2-1-2. Correlation Analysis

In accordance with the records on daily basis rainfall collected for 10 years from 10 stations, correlation analysis on daily basis and monthly basis have been performed. It has been found that there is no good correlation among 13 rainfall stations on daily basis. The results of the correlation analysis on monthly basis has been shown in TABLE II-2-2.

The highest correlation of coefficient is 90% between Rajshahi and Sardah and the second one is 89.8% between Nithpur and Rohanpur.

TABLE II-2-2

***** THE CORRELATION COEF. & REGRESSION LINE OF NORTH RAJSHAHI IRRIGATION PROJECT (1977 ---> 1986 YEAR)

STATION ---> X

		(1) R185	(2) R187	(3) R190	(4) R194	(5) R195	(6) R205	(7) R208	(8) R212	(9) R219	(10) R172
	R	1.000	0.804	0.806	0.808	0.764	0.800	0.799	0.770	0.753	0.740
(1)	A	1.000	0.641	0.788	0.792	0.916	0.830	0.825	0.741	0.745	0.849
R185	B	0.000	1.062	0.975	0.851	1.234	0.567	0.730	0.995	1.240	0.889
	N	*****	93	88	92	88	91	90	91	85	92
	R	0.804	1.000	0.759	0.864	0.718	0.786	0.836	0.686	0.699	0.705
(2)	A	1.007	1.000	0.932	1.060	1.075	1.023	1.072	0.825	0.870	1.015
R187	B	1.063	0.000	1.337	0.515	1.655	0.559	0.550	1.583	1.667	1.085
	N	93	*****	89	99	92	97	98	96	88	98
	R	0.806	0.759	1.000	0.841	0.729	0.840	0.849	0.754	0.797	0.767
(3)	A	0.825	0.618	1.000	0.845	0.891	0.891	0.894	0.738	0.809	0.901
R190	B	1.068	1.425	0.000	0.740	1.534	0.415	0.590	1.238	1.047	0.807
	N	88	89	*****	89	87	90	87	89	85	91
	R	0.808	0.864	0.841	1.000	0.827	0.852	0.898	0.773	0.804	0.780
(4)	A	0.826	0.705	0.837	1.000	1.007	0.897	0.936	0.752	0.808	0.911
R194	B	1.107	0.877	0.962	0.000	1.096	0.441	0.421	1.193	1.120	0.793
	N	92	99	89	*****	89	95	96	94	88	96
	R	0.764	0.718	0.729	0.827	1.000	0.808	0.762	0.749	0.787	0.838
(5)	A	0.637	0.479	0.596	0.679	1.000	0.704	0.656	0.602	0.647	0.802
R195	B	1.012	1.216	1.129	0.608	0.000	0.373	0.813	0.912	0.899	0.269
	N	88	92	87	89	*****	92	88	91	85	94
	R	0.800	0.786	0.840	0.852	0.808	1.000	0.843	0.900	0.835	0.844
(6)	A	0.772	0.603	0.792	0.808	0.929	1.000	0.824	0.834	0.792	0.935
R205	B	1.499	1.626	1.270	1.064	1.515	0.000	1.163	0.815	1.311	0.748
	N	91	97	90	95	92	*****	92	101	89	101
	R	0.799	0.836	0.849	0.898	0.762	0.843	1.000	0.758	0.812	0.755
(7)	A	0.773	0.651	0.807	0.861	0.886	0.862	1.000	0.711	0.782	0.852
R208	B	1.326	1.101	1.034	0.595	1.523	0.482	0.000	1.281	1.148	0.958
	N	90	98	87	96	88	92	*****	93	88	94
	R	0.770	0.686	0.754	0.773	0.749	0.900	0.758	1.000	0.773	0.812
(8)	A	0.801	0.570	0.771	0.795	0.931	0.971	0.808	1.000	0.797	0.973
R212	B	1.407	1.840	1.420	1.160	1.550	0.147	1.233	0.000	1.290	0.594
	N	91	96	89	94	91	101	93	*****	90	99
	R	0.753	0.699	0.797	0.804	0.787	0.835	0.812	0.773	1.000	0.831
(9)	A	0.762	0.561	0.786	0.799	0.958	0.880	0.844	0.749	1.000	0.978
R219	B	1.443	1.819	1.197	1.006	1.244	0.459	0.862	1.154	0.000	0.389
	N	85	88	85	88	85	89	88	90	*****	90
	R	0.740	0.705	0.767	0.780	0.838	0.844	0.755	0.812	0.831	1.000
(10)	A	0.646	0.490	0.653	0.668	0.877	0.761	0.670	0.677	0.706	1.000
R172	B	1.604	1.777	1.477	1.290	1.171	0.718	1.412	1.152	1.271	0.000
	N	92	98	91	96	94	101	94	99	90	*****

Y / X
R : CORRELATION COEFICIENT
REGRESSION LINE : Y=A*X+B
N=THE NUMBER OF DATA

R 185 MANDA

R 187 MOHADEVPUR

R 190 NACHOL

R 194 NITHPUR

R 195 CHAPAI NAWABGANJ

R 205 RAJSHAHI

R 208 ROHANPUR

R 212 SARDAH

R 219 TANORE

R 172 GODAGA I

2-1-3. Areal Rainfall Analysis

As seen in the FIGURE II-1-2, out of 10 raingauge stations, 5 stations namely, Rajshahi, Godagari, Tanore, Nachol and Manda are located in the Study Area. As mentioned in the former paragraph, there is no good correlation among these rainfall station on daily basis. Also the study area is extended for about 150 sq.km in the size and the difference of elevation is about 30 meters, the rainfall distributions are rather different in the daily basis. In order to estimate the effective rainfall for crop water requirements, areal rainfall has been estimated among 5 stations adopting Thiesen Poligon method. The command area ratios for Rajshahi, Tanore, Nachol, Godagari and Manda are 12%, 24%, 26%, 21% and 17%, respectively.

The monthly rainfall of the areal rainfall is shown in TABLE II-2-3 (2) for 1977 to 1986.

TABLE II-2-3 (1) AREAL RAINFALL

MONTHLY RAIN FALL AT RAJSHAHI

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1977	0.0	0.0	0.0	121.1	207.6	499.9	321.0	179.2	97.8	116.2	7.6	33.5	1583.9
78	0.0	39.9	57.6	96.8	165.2	234.6	265.5	162.8	428.4	169.9	21.6	0.0	1642.3
79	36.1	16.8	3.8	79.5	15.2	258.9	498.9	411.5	296.4	47.7	48.3	26.7	1739.8
80	26.1	0.0	41.9	0.0	296.2	395.2	397.2	275.0	297.1	219.4	0.0	0.0	1878.4
81	32.5	31.2	27.8	227.2	291.4	76.2	405.1	191.3	304.0	0.0	0.0	53.6	1640.3
82	0.0	11.7	76.2	132.4	40.1	232.4	177.7	236.2	37.3	18.8	72.5	1.5	1036.8
83	5.1	4.1	1.3	24.0	80.2	148.2	193.9	230.6	131.1	348.0	0.0	20.6	1187.1
84	33.2	0.0	0.0	5.8	109.2	249.0	485.9	275.3	303.9	128.6	0.0	0.0	1590.9
85	4.8	13.5	3.3	48.5	184.0	218.8	263.5	257.4	167.2	51.6	0.0	0.0	1212.6
86	1.5	4.8	2.3	71.1	99.8	222.0	246.8	252.0	504.4	230.3	25.6	18.5	1679.1
AVERAGE	13.9	12.2	21.4	80.6	141.9	253.5	325.5	247.1	256.8	133.0	17.6	15.4	1519.1

MONTHLY RAINFALL AT TANORE

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1977	0.0	0.0	0.0	85.6	178.0	476.8	248.2	196.0	88.9	136.5	0.0	44.5	1454.5
78	2.5	0.0	53.3	116.1	137.6	366.4	163.8	91.7	390.5	52.0	41.9	0.0	1415.8
79	26.7	14.0	0.0	52.6	0.0	195.1	314.6	368.6	318.9	89.3	0.0	35.6	1415.4
80	38.1	14.0	3.8	0.0	259.8	370.7	268.1	173.7	191.0	258.3	0.0	0.0	1577.5
81	19.6	16.5	45.0	222.3	177.0	57.9	662.9	381.8	333.6	0.0	0.0	62.7	1979.3
82	0.0	7.1	50.1	10.7	49.4	503.1	112.3	245.7	24.4	29.7	69.1	0.0	1101.6
83	9.4	0.0	5.6	22.9	85.5	75.2	228.2	306.0	329.3	190.5	0.0	10.9	1263.5
84	17.1	0.0	0.0	0.0	49.5	238.7	332.1	319.2	256.2	131.5	0.0	0.0	1344.3
85	0.0	1.3	21.6	36.6	158.1	219.0	373.9	126.5	283.5	115.0	0.0	0.0	1335.5
86	0.0	6.6	0.0	67.6	63.7	176.3	287.3	211.2	372.9	418.3	0.0	0.0	1603.9
AVERAGE	11.3	6.0	17.9	61.4	115.9	267.4	299.1	242.0	258.9	142.1	11.1	15.4	1449.1

MONTHLY RAINFALL AT NACHOL

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1977	0.0	0.0	0.0	68.6	480.1	496.5	375.9	291.3	231.0	160.1	12.7	0.0	2116.2
78	0.0	2.8	11.2	103.4	146.7	203.7	210.4	75.4	335.8	147.3	17.8	0.0	1254.5
79	12.7	0.0	0.8	64.7	0.0	151.1	529.8	274.8	238.6	29.7	0.0	15.0	1317.2
80	10.2	6.9	2.8	0.0	285.4	139.7	253.1	432.0	84.1	194.3	0.0	0.0	1408.5
81	8.8	15.2	28.7	212.5	252.0	147.2	560.1	208.7	307.8	0.0	0.0	76.2	1817.2
82	0.0	0.0	74.9	0.0	0.8	163.6	187.8	260.4	26.1	8.9	43.9	0.0	766.4
83	2.5	0.0	3.5	3.1	60.5	105.9	359.8	223.4	282.2	249.4	0.0	39.6	1329.9
84	17.8	12.4	0.0	0.0	91.3	184.9	392.7	257.2	245.0	128.6	0.0	0.0	1329.9
85	8.1	0.8	4.6	16.5	126.4	346.0	237.3	209.8	320.2	73.9	0.0	0.0	1343.6
86	0.0	0.0	0.0	67.9	187.9	132.2	354.1	109.9	474.8	386.0	16.5	0.0	1729.3
AVERAGE	6.0	3.8	12.7	53.7	163.1	207.1	346.1	234.3	254.6	137.8	9.1	13.1	1441.2

TABLE II-2-3 (2) AREAL FAINFALL

MONTHLY RAIN FALL AT GODAGARI

810

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
77	0.0	0.0	0.0	99.4	270.3	494.4	256.1	114.7	155.4	186.1	2.5	23.6	1602.5
78	0.0	3.8	9.3	49.0	76.6	340.3	43.3	207.4	387.0	130.1	12.7	0.0	1259.5
79	27.9	3.8	2.5	71.1	8.9	157.5	280.5	265.7	389.9	52.2	6.3	30.0	1296.3
80	54.6	7.9	17.3	0.0	141.6	373.8	250.1	135.9	200.9	257.5	0.0	0.0	1439.6
81	31.7	24.9	81.0	124.8	212.0	39.4	406.5	248.5	321.7	0.0	0.0	53.4	1543.9
82	0.0	94.0	86.3	91.4	12.7	175.2	219.1	118.0	67.6	17.8	74.7	0.0	956.8
83	0.8	0.8	3.6	30.0	94.5	139.4	227.4	265.6	287.1	207.1	0.0	8.9	1265.2
84	28.0	4.1	0.0	8.9	90.1	287.3	222.4	191.6	334.7	176.6	0.0	0.0	1343.7
85	0.0	13.8	45.2	294.6	114.1	296.5	289.7	82.4	139.8	102.9	0.0	0.0	1379.0
86	1.3	12.7	2.1	42.4	142.3	272.5	310.9	238.6	386.0	220.3	24.1	8.6	1661.8
AVERAGE	14.4	16.6	24.7	81.2	116.3	257.6	250.6	186.8	267.0	135.1	12.0	12.5	1374.8

MONTHLY RAINFALL AT MANDA

820

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
77	0.0	0.0	0.0	110.7	308.5	618.9	381.3	141.4	37.3	96.9	48.0	20.3	1763.3
78	0.0	5.3	27.2	74.8	93.5	445.1	232.8	167.9	261.3	10.5	0.0	0.0	1318.4
79	46.4	0.0	0.0	58.7	0.0	144.7	588.4	287.3	99.7	37.0	0.0	0.8	1263.0
80	6.3	3.8	5.0	0.0	285.2	248.3	214.3	291.4	273.9	305.4	0.0	0.0	1633.6
81	0.0	3.8	29.2	116.8	72.6	36.2	207.0	200.1	448.7	0.0	0.0	58.4	1172.8
82	0.0	0.0	6.3	5.1	142.2	211.7	267.1	331.6	8.9	44.5	0.0	0.0	1017.4
83	35.8	0.0	89.4	16.0	100.4	167.5	319.1	253.1	344.1	238.3	0.0	63.5	1627.2
84	21.5	9.4	12.7	8.9	223.3	212.9	358.7	275.4	376.9	203.2	0.0	3.8	1706.7
85	1.3	9.7	6.7	26.7	167.7	168.1	206.1	137.0	299.4	45.5	0.0	5.3	1073.5
86	0.0	16.5	0.0	138.3	86.8	100.5	222.3	75.6	387.6	353.8	14.2	20.8	1416.4
AVERAGE	11.1	4.9	17.7	55.6	148.0	235.4	299.7	216.1	253.8	133.5	6.2	17.3	1399.2

AREAL RAINFALL (WEIGHTED AVERAGE AMONG MANDA,GODAGARI,NACHOL,TANORE AND RAJSHAHI)

900

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
77	0.0	0.0	0.0	89.5	299.3	493.5	347.0	190.0	135.5	149.8	12.0	21.1	1737.7
78	1.0	2.9	23.6	85.1	114.9	316.3	176.9	136.3	347.4	94.7	18.7	0.0	1317.8
79	26.9	6.1	1.4	64.2	1.9	152.7	431.7	306.2	263.4	53.2	1.8	20.1	1329.6
80	25.1	8.0	7.2	1.7	248.6	275.4	273.0	268.3	185.5	236.4	0.0	0.0	1529.2
81	16.7	16.3	46.2	181.0	192.6	87.7	486.1	276.2	344.7	0.0	0.0	62.0	1709.5
82	0.0	22.4	56.2	23.4	42.7	262.6	207.3	246.8	42.8	22.2	47.3	0.0	973.7
83	9.2	0.2	18.2	16.4	89.1	117.5	281.9	250.9	304.9	220.2	0.0	28.3	1336.8
84	20.9	7.8	2.5	3.4	101.9	227.5	331.6	254.0	284.0	156.7	0.0	0.9	1391.2
85	2.3	5.2	17.0	81.7	146.9	249.0	290.1	144.7	254.3	89.0	0.8	1.1	1282.1
86	0.3	8.0	0.5	67.6	122.8	144.3	269.1	122.0	348.0	285.9	12.9	7.1	1388.5
AVERAGE	10.2	7.7	17.3	61.4	136.1	232.7	309.5	219.5	251.1	130.8	9.4	14.1	1399.6

2-2. Probability Analysis of Rainfall

2-2-1. Probability of Drought

To find a droughtness of the Project area in each year, probability analysis has been adopted to the annual areal rainfall, annual total diversion water requirements (Boro-Aman) and annual total effective rainfall for paddy from 1977 to 1986 as shown in TABLE II-2-4.

The droughtest year is in 1982 especially in September, the monthly areal rainfall is only 42.8 mm though the average monthly areal rainfall is 251.1 mm.

As for the discharge and water level in the Ganges river, the annual average, daily minimum and monthly minimum discharges at Hardinge Bridge and daily minimum water level at Rajshahi are shown in TABLE II-2-5.

These minimum values in 1982 is not so low as indicated in the Project area, however, the minimum discharge and water level in 1983 are quite low compared with another year. This means that the drought conditions in 1982 would effect the low flow in the next year of 1983. As for the Ganges river, the lowest discharge is appeared in 1985, but the lowest water level at Rajshahi appeared in 1980.

TABLE II-2-4 Factors for Drought Conditions

Year	Annual Total Rainfall (Area Rainfall) (mm)	Annual Total Diversion Water Requirements (mm)	Annual Total Effective Rainfall (mm)
1977	1,737.7 (10)	1,160.6 (3)	617.9 (8)
1978	1,317.8 (3)	1,223.2 (2)	561.3 (3)
1979	1,329.6 (4)	1,094.4 (5)	631.3 (9)
1980	1,529.2 (8)	930.2 (10)	678.6 (10)
1981	1,709.5 (9)	1,053.3 (6)	575.3 (4)
1982	973.7 (1)	1,434.5 (1)	386.0 (1)
1983	1,336.8 (5)	1,027.4 (7)	617.0 (7)
1984	1,391.2 (7)	1,014.2 (8)	584.5 (5)
1985	1,282.1 (2)	1,001.7 (9)	608.0 (6)
1986	1,388.5 (6)	1,109.2 (4)	507.1 (2)

TABLE II-2-5

	Discharge (m^3/sec)			Water Level (m) Daily Minimum at Rajshahi
	Annual Average (Apr.-Mar.)	Daily Minimum	Monthly Minimum	
1977	11,300	857	912	8.230
1978	14,100	1,310	1,550	8.755
1979	6,620	1,040	1,270	8.595
1980	12,500	874	911	7.742
1981	10,300	877	991	8.074
1982	9,990	1,170	1,280	8.199
1983	10,700	695	820	7.745
1984	11,300	888	981	8.100
1985	13,000	683	771	8.390
1986	-	-	-	8.950

2-2-2. Successive Rainfall Analysis

The daily maximum, 2 day and 3 day maximum of successive rainfall obtained from the observed data at Rajshahi, Tanore, Noachol, Godagari, Manda and also the areal rainfall from 1977 to 1986 for 10 years are shown in TABLE II-2-6.

Based upon the above data, probability analysis has been made and the probable rainfall for each return period are shown in TABLE II-2-7.

The 5-year return period is selected as the design rainfall for drainage. The spot rainfall data at Manda on the 5 year return period shows the highest among the five stations.

Considering the coverage of a command area of drainage system, the value of the areal rainfall will be used for runoff analysis to decide the design capacity of the main drainage canal and regulator.

TABLE II-2-6

Annual Maximum Successive Rainfall.

Unit : mm

	Manda(R-185)			Nachol (R-190)			Tanore(R-219)		
Year	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days
1977	117.9	144.6	174.1	102.4	176.1	219.3	130.8	161.8	195.5
1978	123.2	141.2	193.1	91.4	144.7	187.9	158.8	169.0	188.0
1979	132.1	236.2	236.2	105.4	190.5	199.4	118.1	171.9	184.8
1980	241.3	266.2	288.8	113.0	194.3	194.3	194.3	219.7	228.5
1981	152.4	206.5	253.5	208.3	226.8	242.3	159.0	169.4	244.3
1982	82.5	96.5	123.6	104.9	123.2	141.0	107.9	113.5	114.5
1983	160.0	179.1	181.6	174.0	208.8	219.0	99.6	140.5	151.9
1984	146.1	160.1	179.2	98.3	106.7	137.2	95.3	135.4	173.8
1985	72.4	91.5	105.7	95.3	146.1	146.9	71.1	132.1	165.6
1986	234.9	277.6	319.3	129.3	248.9	334.2	203.2	222.2	273.00

	Godagari(R-174)			Rajshahi(R-205)			Areal Rainfall.		
Year	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days
1977	141.0	219.7	222.2	110.5	153.7	167.7	69.5	86.8	134.1
1978	207.5	234.9	246.3	145.0	190.7	208.2	108.1	122.7	135.9
1979	196.6	227.1	227.1	234.2	302.8	304.8	102.2	184.6	208.1
1980	132.1	226.1	245.4	135.1	178.8	209.8	105.2	156.1	221.3
1981	192.5	230.6	245.3	130.8	146.0	167.2	169.2	190.2	213.7
1982	91.4	100.3	119.9	75.2	79.5	91.4	50.9	75.3	103.8
1983	142.2	153.6	166.3	158.2	178.5	246.1	125.7	152.0	169.5
1984	99.1	105.5	116.8	114.3	147.8	165.6	72.3	95.7	102.4
1985	167.6	167.6	167.6	57.2	95.3	99.1	44.5	69.2	88.8
1986	128.8	162.1	183.9	135.9	172.7	254.0	118.9	191.1	233.8

TABLE II-2-7

Probability Analysis for Maximum Successive Rainfall.

Unit : mm

Return	Manda(R-185)			Nachol(R-190)			Tanore(R-219)		
Period(Year)	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days
2	138.69	172.86	199.00	111.10	174.04	188.71	130.02	160.62	189.87
3	163.16	202.42	229.62	123.49	194.44	213.92	149.27	176.17	210.18
4	178.55	220.57	248.24	132.62	206.48	231.12	160.91	185.53	222.08
5	189.79	233.65	261.58	139.97	214.95	244.33	169.22	192.20	230.41
10	222.34	270.73	299.04	164.69	238.11	285.59	192.42	210.76	253.02
15	240.32	240.75	319.08	180.63	250.14	310.27	204.75	220.60	264.68
20	252.77	304.45	332.72	192.67	258.20	328.15	213.12	227.26	272.46
30	270.03	323.22	351.32	210.74	269.03	353.95	224.49	236.30	282.87
50	291.40	346.13	373.88	253.43	281.93	387.53	238.24	247.20	295.22
100	320.07	376.35	403.43	272.73	298.46	435.42	256.16	261.38	310.95

Return	Godagari(R-174)			Rajshahi(R-205)			Areal Rainfall.		
Period(Year)	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days	1 Day	2 Days	3 Days
2	147.91	175.03	187.50	123.13	154.94	184.62	90.67	128.76	156.48
3	165.61	201.15	212.07	144.72	181.72	215.46	108.15	150.49	181.13
4	176.01	217.63	227.38	158.28	198.90	234.29	119.31	163.50	195.00
5	183.30	229.70	238.51	168.19	211.61	247.80	127.54	172.72	206.59
10	203.14	264.77	270.49	196.85	249.09	285.90	151.70	198.27	236.13
15	213.40	284.22	288.01	212.68	270.21	306.35	165.25	211.72	251.81
20	220.25	297.72	300.09	223.64	258.00	320.30	174.71	220.80	262.43
30	229.43	316.47	316.76	238.82	305.71	339.36	187.93	233.07	276.85
50	240.34	339.73	337.29	257.61	331.66	362.53	204.44	247.82	294.26
100	254.26	371.04	364.67	282.82	367.01	392.96	226.85	266.92	316.93

2-2-3. Design Rainfall Pattern for Drainage Analysis

Due to the large surface storage in the Swamp and retention characteristics of paddy area surrounding the Swamp, it is essential to use fairly long duration of design rainfall. Analysis of rainfall events with duration varying from 1 to 4 days showed that duration increase from 3-day to 4-day will not significantly increase rainfall amount from that accumulated during the previous 3 days. It was, therefore, decided to use 3-day duration design rainfall for the analysis of design floods.

The design daily rainfall for 3-day duration were rearranged from maximum 1, 2 and 3-day rainfall of selected return period as follows :

Day 1 rainfall = (3-day rainfall) - (2-day rainfall)

Day 2 rainfall = 1-day rainfall

Day 3 rainfall = (2-day rainfall) - (1-day rainfall)

To select the observed hourly rainfall, for design purpose, following criteria have been taken into consideration :

a) The total amount of rainfall should be as much as possible but should not be an abnormal value.

b) The hourly rainfall distribution should not be concentrated within a few hours but distributed for a long period with a distinct peak hourly rainfall.

Consequently, observed rainfall from 8th to 10th September 1986 has been selected as representative rainfall pattern for design purpose.

The daily total rainfall was distributed in the respective days by the ratio between the observed daily rainfall and the corresponding return period of rainfall. The ratios for 2, 5 and 10-year return periods for 1st, 2nd and 3rd day are shown in the following TABLE II-2-8.

The hourly rainfall distribution for each return period has been adopted the same ratio of the daily rainfall and the results are shown in TABLE II-2-9.

TABLE II-2-9 Design Rainfall Pattern

	Observed 1986 September			2-year Return Period			5-year Return Period			10-year Return Period		
	8th	9th	10th	1	2	3	1	2	3	1	2	3
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0.2	0	0	0.2	0	0	0.3	0	0	0.3	0
4	0	33.8	0.1	0	34.5	0.2	0	48.5	0.2	0	57.8	0.2
5	0	3.0	0	0	3.2	0	0	4.3	0	0	5.1	0
6	1.2	21.2	0	2.3	21.6	0	2.8	30.4	0	3.1	36.3	0
7	10.6	1.2	0	20.1	1.2	0	24.6	1.7	0	27.5	2.0	0
8	2.0	7.0	0	3.8	7.1	0	4.6	10.1	0	5.2	12.0	0
9	0	11.3	0	0	11.5	0	0	16.1	0	0	19.3	0
10	0	1.5	0	0	1.5	0	0	2.2	0	0	2.5	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0.2	0	0	0.2	0	0	0.3	0	0	0.3	0
14	0	6.8	0	0	6.9	0	0	9.7	0	0	11.6	0
15	0	1.0	0	0	1.1	0	0	1.4	0	0	1.7	0
16	0	0	11.0	0	0	17.9	0	0	21.3	0	0	22.0
17	0	0.6	12.2	0	0.6	20.0	0	0.9	23.7	0	1.0	24.4
18	0	0.9	0	0	0.9	0	0	1.3	0	0	1.5	0
19	0.7	0.2	0	1.3	0.2	0	1.7	0.3	0	1.8	0.3	0
20	0.1	0	0	0.2	0	0	0.2	0	0	0.3	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
Total	14.6	88.7	23.3	27.7	90.7	38.1	33.9	127.5	45.2	37.9	151.7	46.6

3. RIVER WATER LEVEL AND DISCHARGE ANALYSIS

3-1. Low Water Level

3-1-1. Effect of the Farakka Barrage

The construction of the Farakka barrage was commenced in early 1961 and was completed in 1970. The feeder canal of maximum capacity 1,133 m3/sec (40,000 cusec) was completed in the end of 1974. The operation of the barrage was started from April 1975.

In order to define the effect of the diversion water by the barrage to the down stream of the Ganges River in low water level, a probability analysis has been adopted to the observed minimum water level at the Rajshahi, Sardah and Hardinge Bridge.

The probability analysis has been made for the conditions of before and after the Farakka barrage (operation) considering 1975 as a boundary year.

The results are shown in FIGURE II-3-1 and TABLE II-3-1. The difference between the water levels is about 1.9 meter at Rajshahi 1.7 meter at Sardah and 1.3 meter at Hardinge Bridge in 10-year return period. Drawdown of the water level in the upstream site of the Ganges river has more affected by the barrage.

As shown in the TABLE II-3-1, the observed minimum water level before Farakka appeares in 1974 at Rajshahi, Sardah and Hardinge Bridge that is one year before Farakka barrage operation.

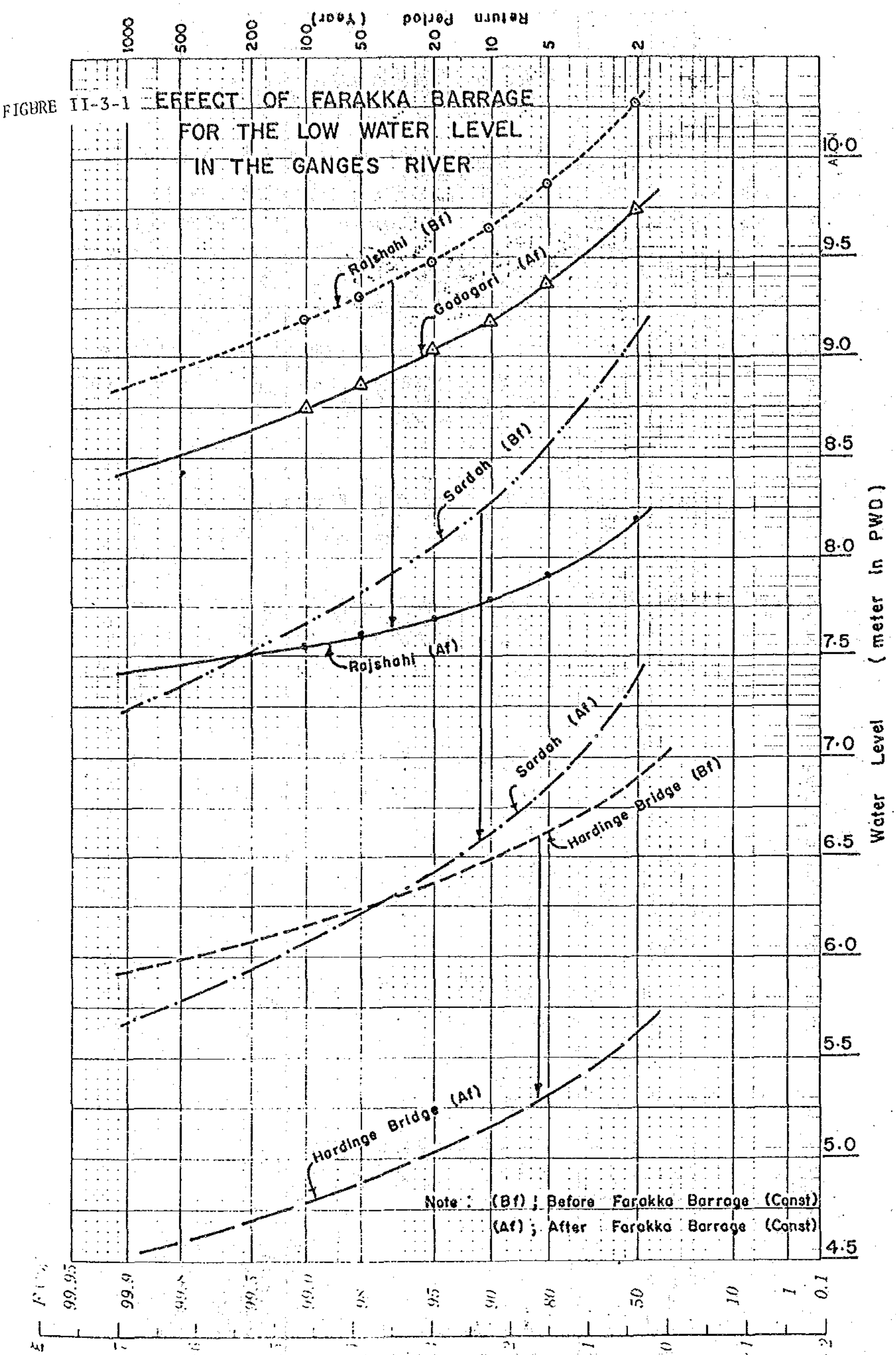


FIGURE II-3-1 EFFECT OF FARAKKA BARRAGE
FOR THE LOW WATER LEVEL
IN THE GANGES RIVER
Return Period (Year)
1000
500
200
100
50
20
10
5
2
Rajshahi (Bf)
Godagari (Af)
Sardah (Bf)
Rajshahi (Af)
Sardah (Af)
Hardinge Bridge (Bf)
Hardinge Bridge (Af)
Water Level (meter in PWD)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
Note : (Bf) ; Before Farakka Barrage (Const)
(Af) ; After Farakka Barrage (Const)
99.95
99.9
99.5
99.0
95
90
80
50
10
1
0.1

TABLE II-3-1 Effect of the Farakka Barrage for the Ganges River Low Water Level

Unit. Meter (PWD)

Return Period	Gadagari After. (1975 ~1980)	Rajshahi site. Before. 2/ (1957 ~1974)	Rajshahi site. After. 1/ (1975 ~1987)	Rajshahi site. Difference	Sardah G.S. Before. 2/ (1963 ~1974)	Sardah G.S. After. 1/ (1976 ~1986)	Sardah G.S. Difference	Harding Bridge. Before. 2/ (1938 ~1974)	Harding Bridge. After. 1/ (1975 ~1986)	Harding Bridge. Difference
2	9.740	10.258	8.189	2,069	9,099	7.354	1.745	6.879	5.609	1.288
3	9.543	10.047	8.025	2,022	8,810	7.090	1.720	6.735	5.446	1.289
4	9.434	9.930	7.942	1.988	8.650	6.945	1.705	6.656	5.356	1.300
5	9.359	9.850	7.889	1.961	8.542	6.847	1.695	6.601	5.295	1.306
6	9.303	9.789	7.850	1.939	8.461	6.773	1.688	6.560	5.249	1.311
8	9.223	9.704	7.798	1.906	8.347	6.670	1.677	6.502	5.184	1.318
10	9.166	9.643	7.763	1.880	8.265	6.596	1.669	6.461	5.137	1.324
15	9.072	9.542	7.706	1.836	8.130	6.474	1.656	6.392	5.060	1.332
20	9.010	9.476	7.672	1.804	8.043	6.396	1.647	6.347	5.010	1.337
30	8.930	9.390	7.629	1.761	7.930	6.294	1.636	6.288	4.944	1.344
50	8.837	9.291	7.582	1.709	7.800	6.178	1.622	6.221	4.869	1.352
100	8.724	9.169	7.529	1.640	7.642	6.036	1.606	6.139	4.778	1.361
Recorded Minimum (Year)	9.21 (1976)	9.19 (1974)	7.74 (1979) (1983)	1,45	7.64 (1974)	6,22 (1976)	1.42	6.20 (1974)	5.03 (1975)	1.17

Note : 1/ After means after the Farakka barrage construction.
2/ Before means before the Farakka barrage construction.

3-1-2. Design Water Level

In accordance with the probability analysis of low water level at Sardah, Rajshahi and Godagari, the probable water level at proposed pumping stations at Kasba, Baraipara and Sultanganj have been estimated by the hydraulic gradient. The water level at each point for each return period and the estimated hydraulic gradient are shown in FIGURE II-3-2 and TABLE II-3-2. Since the Ganges river flow is controlled artificially at the downstream of the Farakka Barrage, a probability analysis will not be adoptable to decide the design water level for pump.

There will be no other way to fix the design water level but adopting the probable values of the low water level. The observed lowest water levels at Rajshahi and Godagari are almost 10-year return period. Also, the difference of the water levels between minimum observed one and 100-year return period at Rajshahi and Godagari are 0.211 meter and 0.486 meter, respectively. Taking into account of the Project life time and safety factor for water level change in future, the 100-year return period has been selected for design water level.

Consequently, the design water level at the proposed pumping stations are -

Unit : meter P.W.D.

Baraipara	:	EL. 8.686
Sultanganj	:	EL. 8.838
Kasba	:	EL. 7.860

FIGURE II-3-2

WATER LEVEL IN THE GANGES AND MAHANANDA RIVERS

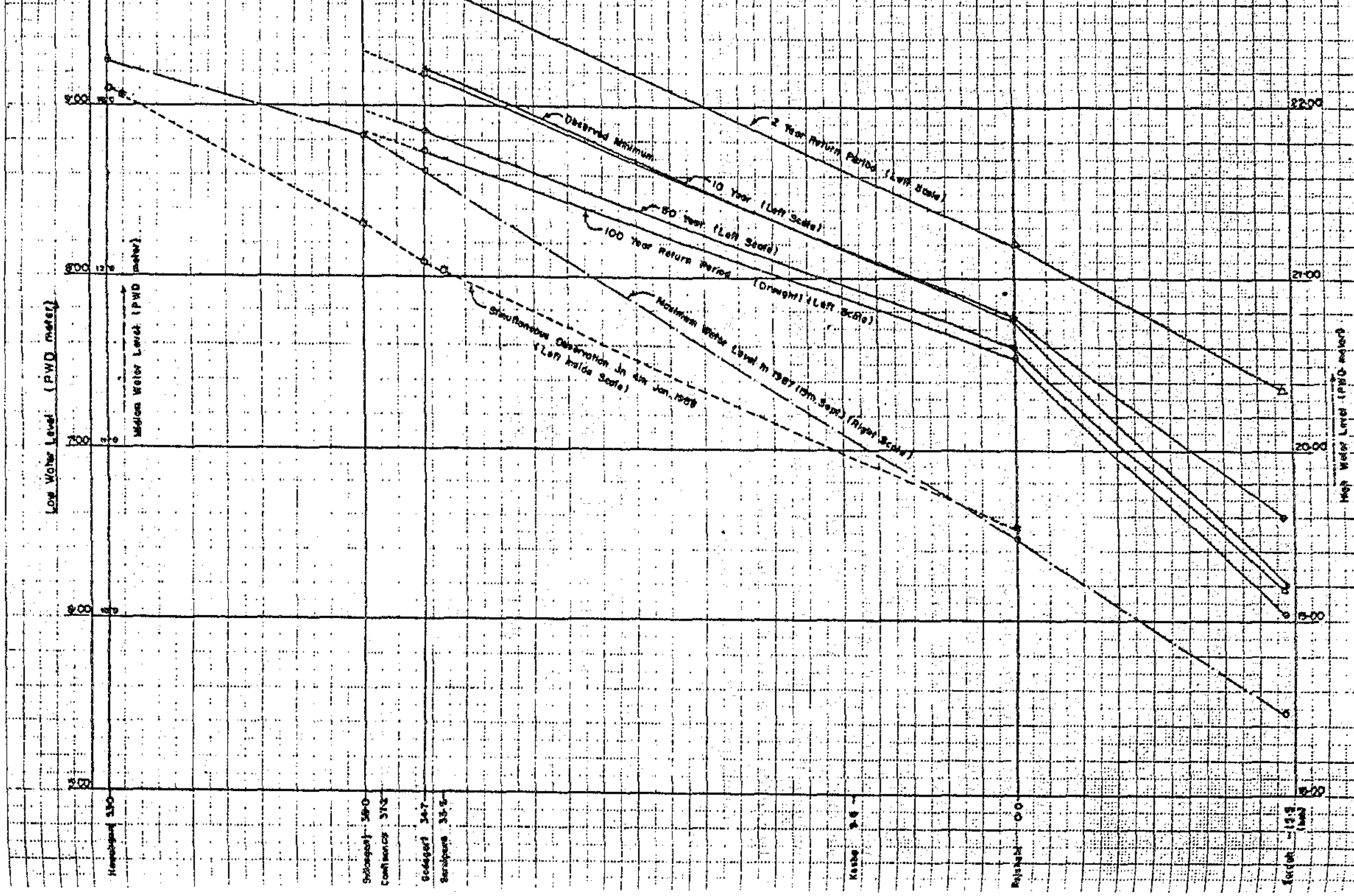


TABLE II-3-2 PROBABILITY OF THE LOW WATER LEVEL AT PROPOSED PUMPING STATION

Unit : PWD meter

Return Period	Probability Analysis				Estimated by Hydraulic Gradient		
	Godagari	Rajshahi	Difference	Unit Difference(m/km)	Kasba	Baraipara	Sultanganj
2	9.740	8.189	1.551	0.04470	8.618	9.691	9.888
3	9.543	8.025	1.518	0.04375	8.445	9.495	9.687
4	9.434	4.942	1.470	0.04236	8.355	9.387	9.576
5	9.359	7.889	1.470	0.04236	8.296	9.312	9.499
6	9.303	7.850	1.453	0.04187	8.252	9.257	9.441
8	9.223	7.798	1.425	0.04107	8.192	9.178	9.359
10	9.166	7.763	1.403	0.04043	8.151	9.122	9.299
15	9.072	7.706	1.366	0.03937	8.084	9.029	9.202
20	9.010	7.672	1.338	0.03856	8.042	8.968	9.137
30	8.930	7.629	1.301	0.03749	7.989	8.844	9.003
50	8.837	7.582	1.255	0.03617	7.929	8.797	8.956
100	8.724	7.529	1.195	0.03444	7.860	8.686	8.838
Distance (km) from Rajshahi	37.7 km	0			9.6 km	33.6 km	38.0 km

3-2. High Water Level

3-2-1. Maximum Flood Water Level

(1) Flood in 1987

The flood in 1987 in and around the Project area was started from the end of July to early August caused by the heavy rainfall. According to the meteorological data observed in the study area, the maximum successive 3-day rainfall in 1987 was recorded from July 31 to August 2 at Rajshahi, Tanore, Nachole and Manda amounting 209.8 mm, 285.8 mm, 353.3 mm and 309.1 mm, respectively.

The water level in the Ganges river at Rajshahi rised at 18.8 meters on the 19th of August and after that the water level was recessed under the danger level. The water level, however, rised again and was recorded the maximum on the 19th of September to 19.46 meters at Rajshahi, which is 1.16 meter higher than the danger level.

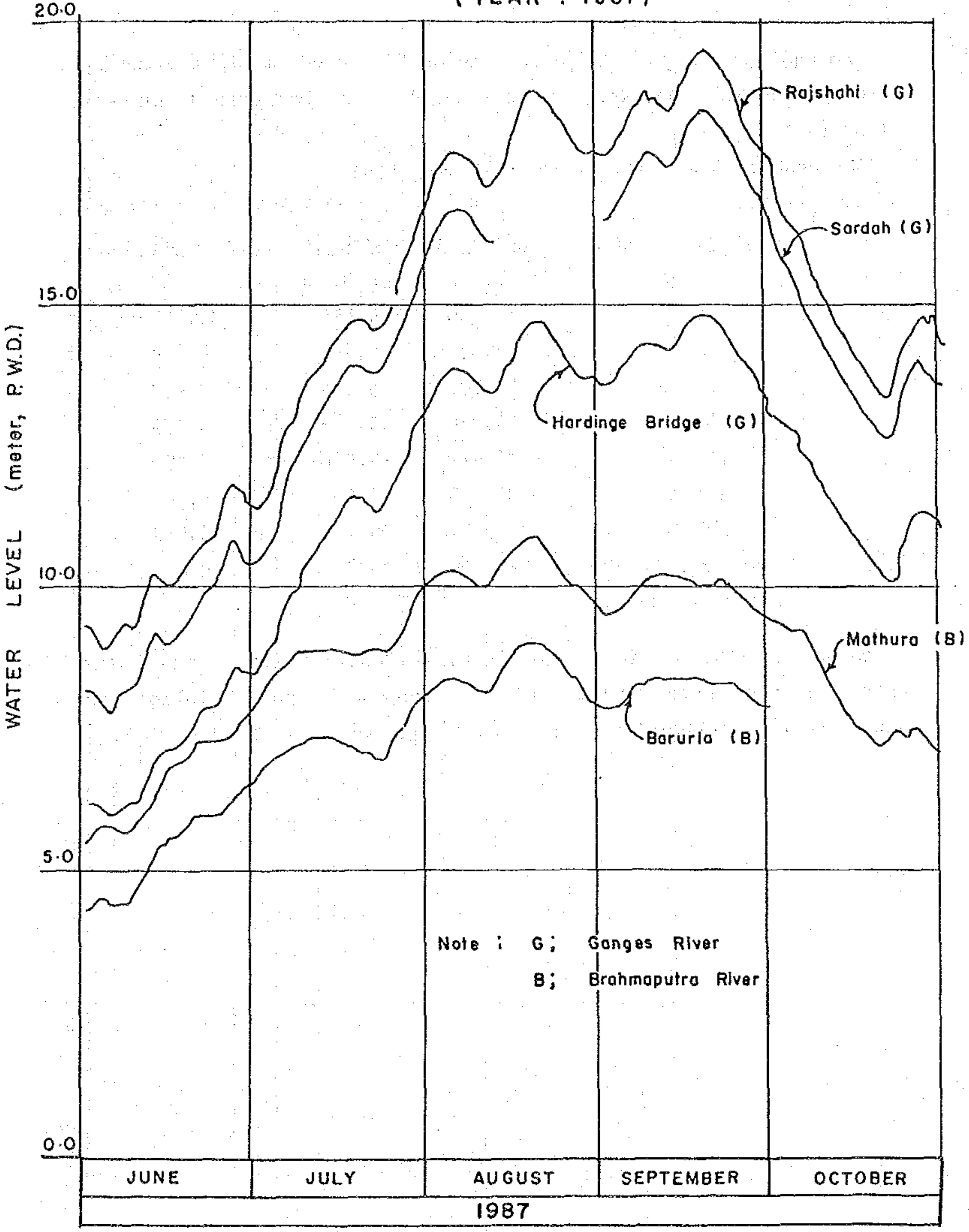
The maximum water levels of the Ganges river in 1987 at Sardah, Rajshahi, Godagari, Sultanganj and Chapai Nawbganj were simultaneously occured on 19th September at 18.46, 19.46, 21.60, 21.80 and 22.24 meter, respectively.

On the other hand, the peak water level in the Jamuna river showed different tendency than that of the Ganges river. The maximum water level at Mathura was recorded at 10.90 meters on the 20th of August while the water level on the 19th of September was only 10.0 meters. As the results, there was one month difference between the floods occured in the Ganges and Jamuna rivers in 1987.

The water level fluctuation in 1987 from June to October at various points in the Ganges and Jamuna rivers are shown in FIGURE II-3-3.

FIGURE II-3-3 WATER LEVEL FLUCTUATION OF THE GANGES AND BRAHMAPUTRA RIVERS

(YEAR : 1987)



(2) Probability Analysis of Flood

Annual maximum water level at Hardinge Bridge, Sardah, Rajshahi and Godagari in the Ganges river are shown in the former TABLE II-1-10 — II-1-15.

Probability analysis has been made on the annual maximum water level at Hardinge Bridge, Rajshahi and Godagari to find the return period of the flood in 1987.

The results are shown in the following table :

Unit : meter in PWD

Return Period	Godagari	Rajshahi	Hardinge Bridge
2	20.672	18.371	14.333
5	21.260	18.850	14.660
10	21.573	19.105	14.834
15	21.732	19.234	14.922
20	21.836	19.318	14.979
30	21.974	19.430	15.055
50	22.135	19.561	15.144
100	22.337	19.725	15.256
Max. W.L in 1987	21.600	19.46	14.80
(Return Period)		(35)	(9)

Based upon the probable water level at Godagari and Rajshahi, the high water level in each return period at proposed pumping station has been estimated by interpolation. The results are shown in TABLE II-3-3.

TABLE II-3-3 Estimated High Water Level at Proposed Pumping Stations

	Probable Water Level				Estimated Water Level		
	Godagari	Rajshahi	Difference (m)	Unit Difference (m/km)	Kasba	Baraipara	Sultanganj
2	20,672	18,371	2,301	0.06103	18.957	20.422	20.690
5	21,260	18,850	2,410	0.06393	19.464	20.998	21.279
10	21,573	19,105	2,468	0.06546	19.733	21.305	21.593
15	21,732	19,234	2,499	0.06626	19.870	21.460	21.752
20	21,836	19,318	2,518	0.06679	19.959	21.562	21.856
30	21,974	19,430	2,544	0.06748	20.078	21.697	21.994
50	22,135	19,561	2,574	0.06828	20.216	21.855	22.155
100	22,337	19,725	2,612	0.06928	20.390	22.053	22.358
Distance from Rajshahi (km)	37.7	0			9.6	33.6	38.0

3-3. River Discharge

3-3-1. Availability of the Water Resources

As for the ground water, deep tube-well project is on-going in the Barind tract of the Project area. There is not enough ground water resources to irrigate about 20,000 to 40,000 ha of land; accordingly, no groundwater utilization for the Project has been considered.

As for the surface water resources, there are four major rivers in and near the Project area for irrigation use. The most reliable source of water is the Ganges river which flows into the southern boundary of the Project area. The Mahananda river flows into the boundary of the Project area. The available dischange of the Mahananda river is about 7 to 8 m^3/sec in the driest months of April and May, which can only be used as supplemental water resource.

Along the eastern boundary of the Project area, the Sib river flows from north to south and confluenced to the Barnai river at Naohata. But the river water dries up during the dry season, except in the depressed areas (so-called Beel in Bangladesh) along the Sib river.

The Atrai river flows in the northern part of the Project area from north to south and confluenced at Manda to the Sib river. But the confluence point had been closed by an embankment by the local people. The discharge of the Atrai river is very small during the dry season.

Accordingly, only the Ganges river has enough water for dry season irrigation. However, during pre-monsoon or post-monsoon, the river flow in the Mahananda, Sib and Atrai rivers can be utilized for supplemental irrigation water supply.

In the Mahananda river, supplemental irrigation water is also expected even during the dry season although the amount will not be enough.

Consequently, the main water resources during the dry season for the irrigation water is the Ganges river and the supplemental irrigation water can be taken from the mahananda river.

Taking into consideration the water level fluctuation in these rivers and the elevation of the Project area, it is necessary to be facilitated with pumping stations for irrigation use.

3-3-2. Ganges River Discharge

(1) Flood Discharge

Annual maximum observed discharges at Hardinge Bridge from 1964 to 1987 have been collected and adapted a probability analysis to verify the return period of the flood in 1987. According to the probability analysis for the annual maximum water level, the return period of the flood water level in 1987 is approximately 35-year.

The results the probability analysis of the maximum flood discharge is shown in the TABLE II-3-4.

The flood in 1987 of 76,000 cum/sec corresponds to 80-year return period.

TABLE II-3-4 Probable maximum and Minimum Discharge at Hardinge Bridge

Return Period	Maximum Discharge	Minimum Discharge
2	51,644	793
5	60,085	695
10	64,862	660
20	69,008	637
30	71,243	627
50	73,905	617
100	77,316	606

(2) Minimum Discharge

Probability analysis for the annual minimum discharge at Hardinge Bridge has been made to estimate the design river discharge in the Ganges river. Taking into consideration of the Farakka Barrage operation from 1975, the records are collected from 1975 to 1986.

The probable low flow discharge at each return period is shown in TABLE II-3-4 together with the flood discharge.

The probability of the drought for design perpose is adopted at 10-year, therefore the design discharge in the Ganges river for drought condition is estimated at 660 m^3/sec.

3-3-3. Mahananda River

Long-term discharge records of the Mahananda river are not available. the Godagari station was in the Mahananda river but due to the Ganges river course shifting the station is now located in the Ganges river. the observation of low flow discharge was terminated since June 1981.

The observation of discharge at Chapai Nawbganj has been started from April 1981 in the Mahananda river. The minimum discharge observed at Godagari is 18.9 m^3/sec in 1979 and at Chapai Nawbganj is 8.35 m^3/sec in 1982. It will be rather difficult to adopt a probability analysis for the minimum discharge at Chapai Nawbganj because the observation period is too short.

According to the draught year analysis mentioned before, the year in 1982 or 1983 is rather drought year. Therefore, the minimum discharge in 1982 at 8.35 m^3/sec has been considered as a design low flow discharge in the Mahananda river.

4. DRAINAGE ANALYSIS

4-1. Method of Runoff Analysis

(1) Runoff Analysis for Slope Area and Rivers

Most Catchment Runoff models for estimating floods are based on empirical approaches which rely heavily on observed data to determine the model parameters. Therefore, when observed data are not available or when characteristics of the catchment area are expected to change, the empirical methods become less reliable.

Characteristics of each individual catchment area are different, both in terms of topography and land use. The runoff model to be used, therefore, should reflect all individual catchment characteristics.

Since there is no observed discharge records in the catchment area, it would not be possible to estimate the runoff based upon empirical method such as unit hydrograph or tank model, these approaches are reliable only when observed records are available for verifications.

In order to solve the problem, an approach utilizing hydraulic equations to compute unsteady flow in open channel which is called Kinematic Wave or Characteristic method was adopted to simulate the overland and channel flows. However, the runoff characteristics from paddy fields are somewhat different from that of overland flow because of large retention capacities of the paddy fields. The retention characteristics of paddy field have to be integrated into the model. This method of runoff analysis is known as the "Compound Characteristics Method".

Basic concepts of the "Compound Characteristics Method" are presented below :

i) Equation of Motion and Continuity

The equations of motion and continuity for the unsteady flow with constant lateral inflow are as follows :

$$\frac{\partial u}{\partial t} + \alpha u \frac{\partial u}{\partial x} - (\alpha - 1) \frac{u}{A} \frac{\partial A}{\partial t} + g \cos\theta \frac{\partial h}{\partial x} = g \sin\theta - \frac{\tau_o}{\rho R} - \frac{\alpha u q}{A}$$

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q$$

where q = the lateral inflow in unit length of the canal

u = the mean velocity

A = the water area

h = the water depth

R = the hydraulic radius

Q = the discharge

α = the coefficient

θ = the slope angle of the canal

ρ = the density of water

γ = shear stress on the canal bottom

g = gravitational acceleration

x = the distance

t = the time

Determination of exact solution of the above equations is very elaborated and not practical. However, approximate solutions can be obtained by assuming the lateral inflow to be steady and uniform,

α = 1 and the shear stress to be given by the equation

$$\frac{\tau_o}{R_o} = \frac{n^2 g \quad u^2}{R^{3/4}}$$

The approximate characteristic solution to the equations is as follows :

$$\frac{dx}{dt} = (1 - \frac{2}{3\beta}) + u \frac{(1 - \frac{2\beta}{3}) uqR^{4/3}}{2 n^2 gAu + qR^{4/3}}$$

where $\frac{dA}{dt} = q$

or $\frac{dQ}{dx} = q$

Subject to $\beta = (R/A) / (dR/dA)$

the relationship between A and u can be given as follows :

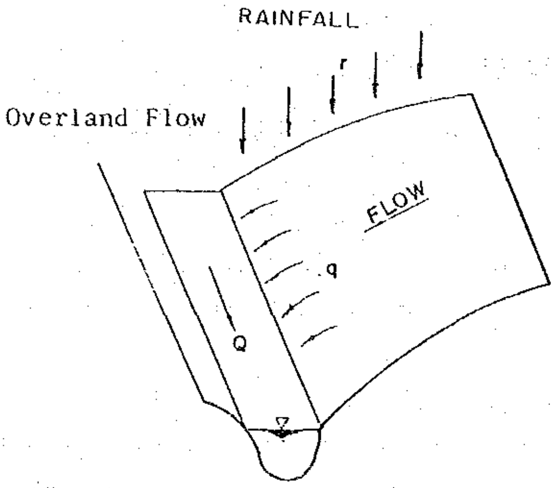
$$u = \sqrt{\left\{\left(1 + \frac{2}{3\beta}\right) \frac{qR^{4/3}}{2gn^2A}\right\}^2 + \frac{R^{4/3}}{n^2} \sin\theta - \frac{2\left(1-\frac{2}{3}\beta\right) u \left(qR^{4/3}/2gn^2A\right)^2}{u + qR^{4/3}/2gn^2A}} - \left(1 + \frac{2}{3\beta}\right) \frac{qR^{4/3}}{2gn^2A}$$

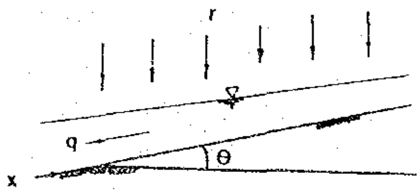
When $q = 0$

$$\frac{dx}{dt} = \left(1 + \frac{2}{3\beta}\right) u$$

$$A = \text{constant or } Q = \text{constant}$$

$$Q = Au = \frac{A}{n} \cdot R^{2/3} \cdot (\sin\theta)^{1/2}$$





The continuity and resistance equations of channel flow can be expressed as :

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \qquad \text{.............. (1)}$$

$$Q = \frac{A}{n} R^{2/3} i^{1/2} \qquad \text{.............. (2)}$$

where i is the energy gradient

For steady and uniform flow condition, the discharge can also be represented by

$$A = KQ^P \qquad \text{.............. (3)}$$

where K and P are constants.

From the above three equations, following equations are derived :

$$\log t = \log K + P \log Q - \log q \qquad \text{.............. (4)}$$

$$\log t = \log K + \log x + (P-1) \log Q \qquad \text{.............. (5)}$$

and if the lateral inflow is neglected (i.e. $q = 0$),

$$x = \frac{1}{KP} Q^{1-P} t \qquad \text{.............. (6)}$$

When applied to overland flow, Q and q have to be replaced by q and σr respectively, where r is the rainfall rate and σ is the coefficient of surface runoff.

Equations (4) and (5) can then be rewritten as :

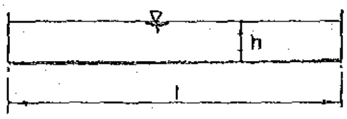
Equi-Rainfall Line

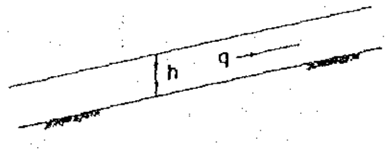
$$\log t = \log K - \log \sigma r + P \log q \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Equi-Distance Line

$$\log t = \log K + \log x + (P-1) \log q \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

For a unit width of a wide rectangular channel





$$R \doteq h$$

$$A = 1 \times h = h$$

$$q = \frac{A}{n} R^{2/3} i^{\frac{1}{2}} = \frac{A^{5/3} i^{\frac{1}{2}}}{n}$$

$$\therefore \quad A = \left(\frac{n}{i^{\frac{1}{2}}}\right)^{0.6} q^{0.6} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

Replacing Q in Equation (3) by q and comparing,

$$K = \left(\frac{n}{i^{\frac{1}{2}}}\right)^{0.6} \quad \text{and}$$

$$P = 0.6$$

Substituting the values of K and P in equation (6) and replacing Q by q,

$$t = 0.6 q^{-0.4} \left(\frac{n}{i^{\frac{1}{2}}}\right)^{0.6} x \quad \ldots\ldots\ldots\ldots\ldots (10)$$

(2) Runoff Analysis for Paddy Area

Runoff from paddy field has the following characteristics :

a) During the early stage of rainfall, the rainfall on paddy field will be stored upto the top of the bund which represent the maximum retention level. The height of bund is about 50 mm to 100 mm and is equal to standing water depth in the field. However, the height of the bund, in other words farm spillway, is normally very small to store the rainfall as much as possible according to the field investigation.

b) Runoff will occur when water depth in the field becomes higher than the top of the bund which usually varies from plot to plot.

c) When rainfall is continued, water level will increase and overspill from every bund in the plot will start. At this time, all of the fields will be flooded and further rainfall will overflow across the bund.

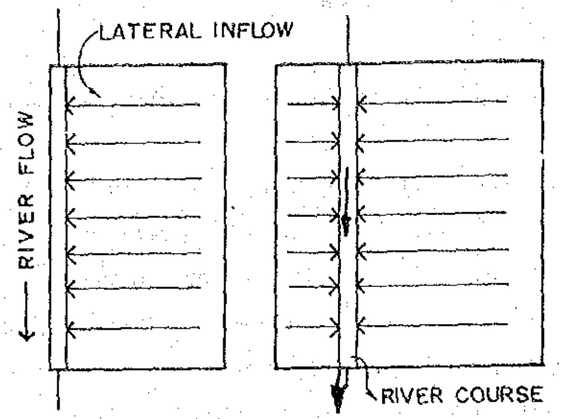
d) All the overspill water will be drained into downstream farm plot and finally into near-by rivers or natural drainage channel which may again used for irrigation in downstream area.

4-2. Sub-basin Networks in the Chatchment Area

(1) Schematic Diagram of the Catchment Area

Based on 1 to 50,000 topographic map, the catchment area of Sib river has been divided into sub-catchment units according to topography and natural water courses. The sub-catchment units were further sub-divided into paddy field which has distinct field storage characteristics and river courses.

The sub-catchment areas were schematized to rectangular shapes corresponding to the actual size. The schematizations were classified into following types as shown below :



The slopes of each sub-catchment area and the river-course were estimated based on the 1:50,000 topographic map. The shapes of the sub-catchment units are represented by the length and width of the schematized areas.

The boundaries of the sub-catchment area for Barind area and Paba area are shown in FIGURE II-4-1 and II-4-2. Corresponding schematized diagrams for both sites are shown in FIGURE II-4-3 and II-4-4 respectively.

The parameters describing characteristics of each sub-basin for the Barind area and Paba area are shown in TABLE II-4-1.

(2) Characteristics of River Courses

Cross sections of existing rivers and their tributaries have been briefly surveyed. Based on the observed cross sections, they are categorized into several types to represent upper mountain area, hilly area and lower flat area.

The representative cross sections have been assigned to several river slopes to find the discharge-flow area relationships by using the Manning's equation in which coefficient of roughness of 0.035 was assumed.

Equations showing relation between flow area and discharge were derived from the plotted points on a logarithmic graph paper.

$$A = KQ^{P}$$

where A = Flow Area (m^2)

Q = Discharge (m^3/sec)

K, P = Coefficients

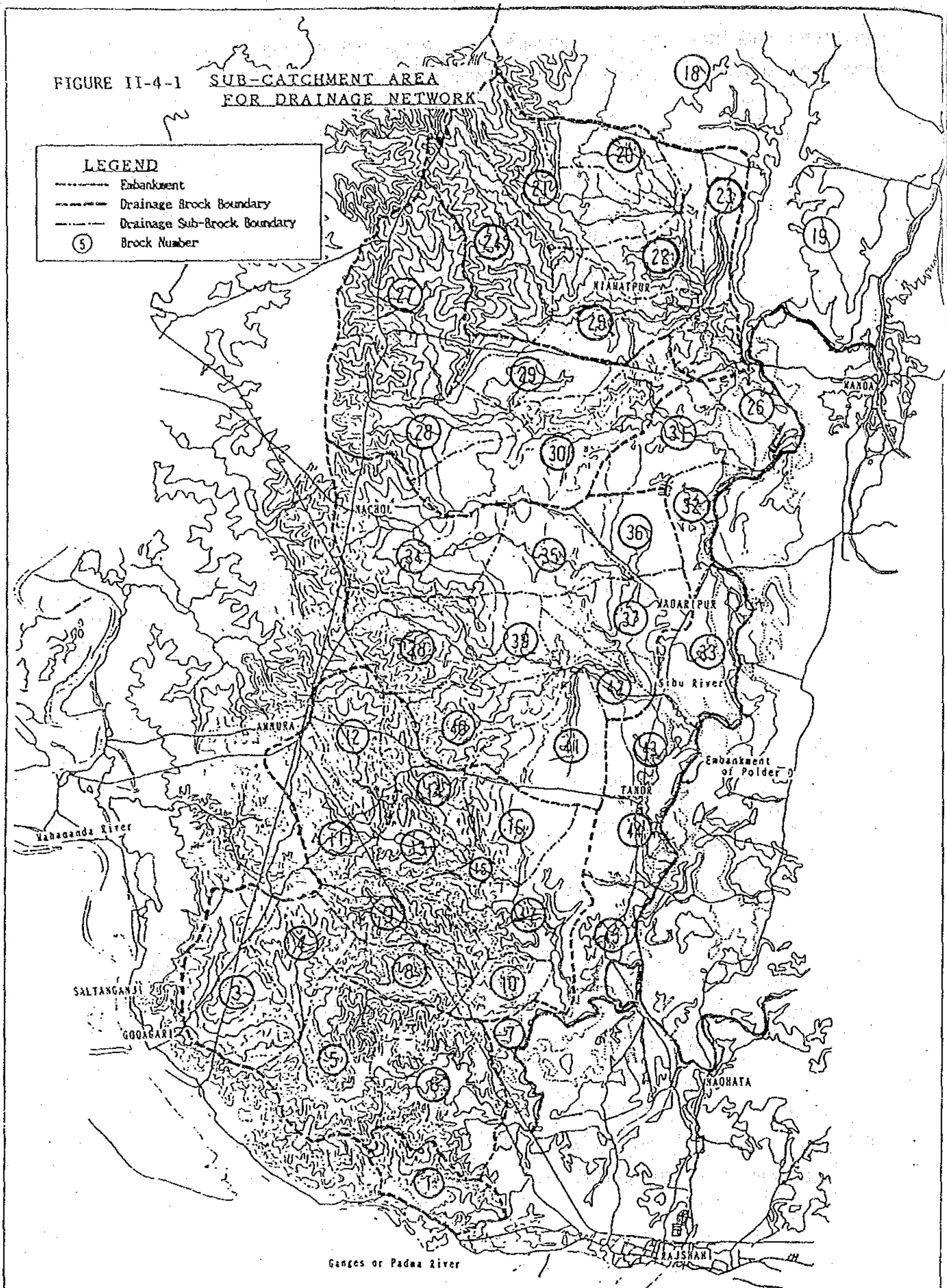
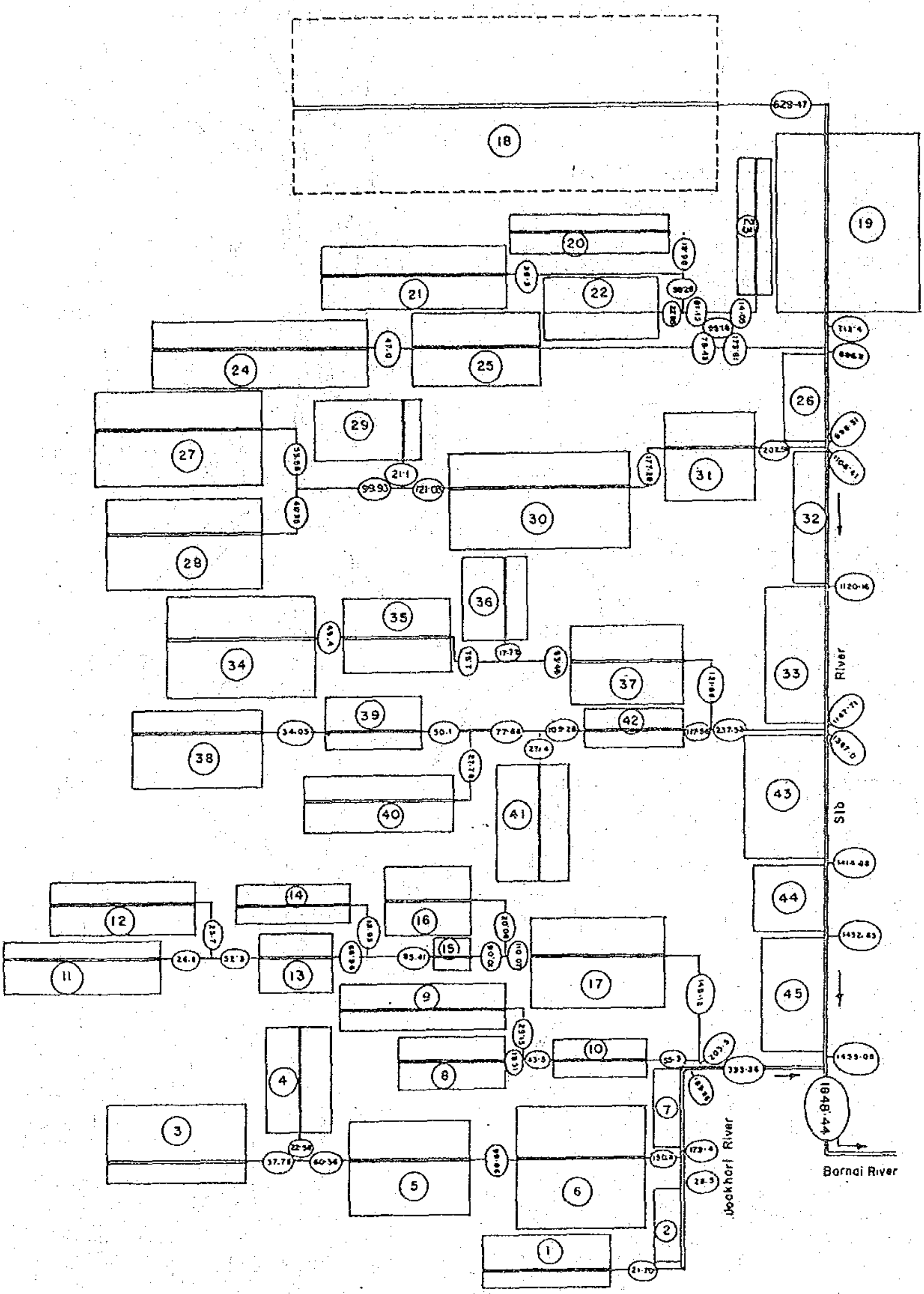


FIGURE II-4-1 SUB-CATCHMENT AREA FOR DRAINAGE NETWORK

FIGURE II-4-2 DIAGRAM OF DRAINAGE NETWORKS



Note: (i) ; shows the number of the sub-catchment area.

(i) ; figure shows the accumulated catchment area in sf.km.

FIGURE II-4-3

DRAINAGE IMPROVEMENT PLAN

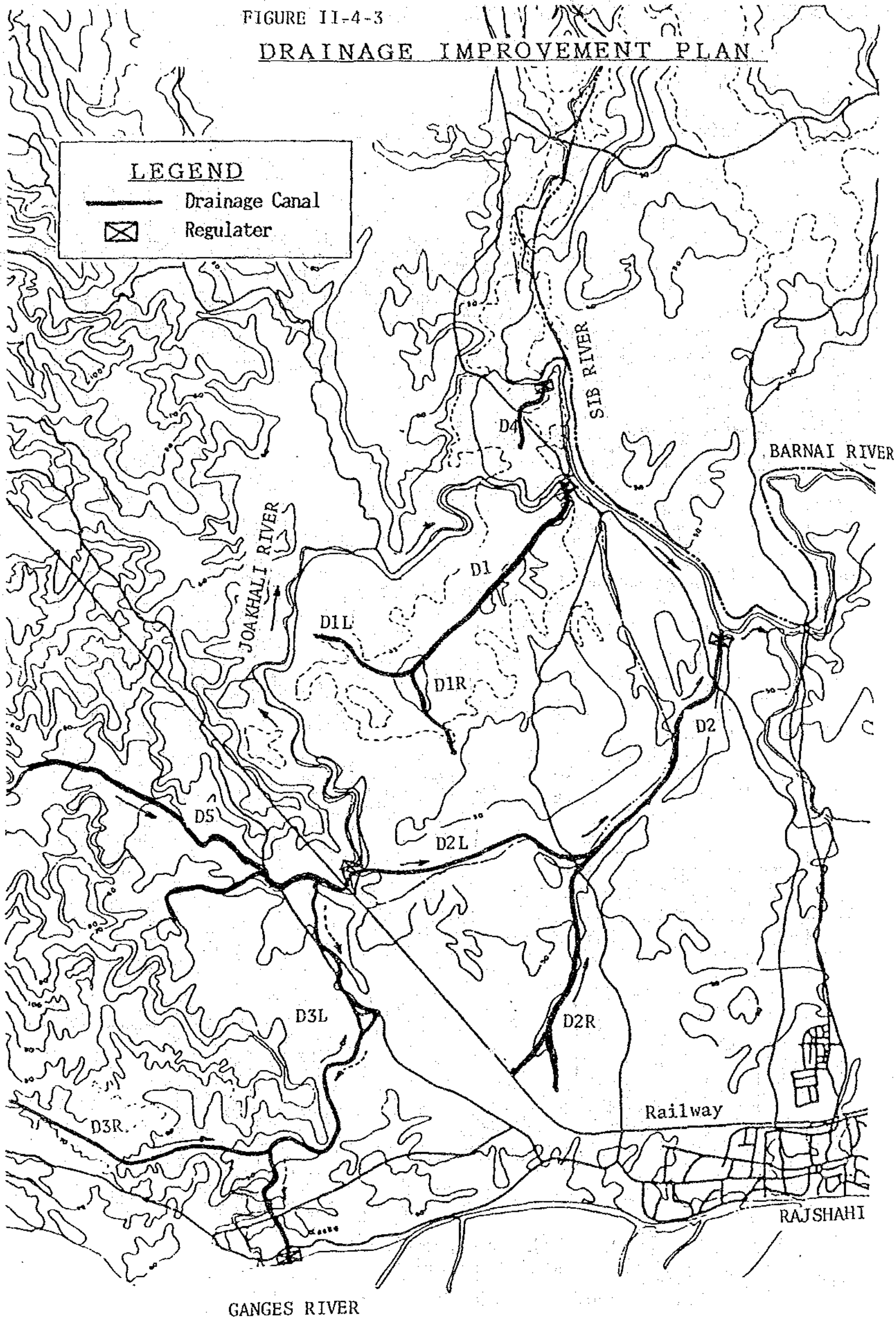


FIGURE II-4-4 FLOOD PLAIN "PABA" DRINAGE NETWORK (I)

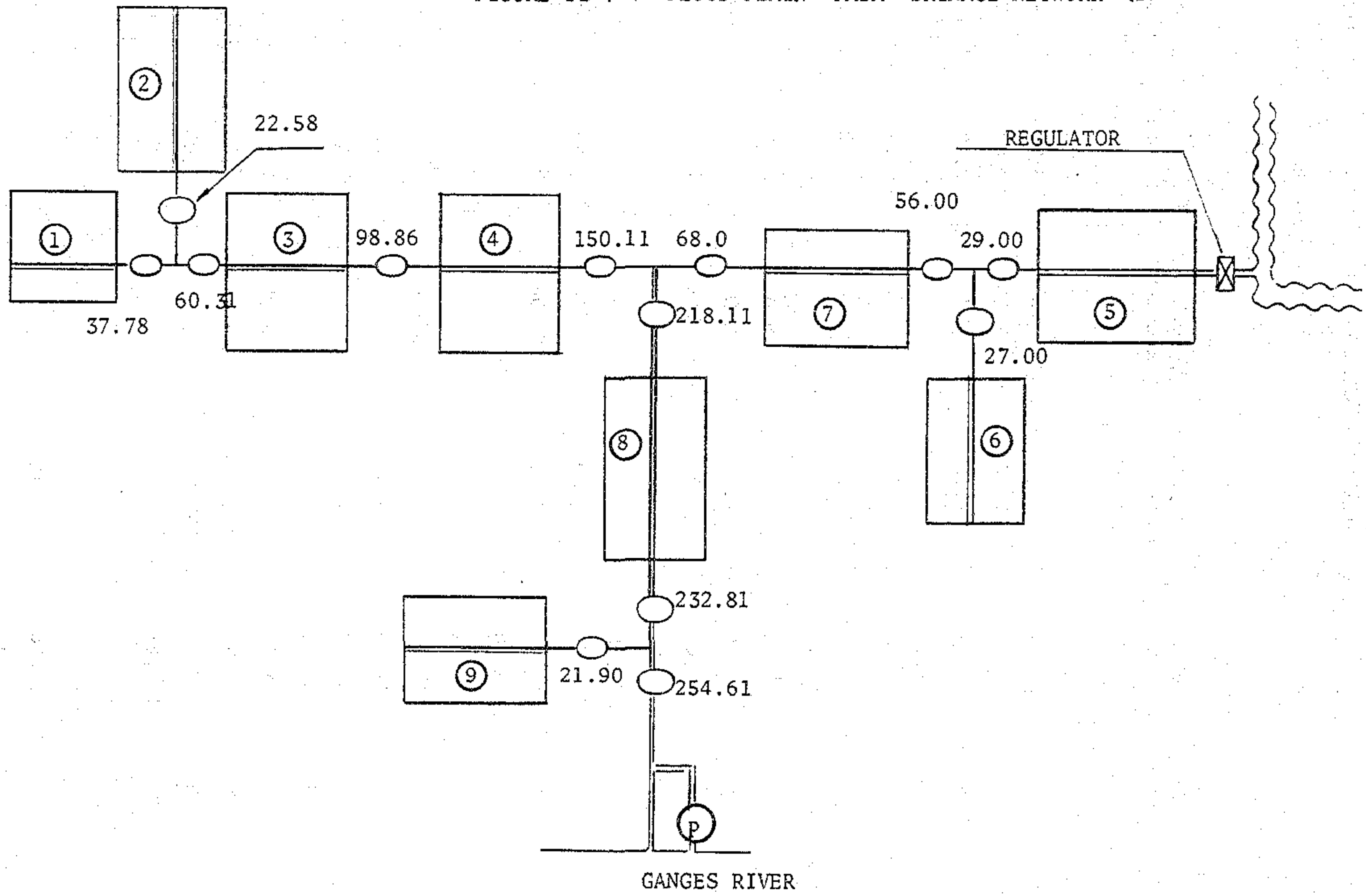


TABLE II-4-1 PARAMETERS EACH SUB-BASIN FOR BARIND AREA AND FLOOD PLAIN AREA

Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope (1:5)
1	21.69		7.23	3.00	–
L	14.46	14.46	7.23	2.00	170
R	7.23	21.70	7.23	1.00	170
100	21.69				
2	6.80		4.54	1.50	
L	6.80	28.50	4.54	1.50	270
101	28.5				
3	37.78		8.04	4.70	
L	27.34	27.34	8.04	3.40	180
R	10.44	37.78	0.04	1.30	110
102	37.78				
4	22.58		5.94	3.80	
L	10.69	10.69	5.94	1.80	170
R	11.89	22.58	5.94	2.00	120
103	22.58				
104	60.36				
5	39.50		7.00	5.64	
L	15.40	75.32	7.00	2.20	220
R	24.10	99.42	7.00	3.44	150
105	99.86				
6	51.05		7.29	7.00	270
L	21.87	121.29	7.29	4.00	260
R	29.16	150.94	7.29	3.00	
106	150.91				
107	179.41				
7	10.45		5.56	1.88	
L	10.45	189.86	5.56	1.88	150
108	189.86				

Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
8	18.30		6.20	2.95	
L	8.68	8.68	6.20	1.40	140
R	9.62	18.30	6.20	1.55	150
109	18.30				
9	25.15		9.67	2.60	
L	13.54	13.54	9.67	1.40	180
R	11.61	25.54	9.67	1.20	180
110	25.15				
111	43.45				
10	11.93		5.19	2.30	
L	6.23	49.68	5.19	1.20	480
R	5.70	55.38	5.19	1.10	190
112	55.38				
11	26.80		8.93	3.00	
L	9.83	9.83	8.93	1.10	170
R	16.97	26.80	8.93	1.90	120
113	26.80				
12	25.70		8.29	3.10	
L	10.78	10.78	8.29	1.30	170
R	14.92	25.92	8.29	1.80	120
114	25.70				
115	52.50				
13	14.48		4.26	3.40	
L	5.98	58.48	4.26	1.40	280
R	8.50	66.98	4.26	2.00	100
116	66.98				
14	18.93		8.60	2.20	
L	11.18	11.18	8.60	1.30	190
R	7.75	18.93	8.60	0.90	200
117	18.93				

Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
118	85.91				
15	4.10		2.20	1.90	
L	2.40	88.31	2.20	1.10	190
R	1.70	90.01	2.20	0.80	200
119	90.01				
16	20.06		5.0	4.01	
L	10.00	10.00	5.0	2.0	120
R	10.06	20.06	5.0	2.01	110
120	20.06				
121	110.07				
17	38.05		7.46	5.10	
L	16.41	126.48	7.46	2.20	200
R	21.64	148.12	7.46	2.90	200
122	148.12				
123	203.50				
124	393.36				

Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
18	629.47				
LL	236.25	236.25			360
R	393.42	629.47			380
125	629.47				
19	82.93		9.99	8.30	
L	54.95	686.60	9.99	5.50	380
R	27.98	717.40	9.99	2.90	330
126	717.40				
20	19.98		9.80	2.20	
L	9.08	9.08	9.80	1.00	350
R	10.90	19.98	9.80	1.20	300
127	14.98				
21	38.30		10.63	3.60	
L	17.04	17.04	10.63	1.60	250
R	21.26	38.30	10.63	2.00	400
128	38.30				
129	58.28				
22	22.85		6.53	3.50	
L	13.05	13.05	6.53	2.00	270
R	9.80	22.85	6.53	1.50	130
130	22.85				
131	81.13				
23	14.05		7.81	1.80	330
L	7.025	7.025	7.81	0.90	330
R	7.025	14.05	7.81	0.90	310
132	14.05				
133	95.18				
24	47.00		12.36	3.80	
L	14.78	14.78	12.36	1.30	200
R	27.22	47.00	12.36	2.50	210

Sub-Basin No.	Total Area Sq;km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
134	47.00				
25	31.43		7.48	4.20	
L	14.97	61.97	7.48	2.00	290
R	16.46	78.43	7.48	2.20	300
135	78.43				
136	173.61				
137	386.01				
26	12.90		5.41	2.38	
R	12.90	898.91	5.41	2.38	300
138	898.91				
27	53.58		9.74	5.50	
L	21.44	21.44	9.74	2.20	210
R	32.14	53.58	9.74	3.30	200
134	53.58				
28	46.35		8.91	5.2	
L	18.73	18.73	8.91	2.1	140
R	27.62	46.35	8.91	3.1	160
140	46.35				
141	99.93				
29	21.10		6.03	3.5	
L	3.50	3.50	1.0	3.5	90
R	17.60	21.60	5.03	3.5	100
142	21.10				
143	121.03				
30	56.25		10.23	5.50	
L	20.45	141.48	10.23	2.00	140
R	35.80	177.28	10.23	3.50	270
144	177.28				

Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
31	30.22		5.99	5.04	
L	10.05	187.33	1.99	5.04	260
R	20.17	207.50	4.0	5.04	280
145	207.50				
146	1106.41				
32	13.75		7.67	1.80	
R	13.75	1120.16	7.67	1.80	740
147	1120.16				
33	27.55		8.10	3.40	
R	27.55	1147.71	8.10	3.40	740
148	1147.71				
34	49.40		8.66	5.70	
L	19.00	19.00	8.66	2.20	160
R	30.40	49.40	8.66	3.50	220
149	49.40				
35	26.30		6.26	4.20	
L	13.77	63.17	6.26	2.20	400
R	12.53	67.70	6.26	2.00	450
150	75.70				
36	17.78		4.81	3.70	
L	5.77	5.77	4.81	1.20	560
R	12.01	17.78	4.81	2.50	370
151	17.78				
152	93.48				
37	28.38		6.31	4.50	
L	12.60	106.08	6.31	2.00	180
R	15.78	121.86	6.31	2.50	200
153	121.86				

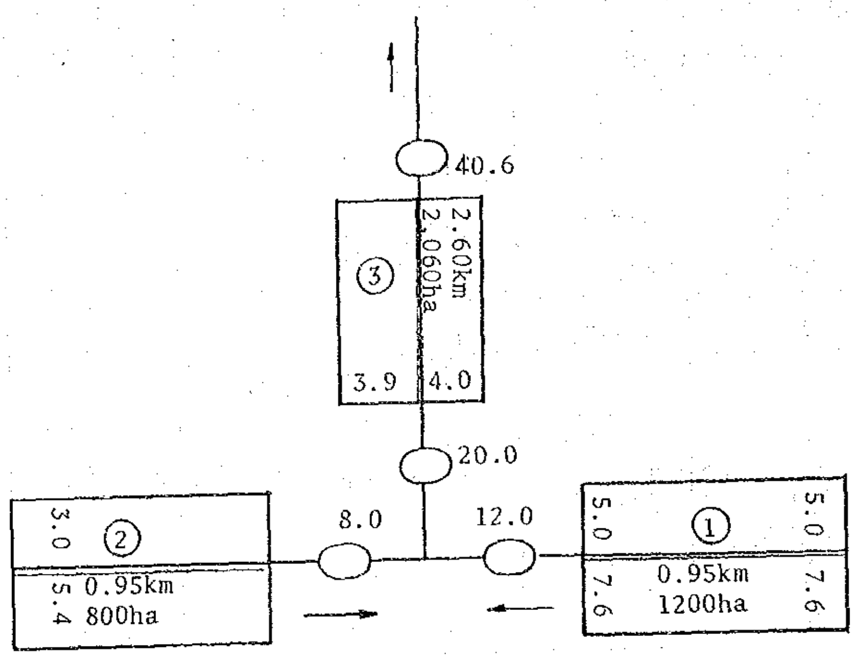
Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
38	34.05		7.56	4.50	160
L	9.86	9.86	7.56	1.30	220
R	24.19	34.05	7.56	3.20	
154	34.05				
39	16.05		5.35	3.00	230
L	10.70	44.75	5.35	2.00	280
R	5.35	50.10	5.35	1.00	
155	50.10				
40	27.78		8.68	3.20	
L	12.15	12.15	8.68	1.40	350
R	15.63	27.78	8.68	1.80	380
156	27.78				
157	77.88				
41	27.40		6.68	4.10	
L	16.71	16.71	6.68	2.50	160
R	10.69	27.40	6.68	1.60	570
158	27.40				
159	105.28				
42	12.28		5.50	2.23	
L	6.77	112.05	5.50	1.23	180
R	5.51	117.56	5.50	1.00	200
160	117.56				
161	239.42				
162	1387.13				
43	27.55		6.14	4.50	
R	27.55	1414.68	6.14	4.50	270
163	1414.68				
44	17.97		4.20	4.04	
R	17.97	1432.65	4.20	4.04	270
164	1432.65				

Sub-Basin No.	Total Area Sq.km	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
45	22.43		6.5	3.45	
R	22.43	1455.08	6.5	3.45	250
165	1455.08				
Total	1848.44				

Sub- Basin No.	Total Area (km^2)	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
1	37.78				
L	27.34	27.34	8.04	3.40	180
R	10.44	37.78	8.04	1.30	110
101	37.78				
2	22.58				
L	10.69	10.69	5.94	1.80	170
R	11.89	22.58	5.94	2.00	120
102	60.36				
3	39.50				
L	15.40	15.40	7.00	2.20	220
R	24.10	39.50	7.00	3.44	150
103	99.86				
4	51.05				
L	21.87	21.87	7.29	4.00	270
R	29.16	51.05	7.29	3.00	260
104	150.91				
5	29.00				
L	10.00	10.00	2.95	6.30	5,000
R	19.00	29.00	2.95	3.50	5,000
105	29.00				
6	27.00				
L	13.00	13.00	2.10	5.00	5,000
R	14.00	27.00	2.10	7.90	5,000
106	27.00				
107	56.00				
7	12.00				

Sub-Basin No.	Total Area (km^2)	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
L	3.00	3.00	2.55	3.7	5,00
R	9.00	12.00	2.55	1.0	5,000
108	68.00				
109	218.11				
8	14.80				
L	8.0	8.0	4.54	1.80	270
R	6.8	14.8	4.54	1.50	500
110	232.81				
9	21.70				
L	14.46	14.46	7.23	2.00	170
R	7.23	21.70	7.23	1.00	170
111	21.70				
112	254.61				

PLOOD PLAIN AREA DRAINAGE NETWORK (II)



Sub-Basin No.	Total Area (km^2)	Cumulative Total Area	Length of Catchment	Width of Catchment	Slope
①	12.00				
L	7.22	7.22	0.95	7.60	5,000
R	4.78	12.00	0.95	5.00	5,000
101	12.00				
②	8.00				
L	5.13	5.13	0.95	5.40	5,000
R	2.87	8.00	0.95	3.00	5,000
101	8.00				
102	20.00				
③	20.60				
L	10.20	10.20	2.60	3.90	5,000
R	10.40	20.60	2.60	4.00	5,000
103	40.60				

4-3. Results of Runoff Analysis

(1) Runoff from Unit Plot of Paddy Field.

The mechanisms of runoff from for paddy field are shown in FIGURE II-4-5 and II-4-6.

According to the design rainfall pattern in hourly basis on 5 year return period, runoff analysis from one unit of paddy field has been performed. The hydrograph is shown in FIGURE II-4-7 . The peak runoff is 3.05 mm/hour which is equivalent to 8.47 l/sec/ha.

(2) Runoff from Catchment Area

On the basis of above runoff hydrograph from one plot of paddy field, the characteristic of farm drain and existing natural river course have been taken into consideration for flood routine analysis by "Kinematic Wave Method". In accordance with the modified drainage networks, the peak discharge for 5-year return period has been analyzed for each sub-basin.

The peak discharge and its catchment area in the Barind area and Paba flood plain area are shown in TABLE II-4-2, and plotted in FIGURE II-4-8.

As seen in the FIGURE II-4-8 , the discharge at each catchment area can be obtained from the following equation;

$$Q = 0.76A + 2.0$$
$$q = -5.0 \times 10^{-4} \times A + 7.85$$

where, Q (m^3/sec) discharge at the catchment area A (sq·km) and q (l/sec/ha) is specific dischage at the catchment area A (sq·km).

As for the Paba flood plain area, the major catchment area is located in the Barind area and the runoff flows into the flood plain area. Therefore, the runoff characteristics are quite similar to that of the Barind area. Flood concentration time in the flat area is more than the sloped area. The difference of the specific peak discharge between the Barind area and flood plain area is very small. Accordingly, the equation mentioned above has been adopted in the Paba flood plain area as well.

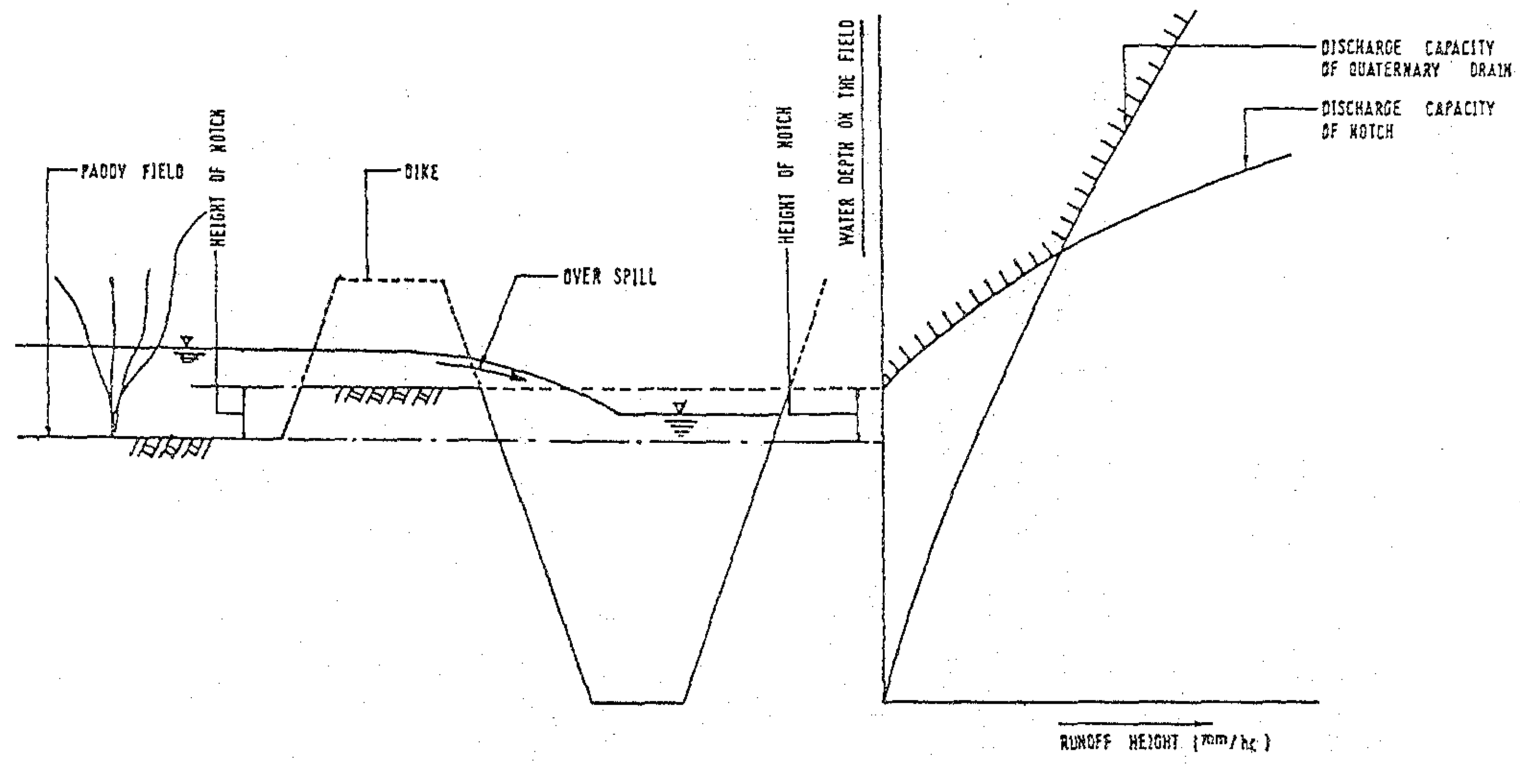
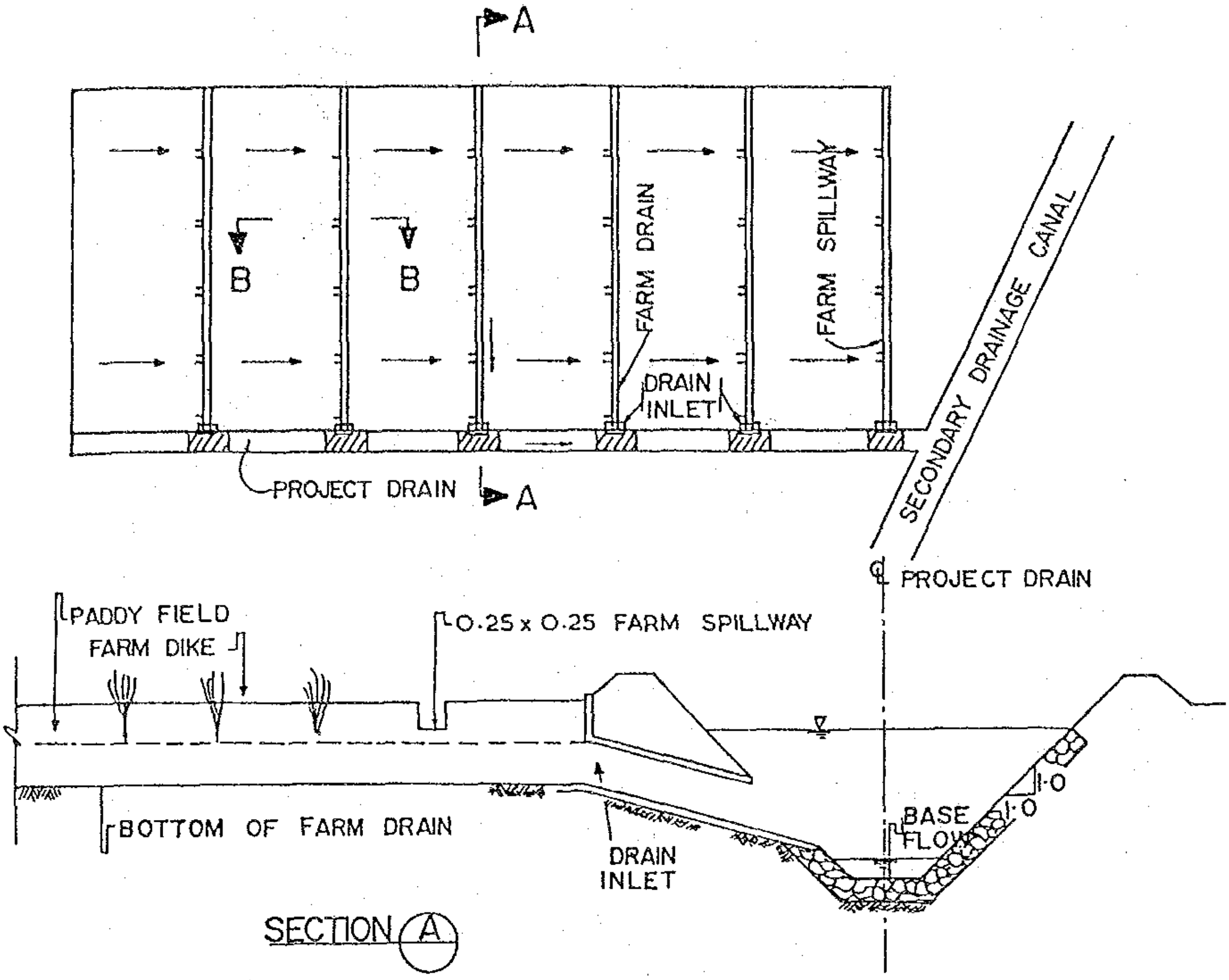


FIGURE II-4-5 THE CHARACTERISTICS OF RUNOFF FROM PADDY FIELD

FIG. II-4-6 DRAINAGE SYSTEM IN THE PADDY FIELD



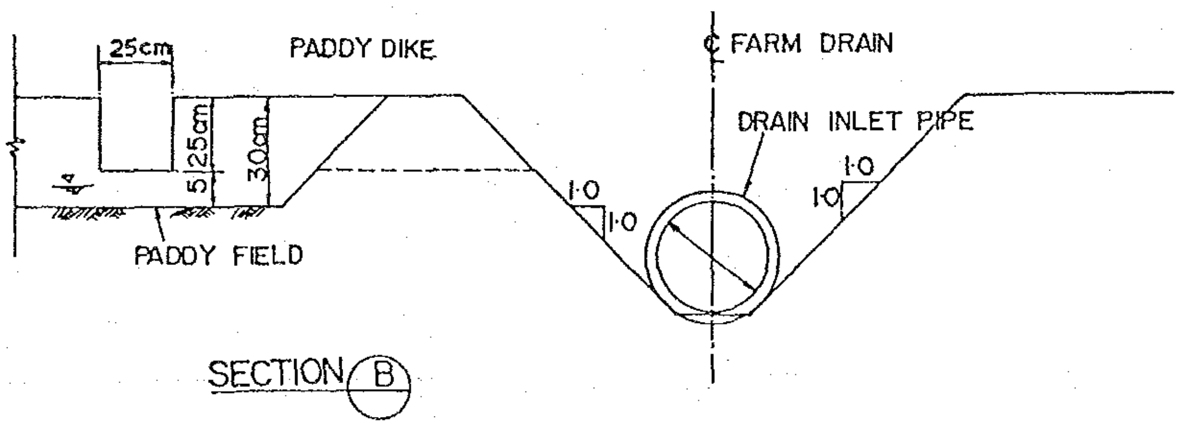


FIGURE II-4-7 RUNOFF FROM ONE PLOT OF PADDY FIELD

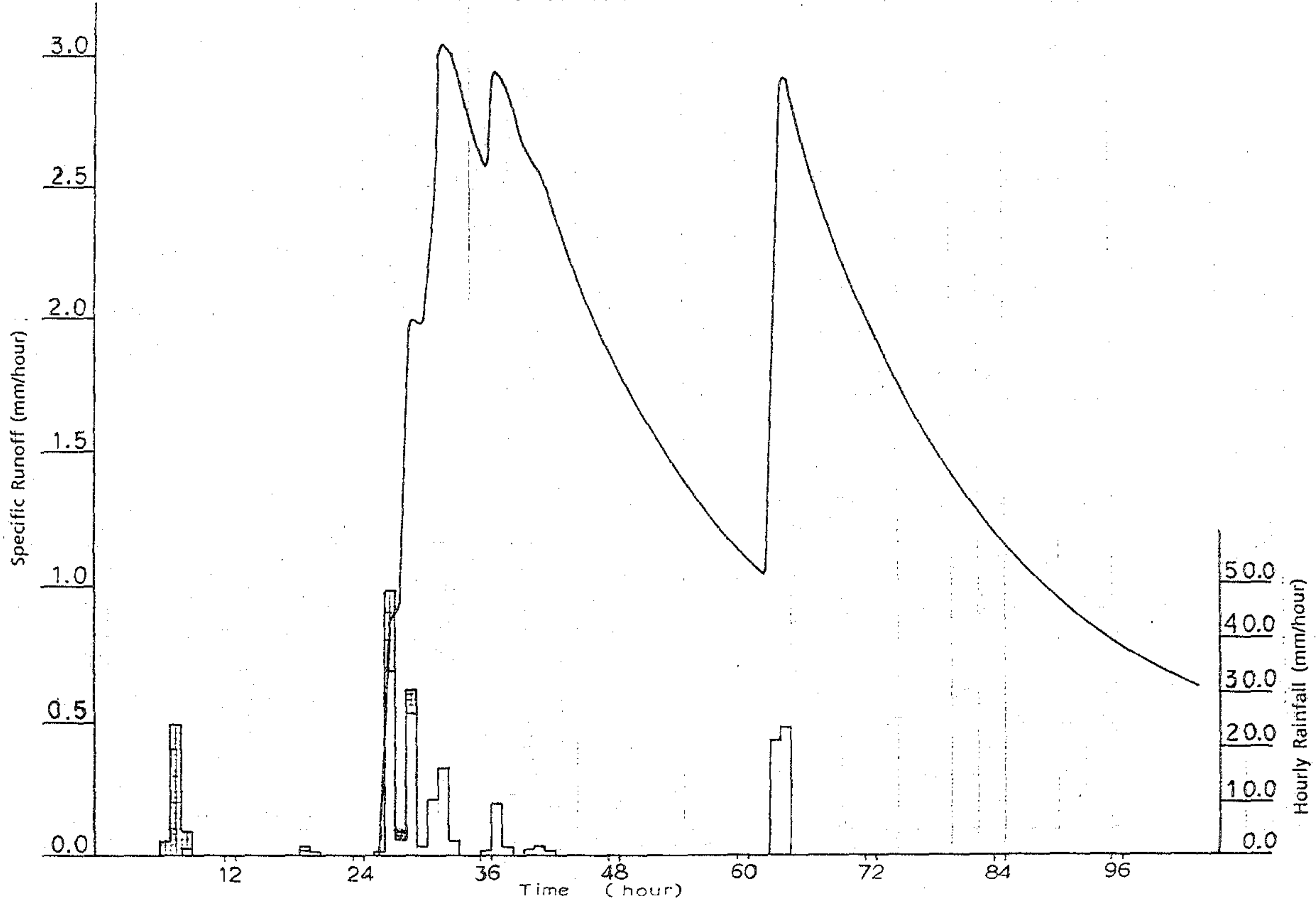


TABLE II-4-2 Relationship between Peak Discharge and Drainage Area(5-Year return period)

Peak Discharge in the Barind Area

Station No.	Drainage Area (km²)	Discharge Q (m³/s)	Specific Discharge q (ℓ/s/ha)
1	21.7	18.0	8.29
2	28.5	23.3	8.18
3	37.8	22.9	6.06
4	60.3	40.8	6.77
5	98.9	72.8	7.36
6	150.8	113.5	7.53
7	179.4	139.8	7.79
8	18.3	15.7	8.58
9	43.5	36.4	8.37
10	55.3	44.9	8.12
11	26.8	22.1	8.25
12	52.5	43.0	8.19
13	67.0	54.0	8.06
14	85.4	68.2	7.99
15	90.0	71.2	7.91
16	110.1	86.1	7.82
17	148.1	155.4	7.79
18	629.5	489.7	7.78
19	712.5	555.0	7.79
20	20.0	17.7	8.85
21	58.3	48.4	8.30
22	81.1	65.9	8.13
23	95.2	76.6	8.05
24	47.0	38.4	8.17
25	78.4	63.1	8.05
26	898.9	701.1	7.80
27	53.6	44.5	8.30
28	99.9	85.5	8.56
29	121.0	101.7	8.40
30	177.3	142.2	8.02
31	207.5	167.5	8.07
32	1,120.2	874.9	7.81
33	1,147.7	894.6	7.79
34	49.4	41.0	8.30
35	75.7	61.3	8.10
36	93.5	74.8	8.00
37	121.9	96.6	7.92
38	34.1	27.3	8.01
39	50.1	40.7	8.12
40	77.9	62.1	7.97
41	105.3	83.0	7.88
42	117.6	91.4	7.77
43	1,414.7	1,092.9	7.73
44	1,432.7	1,102.8	7.70
45	1,455.1	1,111.9	7.64

Peak Discharge in Paba I Flood Plain Area

Paba I

Station No.	Drainage Area (km²)	Discharge Q (m³/s)	Specific Discharge q (ℓ/s/ha)
1	37.8	22.95	6.07
2	60.4	40.80	6.75
3	99.9	72.00	7.21
4	150.9	111.15	7.37
5	29.0	22.65	7.81
6	56.0	38.85	6.94
7	68.0	47.40	6.97
8	218.1	161.40	7.40
9	254.6	174.00	6.83

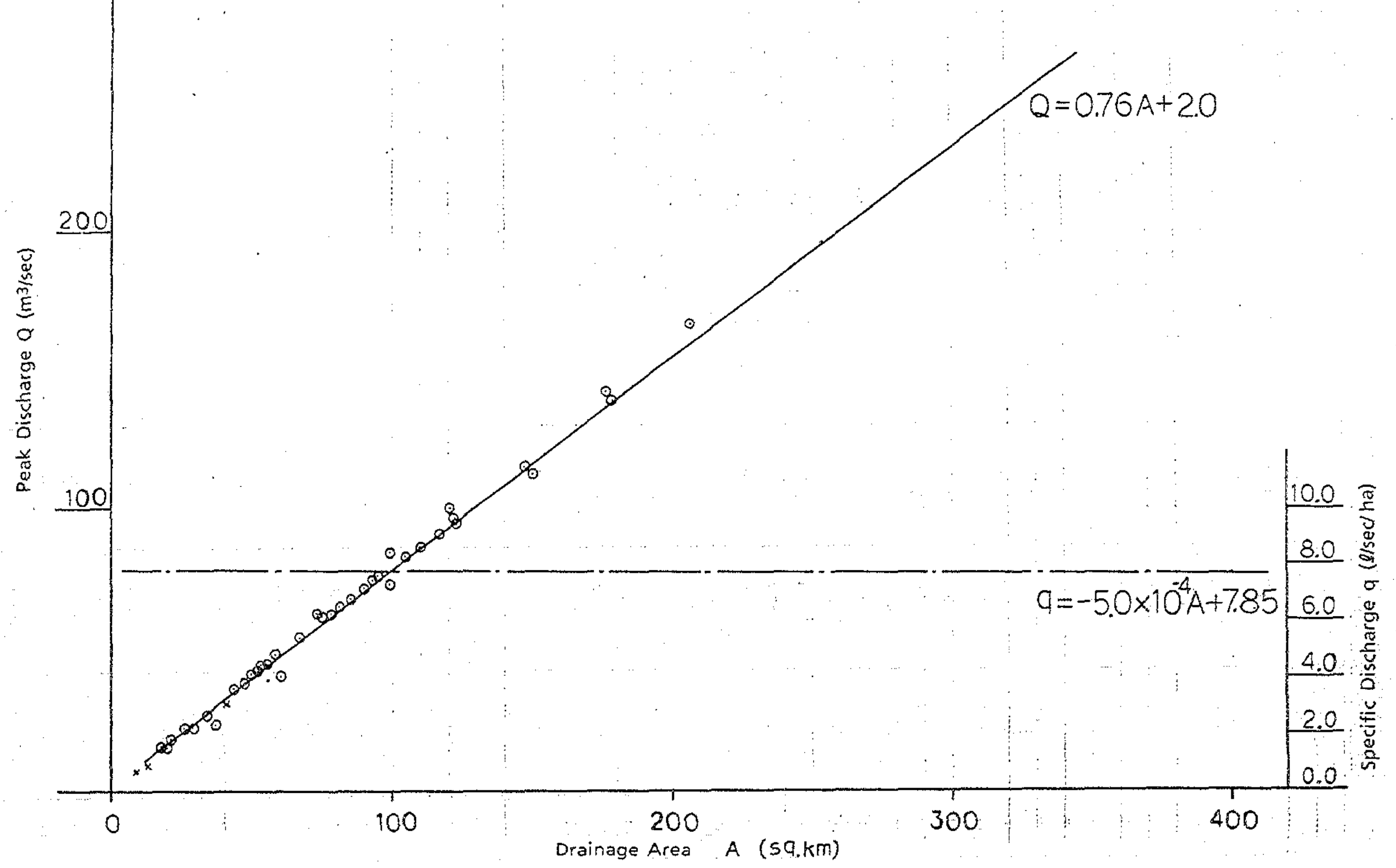
Peak Discharge in Paba II Flood Plain Area

Paba II

Station No.	Drainage Area (km²)	Discharge Q (m³/s)	Specific Discharge q (ℓ/s/ha)
1	12.0	9.38	7.82
2	8.0	6.33	7.91
3	40.6	31.76	7.82

FIGURE. II-4-8 RELATIONSHIP BETWEEN DRAINAGE AREA AND PEAK DISHARGE

(5-Year Return Period)



5. SEDIMENTATION ANALYSIS

5-1. Observed Sedimentation Data

5-1-1. Suspended Sediment Data

Suspended sediment data has been observed at Hardinge Bridge in the Ganges river. The observation has been made intermitently as shown in TABLE II-5-1 from 1976 to 1986. In accordance with the observed data of the suspended sediment, the river discharge record at Hardinge Bridge for the corresponding data has also been shown in the TABLE II-5-1.

5-1-2. Bed Load

Bed load samples at Chapai Nawabganj, Sultanganj in the Mahananda river and at Godagari in the Ganges river have been collected. Grain size analysis for the samples has been made in a laboratory.

The results are shown in the FIGURE II-5-1. The particle size gradation at Godagari is smaller than that of in the Mohannanda river and is shown quite similarity with the one at the Hardinge Bridge.

TABLE II-5-1 (1) BANGLADESH WATER DEVELOPMENT BOARD

SURFACE WATER HYDROLOGY-2

DHAKA

OBSERVED SUSPENDED SEDIMENT DATA

STATION : 90 HARDINGE BRIDGE SUB DIV : PB RIVER : GANGES

DATE	SUSPENDED SAND DISCHARGE (kg/sec)	MAX. SAND CONC. (ppm)	WATER DISCHARGE (m^3/S)
1976. 6. 2	8.42	48.30	1670
6. 5	15.90	80.50	1790
6. 9	58.30	145.00	2250
6. 12	60.50	129.00	3080
6. 16	763.00	805.00	5890
6. 23	177.00	145.00	6340
6. 30	526.00	411.00	5800
7. 7	4160.00	1220.00	12800
7. 14	1770.00	297.00	13400
7. 21	5930.00	982.00	19300
7. 29	1970.00	443.00	19400
8. 6	6790.00	757.00	25100
1979. 4. 5	0.00	0.00	0
4. 11	0.00	0.00	0
4. 18	0.00	0.00	0
4. 25	0.00	0.00	0
5. 2	0.00	0.00	0
5. 16	0.00	0.00	0
5. 23	0.00	0.00	0
6. 6	0.00	0.00	0
6. 20	0.00	0.00	0
6. 27	0.00	0.00	0
7. 4	201.00	177.00	4870
7. 12	306.00	42.30	8320
7. 18	694.00	242.00	10300
7. 25	7150.00	773.00	25400
8. 1	13400.00	869.00	36400
8. 16	7920.00	725.00	26600
8. 22	6750.00	644.00	29900
8. 29	5420.00	946.00	28000
9. 5	4280.00	483.00	18700
9. 12	3720.00	547.00	19000
9. 19	560.00	242.00	13300
9. 26	145.00	64.40	8350
10. 10	847.00	242.00	10400
10. 17	650.00	209.00	8490
10. 24	293.00	161.00	5740
10. 30	146.00	129.00	4390
11. 6	98.90	104.00	3340
11. 13	60.60	64.40	2760
11. 21	51.60	96.60	2320
11. 28	13.80	32.20	2030
12. 5	9.72	32.20	2130
12. 12	2.39	8.05	2080
12. 26	0.00	0.00	0

DATE	SUSPENDED SAND DISCHARGE (kg/sec)	MAX. SAND CONC. (ppm)	WATER DISCHARGE (m^3/S)
1980. 1. 9	0.00	0.00	0
1. 16	0.00	0.00	0
3. 12	0.00	0.00	0
4. 2	0.00	0.00	0
4. 9	0.00	0.00	0
4. 16	0.00	0.00	0
4. 23	0.00	0.00	0
5. 7	0.00	0.00	0
5. 21	0.00	0.00	0
6. 4	0.00	0.00	0
6. 11	0.00	0.00	0
6. 25	0.00	0.00	0
7. 9	1730.00	217.00	12700
7. 16	4200.00	225.00	26500
7. 30	7470.00	773.00	39400
9. 24	7810.00	483.00	31800
10. 1	8370.00	660.00	26700
10. 8	1940.00	290.00	18800
10. 14	316.00	80.50	13700
10. 23	354.00	129.00	9790
11. 1	2442.00	161.00	7610
11. 5	102.00	96.60	6340
11. 12	48.80	80.50	5210
11. 20	49.60	48.30	4560
11. 26	8.25	16.10	4020
12. 3	34.80	80.50	3450
12. 10	9.00	96.60	1730
12. 31	6.97	80.50	2110
1981. 1. 14	76.60	32.20	1670
1. 21	5.97	32.20	1520
1. 28	2.26	16.10	1400
1982. 9. 1	20900.00	644.00	50800
9. 8	5580.00	306.00	59900
9. 15	16100.00	676.00	51400
9. 28	7130.00	434.00	28800
10. 6	2370.00	338.00	14200
10. 13	714.00	145.00	9180
10. 20	174.00	64.40	6580
10. 25	32.80	12.90	5820
11. 1	21.10	8.05	5690
11. 8	9.36	8.05	4650
11. 15	12.70	32.20	4340
12. 13	6.67	12.90	2810

TABLE II-5-1 (2) BANGLADESH WATER DEVELOPMENT BOARD

SURFACE WATER HYDROLOGY-2

DHAKA

OBSERVED SUSPENDED SEDIMENT DATA

STATION : 90 HARDINGE BRIDGE SUB DIV : PB RIVER : GANGES

DATE	SUSPENDED SAND DISCHARGE (kg/sec)	MAX. SAND CONC. (ppm)	WATER DISCHARGE (m^3/S)
1983. 7. 4	8.86	4.83	4030
7. 10	3990.00	483.00	15100
7. 18	2430.00	483.00	13100
7. 25	4280.00	773.00	14700
8. 8	17100.00	1610.00	29700
8. 15	9770.00	1560.00	23600
8. 22	7990.00	1530.00	22000
8. 29	17500.00	1610.00	29700
9. 5	18700.00	1400.00	31300
9. 12	20600.00	1210.00	40400
10. 11	1040.00	1160.00	26100
10. 18	12900.00	1400.00	26900
10. 24	2110.00	386.00	16400
10. 31	1360.00	708.00	11700
11. 8	200.00	80.50	8890
11. 14	89.70	80.50	6890
11. 21	39.80	48.30	5860
11. 28	18.40	48.30	5190
12. 5	0.00	0.00	0
1984. 6. 11	62.20	64.40	4270
6. 18	1230.00	483.00	9070
7. 3	1370.00	418.00	13000
7. 9	6470.00	934.00	15200
7. 17	19700.00	1080.00	29600
7. 30	20900.00	1060.00	33700
8. 6	25700.00	982.00	46600
8. 13	8910.00	724.00	31100
8. 20	6580.00	741.00	23300
8. 28	12300.00	644.00	35500
10. 1	6210.00	1210.00	22800
10. 8	3180.00	886.00	14400
10. 15	1160.00	403.00	9600
10. 22	736.00	338.00	7470
10. 29	344.00	209.00	6900
11. 5	115.00	113.00	5790
11. 12	95.20	64.40	4680
11. 19	51.10	48.30	3810
11. 26	26.50	32.20	3350
12. 3	5.90	16.10	2890
12. 10	0.00	0.00	0
1985. 7. 8	360.00	209.00	7050
7. 15	2200.00	403.00	15900
7. 22	87100.00	757.00	22900
7. 29	11200.00	837.00	29000

DATE	SUSPENDED SAND DISCHARGE (kg/sec)	MAX. SAND CONC. (ppm)	WATER DISCHARGE (m^3/S)
1985. 8. 5	16900.00	660.00	46800
12	9810.00	660.00	31000
20	11200.00	853.00	33700
25	12400.00	805.00	39900
2	16400.00	837.00	42800
9	1340.00	781.00	37000
23	13100.00	821.00	38100
30	13300.00	765.00	37600
7	4390.00	354.00	31900
14	8710.00	676.00	30500
28	10600.00	781.00	33200
4	1860.00	258.00	19600
18	7800.00	209.00	9560
26	8400.00	161.00	7880
4	0.00	0.00	
9	0.00	0.00	
2	2660.00	419.00	
8	2160.00	233.00	
14	3270.00	467.00	
21	1070.00	692.00	
28	14600.00	725.00	
11	1260.00	765.00	
19	6530.00	564.00	
25	18900.00	781.00	
1	2020.00	833.00	
8	9120.00	644.00	
16	9530.00	596.00	
22	11000.00	596.00	
30	2880.00	354.00	
7	3020.00	354.00	
13	2290.00	403.00	
20	2470.00	370.00	
27	1700.00	338.00	
4	1170.00	313.00	
10	848.00	290.00	
24	380.00	145.00	

5-2. Discharge and Sediment Load Relationship

(1) Grain Size Analysis of the Bed load samples

The bed load materials were taken from the proposed pumping station sites at Sultanganj, Godagari and Nawabganj in the river side deposit.

It was found the distribution of the grain sizes are quite similar to that of the bed load at the Hardinge Bridge.

(2) Suspended Load Discharge Analysis

According to the results of the grain size analysis for the bed load material, it has been presumed that the suspended load material analysis at the Hardinge Bridge will be the same characteristics as the proposed sites of the pumping station for the Project.

The observed suspended sediment discharge have been plotted with the river discharge on the log-log paper to find the correlation between them. The results of that are shown in FIGURE II-5-2.

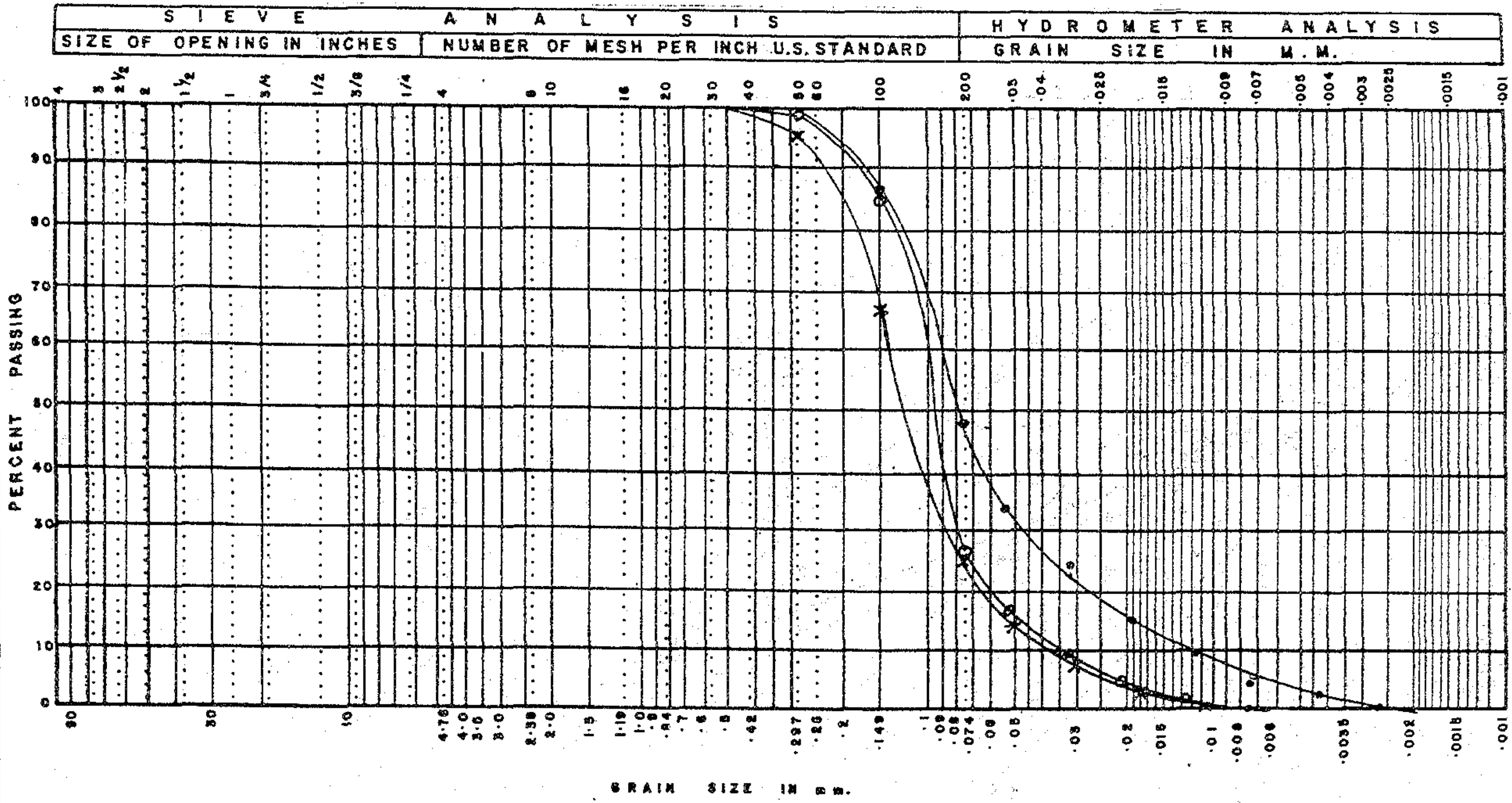
The equation of the unit suspended load material has been obtained as ;

$$q = 25.358 \times 10^{-6} \quad Q_H^{1.6}$$

where q = Unit suspended load discharge (ppm)

Q_H = Water Discharge at Hardinge Bridge (m^3/sec)

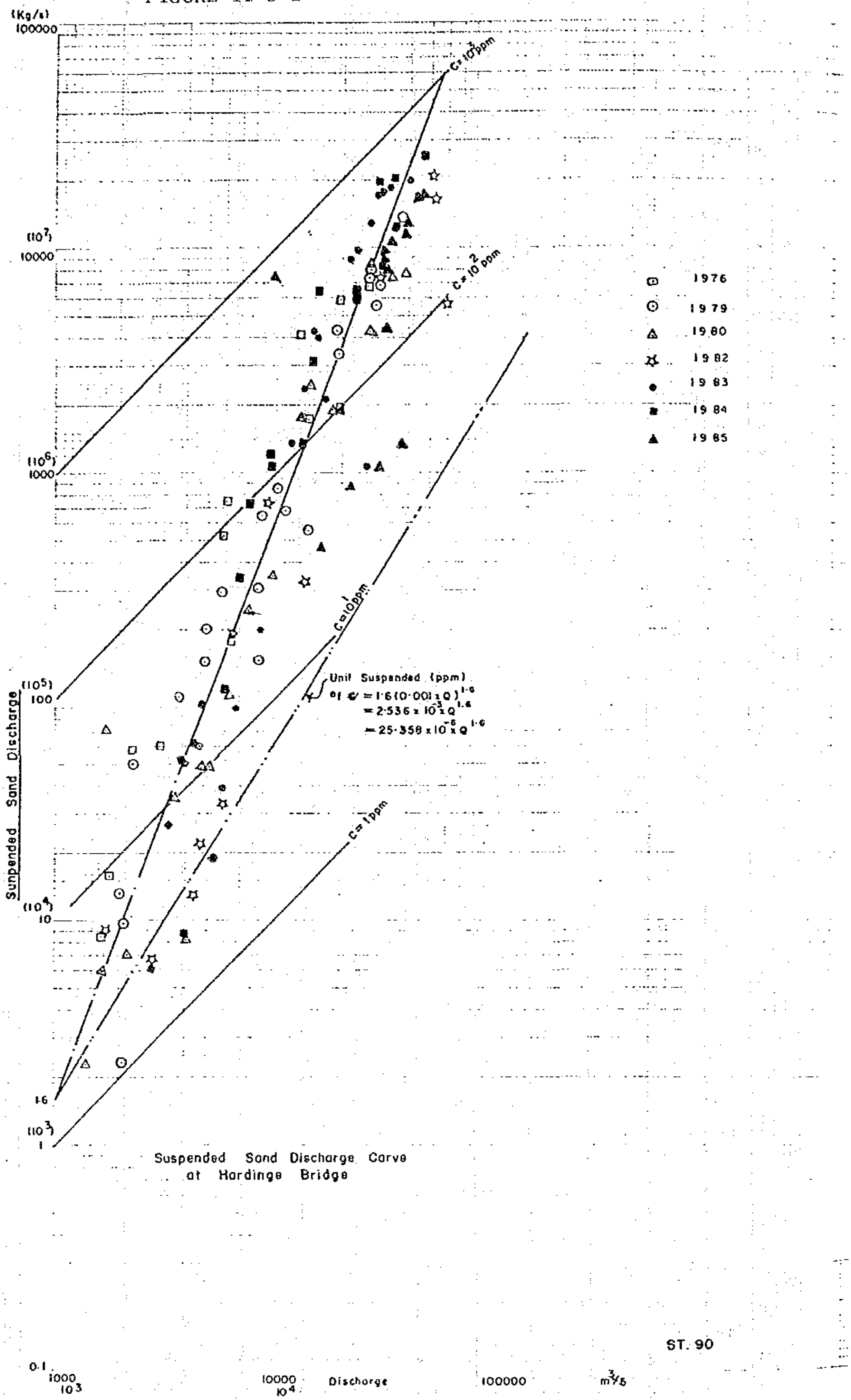
FIGURE II-5-1 PARTICLE SIZE GRADATION



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	FINES (SILT OR CLAY)

LOCATION	BORING NO	SAMPLE NO	Depth - m From To	SOIL CLASSIFCATION (UNIFIED SYSTEM)	
River Sediment at Godagari	River	-	River Bed	Fine SAND, some silt, trace mica	—●—●—●—
River Sediment at Sultanganj	River	-	River Bed	Fine SAND, some silt, trace mica	—×—×—×—
River Sediment at Nawabganj	River	-	River Bed	Fine SAND, some silt, trace mica	—○—○—○—
					—△—△—△—
					—□—□—□—

FIGURE II-5-2



Suspended Sand Discharge Curve at Hardinge Bridge

6. WATER QUALITY

6-1. Water sampling Sites

In order to find a suitability of river water for irrigation and fish culture, water sampling sites have been selected at Beliram and Sultanganj in the Mahananda river, at Godagari and Kasba in the Gamges river and at Nawhata in the Sib river.

The river water has been taken in January 1988 from above mentioned sites. Chemical and physical analysis for the water have been performed at Dhaka University.

The results of the analysis have been summarized in following table.

Sumple No.	①	②	③	④	⑤
pH	7.5	7.7	7.6	8.6	7.5
Ec MS	270	300	230	300	480
Na ppm	19	17	19	17	37
K ppm	3.5	4.0	4.0	4.0	5.0
Ca ppm	13.9	18.6	9.7	18.7	22.3
Mg ppm	9.3	10.3	6.6	10.3	16.6
Fe ppm	0.13	0.17	0.35	0.17	0.11
SO-2 4 ppm	0.93	1.75	1.67	2.16	1.67
PO-3 4 ppm	1.40	1.28	1.71	1.38	1.18
NII4-N ppm	3.16	3.55	2.50	2.96	3.25
NO-N3 ppm	7.37	7.77	11.05	8.69	9.15
Total N ppm	12.37	12.84	14.60	12.80	14.70
Organic Matter ppm	43.27	28.84	57.69	43.27	57.69
Suspended ppm	14.43	14.42	14.42	7.22	21.64

7. RIVER MORPHOLOGY

7-1. Available Records of River Bank Shifting

7-1-1. Existing Records

Available records of the Ganges river bank shifting in the Project area, from Sultanganj to Rajshahi, are quite limited. The records of river bank shifting surveyed by Joint River Commission (JRC) for the Ganges river has mainly covered from Sardah (15 km down-stream from the Rajshahi) to the down-stream of the Hardinge Bridge. There is only one report for the river bank shifting record covering from the Farakka Barrage to the Hardinge Bridge. The report was published in July 1981 by Bangladesh Water Development Board, Water Investigation Directorate and titled "Bank line Movement of the Ganges (From 11 mile below Farakka Barrage to Gorai off take) 1973-1980".

Besides the above report, the following maps and aerial photographs have been collected to obtain more information on the river bank shifting.

1) Maps
   a) Upazilla Map
      Surveyed in Seasons 1914-1916 and published in 1929. Scale 1 inch to 1 mile (1:63,360) Paba upazila was surveyed in 1940.
   b) Topographical Map (1:50,000)
      Surveyed in 1968.
2) Aerial Photographs
   a) Taken in 1975 scale in 1:30,000
   b) Taken in 1983 scale in 1:50,000
      However, the obtained aerial photographs were not included the area along the Ganges river in the down-stream of the Baraipara to Rajshahi.

7-1-2. Topographical Survey

During the field investigation by the JICA Study Team, the river cross section survey from Sultanganj to Baraipara at an interval of 200 m to 500 m have been performed. Also, the cross section survey at Kasba proposed pumping station site has been performed in December 1987. The river bed control maps for Sultanganj to Baraipara and for the Kasba area have been prepared.

7-2. Bank Line Movement

7-2-1. Sultanganj to Baraipara

(1) Plane Movement of the River Bank

All of the available maps and aerial photographs have been adjusted to have a same scale in 1 to 50,000 as shown in FIGURE II-7-3.

As seen in the FIGURE II-7-3, the left bank of the Mahananda to Ganges rivers from Sultanganj to Godagari has changed very much. The Ganges River near Godagari and at the confluence with Mohananda has shifted about 1.3 km during 1975 to 1983. According to the latest survey results (1987) the bank line again moved back to river side from 1983 for about 600 m.

Accordingly, the Ganges River is oscillating near Godagari and the mouth of the Mohananda River.

The river bank at Sultanganj in the Mohananda river and down-stream of Godagari at Baraipara are quite stable for long period. As for the Sultanganj, however, the right bank is not so stable as the left bank. Accordingly, the Sultanganj is not preferable for the proposed pumping station as a year round irrigation purpose from the view point of the river bank stability and the availability of the river water for irrigation during the dry season. Since the river bank is stable enough at Sultanganj, the site can be proposed for a pumping station which is operated during the wet season only.

The Baraipara is the most suitable site for a proposed pumping station for a year round irrigation purpose for the both points of river bank stability and quantity of the available river water during the dry season.

(2) Cross Section Surveys

10 cross section surveys from Mohananda confluence to Baraipara (1.6 km down stream of Godagari) were done across the Ganges river. The contour map of the Ganges river is shown in FIGURE II-7-4.

The observations are as follows :

a) From Mohananda river mouth to Godagari, the river bed is too shall low for pumping stations.

b) The bank line near Godagari is concave and is subjected to serious erosion possibility in future.

c) Near Baraipara Railway Bazar the Ganges bank line is very stable for the last 50 years and channel is very deep near the bank.

d) The deeper portion is located near to the left bank in 1987 and also in 1974 as shown in the cross section survey conducted by the JRC.

e) Pumping Station at Baraipara is considered as the most suitable site.

7-2-2. Kasba to Rajshahi

The aerial photograph taken in 1983 is not available along the Ganges river in the southern portion near the Rajshahi city.

The river bank line movement has been studied by the available upazila map surveyed in 1940, topographic map scale in 1 to 50,000 surveyed in 1968. The most accurate record of the river bank condition is the aerial photographs taken in 1975.

The historical records of river bank movement near Kasba to Rajshahi have been shown in FIGURE II-7-5. As seen in the FIGURE II-7-5 the river bank was eroded around 1940. However, since 1975, the river bank near the Kasba is not changed for about 12 years. The down-stream of Kasba near Rajshahi has been eroded for about 1.3 km from 1975 to 1980.

The cross section of the river in Kasba shows that the river course is located near to the left bank and the depth of water is sufficient for proposed intake site.

Accordingly, the Kasba site has been selected as a proposed pumping station for Paba flood plain area.

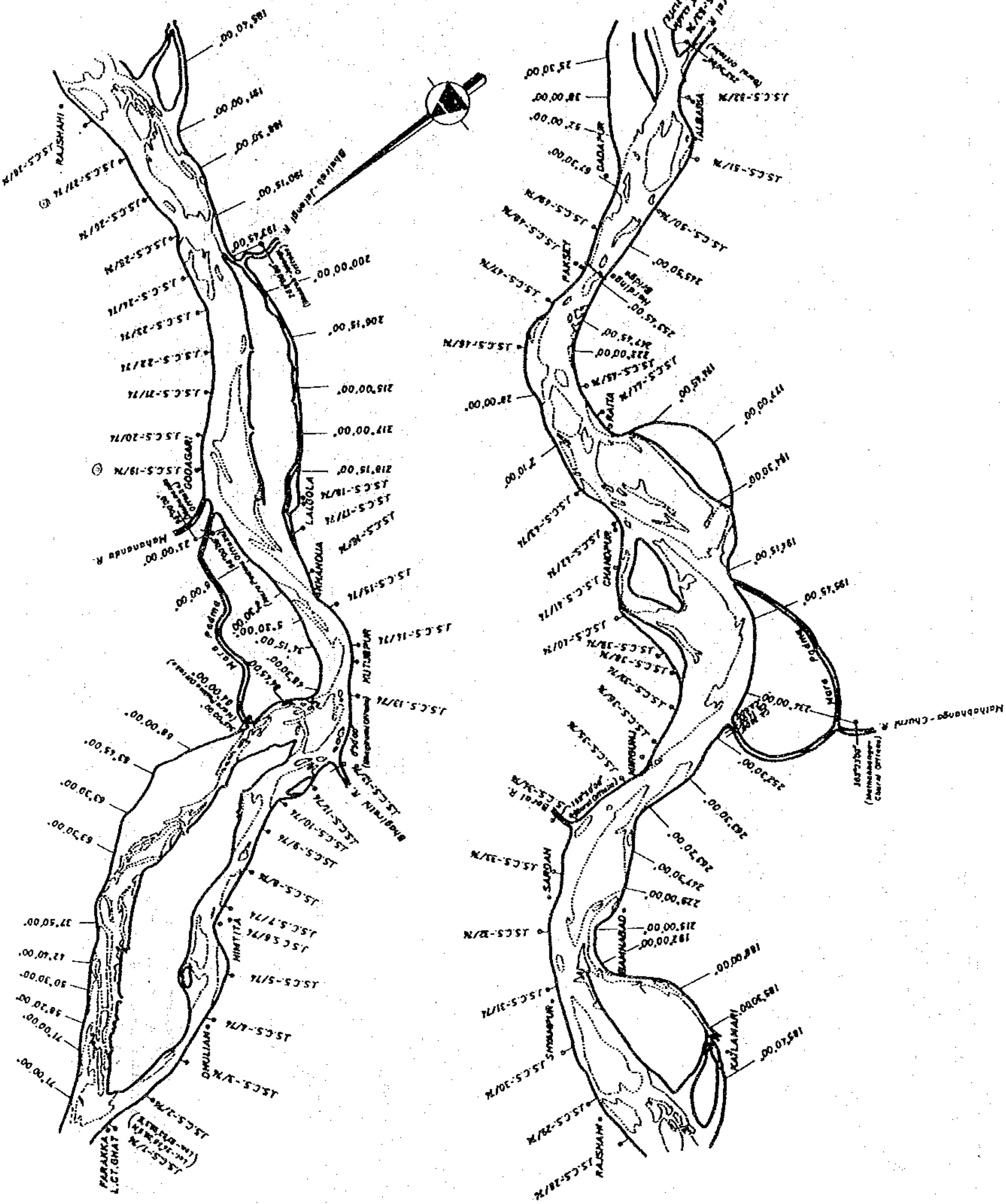
FIGURE II-7-1

INDO-BANGLADESH JOINT SURVEY OF THE GANGA/PADMA

(BELOW FARAKKA TO THE OFFTAKE OF THE GORAI)

Index Plan Showing Approximate Cross Section Lines

(NOT TO SCALE)



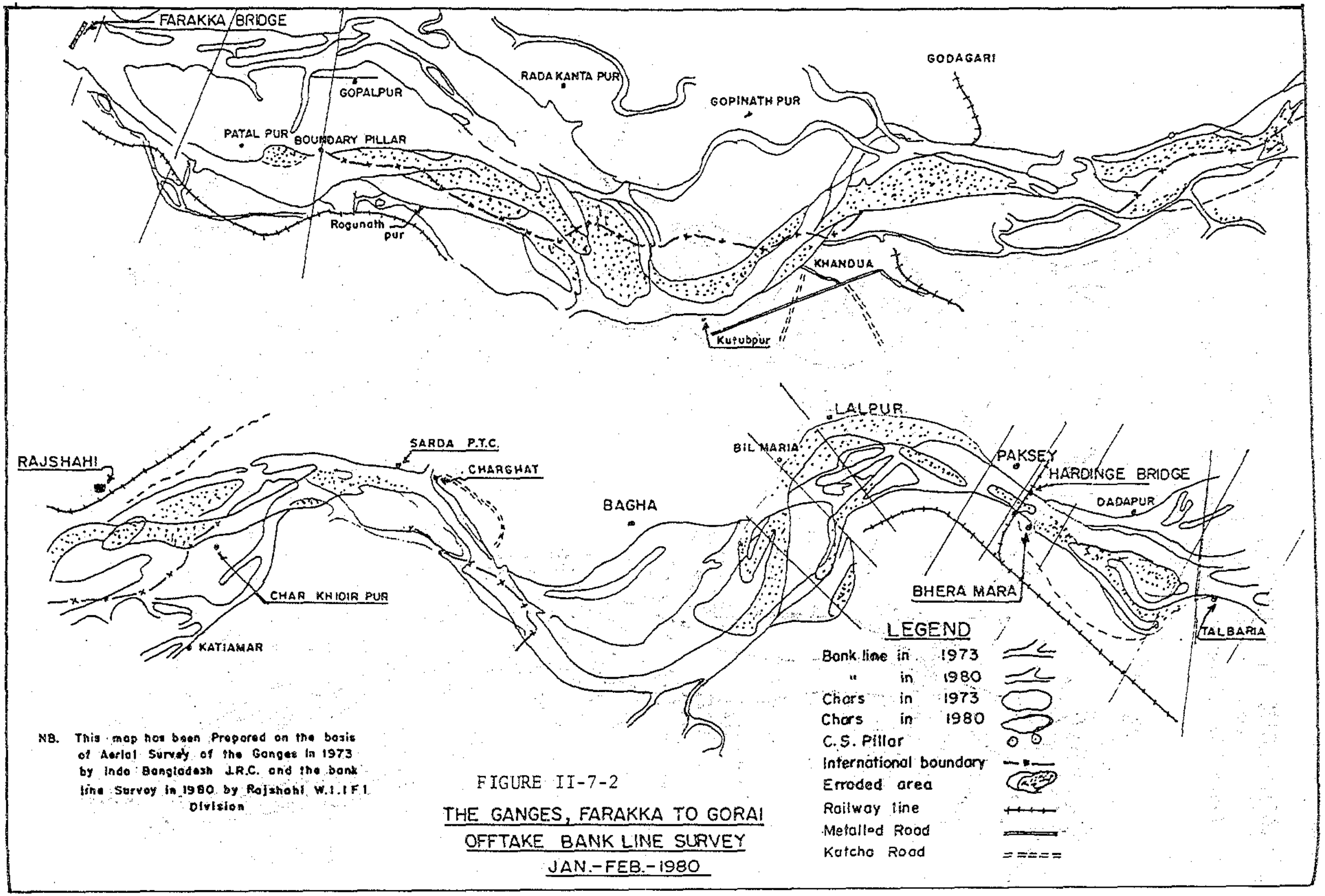


FIGURE II-7-2

THE GANGES, FARAKKA TO GORAI OFFTAKE BANK LINE SURVEY JAN.-FEB.-1980

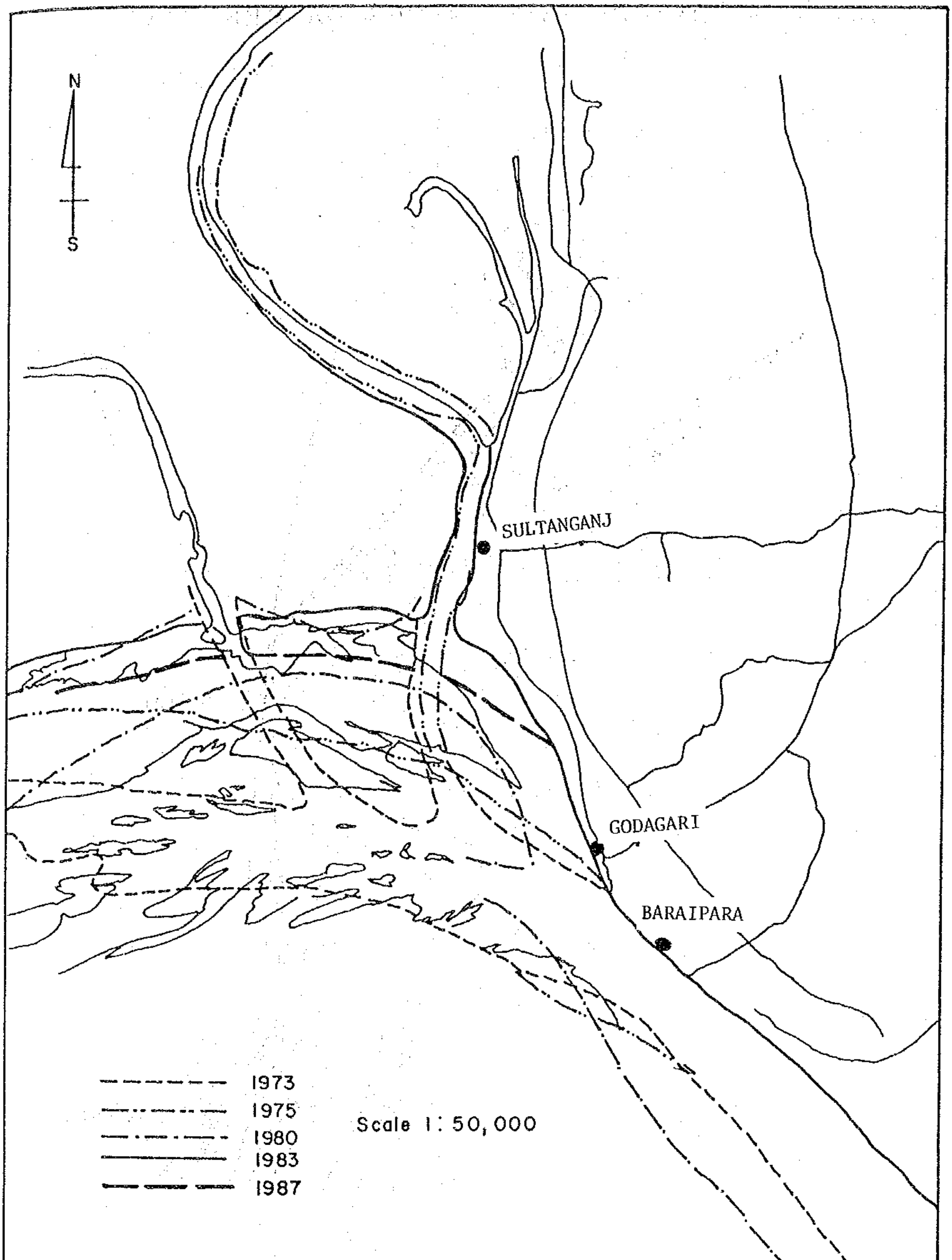
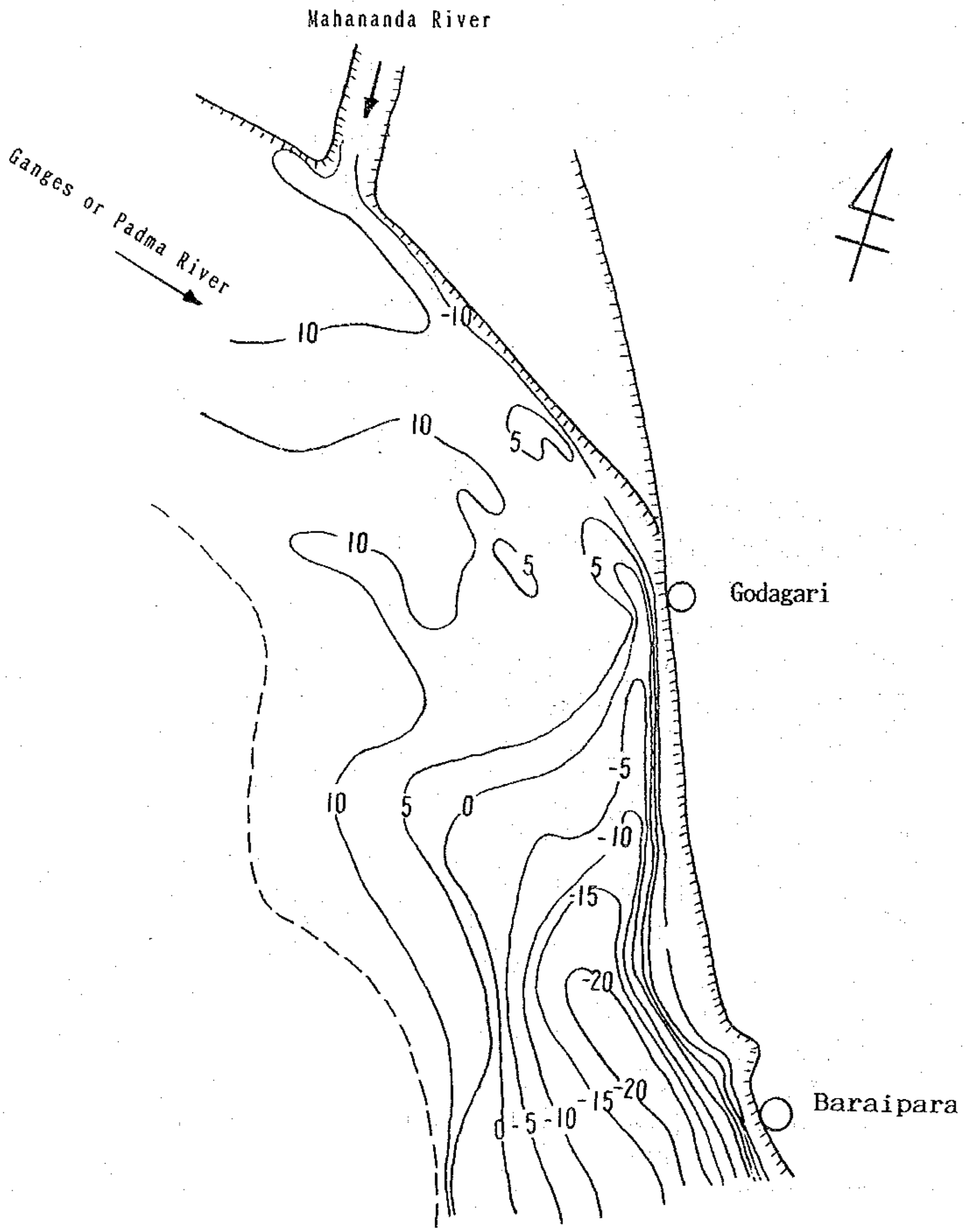


FIGURE II-7-3 RIVER BANK SHIFTING RECORD NEAR GODAGARI

FIGURE II-7-4 CONTOUR MAP IN THE GANGES RIVER



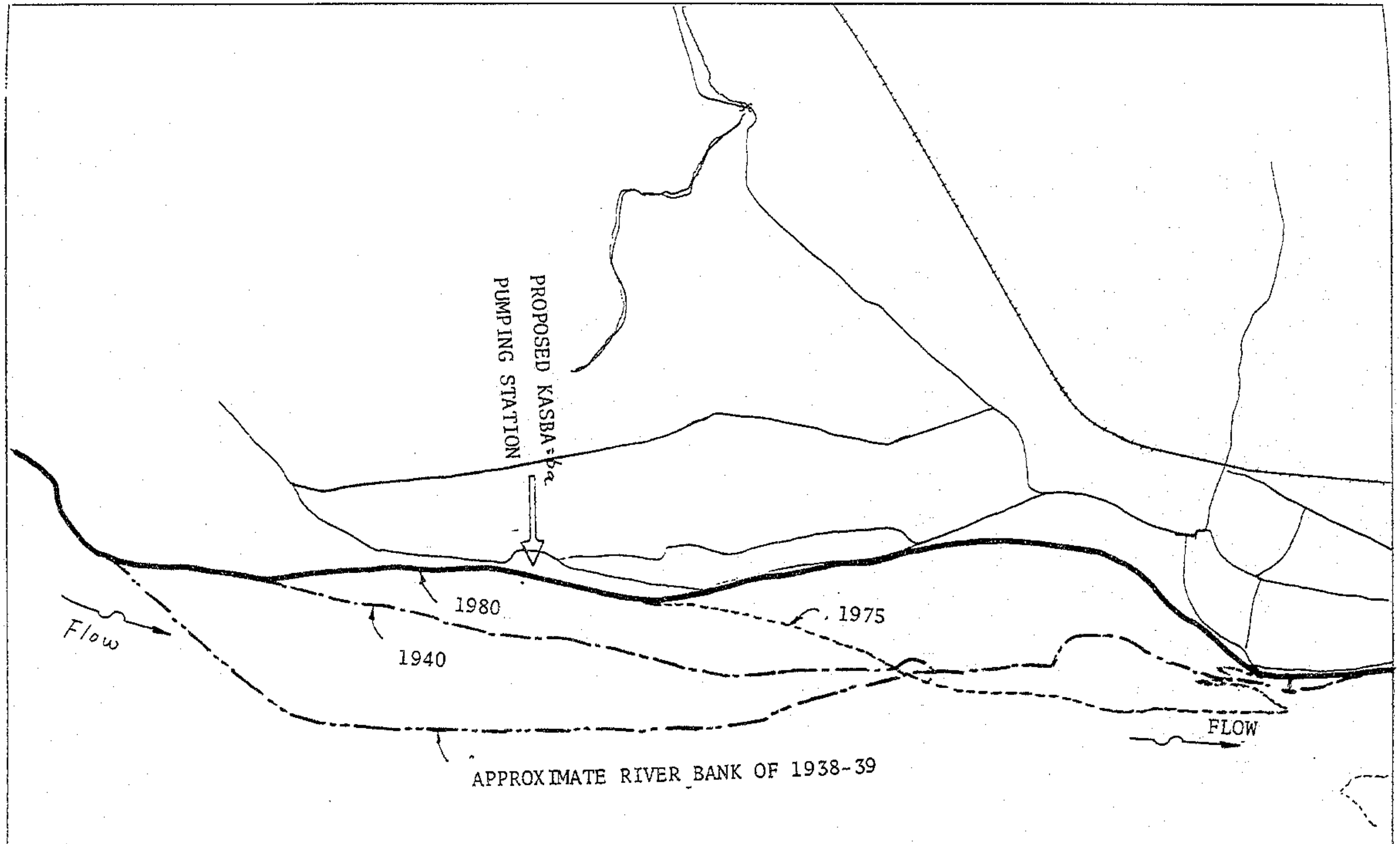


FIGURE II-7-5 RIVER BANK MOVEMENT KASBA TO RAJSHAHI

SCALE 1:50,000

APPENDIX III

TOPOGRAPHY, GEOLOGY AND SOIL MECHANICS

APPENDIX III

TOPOGRAPHY, GEOLOGY AND SOIL MECHANICS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 TOPOGRAPHIC SURVEY

1-1 Bench Mark Value

The basic bench mark values at Rajshahi and Nawabganj are shown in TABLE III-1-1.

TABLE III-1-1 BASIC BENCH MARK VALUE

Location	*) Description of Bench Mark	*) Height in G.T.S (feet)	Height in P.W.D.	
			(feet)	(m)
①Rajshahi	On first step from top of stairs of front or south verandah of the Barendra Reserch Society Museum, Rajshahi.	61.494	63.003	19.203
②Nawabganj	At north end of 3rd step from bottom of flight of north verandah of Munsif's court, Nawabganj.	72.666	74.175	22.609

*) Source: LEVELING OF PRECISION IN INDIA, HEIGHTS OF BENCH-MARKS IN SHEET NO.78 (DARJEELING), 1923.

The relation between G.T.S. Datum and P.W.D Datum is as follows.

P.W.D. = 1.509 + G.T.S.

(Unit ; feet)

For the future reference, permanent bench mark pillars of BWDB standard specification were installed at 7 places at proposed pumping stations and along the main canals.

The heights and locations of these bench mark pillars are shown in TABLE III-1-2.

TABLE Ⅲ-1-2 LIST OF PERMANENT BENCH MARK

BM No.	Height	Description
BM-1	21.575	In the compound of Dackbanglow at Godagari, 13m east from the NE corner at Dackbanglow.
BM-2	20.619	At the south east corner of Mango gerden 15m south of the house of Md. Shuraka bishwash in the Village Baraipara, Godagari.
BM-3	19.734	On the east bank of big ditch and 47m south from main road, 61m south from the house of Md. Azhar mia, S/O. Mozaffar in the village Bhelua (Kasba).
BM-4	27.662	At east edge of main road about 100m west from railway near railbridge and about 50m south from road bridge, east side of village Ghiapukur.
BM-5	25.269	About 70m east from the main road (Tanor-Mundamala), 2 miles south from Mundamala and about 210m south west from the house of Israil Hossain, S/O Loharmandol in the village Chinasho.
BM-6	25.020	About 300m NW from Rajbari Market and about 65m N from road culvert, east side of the house of Saibali & N of main road in the village Dhighipara.
BM-7	17.378	At the north east corner of Eidgah, adjacent of road and about 90m SW from the house of Tofazzel Hossain in the village Nepalpara.

1-2 Presentation of Survey Results

1) Longitudinal sections of the canal alignments were plotted at a scale of 1/200 vertically and 1/8,000 horizontally.

2) Cross sections were plotted at a scale of 1/200 vertically and horizontally except river cross sections of the Ganges and Mahananda river.

3) Plane table results of the pump stations and sampled areas were plotted at a scale of 1/1,000 and 1/2,000, respectively. Contours on the plane maps were presented as for intervals of 0.5m height.

4) All levels were described in metre.

1-3 Error of Closure

Following measurement error were adopted as allowable error in the levelling works.

$$E = 20\sqrt{S}$$

where; E: Erorr of closure (mm)

S: One-way distance of the measurment (Km)

1-4 Bench Mark Pillar

Bench mark pillars which have been installed in this survey work were specified as per BWDB standard type as shown in FIGURE Ⅲ-1-1

1-5 Work Quantity

The quantities of the survey works are shown in the following table.

① Canal Route survey

Barind L=53.7Km
Paba L=19.5Km
Secondary: Barind Sloped L=3.9km
: Barind Flat L=5.0km
: Paba Flood Plain L=2.3km
Baraipara Pumping Sta. to Discharge Pond L=1.4km

② Plane table survey

Sultanganj Pumping Sta. A=28.7ha
(including discharge pond area)
Godagari Pumping Sta. A=22.1ha
Baripara Pumping Sta. A=18.5ha
(including Discharge pond area)
Sampled Area: Barind Sloped A=218ha
Barind Flat A=211ha
Paba Flood Plain A=164ha

③ River Cross-section survey

Mahananda Riv. 4Nos
Ganges Riv. 15Nos
Sib Riv.& Others 13Nos

④ B.M.Survey

Concrete pillar setting 7Nos
Temporary B.M. 131Nos

⑤ Others

1) Staff gauges levelling. 6Nos
2) Railway levelling L=9.7km
3) Head Race (Existing channel) L=1.8km

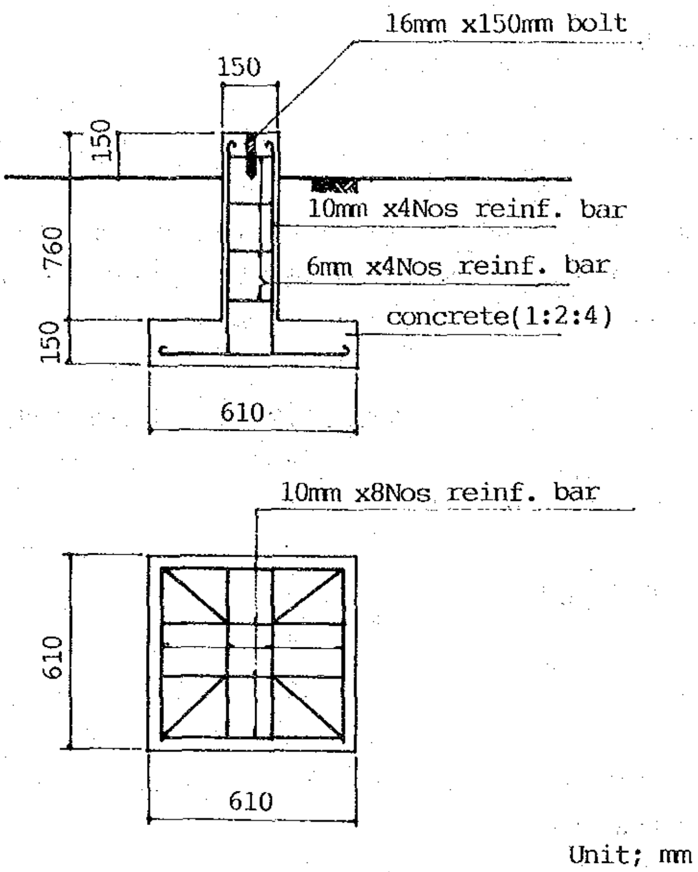


FIGURE Ⅲ-1-1 STANDARD BENCH MARK PILLAR

2 Geology and Soil Mechanics

2-1 Geological and Soil Mechanical Investigation

2-1-1 Field Work

(1) Drilling of Bore holes

A total of 6 nos, exploratory boring were drilled down to a maximum depth of 60 metre below the existing ground level at different locations shown as the following:

Location	Bore Hole No.	Depth-m
Sultanganj	1A	25.35
Sultanganj (108 m north of 1A)	1B	38
Jahanabad	2	60.46
Bhagabandapur (Godagari)	3	38
Kalabona (Kasba)	4	32
Madhabpur	5	20

The location of bore holes are shown at attached location map.(see FIGURE Ⅲ-2-1)

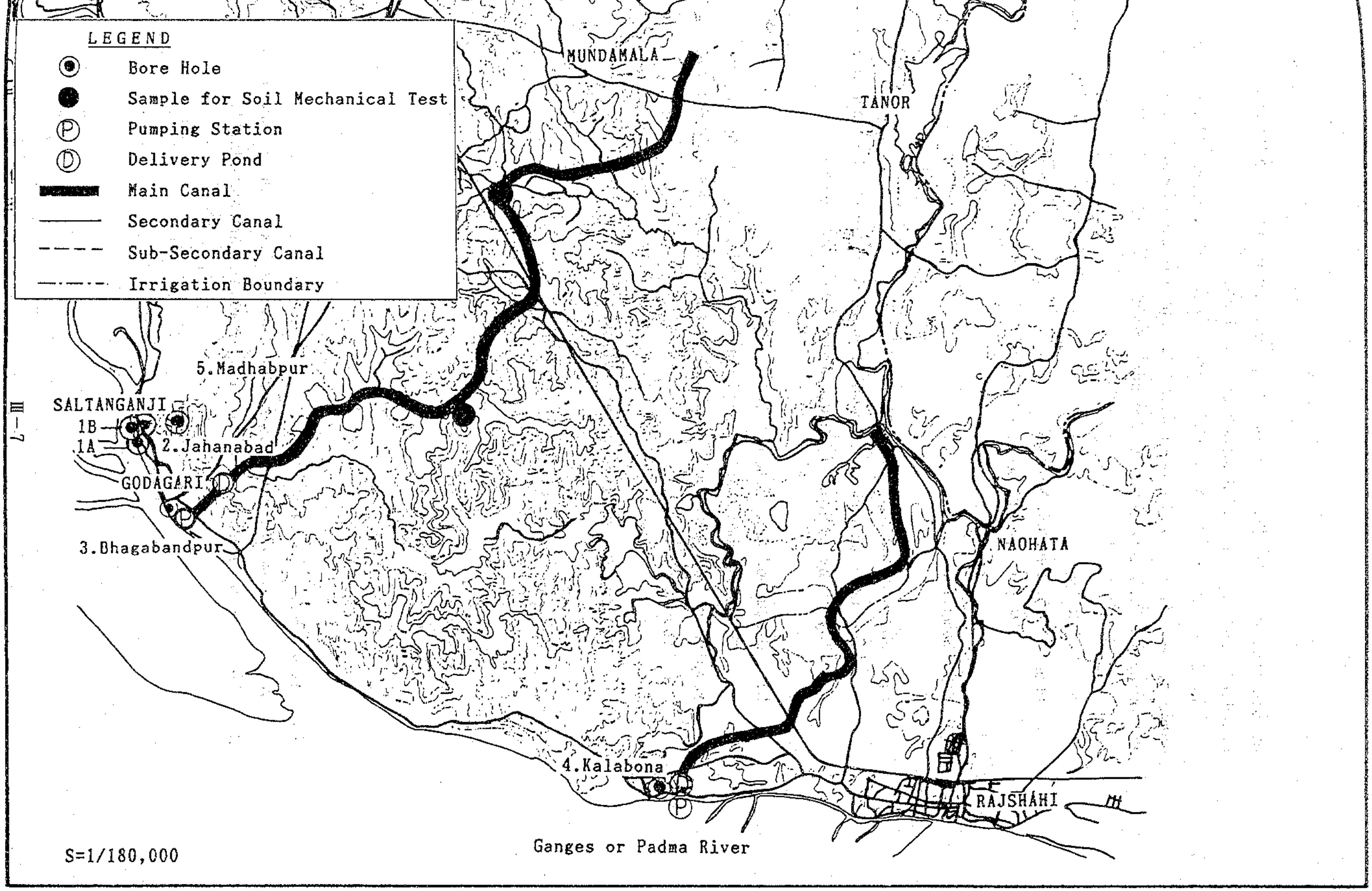
Bore hole No. 1 was drilled up to 25.35 m depth when a hard obstruction was encountered. As further drilling was not possible inspite of best efforts the drilling site was shifted to a new location 108 m north of the first hole. The first hole is now numbered as Bore Hole No. 1A and second hole as Bore Hole No.1B.

The boring was performed by employing percussion method drilling and using 10.16 cm dia casing pipe.

(2) Standard Penentration Test (SPT)

The SPT was performed at specified intervals of 1 m and 1.5 m by driving standard split spoon sampler of 3.5 cm internal diameter with a 63.9 kg hammer dropping freely from a height of 76 cm on average and the number of blows required to drive the sampler for every 15.2

FIGURE Ⅲ-2-1 LOCATION MAP OF GEOLOGICAL INVESTIGATION



cm penetration over 45.6 m depth has been recorded as a measure of standard penetration resistance-N per 30.5 cm.

N-values of stiff soil such as sand, sandy clay under the ground water were revised for foundation design in accordance with the following formula advocated by Terzaghi Peck.

$N' = 15 + \frac{1}{2}(N-15)$

where: N': revised N-value

N : tested N-value (N>15)

(3) Soil Sampling

a) Undisturbed Soil Samples (U)

The undisturbed soil samples were collected from cohesive soil layers by pushing 7 cm dia thin walled and bevel.

b) Disturbed Soil Samples (D)

The disturbed soils cored in the spoon of the split tube sampler of SPT were collected and preserved in polyethlene bags for laboratory tests.

Number of sampling are as follows:

B.H. No.	(U)	(D)
No.1A	3	23
No.1B	3	26
No.2	3	41
No.3	3	26
No.4	3	22
No.5	3	14

(4) Ground Water Table =(GWT)

The GWT was measured and recorded from the existing ground level after 24 hours on finishing of drilling work in each bore hole.

2-1-2 Laboratory Test

The following laboratory tests have been performed on disturbed and undisturbed soil samples collected form the bore holes. The tests were performed in accordance with ASTM/AASHTO standard methods and the test results evaluated as per the accepted code and practice of applied soil mechanics and foundation engineering

Name of Test Performed	Number of Test Performed
Moisture Content	44
Grain Size Analysis (Grading)	44
Mechanical Analysis (Hydrometer)	50
Unit Weight (Wet and Dry)	44
Specific Gravity (Cohesive soil)	14
Unconfined Compression (Natural)	14
Unconfined Compression (Remolded)	14
Consolidation	14
Triaxial Shear (Consolidated undrained)	14

These results related to Baripara and Kasba pumping stations were summarized as shown in TABLE Ⅲ-2-1~Ⅲ-2-2.

TABLE Ⅲ-2-1 SUMMARY OF LABORATORY TEST RUSULTS AT B.H.NO.3

Borehole No.		B.H.-3										
Sample No.		D-1	D-2	U-1	D-3	U-2	D-4	D-5	U-3	D-6	D-7	D-8
Depth-metre		0.50 to 0.96	1.5 to 1.96	2.04 to 2.50	2.5 to 2.96	4.04 to 4.50	4.5 to 4.96	6.0 to 6.46	7.04 to 7.50	7.5 to 7.96	9.0 to 9.46	10.5 to 10.96
Natural moisture Content(%)				26.0		23.4			22.1		21.6	
Specific gravity				2.682		2.680						
Atterberg limits	Liquid limit,W (%)											
	Plasticity index,lp(%)											
Density	Wet (T/m³)			1.88		1.94			1.93		1.93	
	Dry (T/m³)			1.49		1.57			1.58		1.58	
Grain size analysis	Gravel (%)											
	Sand (%)	6	6		2	2	2	2		3	3	3
	Silt or Clay %(Fines)	94	94		98	98	98	98		97	97	97
Consolidation tests	Notural void ratio,eo			0.7815		0.7325						
	Compression index, cc			0.2100		0.1660						
Unconfined Compression tests	Strain at fallure(%)			12		10						
	Stress undist (T/m²)			5.78		14.95						
	Stress remould(T/m²)			5.18		10.83						
	Sensitivity			1.12		1.38						
Triaxial shear tests	φ (degree)					5			6			
	c (T/m²)					7.39			4.22			
SPT N-count		2	3		4		10	8		12	12	13
N'=15+1/2(N-15)		2	3		4		10	8		12	12	13

(cont. TABLE Ⅲ-2-1)

Borehole No.		B. H. −3										
Sample No.		D−9	D−10	D−11	D−12	D−13	D−14	D−15	D−16	D−17	D−18	D−19
Depth-metre		12.0 to 12.46	13.5 to 13.96	15.0 to 15.46	16.5 to 16.96	18.0 to 18.46	19.5 to 19.96	21.0 to 21.46	22.5 to 22.96	24.0 to 24.46	25.5 to 25.96	27.0 to 27.46
Natural moisture Content(%)						19.3						
Specific gravity												
Atterberg limits	Liquid limit,W (%)											
	Plasticity index,lp(%)											
Density	Wet (T/m³)					1.91						
	Dry (T/m³)					1.60						
Grain size analysis	Gravel (%)											
	Sand (%)	5	5	8	8		66	71	84	75	79	86
	Silt or Clay %(Fines)	95	95	92	92		34	29	16	25	21	14
Consolidation tests	Notural void ratio,eo											
	Compression index, cc											
Unconfined Compression tests	Strain at failure(%)											
	Stress undist (T/m²)											
	Stress remould(T/m²)											
	Sensitivity											
Triaxial shear tests	ϕ (degree)											
	c (T/m²)											
SPT N-count		9	11	16	18	18	22	24	30	37	41	42
N'=15+1/2(N-15)		9	11	15	16	16	18	19	22	26	28	28

(cont. TABLE III-2-1)

Borehole No.		B. H. -3										
Sample No.		D-20	D-21	D-22	D-23	D-24	D-25	D-26				
Depth-metre		28.5 to 28.96	30.0 to 30.46	31.5 to 31.96	33.0 to 33.46	34.5 to 34.96	36.0 to 36.46	37.5 to 37.96				
Natural moisture Content(%)												
Specific gravity												
Atterberg limlts	Liquid limit,W (%)											
	Plastlcity index,lp(%)											
Density	Wet (T/m³)											
	Dry (T/m³)											
Grain size analysis	Gravel (%)											
	Sand (%)	91	94	85	92	97	93	86				
	Silt or Clay % (Fines)	9	6	15	8	3	7	14				
Consolidation tests	Notural void ratio,eo											
	Compression index, cc											
Unconfined Compression tests	Strain at fallure(%)											
	Stress undist (T/m²)											
	Stress remould(T/m²)											
	Sensitivity											
Triaxial shear tests	φ (degree)											
	c (T/m²)											
SPT N-count		45	46	48	50	(62)	(56)	(70)				
N'=15+1/2(N-15)		30	30	31	32	38	35	42				

TABLE Ⅲ-2-2 SUMMARY OF LABORATORY TEST RUSULTS AT B.H.NO.4

Borehole No.		B. H. -4										
Sample No.		D-1	D-2	U-1	D-3	U-2	D-4	D-5	U-3	D-6	D-7	D-8
Depth-metre		0.50 to 0.96	1.5 to 1.96	2.04 to 2.50	2.5 to 2.96	4.04 to 4.50	4.5 to 4.96	6.0 to 6.46	7.04 to 7.50	7.5 to 7.96	9.0 to 9.46	10.5 to 10.96
Natural moisture Content(%)		24.4		19.4		18.7			17.6			
Specific gravity				2.684		2.683						
Atterberg limits	Liquid limit,W (%)											
	Plasticity index,lp(%)											
Density	Wet (T/m³)	1.66		1.97		1.98			2.33			
	Dry (T/m³)	1.33		1.65		1.67			1.99			
Grain size analysis	Gravel (%)											
	Sand (%)	3	3	3	3		3	2	2	2	2	2
	Silt or %(Fines) Clay	97	97	97	97		97	98	98	98	98	98
Consolidation tests	Notural void ratio,eo			0.6011		0.6142						
	Compression index, cc			0.1370		0.1250						
Unconfined Compression tests	Strain at failure(%)			8		8						
	Stress undist (T/m²)			17.34		19.24						
	Stress remould(T/m²)			12.30		13.52						
	Senastivity			1.41		1.42						
Triaxial shear tests	ϕ (degree)			4		4.5						
	c (T/m²)			8.10		9.5						
SPT N-count		2	5		13		15	18		19	18	17
N'=15+1/2(N-15)		2	5		13		15	16		17	16	16

(cont. TABLE Ⅲ-2-2)

Borehole No.		B. H. -4										
Sample No.		D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	D-18	D-19
Depth-metre		12.0 to 12.46	13.5 to 13.96	15.0 to 15.46	16.5 to 16.96	18.0 to 18.46	19.5 to 19.96	21.0 to 21.46	22.5 to 22.96	24.0 to 24.46	25.5 to 25.96	27.0 to 27.46
Natural moisture Content(%)		16.2				16.5						
Specific gravity												
Atterberg limits	Liquid limit,W (%)											
	Plasticity index,lp(%)											
Density	Wet (T/m³)	2.31				2.32						
	Dry (T/m³)	1.99				1.99						
Grain size analysis	Gravel (%)											
	Sand (%)	3	3	3	3	3	3	74	69	77	85	86
	Silt or %(Fines) Clay	97	97	97	97	97	97	26	31	23	15	14
Consolidation tests	Notural void ratio,eo											
	Compression index, cc											
Unconfined Compression tests	Strain at failure(%)											
	Stress undist (T/m²)											
	Stress remould(T/m²)											
	Sensitivity											
Triaxial shear tests	φ (degree)											
	c (T/m²)											
SPT N-count		16	15	16	18	19	18	22	31	34	(42)	(46)
N'=15+1/2(N-15)		15	15	15	16	17	16	18	23	24	28	30

(cont. TABLE Ⅲ-2-2)

Borehole No.		B. H. −4										
Sample No.		D−20	D−21	D−22								
Depth-metre		28.5 to 28.96	30.0 to 30.46	31.5 to 31.96								
Natural moisture Content(%)												
Specific gravity												
Atterberg limits	Liquid limit, W (%)											
	Plasticity index, lp(%)											
Density	Wet (T/m³)											
	Dry (T/m³)											
Grain size analysis	Gravel (%)											
	Sand (%)	83	80	89								
	Silt or Clay % (Fines)	17	20	11								
Consolidation tests	Notural void ratio, eo											
	Compression index, cc											
Unconfined Compression tests	Strain at failure(%)											
	Stress undist (T/m²)											
	Stress remould(T/m²)											
	Sensitivity											
Triaxial shear tests	ϕ (degree)											
	c (T/m²)											
SPT N-count		(50)	(64)	(63)								
N'=15+1/2(N-15)		32	39	39								

2-2 Soil Mechanical Analysis

2-2-1 Foundation Analysis of Pump Stations

Foundation piles are requested at the proposed pumping stations to prevent the hydraulic structures from scouring and erosion of the river bank and settlement of foundation. And N-value at the top of proposed piles should be more than 30.

Following analysis shows allowable bearing capacity of the foundation piles at Baraipara and Kasba pumping stations.

The results of allowable bearing capacity of assumptive concrete piles dia. 300mm, 350mm and 400mm are as follows;

TABLE Ⅲ-2-3 RESULTS OF ALLOWABLE BEARING CAPACITY (Ra)

Ra (ton)

Pumping Station	dia. 300mm	dia. 350mm	dia. 400mm
Baraipara	39	47	56
Kasba	45	54	64

Allowable bearing capacity (Ra):

$Ra = 1/n \cdot Ru$

$Ru = qdA = U\Sigma lifi$

where,
- Ra: allowable bearing capacity of pile (t)
- Ru: ultimate bearing capacity of pile (t)
- qd: ultimate bearing strength at the top of pile (t/m2)
- $qd = N(4 \cdot h/D + 10)$
- A : area of pile section (m2)
- U : circumference of pile (m)
- li: length of skin friction (m)
- fi: skin friction strength (t/m2)
- n : safety factor, n=3

TABLE Ⅲ-2-4 COMPUTATION OF ALLOWABLE BEARING CAPCAITY (Ra)

Pump Sta.	Baraipara (B.H.-No.3)			Kasba (B.H.-No.4)		
Pile dia.(D)	Ø300	Ø350	Ø400	Ø300	Ø350	Ø400
Pile length: L (m)	12.0	12.0	12.0	13.0	13.0	13.0
A (m^2)	0.071	0.096	0.126	0.071	0.096	0.126
U (m^2)	0.94	1/10	1/26	0.94	1.10	1.26
N-value at Pile top: N	30	30	30	31	31	31
Design N-value : N	30	30	30	30	30	30
Depth ratio: h/D	5.0	4.3	3.75	5.0	4.3	3.75
qd/N	30.0	27.2	25.0	30.0	27.2	25.0
qd (t/m^2)	900	816	750	900	816	750
qd·A (t)	64	78	95	64	78	95
Σli·fi (t/m)	57.75	57.75	57.75	77.1	77.1	77.1
UΣli·fi (t)	54	64	73	72	85	97
Ru (t)	118	142	168	136	163	192
Ra (t)	39	47	56	45	54	64

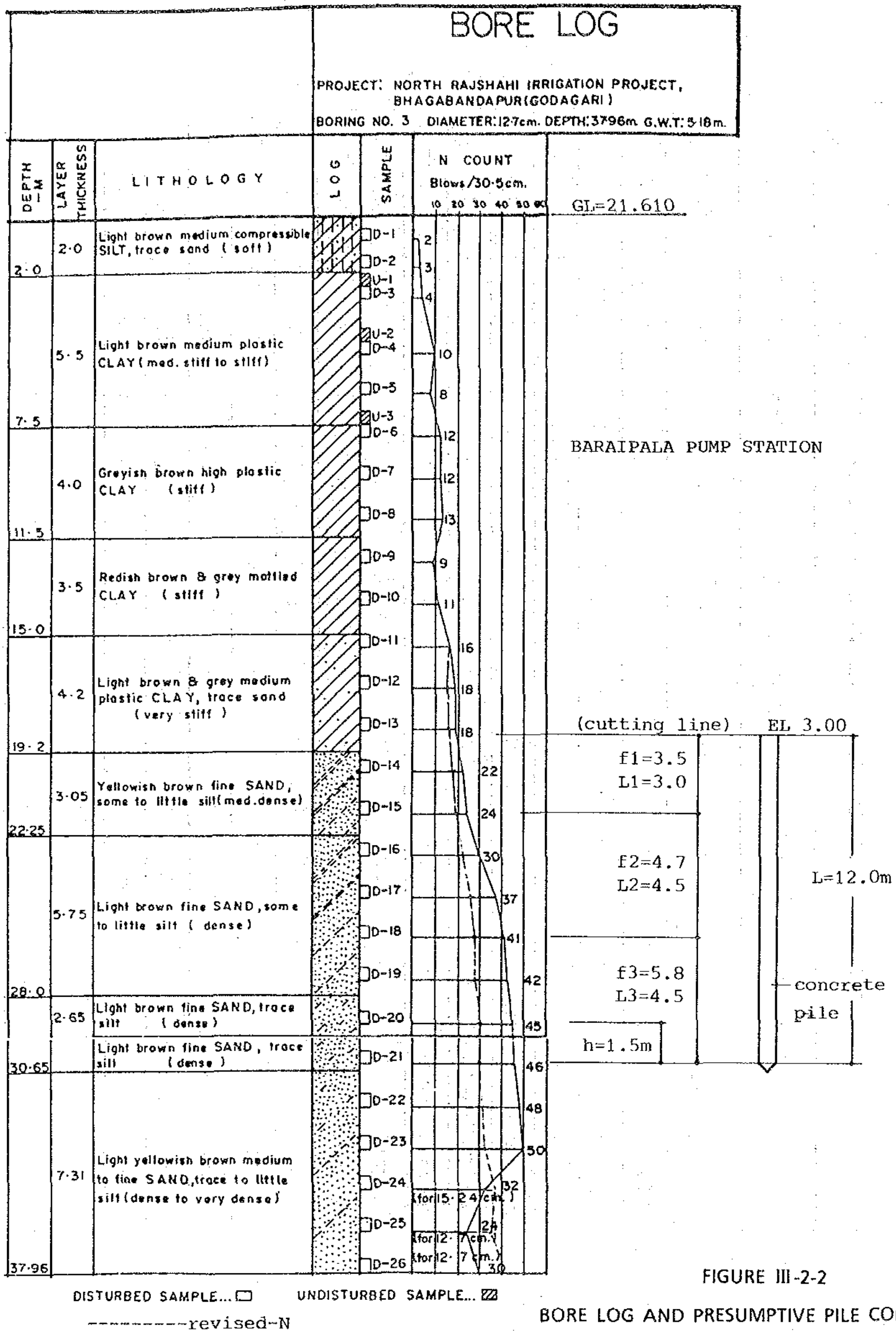


FIGURE III-2-2

BORE LOG AND PRESUMPTIVE PILE CONDITION AT BARAIPALA PUMP STATION

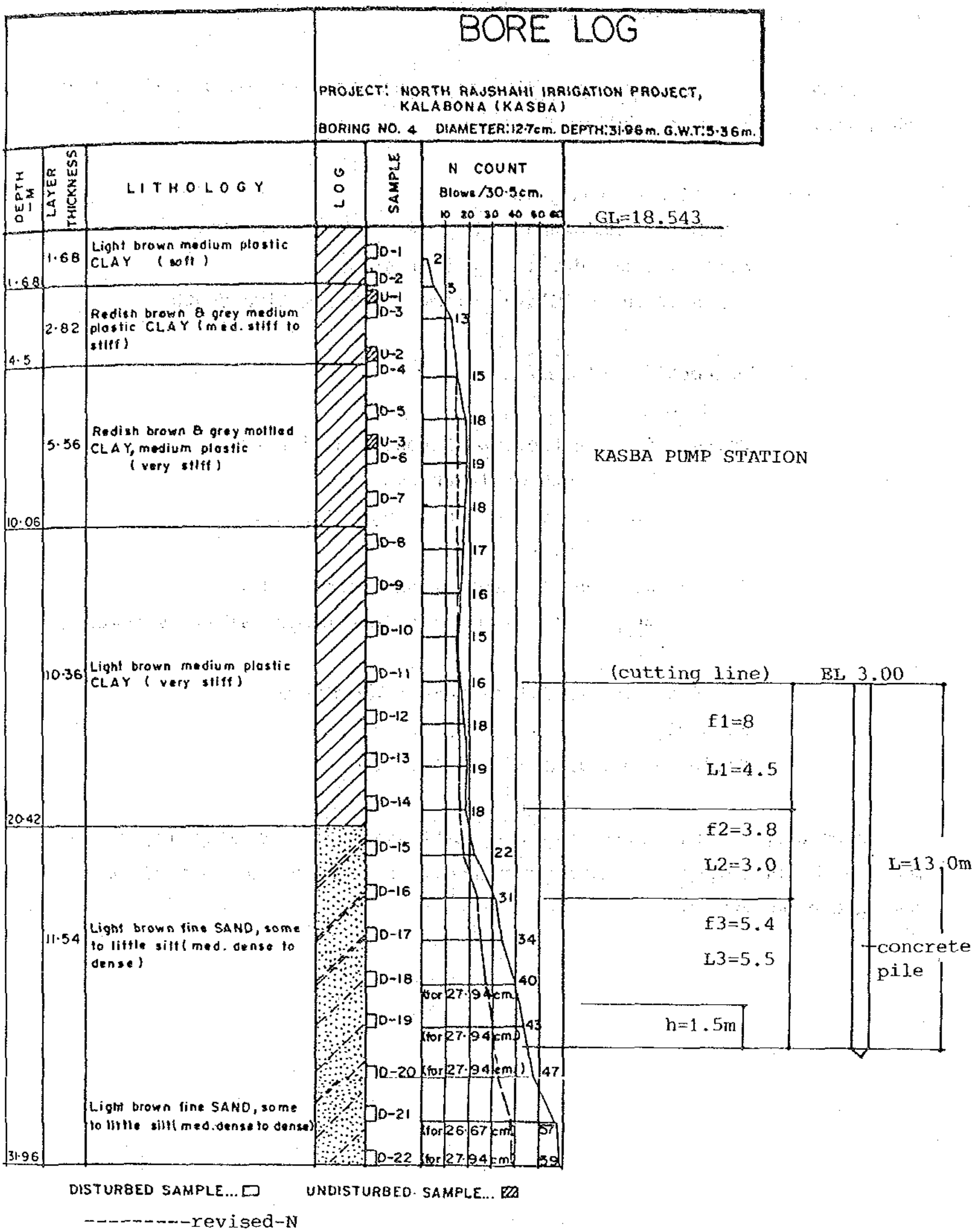


FIGURE III-2-3 BORE LOG AND PRESUMPTIVE PILE CONDITION AT KASBA PUMP STATION

2-2-2 Settlement of Canal Embankment

Analysis of presumptive settlement of the proposed main canal embankment are shown as follows;

a) Condition of Analysis

Height of embankment: h=3.0m

Soil density (dry): w=1.57 t/m3

Depth of layer (Clay): D=10m (Presumptive depth)

b) Presumptive settlemnt

$Sc=H\cdot\Delta p\cdot mV$

Where, Sc: settlement of consolidation (cm)

H: depth of layer (cm)

Δp: consolidation stress (kg/cm2)

$\Delta p=k\cdot h\cdot w$

K: coefficient of influence = 0.4

mv: coefficient of volume compressibility (cm2/kg)

$\Delta p=0.4\times3.0\times1.57=1.88$ t/m2=0.188 kg/cm2

mv=0.014 (see Table Ⅲ-2-5)

$Sc=10.0\times100\times0.188\times0.014=2.63$ cm

According to the above results, settlement of the clay layer below the canal embankment is small such as less than 5 cm, and it may be negligible on the occasion of canal design.

TABLE Ⅲ-2-5 VALUE OF COEFFICIENT OF VOLUME COMPRESSIBILITY (MV)

Sample No.	Range of Pressure - kg/cm2	mv-cm2/kg
Sogona		
B-1	0.0 - 0.25	1.33×10^{-2}
	0.25 - 0.50	1.34×10^{-2}
	0.50 - 1.00	1.25×10^{-2}
	1.00 - 2.00	1.13×10^{-2}
	2.00 - 4.00	9.41×10^{-3}
	4.00 - 8.00	7.00×10^{-3}
		mv = 0.011
B-2	0.0 - 0.25	1.75×10^{-2}
	0.25 - 0.50	1.58×10^{-2}
	0.50 - 1.00	1.61×10^{-2}
	1.00 - 2.00	1.54×10^{-2}
	2.00 - 4.00	1.26×10^{-2}
	4.00 - 8.00	8.97×10^{-3}
		mv = 0.014

Source: Results of consolidation test of sampling soils at Sogona

APPENDIX Ⅳ

SOCIOECONOMY

APPENDIX IV

SOCIOECONOMY

CONTENTS

LIST OF TABLES

LIST OF FIGURES

IV SOCIO-ECONOMY

1. National Background

1-1 Socio-economy

(1) Economy

The Government of Bangladesh has undertaken the First Five-Year (FY 1973-78), Two-Year (FY 1978-80) and the Second Five-Year (FY 1981-85) Plans successively with the objective of satisfying the basic human needs of the people, accelerating the economic growth, establishing food self-sufficiency and promoting self-reliance on national economy for the purpose of getting out of dependence on foreign aid since her independence in 1971. But planned efforts have not achieved the expected target, influenced by external and internal events. Externally, the world economy has worsened as it passed through the period of rapid inflation and stagnation during the last decade followed by the recession in the first half of 1980's because of the first and the second oil crisis and international monetary adjustment. Internally, frequent natural calamities such as floods, droughts, and cyclones have caused significant loss of crops. Generally speaking, however, the national economy of Bangladesh has made remarkable progress.

The gross domestic production (GDP) of Bangladesh recovered its pre-independence level of GDP by 1976/77 (Tk. 7829 crore in 1984-85 at 1972-73 factor cost giving an annual real growth rate of 4.7% from 1976 to 1985. During this period (1973-85), significant development was made in the industries and other sectors with an annual real growth rate of 6.2% and 5.8%, respectively. On the contrary, the agricultural sector dropped to 3.8%.

In spite of the fact mentioned above, the agricultural sector occupied a large portion of GDP, i.e., 54.3% in 1984/85. Also, in industrial sector, the main industries achieving significant development are those related to agriculture, for example, jute and cotton textile industries which use agricultural crops as their raw materials, and fertilizer industry. The fundamental structure of national economy of Bangladesh is therefore based on agriculture.

The cultivated area in Bangladesh amounts to 63% of the total area. 85% of total households is in rural and 85% of total population reside in the rural area. 86% of economically active population is occupied in agriculture. These ratios also show that Bangladesh is primarily an agricultural country.

The annual real growth rates of GDP at constant market prices for six years (1981/82-1985/86) are 0.8%, 3.6%, 4.2%, 4.2%, 4.1%, and 5.2%, respectively. These indicate a steady growth of the economy. GDP at constant factor cost per capita is Tk. 776 in 1984/85 and Tk. 798 in 1985/86. Its average annual real growth rate of population is 2.8%.

In spite of significant development in national economy, Bangladesh still depends on foreign financial aid, which is nearly fifty percent of government financial resources. The ratio of grants to loans in foreign economic aid is about 52-58% to 42-48% during the latest five years. The government of Bangladesh repays foreign debt, ranging from US$660 ~ US$1,120 million (commitment) every year.

In foreign trade, the government has taken export-promoting and import-controlling policy. The total import amount in 1984/85 is Tk. 68,263 million with nominal increasing rate of annual average is 16.3% during 1980/81 to 1984/85.

The total export amount is Tk. 26,225 million with nominal increasing rate of 22.9%. But in the year of 1984/85, growth rate of import exceeded that of export. The excess of import in 1984/85 increased to Tk. 42,000 million. The deficit in balance of payment of foreign trade is covered with current account and off-set by surplus on capital account.

The expenditure on development plan increased drastically during 1980/81 to 1984/85 with annual average nominal increasing rate of 12.0% and reached Tk. 38,800 million in 1984/85. This expenditure is distributed to agriculture, flood control and water resources, power and natural resources, and transport sectors so as to plan food self-sufficiency and capital stocks in fundamental sectors of national economy.

Gross investment in GDP in 1985/86 is 12.7% which decreased as compared with 16% in 1980/81, but was nearly equal to 12.3% in 1983/84 and 13.3% in 1984/85. Gross domestic savings in GDP in 1985/86 is 3.8% which increased remarkably as compared with 0.4% in 1981/82, 0.3% in 1982/83 and 1.2% in 1983/84.

Indices of wholesale price and consumer price show an upward tendency, especially, those of wholesale price are rising at high rate. Annual rising rate of wholesale price is 12.8% in 1981/82, 5.6% in 1982/83, 16.2% in 1983/84, 17.1% in 1984/85, and 11.8% in 1985/86. Annual rising rate of consumer price also shows 16.5% in 1981/82, 9.8% in 1982/83, 9.5% in 1983/84, 11.2% in 1984/85 and 9.8% in 1985/86, though these are not as high rate as those of wholesale price. The national economy of Bangladesh has thus been under the inflation to a considerable degree.

The value of the currency Taka has been comparatively stable as appeared from the exchange rates for US$1.00 against Tk. 29.38 (WES rates) in 1984/85, Tk. 32.74 in 1985/86 and Tk. 33.08 in 1986/87.

(2) Social Conditions

The objectives of social development of Bangladesh are to alleviate poverty, particularly in rural areas, and to satisfy the basic human needs. For this purpose, various necessary programs have been implemented in the national development plans such as the First Five-Year Plan, Two-Year Plan, and the Second Five-Year Plan, etc.

The population, which is the maximum restricting factor, is about 100 million in the small land area of 144,000 sq. km. The population density has reached 698 per sq.km. Owing to the effect of population control policy, the population growth rate was tentatively lowered to 2.32% (1974-81) but it shows rapid increase, i.e. 2.8%, again in the recent years. Therefore, more effective population control measures are required to be undertaken.

The literacy of nationals is about 20%. The government has concentrated on the primary education (for children between 5 to 10 years old). As a result, the number of pupils has increased. The enrolment ratio is about 63%.

Supply of other social infrastructures relating to BHN has increased year by year. The number of beds in hospitals in 1985 is 0.32 bed per 1,000 persons, number of drinking water supply facilities in 1981 is 35 units per 1,000 households in 1985, and available new clothing material is 7.9 m per person in 1985.

In particular, the growth rates of drinking water supply facilities and rural electrification are high, with annual growth of 6.4% and 22.5%, respectively.

Economically active population is about 44% of total population of 10 years and up. About 80% of male population are actively working. Only 8% of female are working 1983-84. About 30% of the total population (about half of the male population and about 5% of female), are engaged in economic activities.

Agriculture provides the highest occupation (61%). In particular, 63% of male are engaged in agriculture. On the other hand, about 26% of total population, excluding students, suffer from unemployment. 40% of total households are engaged as agricultural labour, of which 23% of total available labour forces are only employed.

Urban population is 17.5 million in 1985. The growth rate of urban population during the period from 1974 to 1981 was 11.2%, and 7.2% during the period 1981 to 1985. This is the result of population inflow from rural areas. Accordingly, the working population in urban area has rapidly increased with high growth rate of 4.4% (1974-81) and 5.7% (1981-85). This population inflow to urban area has caused the housing problems and unemployment problem in the urban areas.

At present, average daily calorie intake per capita is 1,950 kilo calories. The necessary calorie is 2,200 kilo calorie and it is estimated that the population taking less amount of the necessary calorie reaches 71% in 1981-82. Namely, more than 70% of the nation are suffering from malnutrition. Furthermore, it is projected that people suffering from malnutrition would increase due to low wage (especially agricultural laborer) and inflation. However, the government has been pursuing programmes for improving calorie-intake condition of the people lying on or below poverty-line through higher food production and distribution. The proportion of population taking calories less than 2,200, 1,800, and 1,600 during 1973/74 has therefore been reduced by 2, 5, and 9 percent, respectively, during 1981/82.

Besides, the indicators of these main social phenomena are shown in Table IV-1-7.

1-2 Agricultural Production and Food Balance

Due to the rapid increase in population, the ratio of land area or arable area to population shows the tendency of decrease year by year. Accordingly, the supply to demand for foods has become unbalanced. This fact induces the nation's malnutrition and increases foods import. So increase in food production and self-sufficiency of foods have been given the highest priority in Bangladesh.

(1) Agricultural Production

Production of foodgrains and major crops is shown in Table IV-1-8.

Cropping area of rice has been decreasing but the production shows increasing tendency, owing to the extension of cultivation technology, expansion of HYV cropped area, increase in irrigation facilities and progress of flood control projects. The rice production in 1984/85 is 14.4 million tons.

Both cropping area and the production of wheat have been increased. The wheat production in 1984/85 is 1.44 million tons. HYV contributes a major portion.

The production of foodgrains (rice and wheat) is 15.8 million tons, which is 95% of production target. Production of other crops such as jute, which is the major exportable product, is shown in Table IV-1-9.

(2) Food Balance

Food balance is shown in Table IV-1-10. As shown in this table, the food deficiency is conspicuous because of the growing demand and population increase even though the supply of foodgrains (rice and wheat) is increasing gradually. The deficiency ratio exceeds 10% and the food self-sufficiency becomes difficult. The food deficiency is supplemented by the import from foreign countries. In 1984/85, 729,000 tons of rice and 1,805,000 tons of wheat are imported. They are the major components of import.

Assuming that 1,600 kilo calories per capita per day are taken from foodgrains, 450 grams of foodgrains are necessary. Based on the population data in 1984/85, a total of 16.09 million ton of foodgrains (equivalent to 24.75 million ton of paddy) is necessary.

1-3 Third Five-Year Plan (1985-1990)

(1) Second Five-Year Plan

The size and actual outlay (monetary base) of the national plans since independence are shown in Table IV-1-11.

The actual outlay of the First Plan was only 47%, but those of the Two-Year Plan and Second Five-Year Plan were nearly 90%. On the other hand, the proportion of aid inflow is gradually decreasing. Still the percentage of aid inflow to the actual outlay remains more than 60%.

The macro-economic changes in each Plan are shown in Table IV-1-12.

During the Second Five-Year Plan, the GDP growth was 3.8% (target 5.4%). However, it is noticed that the export was increased, the import was decreased and the proportion of investment to GDP was increased.

The achievement rate of physical target in the Second Five-Year Plan is shown in Table IV-1-13. As shown in this table, only two sectors; namely, power supply and tea production have achieved the target. Other sectors have not their targets. Especially, cotton, sugar, steel and cement as well as rural electrification and mass education enrolment have not achieved even half of the respective targets.

Food self-sufficiency, which is a major objective of the national plan obtained 90% of the targets.

(2) The Third Five-Year Plan

As mentioned above, the basic objective of all three development plans was to satisfy the basic human needs, accelerate economic growth, establish food self-sufficiency and promote self-reliance. But successive efforts for planned development of the economy in the desired direction have been frustrated by unforeseen developments. There have been recurrent floods and droughts more often in recent years. On the other hand, international economic environment also grew increasingly adverse having debilitating effect on the economy of Bangladesh.

The Third Five-Year Plan has, therefore, been taken up for implementation following the Second Five-Year Plan to achieve these objectives as basic target. Therefore, this Plan takes an integrated view of development in a long-term perspective and has formulated eight major objectives of the Plan, as follows:

1) Reduction of population growth
2) Expansion of productive employment
3) Universal primary education and human resource development
4) Development of technological base for bringing about a long-term structural change
5) Food self-sufficiency
6) Satisfaction of minimum basic needs of the people
7) Acceleration of economic growth
8) Promotion of self-reliance.

The main focus of the Third Plan (TFYP) is the reduction of poverty through expanded and more productive employment. According to current projections, TFYP aims at an average annual real growth rate in gross domestic products (constant factor cost of 1984/85) of 5.4%, while annual population growth is projected to decrease from 2.4% currently to 1.8% at the end of TFYP. Foodgrain output is projected to rise by about 29% during the period, while employment is expected to increase by about 17%. TFYP has a total size of Tk. 386,00 crore (at 1984/85 prices) of which Tk. 250,00 crore is in the public sector and Tk. 136,00 crore in the private sector. About 55% will be financed by external assistance. It is noticed that this is also financed by government's initiative as the same of the Second Plan and hold down the dependence on external assistance (see Tables 2-11 and 2-14).

Concerning the sectoral allocation of the TFYP, the ratio of agriculture, water resource and rural development sectors to total outlay allocation of the TFYP is about 29%. The TFYP emphasized on achievement of food self-sufficiency and alleviation of poverty in rural area by way of rural integrated development. The government placed emphasis on industries, and energy and natural resources sectors also due to strengthening basic structure of economy of Bangladesh and promoting industrialization.

The TFYP aims at an average annual growth rate in GDP (at constant factor cost of 1984/85) of 5.4%; agriculture sector aims at a growth rate of 4.0%, both of which are moderate rates; and domestic savings and investment have been proposed to increase from 4.2% in 1984/85 to 7.0% in 1989/90 and from 17.3% in 1984/85 to 19.0% in 1989/90, respectively.

The main objective of agricultural sector for the TFYP is to attain self-sufficiency in foodgrain production. To attain this, foodgrain production needs to grow at an annual growth rate of 5.2% from the benchmark production of 16.1 million tons (1984/85) for reaching the target of 20.7 million tons in the terminal year (1989/90) of TFYP. This target is set to ensure food availability of 16 oz. (453 g) per capita per day.

The employment target of TFYP has been estimated at 243.8 lac in the terminal year (1989/90) at the rate of 4.8 percent per annum against the projected growth rate of 5.4% for GDP during the plan period, as shown in Table IV-1-18. This means that 50.9 lac men-year of fresh employment will be generated, and it is pointed out that about 67.2 percent of the additional employment will arise from expanded activities in the agricultural sector during the TFYP.

Regarding the projection of external resources, in order to reduce the import amount by means of utilizing investment for the existing facilities effectively, the rate of increase in imports will be pressed down to average annual growth rate of 2.8 percent (1985/86-1989/90), while the exports will increase at average annual growth rate of 4.9 percent by devoting the maximum efforts to exports, as shown in Table IV-1-19.

Besides, the TFYP aims at the achievement of the following targets for water resources development. The primary objective of water resources development is to accelerate the process of technological transformation of agriculture in order to reach higher level of agricultural production, particularly foodgrain.