Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Water Resources Planning Organization

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT FEASIBILITY STUDY

ANNEX F AGRICULTURE

Final Report
March 1998

SNC ♦ Lavalin International
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COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is created to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is all that remains of the past lowland forest. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal by the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

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ACRONYMS AND ABBREVIATIONS

AAEO	Assistant Agricultural Extension Officer
AEZ	Agro Ecological Zone
AST	Agriculture Sector Team
ATAO	Additional Thana Agriculture Officer
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water Development Board
CEC	Cation Exchange Capacity
CERDI	Central Extension Resources Development Institute
cft	cubic feet
CIDA	Canadian International Development Agency
cm	centimetre
DAE	Directorate of Agricultural Extension
DAU	Draft Animal Unit
DOF	Department of Fisheries
DSSTW	Deep Set Shallow Tube Well
DTW	Deep Tube Well
DWR	Deep Water Rice
EMP	Environmental Management Plan
FAO	Food and Agriculture Organization (United Nations Agency)
FAP	Flood Action Plan
FCDI	Flood Control Drainage and Irrigation
FPCO	Flood Plan Coordination Organization
FW	Future With Project
FWO	Future Without Project
GIS	Geographic Information System
ha	hectare
HH	Household
hr	hour
HTW	Hand Tube Well
HYV	High Yielding Variety
ILO	International Labor Organization
JAEO	Junior Agricultural Extension Officer
kg	kilogram
km	kilometre
KK	Kalni-Kushiyara
KKRMP	Kalni-Kushiyara River Management Project
LDC	Land Development Category
LGED	Local Government Engineering Department
LLP	Low Lift Pump
m	metre

mm	millimetre
Mm^3	Million cubic metres
MOA	Ministry of Agriculture
MP	Murate Of Potash
MPO	Master Plan Organization
mt	metric tonne
NCA	Net Cultivated Area
NERP	Northeast Regional Water Management Project
PET	Potential Evapotranspiration
PWD	Public Works Department
SRDI	Soil Resources Development Institute
SSP	Single Super Phosphate
STW	Shallow Tube Well
TAO	Thana Agriculture Officer
Tk	Taka (Bangladesh currency. $1 CDN=approx. Tk 30)
TSP	triple super phosphate
TW	tube well
UNDP	United Nations Development Program
WARPO	Water Resources Planning Organization

GLOSSARY

aman	monsoon rice crop
arum	vegetable grown in the pre-monsoon season
aus	pre-monsoon rice or rice grown in *kharif* I season.
b. aman	broadcast or deep water aman rice grown in *Kharif* I season
bazar	market
beel	floodplain lake that may hold water perennially or dry up during the winter season
bepari	laborer coming from outside the area
boro	rice grown during the dry, winter season
brinjal	eggplant
char	newly emerged land, silted water body
danta	vegetable grown in the pre-monsoon season
dhala	breach across the river bank
doon	traditional irrigation equipment
dry season	5 months: December-April inclusive
haor	depression in the floodplain
jagli	local *boro* variety
karala	vegetable grown in the pre-monsoon season
khal	channel
kharif	monsoon crop season, including the *aus* and *aman* crop
khas	government owned land or water bodies
mauza	lowest level revenue unit
ploughpan	a compact layer, usually about 5 cm thick, occurring immediately below the cultivation layer in some soils. It is formed by repeated pressure from the plough during ploughing of the moist or wet soil.
rabi	dry season
shail	local *boro* variety
t. aman	transplanted aman rice grown in *Kharif* II season or monsoon season
taka (tk)	unit of currency, 1 US $ = 40 taka (approx.)
thana	geo-administrative unit under a district comprising several unions
union	geo-administrative unit under a thana comprising several villages
union parishad	elected local government council at the union level
wet season	7 months: May-November inclusive

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1. INTRODUCTION

1.1 Background

The Kalni-Kushiyara River Management project (KKRMP) covers a gross area of 335,600 ha and extends over the districts of Sylhet, Sunamganj, Moulvibazar, Habiganj and Kishoreganj in the Northeast region of Bangladesh. The study area is shown in Figure F.1.

Due to a major channel avulsion on the Suriya River some 30 years ago, the river has experienced ongoing sedimentation and instability which has lead to bank and homestead erosion, pre-monsoon floods and resulting damages to rice crops, and deteriorating navigation during the dry season.

With the financial assistance of the Canadian International Development Agency (CIDA), the pre-feasibility study of this project was completed in 1994. After review, CIDA together with the Flood Plan Coordination organization (FPCO) and the Bangladesh Water Development Board (BWDB) decided to proceed with the feasibility study.

Given the nature of the problems facing the study area, the project was formulated to meet multiple objectives, including:

- improving the river's stability and providing a more stable environment for development;
- reducing damages to agriculture by reducing pre-monsoon flood damage and improving post-monsoon drainage;
- improving living conditions along the river by reducing erosion damage to villages, and by creating flood-free village platforms, and
- improving navigation during the dry season.

In order to meet the above objectives, the feasibility study proposed an intervention to rehabilitate the Kalni-Kushiyara River to pre-Suriya avulsion conditions. Two Alternatives of the intervention were analyzed. The components are:

- loop cuts, one at Issapur (Alternative 1 only), the second at Katkhal;
- spot dredging of the Dhaleswari River (Alternative 1) or complete dredging (Alternative 2);
- dredging the Kalni River reach between Issapur and Ajmiriganj;
- constructing flood-resistant village platforms from the dredged spoil;
- constructing bank protection works at various sites;
- constructing levees along low banks to reduce spills, and
- maintenance dredging for improved navigation up to Fenchuganj.

The location of the works on the Kalni River reach is summarized in Figure F.2 for Alternative 1 and Figure F.3 for Alternative 2.

1.2 Objectives

This annex of the KKRMP feasibility study report describes the current status of agriculture in the KKRMP study area. It also presents the problems and issues currently affecting the agricultural sector. It then describes the conditions which are likely to prevail in the future if the current situation continues. Finally it analyses the impacts for the KKRMP on future agricultural production.

The report focuses on the issue of crop damages caused by pre-monsoon floods and on the reduction of these damages as a result of the proposed intervention.

1.3 Methodology

The methodology adopted for the agricultural impact assessment of the KKRMP conforms to the methodology presented in the *Guidelines for Project Assessment* (FPCO, 1992) of the Flood Plan Coordination Organization (FPCO), now Water Resources Planning Organization (WARPO).

1.4 Source of Information

Data required by the agricultural study team was obtained from both primary and secondary sources.

Primary Sources of Data
The primary sources included land use surveys, input use monitoring and field interviews. A land use survey provided the basic data to identify major and minor crops grown in the project area, crop sowing time, transplantation and harvest period, and yield levels both under normal and damaged conditions.

The survey was carried out on 10 sample areas. The location of these sites was selected to cover the various sub-regions of the study area. These sub-regions in turn were identified from an examination of a series of maps on flooding characteristics, agro-ecological zones, soil association, land capability and land use association. The sources of these maps were the FAO/UNDP land resources appraisal project, Soil Resources Development Institute (SRDI) reconnaissance soil survey and technical reports of WARPO (MPO). The whole study area was visited to select the exact location of each sample site.

The information on crop production of these sample areas was collected on *mauza* maps and questionnaires. Each land use type, its location and areal extent were recorded on the corresponding *mauza* map.

Input use and crop yields were determined from farm monitoring and crop cuts using a second questionnaire. Information on farming characteristics, cultivation practices, agricultural extension activities, marketing, limitations to agricultural production and suggestions as to the nature of interventions which would solve current problems were obtained from field interviews, group discussions, meetings and seminars.

Secondary Sources of Data

Secondary sources provided information on cultivated areas, land type, use, capability, soils, agriculture extension services, and historical data on crop areas and production. The data was collected from SRDI, FAO/UNDP Land Resource Appraisal Of Bangladesh, WARPO, Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Department of Agricultural Extension (DAE), Central Extension Resources Development Institute (CERDI) and BBS. Findings of other studies have also been considered where applicable.

The Net Cultivated Area (NCA) was determined from several sources. *Thana* maps (scale 1:50,000) compiled by Local Government Engineering Department (LGED) from spot imagery (1989-90) were digitized to obtain the area of infrastructure, homesteads and other non-agricultural areas. BBS statistics were analyzed to determine the area of *khas* and grass land. NERP land use survey and numerous field visits also provided information on these *khas* and grass areas.

The net cropped area of the 10 sample areas included in the land use survey was calculated, then compared with 1983-84 BBS census data. This comparison provides the increase in cropped area during the period over the sampled area. This in turn is prorated to project NCA to obtain the current total cropped area. This estimate was then compared to BBS *thana* statistics (1995) available in districts headquarters

1.5 Report Outline

The report is divided into 9 chapters. Chapter 1, the present chapter presents the introduction. Chapter 2 presents a brief description of the physical characteristics relevant to agriculture, climate, hydrology, agro-ecological zoning, soils and land capability. Chapter 3 describes the individual sample areas and their agricultural characteristics. The present agricultural production system is described in Chapter 4. Chapter 5 describes the recent changes which have taken place in agricultural production. Chapter 6 deals with constraints and limitations to agricultural production. Chapter 7 presents future agricultural production if the present situation is allowed to continue. Chapter 8 presents the impact of the KKRMP on crop production. Other opportunities for the improvement of the agricultural sector are discussed in Chapter 9.

Since several of the chapters refer to administrative units, a map showing *thana* and district boundaries is presented in Figure F.4 for reference.

2. PHYSICAL CHARACTERISTICS

The KKRMP project area covers 335,600 ha. The boundaries of the project area are physical, ie. rivers and roads, and have been selected such that the whole of the *haor* area subject to flash floods from the Kalni-Kushiyara River during the pre-monsoon season is included in the project area. The net cultivated area (NCA) is 279,850 ha, some 83% of the project area. Early flash floods in the pre-monsoon season and deep flooding of the *haor* throughout the monsoon season restrict crop production in cultivated areas. Cropping patterns and crop types are determined by the depth, time and duration of flooding. A significant portion of the project gross area is affected by pre-monsoon floods, typically 21%, 65% and 86% for respectively the 1:2 year, 1:5 year and 1:10 year flood.

The following sections describe the physical characteristics of the project area, ie. land type, physiography, climate, hydrology, agro-ecological zones, soils and their association, land capability, crop suitability, and their influence on agriculture.

2.1 Agro-climate

The climate of the project area is monsoon tropical with hot wet summers and cool dry winters.

Lowest temperatures occur in January with a mean monthly temperature of 12°C and an extreme minimum of 6.2°C. Minimum temperatures start to fall below 20°C in late October in the north and early November in the south. The mean monthly temperature remains below 15°C for 50 to 70 days in the western zone of the project area and for 70 to 90 days in the eastern zone. Highest temperatures occur in April with a mean monthly temperature of 33.3°C and an extreme maximum of 40.4°C.

The rainfall distribution shows a general pattern of gradual increase from south (2,600 mm/year) to north (4,400 mm/year). The mean annual rainfall of the project area is 3,334 mm. Table F.1 presents the seasonal distribution of rainfall for the main gauges within or in the immediate vicinity of the study area. Of particular interest to agriculture are the rainfalls during the dry season and the pre-monsoon season.

Table F.1: Seasonal Distribution of Rainfall

Gauge	Rainfall (mm)				
	Pre-Monsoon April-May	Monsoon June-Sept.	Post-Monsoon Oct.-Nov.	Dry Season Dec.-March	Year
Habiganj	670	1,577	176	116	2,539
Markuli	899	1,354	169	107	3,529
Sylhet	926	2,841	270	172	4,209

Source: NERP, 1995

Potential evapotranspiration (PET) varies from 63 mm/month in December to 107 mm/month in July.

The pre-*kharif* transition period is characterized by unreliable rainfall, which varies from year to year in timing, frequency and intensity, and which provides only an intermittent supply of moisture for crop growth. This transition period increases from 15 to 20 days in the western zone to 30 days in the eastern zone. It starts when precipitation first exceeds 50% of PET after end-February. It ends when precipitation continuously exceeds 50% of PET. Then the *kharif* growing period starts. The mean *kharif* start date varies from 15 to 20 March in the western zone to 1 to 10 April in the eastern zone. The mean *kharif* end date varies from mid December in the south to early January in the north. The standard deviation of *kharif* start and end dates are respectively 10 to 20 days and 20 to 30 days.

The reference *rabi* growing period is longer in the north and than in the south. The mean *rabi* starting date varies from 20 October to 10 November and the mean end date varies from 5-25 March. The standard deviation of *rabi* start and end dates are respectively 15 to 20 days and 15 to 30 days.

2.2 Flooding

WARPO's land classification system, based on monsoon flooding and depth of flooding (flood phase), classifies cultivated lands into 4 land types: F0, F1, F2 and F3 lands. This classification is related exclusively to monsoon season flooding. The flooding depth is less than 0.3 m in F0 lands, 0.3 to 0.9 m in F1 lands, 0.9 to 1.8 m in F2 lands and more than 1.8 m in F3 lands.

2.2.1 Monsoon Flooding

According to an analysis carried out by NERP team (Chapter 2 of the KKRMP Feasibility Main Report) on the 1:2 year monsoon flood: 4% of the cultivated land is food-free (FO) land, 8% is F1 land, 22% is F2 land and 66% is F3 land. Accordingly, the crops occupy about 10% of the net cultivated area (NCA) during the monsoon season. As a result of this extended monsoon season flooding, crops are grown mainly during the dry season and they are harvested before the beginning of the monsoon season.

The proposed KKRMP project does not have any impact, on agriculture, during the monsoon season. It is basically designed to confine pre-monsoon floods within the river channel and to improve post-monsoon drainage.

2.2.2 Pre-monsoon Flooding

In this KKRMP feasibility study, the cultivated land of the project area is classified according to the following 4 pre-monsoon flood level ranges:

- flood free land where the flooding depth is less than 0.3 m;
- shallowly flooded land where the flooding depth varies from 0.3 to 0.9 m;
- moderately flooded land where the flooding depth varies from 0.9 to 1.8 m;
- deeply flooded land where the flooding depth exceeds 1.8 m.

Moreover, unless stated otherwise, any reference to floods or flooding appearing in the remainder of this Annex refers to pre-monsoon conditions.

The analysis of the 1:2 year pre-monsoon flood on the topography of the project area shows that the cultivated area is mostly flood free (Table F.2).

Table F.2: Pre-monsoon Flood Depth in the Cultivated Area

Pre-monsoon Flood Return Period	Cultivated Land (ha)			
	< 0.3 m	0.3-0.9 m	0.9-1.8 m	>1.8 m
1:2 year % of Total Area	233,277 83%	22,625 9%	17,728 6%	6,220 2%
1:5 year % of Total Area	84,648 30%	54,344 19%	95,004 34%	45,854 17%
1:10 year % of Total Area	12,704 5%	35,093 13%	122,944 44%	109,109 38%

Source: NERP, 1996.

The area of flooded land (> 0.3 m) increases significantly for the 1:5 year pre-monsoon flood and represents 70% of the cultivated area. For the 1:10 year pre-monsoon flood, only 5% of the cultivated land is virtually flood free.

2.3 Physiography and Landforms

Three main landform units are found in the project area. These include: Uplands, Lowland Floodplains, and *Haor* and Flood Basin (Figure F.5). The extent of each unit is summarized in Table F.3 and unit boundaries have been synthesized from the classification published by Rashid (1991).

The following discussion illustrates the main features of each landform unit as well as terrain characteristics.

Table F.3: Summary of Land Unit Areas

Landform Unit	Physiographic Unit	Area (ha)	% Project Area
Haor and Flood Basin	Central Basin	211,300	63
	Sylhet Lowland	7,200	2
Lowland Floodplain	Surma/Kushiyara Floodplain	113,700	34
Uplands	Sylhet Hills	3,400	1

Source: Rashid, 1991

2.3.1 *Haor* and Flood Basin

This landform unit is characterized by large saucer-shaped seasonally flooded, inter-fluvial areas known as *haors* within which small, permanent lakes, called *beels*, exist. Flood basins and *haors* are the dominant landform throughout the unit. It forms a low lying, bowl-shaped depression which occupies almost two-thirds of the project area. This unit is bounded by the Surma River to the north, the Surma/Kushiyara floodplain to the east, Ratna to the south and the Baulai River to the west. The elevations typically range from 3 to 5 m. Much of the land is crossed by distributary spill channels and other partly infilled channels which at one time connected the Surma River system to the Kushiyara River.

2.3.2 Lowland Floodplains

Lowland Floodplains have been created as a result of erosion and deposition from the Surma and Kushiyara Rivers. This landform unit covers one-third of the project area. Elevations typically range from 5 to 7 m. River banks consist of wedge shaped ridges particularly well developed on the convex (outer) side of meanders. They often are the highest landscape features in the floodplain and are some 3 to 5 m above the floodplain. These natural levees are formed by sediment deposition when streams overtop their banks.

2.3.3 Uplands

The Uplands land unit occurs in the north-eastern zone and covers 1% of the project area. The unit consists of merging alluvial fans which slope gently outward from the foot of hills into low-lying basins. These merge into the adjoining floodplain basins.

It should be mentioned herein that the upland landform unit has only been included in the project area because the area's boundaries are defined by rivers and roads and as a result this unit is present at the north-eastern margin of the project area. In fact the inclusion of the Uplands landform unit in the project area is for all practical purposes irrelevant because Uplands areas may only be flooded during extreme events. However this unit is adjacent to the Damrir *haor*, a major drainage project (Figure F.1).

2.4 Agro-ecological zones (AEZ)

Based on the agro-ecological zoning (regions and sub-regions) of the UNDP/FAO (1988), the project area is occupied by the Old Meghna Estuarine Floodplain (AEZ 19), Eastern Surma-Kushiyara Floodplain (AEZ 20), Sylhet Basin (AEZ 21), Northern and Eastern Piedmont Plains (AEZ 22), and Northern and Eastern Hill (AEZ 29). The AEZ 19, AEZ 21, AEZ 22 and AEZ 29 are divided into sub-zones (Figure F.6). The sub-zones are differentiated on details of relief and flooding characteristics. The extent of each AEZ is provided in Table F.4.

AEZ 19 occurs in the south-western part of the project area. It consists of smooth, almost level, floodplain ridges and shallow basins. Seasonal flooding is moderately deep. This area is subject to rapid rises in flood levels.

AEZ 20 occurs in the eastern part of the project area. It consists mainly of broad ridges and depressions, Local differences in elevation may range from 6 to 10 m. There is a broad belt of irregular relief, with narrow linear ridges separated by depressions along the Kushiyara River. This AEZ also includes some perennial wetlands with *haors* and *beels*. Ridges are shallowly flooded, *haors* and *beels* are deeply flooded. The whole area is subject to early floods and a rapid rise in flood-levels following heavy local rainfall. Early flood flows are laden with sediments. Water drains rapidly from ridges at the end of the monsoon but *beels* stay wet for most or all of the dry season.

AEZ 21 occupies most of the project area extending from the south-western boundary to the north-western boundary of the project area. This AEZ is divided into three sub-zones: 21a (Western), 21b (Central and Southern) and 21c (northern). It consists of broad depressions and naturally raised river banks. This AEZ includes some perennial wetlands. Ridges are moderately

Table F.4: Agro-ecological Zones

Name of AEZ	AEZ	Sub-Zone	Area ('000 ha)		% Project Area
			Sub-Zone	AEZ	
Old Meghna Estuarine Floodplain	19	c h	56.23 28.63	84.86	25.3
Eastern Surma-Kushiyara Floodplain	20		109.19	109.19	32.5
Sylhet Basin	21	a b c	8.30 118.82 5.08	132.20	39.5
Northern and Eastern Piedmont Plains	22	b	0.37	0.37	0.1
Northern and Eastern Hill	29	c	4.47	4.47	1.3
Rivers and *beels*			4.51	4.51	1.3
Project Area			**335.60**	**335.60**	**100.0**

Source: UNDP/FAO, 1988

flooded and depressions deeply flooded. The whole area is subject to early floods and a rapid rise in flood-levels. Flood-water drains rapidly from the ridges after the rainy season, but *haors* and depressions stay wet for most or all of the dry season.

AEZ 22 occurs on a narrow strips of land in the southern and north-eastern margins of the project area. This AEZ consist of merging alluvial fans which slope gently outward from the foot of the northern and eastern hills into low-lying depressions. The relief is irregular close to the rivers. This area is shallowly to moderately flooded in the rainy season.

AEZ 29 occurs in the southern and eastern margins of the project area. This AEZ has a complex relief which varies from very steeply dissected to gently rolling. It is poorly drained and subject to flash floods.

2.5 Soils

2.5.1 Physical and Chemical Properties

Soils are relatively uniform. Grey, heavy, silty clay loams predominate on the ridges, clay in the basins. Small areas of loamy soils occur alongside rivers, together with mixed sandy and silty alluvium. Peat occupies some *beels*. Except at the margin of *beels*, the cultivated layer of the predominant soils is lighter in texture than lower layers, and there is a strong ploughpan. Most soils have dark grey to black topsoil. In depressions, the upper part or all of the subsoil is also dark colored. In higher areas, the sub-soil is grey-brown to yellow-brown with dark grey coatings on the faces of subsoil cracks. Complex relief and soil patterns occur in the higher Piedmont Plains adjoining the hills. This area is graded into moderately deeply to deeply flooded basins with predominantly clay soils. Deposits range from sands to clays.

Nine General Soil Types occur in the project area. The major components of the General Soil Types are Non-calcareous Dark Grey Floodplain, Non-calcareous Grey Floodplain and Acid Basin Clays . Non-calcareous Dark Grey Floodplain predominates in the south-western zone, Acid Basin Clays in the center-southern part and Non-calcareous Grey Floodplain in the western, northern and eastern zones. Non-calcareous Alluvium, Peat, Non-calcareous Brown Floodplain Soils, Grey Piedmont Soils, Brown Hills Soil and Deep Grey Terrace Soils occur in varying proportions. Table F.5 shows a correspondence between these soil types and major international soil units. Table F.6 provides the physical and chemical properties of typical profiles of these soil types (CERDI 1983).

Table F.5: Correspondence between General Soil Types of Bangladesh and International Soil Units

General Soil Type	FAO-UNESCO Soil Unit	USDA Soil Taxonomy
Non-calcareous Alluvium	Mainly Eutric Fluvisol, Some Cambic Arenosol	Mainly Fluvaquent; Some Hydraquent, Psammaquent, Haplaquent, Ustipsamment and Udifluvent
Non-calcareous Brown Floodplain	Mainly Eutric Gleysol; Some Dystric, Gleyic and Eutric Cambisol; Dystric Gleysol; Cambic Arenosol; and Haplic Alisol	Mainly Eutrochrept; Some Ustochrept, Ustipsamment, Dystrochrept and Haplustult
Non-calcareous Grey Floodplain	Mainly Eutric Gleysol, Some Dystric Gleysol	Haplaquept
Non-calcareous Dark Grey Floodplain	Mainly Eutric Gleysol; Some Dystric, Mollic and Umbric Gleysol; and Umbric Cambisol	Mainly Haplaquept; Some Fluvaquent, Eutrochrept and Haplaquoll
Acid Basin Clays	Eutric Gleysol, Dystric and Mollic Gleysol	Mainly Haplaquept; Some Fluvaquent and Humaquept
Grey Piedmont	Eutric, Dystric and Albic Gleysol	Haplaquept
Deep Grey Terrace	Albic Gleysol, Eutric Planosol	Albaquept, Haplaquent and Haplaquept
Brown Hills	Dystric Cambisol, Ferric Alisol, Dystric Leptosol, Haplic Luvisol	Haplustult, Ustochrept, Dystrochrept, Eutrochrept, Ustorthent, Haplaquept
Peat	Dystric Histosol	Histosol, Haplaquept, Madisaprist

Source: Agro-ecological Regions of Bangladesh, UNDP/FAO, 1988.

The soil reaction is mainly acidic. Topsoil reaction is moderately to strongly or very strongly acidic. Ridge soils have near-neutral sub-soils, but basin soils are medium to very strongly acidic in the upper sub-soil, gradually becoming less acidic or neutral below about 50 cm. Organic matter content in the cultivated layer ranges from 0.5 to 2.5% in most ridge soils and from 2 to 5% or more in basin soils. The soils which occupy *beels* and stay wet for most or all of the dry season, generally have 2 to 5% organic matter in the cultivated layer. Fertility level is medium to high with low pH.

Table F.6: Physical and Chemical Properties of General Soil Types (Page 1 of 2)

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	C (%)	N (%)	pH H_2O	Exchangeable Cations (me/100 g)					BSP (%)	P_2O_5 (ppm)	S (ppm)	Zn (ppm)
							CEC	Ca	Mg	K	Na				
Non-calcareous Alluvium															
0-9	54.2	40.7	5.1	0.38	0.051	6.52	7.36	3.13	1.10	0.14	0.11	61	72	1.1	2.1
9-16	36.2	60.0	3.8	0.20	0.024	6.17	5.52	3.26	1.16	0.42	0.30	93	119	1.7	1.4
16-23	71.2	25.7	3.1	0.14	0.016	6.10	5.09	2.96	1.00	0.10	0.22	84	106	3.2	1.2
23-40	50.1	46.4	3.5		0.028	6.36	7.12	4.57	1.61	0.14	0.25	92	64	4.1	1.4
40-55	25.0	71.5	3.5				7.30	4.62	1.79	0.17	0.28	94		4.3	2.1
55+	10.8	80.1	9.1				9.50	5.60	2.91	0.37	0.30	97		3.4	4.0
Non-calcareous Brown Floodplain															
0-11	61.1	24.8	14.1	0.61	0.056	5.30	6.59	1.52	0.44	0.21	0.35	38	54	13.8	1.9
11-44	49.4	30.1	20.5	0.42	0.040	4.10	7.29	1.38	0.51	0.08	0.13	29	18	0.6	1.5
44-76	38.5	25.0	36.5	0.29	0.046	4.85	5.81	1.73	0.92	0.12	0.20	51	52	0	1.8
76+	51.1	20.4	28.5		0.033	4.30	3.87	1.93	0.85	0.13	0.19	80		0	4.1
Non-calcareous Dark Grey Ploodplain															
0-10	10.6	59.5	29.9	1.59	0.215	5.22	15.27	10.27	2.19	0.32	0.37	86	36	45.7	1.0
10-15	4.3	48.7	47.0	1.02	0.100	5.70	18.13	12.25	3.14	0.27	0.42	38	38	30.5	0.8
15-33	1.8	48.3	49.9	0.91	0.113	6.89	17.83	12.86	3.39	0.25	0.45	82	82	46.9	2.8
33-53	6.2	73.1	20.7		0.049	5.80	11.44	8.18	2.39	0.14	0.42	5	5	50.7	3.3
53-80	7.8	79.5	12.7		0.034	6.80	10.19	7.07	2.35	0.10	0.39	5	5	49.4	2.7
Grey Floodplain															
0-7	25.0	59.3	15.7	0.86	0.089	5.35	4.57	1.31	0.28	0.21	0.20	44	61	10.3	7.4
7-11	24.5	62.1	13.4	0.60	0.059	5.30	4.12	1.39	0.32	0.13	0.32	52	40	0	1.5
11-35	15.5	73.9	10.6	0.37	0.040	5.60	3.55	1.56	0.34	0.10	0.20	62	124	0	3.6
35-47	50.7	35.9	13.4		0.031	5.42	4.03	2.55	0.48	0.12	0.27	85	71	0	3.9
47-99					0.008	5.75	0.94	0.54	0.10	0.04	0	72			2.6
Acid Basin Clays															
0-10	9.4	36.0	54.6	2.11	0.228	4.50	31.91	8.52	3.39	0.51	0.26	40	32	32.2	6.4
10-35	5.5	27.3	67.5	1.80	0.280	4.30	27.82	11.82	5.52	0.49	0.43	66	20	0.3	6.4
35-55	6.0	31.1	61.9	0.90	0.107	4.94	17.96	10.37	5.77	0.37	0.59	95	17	11.6	1.5
55-84	10.1	53.4	36.5		0.046	5.30		5.14	5.39	0.20	0.36		23	8.9	0.9
84-100	45.3	35.2	19.5			5.55		2.90	3.65	0.12	0.23				

Table F.6: Physical and Chemical Properties of General Soil Types (Page 2 of 2)

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	C (%)	N (%)	pH H_2O	Exchangeable Cations (me/100 g)					BSP	P_2O_5 (ppm)	S (ppm)	Zn (ppm)
							CEC	Ca	Mg	K	Na				
Grey Piedmont															
0-15	46.0	44.9	9.1	1.21	0.137	4.95	4.49	1.91	0.37	0.13	0.05	55	77	4.1	1.7
15-26	40.0	49.0	11.0	1.00	0.069	5.20	5.44	1.76	0.53	0.09	0.05	45	55	2.8	1.7
26-47	42.0	30.4	27.6	0.62	0.058	4.85	7.87	3.70	1.64	0.59	0.20	78	40	8.4	1.1
47-77	31.1	45.6	23.3		0.045	5.20	6.39	3.39	1.51	0.08	0.17	81	55	0	1.8
77-100	43.1	34.1	22.8		0.047	4.82	7.43	3.78	1.64	0.09	0.17	76		22.2	2.2
Brown Hills															
0-15	68.9	20.9	10.2	0.76	0.085	4.35	9.29	0.52	0.21	0.16	0.02	10	30	1.7	1.2
15-45	68.0	17.0	15.0	0.70	0.070	4.62	8.61	0.38	0.16	0.07	0.02	7	19	25.9	1.8
45-70	73.0	15.3	11.7	0.42	0.031	4.60	8.95	0.38	0.16	0.05	0.02	7	17	53.6	0.9
70-125+	76.2	15.6	8.2		0.021	4.50	4.90	0.47	0.17	0.04	0.02	14	21	40.4	1.6
Grey Terrace															
0-10	23.4	50.8	25.8	1.15	0.132	5.80	7.36	4.44	0.99	0.14	0.52	83	54	1.0	2.6
10-15	18.5	54.3	27.2	0.95	0.099	5.70	7.41	4.94	1.03	0.11	0.52	93	34	2.7	3.2
15-28	14.5	42.1	43.4	0.41	0.058	6.00	12.05	8.91	1.74	0.14	0.93	97	17	0	2.3
28-46	14.8	35.0	50.2		0.030	6.20	16.42	11.74	3.03	0.29	1.22	99	16	0	1.1
46-65	15.2	34.4	49.8		0.031	6.10	17.55	12.48	2.76	0.19	1.24	95		0	1.1
65-76	14.2	38.4	47.4		0.028	6.00	18.07	12.60	3.83	0.37	1.30			41.2	1.6
Peat															
0-14	3.1	52.6	44.3	2.48	0.218	6.18	31.20	16.59	3.52	0.30	1.00	69	45	283	4.1
14-28	2.0	52.0	46.0	1.74	0.197	6.01	30.48	16.47	8.10	0.17	1.48	86	43	234	2.4
28-51				14.10	0.975	5.55	88.26	66.53	16.20	0.14	4.28	100	53	2171	1.3
51-64				2.29	0.242	5.85	39.86	29.25	14.72	0.48	0.66		198	807	1.1
64+					1.695	5.18	97.09	70.76	15.54	0.93	3.68	93		1066	1.5

Source: Soils of Bangladesh, CERDI, 1983

The level of CEC is high in Acid Basin Clays and Peat, low to medium in the other soil types. The content of phosphate, sulphur and zinc has been measured by CERDI, as available nutrients. The contents of zinc is high while that of other essential nutrients is medium. The status of potassium is low in uplands and low to moderate in lowlands.

Soils located in higher areas are moderately permeable and those located in depressions have a low permeability. The soils of higher lands where transplanted *aman* rice is grown have puddled topsoils and strong ploughpans and hence their permeability is low. The moisture holding capacity is inherently moderate. However puddling of the surface layer and the resulting formation of a strong ploughpan in soils used for transplanted paddy cultivation provides a barrier which retains water despite the low moisture holding capacity.

The predominant deep silty soils have a high capillary potential which keeps most soils wet (and poorly aerated) in the early part of the dry season and moist for most or all of the dry season. Depression soils generally stay wet early in the dry season and many areas stay wet through the dry season. Non irrigated soils become very hard when dry, and basin clays crack widely.

However, most soils stay wet because of irrigated *boro* rice cultivation. Valley clay soils close to hills have a low permeability and low moisture holding capacity.

2.5.2 Soil Series and Soil Associations

Information on soil series and soil associations or complexes present in the project area has been extracted from the SRDI's Reconnaissance Soil Survey Report of Sunamganj and Habiganj subdivisions (SRDI 1976), Kishoreganj subdivision (SRDI 1977), and Sadar (Sylhet) and Moulvibazar subdivisions (SRDI 1986). Individual soils within the project area rarely occur in sufficiently large areas to be mapped individually. Instead, they have been mainly mapped in soil associations which are mapping units containing two or more soils occurring side by side in a distinctive geographical relationship which repeats itself over part or the whole of a particular landscape. In all, there are 21 associations within the project area. They are presented in Figure F.7. The extent of each soil association is presented in Table F.7.

A total of 34 soil series have been identified in the project area. Their description, characteristics under various land phase conditions and their extent within each association are given in Appendix F.1. Land phases have been defined on the basis of relief, flood hazard, hazard of river erosion and external drainage condition in the early dry season.

Following is the description of the soil associations. The number in brackets following the association name refers to the association number appearing in Figure F.7 and Table F.7.

***Goyainghat-Balaganj* (1)**
This association occurs generally in narrow strips on sub-recent levees, mainly along the Kushiyara river in Jagannathpur and Nabiganj Thanas. The soils are developed in sub-recent and some recent sediments. Most of the land is flooded up to 0.3 to one meter for 2 to 5 months during the monsoon season, and dries out early in the dry season. The main association's limitation for agricultural development is soil droughtiness in the dry season. The soil texture varies from silty loam to silty clay loam.

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Table F.7: Soil Associations

Sl. No.	Name of Soil Association	AEZ No.	('000 ha)	Percent of Total Area (%)
1	Goyainghat-Balaganj	20, 21b, 21c	2.16	0.64
2	Goyainghat-Kanairghat	19c, 20, 21b, 29c	40.33	12.02
3	Sullah-Ajmiriganj	19c, 19h, 20, 21a, 21b, 21c	86.57	25.80
4	Phagu-Kanairghat	19c, 20, 21b, 21c	14.03	4.18
5	Phagu (ML)	19c, 20	19.67	5.86
6	Phagu (L)	21a, 21b	4.09	1.22
7	Phagu-Terchibari (L)	19c, 20	4.95	1.47
8	Phagu-Terchibari (VL)	21b, 21c	6.16	1.84
9	Terchibari-Phagu	20, 21b	17.75	5.29
10	Terchibari-Derai	21b, 21c	5.25	1.56
11	Madhabpur-Richi (ML)	19c, 20, 21b	28.93	8.62
12	Richi-Balua	19c, 20, 21b	21.62	6.44
13	Kadipur Complex	20, 29c	1.03	0.31
14	Beanibazar Complex	20	1.74	0.52
15	Astagram-Richi	19h, 21a, 21b	6.81	2.03
16	Goyainghat-Kanairghat (DF)	20	4.10	1.22
17	Kanairghat-Phagu	20, 29c	3.58	1.07
18	Phagu	20, 21a, 29c	36.58	10.90
19	Sullah-Kanairghat	19h, 21b	3.02	0.90
20	Balaganj-Goyainghat	19h	1.45	0.43
21	Richi-Astagram	19h, 21b	25.78	7.68
	TOTAL		**335.60**	**100.00**

Legend: ML: Medium lowland phase, L: Lowland phase, VL: Very lowland phase,
DF: Deeply flood phase
Source: SRDI, 19976, 1977, 1986

Goyainghat-Kanairghat (2)
This association occupies most of the relatively high floodplain in Baniachang, Nabiganj, Balaganj, Fenchuganj, Golabganj, Sylhet and Bishwanath Thanas. The soils are developed in sub-recent alluvium of the Kushiyara river and its tributaries, in levees systems of present and former river courses which have been levelled to their present low relief since their deposition. The normal phase of this association is flooded up to 0.3 to 1.5 m for 2 to 5 months, the deeply flooded phase up to 1 to 3 m for 4 to 7 months. The soils remain moist for a rather short period and are dry for most of the dry season. The main limitation of this association is dry-season droughtiness. The texture varies from silty loam to clay.

Sullah-Ajmiriganj (3)
This unit covers a level to very gently undulating basin system criss-crossed with some narrow linear ridges and inter-ridge depressions in Sullah, Derai, Jagannathpur, Ajmiriganj, Baniachang, Lakhai, Habiganj and Nabiganj Thanas. Locally the landscape is somewhat irregular. The

differences in elevation are small. The ridge soils are moderately deeply flooded and are in constant danger of flood hazard. The basin soils are moderately deeply to deeply flooded. Basin bottom soils remain wet for part or whole of the dry season. The soil texture varies from silty clay to clay.

Phagu-Kanairghat **(4)**
This association occupies nearly level broad basins and level to gently undulating ridges and inter-ridge depressions in Jagannathpur, Derai and Nabiganj Thanas. The differences in elevation are small. The upper and middle parts of ridges are shallowly flooded and the lower part of ridges and basins are moderately deeply flooded. Basin bottom soils are deeply flooded and remain saturated throughout the dry season. The texture is clay over 60% of the association and the remainder silty clay with some silt loam in minor proportion.

Phagu Medium Lowland Phase **(5)**
This association occupies level to nearly level broad basins with some narrow ridges in Habiganj, Nabiganj and Jagannathpur Thanas. The difference in elevation are small. The ridge soils are seasonally moderately deeply flooded and the basin soils are moderately deeply to deeply flooded. Part remains saturated for part or the whole of the dry season. This association consists mainly of clay soils.

Phagu Lowland Phase **(6)**
This association occupies level to nearly level broad basins with some narrow ridges in Sullah and Derai Thanas. The difference in elevation are small. The ridge soils are seasonally shallowly to moderately deeply flooded. basin soils are moderately deeply and deeply flooded, in part slow draining in the dry season. The whole association is in danger of rapid rise and flow of flood water in the rainy season. The main texture of the soils in this association is clay with silty clay in minor proportion.

Phagu-Terchibari Lowland Phase **(7)**
This association occupies level to nearly level basins in Nabiganj, Baniachang and Jagannathpur Thanas. The difference in elevation are small. Basin soils are deeply flooded and basin bottom soils remain saturated for part or the whole of the dry season. Ridge soils are moderately deeply flooded. The whole association is subject to occasional flood hazard. The soils consist mostly of clay.

Phagu-Terchibari Very Lowland Phase **(8)**
This association occupies level to nearly level broad basins with some narrow ridges in Sachna, Derai, Sunamganj and Sullah Thanas. Differences in elevation are small. Basin soils are very deeply to deeply flooded and the ridge soils are moderately deeply flooded. Major part of the basin soils remain saturated for most of the dry season. The texture of the soils is mostly clay with minor areas of silty loam and silty clay.

Terchibari-Phagu **(9)**
This unit occupies level to nearly level broad basins in Jagannathpur, Derai, Sunamganj and Sullah Thanas. Differences in elevation are small. Basin soils are deeply to moderately deeply flooded and part remains saturated for part or the whole of the dry season. Ridge soils are moderately deeply flooded. The texture of the soils is mostly clay with minor areas of silty clay.

Terchibari-Derai **(10)**
This association occupies level to nearly level broad basins in Sullah, Derai and Sunamganj Thanas. Differences in elevation are small. Basins soils are deeply to very deeply flooded and part remains saturated for most of the dry season. The texture of the soils is mostly clay with minor areas of silty clay. In some 30% of the association, the clay layer overlies an organic layer within 1 m.

Madhabpur-Richi Medium Lowland Phase **(11)**
This association occupies level to nearly level broad basins with some ridges in Baniachang, Lakhai, Ajmiriganj and Nabiganj Thanas. Differences in elevation are small. Ridge soils are shallowly to moderately deeply flooded and basin soils are moderately deeply to deeply flooded in the rainy season. Most of the basins, particularly in the eastern *thanas*, are in constant danger of rapid rise of flood water. The soil texture varies from silt loam to silty clay loam with minor areas of clay.

Richi-Balua **(12)**
This association occupies level to nearly level broad basins in Baniachang, Ajmiriganj and Nabiganj Thanas. Differences in elevation are small. Basins are deeply flooded and basin depressions are very deeply flooded in the monsoon season. The texture of the soils is silty clay loam over 90% of the association with silt loam on in the remainder.

Kadipur Complex **(13)**
This association occurs in the northern part of Hakaluki Haor, an extensive floodplain basin in Fenchuganj Thanas. The soils are developed in recent and sub-recent alluvium. Every monsoon, some sediment is brought in, further infilling this basin area. Most of the land is deeply and rapidly flooded in the monsoon season, remains moist for 2 to 3 months and dries out late in the dry season. The general soil texture is clay loam.

Beanibazar Complex **(14)**
This association occurs in various areas in Balaganj and Fenchuganj Thanas. It occupies a landscape of low hills, closely dissected by a network of generally narrow piedmont valleys. The hill soils are developed in generally silty and clayey unconsolidated tertiary folded sediments, the valley soils in sub-recent piedmont soils of different textures.

Astagram-Richi **(15)**
This association occurs in Itna and Mitamain Thanas. It comprises smooth broad landscape without any defined ridges, and basins with some gently undulating basins and basin depressions. Differences in elevation are small. The whole landscape is deeply flooded and subject to flood hazard. The soil texture varies from silty clay to clay.

Goyainghat-Kanairghat Deeply Flooded Phase **(16)**
This association occupies most of the very gently undulating floodplain of Balaganj Thanas. The soil are developed in sub-recent alluvium of the Kushiyara River and its tributaries, in levee systems of present and former river courses which have been levelled to their present low relief since their deposition. The deeply flooded phase of this association is flooded for 4 to 7 months. The soils remain moist for a rather short period and are dry for most of the dry season. The major texture is silty clay loam, with some silt loam.

Kanairghat-Phagu **(17)**
This association occurs in some of the shallower basins located in Sylhet Thanas. Most of the land is flooded for 4 to 7 months during the monsoon season and dries out relatively early in the dry season. The texture of the soils varies from silty clay to clay.

Phagu **(18)**
This association occurs in areas of Itna, Sullah, Balaganj, Golabganj and Sylhet Thanas. The landscape comprises floodplain ridges and basins. The differences in elevation are from 1.5 to 5 m. The ridges are seasonally moderately deeply flooded and the basins are seasonally deeply flooded. The texture is silty clay over 90% of the association, the remainder consisting of silt loam and some clay.

Sullah-Kanairghat **(19)**
This association occurs in Mitamain Thana. The landscape comprises gently undulating basins and basin depressions and very gently undulating ridges. Differences in elevation are small. Basins and basins depressions are seasonally deeply to very deeply flooded, ridges are moderately deeply to deeply flooded with flood hazard. The soil structure varies from silty clay to clay with silt loam over 10% of the area.

Balaganj-Goyainghat **(20)**
The landscape comprises nearly level ridges of the Surma-Kushiyara floodplain in Astagram Thana. Differences in elevation are small. Soils are seasonally moderately deeply to deeply flooded with flood hazard, part with erosion hazard. The texture is silt loam in half the association, silty clay loam in the remainder with minor areas of clay.

Richi-Astagram **(21)**
This association occurs in Mitamain, Nikli and Astagram Thanas. It comprises a characteristically smooth very broad landscape without actually defined ridges or basins. Differences in elevation are very small. Soils are deeply flooded and prone to flood hazard. The texture is mostly silty clay with minor areas of silt loam and clay.

2.6 Land Capability Associations

Based on the characteristics of the soils and land phases of soil associations, the SRDI soil survey reports have rated land capability. A land capability rating grades the soil for overall crop production, independently of the type of crop, and considers the limitation of a soil for crop production throughout the year.

There are four land capability classes and each has subclasses. They are defined as follows:

- Class I. Very good agricultural land - No land of this class was identified in the project area.
- Class II. Good agricultural land - Soils in this class have no to slight limitations for crop production during most of the year, but moderate limitations during the remainder of the year. These soils are level to very gently undulating and generally easy to cultivate. Under traditional management, these soils can produce satisfactory crops for most but not all of the year and are at least moderately productive. With modern management including dry season irrigation, they are capable of giving good to high yields throughout the year.

- Class III. Moderate agricultural land - Soils in this class have either moderate limitations for crop production throughout the year, or severe limitations during one major season and slight to moderate limitations during the remainder of the year. Limitations are due to one or more of the following factors: low water holding capacity; seasonal shallow to moderate flooding; wetness early in the dry season followed by droughtiness; irregular relief difficult to drain or irrigate, and moderate hazard of occasional hazard of rapid rise and flow of water in the rainy season. Under traditional management, these soils can produce moderate to good crops during one season only. Some may also produce low yields. With modern management and major expenditure for irrigation, drainage and/or land leveling, they can produce high yields for at least one crop per year or moderate to good yields during most or all of the year.

- Class IV. Poor agricultural land - Soils in this class have severe limitations for crop production throughout the year. These limitations are due to one or more of the following factors: seasonal deep to very deep flooding combined with water logging in the dry season; severe risk of crop damage or loss by flash floods; hazard of river erosion burial by new alluvial deposit; low bearing capacity; moderate to severe erosion on hill slopes; low nutrient and water holding capacity coupled with severe droughtiness in the dry season. These soils have little potential for development. Under traditional management, they are used for poor to moderate crop growing during only one major season of the year, or they are under grassland and shrubs. Major land improvement and expenditure would be required to improve these soils. This is generally uneconomical.

The land capability of the soils has been grouped by SRDI in the form of associations. These land capability associations are presented in Figure F.8 and their area is presented in Table F.8.

The table also presents the correspondence between land capability associations and soil associations.

The good agricultural land (Class II) represents less than 15% of the project area and the poor agricultural land over 50% of the project area, mostly due to flooding and slow drainage in the post-monsoon season. However, the analysis of the suitability of the land to grow selected common crops as well as the current land use of the project area indicate that the land capability for crop production can be improved significantly by dry season irrigation.

2.7 Crop Suitability

The SRDI soil survey reports have also rated the soil series relative to their suitability for the production of a number of common wet and dry land crops. These ratings, called Crop Suitability Classes range from Class 1 for the most suitable soils to Class 4 for the least suitable. These ratings are similar to the land capability ratings, but they differ in two important respects. A rating for crop suitability grades the soil in respect of individual crops and takes into account the most favorable season of the year to determine the soil-crop relationship.

The crop suitability classes are defined as follows:

- Suitability Class 1: well suited - The crop grows well under traditional management and produces moderate to high yields. For the crop under consideration, the soil has favorable physical and hydrological characteristics during at least one cropping season per year. The soil would produce high or very high yields under modern crop management practices.

Table F.8: Land Capability Associations

Sl. No.	Land Capability Association	Land Capability Sub-class	Soil Association No.	Area ('000 ha) Sub-class	Area ('000 ha) Association	% of Project Area
1	Predominantly good agricultural land	Seasonally shallowly flooded land	2	12.02	12.02	3.6
2	Mainly moderate with some good agricultural land	Seasonally moderately deeply flooded land with some shallowly flooded land	4, 11	15.93	15.93	4.7
3	Mainly moderate with some poor agricultural land	Seasonally moderately deeply flooded land with flood hazard, part shallowly flooded and sandy	1	0.45		
4		Seasonally moderately deeply to deeply flooded land mainly with flood hazard and part slow draining in the dry season	11	23.65		
5		Basins with flood hazard, part slow draining in the dry season	5	16.35	40.45	12.0
6	Mainly poor with some moderate agricultural land	Seasonally deeply and some moderately deeply flooded land, slow draining in the dry season	6, 18	6.49		
7		Seasonally deeply and some moderately deeply flooded land with flood hazard	3, 9	57.74	64.23	19.1
8	Predominantly poor agricultural land	Seasonally deeply and very deeply flooded land, slow draining in the dry season	3, 10, 15 18	37.88		
9		Seasonally deeply flooded land with flood hazard, part slow draining in the dry season	3, 7	5.03		
10		Seasonally deeply and very deeply flooded land with flood hazard, part slow draining in the dry season	8, 12	30.73	73.64	21.9
11	Mainly good agricultural land	Seasonally wet	18	3.02		
12		Seasonally flooded to shallow depth	2, 14	30.78	33.80	10.1
13	Mainly moderate agricultural land	Seasonally deeply flooded	16, 17, 18	37.79	37.79	11.3
14	Mainly poor agricultural land	Seasonally deeply and rapidly flooded	13	1.10	1.10	0.3
15	Poor and good agricultural land	Complex of well drained steep land and seasonally wet land	1	0.52	0.52	0.2
16	Predominantly poor agricultural land	Basins with flood hazard	15, 21	28.29		
17		Seasonally flooded ridges with hazard of river erosion	20	1.48		
18		Ridges with flood hazard and basins slow draining in the dry season	19	3.12		
19		Basins with flood hazard and slow draining in the dry season	3	22.58	55.47	16.6
	Large Beels			0.65	0.65	0.2
	Project Area			**335.60**	**335.60**	**100.0**

Note: Some soil associations have more than one land capability depending on their location in the project area
Source: SRDI, 1976, 1977, 1986

- Suitability Class 2: moderately suited - With traditional management, the crop would produce poor to moderate yields or be subject to occasional hazard of failure. For the crop under consideration, the soil may have unfavorable physical and hydrological characteristics. With modern management, crop yields would be moderate to high. The soil may produce very high yields with a relatively high management intensity or moderate expenditure for irrigation, drainage or flood protection.

- Suitability Class 3: poorly suited - The crop, under traditional management would either not grow or produce poor yields and would be subject to great hazard of failure. The soil has unfavorable physical or hydrological characteristics which cannot be corrected easily. Very intensive management or major expenditure for irrigation, drainage and/or flood protection may be required for the crop under consideration to produce moderate to high yields. The crop is not recommended for this type of soil.

- Suitability Class 4: not suited - With traditional management, little or no production is expected for the crop under consideration. The soil has severe physical or hydrological limitations for this crop. Measures to produce moderate to good yield would be uneconomical.

The crop suitability ratings of the individuals soil series relative to the common crops cultivable in the project areas are presented in Appendix F.1.

On the basis of the SRDI information available, ie. soil suitability ratings and areal extent of soil series within soil associations, a table of soil associations well suited (Class 1) for the cultivation of selected crop has been prepared (Table F.9). Table F.10 presents the land suitability for the cultivation of these same crops in the project area. Two immediate conclusions can be drawn from an analysis of these tables:

- irrigation increases the area well suited for crop cultivation over twenty fold, and

- the overwhelming majority of the project area is well suited for irrigated *boro* rice, a fact confirmed by the current land use.

For wet land crops, most of the area is well suited for rice crops but not for jute. As for dry land crops, they can be grown on a little less than 25% of the project area with moderate investment in modern management or irrigation.

For other common crops, the SRDI soil reports contain only partial information on the crop suitability ratings. For example, the ratings are provided for cotton in the Sunamganj and Habiganj subdivisions only, which together represent some 75% of the project area. The ratings indicate that the soils, even with irrigation, are not generally suitable for this crop, and that major expenditures would have to be incurred in order to improve the soils with sub-surface drainage.

It should be noted that the SRDI reports specify that the ratings are based on scanty data and should not be regarded as final.

Table F.9: Area of Soil Associations Well Suited for the Cultivation of Selected Crops

	Soil Association	Wet Land Crops ('000 ha)							Dry Land Crops ('000 ha)				
		Without Irrigation			With Irrigation				Without Irrigation			With Irrigation	
		Aus	*Aman*	Jute	*Aus*	*Aman*	*Boro*	Jute	Wheat	Pulse & oil seeds	Vegetables	Wheat	Vegetables
1	Goyainghat-Balaganj				1.62	1.62	1.08	0.97				1.62	0.65
2	Goyainghat-Kanairghat				32.26	32.26	32.26	30.25				32.26	2.02
3	Sullah-Ajmiriganj						77.91						
4	Phagu-Kanairghat				2.10	2.10	10.52	1.40				2.10	0.70
5	Phagu (ML)						14.75						
6	Phagu (L)	0.20	0.20		0.20	0.20	3.27	0.20				0.20	
7	Phagu-Terchibari (L)						3.22						
8	Phagu-Terchibari (VL)						2.46						
9	Terchibari-Phagu						7.10						
10	Terchibari-Derai						0.79						
11	Madhabpur-Richi (ML)				1.45	1.45	23.14	1.45				1.45	
12	Richi-Balua						21.62						
13	Kadipur Complex		0.10			0.10	0.88			0.10	0.10		0.10
14	Beanibazar Complex	0.10	0.19		0.10	0.19	0.07			0.03	0.03	0.03	0.03
15	Astagram-Richi						6.13					2.04	
16	Goyainghat-Kanairghat (DF)		3.73			3.73	2.21			0.16	0.16		0.16
17	Kanairghat-Phagu	2.86	3.22		2.86	3.22	3.22	2.51				2.86	
18	Phagu		1.83			1.83	31.09						
19	Sullah-Kanairghat				0.30	0.30	2.27					0.30	0.30
20	Balaganj-Goyainghat	1.31	1.31		1.31	1.31	0.73					1.31	0.73
21	Richi-Astagram						25.78					14.18	
	Total Area ('000 ha)	**4.48**	**10.59**		**42.21**	**48.12**	**270.51**	**36.78**		**0.30**	**0.30**	**58.37**	**4.69**
	% of Project Area	**1.6**	**3.5**	**0.0**	**12.8**	**14.6**	**80.5**	**11.0**	**0.0**	**0.1**	**0.1**	**17.3**	**1.3**

Legend: ML: Medium lowland phase; L: Lowland phase; VL: Very lowland phase; DF: Deeply flooded phase
Source: SRDI, 1976, 1977, 1978

Table F.10: Land Suitability for the Cultivation of Selected Crops in the Project Area

Crop Type			Land suitability for Crop ('000 ha)				Land suitability for Crop (% of Project Area)			
			Well Suited	Moder. Suited	Poorly Suited	Not Suited	Well Suited	Moder. Suited	Poorly Suited	Not Suited
Wetland crops	Without irrigation	*Aus*	4.48	45.47	49.66	207.19	1.6	13.5	15.1	61.2
		Aman	10.59	76.81	90.53	128.88	3.5	22.8	27.2	38.0
		Jute	0.00	48.19	48.23	210.38	0.0	15.1	14.1	62.2
		All Wet Land Crops	**10.59**	**77.87**	**105.68**	**112.65**	**3.5**	**23.7**	**31.2**	**33.1**
	With irrigation	*Aus*	42.21	2.10	54.68	207.80	12.8	0.6	16.6	61.4
		Aman	48.32	36.62	121.57	100.29	14.6	10.9	36.5	29.4
		Boro	270.51	32.70	1.48	2.10	80.5	9.6	0.4	0.9
		Jute	36.78	11.99	47.34	210.68	11.0	4.3	13.9	62.3
		All Wet Land Crops	**278.39**	**26.42**	**0.00**	**1.98**	**83.0**	**7.8**	**0.0**	**0.6**
Dry land crops	Without irrigation	Wheat/Millet/Maize	0.00	77.66	48.07	181.07	0.0	23.1	14.9	53.5
		Pulses & oil seeds	0.30	71.69	53.73	181.07	0.1	21.5	16.4	53.5
		Rabi vegetables/tobacco	0.30	49.81	16.26	240.43	0.1	15.0	4.9	71.5
		All Dry Land Crops	**0.30**	**83.10**	**42.32**	**181.07**	**0.1**	**24.8**	**13.2**	**53.5**
	With irrigation	Wheat/Millet/Maize	58.37	21.86	45.50	181.07	17.3	6.6	14.1	53.5
		Rabi vegetables/tobacco	4.69	47.10	39.58	215.43	1.3	14.3	11.6	64.2
		All Dry Land Crops	**58.67**	**21.64**	**45.42**	**181.07**	**17.4**	**6.5**	**14.1**	**53.5**
All Crops without Irrigation			**10.89**	**107.07**	**76.18**	**112.65**	**3.6**	**32.1**	**22.7**	**33.1**
All Crops with Irrigation			**278.69**	**26.42**	**0.00**	**1.68**	**83.1**	**7.8**	**0.0**	**0.5**

Note: Area of homesteads and *beels* = 28.81 (ha)

3. SAMPLE AREA SURVEYS AND RESULTS

3.1 Land Use Survey

A sample area land use survey was carried out in accordance with the recommendations of the *FPCO Guidelines* (FPCO, 1992). The objectives of this sample land use survey are:

- to assess current land use;
- to assess trends in land use;
- to estimate crop yields under normal and flood-damaged conditions;
- to extrapolate the results to the project area.

In the present case, the sample area land use survey was a pre-requisite to the agricultural study since there has been virtually no new published information nor data since the 1983-84 BBS census of agriculture and livestock.

A questionnaire was designed for the sample area land use survey which contains information on crop production of these sample areas. A sample questionnaire form is presented in Appendix F.2. Each land use type, its location and areal extent were recorded on the corresponding *mauza* map. The *mauza* is the lowest level revenue unit.

During the NERP field survey, information was collected on yields and crop damages for the period 1993-1995. As much as possible, information was also sought from farmers for 1991, a major pre-monsoon flood year, and 1992 which experienced a flash flood with slow recession during February. Generally farmers could recall the damages incurred during the 1991 flood as the flooding was widespread, but reports on damages from the 1992 early flood were scant as the flooding was limited.

A total of 10 sample areas were surveyed during the 1995-96 NERP field survey. The locations of these samples were selected to provide an adequate coverage of the agro-ecological zones present in the project area. Each sample area covers the entire area of 1 or more *mauzas*, in order to compare NERP survey data with Bangladesh Bureau of Statistics (BBS) agricultural statistics which are reported at the *mauza* level. The selected sample areas are shown in Figure F.9. The sample survey covered 10 *thanas*, 14 unions and 32 *mauzas*. Their list is presented in Table F.11. This table also presents the area cultivated in each *mauza* and reported in the BBS 1983-84 census. The total area covering the 10 sample sites represents 5% of the project area.

Land use maps have been developed for all sample sites and are shown in Figures F.10 to F.19. Since local topography determines the depth of pre-monsoon flooding on a sample area, these maps also show the local topography. Sample sites land utilization is presented in Table F.12 and the crop patterns of the cultivated areas shown in Table F.12 are presented in Table F.13. This table also compares the cultivated areas reported in the BBS 1983-84 census and those surveyed by NERP.

Table F.11: List of *Thanas*, Unions and *Mauzas* Covered by the Sample Land Use Survey

Sample Site No.	*Thana*	Union	*Mauza*	BBS 1983-84 Census Cultivated Area (ha)	
				Mauza	Sample Area
1	Astagram	Kastail	Kargaon	556	
			Khala Bhengurail	729	1,285
2	Itna	Mriga	Jhorkandi	158	
			Bastipur	80	
			Ujan Rajibpur	181	
			Mriga	906	1,325
3	Astagram	Abdullahpur	Abdullahpur	1,132	
		Adampur	Chaudanta	259	1,391
4	Jagannathpur	Raniganj	Narikeltala	184	
			Trailakshyanathpur	15	
		Jagannathpur	Bhabanipur chak	82	281
5	Baniachang	Baniachang	Baraora	32	
			Nabipur	117	
			Majlispur	323	
			Shajansri	93	
		Khagapasha	Ahmadpur	364	
			Harni	146	1,075
6	Derai	Taral	Dhal Bada	357	
			Ashram	236	
			Banait	81	
			Kalidram	171	845
7	Derai	Derai Sarmangal	Chandpur	252	
		Karimpur	Kajua	70	
			Sakitpur	239	561
8	Nabiganj	Kurshi	Bajkasara	94	
			Amtail	97	
			Pirajpur	101	
			Uttar Gaharpur	83	375
9	Golabganj	Lakshanaband	Phulsaind	693	693
10	Balaganj	Umarpur	Hamthanpur	103	
			Majlishpur-Paschim	81	
			Mirzashahibpur	91	275

Table F.12: Sample Sites Land Utilization

Land Use	Land Utilization (ha)									
	Sample Site Number									
	1	2	3	4	5	6	7	8	9	10
Cultivated	2,181.5	2,188.3	3,150.6	351.1	1,357.8	1,235.7	608.7	387.2	896.9	426.0
Khas/Grassland	119.2			11.2	179.2	258.1	113.3		11.0	10.2
Homestead	1.9	17.9	19.2	15.9	7.8	30.7	88.1	5.4	135.6	35.2
Bamboo					0.9			0.4		
Pond	0.9	4.7	0.7	3.0	11.1	1.0	4.2	0.5	2.3	4.0
School		0.7	1.2	0.1	0.2	0.7	0.3	0.6		
Garden					0.2	1.8			0.2	
Mosque					0.1	7.8		0.5	0.2	
Field				6.9	0.6	0.7				
Graveyard		0.8	0.6	0.4	1.3	3.0		2.8	2.0	2.1
Office						0.2	11.1			
Bazar						0.3				
Beel		101.6	11.1	5.2	2.8	29.2	74.0	7.6	29.7	0.6
Road	12.1	22.8	31.3	7.2	34.9	22.9	1.3	9.3	22.2	7.5
River/Channel	82.5	76.1	139.7	17.4	71.2	140.0		13.7	21.7	2.4
Embankment					4.8					
Total	**2,398.1**	**2,412.9**	**3,354.4**	**418.4**	**1,672.9**	**1,732.1**	**901.0**	**428.0**	**1,121.8**	**488.0**

Table F.13: Sample Sites Crop Patterns

Crop Pattern		Crop Patterns (ha)											% NCA
		Sample Site Number										All Samples	
		1	2	3	4	5	6	7	8	9	10		
Aus-HYV Transplanted *Aman*					26.4			12.6	189.5		6.9	235.4	1.84
Local Transplanted *Aman*-HYV *Boro*									1.1			1.1	0.01
HYV *boro*-Fallow		1,921.3	1,861.4	2,008.2	13.2	857.7	401.6	596.1	40.5		414.4	8,114.4	63.52
Local *Boro*-Fallow		250.7	88.1	985.9	270.4		769.3			408.9		2,773.3	21.71
Deep Water *Aman*-HYV *Boro*						127.9						127.9	1.00
Deep Water *Aman*-Fallow					41.1	355.0			149.1	479.3		1,024.5	8.02
HYV Transplanted *Aman*-Fallow											4.7	4.7	0.04
Wheat-Fallow				0.3		1.5	3.1					4.9	0.04
Pulses-Fallow			0.1	3.7								3.8	0.03
Groundnut-Fallow				23.9								23.9	0.19
Oilseeds-Fallow			3.9	5.6			3.9					13.4	0.10
Potato-Fallow			0.7	30.3			0.7					31.7	0.25
Sweet Potato-Fallow			2.6	12.6			1.3					16.5	0.13
Spices-Fallow		9.5		28.9		1.6	2.8		0.5			43.3	0.34
Vegetables-Fallow			3.8	6.6		4.1	3.1		0.4			18.0	0.14
Fallow			227.7	44.6		10.0	49.9		6.1	8.7		347.0	2.64
Net Cultivated Area (NCA)	**- NERP, 1995-96 (ha)**	**2,181.5**	**2,188.3**	**3,150.6**	**351.1**	**1,357.8**	**1,235.7**	**608.7**	**387.2**	**896.9**	**426.0**	**12,783.8**	**100.0**
	- NERP, 1995-96 (% gross area)	**91**	**91**	**94**	**84**	**81**	**71**	**68**	**90**	**80**	**87**	**89**	
	- 1983-84 BBS Census (ha)	**1,285**	**1,325**	**1,391**	**281**	**1,076**	**846**	**561**	**375**	**693**	**275**	**8,108**	
	- Increase in cultivated area (ha)	**896**	**863**	**1760**	**70**	**282**	**390**	**48**	**12**	**204**	**151**	**4,676**	
	- Increase in cultivated area (%)	**70**	**65**	**127**	**25**	**26**	**46**	**9**	**3**	**29**	**56**	**58**	

Table F.12 shows a significant variation in the size of individual sample areas. This is due to two factors. First, the area of individual *mauzas* may vary considerably. In addition, the variation in topography and soil associations have both been taken into consideration in selecting the sample areas. Small sample areas have uniform topography and soil characteristics, large areas have a more pronounced variation in topography and/or soil characteristics.

Finally, area-elevation curves have been computed for all sites. They are presented in Figure F.20.

3.2 Farm Monitoring Survey

A second survey, the farm monitoring survey was also carried out in the sample areas. Input, farm machinery, labor and animal use, and crop yields were determined from farm monitoring and crop cuts using a second questionnaire. A sample questionnaire form is presented in Appendix F.3.

3.3 Farm Household Survey

In addition to the land use and farm monitoring surveys, a farm household survey was carried out in the sample areas, to assess farm budgets (Annex E - Economics). A total of 114 households were surveyed. The ratio of large, medium and small farmers households surveyed is close to the national ratio. This survey also provided estimates of crop yields.

3.4 Description of Sample Areas

3.4.1 Sample Area 1

This site is located at the southwestern corner of the project area in Astagram Thana of Kishoreganj district and a map of the sample area is presented in Figure F.10. The sample area consists of only two *mauzas* in Kastail union of Astagram Thana. Land elevations range from 1 to 4 m PWD. The site has been selected in order to assess the impacts of spills from the Baida River during the pre-monsoon season.

The Kalni River bifurcates into the Baida and Dhaleswari rivers near Issapur. The Dhaleswari River is gradually silting. As a result, more flow is diverted into the Baida River during the pre-monsoon season. The right bank of the Baida channel slopes away from the river in a southwesterly direction. Local people apprehend that, in the future, most of the Kalni River pre-monsoon flow will be diverted in this channel due to the ongoing siltation process in the Dhaleswari channel. Part of this flow will spill into the fields and damage *boro* crops.

The site has a gross area of 2,398 ha of which 2,181 ha (91%) is cultivated. Rice crops account for over 99% of the cultivated area. HYV *boro* is the major crop and is grown in the range 2 to 4 m PWD. The crop covers 88.5% of the net cropped area. Local boro covers the remaining rice area and in general is grown in the range 1 to 2 m PWD. Spices are the major non-rice crop and occupy only 0.4% of the net cropped area.

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Comparison of 1983-84 BBS Census statistics and NERP land use survey shows that the cropped area has increased some 70% (Table F.13) since the census, most of it for HYV *boro* cultivation.

In the period 1993-95, there was crop damage in 1993 during the pre-monsoon season, typically 15% of the HYV boro area and 30% of the local boro area. However, farmers reported a trend in gradual increase in pre-monsoon water levels in recent years. They also reported that some 80% of *boro* crops were damaged in the 1991 floods.

3.4.2 Sample Area 2

This site is located some 3 km west of Ajmiriganj on the right bank of the Kalni River and consists of four *mauzas* in Mriga union of Itna Thana in Kishoreganj district. Land elevations range from 3 to 4.8 m PWD (Figure F.11). The site has been selected to assess the impacts of spills and breaches in the river bank during the pre-monsoon season.

In recent years, over bank spill and breaches in the river bank just upstream of Ajmiriganj have become a regular phenomenon. In 1991 a large *dhala* formed at Bheramohona and damaged *boro* crops. In 1992, the breach was closed temporarily. However it breached again in the same year and damaged *boro* crops. The *dhala* was closed permanently in 1993. Local people reported that over bank spills and breaches in the river bank not only damaged their *boro* crops, they also deposited sediments in the fields and reduced their capability for cultivation.

The site has a gross area of 2,413 ha, of which 2,188 ha (91%) is cultivated. Rice crops account for some 89% of the cultivated area. HYV *boro* is the major crop and is grown in the range 3 to 4.8 m PWD. The crop covers 99.5% of the rice cropped area. Local *boro* is grown in the remaining rice area. Oilseeds, sweet potato and vegetables are the major non-rice crops and account for only 0.5% of the net cropped area. An area of 228 ha remains fallow.

Comparison of 1983-84 BBS Census statistics and NERP land use survey shows that the cropped area has increased some 65%, most of it for HYV *boro* cultivation.

During the 1993-95 period, *boro* crops were damaged in all three years by over bank spills during the pre-monsoon season. All *boro* crops were also damaged in 1991.

3.4.3 Sample Area 3

The site is located just north of Issapur village on both banks of the Kalni River and consists of two *mauzas*; one in Abdullahpur union, the second in Adampur union, both in Astagram Thana of Kishoreganj district. Land elevations range from 2 to 4.5 m PWD (Figure F.12). The site has been selected to assess the impacts of spills from the Kalni River on both banks during the pre-monsoon season.

Similarly to site 1, this site is affected by the siltation of the Dhaleswari River and the flow diversion in the Baida River. Local people have reported an increase in crop damages in recent years.

The site has a gross area of 3,354 ha of which 3,150 ha (94%) is cultivated. Rice crops account for some 95% of the cultivated area. HYV *boro* is the major crop and is grown in the range 3 to 4 m PWD. The crop covers 67% of the rice cropped area. Local *boro* covers the remaining rice area and is grown in the range 2 to 3 m PWD. A wide variety of non-rice crops are grown in the area and account for 3.6% of the net cropped area. They include oilseeds, potato, sweet potato and spices. An area of 45 ha remains fallow.

Comparison of 1983-84 BBS Census statistics and NERP land use survey shows that the cropped area has increased some 127% since the 1983-84 BBS census, most of it for the cultivation of HYV *boro*.

Boro crops were damaged in 1993 on both banks and on the right bank in 1994. All *boro* crops were also damaged in 1991.

3.4.4 Sample Area 4

Sample area 4 consists of two *mauzas* located in Raniganj union and one *mauza* located in Jagannathpur union, both in Jagannathpur Thana, Sunamganj district. Land elevations range from 3 to 6 m PWD (Figure F.13). The site has been selected to assess the impacts of over bank spills and breaches in the river banks just outside the submersible embankment of the Naluor Project.

Over bank spill and breaches in the river banks in Raniganj Thana have become a regular phenomenon in recent years. Local people reported that, since 1991, the river spills at this location every year and damages *boro* crops either partially or fully depending on the severity of the flood. They also noted that the area does not require submersible embankments provided the pre-monsoon flows can be confined within the river channel.

The site has a gross area of 418 ha of which 351 ha (84%) is cultivated, all of it in rice. Local *boro* is the major crop and is grown in the range 3-5 m PWD. The crop covers 77% of the rice cropped area. HYV *boro*, B. *aus* and HYV *aman* are grown in the remaining area at elevations above 4.0 m PWD.

Comparison of the 1983-84 BBS Census statistics and NERP land use survey shows that the cropped area has increased some 25% during the period, most of it under HYV *boro* cultivation.

In the period 1993-95, *boro* crop was heavily damaged in 1993, while in 1994 and 1995 damages were not significant. All *boro* crops were also damaged in 1991.

3.4.5 Sample Area 5

The site is located in the northern part of Baniachang Thana. About 50% of the sample area lies within the Sutki River Embankment Project. The sample area consists of four *mauzas* of Baniachang union and two *mauzas* of Khagapasha union, both unions in Baniachang Thana of Habiganj district. Land elevations range from 3 to 6 m PWD (Figure F.14). The site has been selected to assess impacts of spills and breaches in the river banks upstream of Ajmiriganj.

Before the outfall of the Old Kushiyara River silted-up, the area north of Baniachang used to drain to the Kalni-Kushiyara River near Ajmiriganj mainly through the Old Kushiyara River. Now, over bank spills upstream of Ajmiriganj together with spills from the Bibiyana channel and the Shakaborak River accumulate in the northern part of Baniachang Thana, then flow into the

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Sutki River and Jhingari Nadi. Local people reported that the cross-sections of these channels are not adequate to carry the spills. As a result, the depth and duration of flooding have increased and are consequently damaging more crops than in the past.

The site has a gross area of 1,673 ha of which 1,358 ha (81%) is cultivated. Rice accounts for some 99.5% of the cultivated area. HYV *boro* is the major crop and is grown in the range 3 to 4 m PWD. The crop covers 64% of the rice cropped area. Broadcast *aman* is grown in the remaining rice area. Wheat, spices and vegetables are the major non-rice crops and occupy 0.5% of the net cropped area.

Comparison of 1983-84 BBS Census statistics and NERP land use survey indicates that the cropped area has increased some 26% since the census, most of it contributing mainly to HYV *boro* cultivation.

Boro crops were damaged in 1993 and 1994 due to over bank spill and breaches in the Koyer Dhala. *Boro* crops were heavily damaged in 1991.

3.4.6 Sample Area 6

This sample area is located north of Markuli within the Tangua Haor and Bhanda Beel Projects. The sample area consists of four *mauzas* in Taral union of Derai Thana, Sunamganj district. Land elevations range from 2 to 5.5 m PWD (Figure F.15). The site has been selected to assess the impacts of spills and breaches in the river banks within existing submersible embankment projects.

Over bank spills and breaches on the right bank in the vicinity of Markuli have become a regular phenomenon in recent years. Local people reported that since 1991, the river spills and the bank breaches every year either upstream or downstream of the Markuli closure, sometimes in both places. Then, the water rushing through the breaches in turn breaches the submersible embankment and damages *boro* crop.

The site has a gross area of 1,732 ha of which 1,236 ha (71%) is cultivated. Rice crops account for 94.8% of the cultivated area. Local *boro* is the major crop and is generally grown in the range 2-5 m PWD. The crop covers 66% of the rice cropped area. HYV *boro* covers the remaining rice area and is generally grown above 4.0 m PWD, where surface water is available for irrigation. Non-rice crops are not grown in this sample area.

Comparison of 1983-84 BBS Census statistics and NERP land use survey shows that cropped area has increased some 46% since the census, most of it for HYV *boro* cultivation.

Boro crops were damaged in 1993 and 1994 due to breaches in the river bank. Reportedly, all *boro* crops were damaged in 1991.

3.4.7 Sample Area 7

The site is located within the Chaptir Haor and Udgal Beel Projects. The sample area consists of one *mauza* in Derai union and two *mauzas* in Karimpur union, both in Derai Thana of Sunamgamj district. Land elevations range from 3 to 6 m PWD (Figure F.16). The site has been selected to assess the impacts of spills and breaches in the river banks on the existing submersible embankment projects.

Local people reported that generally crops are not damaged in these projects except during high flood events. For example, in 1991, *boro* was damaged due to the onrush of water from adjacent *haors* located north and east of the sample area, and in which sample area 6 is located.

The site has a gross area of 901 ha of which 609 ha (71%) is cultivated, all of it in rice. HYV *boro* is the major crop and accounts for some 98% of the net cropped area. HYV *aman* and broadcast *aus* are grown in the remaining cultivated area.

Comparison of the 1983-84 BBS Census statistics and NERP land use survey shows that the cropped area has increased some 9% since the census, mostly for HYV *boro* cultivation.

There were no crop damages over the 1993-95 period. Substantial damages were reported for 1991.

3.4.8 Sample Area 8

The site is located about 4 km northeast of Nabiganj Thana headquarters. The sample area consists of four *mauzas* located in Kurshi union of Nabiganj Thana in Habiganj district. Land elevations generally range from 4.5 to 7 m PWD (Figure F.17). The sample area has been selected to identify the impacts of spills from the Bibiyana and Shaka Borak Rivers.

The area is subject to flooding by spills from the Bibiyana and Shaka Borak Rivers generally at the end of May or in the first week of June. Local people reported that crops are generally damaged when flooding occurs simultaneously in the Kushiyara and Lungla Rivers.

The site has a gross area of 428 ha of which 387 ha (90%) is cultivated. Rice crops account for 98.2% of the cultivated area. Broadcast *Aus*-HYV transplanted *aman* and broadcast *aman* are the major patterns and account for respectively 49% and 38% of the net cropped area. HYV *boro* accounts for 14.5 % of the net cropped area. Spices and sweet potato are the major non-rice crops and account for 0.2% of the net cropped area.

Comparison of 1983-84 BBS Census statistics and NERP land use survey shows that the cropped area has increased some 3% since the census, most of it for HYV *boro* cultivation.

Crops were damaged in March and June 1994 and in June 1995 due to combined flooding of the Kushiyara and the Lungla Rivers. *Boro* crops were heavily damaged in 1991.

3.4.9 Sample Area 9

This site is located about 2 km north of Fenchuganj Thana headquarter within the Damrir Haor Project. The project provides pre-monsoon and post-monsoon drainage to a net area of about 7,285 ha. The sample area consists of one *mauza* of Lakshanaband union of Golabganj Thana in the Sylhet district. Land elevations generally range from 4 to 7 m PWD (Figure F.18). The site has been selected to assess the impacts of Kushiyara spills into the Damrir Haor Project.

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The Kushiyara River spills through Kurkuchi Khal which is the drainage outlet of the Damrir Haor Project during the pre-monsoon season (Refer Appendix C.3, Annex C: Engineering). Post-monsoon drainage is also delayed due to outfall siltation and high water levels in the Kushiyara River. Local people reported that pre-monsoon flooding and late post-monsoon drainage have become regular phenomena in the project area.

The sample area has a gross area of 1,122 ha of which 897 ha (80%) is cultivated. Rice crops account for 99% of the cultivated area. Local *boro* and broadcast *aman* are the major crops and respectively account for 45.6% and 53.4% of the net cropped area. Non-rice crops are not grown in this sample area. Some 8.7 ha or 1% of the area remain fallow.

The comparison of 1983-84 BBS Census statistics and NERP land use survey indicates that cropped area has increased for some 3% since the census, most of it for HYV *boro* cultivation.

Crops were damaged in 1993 and 1994 during the pre-monsoon season. All *boro* crops were damaged in 1991.

3.4.10 Sample Area 10

The site is located mid-way between Balaganj and Jagannathpur Thana headquarters. The sample area consists of three *mauzas* in Omarpur union of Balaganj Thana in the Sylhet district. Land elevations generally range from 5 to 7 m PWD (Figure F.19). The site has been selected to assess the impacts of spills from the Kushiyara River into the area.

Pre-monsoon spills in Balaganj Thana and runoff accumulated east of the Sherpur-Sylhet road drain into the Sadipur Khal at Sherpur. This channel, which empties into *beels* located west of the Sherpur-Sylhet road, does not have a direct outlet into the Kushiyara River. As a result, flood water accumulates in the *khal* until it overtops the Kushiyara right bank or finds its way into the Baulai River near Dhanpur through the Kamarkhali-Darain River system.

The site has a gross area of 488 ha of which 426 ha (80%) is cultivated, all in rice. HYV *boro* is the major crop and accounts for some 97.3% of the net cropped area. Broadcast *aus* and HYV *aman* occupy the remaining cultivated area.

A comparison of 1983-84 BBS Census statistics and NERP land use survey indicates that the cropped area has increased some 56% since the census, mostly for HYV *boro* cultivation.

Crops were damaged in 1993 and 1994 during the pre-monsoon season. Boro crops were heavily damaged in 1991.

3.5 Crops and Cultivated Areas

The land use survey shows that, in the sample areas, rice dominates crop farming and accounts for some 96% of the net cropped area (Table F.13). Farmers grow four main rice crops; *aus* and deep water *aman* occupy about 11% during the pre-monsoon, transplanted *aman* accounts for less than one percent during the monsoon and *boro* grown during the winter months and harvested during the pre-monsoon season occupies about 85% of the cultivated area. The figures clearly show that these sample sites are mostly single cropped *boro* areas. By comparison, the results of the analysis of the land suitability presented in Table F.10 show that over 80% of the study area is well suited for *boro* cultivation, and another 10% moderately suited.

A comparison between NERP land use survey and the 1983-84 BBS Census of Agriculture shows that the net cultivated area over the 10 sample areas has increased by about 58% during the period since the census took place (Table F.13). A major increase in cropped area took place mainly downstream of Ajmiriganj, particularly in sample areas 1, 2 and 3. In addition, substantial increases also took place in sample areas 6 and 7, following the construction of submersible embankments. As the population increased and, consequently the demand for food grain, farmers started cultivating their fallow lands. In addition, the expansion of mechanized irrigation accelerated the process, and a large portion of the expansion has been dedicated to the cultivation of HYV *boro*.

This trend is confirmed by the NERP field survey. During the survey, farmers reported that the irrigated HYV *boro* area has been gradually expanding because many permanent water bodies have silted up, reduced the availability of local water to grow local *boro* varieties and forced the farmers to rely on the main river systems. The cultivation of local *boro* is not cost effective with mechanized irrigation, particularly when water is transported over long distances.

Expansion of HYV *boro* is also expected from ground water irrigation in Jagannathpur, Nabiganj and Balaganj Thanas where sites 4, 8 and 10 are located (AST 1991). In those *thanas*, surface water irrigation has already been maximized. However, the growth of ground water irrigation is hampered by the depth of the aquifer and the low capacity of the tubewells, as horizontal flow within the aquifer is constrained by the clayish texture of the soil.

3.6 Crop Damages

Various extents of crop damages have been reported by farmers in all years since 1991, albeit to a lesser extent in 1992 and 1995, the latter a bumper crop year. The land use survey was completed in the 1996 dry season. Subsequently, farmers reported limited damages downstream of Ajmiriganj, as a result of a flash flood which occurred on April 6, 1996.

The results of NERP field survey have been compared to those of the MIKE 11 hydrodynamic model on the extent of flooding within the sample areas. The extent of flooding reported by the farmers in the 1993 pre-monsoon flood which is estimated to have a return period in the vicinity of 1:4 year was compared with the results of the hydrodynamic model for the 1:2 year and the 1:5 year pre-monsoon floods. The comparison has its limitations because the 1993 flood does not exactly correspond to one of the floods analyzed with the model and also because the assumptions made in the model as to the mode of flooding may not exactly coincide with those that actually occurred, such as location and extent of breaches. In addition the farmers reports on extent of flooding may somewhat be subjective. Nevertheless this comparison yields interesting results. The comparison is presented in Table F.14. In general, the extent of flooding reported by the farmers for the 1993 flood are in between those calculated by the model for respectively the 1:2 and the 1:5 year pre-monsoon floods, as would be expected. However, exceptions are noted for HYV *boro* areas in sample areas 1, 8 and 10. The discrepancy in sample area 8 arises from the fact that the 1993 flooding occurred as the result of simultaneous floods in the Kushiyara and Lungla Rivers. The model only considered flooding from the Kushiyara River. This results in conservative damages, hence conservative benefits for the immediate area flooded. The case for sample areas 1 and 10 is less clear.

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From this analysis, it may be concluded that the MIKE 11 model output provides results for the samples areas which are confirmed by the land use survey, thus providing confidence that the model results are adequate to assess the flooding pattern in the project area.

Table F.14: Comparison of Sample Areas Flooding

Crop Pattern	Sample Site	% Area Flooded		
		Pre-Monsoon Flood Flow at Sherpur		
		1:2 Year Flood 1,694 $m^3/s^{(1)}$	1993 Flood 2,262 $m^3/s^{(2)}$	1:5 year Flood 2,398 $m^3/s^{(1)}$
HYV *boro*-Fallow	1	23	15	51
	2	31	65	97
	3	27	53	67
	4	30	40	100
	5	40	50	87
	6	45	63	86
	7	0	0	65
	8	5	47	11
	9	N/A	N/A	N/A
	10	97	75	100
Local *boro*-Fallow	1	29	30	55
	2	60	93	98
	3	74	79	88
	4	77	100	100
	5	N/A	N/A	N/A
	6	66	72	100
	7	N/A	N/A	N/A
	8	N/A	N/A	N/A
	9	100	100	100
	10	N/A	N/A	N/A

Note: N/A - crop not cultivated in sample area
(1) Extent of flooding generated by MIKE 11 model
(2) Extent of flooding reported by farmers

3.7 Extrapolation from Sample Areas to Project Area

3.7.1 Crop Area Flooding Assessment

The step by step methodology adopted to determine the area of each crop pattern under each flood depth range is described in Appendix F.4. This methodology essentially extrapolates the results of the sample areas to the project area.

The methodology proposed in the FPCO *Guidelines for Project Assessment* (FPCO, 1992) recommends to delineate homogeneous sub-regions on the basis of agro-ecological regions and sub-regions and agro-climatic zones. Also, the *FPCO guidelines* recommend to group to the extent possible AEZ regions/sub-regions that have broadly similar kinds of cropping patterns, flood risks and cropping potential. After analysis of the parameters indicated in the *Guidelines*, the whole of the NCA has been considered a homogeneous area because:

- the major agro-ecological zones present in the study area (Section 2.4) namely AEZ 19, 20 and 21 have similar characteristics, the other two zones present, AEZ 22 and 29 are marginal because they cover less than 2% of the study area and also because they are less affected by floods;

- during the pre-monsoon season, some 85% of the NCA is under *boro* cultivation, either of the local variety or HYV;

- all samples sites, with the exception of site 7 are regularly affected by pre-monsoon flooding;

- the rainfall during the dry period and the pre-monsoon season does not show a marked variation throughout the project area (Table F.1).

3.7.2 Crop Yields for Project Area

The task of estimating yields for damaged crops is not straightforward because those yields vary in function of the severity of the flood which caused the damages and, at least in theory should be estimated for various flood frequencies. On the other hand, in the absence of published data, these yields for damaged crops are based on affected farmers' recollection of their experience with past floods, subjective in nature and which in turn brings a significant uncertainty in the yield estimates.

In order to show the variation which may occur in reported yields within a single survey, Table F.15 presents the normal and flood-damaged yields estimated by sample area for the two major crops, HYV and local *boro* from NERP land use survey. Standard deviations are high, especially for the flood-damaged crops.

In the present study, normal yields and yields of flood damaged crops have been estimated from a variety of sources, because samples sizes of surveys were relatively small in comparison to the size of the project area and because the estimates were confined to specific historical floods. The sources considered are: NERP Farm Household Survey (1996), NERP Land Use Survey (1995-96), NERP Farm Monitoring Survey (1995-96), Kalni-Kushiyara Pre-Feasibility Study (1994), National Minor Irrigation Development project (1994), a survey conducted on agricultural input and output for the whole of Bangladesh, and finally BBS information published for 1991 and 1993 for the districts of Kishoreganj and Sylhet. The yield estimates from these various sources are presented in Table F.16. It should be noted that yields of flood damaged non-rice crops have not been reported. However their area represents only 1.2% of the total sampled NCA.

The most important crops in the project area are *boro* rice of both HYV and local varieties. For these crops, the average of the yields from the NERP Farm Household and Land Use Surveys has been adopted. For other rice crops which occupy far less area, the selection was based on an assessment by the project Agronomist of the most reliable source(s) of information. For non-rice crops, the normal yield was nominally decreased to obtain a yield for flood damage crop, but, considering the small area occupied by non-rice crops, the net effects on agricultural production and hence economic analysis can be considered negligible.

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Table F.15: Yields of *Boro* Paddy Reported in Land Use Survey

Sample Area	Yield (tonne/ha)			
	HYV *Boro*		Local *Boro*	
	Flood Damage Free Land	Flood Damaged Land	Flood Damage Free Land	Flood Damaged Land
1	5.19	4.45	3.05	2.44
2	3.87	1.97	2.45	0.98
3	5.67	3.02	3.61	1.58
4	3.89	2.72	2.76	0.83
5	5.27	2.27	N/A	N/A
6	3.84	2.50	2.32	1.83
7	3.89	N/A	N/A	N/A
8	4.17	1.22	N/A	N/A
9	N/A	N/A	3.48	1.39
10	4.17	2.10	N/A	N/A
Average	**4.44**	**2.53**	**2.95**	**1.51**
Standard Deviation	**0.72**	**0.94**	**0.53**	**0.58**

Note: N/A - Crop not cultivated in sample area

Table F.16: Crop Yield Estimates

Crop	Yield (tonne/ha) NERP Farm Household Survey (1996)		NERP Land Use Survey (1995-96)		K-K Farm Monitoring Survey (1995-96)	Kalni-Kushiyara Pre-feasibility Study (1994)		NMIDP[1]	BBS[2] (1991 & 1993)	KKRMP Adopted Yields	
	Flood Damage Free Land	Flood-Damaged Land	Flood Damage Free Land	Flood-Damaged Land	Flood Damage Free Land	Flood Damage Free Land	Flood-Damaged Land	Flood Damage Free Land	Average of Damage Free & Damaged Land	Flood Damage Free Land	Flood-Damaged Land
Paddy Rice											
HYV *Boro*	4.95	3.26	4.44	2.53	5.07	4.55	2.75	4.90	4.03	4.69	2.90
L *Boro*	3.28	1.70	2.95	1.51	3.79	2.25	1.45		2.43	3.11	1.60
B *Aus*		0.98	1.48	1.10	1.10	1.25	1.05	2.94	1.69	1.10	1.04
DWR	1.70		2.32	1.50	2.37	1.75	1.45	2.97	1.74	1.93	1.50
LT *Aman*	2.36		2.37		2.52	2.15	1.75	3.08	2.16	2.15	1.75
HYV T *Aman*			3.33	2.24	3.20	3.95	3.55	3.65	3.56	3.20	2.24
Non-Rice											
Wheat			3.95		2.11	2.05		2.75	2.20	2.11	2.00
Pulses			0.70			0.85		1.05	0.81	0.81	0.80
Groundnut	1.48		1.68		2.04				1.01	2.04	2.00
Oilseeds	1.45		1.09		0.91	0.75		0.84	0.73	0.91	0.80
Potato	7.77		8.05		24.70	12.00		18.57	11.15	11.15	10.00
Sweet Potato	21.00		11.68						9.53	9.53	9.00
Spices[3]	17.91		6.02			2.25		3.05	4.17	6.00	5.00
Vegetables[3]			15.33			9.25		16.97	8.95	9.25	9.00

Notes: 1- National Minor Irrigation Development Project (1994)
2- Districts of Sylhet and Kishoreganj
3- Spices and vegetables are considered together in the NERP Farm Household Survey

4. AGRICULTURAL PRODUCTION SYSTEM

Crop cultivation is the main component of agriculture in the KKRMP study area. Rice dominates crop farming since it is well-suited to the land capability and the hydraulic regime. Livestock represents a minor component, and consists mainly of a few cattle per household which are used as draught animals.

4.1 Crops

4.1.1 Crop Season

There are 3 crop seasons in the project area. These are: *kharif* I (pre-monsoon to early monsoon season), *kharif* II (late monsoon season), and *rabi* (dry or winter season).

The characteristics of *kharif* I are unreliable rainfall, high temperature and evaporation, drought at the planting time, flash floods, and rapid rise of flood water. B. *aus* rice and photosensitive deep water *aman* rice are grown in this crop season. A relatively small area is cultivated in this season (Table F.17). *Boro* rice, which is transplanted in the *rabi* season, flowers and ripens in the *Kharif* I season.

Kharif II is characterized by high humidity, heavy rainfall and monsoon floods. Crop production in this season is limited by the variable flood depths. During the peak of the monsoon season, most of the study area may be inundated to a depth of 1 m or more. As a result crops can not be grown in the *kharif* II season. Transplanted *aman* rice is grown in small areas. Deep water *aman* also continues to grow through this season. Photosensitive crops flower when days get shorter.

Table F.17: Area of Major Crops During Kharif and Rabi Seasons

Crop Season	Crop	Area (ha)	% Total
Kharif I	*Aus*	7,446	2.6
	Deep Water *Aman*	25,297	9.0
	Sub-total	**32,743**	**11.6**
Kharif II	Transplanted *Aman*	7,554	2.7
	Sub-total	**7,554**	**2.7**
Rabi	*Boro*	236,762	84.1
	Oilseed	1,031	0.4
	Pulse	112	<0.1
	Potato	1,457	0.5
	Vegetables, Spices	1,843	0.7
	Wheat	153	<0.1
	Sub-total	**241,358**	**85.7**
Total Cropped Area		**281,655**	**100.0**

Source: Land use Survey; NERP, 1995/96.

The *rabi* season is characterized by low rainfall and low humidity, high solar radiation and evapotranspiration rate, low temperature, and a large variation in temperature between days and nights. The conditions during this season are very favorable for higher yields crops. Crop production is mainly governed by the availability of residual soil moisture or water for irrigation. Irrigated *boro* rice is extensively cultivated in vast areas. Short duration local *boro* is cultivated in lands where drainage is delayed after the monsoon, and HYV *boro* in better drained areas. Non rice crops are also grown in this season, such as wheat, potatoes, sweet potatoes, lentils, mustard, groundnut, linseed, tomatoes, beans, *brinjal* (eggplant), chilies, coriander, and cucumbers. The limiting factors for crop production during the *rabi* season are: poor drainage which delay sowing or transplanting, inadequate residual soil moisture, low-moisture holding capacity of soils, plant stress from low temperatures when the crop are planted early and flash floods. Because the drainage is often delayed after the monsoon, crops are not planted on time. This in addition to early flash floods prevents full development of cultivable lands.

4.1.2 Crop Cultivation Practices

Farmers practice sole-stand cropping for the major crops. The system of mixed cropping is preferred for vegetable cultivation. Agricultural production technology is almost exclusively based on manual labor, with the country plough, ladder, rake, hoe and sickle the most important and sometimes the only agricultural tools. The exceptions are low-lift pumps for irrigation and power sprayers for the treatment of crops against diseases and insects. Although modern varieties exist for many crops, at present their use is not very widespread, with the exception of HYV *boro* rice, which with the advent of irrigation has displaced significantly other rice crops. The cultivation practices of major crops are described below.

Rice is the dominant crop in the project area and will continue to be in the foreseeable future. Rice is not merely a food - it is the lifeline of the people in this area where crop production is limited by the complex hydrology and where unstable food production is common because of the ever present risk of flood. Rice is grown in four types of environment. These are rainfed upland (broadcast *aus*), deep water (broadcast *aman*), rainfed lowland (transplanted *aman*) and irrigated (*boro*). Rice is well suited to conditions found in the *rabi* season. The following sections describe the cultivation practices of rice and major non-rice crops, throughout the agricultural year.

Aus

Aus is grown on shallowly flooded lands. It includes photoperiod-insensitive varieties sown in the pre-monsoon season and harvested in the early monsoon season. The crop is mainly broadcast as a dry land crop. Mostly local varieties are grown in the project area. Land preparation is accomplished through three to five ploughings, mostly by country plough, followed by laddering. Fertilizers are either not applied or applied in too small quantities before the final ploughing. Seeds are broadcast and covered by soil. Fields are weeded 2 to 3 times, depending on weed infestation. Rice is harvested manually with a sickle. Plants are cut between 5 and 50 cm above ground depending on the threshing method subsequently used, distance to the threshing floor and straw requirements. More than 50% of the straw or stubble is left in the field which is inaccessible by road and the harvest has to be carried long distances along field levees or by boat. The harvested parts are tied in small bundles and carried to the threshing floor. The most popular method of threshing is trampling of harvested plants by cattle. Occasionally, paddle threshers are used. Sometimes rice is threshed manually by beating on bamboo frames or racks, wooden pieces, or floors. The rice is winnowed mainly by women, and sun-dried before storing it.

Deep water aman

Deep water *aman* is sown broadcast in the pre-monsoon season. This rice includes photoperiod-sensitive local varieties which are harvested in the post-monsoon season. These varieties are grown in the moderately flooded areas at the periphery of *beels* where the rate of rise in water level is slow. Seeds are sown when the land is dry. In some areas seedlings are transplanted in flooded lands once HYV *boro* has been harvested. When the plants are about six to eight weeks old they start to elongate with the gradual rise in water level. They flower when the days get shorter. Once mature, the plants are cut with panicles 60 to 70 cm from the top. Most of the straw is either left in the field or collected later. Post-harvest operations are similar to those used for *aus*.

Transplanted Aman

T. *aman* is grown on shallowly flooded lands once *aus* has been harvested. In low flood years, when the water recedes early, it is also grown on river banks, before HYV *boro* is transplanted on these banks. Both HYVs and local T. *aman* varieties are cultivated. This crop is sown in seed beds and seedlings are transplanted in the monsoon season. It also includes photoperiod-sensitive varieties which are harvested in the post-monsoon season. The land is puddled by 3 to 4 ploughings followed by laddering. Basal doses of fertilizers are applied before the final ploughing. Four to eight week-old seedlings are transplanted on the puddled land. Agricultural practices include weeding, top-dressing of fertilizers and application of pesticides. As they are photosensitive, plants flower when days start to get shorter. Once ripe, they are cut 5 to 15 cm above ground. Post-harvest operations are similar to those used for *aus*.

Boro

Boro rice varieties are photoperiod-insensitive. Plants are transplanted in the early dry season and harvested in the pre-monsoon season. Crops are irrigated. Both local and HYV varieties are transplanted. Local varieties can be classified into two groups according to growth duration: *jagli* and *shail*. They are transplanted as soon as the flood waters have receded. *Jagli* varieties are early maturing. They are well adapted for conditions where flooding occurs early. *Shail* varieties require another 10 to 15 days to mature. They are grown on land where pre-monsoon flooding occur earlier than on HYV cultivated land.

Land preparation begins with the recession of flood water from the fields. Land is puddled by alternatively watering it and ploughing it. Six to eight week-old seedlings, raised on seedbed, are then transplanted on the puddled land. The number of seedlings per hill ranges from 3 to 5. Basal doses of fertilizers are used very often on HYVs lands, but seldom on local varieties. Weeding, top-dressing of nitrogen fertilizer and pesticide application continue until the plants flower. When the crops are ripe, the plants are cut at the base if the field is dry; otherwise they are cut 30 to 50 cm from the top. Post-harvest operations are similar to those of *aus*.

Wheat

Wheat is grown in the *rabi* season. Land is prepared at the beginning of the season with 3 to 4 ploughings followed by laddering. Basal doses of fertilizers are applied before the final ploughing. Seeds are broadcast and covered with soil by shallow ploughing and laddering. Depending on the variety, the crop matures in 100 to 120 days. The plants are cut at the base and carried to the threshing floor in bundles. The grains are detached from the plants by beating against hard objects.

Pulses

Pulses are grown on soil free from water logging. The crops are mostly grown in the *rabi* season. The land is levelled to prevent water logging. Seeds are broadcast and covered with pulverized soil by light ploughing and laddering. Fertilizers are applied during land preparation. Crops are harvested either by pulling or cutting at the base of the plants, leaving the root system intact. Pulses are either grown as pure stand or mixed with other *rabi* crops.

Oilseeds
Oilseeds are grown in the *rabi* season on well-drained soils. Groundnut is the major oilseed grown in the project area. This crop is usually grown as pure stands. Seeds are broadcast and covered with pulverized soil. Basal doses of fertilizers are applied to the soil during the last ploughing. Plants are top-dressed with urea before flowering. Improved varieties are available. Crops are harvested either by pulling or cutting at the base of the plants.

Potato
Potato is one of the tuber crops grown in the *rabi* season. After ploughing and laddering, shallow furrows are made in the ground with a stick or plough for planting tubers. Fertilizers are applied in the bottom of the furrow and the planted seed tubers are covered with pulverized soil. As the crop grows, ridges are developed progressively. Additional nitrogen fertilizer is applied at the side of the row 45 days after planting. The crop is ready for harvest when the leaves of the plant turn yellow and start to dry 80 to 100 days after planting.

Sweet potato is grown in the *rabi* season. Cuttings are planted on shallow ridges which are gradually raised. Fertilizers are applied at the final ploughing and nitrogen fertilizer is top dressed. The crop is planted in early *rabi* season and harvest is completed before the monsoon starts.

Vegetables
Vegetables are grown in the dry season on well drained land. The important vegetables grown in the project area are *brinjal* (egg plant), *arum, danta, karala*, and beans. Both organic and inorganic fertilizers are applied during the preparation of land. Vegetables are grown in pits, in furrows and on raised beds. Seedlings are raised in separate seed beds or in polyethylene bags. *Arum* is grown in medium high to medium low lands where rain water is ponded. The land is well puddled before planting. Local, improved local and modern varieties are used for vegetable cultivation.

Spices
The crops are cultivated on well-drained soil. Chili, and coriander are the major spice crops grown in the project area. They are grown during the dry season. Both manure and fertilizers are applied to the soil. Chili seedlings are raised in separate seed beds and transplanted in rows. Coriander seeds are broadcast.

4.1.3 Land Use and Net Cultivated Area

Table F.18 shows the current landuse pattern in the project area. These figures are based on *thana* maps compiled from spot imagery (1989-90), aerial photographs (1983-84) and topographic maps done by the Local Government Engineering Department (LGED) in 1994 under a UNDP/ILO project. Information from BBS and Department of Fisheries (DOF) was also accessed to determine the area of ponds and information from BBS and the NERP sample areas to determine the area of *khas* and grass land.

Table F.18: Land Use

Land Use	Area (ha)
Cultivated Land	279,850
Settlements	14,779
Beels	13,340
Rivers	10,780
Channels	1,250
Ponds	2,466
Infrastructure	2,491
Khas/Grass Land	10,644
Total	**335,600**

The total area cultivated in the project area is 279,850 ha and accounts for 83% of the study area. Since much of the project area is deeply flooded during the monsoon season, almost all the cultivated lands are used for single cropping once the area has drained in the post-monsoon season.

4.1.4 Crop Patterns

Crop patterns in the project area are mainly determined by physical factors (topography in relation to flooding, flooding characteristics, availability of moisture and irrigation water, and length of the growing season). The risk of flood and drainage problems have a major influence on the type of crop grown in a particular location, sowing or transplantation time of crops, input use and yields. The biological factors (growth duration of crops, varietal characteristics, etc.) and socio-economic factors (financial resources, availability of credit, ratio of input and output of the produce etc.) are also important and therefore are considered by farmers in the selection of crop patterns.

Table F.19 presents the current crop patterns and their respective areas under each flood depth range for the 1:2, 1:5 and 1:10 year pre-monsoon floods. These patterns are based on information which was obtained from the sample sites land use surveys. The area flooded in each flood depth range considered was determined with the MIKE 11 hydrodynamic model (Annex B—MIKE 11 Hydrodynamic Model). The methodology adopted for extrapolating the extent of inundation of crop patterns is described in Section 2.7 and Appendix E.4.

A wide range of crop patterns are practiced in the project area, but the major patterns are rice based accounting for more than 95% of the NCA. Irrigated HYV *boro*-fallow is the major crop pattern covering more than two-thirds of the total NCA. Irrigated local *boro*-fallow is the second major pattern occupying 15% of the NCA. Deep water *aman*-fallow occupies about 8% of the net cultivated area. The broadcast *aus*-transplanted *aman* pattern occupies about 3% of the NCA.

On flood free high ridges and shallowly flooded medium highlands (flood depth from 0.3 to 0.9 m) the main crop patterns are either local *boro*, deep water *aman,* or local broadcast *aus* followed by HYV transplanted *aman*. On irrigated lands, HYV *boro* is cultivated. The crop is sometimes followed by transplanted *aman*. On moderately flooded medium lowlands (where the depth of flooding ranges from 0.9 to 1.8 m), mainly HYV or local irrigated *boro* is grown. Deep water *aman* in the monsoon season and non-rice crops in the dry season are grown on sandy and silty alluvium soils with partial or no irrigation. Deep water *aman* is transplanted in the monsoon season on the periphery of those flooded areas which cannot be irrigated during the dry season. In a few areas, deep water *aman* follows HYV *boro*. In deeply flooded low-lying areas (where the depth of flooding exceeds 1.8 m) local *boro* is grown in the lower zone and HYV *boro* in the upper zone, and deep water *aman* where irrigation is not available in the dry season.

Non-rice crops which include mainly groundnut, sweet potatoes, vegetables and spices are grown in less than 2% of the NCA.

Overall, 94% of the NCA is single cropped, 3% is double cropped and another 3% is fallow.

4.1.5 Crop Calendar

A crop calendar is presented in Figure F.21 which shows the growing season of each crop. Planting time in the *rabi* season depends on both local drainage conditions at the end of the monsoon and depth of flooding in the pre-monsoon. For example HYV *boro* rice, the main crop, is planted late, in mid-January, in flood free land or shallowly flooded land, when the ambient temperature is high enough and not likely to cause stress on the plants. Crops are then harvested in the second half of May. These conditions generate the highest yields.

Table F.19: Extent of Inundation of Crop Patterns - Present Conditions

Crop Pattern	Present Area (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	<0.3	0.3-0.9	0.9-1.8	>1.8	Total	<0.3	0.3-0.9	0.9-1.8	>1.8	Total	<0.3	0.3-0.9	0.9-1.8	>1.8	Total
B. *Aus*-HYV T. *Aman*	7,384	59	3	0	**7,446**	2,679	1,063	2,449	1,255	**7,446**	402	454	3,333	3,257	**7,446**
Loc T.*Aman*-HYV *Boro*	36	0	0	0	**36**	13	5	12	6	**36**	2	2	16	16	**36**
HYV *Boro*-Fallow	166,449	15,856	7,641	659	**190,605**	60,399	38,488	62,779	28,939	**190,605**	9,065	24,752	82,715	74,073	**190,605**
Local *Boro*-Fallow	25,710	4,146	7,993	5,161	**43,010**	9,329	7,642	16,510	9,529	**43,010**	1,400	5,520	19,590	16,500	**4,3010**
DW *Aman*-HYV *Boro*	2,754	354	3	0	**3,111**	999	729	915	468	**3,111**	150	501	1,245	1,215	**3,111**
DW *Aman*-Fallow	18,491	1,479	1,838	378	**22,186**	6,710	3,994	7,963	3,519	**22,186**	1,007	2,468	10,178	8,533	**22,186**
HYV T. *Aman*-Fallow	46	14	12	0	**72**	17	20	27	8	**72**	3	17	32	20	**72**
Wheat-Fallow	151	2	0	0	**153**	55	22	50	26	**153**	8	9	69	67	**153**
Pulses-Fallow	108	4	0	0	**112**	39	19	36	18	**112**	6	10	49	47	**112**
Groundnut-Fallow	700	19	0	0	**719**	254	114	232	119	**719**	38	56	316	309	**719**
Oilseeds-Fallow	262	21	10	19	**312**	95	57	97	63	**312**	14	35	128	135	**312**
Potato-Fallow	926	26	0	0	**952**	336	152	307	157	**952**	50	75	418	409	**952**
Sweet Potato-Fallow	495	10	0	0	**505**	180	77	164	84	**505**	27	36	223	219	**505**
Spices-Fallow	1,290	28	1	0	**1,319**	468	204	428	219	**1,319**	70	98	582	569	**1,319**
Vegetables-Fallow	502	18	1	3	**524**	182	86	167	89	**524**	28	44	227	225	**524**
Fallow	7,973	589	226	0	**8,788**	2,893	1,672	2,867	1,356	**8,788**	434	1,016	3,823	3,515	**8788**
Net Cultivated Area	**233,277**	**22,625**	**17,728**	**6,220**	279,850	**84,648**	**54,344**	**95,003**	**45,855**	279,850	**12,704**	**35,093**	**122,944**	**109,109**	279,850

In moderately to deeply flooded lands, the ever present risk of early flash floods induces farmers to plant early, at the beginning of January. At that time, the ambient low temperature, causes stress on the plants, many of which become infertile as a result. Crops are also harvested in the second half of May. Yields are lower.

Local *boro* is planted in early January in flood free and shallowly flooded areas. The crop is harvested in the latter part of April. In moderately to deeply flooded lands, planting is done as soon as the drainage conditions permit, generally in mid-December, in order to save latter on crops from early rains and flash floods. The crops are harvested in the second half of April. Risk of loss is high.

4.1.6 Crop Areas

Table F.20 presents the area under which individual crops are grown throughout the year, under each flood depth range for the 1:2, 1:5 and 1:10 year floods. This table is derived from Table F.19, where an area under multiple crop cultivation is allocated to each of the crops. It should be noted that, in this table, the separation of the cultivated area into flood level ranges is only relevant for those crops which are affected by floods. The total cropped area is 281,655 ha.

Rice
The land-use survey confirmed that rice dominates crop farming, accounting for 98% of the total cropped area. Thus, the major crop practices in the project area are rice based and most cultivated lands are cropped with rice. Rice is grown in four types of environment. These are rain-fed uplands (b. *aus*), deep water (deep water or broadcast *aman*), rainfed lowland (T. *aman*) and irrigated (*boro*).

Boro is the major rice crop. The crop covers 84% of the total cropped area. T. *aman* or monsoon rice occupies about 3% of the total cropped area, and *aus* or pre-monsoon rice occupies another 3%. Deep water *aman,* which is sown in the pre-monsoon season and harvested with T. *aman*, accounts for 9% of the total cropped area.

About 27% of the total rice area is under local varieties. The HYV varieties cover 73% of the total rice area. The HYVs account for 82% of the total area under *boro* rice, over 99% of the total area under T. *aman*. The *aus* and deep water *aman* varieties are all local.

Non-rice Crops
Non-rice crops account for less than 2% of the total cropped area and consist mainly of spices. They are grown on highest land near rivers. Besides spices, the other non-rice crops, such as oilseeds and groundnut occupy less than 1%, potato occupies 0.3%, sweet potato 0.2%, vegetables 0.2%, wheat 0.05% and pulse 0.04%.

Table F.20: Extent of Inundation of Annually Cropped Area - Present Conditions

Crop	Area (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	<0.3	0.3-0.9	0.9-1.8	>1.8	Total	<0.3	0.3-0.9	0.9-1.8	>1.8	Total	<0.3	0.3-0.9	0.9-1.8	>1.8	Total
RICE															
HYV *Boro*	169,239	16,210	7,644	659	**193,752**	61,411	39,222	63,706	29,413	**193,752**	9,217	25,255	83,976	75,304	193,752
Local *Boro*	25,710	4,146	7,993	5,161	**43,010**	9,329	7,642	16,510	9,529	**43,010**	1,400	5,520	19,590	16,500	43,010
B. *Aus*	7,384	59	3	0	**7,446**	2,679	1,063	2,449	1,255	**7,446**	402	454	3,333	3,257	7,446
DW *Aman*	21,245	1,833	1,841	378	**25,297**	7,709	4,723	8,878	3,987	**25,297**	1,157	2,969	11,423	9,748	25,297
Local T. *Aman*	36	0	0	0	**36**	13	5	12	6	**36**	2	2	16	16	36
HYV T. *Aman*	7,430	73	15	0	**7,518**	2,696	1,083	2476	1,263	**7,518**	405	471	3,365	3,277	7,518
Rice Total	**231,044**	**22,321**	**17,496**	**6198**	277,059	**83,837**	**53,738**	**94,031**	**45,453**	277,059	**12,583**	**34,671**	**121,703**	**108,102**	277,059
NON-RICE															
Wheat	151	2	0	0	**153**	55	22	50	26	**153**	8	9	69	67	**153**
Pulse	108	4	0	0	**112**	39	19	36	18	**112**	6	10	49	47	**112**
Groundnut	700	19	0	0	**719**	254	114	232	119	**719**	38	56	316	309	**719**
Oilseeds	262	21	10	19	**312**	95	57	97	63	**312**	14	35	128	135	**312**
Potato	926	26	0	0	**952**	336	152	307	157	**952**	50	75	418	409	**952**
Sweet Potato	495	10	0	0	**505**	180	77	164	84	**505**	27	36	223	219	**505**
Spices	1,290	28	1	0	**1,319**	468	204	428	219	**1,319**	70	98	582	569	**1,319**
Vegetables	502	18	1	3	**524**	182	86	167	89	**524**	28	44	227	225	**524**
Non-Rice Total	**4,434**	**128**	**12**	**22**	4,596	**1,609**	**731**	**1,481**	**775**	4,596	**241**	**363**	**2,012**	**1,980**	4,596
ALL CROPS	235,478	22,449	17,508	6,220	281,655	85,446	54,469	95,512	46,228	281,655	12,824	35,034	123,715	110,082	281,655

4.1.7 Cropping Intensity

Cropping intensity, defined as the ratio of the cropped area to the NCA, expressed as a percent is very low, at 101%, as:

- deep flooding almost completely restricts crop production in the *kharif* season;
- some cultivable land is not cropped because of delayed drainage after the monsoon, want of soil moisture in the dry season and flood damage.

4.1.8 Crop Production

Rice

All rice production and loss figures presented in this Annex are for paddy rice.

The average rice yield depends on the timing and the duration of flooding. Average yield for the 1:2 year, 1:5 year and 1:10 year flood is estimated to be 3.84 tonnes/ha, 3.02 tonnes/ha and 2.62 tonnes/ha, respectively. Respective yields for flood free land and flood damaged areas are given in Table F.21). Yields are 60% to 90% higher in the dry season than in the pre-monsoon and monsoon seasons. The average HYV rice yield is also higher compared with local rice varieties.

The analysis of crop yields shows that the average yield is 4.10 tonnes/ha in flood free lands compared to 2.5 tonnes/ha in flood-damaged lands. The yield is much higher at the periphery of *beels* than on ridges and river banks. They are less fertile, sandy and contain less silt and organic matters.

Annual rice production varies from 0.82 million to 1.05 million tonnes (Table F.22). HYV rice accounts for 84% of the total rice production. About 97% of HYV rice is produced in the dry season and 3% in the monsoon season. The local rice varieties account for 16% of the total production. About two-thirds of the local rice is produced in the dry season and the remainder in the pre-monsoon and monsoon seasons.

Of the total rice production, 92% is produced in the dry season with local *boro* contributing 10% and HYV *boro* 82%. Pre-monsoon and monsoon rice accounts for the remaining 8%. The pre-monsoon and monsoon rice includes B. *aus*, deep water *aman* and T. *aman*. They account respectively for 5%, 2% and 1% of the total rice production.

Non-rice Crops

About 300 tonnes of wheat are produced annually with an average yield level of 2.1 tonne/ha. Thus it occupies an insignificant part of the annual food grain production in the project area. Annual production of oilseed is 260 tonnes and groundnut 1,450 tonnes with an average yield of 1.65 tonnes/ha and 2.02 tonnes/ha, respectively. About 90 tonnes of pulses are produced with an average yield level of 0.80 tonnes/ha. Annual production of potato and sweet potato is 10,000 tonnes and 4,500 tonnes. The average yield levels are 9.2 tonnes/ha and 5.5 tonnes/ha, respectively. About 7,000 tonnes of spices and 4,700 tonnes of vegetables are produced annually, with average yields of respectively 5.5 tonnes/ha and 9.1 tonnes/ha.

Table F.21: Crop Yield and Production - Present Conditions

Crop	Area (ha)						Yield (tonnes/ha)		Production (tonnes)					
	Flood Damage Free Lands			Flood Damaged Lands			Damage Free Lands	Damaged Lands	Flood Damage Free Lands			Flood Damaged Lands		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year			1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE														
HYV *Boro*	169,239	61,411	9,217	24,513	132,341	184,535	4.69	2.90	793,731	288,018	43,228	71,088	383,789	535,152
Local *Boro*	25,710	9,329	1,400	17,300	33,681	41,610	3.11	1.60	79,958	29,013	4,354	27,680	53,890	66,576
B. *Aus*	7,384	2,679	402	62	4,767	7,044	1.10	1.04	8,122	2,947	442	64	4,958	7,326
DW *Aman*	21,245	7,709	1,157	4,052	17,588	24,140	1.93	1.50	41,003	14,878	2,233	6,078	26,382	36,210
Loc T. *Aman*	36	13	2	0	23	34	2.15	1.75	77	28	4	0	40	60
HYV T. *Aman*	7430	2,696	405	88	4,822	7,113	3.20	2.24	23,776	8,627	1,296	197	10,801	15,933
Rice Total	**231,044**	**83,837**	**12,583**	**46,015**	**193,222**	**264,476**			**946,667**	**343,511**	**51,557**	**105,107**	**479,860**	**661,257**
NON-RICE														
Wheat	151	55	8	2	98	145	2.11	2.00	319	116	17	4	196	290
Pulse	108	39	6	4	73	106	0.81	0.80	87	32	5	3	58	85
Groundnut	700	254	38	19	465	681	2.04	2.00	1,428	518	78	38	930	1,362
Oilseeds	262	95	14	50	217	298	0.91	0.80	238	86	13	40	174	238
Potato	926	336	50	26	616	902	11.15	10.00	10,325	3,746	558	260	6,160	9,020
Sweet Potato	495	180	27	10	325	478	9.53	9.00	4,717	1,715	257	90	2,925	4,302
Spices	1,290	468	70	29	851	1,249	6.00	5.00	7,740	2,808	420	145	4,255	6,245
Vegetables	502	182	28	22	342	496	9.25	9.00	4,644	1,684	259	198	3,078	4,464
Non-Rice Total	**4,434**	**1,609**	**241**	**162**	**2,987**	**4,355**			**29,498**	**10,705**	**1,607**	**778**	**17,776**	**26,006**
ALL CROPS	**235,478**	**85,446**	**12,824**	**46,177**	**196,209**	**268,831**			**976,165**	**354,216**	**53,164**	**105,885**	**497,636**	**687,263**

Table F.22: Crop Production - Present Conditions

Crop	Present Crop Production (tonnes)								
	Flood Damage Free Lands			Flood Damage Lands			Total		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE									
HYV *Boro*	793,731	288,018	43,228	71,088	383,789	535,152	864,819	671,807	578,380
Local *Boro*	79,958	29,013	4,354	27,680	53,890	66,576	107,638	82,903	70,930
B. *Aus*	8,122	2,947	442	64	4,958	7,326	8,186	7,905	7,768
Deep water *Aman*	41,003	14,878	2,233	6,078	26,382	36,210	47,081	41,260	38,443
Loc T. *Aman*	77	28	4	0	40	60	77	68	64
HYV T. *Aman*	23,776	8,627	1,296	197	10,801	15,933	23,973	19,428	17,229
Rice Total	**946,667**	**343,511**	**51,557**	**105,107**	**479,860**	**661,257**	**1,051,774**	**823,371**	**712,814**
NON-RICE									
Wheat	319	116	17	4	196	290	323	312	307
Pulse	87	32	5	3	58	85	90	90	90
Groundnut	1,428	518	78	38	930	1,362	1,466	1,448	1,440
Oilseeds	238	86	13	40	174	238	278	260	251
Potato	10,325	3,746	558	260	6,160	9,020	10,585	9,906	9,578
Sweet Potato	4,717	1,715	257	90	2,925	4,302	4,807	4,640	4,559
Spices	7,740	2,808	420	145	4,255	6,245	7,885	7,063	6,665
Vegetables	4,644	1,684	259	198	3,078	4,464	4,842	4,762	4,723
Non-Rice Total	**29,498**	**10,705**	**1,607**	**778**	**17,776**	**26,006**	**30,276**	**28,481**	**27,613**
TOTAL CROPS	**976,165**	**354,216**	**53,164**	**105,885**	**497,636**	**687,263**	**1,082,050**	**851,852**	**740,427**

4.1.9 Crop Damage

Local and HYV *boro* rice varieties are damaged when they are in the reproductive or ripening stage. Yield of local *boro* will decrease by 50% when 75% of the plant is submerged for 3 days during the ripening stage. When completely submerged, farmers still manage to collect the partially matured panicles. *Boro* is also damaged in winter when young plants are inundated. The winter inundation follows heavy rainfall and occurs mainly in low depressions which do not have sufficient drainage outlets. The flood conditions intensify when the major rivers are also high and their waters spill into the project area. Large tracts of lowlands along the Kushiyara-Kalni River were flooded in late December 1991 by spills from the Kushiyara. In February 1993 *boro* crops were damaged in the project area by rainfall and spills from the Kalni-Kushiyara river.

In *boro* rice areas, farmers do not favor early transplantation because cool temperatures at the reproductive stage induce a high level of sterility and reduces yields significantly. However, in moderately to deeply flooded lands, they are compelled to adopt this practice.

Local varieties of deep water *aman* seedlings are damaged when they are submerged before the plants are capable of elongating with the gradual rise of water.

Local and high yielding varieties of T. *aman* rice are damaged by floods and drainage congestion in the late monsoon season. The damage takes place mostly at the tillering stage. It was observed that yield of these crops decreases by 20% when 25% of the plant is submerged for 3 days at tillering. The loss of yield resulting from partial submergence can be attributed to impaired tillering and smaller leaf surface for photosynthesis.

Farmers attempt to save non-rice crops from flood damage by planting early and by harvesting crops before the onset of flooding.

Table F.23: Crop Production Losses - Present Conditions

Crop	Crop Losses (tonnes)		
	1:2 year	1:5 year	1:10 year
RICE			
HYV *Boro*	43,878	236,890	330,317
Local *Boro*	26,123	50,858	62,831
B. *Aus*	5	286	423
DW *Aman*	1,742	7,563	10,380
Local T. *Aman*		9	13
HYV T. *Aman*	85	4,630	6,829
Rice Total	**71,833**	**300,236**	**410,793**
NON-RICE			
Wheat		11	16
Pulse	1	1	1
Groundnut	1	19	27
Oilseeds	6	24	33
Potato	30	709	1,037
Sweet Potato	6	173	254
Spices	29	851	1,249
Vegetables	5	85	124
Non-Rice Total	**78**	**1,873**	**2,741**

Annual rice losses are estimated to vary from 100,000 tonnes to more than 400,000 tonnes. Annual HYV *boro* losses range from 44,000 to 330,000 tonnes and from 26,000 to 57,000 tonnes for local *boro*.

Annual losses of non-rice crops are estimated to be from 100 tonnes to 3000 tonnes. Table F.23 presents estimated crop losses.

Losses are estimated for each cropping pattern and each flood frequency as:

Area of flood-damaged land * (Damage free land yield - Damaged land yield)

4.2 Input Use

4.2.1 High Yield Varieties

A major part of the rice area is planted with high yield varieties. Farmers switched from local to HYV varieties wherever irrigation was available. BRRI has released 16 HYVs *boro*. HYV wheat and improved varieties of pulses, oilseeds, spices and vegetables are also available. These varieties have been developed by BARI.

4.2.2 Crop Seeds

The average seed rate is 90 kg/ha for broadcast rice, 25 kg/ha for transplanted rice, 130 kg/ha for wheat, 1,600 kg/ha for potato, 35 kg/ha for pulse, and 150 kg/ha for groundnut. Usually, farmers save their seeds from the harvested crop. They sometimes exchange them among themselves. Seeds of HYVs or improved varieties are available at *thana* BADC seed distribution centers. But they are not available in sufficient quantity and the total amount of seeds distributed to the farmers is lower than the average requirements for the cultivation of most crops. In addition, seeds are often not available on time at *thana* distribution centers. The net effect of this shortcomings is a reduction in the potential yield.

4.2.3 Irrigation

As determined by NERP land use survey, a contributing factor to the cultivation of modern rice varieties has been the development of irrigation. Currently the HYV *boro* irrigated area is slightly less than 194,000 ha. Low Lift Pump (LLP) irrigation accounts for 67% of the total irrigated area, or 130,000 ha. Areas irrigated by lifting water through traditional methods account for 31% of the total irrigated area, or some 60,000 ha. Traditional methods of irrigation are mostly practiced in depressions and flood basins, where surface water is available at a level of 1 to 2 m below the cultivated land during the dry season. The equipment consists mainly of swing baskets and *doons*. The majority of the surface water irrigated area is concentrated in Astagram, Nabiganj, Baniachang, Balaganj, Derai, Sullah, and Jagannathpur Thana.

By comparison, information published in 1991 indicates that, for the study area, surface Water irrigation coverage was then 70,000 ha by traditional modes (AST, 1991). There were 3,200 LLP's of various discharge capacities irrigating an area of 55,000 ha.

Present groundwater abstraction for irrigation is not significant. About 2% of the total irrigated area is irrigated by ground water. According to AST (1991), there are 191 shallow tube wells and 77 deep tubewells in the project area. The reported groundwater irrigated area is 4,000 ha, of which 1,700 ha is by shallow tubewells and 2,300 ha is by deep tube wells. Groundwater abstraction is about 17 million m^3 based on MPO's (currently WARPO) estimated groundwater irrigation duty (MPO, 1991). Groundwater irrigation is concentrated in Ajmiriganj, Baniachang, Habiganj, Lakkhai and Astagram Thana.

Based on MPO data the estimated usable ground water recharge within the project area is 406 Mm^3 (MPO, 1991). Of this, about 269 Mm^3 are available within the depth range accessible by force mode technology (DTW). Suction mode STW technologies could withdraw only about 7.0 Mm^3 which indicates STWs are probably not suitable due to aquifer constraints, but about 70 Mm^3 could be withdrawn by deep-set STW (DSSTW). The majority of the groundwater resource potential is located in Baniachang, Nabiganj, Biswanath, Jagannathpur.

4.2.4 Fertilizers

NERP land use survey has confirmed that chemical fertilizers are a major input of HYV rice in the *rabi* season. Nitrogen is the most common and widely used nutrient, with urea the main source of nitrogen. In the project area, annual consumption of urea is about 30,000 tonnes. Phosphate is the second most used fertilizer. The most widely consumed phosphate fertilizer is TSP with an annual consumption of about 15,500 tonnes. Potash is the third most widely used nutrient, with MP the only source of potash. The project area consumes about 5,000 tonnes of MP annually. Fertilizer applications are generally poorly balanced, with a low actual to recommended ratio (Table F.24). Fertilizers are available at local markets. Their price increases in the *rabi* season because of demand.

Table F.24: Fertilizer Use

Crop	Fertilizer Use (kg/ha)					
	Urea		TSP		MP	
	Actual	Recommended	Actual	Recommended	Actual	Recommended
Local T. *Aman*	59	70	59	55	11	40
HYV T. *Aman*	61	185	20	90-95	5	40-70
Local *Boro*	42	90-105	19	50-60	2	25-35
HYV *Boro*	135	180-210	73	90-125	26	50-70
Wheat	130	180-220	61	140-180	-	40-50
Pulse	13	70-80	-	138	-	58
Groundnut	54	50	64	150	-	50
Oilseed	50	140-180	22	90-175	12	60
Potato	96	280	43	185	4	280
Sweet Potato	15	125	15	100	20	150
Vegetable	41	100-150	27	200-300	-	50-150
Spice	116	100	88	200	9	100

Source: The actual rate of application was obtained from farm monitoring and land use survey.
The recommended fertilizers application rate was obtained from DAE 1992 and BARC 1991.

4.2.5 Labor

Labor requirements for the various farm activities vary according to crops. Demand is high during *boro* rice transplantation and harvest. The farm monitoring study shows that average labor requirements for HYV production in the *boro* and *aman* seasons are respectively 205 person-days/ha and 150 person-days/ha. For local rice varieties the labor requirements are 117 person-days/ha for b. *aus*, 101 person-days/ha for b. *aman*, 107 person-days/ha for local t. *aman* and 154 person-days/ha for local *boro*. Vegetables and spices require 181 person-days/ha, Potato 188 person-days/ha, groundnut 167 person-days/ha, sweet potato 116 person-days/ha, oilseeds 115 person-days/ha, wheat 99 person-days/ha and pulses 45 person-days/ha.

4.2.6 Pesticides

Mainly granular types are used in the project area. Other pesticides include conventional pest complexes, acaricides, fungicides and rodenticides. Pesticides are mainly applied on HYV *boro* rice. It is estimated from the farm monitoring study that about 12% of the total cropped land in the project area is treated with pesticides. The application rate is significantly below the recommended rate. On average, the application rate for HYV *boro*, the major crop, is 1.4 kg/ha compared with a recommended dose of 16.8 kg/ha. The application rate varies from 0.5 kg/ha to 1.5 kg/ha for other crops.

4.2.7 Draught Animals

Animal power is essential for land preparation (ploughing, laddering), weed control (raking), threshing, crushing and hauling. On most farms, the land is prepared with bullocks or buffalos. There are very few power tillers.

Draft animal units (DAU) are used to estimate draught animal power. Usually, 1 DAU equals 1 bullock, 2 cows or 0.5 buffalo. The 1989 UNDP/Agriculture Sector Review reports that generally a pair of DAU can cultivate 1.62 ha of land provided that the ploughing time is widely distributed throughout the year. However, there are 0.5 head of draught cattle per ha of cultivated land. This suggests that there is about 4.4 ha of cultivated land per pair of DAU in the project area.

Present draught animal requirements are 41 to 45 bullock days/ha for transplanted HYV rice, 40 to 42 bullock days/ha for transplanted local rice, 39 to 41 bullock days/ha for local broadcast rice, 50 bullock days/ha for vegetables and 40 to 46 bullock days/ha for other non-rice crops. Generally, the supply of draught animals is not adequate.

4.3 Livestock

4.3.1 Population

The most recent data on livestock population is published in the 1983-84 Livestock Census. According to this census, there were then about 250,000 cattle, 8,000 buffalos, 50,000 goats and sheep, and 600,000 chicken in the project area. 47% of households had cattle or buffalos, 15% had goats and/or sheep, and 66% had poultry. Very few households are entirely dependent on their livestock for subsistence.

According to the census about 55% of the total cattle and buffaloes are working animals, 93% of which are used for cultivation, 1% for transportation, 2% for cultivation and transportation, and 4% for other purposes.

4.3.2 Livestock Feeds and Fodder Supply

The main source of cattle feed is rice straw, complemented with rice fields, roadside grazing and communal grazing fields in winter. About 87% of all animal feeds come from cultivated land. Only 13% comes from other sources such as embankments, road sides, and low lands which are usually used on a community basis and therefore are not available for managed forage production. The small areas of communal grazing lands are now over-grazed. Animals hardly receive any concentrated feed except a small quantity of salt and a handful of rice bran/polishing which is produced in the households.

4.4 Agriculture Extension Service

Agricultural extension activities in the project area are carried out by the Department of Agricultural Extension (DAE) through eleven *thana* Agriculture Officers (Astagram, Mitamain, Itna, Ajmiriganj, Baniachang, Nabiganj, Lakhai, Derai, Dowarabazar, Jagannathpur and Moulvibazar) supervised by Deputy Directors in Kishoreganj, Habiganj and Moulvibazar districts headquarters. Each Thana Agriculture Officer (TAO) is supported by a Subject Matter Officer, an Additional Thana Agriculture Officer (ATAO), an Assistant Agricultural Extension Officer (AAEO), a Junior Agricultural Extension Officer (JAEO), and Block Supervisors.

Diffusion and adoption of modern technologies are under the responsibility of this extension personnel. Extension activities are mainly organized through regular visits by the Block Supervisors to sub-blocks. In each sub-block there are contact farmers through which messages concerning improved practices are passed on to the farming community. In addition, the Block Supervisors attends training and conference sessions where farmers' problems are discussed. He also maintains demonstration plots in farmers' fields. The extension activities are supported by the Agricultural Support Services Program whose aim is to concentrate activities in key areas including minor irrigation operation and on-farm water management.

4.5 Marketing

Small-scale intermediaries are involved in moving crops from producers to consumers. There are many primary markets in villages and secondary markets in commercial centers. Crops are sold from the farmers' house to *beparis* (millers, agents of millers or wholesalers, or itinerant traders). There are also local middlemen who act as agents of *beparis* and sellers. Crops are mainly sold through this channel in areas with poor road communications and high transport costs. There are also itinerant traders who barter crops with other goods. Generally, farmers sell surplus crops after retaining an adequate amount for family consumption until the following harvest. The farmers also preserve seeds from their harvest. Small farmers, share croppers and deficit growers have no surplus. However, they sell a portion of their harvest immediately after threshing to repay loans or to meet other needs.

5. RECENT CHANGES IN AGRICULTURAL PRODUCTION

5.1 Land Use

Published information on land use in the project area is available from two sources. The first is the SRDI soil survey reports (SRDI 1976, 1977 and 1983), the second is the BBS 1983-84 census on agriculture. The SRDI soil survey reports have evaluated the present land use at the time of the surveys based on estimates made during soil survey field work supplemented by questioning of local farmers and air photo interpretation. The land use is presented in the form of associations in Figure F.22. The SRDI soil survey reports specify that the information should be considered as indicative only. This map was developed from information obtained between the mid-1960s to the mid 1970s.

Table F.25 presents a comparison of the NCA estimated by NERP in 1995-96 with the one published in the 1983-84 Census of Agriculture. It shows that the NCA increased by more than 47% during the period. In 1983-84, more than one-fifth of the NCA was fallow. Fallow land now accounts for 3% of the net cultivated area. A major contributing factor to this increase in cultivated land has been the development of irrigation. Moreover, many low-lying lands silted up during the period have been brought under cultivation. During the period considered the area dedicated to HYV *boro* cultivation has increased at an annual rate of 12%, Part of this increase was due to the displacement of other rice crops, the remainder consisted in land previously fallow and put under cultivation.

Table F.25: Changes in Crop Area

Crop	Changes in Crop Area (ha)	
	1983/84[1]	1995/96[2]
B. *aus*	24,095	7,446
HYV T. *aus*	1,530	-
B. *aman*	39,564	25,297
Local T. *aman*	16,435	36
HYV *aman*	1,413	7,518
Local *boro*	59,851	43,010
HYV *boro*	49,678	193,752
Wheat	782	153
Oilseeds	4,293	1,031
Pulse	245	112
Other	9,070	3,300
Total Cropped Area	**206,956**	**281,655**
Net Cultivated Area	**190,148**	**279,850**
Cropping Intensity (%)	**109**	**101**

Source: 1. Agriculture Census; BBS, 1983/84.
2. Land Use Survey; NERP, 1996.

The comparison has not been done with other years. In census years, crop data is obtained in much the same way the NERP sample area survey was carried out, with questionnaires and mapping of plots on *mauza* maps. In between census, information on crop is obtained annually at the *mauza* level and aggregated at the *thana* level, but the statistics are not as reliable and not as well documented. In particular it is difficult to obtain information for individual *mauzas* from *thana* headquarters for in-between census years.

Table F.26 presents the actual land use from SRDI soil survey reports. The land use associations and their areas correspond to those presented in Figure F.22. The table is presented herein for information. The level of detail is not sufficient to allow inference on the total area of individual crops.

Table F.26: Actual Land Use from SRDI Soil Survey Reports (mid 1960s to mid-1970s)

Association No.	Land Use Association		Area ('000 ha)		% of Project Area
1	Predominantly double cropped land	*Aus*/jute-*rabi* crops, *aus*-T.*aman*, T.*aman*-*boro*, T.*aman*-*rabi* crops	14.24	14.24	4.2
2	Mainly single with some double cropped land	B.*aman*-fallow or *boro*-fallow with some *aus*-T.*aman*-fallow and mixed *aus* and B.aman-fallow	15.33	15.33	4.6
3	Predominantly single cropped land	B.*aman*-fallow and *boro*-fallow	16.88		
4		*Boro*-fallow with some B.*aman*-fallow and groundnut-fallow	24.03		
5		*Boro*-fallow with some B.*aman*-fallow	18.96		
6		*Boro*-fallow	107.82	167.69	50.0
7	Uncultivated land with some cropped land	*Boro*-fallow and *rabi*-fallow	1.20		
8		*Boro*-fallow	63.87		
9		Double cropped rice land with homesteads and little single cropped rice land	30.94		
10		Single cropped rice land with few homesteads and little double cropped rice land and grassland	37.01		
11		Grassland with some single cropped rice land	1.11		
12		Homesteads with double cropped rice land, little single cropped rice land and forest	3.56	137.69	41.0
	Large Beels		0.65	0.65	0.2
	Project Area		**335.60**		**100.0**

The land use presented in Figure F.22 is the one that was in effect from the mid 1960s to the mid 1970s, depending on the dates of the SRDI surveys. In any case this land use was in effect before the advent of widespread irrigation in the project area. The location of NERP sample areas have also been shown on this Figure. Five of the 10 sample areas, namely samples 1, 2, 3, 9 and 10 are in land use associations formerly identified as predominantly uncultivated lands. Yet as shown in Table F.13, most of the cultivable land of these sample areas was actually cultivated at the time of the NERP land use survey. In these sample areas, the area fallow represents only a minute proportion of the cultivable land except in sample area 3 where it represents 10% of the cultivable land.

5.2 Crops

Rice
Increasing population pressure on the land and dependence on unpredictable harvests have compelled farmers to bring more area under rice over the last ten years. The rice growing area has increased by more than one-third during this period. This increase is due to the expansion of irrigated HYV *boro* rice areas in the dry season. As a consequence rice planted areas have declined in other seasons and for other varieties, t. *aman*, *aus* and deep water *aman*. There is an increase in HYV t. *aman* area which has replaced local t. *aman* mainly because some lands have silted up and because short growth duration modern varieties are now available. All the HYV *aus* lands has been converted into HYV *boro* lands.

Non-rice
During the period, the area under non-rice crops has declined some 75%. Most of the non-rice area has been converted to HYV *boro* rice area.

5.2.1 Cropping intensity

The cropping intensity has declined due mainly to two factors. First, some lands have shifted from broadcast *aus*-deep water *Aman* to irrigated *boro* cultivation because the latter gives higher yields. Second many non-rice crop area have been converted to rice. The intensity is now 101% compared to 109% in the early 1980s.

5.3 Livestock

5.3.1 Population

The Livestock Census of 1983-84 reports an increase in the project area's livestock population from the previous 1977 census. The annual population increase between the two census was about 2% for cattle, 9% for buffalos, 3% for goats and sheep and 6% for poultry. However, the number of cattle per hectare of cultivated land decreased to 1.3 in 1983-84 from 2.7 in 1977. Similarly, the per capita ownership of cattle has declined while that of goat/sheep and poultry has increased. There are no reliable data on livestock in the study area after the 1983-84 census.

The low growth rate of the livestock population in the project area can be attributed to difficult living conditions in the *haor*. Because of lack of homestead space, cattle is often sold at the beginning of the monsoon season and purchased again once the monsoon is over. Remaining animals are fed mainly on crop residues.

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5.3.2 Draught Power Supply

The number of draught animals has decreased between 1977 and 1983-84. Draught cattle head per hectare of cultivated land decreased from 1.46 to 0.73 and buffaloes from 0.03 to 0.02.

5.3.3 Livestock Feeds and Fodder Supply

According to the 1989 UNDP Agriculture Sector Review, shortage of dry matter, digestible proteins and total digestible nutrients has intensified in the country over the past decades. The major reasons identified by the Review are conversion of traditional grazing lands into cereal crops land, replacement of traditional rice varieties by short stemmed HYVs, and increased use of straw for domestic fuel and housing materials.

Conversion of grazing lands to crops is widely held to have reduced fodder sources. However, using food crops as a fodder instead of communal grazing land provides a better control of the livestock population as the population has to match the available fodder. The practice of communal grazing leads to overstocking with a corresponding decline in animal health.

6. LIMITATIONS TO AGRICULTURAL PRODUCTION

The analysis of the agro-ecological characteristics and the agricultural production system in the project area shows that crop production is limited by flooding during the pre-monsoon and monsoon seasons. During the monsoon, crops can be cultivated in 14% of the total cropped area, the remaining is under water. The present practice is to wait for the water to recede in the *rabi* season. In lowlands and depressions, *boro* rice is transplanted as soon as the lands is drained for fear of pre-monsoon flash floods. But early transplantation, when the temperature is low often causes plant sterility and reduces yields.

Boro rice production is unsure and restricted because of the ever present risk of flash floods. Unstable food production and low crop yields are common. As *boro* rice is the major food grain grown in the project area, farmers are faced with extreme hardship if they lose this crop to flash floods. These and other considerations identified in the project area are summarized below.

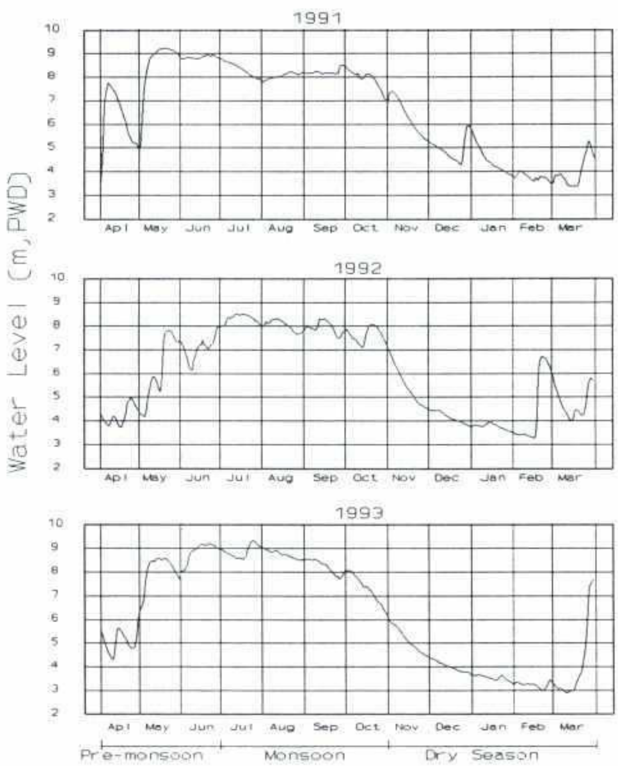
6.1 Floods

The analysis of mean daily water levels of the Kushiyara River at Sherpur shows that floods may occur as early as February and that the water level rises rapidly (Graph F.1).

The extent of flooding and drainage delays have both increased over time as a result of sedimentation.

Floods inundate *boro* rice fields at a time when the HYVs are at the reproductive stage and local varieties are at the ripening or harvest stage. These floods also submerge deep water *aman* rice at their early growth stage and *aus* rice, vegetables, spices and other none-rice crops at harvest stage. Deep water *aman* cannot establish itself in the early stages when it is submerged.

Graph F.1: Depth and Duration of Flooding (Sherpur)



6.2 Slow and Late Drainage

The effective *rabi* crop or *boro* (winter) rice season is getting shorter because drainage delays have increased at the end of the monsoon as a result of river bed sedimentation and, consequently, the land is not ready on time for rice transplantation. Every year large tracts of land cannot be planted on time. Rainfall has also increased in recent years. The general effect over the past decade has been to reduce drainage effectiveness and thus restrain agricultural production. While slow drainage delays rice transplantation in the *boro* season, late drainage delays the sowing of dry land *rabi* crops and may prevent these crops being grown at all in years when flood waters keeps the soils wet until late in the *rabi* season. Slow drainage of early flash flood in *boro* rice lands increases the length of the submergence period.

6.3 Inadequate Irrigation Water Supply

In the project area, 84% of the NCA is irrigated during the dry season and water is pumped by small-scale equipment, either LLPs or traditional, from rivers and *beels* in most irrigated areas. River beds and *beels* have silted up, surface water supply has declined.

There is little ground water use for irrigation, its extraction is expensive, erratic and aquifers are often deep.

6.4 Soil Degradation

Seasonal floods carries huge volume of sediments with a high percentage of sand. During the land use survey, farmers reported that sediment deposition in their field has reduced their capability for cultivation. Sedimentation within the project area fills depressions, change the pattern of soils, degrades them and quickly reduces their fertility and their productivity. Already a large area has been depleted of organic matter. This severely restricts agricultural development and there is an urgent need to deal with this soil degradation issue.

6.5 Unavailability of Suitable Modern Varieties

Rice is well-suited to conditions found in most of the project area. The modern rice HYVs now available have some difficulty adapting to the adverse local agro-climatic conditions. At present, farmers cultivate HYVs during the *rabi* season by adjusting the planting date to the post-monsoon drainage conditions, but this practice presents risks due to unpredictability of flooding in the following pre-monsoon season. Also, HYV *boro* rice when planted early to protect it from these floods, is often damaged by low temperatures during the panicle initiation stage and flowering time

Farmers have found through long and often bitter experience that there is no certainty in the production of present HYVs. This could be avoided if farmers were not to attempt growing HYVs where there is considerable likelihood of flooding. Economic, circumstances, however, are such that farmers have no option but to take risks in order to produce food for their own consumption.

6.6 Decrease in Deep Water Rice Culture

Most of the marginal lands have been converted from deep water *aman* rice to irrigated HYV *boro* due to the changes in the flooding patterns, development of small-scale irrigation facilities and the introduction of flood resistant and fertilizer-responsive high-yielding rice varieties. Before this conversion, farmers would grow two crops on these lands, deep water *aman* rice in the monsoon and dry land *rabi* non-rice crops in the dry season. Although higher rice yields are obtained from HYV *boro* in the dry season, it eliminates non-rice crops production during the dry season, reduces crop intensity because the land remains completely fallow during the monsoon season, destroys deep water habitat and impedes plant diversity and conservation.

6.7 Inefficient Management of Surface Water Used for Irrigation

Since *boro* crops depend on the Kalni-Kushiyara River, channels and *beels* for irrigation during the dry season, agricultural development in those areas depends much on the efficient management of the limited surface water. There is a need to distribute the available surface water more equitably. Moreover, water losses are high as small-scale irrigation facilities are poorly maintained.

6.8 Poor Cultural Practices

The use of old and unhealthy seedlings are common in the production of rice. Seedlings are often damaged during transportation from storage to field. Excess seedlings, often old and unhealthy, are frequently sold to other growers. The low price of these seedlings attracts small farmers. But the yields from those seedlings is low.

Threshing, winnowing and drying of rice is difficult because of lack of homestead space. Courtyards are too small. Therefore these activities take place near rice fields, but they are hampered by rainfall and persistent cloudiness. Then some of the harvest is lost.

6.9 Insufficient Non-rice Crop Production

Supply of vegetables, pulse, fruit is not sufficient to meet the demand as the land suitable for the cultivation of these crops is scarce in this deeply flooded area. Vegetables are sometimes grown in kitchen gardens adjacent to homesteads. This home-based vegetables production plays a vital role in meeting the nutritional requirement of the villager folks. It is also income generating.

6.10 Draught Power Shortage

Many areas suffer a shortage of draught power for land preparation. The shortage is considered an important constraint to crop production in the project area. Mostly small and marginal farmers, and share croppers are affected by draft power shortage. Peak shortages are reported in the short period of *boro* rice land preparation after flood waters have receded.

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6.11 Poor Management of Livestock

The management of livestock animal is quite poor due mainly to limited space for sheltering, shortage of feeds and fodder, inadequate health care, low fertility and overwork. Because they are often not healthy, draught animals are inefficient. Cows have a low calving rate.

6.12 Limited Support Services

Support services are limited,and farmers have difficulties obtaining extension services, seed, fertilizers, and other inputs. The number of agricultural extension workers is also limited and hence farmers have a poor knowledge of the different varieties, appropriate technology, input use, crop production practices and water management. Agricultural extension services tend to concentrate primarily in the use of modern varieties, paying little attention to other areas. In particular, the extension agency is not responsible for advising farmers on irrigation management. There is no strong integration among the agencies to provide support services.

6.13 Credit

Although bank credit is available, farmers cannot get loans at the right time and/or in the required amount. Banks formalities are bureaucratic and request farmers to fill several forms which they hardly understand. Banks are also wary of providing credit to farmers as recovery is poor, particularly when crops are damaged. As a result, most farmers obtain credit from money lenders at exorbitant interest rates.

7. FUTURE WITHOUT PROJECT

The Analysis of future conditions without the KKRMP (FWO) indicates that the extent of pre-monsoon flooding will increase in the project area. The flash flood which occurred in 1993 as early as February and was accompanied by slow drainage during the recession phase suggests that flooding will worsen as sedimentation of river beds, closing of channel outlets continues (Graph F.1).

7.1 Land Utilization Patterns

The land utilization pattern will change slightly as a result of the development of infrastructure, expansion of homesteads and river bank erosion. As a result, 2900 ha of cultivated land will be displaced or lost. Accordingly, present cultivated land will be reduced by about 1% in FWO project scenario. Crops will continue to be grown mainly in the winter season. Winter crops areas, presently some 86% of the NCA will increase by less than 1%. Some 97% winter crops will be irrigated compared to 98% at present. The irrigated area has increased in the late 1980s through the development of small-scale irrigation facilities which provide access to the surface water of perennial rivers and *beels*. Further increase in irrigated area is unlikely because the dry season surface water supply is limited and groundwater will be no more accessible in the future than at present.

Table F.27 summarizes the extent and depth of inundation of the NCA under existing and FWO scenario for various flood conditions. These results were estimated with the MIKE-11 hydrodynamic model (Main Report, Chapter 6).

Table F.27: Inundation of Net Cultivated Area at Present and FWO Conditions

Depth of Inundation (m)	1:2 Year		1:5 Year		1:10 Year	
	Present (ha)	FWO (ha)	Present (ha)	FWO (ha)	Present (ha)	FWO (ha)
< 0.3	233,277	200,987	84,648	61,336	12,704	6,007
0.3-0.9	22,625	39,808	54,344	56,249	35,093	30,886
0.9-1.8	17,728	28,140	95,004	104,751	122,944	112,370
>1.8	6,220	8,010	45,854	54,609	109,109	127,682
TOTAL	**279,850**	**276,945**	**279,850**	**276,945**	**279,850**	**276,945**
% Inundated land	**17**	**27**	**70**	**78**	**95**	**98**

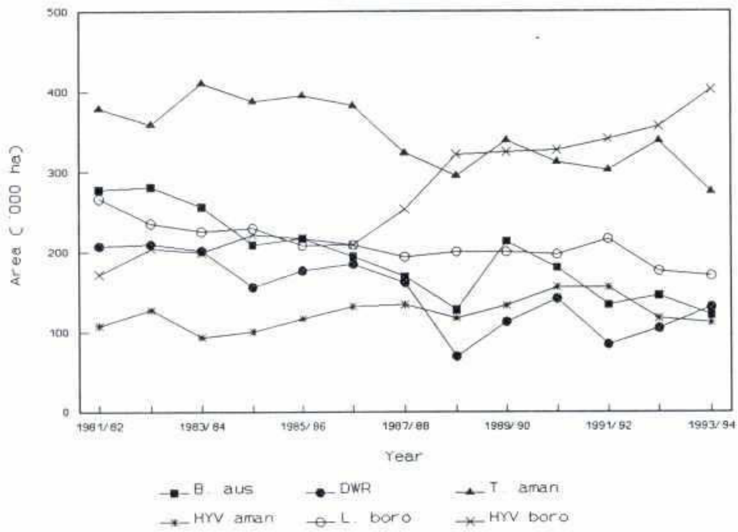
Table F.27 shows that the flooding situation will deteriorate in the future and that this future situation will aggravate the current problems, increasing damages to *boro* crops and depleting rice production.

7.2 Crop Patterns and Cropped Areas

There will be no significant changes in the crop patterns under the FWO scenario (Table F.28). BBS data on trends in crop areas from Sylhet and Kishoreganj regions are presented in Graph F.2 for rice crops and Graph F.3 for non-rice crops. The project area is included in these two regions. Graph F.2 shows that, for the two districts, the area under HYV *boro* cultivation has increased at a 7.5% annual rate between 1983 and 1994, much lower than for the project area (12% annual growth, section 5.1). The reason is that in those districts, the highlands have been fully put under cultivation in the late 1970s. During the mid 1980s to mid 1990s the main increase in HYV *boro* land has been in the *haor*, hence in the project area. The trend shows that HYV *boro* rice area may increase in the future. However, the rate of increase will be low compared to that of the 1980s.

NERP land use survey suggests that the HYV *boro* area could increase, replacing local *boro* on lands aggraded by sediment deposition. Traditional irrigations methods, practiced when the water level is at most 1 to 2 m below the irrigated land, will therefore be displaced by LLPs. A further effect of land aggradation will be to increase b. *aman* production. The cropping intensity will likely increase slightly as HYV *boro* cultivation will follow broadcast *aman* cultivation on aggraded lands. The area of rainfed b. *aus* and t. *aman* will both decrease, b. *aus* because of land aggradation and lack of adequate moisture in the soil, local t. *aman* because of an increase in the extent of flooding.

Graph F.2: Trends in Rice Cropped Area



Source: BBS, 1995

There will be no significant change in non-rice crops areas. The area under wheat and pulse may increase replacing potato due to lack of adequate irrigation supply. Similarly, vegetables and spices may displace HYV *boro* wherever irrigation supply will not be adequate. Deposition of sandy sediments will degrade soils and deteriorate their productivity over extended land tracts. Affected lands will switch to non-rice crops which require less water than rice. The distribution of the crop area in FWO is provided in Table F.29.

Table F.28: Extent of Inundation of Crop Patterns - FWO Scenario

Crop Pattern	Area FWO (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total
B. *Aus*-HYV T. *Aman*	5,639	681	205	14	**6,539**	1,721	1,148	2,356	1,314	**6,539**	169	424	2,636	3,310	**6,539**
Loc T. *Aman*-HYV *Boro*	24	4	1	0	**29**	7	5	10	7	**29**	1	2	11	15	**29**
HYV *boro*-Fallow	141,515	27,926	15,804	2,186	**187,431**	43,206	39,505	69,786	34,934	**187,431**	4,138	21,564	75,404	86,325	**187,431**
Loc *Boro*-Fallow	19,531	4,958	7,944	4,960	**37,393**	5,935	6,542	15,347	9,569	**37,393**	558	4,207	15,703	16,925	**37,393**
DW *Aman*-HYV *Boro*	5,010	1,039	538	89	**6,676**	1,536	1,450	2,449	1,241	**6,676**	153	870	2,798	2,855	**6,676**
DW *Aman*-Fallow	15,120	2,813	2,575	651	**21,159**	4,606	4,052	8,333	4,168	**21,159**	551	2,778	8,698	9,132	**21,159**
HYV T. *Aman*-Fallow	761	102	42	4	**909**	233	165	332	179	**909**	23	68	369	449	**909**
Wheat-Fallow	198	26	8	0	**232**	61	42	83	46	**232**	6	15	93	118	**232**
Pulses-Fallow	119	18	5	0	**142**	36	28	51	27	**142**	4	13	56	69	**142**
Groundnut-Fallow	515	71	21	2	**609**	158	113	217	121	**609**	16	48	242	303	**609**
Oilseeds-Fallow	246	45	22	19	**332**	75	65	117	75	**332**	7	34	126	165	**332**
Potato-Fallow	704	98	29	2	**833**	215	155	298	165	**833**	21	66	333	413	**833**
Sweet Potato-Fallow	401	53	16	1	**471**	123	86	169	93	**471**	12	35	188	236	**471**
Spices-Fallow	1,488	222	86	8	**1,804**	455	346	653	350	**1,804**	48	156	725	875	**1,804**
Vegetables-Fallow	864	144	64	9	**1,081**	264	215	392	210	**1,081**	29	106	434	512	**1,081**
Fallow	8,852	1,608	780	65	**11,305**	2,705	2,332	4,158	2,110	**11,305**	271	1,237	4,553	5,244	**11,305**
Net Cultivated Area	**200,987**	**39,808**	**28,140**	**8,010**	**276,945**	**61,336**	**56,249**	**104,751**	**54,609**	**276,945**	**6,007**	**31,623**	**112,369**	**126,946**	**276,945**

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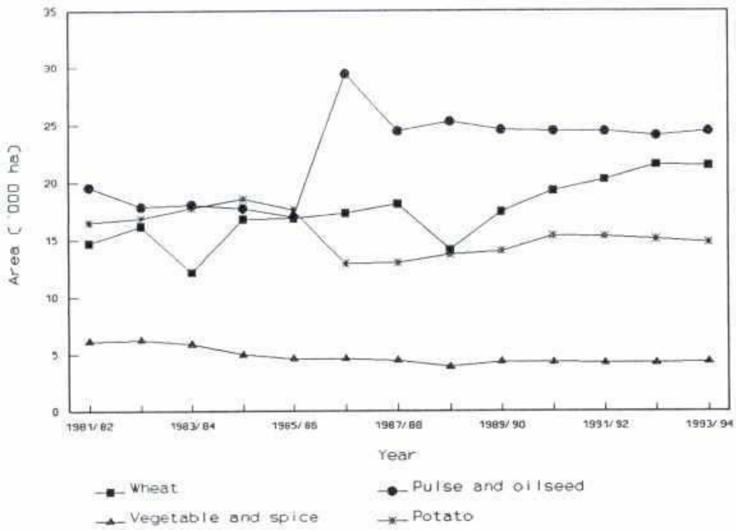
Graph F.3: Trends in Non-Rice Cropped Area



Source: BBS, 1995

7.3 Crop Calendar

The crop calendar for the FWO scenario is presented in Figure F.23. In FWO scenario, post-monsoon drainage, hence planting will be delayed even more than at present. The crop will then be more vulnerable to damage from early rains and flash floods.

7.4 Changes in Annual Food Production

Production will primarily be rice based, but rice crops will be damaged by flooding in most years. The increase in HYV *boro* area replacing local *boro* will have little impact on the rice production (Table F.30).

Overall rice production will decrease as a result of worsening floods. Non-rice production will displace rice in deteriorated lands and wherever irrigation supply is inadequate. The crop production on flood free and flood damage areas in FWO project is provided in Table F.30 and summarized in Table F.31.

7.5 Crop Losses by Flooding

Compared with the present loss of rice production, future losses will increase under the FWO scenario by 62%, 10% and 1% for respectively the 1:2, 1:5 and 1:10 year flood (Table F.32). The loss of non-rice production will increase seven fold for the 1:2 year flood, 34% for the 1:5 flood and 20% for the 1:10 year flood. Estimated production losses under FWO are presented in Table F.32.

Table F.29: Extent of Inundation of Annually Cropped Area in Future Without Project - FWO Scenario

Crop	Area FWO (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total
RICE															
HYV *Boro*	14,6549	28,969	16,343	2,275	194,136	44749	40,960	72,245	36,182	194,136	4,292	22,436	78,213	89,195	194,136
Loc *Boro*	19,531	4,958	7,944	4,960	37,393	5935	6,542	15,347	9,569	37,393	558	4,207	15,703	16,925	37,393
B. *Aus*	5,639	681	205	14	6,539	1721	1,148	2,356	1,314	6,539	169	424	2,636	3,310	6,539
DW *Aman*	20,130	3,852	3,113	740	27,835	6142	5,502	10,782	5,409	27,835	704	3,648	11,496	11,987	27,835
Loc T. *Aman*	24	4	1	0	29	7	5	10	7	29	1	2	11	15	29
HYV T. *Aman*	6,400	783	247	18	7,448	1954	1,313	2,688	1,493	7,448	192	492	3,005	3,759	7,448
Rice Total	198,273	39,247	27,853	8,007	273,380	60508	55,470	103,428	53,974	273,380	5,916	31,209	111,064	125,191	273,380
NON-RICE															
Wheat	198	26	8	0	232	61	42	83	46	232	6	15	93	118	232
Pulse	119	18	5	0	142	36	28	51	27	142	4	13	56	69	142
Groundnut	515	71	21	2	609	158	113	217	121	609	16	48	242	303	609
Oilseeds	246	45	22	19	332	75	65	117	75	332	7	34	126	165	332
Potato	704	98	29	2	833	215	155	298	165	833	21	66	333	413	833
Sweet Potato	401	53	16	1	471	123	86	169	93	471	12	35	188	236	471
Spices	1,488	222	86	8	1,804	455	346	653	350	1,804	48	156	725	875	1,804
Vegetables	864	144	64	9	1,081	264	215	392	210	1,081	29	106	434	512	1,081
Non-Rice Total	4,535	677	251	41	5,504	1387	1,050	1,980	1,087	5,504	143	473	2,197	2,691	5,504
TOTAL CROPS	202,808	39,924	28,104	8,048	278,884	61895	56,520	105,408	55,061	278,884	6,059	31,682	113,261	127,882	278,884

Table F.30: Crop Production on Flood Damage-Free and Flood Damaged Land - FWO Scenario

Crop	Area (ha)						Yield (tonnes/ha)		Production (tonnes)					
	Flood Damage Free Lands			Flood Damage Lands			Flood Damage Free Lands	Flood Damage Lands	Flood Damage Free Lands			Flood Damage Lands		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year			1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE														
HYV *Boro*	146,549	44,749	4,292	47,587	149,387	189,844	4.69	2.90	687,315	209,873	20,129	138,002	433,222	550,548
Loc *Boro*	19,531	5,935	558	17,862	31,458	36,835	3.11	1.60	60,741	18,458	1,735	28,579	50,333	58,936
B. *Aus*	5,639	1,721	169	900	4,818	6,370	1.1	1.04	6,203	1,893	186	936	5,011	6,625
DW *Aman*	20,130	6,142	704	7,705	21,693	27,131	1.93	1.50	38,851	11,854	1,359	11,558	32,540	40,697
Loc T. *Aman*	24	7	1	5	22	28	2.15	1.75	52	15	2	9	39	49
HYV T. *Aman*	6,400	1,954	192	1,048	5,494	7,256	3.2	2.24	20,480	6,253	614	2,348	12,307	16,253
Rice Total	**198,273**	**60,508**	**5,916**	**75,107**	**212,872**	**267,464**			**813,642**	**248,346**	**24,025**	**181,432**	**533,452**	**673,108**
NON-RICE														
Wheat	198	61	6	34	171	226	2.11	2.00	418	129	13	68	342	452
Pulse	119	36	4	23	106	138	0.81	0.80	96	29	3	18	85	110
Groundnut	515	158	16	94	451	593	2.04	2.00	1,051	322	33	188	902	1186
Oilseeds	246	75	7	86	257	325	0.91	0.80	224	68	6	69	206	260
Potato	704	215	21	129	618	812	11.15	10.00	7,850	2,397	234	1,290	6,180	8120
Sweet Potato	401	123	12	70	348	459	9.53	9.00	3,822	1,172	114	630	3,132	4131
Spices	1,488	455	48	316	1,349	1,756	6	5.00	8,928	2,730	288	1,580	6,745	8780
Vegetables	864	264	29	217	817	1,052	9.25	9.00	7,992	2,442	268	1,953	7,353	9468
Total	**4,535**	**1,387**	**143**	**969**	**4,117**	**5,361**			**30,381**	**9,289**	**959**	**5,796**	**24,945**	**32,507**
ALL CROPS	**202,808**	**61,895**	**6,059**	**76,076**	**216,989**	**272,825**			**844,023**	**257,635**	**24,984**	**187,228**	**558,397**	**705,615**

Table F.31: Crop Production - Present Conditions and FWO Scenario

Crop	Crop Production (tonnes)					
	Present			FWO Project		
	1:2	1:5	1:10	1:2	1:5	1:10
RICE						
HYV *Boro*	864,819	671,807	578,380	825,317	643,095	570,677
Local *Boro*	107,638	82,903	70,930	89,320	68,791	60,671
B. *Aus*	8,186	7,905	7,768	7,139	6,904	6,811
DW *Aman*	47,081	41,260	38,443	50,409	44,394	42,056
Loc T. *Aman*	77	68	64	61	54	51
HYV T. *Aman*	23,973	19,428	17,229	22,828	18,560	16,867
Rice Total	**1,051,774**	**823,371**	**712,814**	**995,074**	**781,798**	**697,133**
NON-RICE						
Wheat	323	312	307	486	471	465
Pulse	90	90	90	114	114	113
Groundnut	1,466	1,448	1,440	1,239	1,224	1,219
Oilseeds	278	260	251	293	274	266
Potato	10,585	9,906	9,578	9,140	8,577	8,354
Sweet Potato	4,807	4,640	4,559	4,452	4,304	4,245
Spices	7,885	7,063	6,665	10,508	9,475	9,068
Vegetables	4,842	4,762	4,723	9,945	9,795	9,736
Non-Rice Total	**30,276**	**28,481**	**27,613**	**36,177**	**34,234**	**33,466**
ALL CROPS	**1,082,050**	**851,852**	**740,427**	**1,031,251**	**816,032**	**73,0599**

Table F.32: Crop Production Losses - FWO Scenario

Crop	FWO Crop Losses (tonnes)		
	Pre-monsoon Flood Return Period		
	1:2 year	1:5 year	1:10 year
RICE			
HYV *Boro*	85,181	267,403	339,821
Local *Boro*	26,972	47,501	55,621
B. *Aus*	54	289	382
DW *Aman*	3,313	9,328	11,666
Loc T. *Aman*	1	8	11
HYV *Aman*	1,006	5,274	6,967
Rice Total	**116,527**	**329,803**	**414,468**
NON-RICE			
Wheat	4	19	25
Pulse	1	1	2
Groundnut	3	18	23
Oilseeds	9	28	36
Potato	148	711	934
Sweet Potato	37	185	244
Spices	316	1,349	1,756
Vegetables	54	204	263
Non-Rice Total	**572**	**2,515**	**3,283**
ALL CROPS	**117,099**	**332,318**	**417,751**

8. FUTURE WITH PROJECT

The proposed intervention will increase the conveyance capacity of the Kalni River to the point where the 1:5 year pre-monsoon flood will be confined within the banks of the river. This will result in a Future With Project (FW) characterized by the less frequent inundation of agricultural land and the correspondingly reduced loss of *boro* rice and *rabi* non-rice crops. The proposed intervention includes a structure at Koyer Dhala which will increase irrigation water availability in the dry season. The extra irrigation will likely bring some fallow lands under HYV *boro* cultivation.

Since crop patterns depend on the depth of flooding in the monsoon and drainage of flood water in the post-monsoon season, the KKRMP will have no major impact on cropping patterns and crop calendar. The project will mainly increase flood free areas in the pre-monsoon season and ensure more harvest of winter crops. However, any improvement in drainage of flood water in the post-monsoon season will enable farmers to prepare seedbeds, raise seedlings and prepare the land on time. Two Alternatives are proposed for the project, Alternative 1 with two loop cuts at respectively Issapur and Kathkal and Alternative 2 with only a loop cut at Kathkal and supplementary river dredging. The impact of both alternatives on agriculture have been analyzed and are reported herein.

8.1 Land Utilization Patterns

Compared to the present situation, cultivated land will decrease by 2,426 ha due to development of infrastructure, expansion of homestead area, loop cuts at Issapur (Alternative 1) and Katkhal, disposal of dredge-spoil and construction of levees to control overbank spill in the upstream (Markuli) reach. Accordingly, the present NCA will decrease by about 1% in FW scenario.

Impacts of the KKRMP on flooding and post-monsoon drainage were estimated with the MIKE-11 hydrodynamic model. The analysis shows that flood free land will increase from the FWO scenarios (Tables F.33 and F.34).

Alternative 1
Flood free cultivated lands will increase by almost one-third for the 1:2 year flood, two-fold for the 1:5 year flood and more than sevenfold for the 1:10 year flood compared to that of the FWO scenario (Table F.33).

Alternative 2
The Kalni-Kushiyara River dredging with one loop cut will increase flood free cultivated land by 28% for the 1:2 year flood, 77% for the 1:5 year flood and more than sixfold for the 1:10 year flood compared to that of the FWO condition (Table F.34).

Table F.33: Comparison of Net Cultivated Area - FWO and FW Scenarios: Alternative 1

Flood Depth (m)	Net Cultivated Area (ha)					
	1:2 year		1:5 year		1:10 year	
	FWO	FW	FWO	FW	FWO	FW
< 0.3	200,987	265,405	61,336	116,862	6,007	50,767
0.3-0.9	39,808	485	56,249	49,098	30,886	19,247
0.9-1.8	28,140	7,000	104,751	71,070	112,370	111,465
> 1.8	8,010	4,534	54,609	40,394	127,682	95,945
TOTAL	**276,945**	**277,424**	**276,945**	**277,424**	**276,945**	**277,424**
% Inundated	**27**	**4**	**78**	**58**	**98**	**82**

Table F.34: Comparison of Net Cultivated Area - FWO and FW Scenarios: Alternative 2

Flood Depth (m)	Net Cultivated Area (ha)					
	1:2 year		1:5 year		1:10 year	
	FWO	FW	FWO	FW	FWO	FW
< 0.3	200,987	257,218	61,336	108,776	6,007	45,156
0.30-0.90	39,808	6,657	56,249	49,200	30,886	14,121
0.90-1.80	28,140	8,913	104,751	77,880	112,370	112,281
>1.80	8,010	4,636	54,609	41,568	127,682	105,866
TOTAL	**276,945**	**277,424**	**276,945**	**277,424**	**276,945**	**277,424**
% Inundated	**27**	**7**	**78**	**61**	**98**	**84**

8.2 Crop Patterns and Cropped Areas

The KKRMP will have no impact on crop patterns (Tables F.35 and F.36). It will increase HYV *boro* rice area in flood free land (Tables F.37 and F.38). The increase in HYV rice area will result from the replacement of low-yielding local *boro* rice varieties and availability of adequate surface water for irrigation from the main rivers (and some groundwater), which will bring some fallow land under cultivation of HYV *boro* rice. It will also increase the area under the deep water *aman*-HYV *boro* rice crop pattern. The Koyer Dhala structure will also contribute to bring some fallow land under irrigated HYV *boro* rice.

Table F.35: Extent of Inundation on Crop Patterns - FW Scenario: Alternative 1

Crop Pattern	Area FW: Alternative 1 (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	< 0.30	0.30-0.90	0.90-1.80	>1.80	Total	< 0.30	0.30-0.90	0.90-1.80	>1.80	Total	< 0.30	0.30-0.90	0.90-1.80	>1.80	Total
B. *Aus*-HYV T.	7,361	0	1	0	7,362	3,101	1,303	1,886	1,072	7,362	1,350	522	2,955	2,535	7,362
Loc T. *Aman*-HYV	35	0	0	0	35	15	6	9	5	35	7	2	14	12	35
HYV *boro*-Fallow	196,356	31	2,710	802	199,899	8,4205	35,378	51,210	29,106	199,899	36,646	14,179	80,249	68,825	199,899
Loc *Boro*-Fallow	25,628	308	3,379	3,318	32,633	1,3746	5,775	8,360	4,752	32,633	5,982	2,315	13,100	11,236	32,633
DW *Aman*-HYV	5,038	13	82	30	5,163	2,175	913	1,323	752	5,163	946	366	2,073	1,778	5,163
DW *Aman*-Fallow	18,990	132	702	361	20,185	8,503	3,572	5,171	2,939	20,185	3,700	1,432	8,103	6,950	20,185
HYV T.	67	1	4	0	72	30	13	18	11	72	13	5	29	25	72
Wheat-Fallow	152	0	0	0	152	64	27	39	22	152	28	11	61	52	152
Pulses-Fallow	111	0	0	0	111	47	20	28	16	111	20	8	45	38	111
Groundnut-Fallow	631	0	0	0	631	266	112	162	91	631	116	45	253	217	631
Oilseeds-Fallow	287	0	8	13	308	130	55	79	44	308	56	22	124	106	308
Potato-Fallow	941	0	0	0	941	396	167	241	137	941	173	67	378	323	941
Sweet Potato-Fallow	470	0	0	0	470	198	83	120	69	470	86	33	189	162	470
Spices-Fallow	1,285	0	7	1	1,293	545	229	331	188	1,293	237	92	519	445	1,293
Vegetables-Fallow	562	0	8	3	573	241	101	147	84	573	105	41	230	197	573
Fallow	7,491	0	99	6	7,596	3,200	1,344	1,946	1,106	7,596	1,393	537	3049	2,617	7,596
Net Cultivated Area	265,405	485	7,000	4,534	277,424	**116,862**	**49,098**	**71,070**	**40,394**	**277,424**	**50,858**	**19,677**	**111,371**	**95,518**	**277,424**

Table F.36: Extent of Inundation on Crop Patterns - FW Scenario: Alternative 2

Crop Pattern	Area FW: Alternative 2 (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total
B. *Aus*-HYV T. *Aman*	7,359	0	1	0	7,360	2,886	1,305	2,066	1,103	7,360	1,198	374	2,979	2,809	7,360
Loc T. *Aman*-HYV *Boro*	35	0	0	0	35	14	6	10	5	35	6	2	14	13	35
HYV *boro*-Fallow	193,188	1,994	3,647	814	199,643	78,278	35,405	56,046	29,914	199,643	32,496	10,161	80,802	76,184	199,643
Loc *Boro*-Fallow	21,579	3,621	4,088	3,398	32,686	12,816	5,797	9,176	4,897	32,686	5,320	1,664	13,229	12,473	32,686
DW *Aman*-HYV *Boro*	4,951	93	108	30	5,182	2,032	919	1,455	776	5,182	843	264	2,097	1,978	5,182
DW *Aman*-Fallow	18,155	886	913	369	20,323	7,969	3,604	5,705	3,045	20,323	3,308	1,034	8,225	7,756	20,323
HYV T. *Aman*-Fallow	62	5	5	0	72	28	13	20	11	72	12	4	29	27	72
Wheat-Fallow	151	0	0	0	151	59	27	42	23	151	25	8	61	57	151
Pulses-Fallow	111	0	0	0	111	44	20	31	16	111	18	6	45	42	111
Groundnut-Fallow	631	0	0	0	631	247	112	177	95	631	103	32	255	241	631
Oilseeds-Fallow	284	2	8	14	308	121	55	86	46	308	50	16	124	118	308
Potato-Fallow	942	0	0	0	942	369	167	264	142	942	153	48	381	360	942
Sweet Potato-Fallow	469	0	0	0	469	184	83	132	70	469	76	24	190	179	469
Spices-Fallow	1,286	5	9	1	1,301	510	231	365	195	1,301	212	66	527	496	1,301
Vegetables-Fallow	562	5	10	3	580	227	103	163	87	580	94	30	235	221	580
Fallow	7,453	46	124	7	7,630	2,992	1,353	2,142	1,143	7,630	1,242	388	3,088	2,912	7,630
Net Cultivated Area	**257,218**	**6,657**	**8,913**	**4,636**	**277,424**	**108,776**	**49,200**	**77,880**	**41,568**	**277,424**	**45,156**	**14,121**	**112,281**	**105,866**	**277,424**

Table F.37: Extent of Inundation on Annually Cropped Area - FW Scenario: Alternative 1

Crop	Area FW Scenario: Alternative 1 (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total
RICE															
HYV *Boro*	201,429	44	2,792	832	**205,097**	86,395	36,297	52,542	29,863	**205,097**	37,599	14,547	82,336	70,615	**205,097**
Loc *Boro*	25,628	308	3,379	3,318	**32,633**	13,746	5,775	8,360	4,752	**32,633**	5,982	2,315	13,100	11,236	**32,633**
B. *Aus*	7,361	0	1	0	**7,362**	3,101	1,303	1,886	1,072	**7,362**	1,350	522	2,955	2,535	**7,362**
DW *Aman*	24,028	145	784	391	**25,348**	10,678	4,485	6,494	3,691	**25,348**	4,646	1,798	10,176	8,728	**25,348**
Loc T. *Aman*	35	0	0	0	**35**	15	6	9	5	**35**	7	2	14	12	**35**
HYV T. *Aman*	7,428	1	5	0	**7,434**	3,131	1,316	1,904	1,083	**7,434**	1,363	527	2,984	2,560	**7,434**
Rice Total	265,909	498	6,961	4,541	277,909	117,066	49,182	71,195	40,466	277,909	50,947	19,711	111,565	95,686	277,909
NON-RICE															
Wheat	152	0	0	0	**152**	64	27	39	22	**152**	28	11	61	52	**152**
Pulse	111	0	0	0	**111**	47	20	28	16	**111**	20	8	45	38	**111**
Groundnut	631	0	0	0	**631**	266	112	162	91	**631**	116	45	253	217	**631**
Oilseeds	287	0	8	13	**308**	130	55	79	44	**308**	56	22	124	106	**308**
Potato	941	0	0	0	**941**	396	167	241	137	**941**	173	67	378	323	**941**
Sweet Potato	470	0	0	0	**470**	198	83	120	69	**470**	86	33	189	162	**470**
Spices	1,285	0	7	1	**1,293**	545	229	331	188	**1293**	237	92	519	445	**1,293**
Vegetables	562	0	8	3	**573**	241	101	147	84	**573**	105	41	230	197	**573**
Non-Rice Total	4,439	0	23	17	4,479	1,887	794	1,147	651	4,479	821	319	1,799	1,540	4,479
ALL CROPS	270,348	498	6,984	4,558	282,388	118,953	49,976	72,342	41,117	282,388	51,768	20,030	113,364	97,226	282,388

Table F.38: Extent of Inundation on Annually Cropped Area - FW Scenario: Alternative 2

Crop	Area FW: Alternative 2 (ha)														
	Flood Depth - 1:2 year Pre-monsoon Flood (m)					Flood Depth - 1:5 year Pre-monsoon Flood (m)					Flood Depth - 1:10 year Pre-monsoon Flood (m)				
	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total	< 0.3	0.3-0.9	0.9-1.8	> 1.8	Total
RICE															
HYV *Boro*	198,174	2,087	3,755	844	**204,860**	80,324	36,330	57,511	30,695	**204,860**	33,345	10,427	82,913	78,175	**204,860**
Loc *Boro*	21,579	3,621	4,088	3,398	**32,686**	12,816	5,797	9,176	4,897	**32,686**	5,320	1,664	13,229	12,473	**32,686**
B. *Aus*	7,359	0	1	0	**7,360**	2,886	1,305	2,066	1,103	**7,360**	1,198	374	2,979	2,809	**7,360**
DW *Aman*	23,106	979	1,021	399	**25,505**	10,001	4,523	7,160	3,821	**25,505**	4,151	1,298	10,322	9,734	**25,505**
Loc T. *Aman*	35	0	0	0	**35**	14	6	10	5	**35**	6	2	14	13	**35**
HYV T. *Aman*	7,421	5	6	0	**7,432**	2,914	1,318	2,086	1,114	**7,432**	1,210	378	3,008	2,836	**7,432**
Rice Total	**257,674**	**6,692**	**8,871**	**4,641**	**277,878**	**108,955**	**49,279**	**78,009**	**41,635**	**277,878**	**45,230**	**14,143**	**112,465**	**106,040**	**277,878**
NON-RICE															
Wheat	151	0	0	0	**151**	59	27	42	23	**151**	25	8	61	57	**151**
Pulse	111	0	0	0	**111**	44	20	31	16	**111**	18	6	45	42	**111**
Groundnut	631	0	0	0	**631**	247	112	177	95	**631**	103	32	255	241	**631**
Oilseeds	284	2	8	14	**308**	121	55	86	46	**308**	50	16	124	118	**308**
Potato	942	0	0	0	**942**	369	167	264	142	**942**	153	48	381	360	**942**
Sweet Potato	469	0	0	0	**469**	184	83	132	70	**469**	76	24	190	179	**469**
Spices	1,286	5	9	1	**1,301**	510	231	365	195	**1,301**	212	66	527	496	**1,301**
Vegetables	562	5	10	3	**580**	227	103	163	87	**580**	94	30	235	221	**580**
Non-Rice Total	**4,436**	**12**	**27**	**18**	**4,493**	**1,761**	**798**	**1,260**	**674**	**4,493**	**731**	**230**	**1,818**	**1,714**	**4,493**
ALL CROPS	262,110	6,704	8,898	46,59	282,371	110,716	50,077	79,269	42,309	282,371	45,961	14,373	114,283	107,754	282,371

In order to substantiate the replacement of local *boro* varieties by HYV varieties, an analysis of surface water available and irrigation requirements has been carried out. Table F.39 details the estimate of the water requirements of HYV *boro* during the months of January to April.

Table F.39: Water Requirement for HYV *Boro*

Item	Unit	Jan.	Feb.	Mar.	Apr.
PET[1]	mm	106	124	162	157
Crop Factor		1.20	1.25	1.25	1.20
Crop Evapotranspiration	mm	127	156	203	188
Deep Percolation	mm	62	56	62	60
Land Preparation	mm	100	0	0	0
Crop Water Requirement	mm	289	212	265	248
Effective Rainfall[2]	mm	0	14	43	137
Irrigation Requirement	mm	289	198	222	111
	l/s/ha	1.08	0.82	0.83	0.43
Net Withdrawal[3]	l/s/ha	1.54	1.17	1.19	0.61

Note 1: Sylhet meteorological station
2: Itna (R-112)
3: Irrigation efficiency = 0.7

The additional HYV *boro* area under FW-Alternative 1 scenario compared to present conditions is 11,345 ha (Tables F.20 and F.37). This additional area would require 13 m^3/s of irrigation during February, the low flow month. Most of the crop displacement will occur downstream of Ajmiriganj. Presently, irrigation from the Kalni River takes place in a 2 Km wide band on each bank of the river. Assuming that 75% of these bands are currently irrigated between Ajmiriganj and Issapur during the dry season, a conservative assumption considering the area of infrastructure and crops other than *boro*, the total irrigated area would be 21,750 ha which requires 25 m^3/s from the Kalni River in February. If one considers that the increase in HYV *boro* will be irrigated form the Kalni, the future irrigation requirements below Ajmiriganj will be 38 m^3/s during February. The average February flow at Ajmiriganj from discharge measurements taken by NERP in 1995 and 1996 is 148 m^3/s, resulting in 25% water use for irrigation. In fact, water use on the Kalni will be much less since a significant proportion of irrigation requirements will be met by tributaries of the Kalni and *beels*. Table F.40 presents average discharges during the dry season on the Kalni River and its main tributaries immediately upstream of Ajmiriganj or between Ajmiriganj and Issapur.

Table F.40: Mean Monthly Discharge at Selected Gauging Stations

River	Station		Mean Monthly Discharges (m^3/s)				Period of Record (year)
		Dec.	Jan.	Feb.	Mar.	Apr.	
Kushiyara	Sherpur	261.0	170.7	157.4	226.4	663.5	11
	Ajmiriganj[1]	278.5	192.2	148.5	402.6	974.5	2
Khowai	Shahistaganj	14.9	11.4	10.6	11.4	22.7	28
Karangi	Sofiabad	1.7	1.2	1.1	1.4	4.0	22
Lungla	Motiganj	2.0	1.7	2.3	2.3	6.2	15
Sutang	Sutang Rly. Bridge	1.1	0.8	0.8	0.6	3.0	9

Source: Specialist Study "Surface Water Resources of the Northeast Region, June 1995, NERP - BWDB Stations

Note 1: NERP discharge measurements - 1995 and 1996.

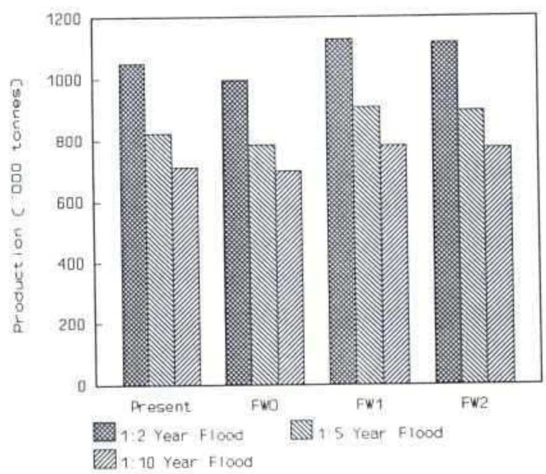
8.3 Crop Calendar

The crop calendar under FW scenario is presented in Figure F.24 for Alternative 1 and in Figure F.25 for Alternative 2. The main changes compared to present conditions, is that because drainage in the post-monsoon season will be accelerated, farmers will plant early in depressions and flood basins, whereas, presently planting takes place late because of the delayed post-monsoon drainage.

8.4 Changes in Crop Production

The confinement of the 1:5 year pre-monsoon flood within the Kalni channel will result in an increase in *rabi* season rice production (Table F.41 for Alternative 1 and Table F.42 for Alternative 2). The project will save *boro* rice crops from early and flash floods. A comparison is made in Graph F.4 of total rice production, between present conditions, FWO, Alternative 1 (FW1) and Alternative 2 (FW2).

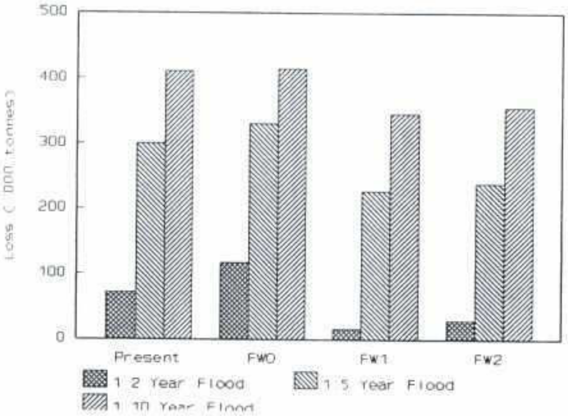
Graph F.4: Changes in Paddy Production - FW



Little non-rice production will be displaced by rice cultivation. It will decrease by less than 1% compared to present conditions and by 17% compared to FWO scenario. However, the project will contribute to grow more spice crops until late in the pre-monsoon season, especially chili, the main spice crop which is harvested between February and flooding time. In addition, crop protection in consecutive years and higher *boro* output may induce farmers to grow non-rice crops in some areas.

8.5 Crop Loss

Graph F.5: Project Impact on Paddy Losses



Crop losses to flooding will decrease significantly compared to that in FWO scenario. The loss of rice production will decrease by 75%, 16% and 14% respectively for the 1:2, 1:5 and 1:10 year flood in Alternative 1 (Table F.43). It will decrease by 59%, 12% and 11% respectively for the 1:2, 1:5 and 1:10 year flood, in Alternative 2 (Table F.44). Timely harvest of *boro* rice crops in a larger flood free area will be the main factor for this gain.

Graph F.5 presents the project's impact on paddy losses.

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Table F.41 Crop Production on Flood Damage-Free and Flood Damaged Land - FW Scenario: Alternative 1

Crop	Area (ha)						Yield (tonnes/ha)		Production (tonnes)					
	Flood Damage Free Lands			Flood Damage Lands			Flood Damage Free Lands	Flood Damaged Lands	Flood Damage Free Lands			Flood Damage Lands		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year			1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE														
HYV *Boro*	201,429	86,395	37,599	3,668	118,702	167,498	4.69	2.90	944,702	405,193	176,339	10,637	34,4236	485,744
Loc *Boro*	25,628	13,746	5,982	7,005	18,887	26,651	3.11	1.60	79,703	42,750	18,604	11,208	30,219	42,642
B. *Aus*	7,361	3,101	1,350	1	4,261	6,012	1.10	1.04	8,097	3,411	1,485	1	4,431	6,252
DW *Aman*	24,028	10,678	4,646	1,320	14,670	20,702	1.93	1.50	46,374	20,609	8,967	1,980	22,005	31,053
Loc T. *Aman*	35	15	7	0	20	28	2.15	1.75	75	32	15	0	35	49
HYV T. *Aman*	7,428	3,131	1,363	6	4,303	6,071	3.20	2.24	23,770	10,019	4,362	13	9,639	13,599
Rice Total	**265,909**	**117,066**	**50,947**	**12,000**	**160,843**	**226,962**			**1,102,721**	**482,014**	**209,772**	**23,839**	**410,565**	**579,339**
NON-RICE														
Wheat	152	64	28	0	88	124	2.11	2.00	321	135	59	0	176	248
Pulse	111	47	20	0	64	91	0.81	0.80	90	38	16	0	51	73
Groundnut	631	266	116	0	365	515	2.04	2.00	1,287	543	237	0	730	1,030
Oilseeds	287	130	56	21	178	252	0.91	0.80	261	118	51	17	142	202
Potato	941	396	173	0	545	768	11.15	10.00	10,492	4,415	1,929	0	5,450	7,680
Sweet Potato	470	198	86	0	272	384	9.53	9.00	4,479	1,887	820	0	2,448	3,456
Spices	1,285	545	237	8	748	1,056	6.00	5.00	7,710	3,270	1,422	40	3,740	5,280
Vegetables	562	241	105	11	332	468	9.25	9.00	5,199	2,229	971	99	2,988	4,212
Non-Rice Total	**4,439**	**1,887**	**821**	**40**	**2,592**	**3,658**			**29,839**	**12,635**	**5,505**	**156**	**15,725**	**22,181**
ALL CROPS	270,348	118,953	51,768	12,040	163,435	230,620			1,132,560	494,649	215,277	23,995	426,290	601,520

Table F.42: Crop Production Flood Damage-Free and Flood Damaged Land - FW Scenario: Alternative 2

Crop	Area (ha)						Yield (tonnes/ha)		Production (tonnes)					
	Flood Damage-Free Land			Flood Damage Land			Flood Damage-Free Lands	Flood Damage Land	Flood Damage_Free Land			Flood Damage Land		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year			1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE														
HYV *Boro*	198,174	80,324	33,345	6,686	124,536	171,515	4.69	2.90	929,436	376,720	156,388	19,389	361,154	497,394
Loc *Boro*	21,579	12,816	5,320	11,107	19,870	27,366	3.11	1.60	67,111	39,858	16,545	17,771	31,792	43,786
B. *Aus*	7,359	2,886	1,198	1	4,474	6,162	1.10	1.04	8,095	3,175	1,318	1	4,653	6,408
DW *Aman*	23,106	10,001	4,151	2,399	15,504	21,354	1.93	1.50	44,595	19,302	8,011	3,599	23,256	32,031
Loc T. *Aman*	35	14	6	0	21	29	2.15	1.75	75	30	13	0	37	51
HYV T. *Aman*	7,421	2,914	1,210	11	4,518	6,222	3.20	2.24	23,747	9,325	3,872	25	10,120	13,937
Rice Total	**257,674**	**108,955**	**45,230**	**20,204**	**168,923**	**232,648**			**1,073,059**	**448,410**	**186,147**	**40,785**	**431,012**	**593,607**
NON-RICE														
Wheat	151	59	25	0	92	126	2.11	2.00	319	124	53	0	184	252
Pulse	111	44	18	0	67	93	0.81	0.80	90	36	15	0	54	74
Groundnut	631	247	103	0	384	528	2.04	2.00	1,287	504	210	0	768	1,056
Oilseeds	284	121	50	24	187	258	0.91	0.80	258	110	46	19	150	206
Potato	942	369	153	0	573	789	11.15	10.00	10,503	4,114	1,706	0	5,730	7,890
Sweet Potato	469	184	76	0	285	393	9.53	9.00	4,470	1,754	724	0	2,565	3,537
Spices	1,286	510	212	15	791	1,089	6.00	5.00	7,716	3,060	1,272	75	3,955	5,445
Vegetables	562	227	94	18	353	486	9.25	9.00	5,199	2,100	870	162	3,177	4,374
Non-Rice Total	**4,436**	**1,761**	**731**	**57**	**2,732**	**3,762**			**29,842**	**11,802**	**4,896**	**256**	**16,583**	**22,834**
ALL CROPS	**262,110**	**110,716**	**45,961**	**20,261**	**171,655**	**236,410**			**1,102,901**	**460,212**	**191,043**	**41,041**	**447,595**	**616,441**

Table F.43: Crop Production - FWO and FW Scenarios

Crop	Crop Production (tonnes)								
	FWO Project			FW Project - Alternative 1			FW Project - Alternative 2		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE									
HYV *Boro*	825,317	643,095	570,677	955,339	749,429	662,083	948,825	737,874	653,782
Local *Boro*	89,320	68,791	60,671	90,911	72,969	61,246	84,882	71,650	60,331
B. *Aus*	7,139	6,904	6,811	8,098	7,842	7,737	8,096	7,828	7,726
DW *Aman*	50,409	44,394	42,056	48,354	42,614	40,020	48,194	42,558	40,042
Loc T. *Aman*	61	54	51	75	67	64	75	67	64
HYV T. *Aman*	22,828	18,560	16,867	23,783	19,658	17,961	23,772	19,445	17,809
Rice Total	**995,074**	**781,798**	**697,133**	**1,126,560**	**892,579**	**789,111**	**1,113,844**	**879,422**	**779,754**
NON-RICE									
Wheat	486	471	465	321	311	307	319	308	305
Pulse	114	114	113	90	89	89	90	90	89
Groundnut	1,239	1,224	1,219	1,287	1,273	1,267	1,287	1,272	1,266
Oilseeds	293	274	266	278	260	253	277	260	252
Potato	9,140	8,577	8,354	10,492	9,865	9,609	10,503	9,844	9,596
Sweet Potato	4,452	4,304	4,245	4,479	4,335	4,276	4,470	4,319	4,261
Spices	10,508	9,475	9,068	7,750	7,010	6,702	7,791	7,015	6,717
Vegetables	9,945	9,795	9,736	5,298	5,217	5,183	5,361	5,277	5,244
Non-Rice Total	**36,177**	**34,234**	**33,466**	**29,995**	**28,360**	**27,686**	**30,098**	**28,385**	**27,730**
ALL CROPS	**1,031,251**	**816,032**	**730,599**	**1,156,555**	**920,939**	**816,797**	**1,143,942**	**907,807**	**807,484**

Table F.44: Crop Production Losses - FW Scenario

Crop	Crop Production Losses (tonnes)					
	FW Project - Alternative 1			FW Project - Alternative 2		
	1:2 year	1:5 year	1:10 year	1:2 year	1:5 year	1:10 year
RICE						
HYV *Boro*	6,566	212,476	299,822	11,968	222,919	307,011
Local *Boro*	10,578	28,520	40,243	16,771	30,003	41,322
B. *Aus*	0	256	361	0	268	370
DW *Aman*	568	6,308	8,902	1,031	6,667	9,183
Loc T. *Aman*	0	8	11	0	8	11
HYV *Aman*	6	4,131	5,828	10	4,337	5,973
Rice Total	**17,718**	**251,699**	**355,167**	**29,780**	**264,202**	**363,870**
NON-RICE						
Wheat	0	10	14	0	11	14
Pulse	0	1	1	0	0	1
Groundnut	0	14	20	0	15	21
Oilseeds	2	20	27	3	20	28
Potato	0	627	883	0	659	907
Sweet Potato	0	144	203	0	151	209
Spices	8	748	1,056	15	791	1,089
Vegetables	2	83	117	4	88	121
Non-Rice Total	**12**	**1,647**	**2,321**	**22**	**1,735**	**2,390**
TOTAL CROPS	**17,730**	**253,346**	**357,488**	**29,802**	**265,937**	**366,260**

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8.6 Agriculture Monitoring Program

As an integral part of the KKRMP Environmental management Plan (EMP) an agriculture monitoring program is proposed which includes two components; agriculture monitoring during project implementation, and long term monitoring program of agricultural benefits.

8.6.1 Baseline Surveys and Data Program

The initial phase of the development of a comprehensive monitoring plan includes:

- design of the monitoring framework;
- identification of the parameters or indicators to be measured, and data sources;
- collection of baseline parameters from the data sources (surveys, etc.), and
- selection of parameters/indicators sampling frequency for monitoring.

As monitoring progresses, the current values of the parameters are compared to the baseline values and the impacts are inferred from the results of the analysis.

With respect to baseline data and information, NERP has already collected and processed, in the context of the KKRMP feasibility study, a wealth of data and information. In the early phase of the project, it is proposed to evaluate the existing pre-project baseline data to determine its completeness and adopt for a particular parameter or indicator, an alternate data collection approach, if the associated existing data is deemed insufficient or deficient. Baseline data and information readily available for agriculture includes:

- land use, crop patterns and cropped areas of individual plots for ten sample areas which comprise the entire area of 34 *mauzas*, an area of 14,927 ha, including maps;

- pre-monsoon flood depth maps for different conditions, present, future without project (FWO) and future with project (FW), for the 1:2, 1:5 and 1:10 year pre-monsoon flood;

- data on agricultural input, yields and crop damage;

- miscellaneous maps.

It is proposed to enter the data on a Geographic Information System (GIS) to keep consistency, centralize the baseline data, simplify processing and reporting. All mapping of NERP has been computerized in Auto-Cad format and the most popular commercial GIS software packages can readily accept this format. A GIS application will also simplify greatly the task of maintaining and updating the data base. Data associated with a particular indicator will be updated in the data base in order to evaluate this indicator status on the target date.

The Net Cultivated Area (NCA) of the project area was estimated from various sources. There is a need to confirm the size of the NCA by an area wide detailed land-use survey which would take 6 months for 12 groups of 4 land use surveyors each. This survey is the more important, because current topographic maps were produced in 1962-64. Since then and with due consideration to the relatively uniform topography (ie. small variation in elevation), this topography has changed as a result of sediment deposition in the *haor*. As a consequence actual crop patterns may, in some areas, be different than those estimated during the KKRMP feasibility study.

Other baseline data include statistical data at the *thana* level. *Thana* GOB offices keep statistics of cropped areas, crop production, employment and others. During census all relevant data is recorded at the *mauza* level, checked, aggregated at the *thana* level, then published in BBS census statistics. In between census, this data is collected annually, in theory, at the *mauza* level, but is not checked and maintained. This information is difficult to access as a result. There is a need for structuring the collection and mainly the processing of this information if it is to be of any use for the monitoring program of the KKRMP. The Capacity Development component of the Project will address this issue.

8.6.2 Monitoring program during Project Implementation

During the project implementation phase, agriculture monitoring will focus on changes in land use and will consider changes in fertility status of the soils. NERP has already completed a semi-detailed land use survey where present use and crops presently grown in each plot have been recorded. The monitoring team will identify any changes in land use which would occur during the construction phase of the project. Mitigation measures will be suggested to the land users and an enhancement program will be proposed. Any change in soil fertility due to the spreading of dredged material will also be noted.

The soil structure, physical and chemical properties, habitat of abiotic complexes, environmental gradients and productivity of the dredged spoil should be examined and monitored. Accordingly, appropriate and cost efficient technologies should be developed on the basis of available resources for the improvement of soil structure and productivity and other environmental gradients.

8.6.3 Long-Term Benefits Monitoring Program

The long-term benefits monitoring program will be designed and implemented to monitor the long term impacts of the project on the socioeconomic environment of the Kalni-Kushiyara River Basin. The long term impacts are related to benefits in agriculture, fisheries, navigation, employment and income. A tentative methodology, to be confirmed during the early phase of the implementation, is proposed following.

The expected outcome of the KKRMP with respect to agriculture is an increase in the production of *boro* paddy. Result indicators and data sources are:

- *boro* paddy estimates from sample area surveys (eg. sample sites considered in the KKRMP analysis on agriculture) and *thana* annual statistics on agriculture, and

- extent of inundated land during pre-monsoon floods. In the KKRMP feasibility study, this parameter has been evaluated indirectly, by hydraulic modelling and spot elevations surveys. In mid-1996, RADARSAT was launched and the imagery of this satellite is ideal to identify water. The possibility of using the digital data of this satellite to map the extent of flooded areas should be investigated in the early phase of the project.

9. OTHER OPPORTUNITIES FOR IMPROVEMENT

The expected increase in agricultural output following implementation of KKRMP is, apart from a moderate spontaneous shift from local *Boro* into HYV *Boro*, entirely due to the reduction of flood damage to crops. No agricultural development efforts will be necessary to achieve the projected increase in crop production.

It is evident, however, that the land and water resources of the project area have the potential for significant further production increases. To pursue the attainment of higher levels of production will become particularly attractive once KKRMP has stabilized the hydrological regime of the project area. This chapter describes a set of agricultural development initiatives that would be appropriate.

9.1 Soil and Land Use Survey and Mapping

The information obtained for the agriculture impact analysis of the project is in accordance with the *FPCO Guidelines* (1992). The information on soils, soil associations, land capability and suitability for the cultivation of selected crops was essentially obtained from secondary sources, mainly SRDI reconnaissance soils surveys carried out from the mid-1960s to the mid-1970s. Other information on general soil types was obtained from CERDI (1983). The fact that this secondary information is not up-to date has no significant impact on the assessment of agricultural benefits of the project because the project is in essence a flood mitigation and drainage improvement project, not an agricultural planning project. However any future agricultural planning in the project area would require as a pre-requisite detailed soil survey and mapping.

The purpose of the soil and land use survey and mapping is to produce a series of maps, typically on a scale 1:20,000 or 1:25,000 for soil, soil suitability and land capability and land use. As a first step, a base map should be prepared from available topographic maps and recent aerial photographs.

Soil Survey and Mapping
All reconnaissance and semi-detailed soil survey information presently available from SRDI should be transferred to the base map. A detailed soil survey should be carried out on a grid with approximately one observation per 50 ha for a total of 5,000-6,000 observations. At each observation point, the soil series should be identified and the soil should be sampled to a depth of 1 m, to define major soil horizons. The samples should be sent for laboratory analysis for both physical and chemical properties. Soil association boundaries should be corrected based on the results of the survey and photo-interpretation to produce an up-to-date soil map of the project area.

Land Use Mapping
As a pre-requisite for agricultural planning, an updated land use map should be prepared based on recent aerial photographs and remote sensing SPOT pictures taken during both dry and post-monsoon periods. These photographs would be interpreted, checked and corrected based on ground truth land use information collected during the soil survey.

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Soil Suitability Map
Based on soils, fertility, land use and flooding information (MIKE II), a soil suitability map should be prepared for dry and wetland crops, in particular local *boro*, HYV *boro*, and B. *aman*.

Land Development Categories
Based on soils, land use, flooding, flood control and irrigation status, land development categories (LDC) would have to identified for the study area. Two important tables would be prepared as follows:

- main cropping pattern by land development categories (LDC)

- main cropping pattern and yield by LDC and land type

The land development categories (LDC) is explained in FPCO guideline (Agricultural Impact Assessment) on page 3 and step 3 of figure 1. Any future agriculture management will be based on LDC.

9.2 Agricultural Planning and Development

Once the area is flood secure and adequate mapping is available for agricultural planning and development an agricultural model may be developed to ensure sustainable and economically viable agriculture in the KKRMP study area. This model should take into account the following areas for improvement:

- efficient management of surface water used for irrigation
- improvement of soil productivity
- deep water rice culture
- development of suitable crop varieties
- platforms for intensive cultivation of non-rice crops
- improvement of livestock, feeds and fodder supply
- improvement in support services
- improvement in credit supply

Each of the above areas for improvement are described in more detail in the following sections.

Efficient Management of Surface Water Used for Irrigation
Surface water irrigation can be improved with the following measures:

- Excavation of *khals* to provide supplementary storage.

- Providing control structures at suitable locations.

- Improvement in the efficiency of surface water use.

- Ensuring equitable water distribution.

- Improved irrigation management.

Improvement of Soil Productivity
A program needs to be developed to regain and maintain the productivity of degraded cultivated lands. The program should identify affected areas, nature of degradation and potential for improvement, and it should develop sound methods to rehabilitate degraded lands and improve the fertility of their soils, including soil management trials.

Reclamation of peat soils or soils where the topsoil consists mainly of peat also needs to be considered in this improvement program and a study should be carried out to determine the best approach. Most *beel* areas are occupied by peat soils. These soils comprises dark grey to black muck occupying more than half the upper 1 m profile. These soils become very strongly acidic when drained.

Deep Water Rice Culture
It is possible to increase deep water or broadcast *aman* rice production in the wet season. This may lead some farmers to shift from rice production during the dry season to high value non-rice crops which require less water for irrigation. Deep water rice can be grown without sacrificing yields but a thorough understanding of current practices and problems associated with deep water rice cultivation is necessary. Deep water rice varieties are adapted to withstand anaerobic conditions. The plants can survive in deep flooding since their stem elongates as the water rises. Even uprooted, the plants survive and produce panicles. Deep water rice also provides shelter for fish and provides food in the form of periphyton on the submerged stems and leaves. DWR varieties can be selected according to the local flooding characteristics.

Development of Suitable Crop Varieties
Quick-maturing varieties with high yield potential are needed in the project area. Cold tolerant *boro* rice varieties need to be developed for early transplantation. Suitable varieties of non-rice crops are also needed which can grow in the winter season before modern *boro* rice varieties can be transplanted.

Platforms for Intensive Cultivation of Non-rice Crops
The raised platforms which are proposed to be built from dredge spoils will, with proper management, contribute to an increase in the cultivation throughout the year of homestead vegetables, pulses, spices and fruits. This in turn will improve nutrition and increase household income. The raised platforms will also provide improved facilities for threshing and drying crops.

Improvement of Livestock, Feeds and Fodder Supply
Most of the livestock feed comes from crop by-products. The supply of these by-products will increase as crops are protected against floods. Improved rice yields will reduce the area required for subsistence cropping and allow some space for forage production. Production of forage, such as maize, can be an important ingredient for livestock feed. More forage production together with better livestock management can improve the supply of draft animals, dairy production and farm incomes.

Also some aquatic ferns and plants, especially azolla, duckweed, and water hyacinth are abundant in the project area. With the management of flood water these could increase feeds supply.

Improvement in Support Services
Support services need to be improved by motivating extension workers, ensuring better interactions between extension workers and farmers, creating local farmers' groups which would assist in the timely transfer of new information and knowledge on agricultural practices to the farmers community, an effective water management system, improvement in skills for establishing effective communication with the farmers and diagnosis of their present requirements and problems, improvement in information delivery to farmers and conveying of information on farmers' needs and constraints to the other agencies providing support services.

Improvement in Credit Supply
The availability of credit is one of the key factors to increase agricultural production in the project area. A credit system that can provide easy access to loans for farmers should be developed. Farmers require both short term loans for their seasonal operation (cost of fertilizers, seeds and labor) and medium term loans for capital investment.

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FIGURES

009

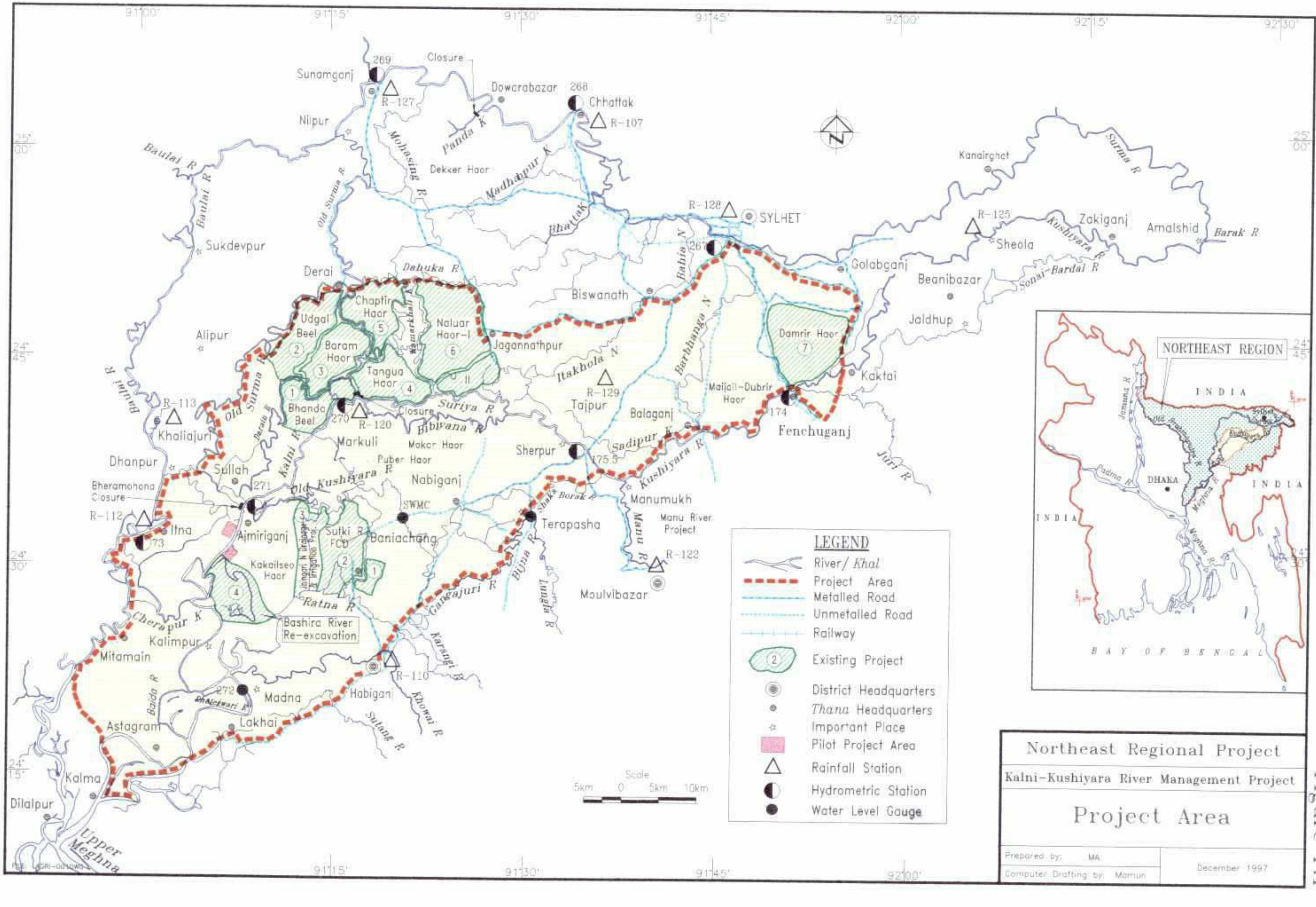
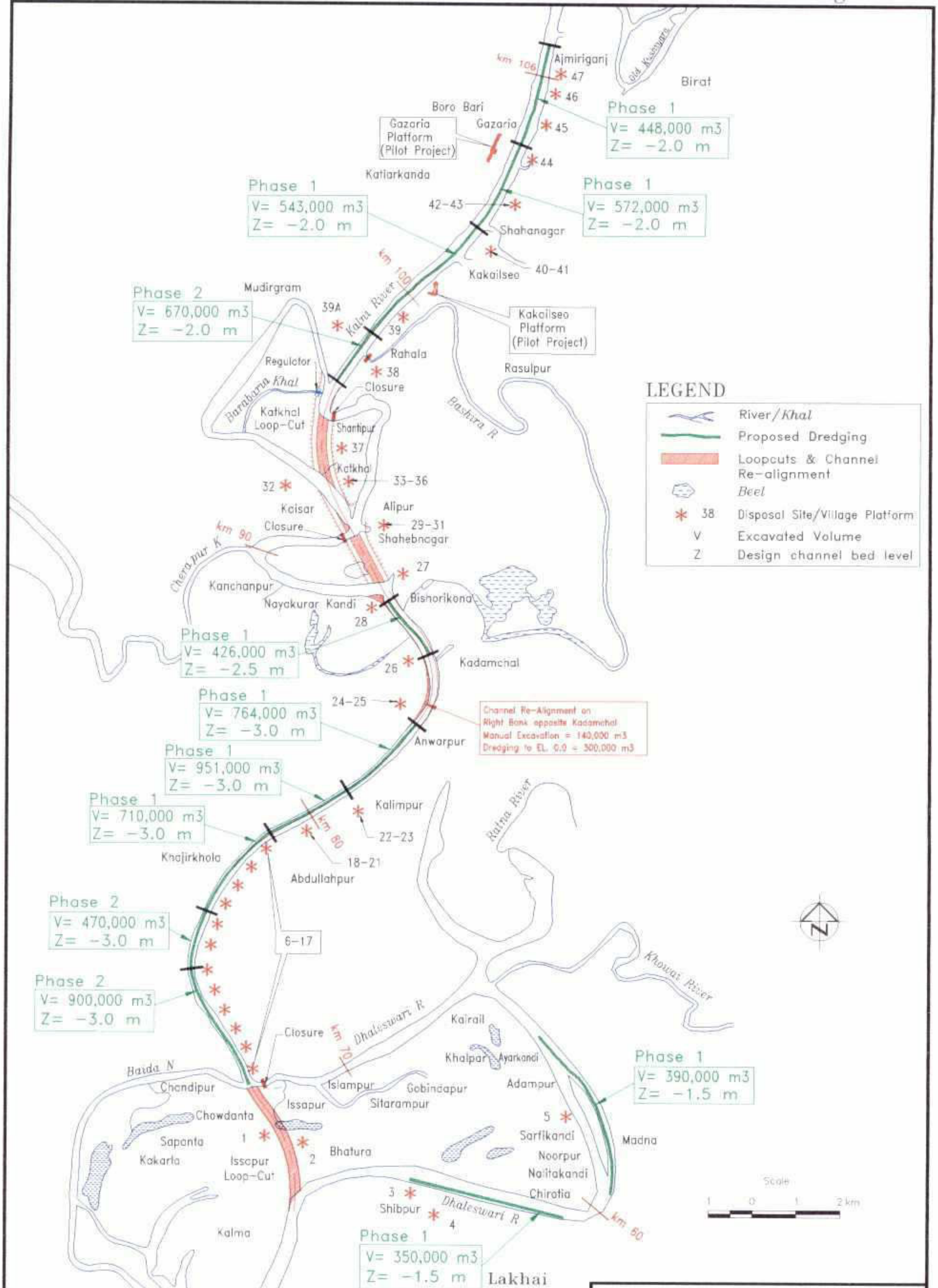


Figure F.1



Northeast Regional Project

Kalni-Kushiyara River Management Project

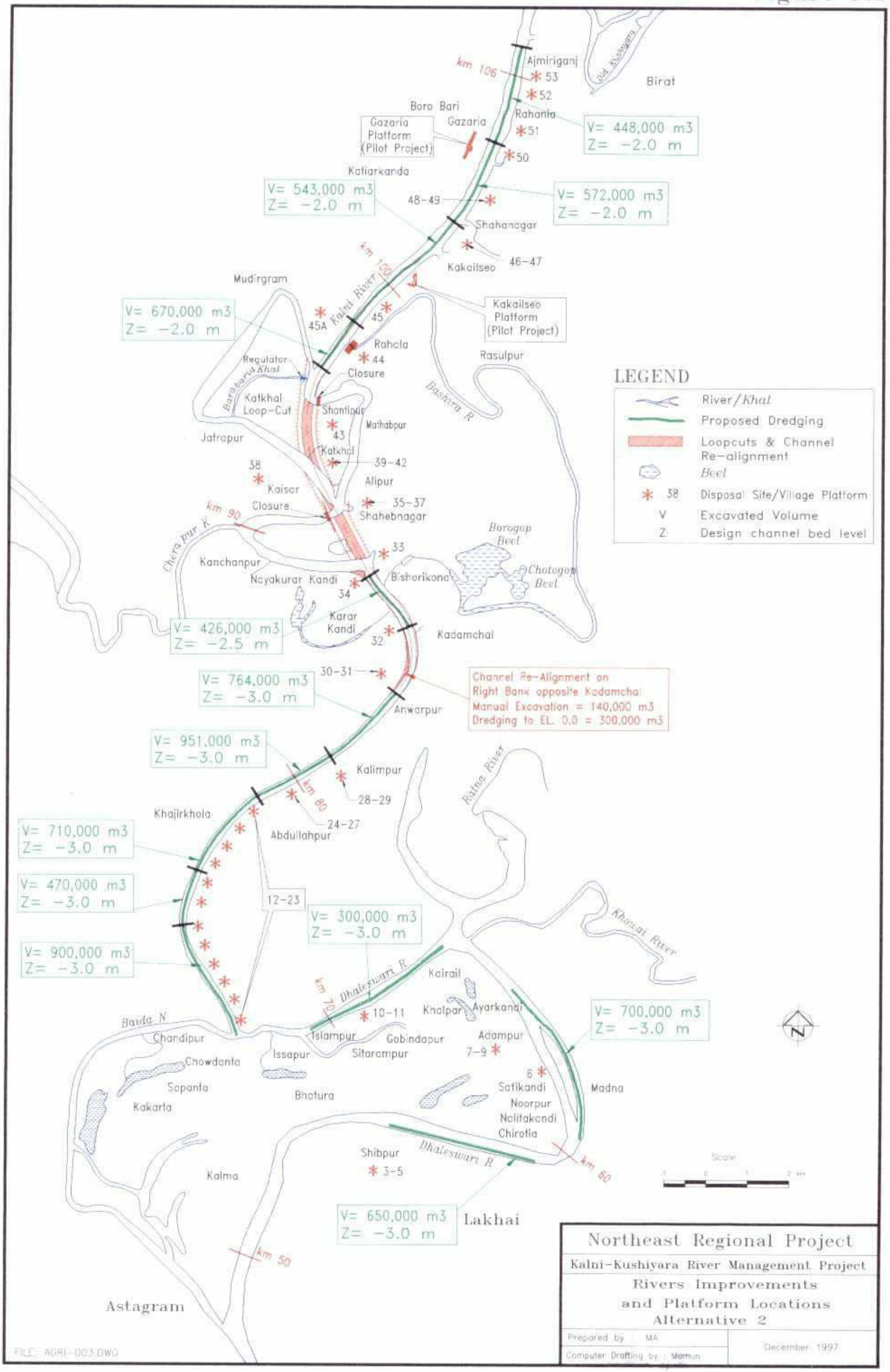
River Improvements and Platform Locations Alternative 1

Prepared by: MA

Computer Drafting by: Mamun

December 1997

Figure F.3



Ajmiriganj
km 106
53
52
Birat
Old Kushiyara
Boro Bari
Gazaria
Rahania
Gazaria Platform (Pilot Project)
51
50
V= 448,000 m3
Z= -2.0 m
Katiarkanda
V= 543,000 m3
Z= -2.0 m
48-49
V= 572,000 m3
Z= -2.0 m
Shahanagar
km 100
Kakailseo
46-47
Mudirgram
Kalni River
45A
45
Kakailseo Platform (Pilot Project)
V= 670,000 m3
Z= -2.0 m
Rahcla
44
Rasulpur
Regulator
Baraburia Khal
Closure
Katkhal Loop-Cut
Shantipur
Mathabpur
Bashira R
Jatrapur
43
Katkhal
39-42
38
Alipur
Kaisar
Closure
35-37
Shahebnagar
km 90
Chera pur K
33
Borogop Beel
Kanchanpur
Nayakurar Kandi
Bishorikona
Chotogop Beel
34
Karar Kandi
V= 426,000 m3
Z= -2.5 m
32
Kadamchal
30-31
V= 764,000 m3
Z= -3.0 m
Anwarpur
Channel Re-Alignment on Right Bank opposite Kadamchal
Manual Excavation = 140,000 m3
Dredging to EL. 0.0 = 300,000 m3
V= 951,000 m3
Z= -3.0 m
Kalimpur
Ratna River
km 80
28-29
Khajirkhola
24-27
Abdullahpur
V= 710,000 m3
Z= -3.0 m
V= 470,000 m3
Z= -3.0 m
12-23
V= 300,000 m3
Z= -3.0 m
Khowai River
V= 900,000 m3
Z= -3.0 m
Dhaleswari R
km 70
Kairail
10-11
Khalpar
Ayarkandi
V= 700,000 m3
Z= -3.0 m
Baida N
Chandipur
Islampur
Gobindapur
Adampur
Issapur
Sitarampur
7-9
Chowdanta
6
Sapanta
Bhatura
Satikandi
Madna
Kakarta
Noorpur
Nalitakandi
Chirotia
Shibpur
Dhaleswari R
3-5
km 60
Kalma
V= 650,000 m3
Z= -3.0 m
Lakhai
km 50
Astagram
LEGEND
River/Khal
Proposed Dredging
Loopcuts & Channel Re-alignment
Beel
38 Disposal Site/Village Platform
V Excavated Volume
Z Design channel bed level
Scale
N
Northeast Regional Project
Kalni-Kushiyara River Management Project
Rivers Improvements and Platform Locations Alternative 2
Prepared by : MA
Computer Drafting by : Mamun
December 1997
FILE: AGRI-003.DWG

Figure F.4

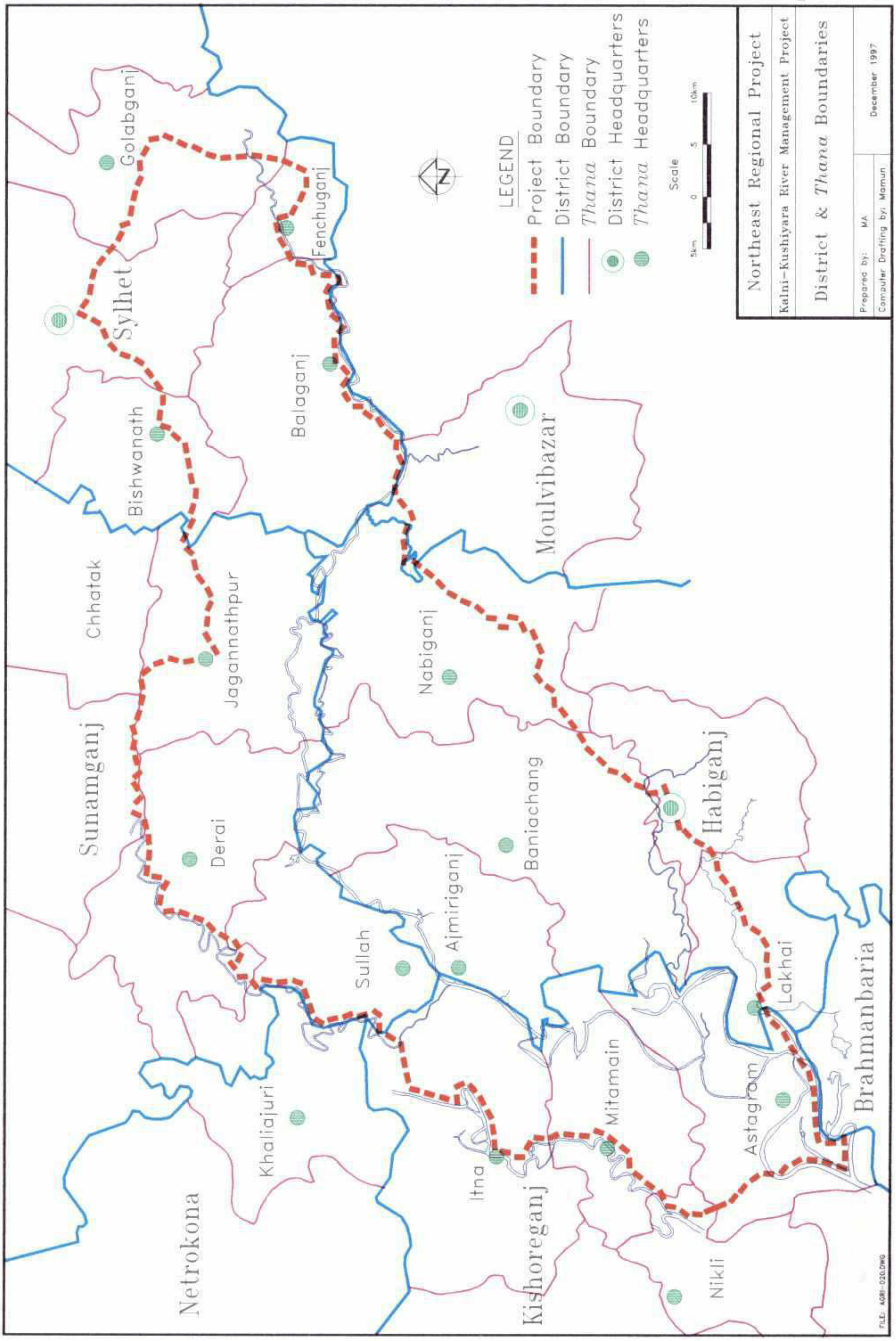
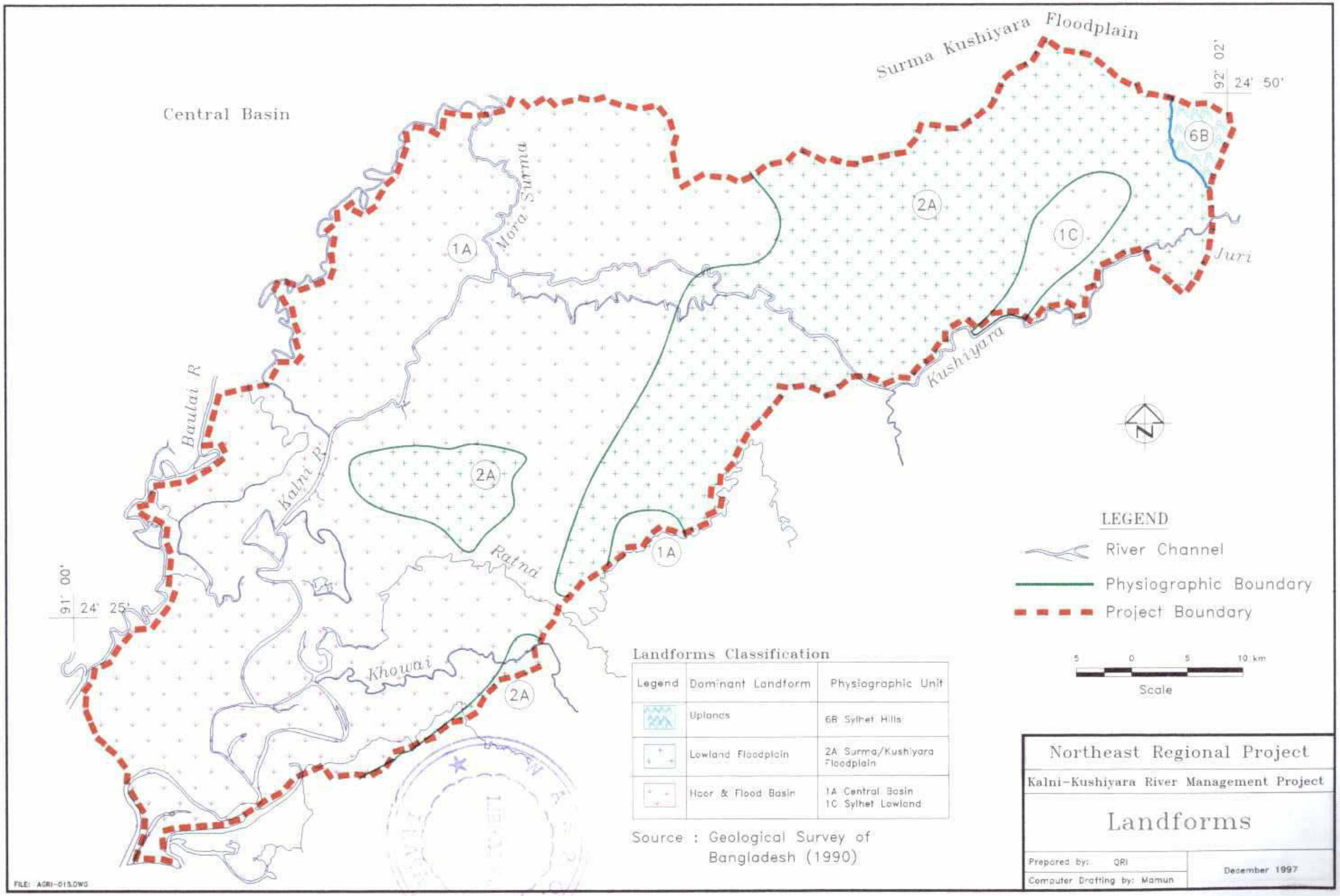

Northeast Regional Project
Kalni-Kushiyara River Management Project
District & *Thana* Boundaries
Prepared by: MA
Computer Drafting by: Mamun
December 1997
LEGEND
Project Boundary
District Boundary
Thana Boundary
District Headquarters
Thana Headquarters
Scale
5km 0 5 10km
Sylhet
Golabganj
Fenchuganj
Balaganj
Bishwanath
Moulvibazar
Chhatak
Jagannathpur
Nabiganj
Sunamganj
Derai
Baniachang
Habiganj
Ajmiriganj
Sullah
Lakhai
Brahmanbaria
Khaliajuri
Mitamain
Astagram
Itna
Netrokona
Kishoreganj
Nikli
FILE: AGRI-020.DWG

Figure F.5



Landforms Classification

Legend	Dominant Landform	Physiographic Unit
	Uplands	6B Sylhet Hills
	Lowland Floodplain	2A Surma/Kushiyara Floodplain
	Haor & Flood Basin	1A Central Basin 1C Sylhet Lowland

Northeast Regional Project

Kalni-Kushiyara River Management Project

Landforms

Prepared by: QRI	December 1997
Computer Drafting by: Mamun	

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Figure F.6

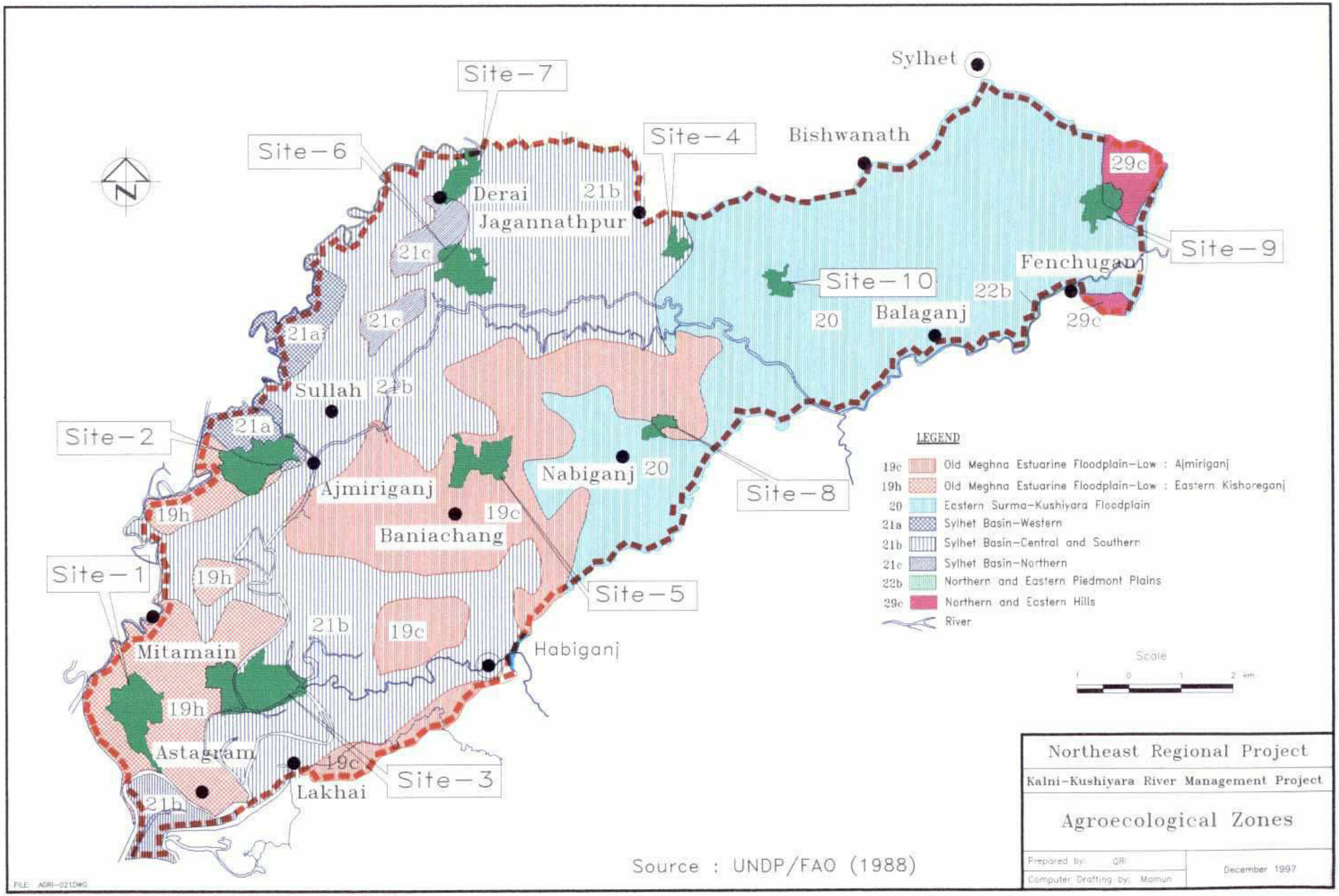
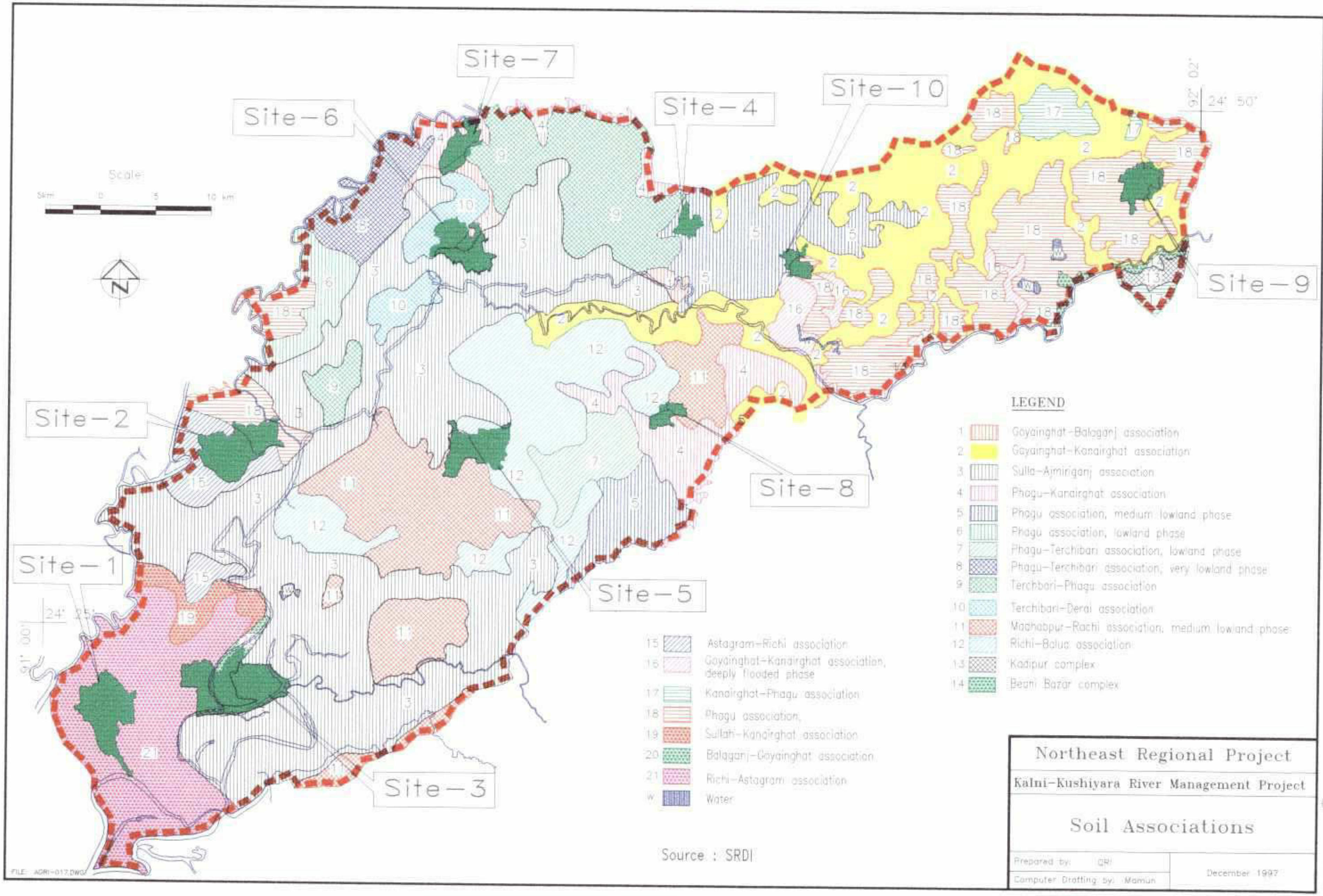


Figure F.7



Site-1
Site-2
Site-3
Site-4
Site-5
Site-6
Site-7
Site-8
Site-9
Site-10
Scale
5km 0 5 10 km
N
24° 50'
92° 02'
24° 25'
91° 00'
LEGEND
1 Goyainghat-Balaganj association
2 Goyainghat-Kanairghat association
3 Sulla-Ajmiriganj association
4 Phagu-Kanairghat association
5 Phagu association, medium lowland phase
6 Phagu association, lowland phase
7 Phagu-Terchibari association, lowland phase
8 Phagu-Terchibari association, very lowland phase
9 Terchbari-Phagu association
10 Terchibari-Derai association
11 Madhabpur-Rachi association, medium lowland phase
12 Richi-Balua association
13 Kadipur complex
14 Beani Bazar complex
15 Astagram-Richi association
16 Goyainghat-Kanairghat association, deeply flooded phase
17 Kanairghat-Phagu association
18 Phagu association,
19 Sullah-Kanairghat association
20 Balaganj-Goyainghat association
21 Richi-Astagram association
W Water
Source : SRDI
Northeast Regional Project
Kalni-Kushiyara River Management Project
Soil Associations
Prepared by: GRI
Computer Drafting by: Mamun
December 1997
FILE: AGRI-017.DWG

Figure F.8

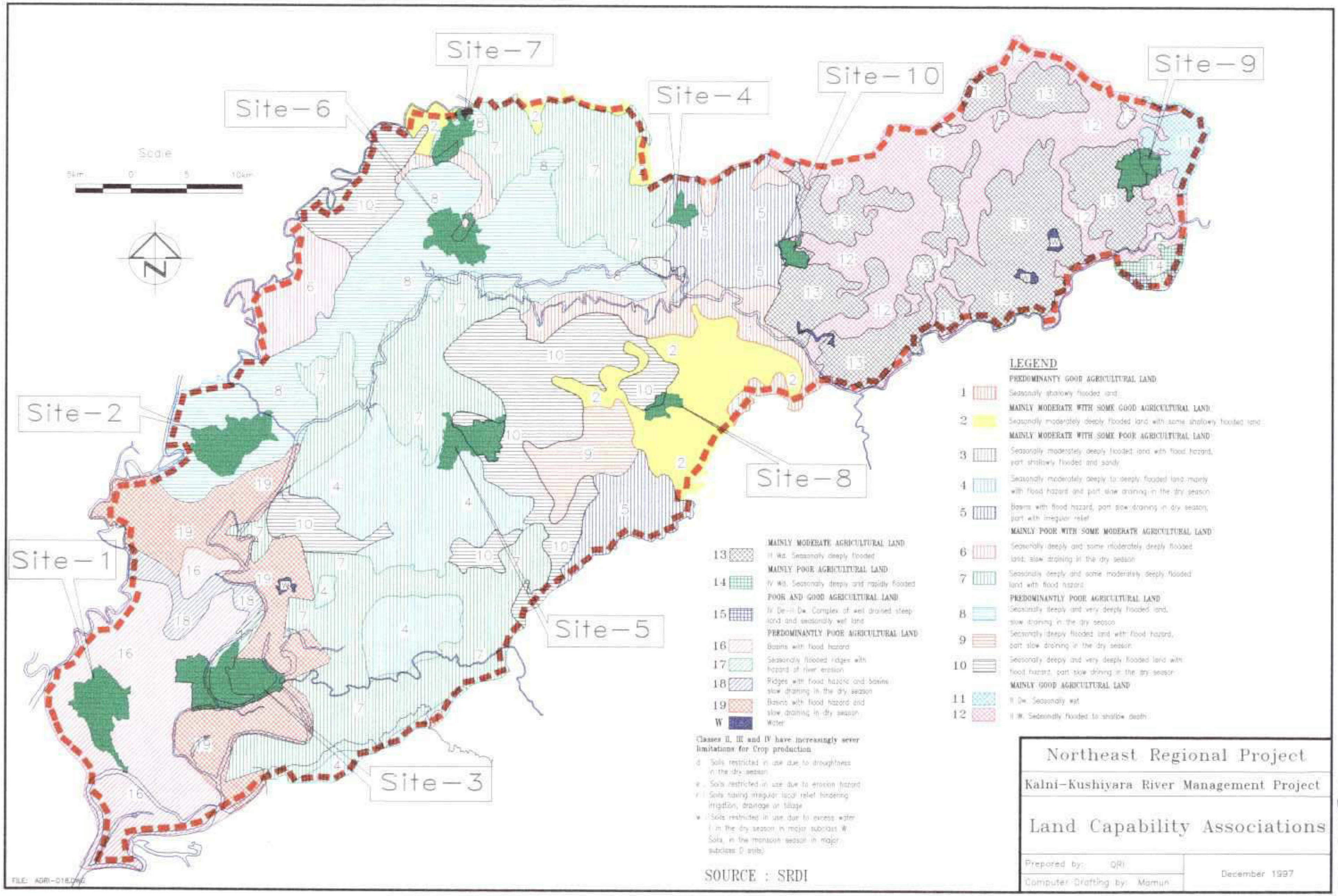
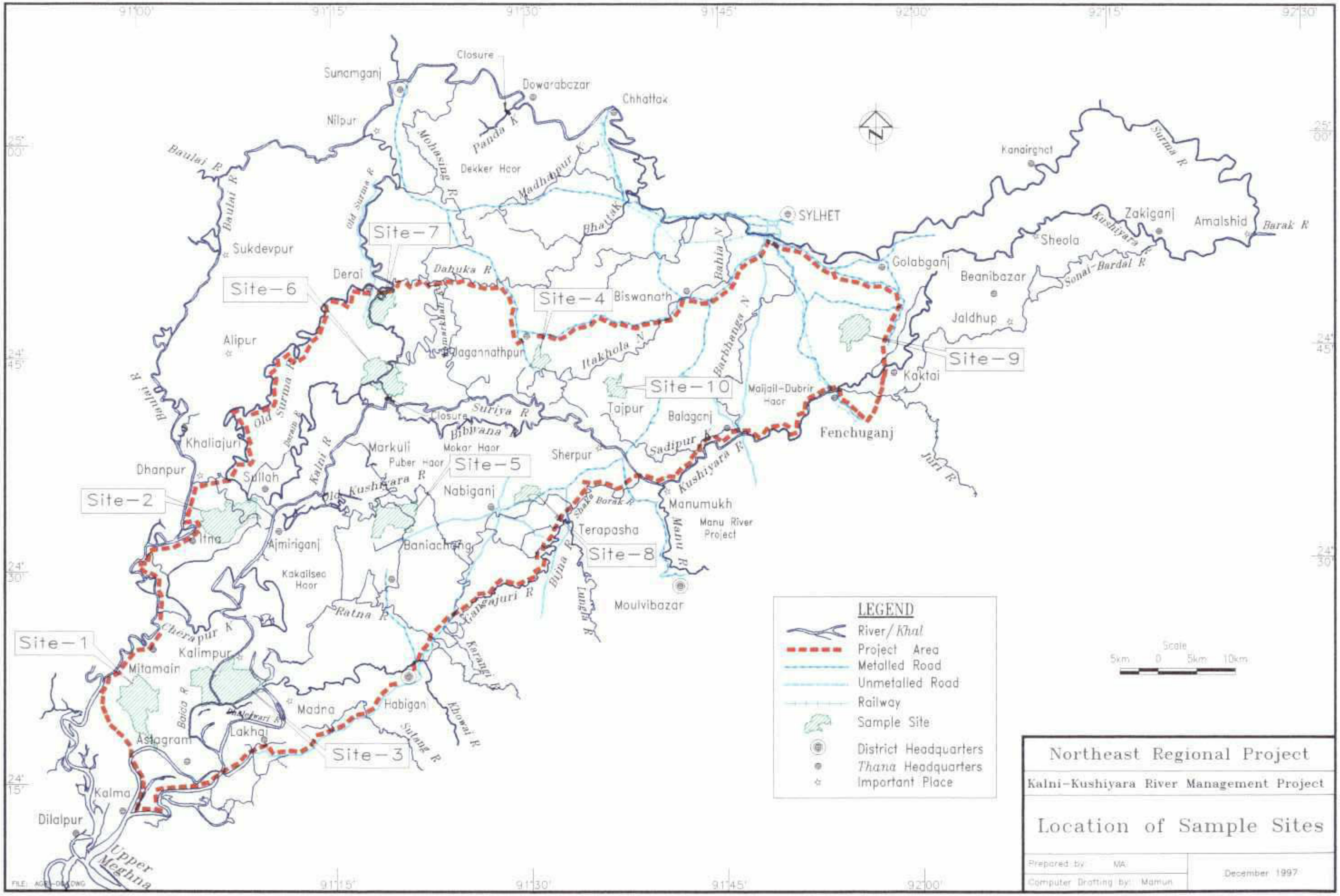

Site-1
Site-2
Site-3
Site-4
Site-5
Site-6
Site-7
Site-8
Site-9
Site-10
Scale
5km 0 5 10km
N
LEGEND
PREDOMINANTY GOOD AGRICULTURAL LAND
1 Seasonally shallowly flooded land
MAINLY MODERATE WITH SOME GOOD AGRICULTURAL LAND
2 Seasonally moderately deeply flooded land with some shallowly flooded land
MAINLY MODERATE WITH SOME POOR AGRICULTURAL LAND
3 Seasonally madestely deeply flooded land with flood hazard, part shallowly flooded and sandy
4 Seasonally moderately deeply to deeply flooded land mainly with flood hazard and part slow draining in the dry season
5 Basins with flood hazard, part slow draining in dry season, part with irregular relief
MAINLY POOR WITH SOME MODERATE AGRICULTURAL LAND
6 Seasonally deeply and some moderately deeply flooded land; slow draining in the dry season
7 Seasonally deeply and some moderately deeply flooded land with flood hazard
PREDOMINANTLY POOR AGRICULTURAL LAND
8 Seasonally deeply and very deeply flooded land, slow draining in the dry season
9 Seasonally deeply flooded land with flood hazard, part slow draining in the dry season
10 Seasonally deeply and very deeply flooded land with flood hazard, part slow draining in the dry season
MAINLY GOOD AGRICULTURAL LAND
11 II Dw. Seasonally wet
12 II W. Sedonally flooded to shallow depth
MAINLY MODERATE AGRICULTURAL LAND
13 III Wd. Seasonally deeply flooded
MAINLY POOR AGRICULTURAL LAND
14 IV Wd. Seasonally deeply and rapidly flooded
POOR AND GOOD AGRICULTURAL LAND
15 IV De-II Dw. Complex of well drained steep land and seasonally wet land
PREDOMINANTLY POOR AGRICULTURAL LAND
16 Basins with flood hazard
17 Seasonally flooded ridges with hazard of river erosion
18 Ridges with flood hazard and basins slow draining in the dry season
19 Basins with flood hazard and slow draining in dry season
W Water
Classes II, III and IV have increasingly sever limitations for Crop production
d Soils restricted in use due to droughtiness in the dry season
e Soils restricted in use due to erosion hazard
r Soils having irregular local relief hindering irrigation, drainage or tillage
w Soils restricted in use due to excess water (in the dry season in major subclass W Soils, in the monsoon season in major subclass D soils)
SOURCE : SRDI
Northeast Regional Project
Kalni-Kushiyara River Management Project
Land Capability Associations
Prepared by: QRI
Computer Drafting by: Mamun
December 1997
FILE: AGRI-018.DWG

Figure F.9



Northeast Regional Project

Kalni-Kushiyara River Management Project

Location of Sample Sites

Prepared by: MA

Computer Drafting by: Mamun

December 1997

Figure F.10

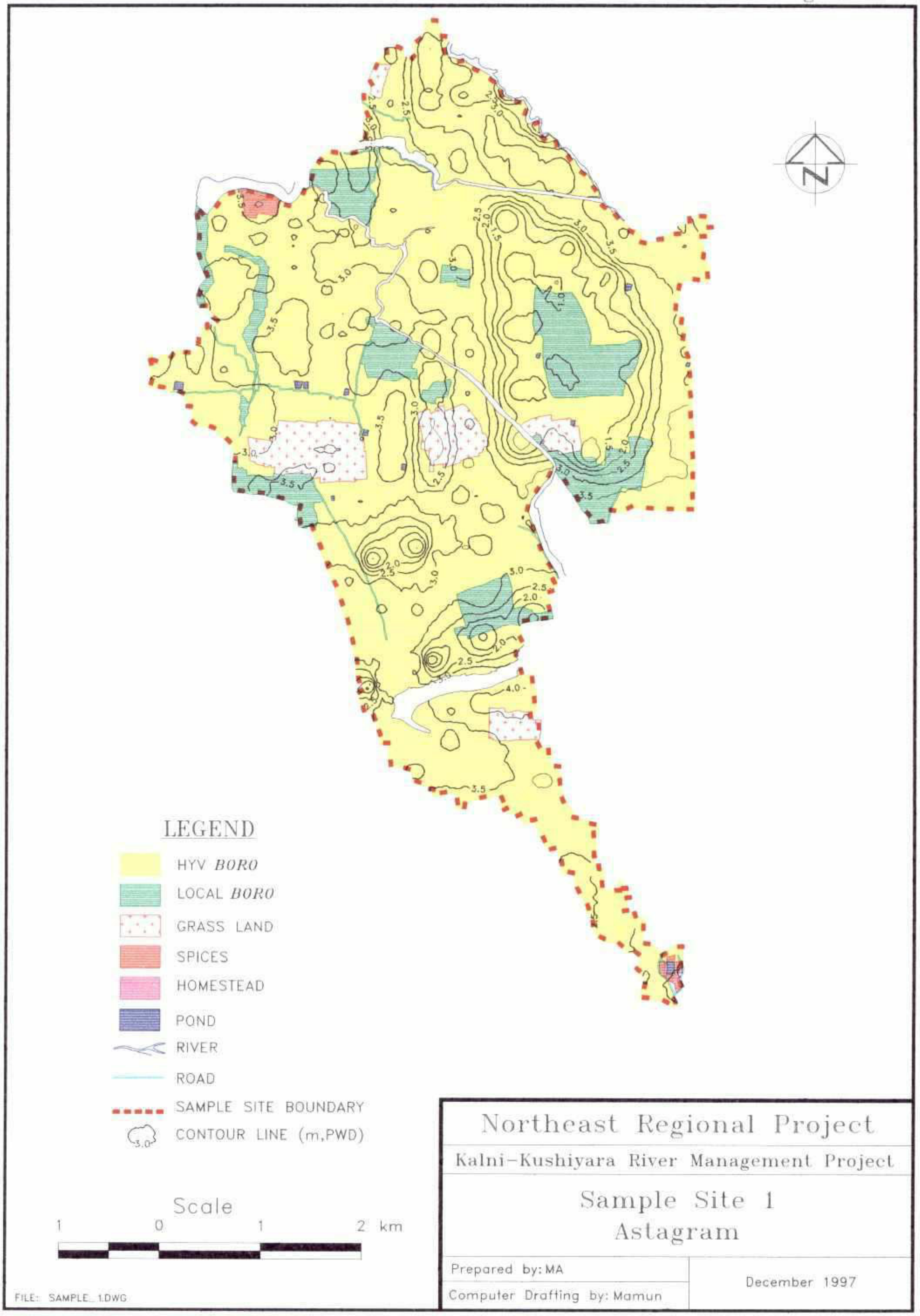
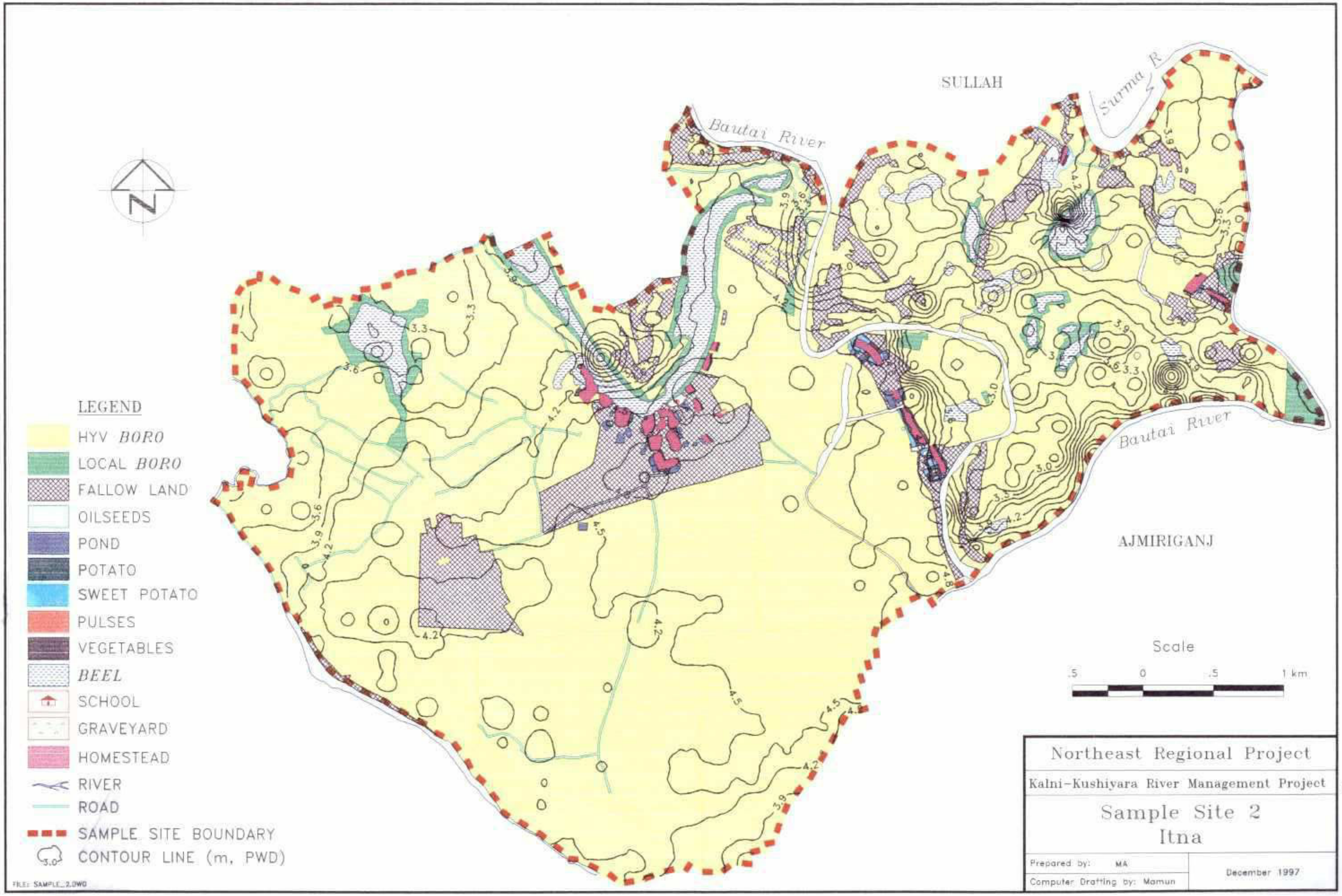

N
LEGEND
HYV *BORO*
LOCAL *BORO*
GRASS LAND
SPICES
HOMESTEAD
POND
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m,PWD)
Scale
1 0 1 2 km
FILE: SAMPLE_1.DWG
Northeast Regional Project
Kalni-Kushiyara River Management Project
Sample Site 1
Astagram
Prepared by: MA
Computer Drafting by: Mamun
December 1997

Figure F.11


SULLAH
AJMIRIGANJ
Bautai River
Bautai River
Surma R.
LEGEND
HYV *BORO*
LOCAL *BORO*
FALLOW LAND
OILSEEDS
POND
POTATO
SWEET POTATO
PULSES
VEGETABLES
BEEL
SCHOOL
GRAVEYARD
HOMESTEAD
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m, PWD)
Scale
.5 0 .5 1 km
Northeast Regional Project
Kalni-Kushiyara River Management Project
Sample Site 2
Itna
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: SAMPLE_2.DWG

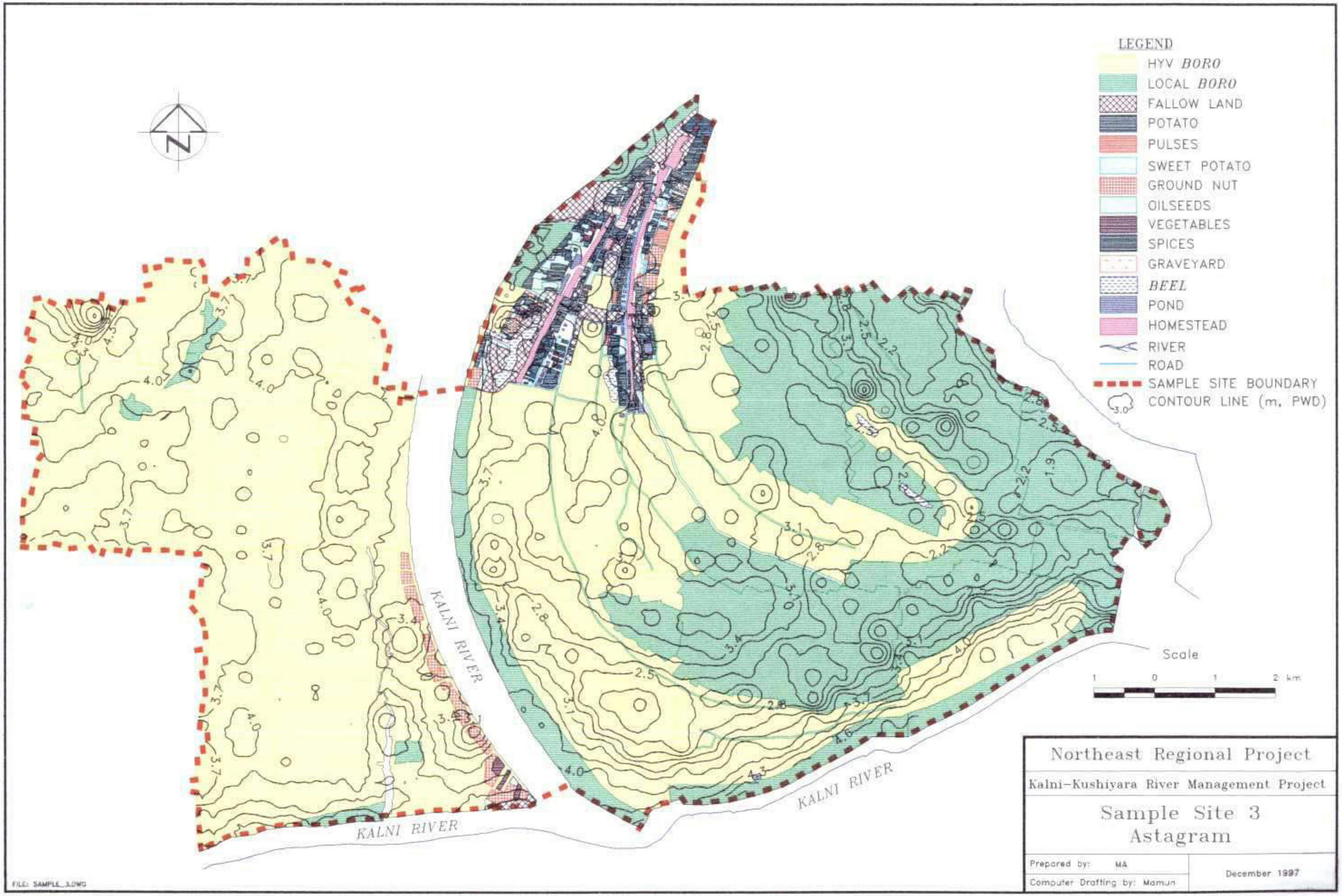

LEGEND
HYV *BORO*
LOCAL *BORO*
FALLOW LAND
POTATO
PULSES
SWEET POTATO
GROUND NUT
OILSEEDS
VEGETABLES
SPICES
GRAVEYARD
BEEL
POND
HOMESTEAD
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m, PWD)
Scale
1 0 1 2 km
KALNI RIVER
KALNI RIVER
KALNI RIVER
N
Northeast Regional Project
Kalni-Kushiyara River Management Project
Sample Site 3
Astagram
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: SAMPLE_3.DWG

Figure F.12

Figure F.13

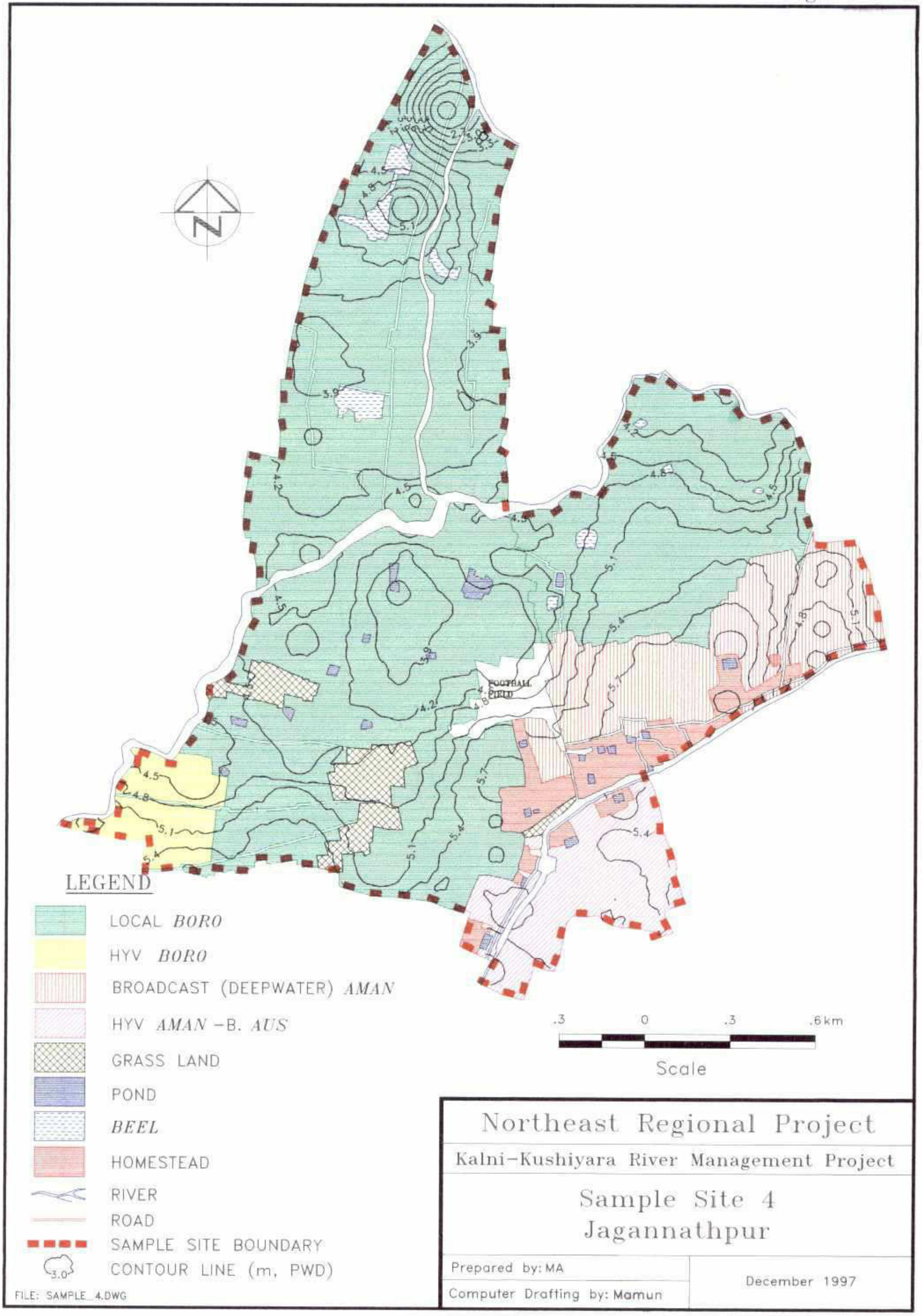

FOOTBALL FIELD
LEGEND
LOCAL *BORO*
HYV *BORO*
BROADCAST (DEEPWATER) *AMAN*
HYV *AMAN* –B. *AUS*
GRASS LAND
POND
BEEL
HOMESTEAD
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m, PWD)
.3 0 .3 .6km
Scale
Northeast Regional Project
Kalni–Kushiyara River Management Project
Sample Site 4
Jagannathpur
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: SAMPLE_4.DWG

Figure F.14

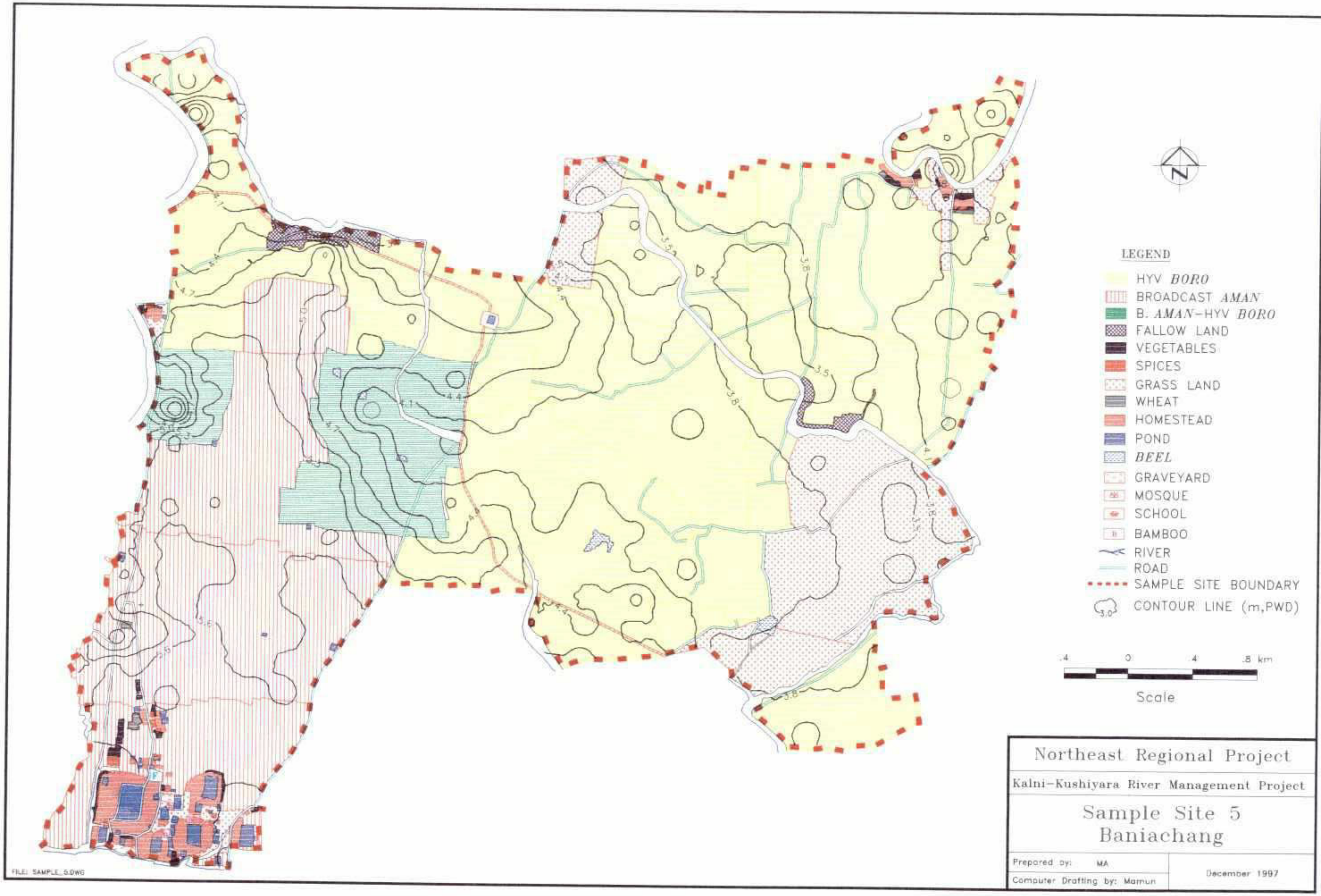
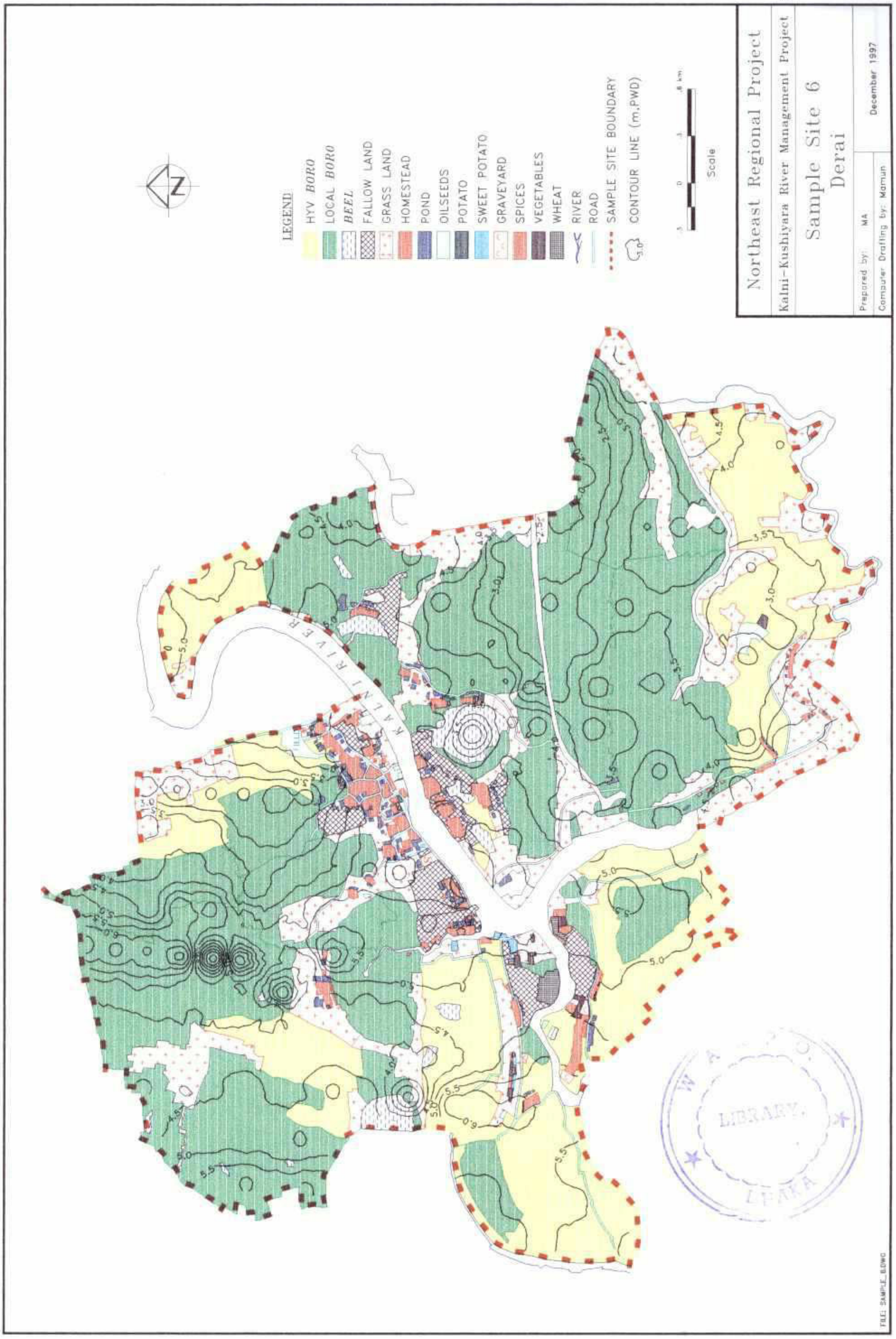
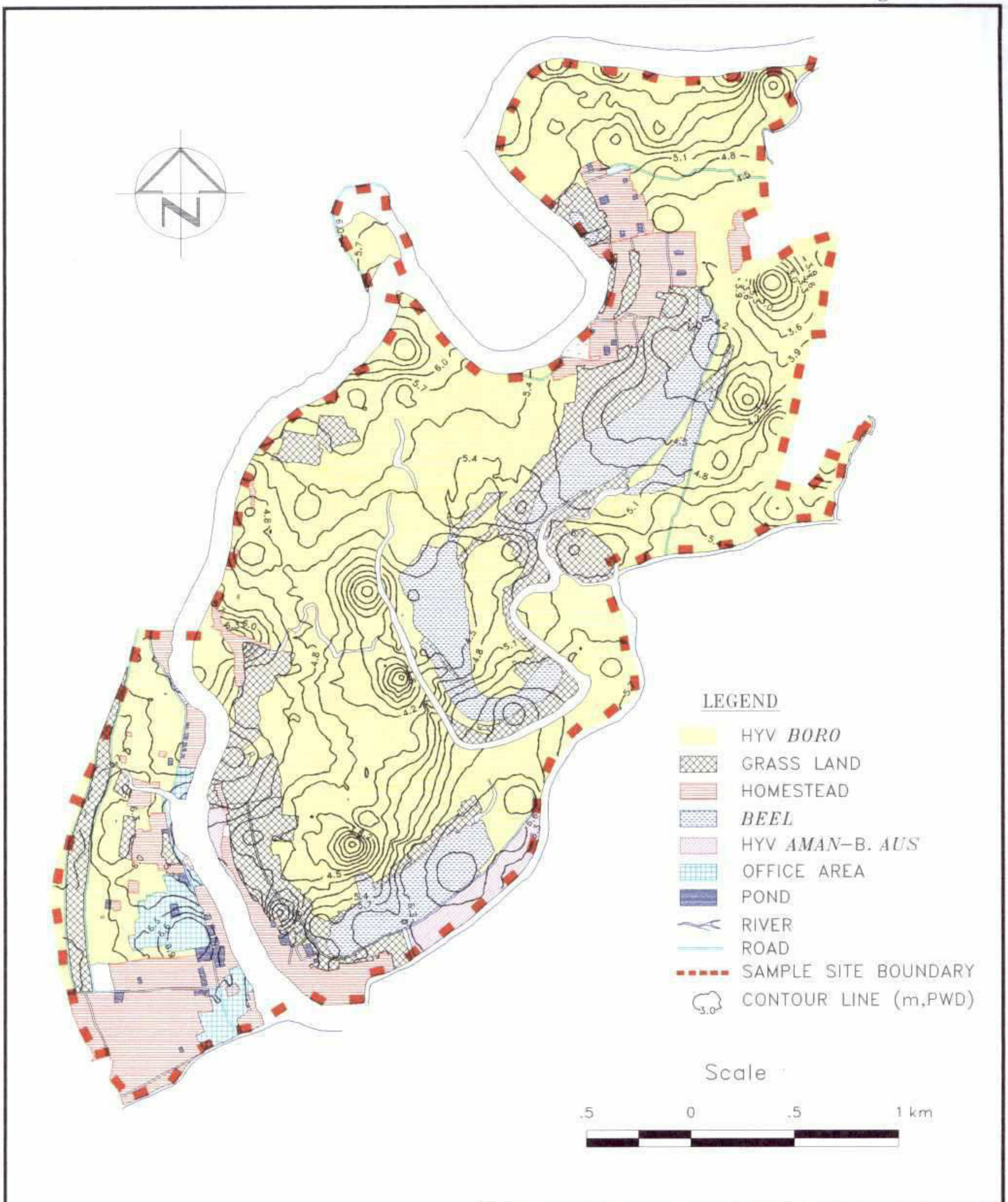

LEGEND
HYV BORO
BROADCAST AMAN
B. AMAN–HYV BORO
FALLOW LAND
VEGETABLES
SPICES
GRASS LAND
WHEAT
HOMESTEAD
POND
BEEL
GRAVEYARD
MOSQUE
SCHOOL
BAMBOO
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m,PWD)
.4 0 .4 .8 km
Scale
Northeast Regional Project
Kalni–Kushiyara River Management Project
Sample Site 5
Baniachang
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: SAMPLE_5.DWG

Figure F.15



LEGEND
HYV BORO
LOCAL BORO
BEEL
FALLOW LAND
GRASS LAND
HOMESTEAD
POND
OILSEEDS
POTATO
SWEET POTATO
GRAVEYARD
SPICES
VEGETABLES
WHEAT
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m,PWD)
Scale
KALNI RIVER
Northeast Regional Project
Kalni-Kushiyara River Management Project
Sample Site 6
Derai
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: SAMPLE_6.DWG



Northeast Regional Project

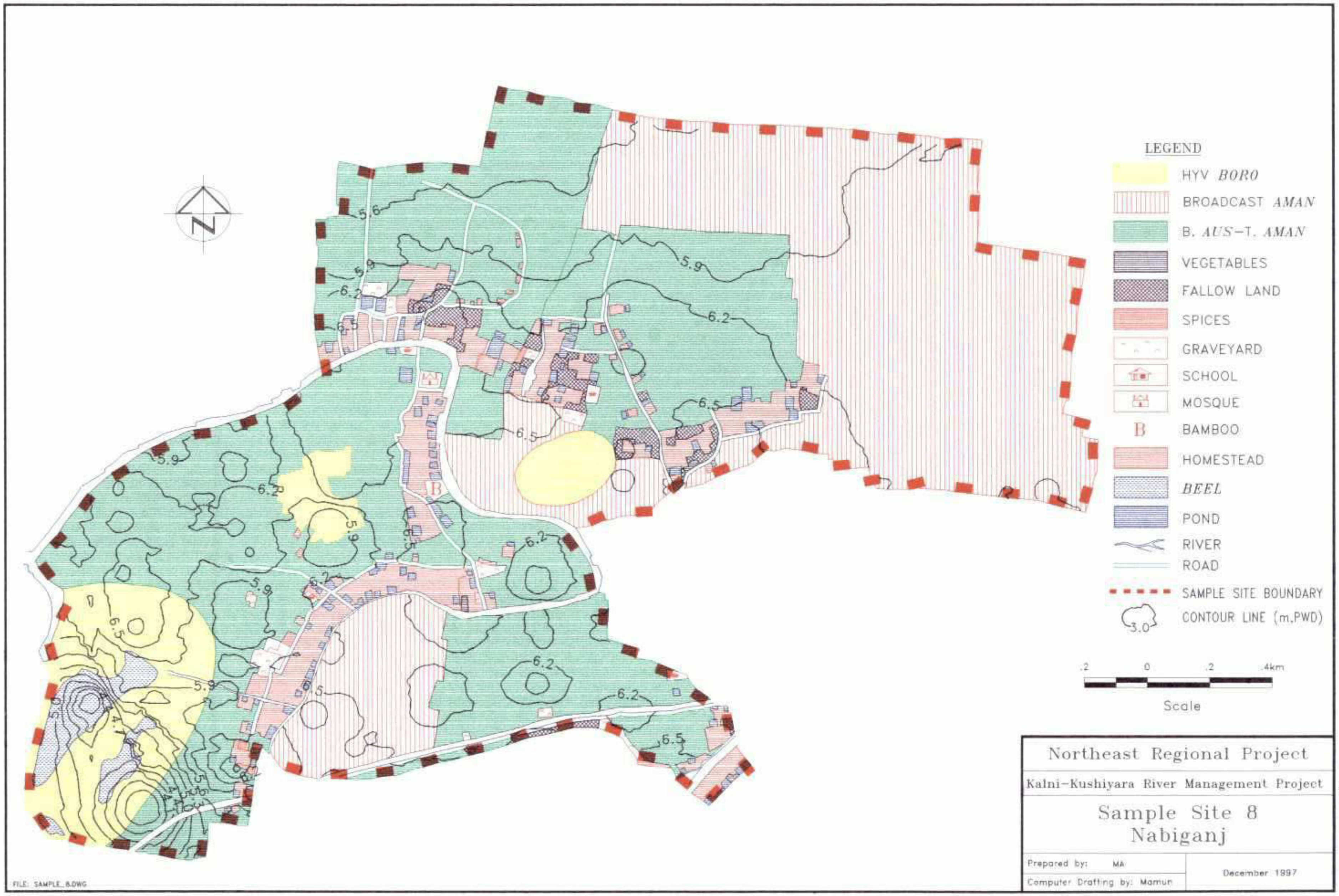
Kalni–Kushiyara River Management Project

Sample Site 7
Derai

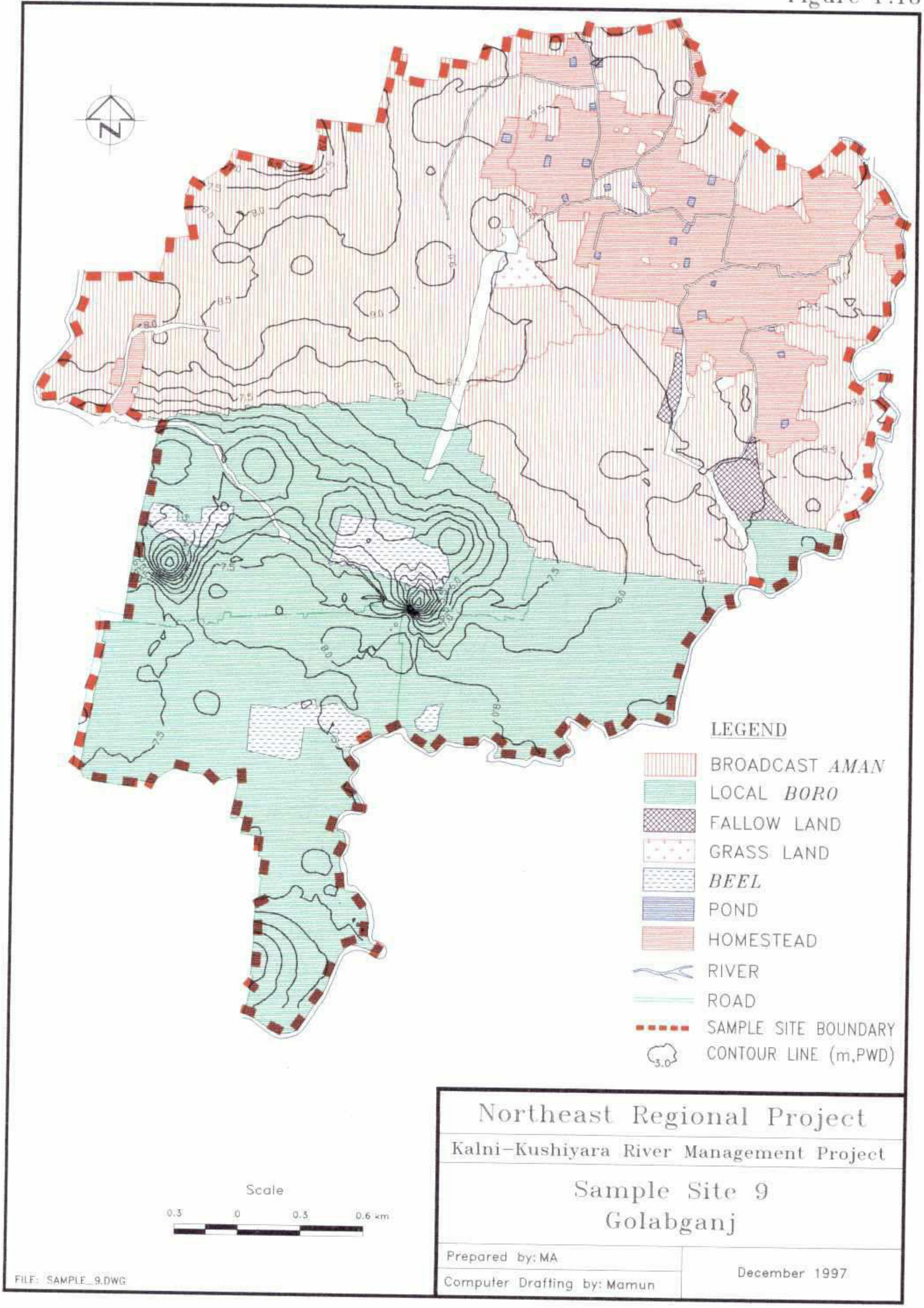
Prepared by: MA	December 1997
Computer Drafting by: Mamun	

FILE: SAMPLE_7.DWG

Figure F.17


LEGEND
HYV *BORO*
BROADCAST *AMAN*
B. *AUS*–T. *AMAN*
VEGETABLES
FALLOW LAND
SPICES
GRAVEYARD
SCHOOL
MOSQUE
B BAMBOO
HOMESTEAD
BEEL
POND
RIVER
ROAD
SAMPLE SITE BOUNDARY
CONTOUR LINE (m.PWD)
3.0
.2 0 .2 .4km
Scale
N
Northeast Regional Project
Kalni-Kushiyara River Management Project
Sample Site 8
Nabiganj
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: SAMPLE_8.DWG

028
Figure F.18



Northeast Regional Project

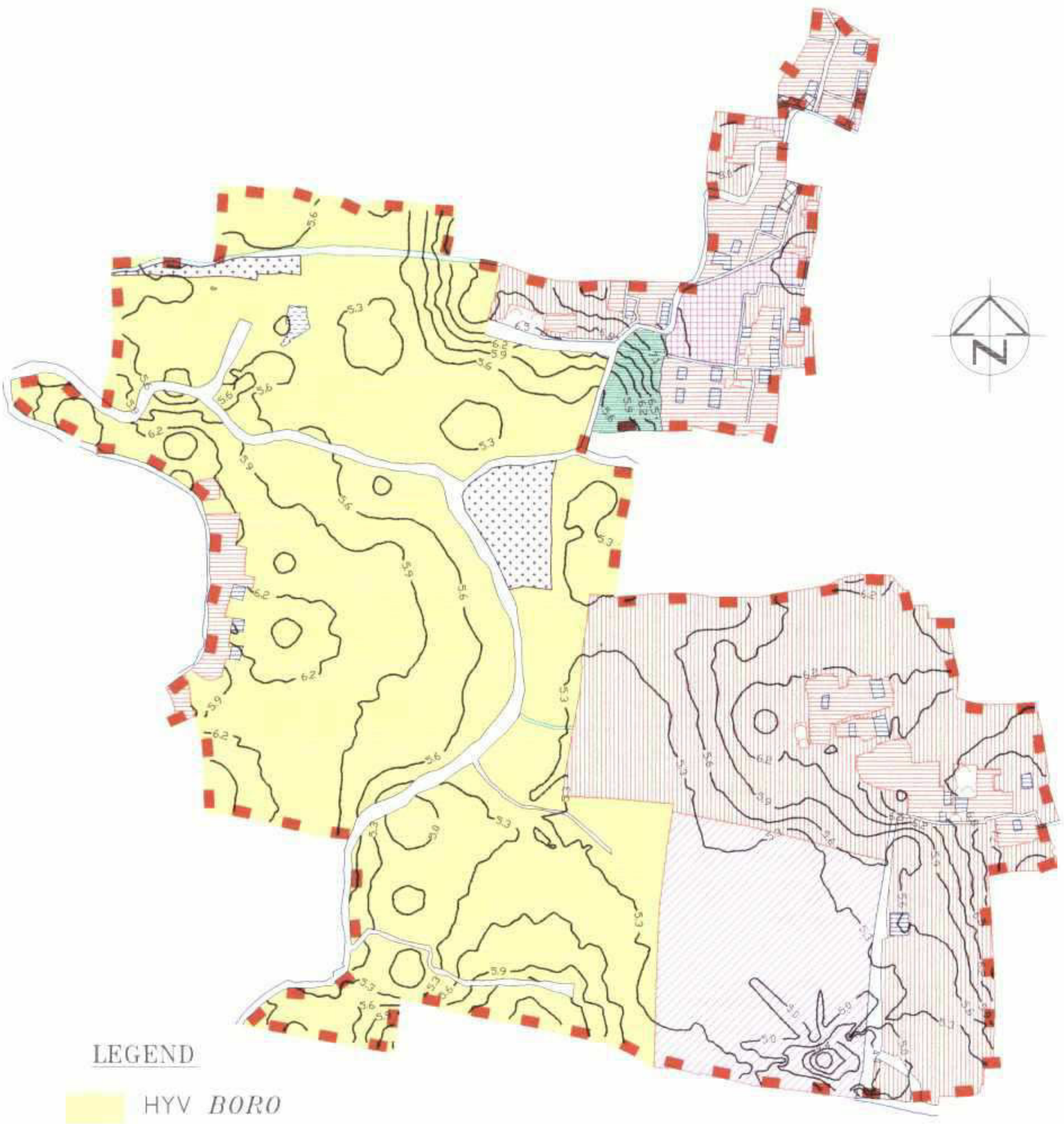
Kalni–Kushiyara River Management Project

Sample Site 9
Golabganj

Prepared by: MA
Computer Drafting by: Mamun

December 1997

Figure F.19



LEGEND

- HYV *BORO*
- BROADCAST *AMAN*
- HYV *AMAN*–HYV *BORO*
- GRASS LAND
- HOMESTEAD
- B. *AUS*–HYV *AMAN*
- HYV *AMAN*
- *BEEL*
- POND
- GRAVE
- SAMPLE SITE BOUNDARY
- CONTOUR LINE (m,PWD)

Scale

0.3 0 0.3 0.6 km

Northeast Regional Project

Kalni-Kushiyara River Management Project

Sample Site 10
Balaganj

Prepared by: MA

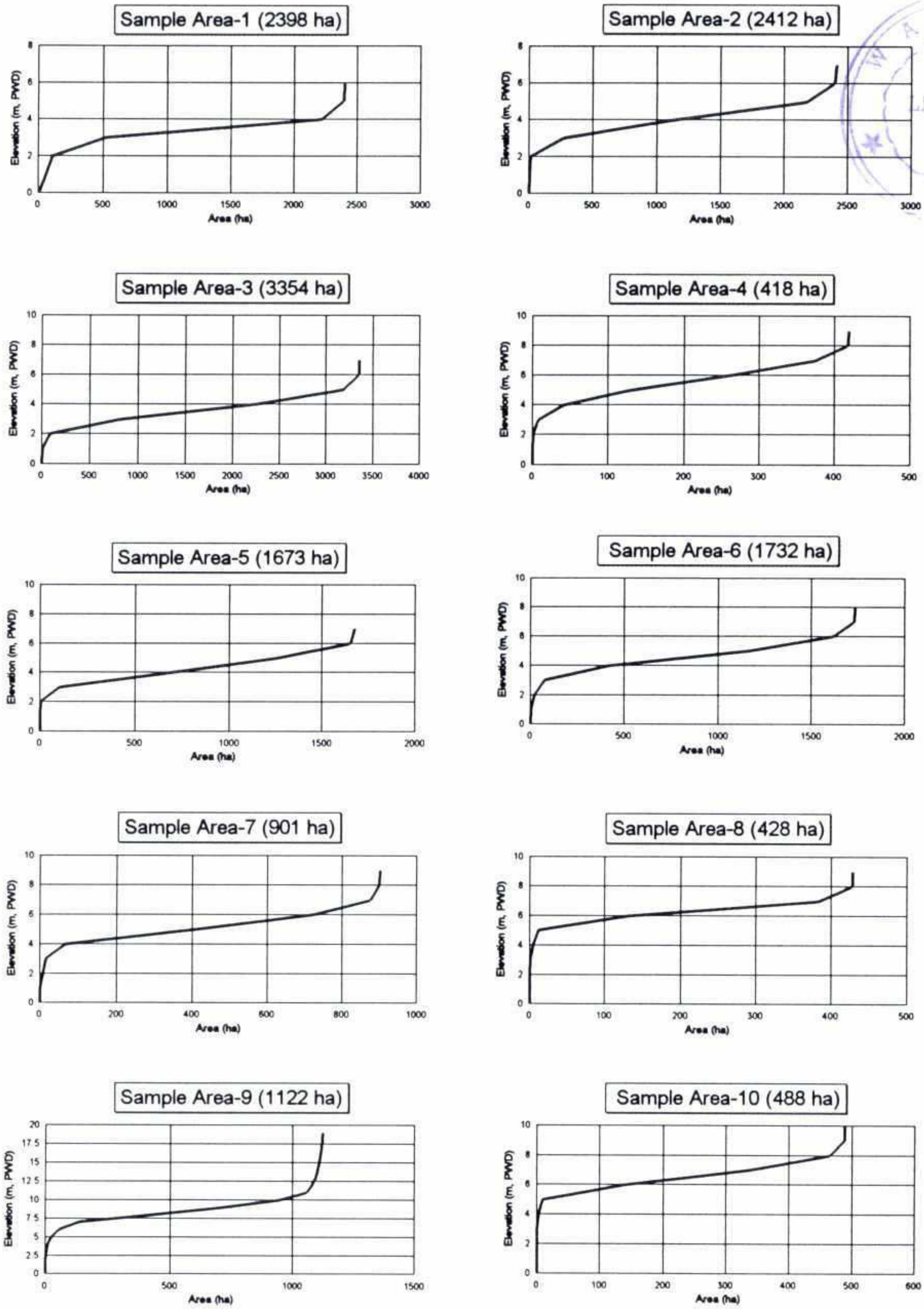
Computer Drafting by: Mamun

December 1997

FILE: SAMP10.DWG

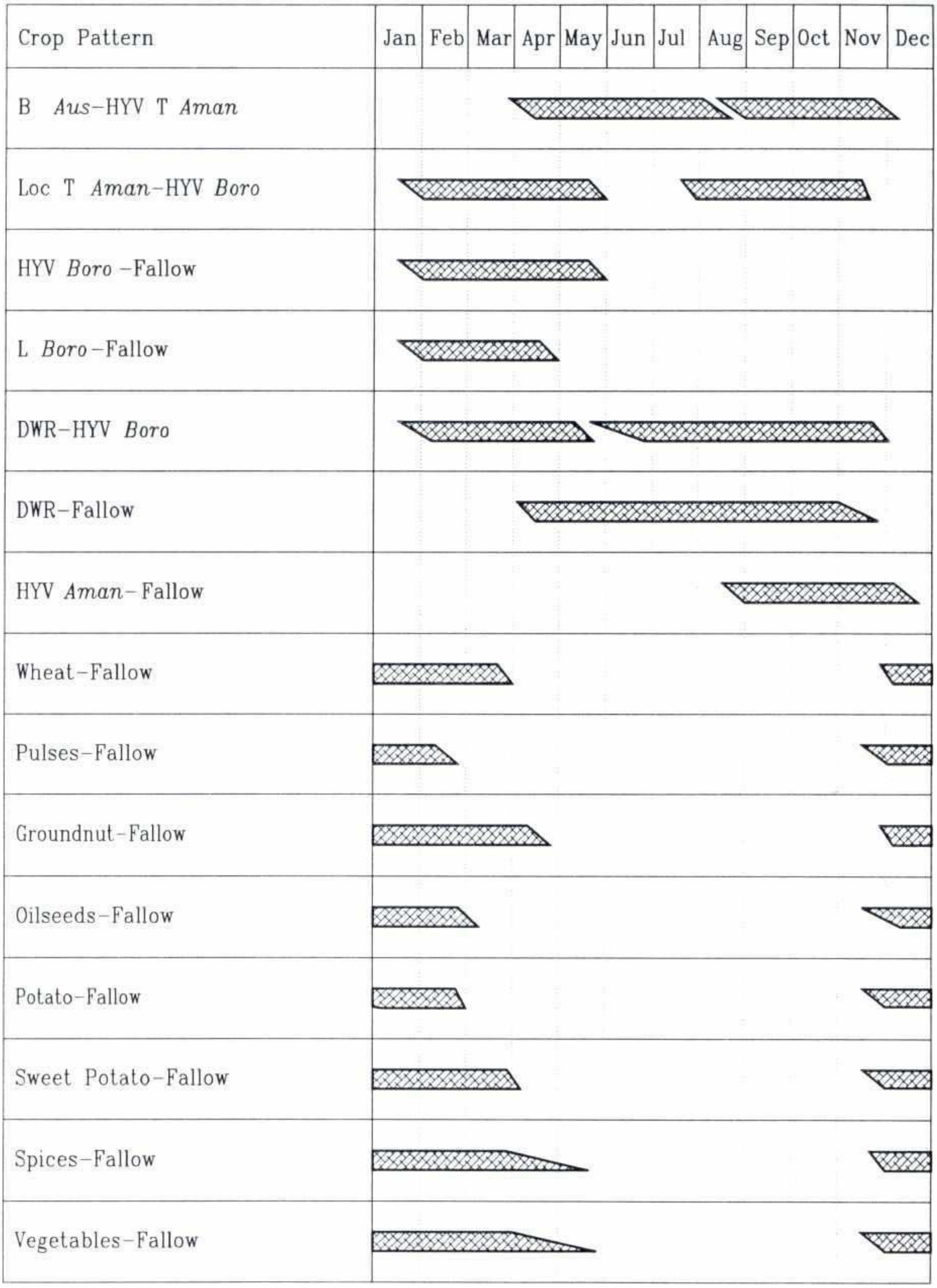
Figure F.20

Area Elevation Curve of Sample Areas

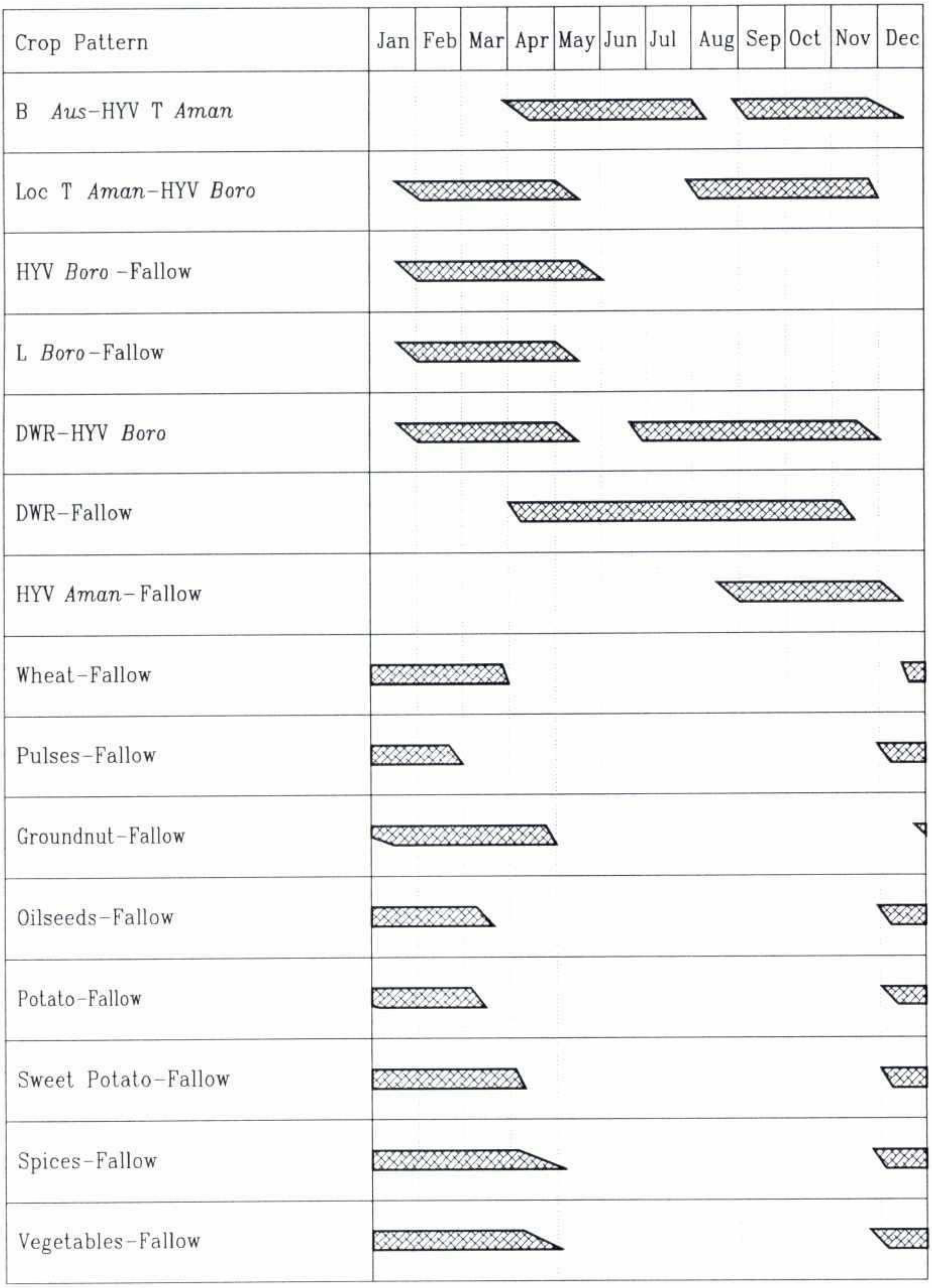


Kalni-Kushiyara River Management Project

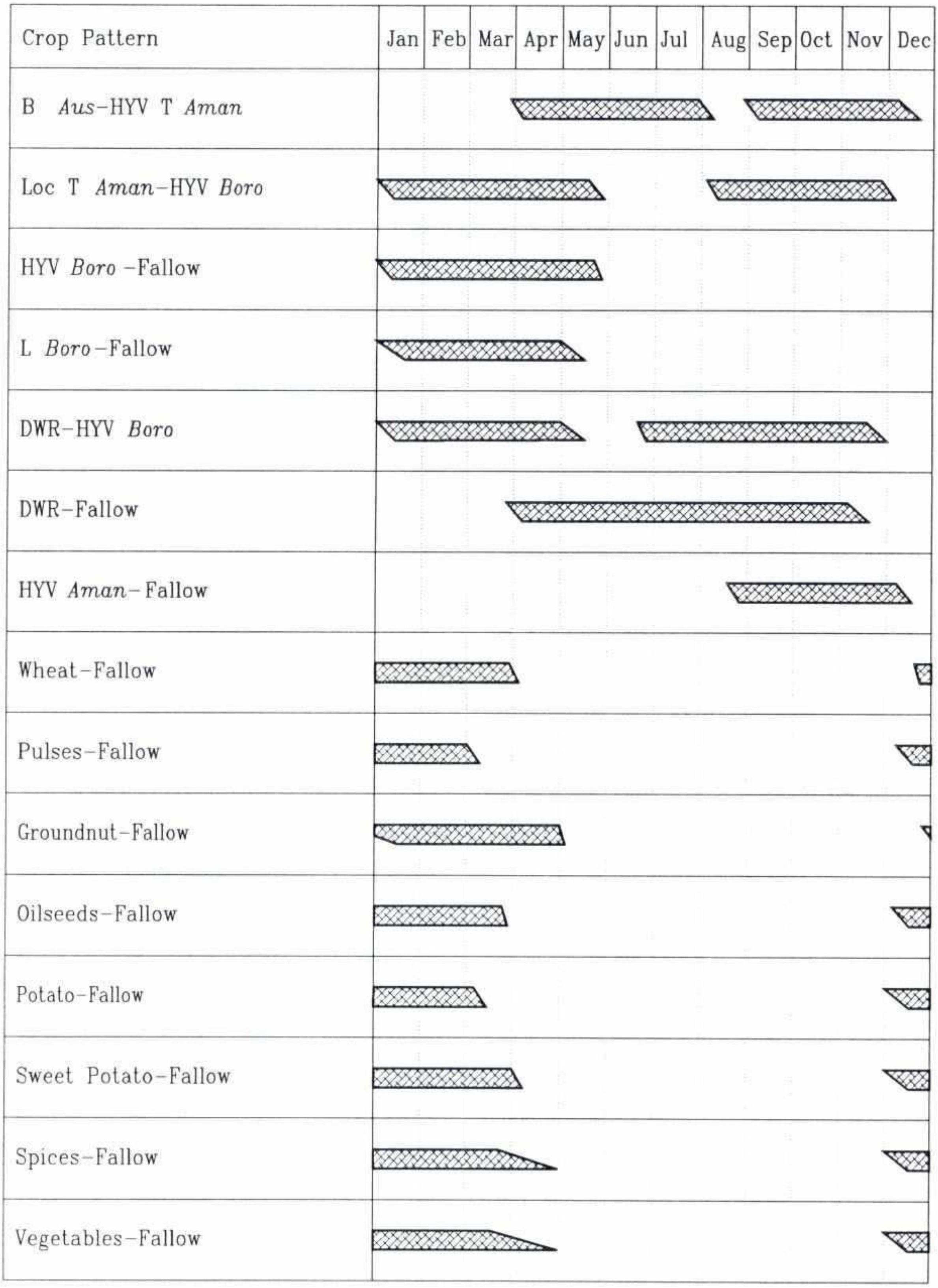
File: AE-1-11F.WK4 Prepared by: Tarek, May97



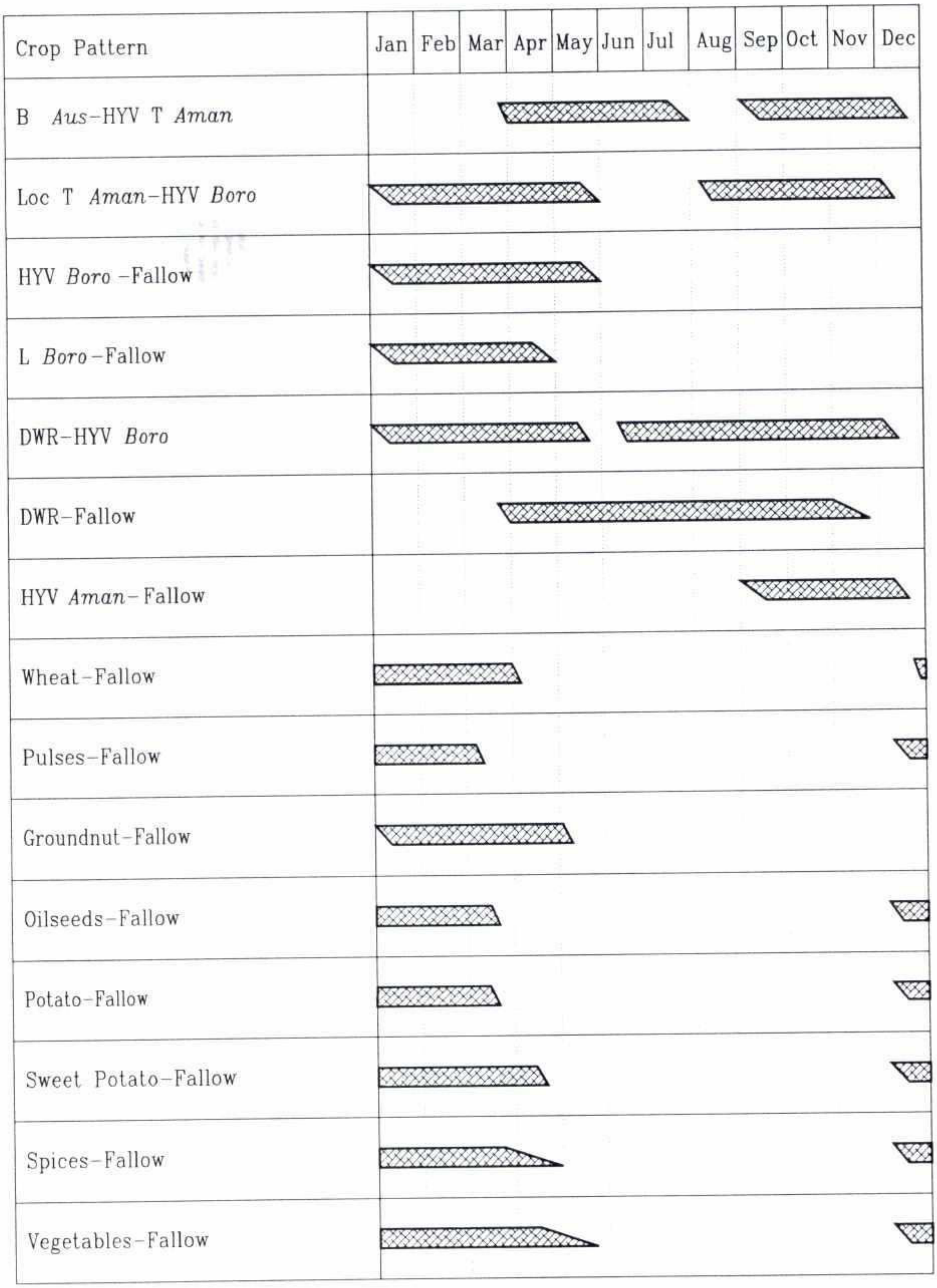
Present Crop Calendar
<0.3 m Pre-monsoon Flood Depth



Present Crop Calendar
0.3-0.9 m Pre-monsoon Flood Depth

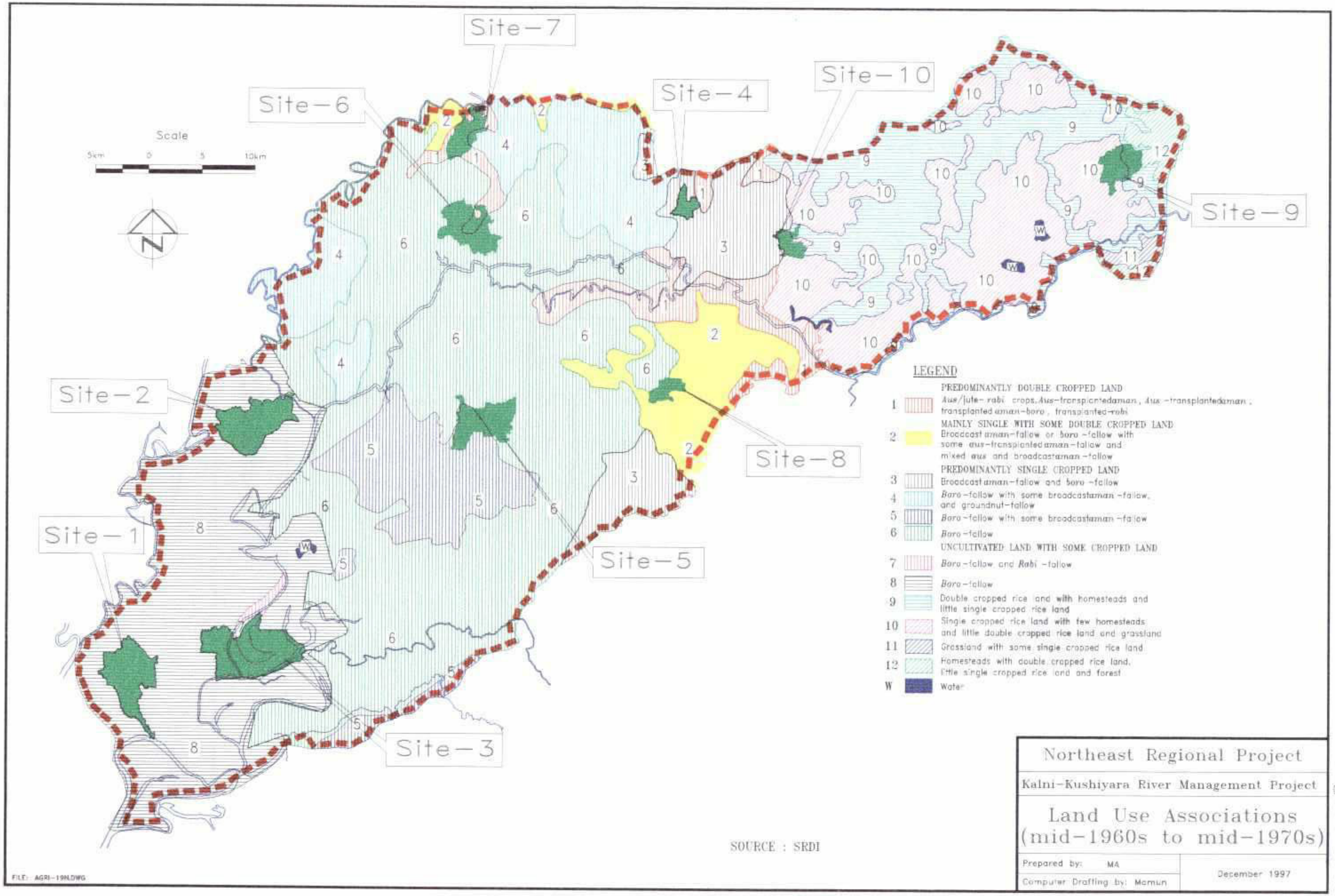


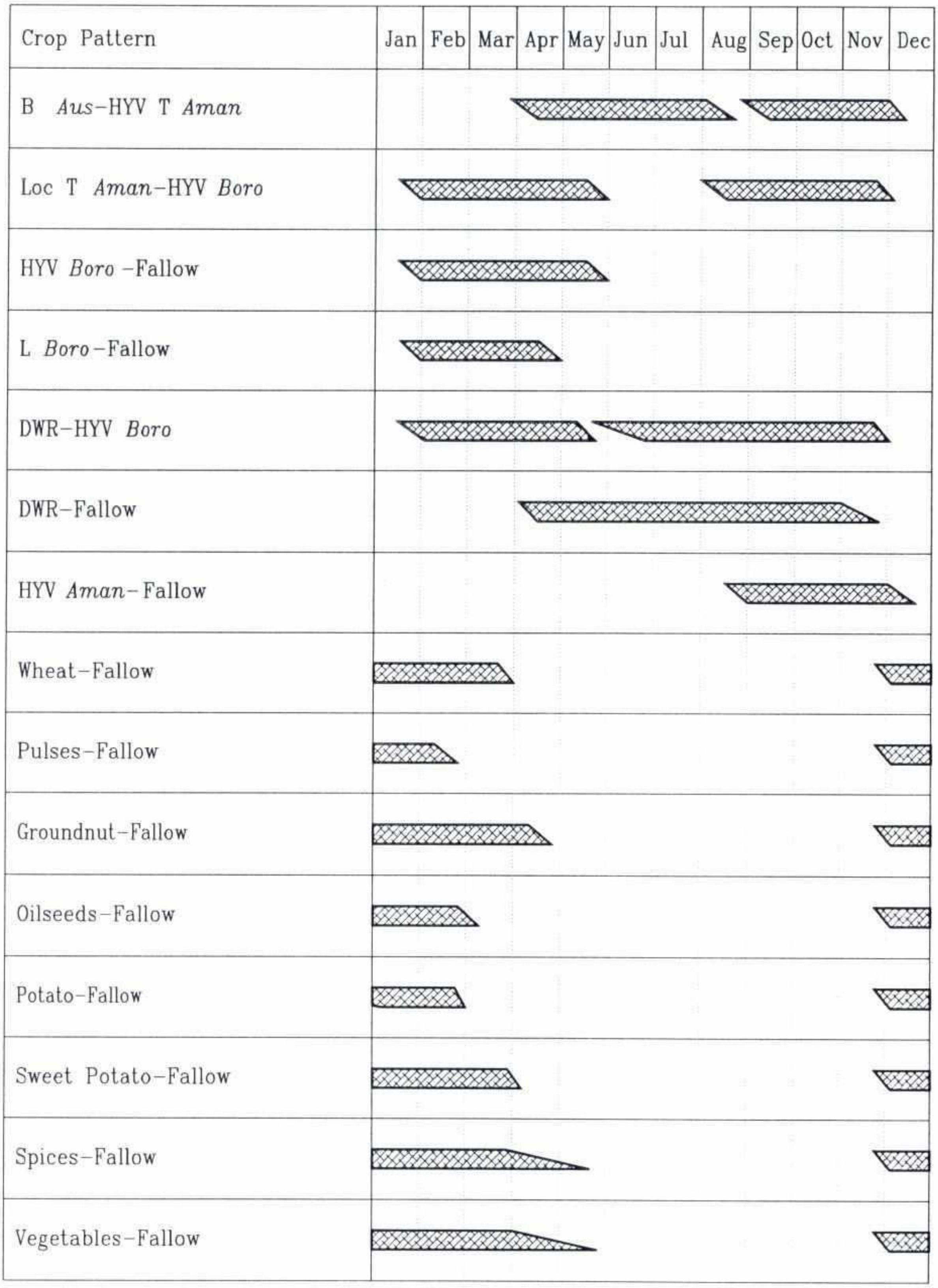
Present Crop Calendar
0.9-1.8 m Pre-monsoon Flood Depth



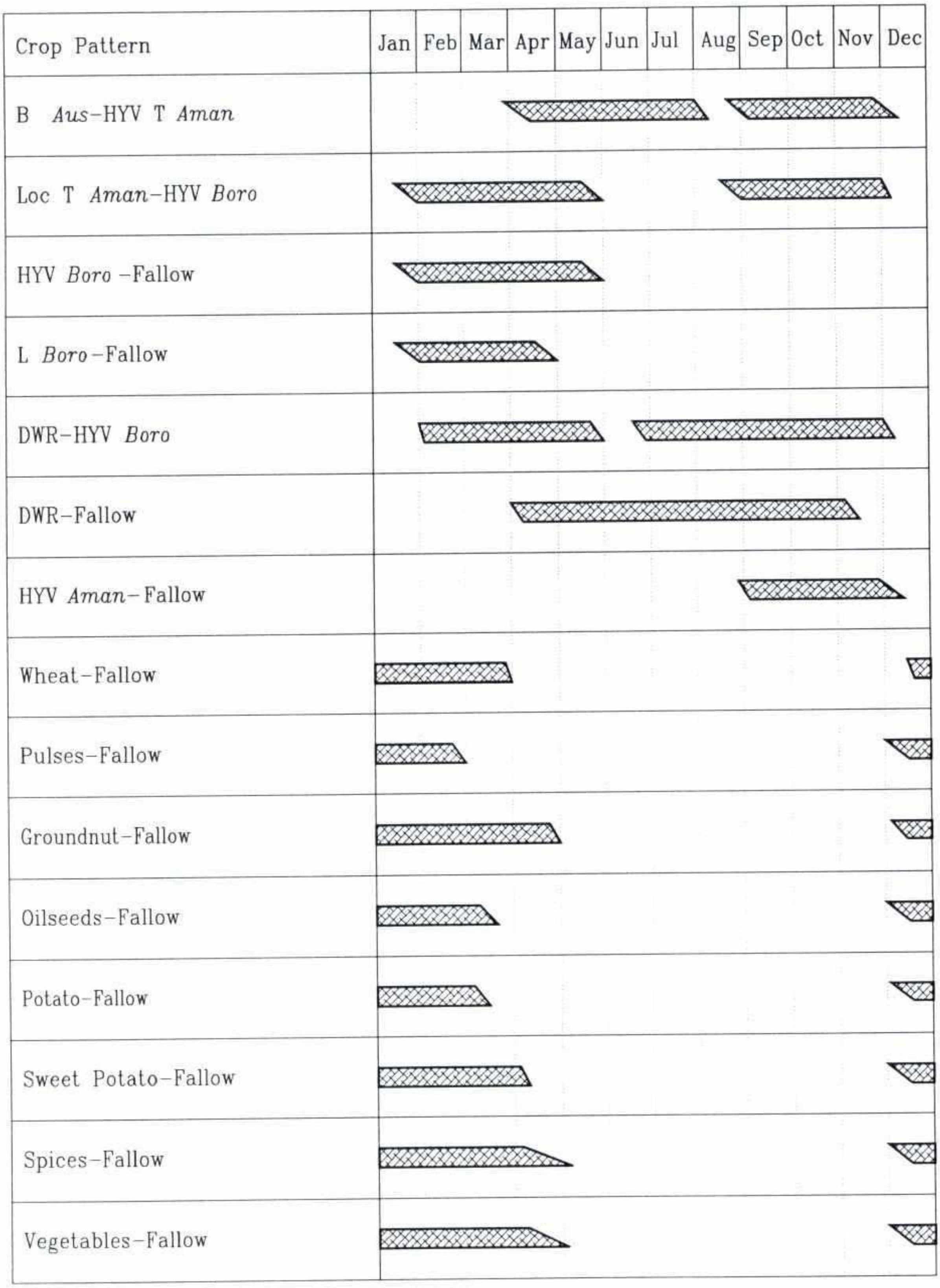
Present Crop Calendar
>1.8 m Pre-monsoon Flood Depth

Figure F.22


Site-1
Site-2
Site-3
Site-4
Site-5
Site-6
Site-7
Site-8
Site-9
Site-10
Scale
5km 0 5 10km
N
LEGEND
PREDOMINANTLY DOUBLE CROPPED LAND
1 Aus/jute-rabi crops, Aus-transplantedaman, Aus-transplantedaman, transplanted aman-boro, transplanted-rabi
MAINLY SINGLE WITH SOME DOUBLE CROPPED LAND
2 Broadcast aman-fallow or boro-fallow with some aus-transplanted aman-fallow and mixed aus and broadcastaman-fallow
PREDOMINANTLY SINGLE CROPPED LAND
3 Broadcast aman-fallow and boro-fallow
4 Boro-fallow with some broadcastaman-fallow, and groundnut-fallow
5 Boro-fallow with some broadcastaman-fallow
6 Boro-fallow
UNCULTIVATED LAND WITH SOME CROPPED LAND
7 Boro-fallow and Rabi-fallow
8 Boro-fallow
9 Double cropped rice land with homesteads and little single cropped rice land
10 Single cropped rice land with few homesteads and little double cropped rice land and grassland
11 Grassland with some single cropped rice land
12 Homesteads with double cropped rice land, little single cropped rice land and forest
W Water
SOURCE : SRDI
Northeast Regional Project
Kalni-Kushiyara River Management Project
Land Use Associations (mid-1960s to mid-1970s)
Prepared by: MA
Computer Drafting by: Mamun
December 1997
FILE: AGRI-19N.DWG

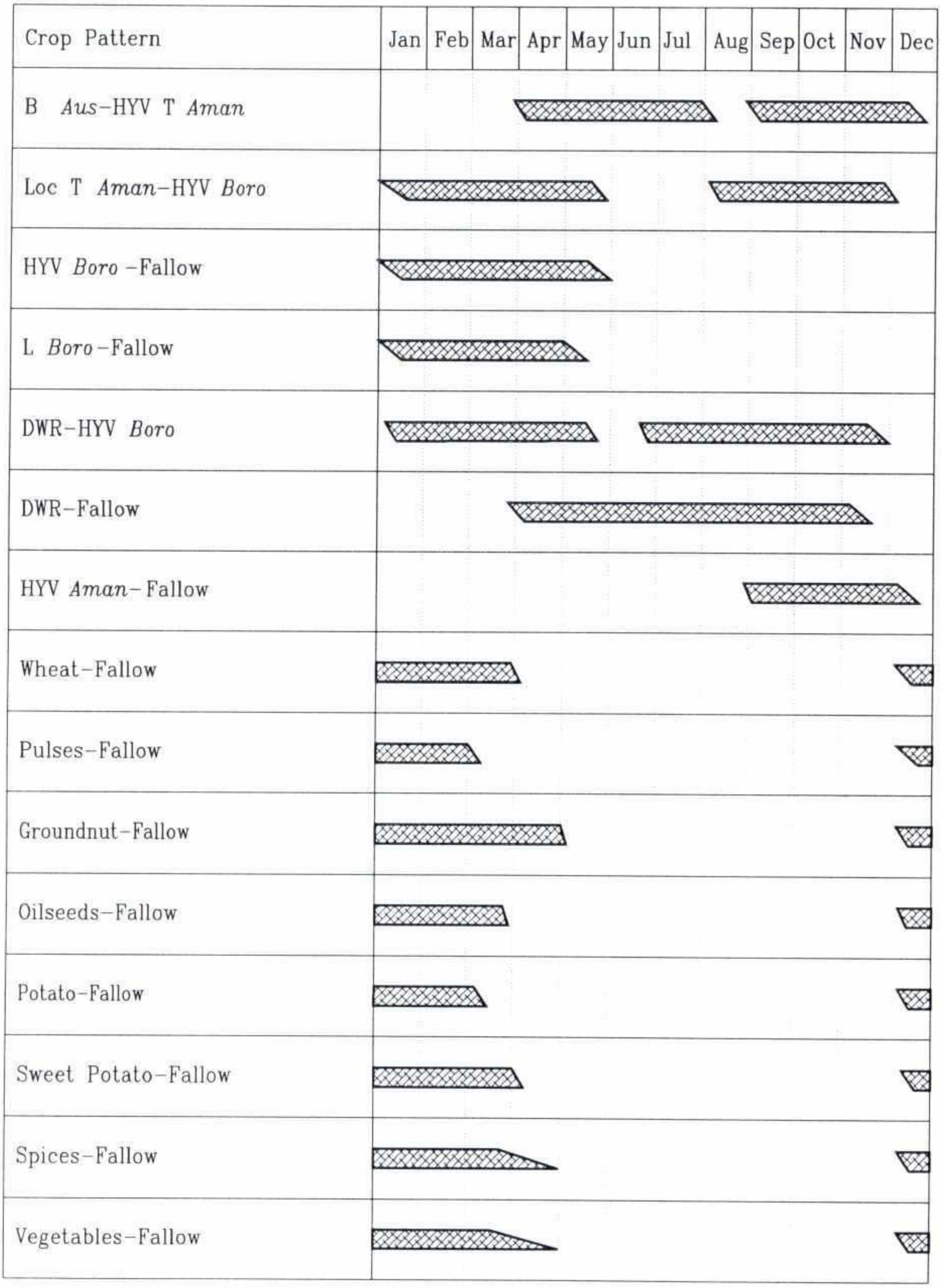


FWO Crop Calendar
<0.3 m Pre–monsoon Flood Depth



FWO Crop Calendar
0.3–0.9 m Pre-monsoon Flood Depth

Figure F.23

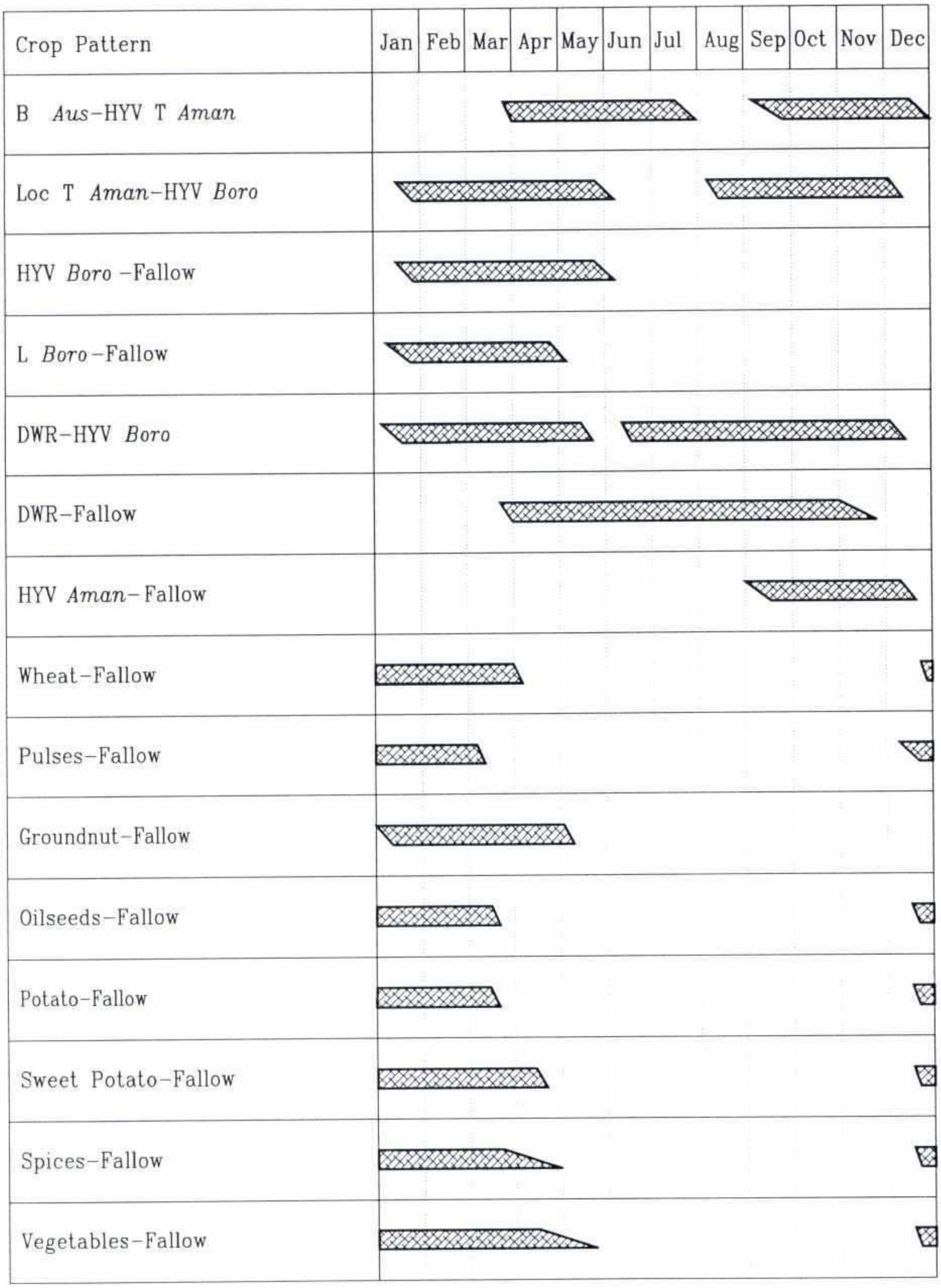


FWO Crop Calendar
0.9-1.8 m Pre-monsoon Flood Depth

Kalni-Kushiyara River Management Project

FILE: KK-166.DWG

Figure F.23

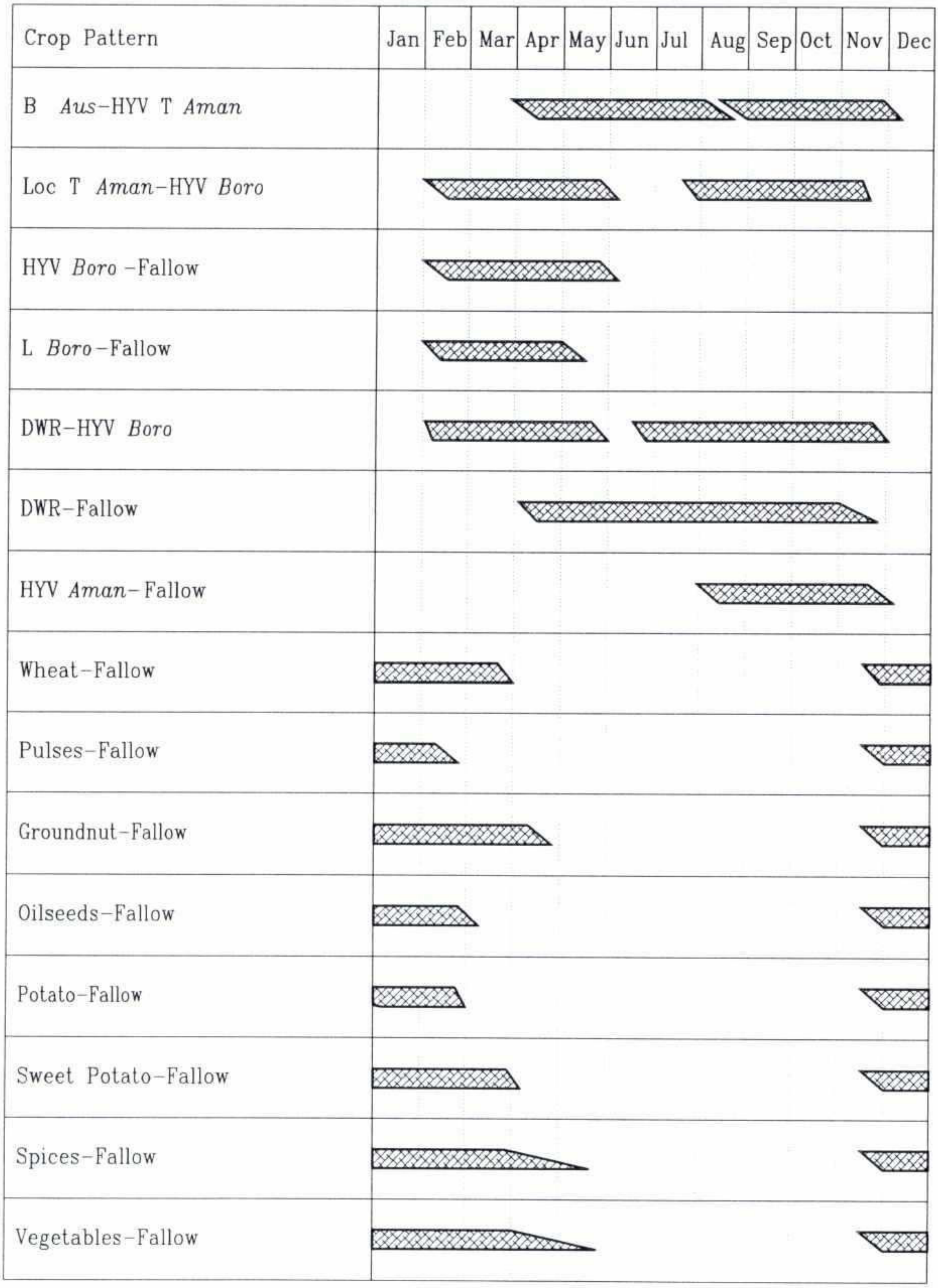


FWO Crop Calendar
>1.8 m Pre-monsoon Flood Depth

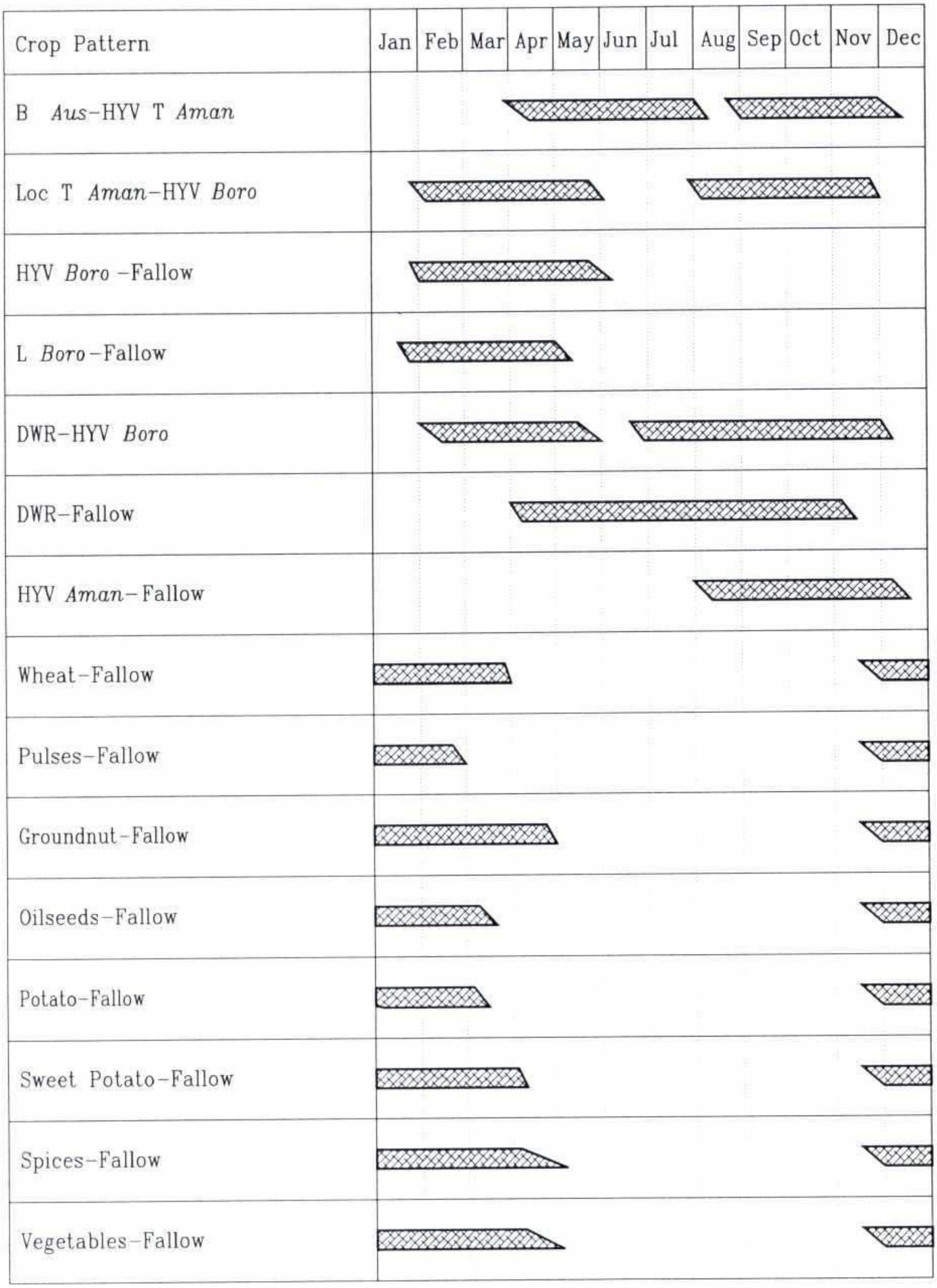
Kalni–Kushiyara River Management Project

FILE: KK–167.DWG

Figure F.24

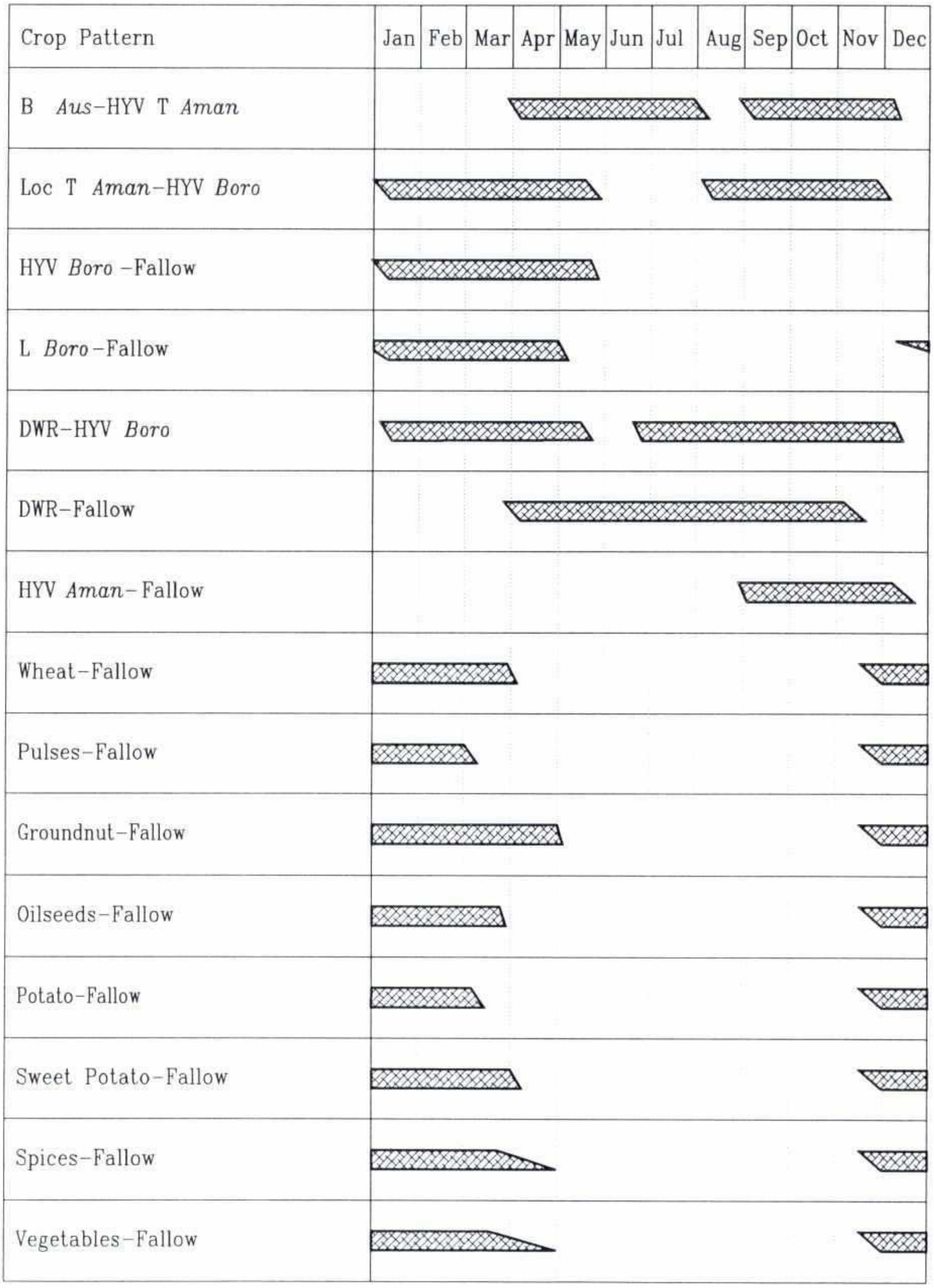


FW Crop Calendar-Alternative 1
<0.3 m Pre-monsoon Flood Depth

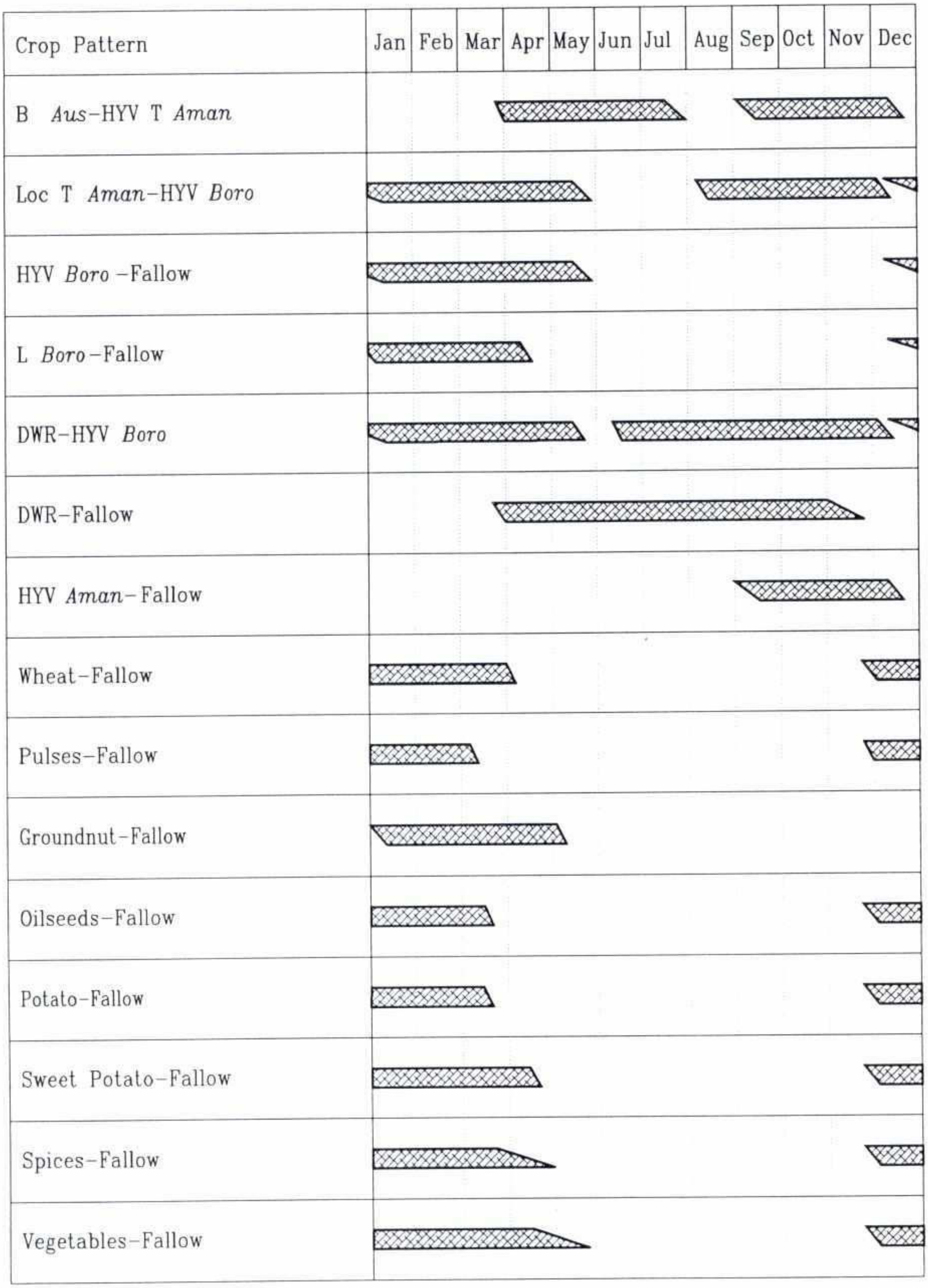


FW Crop Calendar-Alternative 1
0.3-0.9 m Pre-monsoon Flood Depth

Figure F.24



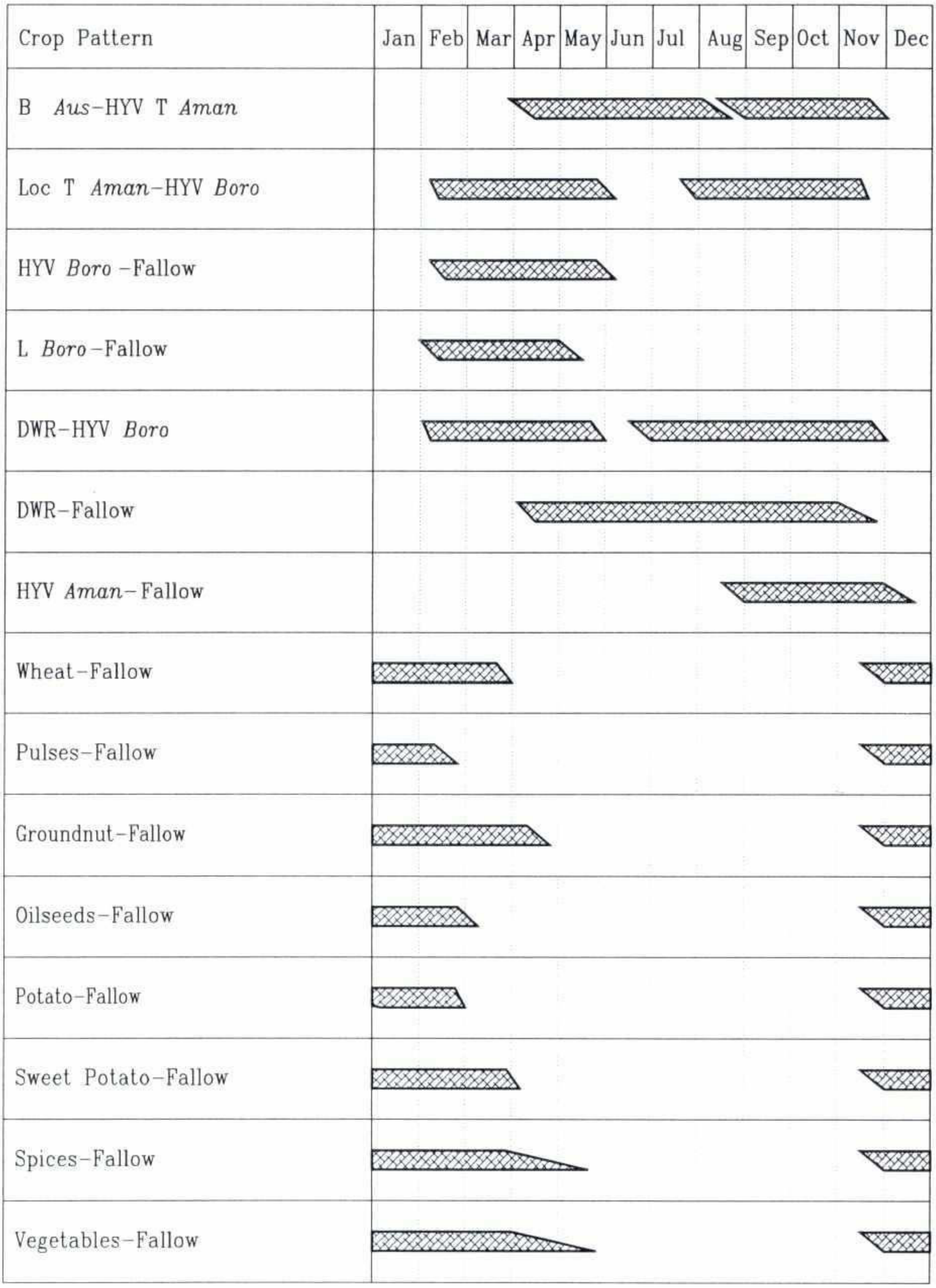
FW Crop Calendar-Alternative 1
0.9-1.8 m Pre-monsoon Flood Depth



FW Crop Calendar-Alternative 1
>1.8 m Pre-monsoon Flood Depth

28D

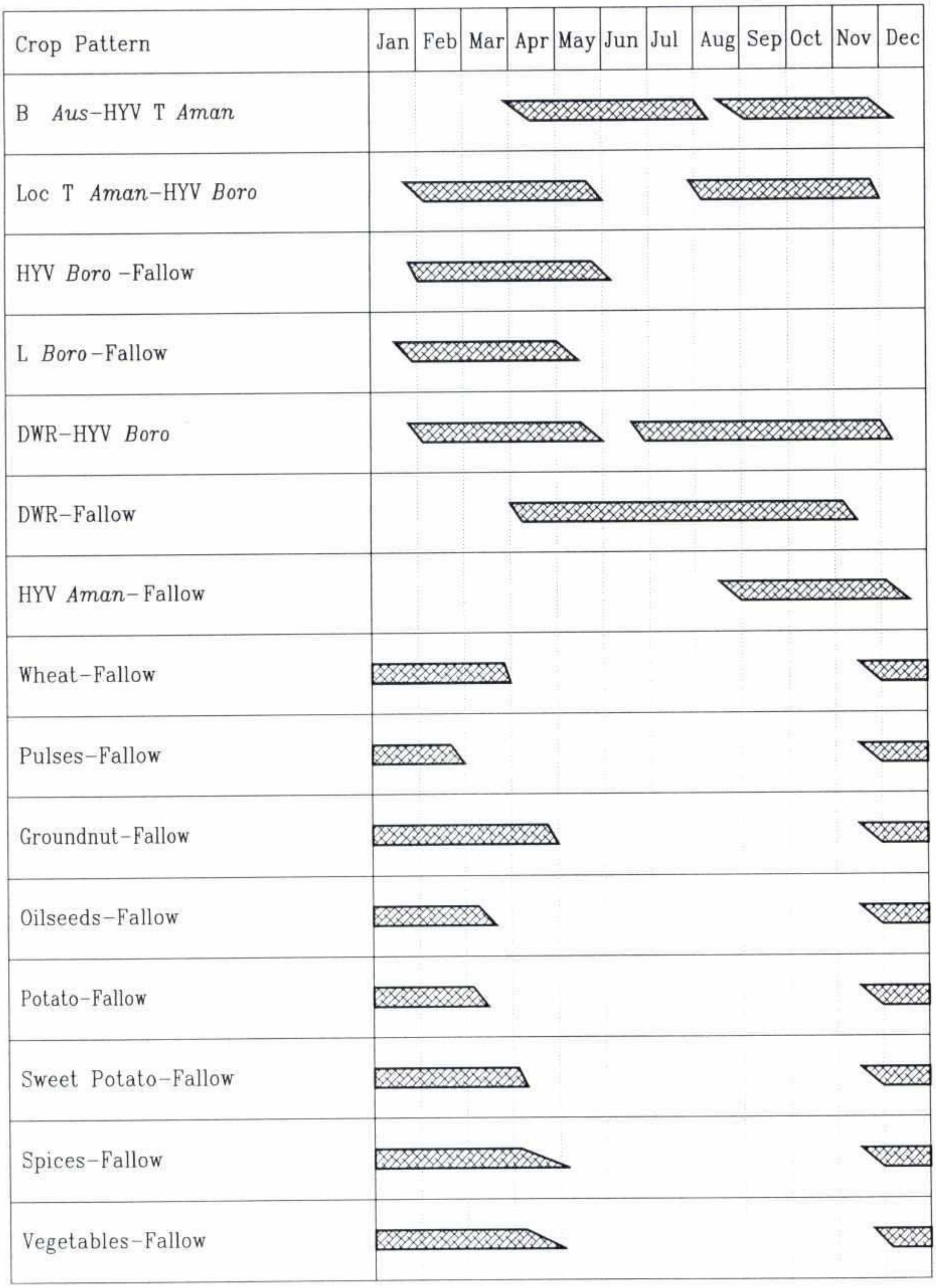
Figure F.25



FW Crop Calendar-Alternative 2
<0.3 m Pre-monsoon Flood Depth

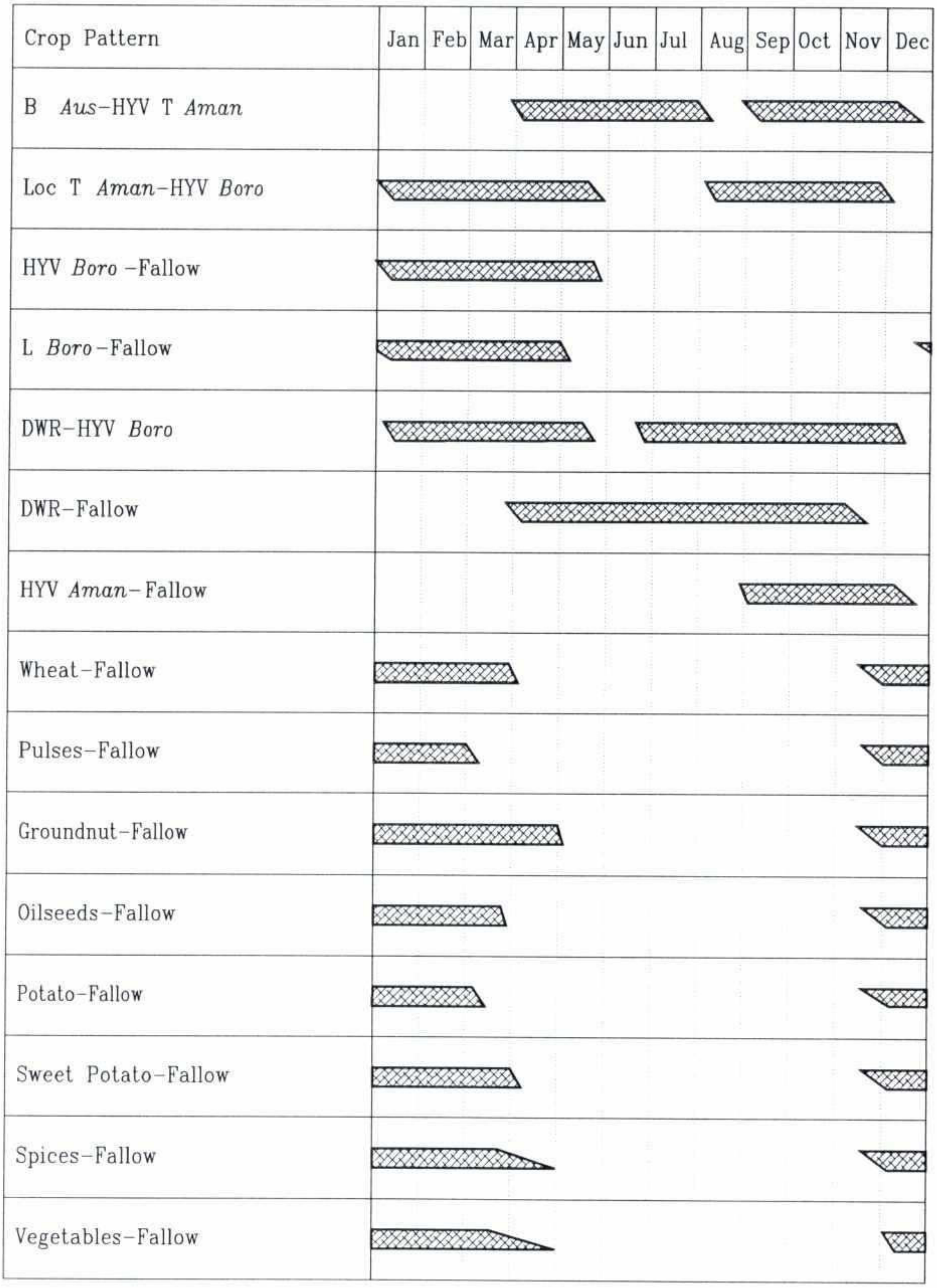
Kalni-Kushiyara River Management Project

FILE: KK-173.DWG

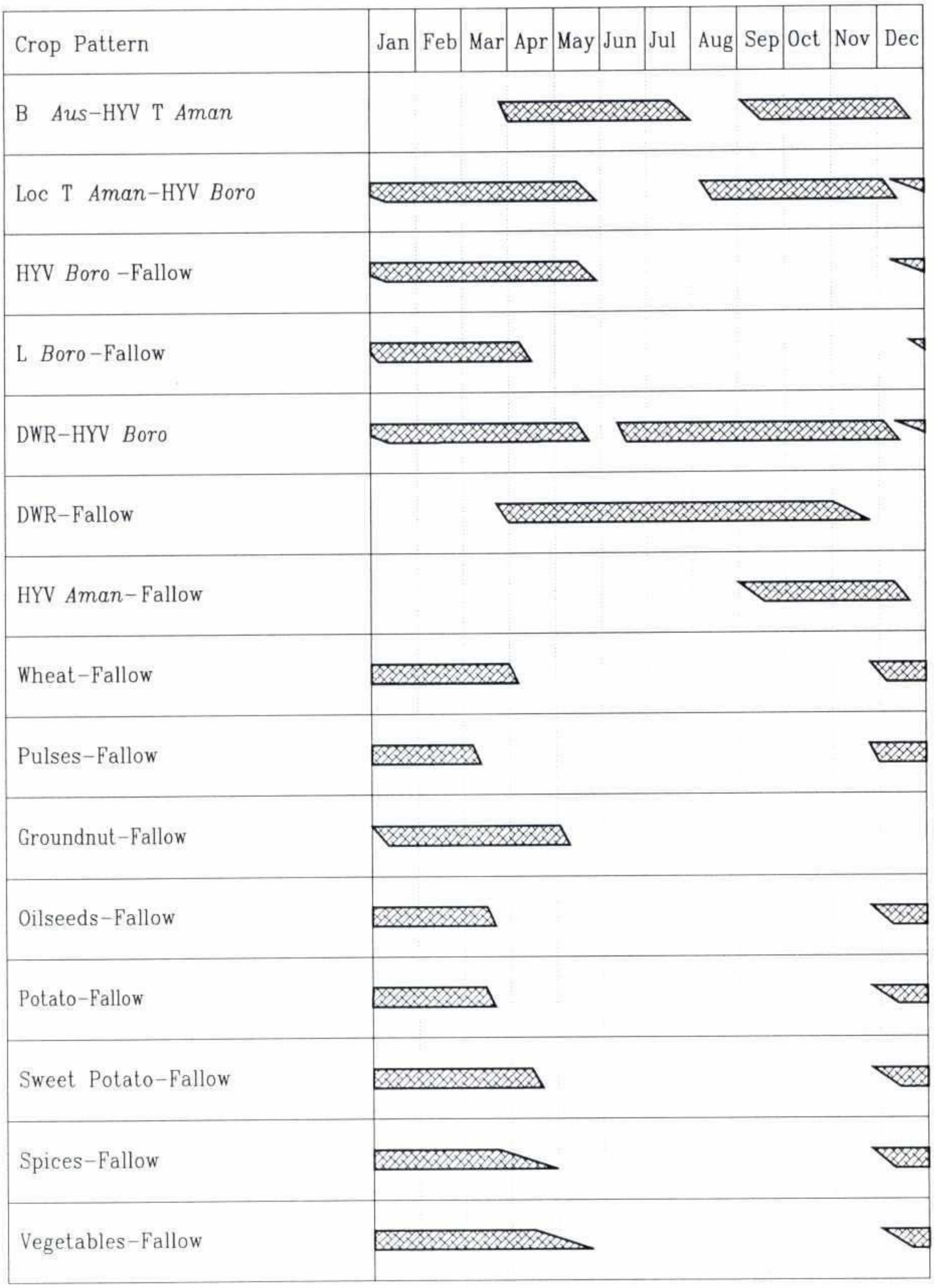


FW Crop Calendar-Alternative 2
0.3-0.9 m Pre-monsoon Flood Depth

Figure F.25



FW Crop Calendar–Alternative 2
0.9–1.8 m Pre-monsoon Flood Depth



FW Crop Calendar-Alternative 2
>1.8 m Pre-monsoon Flood Depth

KALNI-KUSHIYARA RIVER MANAGEMENT PROJECT

ANNEX F
AGRICULTURE

APPENDICES F.1 to F4

March 1998

D80

APPENDIX F.1

SOIL SERIES

1. Description of Soil Series

Thirty four soil series have been identified in the project area. Their description follows.

Ajmiriganj Series
This series consists of seasonally moderately deeply to very deeply flooded, poorly drained, fine textured soils developed in the younger Surma-Kushiyara floodplain deposits. These soils occupy about 5% of the project area. The color of the top soils and subsoil ranges from grey to strong or yellowish brown. The topsoil texture is usually clay. The structure of the subsoil is strong coarse and medium angular blocky. The general soil type of this series is Non-calcareous Grey Floodplain. Two soil phases have been recognized in the project area. These are medium lowland slow draining and lowland. Deep flooding, rapid rise of flood water, late and slow drainage, wetness in the early dry season and heavy consistence are the limitations to crop production in this area.

Astagram Series
This series consists of seasonally flooded, poorly drained soils developed in the fine textured old tidal deposits occupying nearly level very broad basins. About 4% of the project area is occupied by these soils. The topsoil color ranges from dark grey to very dark grey and the texture from silty clay loam to silty clay. In the subsoil, the color varies from dark grey to yellowish brown. The texture of the subsoil ranges from silty clay to clay. Non-calcareous Dark Grey Floodplain is the general soil type of this series. Seasonal deep flooding, rapid rise in flood levels, heavy consistence and drought in the late *rabi* season provide moderate to severe limitations to agricultural development in these soils.

Bajora Series
This series includes seasonally flooded, poorly drained, medium textured soils developed in old tidal deposits of the old Meghna estuarine floodplain. These soils occur in small areas. The topsoil color is very dark grey to strong brown. The texture of the topsoil is usually silty clay loam. Non-calcareous Grey Floodplain is the general soil type. The structure of the subsoil is weak to moderate prismatic and blocky. Shallow to moderately deep flooding, rapid rise of flood water are the limitations to crop production in these soils.

Balaganj Series
This series consists of seasonally flooded, poorly drained, medium textured soils developed on the Surma-Kushiyara floodplain. These soils cover about 1% of the project area. The topsoil color is usually grey, occasionally olive-grey with a silt loam to silty clay loam texture. The subsoil color is grey, mottled yellowish brown and dark brown. The texture of the subsoil ranges from loam to silt loam. The general soil type is Non-calcareous Grey Floodplain. Seasonal shallow to moderately deep flooding and sudden rise in flood water are the limitations to crop production in this series.

Balua Series
This series includes seasonally flooded, poorly drained, moderately fine textured soils developed in the old Meghna estuarine deposits. These soils occupy about 2-3% of the project area. The

topsoil color varies from dark grey to very dark grey and the texture from silty clay loam to clay. The subsoil color varies from very dark grey to very dark grayish brown. The texture is silty clay loam with moderate to strong coarse and medium blocky structure. Non-calcareous Dark Grey Floodplain is the general soil type. Two phases have been identified in the project area; lowland and very lowland. Seasonal shallow to very deep flooding, slow and late drainage of flood water, wetness in the early dry season, drought in the late dry season limit crop production in this area.

Bamai Series
This series consists of seasonally flooded, poorly drained clay soils developed in the old Surma-Kushiyara floodplain deposits. These soils occupy small areas. The color of the topsoil ranges from grey to brown. The texture of the topsoil is clay. The color of the subsoil is grey to yellowish brown. The texture is clay and the structure is coarse prismatic. The general soil type is Non-calcareous Grey Floodplain. Limitations to agricultural production include seasonal moderately deep to deep flooding, drought in the dry season, rapid and sudden rise of flood water, and heavy consistence.

Baniachang Series
This series consists of seasonally flooded, poorly drained, moderately fine textured soils developed in the old Meghna estuarine deposits. These soils occupy about 1-2% of the project area. The topsoil color ranges from dark grey to very dark grey and the texture from silt loam to silty clay loam. The color of the subsoil is olive to light olive-brown. The structure is usually moderate coarse prismatic. Non-calcareous Dark Grey Floodplain is the general soil type. Two soil phases have been recognized in the project area: medium lowland and lowland. Seasonal moderately deep to deep flooding, rapid and sudden rise of flood water and drought in the late dry season are the limitations to crop production in these soils.

Barlekha Series
This series includes generally steep well drained soils developed in moderately fine textured, little consolidated, folded sediments. These soils occur in minor areas on moderately to very steep topography. The topsoil color is grey to dark grey. The texture of the topsoil is sandy loam. The subsoil color is brown to strong brown and the texture is sandy loam to sandy clay loam. The general soil type is Brown Hills Soil. These soils are draughty in the late dry season.

Beanibazar Series
This series consists of generally sloping to steep, moderately well drained soils developed in fine texture, little consolidated folded deposits. These soils occur in minor areas. The color of the topsoil is brown and the texture is clay loam. The color of the subsoil is yellowish brown or strong brown and the texture is clay. Hills Soil is the general soil type. Most of this area is under homestead or thatching grass.

Bijipur Series
This series consists of intermittently flooded, poorly drained, fine sandy loam to silt loam soils developed in relatively young piedmont deposits. These soils occur in minor areas. They have a strong brown to yellowish red topsoil and a grey to olive-grey, finely mottled yellowish brown to yellowish red subsoil. Both topsoil and subsoil consist of a very fine sandy loam. The subsoil structure is prismatic. The general soil type is Grey Piedmont. The soils are intermittently flooded to a shallow depth for a few hours to a few days after heavy monsoon rainfalls, they are poorly drained and become draughty in the dry season.

Derai Series
This series consists of deeply to very deeply flooded, very poorly drained soils. These soils occupy level basin depressions on the Surma-Kushiyara floodplain. They occupy about 1% of the project area. The topsoil color is grey. The texture of the topsoil is clay. The subsoil color is greenish grey to bluish grey and its texture varies from silty clay to clay. The general soil type is Non-calcareous Alluvium. Seasonally deep flooding, late drainage and wetness throughout the dry season are the limitation to agricultural production.

Goyainghat Series
This series includes seasonally flooded, poorly drained, fine textured soils developed on the Surma-Kushiyara floodplain. These soils occupy 8-9% of the project area. The topsoil color is usually grey and the texture ranges from silt loam to silty clay loam. The subsoil color is usually grey, occasionally olive grey, mottled and yellowish brown or strong brown. The structure of the subsoil is moderate coarse, medium prismatic and blocky. Non-calcareous Grey Floodplain is the general soil type. Five soil phases have been identified in the study area; medium highland, medium lowland normal flood,medium lowland flood hazard, deeply flooded and normal. Moderately deep flooding and drought in the dry season limit crop production.

Hakaluki Series
This series consists of seasonally flooded, perennially wet peat or muck peat. These soils occur in minor areas. The color of the topsoil and subsoil is very dark grey. The texture of the topsoil is silt loam and that of the subsoil is peaty muck. The thickness of the organic layer ranges from 10 cm to 25 cm. The general soil type is Peat. Seasonal moderately deep flooding, poor drainage, perennial wetness, low bearing capacity provide severe limitations to agricultural production in these soils.

Humayunpur Series
This series includes seasonally flooded, poorly drained soils developed in moderately fine textured sediments of the old Meghna estuarine floodplain. These soils occur in minor areas. The topsoil color ranges from grey to dark grey and its texture is silt loam. Subsoils are usually grey. The structure of the subsoil ranges from weak to moderate coarse to very coarse prismatic. The texture of the subsoil is usually silt loam. The general soil type is Non-calcareous Dark Grey Floodplain. Seasonal flooding, accompanied by rapid rise of flood water is the limitation to crop production.

Ikram Series
This series consists of intermittently and seasonally flooded, imperfectly to poorly drained, medium textured soils. These soils occupy upper and middle parts of low ridges on the old Meghna estuarine floodplain. They occur in minor areas. The color of the topsoil is grey and its texture is loam. The subsoil color is light olive brown. Its texture is loam to sandy loam. Non-calcareous Grey Floodplain is the general soil type. Shallowly to moderately deeply flooding is the limitation to cropping in these soils.

Itkhola Series
This series includes poorly drained intermittently flooded soils developed in recent clayey piedmont deposits. These soils occur in valleys in association with Manu, Pritimpasa, Barlekha and Kulaura series. They occupy a small area. They have a grey-finely mottled silty clay to clay topsoil with massive or cloddy structure. The texture of the topsoil is silty clay loam. The subsoil is grey to light grey mottled yellowish brown, friable or slightly plastic and strongly sticky silty clay to clay. The general soil type is Brown Hills Soil. These soils are subject to

intermittent flooding after heavy rain. On most of the soils water is ponded for rice cultivation. The soils remain moist for about 2 months, until the middle of the dry season.

Kadipur Series
This series consists of poorly drained, seasonally flooded soils developed in recent floodplain alluvium of the Kushiyara River and its southern tributaries. These soils occur in minor areas in very gently to gently undulating basins. The topsoil color ranges from dark grayish brown to greenish grey, and the structure from silty clay loam to silty clay. The subsoil color is greenish grey with medium distinct strong brown mottles. Its structure is weak medium angular block. Non-calcareous Alluvium is the general soil type. Deep flooding, sudden rise of flood water, late drainage, wet or moist soils in the early dry season, and draughty in the late dry season are the limitations to cropping.

Kanairghat Series
This series consists of seasonally flooded, poorly drained, seasonally dry soils developed in recent clayey floodplain alluvium of the Surma and Kushiyara Rivers and their tributaries. These soils occur on levees and levelled-out abandoned levee complexes. They occupy some 9% of the project area. The color of the topsoil is olive grey. Its texture is finely mottled, friable silt loam to silty clay. The subsoil color is yellowish brown. The texture of the subsoil ranges from silty clay to clay, and its structure from coarse and medium angular blocky to coarse prismatic. The general soil type is Non-calcareous Grey Floodplain. Five phases have been recognized in the project area; medium highland, medium lowland phase normal flood, medium lowland flood hazard, deeply flooded, and normal. Shallow to deep flooding, late drainage, moist soil in the early dry season, drought in the late dry season are limitations to crop production.

Khadimnagar Series
This series consists of generally steep, well drained soils developed in moderately coarse textured, unconsolidated, folded sediments. These soils occur on moderately to very steep topography, in strongly dissected low hill ranges in association with Barlekha and Bijipur series. They occupy a very small area. They have a dark yellowish brown to pale brown very friable to friable sandy topsoil. The structure of the subsoil is granular to fine angular blocky wormcast overlying a dark yellowish brown to brownish yellow friable sandy loam to loamy sand. The general soil type is Acid Basin Clay. These soils are draughty in the late dry season.

Kulaura Series
This series includes well drained, fine textured soils developed on steep to very steep, strongly dissected hills. They are associated with Barlekha and Ghosgaon series on the adjoining hills and Pritimpasa series in the valleys. These soils occupy a small area. The topsoil color is strong brown and its texture varies from clay loam to clay. The color of the subsoil varies from yellowish red to strong brown and its texture from silty clay to clay. The general soil type is Brown Hill. The soils are very steep and subject to severe erosion.

Kushiyara Series
This series includes poorly drained seasonally flooded, seasonally dry soils developed in the recent floodplain alluvium of the Kushiyara River and its tributaries. These soils occur in minor areas. The topsoil color ranges from light brownish grey to grey or olive, its texture from fine sandy loam to silty clay loam, and its structure from massive or platy to moderate coarse angular blocky. The color of the subsoil ranges from greenish grey to olive, and its texture from loam to silty clay loam. It is massive or platy, the consistence is friable when moist to plastic, and non

sticky when wet. Non-calcareous Alluvium is the general soil type. Moderately deep flooding, late drainage, moist soil until the late dry season limit crop production.

Madhabpur Series
This series comprises seasonally flooded, poorly drained, medium textured soils developed in the old Meghna estuarine deposits. These soils occupy about 4-5% of the project area. The color of the topsoil varies from dark grey to very dark grey and its texture is usually silt loam, occasionally silty clay loam. The color of the subsoil color varies from olive to light olive-brown and its structure from weak to moderate coarse prismatic and blocky. The general soil type is the Non-calcareous Dark Grey Floodplain. Two phases have been identified in the project area; medium lowland flood hazard and lowland. Shallow to deep flooding, drought in the late dry season, occasional rapid rise of floodwater, and wetness in the early dry season limit crop production.

Madhyanagar Series
This series includes seasonally flooded, poorly drained, medium textured soils developed in young Surma-Kushiyara alluvium. These soils occupy about 2-3% of the project area. They occur at the margins of basins and in inter-ridge depressions. The topsoil is grey and consists of silt loam. The color of the subsoil color is mottled yellowish brown. It is a silt loam. Non-calcareous Grey Floodplain is the general soil type. Seasonally moderately deep to deep flooding, rapid and sudden rise of flood water and wetness in the early dry season are the major limitations to agricultural production.

Manu Series
This series consists of poorly drained soils developed on sub-recent piedmont flats. These soils occupy a small area. They occur on nearly level piedmont alluvial plains in association with Pritimpasa, Jhenaigati and Ramnagar series. The color of the topsoil varies from light olive-grey to light grey with common fine distinct strong brown mottles, and its texture varies from clay loam to silty clay. The subsoil is grey to yellowish brown and its texture varies from clay to clay loam. Non-calcareous Grey Floodplain is the general soil type. The soils are shallowly or intermittently flooded from rainfall.

Phagu Series
This series consists of seasonally flooded, poorly drained, fine textured soils developed in the Surma-Kushiyara floodplain alluvium. These soils occupy about 20% of the project area. They occur in nearly level to gently undulating basins. The color of the topsoil varies from grey to dark grey and its texture from silty clay to clay. The color of the subsoil is usually grey, occasionally dark grey. Its texture varies from silty clay to clay. The general soil type is Non-calcareous Grey Floodplain. Eight phases have been identified in the project area; medium highland, medium lowland normal flooding, medium lowland flood hazard, lowland, lowland flood hazard, lowland slow draining, rapidly flooded, and normal. Seasonal shallow to deep flooding, rapid and sudden rise of flood water, late and slow drainage, wetness in the early dry season, drought in the late dry season, and heavy consistence provide moderate to severe limitations for agricultural development.

Pritimpasa Series
This series includes intermittently flooded, poorly drained, moderately fine textured soils developed in relatively young piedmont deposits. These soils occupy a small area. The topsoil is olive-grey to light brownish grey and its texture varies from loam to clay loam. The subsoil is grey to olive-grey or mottled yellowish brown to yellowish red. The subsoil texture is clay

loam and its structure is moderate prismatic and patchy along red faces and pores. The general soil type of this series is Grey Piedmont. These soils occupy nearly level to very gently sloping piedmont deposits. Intermittent flooding to a shallow depth from a few hours to a few days after heavy monsoon rainfall, sometimes accompanied by rapid rise and/or onrush of flood-water are the limitations to crop production.

Rauli Series
This series consists of seasonally flooded, poorly drained, moderately fine textured soils developed in the old Surma-Kushiyara floodplain. These soils occur in minor areas. They occupy upper to middle slopes of very gently undulating ridges. Both topsoil and subsoil are grayish brown to dark grayish brown. The texture of the topsoil varies from silt loam to silty clay loam. The texture of the subsoil is usually silty clay loam and its structure is weak to moderate prismatic and angular blocky. The general soil type is the Non-calcareous Grey Floodplain. Two phases have been identified in the project area; medium highland and medium lowland. Seasonal shallow to moderately deep flooding and rapid rise of flood water limit crop production.

Richi Series
This series consists of seasonally flooded, poorly drained, moderately fine textured soils developed in the old Meghna estuarine deposits. These soils occupy about 9-10% of the project area. They occur in nearly level broad basins. The color of the topsoil varies from grey to dark grey, occasionally very dark grey and its texture from silt loam to silty clay loam. The color of the subsoil varies from grey to dark grey and its structure is usually moderately coarse prismatic. Non-calcareous Dark Grey Floodplain is the general soil type. Four phases have been recognized in the project area; nearly level basin/lowland, medium lowland flood hazard, lowland slow draining, lowland flood hazard. Seasonal shallow to deep flooding, flood hazard, late and slow drainage, wetness in the dry season are the agricultural limitations.

Sangar Series
This series includes intermittently and seasonally flooded, imperfectly to poorly drained, moderately fine textured soils, developed in the old Meghna estuarine deposits. These soils occupy about 1% of the project area. They occur on ridges. These soils have light olive-brown to olive-brown, silty clay loam, friable subsoils with weak to moderate coarse prismatic and blocky structure. The general soil type is Non-calcareous Grey Floodplain. Intermittent wetness, seasonally shallow to moderately deep flooding are the limitations to crop production.

Silty Surma-Kushiyara Alluvium Series
This series is a miscellaneous soil type. It includes seasonally flooded poorly drained, almost raw silty spill deposits of Surma and Kushiyara Rivers. These soils occur in minor areas. They occupy very gently undulating ridges. The general soil type is Non-calcareous Alluvium. Both topsoil and subsoil are generally grey to olive-grey. The texture of the topsoil is silty clay loam. The texture of the subsoil varies from silt loam to silty clay loam with little or no profile development. Seasonal flooding, doughtiness in the dry season and risk of river erosion or burial by fresh alluvium provide severe limitations to cropping.

Srighar Series
This series includes seasonally flooded, poorly drained soils. These soils occur in minor areas. The topsoil is usually dark grey and its texture silty clay. The color of the subsoil varies from dark grayish brown to very dark grayish brown. The texture of the subsoil is generally silty clay

loam, rarely silty clay. Non-calcareous Dark Grey Floodplain is the general soil type. Limitations to crop production in these soils include very deep seasonal flooding and rapid rise of flood water.

Sullah Series
This series consists of seasonally moderately deeply to very deeply flooded, very poorly drained, fine textured, strongly gleyed soils developed in basin deposits of the young Surma-Kushiyara floodplain. These soils occupy about 13% of the project area. They occur in gently undulating inter-ridge depressions and basin depressions. The topsoil color is bluish grey, occasionally greenish grey or neutral grey and its texture varies from silty clay loam to clay. The subsoil is grey and its texture varies from silty clay to clay. Its structure is weak to moderate coarse prismatic and angular blocky. Acid Basin Clay is the general soil type. Three phases have been identified in the project area; medium lowland, lowland and depressions. Seasonal moderately deep to very deep flooding, rapid rise of flood water, flood hazard, heavy consistence and perennial wetness are the severe limitations to agricultural production in these soils.

Tajpur Series
This series consists of seasonally flooded, poorly drained, seasonally dry clay soils developed in sub-recent floodplain basin deposits of the Surma-Kushiyara river system. These soils occupy a very small area. They occur in level or slightly depressed areas. The topsoil color varies from grey to dark grey. The texture of the topsoil ranges from clay to silty clay. The subsoil is dark grey to very dark grey, mottled yellowish brown to strong brown. Its texture varies from silty clay to clay. Acid Basin Clay is the general soil type. These are seasonally flooded soils. They remain wet for most of the dry season.

Terchibari Series
This series includes seasonally moderately deeply to very deeply flooded, very poorly drained, permanently wet clay soils developed in sub-recent floodplain basin sediments of the Surma and Kushiyara Rivers and their tributaries. These soils occur in small closed basin depressions. They occupy some 6% of the project area. The color of the topsoil varies from dark greenish grey to very dark grey. It consists of sticky clay with generally cloudy structure. The subsoil is grey to dark grey and consists of sticky clay with a massive or angular blocky structure. The general soil type is Acid Basin Clay. Two soil phases have been recognized in this series; lowland and very lowland. Seasonal deep to very deep flooding, perennial wetness and heavy consistence are the severe limitations to cropping.

2. Extent of Soil Series in Project Area

The area of each soil series within each soil association was evaluated from the information available in the SRDI soil survey reports (SRDI 1976, 1977, 1986). The areas are presented in Table 1. For reference, the names of the soil associations are presented in Table 2. The area occupied by each soil series in the project area is presented in Table 3.

3. Crop Suitability Ratings

Table 4, also adapted from the information available in the SRDI soil survey reports gives the crop suitability rating of the soils in their various land phases for a number of crops adapted to the environment. The SRDI reports specify that the ratings are based on scanty data and should not be regarded as final.

Table 1: Distribution of Soil Series in Soil Associations (page 1 of 2)

	Soil Series	Land Phase	SRDI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
				Area of Soil Series in Soil Association (ha)																				
1	Ajmiriganj	Lowland	1977															0.34						
		Medium lowland slow draining	1976			17.31																		
2	Astagram	Nearly level basin, lowland	1977															3.06						10.31
3	Bajora	Broad ridge, lowland	1977																					1.29
4	Balaganj	Medium highland	1976	0.65	2.02		0.70															0.30		
		Medium highland	1986																				0.73	
5	Balua	Lowland	1976											1.45										
		Very lowland	1976												6.49									
6	Bamai	Lowland	1976							0.50														
7	Baniachang	Medium lowland	1976											1.45										
		Lowland	1976											1.45	2.16									
8	Barlekha		1986														0.70							
9	Beanibazar		1986														0.09							
10	Bijipur		1986														0.09							
11	Derai	Lowland	1976										0.53											
		Very lowland	1976								0.62		1.05											
12	Goyainghat	Medium highland	1976	0.97	18.15		1.40																	
		Medium lowland-Normal flood	1976									0.89												
		Deeply flooded	1986																1.68					
		Normal	1986																	0.36			0.58	
		Medium lowland-Flood hazard	1976			4.33																0.15		
13	Hakaludi		1977																					
14	Humayunpur		1977																					
15	Ikram	Medium highland	1976											1.45										
16	Itkhola		1986														0.03							
17	Kadipur		1986													0.72	0.03		0.16				0.15	
18	Kanairghat	Medium highland	1976		12.10																			
		Deeply flooded	1986													0.10			2.05		1.83			
		Medium lowland-Flood hazard	1976			4.33			0.41	0.25	0.31											0.76		
		Medium lowland-Normal flood	1976	0.11			2.10	1.97				0.89	0.26											
		Normal	1986																	2.51				
19	Khadimnagar		1986														0.03							
20	Kulaura		1986														0.52							
21	Kushiyara		1986													0.10	0.03		0.16					
22	Madhabpur	Medium lowland-Flood hazard	1976											8.68										
		Lowland	1976											4.34	2.16									

Table 1: Distribution of Soil Series in Soil Associations (page 2 of 2)

	Soil Series	Land Phase	SRDI	Area of Soil Series in Soil Association (ha)																				
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
23	Madhyanagar	Lowland	1976			8.66																		
24	Manu		1986														0.03							
25	Phagu	Medium highland	1976		2.02																			
		Lowland	1977															0.34						
		Medium lowland-Normal flood	1976				7.02	8.85				3.55												
		Medium lowland-Flood hazard	1976						0.82															
		Lowland-Flood hazard	1976						2.05	2.48	2.16		0.53											
		Lowland slow draining	1976					3.93				1.78												
		Rapidly flooded	1986													0.05					29.26			
		Normal	1986																	0.36				
26	Pritimpasa		1986														0.03							
27	Rauli	Medium highland	1976						0.20															
		Medium lowland	1976								0.31													
28	Richi	Nearly level basin, lowland	1977															2.04						12.89
		Medium lowland-Flood hazard	1976											4.34										
		Lowland-Slow draining	1976												10.81									
		Lowland-Flood hazard	1976											1.45										
29	Sangar	Medium lowland	1976											2.89										
30	Silty KK		1977																			1.36		
31	Srighar	Lowland	1977															0.34						1.29
32	Sullah	Medium lowland	1976			8.66																		
		Lowland	1976			34.63																		
		Depression, lowland	1977															0.34						
33	Tajpur		1977																					
34	Terchibari	Lowland	1976				0.70	1.97	0.41	1.49	0.31	9.76	0.53									0.15		
		Very lowland	1976								2.16		2.10											
		Lowland	1986																		1.46			
	Homestead			0.43	6.05	4.33	2.10	0.98	0.20							0.01	0.05	0.20	0.04	0.07	4.02	0.15		
	Haor/beel					4.33		1.97		0.25	0.31	0.89	0.26	1.45		0.04	0.09	0.14		0.29		0.15		
	Area of Soil Association ('000ha)			2.16	40.33	86.57	14.03	19.67	4.09	4.95	6.16	17.75	5.25	28.93	21.62	1.03	1.74	6.81	4.10	3.58	36.58	3.02	1.45	25.78

Source: SRDI, 1976, 1977, 1986

Table 2: Soil Associations of Project Area

Sl. No.	Name of Soil Association	('000 ha)	Percent of Total Area (%)
1	Goyainghat-Balaganj	2.16	0.64
2	Goyainghat-Kanairghat	40.33	12.02
3	Sullah-Ajmiriganj	86.57	25.80
4	Phagu-Kanairghat	14.03	4.18
5	Phagu (ML)	19.67	5.86
6	Phagu (L)	4.09	1.22
7	Phagu-Terchibari (L)	4.95	1.47
8	Phagu-Terchibari (VL)	6.16	1.84
9	Terchibari-Phagu	17.75	5.29
10	Terchibari-Derai	5.25	1.56
11	Madhabpur-Richi (ML)	28.93	8.62
12	Richi-Balua	21.62	6.44
13	Kadipur Complex	1.03	0.31
14	Beani Bazar Complex	1.74	0.52
15	Astagram-Richi	6.81	2.03
16	Goyainghat-Kanairghat (DF)	4.10	1.22
17	Kanairghat-Phagu	3.58	1.07
18	Phagu	36.58	10.90
19	Sullah-Kanairghat	3.02	0.90
20	Balaganj-Goyainghat	1.45	0.43
21	Richi-Astagram	25.78	7.68
	TOTAL	**335.60**	**100.00**

Legend: ML: Medium lowland phase, L: Lowland phase, VL: Very lowland phase, DF: Deeply flood phase

Table 3: Distribution of Soil Series in Project Area (page 1 of 2)

	Soil Series	Land Phase	Area ('000 ha) Land Phase	Area ('000 ha) Soil Series	% of Project Area
1	Ajmiriganj	Lowland	0.34		
		Medium lowland slow draining	17.31	17.65	5.2
2	Astagram	Nearly level basin, lowland	13.38	13.38	4.0
3	Bajora	Broad ridge, lowland	1.29	1.29	0.4
4	Balaganj	Medium highland	4.50	4.40	1.3
5	Balua	Lowland	1.45		
		Very lowland	6.49	7.94	2.4
6	Bamai	Lowland	0.50	0.50	0.1
7	Baniachang	Medium lowland	1.45		
		Lowland	3.61	5.06	1.5
8	Barlekha		0.70	0.70	0.2
9	Beanibazar		0.09	0.09	<0.1
10	Bijipur		0.09	0.09	<0.1
11	Derai	Lowland	0.53		
		Very lowland	1.67	2.20	0.7
12	Goyainghat	Medium highland	20.52		
		Medium lowland-Normal flood	0.89		
		Deeply flooded	1.68		
		Normal	0.94		
		Medium lowland-Flood hazard	4.48	28.51	8.5
13	Hakaludi		Minor	Minor	<0.1
14	Humayunpur		minor	Minor	<0.1
15	Ikram	Medium highland	1.45	1.45	0.4
16	Itkhola		0.03	0.03	<0.1
17	Kadipur		1.06	1.06	0.3
18	Kanairghat	Medium highland	12.10		
		Deeply flooded	3.98		
		Medium lowland-Flood hazard	6.05		
		Medium lowland-Normal flood	5.33		
		Normal	2.51	28.97	8.6
19	Khadimnagar		0.03	0.03	<0.1
20	Kulaura		0.52	0.52	0.2
21	Kushiyara		0.30	0.30	0.1
22	Madhabpur	Medium lowland-Flood hazard	8.68		
		Lowland	6.50	15.18	4.5
23	Madhyanagar	Lowland	8.66	8.66	2.6

Table 3: Distribution of Soil Series in Project Area (page 2 of 2)

Soil Series		Land Phase	Area ('000 ha)		% of Project Area
			Land Phase	Soil Series	
24	Manu		0.03	0.03	<0.1
25	Phagu	Medium highland	2.02		
		Lowland	0.34		
		Medium lowland-Normal flood	19.42		
		Medium lowland-Flood hazard	0.82		
		Lowland-Flood hazard	7.20		
		Lowland slow draining	5.71		
		Rapidly flooded	29.32		
		Normal	0.36	65.19	19.5
26	Pritimpasa		0.03	0.03	<0.1
27	Rauli	Medium highland	0.20		
		Medium lowland	0.31	0.51	0.2
28	Richi	Nearly level basin, lowland	14.93		
		Medium lowland-Flood hazard	4.34		
		Lowland-Slow draining	10.81		
		Lowland-Flood hazard	1.45	31.53	9.4
29	Sangar	Medium lowland	2.89	2.89	0.9
30	Silty KK		Minor	minor	<0.1
31	Srighar	Lowland	1.63	1.63	0.5
32	Sullah	Medium lowland	8.66		
		Lowland	35.99		
		Depression, lowland	0.34	44.99	13.4
33	Tajpur		Minor	Minor	<0.1
		Very lowland	4.26		
		Lowland	16.77	21.03	6.3
	Homestead		18.66	18.66	5.6
	Haor/beel		10.15	10.15	3.0
	Area of Soil Association ('000ha)		335.60	335.6	100.0

Source: SRDI, 1976, 1977, 1986

Table 4: Crop Suitability Ratings by Soil Series, Phase or Land Type (Page 1 of 2)

	Soil Series	Land Phase	SRDI Reference	Wet Land Crops							Dry Land Crops				
				Without Irrigation			With Irrigation				Without Irrigation			With Irrigation	
				Aus	*Aman*	Jute	*Aus*	*Aman*	*Boro*	Jute	Wheat	Pulse & oil seeds	Vegetables	Wheat	Vegetables
1	Ajmiriganj	Lowland	1977	4	4	4	4	4	1	4	4	4	4	4	4
		Medium lowland slow draining	1976	4	3	4	4	3	1	4	4	4	4	4	4
2	Astagram	Nearly level basin, lowland	1977	4	4	4	4	4	1	4	4	4	4	4	4
3	Bajora	Broad ridge, lowland	1977	4	4	3	4	4	1	3	2	2	3	1	3
4	Balaganj	Medium highland	1976	2	2	2	1	1	2	2	2	2	2	1	1
		Medium highland	1986	1	1	3	1	1	2	3	2	2	2	1	1
5	Balua	Lowland	1976	4	3	4	4	3	1	4	4	4	4	4	4
		Very lowland	1976	4	3	4	4	3	1	4	4	4	4	4	4
6	Bamai	Lowland	1976	4	3	4	4	3	1	4	4	4	4	4	4
7	Baniachang	Medium lowland	1976	4	3	4	4	3	1	4	4	4	4	4	4
		Lowland	1976	4	3	4	4	3	1	4	4	4	4	4	4
8	Barlekha		1986	4	4	4	4	4	4	4	4	4	4	4	4
9	Beanibazar		1986	4	4	4	4	4	4	4	4	4	4	4	4
10	Bijipur		1986	2	1	3	2	1	4	3	3	2	2	3	2
11	Derai	Lowland	1976	4	4	4	4	4	2	4	4	4	4	4	4
		Very lowland	1976	4	4	4	4	4	2	4	4	4	4	4	4
12	Goyainghat	Medium highland	1976	2	2	2	1	1	1	1	2	2	2	1	2
		Medium lowland-Normal flood	1976	3	2	3	3	2	1	2	3	3	4	2	3
		Deeply flooded	1986	3	1	3	3	1	2	3	3	2	4	2	2
		Normal	1986	1	1	2	1	1	1	2	2	2	2	1	2
		Medium lowland-Flood hazard	1976	4	3	4	4	3	1	4	4	4	4	4	4
13	Hakaluki		1977	4	4	3	4	4	2	3	4	2	3	4	2
14	Humayunpur		1977	4	4	3	4	4	1	3	3	2	3	3	3
15	Ikram	Medium highland	1976	2	2	2	1	1	3	1	2	2	2	1	2
16	Itkhola		1986	1	1	2	1	1	1	2	2	3	3	2	3
17	Kadipur		1986	3	3	2	3	3	1	2	3	3	4	3	4
18	Kanairghat	Medium highland	1976	2	2	2	1	1	1	1	2	2	2	1	2
		Deeply flooded	1986	3	1	3	3	1	1	3	3	2	4	3	4
		Medium lowland-Flood hazard	1976	3	3	3	3	3	1	3	2	3	4	2	3
		Medium lowland-Normal flood	1976	2	2	2	3	2	1	2	2	3	4	2	3
		Normal	1986	1	1	2	1	1	1	1	2	2	2	1	2
19	Khadimnagar		1986	4	4	4	4	4	4	4	4	4	4	4	4
20	Kulaura		1986	4	4	4	4	4	4	4	4	4	4	4	4

Table 4: Crop Suitability Ratings by Soil Series, Phase or Land Type (Page 2 of 2)

	Soil Series	Land Phase	SRDI Reference	Wet Land Crops							Dry Land Crops				
				Without Irrigation			With Irrigation				Without Irrigation			With Irrigation	
				Aus	*Aman*	Jute	*Aus*	*Aman*	*Boro*	Jute	Wheat	Pulse & oil seeds	Vegetables	Wheat	Vegetables
21	Kushiyara		1986	2	2	2	4	4	4	4	2	1	1	2	1
22	Madhabpur	Medium lowland-Flood hazard	1976	3	3	3	3	3	1	3	3	3	4	3	3
		Lowland	1976	4	4	4	4	3	1	4	4	4	4	4	4
23	Madhyanagar	Lowland	1976	4	4	4	4	2	1	4	4	4	4	4	4
24	Manu		1986	1	1	2	1	1	3	2	2	2	2	1	2
25	Phagu	Medium highland	1976	2	2	3	2	2	1	3	3	3	4	3	3
		Lowland	1977	4	4	4	4	4	1	4	4	4	4	4	4
		Medium lowland-Normal flood	1976	3	2	4	3	2	1	4	4	4	4	4	4
		Medium lowland-Flood hazard	1976	4	4	4	4	3	1	4	4	4	4	4	4
		Lowland-Flood hazard	1976	4	4	4	4	3	1	4	4	4	4	4	4
		Lowland slow draining	1976	4	4	4	4	3	1	4	4	4	4	4	4
		Rapidly flooded	1986	4	3	4	4	3	1	4	3	3	4	3	4
		Normal	1986	3	1	3	3	1	1	3	3	3	4	3	3
26	Pritimpasa		1986	1	1	2	1	1	4	2	2	2	2	2	2
27	Rauli	Medium highland	1976	1	1	2	1	1	2	1	2	2	2	1	2
		Medium lowland	1976	3	2	3	4	2	2	3	2	2	2	2	2
28	Richi	Nearly level basin, lowland	1977	4	4	3	4	4	1	3	2	2	3	1	3
		Medium lowland-Flood hazard	1976	3	3	3	3	3	1	3	2	2	2	2	2
		Lowland-Slow draining	1976	4	2	4	4	3	1	4	4	4	4	4	4
		Lowland-Flood hazard	1976	4	3	4	4	3	1	4	4	4	4	4	4
29	Sangar	Medium lowland	1976	3	3	3	3	3	2	3	2	2	2	2	2
30	Silty KK		1977	3	4	3	3	4	2	3	4	2	4	4	4
31	Srighar	Lowland	1977	4	4	4	4	4	1	4	4	4	4	4	4
32	Sullah	Medium lowland	1976	4	4	4	4	4	1	4	4	4	4	4	4
		Lowland	1976	4	4	4	4	4	1	4	4	4	4	4	4
		Depression, lowland	1977	4	4	4	4	4	4	4	4	4	4	4	4
33	Tajpur		1977	4	3	4	4	3	3	4	4	4	4	4	4
34	Terchibari	Lowland	1976	4	4	4	4	4	2	4	4	4	4	4	4
		Very lowland	1976	4	4	4	4	4	2	4	4	4	4	4	4
		Lowland	1986	4	3	4	4	3	2	4	4	4	4	4	4

Source: SRDI, 1976, 1977, 1986
Legend: Crop Suitability Rating
1: Well Suited, 2: Moderately Suited, 3: Poorly Suited,4: Not Suited

APPENDIX F.2

QUESTIONNAIRE FOR SURVEY ON CROP PRODUCTION SYSTEM

Sample Site No.: Thana: Union: Mauza: Mauza Sheet No.: Date:

Name of Crop	Variety	Operation Time (day/month - day/month)			Irrigation			Flooding							Yield (kg/acre)	
		Sowing (seed bed)	Transpln/ Plantatn (main field)	Harvest	Method	Area (acre)	Period (day/month-day/month)	% of Crop Area			Depth (cm) and Period (day/month - day/month)			Frequency	Flood Free (Normal)	Flood damaged
								93	94	95	93	94	95			
Local *Boro*																
HYV *Boro*																
DW *Aman*																
Loc T.*Aman*																
HYV *Aman*																
DW *Aus*																
Wheat																
Pulse																
Groundnut																
Oilseeds																
Potato																
Sweet Potato																
Vegetables																
Spices																
Other																

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QUESTIONNAIRE FOR SURVEY ON INPUT USE AND MARKETING

Sample Site No.: Thana: Union: Mauza: Sheet No.: Date:

Crop	Input Use (kg/acre)							Labor/acre		Quantity Produced (kg/HH)			Quantity Sold (kg/HH)		
	Seed	Manure	Urea	TSP	MP	Other	Pestcd	Hired	Own	Small	Medium	Large	Small	Medium	Large
Local *Boro*															
HYV *Boro*															
DW *Aman*															
Local T. *Aman*															
HYV T. *Aman*															
DW *Aus*															
Wheat															
Pulse															
Groundnut															
Oilseeds															
Potato															
Sweet Potato															
Vegetables															
Spices															
Other															

APPENDIX F.3

FARM MONITORING QUESTIONNAIRE

1. Name of Crop:
2. Name of Variety:
3. Area of the Plot being Monitored:
4. Name of Project:
5. Name of Farmer:
6. Village:
7. Mauza/Union:
8. Thana:
9. Cultivated Land:

   a) Owned .... decimal

   b) Rented in .... decimal

   c) Rented out .... decimal

   d) Other .... decimal

2y2

10. Input Use:

Name	Amount (kg)	Price (Tk)
Seed		
Seedling (no. of bundles)		
Manure		
Basal Urea		
Basal TSP		
Basal MP		
Other Basal Fertilizer		
First Top Dressed Urea		
Second Top Dressed Urea		
Third Top Dressed Urea		
Other Top Dresses Fert		
Liquid Pesticides		
Granular Pesticides		

11. Farm Machinery Use:

Name	Own		Hired
	Fuel Cost (Tk)	Repairing Cost (Tk)	Rental Cost (Tk)
Tiller			
LLP			
STW			
DTW			
Sprayer			
Paddle Thresher			
Other			

12. Labor and Animal Use and Cost:

Operation	Time Day Month	Labor			Animal		
		Hired		Family	Hired		Own
		Day	(Tk/day)	Day	Pair	(Tk/Pair)	Pair
Seedbed Preparation							
Seedling Uprooting							
Seedling Carrying							
Land Preparation							
Transplantation							
Thinning/Raking							
Weeding 1st							
2nd							
3rd							
Fert Top Dressing							
Pest Application							
Irrigation							
Harvesting							
Carrying							
Threshing							
Winnowing							
Storing							
Other							

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13. Irrigation Use:

Number	Method	Time of Irrigation	Total (Hour)	Irrigation Cost (Taka (Tk/hour/day/season)
		Day/Month to Day/Month		
1st				
2nd				
3rd				
4th				
5th				

14. Yield/Production:

Yield/Production (kg)	Main Product	By Product
Yield by Crop Cut		
Total Production Received by Farmer		

APPENDIX F.4

METHODOLOGY FOR CROP AREA FLOODING ASSESSMENT

The following describes the methodology adopted in the KKRMP agricultural study to determine the extent of flooding of individual crop areas for a given flood condition.

1. Homogeneous sub-regions are differentiated within the study area according to the land types, flooding characteristics, agro-ecological zones and sub-zones, soil association, land capability, and land use association. A number of sample areas is selected in each sub-region. The exact location of the sample sites are selected during field visits. In particular the areal extent of a sample site covers entirely a number of *mauzas*.

2. Land utilization pattern, crop areas and crop patterns are determined at each sample site by a field survey. The location, area and crop pattern of each farming plot is recorded on the corresponding *mauza* map (scale 1:3,960).

3. All *mauza* maps included in a sample area are overlaid on a pre-monsoon flood depth map. The flood depth map divide the cultivated land into four flooding depth ranges: less than 0.3 m (no flood damage), 0.3-0.9 m, 0.9-1.8 m, and more than 1.8 m. The area of each crop pattern under each flood range is digitized.

4. The total surveyed area of each crop pattern under each flood range is calculated by summing up the areas over all sample sites. Then the total surveyed cultivated area under each flood range is calculated, summing up all crop pattern areas under this flood range.

5. The percentage of each crop pattern under each flood range is calculated, dividing the area of a crop pattern under that flood range by the total cultivated land under the same flood range. The resulting matrix (crop pattern vs flood range) represents the distribution of cropping patterns under each flood range.

6. Steps 3 to 5 are repeated for all flood conditions considered. A total of 12 matrices were developed, for present conditions, FWO, FW Alternative 1 and FW Alternative 2, each considering the 1:2, 1:5 and 1:10 year flood. An example is shown in Table 1. In the KKRMP study, the study area was considered homogeneous (Annex F, section 3.8.1).

7. Three flood maps for present conditions, for the 1:2, 1:5 and 1:10 year floods are in turn overlaid on *thana* maps (scale 1:50,000) of the study area and all non-agricultural land, infrastructure, homesteads, etc. is digitized also by flood range. The distribution of non-agricultural area by flood range is assumed to apply to any pre-monsoon flood condition for the return period considered, ie. present, FWO and FW, because non agricultural land represents only 16% of the study area, and the resulting error is small under FWO or FW scenarios.

8. The next step is to transfer the flooding pattern from the sampled area to the study area for a given condition. On the corresponding flood depth map, the total area under each flood range is calculated (There are 4 areas in total. Their sum is the study area).

9. For each flood depth range, the non-agricultural area calculated in Step 7 is subtracted form the corresponding area calculated in Step 8. The result is the net cultivated area for the flood range considered.

10. The area of each crop pattern under each flood range is calculated by multiplying the percentage of this crop in this flood range (Step 5) by the total cultivated area under the same flood range (Step 9).

Table 1: Distribution of Cultivated Area by Flood Range
Present Conditions - 1:2 Year Flood

Crop Pattern	Distribution of Cultivated Area (%)			
	Pre-Monsoon Flood Depth (m)			
	< 0.3	0.3-0.9	0.9-1.8	> 1.8
B *Aus*-HYV T *Aman*	3.17	0.26	0.02	0.00
T *Aman*-HYV *Boro*	0.02	0.00	0.00	0.00
HYV *boro*-Fallow	71.35	70.08	43.10	10.59
L *Boro*-Fallow	11.02	18.32	45.09	82.98
DWR-HYV *Boro*	1.18	1.57	0.02	0.00
DWR-Fallow	7.93	6.54	10.37	6.07
HYV *Aman*-Fallow	0.02	0.06	0.07	0.00
Wheat-Fallow	0.07	0.01	0.00	0.00
Pulses-Fallow	0.05	0.02	0.00	0.00
Groundnut-Fallow	0.30	0.08	0.00	0.00
Oilseeds-Fallow	0.11	0.09	0.05	0.30
Potato-Fallow	0.40	0.11	0.00	0.00
S Potato-Fallow	0.21	0.04	0.00	0.00
Spices-Fallow	0.55	0.13	0.00	0.00
Vegetables-Fallow	0.22	0.08	0.00	0.06
Fallow	3.42	2.60	1.28	0.00
Total Cultivated Area	**100.00**	**100.00**	**100.00**	**100.00**