Annex F Irrigation and Drainage

Annex F. Irrigation and Drainage

List of Table

List of Figure

F.1 Irrigation

F.1.1 Crop Evapotranspiration (ET crop) and Effective Rainfall

The crop evapotranspiration and effective rainfall were estimated as described below.

(1) Meteorological Data

The monthly average values of meteorological data, such as the Epan[2/], as shown in Table F.1.2.

Notes: 1/ Class A

2/ Wind velocity = Average value between 1971 and 1984,
Relative humidity = Average value between 1969 and 1984,
Epan = Average value between 1970 and 1976

(2) Estimation of Reference Crop Evapotranspiration (ETo)

The ETo can be obtained from the following formula.

ETo = Kp x Kpan (mm/month or mm/day)

where, Kp : Pan coefficient
Epan : Pan evaporation

Using the pan local condition, wind velocity and average humidity, the year-round Kp is given at 0.75 in Table 18 of FAO Paper No. 24 "Crop Water Requirements." The results of the above calculation are shown in Table F.1.2.

(3) Consumptive Use (ET crop)

The consumptive use (ETcrop) is calculated by the following formula.

ETcrop = ETo x Kc (mm/month or mm/day)

where, kc : Crop coefficient

The values of Kc in the middle and late growing stages were taken from Table 21 of FAO Paper No. 24 "Crop Water Requirements," but the values shown in Part I-2-(c), (d) and (k) of the same FAO paper were used for rice, bananas and cacaos. The Kc in the initial growth stage is based on Fig. 1 of the same paper. In using this figure, the recurrence interval of significant rainfall was estimated from the 36-year rainfall record at La Lola.

The values of Kc and ETcrop are shown in Table F.1.3.

(4) Monthly Effective Rainfall

The monthly effective rainfall was calculated using the 36-year rainfall data at La Lola and Table 5 of FAO Paper No. 25 "Effective Rainfall," and the following values were used.

0 – 25.4 mm	100%
25.4 – 50.8 mm	95%
50.8 – 76.2 mm	90%
76.2 – 101.6 mm	80%
101.6 – 127.0 mm	60%
127.0 – 152.4 mm	40%
More than 152.4 mm	10%

The monthly effective rainfall is shown in Table F.1.4.

Table F.1.1 (1) Comparison of Effective Rainfall with Crop Evapotranspiration(ET Crop) - in case of Monthly Average Rainfall

Unit: mm/month

Description		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
Effective Rainfall		133.4	124.8	119.6	152.3	131.2	133.8	143.2	132.9	121.6	128.0	143.7	152.6
ET_{crop}	Rice	87.3	84.0		89.1	85.8	80.3	73.3	100.1	83.4		62.8	60.1
	Maize	76.8	46.2			76.2	72.7	76.8	52.4			59.3	63.5
	Kidney Bean	69.8	88.2	29.0									
	Tuber Crop					76.2	61.2	62.8	85.8	92.2	90.6	52.4	50.1
	Banana	76.8	75.6	77.4	39.6	38.1	34.4	34.9	57.2	61.5	73.3	69.8	73.5
	Cacao	76.8	92.4	106.5	108.9	104.8	84.2	76.8	104.8	96.6	94.9	76.8	73.5
Water Shortage	Rice	-	-		-	-	-	-	-	-		-	-
	Maize	-	-			-	-	-	-			-	-
	Kidney Bean	-	-	-									-
	Tuber Crop					-	-	-	-	-	-	-	-
	Banana	-	-	-	-	-	-	-	-	-	-	-	-
	Cacao	-	-	-	-	-	-	-	-	-	-	-	-

Note: 1. Effective rainfall is tubulated in Table F.1.4.
2. ET_{crop} is tabulated in Table F.1.3.

Table F.1.1 (2) Comparison of Effective Rainfall with Crop Evapotranspiration(ET Crop) - in case of 70% Monthly Average Rainfall

Unit: mm/month

Description		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
Effective Rainfall		121.5	91.4	86.6	94.7	121.6	125.0	123.1	124.0	98.3	121.7	132.3	135.2
ET_{crop}	Rice	87.3	84.0		89.1	85.8	80.3	73.3	100.1	83.4		62.8	60.1
	Maize	76.8	46.2			76.2	72.7	76.8	52.4			59.3	63.5
	Kidney Bean	69.8	88.2	29.0									63.5
	Tuber Crop					76.2	61.2	62.8	85.8	92.2	90.6	52.4	50.1
	Banana	76.8	75.6	77.4	39.6	38.1	34.4	34.9	57.2	61.5	73.3	69.8	73.5
	Cacao	76.8	92.4	106.5	108.9	104.8	84.2	76.8	104.8	96.6	94.9	76.8	73.5
Water Shortage	Rice	-	-		-	-	-	-	-	-		-	-
	Maize	-	-			-	-	-	-			-	-
	Kidney Bean	-	-	-									-
	Tuber Crop					-	-	-	-	-	-	-	-
	Banana	-	-	-	-	-	-	-	-	-	-	-	-
	Cacao	-	(1%) 1.0	(19%) 19.9	(13%) 14.2	-	-	-	-	-	-	-	-

Note: 1. Effective rainfall is tubulated in Table F.1.4.
2. ET_{crop} is tabulated in Table F.1.3.
3. Number in parenthesis shows rate of water shortage to ET_{crop}

Table F.1.2 Reference Crop Evaportranspiration (ETo)

Description		Month												Remarks
		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	
Wind Velocity	km/day	158	156	168	173	151	134	146	142	146	142	156	161	<175
Relative humidity %		(85) 87	(84) 86	(82) 85	(82) 84	(82) 86	(86) 87	(87) 88	(86) 87	(83) 86	(84) 86	(87) 87	(87) 87	> 70
Pan Coefficient (K^P)		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	
Pan Evaporation	mm/month	93	112	129	132	127	102	93	127	117	115	93	89	
ET_o	mm/month	69.8	84.0	96.8	99.0	95.3	76.5	69.8	95.3	87.8	86.3	69.8	66.8	
ET_o	mm/day	2.3	3.0	3.1	3.3	3.1	2.6	2.3	3.1	2.9	2.8	2.3	2.2	

Note: 1. Average value of wind velocity relative humidity and pan evaporation are taken from observation period of the La Lola Station.

2. Pan is adopted from CLASS A.

3. To determine the value of pan coefficient, location of the station, wind velocity relative humidity are considered.

Table F.1.3 Crop Coefficients and ET Crop

Description		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
ET_o	mm/day	2.3	3.0	3.1	3.3	3.1	2.6	2.3	3.1	2.9	2.8	2.3	2.2
	mm/month	69.8	84.3	96.8	99.0	95.3	76.5	69.8	95.3	87.8	86.3	69.8	66.8
K_c	Rice	1.25	1.0		0.9	0.9	1.05	1.05	1.05	0.95		0.9	0.9
	Maize	1.1	0.55			0.8	0.95	1.10	0.55			0.85	0.95
	Kidney Bean	1.0	1.05	0.3									0.95
	Tuber Crop					0.8	0.8	0.9	0.9	1.05	1.05	0.75	0.75
	Banana	1.1	0.9	0.8	0.4	0.4	0.45	0.5	0.6	0.7	0.85	1.0	1.1
	Cacao	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
ET_{crop} mm/day	Rice	2.9	3.0		3.0	2.8	2.7	2.4	3.3	2.8		2.1	2.0
	Maize	2.5	1.7			2.5	2.5	2.5	1.7			2.0	2.1
	Kidney Bean	2.3	3.2	0.9									2.1
	Tuber Crop					2.5	2.1	2.1	2.8	3.0	2.9	1.7	1.7
	Banana	2.5	2.7	2.5	1.3	1.2	1.2	1.2	1.9	2.0	2.4	2.3	2.4
	Cacao	2.5	3.3	3.4	3.6	3.4	2.9	2.5	3.4	3.2	3.1	2.5	2.4
ET_{crop} mm/month	Rice	87.3	84.0		89.1	85.8	80.3	73.3	100.1	83.4		62.8	60.1
	Maize	76.8	46.2			76.2	72.7	76.8	52.4			59.3	63.5
	Kidney Bean	69.8	88.2	29.0									63.5
	Tuber Crop					76.2	61.2	62.8	85.8	92.2	90.6	52.4	50.1
	Banana	76.8	75.6	77.4	39.6	38.1	34.4	34.9	57.2	61.5	73.3	69.8	73.5
	Cacao	76.8	92.4	106.5	108.9	104.8	84.2	76.8	104.8	96.6	94.9	76.8	73.5

Note 1. Value of K_c was taken from FAO, Irrigation and Draiange Paper No.24.

2. Average interval of rainfall is estimated from the record for 36 years at La Lola Station.

Table F.1.4 Monthly Rainfall and Effective Rainfall at La Lola

(Unit: mm/month)

Year	JAN. O	JAN. R	FEB. O	FEB. R	MAR. O	MAR. R	APR. O	APR. R	MAY O	MAY R	JUN. O	JUN. R	JUL. O	JUL. R	AUG. O	AUG. R	SEP. O	SEP. R	OCT. O	OCT. R	NOV. O	NOV. R	DEC O	DEC R
1950		238		499		184		128		400		578		465	6	145	1	40		260		674		932
51	10	182		611		188		175	5	128		456		321		241		197		319	7	246	2	177
52		317		166	8	80	9	98		192		300		357	7	147	3	57		574	9	278		435
53		497		151		111		170		343		271		322		518	5	81		240		302		405
54		-	4	79		151		278		276		229	6	203	10	210		179		212		604		814
55	6	168		210		211		158		252	2	133	10	260	1	42	8	103		451		379	10	321
56		556	8	98		191		247		468	7	204		568	5	143		266	6	153		375		672
57		236		165	3	59		111		397		370		600		481		136		196		410		588
58		348		495		312	6	73		738	9	214	5	200		229	6	85	2	103	2	140		-
59	3	98		102		165		329	7	165		351		461		266	11	112	1	44		371	9	297
60		265		186		191		206	10	181		295		273		506	4	80	3	127	5	207		522
61	8	177	11	100		214	2	59	3	115		527		607		215		190		392		346		449
62		340	5	83	5	68		149		250		248		383		226		225		276		1,003		771
63		281		120		306		590		280		253	9	250	8	159		139		270		441		699
64	7	171	1	10		203		142		327	6	193		270		243		140		359	8	258	7	274
65		594		273		377	5	66		524		324		755		395		189		341		563		512
66		626		279		159		438		388	4	177	8	244		264		132		308		460		830
67		345	6	89	11	95		399		391		552		363		294		161		224		461	11	324
68		255		305		423		343	9	183	3	162		571	11	211		297		315		430		362
69	9	178		107		114	7	79	1	79		280		370	9	174		390		224		600		632
70		629		779		219		679		328	11	221	2	131	4	130		244	11	190		617		1,446
71		315	7	90		205		257	2	111		436		523	3	110	9	104	9	175	4	172	4	209
72		816		332	9	85		451	11	188		285		576		495		428		280	3	141		510
73		265		160	1	25		131		332		228		-	2	88	10	108	4	132		479		679
74		-		193		138		357	4	119	10	219		398		424	2	52		252		373		336
75		273	3	79		113		158		198		354	7	244		480		195		260		678		630
76		370		168	10	89		158		454	8	209		1,106		455		568	5	149		500		396
77	11	203	2	59		274	8	97		219		525		925		372		395		284		346	1	174
78	4	108		531		175	1	55		225	5	192		320		342		182	8	174		385	8	285
79	5	131	10	99	7	79		597		230		542	3	153		451		166	7	170		329		390
80		210		216	2	45		149	6	163		459	4	187		271		192		228	10	282		913
81		225		328		191		386		218		246	11	264		290		196	10	180		926		342
82	2	88		122		144	10	103	8	173		222		771		609		198		396		303	6	246
83		266	9	98		306	3	64		515	1	133		357		341	7	88		314	1	108	3	205
84		524		263	4	61	4	66		358		258	1	86		476		262		270	11	297		393
85	1	80		248	6	72	11	105		-		492		231		322		161		205	6	211	5	224
Average Rainfall		305		219		167		224		283		309		403		300		187		251		408		497
Effective Rainfall		133.4		124.8		119.6		152.3		131.2		133.8		143.2		132.9		121.6		128.0		143.7		152.6
70% Average Rainfa		186		100		94		105		187		221		262		211		111		168		294		323
70% Effective Rainfall		121.5		91.4		86.6		94.7		121.6		125.0		129.1		124.0		98.3		121.7		132.3		135.2

Note 1. O and R show ranking and monthly rainfall respectivley.
2. Rainfall data is taken from the rainfall recorded at La Lola station.

F.2 General Description of Existing Drainage System

F.2.1 Drainage System

The drainage system inside the study area can be divided into the following five sub-systems.

- Large rivers

  Six large natural rivers with extensive watersheds stretching beyond the boundary of the study area (the Chirripo, Barbilla, Matina, Pacuare, Reventazon, and the Parismina branching from the lower reaches of the Reventazon.)

- Small and Medium rivers

  Small and medium natural rivers flowing mostly within the study area, whose watersheds are much smaller than those of the six large rivers.

- Canals

  Canals constructed by banana companies.

- Navigable Canal

  The Navigable Canal flowing along the low land on the Caribbean coast, which is utilized for transportation in the coastal area and drainage from small rivers in the study area.

- River-mouths

  River-mouths the Matina, Pacuare and Parismina (downstream tributary of the Reventazon), from which large rivers and wastewater from the study area flow into the Caribbean Sea.
  These facilities general descriptions are shown hereunder.

F.2.2 Outline of Existing Drainage Facilities

(1) Large Rivers

The large rivers in the study area, i.e., the Chirripo, Barbilla, Matina (which meets the Chirripo and Barbilla at a distance of about 1 km to the south of Matina), Pacuare, Reventazon and Parismina (which joins the Reventazon in the west of the study area), all have much larger watersheds than the small rivers mentioned in (2), and their cross-sections are also large.

At the confluence with the Navigable Canal flowing along the Caribbean coast, the Matina has a watershed area of 1,365 Km^2 (including 1,106 of the Chirripo and 259 km^2 of the barbilla), the Pacuare 855 km^2, and the parismina 2,796 km^2. The Reventazon's watershed area is 1,801 km^2 at the confluence with the Parismina.

As for the length of these rivers in the study area, the Matina has a length of 34 km (including 3 km of the Chirripo and 11 km of the Barbilla), the Pacuare is 43 km long, and the Reventazon's length, including that of the Parismina, 47 km.

Since all these rivers are natural rivers, their cross-sections are rectangular in shape. Except in the upstream section of the Matina (where the Chirripo and the Barbilla meet) and in its downstream section and in the Pacuare's upstream section, all rivers range from 60 to 90 m in width and from 3 to 5 m in depth.

It is considered that they have a relatively steep gradient of 1/100 - 1/500 in the upstream part of the study area. In the middle and downstream areas, they are estimated to have a gentle slope of 1/2,000 - 1/5000 and follow largely meandering courses.

Table F.2.1 shows an outline of these large rivers.

(2) Small and Medium Rivers

There are many small and Medium rivers flowing through the study area. Their watersheds, which are mostly within the study area, are much smaller than those of the large rivers mentioned in (1). Watershed areas of main small rivers are as shown below.

River	Watershed area (km^2)		
	Inside the area	Outside the area	Total
Rio Toro(including Rio cuba)	15.3	72.5	87.8
Rio Palacios	36.2	6.8	43.0
Rio Madre de Dios	141.2	35.0	176.2
Rio Cimarrones	13.0	23.0	36.0
Rio Chiquero	61.4	-	61.4
Rio Aguas Zarcas	84.5	-	84.5

Note: For watershed areas of other rivers, see Fig. F.2.1 (Drainage System) and Table F.2.6 (Drainage System Areas).

Most of these rivers have a bottom width of 6 -10 m, crown width of 10 - 15 m, and a depth of 2 - 5m, and are serving as principal drainage canals in the area.

Except in the hilly land extending from Monte Verde to Siquirres, most of small rivers flow without joining any large rivers, and pour into the Navigable Canal along the Caribbean coast after meeting in the downstream swampy land in the study areas.

Table F.2.2 shows the lengths of these rivers in the study area.

(3) Canals

There are two canals running in the study area, one constructed by the banana plantation and the other built by the withdrawn plantation that has ceased operation (the greater part of which has now been sold as small farming lots by IDA).

The former is utilized as a drainage canal by the banana plantation. It has a depth of 3 - 4 m and a bottom width of 5 -15 within and in the vicinity of the plantation, but its cross-section becomes smaller in the downstream section far from the plantation where it ranges from 2 to 3 m in both depth and width.

As for the latter canal which was constructed in the plantation which is no longer in operation, though the greater part is positioned as a drainage canal for the small farmland plotted out by IDA, but it is left without any maintenance service at present.

Both canals are joined by small rivers in the study area, but not by any large river.

Table F.2.3 shows the lengths of the two canals in the study area.

(4) Navigable Canal

The Navigable Canal flows through the lowest part of the study area along the Caribbean coast. It connects Moin Port with Bara de Colorado near the Nicaraguan border, and is used for transportation of lumber and farm products from surrounding areas and daily necessities of nearby inhabitants as well as for tourist service.

In the study area (between the Toro and the Parismina), it has a length of 37 km and ranges from 20 - 40 m in width in most parts. However, its width increases to about 200 - 250 m in two sections, i.e. between the Madre de Dios and the Pacuare and between the Chiquero and the Parismina. The canal depth ranges from 2.5 to 5.0 m.

Table F.2.4 show the cross-section and length of the canal.

(5) River-Mouths

The study area embraces river-mouths of three rivers, i.e., the Matina, Pacuare and Parismina, and all large rivers and drainage canals from the project area flow into the Caribbean Sea through these river-mouths. The Matina has a river-mouth width of about 50 m, the Pacuare about 60 m, and tha Parismina about 80. The depth of these river-mouth ranges from 4.5 to 5.5 m in the deepest part.

Since the seawater inflow the rivers from the Caribbean Sea was considered possible, the river water salinity was measured using an electric conductivity meter. The observed EC-values are as follows; At the rivermouths, EC = 0.11 - 0.16 mmho/cm at a depth of 1.0 m and EC = 0.11 - 0.17 m /cm at a depth of 3.0 m. At upstream points 3 km from the river-mouths, EC = 0.11 - 0.16 mmho/cm at a depth of 1.0 m and EC = 0.08 mmho/cm at a depth of 3.0 m.

From these values, it is considered that the agricultural development in the study area will be little influenced by the salinity of water.

Table F.2.5 shows the results of salinity measurement.

Table F.2.1 Otline of Large Rivers

Rivers	Cross-Section ($B^m x H^m$)			Gradient			Watershed (km^2)			Length (km)
	Upstream	Midstream	Downstream	Upstream	Midstream	Downstream	Upstream	Midstream	Downstream	
Matina	172 x 6.0	80 x 4.0	142 x 6.0	1/100	1/2,000	1/2,000	1,365	1,365	1,365	20
Chirripo	-	-	78 x 4.0			1/1,000			1,106	3
Barbilla	-	-	75 x 3.0			1/1,000			1,259	11
Pacuare	240 x 2.8	67 x 4.5	91 x 3.5	1/300	1/2,000	1/2,000	663	855	855	43
Reventazon and Parismina	75 x 4.5	75 x 5.0	89 x 5.5	1/500	1/2,000	1/5,000	1,750	1,801	2,796	47

All of data is on basis of the field survey.

Note 1. All data in downstream is at navigable canal.
2. Gradient is estimated by topographical map with the scale 1/50,000.
3. B and H show the most of width and the most of depth respectively.

Table F.2.2 (1) List of Small and Medium Rivers

Zone	Drainage System	Rivers	Length(km)	Remarks
A	1. Rio Toro	Rio Toro	11.3	1. Drainage system is shown in drainage map.
		Rio Cuba	5.0	
		Rio Rojo	0.9	2. Length is estimated by topographical map.
		Sub-Total	17.2	
	3. Rio Palacios	Rio Palacios	10.5	
		Rio Escondido	4.8	
		Sub-Total	15.3	
	5. Canal San Edmundo	Rio Pascual	1.6	
		Sub-Total	1.6	
	6. Quebrada San Jose	Quebrada San Jose	7.0	
		Sub-Total	7.0	
		Total	41.1	
B	8. Canal Principal	-	3.2	
		-	2.5	
		Quebrada Lyon	11.5	
		-	2.3	
		-	1.8	
		Sub-Total	21.3	
	9. Rio Matina	-	2.0	
		-	1.0	
		-	1.0	
		Quebrada Calderon	1.5	
		-	5.5	
		Sub-Total	11.0	

Table F.2.2 (2) List of Small and Medium Rivers

Zone	Drainage System	Rivers	Length(km)	Remarks
B	12. Madre De Dios	Rio Madre De Dios	24.5	
		Quebrada Pama	8.1	
		-	3.1	
		-	1.0	
		-	0.8	
		-	2.5	
		Rio Ventiseis	6.5	
		Queb. Salsipuedes	2.5	
		-	1.7	
		Sub-Total	50.7	
		Total	77.5	
C	12. Madre De Dios	Rio Cana Azul	16.2	
		Rio Cimarrones Viejo	5.5	
		-	0.7	
		Rio Punta De Riel	1.8	
		-	1.5	
		Sub-Total	25.7	
	13. Rio Cimarrones Viejo	Rio Cimarrones Viejo	4.5	
		-	1.2	
		Sub-Total	5.7	
	14. Rio Cimarrones	Rio Cimarrones	4.6	
		Quebrada Rosita	2.8	
		Sub-Total	7.4	

Table F.2.2 (3) List of Small and Medium Rivers

Zone	Drainage System	Rivers	Length(km)	Remarks
C	15. Rio Pacuare	-	3.5	
		-	2.3	
		-	1.5	
		Sub-Total	7.3	
		Total	46.1	
D	18. Rio Chiquero	Rio Chiquero	17.5	
		Sub-Total	17.5	
	19. Rio Aguas Zarcas	Rio Aguas Zarcas	27.5	
		Sub-Total	27.5	
	20. Quebrada Corona	Quebrada Corona	4.3	
		Sub-Total	4.3	
	21. Brazo Del Rio Reventazon	-	2.5	
		-	15.7	
		-	1.5	
		Sub-Total	19.7	
		Total	69.0	

Table F.2.3 (1) List of Drainage Canal

Zone	Drainage System	Canals	Length(km)	Remarks
A	5. Canal San Edmundo	-	6.0	1. Drainage system is shown in drainage map.
		-	5.5	
		Sub-Total	11.5	2. Length of canal is estimated by topographical map.
		Total	11.5	
B	8. Canal Principal	Canal Cocaleca	4.5	
		Canal Malcriado	5.4	
		Canal Abaca	4.3	
		-	1.5	
		Quebrada Suampo	3.5	
		-	2.2	
		-	7.0	
		-	3.2	
		Canal Abandando	3.5	
		Canal Principal	14.3	
		Sub-Total	49.4	
	9. Rio Matina	-	1.5	
		Sub-Total	1.5	
	12. Rio Madre De Dios	Canal Abandando	1.0	
		Canal Aserradero	6.0	
		Canal Abandando	7.0	
		Canal Sara	9.0	
		-	0.8	
		-	0.5	
		-	7.0	
		Sub-Total	31.3	
		Total	82.2	

Table F.2.3 (2) List of Drainage Canal

Zone	Drainage System	Canals	Length(km)	Remarks
C	12. Rio Madre De Dops	-	4.5	
		-	3.5	
		-	3.8	
		Sub-Total	11.8	
	13. Rio Cimarrones Viejo	Canal Abbandando	13.0	
			0.9	
			0.5	
		Sub-Total	14.4	
	14. Rio Cimarronel		2.3	
		Sub-Total	2.3	
		Total	28.5	
D	18. Rio Chiquero		2.0	
		Sub-Total	2.0	
	20. Quebrada Corona		3.5	
		Sub-Total	3.5	
		Total	5.5	

Table F.2.4 Dimension of Navigable Canal

Section	Location	Cross-Section B (m)	Cross-Section H (m)	Length (km)
Toro-Matina River	at 2km from Toro River	40	5.0	7
	at 5km from Toro River	50	4.0	
Matina-Madre de Dios River	at 1km from Matina River	35	3.5	13
	at 5km from Matina River	27	3.5	
Madore de Dios-Pacuare River	at 2km from Madre de Dios River	260	6.0	4
Pacuare-Parismina River	at 4km from Pacuare River	33	2.5	13
	at 6km from Pacuare River	32	2.8	

Note: B and H show width and depth respectively.

Table F.2.5 Salinity of River Water and River Mouth

(Unit:mmho/cm)

Location	Depth	
	1m	3m
Matina River Mouth	0.16	0.13
3km upstream from Matina River Mouth	0.16	0.08
Pacuare River Mouth	0.17	0.17
3km upstream from Pacuare River Mouth	0.13	0.08
Parismina River Mouth	0.11	0.11
3km upstream from Parismina River Mouth	0.11	0.08

Table F.2.6 Drainage Area by the System

Drainage system	Inside the study area	Outside the study area	Total	Observation
	ha	ha	ha	
1) Rio Toro	1,530	7,250	8,780	
2) Direct Flow to Canal	110	-	110	
3) Rio Paracios	3,620	680	4,300	
4) Direct Flow to Canal	1,600	-	1,600	
5) Canal San Edmundo	2,410	-	2,410	
6) Quebrada San Jose	1,530	400	1,930	Confluence with Rio Matina
7) Direct Flow to Canal	1,800	-	1,800	
8) Canal Principal	7,100	-	7,100	
9) Rio Matina	700	135,800	136,500	
10) Direct Flow to Canal	2,000	-	2,000	
11) Direct Flow to Canal	1,300	-	1,300	
12) Rio Madre de Dios	14,120	3,500	17,620	
13) Rio Cimarrones Viejo	2,950	-	2,950	Confluence with Rio Pacuare
14) Rio Cimarrones	1,300	2,300	3,600	
15) Rio Pacuare	1,200	71,250	72,450	
16) Direct Flow to Canal	1,610	-	1,610	
17) Direct Flow to Canal	850	-	850	
18) Rio Chiquero	6,140	-	6,140	
19) Rio Aguas Zarcas	8,800	-	8,800	
20) Quebrada Corona	1,740	-	1,740	Confluence with Rio Reventazon
21) Brazo del Rio Reventazon	4,590	1,910	6,500	Confluence with Rio Pacuare
Total	67,000		290,090	

F.3 Existing Poor Drainage Conditions

F.3.1 Causes of Poor Drainage

To clear up the causes of poor drainage, the cross-sections of small rivers and canals were measured and their drainage capacities were studied. As a result, the following facts were disclosed.

- Most of small rivers flowing through the flat land have a drainage capacity of less than 2 mm/hr, and their cross-sections are obviously deficient to cope with the runoff from the flat land.
- Rivers flowing through the hilly land, such as the Cimarrones and the Veijo, have a drainage capacity of 10 - 30 mm/hr, so that the surrounding area is maintained in a good drainage condition.
- The canal used for drainage from the banana plantation exhibits high performance as a drainage canal immediately downstream of the plantation, where it has a capacity of 10 - 33 mm/hr. In downstream areas far from the plantation, however, its capacity declines notably.
- The canal running in the abandoned plantation is just as small in drainage capacity as small rivers in the study area.

From the above findings, the following can be said regarding he drainage of flat farmland excluding the banana plantation.

- Small rivers and canals to be used as drainage canals do not have sufficient large cross-sections.
- The terminal drainage canal systems are left without any improvement efforts (virtually inexistent).

As a consequence, the poor drainage conditions mentioned below are caused.

- Surface water cannot be drained quickly, and flooding is caused readily by rainfall.
- The groundwater level rises to excess in the rainy season owing to the absence of a terminal drainage canal system with which to control it.

F.3.2 Drainage Capacity of Small and Medium Rivers and Canals

The drainage capacity of small and medium rivers and canals was calculated using Manning's formula, as shown below.

(1) Cross-section

Cross-sections of small rivers and canals were measured in the field.

(2) Gradient

Gradient of small rivers and canals was estimated from a topographical map with a scale of 1/50,000.

(3) Roughness Coefficient

The following values were adopted for capacity calculation on the basis of the sectional form bed-surface condition and meandering conditions of rivers and canals.

Canal for banana plantation	0.035
Other canal	0.040
Small rivers	0.040

(4) Cross-sectional Area and Wetted Perimeter

A cross-sectional drawing was prepared for measurement of the cross-sectional area and wetted perimeter.

(5) Watershed Area

Watershed areas were measured using the topographic map (1/50,000). Table F.3.1 shows the results of capacity calculation.

F.3.3 Categorization of Drainage Condition

(1) Categories

As a result of interviews with local farmers, it was made possible to divide the whole study area according to the annual frequency of inundation, depth of inundation, period of inundation, groundwater level, etc, and to pale it under seven different categories.

Each of the seven categories is discussed below with specific reference to drainage condition.

- Category I

The area belonging to this category is shown as a permanent swampy area on the topographic map (1/50,000), and is covered with forests.

- Category II

This area has an elevation of less than 10 m in most parts and has no drainage canal system. Its drainage condition is the poorest in all areas falling under other categories excepting Category I. The annual inundation condition and the rainy season groundwater level in this area are as follows.

Frequency of inundation	3 - 4 times
Period of inundation	2 - 3 days
Maximum depth of inundation	0.5[1)]- 0.7[2)] m
Rainy season groundwater level	GL $\pm$ 0 - 0.3 m

1) Major part of farm land
2) Farm land with hollow along small rivers

- Category III

This area is located at an elevation of 10 - 20 m, upstream of the area belonging to Category II, and has no drainage canal system. The drainage condition of this area is the poorest after the Category II area. The annual inundation condition and the rainy season groundwater level are as follows.

Frequency	2 - 3 times
Period	2 days
Depth	0.3[1] - 0.5[2] m
Rainy season groundwater level	GL±0 - 0.3 m

1_/,2_/ Same notes in the case of category II.

- Category IV

This area is located at an elevation of more than 10 m and has no drainage canal system. Since the drainage basin on its upstream side is small, the inundation caused by a rainfall lasts for less than one day and its depth is also small and less than 0.3 m in maximum. However, the groundwater level is high in the rainy season. The annual inundation condition and the rainy season groundwater level are as follows;

Frequency	2 - 3 times
Period	Less than 1 day
Depth	Less than 0.3 m
Rainy season groundwater level	GL±0 - -0.3

- Category V

This is a farmland area along both banks of a large river. It is free from inundation due to rainfall, but is inundated when the river overflows.

The groundwater level in the rainy season is low, registering less than G.L. - 1.0 m.

- Category VI

This is the inclined area located in the southwestern part of the study area at an elevation of 20 - 60 m. Since it has a slope of

1/50 - 1/100, it is free from inundation due to rainfall. The groundwater level is also lower than G.L. - 1.5 m. Hence, its drainage condition is good.

- Category VII

This area is embraced in the banana plantation in the Study Area, and its drainage condition is good.

Table F.3.2 shows the categorization of the study area by drainage condition.

(2) Areas in Poor Drainage Condition

The study area was divided into seven sub-areas (Categories I - VII) as shown in Main Report Fig. 3.8.2 on the basis of the drainage condition survey results. Table F.3.3 shows the area of each of the seven blocks (I - VII) measured by using the topographical map (1/50,000).

F.3.4 Damage by Inundation

The expected increase in agricultural production (yield and value) that can be realized by improving the drainage condition in the poor drainage areas mentioned in F.3.3, was estimated along the following criteria.

- Planted area

The present planted area in the poor drainage areas disclosed by the present land use survey was used.

- Yield increase

The difference between the present yield in the study area and the yield that can be realized by drainage improvement (yield actualized in neighboring areas or the national average yield) was estimated as the expected yield increase. The present yield, the expected yield after drainage improvement and the yield increase are shown below for each crop.

Crop	Present yield (t/ha)	Yield after Drainage Improvement (t/ha)	Yield increase (t/ha)
Annual crop			
Rice	2.7	3.5	0.8
Kidney beans	0.5	1.0	0.5
Maize	1.2	1.7	0.5
Others	6.0	6.8	0.8
(represented by tuber crop)			
Perennial crop			
Banana		- no damaged -	
Cacao	0.35	0.8	0.45
Others	7.0	10.0	3.0
(represented by plantain)			
Livestock	0.25	0.30	0.05

Increase of production value

The increase of production value was estimated by multiplying the present farm gate price by the yield increase. The farm gate price is shown below for each crop.

Annual crop

.Rice	14,200 ¢/t
.Kidney beans	35,788 ¢/t
.Maize	13,669 ¢/t
.Tuber crop	14,000 ¢/t

Perennial crop

.Cacao	95,000 ¢/t
.Plantain	8,500 ¢/t
.Livestock	50,000 ¢/t

Table F.3.4 shows the increase in production value estimated along the above criteria that can be achieved under the present farm management by improving the draining condition.

Table F.3.1 Drainage Capacities of Existing Small and Medium Rivers

$V = 1/n\ I^{1/2}R^{2/3}$ m/s
$Q = a \times V$ m^3/s
$Q = Q \times 360/A$ mm/hr

P: Wetted Perimeter
R: Hydraulic Mean Depth
H: Depth
B: Bottom Width
V: Velocity
A: Watershed
B: Crest Width
I: Gradient
a: Cross Section
n: Coefficient of Roughness
Q: Discharge

Zone	River	B(m)	B(m)	H(m)	I	n	a(m)	P(m)	R(m)	V(m/s)	$Q(m^3/s)$	Q(mm/hr)	A(ha)	Observation
A	Rio Palacios	6.0	9.5	2.5	1/1.000	0.040	15.0	11.2	1.34	0.96	14.4	6.9	750	Upperstream
	Rio Palacios	5.0	9.2	2.5	1/1.500	0.040	14.3	11.2	1.28	0.76	10.9	1.2	3.280	Downstream
	Rio Toro	6.0	16.5	2.0	1/1.500	0.040	25.2	18.0	1.40	0.81	20.4	4.5	1.625	
	Rio Cuba	7.5	12.4	2.7	1/1.500	0.040	14.3	11.2	1.81	0.96	13.7	1.5	3.050	
	Canal (San Edmundo)	6.5	10.8	1.7	1/2.000	0.035	12.8	12.0	1.07	0.67	8.6	6.2	500	Near Banana Plantation
B	Canal Sara	5.0	8.1	3.5	1/2,000	0.040	23.0	12.7	1.81	0.83	19.1	3.4	2.025	
	Quebrada Pama	2.5	4.5	1.4	1/2.000	0.040	4.9	6.5	0.75	0.46	2.3	1.5	550	
	Canal Aserradero	2.0	4.0	1.2	1/2.000	0.040	3.6	5.2	0.69	0.44	1.6	1.0	600	
	Canal Principal	5.0	11.0	3.0	1/500	0.035	24.0	13.6	1.76	1.86	44.6	26.8	600	Upperstream,Near Banana Plantatin
	Canal Principal	14.7	14.7	4.0	1/1,500	0.035	58.8	22.5	2.61	1.40	82.3	13.5	2.200	Middlestream
	Canal Principal	2.1	5.4	2.8	1/2.000	0.035	10.5	8.7	1.21	0.73	7.7	1.2	2.380	Downstream
	Canal (Santa Marta)	2.8	2.8	3.1	1/1.500	0.035	8.7	9.0	0.97	0.72	6.3	9.5	240	Near Banana Plantation
	Quebrada Lyon	7.0	7.0	1.5	1/2.000	0.040	10.5	10.0	1.05	0.58	6.1	1.0	2.190	
	Canal Maloriado	3.0	5.0	2.0	1/2.000	0.040	8.0	7.6	1.05	0.58	4.6	1.3	1.250	
	Rio Madre de Dios(Sara)	7.0	19.5	2.8	1/1.500	0.040	33.9	21.0	1.61	0.89	30.2	2.4	4.500	
C	Rio Cimarrones Viejo	6.0	8.7	2.7	1/1.000	0.040	19.8	11.2	1.77	1.16	23.0	33.1	250	Middlestream. Near Banana Plantation
	Rio Cimarrones Viejo	10.0	18.0	4.5	1/1,500	0.040	63.0	22.0	2.86	1.30	81.9	10.5	2.800	Downstream Rail Road Bridge
	Rio Cimarrones	8.6	19.2	5.6	1/1.000	0.040	97.7	28.2	3.46	1.81	176.8	18.7	3.400	Rail Road Bridge
	Canal (Freeman Dos)	9.0	18.5	4.8	1/5.000	0.035	56.4	21.0	2.69	0.78	44.0	79.2	200	Near Banana Plantation
D	Rio Aguas Zarcas	5.6	6.7	2.1	1/2.000	0.040	12.9	9.8	1.32	0.67	8.6	1.4	2.250	
	Rio Chiquero	3.0	3.0	2.3	1/1.000	0.040	6.9	7.6	0.91	0.74	5.1	1.4	1.300	
	Brazo del Rio Reventazon	56.0	60.0	3.5	1/1.000	0.040	203.0	64.6	3.14	1.69	343.1	24.2	5.100	Rail Road Bridge

Table F.3.2 Present Drainage Situation

(Unit:ha)

Zone	Classification									Total	Remarks
	Swamp	Poor Drainage Area				Good Drainage Area					
	I	II	III	IV	Sub-Total	V	VI	VII	Sub-Total		
A	1,370	5,300	2,250	380	7,930	-	-	1,100	1,100	10,400	
B	1,650	7,620	2,400	3,170	13,190	580	1,710	1,870	4,160	19,000	
C	0	2,960	3,830	-	6,790	630	2,670	1,810	5,110	11,900	
D	2,850	7,150	4,860	-	12,010	1,050	4,430	2,860	8,340	23,200	
TOTAL	5,870	23,030	13,340	3,550	39,920	2,260	8,810	7,640	18,710	64,500	

I: Swamp area
II: Poor drainage area lower than 10m in the elevation
III: Poor drainage area between 10m to 20m M.S.L.
IV: Area at altitude of more than 10m M.S.L.
V: Good drainage area of both sides along large rivers
VI: Area in inclined land between 20m to 60m M.S.L.
VII: Banana plantation

Table F.3.3 Increment of Agricultural Production with the Drainage Improvement

(US$1.0 = ¢ 61.3)

Zone	Crops	Whole Area(ha)	Damaged Area(ha)	Increased Production per ha (t/ha)	Total Production(t)	Unit price (¢/t)	Increased Production Cost (1.000¢)	Increased Production Cost (1.000us$)
A	Rice	1,580	1,580	0.8	1,264.0	14,200	17,949	293
	Kidney Bean	163	163	0.5	81.5	35,788	2,917	48
	Maize	20	20	0.5	10.0	13,669	137	2
	Annual Crops	67	67	0.8	53.6	14.000	750	12
	Banana	456	-	-	-	-		
	Cacao	450	450	0.45	202.5	95.000	19.238	314
	Perennial Crops	56	56	3.0	168.0	8.500	1.428	23
	Cattle Breeding	2.480	2.480	0.05	124.0	50.000	6.200	101
	Sub Total	5.272	4.816		1.903.6		48.619	793
B	Rice	2,890	2.790	0.8	2,232.0	14,200	31.694	517
	Kidney Bean	43	43	0.5	21.5	35.788	769	13
	Maize	349	349	0.5	174.5	13,669	2.385	39
	Annual Crops	238	238	0.8	190.4	14,000	2.666	43
	Banana	904	-	-		-		
	Cacao	1.390	570	0.45	256.5	95.000	24.368	398
	Perennial Crops	258	258	3.0	774.0	8.500	6.579	107
	Cattle Breeding	3,150	2,860	0.05	143.0	50.000	7.150	117
	Sub Total	9.222	7,108		3.791.9		75.611	1.234
C	Rice	200	200	0.8	160.0	14,200	2.272	37
	Kidney Bean	21	21	0.5	10.5	35,788	376	6
	Maize	370	370	0.5	185.0	13.669	2.529	41
	Annual Crops	329	329	0.8	263.2	14,000	3.685	60
	Banana	1,088	-	-	-	-	-	-
	Cacao	660	270	0.45	121.5	95.000	11.543	188
	Perennial Crops	176	176	3.0	528.0	8,500	4,488	73
	Cattle Breeding	3.250	1,930	0.05	96.5	50.000	4.825	79
	Sub Total	6,094	3,296		1,364.7		29,718	484
D	Rice	440	310	0.8	248.0	14,200	3,522	57
	Kidney Bean	48	35	0.5	17.5	35,788	626	10
	Maize	820	580	0.5	290.0	13.669	3,964	65
	Annual Crops	732	510	0.8	408.0	14.000	5.712	93
	Banana	1,712	-	-	-	-	-	-
	Cacao	860	480	0.45	216.0	95.000	20.520	335
	Perennial Crops	228	228	3.0	684.0	8.500	5.814	95
	Cattle Breeding	5.700	5.700	0.05	285.0	50,000	14.250	232
	Sub Total	10.540	7.843		2.148.5		54.408	887
	TOTAL	31.128	23.063		9.208.7		208.356	3.398

F.4 Flood Condition

F.4.1 Flood Damage in 1970

In 1970, the study area was afflicted with a flood with a return period of about 35 years (estimated from the mean daily flow record of the Pacuare). Specifically, the Chirripo, Matina, Barbilla, Pacuare and Reventazon overflowed three times in January, April and December, inundating completely the Study Area each time.

It is considered probable that the study area was inundated not just by the flooding of the five large rivers but also by the flooding of small rivers caused by heavy rainfalls. The rainfall record at La Lola indicates that the rainfall amounted to 616 mm (3 days) during the January 1970 flooding, 496 mm (4 days) during the April flooding, and 532 mm (4 days) during the December flooding.

Accordingly, it is difficult to grasp the influence of flooding of the large rivers imposed on the study area during the floods of 1970.

As described above, small floods of large rivers were frequently recorded even after 1970. Flood water overflowing large rivers runs toward poor drainage areas owing to the surrounding topography and, increases the frequency, depth and period of inundation of such areas.

F.4.2 Damage of Flood[1/] with Return Period of 10 Years

In December 1974, a flood with a return period of about 10 years occured along the Pacuare and the Reventazon, but the occurrence of a flood with this return period is not found for the Chirripo, Barbilla and Matina during the period of data observation. Owing to the short observation period, it is unknown whether a flood with this return period occurred after 1970.

To grasp the influence of the said flood of the Pacuare and Reventazon (the heaviest flood recorded after 1970), interviews were made with the MOPT, Siquirres Regional Office and local farmers. Information obtained from the interviews are summarized below.

- No flood damage was caused after 1970 in the upper reaches of the Reventazon.

- Areas along the midstream and downstream sections of the Reventazon suffered from a flood damage with a water depth of more than one meter influencing the Aguas Zarucas, with the exception of the banana plantation.

- No flood damage was caused after 1970 to Indiana Dos and Indiana Tres which are along the upstream section of the Pacuare.

- Three areas along the midstream section of the Pacuare, i.e., Cultivez, Manila and Perla, suffered from a flood damage with a water depth of more than one meter.

- The flood condition along the lower reaches of the Pacuare is unknown because none of the farmers interviewed lived there in 1974. However, judging from the meandering course of the Pacuare, inclination of the surrounding topography, location of the banana plantation and the Pacuare's midstream capacity (approximately 300 m^3/s), it is estimated that the river overflowed mainly its left bank and its influence extended to the Chiquero.

  Note: 1/ On basis of mean daily discharge.

F.4.3 Damage of Flood 2/ with Return Period of Less Than 10 Years

In recent years, smaller floods as compared with those recorded in 1970 and 1974 occurred frequently at some rivers.

The flood condition as revealed from interviews with the MOPT. Matina Regional Office and local farmers is as summarized below.

- <u>Rio Matina</u>

The river inundates every year in the middle and lower reaches. The inundation lasts for one - two days, with a water depth of 40 - 50 cm in most cases. On the left bank of the river, the flood water flows to Hilda. On the right bank, it overflows the road and runs toward the canal of the banana plantation.

- <u>Rio Chirripo</u>

In 1982, the river inundated at a point downstream of National Route 32, and the flood water reached Estrada. This flood was equivalent to a return period of five years in probability.

- <u>Rio Barbilla</u>

In 1980, the river inundated in the north of Davao, and the flood water came close to Bataan. This flood was equivalent to a return period of five years in probability.

- <u>Rio Pacuare</u>

The river occasionally floods in the middle and lower reaches. Judging from its discharge record and capacity, it is estimated that it flooded about once in two years since 1970, with the inundation lasting for two - three days.

Along the midstream section, the flood influence is observed on the right bank side. The flood water overflows the road between Cultivez and Perla and runs toward the canal in the east. The depth of inundation is about 50 cm.
In the lower reaches, the river overflows mainly the left bank. The depth of inundation is 30 - 40 cm.

- Rio Reventazon

The flood occurs a few times a year in the middle and lower reaches. The depth of inundation usually ranges from 40 to 50 cm, but occasionally reaches 1 m, with a period of two to three days.

The influence of these floods reaches a point 1 km to the west of Maryland and the downstream section of the Aguas Zarcas.

Fig. F.4.2 shows the areas influenced by floods of large rivers with a return period of five years, on the basis of information obtained from interviews with local farmers. Table F.4.2 shows the zones influenced by such floods (including the permanent swampy area).

Note 2/ basis of mean daily discharge

Table F.4.1 Drainage Capacity and Probable Flood Discharge at the River Section with Overflow

River	Location	Gradient	Cross-Sectional Area (m^2)	Capacity (m^3/s)	Probability 1/2 (m^3/s)	Probability 1/5 (m^3/s)	Probability 1/10 (m^3/s)	Watershed (km^2)
Chirripo	Downstream	1/1,000	306	652	460	766	1,033	1,106
Barbilla	Upperstream	1/1,000	179	285	195	312	410	259
Matina	Middlestream & Downstream	1/2,000	288	418	528	885	1,200	1,365
Pacuare	Middlestream & Downstream	1/2,000	220	301	395	653	877	855
Reventazon	Middlestream & Downstream	1/2,000	263	368	613	1,035	1,409	1,801

Note:
1.The gradients of the rivers are estimated by the topographical map, scale 1/50,000.
2.The sections are made by the field survey.
3.The flow capacities are estimated using the Manning formula.

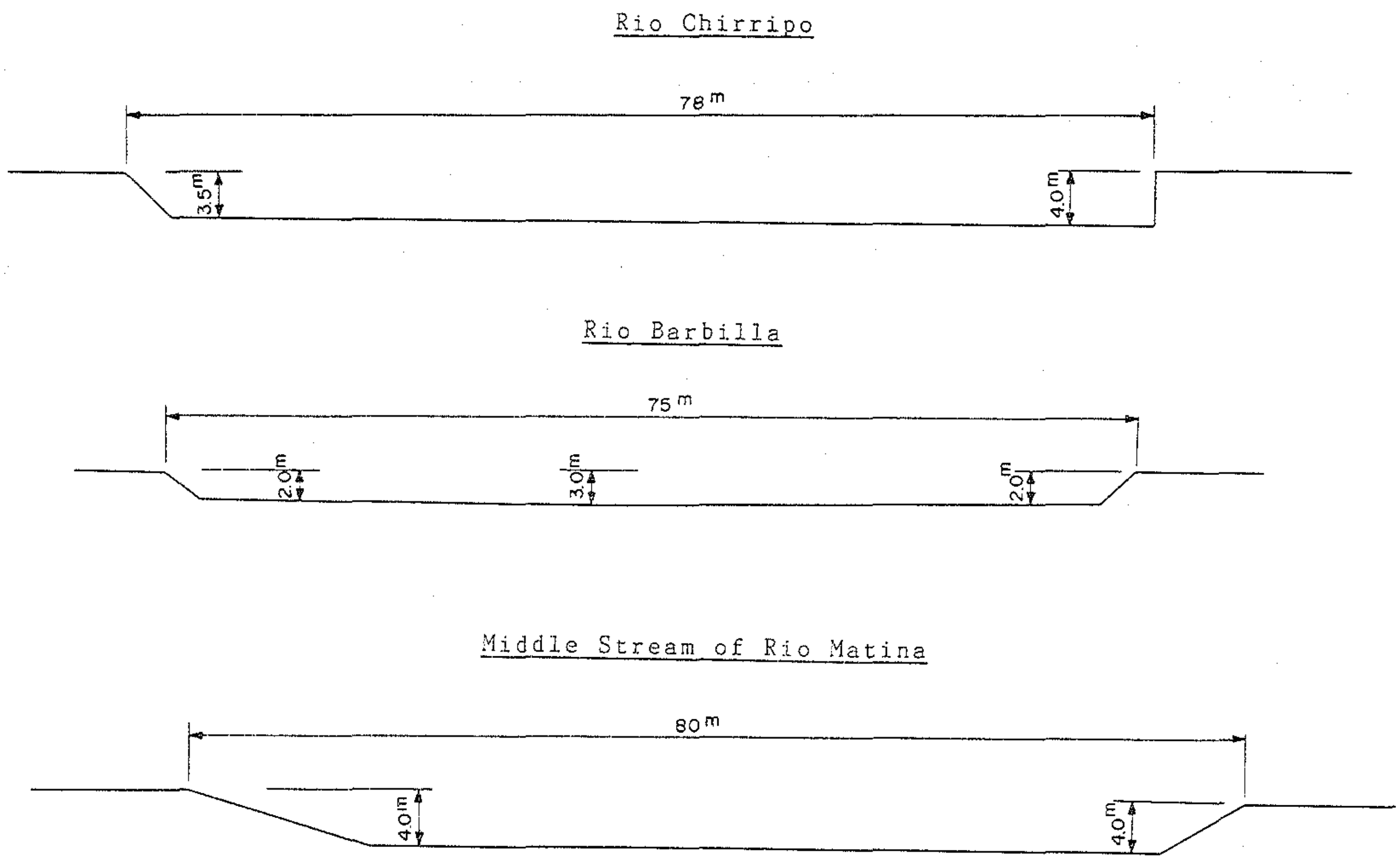
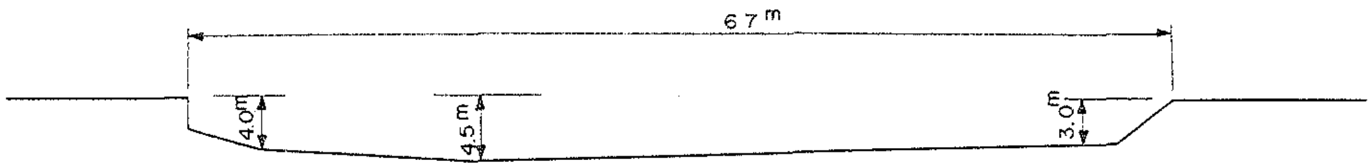


Fig. F.4.1.(1) A Typical Cross Section of Overflowing Large River
(S = 1/500)

Middle Stream of Rio Pacuare



Middle Stream of Rio Revntazon

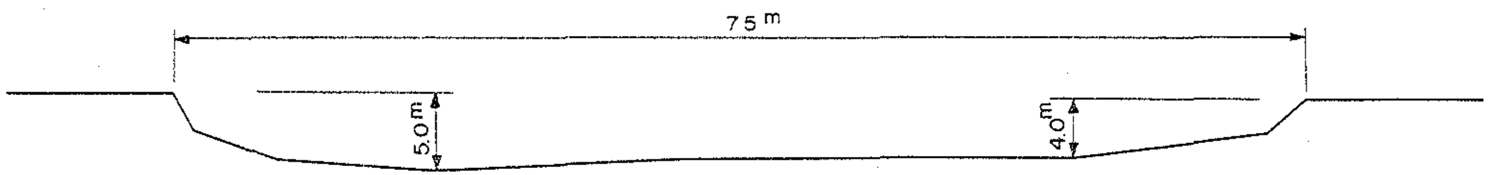


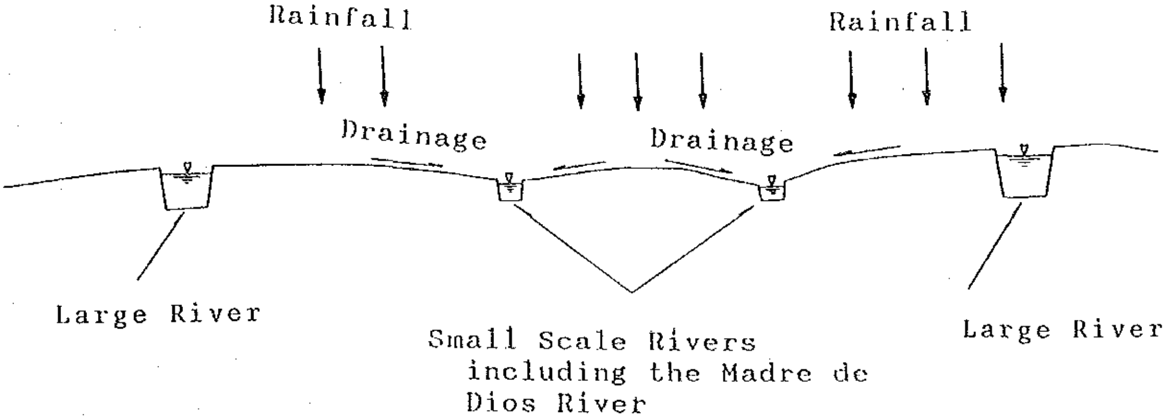
Fig. F.4.1.(2) A Typical Cross Section of Overflowing Large River

(S = 1/500)

F.5 Plan for Principal and Secondary Drainage Canal System

F.5.1 Small Rivers

Besides the large rivers flowing through the study area (the Chirripo, Barbilla, Matina, Pacuare, Reventazon and Parismina), there are some small rivers flowing into the study area from outside. These are the Cuba, Toro, Veinti-Seise and Madre de Dios, and their topographical locations differ from those of large rivers, as shown below.



These small rivers, including the Madre de Dios, now play the role of main canals necessary for drainage from the surrounding farmland area and their tributaries.

Considering the existing drainage system and the present and future land use conditions, it cannot be justified to adopt the same method for the improvement of these small rivers as required for large rivers. For this reason, these small rivers will be developed to main drainage canals by river the full cross-section excavation method.

F.5.2 Location of Principal Drainage Canal

The principal drainage canal system will be constructed in the poor drainage area disclosed in the field survey, with consideration to the existing drainage system as well as to the following points;

(1) Principal drainage canals will be distributed mainly from south to north from the viewpoint of topography and hydraulic advantages.

(2) They will basically be distrubuted at intervals of 3 - 4km to assure the hydraulic function of secondary canals to be arranged in parallel with their contour lines.

(3) Their ends will be connected to the Navigable Canal or to the downstream section of each rivers having a large width and joining the Navigable Canal (i.e., the Toro, Pacuare, Madre de Dios and Chiquero). This arrangement will serve to secure the hydraulic function of the entire system and cut down the cost of the main canal construction in the permanent swamp area. Accoding the field suvey, the depth of the canal and rivers ranges were recognized from Gl-3 m to Gl-4 m.

(4) To cut down the overall canal system construction cost, efforts will be exerted for making effective use of existing canals, especially the ones running from Canal Principal, Canal Sara, Canal Corona and the banana plantation.

(5) For the same purpose, small rivers having sufficient capacity to meet the drainage requirement will be partly included in the drainage system without improvement, excepting the sections where they follow extremely meandering courses.

(6) For the purpose of effective land use, main drainage canals will not be arranged to discharge into large rivers.

The proposed principal drainage canal system is shown in Fig. F.5.1, and the canal lengths in Table F.5.1.

F.5.3 Design Drainage Discharge of Principal Drainage Canal

(1) Formula Used for Estimation

The design drainage discharge was obtained from the rational formula, as shown below;

$$Q = \frac{1}{3.6} \times I \times f \times A$$

Q :	Design drainage discharge	m^3/s
I :	Rainfall intensity during the time of flood Concentration	mm/hr
f :	Runoff Coefficient	
A :	Drainage area	km^2

In the above calculation, the runoff coefficient f was taken at 0.45 in view of the following field conditions.

- The study area are is covered with clayey soil.

- Forest land, natural grassland and farmland for growing perennial crops (bananas, cacao, plantain) constitute the main type of land use in the study area.

- The runoff analysis by the kinematic runoff method using, the proposed B-2 drainage system in block B as a model, disclosed that the peak flood due to a rainfall with 5 years of return period was recorded in 8 hours after the peak rainfall was observed, registering 82.31 m^3/s (watershed area - 41.4 km^2) (see Annex B, Table B.2.6). The calculation of runoff coefficient (f) from the mean rainfall intensity I (16.4 mm/hr ... Category I) which is used in the rational formula (formula for obtaining design drainage water) produced the following result.

$$f = 3.6 \times Q \times 1/r \times 1/A$$
$$= 3.6 \times 82.31 \times 1/16.4 \times 1/41.4$$
$$= 0.44$$

(2) Time of Flood Concentration from Watershed

The time of flood concentration was calculated by Rziha's formula, as shown below.

$$t = \frac{0.00083L}{(H/L)^{0.6}}$$

t : Time of flood concentration (hr)
H : Difference of elevation of river course (m)
L : Length of river course (m)

The above calculation was worked out for each of the proposed principal drainage canals, as shown below.

Category I	t = 4 hr	(t = average 2 hr - 5 hr)
Category II	t = 10 hr	(t = average 7 hr - 12 hr)
Category III	t = 15 hr	(t = average 15 hr - 26 hr)

Table F.5.2 shows the details of calculation of (t) for each of three categories I, II and III.

(3) Rainfall Intensity

The rainfall intensity was obtained from the observation record at La Lola's Catie station located at the approximate center of the study area, and its return period of taken at 5 years after a consultation with SENARA. The rainfall intensity formula is as shown below;

$$I = \frac{229}{t + 4.0}$$

I : Mean rainfall intensity during time of t (mm/hr)
t : Time of flood concentration (hr)

The rainfall intensity calculated for each time of flood concentration (Categories I, II, III) mentioned in (2) is as shown below.

.Category I (t = 4 hr)

$$I = \frac{229}{t + 4.0} = 28.6 \text{ mm/hh}$$

.Category II (t = 10 hr)

$$I = \frac{229}{t + 4.0} = 16.4 \text{ mm/hh}$$

.Category III (t = 20 hr)

$$I = \frac{229}{t + 4.0} = 9.5 \text{ mm/hh}$$

(4) Design Drainage Discharge

The design drainage water per unit area (1 km^2) calculated by the rational formula for each time of flood concentration (categories I, II, III) is as shown below.

Category I

$$q = \frac{1}{3.6} \times I \times f \times A = \frac{1}{3.6} \times 28.6 \times 0.45 \times 1.0 = 3.575 \ m^3/s/km^2$$

Category II

$$q = \frac{1}{3.6} \times I \times f \times A = \frac{1}{3.6} \times 16.4 \times 0.45 \times 1.0 = 2.050 \ m^3/s/km^2$$

Category III

$$q = \frac{1}{3.6} \times I \times f \times A = \frac{1}{3.6} \times 9.5 \times 0.45 \times 1.0 = 1.188 \ m^3/s/km^2$$

Table F.5.3 shows the design drainage water calculated for each proposed main canal.

F.5.4 Design of Principal Drainage Canal

(1) Structure

In view of the purpose of its use and economic efficiency, the principal drainage canal will be designed as an unlined canal, and its side slope will be taken at 1 : 1.5 for the following reasons;

- Environs of the proposed canal lines are covered with sandy clay soil.
- Existing canals have a side slope of 1 : 1.0, but their slope failure can be seen in many places.
- Ease of maintenance should be ensured for the entire canal line.

The canal will have a depth ranging from 3.0 to 5.0 m, to be determined according to the design drainage discharge, with consideration given to the depth of existing canal of the banana plantation and that of the proposed secondary canal.

A service road with a width of 4.0 m will be constructed along the canal course to ensure the ease of canal management and maintenance. The service road will be constructed on one side of the canal if its bed width is smaller than 10.0 m, and on both sides if its bed width is 10.0 m or larger.

The sectional form of the canal is as shown in Main Report Fig. 4.2.2.

(2) Capacity of Principal Drainage Canal

The capacity of the Principal drainage canal was obtained by Manning's formula shown below;

$$V = \frac{1}{n} I^{1/2} R^{2/3}$$

$$Q = A \times V$$

V : Average flow velocity (m/s)

n : Roughness coefficient as earth canal

I : Design gradient of canal

R : Hydraulic mean depth (Sectional area ÷ Wetted perimeter)(m)

A : Sectional area (m^2)

Q : Discharge (m^3/s)

Table F.5.4 shows the canal dimensions determined by hydraulic calculations, and Table F.5.5 shows the capacities of existing canals for their possible inclusion in the principal canal system (cross-section measurement made at site).

It is usually the case that a height allowance (freeboard) is added in determining the cross-section of a drainage canal. In determining the Principal canal dimensions, calculations were worked out with account taken of the purpose and accuracy of the survey so as to provide a safety factor of 1.10 or more which is the ratio of total canal capacity to design drainage discharge.

F.5.5 Design of Secondary Drainage Canal System

(1) Secondary Canal System

The secondary canal system will be constructed to link field drainage canal with principal drainage canals, so that it will often meet the principal canal at a right angle. Various types of canal systems can be proposed since the canal arrangement can be varied according to the arrangement in present farmlands, and future block arrangement in the new settlement. The secondary canal lengths can also vary according to the interval of the main canal. For this reason, the standard drainage system based on the terminal drainage improvement plan shown in Main Report Fig. 4.6.2 will be adopted in the design of the secondary canal system.

(2) Structure

As is the case with the principal canal, the secondary canal will be designed as an unlined canal having a side slope of 1 : 1.0 which is considered suitable judging from the existing condition of the banana plantation's canals.

(3) Dimensions

Since the tertiary canals in the perennial crop farmland are planed to have a depth of 2.0 m, the secondary canal will have a depth of more than 2.0 m. To assure that the system will exhibit the ability to drain rainfall with a return period of five years, the canal capacity was calculated as follows using the standard model for terminal drainage improvement plan;

- Drainage area

  $A = 1.0\ km^2$ (1.0 km x 1.0 km)

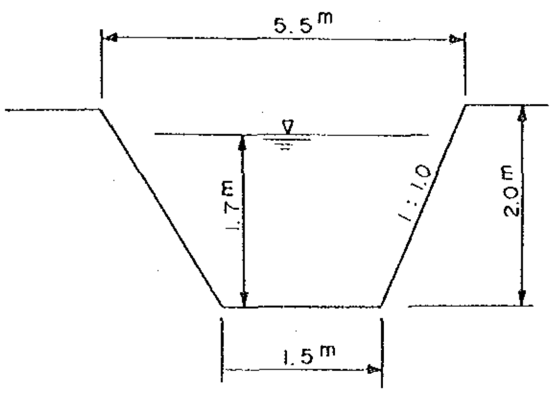
- Design rainfall intensity

$$r = \frac{229}{t + 4.0} = \frac{229}{4 + 4.0} = 28.6\ mm/hr$$

(In consideration of the shortest time of flood concentration in the principal drainage canal and the probable upland crop planting, t = 4hr is adopted)

- Runoff $$Q = \frac{f.r.A}{3.6} = \frac{0.45 \times 28.6 \times 1.0}{3.6} = 3.6\ m^3/s$$

- Section and flow capacity



$A = 5.44\ m^2$

$P = 6.308\ m$

$$R = \frac{A}{P} = 0.862$$

$n = 0.030$

$$I = \frac{1}{2000}$$

$$V = \frac{1}{n} I^{1/2} R^{2/3} = 33.3 \times 0.0224 \times 0.9.6 = 0.675\ m/s$$

$Q = A \times V = 5.44 \times 0.675 = 3.7\ m^3/s \quad 3.6\ m^3/s$

F.5.6 Possibility of Gravity Drainage

Since lowlying areas will be inundated at the time of a flood, a hydraulic analysis was made to study the possibility of gravity drainage by principal canals.

Conditions

Maximum depth of flooding water : 1.58 m M.S.L(1/5 Probability)

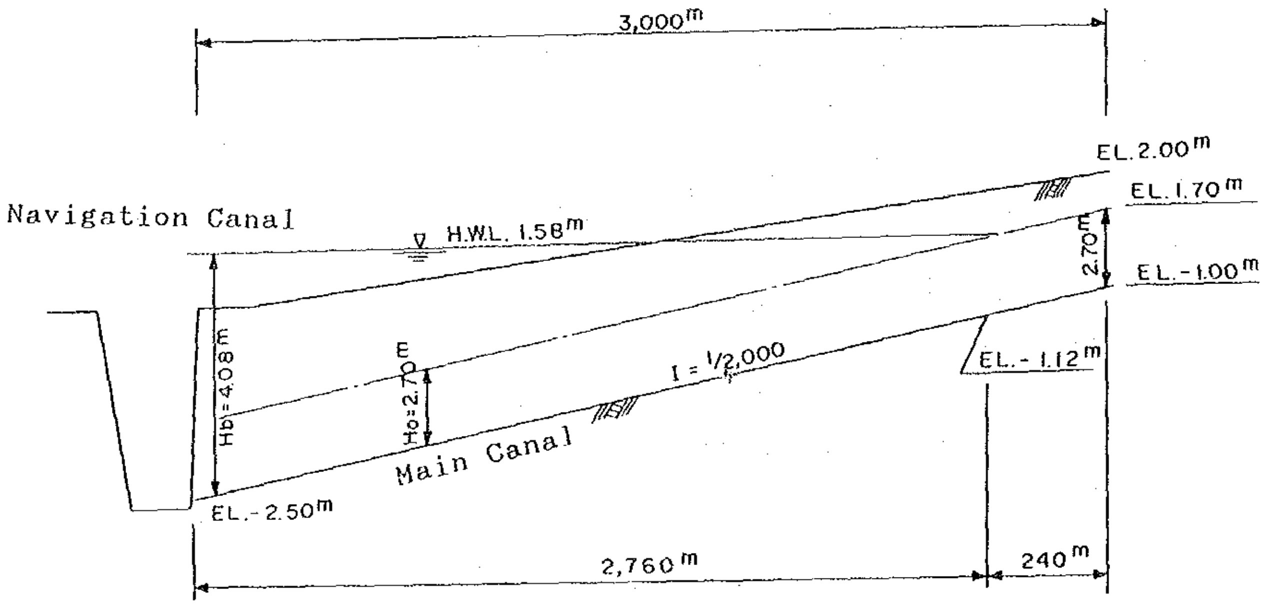
Gradient of canal : 1/2000

Point of location : Ground level 2.00 m (3000 m from the Navigable Canal)

Relation of height of canal bottom and water level, as below.

Calculation of backwater

The backwater was calculated by Poiree's Approximate Formula.



$$Z = Zo - iL + \frac{i^2}{4Zo} L^2 = Zo - iL\,(1 - \frac{iL}{4Zo})$$

Zo = Hb - Ho (As shown in the above figure)

Z : Rising water level in the point L m

i : Gradient of canal

L : Distance (Point of intersection of HWL and Ho ; 2,760 m)

Zo = 4.08 - 2.70 = 1.38 m

$$Z = 1.38 - \frac{1}{2000} \times 2{,}760\,(1 - \frac{1/2000 \times 2{,}760}{4 \times 1.38})$$

$$= 1.38 - 1.04 = 0.34 \text{ m}$$

As can be seen from the above calculation, the water level at a distance of 2,760 m from the Navigable Canal is El 1.92 m (= 1.58 + 0.34). The water level is EL 1.95 m at a point where the ground level is 2.00, as shown below. Accordingly, it can be said that the lowest ground level that will permit the gravity drainage of principal canal is El 2.00 m.

Water level at point where the ground level is 2.0 m (at 3 km point from the Navigable Canal)

V = (1.92 + 1.12) - (1.70 + 1.00) x 240/2760 + 1.92 = 1.95 m

F.5.7 Ordinary Water Level of Canal

In areas where the ground level is about 2.00 m, the bottom of secondary canal will have a lower elevation than the ordinary water level (El 0.60 m). This will cause backwater from the principal canal even when it is used for ordinary drainage. Since this backwater is linked to raise the groundwater level, the ordinary water level of secondary canal was examined, as shown below.

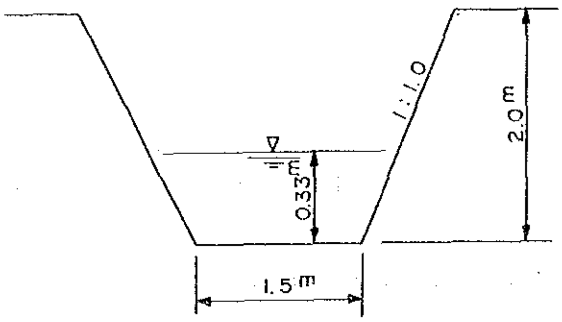
(1) Mean Drainage Discharge

The mean drainage discharge was calculated using the maximum monthly average rainfall (461 mm, December) obtained from the 1970 - 1985 rainfall observation record at La Lola.

Area = 1.0 km^2 (Drainage area of Secondary Canal)

Mean drainage discharge = 461/31 x 1.0/3.6 x 24 = 0.17 m^3/s

(2) Water Depth under Uniform Flow



I = 1/2000
n = 0.03
A = 0.06 m
P = 2.43 m
R = A/P = 0.247

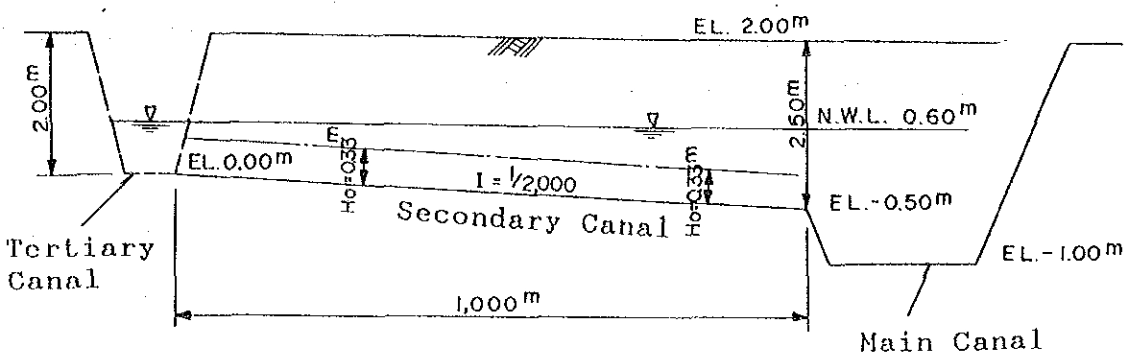
$$V = \frac{1}{n} I^{1/2} R^{2/3} = 33.3 \times 0.0224 \times 0.393 = 0.29 \text{ m/s}$$

$$Q = A \times V = 0.60 \times 0.29 = 174 \text{ m}^3/\text{s} \doteqdot \text{Mean drainage discharge}$$

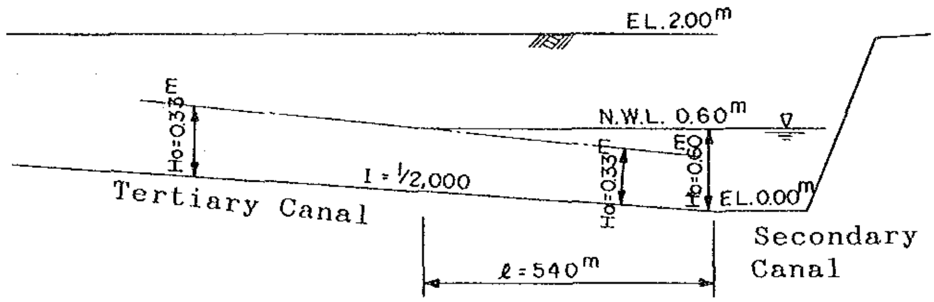
(3) Analysis of Backwater (by Poiree's formula)

Since the ordinary water level of the navigable canal is EL 0.60 m, the water level relationship among the principal canal, secondary canal and tertiary canal can be pictured as shown below.

Main Canal - Secondary Canal



Secondary Canal - Tertiary Canal



The water level rise, Z, in the tertiary canal at a point 540 m from the secondary canal, can be obtained by the following calculation.

$$Zo = Hb - Ho = 0.60 - 0.33 = 0.27 \text{ m}$$

$$Z = Zo - iL\left(1 - \frac{iL}{4Zo}\right) = 0.27 - \frac{1}{2000} \times 540 \left(1 - \frac{1/2000 \times 540}{4 \times 0.27}\right)$$

$$= 0.07 \text{ m}$$

Thus, the backwater influences the tertiary canal by raising its water level from 0.60 (ordinary level) to 0.70 m (= 0.60 + 0.07).

In places where the ground level is 2.00 m, the ordinary groundwater level reaches GL -1.30 m. This does not affect the growth of annual crops because they have no problem with grondwater level of power than GL - (0.50 to 0.60m), but influences the growth of perennial crops that call for a groundwater level of GL -1.50 - -1.00 m. Accordingly, it is not advisable to plant perennial crops in places where the ground leve is 2.00 m.

Table F.5.1 (1) Proposed Principal Drainage Canal

(Unit: km)

Zone	Canals	Total Length	Classification: New Canal	Classification: Improvement River	Classification: Improvement Canal	Remarks
A	A - 1	8.0	6.0	2.0*		
	A - 2	11.6	9.6	2.0*		
	A - 3	3.0	3.0			
	A - 4	3.3	3.3			
	A - 5	11.8	7.8	4.0*		
	Sub-Total	37.7	29.7	8.0		
B	B - 1	12.5	12.5		9.8*	
	B - 2	9.8				
	B - 3	2.2	2.2			
	B - 4	9.9	2.3		7.6*	
	B - 5	6.8			6.8**	
	B - 6	12.7	12.7			
	B - 7	4.8	2.8	2.0*		
	Sub-Total	58.7	32.5	2.0	24.2	
C	C - 1	15.3	0.8	14.5*		
	C - 2	4.7			4.7**	
	C - 3	3.2			3.2**	
	C - 4	1.7	1.7			
	C - 5	1.3	1.3			
	C - 6	4.3	4.3			
	C - 7	5.4	3.4		2.0*	
	C - 8	2.8	2.8			
	Sub-Total	38.7	14.3	14.5	9.9	
D	D - 1	15.5	15.5			
	D - 2	4.8	4.8			
	D - 3	15.2	15.2			
	D - 4	10.4	10.4			
	D - 5	7.5			7.5**	
	D - 6	1.7	1.7			
	Sub-Total	55.1	47.6		7.5	
	TOTAL	190.2	124.1	24.5	41.6	

Note *: Canal to be improved.

**: Existing canal.

Table F.5.2 Time of Concentration

Zone	Drainage Canal	Difference	Length	Time of Concentration	Classification
		m	km	minutes	
A	A - 1	38	13	360	II
	A - 2	8	9	505	II
	A - 3	5	3	115	I
	A - 4	1	3	303	I
	A - 5	11	11	578	II
B	B - 1	12	11	546	II
	B - 2	12	13	714	II
	B - 3	1	2	158	I
	B - 4	5	7	447	II
	B - 5	4	7	514	II
	B - 6	8	13	914	III
	B - 7	280	12	95	I
C	C - 1	395	23	218	I
	C - 2	1	3	303	I
	C - 3	1	4	481	II
	C - 4	1	2	158	I
	C - 5	180	12	123	I
	C - 6	7	5	214	I
	C - 7	10	4	120	I
	C - 8	8	5	198	I
D	D - 1	18	25	1,596	III
	D - 2	6	5	234	I
	D - 3	38	26	1,084	III
	D - 4	8	10	597	II
	D - 5	18	11	428	II
	D - 6	5	4	183	I

Table F.5.3 (1) Design Drainage of Discharge Drainage Canal

Zone	Canal	Classification	Section (km - km)	Length (km)	Watershed (km^2)	Unit Discharge ($m^3/s/km^2$)	Discharge (m^3/s)	Remarks
A	A - 1	II	- 1.0	1.0	30.0	2.050	62	
			1.0 - 3.0	2.0	55.0		113	
			3.0 - 5.0	2.0	61.0		125	
			5.0 - 8.0	3.0	61.0		125	
			Sub-Total	8.0				
	A - 2	II	- 2.0	2.0	8.0	2.050	16	
			2.0 - 4.2	2.2	17.0		35	
			4.2 - 6.2	2.0	31.0		64	
			6.2 - 8.6	2.4	39.0		80	
			8.6 -11.6	3.0	39.0		80	
			Sub-Total	11.6				
	A - 3	I	- 3.0	3.0	7.0	3.575	25	
			Sub-Total	3.0				
	A - 4	I	- 2.0	2.0	5.0	3.575	18	
			2.0 - 3.3	1.3	7.0		25	
			Sub-Total	3.3				
	A - 5	II	- 2.0	2.0	12.0	2.050	25	
			2.0 - 4.0	2.0	17.0		35	
			4.0 - 6.0	2.0	24.0		49	
			6.0 - 8.0	2.0	33.0		68	
			8.0 -10.0	2.0	42.0		86	
			10.0 -11.8	1.8	44.0		90	
			Sub-Total	11.8				
			TOTAL	37.7				

Table F.5.3 (2) Design Drainage Discharge of Principal Drainage Canal

Zone	Canal	Classification	Section (km - km)	Length (km)	Watershed (km^2)	Unit Discharge ($m^3/s/km^2$)	Discharge (m^3/s)	Remarks
	B - 1	II	- 2.0	2.0	10.7	2.050	22	
			2.0 - 4.0	2.0	19.7		40	
			4.0 - 6.0	2.0	29.2		60	
			6.0 - 8.0	2.0	38.5		79	
			8.0 -10.0	2.0	44.0		90	
			10.0 -12.5	2.5	46.0		94	
			Sub-Total	12.5				
	B - 2	III	- 2.4	2.4	18.8	2.050	39	
			2.4 - 4.4	2.0	35.6		73	
			4.4 - 6.0	1.6	41.4		85	
			6.0 - 9.8	3.8	41.4		85	
			Sub-Total	9.8				
	B - 3	I	- 2.2	2.2	5.0	3.575	18	
			Sub-Total	2.2				
	B - 4	II	- 2.3	2.3	0.9	2.050	2	
			2.3 - 4.0	1.7	3.5		7	
			4.0 - 6.0	2.0	7.3		15	
			6.0 - 8.0	2.0	11.2		23	
			8.0 - 9.9	1.9	13.8		28	
			Sub-Total	9.9				
	B - 5	II	- 6.8	6.8	6.0	2,050	12	
			Sub-Total	6.8				

Table F.5.3 (3) Design Drainage Discharge of Principal Drainage Canal

Zone	Canal	Classification	Section (km - km)	Length (km)	Watershed (km^2)	Unit Discharge ($m^3/s/km^2$)	Discharge (m^3/s)	Remarks
	B - 6	III	- 2.0	2.0	6.5	1.188	8	
			2.0 - 4.0	2.0	11.3		13	
			4.0 - 5.7	1.7	15.6		19	
			5.7 - 7.7	2.0	19.6		23	
			7.7 -10.7	3.0	24.6		29	
			10.7 -12.7	2.0	24.6		29	
			Sub-Total	12.7				
	B - 7	I	- 2.0	2.0	13.5	3.575	48	
			2.0 - 4.8	2.8	19.0		68	
			Sub-Total	4.8				
			TOTAL	58.7				
	C - 1	I	- 0.8	0.8	33.8	3.575	121	
			0.8 - 3.0	2.2	59.3		212	
			3.0 - 5.0	2.0	122.7		439	
			5.0 - 6.3	1.3	127.7		457	
			6.3 - 8.3	2.0	136.7		489	
			8.3 -10.3	2.0	148.3		530	
			10.3 -12.7	2.4	156.4		559	
			12.7 -15.3	2.6	156.4		559	
			Sub-Total	15.3				
	C - 2	I	- 4.7	4.7	1.8	3.575	6	
			Sub-Total	4.7				
	C - 3	II	- 3.2	3.2	3.3	2.050	7	
			Sub-Total	3.2				

Table F.5.3 (4) Design Drainage Discharge of Principal Drainage Canal

Zone	Canal	Classification	Section (km - km)	Length (km)	Watershed (km^2)	Unit Discharge ($m^3/s/km^2$)	Discharge (m^3/s)	Remarks
	C - 4	I	- 1.7	1.7	6.0	3.575	21	
			Sub-Total	1.7				
	C - 5	I	- 1.3	1.3	24.3	3.575	87	
			Sub-Total	1.3				
	C - 6	I	- 2.3	2.3	5.5	3.575	20	
			2.3 - 4.3	2.0	31.9		114	
			Sub-Total	4.3				
	C - 7	I	- 2.0	2.0	12.8	3.575	46	
			2.0 - 4.0	2.0	19.1		68	
			4.0 - 5.4	1.4	21.9		78	
			Sub-Total	5.4				
	C - 8	I	- 2.8	2.8	20.7	3.575	74	
			Sub-Total	2.8				
	D - 1	III	- 2.0	2.0	4.5	1.188	5	
			2.0 - 4.3	2.3	6.5		8	
			4.3 - 6.3	2.0	26.4		31	
			6.3 - 8.3	2.0	31.4		37	
			8.3 -10.3	2.0	46.7		55	
			10.3 -12.3	2.0	51.7		61	
			12.3 -15.5	3.2	61.5		73	
			Sub-Total	15.5				
			TOTAL	38.7				

Table F.5.3 (5) Design Drainage Discharge of Principal Drainage Canal

Zone	Canal	Classification	Section (km - km)	Length (km)	Watershed (km^2)	Unit Discharge ($m^3/s/km^2$)	Discharge (m^3/s)	Remarks
	D - 2	I	- 2.0	2.0	9.5	3.575	34	
			2.0 - 4.8	2.8	12.3		44	
			Sub-Total	4.8				
	D - 3	II	- 2.0	2.0	18.8	2.050	39	
			2.0 - 4.0	2.0	24.8		51	
			4.0 - 6.0	2.0	31.1		64	
			6.0 - 8.0	2.0	38.1		78	
			8.0 -10.0	2.0	44.4		91	
			10.0 -12.0	2.0	49.7		102	
			12.0 -14.6	2.6	53.0		109	
			14.6 -15.2	0.6	53.0		109	
			Sub-Total	15.2				
	D - 4	II	- 2.0	2.0	5.3	2.050	11	
			2.0 - 4.0	2.0	12.8		26	
			4.0 - 6.0	2.0	20.8		43	
			6.0 - 8.0	2.0	29.6		61	
			8.0 -10.4	2.4	36.9		76	
			Sub-Total	10.4				
	D - 5	II	- 2.0	2.0	12.0	2.050	25	
			2.0 - 4.0	2.0	17.0		35	
			4.0 - 6.0	2.0	20.5		42	
			6.0 - 7.5	1.5	21.4		44	
			Sub-Total	7.5				
	D - 6	I	- 1.7	1.7	14.0	3.575	50	
			Sub-Total	1.7				
			TOTAL	55.1				

Table F.5.4 (1) Dimension of Proposed Principal Drainage Canal

Zone	Canal	Section (km - km)	Length (km)	Design Discharge (m^3/s)	Slope (1 : S)	Canal (m)	Depth Bed (m)	Capacity (m^3/s)	Safety Factor
A	A - 1	- 1.0	1.0	62	500	6.0	3.0	71.4	1.2
		1.0 - 3.0	2.0*	113	500	12.0	3.0	123.7	1.1
		3.0 - 5.0	2.0	125	1,400	14.0	4.0	142.0	1.1
		5.0 - 8.0	3.0	125	1,600	16.0	4.0	148.9	1.2
		Sub-Total	8.0						
	A - 2	- 2.0	2.0*	16	1,000	1.5	3.0	24.5	1.5
		2.0 - 4.2	2.2	35	1,000	5.0	3.0	44.5	1.3
		4.2 - 6.2	2.0	64	1,000	10.0	3.0	74.9	1.2
		6.2 - 8.6	2.4	80	1,600	16.0	3.0	89.1	1.1
		8.6 -11.6	3.0	80	1,600	16.0	3.0	89.1	1.1
		Sub-Total	11.6						
	A - 3	- 3.0	3.0	25	500	1.5	3.0	34.6	1.4
		Sub-Total	3.0						
	A - 4	- 2.0	2.0	18	2,000	2.0	3.0	19.3	1.1
		2.0 - 3.3	1.3	25	2,000	5.0	3.0	31.5	1.3
		Sub-Total	3.3						
	A - 5	- 2.0	2.0	25	1,000	2.0	3.0	27.1	1.1
		2.0 - 4.0	2.0*	35	1,000	4.0	3.0	38.5	1.1
		4.0 - 6.0	2.0*	49	1,000	7.0	3.0	56.5	1.2
		6.0 - 8.0	2.0	68	1,000	10.0	3.0	74.9	1.1
		8.0 -10.0	2.0	86	1,000	10.0	4.0	128.2	1.5
		10.0 -11.8	1.8	90	1,000	10.0	4.0	128.2	1.4
		Sub-Total	11.8						
		TOTAL	37.7						

Table F.5.4 (2) Dimension of Proposed Principal Drainage Canal

Zone	Canal	Section (km - km)	Length (km)	Design Discharge (m^3/s)	Slope (1 : S)	Canal (m)	Depth Bed (m)	Capacity (m^3/s)	Safety Factor
B	B - 1	- 2.0	2.0	22	1,000	1.5	3.0	24.5	1.1
		2.0 - 4.0	2.0	40	1,000	5.0	3.0	44.5	1.1
		4.0 - 6.0	2.0	60	1,000	9.0	3.0	68.8	1.1
		6.0 - 8.0	2.0	79	1,000	9.0	4.0	118.4	1.5
		8.0 -10.0	2.0	90	1,000	9.0	4.0	118.4	1.3
		10.0 -12.5	2.5	94	1,000	9.0	4.0	118.4	1.3
		Sub-Total	12.5						
	B - 2	- 2.4	2.4*	39	1,000	5.0	3.0	44.5	1.1
		2.4 - 4.4	2.0*	73	1,000	6.0	4.0	81.6	1.1
		4.4 - 6.0	1.6*	85	1,000	9.0	4.0	118.4	1.4
		6.0 - 9.8	3.8*	85	1,000	9.0	4.0	118.4	1.4
		Sub-Total	9.8						
	B - 3	- 2.2	2.2	18	1,000	1.5	3.0	24.5	1.4
		Sub-Total	2.2						
	B - 4	- 2.3	2.3	2	500	1.5	3.0	34.6	17.3
		2.3 - 4.0	1.7*	7	500	1.5	3.0	34.6	4.9
		4.0 - 6.0	2.0*	15	500	1.5	3.0	34.6	2.3
		6.0 - 8.0	2.0*	23	500	1.5	3.0	34.6	1.5
		8.0 - 9.9	1.9*	28	500	1.5	3.0	34.6	1.2
		Sub-Total	9.9						
	B - 5	- 6.8	6.8	12	Utilization of Existing Canal				
		Sub-Total	6.8						

Table F.5.4 (3) Dimension of Proposed Principal Drainage Canal

Zone	Canal	Section (km - km)	Length (km)	Design Discharge (m^3/s)	Slope (1 : S)	Canal (m)	Depth Bed (m)	Capacity (m^3/s)	Safety Factor
	B - 6	- 2.0	2.0	8	2,000	1.5	3.0	17.3	2.2
		2.0 - 4.0	2.0	13	2,000	1.5	3.0	17.3	1.3
		4.0 - 5.7	1.7	19	1,000	1.5	3.0	24.5	1.3
		5.7 - 7.7	2.0	23	1,000	2.0	3.0	27.1	1.2
		7.7 -10.7	3.0	29	1,000	3.0	3.0	32.9	1.1
		10.7 -12.7	2.0	29	2,000	3.0	3.0	32.9	1.1
		Sub-Total	12.7						
	B - 7	- 2.0	2.0*	48	1,000	7.0	3.0	56.5	1.2
		2.0 - 4.8	2.8	68	1,000	10.0	3.0	74.9	1.1
		Sub-Total	4.8						
		TOTAL	58.7						
C	C - 1	- 0.8	0.8*	121	500	3.0	5.0	152.3	1.3
		0.8 - 3.0	2.2*	212	500	8.0	5.0	239.1	1.1
		3.0 - 5.0	2.0*	439	500	20.0	5.0	482.9	1.1
		5.0 - 6.3	1.3*	457	1,000	32.0	5.0	520.0	1.1
		6.3 - 8.3	2.0*	489	1,000	34.0	5.0	550.1	1.1
		8.3 -10.3	2.0*	530	1,000	36.0	5.0	580.2	1.1
		10.3 -12.7	2.4*	559	1,600	50.0	5.0	626.3	1.1
		12.7 -15.3	2.6*	559	1,600	50.0	5.0	626.3	1.1
		Sub-Total	15.3						
	C - 2	- 4.7	4.7	6	Utilization of Existing Canal				
		Sub-Total	4.7						

Table F.5.4 (4) Dimension of Proposed Principal Drainage Canal

Zone	Canal	Section (km - km)	Length (km)	Design Discharge (m^3/s)	Slope (1 : S)	Canal (m)	Depth Bed (m)	Capacity (m^3/s)	Safety Factor
	C - 3	- 3.2	3.2	7	Utilization of Existing Canal				
		Sub-Total	3.2						
	C - 4	- 1.7	1.7	21	2,000	3.0	3.0	23.2	1.1
		Sub-Total	1.7						
	C - 5	- 1.3	1.3	87	1,000	7.0	4.0	99.0	1.1
		Sub-Total	1.3						
	C - 6	- 2.3	2.3	20	1,000	1.5	3.0	24.5	1.2
		2.3 - 4.3	2.0	114	1,000	10.0	4.0	128.2	1.1
		Sub-Total	4.3						
	C - 7	- 2.0	2.0*	46	800	6.0	3.0	56.4	1.2
		2.0 - 4.0	2.0	68	800	9.0	3.0	76.9	1.1
		4.0 - 5.4	1.4	78	800	12.0	3.0	97.8	1.3
		Sub-Total	5.4						
	C - 8	- 2.8	2.8	74	500	8.0	3.0	97.2	1.3
		Sub-Total	2.8						
		TOTAL	38.7						

Table F.5.4 (5) Dimension of Proposed Principal Drainage Canal

Zone	Canal	Section (km - km)	Length (km)	Design Discharge (m^3/s)	Slope (1 : S)	Canal (m)	Depth Bed (m)	Capacity (m^3/s)	Safety Factor
D	D - 1	- 2.0	2.0	5	700	1.5	3.0	29.2	5.8
		2.0 - 4.3	2.3	8	700	1.5	3.0	29.2	3.7
		4.3 - 6.3	2.0	31	700	3.0	3.0	39.2	1.3
		6.3 - 8.3	2.0	37	700	4.0	3.0	46.2	1.2
		8.3 -10.3	2.0	55	700	5.0	4.0	95.6	1.7
		10.3 -12.3	2.0	61	700	5.0	4.0	95.6	1.6
		12.3 -15.5	3.2	73	700	5.0	4.0	95.6	1.3
		Sub-Total	15.5						
	D - 2	- 2.0	2.0	34	500	2.0	3.0	38.4	1.1
		2.0 - 4.8	2.8	44	500	4.0	3.0	54.6	1.2
		Sub-Total	4.8						
	D - 3	- 2.0	2.0	39	1,000	5.0	3.0	44.5	1.1
		2.0 - 4.0	2.0	51	1,000	7.0	3.0	56.5	1.1
		4.0 - 6.0	2.0	64	1,000	7.0	4.0	99.0	1.5
		6.0 - 8.0	2.0	78	1,000	7.0	4.0	99.0	1.3
		8.0 -10.0	2.0	91	1,000	8.0	4.0	108.7	1.2
		10.0 -12.0	2.0	102	1,000	9.0	4.0	118.4	1.2
		12.0 -14.6	2.6	109	1,000	10.0	4.0	128.2	1.2
		14.6 -15.2	0.6	109	1,000	10.0	4.0	128.2	1.2
		Sub-Total	15.2						
	D - 4	- 2.0	2.0	11	1,000	1.5	3.0	24.5	2.2
		2.0 - 4.0	2.0	26	1,000	3.0	3.0	32.9	1.3
		4.0 - 6.0	2.0	43	1,000	6.0	3.0	50.5	1.2
		6.0 - 8.0	2.0	61	1,000	9.0	3.0	68.8	1.1
		8.0 -10.4	2.4	76	1,000	12.0	3.0	83.6	1.1
		Sub-Total	10.4						

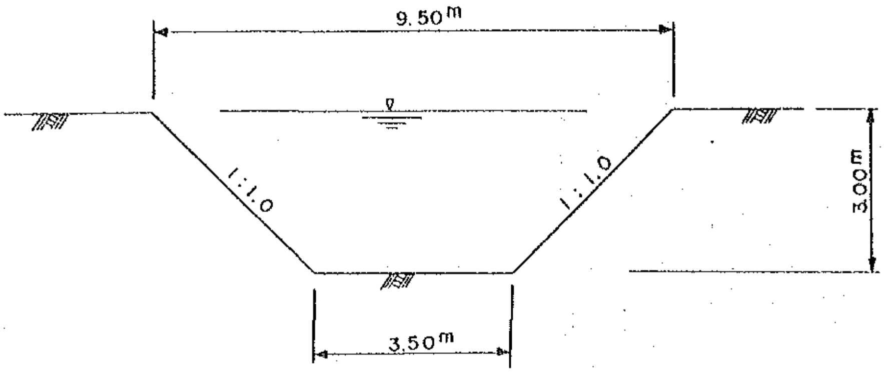
Table F.5.4 (6) Dimension of Proposed Principal Drainage Canal

Zone	Canal	Section (km - km)	Length (km)	Design Discharge (m^3/s)	Slope (1 : S)	Canal Bed (m)	Depth (m)	Capacity (m^3/s)	Safety Factor
	D - 5	- 2.0	2.0	25	Utilization of Existing Canal				
		2.0 - 4.0	2.0	35	Utilization of Existing Canal				
		4.0 - 6.0	2.0	42	Utilization of Existing Canal				
		6.0 - 7.5	1.5	44	Utilization of Existing Canal				
		Sub-Total	7.5						
	D - 6	- 1.7	1.7	50	1,000	7.0	3.0	56.5	1.1
		Sub-Total	1.7						
		TOTAL	55.1						

Note : * is where river training by means of extending the width is carried out.

Table F.5.5 (1) Drainage Capacity of Existing Available Canal without Improvement

(1) CANAL B - 5



$A = (9.50 + 3.50) \times 1/2 \times 3.00 = 19.5\ m^2$

$P = 3.0 \times 1.414 \times 2 + 3.50 = 12.0\ m$

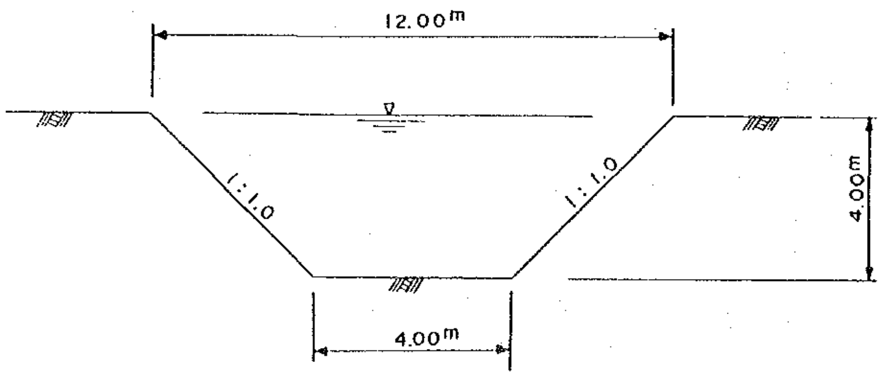
$I = 1/500$

$V = 1/n \times I^{1/2} \times R^{2/3} = 1/0.035 \times (1/500)^{1/2} \times (19.5/12.0)^{2/3}$

$= 1.77\ m/s$

$Q = A \times V = 19.5 \times 1.77 = 34.5\ m^3/s > 12.0\ m^3/s$

(2) CANAL C - 2



$A = (12.00 + 4.00) \times 1/2 \times 4.00 = 32.0\ m^2$

$P = 4.0 \times 1.414 \times 2 + 4.00 = 15.3\ m$

$I = 1/5{,}000$

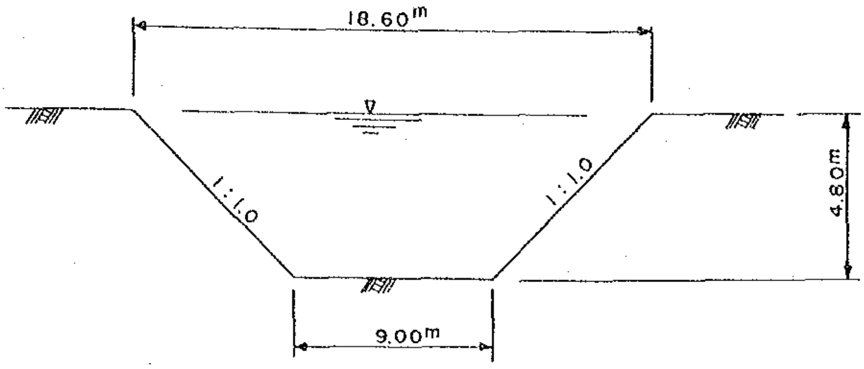
$V = 1/n \times I^{1/2} \times R^{2/3} = 1/0.035 \times (1/5{,}000)^{1/2} \times (32.0/15.3)^{2/3}$

$= 0.66\ m/s$

$Q = A \times V = 32.0 \times 0.66 = 21.1\ m^3/s > 6.0\ m^3/s$

Table F.5.5 (2) Drainage Capacity of Existing Available Canal without Improvement

(3) CANAL C - 3



$A = (18.60 + 9.00) \times 1/2 \times 4.80 = 66.2\ m^2$

$P = 4.8 \times 1.414 \times 2 + 9.00 = 22.6\ m$

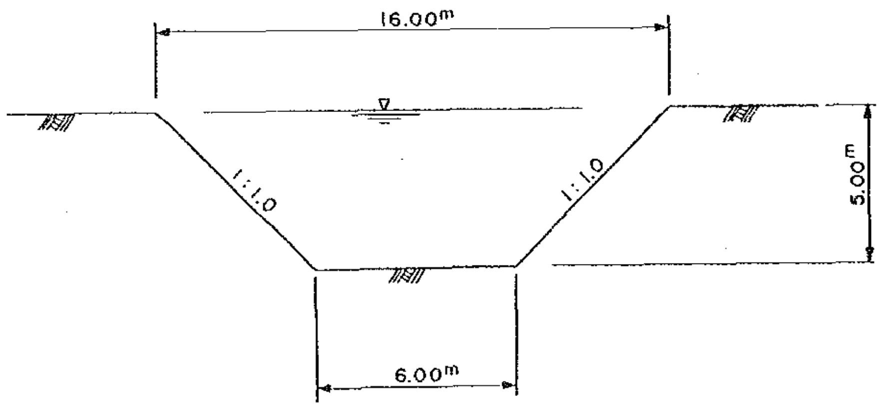
$I = 1/5,000$

$V = 1/n \times I^{1/2} \times R^{2/3} = 1/0.035 \times (1/5,000)^{1/2} \times (66.2/22.6)^{2/3}$

$= 0.83\ m/s$

$Q = A \times V = 66.2 \times 0.83 = 54.9\ m^3/s > 7.0\ m^3/s$

(4) CANAL D - 5



$A = (16.00 + 6.00) \times 1/2 \times 5.00 = 55.0\ m^2$

$P = 5.0 \times 1.414 \times 2 + 6.00 = 20.1\ m$

$I = 1/1,000$

$V = 1/n \times I^{1/2} \times R^{2/3} = 1/0.035 \times (1/1,000)^{1/2} \times (55.0/20.1)^{2/3}$

$= 1.77\ m/s$

$Q = A \times V = 55.0 \times 1.77 = 97.4\ m^3/s > 44\ m^3/s$

F.6 Flood Protection Plan

F.6.1 Flood Protection Work

River embankment for flood protection is proposed for all river sections excluding the following which were found to have been exempted from flood damage since 1970 by the field survey.

- Upstream section of Rio Pacuare
- Upstream section of Rio Reventazon

The flood protection work will be carried out for each of the river sections mentioned below, with consideration given to the topography and land use conditions around the river course.

- Rio Chirripo

  Flood protection is proposed for the section from National Route 32 to the confluence with the Matina, excluding the 1-km section immediately downstream of the national road. Embankment will be constructed on the right side of the river because a constant swampy area extends on the left side.

- Rio Barbilla

  Flood protection is proposed for the section from the north of Davao to the confluence with the Matina. Embankment will be constructed only on the left side of the river because the right bank has a rather steep slope (about 1/50).

- Rio Matina

  Embankment construction is proposed for both sides of the river section from the junction of the Chirripo and the Barbilla to Barra Matina Norte. It should be carried out with account taken of the land use plan. However, the section where the embankment construction is now carried out by the banana plantation in Barra

Matina Sur will be excluded.

- Rio Pacuare

Embankment construction is proposed for the left side of the section from indiana Tres to the downstream of the Imperio settlement now being developed by IDA. This should be also carried out with attention paid to the land use plan. Embankment construction is also proposed for the right side of the section from indiana Tres to the banana plantation located at the most downstream of the river.

- Rio Reventazon and Rio Parismina

Embankment of the Reventazon is proposed for both sides of the section from a point about 2 km to the north of Carmen to the confluence with the Parismina. Embankment of the Parismina, to be carried out with attention paid to the land use plan, is proposed for the 2km section (straight line distance) from the confluence of the Reventazon and the Parismina.

Table F.6.1 shows the embankment length for each river.

F.6.2 Alternative Study of Flood Protection Work

(1) Basic Concept

For the formulating of a suitable plan for river embankment for flood protection, and alternative study of flood discharge with a return period of 2 years, 5 years, 10 years and 20 years was made in comparison with the cost-benefit ratio shown below.

- Cost-Benefit ratio

Annual depreciation cost of river embankment (c)
Annual estimated amount that can be saved by flood protection (benefit - B)

(2) Dimensions of Flood Protection Work

Prior to the cost-benefit analysis, two factors in the flood protection work (embankment height H, major bed width B) for flood discharge with different return periods (2 -20 years) were studied.

Since the land price is low in the study area, the cost of flood protection work can be reduced by making the embankment height small and the major bed width large.

The hydraulic analysis for this purpose was made using manning's formula. Table F.6.2 shows the results of analysis.

$$V = \frac{1}{n} I^{1/2} R^{2/3}$$

$$Q = V \times A$$

V	: Average flow velocity	m/s
n	: Roughness coefficient	0.035
I	: Gradient of river bed (Estimated by topographical map ; 1/50,000)	
R	: Hydraulic mean depth (A/P)	
P	: Wetted perimeter	m
A	: Cross Sectional area of flow	m^2
Q	: Amount of flow	m^3/s

For flood protection of the Parismina and the Matina, the following points were taken into consideration.

- Rio Parismina

Since the river follows an extremely meandering course, the embankment will be designed to cover the meandering width along a straight line.
A design river width of about 1 km can be secured if the embankment is designed according to the above mentioned.
Accordingly, the flood protection work can be made equivalent to the same to that of the Reventazon.

- Rio Matina

The cross-section at was measured the point where the railway crosses the river, and the capacity at that point was examined (see Table F.6.3).
The Capacity at the said point was estimated at about 4,300 m^3/s which is large enough to cope with the river's flood discharge with a return period of 40 years.
Accordingly, the railway bridge at the said point will not be reconstructed in this project.

(3) Estimation of Construction Cost and Depreciation Cost

Rough cost estimation (including land acquisition cost) was made for the flood protection work that can cope with flood discharge with a return period of 2 - 20 years. Table F.6.4 shows the results of estimation.

The annual depreciation cost (C) within the life year of the flood protection work was also estimated using the following formula. Table F.7.6 shows the results of estimation.

$$C = \frac{i(1+i)^n}{(1+i)^n-1} \times C$$

C : Annual depreciation

i : Interest rate (12 %)

n : Life year of facility (25 years)

C : Facilities construction cost

(4) Benefit (B)

Fig. F.6.2 shows the estimated amount of damage calculated for floods with different return periods that the study area have encountered. Table F-6-7 shows the benefit (estimated annual amount of damage that can be reduced) by the implementation of the flood protection work.

The benefit estimation was made on the following condition.

- Flood damage is to be estimated only for agricultural products because there are few public facilities in the study area and also because the interviews with local inhabitants disclosed that houses were inundated but none were washed away by flood in the past.

- Amount of damage is to be estimated for floods with 1, 5 and 10 years of return period because the extent of inundation caused by these floods were made clear from interviews with local inhabitants. Damage due to floods with longer return periods shall be estimated from a graph showing the flood damage curve (Fig. F.6.2).

- The banana plantation is to be excluded from the damage estimation because it has facilities for flood protection.

- Flood damage is to be construed to occur only in the inundated area excluding the land not included in the land use plan.

- Flood damage is to be estimated for the crop-wise planted area which is the product of damaged planted area and design crop intensity, by assuming the case where the project is implemented in the study area.

- Crop-wise flood damage is to be estimated from the damage rate investigated at the experiment stations at CATIE, ASBANA, and Finca Castro.

- Design yield to be realized by the project implementation is to be used as the crop yield per ha. amount of damage is to be obtained multiplying the quantity damaged by the unit selling price. The farmer's producer price should be used as the unit selling price.

(5) Alternative Study Based on B/C Ratio

Fig. F.6.3 shows the results of calculation worked out to obtain the benefit derivable from the flood protection work that can cope with flood discharges with 2 - 20 years of return period, the annual depreciation of the flood protection works, and the benefit-cost ratio.

The above calculation indicates the desirability of determining the dimensions of flood protection work for floods with 5 -20 years of return period. However, the flood with a return period 5 years was selected for determining the dimensions for the following reasons.

- B/C ratio is the highest for flood with a return period of 5 years.

- Inland benefited area from flood protection work consists mostly of farmland.

- If the flood protection work is carried out to cope with the flood with a return period of 5 years, it is possible to control floods with longer return periods (10 -20 years) within the freeboard.

Table F.6.8 shows the dimensions and length of embankments.

F.6.3 Flood Water Level in Low-Lying Area

It is known at present that flood water overflowing rivers runs down through the farmland and inundates low-lying areas. When the drainage condition is improved and flood protection work is completed under the project, it is probable that the flood concentration will become much more intensified than it is at present, and this is liable to make the foold water level in lowlying areas higher than it was before.

For this reason, calculation of drainage water balance was made for the flood with a return period of 5 years to compare the inundation condition in low-lying area at present with that after the project completion. As a result, it was found that the flood water level would increase only by a slight margin after the project completion (maximum 36 cm in flood water level, 8 hours in inundation period).(See Annex B.3)

On the basis of this calculation and considering the following points, it is not planned to carry out the flood protection work (enlargement of river-mouth cross-section, construction of additional floodway, etc.) in the low-lying areas.

- Judging from the calculation for the flood with 5 years of return period and cross-sections of large rivers, it is considered that the depth of inundation at the time of flood or ordinary water level will show a negligible change after the project completion.

- Small part of the inundation area is used for agricultural production focused on livestock products and cacao, but it is considered that this agricultural production will not be influenced by the rise of flood water level after the project completion.

- The greater part of the inundation area is covered with a virgin forest, but it is believed that the rise of flood water level after the project completion will produce no adverse impact on the natural environment (eco-system) in the area.

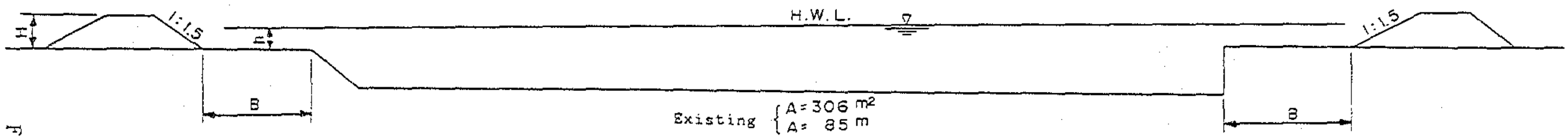
Table F.6.1 Dike Length for Flood Protection

(Unit: km)

Rivers	Right Bank	Left Bank	Total
Chirripo	–	1.3	1.3
Barbilla	8.8	–	8.8
Matina	13.3	9.0	22.3
Pacuare	27.7	25.7	53.4
Reventazon (including Parismina River)	17.2	15.2	32.4
TOTAL	67.0	51.2	118.2

Table F.6.2 (1) River Cross Section Needed According to Probable Flood Discharge - Rio Chirripo

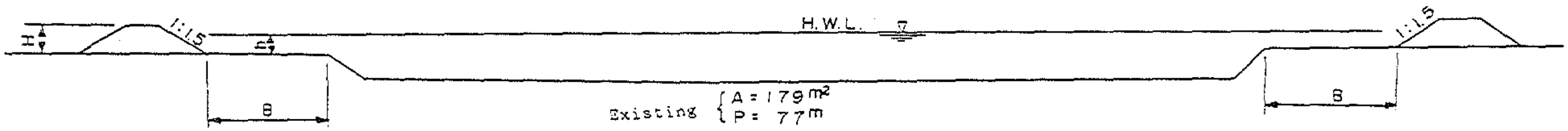
(S = 1/500)



Probability	Design Discharge (m^3/s)	B (m)	H (m)	h (m)	Slope	A (m^2)	P (m)	V (m/s)	Capacity (m^3/s)
1/2	1,133	800	2.5	1.5	1/1,000	666	250	1.74	1,159
1/5	1,870	150	3.0	2.0	1/1,000	1,068	392	1.76	1,879
1/10	2,409	150	3.5	2.5	1/1,000	1,253	394	1.95	2,443
1/20	2,965	150	4.0	3.0	1/1,000	1,455	398	2.14	3,113

Table F.6.2 (2) River Cross Section Needed According to Probable Flood Discharge - Rio Barbilla

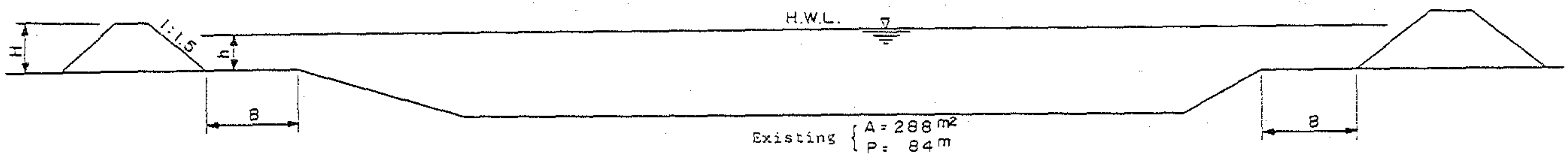
(S = 1/500)



Probability	Design Discharge (m^3/s)	B (m)	H (m)	h (m)	Slope	A (m^2)	P (m)	V (m/s)	Capacity (m^3/s)
1/2	478	15	2.0	1.0	1/1,000	287	111	1.71	491
1/5	714	45	2.5	1.5	1/1,000	430	172	1.66	714
1/10	876	45	3.0	2.0	1/1,000	515	174	1.86	956
1/20	1,037	70	3.0	2.0	1/1,000	615	224	1.77	1,088

Table F.6.2 (3) River Cross Section Needed According to Probable Flood Discharge - Rio Matina

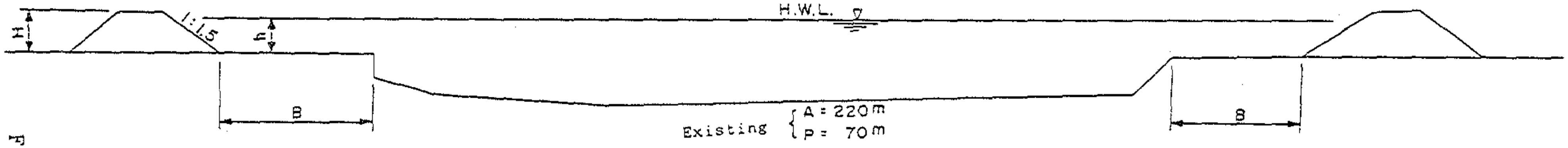
(S = 1/500)



Probability	Design Discharge (m^3/s)	B (m)	H (m)	h (m)	Slope	A (m^2)	P (m)	V (m/s)	Capacity (m^3/s)
1/2	1,284	150.0	3.0	2.0	1/2,000	1,058	391	1.24	1,311
1/5	2,151	150.0	4.0	3.0	1/2,000	1,442	395	1.52	2,192
1/10	2,789	150.0	5.0	4.0	1/2,000	1,832	398	1.77	3,242
1/20	3,452	150.0	5.5	4.5	1/2,000	2,030	400	1.89	3,836

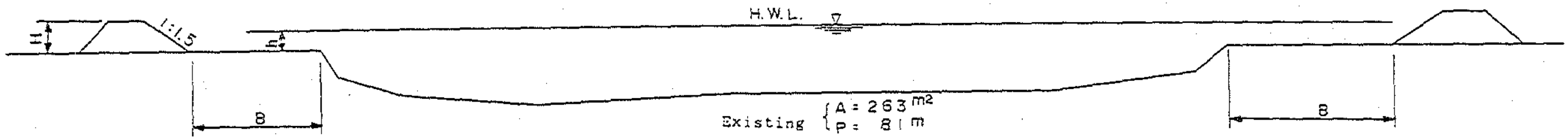
Table F.6.2 (4) River Cross Section Needed According to Probable Flood Discharge - Rio Pacuare

(S = 1/500)



Probability	Design Discharge (m^3/s)	B (m)	H (m)	h (m)	Slope	A (m^2)	P (m)	V (m/s)	Capacity (m^3/s)
1/2	973	120.0	3.0	2.0	1/2,000	840	317	1.23	1,033
1/5	1,577	150.0	3.5	2.5	1/2,000	1,148	350	1.41	1,619
1/10	2.013	150.0	4.5	3.5	1/2,000	1,522	383	1.60	2,435
1/20	2.461	150.0	5.0	4.0	1/2.000	1.712	377	1.75	2,996

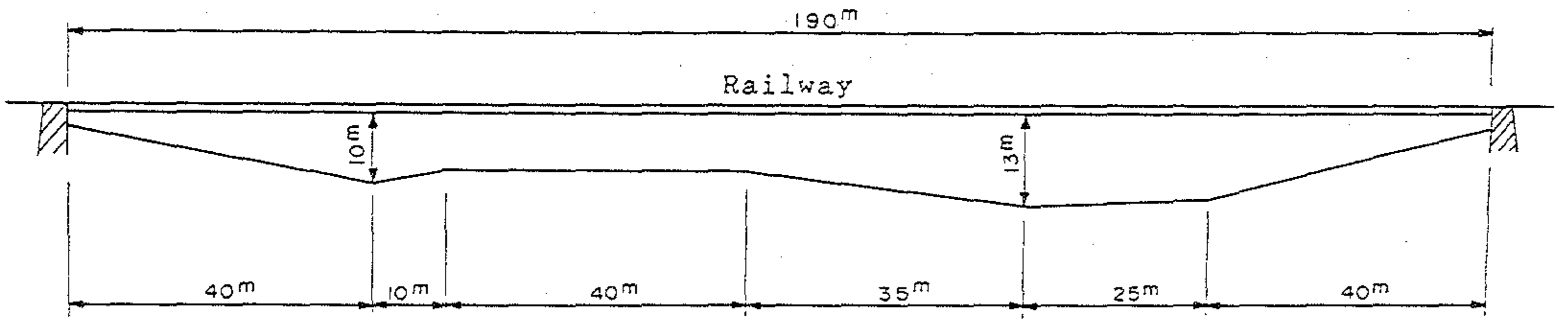
Table F.6.2 (5) River Cross Section Needed According to Probable Flood Discharge - Rio Reventazon



Probability	Design Discharge (m^3/s)	B (m)	H (m)	h (m)	Slope	A (m^2)	P (m)	V (m/s)	Capacity (m^3/s)
1/2	1,515	130.0	3.5	2.5	1/2,000	1,115	350	1.39	1,550
1/5	2,585	150.0	4.5	3.5	1/2,000	1,602	394	1.63	2,619
1/10	3,383	150.0	5.5	4.5	1/2,000	1,991	397	1.87	3,723
1/20	4,220	150.0	6.0	5.0	1/2,000	2,188	399	1.99	4,354

Table F.6.3 Drainage Capacity at Railway Bridge of Rio Matina

(S = 1/1,000)



$A = 1,650 m^2$

$P = 197 m$

Slope: 1/2,000

Roughness Coefficient: 0.035

Calculation of Capacity

$V = 1/n \times I^{1/2} \times R^{2/3} = 1/0.035 \times (1/2,000)^{1/2} \times (1,650/197)^{2/3}$

$= 2.64^{m/s}$

$Q = A \times V = 1,650 \times 2.64 = 4,356\ m^3/s$

Table F.6.4 (1) Approximate Construction Cost of Flood Protection Facility (Probability : 1/2)

Description	Dimension (m)	Length	Unit Price (1,000¢/km)	Construction Cost (1,000¢)	Remarks
Embankment Work		km			
Right bank side of:					
Chirripo	H = 2.5	1.3	3,927	5,105	
Matina	H = 3.0	9.0	5,253	47,277	
Pacuare	H = 3.0	25.7	5,163	132,689	
Reventazon	H = 3.5	15.2	6,453	98,086	
Left bank side of:					
Barbilla	H = 2.0	8.8	2,742	24,130	
Matina	H = 3.0	13.3	5,253	69,865	
Pacuare	H = 3.0	27.7	5,163	143,015	
Reventazon	H = 3.5	17.2	6,453	110,992	
Sub Total				631,159	
Purchase of Land:		ha			
Chirripo		15	70	1,050	
Matina		410	70	28,700	
Barbilla		45	70	3,150	
Pacuare		825	70	57,750	
Reventazon		535	70	37,450	
Sub Total				128,100	
Preparatory work				63,116	
TOTAL				822,375	

(13,416 x 1,000US$)

Table F.6.4 (2) Approximate Construction Cost of Flood Protection Facility (Probability : 1/5)

Description	Dimension (m)	Length	Unit Price (1,000¢/km)	Construction Cost (1,000¢)	Remarks
Embankment Work		km			
Right bank side of:					
Chirripo	H = 3.0	1.3	5,253	6,829	
Matina	H = 4.0	9.0	7,899	71,091	
Pacuare	H = 3.5	25.7	6,513	167,384	
Reventazon	H = 4.5	15.2	9,429	143,320	
Left bank side of					
Barbilla	H = 2.5	8.8	3,822	33,633	
Matina	H = 4.0	13.3	7,899	105,056	
Pacuare	H = 3.5	27.7	6,513	180,410	
Reventazon	H = 4.5	17.2	9,429	162,178	
Sub Total				869,901	
Purchase of Land:		ha			
Chirripo		25	70	1,750	
Matina		410	70	28,700	
Barbilla		70	70	4,900	
Pacuare		990	70	69,300	
Reventazon		600	70	42,000	
Sub Total				146,650	
Preparatory work				89,990	
TOTAL				1,103,541	

(18,002 x 1,000US$)

Table F.6.4 (3) Approximate Construction Cost of Flood Protection Facility (Probability : 1/10)

Description	Dimension (m)	Length	Unit Price (1,000¢/km)	Construction Cost (1,000¢)	Remarks
Embankment Work		km			
Right bank side of:					
Chirripo	H = 3.5	1.3	6,513	8,466	
Matina	H = 5.0	9.0	11,085	99,765	
Pacuare	H = 4.5	25.7	9,429	242,325	
Reventazon	H = 5.5	15.2	12,885	195,852	
Left bank side of:					
Barbilla	H = 3.0	8.8	4,938	43,454	
Matina	H = 5.0	13.3	11,085	147,431	
Pacuare	H = 4.5	27.7	9,429	261,183	
Reventazon	H = 5.6	17.2	12,885	221,622	
Sub Total				1,220,098	
Purchase of Land:		ha			
Chirripo		25	70	1,750	
Matina		410	70	28,700	
Barbilla		70	70	4,900	
Pacuare		990	70	69,300	
Reventazon		600	70	42,000	
Sub Total				146,650	
Preparatory work				122,010	
TOTAL				1,488,758	

(24,286 x 1,000US$)

Table F.6.4 (4) Approximate Construction Cost of Flood Protection Facility (Probability : 1/20)

Description	Dimension (m)	Length	Unit Price (1,000¢/km)	Construction Cost (1,000¢)	Remarks
Embankment Work		km			
Right bank:					
Chirripo	H = 4.0	1.3	7.899	10,269	
Matina	H = 5.5	9.0	12,885	115,965	
Pacuare	H = 5.0	25.7	11,085	284,885	
Reventazon	H = 6.0	15.2	14,811	225,127	
Left bank:					
Barbilla	H = 3.0	8.8	5,013	44,114	
Matina	H = 5.5	13.3	12,885	171,371	
Pacuare	H = 5.0	27.7	11,085	307,055	
Reventazon	H = 6.0	17.2	14,811	245,749	
Sub Total				1,404,535	
Purchase of Land:		ha			
Chirripo		25	70	1,750	
Matina		410	70	28,700	
Barbilla		90	70	6,300	
Pacuare		990	70	69,300	
Reventazon		600	70	42,000	
Sub Total				148,050	
Preparatory Work				140,453	
TOTAL				1,693,038	

(27,619 x 1,000US$)

Table F.6.5 (1) Unit Construction Cost of Flood Protection Dike

(P=1/2, 1/5)

River	Dimension	Excavation			Arrangement of Slope			Reclamation			Unit Cost	
	(m)	Quantity (m^3)	Unit Cost (¢)	Cost (¢)	Quantity (m^2)	Unit Cost (¢)	Cost (¢)	Quantity (m^2)	Unit Cost (¢)	Cost (¢)	(¢/m)	(1,000¢/km)
Probability 1/2												
Chirripo	H = 2.5	26.9	180	3,040	9.0	60	540	115	3	345	3,927	3,927
Barbilla	H = 2.0	12.0		2,160	7.2		432	50		150	2,742	2,742
Matina	H = 3.0	22.5		4,050	10.8		648	185		555	5,253	5,253
Pacuare	H = 3.0	22.5		4,050	10.8		648	155		465	5,163	5,163
Reventazon	H = 3.5	28.9		5,202	12.6		756	165		495	6,453	6,453
Probability 1/5												
Chirripo	H = 3.0	22.5	180	4,050	10.8	60	648	185	3	555	5,253	5,253
Barbilla	H = 2.5	16.9		3,042	9.0		540	80		240	3,822	3,822
Matina	H = 4.0	36.0		6,480	14.4		864	185		555	7,899	7,899
Pacuare	H = 3.5	28.9		5,202	12.6		756	185		555	6,513	6,513
Reventazon	H = 4.5	43.9		7,902	16.2		972	185		555	9,429	9,429

Table F.6.5 (2) Unit Construction Cost of Flood Protection Dike
(P=1/10, 1/20)

River	Dimension	Excavation			Arrangement of Slope			Reclamation			Unit Cost	
	(m)	Quantity (m^3)	Unit Cost (¢)	Cost (¢)	Quantity (m^2)	Unit Cost (¢)	Cost (¢)	Quantity (m^2)	Unit Cost (¢)	Cost (¢)	(¢/m)	(1,000¢/km)
Probability 1/10												
Chirripo	H = 3.5	28.9	180	5,202	12.6	60	756	185	3	555	6,513	6,513
Barbilla	H = 3.0	22.5		4,050	10.8		648	80		240	4,938	4,938
Matina	H = 5.0	52.5		9,450	18.0		1,080	185		555	11,085	11,085
Pacuare	H = 4.5	43.9		7,902	16.2		972	185		555	9,429	9,429
Reventazon	H = 5.5	61.9		11,142	19.8		1,188	185		555	12,885	12,885
Probability 1/20												
Chirripo	H = 4.0	36.0	180	6,480	14.4	60	864	185	3	555	7,899	7,899
Barbilla	H = 3.0	22.5		4,050	10.8		648	105		315	5,013	5,013
Matina	H = 5.5	61.9		11,142	19.8		1,188	185		555	12,885	12,885
Pacuare	H = 5.0	52.5		9,450	18.0		1,080	185		555	11,085	11,085
Reventazon	H = 6.0	72.0		12,960	21.6		1,296	185		555	14,811	14,811

Table F.6.6 Annual Depreciation and B/C of Flood Protection Facility

[Terms]

1. the life : 25 years
2. Interest : 12%
3. Construction Cost (C') : shown in TABLE F.6.4
4. Benefit (B) : shown in TABLE F.6.7

Probability	Construction Cost(C') 1,000US$	Annual Depreciation (C) 1,000US$	Benefit (B)	B/C
		$\{i(1+i)^n/(1+i)^n-1\} \times C'$		
1/2	13,416	$= \{0.12(1+0.12)^{25}/(1+0.12)^{25}-1\} \times 13,416$ = 1,711	1,563	0.91
1/5	18,002	$= \{0.12(1+0.12)^{25}/(1+0.12)^{25}-1\} \times 18,002$ = 2,295	3,512	1.53
1/10	24,286	$= \{0.12(1+0.12)^{25}/(1+0.12)^{25}-1\} \times 24,286$ = 3,096	4,232	1.37
1/20	27,619	$= \{0.12(1+0.12)^{25}/(1+0.12)^{25}-1\} \times 27,619$ = 3,521	4,662	1.32

Table F.6.7 Damage by Probable Flood and Benefit by Flood Protection

Probability	Coefficient	Extent of Damage (1,000US$)	Average Extent of Damage (1,000US$)	Extent of Damage Considering Probability (1,000US$)
1/2 (0.50)	0.50	6,250	3,125	1,563
1/3 (0.33)	0.17	6,500	6,375	1,084
1/5 (0.20)	0.13	6,800	6,650	865
1/7 (0.14)	0.06	7,200	7,000	420
1/10 (0.10)	0.04	7,800	7,500	300
1/15 (0.07)	0.03	8,700	8,250	248
1/20 (0.05)	0.02	9,500	9,100	182
1/30 (0.03)	0.02	10,400	9,950	199
1/50 (0.02)	0.01	12,000	11,200	112
(Benefit of Probability)				(1,000US$)
1/2	(B)			1,563
1/5	(B)			3,512
1/10	(B)			4,232
1/20	(B)			4,662

Table F.6.8 Dimension of Proposed Flood Protection Facility

River	Watershed	Design Discharge	Capacity	Average Velocity	Slope	Height (H)	Major Bed of River Land (B)	Length of Embankment Right-Side	Left-Side	Total
	km^2	m^3/s	m^3/s	m/s		m	m	m	km	km
Chirripo	1,106	1,870	1,879	1.76	1/1,000	3.0	150		1.3	1.3
Barbilla	259	714	714	1.66	1/1,000	2.5	45	8.8		8.8
Matina	1,365	2,151	2,192	1.52	1/2,000	4.0	150	13.3	9.0	22.3
Pacuare	855	1,577	1,619	1.41	1/2,000	3.5	150	27.7	25.7	53.4
Reventazon (including Parismina)	1,801	2,585	2,619	1.63	1/2,000	4.5	150	17.2	15.2	32.4
Total								67.0	51.2	118.2

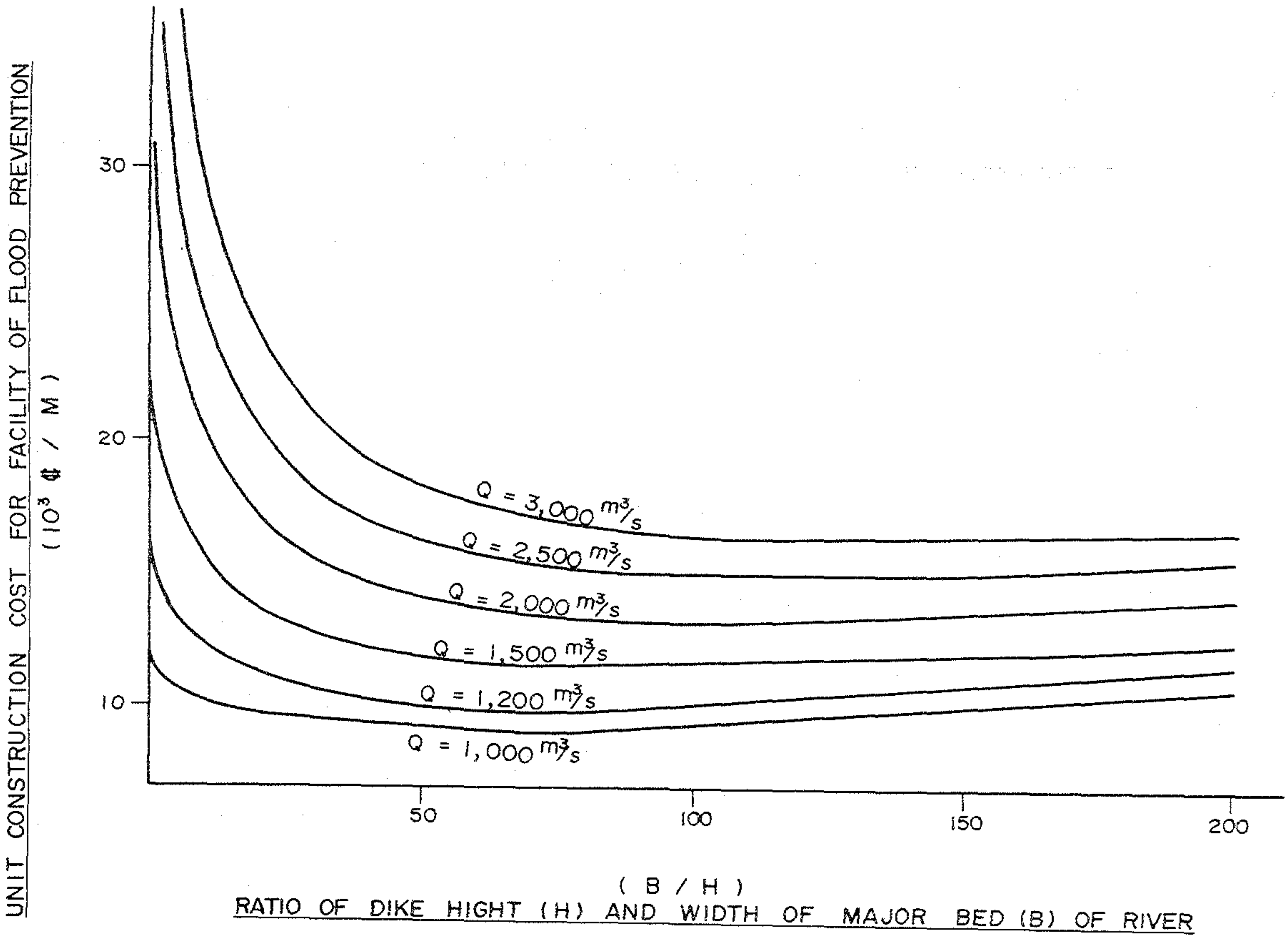


Fig. F.6.1 Relationship between Unit Construction Cost of Dike and Dimension of River Cross Section

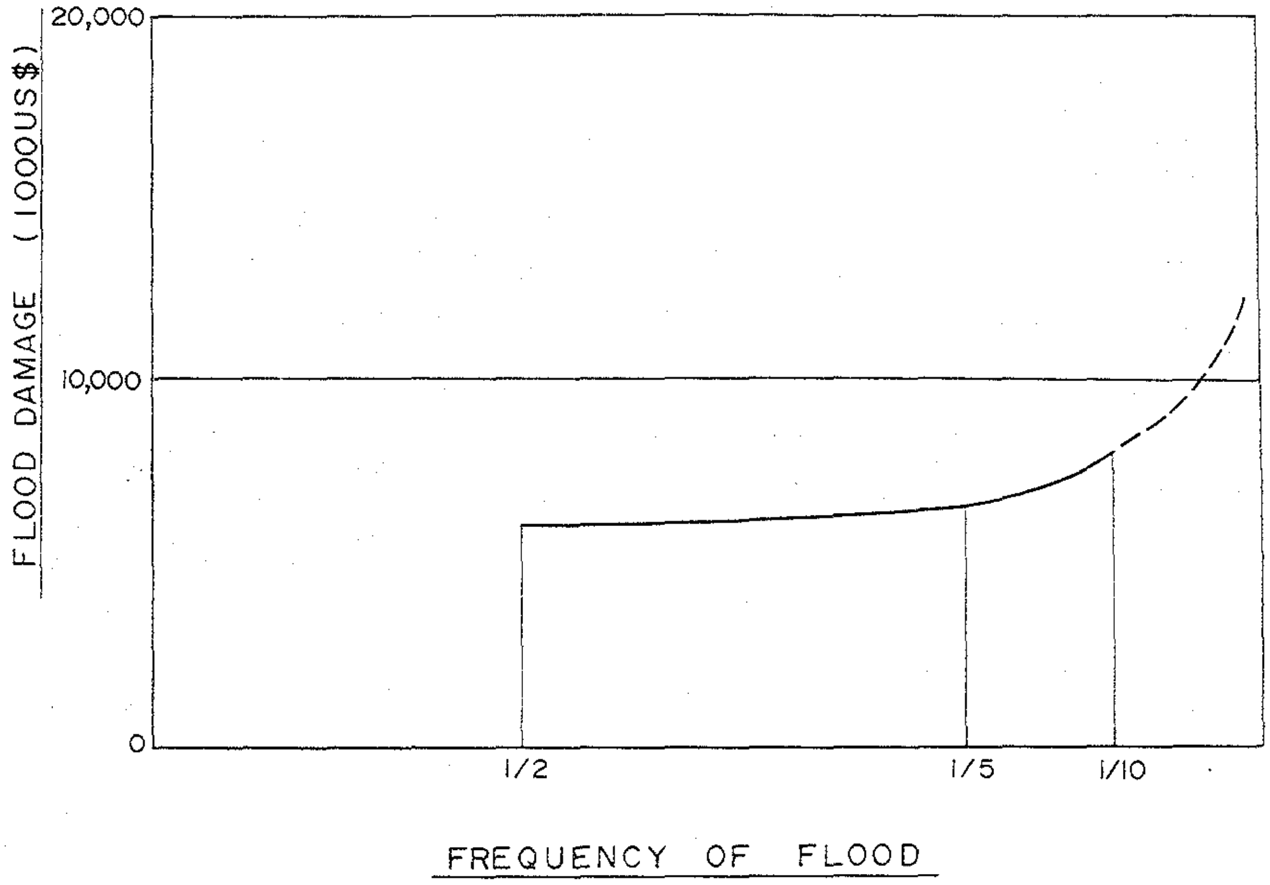


Fig. F.6.2 Damage by Probable Flood and Expected Benefit by Flood Protection

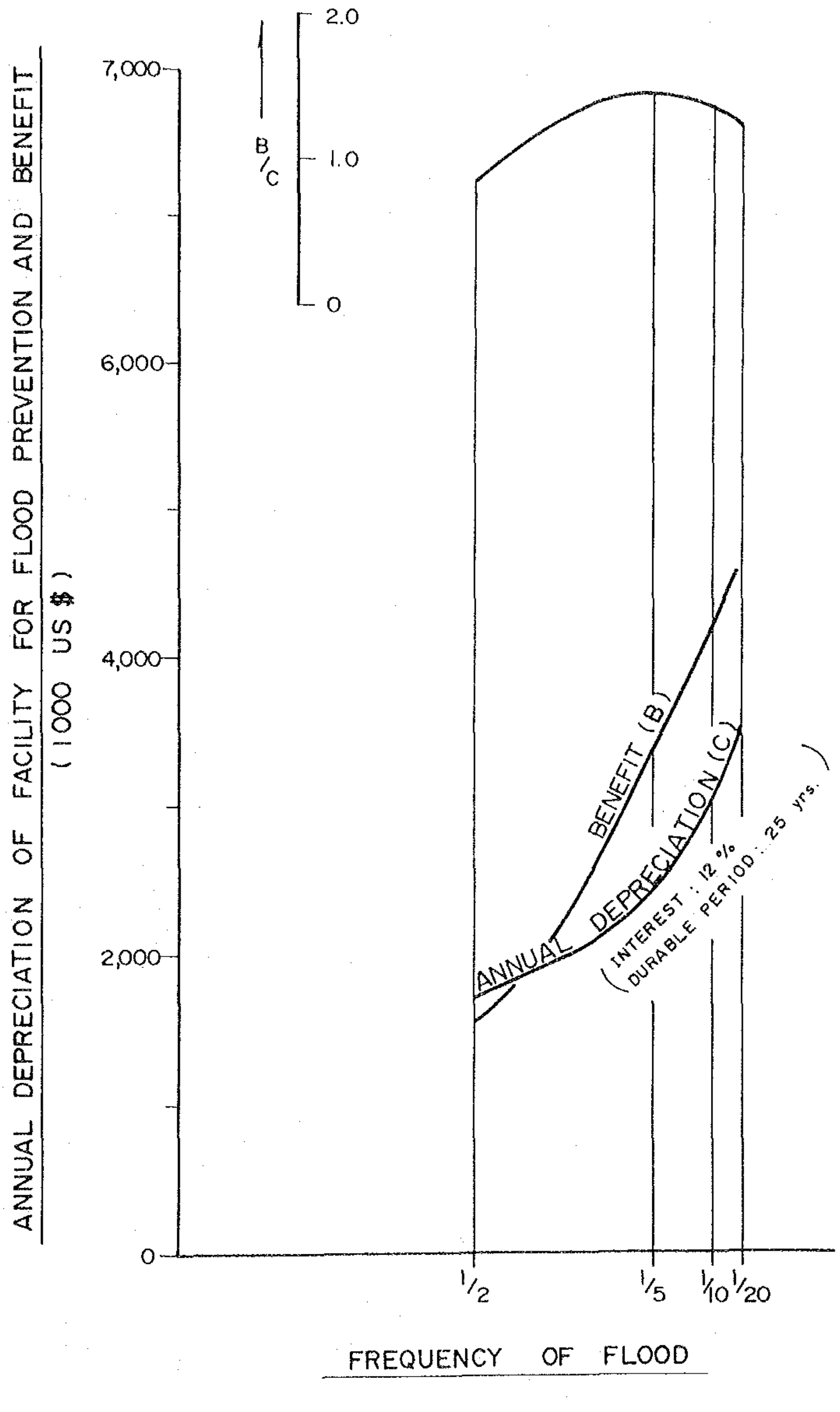
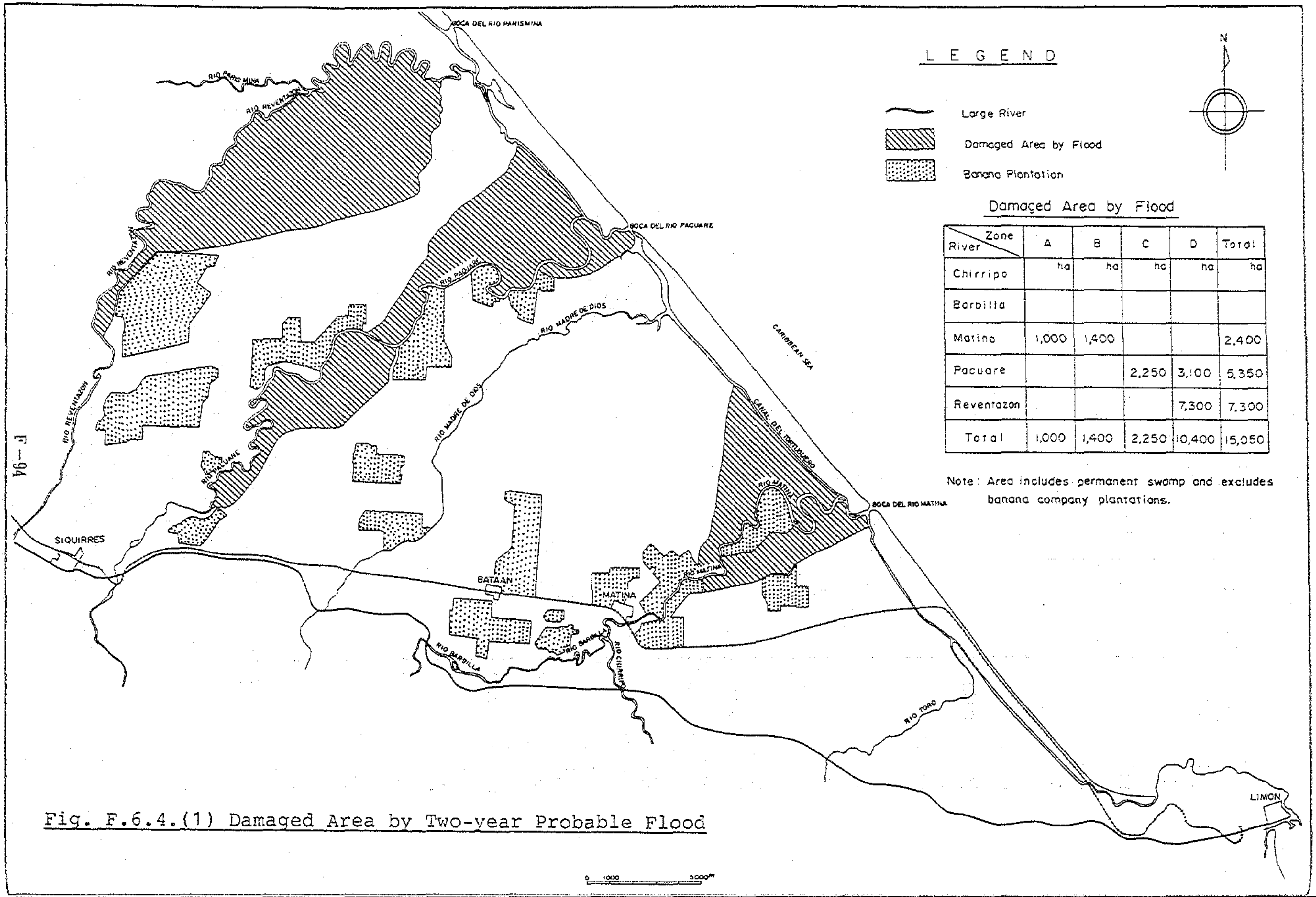


Fig. F.6.3 B/C of Flood Protection Facility

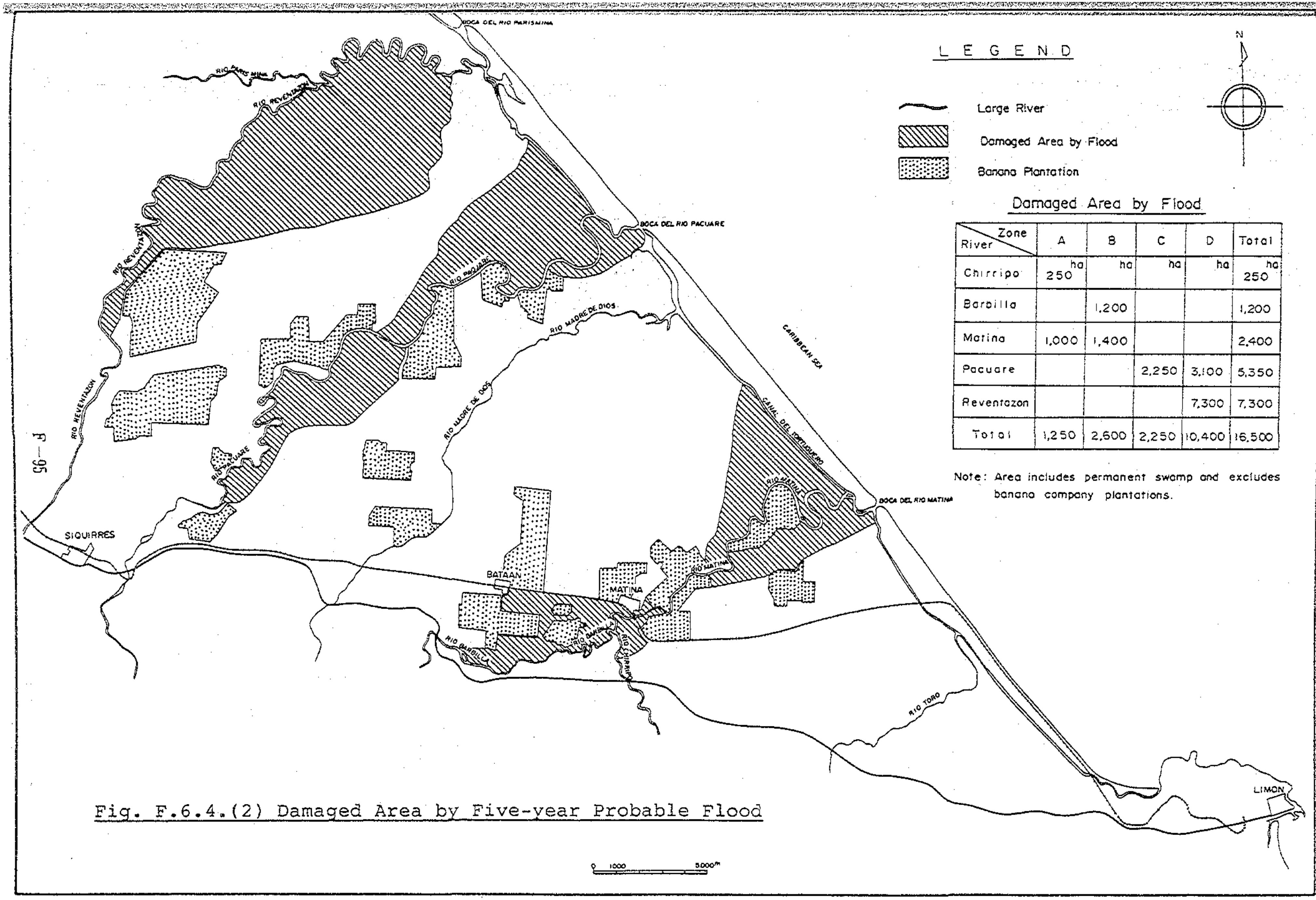


Damaged Area by Flood

Zone / River	A	B	C	D	Total
Chirripo	ha	ha	ha	ha	ha
Barbilla					
Matina	1,000	1,400			2,400
Pacuare			2,250	3,100	5,350
Reventazon				7,300	7,300
Total	1,000	1,400	2,250	10,400	15,050

Note: Area includes permanent swamp and excludes banana company plantations.

Fig. F.6.4.(1) Damaged Area by Two-year Probable Flood

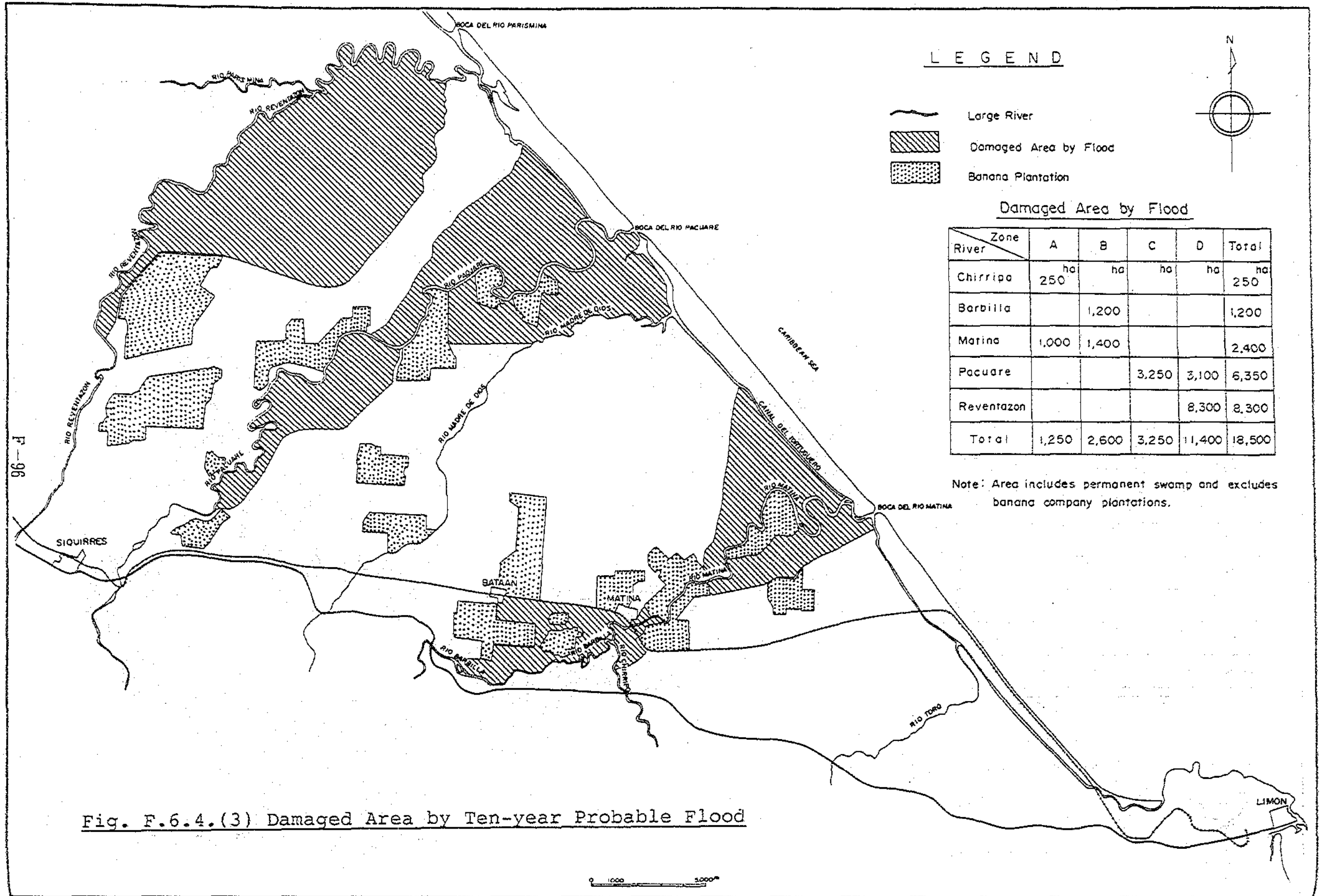


Damaged Area by Flood

River \ Zone	A	B	C	D	Total
Chirripo	250 ha	ha	ha	ha	250 ha
Barbilla		1,200			1,200
Matina	1,000	1,400			2,400
Pacuare			2,250	3,100	5,350
Reventazon				7,300	7,300
Total	1,250	2,600	2,250	10,400	16,500

Note: Area includes permanent swamp and excludes banana company plantations.

Fig. F.6.4.(2) Damaged Area by Five-year Probable Flood



Damaged Area by Flood

River \ Zone	A	B	C	D	Total
Chirripo	ha 250	ha	ha	ha	ha 250
Barbilla		1,200			1,200
Matina	1,000	1,400			2,400
Pacuare			3,250	3,100	6,350
Reventazon				8,300	8,300
Total	1,250	2,600	3,250	11,400	18,500

Note: Area includes permanent swamp and excludes banana company plantations.

Fig. F.6.4.(3) Damaged Area by Ten-year Probable Flood