THE PEOPLE'S REPUBLIC OF BANGLADESH

FEASIBILITY REPORT

ON

NARAYANGANJ-NARSINGDI IRRIGATION PROJECT

VOLUME [illegible] MAIN TEXT

JAPAN INTERNATIONAL COOPERATION AGENCY

THE PEOPLE'S REPUBLIC OF BANGLADESH

FEASIBILITY REPORT ON NARAYANGANJ-NARSINGDI IRRIGATION PROJECT

VOLUME I : MAIN REPORT

JULY 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

P R E F A C E

The Government of the People's Republic of Bangladesh, which attaches a high priority to the N-N Irrigation Project aimed at rice production increase through the improvement of facilities for irrigation, drainage and flood control, requested the Government of Japan, in 1976, for its cooperation in the project survey.

In response to this request, the Government of Japan decided to conduct surveys on the Project, and the Japan International Cooperation Agency (JICA) dispatched a preliminary survey team in March 1977, and a feasibility study team in October 1977.

These teams are indebted very much to the officials concerned of the Government of Bangladesh for the smooth and efficient conduct of their survey and study as well as for the preparation of the Final Report which is being submitted herewith in two volumes: (i) Main Report and (ii) Notes.

I sincerely hope that this Report would contribute to the agricultural development in your country and to the promotion of friendship between our two countries.

I take this opportunity to express my deep gratitude to the Government of Bangladesh for their assistance and cooperation extended to our survey teams.

July, 1978

Shinsaku HOGEN
President
JAPAN INTERNATIONAL COOPERATION AGENCY

LETTER OF TRANSMITTAL

Mr. Shinsaku HOGEN,
President,
Japan International Corporation Agency,
Tokyo, Japan

July 31, 1978

Feasibility Study Report on the Narayanganj-
Narsingdi Irrigation Project, Bangladesh

Dear Sir;

We have the honour to submit herewith the Feasibility Study Report on the captioned project in two volumes which have been completed by the study team headed by the undersigned. An intensive feasibility study conducted by the team comprising twelve experts took two and half months commencing from October 1977, when the project area assumed the dry season aspects of its yearly cycle of the Nature and life. The findings obtained during the interim survey which took place two months prior to our feasibility study (in August 1977) were duly taken into consideration as to reflect the wet season aspects of the same project area.

Before leaving Bangladesh, the team submitted to its Government an Interim Report (dated December 19, 1977) which contained some of the basic understandings, norms and standards on which it might proceed on preparing a Draft Report on the project. After returning to the home office, the team continued on assimilation and analysis of the collected data and information while formulating, in a broader way, agricultural development strategy based on infrastructural improvements proposed under the project. In the meanwhile, the undersigned and the project economist were invited to Dacca, in February 1978, to receive the Bangladesh Government's comments on the above-mentioned Interim Report and to exchange opinions on the consistency among various project components and the final shape of the Feasibility Study Report to be prepared on the project.

Hence this Report is the concluding document and the final produce after a series of work undertaken by the team under the general supervision of the Advisory Group which was organized by your appointees for this specific project-study. Upon conclusion of our assignment, we would like to say that the project is technically feasible and economically sound and, therefore, it should proceed to the next stage of detailed designing along the recommendations presented in this report.

Finally, we wish to express our sincere-most appreciation and gratitude to the personnel of your Agency, the Embassy of Japan in Bangladesh, and the officials concerned of the Government of Bangladesh for the courtesies and cooperation liberally afforded us during our field survey and home office work.

Very truly yours,

Masamitsu FUJIOKA
Leader

Bangladesh N-N Irrigation
Project Feasibility Study Team

(Director, Japan Engineering
Consultants Co., Ltd.)

SUMMARY AND CONCLUSIONS

i. The Government of the People's Republic of Bangladesh requested the Government of Japan to undertake techno-economic study for finding out ways and means to solve the intrinsic difficulties inherent to the agriculture having been traditionally followed by the farmers in the Ganges-Brahmaputra-Meghna deltaic region of the country. The project is meant for breaking through the constraints and bringing in new agricultural development strategy in some 150,000 ac (Plan A) area comprising five thanas of Narsingdi, Rupganj, Araihazar, Baidyer Bazar and Narayanganj as far as they are contained within a 13 mile x 21 mile square which is broadly confined by the Tungi-Narsingdi railway line in the north, the Meghna River in the east and south, and the Sitalakhya River in the west. It means that the project area belongs to Dacca District, within a radius of 15 miles from the nation's capital of Bangladesh.

ii. The project aims at turning the said area, which would be over-flooded nearly half as much of its land during wet season and, alternatively put in quasi-drought conditions during dry season, flood-free and year-round irrigable, by constructing 60 mile-long embankment along the Sitalakhya and Meghna River banks and through provision of three pumping stations which would drain surplus rainwater during wet season and pump in river-water during dry season. All over the area thus made free from both flood and drought, irrigation/drainage networks would run in parallel with O&M roads; district and union roads would be repaired, together with village-to-village katcha roads; rural markets would be built side by side with fertilizer and general godowns; fish ponds would be rehabilitated and enlarged; TTDC buildings would be expanded to accommodate more number of development-busy officers and BADC workshops would be properly equipped to repair, recondition and re-allocate elsewhere the pumps and tubewells which would become surplus under the project. Physical infrastructure being completed, the project would not forget to strengthen the farmer supporting services toward not only land owning farmers but also landless workers through intensification of the Government extension services and consolidation of farmers' organization along TCCA-KSS system which would provide the member-farmers with rural credit, input supply and marketing services in a single package; animal health and fisheries would be looked after with full intensity in view, respectively, of replenishing efficient animal power for farming and creating employment and, jointly, to help make the inhabitants' diet richer.

iii. Needless to say, agricultural production potential would be enormously augmented - the emphasis would naturally be put on an increased production of food grains, particularly rice, and export item like jute, but the best care has been paid to make land utilization within the area fully developed. This is the reason why five different cropping patterns each of five year rotation have been introduced. They would be most responsive to topography, profile and soil conditions met in the area and help increase the cropping intensity from the current 129% to 206%. As the livestock improvement programme has been incorporated with agricultural development project, supply of animal power would be increasingly guaranteed to facilitate the area farmers in adhering to the very much intensified cropping calendars in enormously expanded farmlands making, thereby, an introduction of mechanized farming dispensable.

iv. Consequently, at full development, annual production of rice would amount to 220,000 tons; wheat, 4,700 tons; upland crops (pulses, oil seeds, vegetables, sugar cane, etc), 26,000 tons; and jute, 8,750 tons; their incremental ratios in percent reaching as much as 440, 5,000, 290 and 160, respectively, compared to the present. Apart from sizeable labour requirements called for the basic and supporting infrastructural construction works, which might be of comparatively shorter periods, the project would create semi-permanent source of labour employment through expansion of cropped area and adoption of intensive farming techniques. Significant employment opportunities generating in various subsidiary branches of agriculture taken into account, gainfull employment conditions would prevail in the project area provided that migrant labourers could ever be checked from flowing into it.

v. Although this feasibility study has been focused at Phase I area the project is proposed for stage-by-stage implementation or in three alternative ways in consideration of the availability of necessary resources and administrative capacity, starting from Phase I/Stage 1 to Phase I, and then to Plan B. As supporting infrastructural facilities and farmer supporting services are projected to cover the whole project area broadly according to the IRDP strategy, the nomenclature of the above three different extents of the project coverage is mainly attributable to the contents of the basic infrastructural works, most conspicuously, that of the pumping stations. In this sense, Phase I/Stage 1 is synonimous with the command area of Pumping Station No.1; Phase I, with that of Pumping Stations No.1 and No.2 combined; and Phase II (which forms a part of Plan B area together with Phase I area), that of Pumping Station No.3.

vi. Project implementation would call for effective coordination among a number of Government departments and agencies. To achieve this, committee systems would need to be established at Central, Project area and thana levels, composed of officers from participating agencies.

vii. Project implementation would require three years for the basic civil works construction and five to seven years for full agricultural development. The difference in the period required for attaining full agricultural development reflects the function of spill-over effects of the beneficial results obtainable in the area coming first under the project to other area or areas which would be coming later. Implementation period visualized for each project component is shown in "Progress Bar Chart" attached.

viii. Agricultural production in full development year and its comparison with the current or "without the project" one would be as follows:

Table 1 Implementation Progress Bar Chart

	Project Works	Project Work Item/Components	Phase/Stage	PROJECT YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14
I	BASIC INFRA-STRUCTURE	1) Embankment 2) Pumping Stations 3) Irrigation/Drainage 4) Road Networks	I/1		1 2 3 4												
			I/2					2 3 4									
			II								1 2 3 4						
II	SUPPORTING FACILITIES	PWP: 1) Pucca Roads 2) Katcha Roads 3) Rural Markets 4) Fish Ponds Thana Facilities: 1) TTDC Buildings 2) TCCA Storages 3) RADC Workshops	I/1														
			I/2														
			II														
III	INSTI-TUTIONAL RE-CON-STRUCTION	Reorganization of Traditional Co-ps to TCCA-KSS & Expansion of TCCA-KSS system	I/1														
			I/2														
			II														
IV	SUPPORTING SERVICES	1) Rural Credit 2) Input Supply 3) Extension 4) Marketing	I/1														
			I/2														
			II														
V	AGRICUL-TURAL PRODUCTION FISHERIES LIVESTOCK		I/1														
			I/2														
			II														

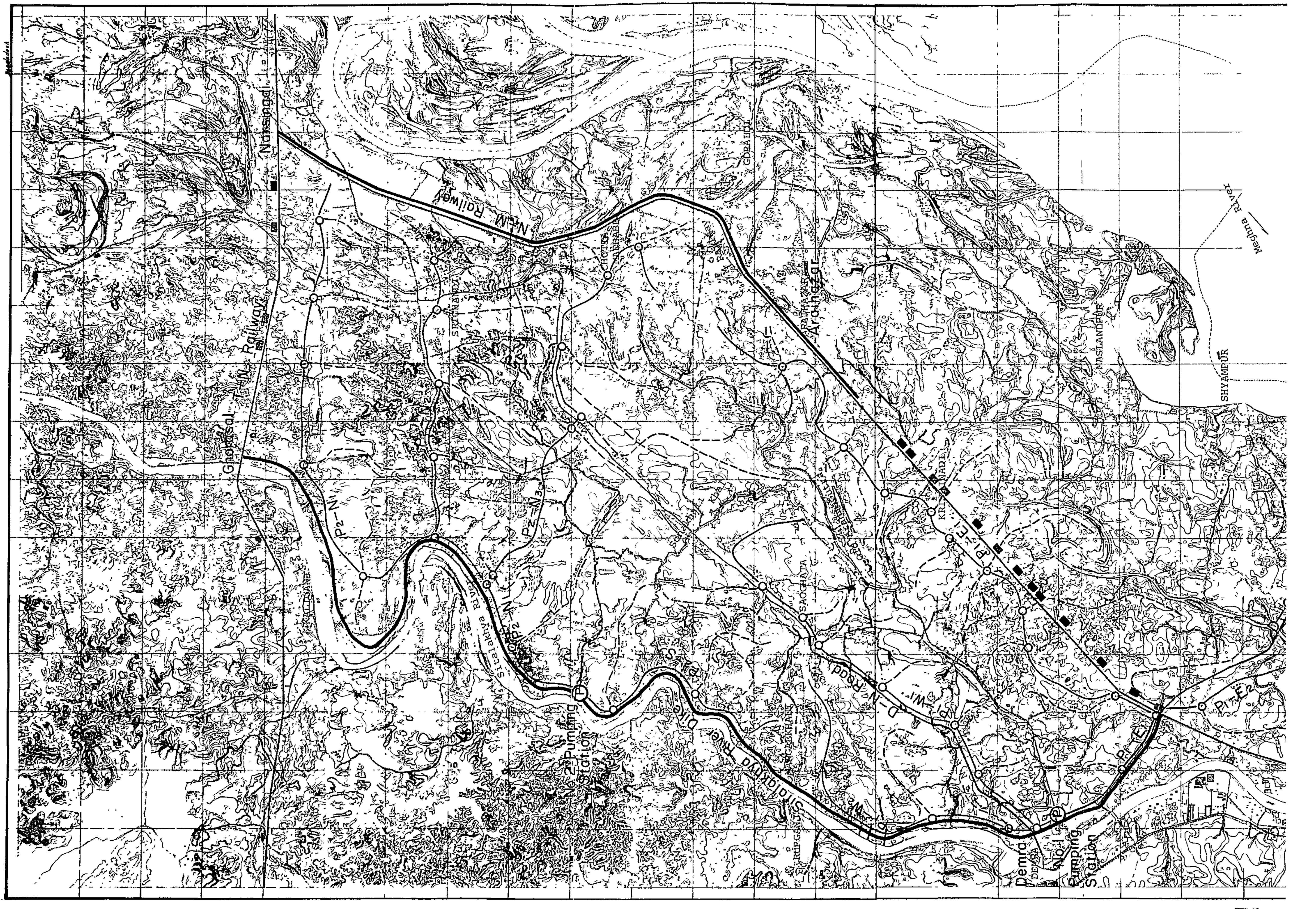
<table>
<tr><td colspan="3">Project Area</td><td>Phase I/ Stage 1</td><td>Phase I (Phase I/Stage 2, in parenthesis)</td><td>Plan B (Phase II, in parenthesis)</td></tr>
<tr><td rowspan="3">Project Implementation Period (Years)</td><td colspan="2">Construction</td><td>3</td><td>6 (3)</td><td>9 (3)</td></tr>
<tr><td colspan="2">Agricultural Development</td><td>7</td><td>6</td><td>5</td></tr>
<tr><td colspan="2">Total</td><td>10</td><td>12 (9)</td><td>14 (8)</td></tr>
<tr><td colspan="3">Full Development Year</td><td>Year Ten</td><td>Year Twelve</td><td>Year Fourteen</td></tr>
<tr><td rowspan="8">/1 Farm Production in Full Development Year</td><td rowspan="2">Rice</td><td>Current</td><td>13.3</td><td>33.3</td><td>49.4</td></tr>
<tr><td>w/project</td><td>59.6</td><td>141.1</td><td>219.4</td></tr>
<tr><td rowspan="2">Wheat</td><td>Current</td><td>0.025</td><td>0.06</td><td>0.094</td></tr>
<tr><td>w/project</td><td>0.86</td><td>3.8</td><td>4.7</td></tr>
<tr><td rowspan="2">Up-/2 land crops</td><td>Current</td><td>2.4</td><td>5.6</td><td>9.0</td></tr>
<tr><td>w/project</td><td>7.4</td><td>17.7</td><td>25.8</td></tr>
<tr><td rowspan="2">Jute</td><td>Current</td><td>1.5</td><td>0.9</td><td>5.5</td></tr>
<tr><td>w/project</td><td>2.5</td><td>3.2</td><td>8.7</td></tr>
<tr><td colspan="2" rowspan="2">Cropping Intensity (%)</td><td>Current</td><td>129</td><td>128</td><td>129</td></tr>
<tr><td>w/project</td><td>209</td><td>200</td><td>206</td></tr>
</table>

/1 : In thousand tons;

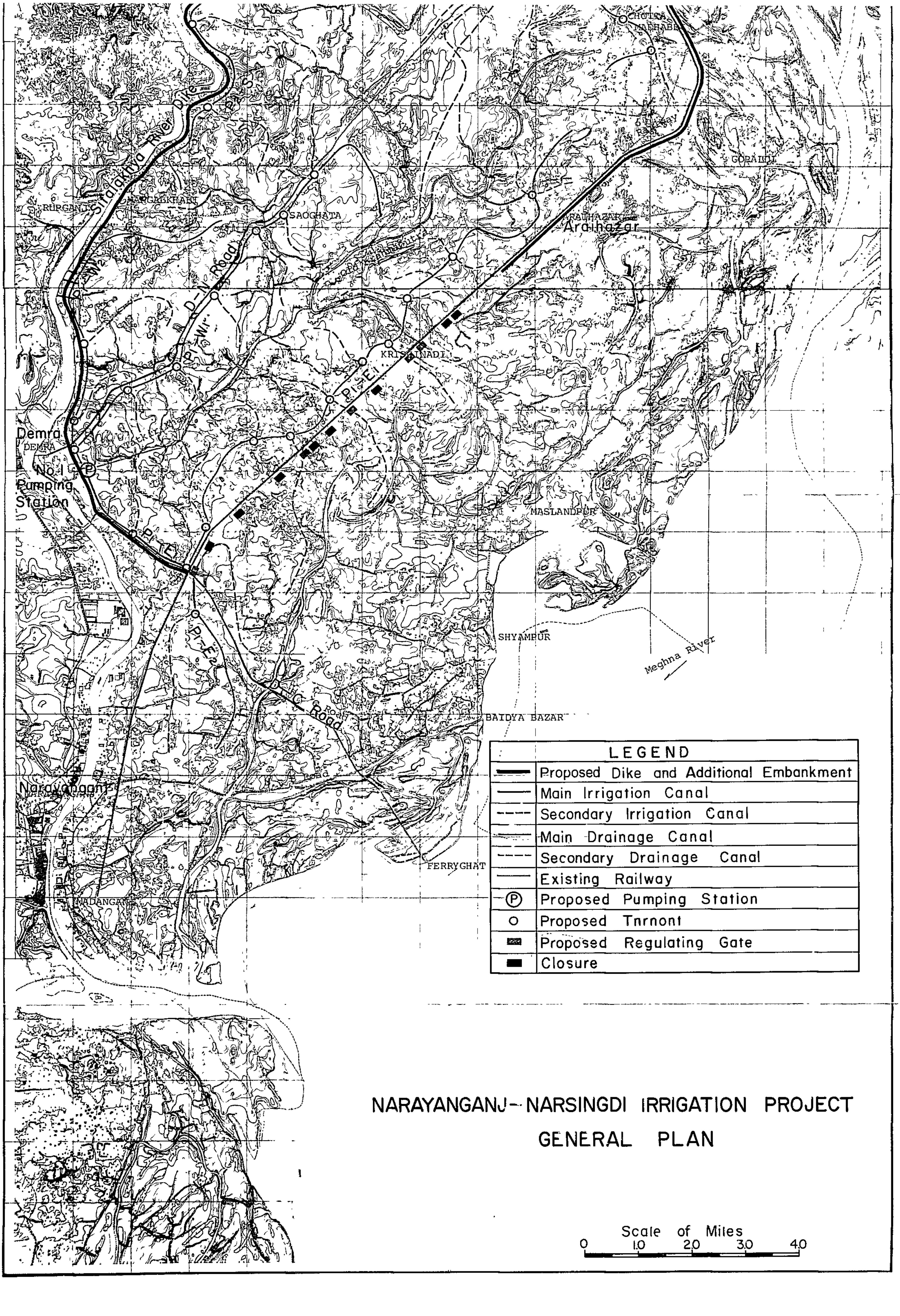
/2 : Including pulses, oil seeds, vegetables, sugar cane, etc.

ix. Total project cost including the capital investment and O&M costs during the project life is estimated in both local component and foreign component for each of the three different project coverages. Economic rates of return are also estimated accordingly. The sensitivity tests with a number of assumptions have been made with Phase I project only, as follows:

	Total Cost (in US$ equivalent)	Foreign Exchange Component (%)	IRR (%)	Sensitivity Test Results (%)
Phase I/Stage 1	34.5 Million	52.5	14.9	-
Phase I	60.7 Million	51.3	19.9	14 - 20
Plan B	95.1 Million	52.9	20.2	-



Narsingdi
N-M Railway
Ghorasal
Araihazar
Meghna River
SHYAMPUR
MASLANDPUR
GOPALDI
P2-N1
P2-N3
P1-E1
P1-E2
Sitalakhya River
Sitalakhya River Dike
D-N Road
No.2 Pumping Station
No.1 Pumping Station
Demra



NARAYANGANJ-NARSINGDI IRRIGATION PROJECT
GENERAL PLAN

Statistical Data for N-N Irrigation Project

1. Project Area

Whole Area		147,159 Ac
Plan B:	Gross Area	111,600 "
	Net Area	88,200 "
Phase I:	Gross Area	71,600 "
	Net Area	57,000 "
Phase II:	Gross Area	40,000 "
	Net Area	31,200 "

2. Flood Protection Embankment

New Dike (Sitalakhya River Dike)		21.5 Miles
Additional Embankment;	N-M Railway	11.6 "
	D-C Road	3.4 "
Crest Elevation;	Sitalakhya River Dike	26.5 ∿ 23.4 ft
	N-M Railway	25.7 ∿ 23.5 "
Crest Width of New Dike		20 ft
Side Slopes;	River Side	3 : 1
	Land Side	2.5 : 1
Related Structure;	Regulating Gates	6 Nos.
	Closures	9 "

3. No.1 Pumping Station Area

Gross Area		29,400 Ac
Net Area		32,400 " (including 8,600 Ac in Phase II Area)
Catchment Area for Drainage		37,000 Ac
No.1 Pumping Station;	Total Capacities of Pumps	1,240 Cusecs ($35m^3/s$)
	Type of Pumps	Vertical Mixed Flow Pump
	Bore and Nos.	⌀1,650 mm × 6 Nos.
	Moter Output	550 kW per pump

Main Irrigation Canal;	Type	Earth Canal
	Length	36.25 Miles
	Design Discharges	435 ∿ 46 Cusecs
	Gradient	1/20,000
Secondary Irrigation Canal;	Type	Earth Canal
	Length	68.6 Miles
	Gradient	1/10,000
Main Drainage Canal;	Type	Earth Canal
	Length	6.25 Miles
	Design Discharges	1,240 Cusecs
		1,120 "
		920 "
	Gradient	1/20,000
Related Structures;	Turnouts	22 Nos.
	Check Gates	4 "
	Aqueducts	15 "
	Bridges	208 "
	Siphons	4 "
	Regulating Gates	1 "

4. No.2 Pumping Station Area

Gross Area		42,200 Ac
Net Area		33,200 "
Catchment Area for Drainage		34,600 "
No.2 Pumping Station;	Total Capacities of Pumps	1,240 Cusecs ($35m^3/s$)
	Type of Pumps	Vertical Mixed Flow Pump
	Bore and Nos.	⌀1,650 mm × 6 Nos.
	Moter Output	600 kW per pump

Main Irrigation Canal;	Type	Earth Canal
	Length	34.3 Miles
	Design Discharges	653 ∿ 35 Cusecs
	Gradient	1/20,000
Secondary Irrigation Canal;	Type	Earth Canal
	Length	81.8 Miles
	Gradient	1/10,000
Main Drainage Canal;	Type	Earth Canal
	Length	8.5 Miles
	Design Discharges	1,240 Cusecs
		950 "
		380 "
		270 "
	Gradient	1/20,000
Related Structures;	Turnouts	20 Nos.
	Check Gates	4 "
	Aqueducts	8 "
	Bridges	190 "
	Siphones	1 "

THE PEOPLE'S REPUBLIC OF BANGLADESH

FEASIBILITY REPORT ON N-N IRRIGATION PROJECT

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V. THE PROJECT

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GLOSSARY

Aman	-	Rice planted before or during the monsoon and harvested in November or December (B. Aman is broadcast, T. Aman is transplanted)
Aus	-	Rice planted during March and April and harvested during July and August (B. Aus is broadcast, T. Aus is transplanted)
Beels	-	Depressions
Boro	-	Rice planted in winter and harvested during April to June.
Char	-	Low-lying sandy land
Comilla Cooperatives	-	A system of two-tier cooperatives (at village and thana levels) developed at the Bangladesh Academy for Rural Development (Comilla) in the 1960s. The system emphasized increasing the productivity of the small farmers through training and by increasing their access to farm inputs such as irrigation, credit and fertilizers.
District	-	Administrative unit in Bangladesh. There are 19 Districts in the country.
Katcha	-	Temporaty (dirt) road
Khals	-	Natural channels
Kharif	-	Summer season
Mouja	-	Originally a cadastral map (now a map in which relative locations can be found)
Paddy	-	Unhulled rice
Pucca	-	Permanent (paved) road
Rabi	-	Dry season
Thana	-	Administrative unit in Bangladesh. There are 413 thanas in the country.
Union	-	A unit of local self government. There are about ten unions in each thana.

FISCAL YEAR

July 1 to June 30

CURRENCY EQUIVALENTS

In November 1977, Bangladesh Bank fixed floor and ceilling rates for purchase and sale of US dollar. The Bank's lowest and highest rates for spot as well as forward buying up to six months are Tk 15.1104 and Tk 15.2580 respectively for each dollar. The lowest and highest rates for spot selling are Tk 15.1464 and Tk 15.2944 per dollar. Accordingly, the rate below has been used through this report, except where stated to the contrary:

US$ 1	=	Tk 15.0	= Yen 225.0
Tk 1	=	US$0.066	
Tk 1 million	=	US$66,667	

WEIGHTS AND MEASURES

1 acre (ac)	: 0.405 hectare (ha)
1 bigha	: 0.33 ac
1 mile (mi)	: 1.609 kilometers (km)
1 square mile (sq mi)	: 640 ac (259 ha)
1 foot (ft)	: 30.5 centimeters (cm)
1 maund (md)	: 82.3 lbs. (37.3 kg) = 40 seers
1 metric ton (ton)	: 26.8 md = 2,205.64 lbs
1 cubic foot per second (cusec)	: 0.0283 cu meters per secound
1 seer (sr)	: 2.05725 lbs. = 0.9331 kilograms (kg)
1 hectare	: 2.4711 ac
1 cubic foot (cft)	: 0.0283 cubic meter
1 yard	: 36 inches = 0.914 meter
1 bale of Jute	: 400 lbs.

PRINCIPAL ABBREVIATIONS AND ACRONYMS USED

BADC	-	Bangladesh Agricultural Development Corporation
BWDB	-	Bangladesh Water Development Board
BRRI	-	Bangladesh Rice Research Institute
CERDI	-	Central Extension Resources Development Institute
CPEC	-	Central Project Evaluation Committee
FAO	-	Food and Agriculture Organization
GOB	-	Government of Bangladesh
IDA	-	International Development Association
IDPCC	-	Inter-Departmental Project Coordination Committee
IRDP	-	Integrated Rural Development Programme
IRRI	-	International Rice Research Institute (Philippines)
KSS	-	Village Cooperative Society (Krishi Sambaya Samitia)
MSL	-	Mean Sea Level
O&M	-	Operation and Maintenance
PADS/C	-	Project Agricultural Development Sub-Committee
PCS/C	-	Project Construction Sub-Committee
PIC	-	Project Implementation Committee
PWD	-	Public Work Department
RWP	-	Rural Works Programme
TCCA	-	Thana Central Cooperative Association
TPEC	-	Thana Project Executive Committee
TTDC	-	Thana Training & Development Center
UMPCS	-	Union Multi-Purpose Cooperative Society
UNDP	-	United Nations Development Programme

FREQUENTLY USED ABBREVIATIONS FOR OFFICERS

DAO	-	District Agricultural Officer
DCDD	-	Deputy Commissioner Dacca District
DFO	-	District Fishery Officer
DLO	-	District Livestock Officer
TAO	-	Thana Agricultural Officer
TCO	-	Thana Cooperative Officer
TEO	-	Thana Extension Officer
TFO	-	Thana Fishery Officer
TLA	-	Thana Livestock Assistant
TLO	-	Thana Livestock Officer
UAA	-	Union Agricultural Assistant
VAS	-	Veterinarian Assistant Surgeon
VFA	-	Veterinarian Field Assistant

I INTRODUCTION

Feasibility study on the Narayanganj-Narsingdi Irrigation Project which was conducted by the request of the Government of the People's Republic of Bangladesh took the course as briefed below:
In the former part of its study, the team carried out general survey and fact-finding study all over the so-called Plan A area, having some 147,600 ac (59,000 ha) within the boundary set by the T-N Railway in the north, the Meghna River in the east and south, and the Sitalakhya River in the west, which had been demarcated by the pre-feasibility study team as the maximum extent of the project area. In the joint-conference held between the officials concerned of the Government of Bangladesh upon completion of the Plan A area study, it was mutually agreed upon that Plan A area includes some marginal portions, particularly along the Meghna River, which do not warrant technical soundness and economic justification under the project; hence the area excluding such zones was eventually identified as Plan B area or the "whole project area." In the second stage of the study which was concerned with scrutinization of the existing facilities, topography, profiles, soils and the current patterns of agricultural production, etc., on one hand, and with the examination of the practicability of resources mobilization in terms of both the financial and the physical as well as the establishment of administrative, executive and institutional structures called for project implementation, on the other. As a result, it became increasingly clear that the project implementation would better take place stage by stage. According to this judgement, Plan B area has been divided into two parts of Phase I and Phase II. Phase I area was further divided into Stage 1 and Stage 2, mainly from the viewpoint of the engineering procedures to be adopted for construction of the civil works.

Irrespective of the size of the project area which primarily depends upon the extent of the construction works meant for the basic infrastructure (flood-protection embankment, pumping stations, irrigation/drainage facilities and on-farm facilities), utmost care has been taken to ensure the highest possible production through provision of the supporting infrastructure and strengthening of the farmer services. The agricultural production programme to be implemented on the basis of the above arrangement is incorporated with livestock and fisheries improvement programmes.

The area which has been overflooded half as much of its land during each monsoon season and suffering from quasi-drought conditions during every dry season would turn flood-proof and inundation-free and irrigable all through the year through the provision of the basic infrastructure. This would help enormously expand the land under crops and make adoption of intensive farming technique rewarding. The ensuing production-increases would, therefore, be obvious. In addition to such a basic infrastructure, the supporting facilities like the district-, union- and village-roads, rural markets, fish ponds, TTDC buildings, TCCA storages and BADC workshop strengthening would be provided so that agricultural production combined with livestock and fisheries improvement programmes would take place in a planned manner all over the project area. The Comilla type cooperatives would be so encouraged as to leave no village in the project area unorganized into TCCA-KSS. TCCA-KSS in each village would help its member-farmers prepare, under the guidance of the extension officers, village-wide farm plan and supply all inputs required for its implementation in hypothecation of the food grains which it would collect and market after the harvest. The Government extension services would be greatly strengthened to enable the area farmers to plan, execute and harvest the crops according to the cropping patterns (each of 5 year rotation) in four sets each combining the given soils, profile and topography in the most productive manner. In the people's welfare aspects, the employment probelm among the landless workers and the marginal farmers would be virtually solved by the time of the project's full development. Apart from multifarious social benefits obtainable through implementation of the project, the livestock and fisheries improvement programmes incorporated with the agricultural production plan would help make the people's dietary contents very much richer. In conclusion, cost-benefit calculation has been made for each stage of Phase I/Stage 1, Phase I, and Plan B, in consideration of the stage-wise implementation of the Project.

This report has been presented in two volumes -- the Main Report

(Volume I) containing the principal facts, project approaches, techno-economic studies, conclusions and recommendations, and the Notes (Volume II), containing all the background engineering and other information upon which the formulation and evaluation of the project has been based. This report is based on the results of the feasibility study conducted by the team during 2.5 months beginning in October 1977 and also incorporates the comments given by the Government of Bangladesh on the contents of the Interim Report (dated December 19, 1977) as well as its remarks referring to the final shape of documentation, obtained in February 1978.

II BACKGROUND

Nature

Bangladesh is located at the eastern tip of Indian subcontinent being surrounded by India in the west, north and east, but facing to the Bay of Bengal in the south and boardering to Burma on the southeastern end. It is a deltaic country formed mainly by the Padma (Ganges), the Jamuna, the Brahmaputra, the Meghna, and the Madhumati which are flowing into the Bay of Bengal, with the total area of 55,598 sq.mi. Topographically speaking, it is flat by 90% of its total area except the hill tract running on its eastern boarder from north to south. Central deltaic region is made up of new alluvium; the western region, of sand, clay and silt carried down by the rivers; and the eastern hill tract, of laterite. There are three seasons: summer (March-June), monsoon (July-October) and winter (November-February) in Bangladesh. Average annual rainfall over the country is 82.7 inches; about 90% of which falls in a 6-month period from May to October, but 70% of it falls in a concentrated manner during June and August. Only 4% of the total annual rainfall comes during winter which is thereby called "dry" season. Regional distribution of rainfall is quite uneven: 70.9 inches in the western region, twice as much (137.8 inches) in the eastern region, and over 196.9 inches in the northeastern hill tract which represents the highest rainfall in the world. Due to the flatness of the land reticulated by more than 230 river systems, 60% of the country's cultivable land is annually submerged by flood water during the monsoon season. Along the coastal area in the south, upto 80.8 miles inland is affected by salinity from invading tide. Seasonal averages of the maximum and minimum temperatures are respectively 32.7°C and 20.5°C during monsoon season and 26.8°C and 13.8°C during winter. Although annual mean humidity is about 80%, the maximum humidity often goes beyond 90% at the change of season from monsoon to winter.

According to the 1974 census, the population of Bangladesh was 76.4 million in the former part of the 1970's and is estimated at 82.7 million in the year 1977. Population density according to this estimate would be 1488 per sq.mi, which is the highest in the world.

National Economy

Gross Domestic Products (GDP) in 1976/77 is estimated at 58,882 million Taka at market price and per capita income at 1,208 Taka, or US$80.5, which is among the world's lowest. But, its average growth rate per year between 1973 and 1977 has been nearly 7%. This period falls in the term of the First Five Year Plan (1973-1978) which aimed at economic independence of the country through, inter alia, self-sufficiency in food, and a rapid increase of production in general by means of reconstruction and rehabilitation of economic structure so that employment opportunities would be increasingly created; the income thus increased was sought to be more equitably distributed vis-a-vis population control. Its performance, however, has not been quite satisfactory under the adverse conditions both domestically and internationally, such as the drawback of agricultural production due to erratic weather and business recession all over the world which had been triggered by the oil crisis. Some basic controversies have so far been pointed out with the First Five Year Plan, among which the following would deserve attention: (a) targets being too ambitious; (b) many projects included in the Plan were financially unsubstantiated; (c) insufficient physical inputs to attain projected outputs, and (d) discouraging response to the Government development programmes particularly among the rural community. The Government was not unconscious of these facts and prepared a Two Year Plan (1978-1980) before the First Five Year Plan accomplishes its given term. The Two Year Plan gives top priority at agricultural production-increase, rural development, and population control, aiming at 5.6% economic growth rate through 4.1% annual farm production increase.

Agriculture

Bangladesh is predominantly an agricultural country with more than 50% of its GDP, at least 75% of its total employed labour, and 90% of its foreign exchange earnings attributable to agriculture. Yet, the environmental conditions surrounding its agriculture are not very favourable. Out of the total land area of 35.3 mil.acres, 23.2 mil.acres is cultivable but the cropped area remained 21.0 mil.acres in 1976/77, with the cropping intensity of 148.5% - 58% of the cropped area is single cropped; 35%, double cropped; and 7%, triple cropped. Low cropping intensity speaks for its agriculture which has been traditionally carried on under the whims of Nature, particularly flood and drought, which make alternative visits every year. Rice is the single largest crop occupying 85.3% of the cropped area, with the total production of 11.6 million tons (1976/77); jute occupies 5.6% of the cropped area, turning out 858 thousand tons; pulses, oil seeds, sugar cane, tea, etc remain minor crops, each occupying 1 - 3% of the total cropped area. 1976/77 production of sugar cane, tea, and condiments and spices was 6,400, 33, and 289, respectively, each in thousand tons. In the previous year (1975/76), rice production reached 12.6 million tons, ever the highest in Bangladesh. Jute production is dwindling due to diminision of cropped area while its unit yield remains stagnant.

11.85 million households with 69.03 million population are spreading over its rural area. According to a recently conducted survey, more than one-half of rural households have no land at all, and 75% of the land-owning households are those having less than 2 ac; only 25% of them have more than 2 ac each. Farmland is usually fragmented into many small parcels, and the size of each plot is rapidly diminishing through inheritance based on equal division of properties.

The constraints of Bangladesh agriculture may be summarized as follows:

(a) Natural Handicaps

Flood: Heavy and concentrated rainfall during monsoon season, combined with enormous volume of river water flowing down from the neighbouring countries and converging in Bangladesh delta, causes annual flood which would submerge 2.5 mil. acres by the depth of 15 ft and another 5.4 mil. acres by the depth of over 3 ft. Most of these areas are either totally put out of cultivation or used in less effective manner.

Drought: During winter which brings only 4% of the annual rainfall, farmland mostly formed with silt and clay would solidify itself and largely left uncultivated if not artificially irrigated. Thus, only 16.5% of the total farmland is cultivated during winter, one-half of which through artificial irrigation and the other half by utilizing land-held moisture.

(b) Input Supplies and Farmer Supporting Services

Seeds: IR-8 HYV of rice which was introduced since 1967 has not achieved remarkable contribution to total rice production as it failed to be properly adopted due to varieties of reason, some technical, some physical, and some social. Unit yield of so-called HYV reached a summit of 0.49 tons/ac in 1975/76, but it is far from the potential yield it should have. In 1976/77, the cropped area under HYV declined. This may have wider implications over other fields of input such as water (irrigation facilities), fertilizers and chemicals as will be discussed later. 11.4 thousand tons of paddy seeds, mostly HYV, were supplied from BADC during 1976/77.

Fertilizers and Chemicals: 513 thousand tons of fertilizers and a considerable amount of agricultural chemicals were also supplied from BADC during 1976/77.

Others: BADC is supplying increasing number of pumps and tube-wells under the Minor Irrigation Scheme. Generally speaking, current supply of all these productive materials put together is far too small to adequately meet the demand. Poor net return from farming due to inadequacies prevailing in all fields of farmer-supporting services like input supply, extension, rural credit, marketing, transport, etc helps make input materials costlier than otherwise and almost prohibitive for smaller farmers.

(c) Institutions

Government agencies held responsible for such services as extension, training, research and development are usually under-staffed and poorly financed.

Farmers organizations and rural institutions fail to tap hidden energies and potential productivity buried among the rural mass in response to development programmes sponsored by the Government because they do not know how to utilize available input resources and existing facilities as pumping-priming water.

III THE PROJECT AREA

3.1 Location and Area

The project area is located at the centre of Bangladesh, approximately 20 km east from the capital, Dacca (Fig. 3-1). The project area is bordered by the Tungi-Narsingdi Railway in the north, the Meghna in the east and south and the Sitalakhya River in the west, covering a gross area of 147,160 ac (59,600 ha).

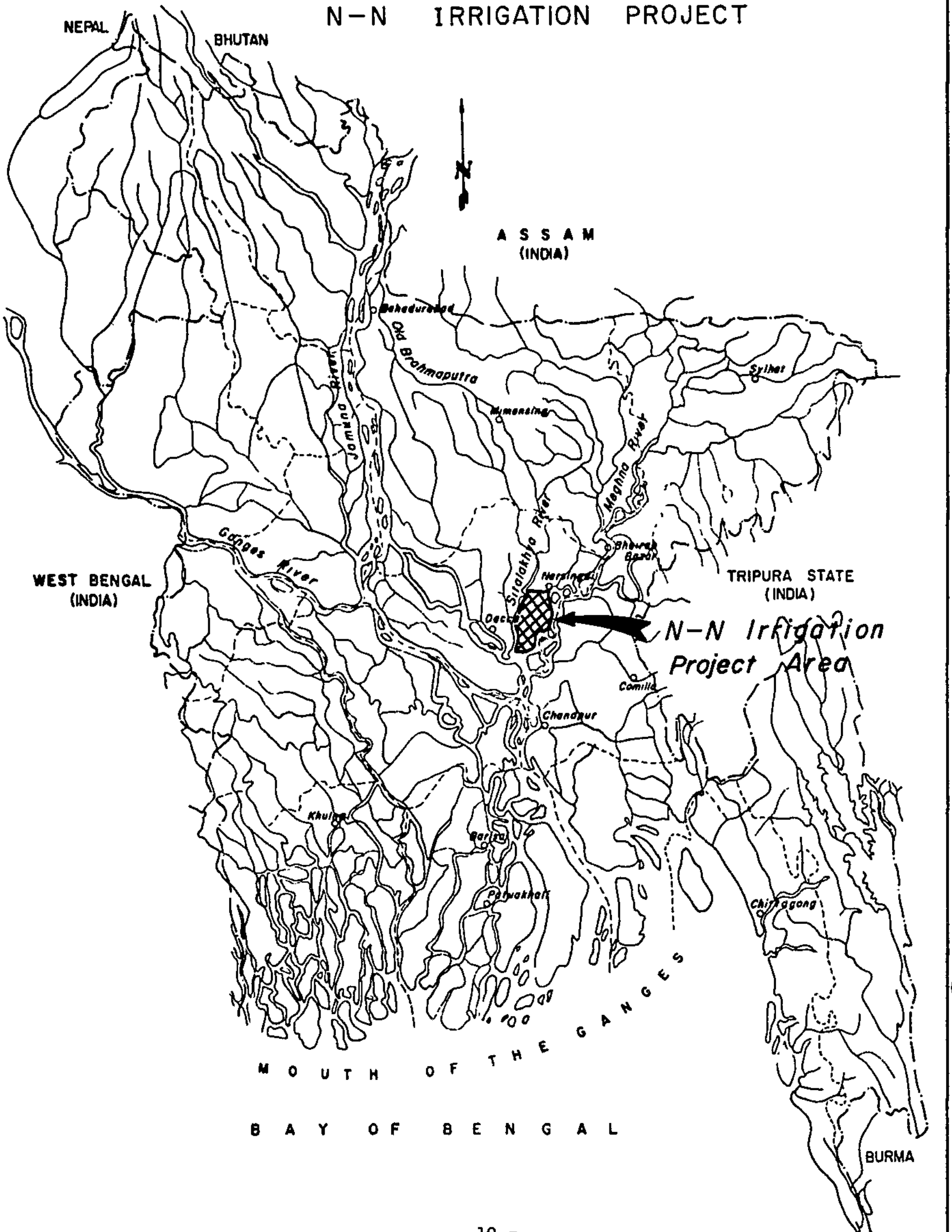
The project area, which belongs to Dacca District, involves five Thanas of Narsingdi, Baidya Bazar, Araihazar, Narayanganj and Rupganj. Table 3-1 gives its area on Thana basis.

Table 3-1 Thana-Wise Areas

Thana	Area (Ac)
Narsingdi	27,880 Ac
Araihazar	38,210 Ac
Baidya Bazar	36,550 Ac
Rupganj	30,140 Ac
Narayanganj	14,380 Ac
Total	147,160 Ac

Thana-wise structure of the project area is shown in Fig. 3-2.

Fig. 3-1 LOCATION MAP OF N-N IRRIGATION PROJECT



3.2 Topography and Profile

Most of the project area (about 94% of the entire area) spreads between 7.5 ft and 19.5 ft in elevation. The ground level of the whole area is generally slanting southward, excepting along the Sitalakhya River and at the centre, where land blocks over 19.5 ft are existing as shown in Fig. 3-2. The swampy areas are mostly spreading in between these heights. The areas lower than 7.5 ft are made up of such swamps and riverbeds. Table 3-2 shows the whole area by different ground levels.

Many villages are scattering over within the project area but they are invariably situated above the inundation level during the monsoon season which would reach as high as 17 ft or so according to our assessments based on the interview results with the local people. Excepting village settlement areas, the whole project area is mostly inundated during flooding season.

Table 3-2 N-N Irrigation Project Area by Ground Levels /1 /2

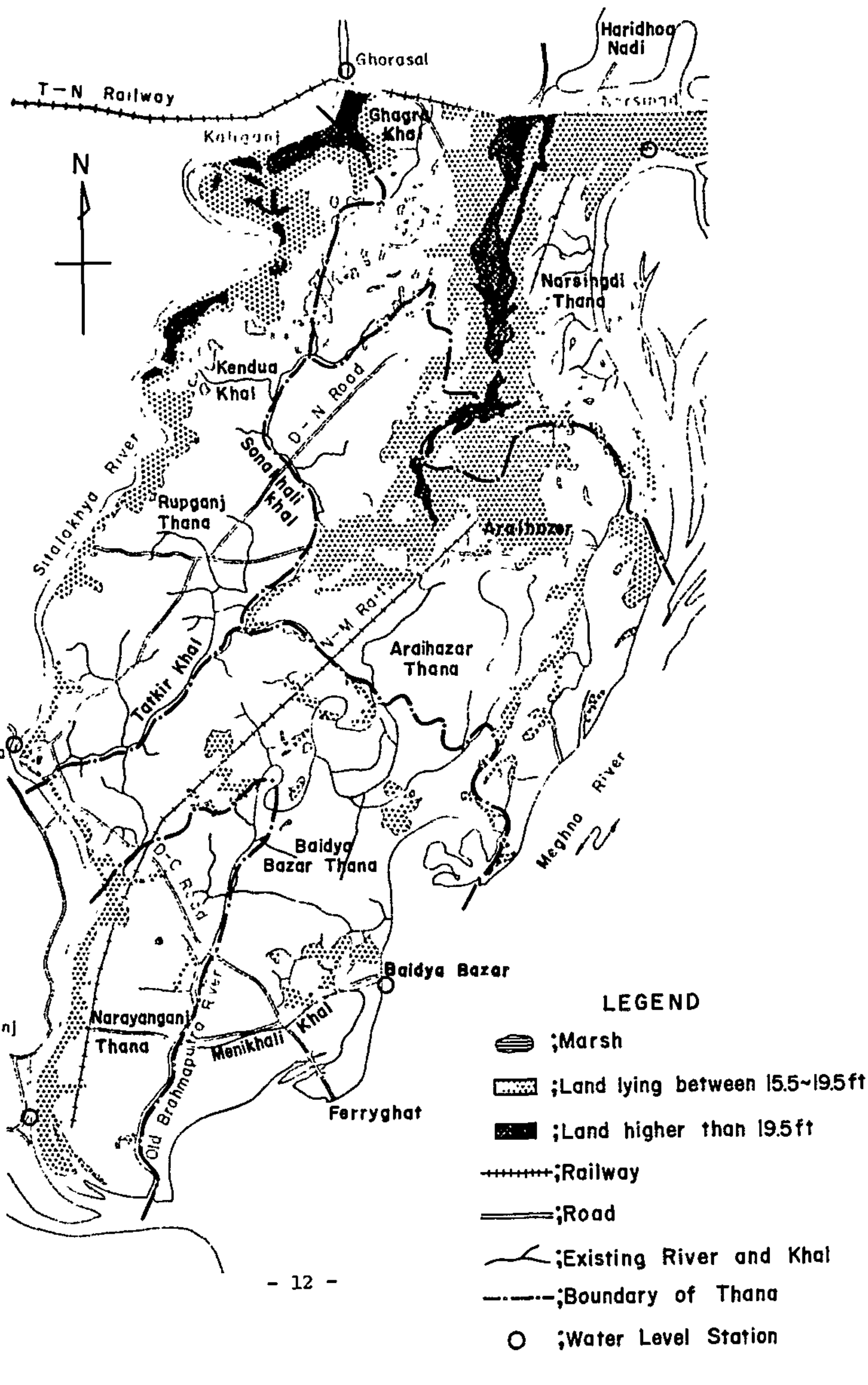
above 25.5 ft	148 Ac (60 ha)
21.5 ∿ 23.5 ft	1,852 Ac (750 ha)
19.5 ∿ 21.5 ft	5,012 Ac (2,030 ha)
17.5 ∿ 19.5 ft	10,963 Ac (4,440 ha)
15.5 ∿ 17.5 ft	15,901 Ac (6,440 ha)
13.5 ∿ 15.5 ft	18,247 Ac (7,390 ha)
11.5 ∿ 13.5 ft	55,086 Ac (22,310 ha)
9.5 ∿ 11.5 ft	31,111 Ac (12,600 ha)
7.5 ∿ 9.5 ft	6,913 Ac (2,800 ha)
below 7.4 ft	1,926 Ac (780 ha)
Total	147,159 Ac (59,600 ha)

/1 The project area implies the area which is enclosed by the Meghna River, the Sitalakhya River, and the T-N Railway.

/2 Elevation is shown in PWD standard.

Fig. 3-2 TOPOGRAPHIC MAP

BANGLADESH N-N IRRIGATION PROJECT



3.3 Climate

The climatical features of Bangladesh can be divided into the following three categories with different rainfal patterns.

a) Summer season (or northeastern season): March-May
b) Monsoon season (or rainy season) : June-October
c) Winter season (or dry season) : November-February

The rainfall in Bangladesh is characterized by large seasonal variations. Rainfall records are available for five stations in and around the project area, i.e. Dacca, Narayanganj, Narsingdi, Kaliganj, and Bancharanpur. Rainfall records at Dacca station have been adopted as the design rainfall records for the project. The other climatical data are also available at Dacca station.

The mean monthly rainfalls for the last ten years recorded at the observatory at Dacca are given in Table 3-3. As shown in Table 3-3, only a little rainfall occurs during the dry season, while about 80% of annual rainfall concentrates in the monsoon period. During the monsoon season, the huge runoff due to the concentrated rainfall would be combined with an enormous rise of the major river flow, causing an annual flooding over as much as one-third of the whole country.

Table 3-3 Mean Monthly Rainfall at Dacca

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
in.	0.16	0.42	3.01	4.21	11.17	13.90	16.73	14.34	9.10	6.08	1.24	0.34	80.70
mm	4	11	76	107	284	353	425	364	231	154	31	9	2,049

The mean annual temperature is about 78°F (25.6°C), but the average monthly temperature ranges from 66°F (19°C) to 85°F (29.5°C) with a variation of about 20°F (10°C) between the highest and the lowest of the annual temperature. Under the influence of the continental climate, there is a considerable difference between the highest and the lowest of the daily temperature. Mean monthly temperatures at Dacca are shown in Table 3-4.

Table 3-4 Mean Monthly Temperatures at Dacca

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
°F	65.7	70.7	79.2	83.8	84.6	83.4	82.5	82.7	80.8	81.2	74.4	67.0	78.0
°C	18.7	21.5	26.2	28.8	29.2	28.6	28.1	28.2	27.1	27.3	23.6	19.4	25.6

Mean relative humidity varies from 67% to 90% at Dacca. Daily relative humidity, however, shows large variations ranging from 80% to 95% during the monsoon season, and from 45% to 95% during the dry season. Mean monthly relative humidities at Dacca are represented in Table 3-5.

Table 3-5 Mean Monthly Relative Humidity at Dacca

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
%	75	67	67	76	82	87	89	88	88	85	81	77	80

Mean monthly evaporation, sun-shine hours, and wind velocity at Dacca are given in Table 3-6.

Table 3-6 Mean Monthly Evaporation, Sun-Shine Hour, and Wind Velocity

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total
Evaporation	in.	2.34	3.33	5.34	6.31	6.40	4.17	4.02	3.73	3.65	3.34	2.93	2.31	47.87
	mm	95	85	136	160	163	106	102	95	93	85	94	59	1,273
Sun-Shine Hour		9.1	9.3	9.0	9.1	8.5	5.5	5.1	6.0	6.1	7.6	8.4	9.3	-
Wind Velocity	6:00 AM	0.5	0.7	1.6	2.8	2.4	2.8	2.8	2.3	1.6	0.6	0.4	0.4	-
	9:00 AM	1.4	2.0	2.6	4.2	3.7	3.8	3.7	3.3	2.9	2.0	1.7	1.4	-
	6:00 PM	0.9	1.1	2.4	4.6	4.0	3.6	3.7	3.3	2.2	1.3	0.9	0.7	-

3.4 Hydrology

The project area is bordered by the rivers in three directions: the Maghna River in the east and south, and the Sitalakhya River in the west. A discharge observatory for the Meghna River is located at Baidya Bazar, about 30 km upstream from Narsingdi. Flow levels are available for observatories at Narsingdi, Baidya Bazar, and Ferryghat (on the left bank of the Meghna River). Along the Sitalakhya River, there is an observatory at Demra for the river discharge, and those for flow levels are situated, from upstream downwards, at Ghorasal, Demra, and Narayanganj.

In the vicinity of the project area, the flow levels of both the Meghna and the Sitalakhya Rivers fluctuate under the influence of tide. Discharge observation was made for the time at which the rivers carry very large water and least affected by fluctuations in tidal water level. Therefore, data on discharges are not available for the dry season when irrigation water supply is necessary.

The annual maximum discharges at Baidya Bazar and Demra during the period of 1964∿1972 are shown in Table 3-7.

Table 3-7 Annual Maximum Discharges

River	Gauging Station	Annual Maximum Discharge					
		Unit	1964/65	1967/68	1969/70	1970/71	1972/73
Meghna	Bairab Bazal	Cusecs	435,000	450,000	406,000	487,000	406,000
		m^3/sec	12,300	12,700	11,500	13,800	11,500
Sita-lakhya	Demra	Cusecs	-	63,000	73,300	-	65,100
		m^3/sec	-	1,780	2,080	-	1,840

Mean monthly flow levels recored at three observatories for each of the rivers for the past seven years (1967∿1973) are indicated in Table 3-8 and 3-9, respectively.

Table 3-8 Flow Levels of the Maghna River /1 /2

Month \ Station	Narsingdi	Baidya Bazar	Ferryghat
	ft	ft	ft
Jan.	4.82	4.69	5.01
Feb.	4.36	4.19	4.39
Mar.	4.58	4.17	4.89
Apr.	6.01	5.46	5.88
May	8.21	7.38	7.78
Jun.	12.48	11.19	11.38
Jul.	16.79	15.11	15.41
Aug.	18.16	16.61	16.81
Sep.	17.04	15.42	15.40
Oct.	14.09	12.49	12.60
Nov.	8.78	8.12	8.21
Dec.	6.13	5.74	6.23
Maximum	22.90 1975. 8. 31	19.75 1964. 8. 11/12	19.25 1970. 8. 6 & 20

Notes: /1 The flow levels have been calculated from the monthly mean levels during the seven years;

/2 The flow elevation is shown in PWD standard.

Table 3-9 Flow Levels of the Sitalakhya River /1 /2

Station / Month	Ghorasal	Demra	Narayanganj
	ft	ft	ft
Jan.	4.60	5.07	4.77
Feb.	4.17	4.58	4.21
Mar.	4.54	5.00	4.41
Apr.	5.64	6.07	5.40
May	7.18	8.04	7.70
Jun.	13.09	12.15	11.39
Jul.	17.92	16.40	15.45
Aug.	19.32	17.74	16.94
Sep.	17.74	16.69	15.77
Oct.	14.25	13.51	12.75
Nov.	8.54	8.69	8.24
Dec.	5.73	6.28	5.82
Maximum	22.60 1962. 9. 4	22.20 1955. 8. 21	20.20 1955. 8. 20/21

Notes: /1 The flow levels have been calculated from the monthly mean levels during the seven years;

/2 The flow elevation is shown in PWD standard.

3.5 Geology

The project area belongs to the modern flood plain which covers about 87% of the entire country of Bangladesh, particularly to that which was originally formed by the Old Brahmaputra River and the Meghna River.

According to the boring data obtained in sinking of the tube-wells within the project area, a layer made up of the mixture of silt, clay and sand is found closer to the surface and it gradually turns into sandy layer as depth increases.

3.6 Soils

All the soils of the Project area are developed over unconsolidated alluvial sediments. There are two main kinds: compact Madhupur clay which occupies dissected terrace topography; and recent or sub-recent mixed flood plain sediments deposited by Ganges, Brahmaputra and Meghna Rivers.

From the physiographical viewpoint, the Project area is divided into three portions, i.e. the Madhupur tract, the Old Brahmaputra flood plain and the Young Brahmaputra flood plain. The soils in each division are described as follows.

In the Madhupur tract, the area of deeply dissected terrace with local alluvium in valleys is occupied by Tejgaon-Khilgaon soil association which has deep upland soils. Both the soil associations of Naraibag-Payati-Sayek and Naraibag-Payati, having also deep upland soils, occur in the area of mixed closely dissected terrace and flood plain. On such area consisting of shallow upland soils as mixed closely dissected terrace and flood plain, Sabhar Bazar-Gerua soil association develops.

In the Old Brahmaputra flood plain, Sonatala-Silmandi and Silmandi-Sonatala soil associations extend on flood plain ridges defined as smoothed-out river levees. The basin part of the flood plain is occupied by Naraibag-Siddhirganj soil association. On the areas where the landscape comprises mixtures of ridges, basins and old river channels, two soil associations, Naraibag-Sonatala and Naraibag-Jalkundi, are recognized.

In the Young Brahmaputra flood plain, Sabhar Bazar-Sonatala-Silmandi soil association extends over the landscape of young meander flood plain.

The following table presents the summary of descriptions on each soil association, of which details are given in the Notes. These individual soil associations are shown as mapping unit on the soil map attached to the Notes.

There are seven land capability associations identified within the Project area as illustrated on the land capability association map attached to the Notes. These land capability associations are also listed up in the following table with their extent and the soil association included. A summary of agricultural development possibility of each land capability association is presented in the following paragraphs and the detailed are described in the Notes.

A-1: The area of seasonally flooded ridges and basins classified into "mainly good and very good agricultural land" is well suited for irrigation and pump drainage: sugarcane, bananas, cereals and oilseeds on ridges and two transplanted rice crops in depressions.

B-4: The area of seasonally shallowly flooded ridges and basins classified into "good and moderate agricultural land" is as A-1, but more land suitable for two transplanted rice crops per year.

B-6: The area of mainly seasonally flooded ridges and basins with some moderate or poor land on hillocks classified into "good and moderate agricultural land" is well suited for irrigation of dry-land crops on ridges and Boro paddy in basins during the dry season. Pump drainage probably more costly than A-1, but pump irrigation from rivers easier. Where feasible, opportunities of suitability for two transplanted rice crops similar to B-4.

C-8: The area of mainly closely dissected highland with deep soils, with seasonally flooded valleys classified into "mainly moderate agricultural land" is well suited for irrigation of sugarcane, oilseeds and cereals on highland and suitable for one or two transplanted rice crops per year in part highland and part valley, but irrigation of highland mainly by small tube-wells.

C-9: The area of seasonally deeply flooded ridges and basins, dry in the dry season classified into "mainly moderate agricultural land" is well suited for irrigation of dry-land crops on ridges and Boro paddy in basins during the dry season. Pump drainage probably more costly than A-1.

D-17: The area of complex of hillocks and seasonally deeply flooded land classified into "poor and moderate agricultural land" is well suited for irrigated Boro rice where clayey soils developed.

D-18: The area of seasonally deeply flooded land, droughty in the dry season classified into "poor and moderate agricultural land" is well suited for irrigated Boro rice. Two transplanted rice crops could be grown in parts of Naraibag-Siddhirganj soil association with costly pump drainage.

Table 3-10 Summary of soil association descriptions

Soil Association	Name of Thana Included	Acreage and Proportion			
		Project Area		Adjacent Area	
		(arce)	(%)	(arce)	(%)
Tejgaon-Khilgaon, closely dissected phase	Narsingdi, Rupganj, Baidya Bazar, Narayanganj	8,400	11.7	2,300	20.2
Naraibag-Payati-Sayek	Rupganj	4,900	6.8	-	-
Naraibag-Payati	Rupganj, Baidya Bazar, Narayanganj	2,400	3.4	-	-
Sabhar Bazar-Gerua	Narsingdi, Rupganj	1,200	1.7	-	-
Sonatala-Silmandi	Narsingdi, Araihazar	8,200	11.4	-	-
Silmandi-Sonatala	Araihazar, Baidya Bazar	800	1.1	2,100	18.4
Naraibag-Siddhirganj	Narsingdi, Araihazar, Rupganj, Baidya Bazar	27,600	38.6	-	-
Naraibag-Sonatala	Narsingdi, Araihazar, Baidya Bazar	9,700	13.5	-	-
Naraibag-Jalkundi	Rupganj, Baidya Bazar, Narayanganj	6,700	9.4	7,000	61.4
Sabhar Bazar-Sonatala -Silmandi	Rupganj	1,700	2.4	-	-
Total		71,600		11,400	

Table 3-11 Land Capability Associations

Land Capability Association	Acreage and Proportion				Soil Association Included
	Project Area (acre)	(%)	Adjacent Area (acre)	(%)	
A. Mainly good and very good agricultural land					
1. Seasonally flooded ridges and basins	9,900	13.8	-	-	-Sonatala-Silmandi -Sabhar Bazar-Sonatala -Silmandi
B. Good and moderate agricultural land					
4. Seasonally shallowly flooded ridges and basins	10,500	14.6	2,100	18.4	-Silmandi-Sonatala -Naraibag-Sonatala
6. Mainly seasonally flooded ridges and basins with some moderate or poor land on hillocks	1,200	1.7	-	-	-Sabhar Bazar-Gerua
C. Mainly moderate agricultural land					
8. Mainly closely dissected highland with deep soils, with seasonally flooded valleys	8,400	11.7	2,300	20.2	-Tejgaon-Khilgaon, closely dissected phase
9. Seasonally deeply flooded ridges and basins, dry in the dry season	6,700	9.4	7,000	61.4	-Naraibag-Jalkundi
D. Poor and moderate agricultural land					
17. Complex of hillocks and seasonally deeply flooded land	7,300	10.2	-	-	-Naraibag-Payati-Sayek -Naraibag-Payati
18. Seasonally deeply flooded land, droughty in the dry season	27,600	38.6	-	-	-Naraibag-Siddhirganj
Total	71,600		11,400		

3.7 Agricultural Production

The present cropped area in the project area (Plan B) is about 113,830 ac which, on a net cultivable area of 88,200 ac, gives an overall cropping intensity of about 130%, as compared with the national average of 136%.

Paddy accounts for about 93% of the cropped area. There are four seasonal paddy: Aus, Broadcast Aman (B. Aman), Transplanted Aman (T. Aman), and Boro. Double paddy cropping is practiced at present on some land. Aus is grown on 27,350 ac, B. Aman on 46,500 ac, T. Aman on 3,880 ac and Boro on 20,520 ac. In Aus and Aman paddy cultivation, local variety predominates, with only 2% of high yielding variety (HYV); the situation is completely reversed with Boro which is overwhelmingly done with HYV (90%). The local verieties yield only an average of (tons/ac): Aus and B. Aman-0.29 ∿ 0.33; T. Aman-0.55, and Boro-0.59. The HYV Aus, T. Aman and Boro paddy yield about 1.0, 1.0 and 1.2 per ac, respectively.

Jute with an average yield of about 0.6 t/ac accounts for 10,000 ac or about 9% of the cropped area. About 4,650 ac of wheat, dry season pulses, oilseeds and vegetables are grown utilizing residual soil moisture and minor supplemental irrigation.

Agricultural production in the area in 1976 ∿ 77 was estimated at about 49,300 tons of paddy and 6,000 tons of jute. Production data of minor crops such as pulses, oilseeds and vegetables are incomplete.

Farmers have accepted the use of chemical fertilizers for high yielding varieties. Farm work is carried out by an estimated 30,000 draft animals and by manual labour. Animal health is poor and severely restricts farm draft power. Diseases cause an annual death rate of some 8% and keep about one-fifth of animal unfit for work. Most of the animals are infected with parasites.

Fish taken from such rivers as the Meghna, the Sitalakhya and the Old Brahmputra, as well as local tanks, fish ponds, khals and beels, means a lot for the project area as it provides employment to the many and supplies a significant protein adjunct to the rural diet. Catches particularly from the local tanks, khals and beels are reported to be deteriorating annually-possibly due to overfishing, silting or pollution from agricultural chemicals.

Several of the villages in the project area are traditional handloom centres, and have been manufacturing textiles of high quality. For the last several years, however, the handloom industry has experienced serious shortages of funds and lack of raw materials including yarn, dyes, chemicals and spares, resulting in closing down of many such looms. Large number of affected weavers are unemployed compounding the already serious labour situation.

3.8 Storage, Marketing and Transportation

Farm produce in the project area is largely for subsistence. Less than 10% of total paddy crop and a somewhat higher percentage of vegetables, fruits (particularly banana) and pulses are marketed. Jute is the only crop grown primarily for the market.

Farmers take their produce by carry-pole, oxcart, rickshaw and boat to the village markets, where it is bought by small traders and then sold to successively large brokers before reaching the wholesale dealers in the town market. Small farmers usually sell soon after harvest. Traditionally, the lowest paddy price is received during November-January for the main Aman crop. The Government has been entering the food grain market by opening the Procurement Centres all over the country during the rice harvesting season and paddy (and rice) thus collected is transported to the Food Ministry's godowns which, however, have storage capacity being equal only to about 10% of the annual total rice production in the country. Milling of the Government-procured paddy is still undertaken by the private sector. In 1976/77, the Ministry of Food offered a procurement price of Tk 74 per maund plus another Tk 4 for transport cost.

Farmers usually store paddy in containers of bamboo strips and clay, placed inside their houses. The containers are only satisfactory if paddy is well dried. Many of the private dealers have small godowns for the storage of paddy and rice. Substantial storage losses, particularly of the monsoon harvested Aus and Boro paddy are suspected. Rice for home consumption is processed by hand pounding and by rice huskers operated by village entrepreneurs. Most marketed paddy is milled in commercial mills. There are also privately operated oilseed mills and jute balers.

Storage of fertilizers and other input materials for agricultural production in the project area is taken care of by the BADC; it has one general godown with the capacity of 500 tons at Narsingdi, and two 400-ton-capacity fertilizer godowns, one at Narsigndi and the other, at Baidya Bazar.

Riparian traffic and transportation along the Sitalakhya River and along as well as across the Meghna River is of great significance for socio-economic activities within the project area. Railway lines forming "T" shape in the northern part of the project area run for the total length of 27 miles, and the national highways forming "L" shape in the southern part of the area, for 53 miles in total. The dirt roads connecting the railway lines and national highways with the villages are largely innundated during the flooding period of the monsoon season and their function is replaced by countless country-boats.

3.9 Population, Farm Size and Land Tenure

The total population in the project area, which is comprised of five Thanas, is estimated at 742,000 of which about 72,000, or less than 10%, are primarily non-agricultural. A socio-economic survey conducted during the feasibility study indicates an existence of some 113,800 agriculture-dependent households with an average of 5.9 members per household, making the total rural population about 671,400. Among the rural families, about 20% are landless and another 20 ∿ 25% are presumably marginal farmers each owning one acre or less.

The average project area farm size is about 1 ac and farmland per capita of rural population is only about 0.17 ac. Most farm holdings in the area are heavily fragmented with plot sizes averaging about 0.3 ac.

Because of the limited employment opportunities in industrial sector, the means of subsistence left with the landless and marginal are predominantly agricultural. Almost half as many landless and marginal farmers are working as agricultural labourers and share croppers. Share-cropping is a main feature of the life of the marginal farmers as they have the skill and implements, while agricultural labouring is the main occupation of the landless persons. Share croppers cultivate a larger acreage, though individually in very small parcels, than that belonging to the marginal farmers; the landless usually find it difficult to get confidence of the land owners as their share croppers but merely as their labourers, mainly because they have neither skill nor implements. Share cropping is usually based on a 50-50 sharing of crop with cash inputs shared on a variable basis between the landowner and the share cropper. On the average, agricultural labourers can find gainful employment for three months out of a year. Some landless and marginal farmers work as rickshaw pullers and traders.

Small farmers have greater illiteracy rates, smaller membership rates in farmers groups, fewer livestock and lower access to irrigation water and to institutional credit. These factors combine to constrain small farmers' productivity and depress their income.

The Government's family planning and rural health schemes have so far reached the villages but only superficially and the problems being faced by population are most acute. On the other hand, the form of education is inadequate to meet the needs of rural people. They mostly lack the capability to understand the objectives of various rural development programmes and hence their participation in the development programme is almost marginal.

IV THE OVERALL PLAN

4.1 Development Plan

4.1.1 Engineering Works

(1) Basic Policy

Under the given climatical, hydrological and topographical conditions, the project area would have its agricultural production potentials enormously increased by being equipped with irrigation, flood protection and drainage facilities. Basic policies for irrigation, drainage and flood protection can be described as follows:

(i) Irrigation

During the dry season, the low-level river water can be made available to the project area by providing pumping facilities and irrigation canal systems.

(ii) Drainage

The pumping facilities meant for irrigation water supply during the dry season can be utilized, during the monsoon season, for draining rainfall water through drainage systems.

(iii) Flood Protection

The regulation of the flood flows in the upper stream portions of the major rivers flowing into Bangladesh is made extremely difficult due to a lack of suitable dam-site within its own territory. Polder dike system seems to be the only way to protect the project area from flooding. Thus, it would be enclosed by flood-protection embankments.

(2) Alternative Plans

Two alternative flood-protection dike alignments would be conceivable based on different assumptions as follows:

Plan A: To maximize the size of beneficiary area by extending a new dike alignment along the marginal portion of the whole area without any consideration of utilizing the existing transportation roadbeds as substitutes for flood-protection dikes.

Plan B: Through the maximum utilization of the existing transportation roadbeds as flood-protection embankments and by sacrificing some peripheral portions which do not warrant stable engineering works nor worthy economic return, make the project much more sound and viable both technically and economically.

(i) Comparison of Areas and Proposed Works

(a) Flood-Protection Embankment

Plan A: The entire area of 133,300 ac (54,000 ha) which is enclosed by the Meghna River, the Sitalakhya River, and the Railway-line (in the north) would make the project area.

Plan B: The beneficiary area would comprise 111,600 ac (45,200 ha) by excluding southern part of Narayanganj-Baidya Bazar Road and the northwestern portion along the Meghna River.

Fig. 4-1 ALTERNATIVE OF THE OVERALL PLAN

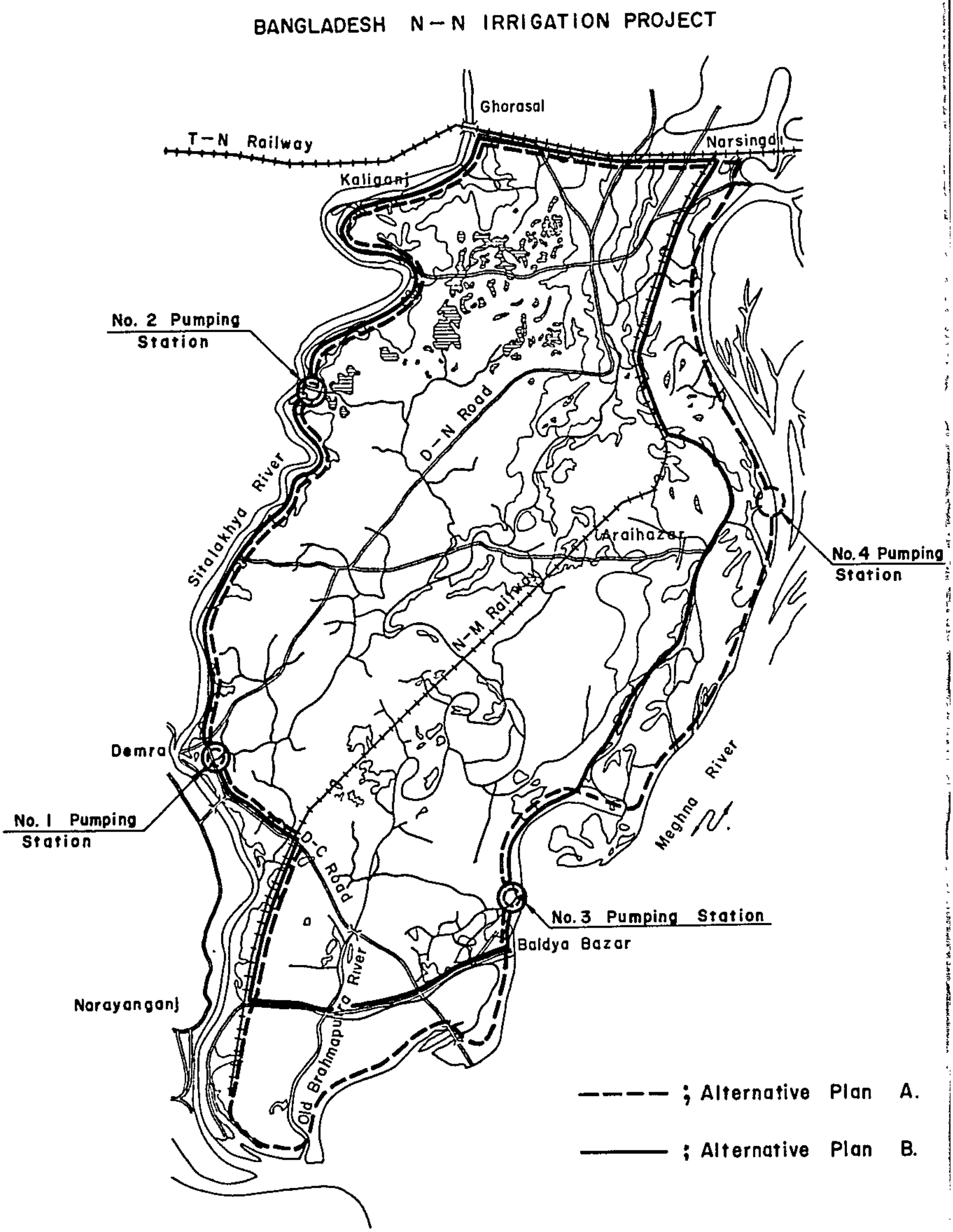


Table 4-1 Areas Covered by Plan A and Plan B

Alternative Plan	Gross Area	Irrigable Area	Homestead, Forest and Others
A	133,300 Ac (54,000 ha)	106,100 Ac (43,000 ha)	27,200 Ac (11,000 ha)
B	111,600 Ac (45,200 ha)	88,200 Ac (35,700 ha)	23,400 Ac (9,500 ha)

Table 4-2 Comparison of the Length of Embankment between Plan A and Plan B

Item \ Alternative Plan	A	B
1. Sitalakhya River Side		
New dike	24.1 Miles (39.0km)	21.5 Miles (34.8km)
Existing Road (D-C) /1	3.4 Miles (5.4km)	3.4 Miles (5.4km)
Railway (N-M) /2	6.8 Miles (10.9km)	4.2 Miles (6.7km)
Sub Total	34.3 Miles (55.3km)	29.1 Miles (46.9km)
2. Meghna River Side		
New dike	30.0 Miles (48.0km)	16.0 Miles (25.6km)
Railway	-	7.0 Miles (11.2km)
Sub Total	30.0 Miles (48.0km)	23.0 Miles (36.8km)
3. Narayanganj-Baidya Bazar Road	-	6.7 Miles (10.7km)
Total	64.3 Miles(103.3km)	58.8 Miles (94.4km)
Summary; Proposed New Dike	54.1 Miles (87.0km)	37.5 Miles (60.4km)
Existing road available	3.4 Miles (5.4km)	10.1 Miles (16.1km)
Railway available	6.8 Miles (10.9km)	11.2 Miles (17.9km)

/1 (D-C): Dacca-Chittagong

/2 (N-M): Narsingdi-Madanganj

(b) Pumping Facilities: Location of irrigation-cum-drainage pumping station should satisfy the following criteria:

i) To connect with the existing drainage channels;

ii) Proximity to the rivers as the sources of irrigation water;

iii) To have good foundation durable for structure;

iv) Being conveniently situated for power supply; and

v) Easy access to the existing roads to facilitate for construction work.

Under these circumstances, four pumping stations are deemed essential for Plan A, but three would be sufficient for Plan B. (See Fig. 4-1).

Table 4-3 Beneficiary Areas Covered by Irrigation-cum-Drainage Pumping Stations

Pumping Station	Plan A		Plan B	
	Irrigation Ac	Drainage Ac	Irrigation Ac	Drainage Ac
No.1	35,400 (14,350)	37,000 (15,000)	32,400 (13,150)	37,000 (15,000)
No.2	33,200 (13,450)	34,600 (14,000)	33,200 (13,450)	34,600 (14,000)
No.3	19,300 (7,800)	34,000 (13,800)	22,600 (9,100)	40,000 (16,200)
No.4	18,200 (7,400)	27,700 (11,200)	-	-
Total	106,100 (43,000)	133,300 (54,000)	88,200 (35,700)	111,600 (45,200)

Note: The figures in the parenthesis indicate a hectare unit.

Table 4-4 Comparative Study on Drainage Capacities under Different Pumping Stations

Pumping Station \ Alt. Plan	A	B
No.1	1,236 cusecs = 35 m^3/sec	1,236 cusecs = 35 m^3/sec
No.2	1,236 cusecs = 35 m^3/sec	1,236 cusecs = 35 m^3/sec
No.3	1,165 cusecs = 33 m^3/sec	1,413 cusecs = 40 m^3/sec
No.4	954 cusecs = 27 m^3/sec	-
Total	4,591 cusecs =130 m^3/sec	3,885 cusecs =110 m^3/sec

(c) Irrigation and Drainage Systems: Distribution of irrigation water after it is pumped up from rivers would be made through canal system based on gravity, except for small portions which will be irrigated by use of supplementary low-head pumps.

Intrusion of flood water from the rivers through the openings of the existing channels will be controlled by regulating suliceways built along the dikes. Drainage, therefore, concerns only with runoff from rainfall water which would be accumulated within the project area protected by dike system. The existing drainage channels /1 are proposed to function as the main drainage channels through their improvements.

/1 For instance, Old Brahmaputra River, Sonakhali Khal and Tatkil Khal.

(ii) Comparison of Construction Costs

Table 4-5 Cost Comparison between Plan A and Plan B /4 /5 (Unit: 1,000 Tk)

Item	Unit	Unit Cost	Plan A (106,100 Ac)		Plan B (88,200 Ac)	
			Quantity	Amount	Quantity	Amount
1. Dike						
Sitalakhya River	Mile	1,400	24.1	33,740	21.5	30,100
Meghna River	Mile	1,700	30.0	51,000	16.0	27,200
D-C Road /1	Mile	450	3.4	1,836	3.4	1,836
N-B Road /2	Mile	720	-	-	6.7	4,824
N-M Railway /3 (D-C Road-Narsingdi)	Mile	800	-	-	7.0	5,600
N-M Railway (D-C Road-Madanganj)	Mile	-	6.8	-	4.2	-
Sub-Total			64.3	86,576	58.8	69,560
2. Related Structures of Dike System						
Closures	Nos.	500	12	6,000	6	3,000
Sluiceway	Nos.	3,000	15	45,000	8	24,000
- do - (Brahmaputra R.)	Nos.		1	30,000	1	20,000
Sub-Total				81,000		47,000

Item	Unit	Unit Cost	Plan A (106,100 Ac)		Plan B (88,200 Ac)	
			Quantity	Amount	Quantity	Amount
3. Pumping Plants						
Mechanical Works	Station	75,000	3	225,000	3	225,000
- do -	Station		1	95,000	-	-
Civil Works	Station	30,000	3	90,000	3	90,000
- do -	Station		1	45,000	-	-
Sub-Total				455,000		315,000
4. Contingencies (20%)				124,515		86,312
Total				747,091 ≑747,000		517,872 ≑518,000
Per Ac. (per ha.)				7,040Tk/Ac (17,400Tk/ha)		5,870Tk/Ac (14,500Tk/ha)

/1: Dacca-Chittagong Road;

/2: Narayanganj-Baidya Bazar Road;

/3: Narsingdi-Madanganj Railway;

/4: In preparation of the above Cost Comparison Table, the common components such as irrigation-drainage facilities and road systems have been excluded because there is little difference between their per acre costs;

/5: Cost estimation is based on the unit rates used in the Report, "Hail Haor Irrigation Project, 1976".

(iii) <u>Identification of the Overall Project Area</u>

Cost comparison between Plan A and Plan B proves that the latter is definitely more advantageous than the former both technically and economically. Moreover, the peripheral portions to be cut off under Plan B consist of swamp areas (Beel) to a large extent and, therefore, of low productivity. Plan B has, thus, been identified as the "Overall Project Area".

4.1.2 Agricultural Development Plan

(1) Agricultural Development and Labour Employment

In the project area (and, in fact, in the whole Bangladesh), the rural economy has been characterized by low productivity of the predominantly subsistence agriculture, huge unemployment, high population growth and consequent rural poverty. Low agricultural productivity is the resultant factor of traditional technologies, increasing pressure on limited land and poor institutional facilities at the grass-root level to support development activities. The Government of Bangladesh has, therefore, adopted a rural development strategy which emphasizes increasing agricultural production along with creation of employment opportunities for participation of those left out before and at the same time stresses that the existing opportunities need to be reallocated and redistributed through strengthening of rural institutions. (The status of the rural poor can undergo transformation, if they are given access to production processes.) The strategy also pays particular emphasis on integrated approach towards development, having complementarity of different sectoral programmes in view.

Having all these in view, the Government's rural development policy has been designed to fulfil the following five basic objectives:

(a) Increase of agricultural production at an accelerated pace,

(b) Creation of new employment opportunities for the rural poor,

(c) More broad-based spread of incremental benefits,

(d) Strengthening of rural institutions for effective delivery of development services and supplies to all, irrespective of their present economic and social status, and

(e) Improvement of rural infrastructure.

The concerted efforts towards the attainment of the above objectives have indeed been made in the form of the Integrated Rural Development Programme and three thanas out of five which are involved in the project area (Narsingdi, Rupganj and Baidya Bazar) came under the programme at different points of time. As much improvement has been made in each of these thanas since then, despite many difficulties and continuing constraints, people in the remaining two thanas (Araihazar and Narayanganj) are desirous of coming under the IRDP, as the aims and objectives of the programme are sound and it could play a vital role in rural development. Nevertheless, the informed observors do seldomly disagree that utilization of existing human and physical resources in these three thanas still remain far below the desirable limit. Is there no effective way for break-through so that the IRDP could attain its proclaimed aims fully?

This Project means to initiate such a break-through by tackling the Government policy (e) Improvement of Rural Infrastructure, in a near perfect manner, as has been described in the preceding sections. Should "the rural infrastructure" be "improved" in terms of flood-control, irrigation and drainage as has been outlined in the preceding sections, a new vista for agricultural development would be open in the project area. The area whose productivity has been kept under-exploited due to flooding and semi-drought conditions alternatively through a year would turn flood-proof and inundation-free during the monsoon season and irrigable during the dry season, to a large extent. The cropping intensity would thus be very much increased, side by side with introduction of optimal crop production patterns through ideal combination of the given topography and soil(s). This would allow the Government and the local community to go ahead with the priority measures towards the attainment of the goals of the IRPD, inter alia, as follows:

(a) Rapid expansion of the seed-based (HYV and fertilizer) technology,

(b) Changes in the cropping pattern along with increased application of labour-intensive technologies, and

(c) Development of rural institutions with direct involvement of small and marginal farmers and landless labourers not only as a receiving mechanism of development services but also an effective tool of ensuring equity in the distribution of income.

Needless to say, infrastructural improvement alone would not offer an absolute and automatic key for solving the problems. There should not remain such constraints on the delivery services to the small farmers as the lack of mobility, accessibility, information and clearly defined instruction to the field officers; the existence of mutiple agencies doing the same work but adopting different criteria and procedures thus resulting in co-existence of the softer and harder approaches affecting discipline in resource utilization and credit repayment should be re-examined, stream-lined and put into a proper order; the inter-agency rivalry that creates unhealthy competition and consequent wastage of resources and, at times, under-utilization of institutional facilities should be washed away so that the rural poor could be reached by means of well concerted efforts. On policy issues - if we were allowed to discuss freely -, rationalisation of pricing of both input and output would be necessary in order to achieve optimal factor combination in production and for modernisation of agriculture. Some minimum amount of agrarian reform may be conducive to making farm size more economical and crop planning more efficient which may have to include rationalisation in the ownerships (and farm management) of contiguous parcels of land.

We visualize in terms of fuller implementation of the IRDP in the project area, the formulation and concerted action for materializing the basic programme package including the following:

(i) Strengthening of the TCCA-KSS co-operative system and re-organization of other types of co-operatives (amalgamation of other co-operatives) into it;

(ii) Administration of rural credit with improved credit discipline against crop hypothecation covering all farmers irrespective of the size of land-holding and the kind of land tenure;

(iii) Intensification of agricultural extension system through training and visit system (T&V system);

(iv) Adequate and timely supply of agricultural inputs through TCCA-KSS system;

(v) Animal health programme for draft animals, dairy, etc.;

(vi) Development of fish ponds for the landless;

(vii) Development of physical infrastructure at thana and rural areas through rural works programme; /1; and

(viii) Inclusion of new components like rural industries and cooperative marketing.

While the above will take care of agricultural production and expand opportunities for rural poor, it is necessary to build in the project area the linkage with some other socially oriented supportive programme components namely;

(a) Nutrition,

(b) Health and medical facilities,

(c) Population control, and

(d) Education.

/1 : The primary physical infrastructure for flood-control, irrigation and drainage as well as main road network would be completed under the Project, some other rural works such as construction of ware-houses, markets and processing facilities and rehabilitation of delapidated fish ponds should be undertaken through Rural Works Programme.

(2) Agricultural Production

The basic infrastructure in terms of the flood-protection embankment, pumping stations, irrigation/drainage canal systems, and on-farm facilities would enormously increase the agricultural production potentials in the project area. Through techno-economic comparative studies conducted with two alternative plans of A and B, in view of identifying the scale of the project which would bring the maximum investment effects, the latter has been eventually approved.

Agriculture which has been continued for centuries in Plan B area is basically governed by climatic, topographic and soil conditions and its land utilization has been regulated by particular co-relationships between topographic conditions and soils as well as fluctuations in flood water level during monsoon season. Accordingly, Plan B area can be roughly divided into five agronomic regions mainly classified by elevation as shown in Table 4-6.

After the completion of the basic infrastructure, the area would turn flood-proof and inundation-free during monsoon season and irrigable all through the year. This would enable re-grouping of land-classification and introduction of radically new cropping patterns, as illustrated in Figs. 4-2 through 4-5.

Accordingly, the crop production pattern would be very much improved in Plan B area as shown in Table 4-8.

Detailed explanation on this radical change of land use would be made in the corresponding section of the Notes (Volume II of this report).

Table 4-6 Current Land Use in Plan B Area under the Influences of Flooding Season Inundation Levels & Topographic Conditions

	Situation during Monsoon Season		Land Use according to Topographical Conditions						Gross Area
	Water Depth	Depth & Period of Inundation	High terrace Edges & Hillocks	Level Upland	Flood Ridges	Flood Plain	Basin	Depression	(Ac.) (%)
Highland (1)	Over 3' above water level	Flood-free	Homestead area						3,950 (3.5)
Highland (2)	Upto 3' above water level	Flood-free	Homestead area	Perennial or annual dry land crops					9,150 (8.2)
Medium Highland	Water depth Upto 3'	Inundation depth within 1 foot continuously for 6 days during late July and early August		T. Aus or T. Aman	T. Aus or T. Aman with Rabi crops				17,700 (15.9)
Medium Lowland	Water depth 3'-6'	Maximum inundation depth 3' in July and August				T. Aus or B. Aman with Rabi crops	T. Aus or B. Aman with irrigated Boro (partly)		49,450 (44.3)
Lowland (1)	Water Depth 6' 9'	Inundation depth above 6' from mid-June to mid-September					B. Aman with irrigated Boro (partly)		27,850 (24.9)
Lowland (2)	Water depth more than 9'	Inundation depth above 9' from early June to end September						B. Aman	3,500 (3.1)
									111,600 (100.0)

Table 4-7 Level-wise Land Use in Plan B Area

(Comparison between the Current and W-Project)

	Current Land Classification		Re-Grouping of Land Classification Under the Project				
	Gross Area (Ac.)	Net Area (Ac.)	Gross Area (Ac.)	Land Use Pttern	Gross Area (Ac.)	Net Area (Ac.)	Cropping Pattern
Highland (1) over 3' above water level	3,950 (3.54%)	2,700	3,700 (3.32%)	(1)	3,700 (3.32%) above the	2,700 main canal	(A)
		180	250 (0.22%)	(2)	76,600 (68.64%)	57,400	(B)
Highland (2) upto 3' above water level	9,150 (8.20%)	6,750	9,150 (8.20%)				
Medium Highland water depth ~3'	17,700 (15.86%)	13,100	17,700 (15.86%)				
Medium Lowland water depth 3'~6'	49,450 (44.31%)	37,340	49,450 (44.31%)				
Lowland (1) water depth 6'~9'	27,850 (24.96%)	30	50				
		12,900	14,600 (13.08%)	(3)	above the water level 14,600	12,900 inundated very shallowly	
		1,500 360	12,800 400	(4)	inundated shallowly 14,280 (12.80%)	12,980	(C)
Lowland (2) water depth more than 9'	3,500 (3.14%)	1,040	1,080				
		2,300	2,420	(5)	2,420 (2.17%) inundated moderately	2,300	(D)
Total	111,600 (100.00%)	88,200	111,600		111,600 (100.00%)	88,200	

Fig. 4—2 PROPOSED CROPPING PATTERN "A"

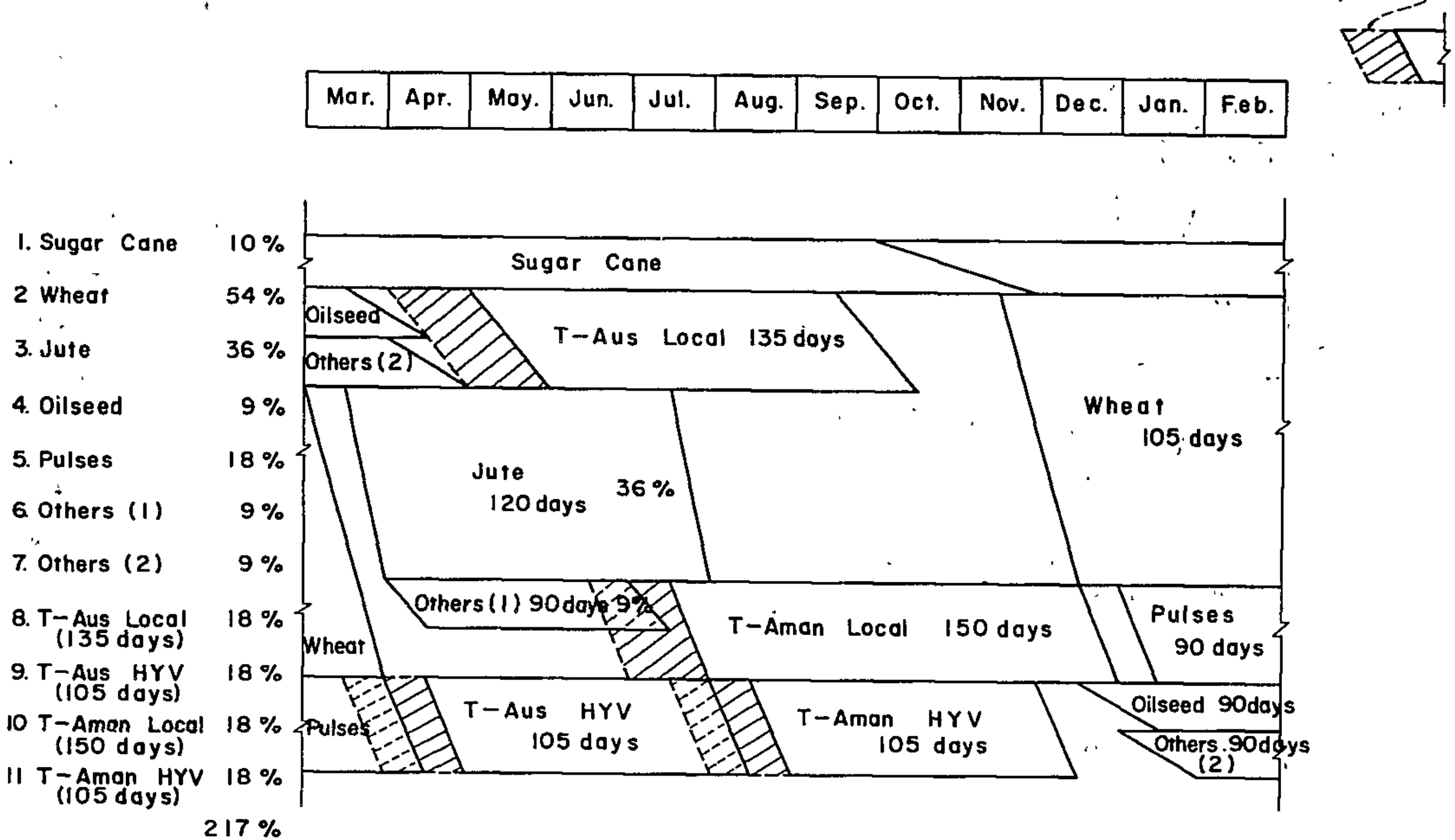
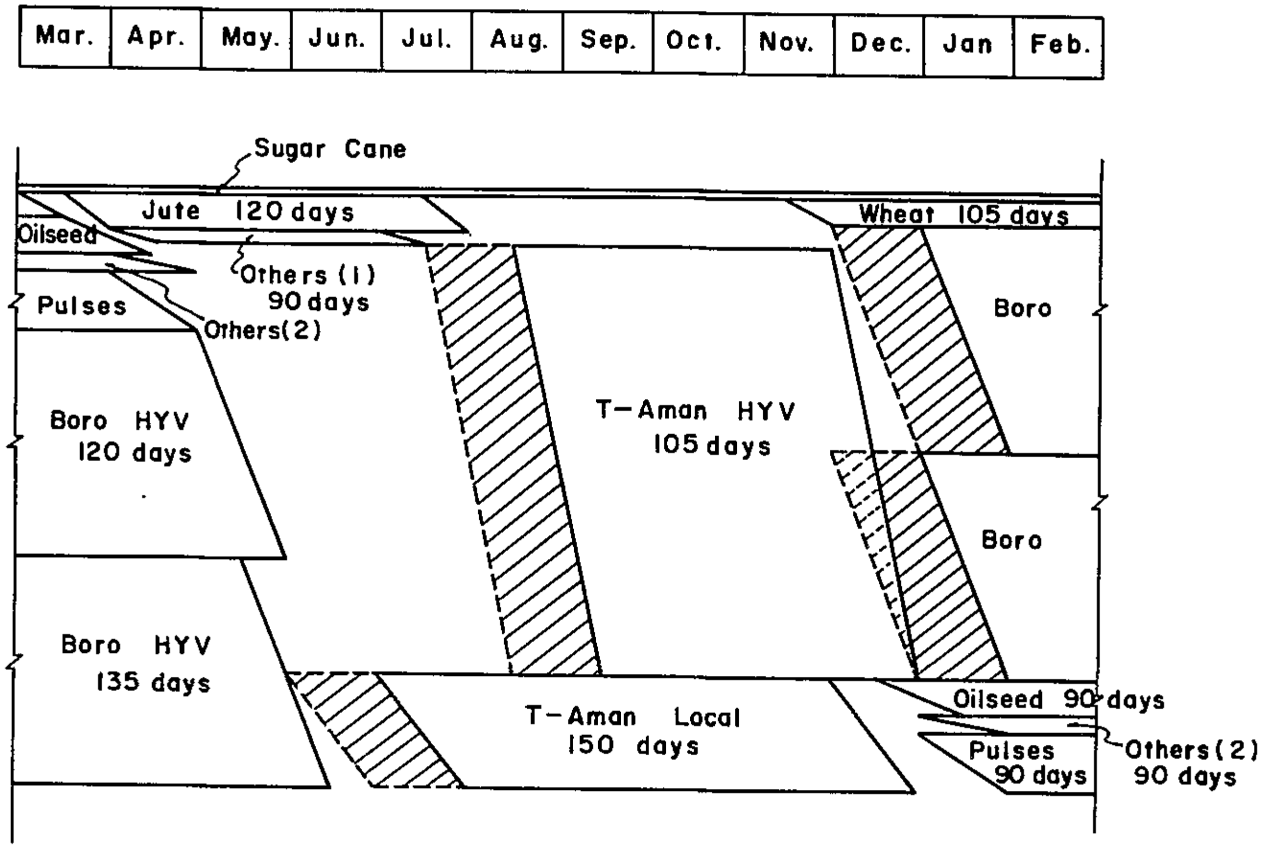


Fig. 4-3 PROPOSED CROPPING PATTERN "B"



Crop	Intensity
1. Sugar Cane	1 %
2 Wheat	4 %
3 Jute	6 %
4 Oilseed	6 %
5 Pulses	10 %
6 Others (1)	2 %
7 Others (2)	3 %
8 T-Aman HYV (105 days)	72 %
9 T-Aman Local (150 days)	19 %
10 Boro HYV (120 days)	38 %
11 Boro HYV (135 days)	38 %
	199 %

Fig. 4−4 PROPOSED CROPPING PATTERN "C"

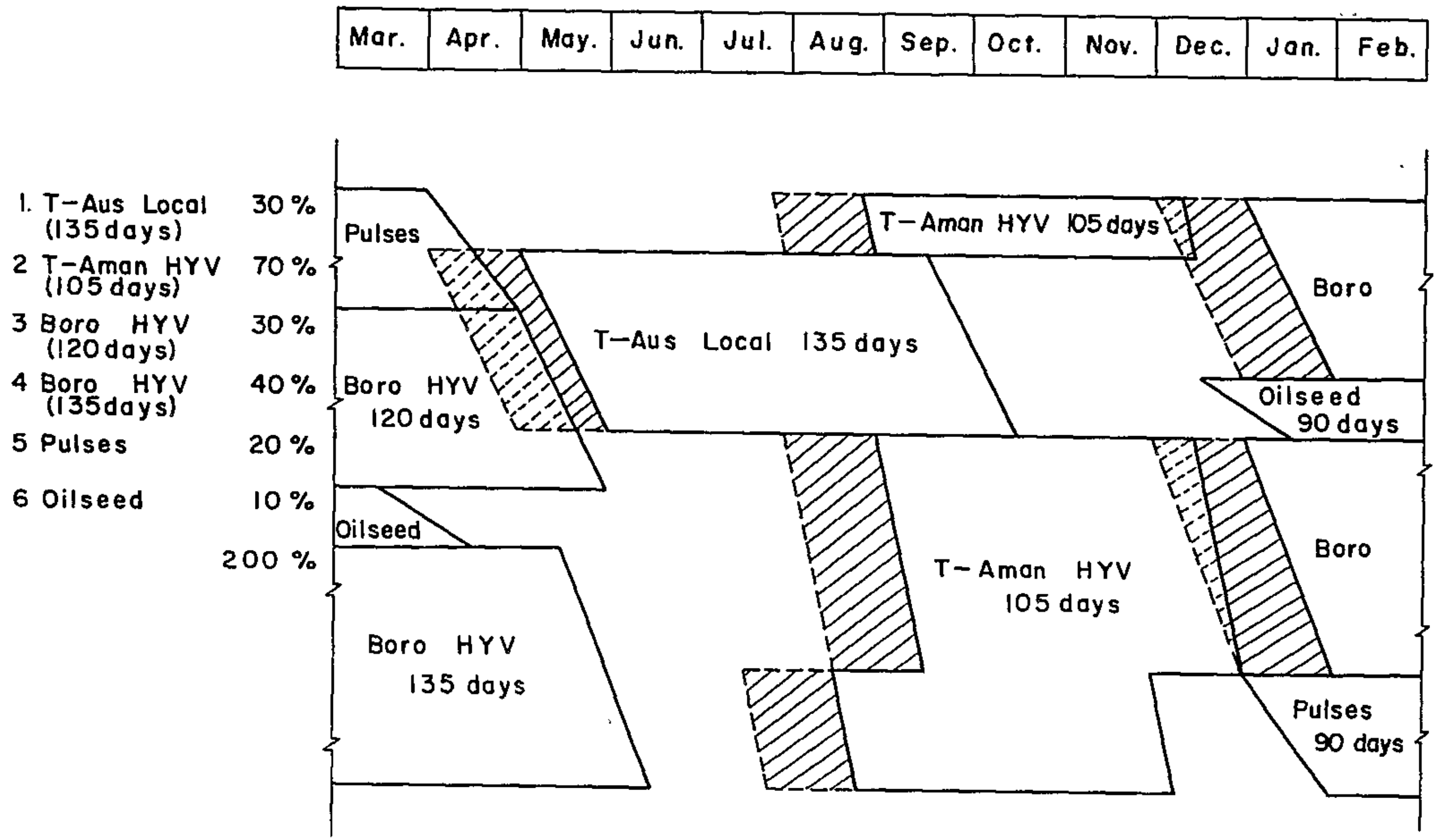


Fig. 4-5 PROPOSED CROPPING PATTERN "D"

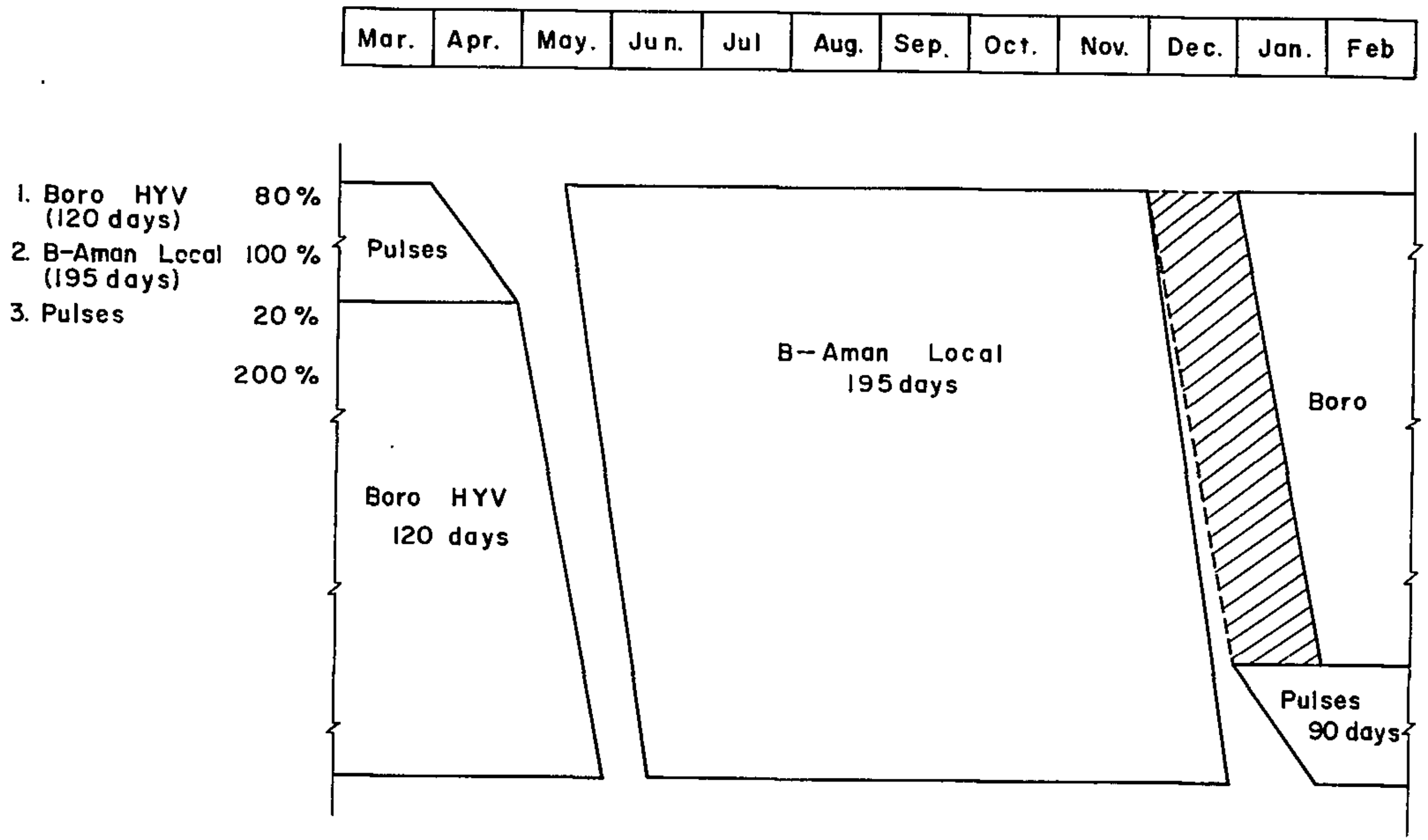


Table 4-8 Area Planted With Differents Crops in Plan B Area
(Differences Between Wrent & W/Project)

		Current	W/Project
I Paddy			
T.Aus	HYV	1,000	486
	LIV		4,356
	Local	26,350	
B.Aman	Local	46,500	2,300
T.Aman	HYV	470	60,132
	LIV		13,843
	Local	3,410	
Boro	HYV	18,500	64,298
	Local	2,020	
Sub Total		98,250	145,414
2 Upland Crops			
Wheat		470	4,270
Pulse		2,500	10,556
Oil Seeds		1,210	5,751
Summer			4,001
Winter		470	2,200
Sub Total		4,650	24,578
3 Perennial & Industrial Crops			
Jute		10,000	10,800
Sugar cane		930	1,100
Sub Total		10,930	11,900
Total		113,830	181,893

4.2 Stage-Wise Implementation of Development Plan

(1) General

The whole project covers a huge area of 147,160 ac (59,600 ha) and the total cost required for its implementation would amount to an enormous value. Its implementation at a single stroke, construction works and agricultural development schemes combined, thus involving multifarious problems of operation and management of the facilities provided under the project and guidance and extension for agricultural production-increases, would mean a formidable task which is deemed almost impossible or unrealistic, judging from the availability of financial resources and institutional establishments and technical personnel called for its execution. For the ultimate success of the project, therefore, it would be preferable to plan for a stage-wise implementation and a gradual expansion of the project area through accumulation of benefits.

The whole project area has accordingly been divided into two parts, the one for immediate project implementation under Phase I, and the other, that is, Phase II which would come under the project after the completion of Phase I. Feasibility study has been conducted for Phase I and an overall plan was prepared for Phase II. Phase I area has been further sub-divided into Stage 1 and Stage 2 from the engineering point-of-view.

(2) Implementation of the Overall Plan

The project area can be divided by the two important transport lines, i.e. Dacca-Narsingdi Road and Narsingdi-Madanganj Railway, into three portions; they would be tentatively named the Northern Region, the Central Region, and the Southern Region, respectively. Present drainage in the project area is made through several drainage systems, mainly the Old Brahmaputra River which is connected by Tatkir Khal and Sonakhali Khal both running southward.

The monsoon season being over, flood water gradually recedes towards the rivers through the Old Brahmaputra River and the Tatkir Khal. Assuming that the Central Region should be enclosed by flood-protection dikes, the Northern Region which is situated at the upper-most part of the stream would have no means to drain its water; as for the Central Region, there should be no difficulty in drainage as it has an outlet to the Sitalakhya River. In consideration of these drainage conditions, the Northern Region and the Central Region should be separated from the Southern Region with the Narsingdi-Madanganj Railway as a dividing line; the Northern and Central Regions would consist of Phase I area, while the Southern Region, Phase II area. Priority of project implementation should be given to Phase I part, because there would arise no drainage difficulty due to its being located in the upper stream area and also because of the existence of Dacca-Narsingdi Road as a very convenient access road for construction purposes.

(3) Phase I and Phase II

As illustrated in Fig. 4-6, the project area has been phased into two parts with the N-M Railway as a dividing line, i.e. the Northern Region forming Phase I and the Southern Region forming Phase II. Thana-wise distribution of the project areas is shown in Table 4-9.

Pumping stations No. 1 and No. 2 would be constructed in the Phase I area, while pumping station, No. 3 in the Phase II area. The area for irrigation assigned to each pumping station somewhat differs from that for drainage, as shown in Fig. 4-7.

Fig. 4-6 PHASE I AND PHASE II

BANGLADESH N-N IRRIGATION PROJECT

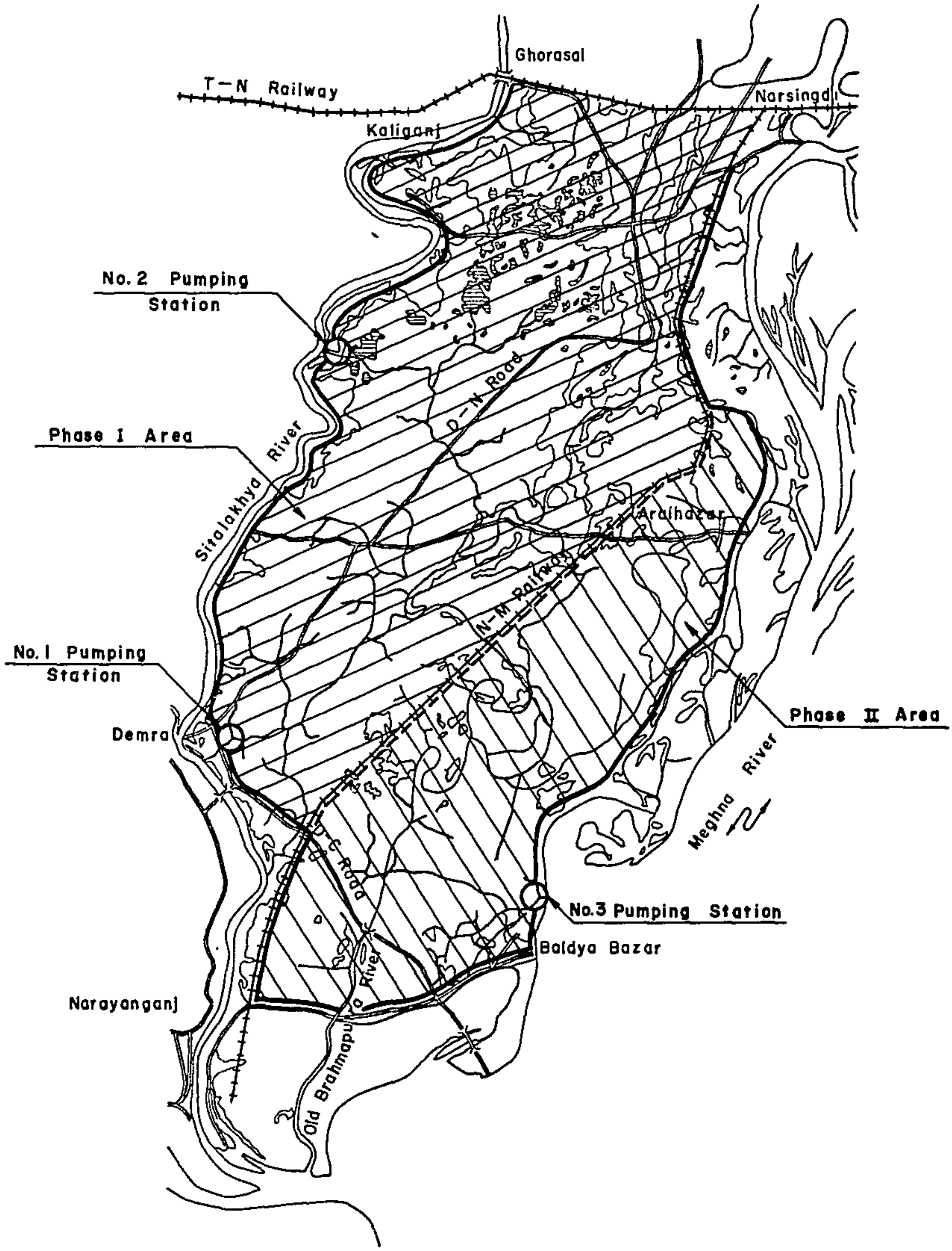


Table 4-9 Thana-wise Distribution of Area Among the Whole Project Area Plan A And Plan B as Sub-divided into Phase I & Phase II

(Cross Area in Acres)

Name of Thana	Administrative Area of Thanas	The Whole Project Area	Plan A Area	Plan B Area		
				Phase I	Phase II	Total
Narsingdi	52,480	27,880	26,630	21,400		21.400
Araihazar	45,440	38,210	33,690	13,000	12,730	25,730
Baidya Bazar	42,240	36,550	33,086	6,700	21,880	28,580
Rupganj	65,280	30,140	29,100	29,100		29,100
Narayanganj	18,560	14,380	10,494	1,400	5,390	6,790
	224,000	147,160	133,000	71,600	40,000	111,600

Fig. 4-7 Detailed Area by Phases

Whole Project Area

Area \ Item	Irrigation	Drainage
Gross	111,600 ac (45,200)ha	111,600 ac (45,200)ha
Net	88,200 ac (35,700)ha	-

Phase 1

Area \ Item	1/ Irrigation	Drainage
Gross	82,900 ac (33,600)ha	71,600 ac (29,000)ha
Net	65,600 ac (26,600)ha	-

Phase 2

Area \ Item	2/ Irrigation	Drainage
Gross	28,700 ac (11,600)ha	40,000 ac (16,200)ha
Net	22,600 ac (9,100)ha	-

No.1 Pumping Station

Area \ Item	Irrigation	Drainage
Gross	29,400 ac (11,900)ha	37,000 ac (15,000)ha
Net	23,800 ac (9,650)ha	-

Gross	11,300 ac (4,600)ha
Net	8,600 ac (3,500)ha

Total

Gross	40,700 ac (16,500)ha	37,000 ac (15,000)ha
Net	32,400 ac (13,150)ha	-

No.2 Pumping Station

Area \ Item	Irrigation	Drainage
Gross	42,200 ac (17,100)ha	34,600 ac (14,000)ha
Net	33,200 ac (13,450)ha	-

No.3 Pumping Station

Area \ Item	Irrigation	Drainage
Gross	28,700 ac (11,600)ha	40,000 ac (16,200)ha
Net	22,500 ac (9,100)ha	-

Note:

1/ Irrigation Area

	Phase 1	Phase 2	Total
Gross	71,600 ac (29,000)ha	11,300 ac (4,600)ha	82,900 ac (33,600)ha
Net	57,000 ac (23,100)ha	8,600 ac (3,500)ha	65,600 ac (26,600)ha

2/ Irrigation Area

	No.3 pump	Phase 1	Total
Gross	28,700 ac (11,600)ha	11,300 ac (4,600)ha	40,000 ac (16,200)ha
Net	22,600 ac (9,100)ha	8,600 ac (3,500)ha	31,200 ac (12,600)ha

V THE PROJECT

5.1 General

The Project comprises three categories of programmes. The first is the Construction Programme; the second, Agricultural Production Programme; and the third, Supporting Infrastructure and Farmer Service Programme. It is important to note that they are not mechanically packaged into a bundle, but organically fused into one entire Project: the first (construction programme) provides the physical basis for implementation of the second (agricultural production programme) and its success is guaranteed only if the third (supporting infrastructure and farmer services programme) will be properly put into effect. As has been discussed in the preceding sections, the project implementation will be limited primarily within the area demarcated as the Plan B-Phase I, as far as the first and the second programmes are concerned. It is strongly recommended that Araihazar and Narayanganj thanas might be brought under the IRDP as early as practicable so that when the third programme (for strengthening of the supporting facilities and farmer services) should start reinforcing the present IRDP framework and function in Phase I area, the similar enlivening measures could be taken in Araihazar and Narayanganj thanas, thus offering the overall project benefits to the entire Plan B area as and when the similar construction programme and agricultural production programme would come to be adopted towards Phase II area.

Before entering the detailed and technical explanations on the project meant for Phase I area, it would be advisable to make a brief introduction to the scope, extent and major components of each one of the three programmes proposed under this project.

A: Construction Programme: This programme aims at turning the project area (Phase I) flood-proof and inundation-free during rainy season and irrigable to the maximum extent during dry season by (i) construction of new flood-control embankment along the Sitalakhya River bank and (ii) strengthening of the roadbeds of the existing Dacca-Chittagong Road and Narsingdi- Madanganj Railway with regulators and closures, as well as (iii) provision of pumps which would drain run-off from the heavy and concentrated rainfall out, and by turn pump the riverwater into, the enclosure during rainy season and dry season, respectively. As the project area would be equipped with adequate irrigation/drainage network, it should be turned cultivable all through the year.

B: Agricultural Production programme: This programme would be implemented based on the farm production plans worked out village-wise according to the proposed cropping patterns all over Phase I area by each KSS with technical advices given by the extension officers, and backed up by timely supply of inputs and effective marketing of the products (without intermediary exploitation) through the same KSS. Both need to be adequately endorsed by rural credit through IRDP-TCCA-KSS.

C: Supporting Infrastructure and Farmer Services Programme: This programme comprises rural works; thana facilities; rural credit; and strengthening of rural institutions and services, such as (a) TCCA-KSSs; (b) Agricultural Extension; (c) Livestock (and Poultry) Improvement; (d) Pond Fisheries; and (e) Training.

5.2 Flood Protection Plan

5.2.1 River Water Levels

(1) Actual Water Levels

Water levels for the past seven years (1967 ~ 1974), which are given in Fig. 3-2, are available for six stations along the Sitalakhya River and the Meghna River. For each year, the highest and the lowest water levels are illustrated in Table 5-3. The following six water-level gauging stations are located along the two rivers:

Table 5-1 Water-Level Gauging Stations

River name	Station (No.)
Sitalakhya	Ghorasal (No.178)
"	Demra (No.179)
"	Narayanganj (No.180)
Meghna	Narsingdi (No.274)
"	Baidya Bazar (No.275)
"	Meghna Ferryghat

(2) Projected Flood Water Levels

Referring to the past observed data (1964 ~ 1976) provided by B.W.D.B., the calculation of probabilities has been made for each of the stations (shown in Table 5-2). For probability analysis, there exist no definite criteria but a common practice in Bangladesh of using 20 ~ 50 years data for determining the flood water level. In our case, the projected flood water level has been set above the maximum flood water level observed in the past and the crest level of the dike above a 100-year probable water level, by taking into account the socio-economic aspects as well as the cases adopted by the similar projects. As the water level satisfying these conditions falls within the 25-year probable water levels observed by most of the water level gauging stations along the two rivers, 25-year probable water levels have been adopted. Water surface gradients based on the 25-year probable water levels are represented as follows:

Siltalakhya River

Ghorasal - Demra: 1/80,000

Lower than Demra: 1/36,000

Meghna River 1/60,000

Table 5-2 Probable Water Levels (P.W.D. feet)

River	Station \ Return Period	2.33 year	5 year	10 year	25 year	50 year	100 year	200 year
Sitalakhya River	Ghorasal	21.13	21.99	22.68	23.56	24.21	24.86	25.51
	Demra	19.51	20.42	21.17	22.11	22.80	23.49	24.18
	Narayanganj	18.08	18.96	19.67	20.57	21.24	21.91	22.57
Meghna River	Narsingdi	19.72	20.67	21.44	22.42	23.14	23.86	24.58
	Baidya Bazar	18.08	18.84	19.46	20.25	20.83	21.40	21.98
	Saitnal	17.11	17.90	18.55	19.36	19.96	20.56	21.16

Table 5-3 Annual Max. H.W.L & Min. L.W.L

(Unit: P.W.D. ft)

Year / Station	1967/68		1968/69		1969/70		1970/71		1971/72		1972/73		1973/74		1974/75		Danger	Recorded * Extremes	
	H.W.L	L.W.L	H.W.L	L.W.L	H.W.L	L.W.L	H.W.L	L.W.L	H.W.L	L.W.L	H.W.L	L.W.L	H.W.L	L.W.L	H.W.L	L.W.L	Level	H.W.L	L.W.L
Lakpur	20.82	3.08	22.75	3.07	21.97	3.20	23.57	3.18	22.65	3.17	21.17	3.00	22.65	3.46			19.00	28.25 Aug.'59	3.00 Feb.'73
Ghorasal	19.60	2.60	21.40	2.50	20.55	2.50	22.20	2.30	21.05	2.60	19.75	2.50	20.95	2.85			18.50	22.60 Sep.'62	2.30 Mar.'71
Demra	17.90	3.00	19.93	2.85	19.27	2.85	20.10	3.00	19.95	2.78	17.85	2.80	19.30	2.90			16.50	22.20 Aug.'55	2.00 Feb.'61
Narayanganj	17.00	2.50	19.35	2.25	18.30	2.15	19.45	2.30	18.90	2.40	16.80	2.30	18.10	2.10	20.45	2.85	18.00	20.20 Aug.'55	1.40 Jan.'53
Bairab Bazar	20.50	3.45	22.20	3.15	22.00	3.20	23.30	3.35			20.00	3.20	21.25	3.50			21.50	25.10 Aug.'55	2.90 Feb.'65
Narsindi	18.49	3.09	20.09	2.95	19.68	3.08	20.75	2.95	20.05	3.10	17.85	2.75	19.10	2.77	22.50	3.05	17.00	22.90 Aug.'54	1.90 Jan.'51
Badya Bazar	16.63	2.08	18.53	2.30	18.00	2.30	19.10	2.60	18.50	2.20	16.45	1.15	17.80	1.00			17.00	19.75 Aug.'64	1.00 Mar.'74
Meghna Ferryghat	16.60	2.30	18.55	2.80	18.46	2.76	19.25	2.80	18.85	2.95	16.75	2.55	17.85	2.90			16.50	19.25 Aug.'70	2.30 Apr.'68
Saitnal	15.70	2.24	18.00	2.15	17.10	2.05	17.90	1.55	18.70	2.00	15.80	1.05	17.20	0.40			14.00	19.63 Aug.'55	0.13 Jan.'68
Chandpur	14.80	2.10	15.85	1.00	15.90	2.00	16.30	2.00	16.95	2.50	15.05	1.90	16.30	1.90			13.00	17.54 Aug.'55	0.30 Feb.'61

Notes: Water Year 1967/68 = Apr. 1967 ∿ Mar. 1968

5.2.2 Embankment Plan

(1) General Description

The project area is proposed to be enclosed by dikes. Along the Sitalakhya River, a new dike would be constructed from Ghorasal to Demra; elsewhere the existing roads and railway would be utilized as flood-protection dike. Among the existing roads and railway to be utilized as flood-protection dike, the D-C Road and the N-M Railway have crest levels lower than that projected for the flood-protection dike encircling the project area, the former between Demra and its crossing point with the N-M Railway and the latter, between Narsingdi and Araihazar, requiring additional embankment to raise their crest levels. The T-N Railway running along the northern border of the project area and the section of the N-M Railway between Araihazar and its crossing point with the D-C Road would be utilized as they are because they are maintaining the crest levels high enough to meet the requirement. The length of the dike to be newly constructed and that requiring additional embankment are given in Table 5-4.

Table 5-4 Length of Embankment

	Length
Enbankment	21.5 Miles (34.6km)
Additional Embankment	15.0 Miles (24.2km)
D-C Road	3.4 Miles
N-M Railway	11.6 Miles
Total	36.5 Miles (58.8km)

Bridges, culverts and other facilities along the T-N Railway and the N-M Railway (the section between Araihazar and its crossing point with the D-C Road) would be equipped with cut-off facilities such as regulating gates or closures. Width of the new dike has been determined at 20 ft (6.0 m) for vehicular traffic in future.

(2) Alignment of New Dike

The new dike along the Sitalakhya River would be built in parallel with the main stream at least 200 ft away from the river. This is to avoid future erosion of the riverbed on the one hand to locate borrow pits in between the river and the new dike on the other.

(3) Freeboard

Freeboard is an important factor in determining the crest level of the dike; it is to prevent the flood water level to temporarily rise beyond the crest due to gales, swellings, splashes, etc and/or to facilitate for inspection and removal of lumbers and other obstacles flowing down the river during flood time. Wind velocity often reaches at its maximum in Bangladesh during April and May, but it ranges between 30 ∿ 40 knots in the flooding season of July and August. It is, therefore, uneconomical to allow very high value as freeboard. As 2 ∿ 3 ft freeboard is a common practice in this country, we have adopted 3 ft.

(4) Crest Levels

Crest level of the dike equals to the sum-total of the projected flood water level (as discussed in the preceding section) and the freeboard (3 ft). The crest levels of the dike are shown in Table 5-5.

Table 5-5 Proposed Crest Elevation of Dike

River	Station	H.W.L.	Crest Level
Sitalakhya	Ghorasal	23.5	26.5 feet(PWD)
	Demra	22.2	25.2
	Narayanganj	20.4	23.4
Meghna	Narsingdi	22.7	25.7
	Baidya Bazar	20.5	23.5

(5) Cross Section of the Dike:

(i) Crest Width

As it is desirable from the regional development point-of-view to utilize the crest of the dike as roadway, the crest width has been made big enough for motor traffic. The crest width proportionate to the dike height (maximum: 13.0 ft, average: 8.4 ft) would be 15 ft or so, but for its use as the motor road, it has been determined at 20 ft (6.0 m).

(ii) Side Slope

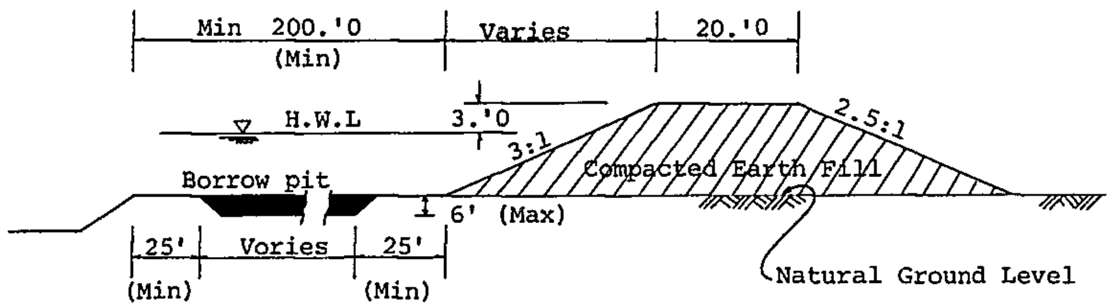
Side slope is determined, depending upon the geological conditions of the embankment (filling) and/or its foundation, the sequence of flood time, the existence of berm, and the safety against seepage as discussed above. Although geological conditions have not been closely studied, the estimated values obtainable from the other project adjacent to ours have been adopted for stability analysis. The proposed dike is rather a low one, being 13.0 ft (about 4.0 m) at the maximum, and workability taken into account, no berm would be built.

Slope stability analysis has been made with two cases of cross section, the one for new embankment along the Sitalakhya River, and the other with that of the site which was deemed most precarious of all the existing roadbeds, on the assumption that the safety factor should be above 1:3. Consequently, the cross section of the existing roadbed was found safe enough with 1:3 safety factor, and the side slopes of the new embankment have been determined at 3:1 on the river side and 2.5:1 on the country side. The results of the slope stability analysis are shown in Table 5-6, and the cross section of the new embankment is illustrated in Fig. 5-1.

Table 5-6 Results of Slope Stability Analysis

Case	Sitalakhya River		N-M Railway	
	Outside	Inside	Outside	Inside
H.W.L	1.41	1.35	1.28	1.35
Rapid Drawdown	1.41	-	1.26	-

Fig. 5-1 Standard Cross Section of Embankment



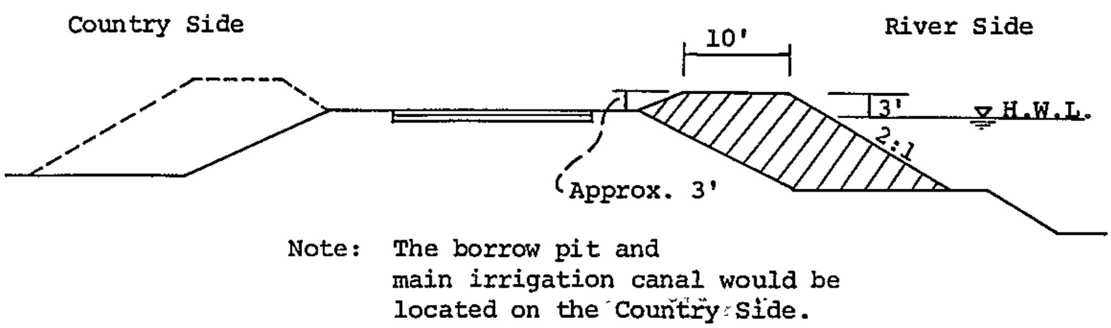
(iii) Borrow Pit

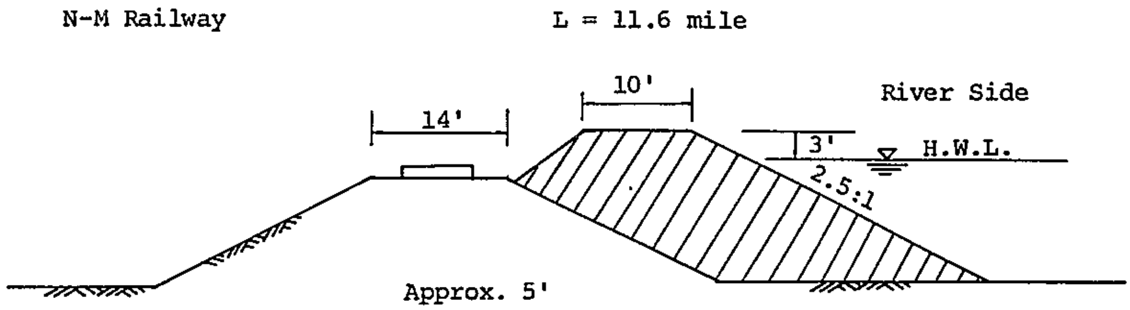
Borrow pit has been proposed on the river side, keeping distances of 25 ft each from both the foot of the slope and the stream, with the maximum excavation depth of 6 ft. Each plot of the borrow pit should measure up to 150 ft on both sides; new pit may be dug but with a partition wall which separates the new one from the old. In the detailed design, the suitability of the materials for embankment should be tested and the embankment work properly specified.

(6) Additional Embankment

As has been discussed in the "General Description", 3.4 mi (5.5 km) of the D-C Road and 11.6 mi (18.6 km) of the N-M Railway would need additional embankment to have their existing roadbeds raised higher than the projected dike crest. Additional slope bank would thus be effected as illustrated in the below:

Fig. 5-2 Standard Cross Section of Additional Embankment





(7) Related Structures

To prevent the inflow of water from outside, all the channels and waterways running in and out of the project area should be closed except the natural drainage canals. Each natural drainage canals would be equipped with regulating gate which is opened when the outside water level is lower than the inside water level and remains closed if otherwise. The flood-protection dike would be equipped with the related structures as shown below:

Table 5-7 List of Related Structures for Dike

Works / Type / Dike	Regulator				Closures				Remarks
	I	II	III	Total	I	II	III	Total	
N-M Railway	1	-	3*	4	0	7	1	8	*Irrigation Regulator
T-N Railway	0	3	0	3	1	-	-	1	
Total*	1	3	3	7	1	7	1	9	*In numbers

5.3 Drainage Plan

5.3.1 Design Standard

The design standards currently in use in Bangladesh being unapplicable to this kind of drainage work proposed under the project, it has been designed on the basis of the following assumptions:

1) Inflow of water from outside would be completely shut out during the rainy season by the dike system encircling the project area;

2) Inundation level within the project area which governs the size of the cultivable area under each cropping pattern, would be a function of the drainage capacity of the pumps and the runoff from the local rainfall;

3) Taking (a) drainage capacity of the pumps and (b) runoff from the local rainfall as two variable factors, techno-economic comparative study would be made to work out such a drainage plan as to bring the highest return to the investment to be made for its execution.

5.3.2 Hydraulic Analysis

In order to make a plan for providing pump facilities in the project area, it is necessary to grasp drainage discharge flowing out of the area. For this purpose, hydraulic data will be analysed as follows:

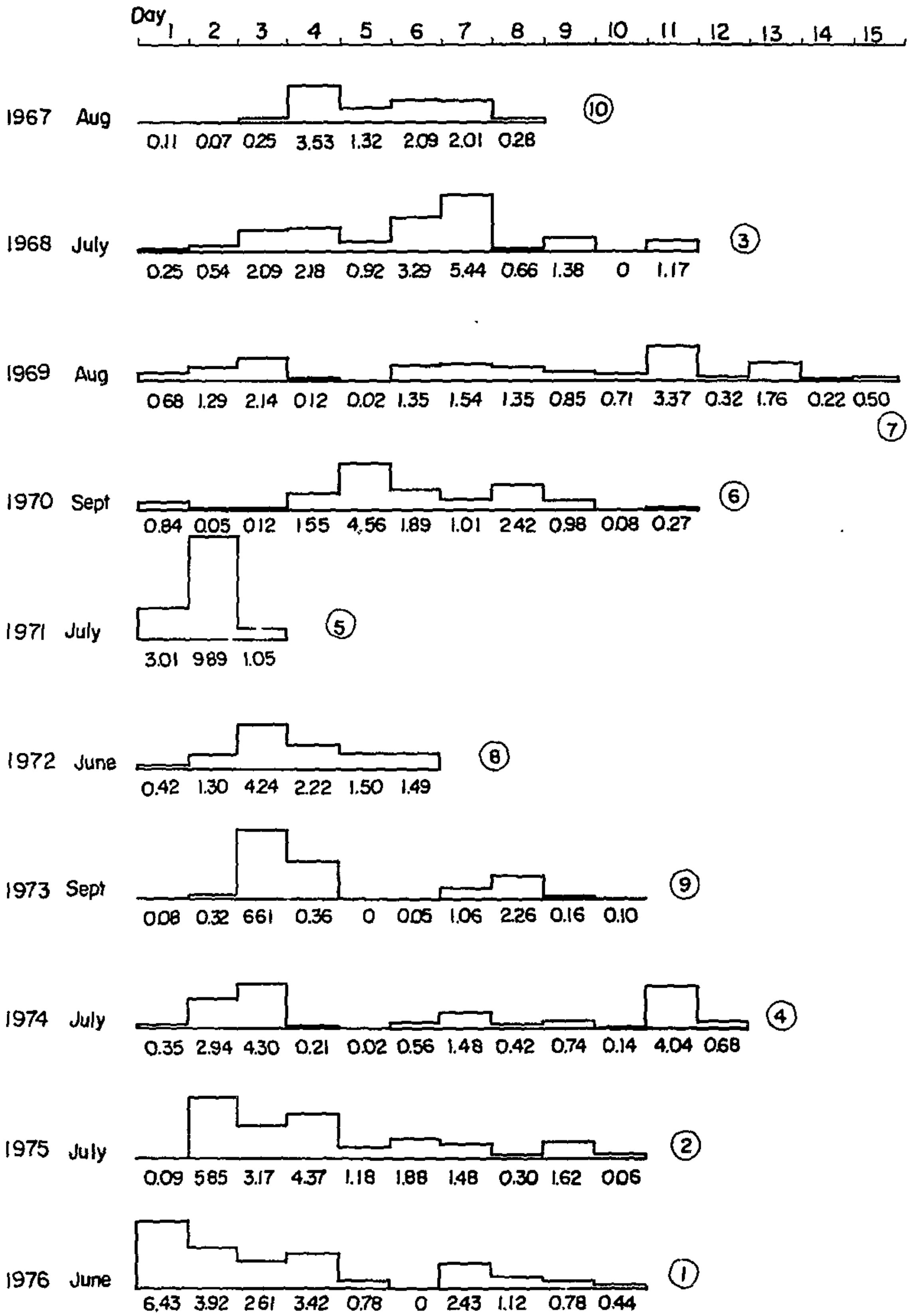
1) Rainfall Records: The rainfall records available at Dacca observatory have been adopted as the basic precipitation figures for the project area.

2) Selection of Rainfall Types: The maximum rainfall records have been picked up from amongst the annual continuous rainfalls recorded at Dacca station, as represented in Table 5-8 and Fig. 5-3.

Table 5-8 Typical Rainfall from 1967 to 1976

Year	Month	Date															Total	Continuous Day					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		1 day	2 days	3 days	4 days	5 days	10 days
1967	Aug.	0.11	0.07	0.25	3.53	1.32	2.09	2.01	0.28								9.66	-	-	-	-	-	-
1968	June	0.06	1.06	0.08	0.66	3.72	5.69	0.21	0.24	0.97	0	1.35	1.62	0.05			15.71	-	1/3	1/2	1/2	1/2	1/2
	July	0.25	0.54	2.09	2.18	0.92	3.29	5.44	0.06	1.38	0	1.17					17.32	-	1/2	1/2	1/3	1/3	1/3
1969	Aug.	0.68	1.29	2.14	0.12	0.02	1.35	1.54	1.35	0.85	0.71	3.37	0.32	1.76	0.22	0.50	16.22	-	-	-	-	-	-
1970	July	0.07	0.12	0.23	0.17	0.56	0.58	4.33	5.95	0.45							12.46	1/2	1/4	1/3	1/2	1/2	-
	Sept.	0.84	0.05	0.12	1.55	4.56	1.89	1.01	2.42	0.98	0.08	0.27					13.77	-	-	-	-	1/2	-
1971	July	3.01	9.89	1.05													13.95	1/10	1/10	1/15	1/5	1/3	-
1972	May	0.54	9.09	0.77													10.40	1/5	1/3	1/2	1/2	-	-
	June	0.42	1.30	4.24	2.22	1.50	1.49										11.17	-	-	-	-	-	-
1973	May	0.17	0.24	2.95	0	1.35	0.19	2.14	3.95								10.99	-	-	-	-	-	-
	Sept.	0.08	0.32	6.61	0.36	0	0.05	1.06	2.26	0.16	0.10						11.00	1/2	-	-	-	-	-
1974	July	0.35	2.94	4.30	0.21	0.02	0.56	1.48	0.42	0.74	0.14	4.04	0.68				15.88	-	-	-	-	-	1/2
1975	July	0.09	5.85	3.17	4.37	1.18	1.88	1.48	0.30	1.62	0.06						20.00	1/2	1/2	1/5	1/5	1/5	1/5
1976	June	6.43	3.92	2.61	3.42	0.78	0	2.43	1.12	0.78	0.44						21.93	1/2	1/4	1/5	1/10	1/5	1/10

Fig. 5-3 RAINFALL TYPE



3) Rainfall probabilities: In order to estimate rainfall probabilities from the data discussed in the preceding section, the maximum run-off from different patterns of continuous rainfalls have been studied. Thus, continuous rainfall days have been classified into the following six cases: (1) 1-day rainfall, (2) 2-day continuous rainfall, (3) 3-day continuous rainfall, (4) 4-day continuous rainfall, (5) 5-day continuous rainfall, and (6) 10-day continuous rainfall. For these six cases, the rainfall probabilities have been computed based on the maximum rainfall as are given in the Notes "Annex IV". The rainfalls of different probabilities: (1) 2-year probability, (2) 3-year probability, (3) 4-year probability, (4) 5-year probability, (5) 10-year probability, (6) 15-year probability, (7) 20-year probability, (8) 30-year probability, (9) 40-year probability, and (10) 50-year probability are shown in Table 5-9. Under these conditions, typical rainfalls are stated in the right half of Table 5-8.

Probability Analysis by Gumbel Method

The results of the probability analysis by Gumbel Method are as follows:

Table 5-9 Probable Continuous Rainfall by Gumbel Method

Probable Year \ Continuous days	1 day	2 days	3 days	4 days	5 days	10 days
2	6.0	8.2	9.5	10.3	11.4	14.7
3	7.2	9.6	11.1	12.1	13.3	16.6
4	7.9	10.5	12.1	13.3	14.5	17.9
5	8.5	11.2	12.9	14.1	15.4	18.8
10	10.2	13.1	15.1	16.6	18.0	21.5
15	11.1	14.2	16.4	18.0	19.5	23.0
20	11.8	14.9	17.3	19.0	20.5	24.1
30	12.7	16.0	18.5	20.4	22.0	25.5
40	13.4	16.7	19.4	21.4	23.0	26.6
50	13.9	17.3	20.0	22.1	23.8	27.4

4) Run-Off Calculation: Runoff from different patterns of rainfall discussed in the above has been calculated on the following assumptions:

(i) Run-off Coefficient

Annual rainfall is concentrated in three months of June, July and August, and in each of them more than 20 days are rainy days. Typical rainfalls so far obtained also fall within these three months. Run-off coefficient has been assumed as 100%, as the ground surface would have been saturated by some rains falling prior to the said period.

(ii) Time Process for Flood Discharge

From the topographical features of the project area, the rain falling within the dike system would flow into lowest levelled portion within no time and its water level reaching the pump station elevation again without taking much time. Therefore, the time required for the rainfall amassed to flood discharge is ignorable. Under these assumptions, the flood discharges have been estimated as per Table 5-10.

Table 5-10 Runoff by Rainfalls

Day	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th	
	R	Runoff	R	Runoff	R	Runoff	R	Runoff	R	Runoff	R	Runoff	R	Runoff	R	Runoff	R	Runoff	R	Runoff
1	6.43	x103 59.82	0.09	x103 0.84	0.25	x103 2.33	0.35	x103 3.26	3.01	x103 28.00	0.84	x103 7.81	0.68	x103 6.33	0.42	x103 3.91	0.08	x103 0.74	0.11	x103 1.02
2	3.92	36.47	5.85	54.42	0.54	5.02	2.94	27.34	9.89	92.01	0.05	0.47	1.29	12.00	1.30	12.09	0.32	2.98	0.07	0.65
3	2.61	24.28	3.17	29.49	2.09	19.44	4.30	39.99	1.05	9.77	0.12	1.12	2.14	19.91	4.24	39.43	6.61	61.47	0.25	2.33
4	3.42	31.82	4.37	40.65	2.18	20.28	0.21	1.95			1.55	14.42	0.12	1.12	2.22	20.65	0.36	3.35	3.53	32.83
5	0.78	7.26	1.18	10.98	0.92	8.56	0.02	0.19			4.56	42.42	0.02	0.19	1.50	13.95	0	0	1.32	12.28
6	0	0	1.88	17.49	3.29	30.61	0.56	5.21			1.89	17.58	1.35	12.56	1.49	13.86	0.05	0.47	2.09	19.44
7	2.43	22.61	1.48	13.77	5.44	50.61	1.48	13.76			1.01	9.40	1.54	14.33			1.06	9.86	2.01	18.69
8	1.12	10.42	0.30	2.79	0.06	0.56	0.42	3.91			2.42	22.51	1.35	12.56			2.26	21.02	0.28	2.60
9	0.78	7.26	1.62	15.07	1.38	12.84	0.74	6.88			0.98	9.12	0.85	7.91			0.16	1.49		
10	0.44	4.09	0.06	0.56	0	0	0.14	1.30			0.08	0.74	0.71	6.61			0.10	0.93		
11					1.17	10.88	4.04	37.57			0.27	2.51	3.37	31.35						
12							0.68	6.32					0.32	2.98						
13													1.76	16.37						
14													0.22	2.05						
15													0.50	4.65						
Year	1976		1975		1968		1974		1971		1970		1969		1972		1973		1967	
Month	June		July		July		July		July		Sept.		Aug.		June		Sept.		Aug.	

Notes: R : Rainfall inch
Runoff: Ac-ft.

5.3.3 Drainage Analysis

Drainage analysis aims at estimating inundation levels and inundation areas in the project area when rainfall water is drained by pumps.

(1) Pumping Capacity

Since there exists no criterion to predetermine pumping capacity for this project area, the following five different cases of pumping capacity have been considered to find out the optimum one to suit the inundation situations obtainable under the project.

Table 5-11 Pumping Capacities

Pumping Capacity	
m^3/sec	cusecs
90	3,200
110	3,900
130	4,600
150	5,300
170	6,000

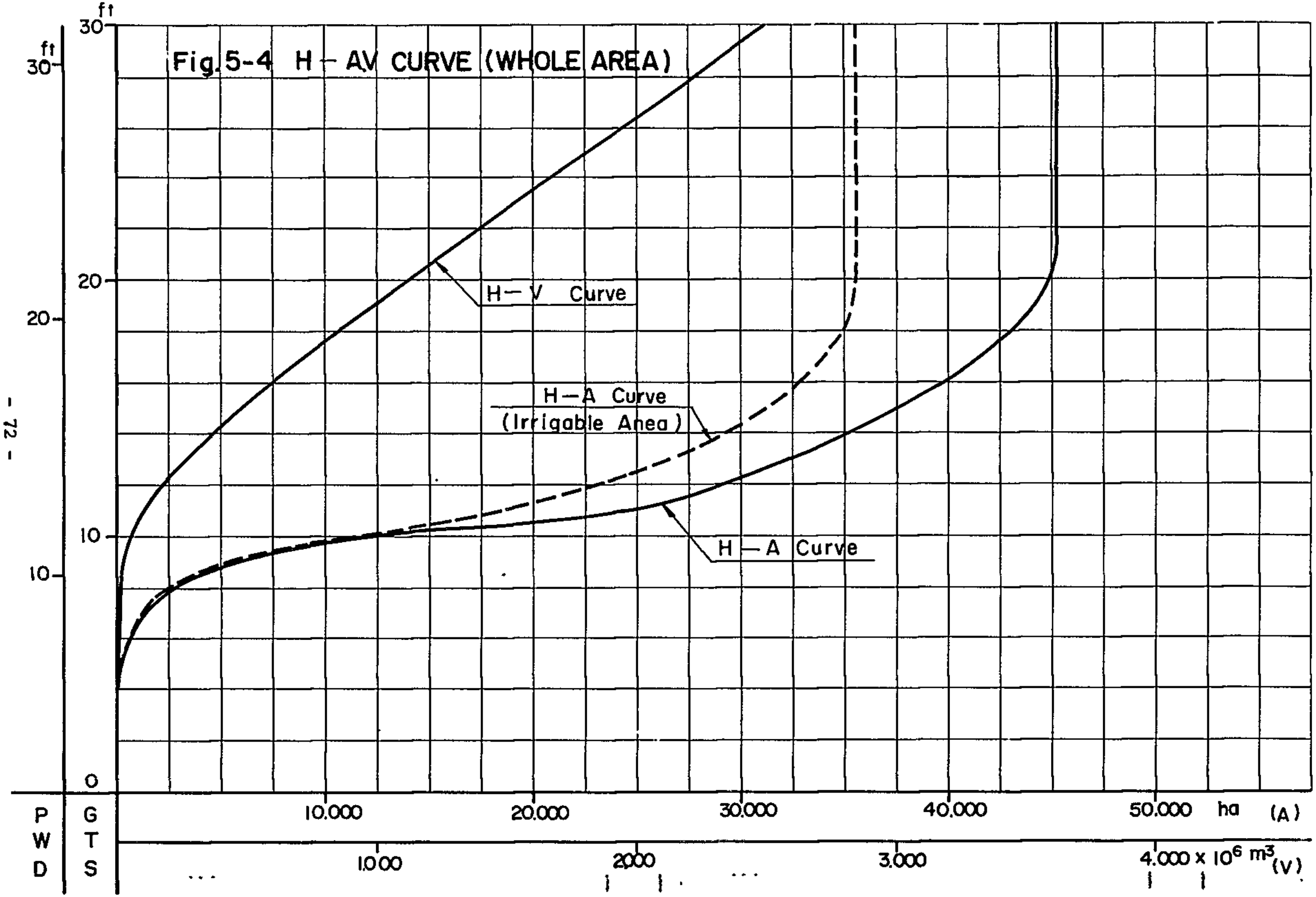
(2) Particularity of the Project Area

The relationships between elevations and drainage areas as well as pumping capacities in the project area are shown in Table 5-12 and Fig. 5-4.

Table 5-12 Area and Capacity of Whole Area (Plan B Area)

Elevation	Area	Capacity	Cumulative Capacity	Irrigable Area
7.5 P.W.D. ft.	590 ha.	0 $\times 10^6 m^3$	0 $\times 10^6 m^3$	10 ha
9.5	2,720	10.0	10.0	
11.5	12,270	45.7	55.7	11,690
13.5	29,190	126.4	182.1	
15.5	34,790	195.0	377.1	29,360
17.5	39,680	227.0	604.1	
19.5	43,050	252.2	856.3	34,940
21.5	44,590	267.1	1,123.4	
23.5	45,150	273.5	1,396.9	35,650
25.5	45,170	275.3	1,672.2	
27.5	45,180	275.4	1,947.6	35,680
29.5	45,190	275.4	2,223.0	
31.5	45,190	275.5	2,498.5	35,690
33.5	45,200	275.5	2,774.0	35,700
35.5				
Total	45,200 ha		2,774.0 $\times 10^6 m^3$	35,700 ha

Fig. 5-4 H - AV CURVE (WHOLE AREA)



(3) Drainage Analysis

Data on pumping capacity calculation to meet different patterns of seasonal rainfall are given in the Notes 4-5. Pumping capacity has been computed on the assumptions that outside water level is continuously high and fluctuation of inside water level is not so large and pumping capacities are constant irrespective of their heads.

Areas covered by different inundation levels have been estimated on the basis of inundation situation obtainable through the establishment of rainfall type. The relationship between different inundation levels and permissible number of days to the crops arranged under different cropping patterns are shown as follows:

Table 5-13 Areas under Different Cropping Patterns

Inundation Conditions	Cropping Patterns
Area spreading above the lowest water level of the main irrigation canal	A
Area which would be inundated below 1 ft, not longer than 7 days	B
Area inundated between 1∿3 ft	C
Area inundated between 3∿6 ft	D

Table 5-14 Cropped Areas by Cropping Patterns under Different Rainfall Types and Pump Capacities

Rainfall type	Pump Capacity	A	B	C	D	Total
1st	3,200	2,700	28,600	45,900	11,000	88,200
	3,900	2,700	30,400	45,400	9,700	88,200
	4,600	2,700	31,400	45,600	8,500	88,200
	5,300	2,700	33,100	45,000	7,400	88,200
	6,000	2,700	34,900	43,500	7,100	88,200
2nd	3,200	2,700	29,400	45,900	10,200	88,200
	3,900	2,700	31,400	45,200	8,900	88,200
	4,600	2,700	32,400	45,300	7,800	88,200
	5,300	2,700	33,700	45,100	6,700	88,200
	6,000	2,700	35,600	43,700	6,200	88,200
3rd	3,200	2,700	34,900	44,200	6,400	88,200
	3,900	2,700	37,500	42,500	5,500	88,200
	4,600	2,700	45,400	35,100	5,000	88,200
	5,300	2,700	56,600	24,500	4,400	88,200
	6,000	2,700	63,800	18,100	3,600	88,200
4th	3,200	2,700	55,400	25,900	4,200	88,200
	3,900	2,700	65,300	17,200	3,000	88,200
	4,600	2,700	70,300	13,300	1,900	88,200
	5,300	2,700	73,300	10,600	1,600	88,200
	6,000	2,700	74,500	9,500	1,500	88,200
5th	3,200	2,700	36,200	41,900	7,400	88,200
	3,900	2,700	37,800	40,600	7,100	88,200
	4,600	2,700	44,000	34,800	6,700	88,200
	5,300	2,700	49,100	30,000	6,400	88,200
	6,000	2,700	50,400	28,900	6,200	88,200

Table 5-14 Cropped Areas by Cropping Patterns under Different Rainfall Types and Pump Capacities (Cont'd)

Rainfall type	Pump Capacity	A	B	C	D	Total
6th	3,200	2,700	46,600	34,500	4,400	88,200
	3,900	2,700	51,600	30,300	3,600	88,200
	4,600	2,700	60,500	22,000	3,000	88,200
	5,300	2,700	66,800	16,400	2,300	88,200
	6,000	2,700	72,700	11,000	1,800	88,200
7th	3,200	2,700	55,400	27,100	3,000	88,200
	3,900	2,700	71,500	12,500	1,500	88,200
	4,600	2,700	78,100	6,900	500	88,200
	5,300	2,700	81,100	4,400	-	88,200
	6,000	2,700	81,800	3,700	-	88,200
8th	3,200	2,700	56,600	25,400	3,500	88,200
	3,900	2,700	64,500	18,000	3,000	88,200
	4,600	2,700	69,700	13,500	2,300	88,200
	5,300	2,700	72,700	11,000	1,800	88,200
	6,000	2,700	75,800	8,600	1,100	88,200
9th	3,200	2,700	63,000	19,800	2,700	88,200
	3,900	2,700	66,800	16,400	2,300	88,200
	4,600	2,700	70,300	12,900	2,300	88,200
	5,300	2,700	70,900	12,300	2,300	88,200
	6,000	2,700	71,500	12,000	2,000	88,200
10th	3,200	2,700	66,900	15,900	2,700	88,200
	3,900	2,700	70,300	12,900	2,300	88,200
	4,600	2,700	72,700	11,000	1,800	88,200
	5,300	2,700	75,400	8,900	1,200	88,200
	6,000	2,700	77,000	7,700	800	88,200

Table 5-15 Relationships between Pump Capacities and Operation Days under Different Rainfall Types

Rainfall Type	Pump Capacity	Continuous Operation days	Mean Inside Water Level under Operation	Rainfall Type	Pump Capacity	Continuous Operation days	Mean Inside Water Level under Operation
	cusec	day	ft		cusec	day	ft
1st	3,200	32	12.2	6th	3,200	19	11.1
	3,900	26	12.2		3,900	16	10.8
	4,600	22	12.1		4,600	13	10.8
	5,300	19	12.1		5,300	11	10.6
	6,000	17	11.8		6,000	9	10.6
2nd	3,200	29	12.1	7th	3,200	23	10.6
	3,900	24	11.9		3,900	19	9.6
	4,600	20	11.9		4,600	15	9.6
	5,300	17	11.9		5,300	13	9.0
	6,000	15	11.9		6,000	9	8.7
3rd	3,200	24	11.5	8th	3,200	15	11.0
	3,900	19	12.1		3,900	12	10.9
	4,600	16	11.3		4,600	10	10.7
	5,300	14	11.1		5,300	9	10.4
	6,000	12	10.9		6,000	8	10.3
4th	3,200	22	11.3	9th	3,200	15	11.1
	3,900	18	11.1		3,900	12	11.0
	4,600	15	10.8		4,600	10	10.9
	5,300	13	10.4		5,300	9	10.6
	6,000	11	10.2		6,000	8	10.3
5th	3,200	20	11.6	10th	3,200	13	10.9
	3,900	16	11.6		3,900	11	10.6
	4,600	14	11.4		4,600	9	10.6
	5,300	12	11.4		5,300	8	10.3
	6,000	10	11.5		6,000	7	10.1

5.3.4 Economic Comparative Studies

Using the data available from the above drainage calculation, estimation of gross annual benefits from agricultural production under different rainfall types has been made on the following assumptions:

(a) Agricultural production will take place in the area which was successfully cropped during the past ten years:

(b) Agricultural production there would follow the cropping patterns proposed under the project and in the pump-drainage conditions.

The results of the above estimation are shown in Table 5-16 in gross annual benefits, and in Table 5-17 in net annual benefits.

Table 5-16 Gross Annual Benefits by Different Rainfalls and Pumping Capacities

(Unit: Tk100,000)

Rainfall Type	Pumping Capacity	Farm Income		Incremental Farm Income	Operation Cost	Gross Benefit
		With Project	Without Project			
1	3200	5040	1445	3595	116	3479
	3900	5074	"	3629	129	3500
	4600	5100	"	3655	143	3512
	5300	5131	"	3686	157	3529
	6000	5151	"	3706	171	3535
2	3200	5057	"	3612	116	3496
	3900	5093	"	3648	129	3519
	4600	5117	"	3672	143	3529
	5300	5144	"	3699	157	3542
	6000	5168	"	3723	171	3552
3	3200	5139	"	3694	116	3578
	3900	5175	"	3730	129	3601
	4600	5242	"	3797	143	3654
	5300	5335	"	3890	157	3733
	6000	5400	"	3955	171	3784

Rainfall Type	Pumping Capacity	Farm Income With Project	Farm Income Without Project	Incremental Farm Income	Operation Cost	Gross Benefit
4	3200	5289	1445	3844	116	3728
	3900	5374	"	3929	129	3800
	4600	5429	"	3984	143	3841
	5300	5468	"	4023	157	3866
	6000	5488	"	4043	171	3872
5	3200	5159	"	3714	116	3598
	3900	5191	"	3746	129	3617
	4600	5247	"	3802	143	3659
	5300	5297	"	3852	157	3695
	6000	5319	"	3874	171	3703
6	3200	5228	"	3783	116	3667
	3900	5278	"	3833	129	3704
	4600	5347	"	3902	143	3759
	5300	5405	"	3960	157	3803
	6000	5450	"	4005	171	3834
7	3200	5266	"	3821	116	3705
	3900	5361	"	3916	129	3787
	4600	5424	"	3979	143	3836
	5300	5470	"	4025	157	3868
	6000	5493	"	4048	171	3877
8	3200	5267	"	3822	116	3706
	3900	5356	"	3911	129	3782
	4600	5394	"	3949	143	3806
	5300	5439	"	3994	157	3837
	6000	5472	"	4027	171	3856
9	3200	5281	"	3836	116	3720
	3900	5367	"	3922	129	3793
	4600	5395	"	3950	143	3807
	5300	5435	"	3990	157	3833
	6000	5462	"	4017	171	3846
10	3200	5285	"	3840	116	3724
	3900	5370	"	3925	129	3796
	4600	5398	"	3953	143	3810
	5300	5440	"	3995	157	3838
	6000	5468	"	4023	171	3852

Table 5-17 Net Annual Benefits by Different Rainfalls and Pumping Capacities

(Unit: TK100,000)

Rainfall Type	Pumping Capacity	Gross Benefit	Depreciation	Net Benefit
1	3200	3479	427	3052
	3900	3500	495	3005
	4600	3512	562	2950
	5300	3529	629	2900
	6000	3535	697	2838
2	3200	3496	427	3069
	3900	3519	495	3024
	4600	3549	562	2967
	5300	3542	629	2913
	6000	3552	697	2855
3	3200	3578	427	3151
	3900	3601	495	3106
	4600	3654	562	3092
	5300	3733	629	3104
	6000	3784	697	3087
4	3200	3728	427	3301
	3900	3800	495	3305
	4600	3841	562	3279
	5300	3866	629	3237
	6000	3872	697	3175
5	3200	3598	427	3171
	3900	3617	495	3122
	4600	3659	562	3097
	5300	3695	629	3066
	6000	3703	697	3006
6	3200	3667	427	3240
	3900	3704	495	3209
	4600	3759	562	3197
	5300	3803	629	3174
	6000	3834	697	3137

Rainfall Type	Pumping Capacity	Gross Benefit	Depreciation	Net Benefit
7	3200	3705	427	3278
	3900	3787	495	3292
	4600	3836	562	3274
	5300	3868	629	3239
	6000	3877	697	3180
8	3200	3706	427	3279
	3900	3782	495	3287
	4600	3806	562	3244
	5300	3837	629	3208
	6000	3856	697	3159
9	3200	3720	427	3293
	3900	3793	495	3298
	4600	3807	562	3245
	5300	3833	629	3204
	6000	3846	697	3149
10	3200	3724	427	3297
	3900	3796	495	3301
	4600	3810	562	3248
	5300	3838	629	3209
	6000	3852	697	3155

5.3.5 Optimum Pump Capacity

As would be known from the Net Annual Benefits Table, the lower the probability or the higher the frequency of rainfall, the larger becomes the net annual benefit. Advantage-oriented selection of the pumping capacity also depends on the rainfall pattern: Qp=3200 cusecs (90 m^3/sec) tends to be more advantageous for the rainfall pattern which is characterized by less rainfall frequency, but that characterized by higher rainfall frequency tends to make Qp=3900 cusecs (110 m^3/sec) more advantageous.

Rainfall patterns which promise large net annual benefits are the following five: the 4th, 7th, 8th, 9th and the 10th (rainfall distribution of each rainfall pattern is shown in Fig. 5-3). The rainfall pattern which has a peak at its centre or the "pyramid"-type rainfall brings the worst inundation damage. As the 4th, 7th and the 9th do not belong to the "pyramid"-type because of non-continuity of rainfall: the benefits accruing from pump drainage would accordingly not be so deserving. On the other hand, the 8th and the 10th, particularly the latter, if combined with the pumping capacity of Qp=3900 cusecs (110 m^3/sec) would be the most advantageous.

As it has already been admitted in the above that the higher frequency rainfall pattern tends to make Qp=3900 cusecs more advantageous, adoption of this capacity for drainage would be justifiable. The D-N-D project and the N-N project may be compared in their unit drainage discharge:

$$\text{D-N-D Project} = \frac{14.5\ m^3/sec}{5800\ ha} = 2.5\ \ell/sec/ha$$

$$\text{N-N Project} = \frac{110\ m^3/sec}{45200\ ha} = 2.4\ \ell/sec/ha$$

This is not a mere coincidence but a logical agreement because the D-N-D project is both geographically adjacent and functionally similar to the N-N project.

5.3.6 Drainage Plan for Phase I Area

Drainage discharge for the entire area has been determined at 110 m^3/sec through the above analysis. This drainage discharge would be allocated between Phase I Area and Phase II Area according to their size. Pumping Stations No. 1 and No. 2 are proposed for Phase I, and Pumping Station No. 3 for Phase II; drainage discharges by these pumping stations are given in two areas of Phase I and Phase II in Table 5-18.

Table 5-18 Drainage Discharges by Pumping Stations and Phases

Phase	Pumping Station	Drainage Area	Drainage Discharge
I	No. 1	37,000 Ac	35 m^3/sec
	No. 2	34,600 "	35 "
	Sub-Total	71,600 "	70 "
II	No. 3	40,000 "	40 "
Total		116,000 "	110 "