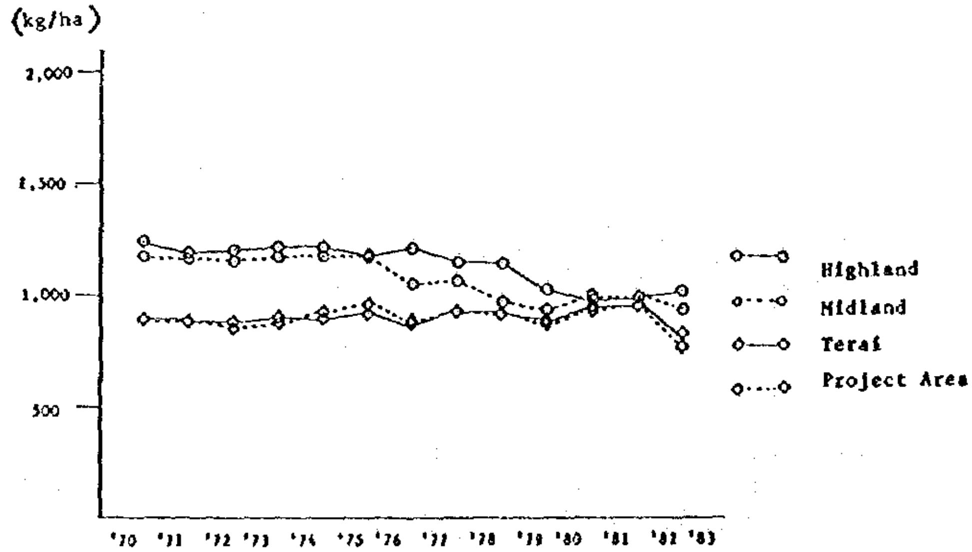


FIG. 5-2-14 FLUCTUATION IN MILLET YIELD FOR EACH ZONE

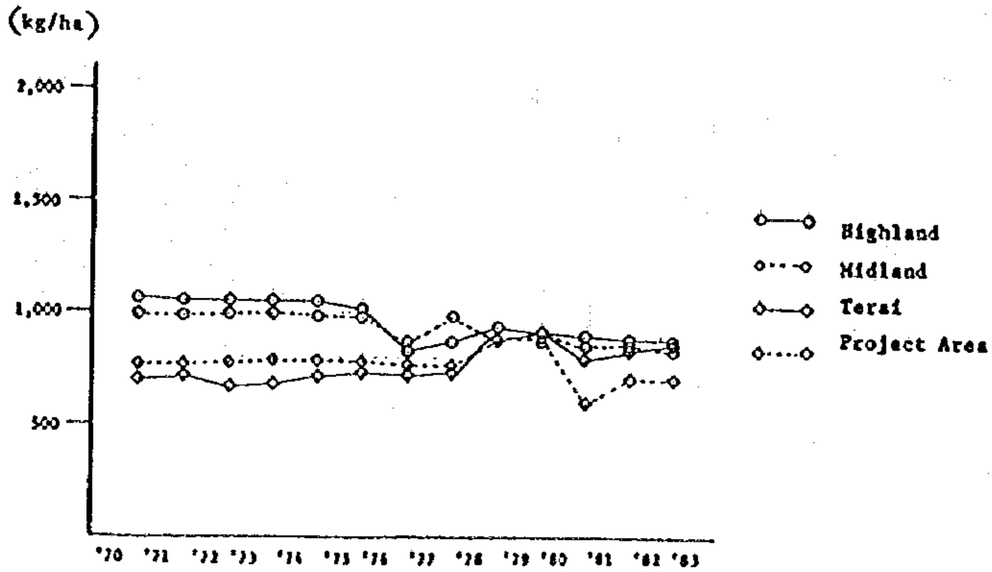


FIG. 5-2-15 FLUCTUATION IN BARLEY YIELD FOR EACH ZONE

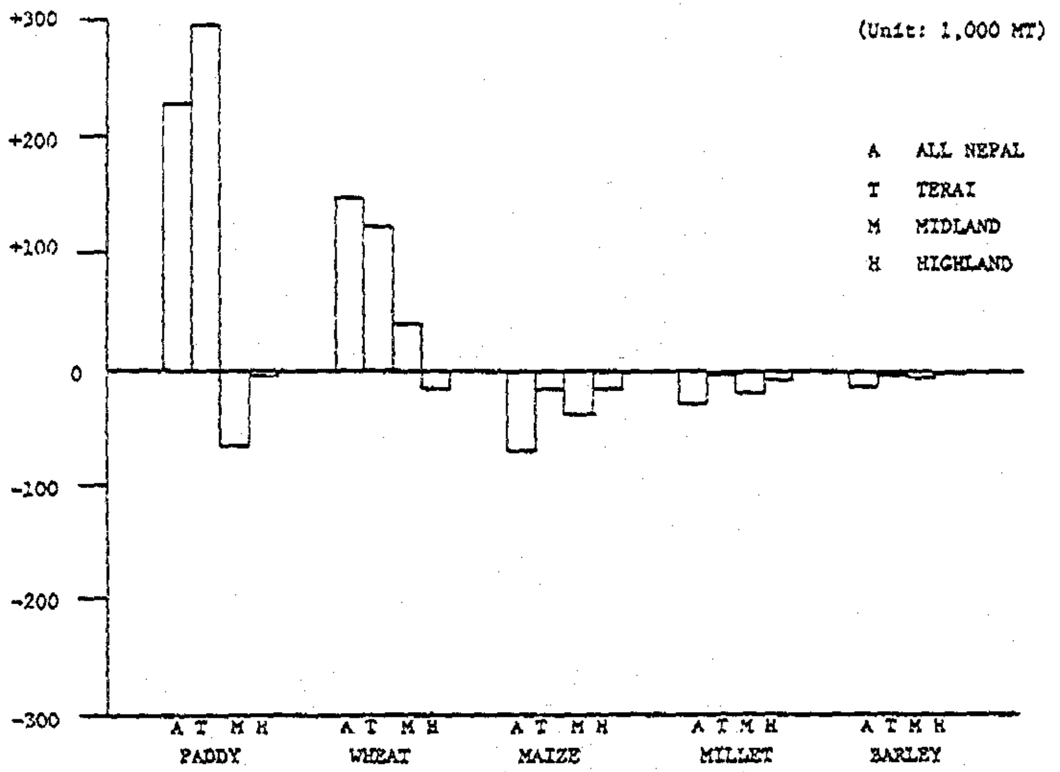


FIG. 5-2-16 FOOD BALANCE IN NEPAL BY DIFFERENT ZONE 1981/82

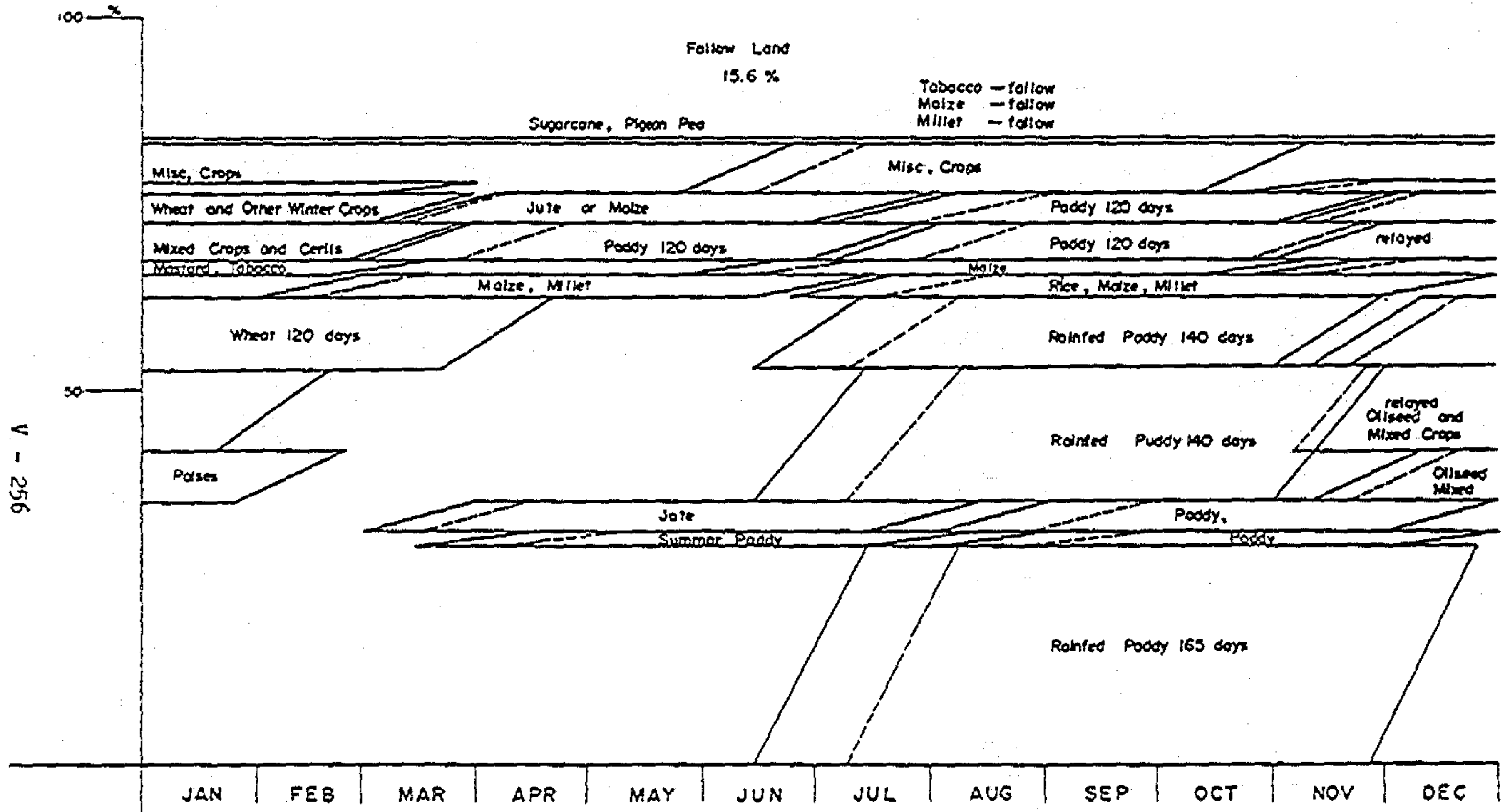
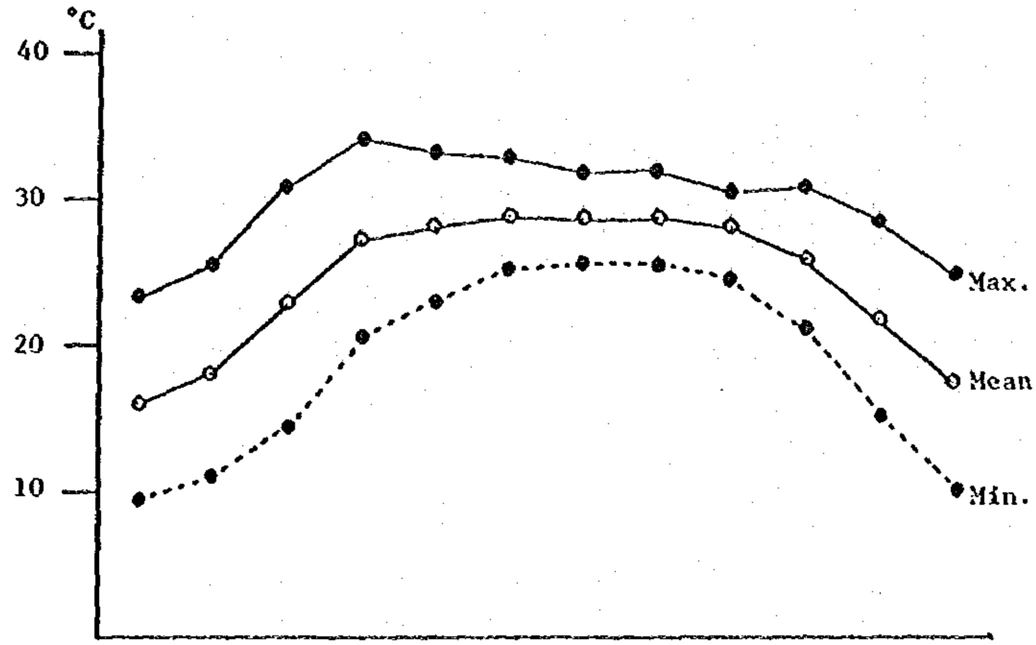
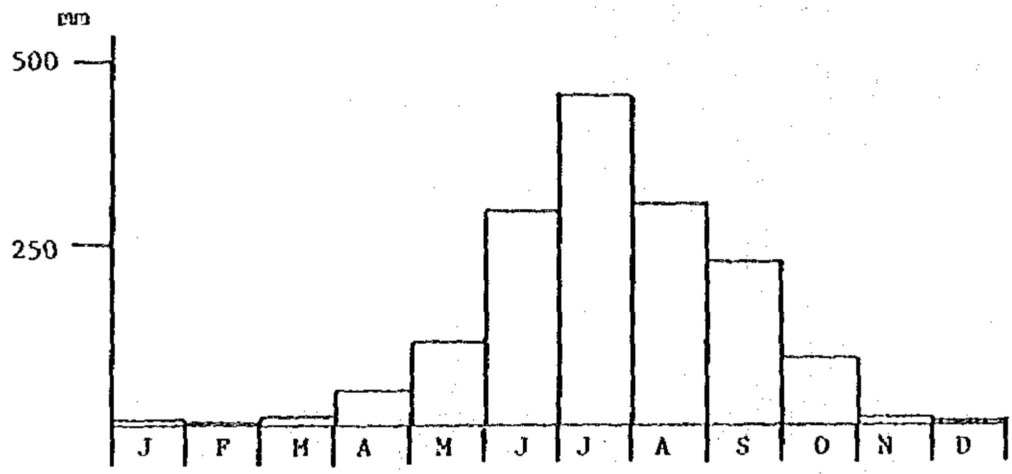


FIG. 5-2-17 PRESENT CROPPING PATTERN IN THE STUDY AREA



Max., Min. and Mean Temperatures



Monthly Rainfall Distribution

FIG. 5-2-18 CLIMATOLOGICAL CONDITIONS IN THE PROJECT AREA

Source: Climatological Record of Nepal 1971 - 1980, (1982) DHM, Ministry of Water Resources, Kathmandu

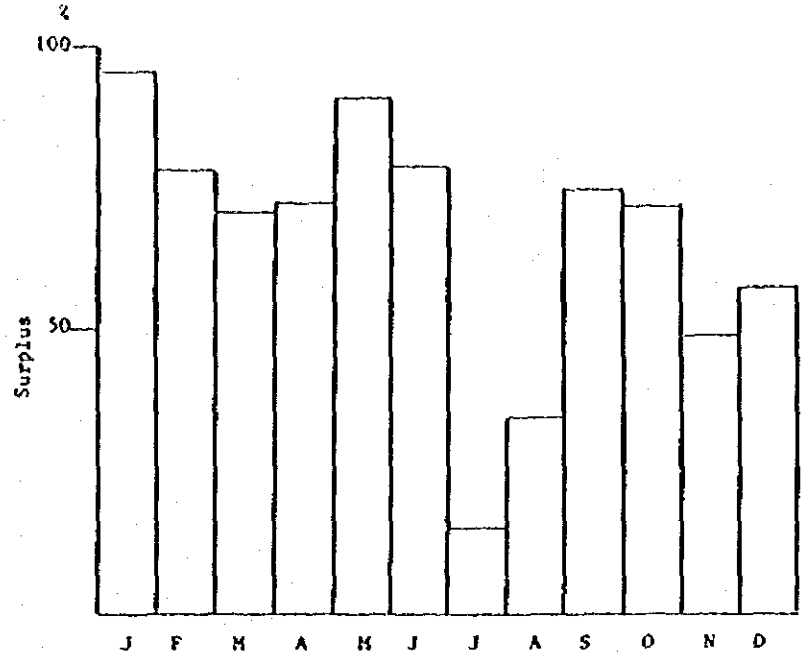


FIG. 5-2-19 PRESENT MANPOWER BALANCE IN THE STUDY AREA

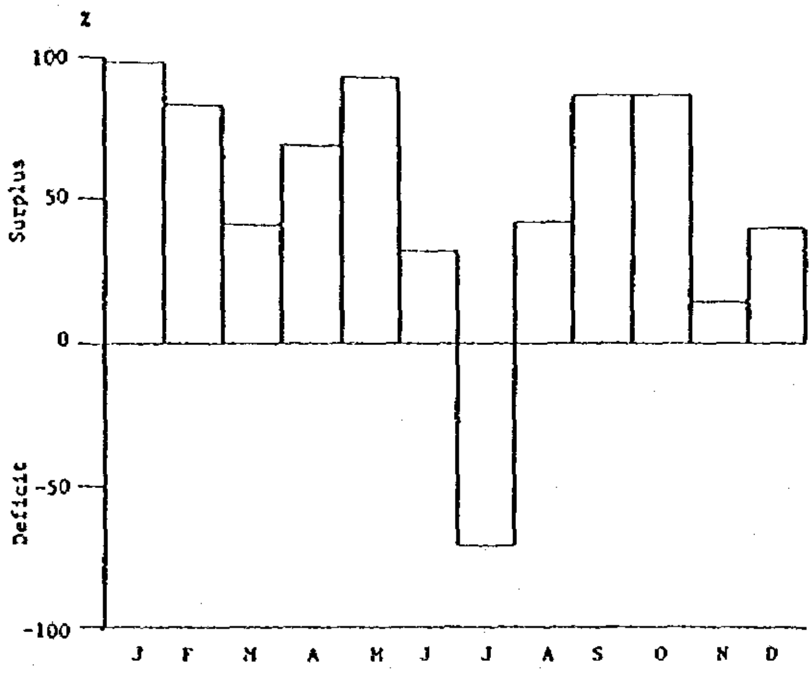


FIG. 5-2-20 PRESENT DRAFT ANIMAL LABOR BALANCE IN THE STUDY AREA

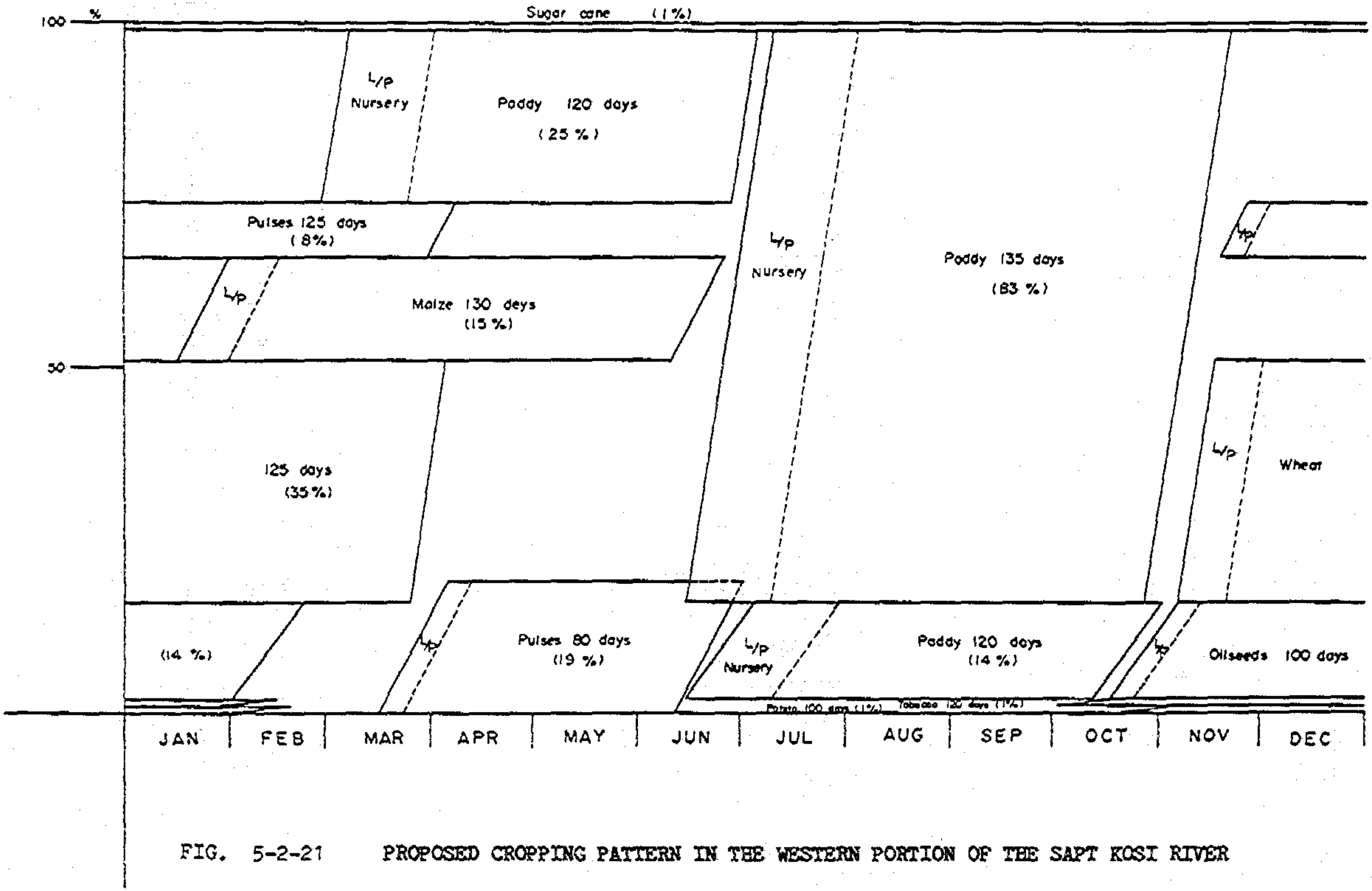


FIG. 5-2-21 PROPOSED CROPPING PATTERN IN THE WESTERN PORTION OF THE SAPT KOSI RIVER

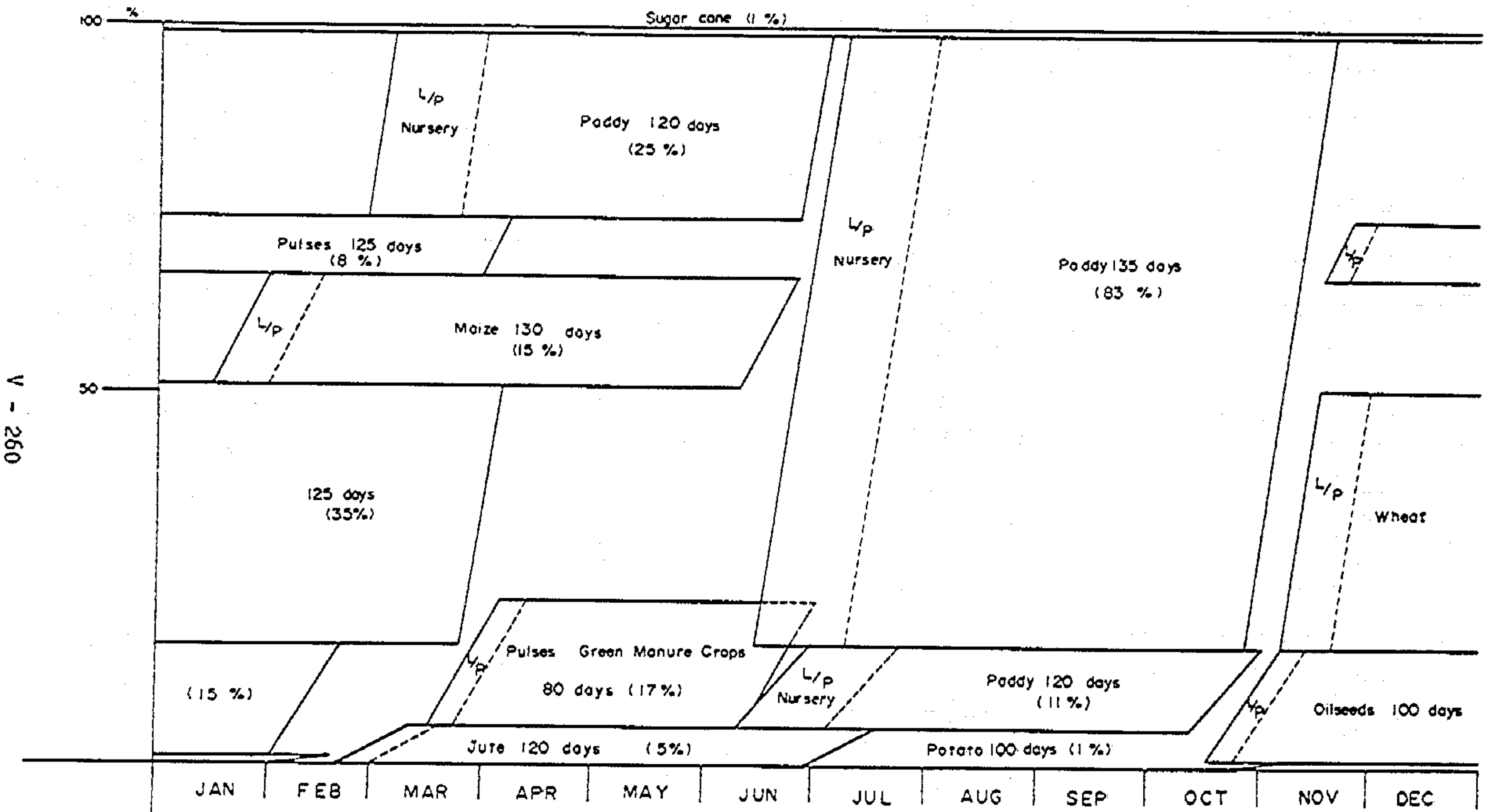


FIG. 5-2-22 PROPOSED CROPPING PATTERN IN THE EASTERN PORTION OF THE SAPT KOSI RIVER

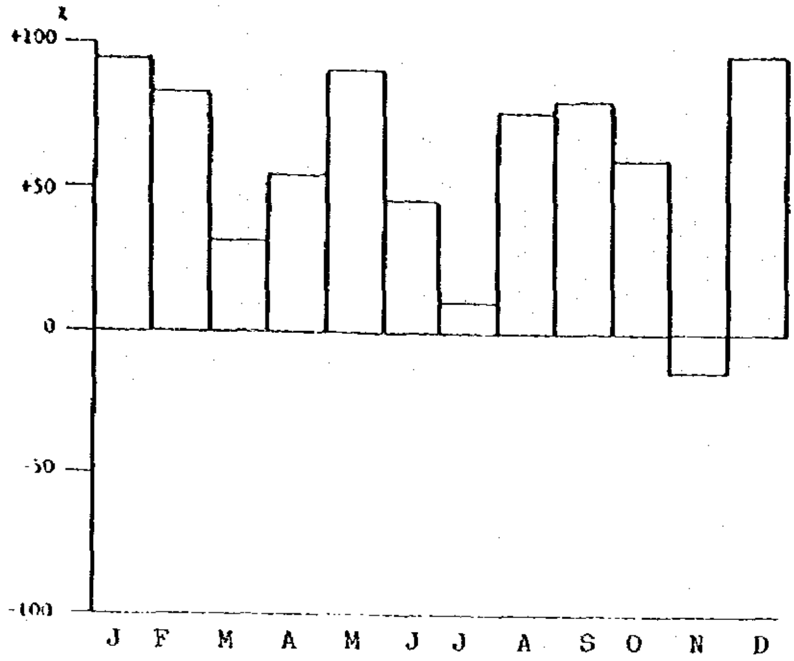


FIG. 5-2-23 FUTURE MANPOWER BALANCE: EASTERN STUDY AREA

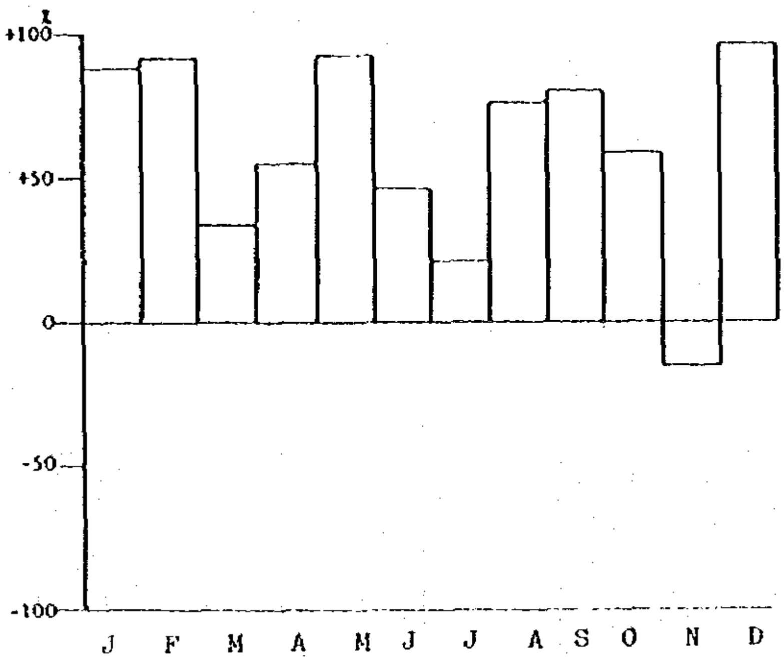


FIG. 5-2-24 FUTURE MANPOWER BALANCE: WESTERN STUDY AREA

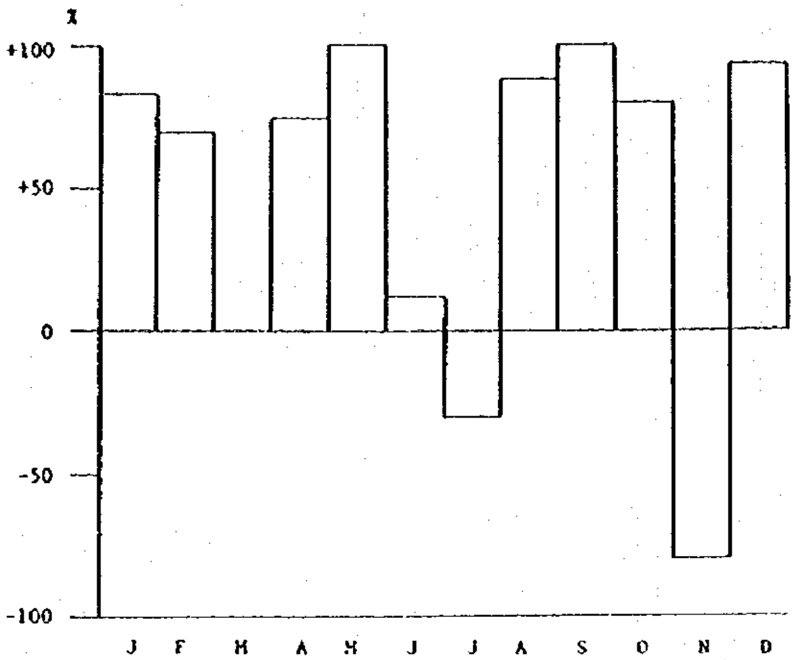


FIG. 5-2-25 FUTURE DRAFT ANIMAL LABOR BALANCE: EASTERN STUDY AREA

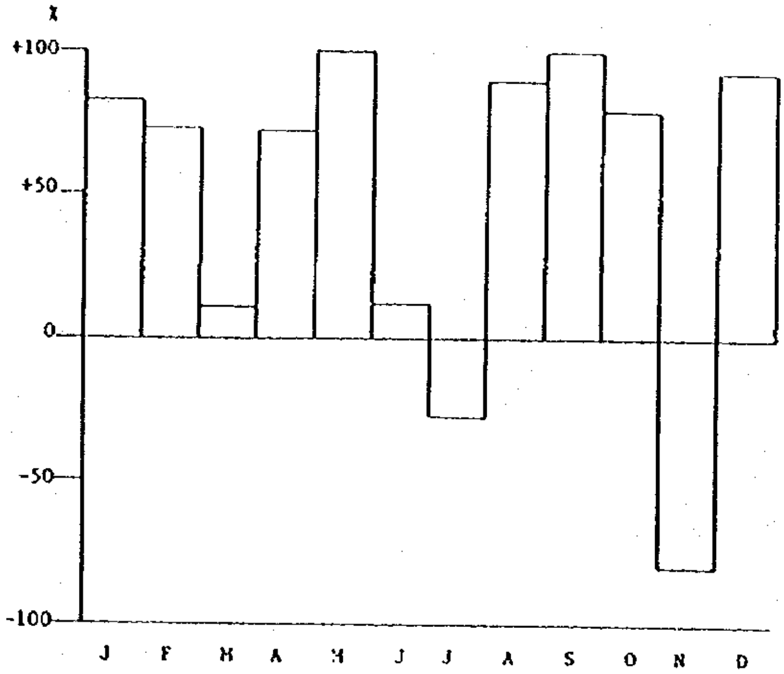
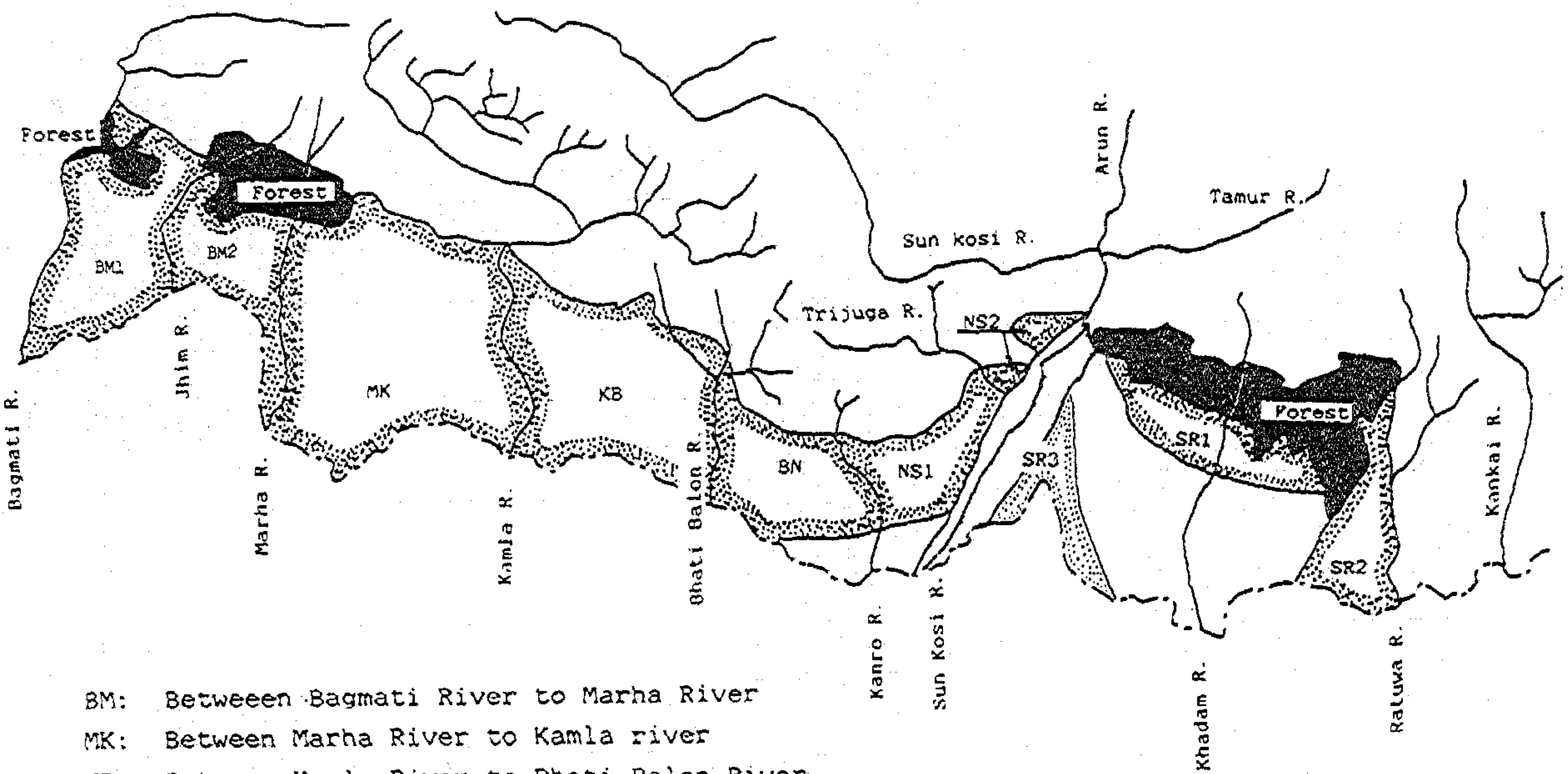


FIG. 5-2-26 FUTURE DRAFT ANIMAL LABOR BALANCE: WESTERN STUDY AREA



BM: Betweeen Bagmati River to Marha River
MK: Between Marha River to Kamla river
KB: Between Kamla River to Bhati Balon River
BN: Between Bhati Balon River to Kanro River
NS: Between Kanlo River to Sapt Kosi River
SR: Between Sapt Kosi River to Ratuwa River

FIG. 5-3-2 **DELINEATION OF IRRIGATION AREA**

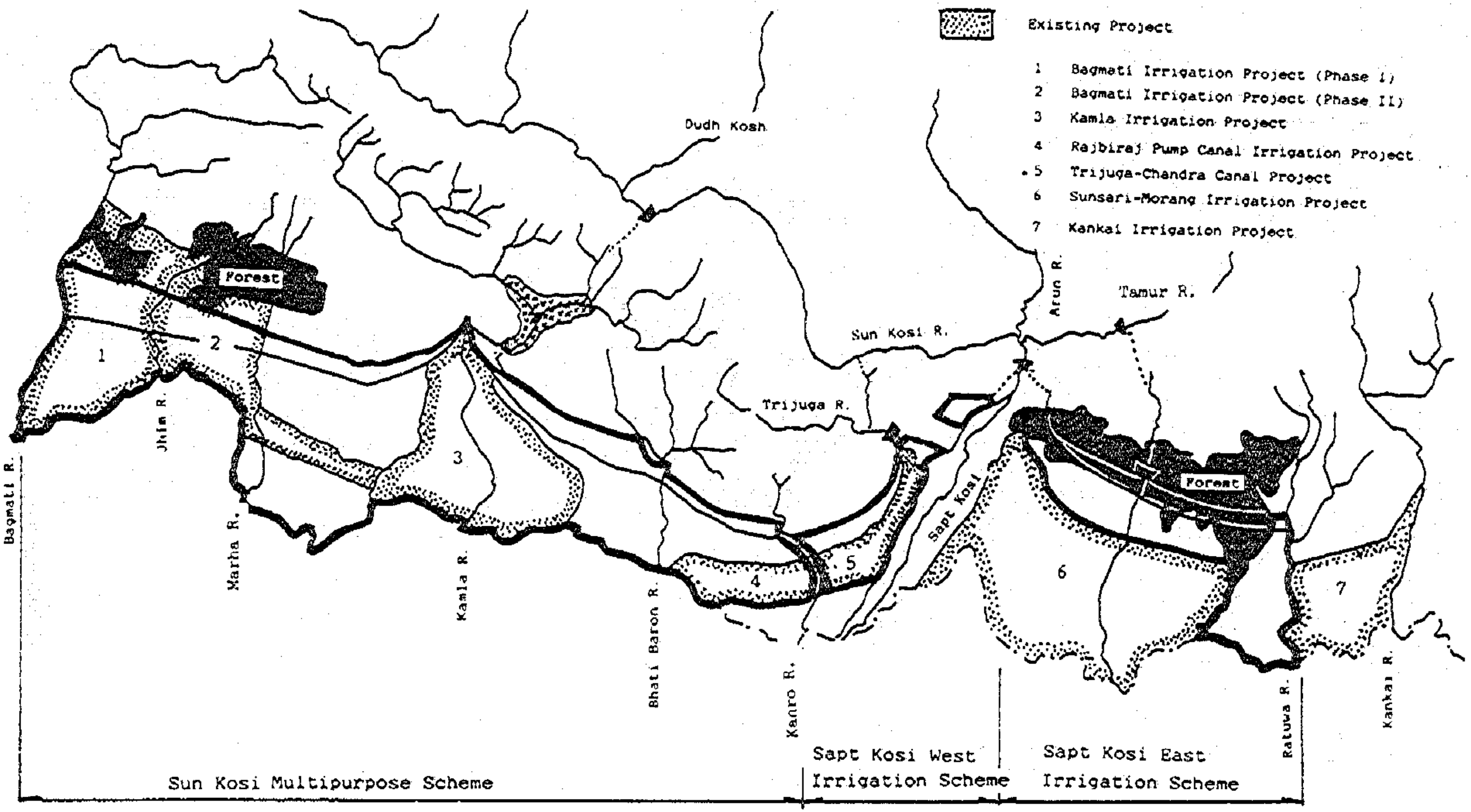


FIG. 5-3-3 POTENTIAL IRRIGATION SCHEMES

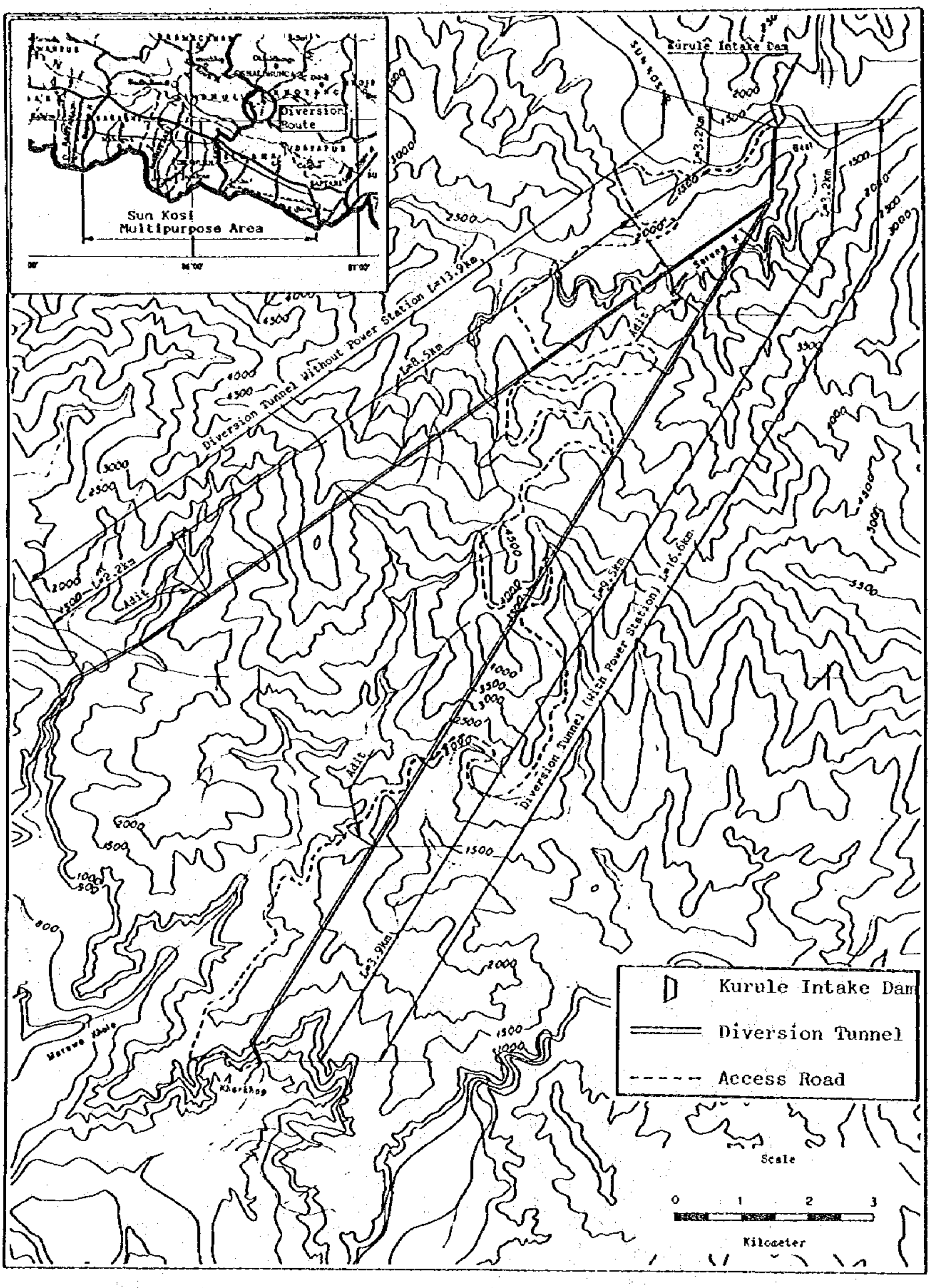


FIG. 5-3-4 DIVERSION ROUTE OF SUN KOSI MULTIPURPOSE SCHEME

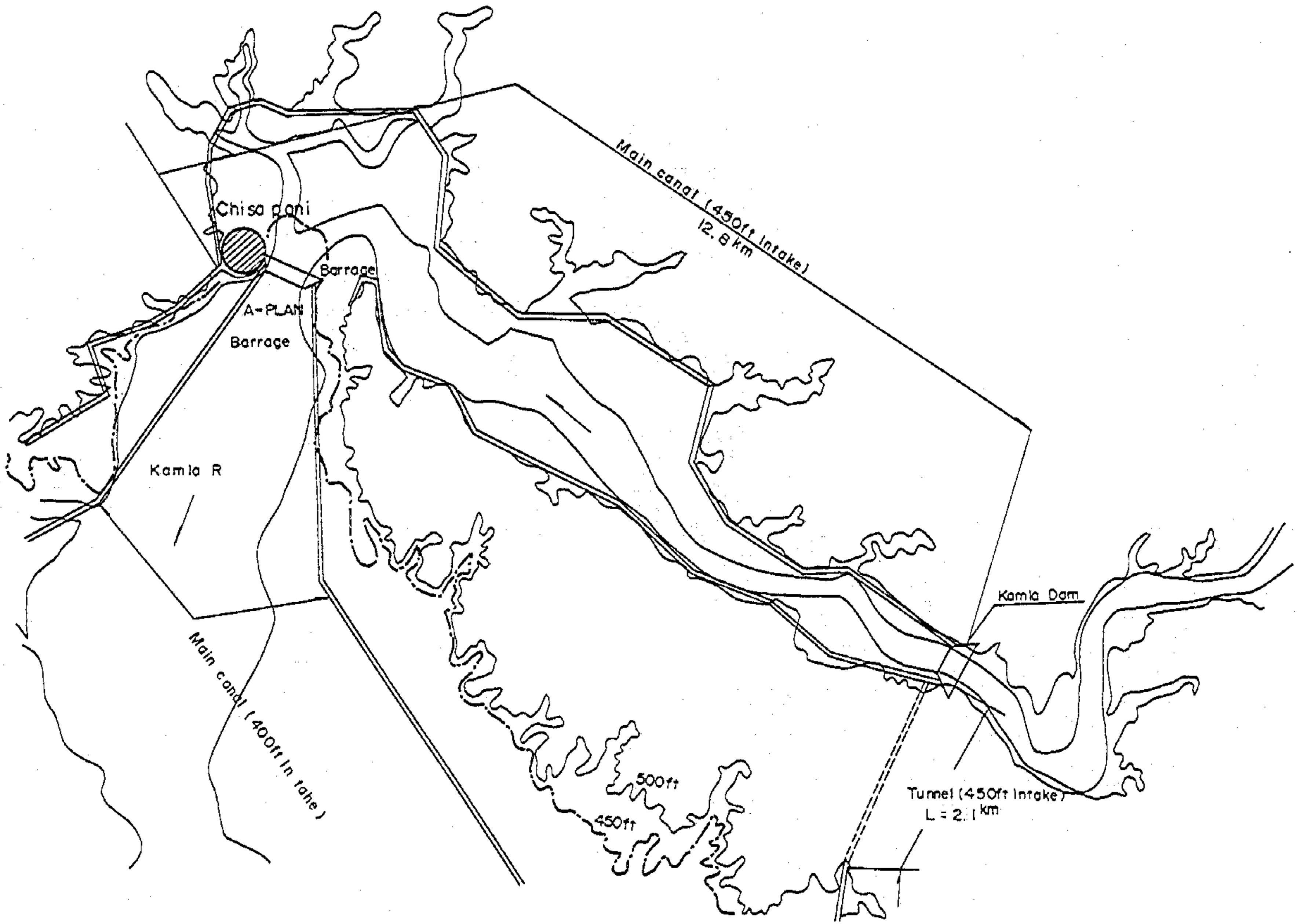


FIG. 5-3-5 ALTERNATIVE PLAN OF MAIN CANAL INTAKE FOR SUN KOSI MULTIPURPOSE SCHEME

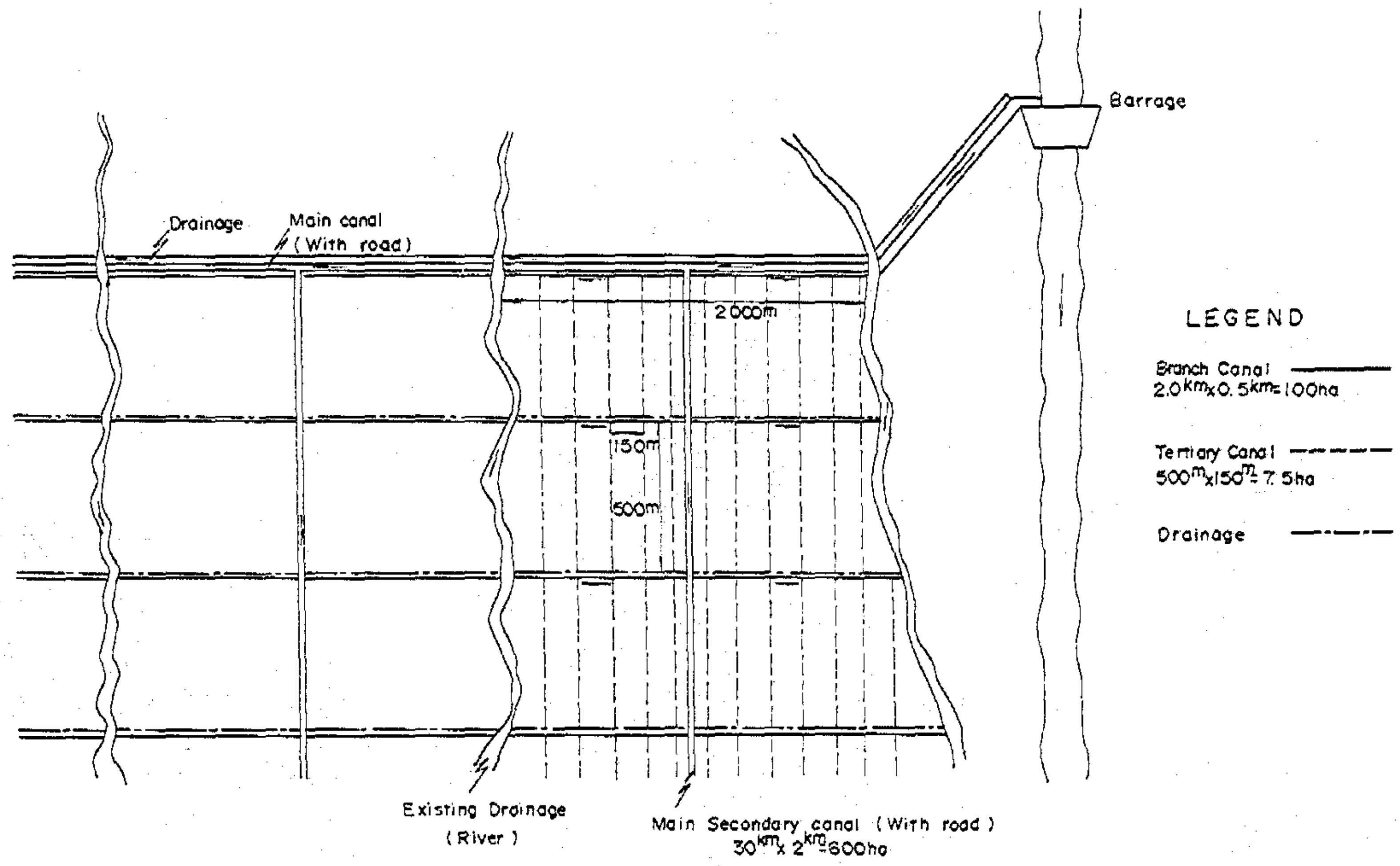


FIG. 5-3-6 **IRRIGATION SYSTEM MODEL**

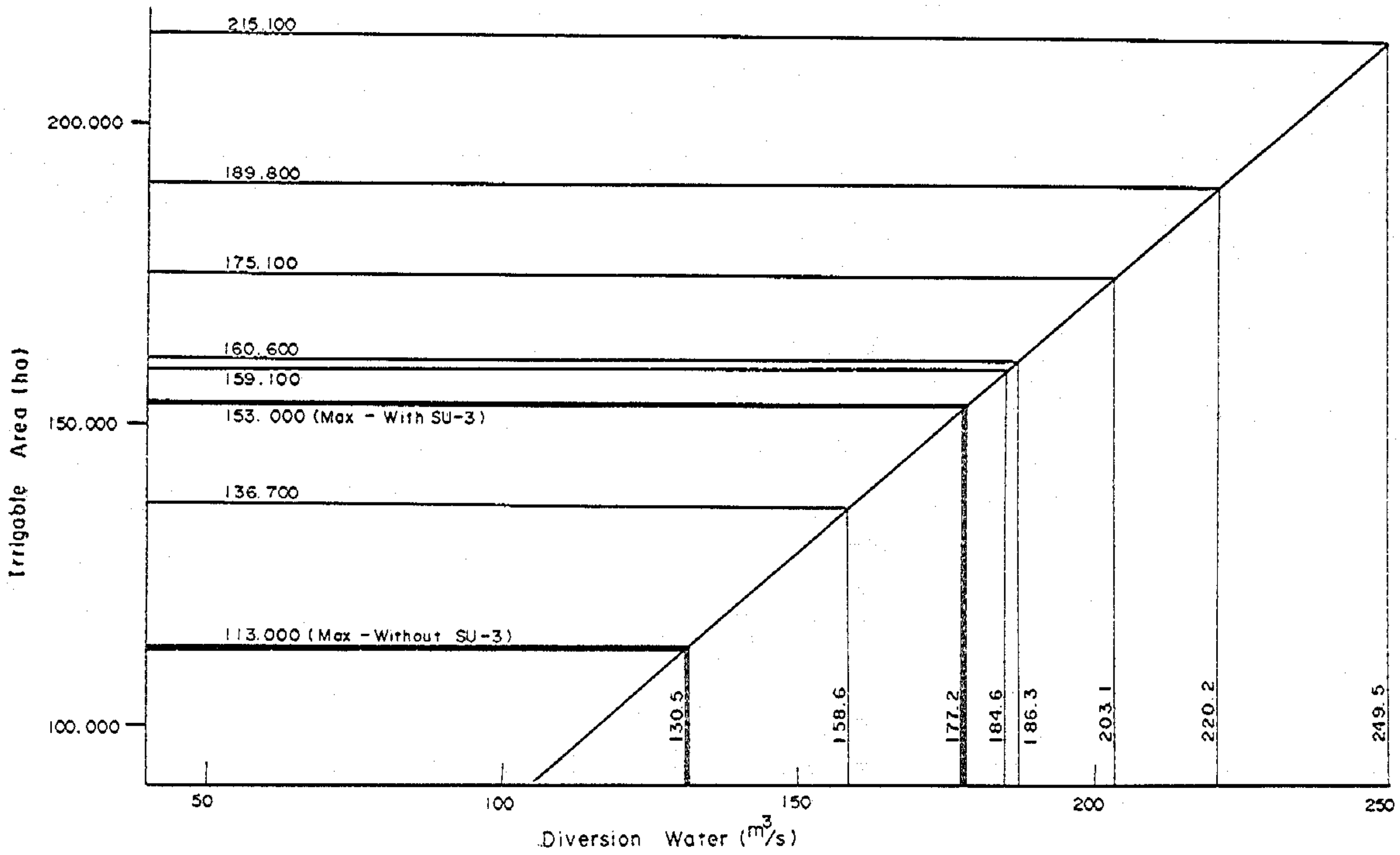


FIG. 5-3-7 IRRIGABLE AREA BY ONLY DIVERSION WATER FROM SUN KOSI RIVER

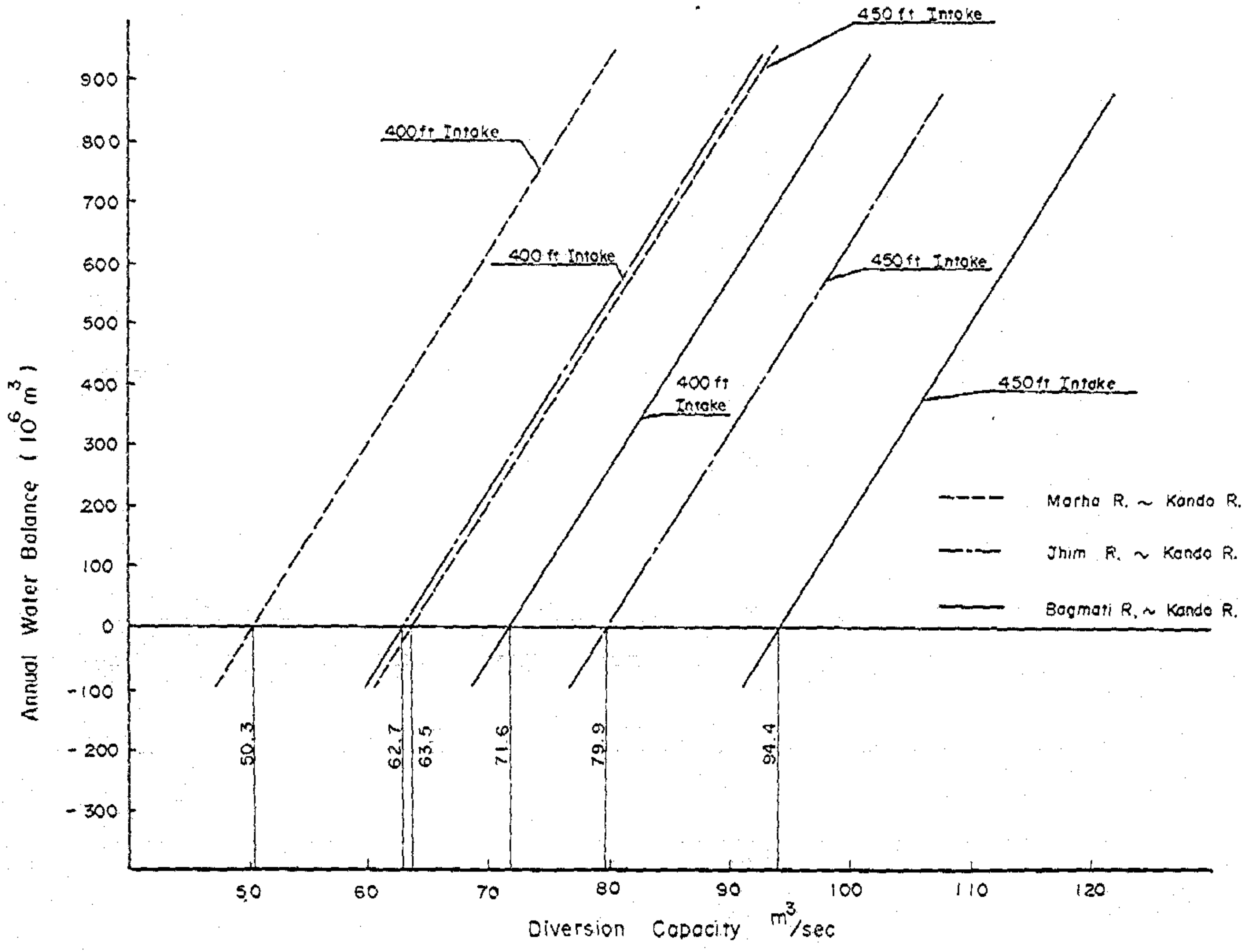


FIG. 5-3-8 **ANNUAL WATER BALANCE OF EACH PLAN FOR SUN KOSI MULTIPURPOSE SCHEME**

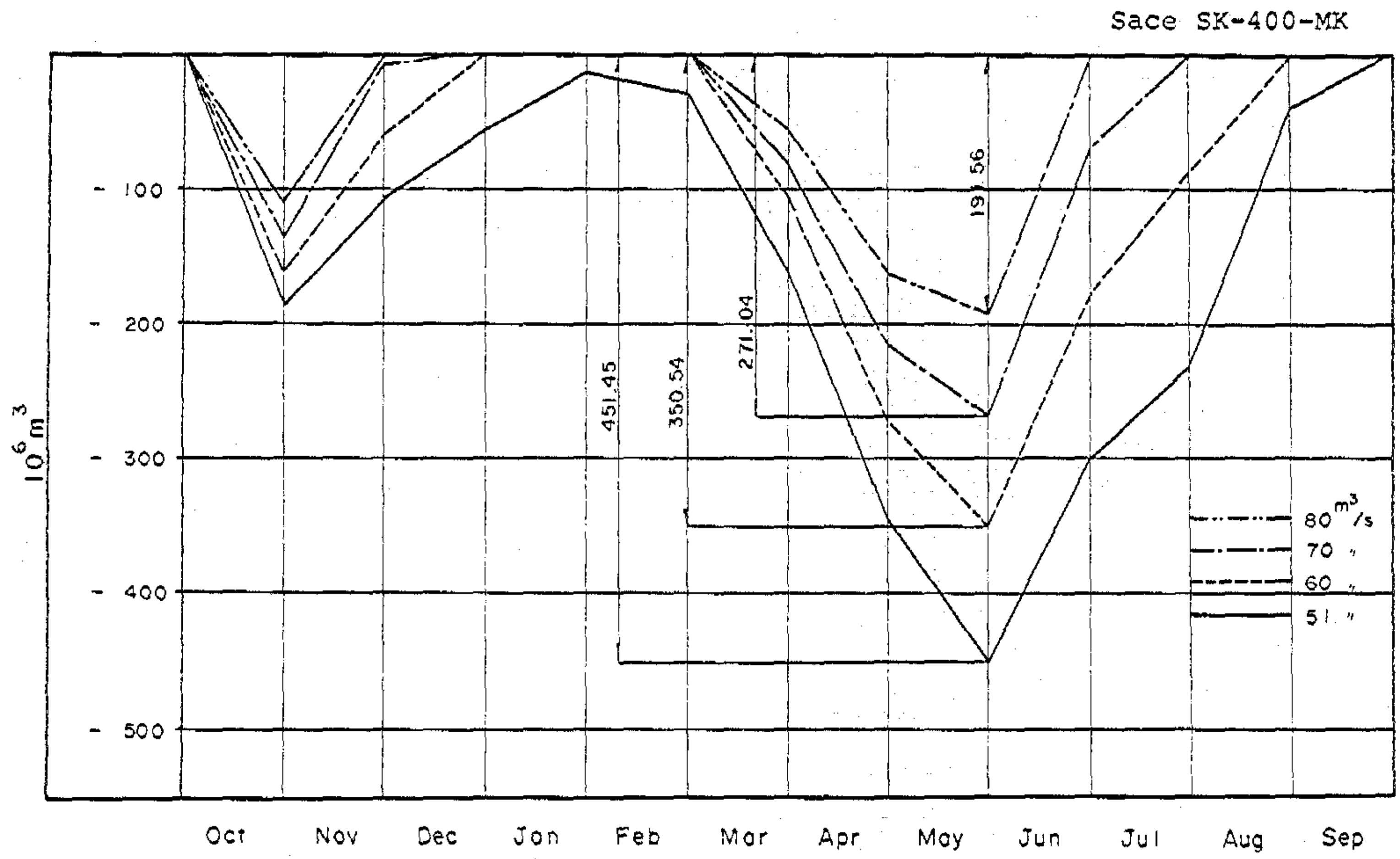


FIG. 5-3-9 **KAMLA DAM RESERVOIR MASS CURVE**

(1 of 6)

Case SK-450-MK

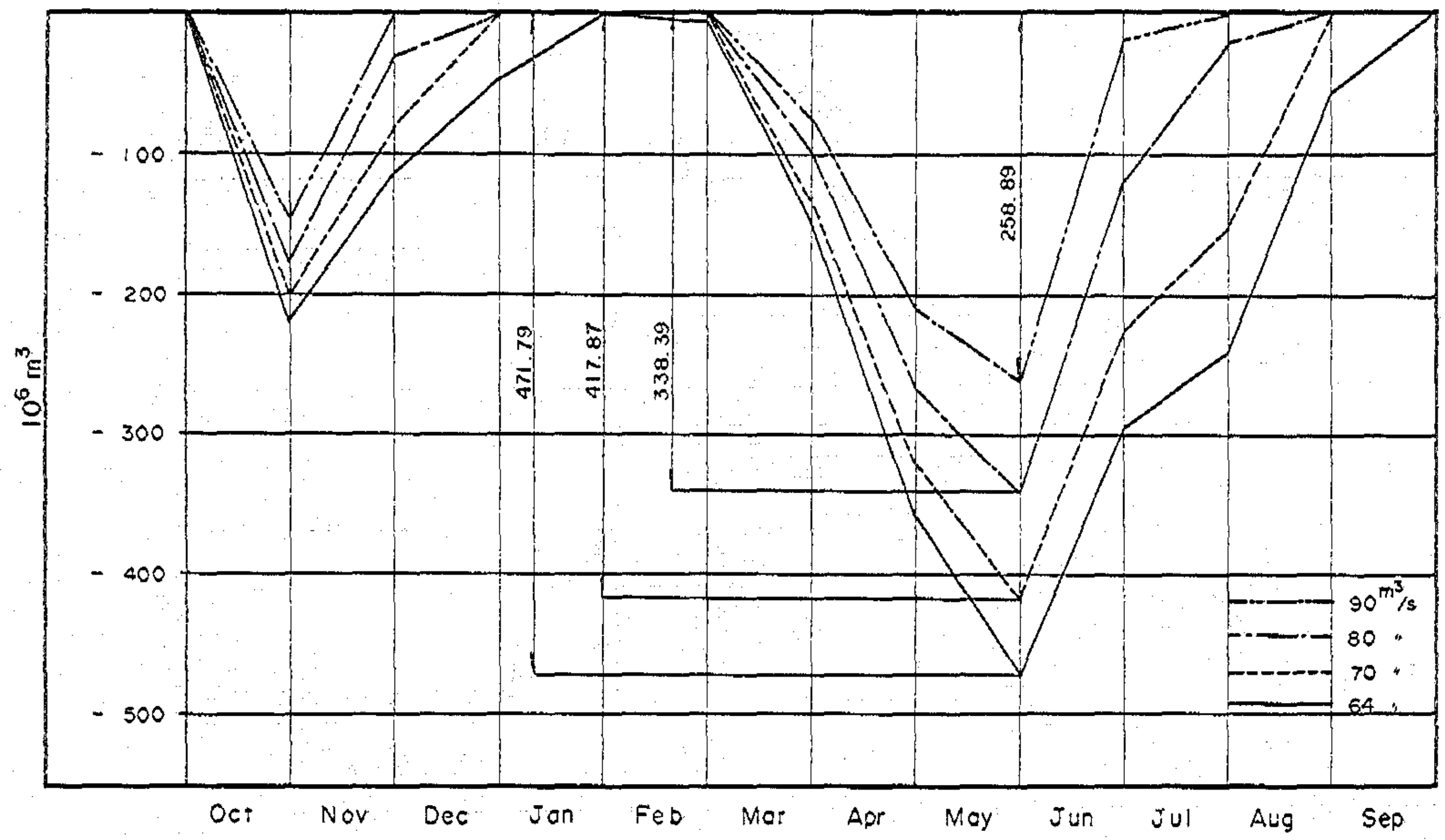


FIG. 5-3-9 **KAMLA DAM RESERVOIR MASS CURVE**

(2 of 6)

Case SK-400-JK

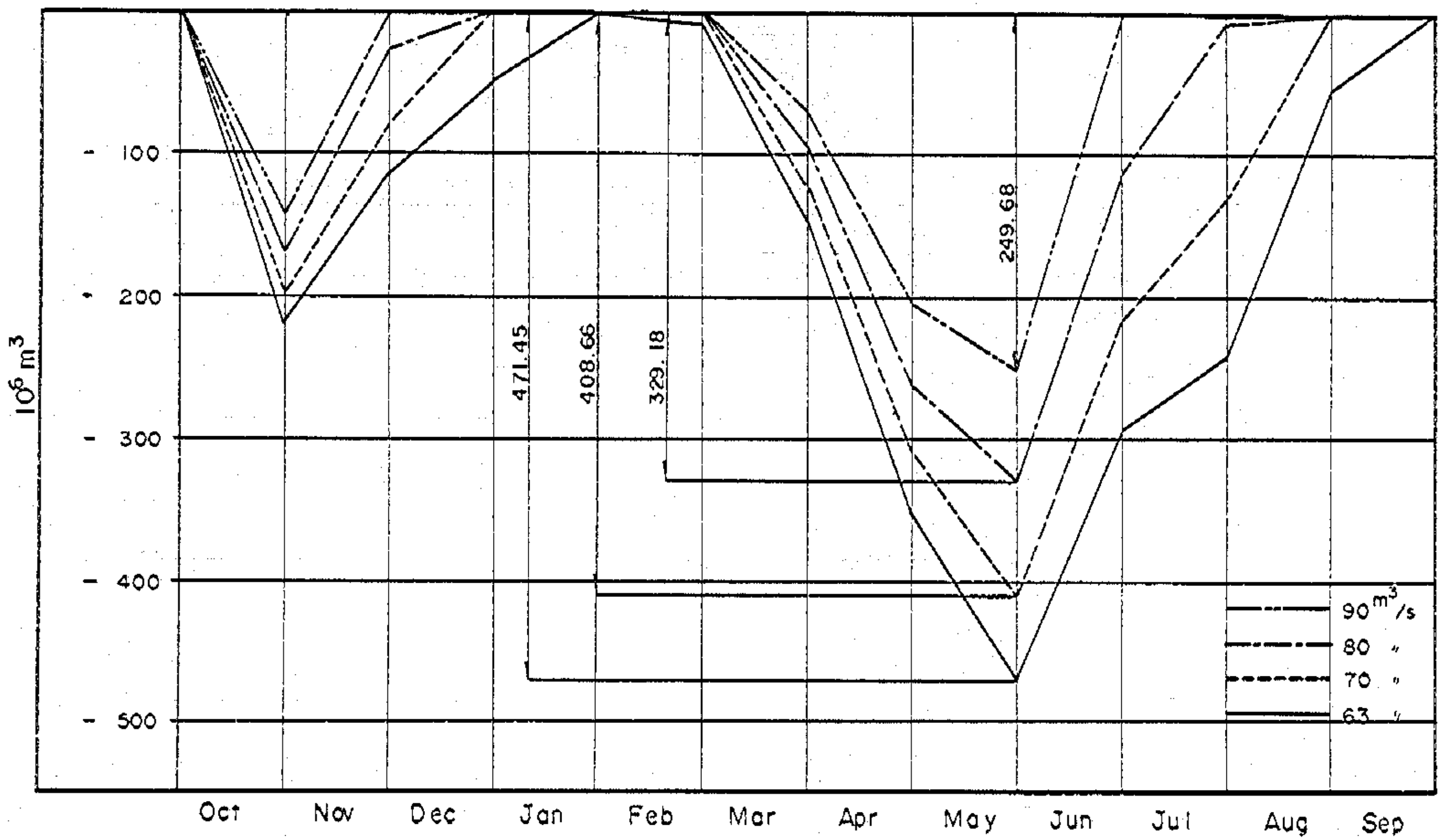


FIG. 5-3-9 **KAMLA DAM RESERVOIR MASS CURVE**
(3 of 6)

Case SK-450-JK

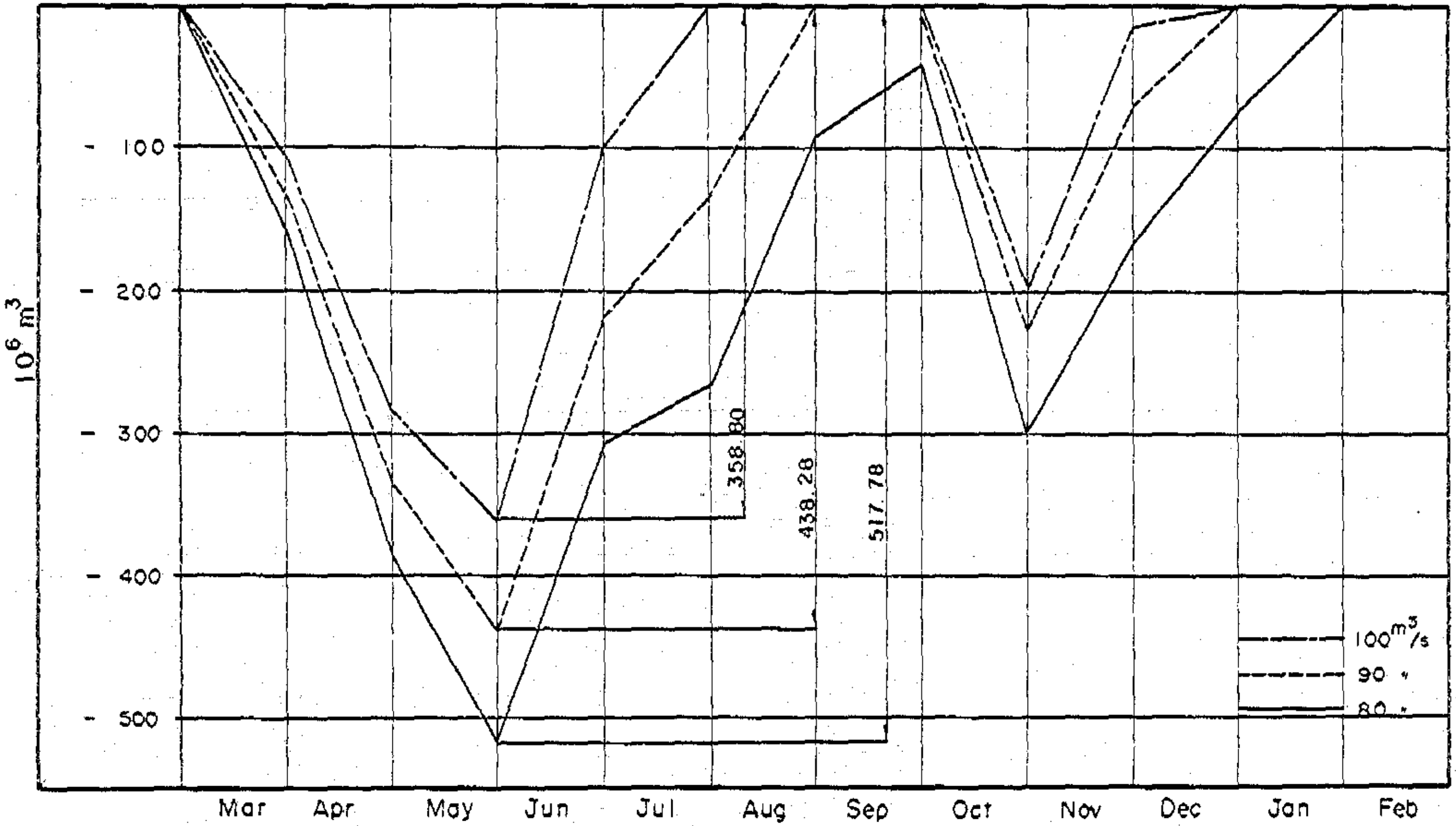


FIG. 5-3-9 **KAMLA DAM RESERVOIR MASS CURVE**

(4 of 6)

Case SK-400-BK

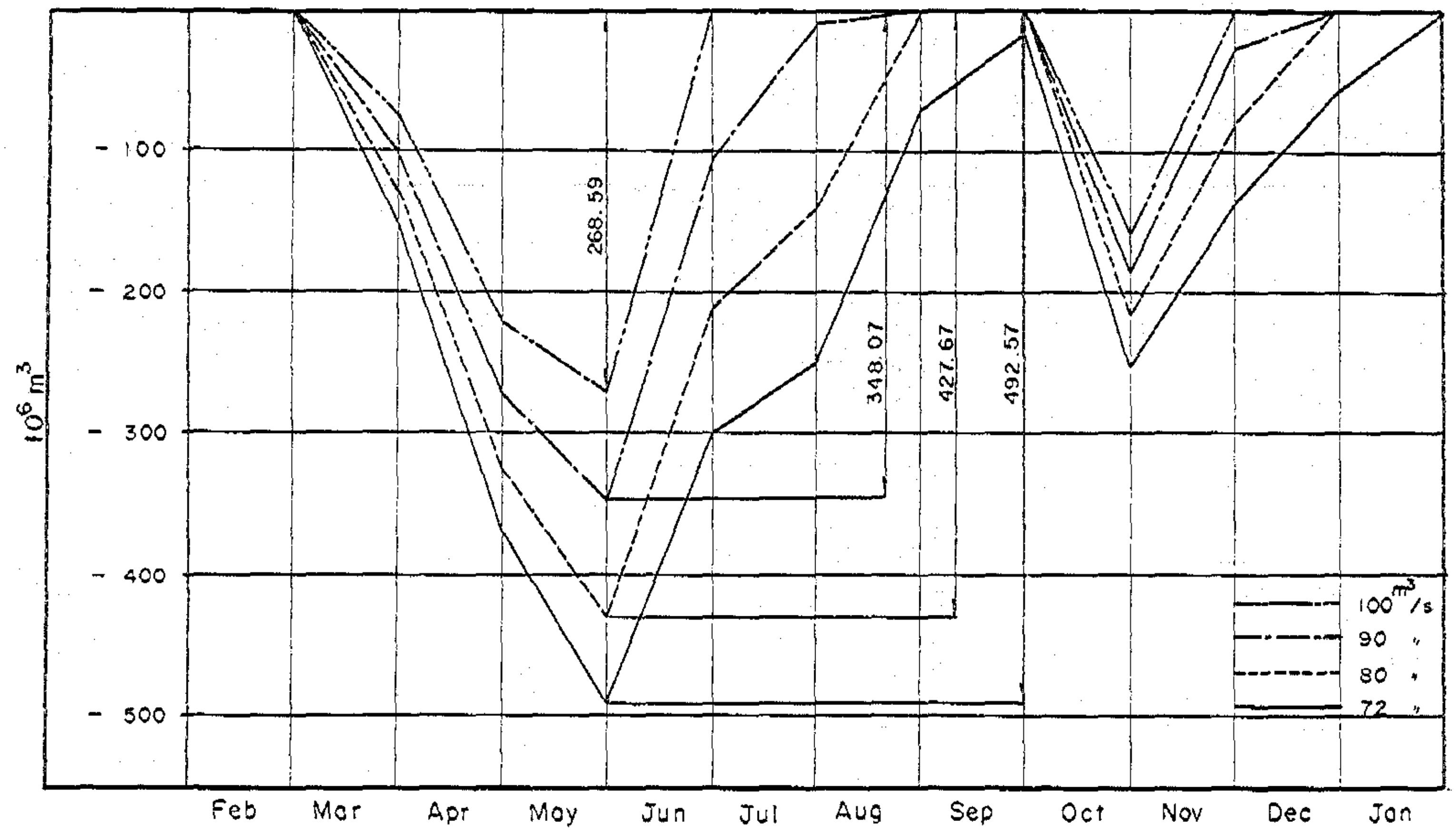


FIG. 5-3-9 **KAMLA DAM RESERVOIR MASS CURVE**

(5 of 6)

Case SK-450-BK

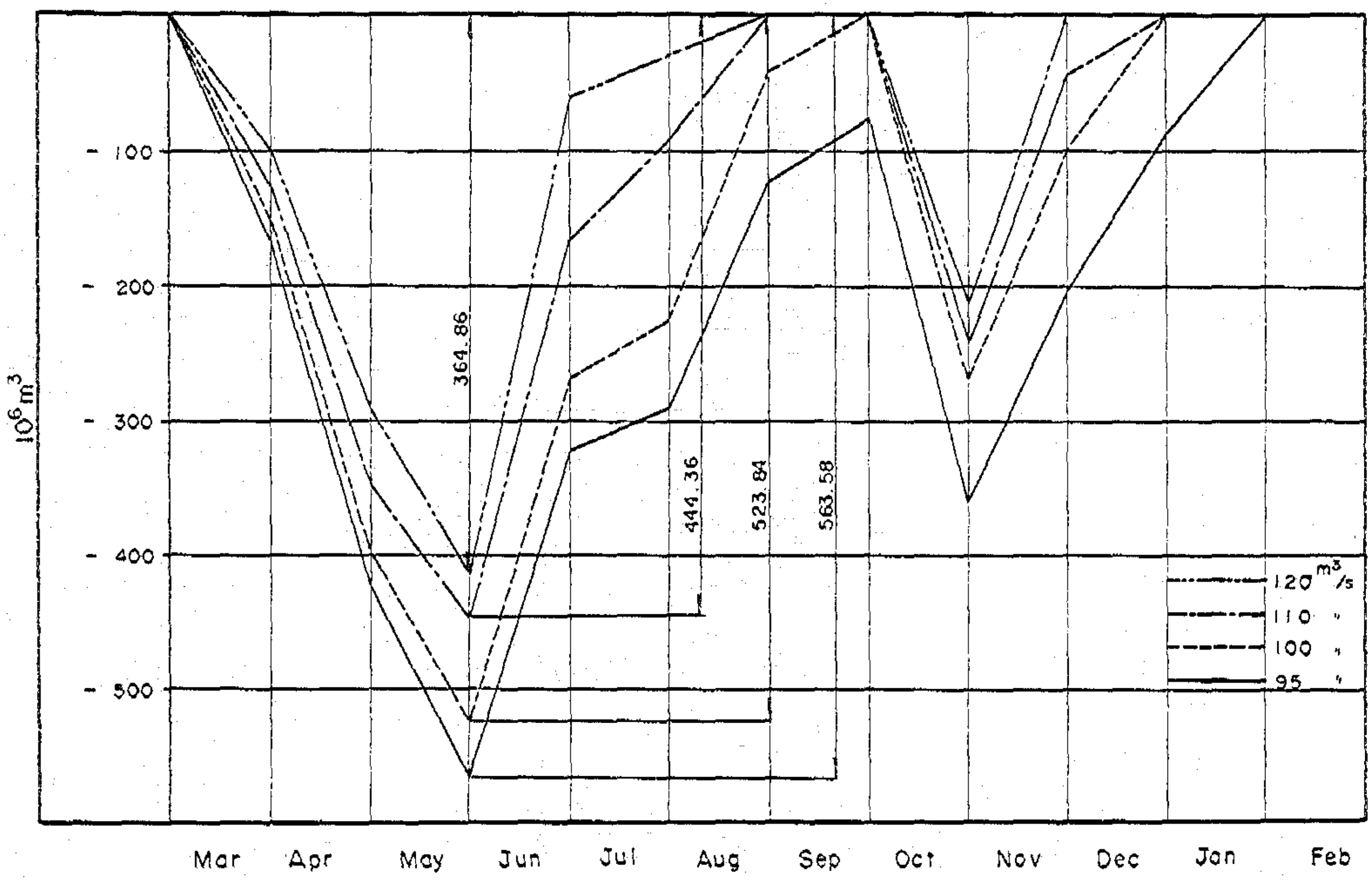


FIG. 5-3-9 **KAMLA DAM RESERVOIR MASS CURVE**
(6 of 6)

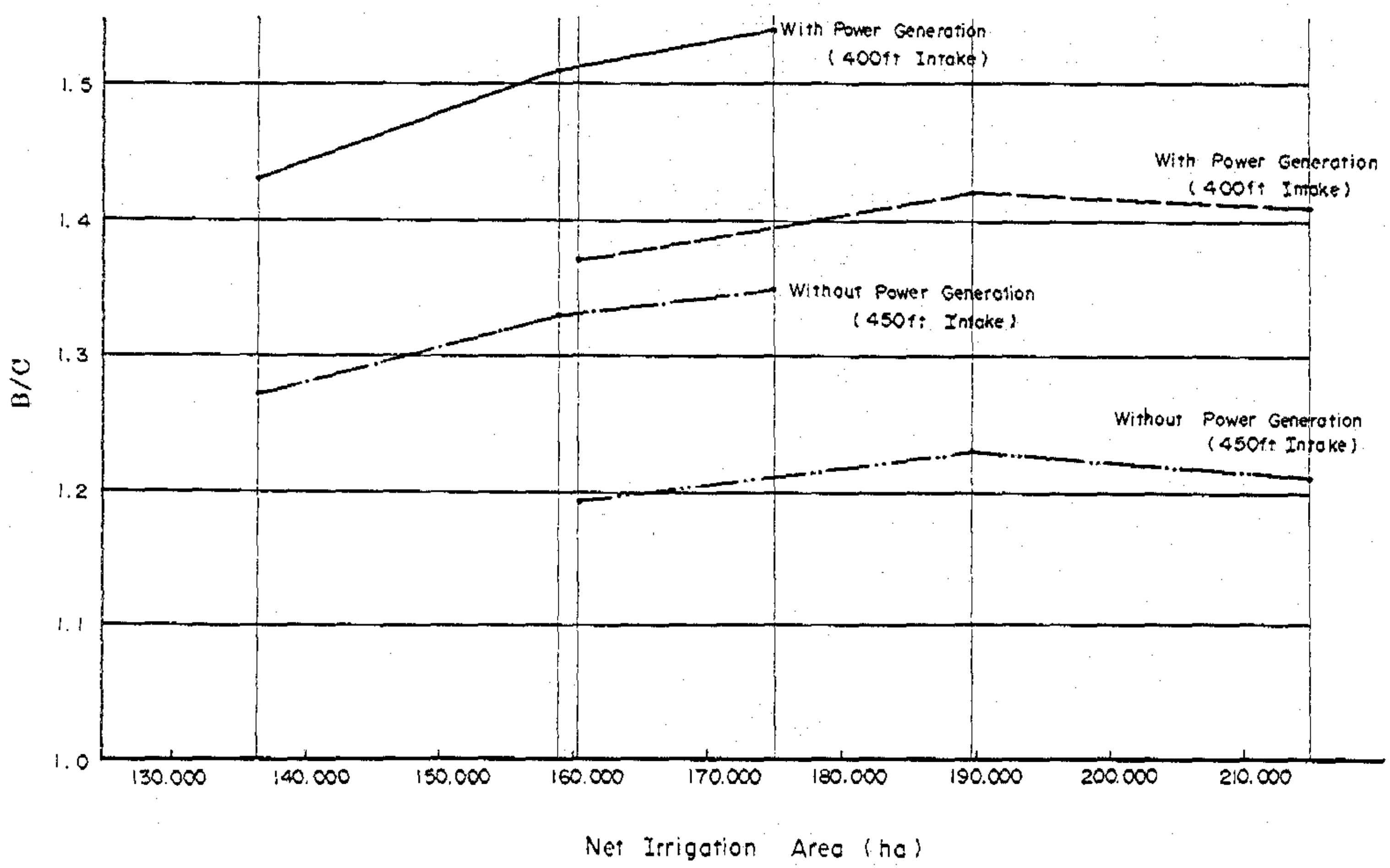
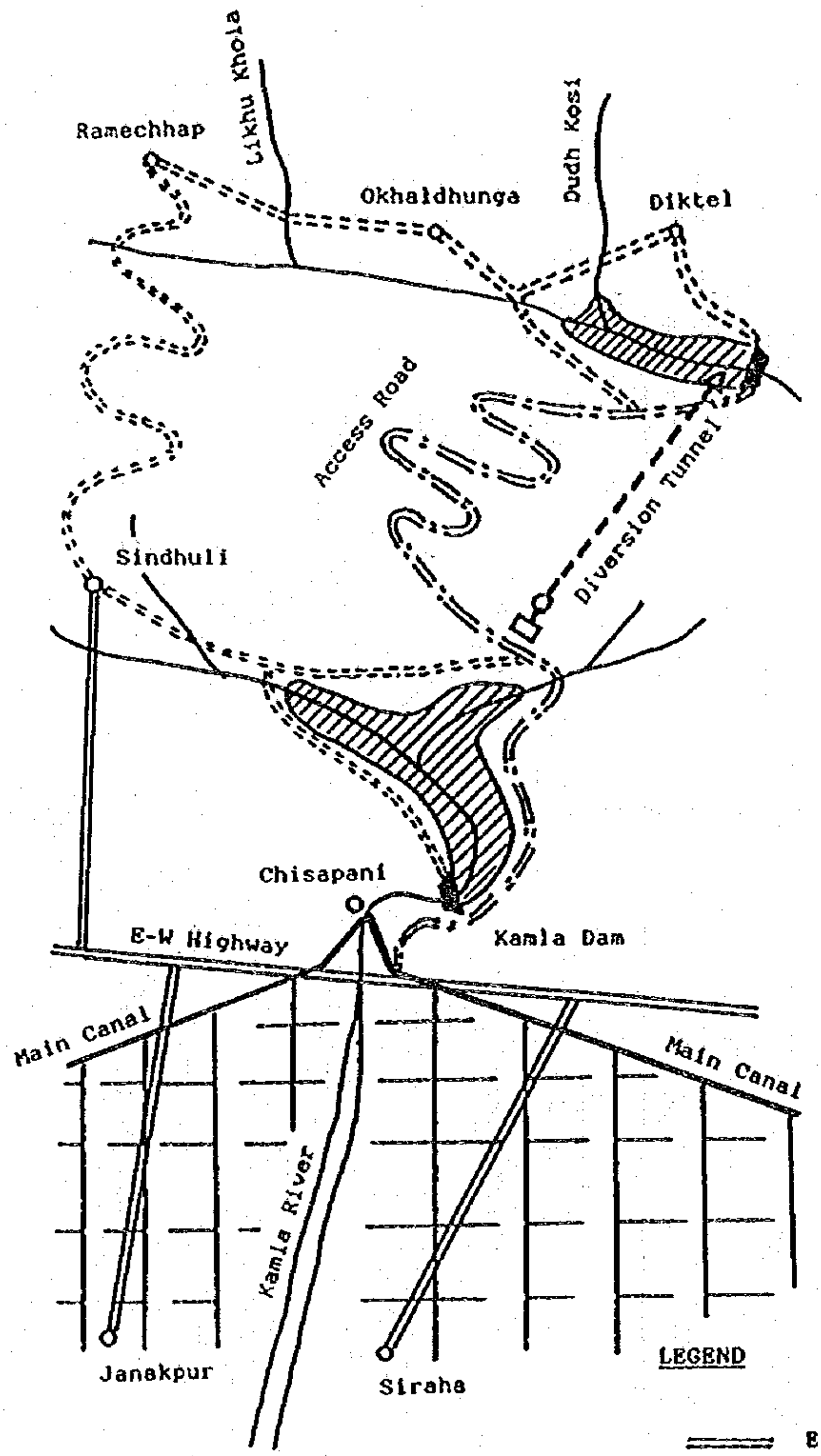


FIG. 5-3-10 B/C RATIO OF EACH PLAN FOR SUN KOSI MULTIPURPOSE SCHEME



Components to be developed

HILL

- Road and Transportation
- Electrification
- Agriculture
- Soil Conservation and Afforestation
- Inland Fishery
- Others

INNER TERAI

- Soil Conservation and Afforestation
- Agriculture
- Electrification
- Road and Transportation
- Inland Fishery
- River Training
- Others

TERAI

- Agriculture
- Flood Mitigation
- River Training
- Electrification
- Road and Transportation
- Small and Medium Industries
- Others

LEGEND

Existing Road

Access Road

Expected Extension Road

FIG. 5-3-11 EXPECTED COMPREHENSIVE RURAL DEVELOPMENT EFFECTS INDUCED BY SUN KOSI MULTIPURPOSE SCHEME

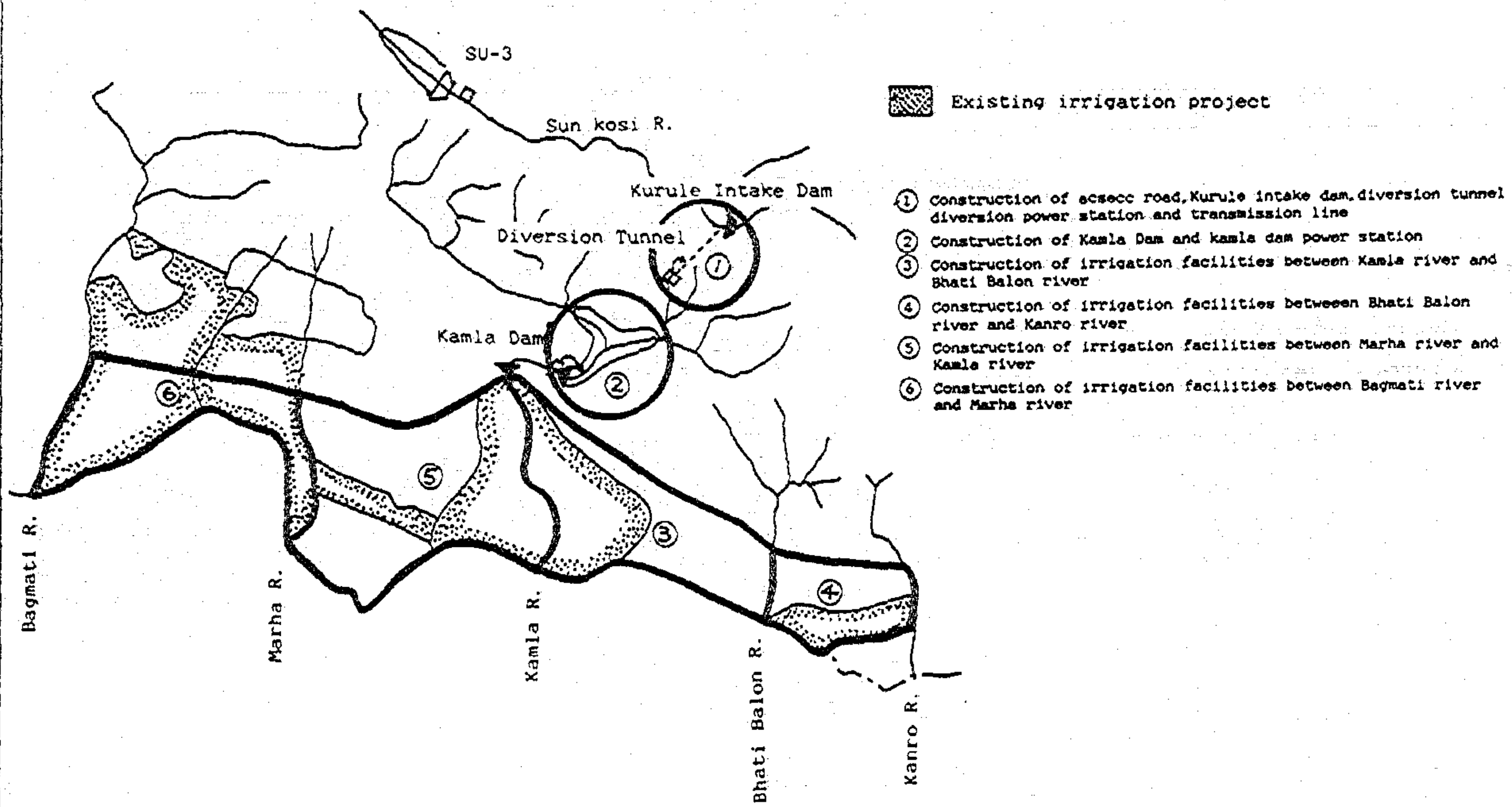


FIG. 5-3-12 DIVIDED IMPLEMENTATION WORKS FOR STAGE DEVELOPMENT IN SUN KOSI MULTIPURPOSE SCHEME

SUN KOSI MULTIPURPOSE SCHEME

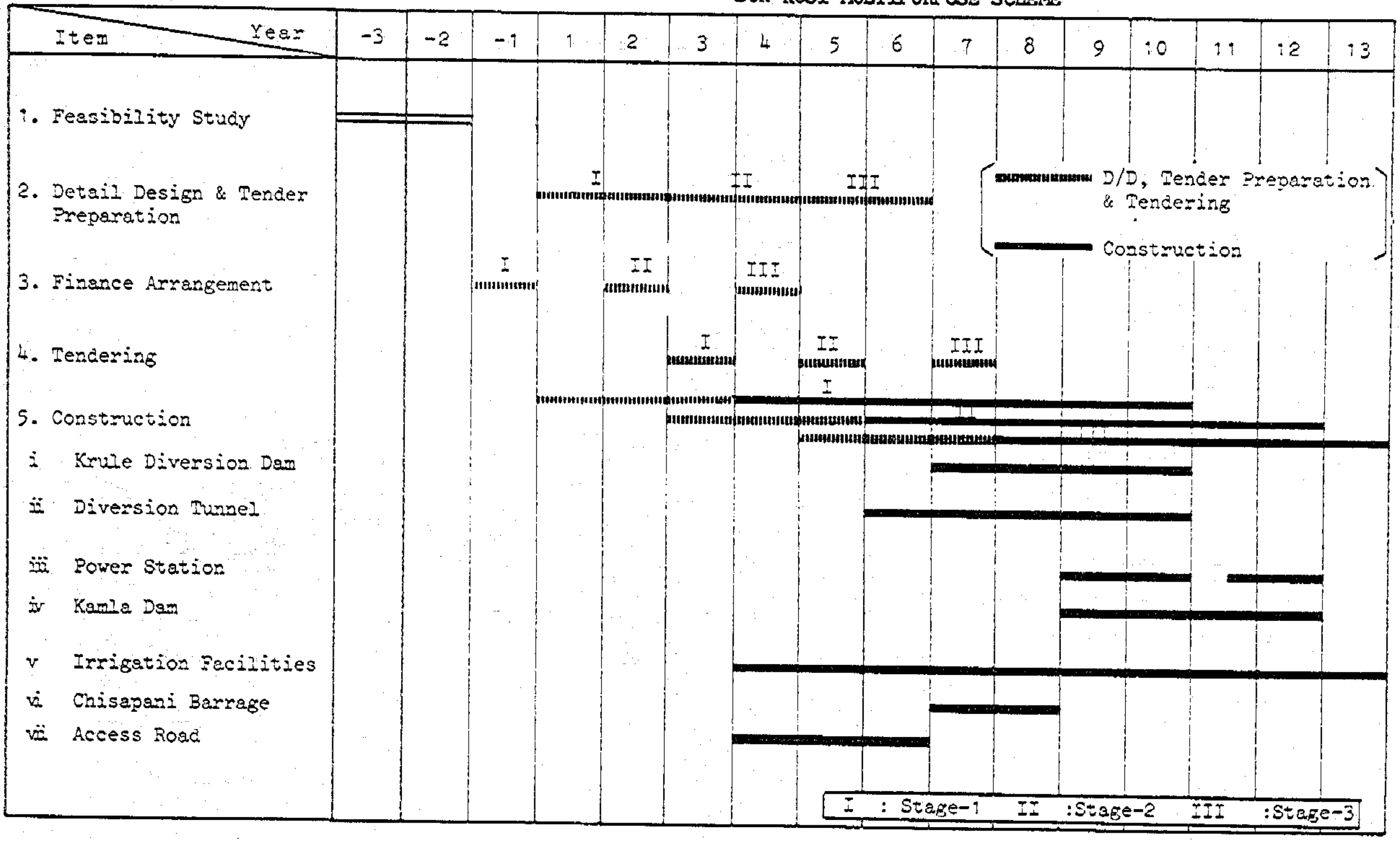


FIG. 5-3-13 IMPLEMENTATION SCHEDURE (Phase-I)

APPENDIX VI

WATERSHED MANAGEMENT AND OTHERS

APPENDIX VI

WATERSHED MANAGEMENT AND OTHERS

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WATERSHED MANAGEMENT AND OTHERS

1. WATERSHED MANAGEMENT

1.1 Soil Erosion and Sedimentation

1.1.1 Present Status of the Kosi Basin

The Himalaya Mountains, the world's highest range, is included within the Kosi Basin. This range is characterized by steep, geologically young mountains and numerous faults and folds caused by tectonic movement of the earth during formation. As the area is within the monsoon belt, there is a distinct division between wet and dry seasons. The erosion caused by these natural climatic conditions is further compiled by stripping of the natural vegetation for human activities, which speeds up the processes of erosion, sediment runoff, and sedimentation. Population increase in recent years for example has resulted in a rapid extension of cultivated land. The same has resulted in increased cutting of natural forest growth for fuel and increased grazing which have noticeably damaged the natural vegetative cover and environment of this mountain area.

The above conditions are responsible for the recurring landslides, avalanches and soil sedimentation in many spots within the Kosi Basin. Sediment discharge caused by erosion in the Himalayan glacial terrain and vast sediment discharge caused by erosion in the tributaries of the midland and the Mahabharat Mountain Range, results in massive soil sedimentation in the lower reaches of the river, particularly during monsoon season. There are riverbank protection works on both sides of the lower reaches of the Sapt Kosi River in the Terai Zone. However, cumulative layers of sedimentation over the years have resulted in a rising riverbed (1-2m), particularly on the right embankment, which poses a serious problem.

According to the studies made by Dr. C. K. Sharma, sedimentation loads (suspended loads) at the main lower streams of the Kosi River can be tabulated as presented on the following page.

TABLE 6-1-1 SEDIMENTATION LOAD OF THE SAPT KOSI

River	Catchment Area at Tribeni (km^2)	Annual Sediment (m^3)	Sediment Load (suspension) (m^3/km^2)
Sun Kosi	19,230	54,200,000	2818
Arun	36,533	34,600,000	947
Tamur	5,900	29,600,000	5,016
Total (Sapt Kosi)	61,663	118,400,000	1,920

This table is highly representative of the topological characteristics and soil production of the three basins. The Team made computations to forecast the specific sediment load for each basin. The computations were based on, among other data, charts showing the actual figures of sedimentation load measured for dams in Japan, inference formulas using the coefficient of relief estimated by the relative relief ratios of these basins, charts for relationship between the measured suspended sediment loads and water erosion, R.S. Varshney's formula, and measured data on disasters that have taken place in Japan. The results were compared with renowned cases of sedimentationand when compared with Dr. K. Sharma's figures, the same show an approximate correlation. The details are presented in FIG. 6-1-3.

1.1.2 Causes of Soil Erosion

Erosion occurs as a result of the interplay between a wide range of complicated factors. The most typical factors are shown in the flow chart on the following page.

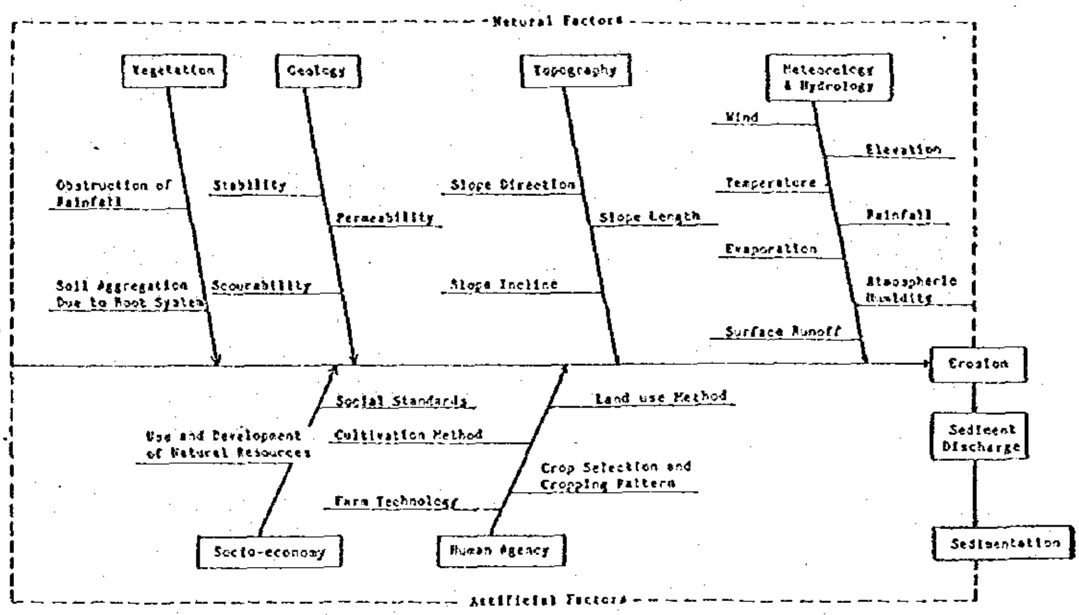

FIG. 6-1-1 FLOW CHART OF EROSION CAUSES

1.1.3 Estimation of Soil Erosion and Sedimentation

(1) Soil Erosion

The Kosi Basin is subject to recurring disasters due to water erosion and glaciation. The Basin has been producing vast sediment discharges year after year. These discharges are due to landslides, avalanche of earth and rock as well as river erosion. Soil conservation, in particular, is critical from the viewpoint of basin management including preservation of water, and is regarded as extremely important for large-scale development of water resources in the future.

There are two methods to derive quantative estimation of erosion and sedimentation which might be applicable to the Kosi Basin. One method includes use of formulas, while the other applies inference based on measured data of sedimentation that has occured at existing dams in Nepal and similar basins in the world. In the former method, existing documents dealing with sedimentation engineering provide reference. On the other hand, measured figures for sedimentation are very rare in Nepal in general, and particularly more so in the case of the Kosi Basin. As a result, the Team estimated sediment yield of the Kosi Basin by inference based on the application of reported measurements of areas and rivers with high sediment yields in the world (including Japan).

The Team made computations using the formula hereunder, to derive an approximate value of erosion. In addition, from inference based on use of a formula for sedimentation and from comparative study based on a graphic representation of actual measurements of sedimentation in other parts of the world, an estimated figure of sedimentation the Kosi Basin was obtained.

The function of the magnitude of erosion can be expressed by the following formula.

$$Sp = f\,(Xk,\ Xh,\ Xm,\ Xs,\ Xg,\ Xv,\ Xt,\ Xek)$$

where,

Sp	: magnitude of erosion
Xk	: climatic factor
Xh	: hydrological factor
Xm	: topographical factor
Xs	: soil factor
Xg	: geological factor
Xv	: vegetation factor
Xt	: artificial factor
Xek	: social and economic factor

Careful study of the above factors which are extremely complicated in their interaction, suggest how difficult it is to develop a model of erosion progress. Dr. Milos Holy conducted a study of these erosion factors and their interaction and found that the formula could be reduced into a more simple form.

$$Sp = f\,(a,\ Xh,\ S',\ L')$$

where,

a	: miscellaneous
Xh	: hydrological factor
S'	: factor of gradient
L'	: factor of slant

Dr. M. Holy carried out field tests and confirmed the formula for a gradient of 44.5% and a slant of 19.8m. Fifteen years of observation presented the opportunity for Dr. M. Holy to develop the following formula for open space.

$Sp = aq^b$

where,

Sp : loss of soil (kg/ha)
q : surface runoff due to rainfall (m^3/ha)
a, b : factors of local condition
(for surface erosion, a = 2.002, b = 1,103
hill erosion, a = 0.210, b = 2,645)

It is assumed that these two factors were developed based on the magnitude of erosion obtained on a slant when the field tests were conducted. Computations with respect to the hypsographic features of the Kosi Basin gave, on the other hand, a difference in elevation of approximately 1100-1500m/14km^2, or $1.5/\sqrt{14}$ equaling approxmately 40.1% for gradient.

This value is judged to be a close approximation to the value for the aforesaid field test (44.5%). The Team accordingly made computations to determine the loss of soil by erosion in accordance with Dr. Milos Holy's formula and obtained the following results:

$Sp = aq^b$

where,

Sp : loss of soil (kg/ha)
q : surface runoff due to precipitation ($m^3/ha/yr$)
a : 2.002
b : 1.103

On the basis of the above calculations, erosion in the Kosi Basin is presented in the table on the following page.

TABLE 6-1-2 EROSION IN THE KOSI BASIN
(Holy's Formula)

River	Sapt Kosi	Sun Kosi	Arun	Tamur
Area	61,000km^2 100%	19,000km^2 31%	36,000km^2 59%	6,000km^2 10%
Average runoff (m^3) (1948 - 1971)	50,900x10^6 100%	22,400x10^6 44%	18,300x10^6 36	10,100x10^6 20%
q (m^3/ha.yr)	8,344.3	11,789.5	5,083.3	16,833.3
Sp (kg/ha)	42,340.6	61,990.3	24,510.3	91,818.2
ΣSpw=SpxA (ton)	258.3x10^6	117.8x10^6	88.2x10^6	55.1x10^6
ΣSpv=ΣSpw÷1.7 (m^3) r=1.7t/m^3	151.9x10^6	69.3x10^6	51.9x10^6	32.4x10^6
Specific erosion (m^3/km^2)	2,490	3,647	1,442	5,400
Average erosion depth (mm)	2.49	3.65	1.44	5.40

(2) Sedimentation

Sedimentation phenomena are dominated by many elements, such as catchment area, geology, topography, surface soil covering, hydro-meteorological condition, hydraulic characteristics of the river course, various artificial actions, surroundings of envisioned reservoirs, location, scale, shape hydraulic property, water level fluctuation, characteristics of transported sediment, trap efficiency and time. All are multiplex correlative phenomena. Therefore, it is generally, difficult to estimate exact sediment discharge and condition of sediment distribution.

The Team made computations to estimate specific sedimentation in the Kosi Basin. The results of the different methods are summarized in TABLE 6-1-3. As tabulated in the said table, the Team made calculations to estimate the sedimentation for each river in the Kosi Basin based on collected data and survey results obtained during the survey period. Further summarization was achieved through use of recorded measurements of sedimentation throughout the world. As a result, the following equation was developed and used to estimate the sediment yield at each river in the Kosi Basin.

$$Qs = \alpha A^{-\beta}$$

where,

Qs	:	sedimentation (m^3/km^2 per year)
A	:	catchment area (km^2)
α, β	:	factors

Each of the above factors might represent what has been determined by natural erosion and artificial factors inherent to the particular rivers.

Although actual sediment yield should represent the sum of suspended load and bed load, a proper method to determine the bed load is not available. In many documents and papers, the suspended load is given as the value increased by 20-30% to allow for bed load. In the present study, the results obtained from nine different case calculations are given in diagramatic form (FIG. 6-1-2). Judging from the trends of the diagram, bed load largely equivalent to 20-30% of the suspended load is considered appropriate only for maximum values of suspended load.

The specific sediment yield-catchment area curve in FIG. 6-1-2 has an approx. parallel inclination with $Qs = 1.534 \times 10^4 A^{-0.264}$ according to Dr. Varshney's formula. Since the Kosi Basin is situated in Nepal to the north of India, the Team has proposed the following formula, which allows for suspended load of maximum value range and which shows some parallel relation with Varshney's formula as shown in FIG. 6-1-2.

$$Qs = 3.8104 \times 10^4 A^{-0.264}$$

where,

Qs	:	annual specific sediment in $m^3/km^2/yr$
A	:	catchment area in km^2

The sediment yield of each river in the Kosi Basin was computed using the above formula, and the results are tabulated below.

TABLE 6-1-4 **APPLICABLE SPECIFIC SEDIMENT LOAD**

River	Sapt Kosi	Sun Kosi	Arun	Tamur
Catchment area (km^2)	61,000	19,000	36,000	6,000
$Qs=3.8104x10^4A^{-0.264}$	2,078	2,827	2,388	3,823
m^3/km^2yr	2,100	2,850	2,400	3,850

The figures shown in the above table also take into account the results of analyses made on sampled specimens and surveys conducted on the rivers of the Kosi Basin and consequently the same are considered sufficiently applicable estimatation of specific sedimentation. However, application of this formula to other rivers in Nepal should be effected with care since the factors have a rather large range, as shown in FIG. 6-1-2.

FIG. 6-1-3 plots, by way of illustration, the relation between specific sediment yield and catchment area of some rivers in Japan, those with relatively high sediment yields in China and other renowned examples. The figure also provides a useful comparison with estimated specific sediment yields of the Kosi Basin. Comparison between the foregoing table and FIG. 6-1-3 indicates that Kosi Basin estimations are larger than any of the largest specific sediment yield figures for the Japanese river system, more closely approximating the larger values of the Chinese river system. The same can therefore be included among the larger figures for renowned examples of sedimentation throughout the world.

The Kosi Basin is thus characterized as a river in a severe state of erosion owing to natural conditions (vegetation, geography, topography, climate) as well as artificial conditions, and the values of specific sediment yield estimated by the Team are considered to accurately reflect this fact.

Designed values of sediment yield for Nepalese dam sites and sediment load (existing, under planning, and surveyed) are shown in TABLE 6-1-5, 6-1-6, and FIG. 6-1-4.

1.1.4 Investigation of Landslides

The Team endeavored to obtain the present status of landslide conditions in the Kosi Basin. Investigation was carried out by using topographical maps with a scale of 1 : 50,000 and aerial photos with a scale of 1 : 80,000 and 1 : 20,000.

The following aerial photos[1/] were also used:

- Tama Kosi River Basin	18 sheets of 14 scenes (scale 1/80,000)
- Dudh Kosi River Basin	14 sheets of 10 scenes (scale 1/80,000)
- Arun River Basin	12 sheets of 9 scenes (with six 1/20,000 scale photos of 5 scenes)
- Tamur River Basin	11 sheets of 9 scenes (1/20,000 scale photos)

The investigation areas were selected in the area along the river where hydropower projects are planned, the total area being 3,054km² which is 5% of the entire basin. The results of the investigation are detailed in TABLE 6-1-7 and 6-1-8. It was estimated from the same that approximately 3% of the basin is assummed landslide area, with the most heavy landslide area, approximately 14% found in the Tamur River basin.

1.2 Mitigation of Soil Erosion

1.2.1 General

Mitigation of soil erosion is not only essential for preservation of land and protection of environment but also for exploitation of natural resources. The objective of soil erosion mitigation is to preserve, among other things, water and soil, the most important natural resources, and

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1/ Since: 1 scene = $90km^2$, in $\frac{1}{80,000}$ photo

1 scene = $6km^2$, in $\frac{1}{20,000}$ photo

thereby protect a wide range of areas related to the national economy (farming, water supply management, living environment) against the possible effects of water and soil deterioration.

The four basic approaches to mitigation of soil erosion are:

- technical approach for agriculture and forest
- technical approach for prevention of surface runoff
- technical approach for prevention of concentrated discharge
- chemical

The objectives of mifigation are preservation and improvement of the natural environment (water and soil), and preservation of the social environment. Since mitigation of erosion in the Kosi River Basin in Nepal is expected to demand a substantial investment, it may be advisable to divide the tasks for the same into two parts -- long-term and short-term -- as shown in the flow chart presented in FIG. 6-1-5.

1.2.2 Agricultural and Afforestation Technology

The agricultural and afforestation technologies employed in mitigation of soil erosion include appropriate location of cultivated areas, effectively designed land classification, improvement of traffic network, conservation in field and forest, and utilization of vegetation as a protective covering. In this connection, the items below may be considered.

(1) Shape, Area and Location of Arable Land

The shape, area and location of arable land should be in harmony with nature, adapted to local conditions of water and wind and made to follow the natural terrain.

(2) Traffic Network

Roads should be constructed along the ridge of a mountain or its vicinity, avoiding the hillsides where construction could cause or encourage landsliding.

(3) Tillage

In an area subject to soil erosion, tillage should be practiced along the contour line (contour plowing) to prevent run-off of soil.

(4) Protective Vegetation

Protective vegetation should include at least the following:

a) Crop rotation: systematic planting for periodic shifting of crops in a particular field patch;

b) Strip farming: Alternative protective and protection strips;

c) Preparation of grassland: Areas subject to soil erosion, unless inclined or afforested, should be made into permanent grassland;

d) Reserve forest zone: Where land is subject to extremely severe soil erosion and is unsuitable for farming, it should be prepared as a reserve forest zone of sufficient size to provide effective protection to neighboring arable land (windbreak, penetrative woodland, shade forest); and,

e) Afforestation: Reafforestation should be effected while limiting timber cutting. Current management of woodland capable of prevention of soil erosion needs to be reconsidered.

(5) Education Program

An education program for environmental preservation at schools and social education institutes should be developed.

1.2.3 Technical Approach for Prevention of Surface Runoff

Preservation of soil can be achieved by improvement of the gradient and oblique length of slopes thereby creating the condition where water infiltrates underground without pooling on the surface or resulting in surface runoff.

Technical approaches to soil preservation may be divided into the following 6 categories:

a) Creation of penetrative zones (continuous penetrative channel of large width) in the hillside oblique section by planting bushes and shrubs;

b) Construction of protection works where fields extend in a wide belt along the contour line, to limit the flow of water in a direction perpendicular to the contour line;

c) Construction of short-cuts (water collecting channels) in a hillside oblique section;

d) Earthwork to prevent erosion (water collecting earthwork) in a hillside oblique section;

e) Improvement of terraced fields (earth-banked terraced fields, masonry terraced fields) into a rigid structure; and

f) Construction of drainage canals that permit drainage of surface water into the nearby rivers.

In addition to the above-mentioned approaches, sufficient consideration should be given to soil preservation in future excavation of rivers in the region of the Basin, improvement of traffic networks, and the construction of irrigation systems.

1.2.4 Technical Approach for Prevention of Concentrated Discharge

Concentrated discharge causes gully erosion, the most devastating type of river erosion. Measures aimed at prevention of surface runoff are effective in preventing gully erosion. Such measures include utilization of agricultural and botanical techniques in efficient combination with civil engineering techniques.

Civil engineering approaches to the control of concentrated discharge include among others the following items.

(1) Check Dam

Check dams serve to reduce the speed of surface runoff thus preventing gully erosion in the lower reaches of a river. The same also impoundloose sediments and stabilize the riverbed.

(2) Countermeasures for the Gully and Valley Beds

The principal countermeasures include valley top and bed solidification works, which are subdivided into embankment works, valley bed improvement works, and slope stabilization works. Digging and expansion of gully and valley beds should be prevented, and slopes should be stabilized by replanting.

(3) Countermeasures for Mountain Torrents

Concentrated surface runoff is capable of eroding the bed and banks of a gorge, producing and moving earth and sand. Countermeasures include prevention of discharge by improving the conditions of the basin and mitigation of the gorging effects of flowing water by improving the gradient of the torrent bed.

(4) Improvement of Drainage Facilities in Terraced Fields

The drainage facilities in terraced fields are in some cases several centuries old. In addition, recently constructed facilities are poorly maintained. Accordingly drainage facilities should be surveyed and rehabilitated where necessary.

As for agricultural and botanical measures, there are many Hill areas that have been developed in the Kosi River Basin. The entire Basin has an area of almost 60,000km^2, with nearly 33,000km^{2}in the Nepalese portion, and farming dominates 6,000km^2 or 18.3% of the latter.

TABLE 6-1-9 and 6-1-10 show the status of population and land utilization in the Study area. Agriculture has mainly been discussed in relation to the problem of food supply. In Nepal, however, farming also functions to protect the natural environment. When well-managed farmland receives heavy rainfall, it is discharged slowly and it is estimated that existing farmland is capable of sustaining up to 300 million tons of water in the assumed reservoir depth of 5 centimeters. Terraced fields, apart from their natural role of crop production, help to prevent floods and thus preserve land and vegetation by functioning as a water reservoir.

Where management of farmland is inadequate, and the catchment and drainage of water is poor, a long period of rainfall produces concentrated discharge, which carries off loose earth and sand in addition to runoff discharge. The Sapt Kosi River is subject to recurring sediment discharges of huge volumes flowing from the upper reaches to the 3 major rivers. Although this is often attributed to concentrated heavy rainfall and unorganized deforestation, poor management of farmland in the paddy and terraced fields in addition to improper catchment and drainage of water therein is also believed to be responsible.

Apart from the paddy and terraced fields, woodlands, plains, grasslands and grazing lands are all considered to have inherent reservoir-type water retention capacity and thereby help prevent soil erosion. Poor management of woodlands, plains, grazing lands and farmland is associated with the inability of the Basin to preserve soil and water adequately and, thus, is a cause of erosion of mountain surfaces and farmland during concentrated heavy rainfall. This has resulted in a vicious cycle of developing new terraced fields and subsequent destruction of the natural environment with loss of topsoil, due to failure to exploit the water retention capacity of paddy and terraced fields.

Agriculture then, through well managed paddy and terraced fields, can preserve water supply sources, purify the air and maintain the natural environment. Consequently, it is important to improve and restore inherent water retention capacity, with emphasis on improvement of existing paddy and terraced fields in the Hill Area and related catchment and drainage facilities.

1.2.5 Chemical Erosion Control

Slopes produced by various types of construction works such as the improvement of rivers or roads, development of housing sites, or exploitation, are subject to severe erosion until they are stablized.

Erosion of slopes is seen on the oblique sides of roads. The construction of permanent slope protection by various planting techniques on these slopes requires a long time. Therefore, as a temporary method of protection, chemical erosion control is often employed. Use of high polymer materials for chemical erosion control is known to be an effective means to minimize erosion. However, care should be taken to guard against possible pollution from the same. These high polymer materials include petroleum derivatives and secondary products such as asphalt, polyethylene, resins, and other materials containing polyolefin, synthetic rubber, latex, prevulcanized latex, emulsion, and bitumen. These materials are highly thermally stable and highly resistant to oxidization. Moreover, these materials harden the surface soil very easily, waterproof the soil particles, and serve to reduce evaporation of water.

1.3 Improvement of Devastated Area

1.3.1 General Countermeasures

Efforts to improve the devastated areas in the Kosi River Basin are directed at mitigating the vast discharge of soil and sand which occur as a result of landslides, surface erosion in hill areas, avalanche of earth and rocks, and washouts. The frequent occurence of these phenomena is due to the particular topographical and geographical features inherent to the region.

The Himalaya area is a stratification of alluvial soil raised in violent foldings that caused the old layers to move from the south and overlap onto the new layers. The upheaval of the Himalayas resulting from orogenic movement in the remote past caused violent erosion and the deposit of vast quantities of sand and rock at the bases of the mountains and on the marine floor. The layers produced during this immature period are subject to severe erosion during the monsoon period (May to October).

Applicable methods for improvement of the devastated Hill Area are presented in FIG. 6-1-6 and consist of hillside and torrent works.

1.3.2 Approach to Protection from Landslide

Rough estimation of landslides is presented in section 1.1.4. Many landslide spots and collapsed mountain slopes were observed in the Kosi Basin during the study period. It will require an extensive time period and large investments to protect the lands from the same and thereby establish a stable basin. A step by step program, however, is required.

The Team carried out a landslide protection works study at some sampled places selected from a unit area of $100km^2$ from the vicinities of high priority projects sites; (Sun Kosi No. 3, Tama Kosi No. 3 and Arun No. 3). A profile of protection works and rough cost estimates at each site are tabulated below.

TABLE 6-1-11 PROTECTION WORKS PER SAMPLES $100km^2$

Unit: US$

	Sun Kosi	Tama Kosi	Arun
1. Area of landslide	80ha	1,390ha	350ha
2. Protection works			
(1) River revetment	7,800m	18,000m	12,000m
(2) Spare works	850m	1,960m	1,300m
(3) Gabion check dams	68 sites	1,750 sites	253 sites
(4) Consolidation dam	6 sites	114 sites	17 sites
(5) Slope protection	80ha	1,390ha	350ha
3. Estimated cost			
(1) Mountain slope	300,000	5,056,000	1,243,000
(2) Stream and river	300,000	1,140,000	408,000
(3) Total	600,000	6,196,000	1,651,000

Rough cost estimate of erosion and torrent control indicates that an average investment of 3 10^6US$/100km^2 will be required.

The above cost estimates preliminarily represent direct construction costs. The area for which erosion countermeasures are required, excluding the Kosi Basin in Tibet and glacier areas, is roughly 33,300km^2 and the cost for the same will therefore be about 1,000x10^6US$. Such an amount would be the minimum requirement for soil erosion protection.

1.3.3 Watershed Management Recommendations

As aforementioned, watershed management of the Kosi Basin is a large-scale project requiring substantial time and large investments. On the other hand, water resources development, particularly hydropower development, in the Basin has potentially great returns. Hydropower development is expected to provide the opportunity to improve the Basin's watershed. It is recommended that after commissioning of relevant power station operation, 5% of the generated value of the hydropower project should be used for Basin watershed management.

Watershed improvement for Sun Kosi No. 3, Tama Kosi No. 3 and Arun No. 3, were studied. The investment costs and time requirements for the improvement of their respective basins are provided in the table below. A rough estimation of the required investment cost was made on the assumption of 3x10^6US$ per 100km^2 for watershed protection and maintenance works.

TABLE 6-1-12 INVESTMENT COST AND TIME REQUIREMENT FOR WATERSHED IMPROVEMENT OF PRIORITY SCHEMES

	Unit	Sun Kosi No.3	Tama Kosi No.3	Arun No.3
C.A.	km^2	5,520	2,753	32,332
Installed capacity	MW	536	123	240
Energy cost	US ¢/kWh	4.35	5.77	2.29
Expected annual sales of energy at site	10^6US$	90.0	34.8	45.0

TABLE 6-1-12
con't

	Unit	Sun Kosi No.3	Tama Kosi No.3	Arun No.3
5% of annual sales	10^6US$	4.5	1.7	2.3
Protected area[1/]	km^2	5,000	2,500	4,500
Required investment cost	10^6US$	150	75	135
Required time	year	33	44	59

1/ Protected area excludes the Tibetan and glacier area.

The above expenditures are indispensable for water resources development from the viewpoint of maintenance and improvement of water resources in the devasted Basin. Furthermore, the same will create employment opportunities for local labor. With regards to present conservation in the Kosi Basin, the following table was adopted from the LRMP, Draft Land System Report, 1983, and clearly illustrates the need for watershed management.

TABLE 6-1-13 **SOIL EROSION RATE**

Type of Land	Soil	ton/ha/yr	($m^3/km^2/yr$)
Well managed	Forest land	5	(312)
Well managed	Bench terrace	10	(625)
Poorly managed	Sloping terraces	20	(1,250)
Degraded	Range land	40	(2,500)

To realize watershed protection and maintenance through the above plans will require further study. Upon implementation of a concrete project, an appropriate organizational framework will be established and a watershed management center should be set up at the respective hydropower development sites.

1.4 Afforestation

1.4.1 Background

Natural erosion is estimated to account for half the erosion in the Hill Area[1/] and is partly a result of the exceptionally heavy monsoon rainfall patterns prevailing in the same. The huge amount and considerable speed of runoff from precipitation and snow melt results in a natural erosion process which has far-reaching effects.

Man-made erosion, which is responsible for the other half of total erosion in the Hill Area, is primarily the result of high population density, friability of soils, cultivation on steep slopes without adequate soil conservation measures[2/], overgrazing of mountain pastures and forest lands, and scavenging for fuel wood and fodder. Although about 87% of all wood is used as fuel, forests are also important to the people in rural areas as a source of fodder for livestock. It has been estimated that 75% of feed requirements are met from forest, grassland and trees in rural areas. Commercial and non-commercial energy consumption by types of fuels is tabuluated in TABLE 6-1-14.

TABLE 6-1-14 TOTAL COMMERCIAL AND NON-COMMERCIAL ENERGY CONSUMPTION BY TYPES OF FUELS (1974/75)

Fuels	Coal Ton Replacement	%
A. Commercial		10.74
1. Coal	64,480	0.90
2. Petroleum Fuels	613,546	8.58
3. Electricity	90,331	1.26
B. Non-Commercial		89.26
1. Fuel wood	6,204,000	86.78
2. Husk	86,000	1.21
3. Dung cake	28,800	0.39
4. Vegetable Wastes, etc.	62,757	0.88
Total	7,149,114	100.00

Source: Energy Sector Study by University of Tribhuvan, 1976.

1/ FAO/UNDP Watershed Management Project Studies, 1977.

2/ Although terraces are highly developed in the Hills, manpower required for adequate maintenance is high and in many areas, terraces are inefficient because of insufficient maintenance.

This consumption of wood for fuel, etc. accelerated more erosion of the hill or mountain slopes. Forest area has declined from 45% in 1964 to 34% in 1974 and only 29% now remains[1/]. Studies by a Rural Energy Sector Study Team from the Tribhuvan University in Kathmandu indicate that if the present rate of forest destruction is continued, pressures of increasing population and fuel wood and fodder demands would result in the complete disappearance of all accessible forest in the Hills in the next 12-14 years and in the Terai Area in 15-20 years.

In short, the most critical problems arising from deforestation are those associated with loss of topsoil and potential agricultural land thereby leading to declining food crop production and secondly, the adverse effect of increased stream runoff on water supplies in the Hill Area, and resultant downstream flooding effects.

Sheet, gully and landslide erosions, together with the scouring effect of torrents and streams, produce sand and silt in huge quantities, which are transported to the Terai and Gangetic plains. If these slopes are exposed to violent monsoon downpours without protective vegetation, fertile soils from the same may be lost forever and their potential usefulness permanently reduced.

Sand and silt are deposited when river flow velocity is reduced, as when rivers flow into the plains, for example, and these deposits constantly raise the riverbed. According to Nepalese observers, the beds of Terai rivers are rising by 15 to 30cm annually[2/]. This leads to flooding as well as to considerable shifts in the course of the rivers.

For example, it has been estimated that the total silt volume removed by the Karnali River amounts to $75^{10^6}/m^3$ annually, equivalent to a 1.7mm layer, for the whole catchment area, while preliminary estimates indicate that erosion ranges from 30-75t/ha/yr[3/]. Thus, in total, Nepal

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1/ Country Monograph (Nepal) ESCAP, 1984. Export Group Meeting on the Integration of Environment into Development

2/ HMG, Draft Proposals of Task Force on Land Use and Erosion Control, 1974

3/ IBRD, Nepal Agricultural Sector Survey, Vol.III, Annex 6, Pg.2.

may be losing as much as about 240$10^6$/m^3 of soil annually[1/]. Topsoil washing into India and Bangladesh is now Nepal's most precious export, but one for which it receives no compensation.

1.4.2 Role of Afforestation

With the continuing deterioration of forest wealth, the mountain ecosystem has been badly affected. Numerous publications and study reports have drawn the world's attention to the serious erosion problems of the Himalayas affecting the lives of millions of people in the Gangetic plain. However, a recent study has shown that in the larger part of Nepal, environmental degradation has not become irreversible. Stabilization of the soil is possible if appropriate measures are taken for the development of a stable land use system[2/].

Although the potential for erosion in the Kosi Basin is greater, as mentioned above, such erosion is not due to man-made causes alone. The area has been subject to flooding and silting for at least the last 200 years. This is a natural cycle and will continue to occur[3/]. In the Hill Area, therefore, if there are no accompanying changes in land use practices, the effect of soil and water conservation works on the Sapt Kosi, even if they are implemented on a large scale with high investment, will not be very significant.

In spite of this, erosion problems must not be ignored. A distinction should be made between natural, inevitable erosion and accelerated man-caused erosion. Accelerated erosion occurs with sediment runoff from bare agricultural land, sparsely cropped areas, light or overgrazed forests and abandoned land.

Badly eroded areas and large landslides are found in the Sapt Kosi River catchment area as well as many other parts of Nepal. Considering

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1/ Country Monograph (Nepal) ESCAP, 1984. Export Group Meeting on the Integration of Environment into Development.

2/ A reconnaissance inventory of the major ecological land units and their watershed condition. Summary Report. FAO, 1980.

3/ The Sapt Kosi Unsolved Problems of Flood Control in the Nepalese Terai. HMG/FAO/UNDP, 1979.

the very steep, rough topography of this young mountain area, however, it is surprising that the situation is not worse. New vegetation grows very quickly over steep rocky landslides in the Hill Area so that often a landslide can scarcely be identified after 1-3 years. Recently much has been written about erosion in Nepal, and it is possible that the problems of erosion have been somewhat exaggerated. Rather than conducting a new study of erosion, however, some clarification of the work already completed is required[1/]. The best method to combat soil erosion is large scale afforestation, a reduction in deforestation and better forest management.

1.4.3 Present Afforestation Projects

In order to ensure a sustained supply of fuel wood and fodder, as well as building materials for the rural population and to improve soil and water conservation, HMG has designed and implemented many integrated development projects in the various districts especially in the hill districts. One of the components of the same is the development of existing forests and extension of forest area by afforestation with participation of the rural people.

The various Integrated Rural Development projects (IRD projects) as well as the Community Forestry Development project presently in operation and their financing agencies are listed below:

- Rasuwa-Nuwakot IRD	World Bank/HMG
- Kosi-Hill Area Rural Development Project (KHARDEP)	UK/HMG
- Sagarmatha IRD	Asian Dev. Band/HMG
- Nepal-Australia Forestry Project (NAFP)	Australian Govt./HMG
- Integrated Hill Development Project (IHDP)	SATA/HMG
- Resource Conservation and Utilization Project (RCUP)	USAID/HMG
- Tinau Watershed Project	GTZ/SATA/HMG

1/ F. Zollinger; Analysis of River Problems and Strategy for Flood Control in the Nepalese Terai. FAO/MHG/UNDP, NEP/74/020, IWM/WP/12.

- Rapti Area Development Project — USAID/HMG
- Karnali-Bheri IRD (K-BIRD) — CIDA/HMG
- Community Forestry Development and Training Project (CFDTP) — IDA/USAID/UNDP/HMG
- Ratuwamai Afforestation Project — Self-financed
- Forest Survey & Research Project — Self-financed
- Afforestation Project — Self-financed
- Resin & Turpentine Project — USSR
- Silvicultural Research Project — ODA

Each of the above projects covers from one to 29 administrative districts in the Hill Area. All 55 hill districts of Nepal are covered by these projects sector projects combined[1/]. All districts in the Hill Area of the Kosi Basin are covered by afforestation programs in the above listed projects. Each district has its own projects exclusively involved with the afforestation program as tabulated below.

TABLE 6-1-15 **AFFORESTATION PROJECTS BY DISTRICT**

Project	District	Zone
KHARDEP	- Sankhuwasabba	Kosi
	- Dhankuta	"
	- Terathum	"
	- Bhojpur	Sagarmatha
Sagarmatha IRD	- Udyapur	Sagarmatha
NAFP	- Sindhu-Palchok	Bagmati
	- Karve Palanchok	"
IHDP	- Dolkha	Janakpur
CFDTP	- Ramechhap	Janakpur
	- Sindhuli	"
	- Solukhumbu	Sagarmatha
	- Okhaldhunga	"
	- Khotang	"
	- Taplejung	Mechi
	- Panchthar	"
	- Ilam	"

1/ Introduction to Policy, Legislation and Programmes of Community Forestry Development in Nepal, 1982.

1.4.4 Development Program

In the Sixth Plan (1980-85), one of the 3 objectives for the forest sector is Conservation of Natural Resources consisting of ways and means of preventing or retarding natural disasters such as soil erosion, floods and landslides, protection of soil fertility, and safeguarding of rivers and rivulets. For this purpose, high priority has been given to works relating to soil and catchment area conservation and scientific land use, and such works will be conducted with special emphasis on local participation.

Top priority has been given to community forest development and afforestation programs, which are being conducted in the mountainous region as mentioned above. The principal physical targets in the forest sector in the Draft Sixth Plan are tabulated below.

TABLE 6-1-16 **TARGET AREA FOR AFFORESTATION**

Programs	Unit	Target
Conservation and Improvement of Forests	ha	82,189
Afforestation	ha	42,872

Source: The Sixth Plan (1980-85), Part 1 (A Summary), 1981

As of 1982, 14 major afforestation works are to be executed by the Forest Department during the Plan and are intended to cover an area of 71,427ha on both a self-financed and donor assistance basis. This target is ambitious however, in view of the modest afforestation performance during the Fifth Plan. That is, in spite of the 20,000ha afforestation target during the Fifth Plan, actual achievement was only 9,864ha, mainly due to lack of organization, manpower and financial resources. Actual expenditures on afforestation during the Fifth Plan were only 4.6% of the total outlay on forestry.

In the 15 years of development planning only about 20,000ha have been afforested in Nepal whereas during the same period more than 2 million ha of forest have disappeared[1/].

1.4.5 Conclusion

As mentioned above, afforestation is a most urgent need of national development in Nepal. There are many countermeasures that can be used in the development approach. however, substantial investment and manpower will be required.

In these circumstances, parallel with the present efforts of afforestation, rapid extension of fodder trees should be made immediately by Government activities for soil conservation, supply of fodders and fuel.

Afforestation by planting fodder trees in comparison with other trees is an easy and low cost task for farmers. Fodder trees can be planted anywhere, including footpaths between farm fields, surrounding farm houses, terraces and/or steep slopes. Adaptable fodder trees should be selected and recommended by the Government for propagation and planting as a special urgent countermeasure. Such a program would be helpful to meet farmers' basic requirements and environmental protection at a low cost.

1/ Nepal Agriculture Sector Strategy Study, Vol II, ADB, 1982

2. RIVER MANAGEMENT

2.1 Survey Results Near the Junction of the Trijuga and Sapt Kosi Rivers

As shown in FIG. 6-2-1 and 6-2-2, the Trijuga River joins the lower reaches of the Sapt Kosi River about 21km upstream of Bhimnagar Barrage located on the Indian border. The Trijuga basin has an area of approximately 800km^2. The Chandra Canal barrage is situated on the Trijuga River about 7km upstream of the confluence with the Sapt Kosi River. The Chandra Canal runs southeast, almost parallel with the Sapt Kosi River. In the area between the Sapt Kosi River and the Canal, there are numerous farm villages and cultivated fields.

The barrage has five gates, apart from emergency gates provided for floods and discharge of excessive soil and sand. The gradient of the riverbed in the upstream direction at this point is approximately 1/1000 to 1/1500. The front of the dam is almost imbedded in sand and soil except for the flume inlet gate side. The Team learned from interviews during the survey that seasonal flooding raises the water level some 1.5m above the top of the dam every year. During dry season, on the other hand, the inlet gate of the flume takes most of the river water, leaving the river downstream of the dam more or less dried up.

The Trijuga River is subject to erosion along both banks downstream of the barrage since the water level rises against the right bank during a flood. Farmland is annually eroded, although slightly, on the right side of the river. Since those settlements in the vicinity of the Sapt Kosi River junction have fields more than 1m above the flood water level of the Sapt Kosi River, no flood damage has been reported to lives or property in the past.

The junction of the Sapt Kosi and Trijuga River is separated from the Bhimnagar Barrage by about 21km. The Sapt Kosi River has no embankment more than 9km upstream of the barrage because the right bank is 1-2m above the flood water levels. Instead, sluice works are installed at an interval of 2-3m. The river was embanked by India over the remaining 12km with sluice works at 1-2km interval. Detailed information is presented in charts devised in accordance with the survey results.

2.2 Review of the Survey Results

Upon review of the survey results on the west embankment of the Sapt Kosi River, six points along the river were determined to require rehabilitation (FIG. 6-2-1).

Construction of additional protection works is unnecessary along the Sapt Kosi River for about 12km upstream of the Bhimnagar Barrage as this section is completely embanked along the right (west) side with closely situated cross levees and no damage has occured due to flood in the past.

The six points which require rehabilitation and a description of the necessary work are presented hereunder.

(1) A 10m section of embankment about 7km upstream from the Bhimnagar Barrage has been damaged apparently by drainage from nearby fields. Repairs of the revetment as well as of neighboring drainageways are necessary in this section.

(2) The Sapt Kosi River lacks embankment for 9km from 12km upstream of the Bhimnagar Barrage. Although the Team agrees that embanking this section of the river is unnecessary since the elevation of the area is about 1-2m higher than the flood water level, the construction of a revetment would be desirable to prevent erosion of the river banks during floods.

(3) The section between the intake dam of the Chandra Canal Barrage to the Sapt Kosi River covers a distance of 7km. If the river is embanked for about 1km immediately downstream of the dam in this section, erosion of the river banks in the vicinity of the Tatephur Village will be prevented. No embankment is necessary for the remaining distance of 6km. However, the construction of a revetment would prevent erosion of the fields in this section.

(4) The Trijuga River is subject to less erosion along the left bank near the Chandra Canal Barrage compared with the right bank, as the latter is more exposed to flood waters. Consequently, reinforcement of the right bank with revetment works is necessary.

(5) In addition, revetment of a section of the left bank for 1km immediately downstream of the dam is required to protect the settlements on the left side of the river.

(6) The intake dam on the Trijuga River extends for about 350m. About 10m of the dam on the left bank is damaged and requires repairs.

2.3 Plan and Design of Renovative Work

2.3.1 Estimation of Flood Discharge

The catchment of the Trijuga River has an area of 800km^2. The river runs through the northern section of the Terai Zone. Although there is a meteorological gauging station in the basin of the same, the station possesses no record of weather reports about this area. Consequently, precipitation in the area could not be inferred except on the basis of available records of weather made in the area adjacent to the basin. The following three meteorological gauging stations were selected for their location near the basin and in the range of the Terai Area, and rainfall records for the same are presented in TABLE 6-2-1.

- No. 1111 Janakapur Airport
- No. 1114 Hardinath
- No. 1319 Biratnagar Airport

Frequency was inferred from available maximum precipitation recorded in the past years (1971 - 1980) obtained at these three stations.

From these records, the probability F(x) was computed using the equation F(x) = (2i-1)/2N x 100 and the results were plotted on Hazen log paper as FIG. 6-2-3. On the same Hazen log paper, there is the relationship 1/T = F(x) between the probability F(x) and the return period T from which a probable value of precipitation over 100 years for each of the three stations can be obtained (TABLE 6-2-2). Consequently, the value of x, when computed as a 100 year period probable value, is obtained as corresponding to the value of 1% (1/T = 1/100) on the axis of ordinate or where the curve intersects 1% on the axis of ordinate, as follows:

- 300/24 mm/hr for No. 1111 Janakpur Airport
- 250/24 mm/hr for No. 1114 Hardinath
- 200/24 mm/hr for No. 1319 Biratnagar Airport

From the above, the minimum value of 200/24hr was selected.

To simplify calculations, Rational's formula was employed to compute peak flood discharge. As a result, the peak flood discharge is 2,279mm^3/s in a 100 year year return period for 800km^2 C.A. of Trijuga River.

The flood discharge thus obtained shows a close approximation to existing Nepalese figures. The Nepalese figures are shown in diagram form in FIG. 6-2-4 for reference.

2.3.2 Improvement of Embankments

Using the Manning formula with roughness factor of 0.04 and river gradient of 1/744, water depth above the barrage assumed at 3.28m at 2,279m^3/s flood discharge. Since the banks of the river are currently about 2.5m high, respectively, an extension of some 0.8m or more of embankment along with revetment on both banks would be safe in the case of a 100-year period flood probability of 2279m^3/sec. The team therefore recommends the rive training works presened, in FIG. 6-2-6 and 6-2-7.

2.4 Volume and Cost of River Renovation

The cost for the construction of a cylinder/1m of extension was computed by the equation:

$$C = 22.8 \times H \text{ (US\$)}$$

where,

C : construction cost per meter of cylinder
H : height of embankment

Although H = 3.5m according to design, to simplify calculations, 4m was used. A top width of 3m was selected for the embankment design. Consequently, the approximate was computed as follows:

$$C = 22.8 \times 4 = 91.2 \text{ (US\$)/m}$$

The entire lengths of the cylinders to be constructed are 2.5km for the embankment and 15.3km for the revetment. The length of the water protection extension is 1.7km = 10m x (3 + 14). From the above, the entire length of the cylinders is (2.5 + 1.7 + 15.3/2) = 11.9km. Accordingly, the total construction cost is estimated at 1.085.280 US dollars (C = 11900 x 91.2) or 1.1 million US dollars in approximation.

The approximate gabion volumes are shown in TABLE 6-2-3.

3. NAVIGATION

3.1 Background

Access from Kathmandu to most cities except Jiri and Dhankuta in the Kosi Basin is only possible by air due to the lack of adequate serviceable roads. Common travel in the Hill and Mountain Areas is by footpaths. For trips, trades and logistics, people in the area spend days in walking, sometimes fording rivers to reach their destination. Footpaths are used for general transportation and the network is extensively developed; the total length of footpaths is estimated at 15,000-20,000km in Nepal. Ferry services and manual ropeways also exist at many locations along rivers. In the Study Area, the Kathmandu - Dhankuta Highway is planned which is envisioned to greatly improve mobility in the area. However, considerable time may be required before actual implementation.

HMG is giving attention to the development of adequate inland waterways on major rivers. This is a new policy of the government which has traditionally given development priority to roads and airways. Advantages of waterway transportation in comparison with roads and airways is considered to be the relatively small initial investment and low operation and maintenance costs.

In this connection HMG established the Inland Waterway Section under the Ministry of Works and Transportation in 1981. The Section has been conducting a project of "Inland Waterway Development" which investigates major rivers for their navigability. Special attention has been given to the Sun Kosi, Kali Gandaki and Bheri rivers (FIG. 6-3-1). In this connection, TABLE 6-3-1 compares the various existing transportation systems and their costs for the nation.

3.2 Navigation Potential

Navigation activities on the Kosi are limited to river-crossing by ferry and adventure type raft services. But these services utilize present uncontrolled flow of rivers; therefore, natural hazards and seasonal changes in river flow are inherent. Frequency and size of canoe used in ferry service are conditional to the locality. In the case of Chatra Ghat on the Sapt Kosi a large size canoe, about 10m long, is used in dry season. It takes approximately 8 minutes to cross carrying 80 persons in very crowded conditions. Long distance ferry service on a regular schedule does not exist on the Kosi.

HMG is interested in both international and domestic navigation; but for the time being domestic navigation is given more attention because of relative ease of implementation. As a landlocked country, however, accessibility from the Nepal-India border to Calcutta by river is considered a very attractive alternative transportation against roads, railroads or airways. Present cargo transportation for third country tradings[1/] is undertaken by overland trucking through Calcutta (75%) and Chittagong (5%), besides air transportation (10%). This trend will continue[2/] since air transportation will be continuously restrained by cargo handling capacities at the Tribhuvan Airport. Average overland traffic[3/] for third countries amounts to about 450,000 tons/year. About 60% of the annual volume goes through Biranj Customs Post; Calcutta is the place for shipping-out and receiving. FIG. 6-3-2 shows the major trucking routes in Nepal and India.

According to limited information[4/] navigation services in north-eastern India are available for a portion from Calcutta to Farakka and Farakka to Assam, and there is limited distance service near Patna. Details on frequencies, fares, and payloads of ships used for the said services were not available, but cargo movement in the north-eastern region between August '82 and July '83 amounted to 27,405t.

Recent surveys have indicated that inland waterway transportation in the region is no longer competitive with other modes of transportation,

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1/ "Projection Nepal's Transit Traffic for the Sixth Plan Period 1980/81 to 1984/85 Including Updated Volume Statistics for 1979/80 & 1980/81", UNCTAD/ESCAP, RAS/81/114, NEP/82/002, Ref. 83-39.

2/ "Transit Cargo Congestion and the Need for More Transhipment Facilities", UNCTAD/ESCAP/, RAS/72/077, NEP/72/077, Ref. 81-23, Feb. 1981.

3/ "Nepal Overseas Trade Statistics 1979-80", Trade Promotion Centre, Kathmandu.

4/ A newspaper cutting of the Statesman, Calcutta. May, 1983, exact date unknown.

dropping from the 1950 level of 60% to only 3% in 1982. Such drastic change was caused by (i) development of roads and railways, (ii) lack of facilities for night navigation, and (iii) lack of infrastructure facilities. In order to re-utilize traditionally cost effective water-borne transportion, the Government of India is now very keen on revitalizing inland waterway transportation. This new policy and its implementation would be benefical to Nepal for general trade with India.

Navigability on the Kosi with regards to a route from Calcutta to the Nepal border has been discussed very briefly elsewhere1/, and 3 recommendations resulted; namely (i) a detailed survey of the Sapt Kosi from Chatra up to its confluence at the Ganges, (ii) installation of a lock to pass boats across the Bhimnagar Barrage, and (iii) arrangement of returning canal water to be used for power generation to the Sapt Kosi main stream after power generation to ensure adequate water depth for navigation.

Navigability on the Gandak River as an international waterway has also been studied2/. The report concluded that dry season traffic to and from Nepal could be effected by a barge similar to the Central Inland Water Transport Cooperation, India's "Cachar Barge" operating at a draft of 90cm based on preliminary calculation, details of which were not shown in the report. The study also pointed out the necessity of some river training works to be undertaken at reasonable cost to ensure a 90cm channel during 345 days/yr (90% occurrence) up to the border of Nepal.

Recognizing the present sizable navigation activities on the Ganges River in the north-eastern region it may be concluded that navigational potential of the Kosi from its confluence at the Ganges River to the Nepal border should be confirmed through further professional investigations with the cooperation of the Government of India.

1/ "Report on Inland Waterways for Nepal", A.B. Thapa, 22 Mar., 1967, Kathmandu.

2/ 'Inland Water Transport in Nepal', Report of a Mission by J.M. Deplax from 20-29 Nov., 1982 at the Request of H.M.G. of the Nepal.

Concerning domestic navigation, a preliminary study conducted during Part A and B on the Sun Kosi, the Arun, and the Tamur suggests high potentiality based on (i) general field inspection from a helicopter, (ii) longitudinal profiles estimated from existing 1/50,000 maps as shown in FIG. 6-3-3 and (iii) field measurements of river cross-section and flow at 5 gauging stations on the Sun Kosi and the Tamur (to be shown in the final report). Present adventure type rafting on the Sun Kosi may reinforce the above preliminary judgement.

Navigation by barge with less than one meter draft may be possible in dry season (i) on the entire Sapt Kosi, (ii) up to Dalalghat on the Sun Kosi, (iii) up to Tumlingtor near Khandbari on the Arun, and (iv) up to the vicinity of Talplejung on the Tamur. It is strongly recommended to carry out systematic technical surveys on the above 3 rivers for possible subsequent detailed studies.

3.3 Recommendations

Despite the importance of inland navigation, technical information required for evaluating the feasibility of both domestic and international aspects of the same is very scarce; therefore, as an initial step, preliminary investigations are strongly recommended. Separate recommendations are presented below for international and domestic aspects of inland navigation, respectively.

International Waterway Study

1) For the Kosi River from the Nepalese border to the confluence point at the Ganges River:

- longitudinal and cross-sectional profiles with leveling information
- daily discharge records
- siltation and sediment loads
- effects of current or possible scouring
- horizontal shifting of main stream
- other relevant hydrographic and hydrological survey data

2) For Bhimnagar Barrage, canals, power stations and other structures on the Sapt Kosi River:

- layout of structures describing relative horizontal distance from the river
- effective water depth of flow
- location of bridges and clearance of the same
- cross-sectional and longitudinal profiles of channels

3) For the present waterway transportation services of the route from the Ganges River through Farakka Barrage, Feeder Canal, Jangipur Barrage, the Bhagithi and Hooghly rivers reaching Calcutta:

- details on waterway services in terms of frequency, type of ship, fare and payload per ship
- management and operational information
- maintenance information
- future expansion programs

Collection of the above information will require cooperation of the Government of India, and it may take some time before a detailed study can be started.

Domestic Waterway Study

Investigation on domestic navigation, however, can be expeditiously executed according to programs formulated by Nepal. To effectively develop a domestic inland waterway transportation system in the Study area, a prototype ship for field investigation is recommended. Preliminarily the following would be initial steps towards commercial operation of waterway transportation.

1) First phase: preliminary study

Comprehensive investigations should be carried out for a period of 1-2 years using a prototype ship to collect data on topography, hydrology, and navigability of the Sapt Kosi, Sun Kosi, Arun, and Tamur rivers. Investigation areas should consist of:

- the entire Sapt Kosi between the point of confluence of the Sun Kosi, Arun and Tamur rivers and the Nepal-India border, approximately 50km in length
- from the confluence point up to Dalalghat on the Sun Kosi, about 170km in length
- from the confluence point up to Tumlingtar on the Arun, about 50km in length
- from the confluence point up to Phulbari on the Tamur, about 90km in length

The study shoulddetermine the navigability of the 4 rivers based on analyses of the collected data and actual field surveys. Expected outputs of the Study are:

- possible navigation route
- preparation of river navigation chart (FIG. 6-3-4)

- required infrastructure works including wharf, service dock, river training, dredging, buoys and beacons for ensuring navigation route and safety
- scope of navigation services and future expansion program
- discussions on slipway or lift for ensuring passage through a multipurpose dam to be constructed in the future
- basic economic evaluation

Required equipment include:

- a flat self-propelled barge which is about 15m long, 8m wide, 1m deep, with 30 tons cargo capacity
- a sonar
- a radar
- sets of navigation equipment & ground survey equipment
- a flow velocity meter
- a Catamaran type steel boat, diesel powered 450PS x 2, approx. 20m x 6m x 2m (FIG. 6-3-5)

The Catamaran type boat will be used for collecting data necessary for the navigability study. The recommended flat barge is self-propelled for carrying cargoes during field surveys, but it can be readily used as a landing craft which will enable the survey boat to land on the shore at virtually any location along a river for loading and unloading purposes as shown in FIG. 6-3-6. The boat will also be used for a general ferry service after completion of the field surveys.

2) <u>Second phase: feasibility study</u>

A detailed feasiblity study should be conducted for a period of one year to formulate a detailed implementation plan, continue test operation of the boat for collecting operational data, perform economic evaluation, and recommend an institutional organization for commercial operation.

3) <u>Third phase: construction of infrastructures</u>

Execution of infrastructure construction, manpower training in the areas of operation and maintenance, and procurement of vessels within a one year period is planned.

4) <u>Fourth phase: commercial operation</u>

This is the last phase for starting commercial operation. All the necessary preparatory works and program adjustments should be incorporated at this stage.

4. WATER USAGE FOR FISHERY

4.1 General

Fisheries development represents a largely untapped sector in the field of water resources development the potential of which should not be overlooked. It can contribute in several ways, by:

a) providing a low cost source of supplementary protein;

b) acting as potential source of employment and income generation; and,

c) facilitating establishment of more ecologically balanced land and water resources.

Although landlocked, Nepal is blessed with sufficient water resources to permit fish production at levels which can make a significant impact on the quality and quantity of food supply in the country. In view of the serious nutrition problem Nepal now faces, it is essential that all channels to increase food supply be pursued, and fisheries along with livestock production are especially important because of their ability to supply animal protein. The value of fish production has long been recognized, and accordingly the Government has been including fisheries development in its five-year plans.

4.2 Potential Resources

4.2.1 Inland Water Resources

As Nepal is a landlocked country, production of fish within the same is entirely dependent on the proper utilization of its inland water resources. The water resources available for fish production in Nepal, the Project Area and the dam reservoirs planned under the Project are detailed below and presented in TABLE 6-4-1, 6-4-2 and 6-4-3.

The latest data on physical land use show that water bodies cover 2.84% of the total area of the country. Besides these natural water bodies, there are about 5,000ha of village tanks and ponds mostly concentrated in the southern plain, or Terai Area. An additional 198,481ha of irrigated paddy field and 750ha of man-made reservoirs add seasonal, as well as perennial water bodies to the total. Moreover, the trend towards hydropower and irrigation projects will add more water bodies in future.

According to this Study, about 31,000ha of dam reservoirs would be created by Project development. Development of this water resource is feasible from both ecological and economical viewpoints.

4.2.2 Fish Resources

(1) Fish species in Nepal

A systematic detailed study on the biology and distribution of fish species in the varied ecological niches of inland water bodies in Nepal is still to be carried out. However, records indicate that these inland water resources are considerably rich in the same. A recent work, "A General Bibliography on Fish and Fisheries of Nepal" shows a total of 164 indigenous fish species distributed in various river systems and water bodies from a few hundred meters to 4,000m in altitude.

Besides indigenous fish species, seven exotic fish species of commercial value have also been introduced in the country. Three of these are cold water species which do not presently exist (Salmo gairdeii, Salmo trutta and Onchorynchus rhoduras, while four commercially valued warm-water culture fish species (Cyprinus carpio (common carp), Ctenopharyngodon idella (grass carp), Hypopthalmichthys molitrix (silver carp) and Aristichtys nobilis (big head carp)) are being cultured along with commercially highly valued indigenous fish species. Besides the cultivable indigenous fish species, Schizothorax spp. Schizothoracthys spp. Tor spp. are dominant fish species in most of the hill-streams of the mid-hill and mountain region. Many other fish species of commercial value also exist but their biology has yet to be studied.

(2) Fish in the Terai Area

A broad spectrum of fish species exist in the Terai Area. Those which contribute to commercial fisheries of the same are Thed (Labco dero), Karsa (Labeo gonius), Naini or Mirgal (Cirrhina mirgala), Vakur (Catla catla), and Rohu (Labeo rohita). Catfish are also known to exist in the deep pools of the area including Gounch (Bagarius bagarius), Magur (Clarias batrachus) and Singhi (Heteropneustes fossilis). Important sheatfish that occur in the ox-bows of the river downstream include Buhari (Wallage attu), Jalkapoor (Clupisoma gaura), Bachawa (Eutropiichthys vacha), Belgara (Rita rita) and Tenger (Mystus vittatus, Mystus seenghala).

Pools and rapids downstream are colonized by River Carp which are of potential commercial value. The more important species include Thed (Labeo dero, Karsa (Labeo gonius), Rohu (Labeo rohita), Bata (Labeo bata), Rewa (Cirrhina rewa), Mri gala (Cirrhina mirgala), Karonch (Labeo calbasu) and Vakur (Catla catla). Besides these principal species several melanic or natural hybrids are known to exist in this area.

Back and sheltered waters downstream are inhabited by freshwater eels. The stone eels such as Dhungae Bam (Mastacembalus pancalus) and (Mastacembalcus armatus) are not as common as the freshwater eel or Rajbam (Anguilla bengalensis). Mud eels or Bam (Amphipnous cuchia) are also numerous in the downstream areas.

The main fish of the Terai Area are the Featherbacks or knife fishes (Notopterus chital and Notopterus notopterus). Murrel or Snakeheads are also fairly common. The important Murrel game species in the Terai Area is Saur (Channa maurulius). This species is found in swampy areas along boggy river banks and in sheltered waters.

Throughout the Terai Area, commercial fishing occurs during the monsoon. Fish enter flooded marigots, irrigation channels and rice fields, and are caught there. In downstream swamps and old river channels, swamp fishery is practiced including the catching of Eel, (Amphipnous cuchia), Singhi (Heteropneustes fossilis), Magur (Clarius batrachus), Saur (Channa marulius, Channa striatus), Sehari (Puntius ticto, P. shophore, P. sarana), and Garrahi (Noemachelius botia). These fish are commonly scooped or netted from swampy ditches with little effort. Most fish caught in river bank swamps or in rice field channels are also scooped by means of bamboo baskets and fish pots.

4.3 Administrative Organization

The Government has built 12 fish farms, fisheries development centers and hatcheries in various parts of the country.

The government agency charged with the administration and management of fisheries was formerly the Department of Fisheries under the Ministry of Agriculture. However, in a reorganization, fisheries activity was transferred to the Fisheries Division of the Department of Agriculture. As this division is very small, it is presently charged only with the full operation of national projects and technical support of the other fishery officers assigned to the economic development regions. Administratively, the regional fishery officers and technicians are under the directors of the various regional directorates. There are about 77 fishery personnel in the country including: fisheries development officers, assistant fisheries development officers, junior technicians and junior technical assistants (TABLE 6-4-4).

On the other hand, in 1981 the Fisheries Statistics Unit (FSU) was created under the Agricultural Statistics Division of the Department of Food and Agricultural Marketing Services (DFAMS) with the responsibility of preparing for and gathering fishery data belonging to both fish farms and their operations and family members engaged in the catching of fish from lakes, rivers, paddy fields, irrigation canals, dams and barrages as their source of livelihood.

It appears that the present Fisheries Division is inadequate in terms of number of personnel and necessary authority to provide technical and administrative support of the country's fishery potential. As fisheries development progresses and external assistance projects increase, it is expected that this Division will be expanded and vested with appropriate authority to be able to meet its functions properly.

4.4 Present Status of Fisheries

4.4.1 Capture Fisheries

Capture fisheries in Nepal are widely scattered and unorganised. The fishermen living along the rivers and lakes use traditional fishing gear. To promote capture fisheries, three cold water fish species; namely, Brown Trout (Salmo gairdeii), Rainbow Trout (Salmo trutta) and Amago (Onchorhynchus rhoduras) were introduced on an experimental basis without any success. Presence of heavy silt is considered the cause of failure. However, experiments on induced breeding of indigenous cold water fish species such as Asala (Schizothorax/Schizothoracthys spp.), Katle (Accrosochilus hexagonalepis) and Mahaseer (Tor spp.) have been successfully carried out. Further efforts are being made to propagate the same on a mass scale for open water stocking to increase production of capture fisheries.

4.4.2 Culture Fisheries

Traditionally culture practices were restricted to wealthy families and the objective was delicacy of product and recreation rather than direct economic return. Usually, farmers allow either flood water into the ponds or stock spawn collected from rivers in their ponds resulting in nominal production only.

Modern fish culture was initiated in the early 1950s. With the selection of suitable fish species, initial steps were taken to construct a small and medium sized fish seed production center at Parawanipur and Godawari in the Kathmandu valley in 1960. Subsequently, efforts were made to develop propagation techniques as well as to identify potential locations for Fisheries Development Programmes in the Terai Zone along with the establishment of other Fisheries Development Centers. At present there are 12 Fisheries Development Centers in the country which are mainly engaged in pure fish seed production and distribution of the same. As a result of quality egg supply and extension service extended by the public sector fish farms to those concerned, an increasing number of people are practising fish culture as a side job. Recognising the potential of inland fisheries for employment generation as well as income, the Government has launched an

Aquaculture Development Project with financial assistance from the Asian Development Bank and technical assistance from UNDP. The Project aims to accelerate the development of warm-water fisheries in the 16 districts of the Terai Area and the inner-terai districts of the Western, Central and Eastern Development Regions. The Project is also designed to strengthen the production, research and training facilities in the public sector.

The sub-sector Fisheries Development Programme presently covers 36 districts in the country with production and supporting services for fish producers. To enhance fish production in the country, attempts are being made for mass application of polyculture from monoculture. Similarily, integrated fish farming with animal husbandry (especially ducks and pigs) and with horticulture (especially bananas) has been widely accepted by farmers.

Cage fish culture is recognised as being economically viable in the lakes of Pokhara valley. Since 1978, private fish growers have undertaken cage fish culture in Pokhara valley and the total volume has reached about 12,000m^3. The Agriculture Development Bank has been providing credit facilities to accelerate fisheries development in ponds as well as in cage fish culture.

4.4.3 Fish Species

Presently, the fish species being used for fish culture in Nepal are the indigenous Indian Major Carp-Rohu (Labio rohita), Catla (Catla catla) and Mrigal (Cirrhina mrigala), exotic Chinese carp (Grass carp-Ctenopharyngodon idella), Silver carp - (Hypopthalmichthys molitrix and Bighead carp - Aristichthys nobilis) and the common carp (Cyprinus carpio).

4.4.4 Current Fish Production

Fish production in Nepal in 1979/80 was estimated by the Government at 2,900t (TABLE 6-4-5). This is a rough approximation as there is no systematic collection of fisheries statistics in the country. Out of this total, capture fisheries provide 2,200t while 700t comes from aquaculture. According to Government estimates, capture fisheries from rice fields in the Terai provide 1,600t/year (more than half of total fish production) and constitute the largest source of fish supply in Nepal. Aquaculture production mainly comes from private fish farms (650t/year), and the remaining from Government farms. In 1981/82 fish production was estimated to have increased to about 3,900t including 1,700t from pond fish culture.

4.4.5 Production Target

Aquaculture has the greatest potential for increased fish production as there is ample opportunity to expand the area under culture, and because pond yields can be sustantially increased by improved management. There is less potential for production increases from capture fisheries because production cannot be influenced by human intervention to as great an extent as in aquaculture.

Targets for fish production in the Sixth Plan (1980-1985) include a doubling of total fish production from about 2,900t in 1979/80 to 6,168t in 1984/85, and an increase in production available for per capita consumption from 225g in 1979/80 to 415g in 1984/85.

An ADB study team estimates that with a high level of investment and development, 27,000t of fish can be produced annually in Nepal by the year 2000 (TABLE 6-4-5). This can be compared with the current annual production of about 4,000t.

4.5 Necessity of Aquaculture Development

4.5.1 Estimated Profit of Aquaculture

(1) National Benefit

In light of the present circumstances such as fuel and food shortage, presence of cheap labor force, etc., aquaculture development is considered as one of the major sources of protein for food and for earning valuable foreign exchange. However, at present, the following constraints against the development of fish culture exist due to the short history of fish culture in Nepal.

a) absence of base-line studies on natural water resources (rivers, lakes and reservoirs) for their rational development;

b) lack of studies on production potential of indigenous fish species, etc;

c) lack of infrastructures in fish fly production, research and training;

d) lack of trained and experienced manpower in the field of fish production and extension services;

e) lack of awareness amongst the rural inhabitants in this new field of agriculture as they are traditionally oriented to cereal crops only;

f) inadequate availability of resources to expedite investments for production expansion;

g) poor management practices in private sector fish culture; and,

h) poor marketing facilities, including inadequate roads, transportation system, markets, trading centers, ice plants and/or cold storage, which prevent products from reaching the market in good condition, and thus farmers from getting fair prices for their products.

4.6 Effects of Hydroelectric Development on Fisheries

4.6.1 Ecological Considerations

The proposed dams and any downstream weirs for diversion of flows for irrigation purposes will act as barriers to fish migration. Since data relating to migrating species, times of migration, hydrobiological conditions necessary for migration and the numbers of fish migrating are not available, only general comments on the implications of such structures and the reservoir can be advanced.

According to one report, extensive seasonal migration of fish occurs in the Bagmati River system. The summer fish run occurs during the early monsoon (i.e. May and June) while the autumn fish run occurs during September and October. Most fish migrate upstream during early June to breed in the headwaters. They remain there for about 3-4 months before migrating downstream as levels recede during late autumn (September and October). With the construction of a high dam, the upward migration of fish will be obstructed but the major economically important species like Catla catla, Mirgal and Rohu will probably adapt to reservoir conditions.

Another report suggests that the Tamur River has become the favourite habitat of the Jalkapoor, which is favored by the local people for its delicious meat. The Jalkapoor migrates extensively moving downstream to the Sapt Kosi in winter and upstream in May or June for breeding.

Local upstream fishermen report that the number of Jalkapoor has considerably decreased in recent years, particularly since the construction of the Kosi barrage. Although it is equipped with a fish ladder, the barrage still forms a barrier to the Jalkapoor, and local fishermen catch tons of fish at the barrage every year. This may be one reason for the decreasing Jalkapoor population in the Tamur. Another is the occurrence of frequent mud flows and major floods.

4.6.2 Electric Consumption for Aquaculture

Fish culture facilities, especially those for modern type intensive aquaculture, will require considerable electric machinery and/or equipment for fish production, principal of which are pumps, lights, compressors, water wheels, fountains for airation, refrigerators, minerals, cutters and feed choppers.

Accordingly, some amount of electricity will be consumed by the aquaculture industry. Estimation of the electric consumption on the basic unit of aquaculture facilities, however, is very difficult at present, because electric requirement will depend on the type of fish, stage of growth, purpose of electric machinery and environmental conditions. Results of a sample survey of electric consumption in the aquaculture industry in Japan is introduced for reference is estimation of electric consumption and is presented as TABLE 6-4-6.

According to the said table, electric consumption per annum for pond fish culture is about 100,000 KWh/ha. At present, about 2,640ha of ponds exist in the Project area. If these ponds were equipped with electric facilities, about $264 10^6$kWh of electricity would be required. Furthermore, from the viewpoint of topographic conditions and economic profitability after construction of the Kamla reservoirs, a number of fish ponds could be established around the Kamla reservoirs. In this case, electricity consumption would be substantial.

4.7 Conclusions and Recommendations

With the exception of some river systems, survey of fish species in the Project area has not been carried out in a systematic manner. However, the river systems of Nepal provide habitats for fresh water fish ranging from mountain snow trout (Asla) in the upper reaches to a variety of indigenous carp in the lower sections. Nepal is blessed with sufficient water resources to permit fish production at levels which can make a significant impact on the quality and quantity of food supply in the country, and can also earn valuable foreign exchange.

The increasing trend towards hydropower and irrigation development is sure to add more water bodies in future. According to this study, about 31,000ha of dam reservoirs would be created at full development. These water resources should be developed in consideration of ecological and economical factors. Recommendations for aquaculture development in Nepal, especially in the Project area, are given below.

(1) As an urgent requirement, basic studies on water resources for fishery development including natural fish ecology and existing fisheries in the Master Plan Project Area should be implemented.

(2) As the lack of existing data on the basic aquatic ecology of Kosi and other river systems in the Project area makes it difficult to assess the effects of hydroelectric project development in the Kosi River Basin, more data should be obtained.

In addition to the above, potential for increased fish production exists through expansion as well as intensification of fish culture practices. The following development program is therefore recommended.

First Step

(1) Janakpur F.D.C

- Breeding and fish seed distribution of warm water fishes (ex. Indian Common Carp. etc.)
- Combination of one or more other fish species in culture practice with detailed biological and ecological study to increase productivity per unit water surface

- Improved feeding practices by applying techniques of polyculture, intensifying cultural practices with supplementary feeding and by feedback from research and private sector fish growers to increase the production of fish to 2,000 -2,400kg/ha per annum
- Development of aquaculture in the ever growing paddy fields (Rice-cum-Fish culture)
- Development of fish culture in existing ponds, as well as developing, new ponds in the Terai Area.

(2) Godawari F.D.C.

- Breeding and fish seed distribution of temperate water fishes (ex. chinese carp etc.)
- Manpower training for breeding and reproduction technologists

(3) Pokhara F.D.C.

- Development of open water fish culture as well as cage fish culture in lakes and manmade reservoirs of the Terai Area and mid-hills along with limnological studies
- Manpower training for cage fisheries

(4) Trisuli F.D.C.

- Ecological and biological research on both foreign and indigenous fish species in cold water (ex. Asala etc.)
- Testing and development of river stocking in hilly and mountain areas

(5) Hetauda F.D.C.

- Research and extension of integrated fish production with livestock and horticulture (ex. fishery with duck farming)

(6) Fatepur F.D.C.

- Development and extension of organization and management of fishery associations or cooperatives through trial at selected panchyats in Saptari District, where a number of fishery ponds are concentrated

Second Step

- Research and development of fish market, transportation and cold storage and/or ice plant
- Research, development and training in processing of fish products (ex. stockfish, smoked fish, canning etc.)
- Promotion of export to neighboring countries

Third Step

- Research and development of special aquaculture for export purposes (ex. bullfrogs, crocodiles, soft-shelled turtles, etc.)

5. Tar Irrigation

5.1 General

Due to the shortage of idle land in the new reclamation area, agricultural development is mainly focused on increasing crop productivity and cropping intensity. Available land area has already been developed in a marginal area. For example, in the catchment area of the Dudhu Kosi River in the Study area, paddy is cultivated up to 2,500m above sea level, and pasture land for animal grazing is extended nearly to the snow line of about 5,000m. Terrace fields including paddy land are developed in the Hill Area reaching to the hilltops. Some selected farmlands are presently provided with irrigation water in the form of tar irrigation, with intake from local streams by small scale run-of-river type diversion and along the canal.

5.2 Present Conditions

According to the feasibility study reports conducted by the Department of Irrigation, Hydrology and Meteorology under the Ministry of Water Resources, 228 small and medium scale irrigation projects have been studied which cover 22 districts within the Mechi, Kosi, Sagarmatha, Janakpur and Bagmati zones (FIG. 6-5-1). The proposed area is about 131,000ha including a part of the Terai Area and the size of each possible project area varies from 6-8,000ha. Among these proposed project areas, as of 1983, a detailed survey has been conducted on 17 areas (TABLE 6-5-1).

In the area of the above mentioned zones, 228 tar irrigation sites have been listed, in which 105 sites with 61,000ha are feasible, while 20 sites with 30,000ha are provisionally feasible. In particularly, the Kosi Zone with 29 potential project sites will be given special attention, in view of the concentrated development activities through the Kosi Hill Area Rural Development Programme (KHARDEP) situated in the Study area. In this connection, if more detailed investigation and study on tar irrigation is undertaken in the Study area more sites as a whole may be expected to be identified.

5.3 Tar Irrigation Development

The success of tar irrigation systems depends on availability of water resources. Extension of canal alignment is also an important factor to control command area for the same. Irrigation systems differ depending on the topography; however, most of the same are existing plot to plot systems.

Development of appropriate technology for tar irrigation systems using locally available materials such as rock, bamboo and wood materials is required for construction of necessary intake weir and extension of the canal. For example, if the irrigation area is small a bamboo flume system can be considered in order to minimize the water seepage.

Another posibile irrigation system in the Hill Area could be the combination of a pond and sprinkler irrigation system. If small irrigation ponds can be constructed in the upper stream and/or valley, vinyl water pipes connected with plastic sprinkler nozzles would be useful for sprinkler irrigation without water pressure when there is a 6-8m head or more.

The system is very valuable for saving water resources and soil conservation at low cost. Similar sprinkler irrigation systems are presently being operated by farmers in the Andes mountain area in South America. Conditions in the Hill Area in Nepal are very similar to those of the Andes and as such the pond-sprinkler system warrants model testing as an initial development step. The system should be tested by the Government at selected model sites in the Hill Area.

It is recommended that operation and maintenance of irrigation facilties including rehabilitation of existing canals and intake weirs be handled by water users associations. In this connection, formulation of the optimal unit scale of each association should be considered from the viewpoint of operation and maintenance in terms of size of benefit area and distance for field management.

5.4 Further Study

Under the development plan, the envisaged irrigable area will be increased on the downstream side of the proposed dam site with an upward water table after construction of dams. Therefore, tar irrigation study in the Study area will be limited to unirrigated farmland located in the downstream area of the dam site and around the dam reservoirs. The following items outline the major concept for further study on tar irrigation.

a) formulation of a 1:2,000 scale map for the proposed site;

b) delineation of irrigable area for gravity irrigation according to reservoir level at the proposed dam site;

c) fixation of possible canal alignment;

d) comparison study on unit water requirement, conveyance loss and field loss in the plain and hill areas;

e) study on lift irrigation using electric motors after construction of hydropower stations and dams;

f) evaluation of the suitability of the plot to plot irrigation system and overflow irrigation system;

g) formulation of drainage system design; and,

h) pond and sprinkler irrigation system trials.

Project formulation will be studied from technical and economic aspects. The tar irrigation project, on the other hand, should take into account soil and land conservation. Generally, in the Hill Area, distance between farmers' residences and farmland substantially affects farming practices. Therefore, irrigation areas should be formulated in consideration of the expected time spent in the fields as well as in travelling to and from the same.

TABLE 6-1-3 ESTIMATION OF SPECIFIC SEDIMENTATION IN THE RESERVOIR BY VARIOUS METHODS

($m^3/km^2 \cdot yr$)

River	Sapt Kosi	Sun Kosi	Arun	Tamur
Area	61,000km2 100%	19,000km2 31%	36,000km2 59%	6,000km2 10%
Tanaka Formula				
Hypsographic coefficient (x)	259.953 1/	212.538 2/	273.167 2/	330.814 2/
Use of the formula for gneisses (m^3/km^2hr)	Qs=9.0X-524 =9.0x259.953 -524 =1,816	Qs=9.0X-524 =9.0x212.538 -524 =1,389	Qs=9.0X-524 =9.0x273.167 -524 =1,935	Qs=9.0X524 =9.0x330.814 -524 =2,453
Specific sediment yield Qs (m^3/km^2yr)	1,850	1,400	2,000	2,500
Discharge vs suspended bed material concentration	2,078	1,303	183	2,640
Upper bound measured suspended sediment load chart of Japan	1,997	1,166	183	721
Meyor-Peter	1,576	1,358	832	6,947
R.S. Vershney formula	837	1,138	961	1,534
Recorded measurements in India	1,500	2,000	1,700	2,800
Milos Holy formula	1,583	2,324	920	3,440
Recorded measurements of sediment-ation in Japan (Tenryu River)	280	500	350	1,200
Sediment discharge of disasters in Japan	788	1,121	1,000	1,909

1/ The calculation is based on the areal proportion of Sapt Kosi to the total area of the Sun Kosi, Arun and Tamur rivers combined.

2/ The figure is based on the respective basin area.

TABLE 6-1-5 PREVIOUS REPORTED SEDIMENT YIELD FOR DESIGN

Reported Date	Catchment Area km²	Dam	Specific Sediment Yield m³/km²/yr
Japan, 1982	31,000	Sapt Gandaki	2,800
India, 1981	61,000	Kosi High Dam (Sapt Kosi)	1,430
China, 1972	2,340	Sun Kosi Power Station	1,795
Japan, 1983	156	Kulekani	700
Canada, 1982	5,640	Mulghat	5,053
Japan, 1972	1,550	Kamla	1,820
Switzerland, 1977	42,890	Chisapani	2,098

TABLE 6-1-6 COMPARISON OF SUSPENDED SEDIMENT[1/] LOADS DERIVED FOR NEPAL

River	Location	Catchment Area km²	Load m³/km²/yr	Reference
Seti	Phoolbari	582	3,290	this report
Trisuli	Betrabati	4,110	660	
Karnali	Chisapani	42,840	2,220	
Gandak	Bhaisolatan	36,000	3,275	30
Kosi	Barahkshetra	59,000	2,083	
Sun Kosi	Tribeni	19,230	2,818	
Arun	Tribeni	36,533	947	11
Tamur	Tribeni	5,900	5,016	
Kosi	Chatra	61,600	1,880	22
Rivers of Himalayan region[2/]	-		2,638	18

1/ Gandaki River Basin Power Study, Basin Study P.44., Volume 1, Main Report, 1979

2/ This is the mean total sediment load (adjusted for bedload and deficiencies of suspended sediment sampling of 21 rivers).

TABLE 6-1-7 DETAILS OF LANDSLIDE AREA

	Description	Number	Area
I.	Tama Kosi River Basin		
	- relatively distinct landslide	45	$17.3km^2$
	- indistinct landslide	152	$32.9km^2$
	Total	197	$50.2km^2$
	- large landslide		
	indistinct		$2.8km^2$
	distinct		$2.7km^2$
	- average site area/landslide		$0.25km^2$ (=50.2/197)
II.	Dudh Kosi River Basin		
	- relatively distinct landslide	45	$10.8km^2$
	- indistinct landslide	89	$12.2km^2$
	Total	134	$23.0km^2$
	- large landslide		
	distinct		$1.03km^2$
	indistinct		$1.00km^2$
	- average site area/landslide		$0.17km^2$ (=23.0/134)
III.	Arun River Basin		
	- relatively distinct landslide	18	$3.3km^2$
	- indistinct landslide	34	$6.5km^2$
	Total	52	$9.8km^2$
	- large landslide		
	indistinct		$1.7km^2$
	distinct		$0.7km^2$
	- average site area/landslide		$0.19km^2$ (=9.8/52)
IV.	Tamur River Basin		
	- relatively distinct landslide	19	$2.3km^2$
	- indistinct landslide	39	$5.3km^2$
	Total	58	$7.6km^2$
	- large landslide		
	indistinct		$1.03km^2$
	distinct		$0.59km^2$
	- average site area/landslide		0.13^2km (=7.6/58)

Note: 1/ In the landslide site maps, a relatively distinct landslide site is depicted in red while an indistinct landslide site is shaded pink.

2/ Each landslide site is attached with a serial number (Site No.) to permit correspondence between the landslide site map and the corresponding table.

3) The photographic map scale is approximately 1/80,000 except that a 1/20,000 scale is used for parts of the Arun River Basin and the Tamur River Basin.

TABLE 6-1-8 LANDSLIDES IN THE KOSI BASIN

Term	River	Sapt Kosi	Sun Kosi	Arun	Tamur	Remarks
A	Catchment Area (km^2)	61,000	19,000	36,000	6,000	
B	Investigation Area (km^2)	3,054	2,160	840	54	
C	Results of Investigation number of landslides	441	Tama Kosi 197 Dudh Kosi 134	18+34=52	19+39=50	
D	Landslide Area (km^2)	90.5	Tama Kosi 50.2 Dudh Kosi 23.0	9.8	7.5	
E	Landslide Area of Unit (km^2/place)	0.205	0.221	0.188	0.129	D + C
F	Landslide Point of Unit Area (place/km^2)	0.144	0.153	0.0619	1.0741	C + B
G	Expectation of Total Landslide Area in Kosi Basin (km^2)	1,801	642	419	831	FxExA
H	Ratio of Landslide Area to Catchment Area (%)	2.95	3.38	1.16	13.85	(G+A)x 100%

TABLE 6-1-9 POPULATION IN THE STUDY AREA

	1971	1981	Annual Growth rate
Mountains & Hills	2,296.271	2,631.232	1.37
Terai	2,218.533	3,310.103	4.08
Total	4,514.8	5,941.335	2.70

TABLE 6-1-10 LAND USE IN THE STUDY AREA IN 1982

	Physical Area (km^2)	Cultivated Land (km^2)
Mountain	10,440	455 (4.36%)
Hills	20,370	5,743 (28.2%)
Terai	10,864	7,281 (67.0%)
Total	41,674	13,479 (32.3%)

TABLE 6-2-1 **MAXIMUM RAINFALL RECORDED IN THE TERAI AREA (1971 - 1980)**

(mm/24hr)

Station Index / Year	1111 JANAKPUR AIRPORT	1114 HARDINATH	1319 BIRATNAGAR AIRPORT
1971	79 (Jun 11)	99 (Jul 10)	121 (Jun 2)
1972	150 (Jun 25)	100 (Aug 10)	142 (Sept 26)
1973	132 (Jun 15)	144 (Jun 15)	145 (Aug 5)
1974	82 (Aug/3)	107 (Jul 4)	202 (Jul 2)
1975	135 (Jul 27)	141 (Jun 25)	159 (Jun 16)
1976	229 (Aug 19)	168 (Aug 19)	128 (Jun 16)
1977	98 (Jul 20)	68 (Oct 6)	155 (Jul 20)
1978	168 (Jul 16)	194 (Jul 16)	148 (Jul 20)
1979	68 (Jun 21)	111 (Aug 14)	146 (Aug 21)
1980	45 (JUl 29)	68 (Sept 21)	146 (Sept 21)

Note: Brackets indicate recorded date.

TABLE 6-2-2 RETURN PERIOD

INDEX NO.	Order (i)	Maximum Precipitation (mm/24hr)	Standard Return Period $\frac{2i-1}{2N} \times 100$
	1	229	5.0
	2	168	15
	3	150	25
No. 1111	4	135	35
JANAKPUR	5	132	45
AIRPORT	6	98	55
	7	82	65
	8	79	75
	9	68	85
	10	45	95
	1	194	5
	2	168	15
	3	144	25
	4	141	35
No. 1114	5	111	45
HARDINATH	6	107	55
	7	100	65
	8	99	75
	9	68	85
	10	68	95
	1	205	5
	2	159	15
	3	155	25
No. 1319	4	148	35
BIRATNAGAR	5	146	45
AIRPORT	6	146	55
	7	145	65
	8	142	75
	9	128	85
	10	121	95

Note: N = number of record years; i = Order

TABLE 6-2-3 REQUIRED QUANTITY OF GABION

Section	Extension (m)	V_1 (m^3)	V_2 (m^3)	V_1+V_2 (m^3)
Right bank o - b (FIG. 6-2-7)	2,500	87,500	1,050	88,550
b - e (FIG. 6-2-7)	13,800	227,725	4,900	232,625
Left bank and residential section	1,500	30,188	-	30,188
Total	16,300	345,413	5,950	351,363

TABLE 6-3-1 **COMPARISON STUDY OF TRANSPORTATION IN NEPAL**

Base Line: 1983

	Speed (km/hr)	Max.Cargo Capacity (kg)	Max.Passenger Capacity (person)	Fuel Consumption (ℓ/hr)	Charter Fee with Fuel (Rs/hr)	Mar.Cruise Distance in one Flight (hrs)	Remarks
Helicopter							
Allouette (Army)	150	280	4	200	8,200	3	
Puma (Army)	200	1,300	16	600	20,000	3	
Airplane							
Pilatus Porter (RNAC)	200	6,000	8	200-220	8,400	4	
Twin Otter (RNAC)	240	14,000	14	350-400	9,000	5.5	
Bus	80	-	60	10	-	-	Bus charge/person KTM - Birat: 70Rs Birat - Dankuta: 40Rs
Truck	60	10,000	-	10	-	-	
Porter	2	50	-	-	30-40 Rs/day + Food		- 50kg; 4days, 200Rs
Ship (Proposed)	30	150,000	30	-	-	-	Ferry boat with Cargo Barge construction: $150 \cdot 10^4$ US$

TABLE 6-4-1 WATER RESOURCES AND ESTIMATED AREA IN NEPAL

Types of Water Resources	Estimated Area 1983 (ha)	Additional Projected Area (ha)
1. Natural waters		
a) Rivers	395,000	-
b) Lakes	5,000	-
c) Reservoirs 1/	750	78,000 2/
2. Ponds	5,000	1,000
3. Irrigated paddy fields	198,481	-

1/ Estimated to be completed by the end of 1982.

2/ - Gandaki River Basin Power Study, 45,000ha
- Bagmati Multipurpose Project, 9,000ha
- Chisapani Hydroelectric Project (Karnali River), 24,000ha

Source: DOA, Fisheries Development Division

TABLE 6-4-2 EXISTING PONDS IN THE PROJECT AREA

Development Region & District	Total No. of Ponds	Total Area (ha)	Average Size of Water Body (ha)	Survey Year
Eastern Development Region				
1. Jhapa	256	118.50	0.46	1979
2. Morang	286	113.44	0.40	1978
3. Sunsari	352	70.38	0.20	1978
4. Saptari	1,480	497.50	0.33	1978
5. Siraha	1,062	420.36	0.40	1977
Central Development Region				
1. Dhanusa	1,587	548.51	0.35	1974
2. Mahottari	1,082	614.70	0.57	1974
3. Sarlahi	395	258.83	0.65	1976
Total	6,500	2,642.22	0.41	-
Nepal Total	10,317	5,700.00	0.48	

Source: Fish and Fishery Development in Nepal, 1983

TABLE 6-4-3 PROJECTED DAM RESERVOIRS

Name of Reservoirs & Pondage	Area of Water Surface (ha)
1. Sapt Kosi High Dam	14,000
2. Sun Kosi No. 1	3,100
3. Sun Kosi No. 2	5,500
4. Sun Kosi No. 3	2,500
5. Dudh Kosi	330
6. Tamur No. 1 (Reservoir type)	300
7. Tamur No. 2	200
8. Tamur No. 3	200
9. Tama Kosi No. 3	120
10. Tama Kosi No. 4	100
11. Indrawati No. 1	120
12. Kamla Reservoirs	4,400
Total	31,170

TABLE 6-4-4

EXISTING GOVERNMENT FISH FARMS IN NEPAL

(As of December 1983)

Name of Fish Farm	Location	Administrative Control	Water Surface Area (ha)	No. of Officers	No. of JTs and JTAs	No. of Adm. Staff	Purpose of Station
Central Development Region							
1. F.D.C., Codawari	Codawari, Lalitpur	Fisheries Division, DOA, Kathmandu	2.80	4	4	2	Breeding and fish seed distribution
2. Fish Hatchery, Balaju	Balaju, Kathmandu	Central Regional Agricultural Directorate	2.25	1	2	1	Breeding and fish seed distribution
3. F.D.C., Trisuli	Trisuli, Numakot	Central Regional Agricultural Directorate	1.00	1	1	1	Fish experimental station
4. F.D.C., Parvanipur	Parvanipur, Paras	Agricultural Station, Parwanipur	2.60	1	1	1	Breeding and fish seed distribution
5. F.D.C., Janakpur	Janakpur, Dhanusa	Central Regional Agricultural Directorate	4.70	1	3	2	Breeding and fish seed distribution and fish production
6. Commercial Fish Farm Pipley (Hetauda)	Pipley, Hetauda, Makawanpur	Central Regional Agricultural Directorate	28.70	1	3	2	Fish production
7. F.D.C., Bhandara	Bhandara, Chilwar	Central Regional Agricultural Directorate	36.00	1	2	2	Fish production and mitigation
Western Development Region							
8. F.D.C., Pokhara	Baidam, Pokhara, Kaski	Western Regional Agricultural Directorate, Pokhara	0.30	4	11	6	Lake development
9. F.D.C., Bhairahwa	Thutbepi-pal, Bhairahwa, Rupandehi	Western Regional Agricultural Directorate, Pokhara	18.60	2	5	1	Breeding and fish seed distribution
Eastern Development Region							
10. F.D.C., Tarahara	Tarahara, Sunsari	Tarahara Agricultural Research Station, Eastern Regional Agricultural Directorate	3.70	1	1	1	Breeding and fish seed distribution
11. F.D.C., Fatepur	Fatepur, Saptari	Eastern Regional Agricultural Directorate	2.01	1	2	1	Breeding and fish seed distribution
Far Western Development Region							
12. F.D.C., Dhangarhi	Geta, Dhangarhi, Kailali	Far Western Regional Agricultural Directorate, Nepalganj	5.80	1	2	1	Breeding and fish seed distribution

Source: Fisheries Development Division, Department of Agriculture

TABLE 6-4-5 PRESENT AND POTENTIAL FISH PRODUCTION

(Unit: t)

Production	1979/80	1981/82 1/	1984/85 2/	2000 3/
1. Capture Fisheries				
a. Rice Field Rivers & Lakes	2,200	2,200	2,200	4,000
b. Reservoirs	-	-	n.a.	2,500
2. Aquaculture				
a. Ponds	700	1,700	n.a.	18,000
b. Cages	-	-	50	500
c. Rice-cum-Fish				18,000
3. Total Production	2,900	3,900	6,267.5	26,800
4. Production Available for per Capita Consumption (gr)	225(gr)	-	415(gr)	-

Source:

1/ Fisheries Development Division, DOA

2/ The Sixth Plan (1980-1985)

3/ Nepal Agriculture Sector Strategy Study. ADB, 1983

TABLE 6-4-6 ELECTRIC CONSUMPTION OF AQUACULTURE IN JAPAN

Fish	No. of Samples (m^2)	Area of Pond (kwh)	Electric Capacity of Facility	Electric Consumption per annum (kwh)	Scientific Name
Eel	19	407,652	931	1,854,759	Anguilla japonica
Smelt (Ayu)	21	48,349	1,066	4,388,842	Plecoglossues altivelis
Carp	27	242,074	326	1,067,907	Cyprinus spp.
Trout	17	41,664	301	746,941	Salmo spp.
Goldfish	5	33,729	26	135,403	Carassius auratus
Snapping Turtle	5	1,500	45	41,606	Amyda sineusis
Others	7	46,726	84	270,946	
Total	101	821,694 (82 ha)	2,779	8,506,404	
Average		8,136	33.9/ha	103,737/ha	

Source: Sample Survey of Electric Consumption in Aquaculture, 1971
Association of Agricultural Electrification, Japan

TABLE 6-5-1
(1 of 9)

ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE MECHI ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
1. TAPLEJUNG DISTRICT					
OSE	M-1		250	Infeasible	
2. PANCHATHAR DISTRICT					
Changthapu	M-2	Changthapu	90	Feasible; recommend detail survey	Attached w/Washong KHOLA
Namdu	M-3		1,350	Feasible	
Kaphal	M-4		300	Infeasible	
Lungkhuwa	M-5	Sampuwa, Angsarang Mehelbote, Adarsha	500	Feasible	Detail survey on-going
Yasok	M-6	Yashok	135	Infeasible	
Nawa Khola	M-7		240	Repairs needed	
Arubote	M-8	Arubote	350	Infeasible	
Kurunba	M-9	Kurumba	125	Feasible	
Sanche Khola	M-10	Bharapa, Kunga	140	Feasible	
Chisang Khola	M-11	Durdunba	300	Infeasible	
Ginyuwa Khola	M-12	Ginyuwa, Phakdep	400	Infeasible	Detail survey on-going
Washong Khola	M-13	Chyang thapu	200	Feasible	
3. ILAM DISTRICT					
Dev Mai Khola	M-14	Chamaita	1,200	Feasible	
Tama Khola	M-15	Imang	60	Infeasible	
Khawana Khola	M-16	Shakkra	60	Infeasible	
Jogmai Khola	M-17	Suyang, Namsaling	600	Recommend further study	
Puwa Khola	M-18		300	Feasible	
Adheri Khola	M-19	Godak	150	Recommend for detail survey	
Tangting Khoyan Khola	M-20	Shantipur	170	Feasible	
Survey Khola	M-21	Naya Bazaar	40	Feasible	
Badamtar	M-22	Shantipur	125	Feasible	

TABLE 6-5-1
(2 of 9)
con't

ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE MECHI ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
4. JHAPA DISTRICT					
Sidohi Khola	M-23	Bahundangi	2,800	Feasible	
Dhar dhare Khola	M-24	Garamari	48	Feasible for groundwater	Attached w/Bhutani Khola
Butani Khola	M-25		1,200		
Hadiya Khola	M-26	Chandragadhi	700	Feasible	Duplicated to Index No. 102T68210
Surung Khola	M-27		800	Integrated	
Gaura DAHA	M-28	Gauradaha	2,400	Detail survey on-going	Rehabilitated location is unidentified
Kisni Khola	M-29	Gauradaha	2,200	Infeasible	
Bhutane Khola	M-30	Rajgadh	400	Feasible	
Andhuwa Khola	M-31		2,690		
Ninda Khola Dhula bari	M-32			Infeasible	
Prithvinagar	M-33	Prithvinagar, Baniyani	2,000	Feasible (?)	

Note: Khardep Project: Kosi Hill Area Rural Development Program; LUI: Location is unidentified

TABLE 6-5-1
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ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE KOSI ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
1. SANKHUNWASBHA DISTRICT					
Num	K-1		40		Khardep Project
Bor Dev	K-2		15		Khardep Project
Kurkuseni	K-3		30		Khardep Project
Pangma	K-4				Khardep Project
Himasima Khola	K-5	Mairn, Siddhakali	8,000	Considered	
Tumling Tar	K-6	Tumling Tar	600	Considered	
Mamling	K-7		50		Khardep Project
Tama Phok	K-8		50		Khardep Project
Pangama	K-9		100	Feasible	
Panma Khola Khadbari	K-10	Khadbari			
Pagma, Khola	K-11	Pagma, Manokemana	1,000	Feasible	
2. BHOJPUR DISTRICT					
Chauki Danda	K-12		40		Khardep Project
Lumba Khola	K-13	Surkhe	200	Feasible	
Keurin Panee	K-14		25		Khardep Project
Boya	K-15		40	Feasible	Khardep Project
Sisne Khola	K-16		760	Unstated	Attached w/Dunaiua Bazar
Pancha Kanya	K-17		75		Khardep Project
Nagdah Pahardani Paiyapani	K-18	Taksar	150	Detail survey	
Mane Bhanjyang	K-19		25		Khardep Project
Khukala	K-20		20		Khardep Project
Machhuwa Bazar	K-21		45		Khardep Project
Haija Kharang	K-22		30		Khardep Project
Jogedatar	K-23		45		Khardep Project
Chhange Khola	K-24	Kudalawli,, Kimalung	200	Detail survey	
SHYAM Khola	K-25	Keurenigur Mulpani, Topogachhi	350	Feasible	
Hegrayo Khola	K-26		250		Location is unidentified
Pachame Khola	K-27	Singhang	50	Feasible	
Kawa Khola	K-28	Ranibus	40	Feasible	
Khume Khola	K-29	Devanter	16	Infeasible	
Raktan Khola	K-30	Kasanpur	60	Repair	
Khakuwa Khola	K-31	Deuseli	1,035	Feasible	
Singane Khola	K-32		775	Detail survey	
Sangpang DEURALI	K-33	Sangpang, Deurali	1,555	Unstated	
Hengrame Khola	K-34	Yaku	350	Infeasible	

TABLE 6-5-1 (4 of 9) con't

ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE KOSI ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
3. TEHRATHUM DISTRICT					
Koya Khola	K-35	Khamulung	700	Feasible	
Phunga Khola	K-36		500	Feasible	
Phunguwa Khola	K-37		2,000	Considerable	
Samadu Khola	K-38		100		Khardep Project
Morhang	K-39		50		Khardep Project
Aathari Khola	K-40		200	Considerable	
Basantapur	K-41		13		Khardep Project
Solma	K-42		8		Khardep Project
Piguwa Khola	K-43		2,000	Feasible for lift irrigation	
Chhathar Okhre	K-44		60		Khardep Project
Teliya Khola	K-45		417	Infeasible	
Sungnam	K-46		25		Khardep Project
Sadhuwa	K-47			Considered	Khadep Project location is unidentified
Fugua Khola	K-48	Hwak	2,880	Feasible	
4. DHANKUTA DISTRICT					
Kewa Khola	K-49		150	Detail survey	
Jitpur	K-50		45		Khardep Project
Hattikhark	K-51		35		Khardep Project
Chaungwaha	K-52		30		Khardep Project
Uttar Bahni	K-53	Nigare	1,000	Infeasible/Consi	
Teliya Khola	K-54	Telia	1,480	Feasible	Repair
Pilitar	K-55		15		Khardep Project
Belhara Besi	K-56		40		Khardep Project
Dilung Tar	K-57		8		Khardep Project
Luke	K-58		30		Khardep Project
Khani Tar	K-59		20		Khardep Project
Diyale Tar	K-60	Sane, Ghorli-kharka Diyale Desi	840	Feasible	
Mahendra Kulo*	K-61	Nampu, Chauna	575	Feasible	*
Hanguwa Khola	K-62	Nuga	250		

TABLE 6-5-1
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con't

ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE KOSI ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
5. MORANG DISTRICT					
Solti Khola	K-63		200	Feasible	
Bakra Khola	K-64		3,000	Feasible	
Betarna Khola	K-65		70	Feasible	
Gachhiya Khola	K-66		275	Considered	
Kisti Khola	K-67		1,200	Feasible	
Bhariya Khola	K-68		1,200	Considered	
Kajala Khola	K-69		2,900	Repair	
Gachhiya Khola	K-70				BUDHI & LOHANDRA DIMENSION PROJECT
Judi Khola	K-71	Mathigung	1,000	Infeasible	
Amtola Betona	K-72		1,000	Feasible	Rangeli Rd. 5 km Wart Biratnagar A/P 21 km from KHOCHENI KHOLD
Kuruwa Khola	K-73		2,000	Considered	
6. SUNSARI DISTRICT					
Tonga Khola	K-74		2,800	Feasible	
Chanda Mohana	K-75	Rajgung sunwari	1,000	Feasible	
Tengro Khola	K-76	Itahri	2,400		

TABLE 6-5-1
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ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE SAGARMATHA ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
1. SOLUKHUMBU DISTRICT					
Meyo Batase Khola	S-1	Kagel, Panchan	80	Feasible	
Solu Khola	S-2	Tingla, Salyan	500	Feasible	
2. OKHALDHUNGA DISTRICT					
Salele Khola	S-3	Ragani	500	Unstated	
Hokse Tar	S-4	Ranibar	45	Feasible	Detail survey
Parapu Panchayat	S-5	Parapu	68	Infeasible	
Kuibir Tar	S-6	Khani Bhauyyang	175	Feasible	Detail survey
Thotne Khola	S-7	Mankha	696	Considered	
Ghusei	S-8	Diyale	600	Considered	Detail survey Serna Khola
Sisne Khola	S-9	Thulochhap	95	Infeasible	
Bange Khola	S-10	Khani Bhauyyang	17	Infeasible	
Reyal Tar	S-11	Phedigath	125	Feasible	
Narmade Shor Tar	S-12	Tarkerabani	750	Feasible	
Kumal Tar *	S-13	Kuhnibeer	300	Unstated	KHATRI TAR
3. KHOTANG DISTRICT					
Nerpa Khola	S-14			Feasible	
Nirmali Danda	S-15	Nirmali Danda	2,654	Infeasible	Detail survey
Tawa Khola	S-16	Lickki Ranche Gaon	50	Infeasible	
Dhiplung Khola	S-17	Temma		Feasible	
Sapsu	S-18		212	Feasible	
Tawa Khola	S-19		680	Feasible	
Mekhu Khola	S-20	Mastinbisha	20	Feasible	
Tawa Khola	S-21	Temma	250	Feasible	
Rawa Khola	S-22	Kharpa	1,600	Infeasible	
4. UDAYPUR DISTRICT					
Kindu Churmi Tar	S-23		20	Repair	
Kuene Tar	S-24		14	Infeasible	
Rakula	S-25	Thana	45	Infeasible	
Yari Khola	S-26	Luanse	190	Infeasible	
Sorup Tar	S-27	Lapha, Saruptar	55	Repair	Supply financial aid
Ratomato	S-28		60	Repair	
Tawa Khola	S-29		2,000	Feasible	
Tarrang Khola	S-30	Taprang	125	Feasible	
Baraha Baruwa Khola	S-31		12		Location is unidentified

TABLE 6-5-1
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con't

ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE SAGARMATHA ZONE AS OF 1983

	Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
	Ranibas	S-32	Thula Khada Khabu	125	Feasible	
	Tawa Khola	S-33		50		(SORUNG CHHABASI)
	Tawa Khola	S-34	Muksar	1,000	Infeasible	
	Kunai Tar	S-35	Kunai Basi, Basbake	13	Feasible	As district program
	Baraha Baruwa Khola	S-36	Baraha	12	Infeasible	Location is unidentified
	Ratmate	S-37	Aptar	60	Infeasible	Location is unidentified
	Banuwa Khola	S-38	Gaighat	180	Feasible	
	Kindu Dhurusi Tar	S-39		20	Infeasible	
	Sindure Besi	S-40	Sorung Chhalise	50	Feasible	
	Tawa Khola	S-41	Katari	2,000	Feasible	
	Yari Khola	S-42	Ruptar, Katahare	40	Infeasible	
5.	SIRAHA DISTRICT					
	Kakaka Bahadur	S-43		17	Feasible	
	Saraswati Band	S-44		13	Feasible	
	Bokai Chaudhari	S-45		133	Feasible	
	Radal Bab	S-46	Bastipur	17	Feasible	
	Band Khola	S-47		1,043	Considered	
	Baburam Khola	S-48	Dhangadi	300	Feasible	
	Sahaja Khola	S-49		338	Infeasible	
	Khuti	S-50		6,660	Considered	
	Kalyan	S-51		900	Feasible	
	Kalyan Desti	S-52	Maubahi	900	Feasible	
	Bahaya Khola	S-53	Gauripur		Infeasible	
	Bihul Nadi	S-54	Malharia	250	Feasible	
	Khayan Khola	S-55		350	Infeasible	
	Rawa Khola	S-56	Bhadaiya	1,043	Feasible	
6.	SAPTARI DISTRICT					
	Kharga Khola	S-57	Kalyanpur	600	Feasible	Recommended for tube well
	Mahuli Khola	S-58	Bakdhua	1,533	Infeasible	
	Parswahi	S-59		825	Infeasible	
	Belahi	S-60		800	Feasible	
	Bhutani Ghor	S-61		1,800	Infeasible	
	Daha	S-62			Infeasible	
	Bhutani Chardaha	S-63	Tarahi, Lapripur Hatebli	1,800		
	Kagaradhar	S-64	Shanjeha	1,000	Infeasible	

TABLE 6-5-1
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ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE JANAKPUR ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
1. DOLKHA DISTRICT					
Charnabati	J-1		6	Considered	
Namou	J-2	Kavre, Gauri Muri	350	Considered	
Jhakra Khola	J-3	Gaura Gaun	100	Feasible	Detail survey
2. RAMECHHAP DISTRICT					
Tindhare Dovan	J-4	Phulasi	950	Feasible	Detail survey
Lubughat Gumari Chour	J-5		125	Feasible	
Birta	J-6		93	Feasible	
Sampu Panchayat	J-7	Sampu	155	Unstated	
3. SINDHULI DISTRICT					
Mahendra Jhadi	J-8		350	Feasible	Detail survey
Jhadi	J-9		115	Feasible	
Gaduli Khola	J-10		160	Feasible	
Tari	J-11		3,500	Considered	
Mahendra Lada Vir	J-12	Dudhauli	3,000	Feasible	
Kurathauri	J-13	Kurathouli	105		Kamala River
Maistan	J-14	Bhiman	20	Feasible	Kamala River
4. SARLAHI DISTRICT					
Soti Khola	J-15		133		Detail survey
Sapana Nadi	J-16	Gauri Shankar	1,000	Feasible	
Hempuri	J-17	Hempur	300		Under Bagmati area
5. MAHOTTARI DISTRICT					
Sonma	J-18	Sonama	1,000	Feasible	
Kantawa	J-19	Khairahani	900	Feasible/Considered	(Raghunathpur)
Ratauli Biamigadhi	J-20		900	Feasible/Considered	
Raghnathpur-somna	J-21	Raghnathpur, Somna	2,450	Infeasible	
6. DHANUSA DISTRICT					
Bharatpur	J-22		670	Considered	
Uma Prempur	J-23		195	Infeasible/Considered	
Bega Sibapur	J-24		10	Feasible	
Jamuni	J-25		2,000	Feasible	Detail survey

TABLE 6-5-1 (9 of 9) ON-GOING & PROPOSED TAR IRRIGATION PROJECTS IN THE BAGMATI ZONE AS OF 1983

Project Name	Code No.	Village Panchayat	Command Area in ha	Recommendation Status	Remarks
1. SINDHUPALCHOK DISTRICT					
Manghakal	B-1		42	Infeasible	
Lukum Khola	B-2	Dawachaur	400	Infeasible	
Chhahare Khola	B-3		550	Feasible	
Syalile	B-4		200	Infeasible	
Chalchepat	B-5		120	Infeasible	
Chattekulo	B-6		250	Feasible	
Lamsoti Boguw	B-7	Ghuskun Jagale	225	Infeasible	
SINDHUKOT	B-8	Sindhukot	125	Infeasible	
Boprang & Khallo Khola	B-9	Haibung	125	Feasible	
Chinghur Khola	B-10	Bhotang	110	Infeasible	
Handi Khola	B-11	Nawalpur	400	Feasible	
Jalbirkot, Phulping Khola	B-12	Phulping Kot	225	Feasible	
Chatte Khola	B-13	Chokati	28	Feasible	
2. KABHRE PLANCHOK DISTRICT					
Jyamdi Ga Pan	B-14		30	Feasible	
Ghatte Khola	B-15		100	Feasible	Detail survey
Saleri Khola	B-16		35	Feasible	
Dapchha Besi	B-17	Dapchha	50	Infeasible	
Sundi Khola	B-18	Sarda	60	Infeasible	
Nepalbesi Phant	B-19	Chalal	80	Feasible	Detail survey
Panauti	B-20	Mahendra Jyoti	55	Considered	
Danda Gaon	B-21	Kanpur	22	Feasible	
Ranghu Chour	B-22	Katunje Besi	35	Feasible	
Kaldhar Besi	B-23	Chapakhori	40	Feasible	
Piple Tar	B-24				
Bismure	B-25		20	Feasible	
Doran Khola Rapsatar	B-26	Bhumalfar	7		
Dauwa Bensi	B-27	Bhumalfar	15		
Tari Khet	B-28	Sim Khet Tar	9		
Yargbel Khola	B-29	Sharmthali	150	Feasible	
Khahare Pangu	B-30	Khahare Pangu	175	Feasible	