5) Runoff

Total runoff is the amount of surface runoff and groundwater. Surface runoff was calculated by each unit hydrograph and each basin's hourly rainfall distribution. The results of the computer calculation in each basin are shown in Fig. H-8, 9, 10, 11.

6) Estimation of runoff capacity

The runoff capacity for each schemes can be calculated by using the basic factors described in paragraph (1) to (5). The estimated monthly and annual runoff capacities for each schemes are shown below:

(Unit : 10^3 m^3)

Month	Black Right	Black Left	Broad Right	Broad Left
J	280	720	470	430
F	300	770	550	510
M	400	1,040	460	420
A	820	2,120	1,910	1,750
M	1,220	3,140	1,650	1,530
J	820	2,100	630	580
J	820	2,100	1,090	1,010
A	1,050	2,710	1,260	1,160
S	990	2,550	1,710	1,570
O	1,250	3,220	1,960	1,810
N	540	1,380	960	890
D	280	720	370	340
Total	8,770	22,570	13,020	12,000

2.2.6 Pumping drainage plan

1) Design flood

The flood runoff from each area was estimated by the unit hydrograph in Fig. H-8 to H-11. The peak runoff at each pump station is summarized below.

Pump station	Peak runoff
Holland	25.0 m^3/s
Black River Left	51.5 m^3/s
Broad River Right	36.4 m^3/s
Broad River Left	23.0 m^3/s

2) Drainage requirement

Drainage requirement was determined based on the water balance calculation and the following conditions taking into consideration the growing stage of rice prospected flood season.

- Allowable inundation depth and duration on the lowest paddy field is set at 30 cm and 96 hours respectively.
- Allowable inundation duration is set at 48 hours in case of the depth of more than 30 cm.

The water balance calculation is according to the above-mentioned flood hydrograph and three alternative capacities envisaged. The results of the calculations are shown in Table H-12 and Figs. H-12 to H-15.

Based on the above results, design discharges and peak discharges of the required pumps were decided as follows:

(Unit: m^3/s)

Pump Station	Design Discharge 1/	Peak Discharge 2/
Holland	4.5	5.2
Black River Left	7.5	8.7
Broad River Right	6.0	6.7
Broad River Left	4.5	5.0

Note: Pump-up discharge increases with decrease of pump head.
1/: Design discharge: Discharge of the design pump head
2/: Peak discharge : Discharge of the assumed minimum pump head

Table H-1 BREAKDOWN OF PROJECT AREA

Block	Segment		Total	Upland Area			Swamp Area			Residential Area	Irrigable Area	
				Clay	Silt	Gravel	Herbage	Forest	Mangrove		Gross	Net
Black Right Bank	Estate Upper	(1)	750		750						550	
	" Lower	(2)	650		650						600	560
	Lacovia	(17)	260							260		
	Y.S. River Left	(9)	490				350	140				
	Right	(10)	390				340	50				
Black Left Bank	Holiday Pen	(8)	860	250			520	90			505	400
	Styx River	(12)	410				400	10			400	300
	Hatfield	(7)	310	160			150				295	220
	Slipe	(3)	740			740						
Broad River Basin	Broad Right	(13)	1,290				1,290				1,065	800
	" Left	(14)	1,200				1,200				970	800
	Arlington	(4)	660			660						
	Mountainside	(6)	760			760						
Estuary & M.Quarters	Black Estuary	(15)	1,460				1,160		300			
	M.Quarters Right	(11)	660				660					
	Luana	(5)	520		520						315	
	Black River Town	(16)	40							40		
				410	1,920	2,160	6,070	290	300		(4,700)	(3,080)
	Total				4,490			6,660		300		

Table H-2 (1/5) AVERAGE CONE INDEX IN EACH 0.5 M LAYER

Site	0-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
				Black River Left bank						
L,No.5, 100	0.15	0.30	0.54	0.70	0.77	0.92	1.69	1.97	1.69	2.02
200	0.58	0.15	0.82	0.77	0.58	0.89	0.70	0.77	0.70	0.86
300	0.58	0.40	0.70	0.82	1.08	1.26	1.20	1.08	1.08	1.20
L.No.6,100	0	3.28	7.10							
200	0.58	1.37	1.69	1.58	2.02	0.73	7.10			
300	0.54	1.15	1.69	1.31	1.53	1.64	1.80	7.10		
400	0.54	1.06	1.26	0.86	2.40	7.10				
500	0.65	1.15	1.31	1.48	1.26	1.69	1.48	7.10		
600	0.70	1.06	1.26	1.37	1.37	1.37	1.64	1.86	2.19	2.19
BL.No.2	0.40	0.86	0.92	0.65	0.65	0.74	0.82	0.92	0.58	0.74
BL.No.6	2.07	3.50	7.10							
				Styx River						
L.No.11,100	0	7.10								
200	0.70	1.80	7.10							
300	0.50	1.08	1.31	7.10						
400	0.30	0.50	1.09	7.10						
500	0.15	0.58	1.37	7.10						
SX.No.2	0.50	0.54	0.54	1.64	7.10					
				Y.S. River Left bank						
L.No.12,100	0.40	0	0.86	1.37	1.64	7.10				
200	0.15	0.30	0.70	1.08	1.86	3.11	7.10			
300	0.15	0	0.77	0.82	1.08	1.37	1.86	3.17	7.10	
400	0.30	0.15	0	0.15	0.58	0.98	1.58	2.24	7.10	
500	0.58	0.54	0	0.40	0.64	0.50	0.40	0.92	1.08	0.77

Table H-2 (2/5) AVERAGE CONE INDEX IN EACH 0.5 M LAYER

Site		0-05	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
L,No.13,	100	1.04	1.20	1.48	1.20	1.04	1.75	7.10			
	200	0.70	0.77	0.98	1.04	1.09	0.82	0.86	0.82	0.86	0.86
	300	0.74	0.74	0.74	0.86	1.04	0.65	1.06	1.37	0.92	0.58
	400	0.54	0.77	0.89	0.92	1.04	1.37	0.98	0.92	0.70	0.82
	490	0.15	0.54	0.82	1.15	1.15	1.20	1.08	0.98	0.74	0.86
YS No.1		3.50	3.17	2.07	1.86	1.69	4.10	7.10			
YS No.2		1.75	1.26	1.15	1.42	1.86	2.62	7.10			
YS No.3		0	0	0.54	7.10						
YS No.4		0	0	0.77	7.10						
BL No.1		0.50	0.77	1.06	0.74	0.98	1.80	2.90	7.10		
BL No.3		0.54	0.98	1.26	1.26	1.53	1.86	2.02	2.90	3.77	7.10
BL No.4		0.54	0.86	1.31	1.04	0.86	1.04	1.08	1.08	1.08	1.26
BL No.5		0.92	1.80	0.98	1.04	1.09	1.09	1.58	3.72	7.10	
L.No.16,	100	0	0.50	0.92	2.30	1.69	1.37	1.48	1.37	1.37	2.57
	300	0.89	1.08	0.98	1.04	1.09	1.20	1.15	0.89	0.92	0.98
	400	0.50	0.70	0.92	0.74	0.70	0.86	0.98	0.86	1.08	1.09
	500	0.54	0.74	0.89	0.65	0.86	1.06	0.98	0.89	1.08	1.09
	600	0.40	0.58	0.86	0.70	0.89	0.89	0.98	0.82	0.77	0.77
Y.S. River Right bank											
L.No.2,	50	0.82	0.74	0.89	0.77	0.74	0.77	0.77	0.86	7.10	
	100	0.92	1.08	0.92	0.86	0.82	0.77	0.86	0.77	1.04	1.08
	200	0.86	0.77	0.82	0.70	0.65	0.74	0.86	0.77	0.70	0.74
	250	0.30	0.58	0.50	0.30	0	0.98	0.65	0.40	0.30	0.65
	300	0	0	0	0	0.54	0.74	0.74	0.77	0.70	0.92
	350	0	0	0.40	0.86	1.20	0.98	1.64	1.26	0.89	1.15
	400	0	0	0	0.58	0.65	0.74	0.82	0.70	0.98	0.89
	500	0	0	0.58	0.74	0.58	0.77	0.92	0.74	0.77	1.04
L.No.3	20	0.89	0.74	0.54	0	0.71	1.04	1.06	0.92	1.09	1.06
	100	0	1.15	1.31	1.42	1.08	1.80	1.31	1.20	1.91	2.40
	200	0.58	0.74	1.20	1.26	1.08	0.86	0.86	0.92	1.48	2.02
	300	0	0	0.65	0.98	0.82	0.58	0.82	0.89	0.77	0.98
	400	0.15	0	1.04	1.48	0.58	0.70	0.77	0.04	1.08	1.53
	500	0.54	0.86	1.09	0.89	0.54	0.70	0.74	0.74	0.70	0.74

Table H-2 (3/5) AVERAGE CONE INDEX IN EACH 0.5 M LAYER

Site	0-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
L.No.14,100	0	0.30	0.50	0.65	0.15	0.50	0.89	1.09	1.37	1.53
200	0	0	0.58	0.74	0.77	0.77	1.04	0.82	0.82	0.82
300	0	0.30	0.82	0.92	1.58	1.09	1.80	1.58	2.40	2.90
400	0.40	0.40	0.77	1.64	1.75	1.31	1.53	1.31	1.26	1.26
500	0	0	0.65	1.31	0.58	0.74	0.89	1.48	1.64	1.64
M.Q.No.1	0.40	0.30	0.74	0.58	0.50	0.40	0.70	0.58	0.82	0.98
M.Q.No.3	0.65	0.54	0.77	0.54	0.65	0.92	0.89	1.06	0.54	0.89
M.Q.No.4	0.74	0.86	0.89	1.04	0.92	1.08	0.98	1.08	0.65	0.89
Broad River Right bank										
L.No.8, 100	0.30	0.92	7.10							
200	0.40	0.74	0.98	1.15	1.69	7.10				
300	0.50	0.58	1.06	0.98	1.86	1.58	4.15	7.10		
400	0	0.03	0.77	1.20	2.24	3,83	7.10			
500	0	0.40	0.82	1.58	7.10					
L.No.9, 100	1.09	2.51	3.93	7.10						
200	1.69	1.69	7.10							
300	0.82	2.40	5.09	7.10						
400	4.70	7.10								
500	0.40	1.04	3.17	7.10						
600	0.40	1.14	7110							
700	0	0	1.58	7.10						
800	0.15	2.07	7.10							
900	0.50	0.50	0.89	1.31	1.37	2.79	7.10			
L.No.10,100	0.98	1.09	1.48	1.91	3.99	7.10				
200	0.74	1.20	7.10							
300	0.15	0.77	1.09	1.31	7.10					
400	0.58	1.08	1.08	7.10						
500	0.30	0.86	0.86	0.98	1.15	3.17	7.10			
600	0	0.50	0.89	1.08	7.10					

Table H-2 (4/5) AVERAGE CONE INDEX IN EACH 0.5 M LAYER

Site		0-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
L.No.15	0	0.50	0.40	0.77	1.08	1.37	1.15	1.42	2.30	7.10	
	100	0.89	0.50	0.92	1.42	1.42	1.91	2.79	7.10		
	200	0.77	0.54	1.08	1.31	1.64	1.91	2.46	7.10		
	300	0.54	0.50	1.08	1.15	1.15	7.10				
	400	0	0	3.93	1.04	1.31	7.10				
BR.No.2		0.50	0.65	0.89	1.31	1.48	7.10				
BR.No.4		0.70	0.70	0.89	1.14	1.20	1.15	1.58	7.10		
BR.No.6		1.08	0.92	0.40	7.10						
SX.No.1		0.54	0.40	0.70	1.04	2.02	2.19	7.10			
Broad River Left bank											
L.No.17,	100	0.89	7.10								
	200	0.92	1.20	7.10							
	300	0.92	1.48	7.10							
	400	0.65	1.06	7.10							
	500	0.74	0.86	1.08	1.31	7.10					
	600	0.58	1.08	7.10							
	700	0.58	0.77	0.65	1.15	7.10					
BR.No.1		0.65	0.77	0.82	0.92	0.98	1.08	1.20	1.31	7.10	
BR.No.3		0.70	0.70	1.04	1.09	1.09	1.80	2.13	1.97	3.99	7.10
BR.No.5		0.50	0.86	0.70	1.31	0.92	1.42	1.75	1.53	1.58	1.86
MS.No.1		0.70	0.89	1.04	1.48	1.69	1.91	2.07	1.97	7.10	
MS.No.2		0.86	1.37	0.58	0	0.15	0.65	0.82	7.10		
MS.No.3		0.30	0.70	0.89	1.09	1.06	1.09	7.10			
MS.No.4		0.65	1.20	1.09	1.04	7.10					
AG.No.1		1.42	2.57	2.51	2.30	0.65	7.10				
Middle Quarters River Right bank											
L.No.1,	400	0.82	7.10								
	500	0.50	0.92	7.10							

Table H-2 (5/5) AVERAGE CONE INDEX IN EACH 0.5 M LAYER

Site		0-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
					Middle Quarters River Right bank (Cont'd)						
L.NO.1	600	0.89	1.31	1.75	1.69	1.69	7.10				
	700	0.15	0.82	1.04	1.37	1.09	1.53	1.97	7.10		
	800	0	0.54	0.77	0.74	0.77	0.89	1.15	1.04	0.98	1.09
	900	0.15	0.30	0.58	0.54	0.70	0.58	0.58	0.40	0.70	0.98
	1,000	0	0.30	0.54	0.54	0.65	0.58	0.70	0.70	0.54	0.89
	1,100	0.54	0.15	0.50	0	0.30	0.54	0.65	0.58	0.54	0.70
	1,200	0.30	0	0	0.30	0.74	0.50	0.70	0.54	0.70	0.92
	1,300	0.50	0.50	0.40	0.40	0	0.40	0.40	0.40	0.40	0.40
MQ.No.2		0.54	0.15	0.54	0.54	0.50	0.65	0.74	0.58	0.70	0.74
MQ.No.7		0.86	0.89	1.06	0.77	0.58	0.65	0.74	0.58	0.82	0.92
					Black River Estuary						
L.No.4,	100	0	0	0.40	0.74	0.65	0.77	0.82	0.92	0.74	0.86
	197	0.40	0.65	0.74	1.08	2.24	7.10				
BL.No.7		0	0	0.50	0.54	0.30	0.30	0	0.30	0.65	0.98
BL.No.8		0.65	0.98	2.19	1.91	1,08	1.04	0.98	1.42	0.82	1.08
BL.No.9		0.58	0	0.30	0.50	1.69	1.20	0.89	0.82	1.58	0.86
BL.No.10		0.58	0.82	0.74	0.77	0.77	1.09	0.89	0.77	0.86	1.20
BL.No.11		0	0	0	0.15	0	0.50	0	0.30	0	0.30
MQ.No.5		0.65	0.30	0.50	0.40	0.54	0.54	0.40	0.58	0.65	0.77
MQ.No.6		0	0	0.50	0.40	0.54	0.50	0.40	0.50	0.54	0.65
BR.No.7		0	0	0.54	0.65	0.70	0.65	1.04	0.98	7.10	

Table H-3 (1/2) CLASSIFICATION OF BEARING CAPACITY IN SWAMP AREA

Segment and Survey Site	Number of Survey Datum	Frequency qc>0.5 within 1.0m	qc>1.0 within 2.0m	qc>7.0 within 5.0m	Number of Eligible Datum	Evaluation
Black R.						
Left Bank						
Line No. 5	9	3 - 2	3 - 0	3 - 0	2	Eligible 23
Line No. 6	18	6 - 6	6 - 6	6 - 5	17	Survey 33
Spots	4	2 - 2	2 - 1	2 - 1	4	70%
Total	33	11 -10	11 - 7	11 - 6	23	(Good)
Styx R.						
Both Banks						Eligible 18
Line No. 11	15	5 - 5	5 - 5	5 - 5	15	Survey 18
Spots	3	1 - 1	1 - 1	1 - 1	3	100%
Total	18	6 - 6	6 - 6	6 - 6	18	(very good)
Y.S. R.						
Left Bank						
Line No. 12	15	5 - 1	5 - 2	5 - 4	7	
Line No. 13	15	5 - 5	5 - 3	5 - 1	9	Eligible 43
Line No. 16	15	5 - 5	5 - 1	5 - 0	6	Survey 69
Spots	24	8 - 6	8 - 8	8 - 7	21	62%
Total	69	23 -17	23 -14	23 - 12	43	(No good)
Y.S. R.						
Right Bank						
Line No. 2	24	8 - 4	8 - 1	8 - 1	6	
Line No. 3	18	6 - 4	6 - 4	6 - 0	8	Eligible 19
Line No. 14	15	5 - 0	5 - 2	5 - 0	2	Survey 66
Spots	9	3 - 2	3 - 1	3 - 0	3	29%
Total	66	22 -10	22 - 8	22 - 1	19	(Bad)

Table H-3 (2/2) CLASSIFICATION OF BEARING CAPACITY IN SWAMP AREA

Segment and Survey Site	Number of Survey Datum	Frequency qc>0.5 within 1.0m	Frequency qc>1.0 within 2.0m	Frequency qc>7.0 within 5.0m	Number of Eligible Datum	Evaluation
Broad R.						
Right Bank						
Line No. 8	15	5 - 3	5 - 5	5 - 5	13	
Line No. 9	27	9 - 8	9 - 9	9 - 9	26	Eligible 82
Line No. 10	18	6 - 6	6 - 5	6 - 6	17	Survey 87
Line No. 15	15	5 - 4	5 - 5	5 - 5	14	
Spots	12	4 - 4	4 - 4	4 - 4	12	94%
Total	87	29 -25	29 -28	29 - 29	82	(Very good)
Broad R.						
Left Bank						Eligible 43
Line No. 17	21	7 - 7	7 - 7	7 - 7	21	Survey 45
Spots	24	8 - 8	8 - 7	8 - 7	22	96%
Total	45	15 -15	15 -14	15 -14	43	(Very good)
Black R.						Eligible 8
Estuary						Survey 30
Spots	30	10 - 4	10 - 2	10 - 2	8	27%
						(Bad)
M. Quarter R.						Eligible 6
Line No. 1	19	6 - 3	6 - 0	6 - 0	3	Survey 24
Spots	6	2 - 2	2 - 1	2 - 0	3	25%
Total	24	8 - 5	8 - 1	8 - 0	6	(Bad)

Table H-4 PEAT THICKNESS OF EACH SEGMENT

Segment	Total Area	Peat Thickness							Remarks
		Less than 3 m		3 m to 6 m		More than 6 m		Max Depth	
		Area	Rate	Area	Rate	Area	Rate		
	ha	ha	%	ha	%	ha	%	m	
Black R. Left Bank	760	608	80	137	18	15	2	7	
Styx R. Both Banks	410	402	98	8	2	0	0	5	
YS R. Right Bank	390	0	0	0	0	390	100	12	
" Left Bank	490	167	34	54	11	269	55	10	
Broad R Right Bank	1,290	1,135	88	155	12	0	0	4	
" Left Bank	1,200	1,080	90	120	10	0	0	5	
M.Quarter R. Right B	660	46	7	343	52	271	41	10	
Black R. Estuary	1,460	993	68	321	22	146	10	11	
Total	6,660	4,431	67	1,138	17	1,091	16		

Table H-5 MOISTURE RATIO AND IGNITION LOSS

Sample No.	Moisture Ratio Natural Dry	Moisture Ratio Complete Dry	Ignition Loss	Note
No. 1-300- 0-30	886	1,177	59.7	
-60-90	735	1,048	59.2	
300	768	1,174	37.4	
No. 1-350- 0-30	1,360	1,779	59.8	
90-200	863	1,145	67.2	
300	960	1,197	60.7	
No. 1-400- 0-30	1,196	1,620	62.6	
30-90	1,093	1,267	59.9	
No. 1-500-30-90	791	1,073	36.6	
No. 4-100-30-90	824	1,076	49.0	
No. 6-100- 0-30	829	1,176	44.8	
No. 6-500- 0-30	765	1,431	86.5	
-30-90	460	676	42.7	
No. 9-100-30-90	324	616	78.4	
No. 9-300- 0-30	650	1,497	40.3	
30-90	510	793	51.5	
No. 9-500- 0-30	820	1,304	70.2	
No. 9-700- 0-30	751	988	62.5	
30-90	701	924	76.4	
No. 9-900- 0-30	1,110	1,460	57.7	
30-90	1,079	1,832	53.2	
No.11-100- 0-50	538	847	24.2	
No.11-300- 0-50	533	777	67.3	
BL.No.1 0-30	985	1,194	62.5	
BL.No.3 0-30	798	1,630	37.0	
30-90	561	1,123	63.8	
BL.No 5 0-30	548	860	48.1	
BR.No.2 0-50	547	1,086	71.4	
BR.No.4 50-100	709	1,190	59.5	
MQ.No.2 50-100	803	1,650	31.3	
MS.No.1 0-30	421	1,823	61.5	
MS.No.3 0-30	373	1,387	65.8	
MS.No.4 0-30	631	1,319	65.0	
AG.No.1 0-30	400	709	42.3	
SX.No.1 0-30	495	1,716	55.3	
Average	735	1,216	56.3	

TABLE H-6 SHRINKAGE OF PEAT SOIL

Survey Site	Long Side Length	Long Side Ratio	Short Side Length	Short Side Ratio	Height Length	Height Ratio
	mm	%	mm	%	mm	%
	Original Dimension					
	280		214		98	
Line No. 3,500m	255	8.9	191	10.7	72	26.5
No. 5,200m	207	26.1	171	20.1	68	30.6
No. 6,300m	253	9.6	188	12.1	83	15.3
No. 8,300m	255	8.9	195	8.9	86	12.2
No. 9,500m	243	13.2	183	14.5	68	30.6
No.11,100m	259	7.5	204	4.7	91	7.1
No.13,300m	252	10.0	192	10.3	75	23.5
No.14,300m	255	8.9	185	13.6	82	16.3
No.15,300m	256	8.6	188	12.1	86	12.2
Average	248	11.4	189	11.7	79	19.4

Table H-7 SELECTION OF RECLAIMABLE LAND

(Unit: %)

Segment	Bearing Capacity		Soil Property		Settlement		Evaluation
	Value	Category	Value	Category	Value	Category	
Black River Right Bank	100	I	IIpl	II	100	I	Suitable
Black River Left Bank	70	III	IVpr	III	80	II	Suitable
Styx River Both Banks	100	I	IVbr	IV	98	I	Suitable
Y.S. River Left Bank							
Upper reaches	78	III	IIIpl	III	100	I	Suitable
Lower reaches	50	V	Vbr	IV-V	52	V	Unsuitable
Total	62	IV	IIIpl-Vbr	III-V	34	V	Unsuitable
Y.S. River Right Bank	29	V	Vbr	V	0	V	Unsuitable
Broad River Right Bank	94	I	IIIr-IVbr	III-IV	88	II	Suitable
Broad River Left Bank	96	I	IVbr	IV	90	I	Suitable
Middle Quarter River Right Bank	25	V	Vbr	V	7	V	Unsuitable
Black River Estuary	27	V	Vbc	V	68	IV	Unsuitable

Table H-8 UNIT DRAINAGE DISCHARGE (IN MAY)

DESCRIPTION	UNIT	HOLLAND	BLACK RIVER LEFT			BROAD RIVER BASIN
			HATFIELD	FRENCH./HOLIDAY.	STYX	
Gross water requirement	(Gr) mm/day	7.97	10.00	11.57	12.37	12.1
80% dependable rainfall	(R) mm	185	117	117	117	105
ER for paddy field	(ER) mm	139	88	88	88	79
(R-ER)/31 day	(ΔR) mm/day	1.48	0.94	0.94	0.94	0.84
Consumptive use	(Cu) "	6.5	6.5	6.4	6.4	6.4
Gr + ΔR - ETc	(Qℓw) "	2.95	4.44	6.11	6.91	6.54
Present Gw in-flow	(Gw.p) m^3/sec	-	-	-	-	1.6
Increased Gw in-flow	(Gw.i) "	-	-	-	-	1.9
Differential[1)]	(ΔGw) "	-	-	-	-	0.3
- do -	(Gw) mm/day	-	-	-	-	1.30
Gr + ΔR - ETc + Gw	(Qℓw) "	-	-	-	-	7.84
Acreage	(A) ha	990	300	500	400	2,000
Unit drainage discharge	(Qℓ) $\times 10^{-4}$ m^3/sec/ha	3.4		6.9		9.1

Note: 1) Differential in-flow between present and developed stage is recognized to flow into the Project area at the Broad River Basin and remains into the reserved area which is featured by blue-holes.

Table H-9 HOURLY RAINFALL AT HOLLAND STATION

1st day					2nd day					3rd day				
Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall	Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall	Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall
1	1.45	1.45	0	0	25	3.00	69.00	50	1.50	49	0.53	204.53	90	0.48
2	1.45	2.90	0	0	26	3.00	72.00	50	1.50	50	0.53	205.06	90	0.48
3	1.54	4.44	0	0	27	3.20	75.20	50	1.60	51	0.56	205.62	90	0.50
4	1.63	6.07	0	0	28	3.39	78.59	50	1.70	52	0.59	206.21	90	0.53
5	1.71	7.78	0	0	29	3.59	82.18	50	1.80	53	0.62	206.83	90	0.56
6	1.80	9.58	0	0	30	3.78	85.96	50	1.89	54	0.65	207.48	90	0.59
7	2.05	11.63	10	0.21	31	4.30	90.26	50	2.15	55	0.75	208.23	90	0.68
8	2.30	13.93	10	0.23	32	4.82	95.08	50	2.41	56	0.84	209.07	90	0.76
9	2.55	16.48	10	0.26	33	5.33	100.41	80	4.26	57	0.94	210.01	90	0.85
10	2.80	19.28	10	0.28	34	5.85	106.26	80	4.68	58	1.03	211.04	90	0.93
11	3.78	23.06	10	0.38	35	7.91	114.17	80	6.33	59	1.39	212.43	90	1.25
12	4.77	27.83	10	0.48	36	9.97	124.14	80	7.98	60	1.74	214.17	90	1.57
13	5.75	33.58	30	1.73	37	12.02	136.16	80	9.62	61	2.10	216.27	90	1.89
14	6.73	40.31	30	2.02	38	14.08	150.24	80	11.26	62	2.45	218.72	90	2.21
15	5.59	45.90	30	1.68	39	11.68	161.92	80	9.34	63	2.03	220.75	90	1.83
16	4.44	50.34	50	2.22	40	9.28	171.20	80	7.42	64	1.62	222.37	90	1.46
17	3.30	53.64	50	1.65	41	6.88	178.08	80	5.50	65	1.20	223.57	90	1.08
18	2.15	55.79	50	1.08	42	4.48	182.56	80	3.58	66	0.78	224.35	90	0.70
19	2.01	57.80	50	1.01	43	4.19	186.75	80	3.34	67	0.73	225.08	90	0.66
20	1.87	59.67	50	0.94	44	3.91	190.66	80	3.13	68	0.68	225.76	90	0.61
21	1.72	61.39	50	0.86	45	3.62	194.28	80	2.90	69	0.63	226.39	90	0.57
22	1.58	62.97	50	0.79	46	3.33	197.61	80	2.66	70	0.58	226.97	90	0.52
23	1.52	64.49	50	0.76	47	3.20	200.81	90	2.88	71	0.52	227.49	90	0.47
24	1.51	66.00	50	0.76	48	3.19	204.00	90	2.87	72	0.51	228.00	90	0.46
Total	66.00			17.34		138.00			102.30		24.00			21.64

Estimating Runoff Coefficient $f = 141.28 / 228.0 = 0.62$

Table H-10 HOURLY RAINFALL AT LACOVIA STATION

1st day					2nd day					3rd day				
Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall	Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall	Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall
1	1.30	1.30	0	0	25	3.65	63.65	50	1.83	49	0.63	227.63	90	0.57
2	1.30	2.60	0	0	26	3.65	67.30	50	1.83	50	0.63	228.26	90	0.57
3	1.39	3.99	0	0	27	3.89	71.19	50	1.95	51	0.68	228.94	90	0.61
4	1.48	5.47	0	0	28	4.12	75.31	50	2.06	52	0.72	229.66	90	0.65
5	1.57	7.04	0	0	29	4.35	79.66	50	2.18	53	0.76	230.42	90	0.68
6	1.65	8.69	0	0	30	4.58	84.24	50	2.29	54	0.80	231.22	90	0.72
7	1.87	10.56	10	0.19	31	5.20	89.44	50	2.60	55	0.91	232.13	90	0.82
8	2.09	12.65	10	0.21	32	5.82	95.26	50	2.91	56	1.02	233.15	90	0.92
9	2.31	14.96	10	0.23	33	6.44	101.70	80	5.15	57	1.13	234.28	90	1.02
10	2.53	17.49	10	0.25	34	7.05	108.75	80	5.64	58	1.23	235.51	90	1.11
11	3.43	20.92	10	0.34	35	9.55	118.30	80	7.64	59	1.66	237.17	90	1.49
12	4.33	25.25	10	0.43	36	12.05	130.35	80	9.64	60	2.09	239.26	90	1.88
13	5.23	30.48	30	1.57	37	14.55	144.90	80	11.64	61	2.52	241.78	90	2.27
14	6.13	36.61	30	1.84	38	17.05	161.95	80	13.64	62	2.95	244.73	90	2.66
15	5.09	41.70	30	1.53	39	14.15	176.10	80	11.32	63	2.45	247.18	90	2.21
16	4.04	45.74	30	1.21	40	11.24	187.34	80	8.99	64	1.95	249.13	90	1.76
17	3.00	48.74	30	0.90	41	8.34	195.68	80	6.67	65	1.45	250.58	90	1.31
18	1.95	50.69	50	0.98	42	5.43	201.11	90	4.89	66	0.95	251.53	90	0.86
19	1.83	52.52	50	0.92	43	5.08	206.19	90	4.57	67	0.89	252.42	90	0.80
20	1.70	54.22	50	0.85	44	4.72	210.91	90	4.25	68	0.83	253.25	90	0.75
21	1.58	55.80	50	0.79	45	4.36	215.27	90	3.92	69	0.77	254.02	90	0.69
22	1.45	57.25	50	0.73	46	4.00	219.27	90	3.60	70	0.70	254.72	90	0.63
23	1.38	58.63	50	0.69	47	3.87	223.14	90	3.48	71	0.65	255.37	90	0.59
24	1.37	60.00	50	0.69	48	3.86	227.00	90	3.47	72	0.63	256.00	90	0.57
Total	60.00			14.35		167.00			126.16		29.00			26.14

Estimating Runoff Coefficient f = 166.65 / 256 = 0.65

Table H-11 HOURLY RAINFALL AT BURNT SAVANNA STATION

1st day					2nd day					3rd day				
Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall	Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall	Time	Hourly Rainfall	Accumulated Rainfall	Runoff Percent	Effective Rainfall
1	1.30	1.30	0	0	25	2.50	62.50	50	1.25	49	0.52	175.52	80	0.42
2	1.30	2.60	0	0	26	2.50	65.00	50	1.25	50	0.53	176.05	80	0.42
3	1.39	3.79	0	0	27	2.67	67.67	50	1.34	51	0.56	176.61	80	0.45
4	1.48	5.47	0	0	28	2.83	70.50	50	1.42	52	0.59	177.20	80	0.47
5	1.57	7.04	0	0	29	2.99	73.49	50	1.50	53	0.62	177.82	80	0.50
6	1.65	8.69	0	0	30	3.15	76.64	50	1.58	54	0.65	178.47	80	0.52
7	1.87	10.56	10	0.19	31	3.59	80.23	50	1.80	55	0.75	179.22	80	0.60
8	2.09	12.65	10	0.21	32	4.02	84.25	50	2.01	56	0.84	180.06	80	0.67
9	2.31	14.96	10	0.23	33	4.45	88.70	50	2.23	57	0.94	181.00	80	0.75
10	2.53	17.49	10	0.25	34	4.88	93.58	50	2.44	58	1.03	182.03	80	0.82
11	3.43	20.92	10	0.34	35	6.60	100.18	80	5.28	59	1.39	183.42	80	1.11
12	4.33	25.25	10	0.43	36	8.31	108.49	80	6.65	60	1.74	185.16	80	1.39
13	5.23	30.48	30	1.57	37	10.02	118.51	80	8.02	61	2.10	187.26	80	1.68
14	6.13	36.61	30	1.84	38	11.73	130.24	80	9.38	62	2.45	189.71	80	1.96
15	5.09	41.70	30	1.53	39	9.73	139.97	80	7.78	63	2.04	191.75	80	1.63
16	4.04	45.74	30	1.21	40	7.73	147.70	80	6.18	64	1.62	193.37	80	1.30
17	3.00	48.74	30	0.90	41	5.73	153.43	80	4.58	65	1.20	194.57	80	0.96
18	1.95	50.69	50	0.98	42	3.73	157.16	80	2.98	66	0.78	195.35	80	0.62
19	1.83	52.52	50	0.92	43	3.50	160.66	80	2.80	67	0.73	196.08	80	0.58
20	1.70	54.22	50	0.85	44	3.26	163.92	80	2.61	68	0.68	196.76	80	0.54
21	1.58	55.80	50	0.79	45	3.02	166.94	80	2.42	69	0.63	197.39	80	0.50
22	1.45	57.25	50	0.73	46	2.78	169.72	80	2.22	70	0.58	197.97	80	0.46
23	1.38	58.63	50	0.69	47	2.65	172.37	80	2.12	71	0.52	198.49	80	0.42
24	1.37	60.00	50	0.69	48	2.63	175.00	80	2.10	72	0.51	199.00	80	0.41
Total	60.00			14.35		115.00			81.94		24.00			19.18

Estimating Runoff Coefficient f = 115.47 / 199 = 0.58

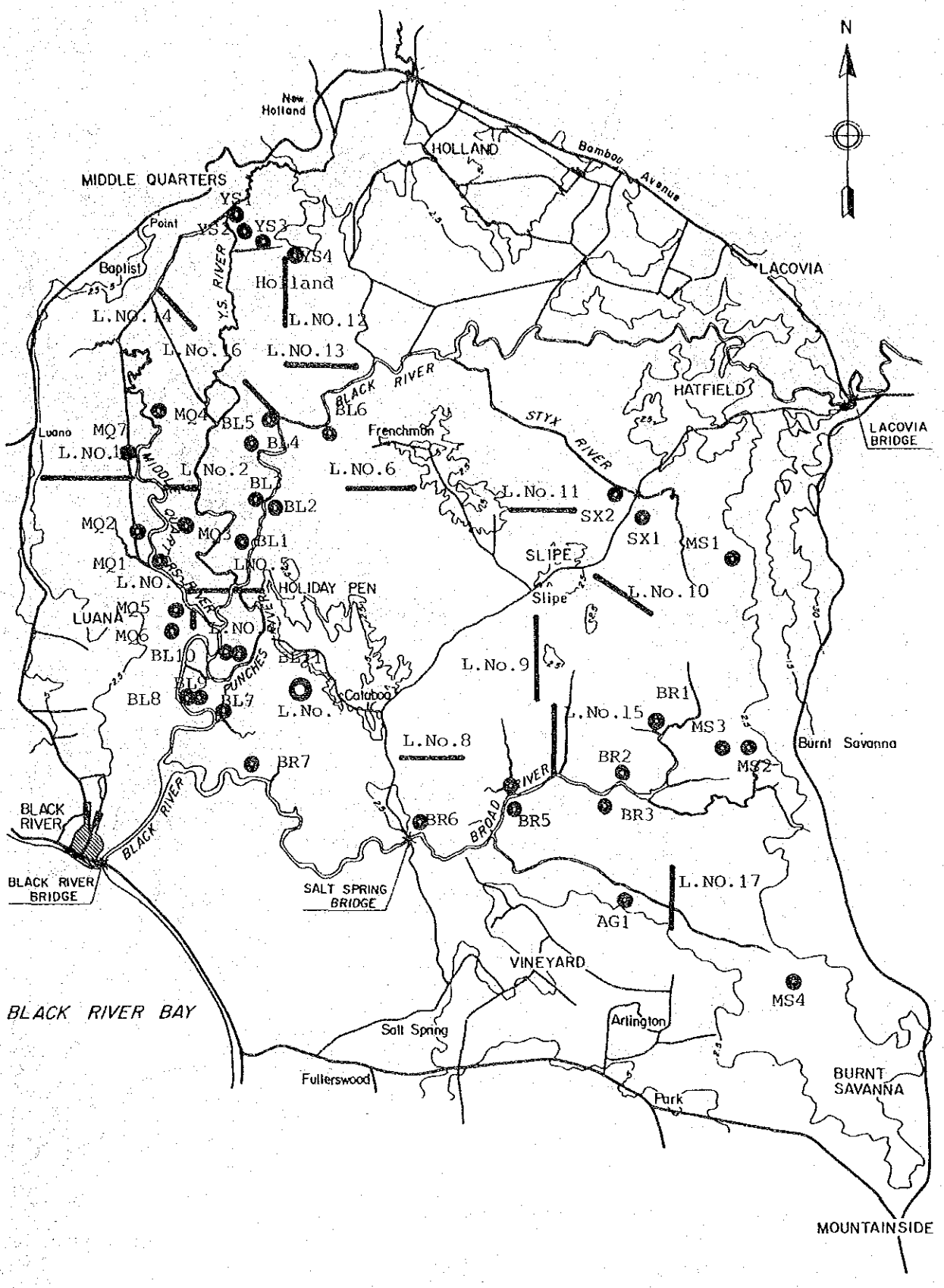
Table H-12 ALTERNATIVE CASE STUDY FOR SPECIFICATIONS OF DRAINAGE PUMPS

Pump Station	Alternative Case	Design Discharge (m^3/sec)	Peak Discharge (m^3/sec)	Inundated Duration (hours)	
				GLa.	WLa.
Holland	I: ø700 mm x 3 sets	3.5	4.0	83	63
	II: ø700 mm x 4 sets	4.7	5.4	60	44
	III: ø800 mm x 3 sets	4.5	5.2	61	46
Black River Left	I: ø700 mm x 5 sets	5.8	6.8	110*	64*
	II: ø700 mm x 6 sets	7.0	8.1	96	50*
	III: ø800 mm x 5 sets	7.5	8.7	86	45
Broad River Right	I: ø700 mm x 4 sets	4.7	5.2	110*	26
	II: ø700 mm x 5 sets	5.8	6.5	84	0
	III: ø800 mm x 4 sets	6.0	6.7	75	0
Broad River Left	I: ø700 mm x 3 sets	3.5	3.9	115*	28
	II: ø700 mm x 4 sets	4.7	5.2	76	0
	III: ø800 mm x 3 sets	4.5	5.0	81	0

Remarks: WLa.: Inundation duration over Allowable inundation water level.

GLa.: Inundation duration over Datum ground elevation.

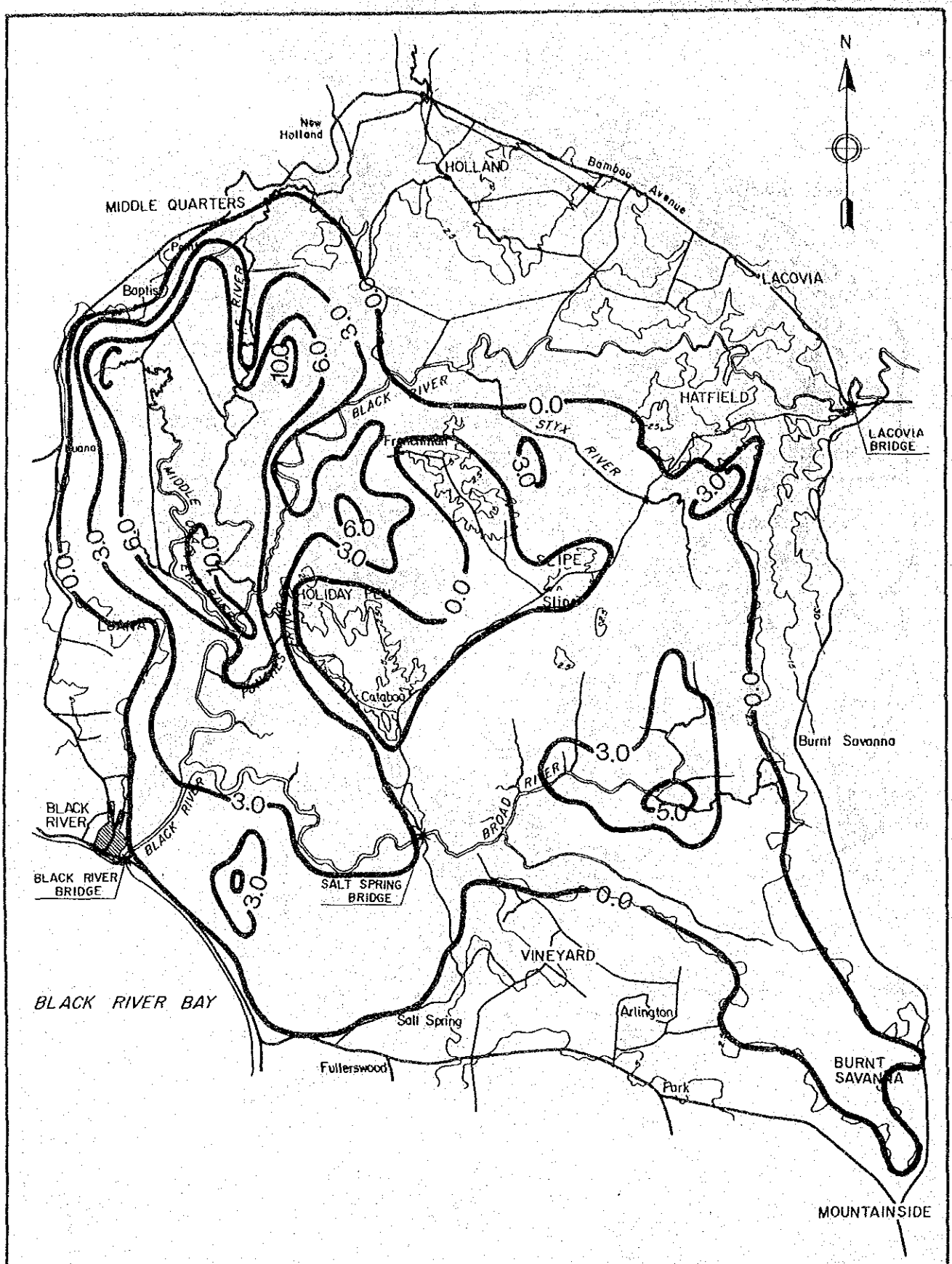
*: Shortage of pump capacity



BLACK RIVER LOWER MORASS AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-1 LOCATION MAP OF PHYSICAL SOIL SURVEY SITE

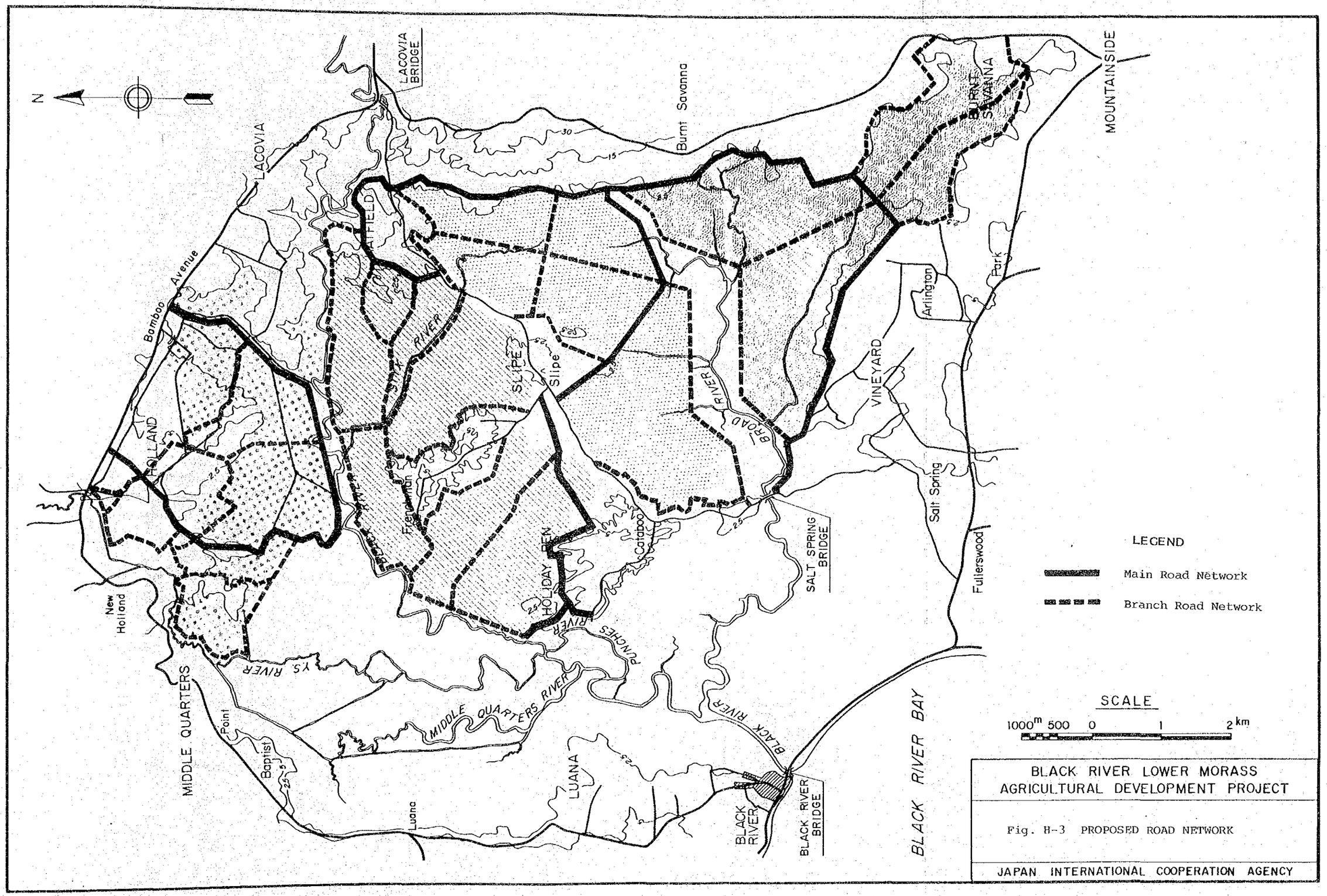
JAPAN INTERNATIONAL COOPERATION AGENCY



BLACK RIVER LOWER MORASS AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-2 PEAT THICKNESS MAP

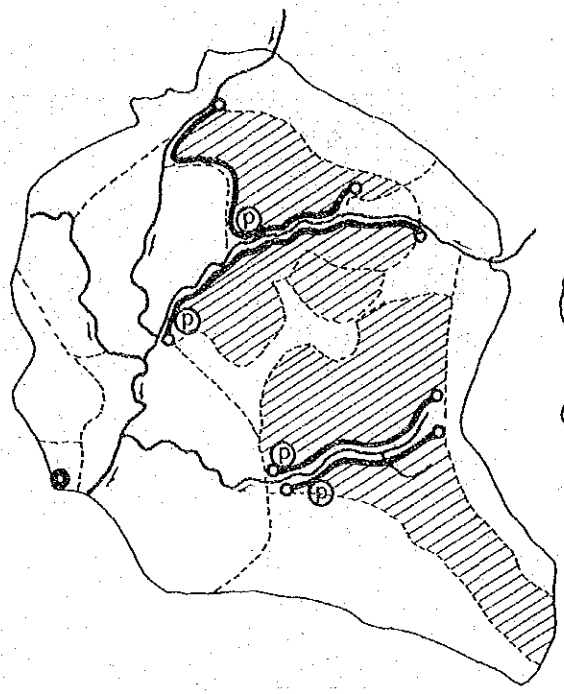
JAPAN INTERNATIONAL COOPERATION AGENCY



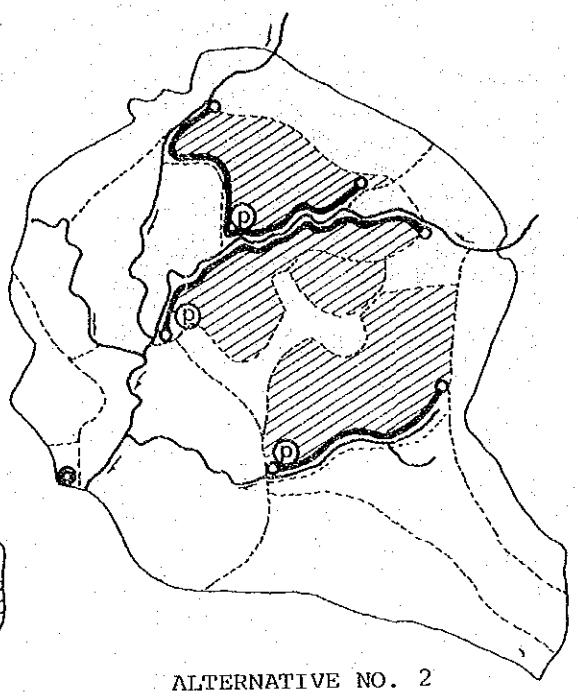
BLACK RIVER LOWER MORASS AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-3 PROPOSED ROAD NETWORK

JAPAN INTERNATIONAL COOPERATION AGENCY



ALTERNATIVE NO. 1



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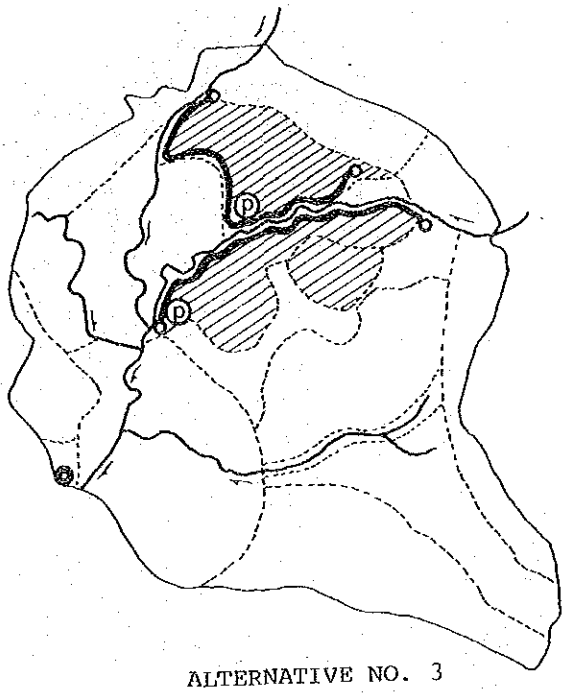


ALTERNATIVE NO. 3

LEGEND

RIVER

EMBANKMENT

SEGMENT BORDER

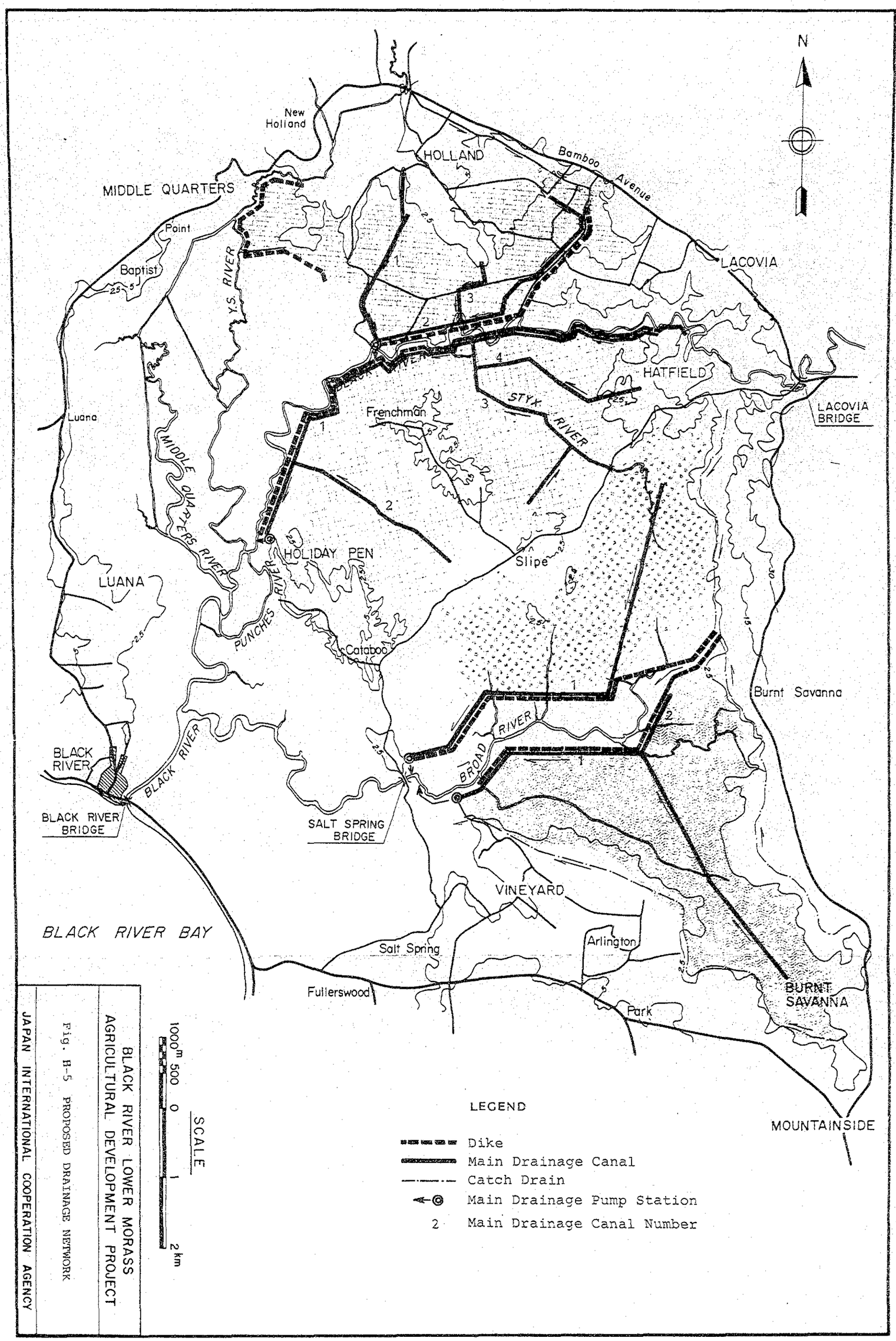
DRAINAGE PUMP STATION

SEGMENT PROPOSED DEVELOPMENT

BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-4 ALTERNATIVE PLANS

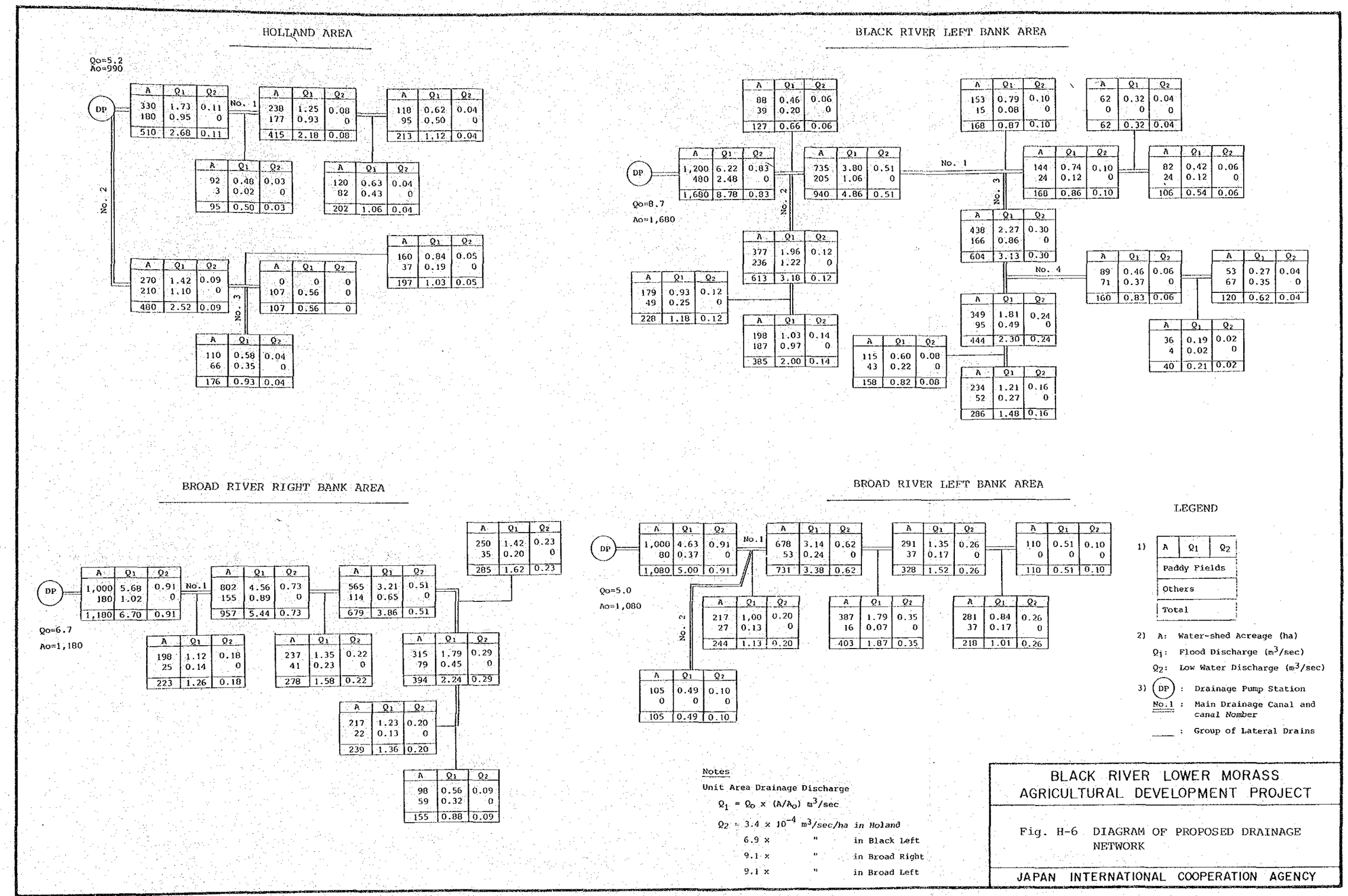
JAPAN INTERNATIONAL COOPERATION AGENCY



BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. II-5 PROPOSED DRAINAGE NETWORK

JAPAN INTERNATIONAL COOPERATION AGENCY

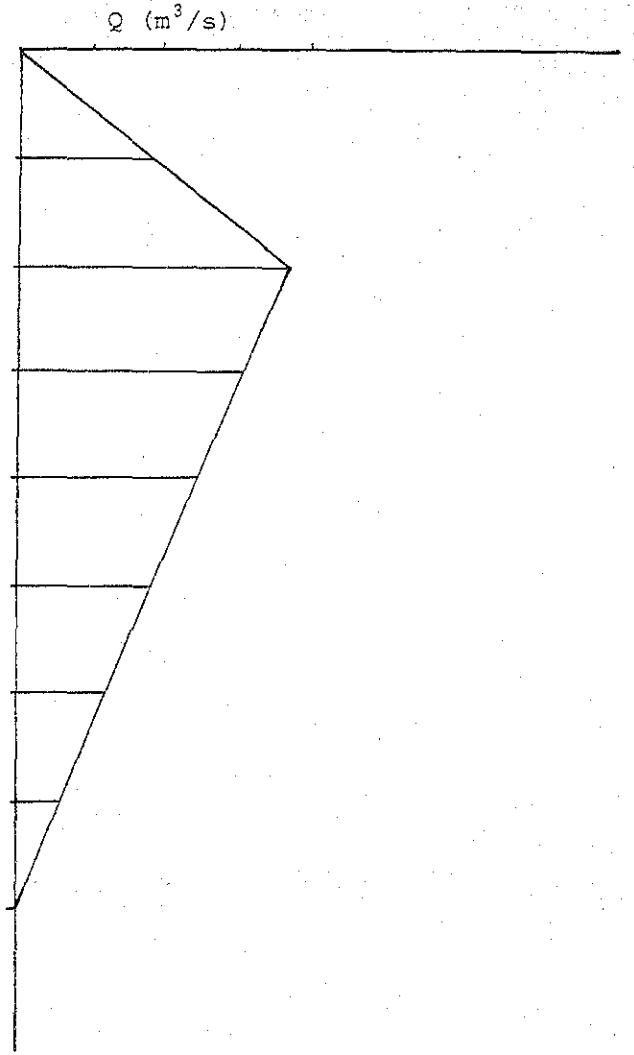


BLACK RIVER LOWER MORASS AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-6 DIAGRAM OF PROPOSED DRAINAGE NETWORK

JAPAN INTERNATIONAL COOPERATION AGENCY

BROAD RIVER LEFT BANK	BROAD RIVER RIGHT BANK	BLACK RIVER LEFT BANK	HOLLAND
0.000	0.000	0.000	0.000
0.375	0.410	0.584	0.345
0.749	0.821	1.168	0.690
0.624	0.684	0.973	0.575
0.500	0.547	0.779	0.460
0.375	0.410	0.584	0.345
0.250	0.274	0.389	0.230
0.125	0.137	0.295	0.115
0.000	0.000	0.000	0.000

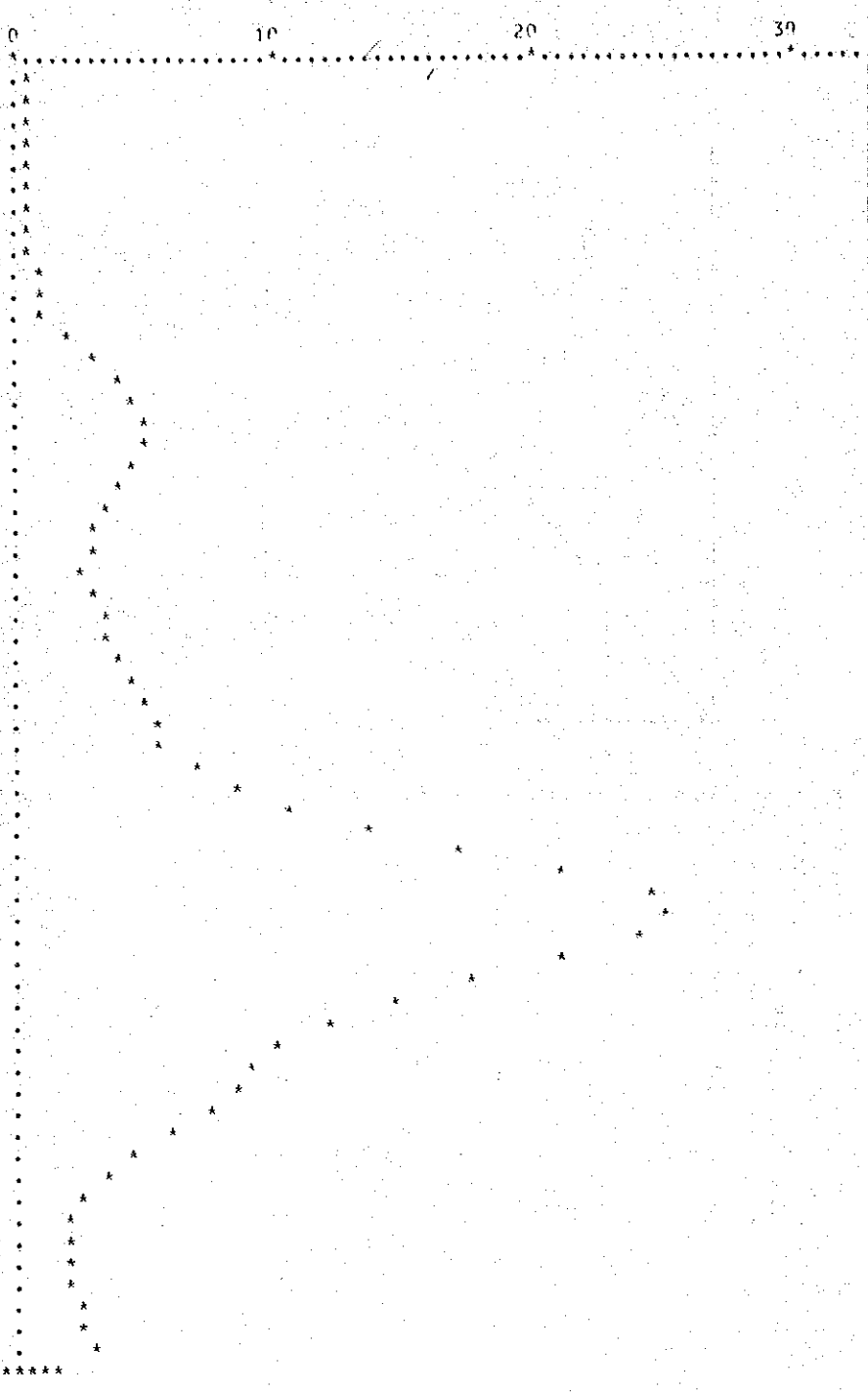


BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-7 UNIT HYDROGRAPH FOR EACH BLOCK

JAPAN INTERNATIONAL COOPERATION AGENCY

N	TQ	BF	TTQ
1	0.000	0.346	0.346
2	0.000	0.346	0.346
3	0.000	0.346	0.346
4	0.000	0.346	0.346
5	0.000	0.346	0.346
6	0.000	0.346	0.346
7	0.072	0.346	0.418
8	0.224	0.346	0.570
9	0.369	0.346	0.715
10	0.505	0.346	0.851
11	0.652	0.346	0.998
12	0.836	0.346	1.182
13	1.442	0.346	1.788
14	2.524	0.346	2.870
15	3.414	0.346	3.760
16	4.168	0.346	4.514
17	4.747	0.346	5.093
18	4.710	0.346	5.056
19	4.307	0.346	4.653
20	3.786	0.346	4.132
21	3.296	0.346	3.642
22	2.878	0.346	3.224
23	2.521	0.346	2.867
24	2.317	0.346	2.663
25	2.471	0.346	2.817
26	2.918	0.346	3.264
27	3.342	0.346	3.688
28	3.771	0.346	4.117
29	4.184	0.346	4.530
30	4.557	0.346	4.903
31	4.932	0.346	5.278
32	5.357	0.346	5.703
33	6.434	0.346	6.780
34	8.190	0.346	8.536
35	10.355	0.346	10.701
36	13.315	0.346	13.661
37	16.889	0.346	17.235
38	20.894	0.346	21.240
39	23.944	0.346	24.290
40	24.651	0.346	24.997
41	23.450	0.346	23.796
42	20.608	0.346	20.954
43	17.147	0.346	17.463
44	13.976	0.346	14.322
45	11.406	0.346	11.752
46	9.608	0.346	9.954
47	8.544	0.346	8.890
48	8.101	0.346	8.447
49	7.130	0.346	7.476
50	5.416	0.346	5.762
51	4.039	0.346	4.385
52	2.983	0.346	3.329
53	2.224	0.346	2.570
54	1.731	0.346	2.077
55	1.546	0.346	1.892
56	1.681	0.346	2.027
57	1.853	0.346	2.199
58	2.050	0.346	2.396
59	2.346	0.346	2.692
60	2.816	0.346	3.162



***** BLACK RIVER RIGHT BANK *****

LEGEND

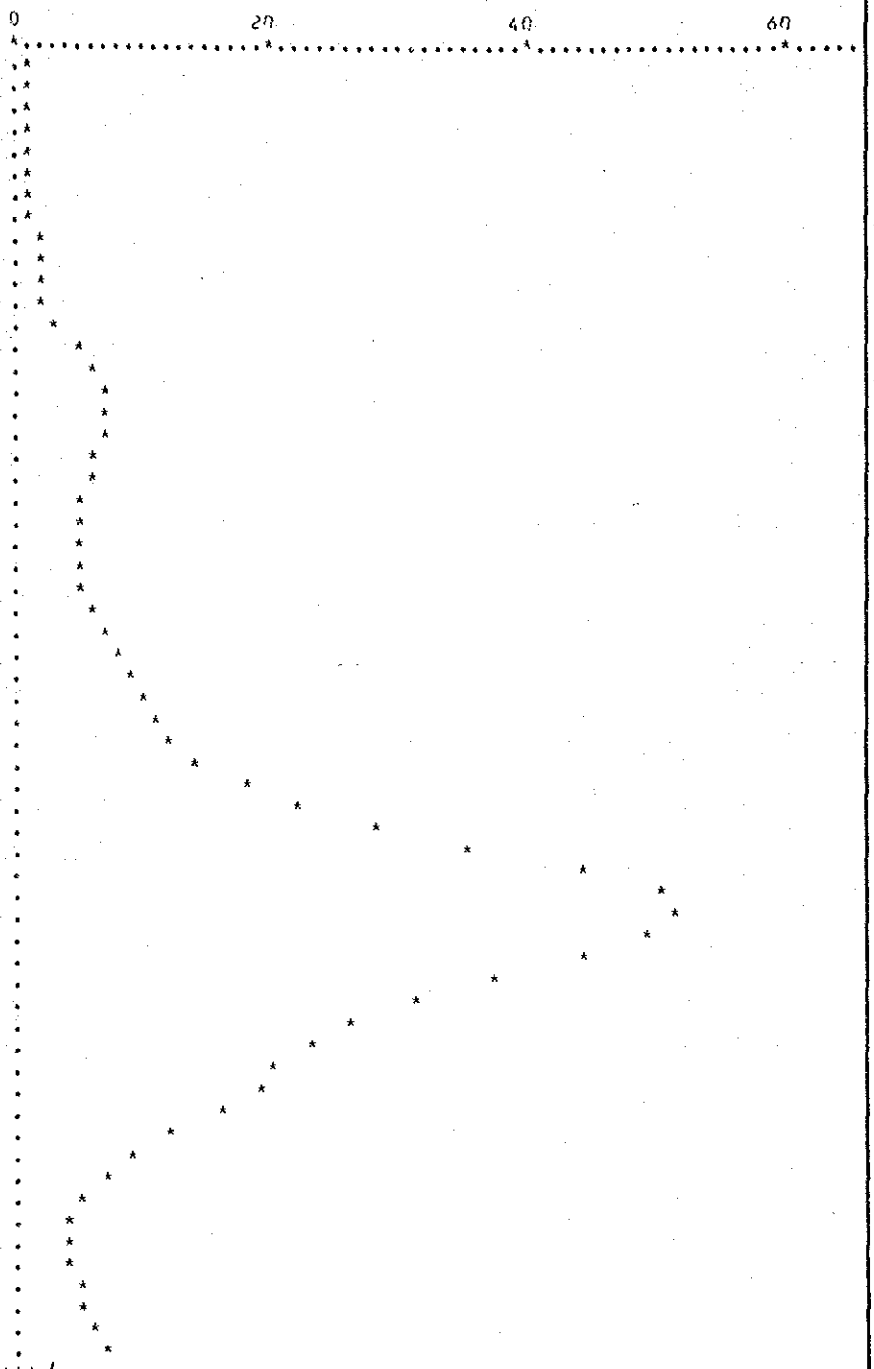
N - Time
TQ - Direct Runoff
BF - Base Flow
TTQ - Total Runoff Discharge

BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-8 HYDROGRAPH
-BLACK RIVER RIGHT BANK-

JAPAN INTERNATIONAL COOPERATION AGENCY

N	TQ	BF	TTQ
1	0.000	0.942	0.942
2	0.000	0.942	0.942
3	0.000	0.942	0.942
4	0.000	0.942	0.942
5	0.000	0.942	0.942
6	0.000	0.942	0.942
7	0.111	0.942	1.053
8	0.345	0.942	1.287
9	0.564	0.942	1.506
10	0.767	0.942	1.709
11	0.989	0.942	1.931
12	1.267	0.942	2.209
13	2.198	0.942	3.140
14	3.868	0.942	4.810
15	5.246	0.942	6.188
16	5.939	0.942	6.881
17	6.011	0.942	6.953
18	5.762	0.942	6.704
19	5.416	0.942	6.358
20	4.886	0.942	5.828
21	4.407	0.942	5.349
22	4.051	0.942	4.993
23	3.780	0.942	4.722
24	3.580	0.942	4.522
25	4.086	0.942	5.028
26	5.314	0.942	6.256
27	6.435	0.942	7.377
28	7.501	0.942	8.443
29	8.474	0.942	9.416
30	9.322	0.942	10.264
31	10.127	0.942	11.069
32	10.981	0.942	11.923
33	13.175	0.942	14.117
34	16.753	0.942	17.695
35	21.161	0.942	22.103
36	27.210	0.942	28.152
37	34.531	0.942	35.473
38	42.757	0.942	43.699
39	49.038	0.942	49.980
40	50.513	0.942	51.455
41	48.073	0.942	49.015
42	42.585	0.942	43.527
43	36.060	0.942	37.002
44	30.087	0.942	31.029
45	25.109	0.942	26.051
46	21.580	0.942	22.522
47	19.234	0.942	20.176
48	17.861	0.942	18.803
49	15.410	0.942	16.352
50	11.542	0.942	12.484
51	8.477	0.942	9.419
52	6.173	0.942	7.115
53	4.555	0.942	5.497
54	3.554	0.942	4.496
55	3.177	0.942	4.119
56	3.453	0.942	4.395
57	3.798	0.942	4.740
58	4.185	0.942	5.127
59	4.767	0.942	5.709
60	5.710	0.942	6.652



** BLACK RIVER LEFT BANK ****

LEGEND

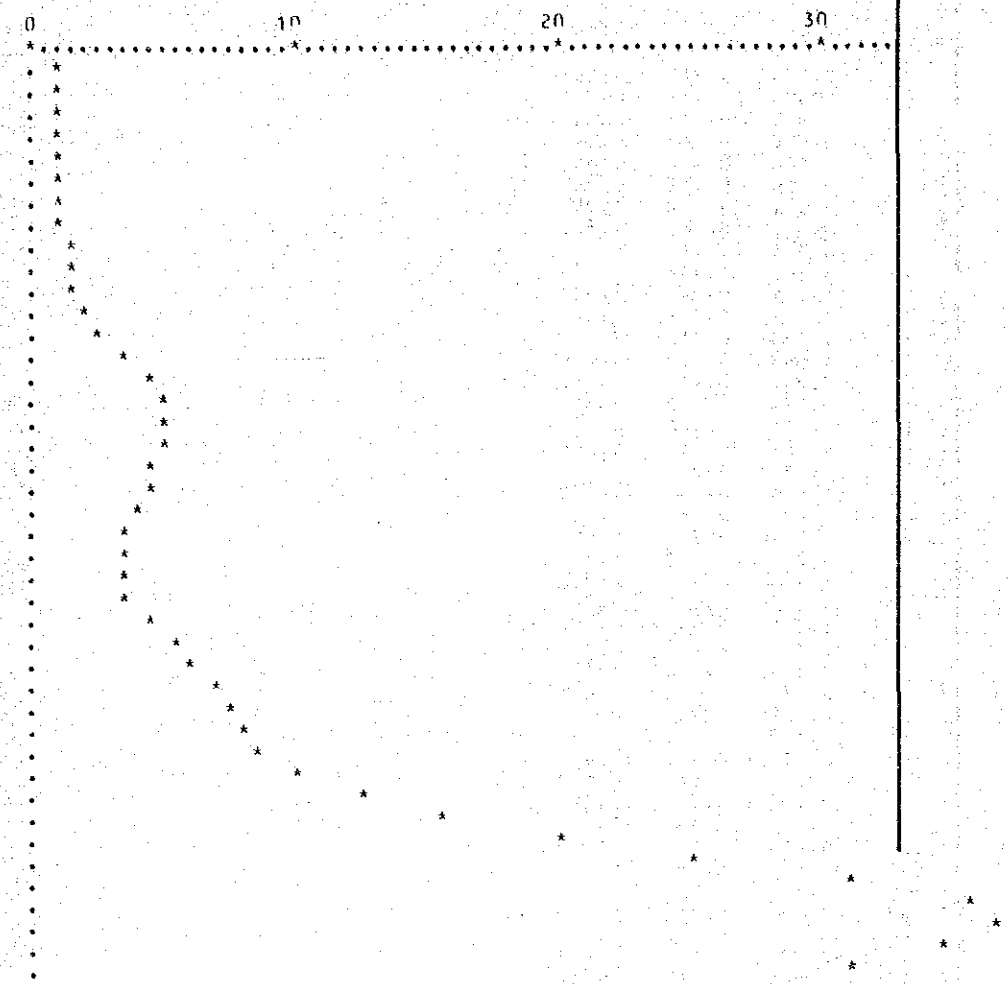
N - Time
TQ - Direct Runoff
BF - Base Flow
TTQ - Total Runoff Discharge

BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-9 HYDROGRAPH
-BLACK RIVER LEFT BANK-

JAPAN INTERNATIONAL COOPERATION AGENCY

N	TQ	BF	TTQ
1	0.000	0.870	0.870
2	0.000	0.870	0.870
3	0.000	0.870	0.870
4	0.000	0.870	0.870
5	0.000	0.870	0.870
6	0.000	0.870	0.870
7	0.078	0.870	0.948
8	0.242	0.870	1.112
9	0.397	0.870	1.267
10	0.539	0.870	1.409
11	0.695	0.870	1.565
12	0.890	0.870	1.760
13	1.544	0.870	2.414
14	2.718	0.870	3.588
15	3.686	0.870	4.556
16	4.173	0.870	5.043
17	4.224	0.870	5.094
18	4.049	0.870	4.919
19	3.806	0.870	4.676
20	3.434	0.870	4.304
21	3.097	0.870	3.967
22	2.847	0.870	3.717
23	2.657	0.870	3.527
24	2.516	0.870	3.386
25	2.871	0.870	3.741
26	3.734	0.870	4.604
27	4.522	0.870	5.392
28	5.270	0.870	6.140
29	5.954	0.870	6.824
30	6.551	0.870	7.421
31	7.116	0.870	7.986
32	7.716	0.870	8.586
33	9.257	0.870	10.127
34	11.772	0.870	12.642
35	14.869	0.870	15.739
36	19.119	0.870	19.989
37	24.263	0.870	25.133
38	30.044	0.870	30.914
39	34.458	0.870	35.328
40	35.495	0.870	36.365
41	33.780	0.870	34.650
42	29.925	0.870	30.795
43	25.341	0.870	26.211
44	21.144	0.870	22.014
45	17.646	0.870	18.516
46	15.165	0.870	16.035
47	13.516	0.870	14.386
48	12.551	0.870	13.421
49	10.830	0.870	11.700
50	8.111	0.870	8.981
51	5.956	0.870	6.826
52	4.338	0.870	5.208
53	3.203	0.870	4.073
54	2.497	0.870	3.367
55	2.232	0.870	3.102
56	2.427	0.870	3.297
57	2.669	0.870	3.539
58	2.941	0.870	3.811
59	3.350	0.870	4.220
60	4.012	0.870	4.882



* BROAD RIVER RIGHT BANK ****

LEGEND

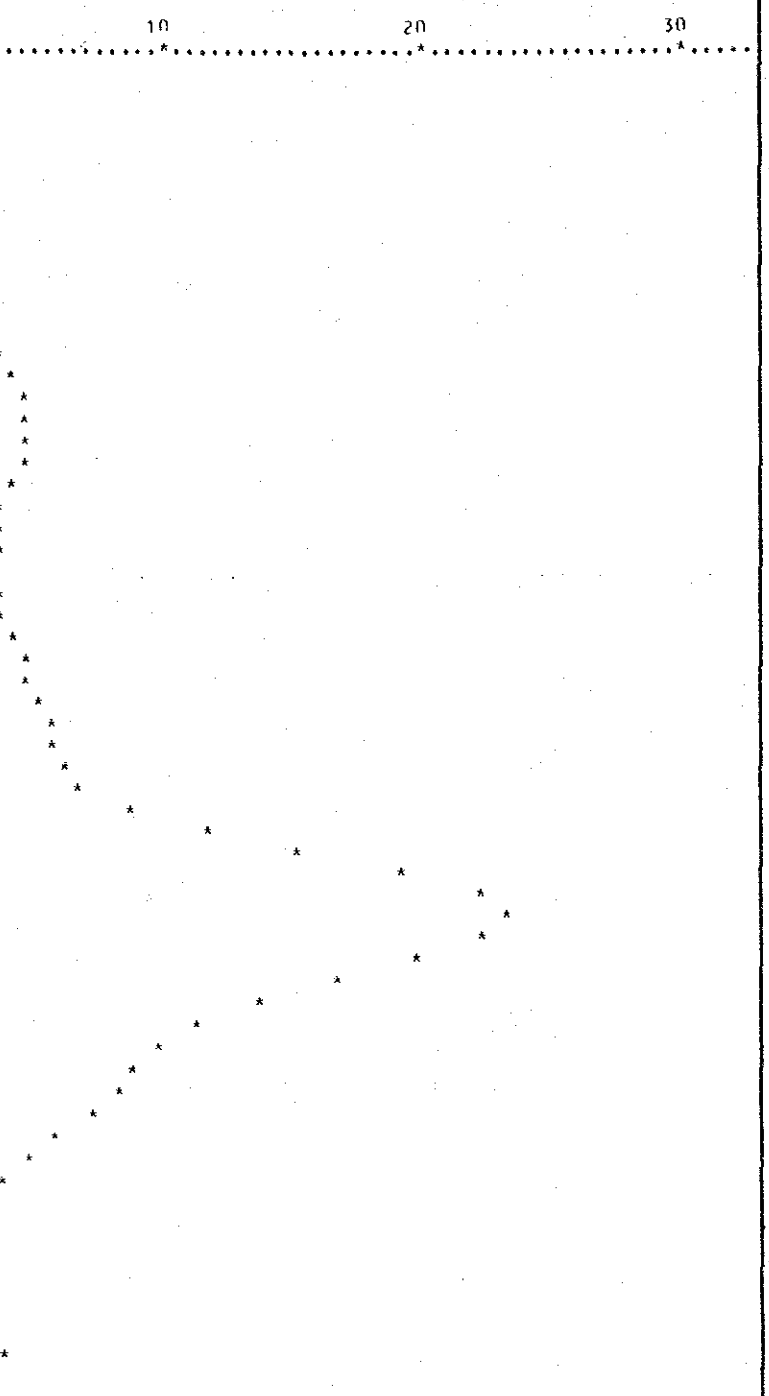
N - Time
TQ - Direct Runoff
BF - Base Flow
TTQ - Total Runoff Discharge

BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-10 HYDROGRAPH
-BROAD RIVER RIGHT BANK-

JAPAN INTERNATIONAL COOPERATION AGENCY

N	TQ	BF	TTQ
1	0.000	0.857	0.857
2	0.000	0.857	0.857
3	0.000	0.857	0.857
4	0.000	0.857	0.857
5	0.000	0.857	0.857
6	0.000	0.857	0.857
7	0.071	0.857	0.928
8	0.221	0.857	1.078
9	0.362	0.857	1.219
10	0.492	0.857	1.349
11	0.635	0.857	1.492
12	0.813	0.857	1.670
13	1.410	0.857	2.267
14	2.482	0.857	3.339
15	3.365	0.857	4.222
16	3.810	0.857	4.667
17	3.857	0.857	4.714
18	3.698	0.857	4.555
19	3.476	0.857	4.333
20	3.136	0.857	3.993
21	2.828	0.857	3.685
22	2.600	0.857	3.457
23	2.426	0.857	3.283
24	2.297	0.857	3.154
25	2.405	0.857	3.262
26	2.758	0.857	3.615
27	3.104	0.857	3.961
28	3.464	0.857	4.321
29	3.815	0.857	4.672
30	4.140	0.857	4.997
31	4.476	0.857	5.333
32	4.862	0.857	5.719
33	5.340	0.857	6.197
34	5.885	0.857	6.742
35	7.462	0.857	8.319
36	10.487	0.857	11.344
37	14.067	0.857	14.924
38	18.038	0.857	18.895
39	21.141	0.857	21.998
40	22.127	0.857	22.984
41	21.221	0.857	22.078
42	18.648	0.857	19.505
43	15.495	0.857	16.352
44	12.660	0.857	13.517
45	10.335	0.857	11.192
46	8.709	0.857	9.566
47	7.640	0.857	8.497
48	7.022	0.857	7.879
49	6.073	0.857	6.930
50	4.606	0.857	5.463
51	3.448	0.857	4.305
52	2.580	0.857	3.437
53	1.978	0.857	2.835
54	1.613	0.857	2.470
55	1.488	0.857	2.345
56	1.616	0.857	2.473
57	1.779	0.857	2.636
58	1.966	0.857	2.823
59	2.251	0.857	3.108
60	2.706	0.857	3.563



** BROAD RIVER LEFT BANK ****

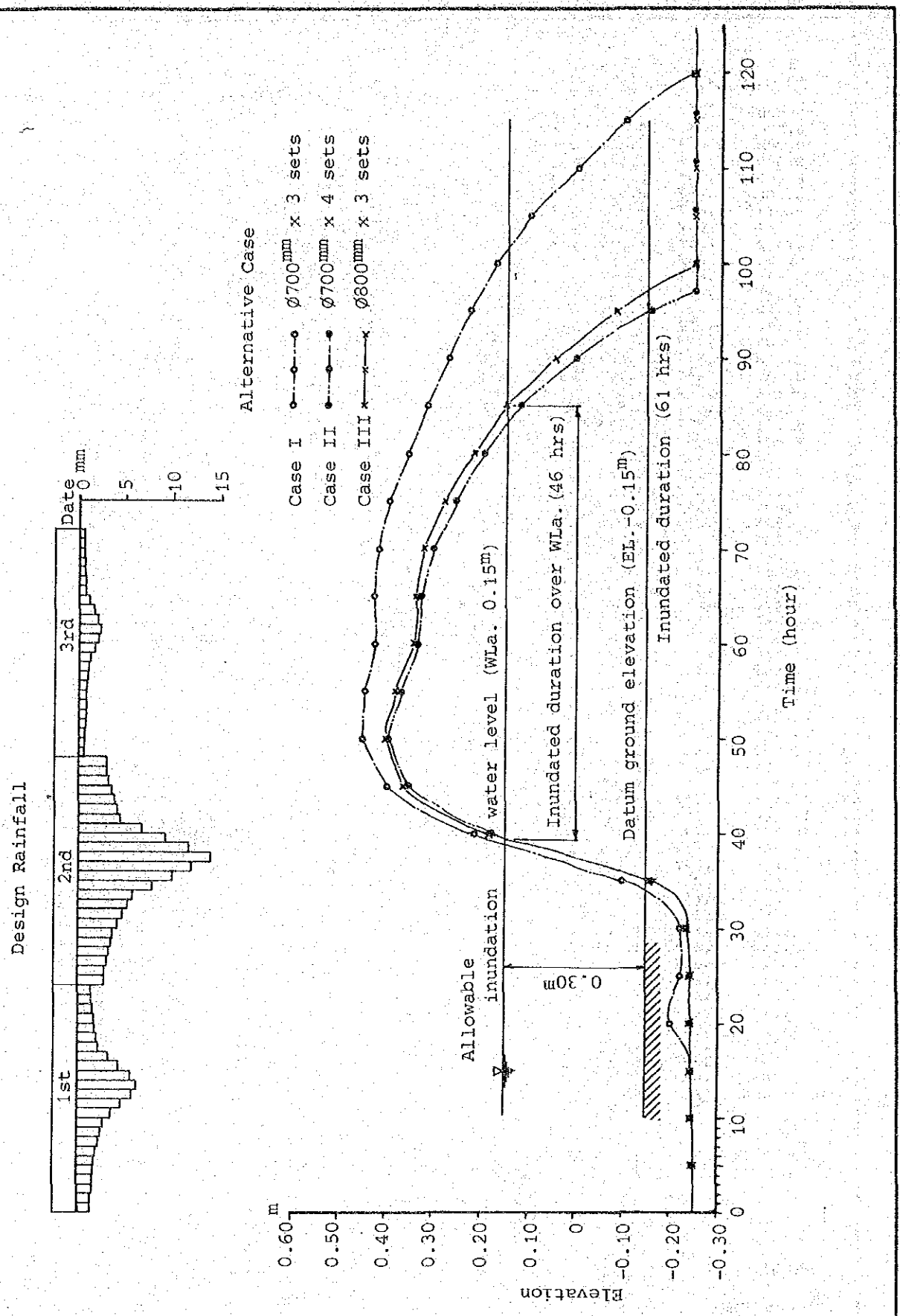
LEGEND

N - Time
TQ - Direct Runoff
BF - Base Flow
TTQ - Total Runoff Discharge

BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-11 HYDROGRAPH
-BROAD RIVER LEFT BANK-

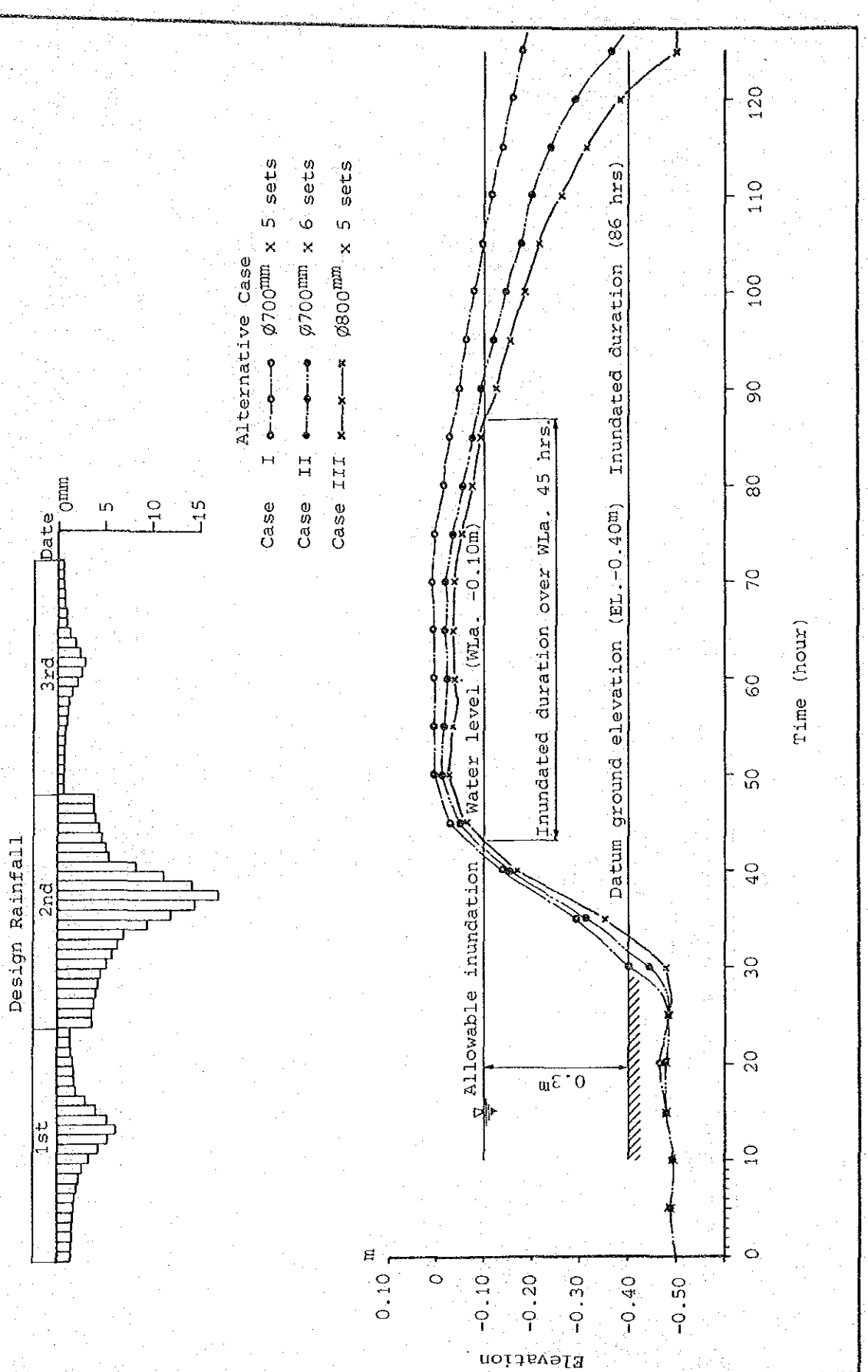
JAPAN INTERNATIONAL COOPERATION AGENCY



BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-12 INUNDATION CURVE
- HOLLAND AREA -

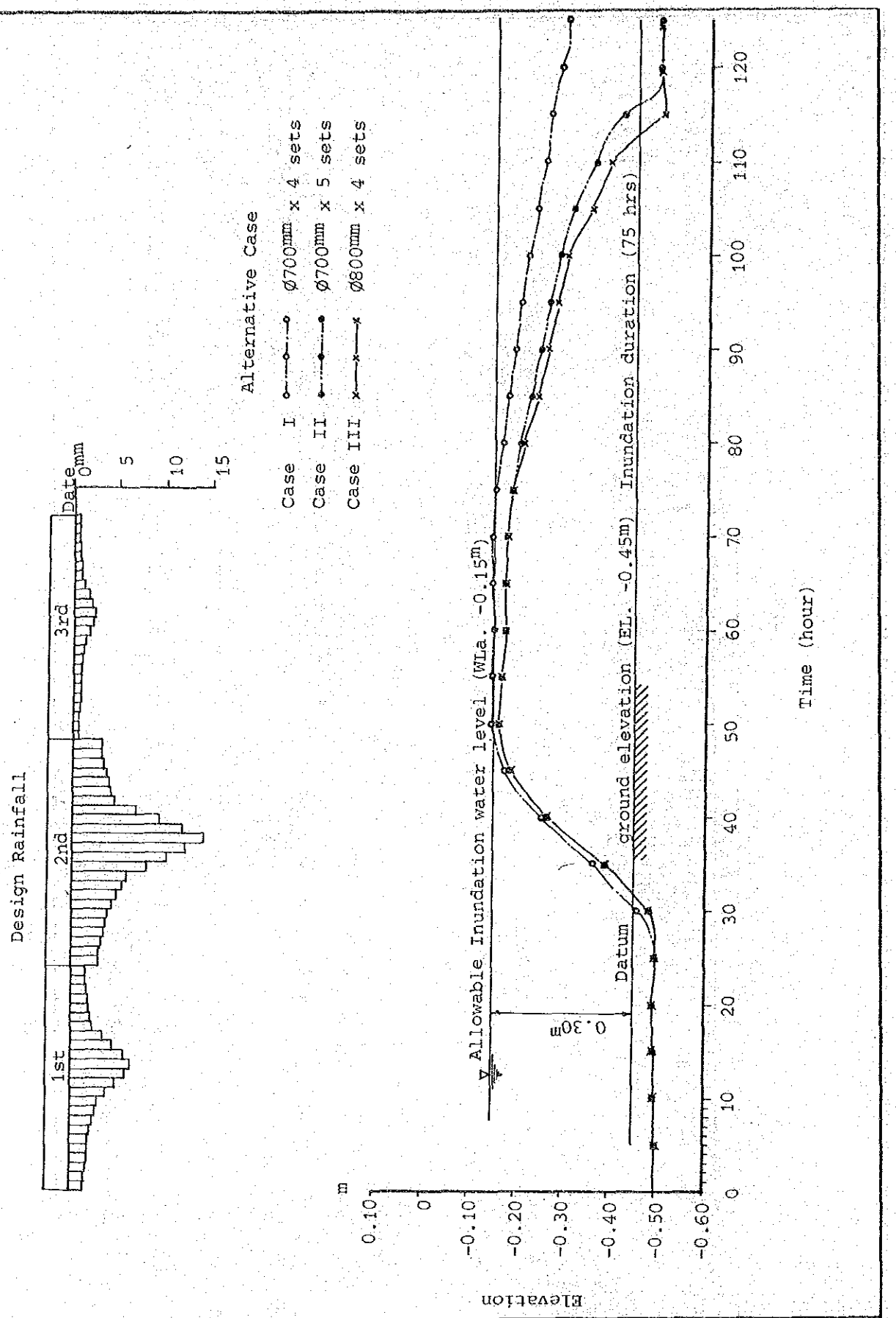
JAPAN INTERNATIONAL COOPERATION AGENCY



BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-13 INUNDATION CURVE
- BLACK RIVER LEFT BANK AREA -

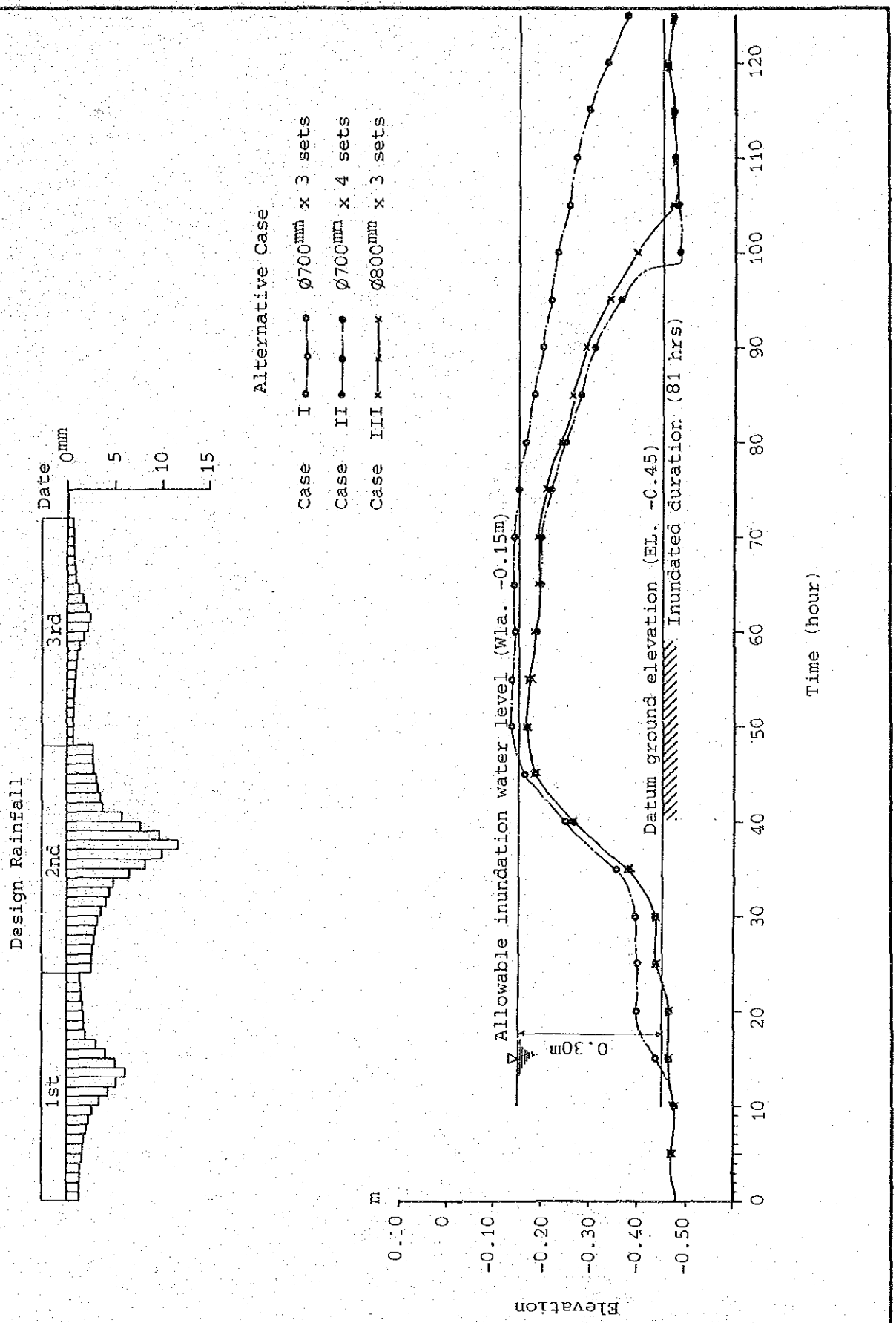
JAPAN INTERNATIONAL COOPERATION AGENCY



BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-14 INUNDATION CURVE
- BROAD RIVER RIGHT BANK AREA -

JAPAN INTERNATIONAL COOPERATION AGENCY



BLACK RIVER LOWER MORASS
AGRICULTURAL DEVELOPMENT PROJECT

Fig. H-15 INUNDATION CURVE

- BROAD RIVER LEFT BANK AREA -

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX I

IRRIGATION

ANNEX I

IRRIGATION

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ANNEX I

IRRIGATION

1. PRESENT CONDITION

1.1 Land Use and Existing Irrigation System

The project area of about 11,450 ha located in central south coast of St. Elizabeth parish covers a sugar cane estate, mostly in Holland Estate, pasture of upland grassland and some mixed farming land as well as swamp and forest. The present land use described in Annex G shows that, although about 6,760 ha or 59% of the total project area are covered by swamp and forest, there exist about 2,760 ha or 24% of pasture, 920 ha or 8% of sugar cane, and about 680 ha or 6% of upland crops / pastures mixed farming land and about 330 ha or 3% of other mixed farming land including paddy.

There are no systematic irrigation facilities even for the sugar cane of the Holland Estate which had an intake structure across the Y.S. River about 1.5 km upstream of the Santa Cruz - Black River Highway (Bamboo avenue) crossing. The intake structure and canal were constructed for supplying cooling water to the sugar factory since the late 1920s when it was established. The facilities might be used to supply some irrigation water for sugar cane when necessary. However, at present, they are derelict and not used even for irrigation since the factory was closed in 1981.

1.2 Irrigation Developments Outside the Lower Morass

In Pedro Plain, south of the Lower Morass, an irrigation system, the Hounslow irrigation scheme, is being operated. A successful and advanced irrigation practice has been introduced. At present, 670 ha (1,680 ac) are irrigated by sprinklers from four wells for such upland crops as groundnuts, soya beans, water melons, various kinds of vegetables and so on.

In the Upper Morass of the Black River, about 3,600 ha (9,000 ac) of farmland were developed with the construction of flood protection dikes along the Black River, drainage canal systems and three drainage pump stations by the Black River Uqper Morass Development Company Limited (hereinafter called "BRUMDEC"). These constructions were completed in November 1981. Most of the originally designed irrigation facilities have not been constructed.

BRUMDEC commenced rice cultivation in 1981 during construction, and now manages about 2,200 ha (5,515 ac) of paddy fields. Most of the paddy fields are not irrigated systematically but water levels in drainage canals are kept high enough to facilitate sub-surface flow into the fields. Only a limited area including the Elim rice research station located at north-east corner of the Upper Morass is irrigated with water diverted from the Elim River, one of the tributaries of the Black River. Flood irrigation is practised in these paddy fields.

In the Parish of Westmoreland, about 60 km west of Black River, the Meylersfield West Polder Project has been implemented for mechanized small-holders irrigated rice cultivation. The irrigation system and land clearing of about 140 ha (345 ac) were completed by the end of October 1982. Production was commenced in 1983. The total rice cultivated acreage was about 70 ha (180 ac) in 1983 and at present is about 100 ha (250 ac) or three-fourth of total land. Flood irrigation is practised by pumping water from the river and regulating it in a farm pond. Operation and maintenance of irrigation and drainage systems are undertaken by the said project which, however, is facing expensive requirements to prevent irrigation and drainage canals from clogging by weeds. The following shows the expenditures in 1983 and 1984 (until August) for operation and maintenance of both irrigation and drainage systems.

Description	1983 (Jan. - Dec.)	1984 (Jan. - Aug.)
Area planted	70 ha (180 ac)	100 ha (250 ac)
Total Expenditure for O & M	J$132,000	J$133,000
Annual Expenditure	J$132,000	J$200,000
per unit area	J$1,900/ha (730 ac)	J$2,000/ha (800/ac)
for drainage pump	J$700/ha (270/ac)	J$810/ha (325/ac)
for Irrigation pump	J$800/ha (310/ac)	J$960/ha (385/ac)
for Maintenance of Irrigation canal	J$400/ha (150/ac)	J$230/ha (90 ac)

1.3 Existing Development Plan

Technical and economical viabilities of the agricultural development in the Black River Lower Morass were first studied by Grontmy of the Netherlands in 1964 as the Black River Morass Reclamation Project. Since submission of the feasibility report by Grontmy in September 1964, some works have been implemented within the Lower Morass. These have comprised the construction of about 2 km of embankment to divert the Y.S. River and a dredged by-pass channel of the Y.S. River to and along the Middle Quarters River. A bridge across the Styx River at its confluence with the Black River was also constructed at this stage in April 1973. However, neither road nor dike was constructed along the left bank of the Black River. Such construction was suspended in the mid 1970s when efforts were concentrated on the implementation of the Upper Morass Development Project.

Except for some drainage improvement works on the Holland Estate in the 1970s, no other projects have been implemented in the Black River Lower Morass. At present, under the Agro 21 programme, an early development of a part of the Holland Estate for rice cultivation is under study.

2. DEMARCATION OF AREA FOR IRRIGATION DEVELOPMENT

2.1 Factors to be Considered in the Selection of Area

1) Land suitability classification

Based on the evaluation of land capability, the areas classified in Grade II, III and IV were taken up as the areas for agriculture. In this evaluation, the factors affecting the delineation are soil texture, topography, soil depth, fertility, drainability, soil salinity and acidity and soil physical properties. These are described in detail in Annex D.

2) Present land use

The present land use and vegetation were also taken into account for the delineation, viz., the western marshland sandwiched between the Black River and the Middle Quarters River is intensively used as shrimp fishing area by local fishermen, while the lower basin of the Black River is covered by mangrove forest. Detailed explanation is made in Annexes D and G.

3) Soil physical characteristics

In the project area, a vast marshland composed of peat extends over about 5,100 ha of the lowland. The peat layer is from 1 m to 10 m in depth. The extremely low bearing capacity of these peat soils would require considerable expense for construction of irrigation and drainage infrastructures. In addition, subsidence of soils after implementation could be relatively large due to desiccation and consolidation of soils as well as due to progressive biological oxidation of peat. From these viewpoints, peat soils of more than 4 m depth are excluded from the agricultural development to be proposed. This is explained in detail in Annexes E and H.

4) Peat mining plan area

According to the Environmental Feasibility Study of the Jamaica Peat Resources Utilization Project prepared by Natural Resources Conservation Department (hereinafter "NRCD") in September 1981, a large potential of peats volume is located in the Middle Quarters River basin, which is excluded from the agricultural development area.

5) Ecological considerations

In the Lower Morass noticeable and perculiar herbaceous swamp and swamp forests and precious wildlife are observed. The Black River Morass system offers one of the few diverse and stable wetland habitats in the Caribbean for many forms of wildlife. In order to minimize the environmental impacts on the above, the development area was carefully delineated on particularly in regard to the swamp forest and surroundings of the Broad River. A detailed explanation is given in Annex K.

2.2 Area to be Developed

The area to be developed for the feasibility of the project was selected from the project area of about 11,450 ha taking the above factors into consideration.

For the sake of establishing of efficient irrigation systems, the area to be studied was divided into four sub-areas. These are (1) the Black River right bank bounded by the Middle Quarters River, (2) the Black River left bank bounded by the Lacovia - Cataboo road and the edge of the swamp along the Island of Cataboo and Holiday Pen, (3) the Broad River Basin bounded by the Lacovia - Cataboo - Black River road and the Lacovia - Mountainside - Black River road, (4) the western part of the Middle Quarters River and the estuary of the Black River and Broad River. The fourth sub-area, however, was excluded from the development from the viewpoint of topography, present land use and inadequate irrigation water availability (see Fig. I-1). The respective areas of the proposed sub-areas are as follows:

(Unit: ha)

Area	Gross	Net (Acres)
Black River right bank	680	560 (1,400)
Black River left bank	1,200	920 (2,300)
Broad River Basin	2,000	1,600 (4,000)
Estuary - Middle Quarters	-	-
Total	3,880	3,080 (7,700)

A total area of 720 ha is left as it is for the existing Holland Estate, in which sugar cane is presently cultivated in 910 ha (2,275 ac.). As mentioned in the previous Section 2.1, (5) both sides of the Broad River (360 ha) are preserved from the agricultural development.

The location of each sub-area is shown in Fig. I-1 and breakdown of physical area is shown in Table I-1. A detailed explanation of each of the sub-areas is given below.

1) The Black River Right Bank

The right bank area of the Black River, about 2,540 ha, consists of three sub-areas, 260 ha in Lacovia, 1,400 ha in the Holland Estate and 880 ha along the Y.S. River (on both banks). There are nine main soil types in this area, of which five are in upland area of Lacovia and the Holland Estate and four in inundated area along the Y.S. River as shown in Table D-15 in Annex D. Most of the land covered by upland soil (1,580 ha) in the Holland Estate and Lacovia are classified as suitable (Class II) for upland crops as well as for paddy cultivation, while about 390 ha or 40% of wetland in inundated area would be moderately suitable (Class III and IV) for rice cultivation and only 170 ha or 18% are for upland crops. The rest of inundated soils would be marginally suitable or unsuitable for rice cultivation as well as for upland crops.

As Lacovia is a village where mixed culture of trees, grassland or pasture, upland crops, vegetables, etc. in house yards is predominant, no agricultural development was considered. Accordingly, the irrigable area was delineated in the Holland Estate including suitable areas along the Y.S. River.

Holland Estate

Out of 1,900 ha (4,750 ac) of registered acreage, about 200 ha (500 ac) are located outside the project area (north of Bamboo avenue) and about 300 ha (750 ac) are undeveloped swamp and forest lying between the Y.S. River and the Black River, where the soils are only marginally suitable for agricultural development not only from such technical points of view as soil conditions (see Annex D) and soil mechanical

conditions (see Annex E and Annex H) but also from environmental considerations (see Annex K and Annex L). Thus the present arable land of the Holland Estate in the project area was estimated to be 1,400 ha (3,500 ac). Out of 1,400 ha as shown in Table I-2, 910 ha (about 2,300 ac) are under cultivation of sugar cane, 110 ha (about 280 ac) are under a mixed culture of paddy and swampy grass (fallow) and about 180 ha (450 ac) are covered with grasses or in fallow. The remaining 180 ha (450 ac) are swampy grassland lying along the Black River right bank and left bank of the upper reach of the Y.S. River, exclusive of about 20 ha (50 ac) of factory and quarters yards.

The main arable lands of the Holland Estate have three particular characteristics. The elevation is an above El. 3.00 m. About 85% of a gross 540 ha is covered mainly with cane fields (about 460 ha or 85%), some grassland (60 ha or 11%), and factory and quarters yards (20 ha or 4%). This land is gently undulating and its surface slope ranges from 1/500 to 1/30 or 1/200 on an average. These areas would be moderately suitable for irrigated upland crops farming.

There are also about 370 ha of low lying flat land below El. 1.00 m, with only 70 ha or 19% of cane fields and where a mixed culture of rice and swampy grass (fallow) is dominant on 90 ha or 24%. The remainder is occupied by grassland (40 ha or 11%) and swamp (170 ha or 46%). The slope of these areas is quite gentle: less than 1/1,000. These areas would be suitable for paddy cultivation.

In-between above two areas there are about 490 ha lying between El. 1.00 m and El. 3.00 m. About one third of this land is composed of rather steepy sloping strips sandwiched between the elevated and low lying areas. The slopes range from 1/200 to 1/30. The rest is a flat land with gentle surface slopes of about 1/500 on an average. About 380 ha or 78% of this land are cultivated with sugar cane at present, while 90 ha or 18% are grassland or swamp and 20 ha or 4% are paddy field. The flat area in this category would be suitable for irrigated paddy cultivation while the sloped strips would be only moderately suitable for the same purpose.

In general, paddy rice is grown by flood irrigation method. Land suitable for paddy cultivation should be flat and its soils should be reasonably impermeable. Most of the soils in the Holland Estate are classified as clay soil as shown in soil map in Annex D. The irrigable area for rice cultivation was generally delineated within the flat land, excluding the elevated undulating lands above El. 3.0 - 4.0 m and the sloping lands lying below El. 3.00 m where economical land levelling works would require reduction in the size of a farm plot to as small as 0.4 ha (1.0 ac). Thus, the irrigable area delineated is about 680 ha gross (560 ha net), of which present land use is shown below:

(Unit: ha)

Present Land Use	Below El. 1.0 m	El. 1.0 - El. 3.0 - El. 4.0 m	Total
Cane fields	70	240	310
Paddy fields	90	20	110
Grass/Pasture	40	50	90
Swamp	160	10	170
Total	360	320	680

Accordingly, the remaining area of 720 ha would be reserved for sugar cane and other crops. The present land use is shown below.

(Unit: ha)

Present Land Use	Below El. 1.0 m	El. 1.0 - El. 3.0 - El. 4.0 m	Above 4.0 m	Total
Factory & Quarters	0	0	20	20
Cane fields	0	150	450	600
Grass/Pasture	0	30	60	90
Swamp	10	0	0	10
Total	10	180	530	720

2) The Black River Left Bank

The left bank area of the Black River, about 2,320 ha, consists of four (4) sub-areas, 370 ha of Hatfield, 410 ha of Styx River basin, 800 ha of Frenchman-Holiday Pen and 740 ha of the Island of Slipe and Cataboo.

In Hatfield and Frenchman-Holiday Pen upland area, there are six (6) main soil types. Out of these, five are classified as suitable or moderately suitable (Class II and III) for both upland crops and rice cultivation, with their area of 900 ha or 86% and the rest is marginally suitable with extremely rocky complex. However, the Island of Slipe and Cataboo are village areas where a mixed culture of trees, pastures and partly upland crops is predominant. The irrigable area in such upland is, therefore, delineated mainly in Hatfield.

The Styx River basin and Frenchman-Holiday Pen are wetlands, and three main soil types are observed in the inundated area, except for some forest land. One is mineral soil (clay) observed along the natural levee on the left bank of the Black River. The other two are inundated peat. The whole of this land is classified as moderately suitable (Class III or IV) for rice cultivation but only marginally suitable for upland crops.

The irrigable areas delineated for rice cultivation after planning of the irrigation canal networks totalled about 1,200 ha gross (920 ha net), in the left bank of the Black River as shown below:

(Unit: ha)

Sub-area	Gross	Net
Hatfield	300	220
Styx River Basin	400	300
Frenchman-Holiday Pen	500	400
Total	1,200	920

3) Broad River Basin

The Broad River Basin of about 3,910 ha is divided into four sub-areas based on their topographic characteristics, i.e., the Broad River right bank area of about 1,290 ha, the left bank area of about 1,300 ha, a strip of about 760 ha of mountain skirt along the Lacovia - Mountainside road, and the Vineyard - Arlington are of about 560 ha in southern elevated land of the project area. Both right and left bank areas of the Broad River are covered with peat and are classified as moderately suitable for rice cultivation but only marginally suitable for upland crops. On the other hand, in the strip of mountain skirt and Vineyard - Arlington area, there are seven main soil types. About 230 ha in the strip of mountain skirt and 190 ha in Vineyard - Arlington, covered by three out of seven soil types, are classified as suitable for irrigated farming. The suitable land in the strip of mountain skirt was included in the irrigable area of both right and left bank areas of the Broad River. The irrigable area in Vineyard was included under the Pedro Plain Irrigation Project. The irrigable area delineated amounts to about 2,000 ha gross and 1,600 ha net, consisting of 1,000 ha on the right bank and 1,000 ha on the left bank as below:

(Unit: ha)

Broad River Basin	Gross	Net
Right Bank	1,000	800
Left Bank	1,000	800
Mountain skirt	included in above	
Vineyard - Arlington	included in Pedro Plain	
Total	2,000	1,600

The above areas exclude the 360 ha set aside for conservation and protection of natural environment.