(9 %) and 5,000 (1 %) distribute in the rural and mountain areas, respectively.

The total number of buildings in the Study Area is estimated at 107,000 in 1992, and its regional distribution is nearly proportional to the population distribution. Detailed distribution of population together with buildings is provided in *Table* 4.8.

In the Study Area, the 1992 population in the Rio Choloma basin, which will take the high priority of executing the project, is estimated at about 58,500 in total, composed of 54,500 in the central city area, 3,400 in the highland area and 500 in the lowland area. Number of buildings is estimated at about 13,000 in the whole basin in the same year.

4.2.3 Land Use

The Study Area is characterized by ample and fertile valley and forest mountains, and provides favorable conditions for agriculture, cattle breeding and forestry. San Pedro Sula, which is the second largest city of Honduras, has expanded on the basis of such favorable condition.

The Study Area has an area of 717 km^2, and its administrative boundary is illustrated in *Fig*. 4.1. A breakdown of the land use by river basin in the Study Area is given in *Table* 4.9, and the total area of each river basin is summarized as follows:

	Unit : sq. km
(1) Chamelecon lower basin	25
(2) Cuabanos canal	125
(3) Rio Choloma	104
(4) Chamelecon middle basin	39
(5) Rio Blanco/San Roque canal	186
(6) Rio El Sauce	118
(7) Rio El Sauce (viejo)/Chotepe canal	100
(8) Chamelecon upper basin	11
(9) La Lima airport	9
Total	717

Fig. 4.2 illustrates the present situation of land use in the Study Area. From the land use point of view, the Study Area is broadly divided into two zones, highland and lowland, by the north-south trunk road (CA-5).

The highland zone, located in the western part of the Study Area, is covered by a tropical rain forest which consists of pine, cedar and wide leaves trees (mahogany, mango, almond, palm, avocado, etc.). The area of the whole highland zone is estimated at about 304 sq. km, or 42 % of the Study Area.

On the other hand, in the lowland zone, where lies the eastern part of the Study Area, the dominant use is natural and cultivated pastures for cattle breeding, except urban areas.

Out of the lowland zone, the area along the Rio Chamelecon forms a mixed agricultural land which is composed of small-scale villages and fields of sugar cane, pasture, bananas, maize, rice, various vegetables and brushwood, etc. The total area of the lowland zone is estimated at about 413 square km, or 58 % of the Study Area (*Table 4.10*).

The major urban areas are located in three cities of San Pedro Sula, Choloma and La Lima. The first two cities spread over both highland and lowland zones as a boundary with the national road CA-5. The La Lima city lies in the southern part of the lowland zone. Out of them, the San Pedro Sula city and its surrounding areas form a large industrial zone as well as commercial and residential zones. Besides, the JICA Study Team surveyed a detailed land use in the San Pedro Sula and Choloma cities, taking into consideration that the situation of land use in these cities will be an important factor for analyzing the potential flood damage. The detail is described in the Supporting Report B.

4.2.4 Agriculture and Industry

Honduras is a traditional agricultural country which produces almost all tropical crops. The country is divided into seven agricultural regions, and the Study Area is located in the Northern Region (Region No. 3). Among Regions, the Region No. 3 occupies a high position on agricultural production, and in the agricultural year 1992/1993, it produced 2,791,870 quintals of maize, 92,970 quintals of beans (frijoles) and 339,280 quintals of rice.

The Study Area occupies an important position in the productions of bananas and sugar cane which are the major export goods of Honduras. Presently, these plantations in the Study Area are estimated at 600 has. for bananas, and 2,700 has. for sugar cane.

Apart from the agricultural crops, an extensive cattle farming industry, which is operated using the wide pasture, is expanded in the Department of Cortes and the Study Area. The number of cattle carved in the Department of Cortes was 83,400 heads in 1984 and 39,500 heads in 1986 which corresponded to 35 % and 19 % of the total number in the country.

The San Pedro Sula city and its surrounding areas form the greatest industrial zone in the country, and produce various daily necessities and industrial raw materials at small- and middle-scale factories, which are estimated at around 1,500 in number in 1992.

4.2.5 Prices and Wage

Wholesale and consumer prices in San Pedro Sula indicated the average rise rate of about 19 % and 16 % per annum respectively during the period 1987-1992, and such high rise rate of prices had an unfavorable influence on improvement in living standard of inhabitants.

The Government has controlled the minimum wage to ensure a living standard for workers since 1981. The minimum wage as of July 1991 in San Pedro Sula indicated from Lps. 9.20 to Lps. 18.40 per day, ranging in accordance with industrial sectors and scale of enterprises.

TABLES

TABLE 4.1 GROSS DOMESTIC PRODUCT (GDP) AND GROSS NATIONAL PRODUCT (GNP), 1987-1991

Unit : Million Lempiras

Items	1987	1988	1989	1990	1991	Average Annual Growth Rate (%) 1987- 1991
Contribution of each sector to GDP						
Agriculture, Forestry & fishery	1,518	1,630	1,951	2,503	3,262	21.1
Mining & Quarrying	105	115	158	194	269	26.5
Manufacturing Industry	1,055	1,230	1,389	1,823	2,424	23.1
Construction	311	343	464	574	623	19.0
Electricity, Gas & Water	236	242	276	353	476	19.2
Transportation & Communications	509	560	648	703	770	10.9
Wholesale & Retail	952	1,019	1,089	1,289	1,857	18.2
Banking, Insurance & Real Estate	482	554	712	826	1,145	24.1
Dwelling Property	612	670	721	790	906	10.3
Public Administration & Defence	439	472	773	814	1,050	24.4
Other Services	964	1,062	1,075	1,290	1,507	11.8
GDP at constant factor cost (1978 = 100)	7,183	7,897	9,256	11,159	14,289	18.8
GDP at market prices	8,128	8,913	10,334	12,540	16,406	19.2
GDP at market prices in real terms	4,674	4,896	5,161	5,165	5,281	3.1
Net factor payments from abroad	(404)	(466)	(622)	(947)	(1,132)	
GNP	7,724	8,447	9,712	11,593	15,274	18.6
Per capita GNP (in Limpiras)	1,791	1,895	2,109	2,437	3,107	14.8
Per capita real GNP (in lempiras)	1,024	1,033	1,051	1,019	1,015	(0.2)

Source : Honduras en Cifras, 1987-1989 y 1989-1991, Banco Central de Honduras
Note : Figures in parenthesis () mean a negative.

TABLE 4.2 BALANCE OF INTERNATIONAL PAYMENTS, 1989-1991

Unit : Million of US$

Items	1989	1990	1991
1. Trade balance	48.5	(21.9)	(55.6)
(1) Exports	883.4	847.8	807.9
(2) Imports	834.9	869.7	863.5
2. Service account	(314.8)	(323.6)	(322.1)
3. Transfer account	72.0	233.1	157.9
4. Current account	(194.3)	(112.4)	(219.8)
5. Capital account	257.6	217.7	142.4
6. Errors & Omissions	(65.0)	(67.6)	105.4
7. Balance of Payments	(1.7)	37.7	28.0

Source : Banco Central de Honduras
Note : Figures in parenthesis () mean a negative.

TABLE 4.3 REVENUE AND EXPENDITURE OF THE CENTRAL GOVERNMENT, 1987-1991

Unit : Million Lempiras

Particulars	1987	1988	1989	1990	1991	Average Annual Growth Rate (%) 1987-1991
Revenue	2,402.7	2,754.5	2,995.7	3,471.9	4,643.7	17.9
Current revenue	1,327.6	1,439.6	1,532.4	2,061.5	2,911.2	21.7
Tax revenue	1,122.5	1,183.2	1,295.8	1,852.9	2,529.3	22.5
Income tax	298.1	340.8	366.6	430.7	623.6	20.3
Tax on property	10.3	12.1	14.4	15.6	20.0	18.0
Tax on production, domestic trade and transaction	370.0	415.6	459.0	690.2	956.0	26.8
Import duties	348.8	347.9	389.0	497.9	691.1	18.6
Export duties	94.3	65.3	65.7	217.3	237.1	25.9
Other taxes	1.0	1.5	1.1	1.2	1.5	10.7
Non-tax revenue	33.4	34.9	16.4	23.2	81.7	25.1
Transfers	46.7	63.8	64.6	59.9	186.1	41.3
Other revenue	125.0	157.7	155.6	125.5	114.1	(2.3)
Capital revenue	1,134.0	1,496.1	1,486.5	1,300.0	1,410.0	5.6
Internal debt	740.7	935.6	1,126.1	352.6	235.2	(24.9)
External debt	287.1	442.3	298.2	867.5	1,010.3	37.0
Transfers	106.2	118.2	62.2	79.9	164.5	11.6
Other revenue	(38.9)	(181.2)	(23.2)	110.4	322.5	-
Expenditure	2,402.7	2,754.5	2,995.7	3,471.9	4,643.7	17.9
Current expenditure	1,507.4	1,650.7	1,873.6	2,244.2	2,693.9	15.6
Consumption	1,326.9	1,480.0	1,669.6	1,968.8	2,294.7	14.7
Current transfers	180.5	170.7	204.0	275.4	399.2	21.9
Capital expenditure	357.6	417.7	407.0	824.0	780.7	21.6
Direct investment	273.6	309.0	332.7	273.5	512.8	17.0
Indirect investment	84.0	108.7	74.3	550.5	267.9	33.6
Pre-investment	0.0	0.0	0.0	0.0	0.0	
Net lending	92.6	37.2	2.0	(43.7)	146.9	12.2
Amortization of public debt	445.1	648.9	713.1	447.4	1,022.2	23.1
Internal	377.0	526.0	608.1	309.7	519.7	8.4
External	68.1	122.9	105.0	137.7	502.5	64.8

Source : Banco Central de Honduras
Note : Figures in parenthesis () mean a negative.

TABLE 4.4 AREA AND POPULATION OF HONDURAS

Administrative Unit	Area (km2)	Census Population			Annual Population Growth Rate (%)		Population Density (persons/km2)		
		1961	1974	1988	1961-1974	1974-1988	1961	1974	1988
Honduras	112,088	1,884,765	2,656,948	4,443,721	2.68	3.74	16.8	23.7	39.6
Department									
1. Atlantida	4,251	92,914	148,285	238,741	3.66	3.46	21.9	34.9	56.2
2. Colon	8,875	41,904	77,750	149,677	4.87	4.79	4.7	8.8	16.9
3. Comayagua	5,196	96,442	136,619	239,859	2.72	4.10	18.6	26.3	46.2
4. Copan	3,203	126,183	151,859	219,455	1.43	2.66	39.4	47.4	68.5
5. Cortes	3,954	200,099	369,616	662,772	4.83	4.26	50.6	93.5	167.6
6. Choluteca	4,211	149,175	193,336	295,484	2.01	3.08	35.4	45.9	70.2
7. El Paraiso	7,218	106,823	140,793	254,295	2.15	4.31	14.8	19.5	35.2
8. Francisco Morazan	7,946	284,428	453,597	828,274	3.66	4.39	35.8	57.1	104.2
9. Gracias a Dios	16,630	10,905	20,738	34,970	5.07	3.80	0.7	1.2	2.1
10. Intibuca	3,072	73,138	81,815	124,681	0.87	3.06	23.8	26.6	40.6
11. Islas de la Bahia	261	8,961	13,194	22,062	3.02	3.74	34.3	50.6	84.5
12. La Pas	2,331	60,600	66,046	105,927	0.66	3.43	26.0	28.3	45.4
13. Lempira	4,290	111,546	127,782	177,055	1.05	2.36	26.0	29.8	41.3
14. Ocotepeque	1,680	52,540	51,038	74,276	(0.22)	2.72	31.3	30.4	44.2
15. Olancho	24,351	110,744	151,436	283,852	2.44	4.59	4.5	6.2	11.7
16. Santa Barbara	5,115	146,909	186,106	278,868	1.84	2.93	28.7	36.4	54.5
17. Valle	1,565	80,907	91,901	119,965	0.98	1.92	51.7	58.7	76.7
18. Yoro	7,939	130,547	195,037	333,508	3.14	3.91	16.4	24.6	42.0

Source : Censo Nacional de Poblacion y Vivienda, 1961, 1974 y 1988, Direccion General de Estadistica y Censos

TABLE 4.5 AREA AND POPULATION OF DEPARTMENT AND MUNICIPALITIES RELATED TO THE STUDY AREA

Department and Municipalities	Area (km2)	Census Population			Annual Population Growth Rate (%)		Population Density (persons/km2)		
		1961	1974	1988	1961-1974	1974-1988	1961	1974	1988
Department of Cortes	3,954	200,099	369,616	662,772	4.83	4.26	50.6	93.5	167.6
Munici. related to Study Area	1,871	137,988	281,247	500,886	5.63	4.21	73.8	150.3	267.7
San Pedro Sula	905	95,464	200,881	326,943	5.89	3.54	105.5	222.0	361.3
Choloma	459	13,566	36,258	66,802	7.86	4.46	29.6	79.0	145.5
La Lima	116	-	-	45,778	-	-	-	-	394.6
Puerto Cortes	391	28,958	44,108	61,363	3.29	2.39	74.1	112.8	156.9
Other Municipalities	2,083	62,111	88,369	161,886	2.75	4.42	29.8	42.4	77.7
Omoa	383	9,782	13,946	22,539	2.77	3.49	25.5	36.4	58.8
Pimienta	61	2,557	3,877	6,414	3.25	3.66	41.9	63.6	105.1
Potrerillos	88	5,036	9,097	12,267	4.65	2.16	57.2	103.4	139.4
San Antonio de Cortes	227	7,247	9,697	16,018	2.27	3.65	31.9	42.7	70.6
San Francisco de Yojoa	97	4,877	6,422	10,655	2.14	3.68	50.3	66.2	109.8
San Manuel	139	7,087	8,761	17,157	1.64	4.92	51.0	63.0	123.4
Santa Cruz de Yojoa	726	14,575	21,238	42,668	2.94	5.11	20.1	29.3	58.8
Villanueva	362	10,950	15,331	34,168	2.62	5.89	30.2	42.4	94.4

Source : Poblacion y Vivienda por Departmento y Municipio, Censo 1961, 1974 y 1988, Secretaria de Planificacion, Coordinacion y Presupusto

TABLE 4.6 (1/2) CENSUS POPULATION OF URBAN AND RURAL AREAS IN THE DEPARTMENT CORTES

Department and Municipalities	1961			1974			1988		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Honduras	573,542	1,311,223	1,884,765	989.617	1,667,331	2,656,948	1,693,339	2,550,382	4,443,721
Dep. Cortes	94,474	105,625	200,099	208,083	161,533	369,616	425,813	236,959	662,772
Munici. related to Study Area	80,280	57,708	137,988	185,969	95,278	281,247	386,693	114;193	500,886
San Pedro Sula	58,632	36,832	95,464	150,991	49.890	200,881	287,350	39,593	326,943
Choloma	4,600	8,966	13,566	9,161	27,097	36,258	39,054	27,748	66,802
La Lima	-	-	-	-	-	-	28,703	17,075	45,778
Puerto Cortes	17,048	11,910	28,958	25,817	18,291	44,108	31,586	29,777	61,363
Other Municipalities	14,194	47,917	62,111	22,114	66,255	88,369	39,120	122,766	161,886
Omoa	904	8,878	9.782	1.308	12,638	13,946	1,392	21,147	22,539
Pimiente	1,605	952	2,557	1,708	2.169	3.877	3,290	3,124	6,414
Potrerillos	2,895	2,141	5,036	5,405	3,692	9,097	8,913	3,354	12,267
San Antonio de Cortes	1,710	5,537	7,247	2,352	7,345	9,697	3,259	12,759	16,018
San Francisco de Yojoa	750	4,127	4,877	945	5,477	6,422	1,578	9,077	10,655
San Manuel	1,164	5,923	7,087	2,208	6,553	8,761	3,563	13,594	17,157
Santa Cruz de Yojoa	1,210	13,365	14,575	1,848	19,390	21,238	5,144	37,524	42,668
Villanueva	3,956	6,994	10,950	6,340	8,991	15,331	11,981	22,187	34,168

TABLE 4.6 (2/2) CENSUS POPULATION OF URBAN AND RURAL AREAS IN THE DEPARTMENT CORTES

Department and Municipalities	Population Distribution of Urban and Rural Areas 1961		1974		1980		Average Annual Growth Rate (%) 1961-1974			1974-1988		
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Total	Urban	Rural	Total
Honduras	30.4	69.6	37.2	62.8	42.6	57.4	4.29	1.87	2.68	4.74	3.08	3.74
Dep. Cortes	47.2	52.8	56.3	43.7	64.2	35.8	6.26	3.32	4.83	5.25	2.77	4.26
Munici. related to Study Area	58.2	41.8	66.1	33.9	77.2	22.8	6.68	3.93	5.63	5.37	1.30	4.21
San Pedro Sula	61.4	38.6	75.2	24.8	87.9	12.1	7.55	2.36	5.89	4.70	(1.64)	3.54
Choloma	33.9	66.1	25.3	74.7	58.5	41.5	5.44	8.88	7.86	10.91	0.17	4.46
La Lima	-	-	-	-	62.7	37.3	-	-	-	-	-	-
Puerto Cortes	58.9	41.1	58.5	41.5	51.5	48.5	3.24	3.36	3.29	1.45	3.54	2.39
Other Municipalities	22.9	77.1	25.0	75.0	24.2	75.8	3.47	2.52	2.75	4.16	4.50	4.42
Omoa	9.2	90.8	9.4	90.6	6.2	93.8	2.88	2.75	2.77	0.45	3.75	3.49
Pimienta	62.8	37.2	44.1	55.9	51.3	48.7	0.48	6.54	3.25	4.79	2.64	3.66
Potrerillos	57.5	42.5	59.4	40.6	72.7	27.3	4.92	4.28	4.65	3.64	(0.68)	2.16
San Antonio de Cortes	23.6	76.4	24.3	75.7	20.3	79.7	2.48	2.20	2.27	2.36	4.02	3.65
San Francisco de Yojoa	15.4	84.6	14.7	85.3	14.8	85.2	1.79	2.20	2.14	3.73	3.67	3.68
San Manuel	16.4	83.6	25.2	74.8	20.8	79.2	5.05	0.78	1.64	3.48	5.35	4.92
Santa Cruz de Yojoa	8.3	91.7	8.7	91.3	12.1	87.9	3.31	2.90	2.94	7.59	4.83	5.11
Villanueva	36.1	63.9	41.4	58.6	35.1	64.9	3,69	1.95	2.62	4.65	6.66	5,89

Source : Poblacion y Vivienda por Departmento y Municipio. Censo 1961. 1974 y 1988.
Secretaria de Planificacion, Coordinacion y Presupusto

Note : Figures in parenthesis () mean a negative.

TABLE 4.7 POPURATION,NUNBER OF RESIDENTIAL HOUSES AND AVERAGE FAMILY SIZE IN THE DEPARTMENT CORTES

Department and Municipalities	Area (km2)	Population			Total Number of Houses(*)			Family Size (persons/house)			Average Number of Houses per km2		
		1961	1974	1988	1961	1974	1988	1961	1974	1988	1961	1974	1988
Honduras	112,088	1,884,765	2,656,948	4,443,721	325,492	526,566	906,698	5.79	5.05	4.90	2.90	4.70	8.09
Dep. Cortes	3,954	200,099	369,616	662,772	35,969	72,475	139,905	5.56	5.10	4.74	9.10	18.33	35.38
Munici. related to Study Area	1,871	137,988	281,247	500,886	24,930	54,467	106,302	5.54	5.16	4.71	13.32	29.11	56.82
San Pedro Sula	905	95,464	200,881	326,943	16,752	38,254	69,526	5.70	5.25	4.70	18.51	42.27	76.82
Choloma	459	13,566	36,258	66,802	2,638	7,099	13,204	5.14	5.11	5.06	5.75	15.47	28.77
La Lima	116	-	-	45,778	-	-	9,872	-	-	4.64	-	-	85.10
Puerto Cortes	391	28,958	44,108	61,363	5,540	9,114	13,700	5.23	4.84	4.48	14.17	23.31	35.04
Other Municipalities	2,083	62,111	88,369	161,886	11,038	18,008	33,603	5.63	4.91	4.82	5.30	8.65	16.13
Omoa	383	9,782	13,946	22,539	1,957	2,972	4,940	5.00	4.69	4.56	5.11	7.76	12.90
Pimiente	61	2,557	3,877	6,414	479	784	1,237	5.34	4.95	5.19	7.85	12.85	20.28
Potrerillos	88	5,036	9,097	12,267	953	1,834	2,453	5.28	4.96	5.00	10.83	20.84	27.88
San Antonio de Cortes	227	7,247	9,697	16,018	1,281	2,043	3,244	5.66	4.75	4.94	5.64	9.00	14.29
San Francisco de Yojoa	97	4,877	6,422	10,655	828	1,490	2,122	5.89	4.31	5.02	8.54	15.36	21.88
San Manuel	139	7,087	8,761	17,157	1,184	1,571	3,477	5.99	5.58	4.93	8.52	11.30	25.01
Santa Cruz de Yojoa	726	14,575	21,238	42,668	2,475	4,315	8,542	5.89	4.92	5.00	3.41	5.94	11.77
Villanueva	362	10,950	15,331	34,168	1,881	2,999	7,588	5.82	5.11	4.50	5.20	8.28	20.96

Source : Poblacion y Vivienda por Departamento y Municipio, Censo 1961, 1974 y 1988, Secretaria de Planificacion, Coordinacion y Presupuesto

Note : (*) Collective buildings are not included in number of houses.

TABLE 4.8 ESTIMATES OF POPULATION AND NUMBER OF BUILDINGS IN THE STUDY AREA IN 1992

Municipalities	Population				Number of Buildings			
	Urban	Rural	Mountain	Total	Urban	Rural	Mountain	Total
San Pedro Sula	378,632	2,506	2,420	383,558	79,957	480	484	80,921
Choloma	68,819	29,833	2,870	101,522	15,149	4,325	574	20,048
La Lima	19,927	0	0	19,927	4,429	0	0	4,429
Puerto Cortes	0	15,288	0	15,288	0	1,721	0	1,721
Total	467,378	47,627	5,290	520,295	99,535	6,526	1,058	107,119

TABLE 4.9 LAND USE BY RIVER BASIN IN THE STUDY AREA IN 1992

Unit : Sq. km

Classification	Chame-lecon (lower)	Cuabanos Canal	Rio Cholosa	Chame-lecon (middle)	Rio Blanco & Sanroque Canal	Rio Bl Sauce	Rio Bl Sauce & Chotepe Canal	Chame-lecon (upper)	La Lima Airport	Total
Banana	0	3	0	5	1	2	3	0	1	15
Corn/Rice	0	3	0	1	0	0	2	2	0	8
Vegetable *)	1	0	0	4	3	0	13	3	0	24
Other crops	6	7	0	10	10	4	0	0	0	37
Cultivated pasture	2	24	5	9	32	31	7	1	0	111
Natural pasture	2	45	14	6	46	6	18	2	0	139
Mountain area **)	9	29	61	0	31	6	3	0	0	139
Brushwood	0	5	6	0	21	7	2	1	0	42
Forest	4	5	9	0	26	46	10	0	0	100
Bult-up area	1	1	8	2	7	7	41	2	7	76
Water bodies	0	3	2	2	9	9	1	0	0	26
Total	25	125	105	39	186	118	100	11	8	717

Note : *) includes citlics and sugar-cane
**)includes agricultural and pasture lands

TABLE 4.10 LAND USE IN THE STUDY AREA IN 1992

Unit : Sq. km

Classification	1) Highland	2) Lowland	Total	Share (%)
Banana	0	15	15	2
Corn/Rice	0	8	8	1
Vegetable *)	0	24	24	3
Other crops	0	38	38	5
Cultivated pasture	4	106	110	16
Natural pasture	0	139	139	19
Mountain area **)	139	0	139	19
Brushwood	38	4	42	6
Forest	99	1	100	14
Built-up area	21	55	76	11
Water bodies	3	23	26	4
Total	304	413	717	100

Note : 1) Western part of the Study Area
2) Eastern part of the Study Area
*) includes citlics and sugar-cane
**)includes agricultural and pasture lands

FIGURES

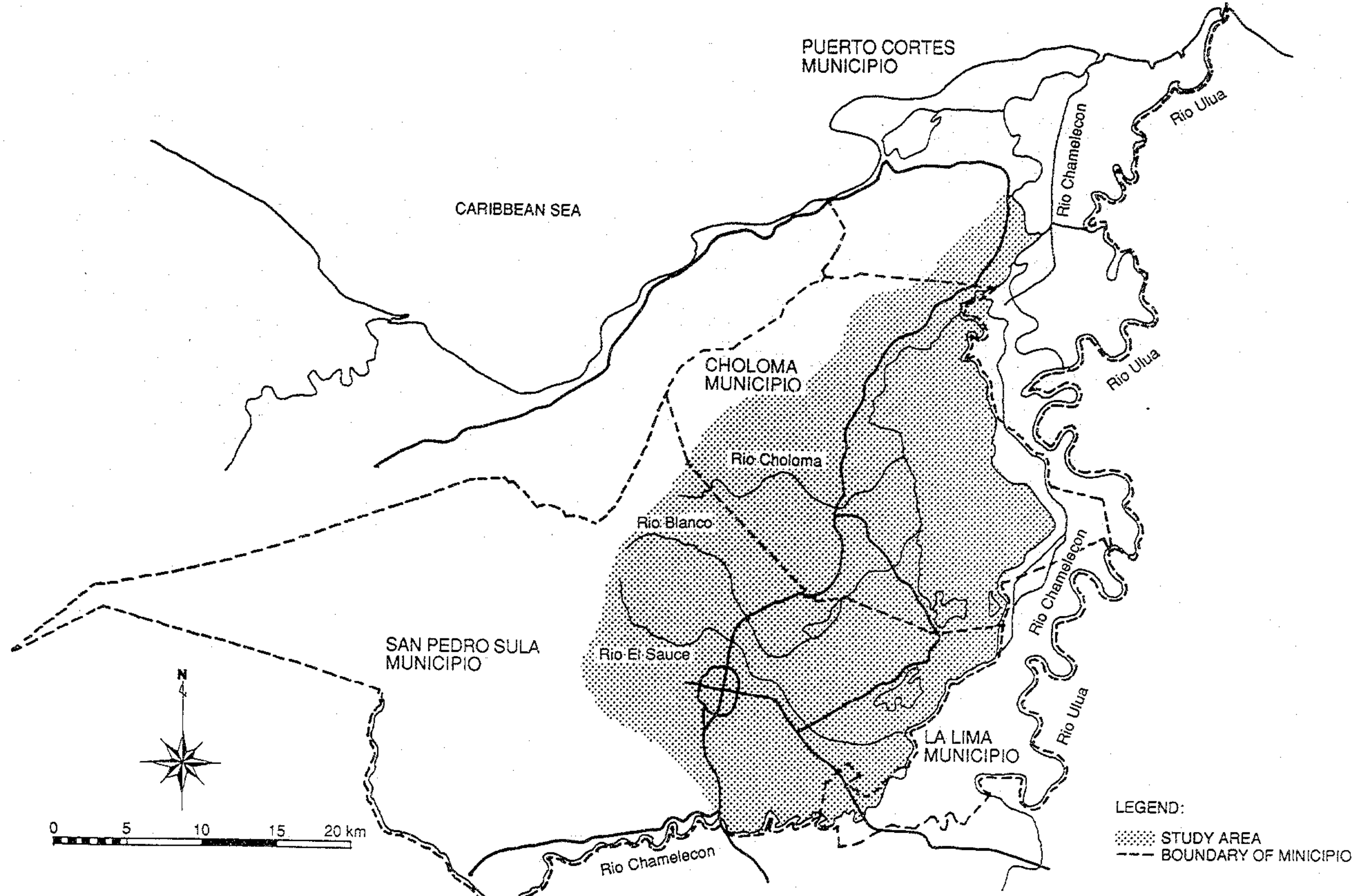


FIG. 4.1 ADMINISTRATIVE BOUNDARY OF THE STUDY AREA

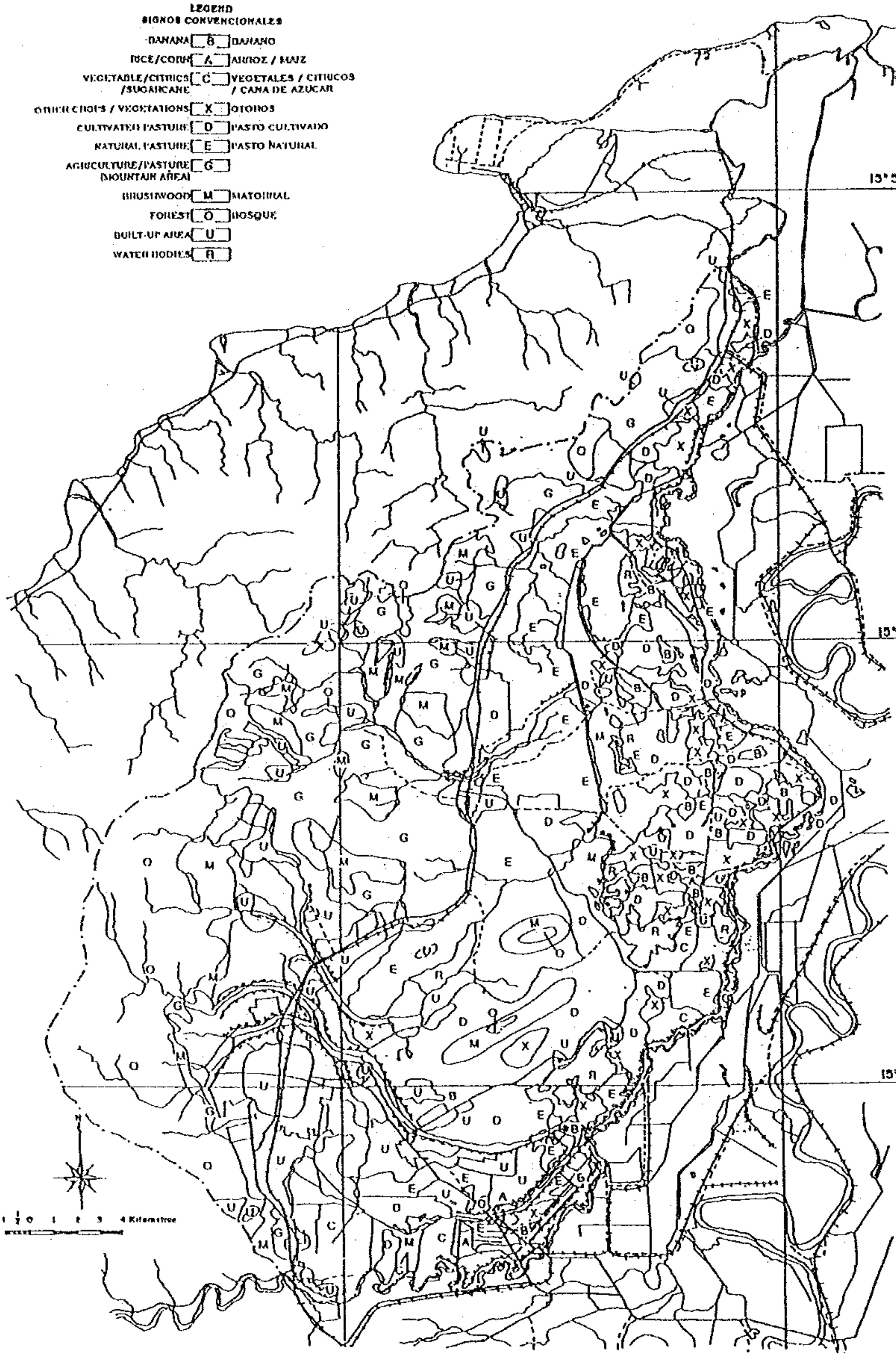


FIG. 4.2 **PRESENT LAND USE OF THE STUDY AREA**

FLOOD OF THE RIO CHOLOMA BY THE HURRICANE "FIFI" IN 1974
(DESTROYED NATIONAL ROAD BRIDGE)

CHAPTER 5
FLOOD AND FLOOD DAMAGE

CHAPTER 5 FLOOD AND FLOOD DAMAGE

5.1 General

The study area is vulnerable to erosion, sedimentation and floods. In the hurricane Fifi of 1974 the study area experienced the most severe debris flows and floods on record. The study area has suffered from several floods since 1974.

In order to get a clear picture of the flood situations, current floods and flood damages have been surveyed and studied through the available data and supplementary questionnaires. The questionnaire survey was carried out from the end of September 1992 through October 1992 and a supplementary questionnaire survey was conducted from June 1993 to July 1993. A questionnaire survey was conducted in the supposed hazard areas likely affected by the floods in 1974, 1990 and yearly. The questionnaire survey aimed :

- to make clear the conditions of the past floods such as area, depth and duration of flooding and sedimentation,
- to get the information of flood damages to buildings, house assets and others caused by floods
- to get the information of land use, property, household assets, etc.

During the master plan stage, data and information were collected from 628 households. The survey area is shown in *Figs* 5.1 and 5.2. The flood hazard maps of the three floods (1974 flood, 1990 flood, and yearly flood) are prepared based on the collected data and information through the questionnaire survey and shown in *Figs* 5.3~5.5.

During the feasibility study stage, supplementary surveys were conducted on flood conditions in Choloma area. The flood conditions and socio-economic data collected, were analyzed and used for the project evaluation.

5.2 Flood Conditions

5.2.1 1974 Flood (Hurricane Fifi)

Most part of the valley floor was submerged by the flood. The flood area is estimated to be 340 square km. According to the result of the questionnaire survey the depth of flooding from the ground level was estimated to be 1.08 meters on average, and the thickness of sediment deposits was estimated to be 0.29 meters on average, and the duration of flooding was estimated to be ten (10) days on average (*Table* 5.1).

The cities in the valley floor such as Blanquito, Choloma, La Lima, Fesitranh, Santa Marta, Calpules and Chamelecon, were mostly submerged by the floodwater from the Rio Chamelecon. The urban areas of Choloma was affected by the Rio Choloma. Calpules, Fesitranh Santa Marta and Universidad were suffered from the floodwater of the Rio Blanco and the Rio El Sauce.

The area that was most severely affected by the hurricane Fifi extended towards from the north side of the Santa Ana valley to the Choloma valley. The hurricane caused extensive landslides on the steep mountain slopes of the Merendon mountains, especially in the Rio Choloma and the Rio Blanco basins. It caused large debris flows in the Rio Choloma and the Rio Blanco basins and as many as 2,500 persons were lost in the debris flows in the Rio Choloma basin. Approximately 4,000 houses were damaged and 20,000 people were injured or affected by the flood from the Rio Choloma (*Table* 5.2).

Severe problems of sedimentation and inundation have been caused in the valley floor downstream. The valley floor is suffering from a heavy sedimentation and floods not only from the Rio Chamelecon and the Rio Ulua, but also from their tributaries.

5.2.2 1990 Flood (Hurricane Gilbert)

The flood area was estimated to be 190 square km. A large part of the valley floor along the Rio Chamelecon and the Rio Choloma were inundated. The average depth of flooding was 0.86 meters, and the duration of inundation was eight (8) days and the thickness of sediment deposits was estimated to be 0.15 meters in average. The areas of Calpules, Santa Marta, Chamelecon, Lima, Monterrey and Blanquito were inundated. The major source of floodwater was supposed from the Rio Chamelecon. The flooding from the tributary rivers were reported at Choloma, Universidad, Calpules, Santa Marta and Monterrey. The areas of Universidad, Calpules, Santa Marta and Monterrey were inundated 0.55 meters on average and sedimentation 0.09 meters on average (*Table* 5.3).

5.2.3 Yearly Flood

The western part of the Choloma urban area and a part of Lima are inundated yearly by floodwaters from the Rio Choloma and the Rio Chamelecon respectively. The average flooding depths are 0.73 meters at Choloma, 0.40 meters at Lima.

Also Universidad, Calpules, Santa Marta, Chamelecon, Monterey and Blanquito are inundated every year. It is reported that the flood depth is about 0.26 meters, the thickness of sedimentation is 0.06 meters and the duration of inundation is about two(2) days (*Table* 5.4).

5.3 Flood Damage Analysis

5.3.1 General

For the purpose of evaluating a benefit expected by executing the project, a flood damage potential is estimated for each probable flood discharge, using number and kinds of assets in the probable flood area, appraisals of the assets and damage rates of assets submerged by floods. In addition to the damage to the said assets, economic losses such as business suspension loss, traffic interruption loss and expenditure of emergency measure cost are assessed as the flood damage.

The flood damage is firstly estimated by return period (2-, 5-, 30-, 50- and 100-year) about the three river basins of Rio Choloma, Rio Blanco and Rio El Sauce, and finally an average annual damage is calculated by using the said flood damage by return period on the same three rivers.

According to the result of hydrological and hydraulic analyses, the flood return period of Rio Choloma corresponds approximately to 50-year for the 1974 flood and 2-year for the 1990 flood, and the flooded areas are estimated at 36 sq. km. and 12 sq. km. respectively. Moreover, the potential flood area is estimated at 83 sq. km. for the Rio Blanco and 36 sq. km. for the Rio El Sauce.

5.3.2 Assets in Potential Flood Area

1) Distribution of Assets in Potential Flood Area

Assets in the potential flood area are mainly composed of general assets (buildings and household effects in buildings), agricultural crops, public facilities and others. In the present study, the general assets are classified into residential houses, farm houses, shops, churches, clinics, schools, offices and factories. Major crops planted in the agricultural land are maize, rice, beans, sugar cane, bananas, platanos, vegetables, and cultivated and natural pastures.

Based on field survey, hydraulic analysis and other information, number and kinds of the assets to be inundated by the probable flood discharge of rivers are estimated as shown in *Table* 5.5, and a breakdown of the assets to be submerged by water depth is provided in *Tables* I.2.1, I.2.2 and I.2.3 of Supporting Report I.

2) Appraisals of Assets in the Study Area

Amounts of damage to assets submerged could be estimated using number and appraisal of each asset and an assumed damage rate. Based on assets survey in the Study Area by the Study Team, the average appraisals of buildings and household effects at the prices of June 1993, together with an average distribution of the household effects above floor level per house, are given in *Table* 5.6.

The flood damage to agricultural crops planted would be defined as a reduction in the profit which is given by subtracting harvest cost from the production amount. In order to estimate this damage, unit production (Lps./ha) and unit harvest cost (Lps./ha) of major agricultural crops are estimated based on agricultural statistics of Honduras and the field survey by the Study Team, and the results are summarized in *Table* 5.7.

5.3.3 Estimates of Damage Caused by Probable Flood Discharge

1) Rate of Flood Damage to Assets

Rate of the damage caused by floods to the assets would be mainly related to water depth and duration of inundation in the flooded area. However, the past floods of Rio Choloma, Rio Blanco and Rio El Sauce provide a correlation between water depth and inundated duration. Accordingly, in the present study the water depth is approximately assumed to be used as a representative parameter for estimating the damage rate.

The rate of damage to assets submerged is assumed on the basis of the flood damage rate applied by the Ministry of Construction of Japan, and taking into consideration the flood damage conditions of the said three rivers in 1974 and 1990 and the flood damage in other tropical countries.

Table 5.8 provides the damage rate to assets such as buildings, household effects and planted crops submerged by floods. The damage rate is categorized into two conditions; one considers a sediment of debris, sand and earth in the assets submerged, and the other excludes the sediment from consideration.

Based on a result of the sediment flow analysis on debris, sand and earth in the Study Area, the sediment condition is applied to flood damages in the Rio Choloma basin and some parts of the Rio Blanco and Rio El Sauce basins. While, the non-sediment condition is applied in the remaining parts of the Rio Blanco and Rio El Sauce basins.

2) Estimates of Flood Damage to General Assets and Agricultural Crops

The damage to buildings submerged in the inundation area can be estimated by using number of buildings, average appraisal per building and average damage rate of buildings.

The damage to household effects submerged would be estimated from number of buildings, average appraisal of household effects per building, average distribution of household effects above floor level in a building and average damage rate of household effects submerged.

Calculations of the damage amounts to buildings and household effects are conducted by kind of buildings and by inundation depth, and the total damage amount is estimated by adding these amounts together.

The damage to an agricultural crop planted in the inundation area can be estimated based on inundation area, profit from crop production per unit area and average damage rate of crop submerged. This estimate is made by kind of crop and by inundation depth, and the total amount of damage to agricultural crops could be estimated by summing up the damage amounts of individual crops.

Detail of the damage estimates above is described in the Supporting Report I, and *Table* 5.9 provides a summary of damage estimated by probable flood of each river.

3) Other Flood Damages and Losses

Other major damages and losses caused by flood would be represented by 1) damage to public facilities, 2) economic loss due to business suspension of inhabitants and enterprises, including economic loss due to traffic interruption, and 3) expenditure of emergency measure cost.

a) Damage to Public Facilities

The public facilities include roads, bridges, railways, river dykes, agricultural facilities, electricity and telecommunication systems, etc. The flood damage to these facilities is estimated based on the actual flood damages in 1969 and 1974, and its amount is assumed to be 15 % of the total sum of damage to general assets and agricultural crops.

b) Economic Losses due to Business Suspension including Traffic Interruption

The past heavy floods damaged lots of inhabitants and enterprises in and around the Study Area. Based on records of the 1969- and 1974-flood, the economic loss of the business suspension, including the business loss due to traffic interruption, is assumed to be 5 % of the damage to the general assets and agricultural crops.

c) Emergency Measure Expenses

Based on the damage records in the past floods, the flood emergency measure expenses are assumed to be 10 % of the total damage amount of general assets and agricultural crops.

4) Summary of Flood Damage by Return Period

Table 5.9 provides flood damages with return periods of 2-, 30-, 50- and 100-year for the Rio Choloma and with return periods of 5-, 30-, 50- and 100-year for the Rio Blanco and the Rio El Sauce. Besides these damages, the flood damage with 5-year return period on the Rio Choloma is estimated to be Lps. 65 million by interpolation from damages with other return periods of the Rio Choloma, for the purpose of improving the estimated value of average annual flood damage.

5.3.4 Average Annual Flood Damage

The average annual damage of a river for the period from a year with innocuous discharge to any probable year with flood discharge can be estimated using the total damage for each return period shown in *Table* 5.9, taking the probability of occurrence of flood discharge into account. The result is summarized as follows:

Average Annual Flood Damage (in 1,000 Lps.)

Return Period (years)	Choloma Basin	Blanco Basin	l Sauce Basin	Blanco & El Sauce Basins
2	5,882	-	-	-
5	19,161	7,144	17,862	25,006
30	49,392	21,490	29,938	51,428
50	55,855	23,716	31,353	55,069
100	62,747	25,656	32,696	58,352

After the master plan stage, number and appraisals of assets to be submerged in the flood area were surveyed again in more detail for the purpose of the feasibility study, and some parts on the assets were improved.

As a result, the average annual flood damage increased somewhat as a whole, compared with the foregoing values. However, such a little increase in the damage will have no influence on a conclusion of the Master Plan.

It is expected that these flood damages will be reduced by executing the project, and the reduced damage would be an economic benefit of the project.

TABLES

TABLE 5.1 1974 FLOOD

Zone	Water Depth from the Ground Level (cm)	Water Depth from the Floor Level (cm)	Sed. Depth from the Ground Level (cm)	Sed. Depth from the Floor Level (cm)	Duration (days)	Number of Samples	Source of Water
STUDY AREA	106	79	28	1	10	204	
External	108	80	29	1	10	200	
Internal	50	40	9	X	11	4	
EXTERNAL							
A1: Calpules	136	119	15	X	3	5	Rio Blanco
A1: Calpules	146	134	7	X	5	12	Rio Chamelecon
A1: Calpules	73	26	0	X	3	2	Rio El Sauce
A2: Santa Marta	83	33	17	X	4	2	Rio Chamelecon
A2: Santa Marta	108	68	17	X	7	6	Rio Choloma
A2: Santa Marta	104	93	24	13	6	3	Rio El Sauce
A3: Lima	93	70	23	X	3	3	Rio Chamelecon
B1: Universidad	122	86	25	X	6	25	Rio El Sauce
B2: Fesitranh	99	80	33	17	4	34	Rio Chamelecon
B2: Fesitranh	133	103	23	X	5	3	Rio El Sauce
B3: Chamelecon	141	107	31	X	5	11	Rio Chamelecon
C1: Choloma	75	58	25	8	8	5	Rio Chamelecon
C1: Choloma	102	79	36	14	15	31	Rio Choloma
C2: Monterrery	80	65	24	9	18	20	Rio Choloma
C3: Blanquito	100	83	33	2	26	18	Rio Chamelecon
C3: Blanquito	98	53	34	X	8	8	Rio Choloma
C3: Blanquito	97	31	39	X	8	12	Other Rivers
INTERNAL							
A1: Calpules	45	36	18	9	9	2	Rain
B2: Fesitranh	55	45	0	X	13	2	Rain

Note; X=below the level

TABLE 5.2 MAJOR EVENTS AND TOPICS AT THE DAYS OF FIFI IN CHOLOMA

Memorendam of the1974 flood in Choloma(major sources; newspapers and interview to the residents)

Day	Time	Major events at Choloma City	At La Jutosa/Ocotillo/Majaine/Portillo
17 Sept.(Tue)		Rain began at 10:00 p.m. contineously	Rain began at 10:00 p.m. contineously
18 Sept.(Wed)		Heavy rain with strong wind all the day	Heavy rain with strong wind all the day
		The airport was closed and all flights were cancelled	
	18:00	General warning by radio, but with no detail information, so that people were not so cautious	General warning by radio, but with no detail information, so that people were not so cautious
		The road(SPS-Pto Cortes) is flooded with water up to 30 cm	
	22:00	Water depth of the road increased by 1 m	
19 Sept.(Thr)	1:00		Flood water with sand and stones came at Ocotillo
		Some people were evacuated to other places	Water higher than the roof of the houses at Ocotillo
	3:00	Flood water hits Choloma city area and the road and railway bridges were washed away in a few minutes	People evacuated to the mountain at Ocotillo/La Jutosa 25houses(85persons) were damaed at Portillo(14ha)
		Almost all the city area was inunded and 2/3 of the Choloma submerged	16 persons were killed by land slide at Ocotillo
		People were floated and drowned, and some people evacuated at 2nd floor of neighbor's houses	100 houses(1000 persons), 5 ha of village area were destroyed, and livestock and all crops were totally washed away at La Jutosa
	6:00	Flood water depth went down	10 houses(80 persons) were washed away with land-slide and the road was washed away at Majaine
20 Sept.(Fri)		Choloma was still flooded, there are no power supply and water	Water depth approx. 10 meter at La Jutosa
		Up to this date there have been 70 bodies burried in Choloma and 22 bodies in Quebrada Seca	95% of La Jutosa and Ocortillo were destroyed
		At a school in Quebrada Seca, the water depth is 2 m	
		There are hundreds of people on the roofs of the houses were asking for help	
		80% of the people in Choloma city lost thier houses	
21 Sept.(Sat)		2/3 of Choloma city are flooded	
22 Sept.(Sun)		Choloma city is isolated	Flood water was stabilized at La Jutosa
23 Sept.(Mon)		Electricity supply was recovered in some area	People suffered from no food/communication and sick
24 Sept.(Tue)			People recieved foodstuff from the rescue(French aid)
25 Sept.(Wed)		People recieved food, clothing, medicines, etc. by air	
28 Sept.(Sat)		One water well was built, capacity 60,000 gal/day	
4 Oct.		Rescue from University Tegc. started to work	
		Railway briges was reconstructed	
		Road was connected by temporal bridge	
9 Oct.		3 water well were built but with no distribution tank	
10 Oct.		1,640 bodies have been incinerated and 240 people are missing in Choloma by this time	125 bodies were found and burried
		People were suffering from the sickness	
		Reconlruction works were started	
After 1 month		Electricity supply was recovered	Road was connected to Choloma at Ocotillo
		Provisional wooden bridge was built	
After 3 months		Water supply was recovered completely	
After 1 year		Reconstrudion work were completed so far	Completion of new settlement area in La Nueva Jutosa with church, hospital and school
After 2 years		Permanent concrete bridge was built	Completion of reconstruction at the Ocotillo

Estimation of Flood Damages to the People and Houses(Rio Choloma Area)

	Damaged/Injured	Destroyed/Killed
La Jutosa	80-100 houses, 1,500 persons	50 people were killed
Ocotillo	40-50 houses, 1,000 persons	31 people were killed
Choloma city*)	3,000 houses, 15,000 persons	2,000 people were killed
Other areas	500 houses, 1,500 persons	
TOTAL	Approximately 4,000 houses and 20,000 persons	Approximately 2,500 people killed

Reference Information

Around 90,000 people were injured in San Pedro Sula
Approximately 1,600 ha area of banana were destroyed in the Sula Valley
60% of the railway was destroyed in Honduras
Total cost of the damage was $300-400 millions in Honduras
Preliminary estimate show that there could be a total of 10,000 deaths in nationwide

*)Especially at Guayabal, San Antonio, Pueblo Nuevo, La Playa and Conception

TABLE 5.3 1990 FLOOD

Zone	Water Depth from the Ground Level (cm)	Water Depth from the Floor Level (cm)	Sed. Depth from the Ground Level (cm)	Sed. Depth from the Floor Level (cm)	Duration (days)	Number of Samples	Source of Water
STUDY AREA	79	49	13	X	7	117	
External	86	58	15	X	8	91	
Internal	55	17	9	X	3	26	
EXTERNAL							
A1: Calpules	107	85	14	X	6	4	Rio Chamelecon
A2: Santa Marta	65	48	9	X	6	2	Rio Blanco
A2: Santa Marta	105	75	14	X	6	27	Rio Chamelecon
A3: Lima	116	56	14	X	4	13	Rio Chamelecon
B3: Chamelecon	72	48	13	X	3	18	Rio Chamelecon
C1: Choloma	45	18	15	43	6	2	Rio Chamelecon
C1: Choloma	65	55	25	15	9	7	Rio Choloma
C2: Monterrery	57	41	14	X	25	15	Rio Chamelecon
C3: Blanquito	100	100	30	30	4	1	Rio Chamelecon
C3: Blanquito	60	60	20	20	9	2	Other Rivers
INTERNAL							
A1: Calpules	52	39	13	X	4	7	Rain
A2: Santa Marta	89	14	6	X	3	7	Rain
B1: Universidad	18	X	0	X	1	6	Rain
B3: Chamelecon	20	X	0	X	5	1	Rain
C2: Monterrery	59	36	15	X	5	4	Rain
C3: Blanquito	70	50	40	20	3	1	Rain

Note; X=below the level

TABLE 5.4 ANNUAL FLOOD

Zone	Water Depth from the Ground Level (cm)	Water Depth from the Floor Level (cm)	Sed. Depth from the Ground Level (cm)	Sed. Depth from the Floor Level (cm)	Duration (days)	Number of Samples	Source of Water
STUDY AREA	27	X	7	X	2	153	
External	66	48	16	X	8	5	
Internal	26	X	6	X	2	148	
EXTERNAL							
A3: Lima	40	0	3	X	1	1	Rio Chamelecon
C1: Choloma	73	60	19	6	10	4	Rio Choloma
INTERNAL							
A1: Calpules	29	X	4	X	1	23	Rain
A2: Santa Marta	26	X	3	X	1	9	Rain
B1: Universidad	11	X	1	X	1	16	Rain
B2: Resitranh	4	1	0	X	1	1	Rain
B3: Chamelecon	12	X	2	X	1	40	Rain
C1: Choloma	37	21	11	0	3	24	Rain
C2: Monterrery	41	28	12	0	9	8	Rain
C3: Blanquito	40	9	13	0	2	27	Rain

Note; X=below the level

TABLE 5.5 (1/2) NUMBER OF BUILDINGS AND AREA OF AGRICULTURAL LAND SUBMERGED BY PROBABLE FLOOD DISCHARGE

A. Number of Buildings

Return Period (Year)	Water Depth (m) 0.00-0.50	0.51-1.00	1.01-1.50	1.51-2.00	2.01-2.50	Over 2.50	Total
1. Rio Choloma Basin							
1-1. Sediment Area							
2	131	69	29	18	10	4	261
30	1,962	1,010	459	272	175	90	3,968
50	4,140	2,135	1,100	594	380	190	8,539
100	4,389	2,222	1,160	635	404	205	9,015
2. Rio Blanco Basin							
2-1. Sediment Area							
5	2	1	0	0	0	0	3
30	397	229	72	14	7	0	719
50	445	257	80	16	8	0	806
100	498	292	89	18	9	0	906
2-2. Non-Sediment Area							
5	458	272	64	9	0	0	803
30	762	421	148	29	14	0	1,374
50	901	522	165	33	16	0	1,637
100	1,064	620	195	38	20	0	1,937
3. Rio El Sauce Basin							
3-1. Sediment Area							
5	177	101	24	2	0	0	304
30	269	158	50	10	5	0	492
50	304	177	55	11	5	0	552
100	456	266	84	15	9	0	830
3-2. Non-Sediment Area							
5	12	7	2	0	0	0	21
30	924	538	168	33	16	0	1,679
50	1,035	604	190	37	18	0	1,884
100	1,165	677	212	41	19	0	2,114

Note : Breakdowns by kinds of assets are provided in Tables I.2.1, I.2.2 and I.2.3 of Supporting Report I.

TABLE 5.5 (2/2) NUMBER OF BUILDINGS AND AREA OF AGRICULTURAL LAND SUBMERGED BY PROBABLE FLOOD DISCHARGE

B. Area of Agricultural Land (has.)

Return Period (Year)	Water Depth (m) 0.00-0.50	0.51-1.00	1.01-1.50	1.51-2.00	2.01-2.50	Over 2.50	Total
1. Rio Choloma Basin							
1-1. Sediment Area							
2	327	291	257	191	121	85	1,272
30	641	575	503	380	238	176	2,513
50	804	717	633	480	300	219	3,153
100	897	802	705	534	334	242	3,514
2. Rio Blanco Basin							
2-1. Sediment Area							
5	215	144	57	12	0	0	428
30	405	274	214	69	18	0	980
50	573	392	306	97	27	0	1,395
100	639	435	340	109	30	0	1,553
2-2. Non-Sediment Area							
5	340	231	87	20	0	0	678
30	1,068	728	571	180	50	0	2,597
50	1,253	854	669	215	60	0	3,051
100	1,408	951	756	241	68	0	3,434
3. Rio El Sauce Basin							
3-1. Sediment Area							
5	6	4	2	0	0	0	12
30	17	10	7	2	0	0	36
50	20	10	7	2	0	0	39
100	20	12	9	3	0	0	44
3-2. Non-Sediment Area							
5	217	143	66	15	0	0	441
30	415	282	222	70	20	0	1,009
50	498	340	268	86	25	0	1,217
100	560	383	301	97	25	0	1,366

Note : Breakdowns by kinds of assets are provided in Tables I.2.1, I.2.2 and I.2.3 of Supporting Report I.

TABLE 5.6 AVERAGE APPRAISALS OF BUILDINGS AND HOUSEHOLD EFFECTS (AT THE 1993 PRICES)

Kind of Buildings	Average Appraisal of Building (Lps.)	Average Appraisal of Household Effects (Lps.)	Accumlative Distribution of Household Effects above Floor Level (%)					
			to 0.5 m	to 1.0 m	to 1.5 m	to 2.0 m	to 2.5 m	to 3.0 m
1. Residential Houses								
High Class	402,600	104,800	34.8	65.7	92.3	99.9	100.0	100.0
Middle Class	114,700	21,480	41.3	66.9	95.1	98.5	100.0	100.0
Low Class	48,100	9,420	44.2	74.3	95.9	99.8	100.0	100.0
Poor Class	11,000	3,370	52.0	72.7	97.3	99.7	100.0	100.0
2. Farm House	192,400	667,960	39.1	72.5	98.4	99.9	100.0	100.0
3. Shop	92,400	30,460	49.8	75.8	88.9	99.9	100.0	100.0
4. Church	322,500	18,620	50.4	61.8	74.3	77.9	100.0	100.0
5. Clinic	39,200	22,520	53.5	83.2	97.8	99.5	100.0	100.0
6. School	333,400	18,300	53.3	85.1	93.7	95.5	100.0	100.0
7. Office	205,500	23,090	53.1	92.3	98.4	100.0	100.0	100.0
8. Factory	29,800	66,370	93.7	99.7	100.0	100.0	100.0	100.0

Note : Household effects include equipment and materials.

TABLE 5.7 UNIT PRODUCTION AND UNIT HARVEST COST OF AGRICULTURAL CROPS (AT THE 1993 PRICES)

Agricultural Crops	Unit Yield (tons/ha)	Unit Price (Lps./ton)	Unit Production (Lps./ha)	Unit Harvest Cost (Lps./ton)	Unit Harvest Cost (Lps./ha)	Unit Profit (Lps./ha)
Maize	2.3	1,520	3,496	300	690	2,806
Rice	3.3	1,820	6,006	200	660	5,346
Beans	0.7	1,520	1,064	250	175	889
Sugar Cane	100.0	90	9,000	5	500	8,500
Banana	50.0	1,120	56,000	100	5,000	51,000
Platano	17.0	810	13,770	45	765	13,005
Vegetables	6.5	1,520	9,880	150	975	8,905
Fruits	17.0	1,120	19,040	100	1,700	17,340
Other crops	6.5	1,520	9,880	150	975	8,905
Pasture (reformed)	26.0	110	2,860	0	0	2,860
Pasture (natural)	9.0	110	990	0	0	990

TABLE 5.8 (1/2) DAMAGE RATE TO ASSETS SUBMERGED BY FLOOD

Case A: Sediment

Assets	Water Depth above Floor Level (in Meter)					
	0.00-0.50	0.51-1.00	1.01-1.50	1.51-2.00	2.01-2.50	over 2.50
1. Buildings						
Residential Houses						
High Class	0.28	0.57	0.78	0.78	0.78	0.78
Middle Class	0.28	0.57	0.78	0.78	0.78	0.78
Low Class	0.28	0.57	0.78	0.78	0.78	0.78
Poor Class	0.28	0.57	0.78	0.78	0.78	0.78
Farm House	0.28	0.57	0.78	0.78	0.78	0.78
Shop	0.28	0.57	0.78	0.78	0.78	0.78
Church	0.28	0.57	0.78	0.78	0.78	0.78
Clinic	0.28	0.57	0.78	0.78	0.78	0.78
School	0.28	0.57	0.78	0.78	0.78	0.78
Office	0.28	0.57	0.78	0.78	0.78	0.78
Factory	0.28	0.57	0.78	0.78	0.78	0.78
2. Household Effects						
Residential Houses						
High Class	0.29	0.69	0.85	0.85	0.85	0.85
Middle Class	0.29	0.69	0.85	0.85	0.85	0.85
Low Class	0.29	0.69	0.85	0.85	0.85	0.85
Poor Class	0.29	0.69	0.85	0.85	0.85	0.85
Farm House	0.33	0.57	0.78	0.78	0.78	0.78
Shop	0.33	0.60	0.80	0.80	0.80	0.80
Church	0.33	0.60	0.80	0.80	0.80	0.80
Clinic	0.33	0.60	0.80	0.80	0.80	0.80
School	0.33	0.60	0.80	0.80	0.80	0.80
Office	0.33	0.60	0.80	0.80	0.80	0.80
Factory	0.33	0.60	0.80	0.80	0.80	0.80
3. Agricultural Crops						
Maize	0.52	1.00	1.00	1.00	1.00	1.00
Rice	0.52	1.00	1.00	1.00	1.00	1.00
Beans	0.55	0.81	1.00	1.00	1.00	1.00
Sugar Cane	0.30	0.70	0.90	0.90	0.90	0.90
Banana	0.30	0.70	0.95	0.95	0.95	0.95
Platano	0.30	0.70	0.95	0.95	0.95	0.95
Vegetables	0.55	0.81	1.00	1.00	1.00	1.00
Fruits	0.30	0.70	0.95	0.95	0.95	0.95
Other crops	0.52	1.00	1.00	1.00	1.00	1.00
Pasture(cultivated)	0.20	0.40	0.90	0.90	0.90	0.90
Pasture(natural)	0.20	0.30	0.60	0.60	0.60	0.60

TABLE 5.8 (2/2) DAMAGE RATE TO ASSETS SUBMERGED BY FLOOD

Case B: Non-Sediment

Assets	Water Depth above Floor Level (in Meter)					
	0.00-0.50	0.51-1.00	1.01-1.50	1.51-2.00	2.01-2.50	over 2.50
1. Buildings						
Residential Houses						
High Class	0.12	0.21	0.31	0.31	0.69	0.69
Middle Class	0.12	0.21	0.31	0.31	0.69	0.69
Low Class	0.12	0.21	0.31	0.31	0.69	0.69
Poor Class	0.12	0.21	0.31	0.31	0.69	0.69
Farm House	0.12	0.21	0.31	0.31	0.69	0.69
Shop	0.12	0.21	0.31	0.31	0.69	0.69
Church	0.12	0.21	0.31	0.31	0.69	0.69
Clinic	0.12	0.21	0.31	0.31	0.69	0.69
School	0.12	0.21	0.31	0.31	0.69	0.69
Office	0.12	0.21	0.31	0.31	0.69	0.69
Factory	0.12	0.21	0.31	0.31	0.69	0.69
2. Household Effects						
Residential Houses						
High Class	0.09	0.19	0.33	0.33	0.67	0.67
Middle Class	0.09	0.19	0.33	0.33	0.67	0.67
Low Class	0.09	0.19	0.33	0.33	0.67	0.67
Poor Class	0.09	0.19	0.33	0.33	0.67	0.67
Farm House	0.18	0.30	0.39	0.39	0.71	0.71
Shop	0.15	0.30	0.40	0.40	0.73	0.73
Church	0.15	0.30	0.40	0.40	0.73	0.73
Clinic	0.15	0.30	0.40	0.40	0.73	0.73
School	0.15	0.30	0.40	0.40	0.73	0.73
Office	0.15	0.30	0.40	0.40	0.73	0.73
Factory	0.15	0.30	0.40	0.40	0.73	0.73
3. Agricultural Crops						
Maize	0.34	0.50	0.82	0.82	0.82	0.82
Rice	0.34	0.50	0.82	0.82	0.82	0.82
Beans	0.41	0.60	0.81	0.81	0.81	0.81
Sugar Cane	0.30	0.50	0.70	0.70	0.90	0.90
Banana	0.30	0.50	0.70	0.75	0.95	0.95
Platano	0.30	0.50	0.70	0.75	0.95	0.95
Vegetables	0.42	0.67	0.91	0.91	0.91	0.91
Fruits	0.30	0.50	0.70	0.75	0.95	0.95
Other crops	0.34	0.50	0.82	0.82	0.82	0.82
Pasture(cultivated)	0.10	0.30	0.90	0.90	0.90	0.90
Pasture(natural)	0.10	0.20	0.50	0.50	0.50	0.50

TABLE 5.9 (1/3) SUMMARY OF FLOOD DAMAGE IN RIO CHOLOMA BASIN

Unit : Lps. 1,000

Items	Return Period (years)			
	2	30	50	100
1. Agricultural products	1,362	3,010	4,039	4,528
2. Buildings	12,975	176,261	398,234	418,960
3. Household effects	3,761	47,781	114,454	120,092
Sub-total	18,099	229,053	516,727	543,580
4. Public facilities	2,715	34,358	77,509	81,537
5. Business losses	905	11,453	25,836	27,179
6. Emergency measures	1,810	22,905	51,673	54,358
Total	23,528	297,768	671,745	706,654

TABLE 5.9 (2/3) SUMMARY OF FLOOD DAMAGE IN RIO BLANCO BASIN

(A) Sediment Area

Unit : Lps. 1,000

Items	Return Period (years) 5	30	50	100
1. Agricultural products	564	1,321	2,125	2,368
2. Buildings	217	68,190	76,145	85,733
3. Household effects	448	13,244	14,641	16,550
Sub-total	1,229	82,754	92,911	104,651
4. Public facilities	184	12,413	13,937	15,698
5. Business losses	61	4,138	4,646	5,233
6. Emergency measures	123	8,275	9,291	10,465
Total	1,598	107,581	120,785	136,047

(B) Non-Sediment Area

Items	Return Period (years) 5	30	50	100
1. Agricultural products	2,185	12,500	14,104	15,891
2. Buildings	8,322	17,273	23,053	29,495
3. Household effects	2,002	6,163	8,076	10,292
Sub-total	12,509	35,936	45,233	55,678
4. Public facilities	1,876	5,390	6,785	8,352
5. Business losses	625	1,797	2,262	2,784
6. Emergency measures	1,251	3,594	4,523	5,568
Total	16,262	46,717	58,803	72,381

(C) Total (Sediment & Non-Sediment Areas)

Items	Return Period (years) 5	30	50	100
1. Agricultural products	2,749	13,821	16,229	18,259
2. Buildings	8,539	85,463	99,198	115,228
3. Household effects	2,450	19,407	22,717	26,842
Sub-total	13,738	118,690	138,144	160,329
4. Public facilities	2,061	17,804	20,722	24,049
5. Business losses	687	5,935	6,907	8,016
6. Emergency measures	1,374	11,869	13,814	16,033
Total	17,860	154,297	179,587	208,428

TABLE 5.9 (3/3) SUMMARY OF FLOOD DAMAGE IN RIO EL SAUCE BASIN

(A) Sediment Area Unit : Lps. 1,000

Items	Return Period (years)			
	5	30	50	100
1. Agricultural products	8	43	44	49
2. Buildings	27,775	46,825	51,845	78,662
3. Household effects	4,535	8,079	8,867	13,503
Sub-total	32,318	54,947	60,756	92,214
4. Public facilities	4,848	8,242	9,113	13,832
5. Business losses	1,616	2,747	3,038	4,611
6. Emergency measures	3,232	5,495	6,076	9,221
Total	42,014	71,431	78,983	119,878

(B) Non-Sediment Area

Items	Return Period (years)			
	5	30	50	100
1. Agricultural products	928	3,810	4,366	4,890
2. Buildings	729	15,624	17,822	19,832
3. Household effects	374	2,747	3,215	3,508
Sub-total	2,031	22,181	25,403	28,230
4. Public facilities	305	3,327	3,810	4,235
5. Business losses	102	1,109	1,270	1,412
6. Emergency measures	203	2,218	2,540	2,823
Total	2,640	28,835	33,024	36,699

(C) Total (Sediment & Non-Sediment Areas)

Items	Return Period (years)			
	5	30	50	100
1. Agricultural products	936	3,853	4,410	4,939
2. Buildings	28,504	62,449	69,667	98,494
3. Household effects	4,909	10,826	12,082	17,011
Sub-total	34,349	77,128	86,159	120,444
4. Public facilities	5,152	11,569	12,924	18,067
5. Business losses	1,717	3,856	4,308	6,022
6. Emergency measures	3,435	7,713	8,616	12,044
Total	44,654	100,266	112,007	156,577

FIGURES

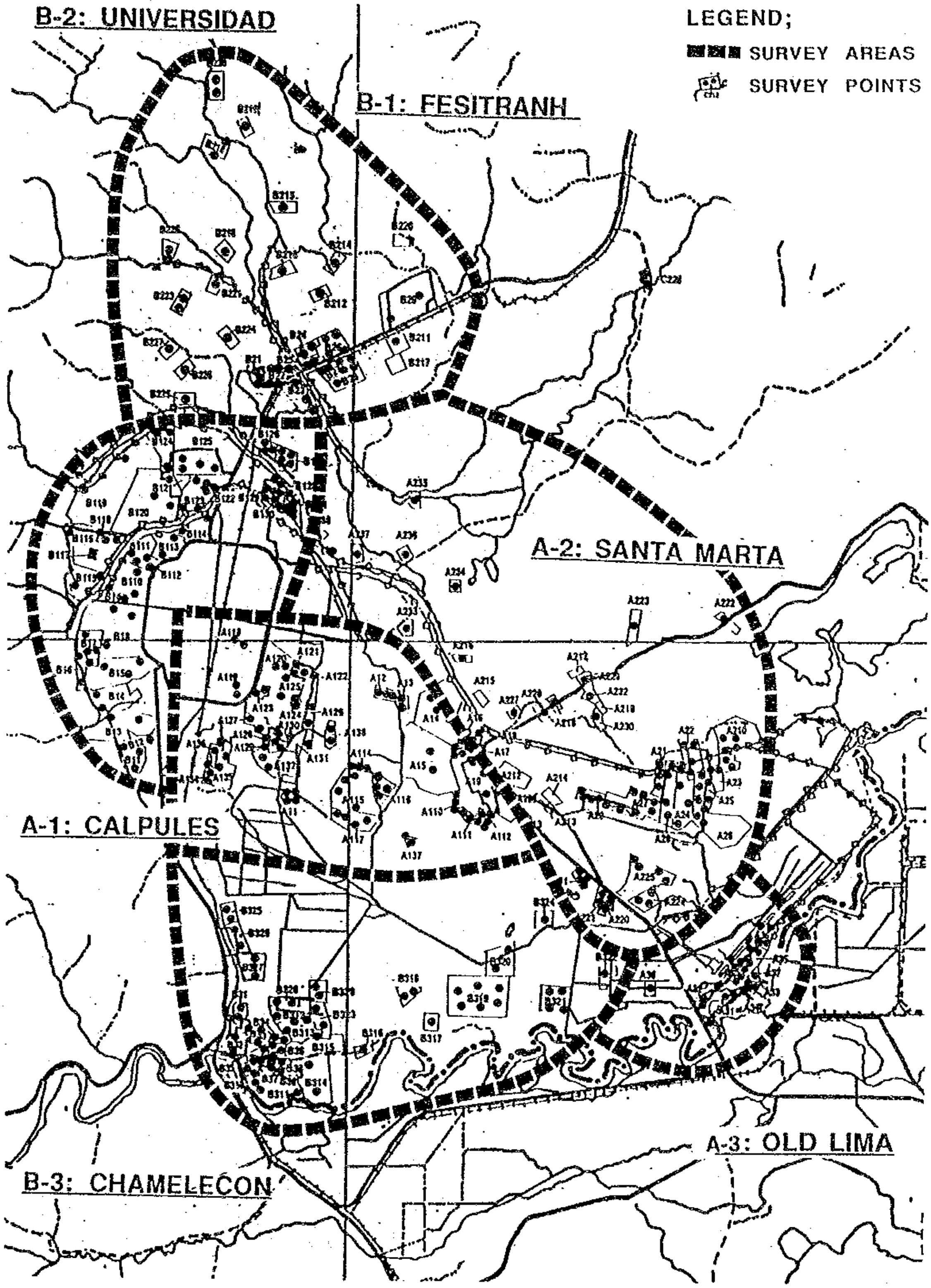


FIG. 5.1 SURVEY ZONE MAP OF RIO EL SAUCE AND RIO BLANCO AREA

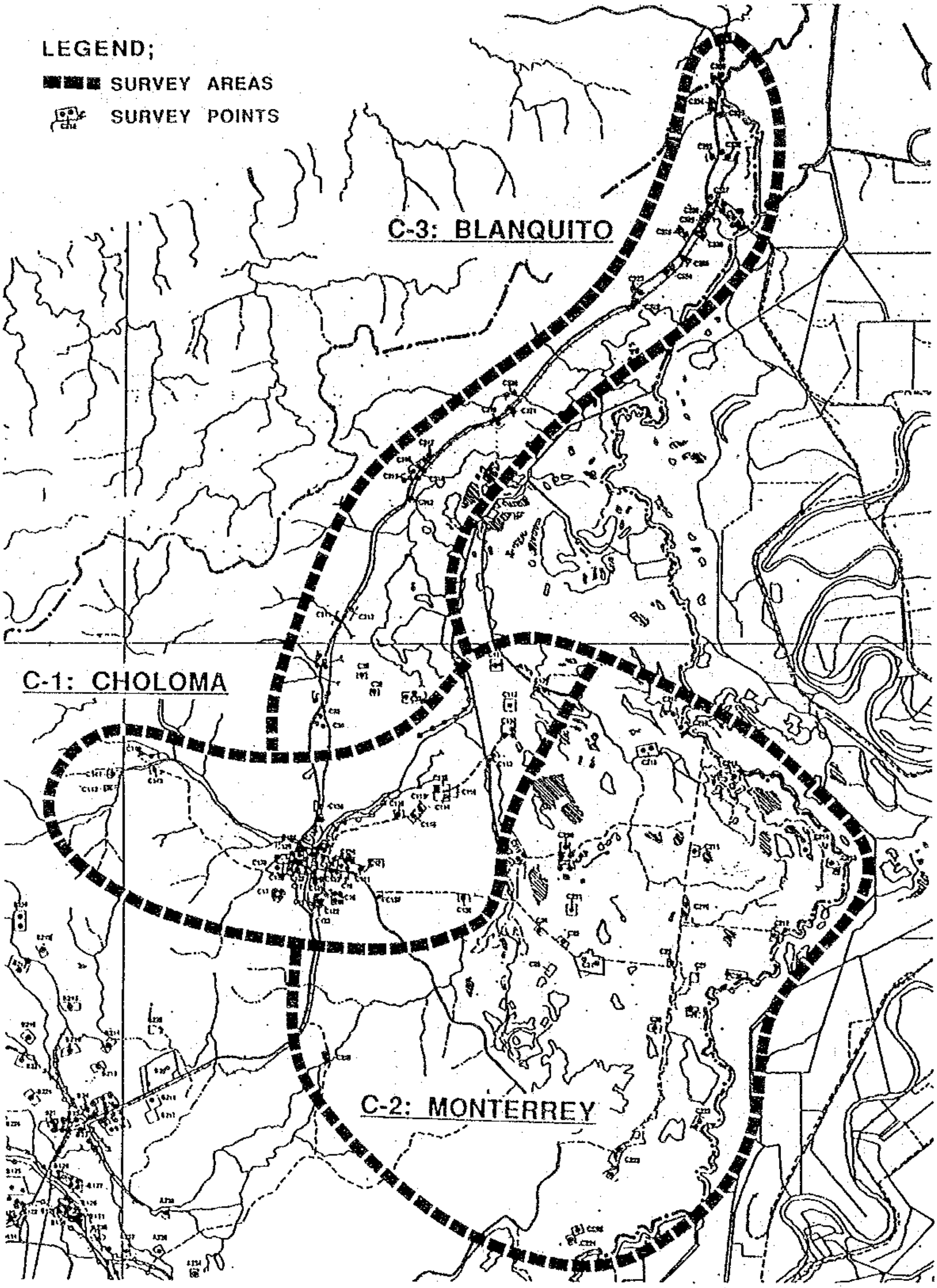


FIG. 5.2 SURVEY POINTS MAP OF RIO CHOLOMA AREA

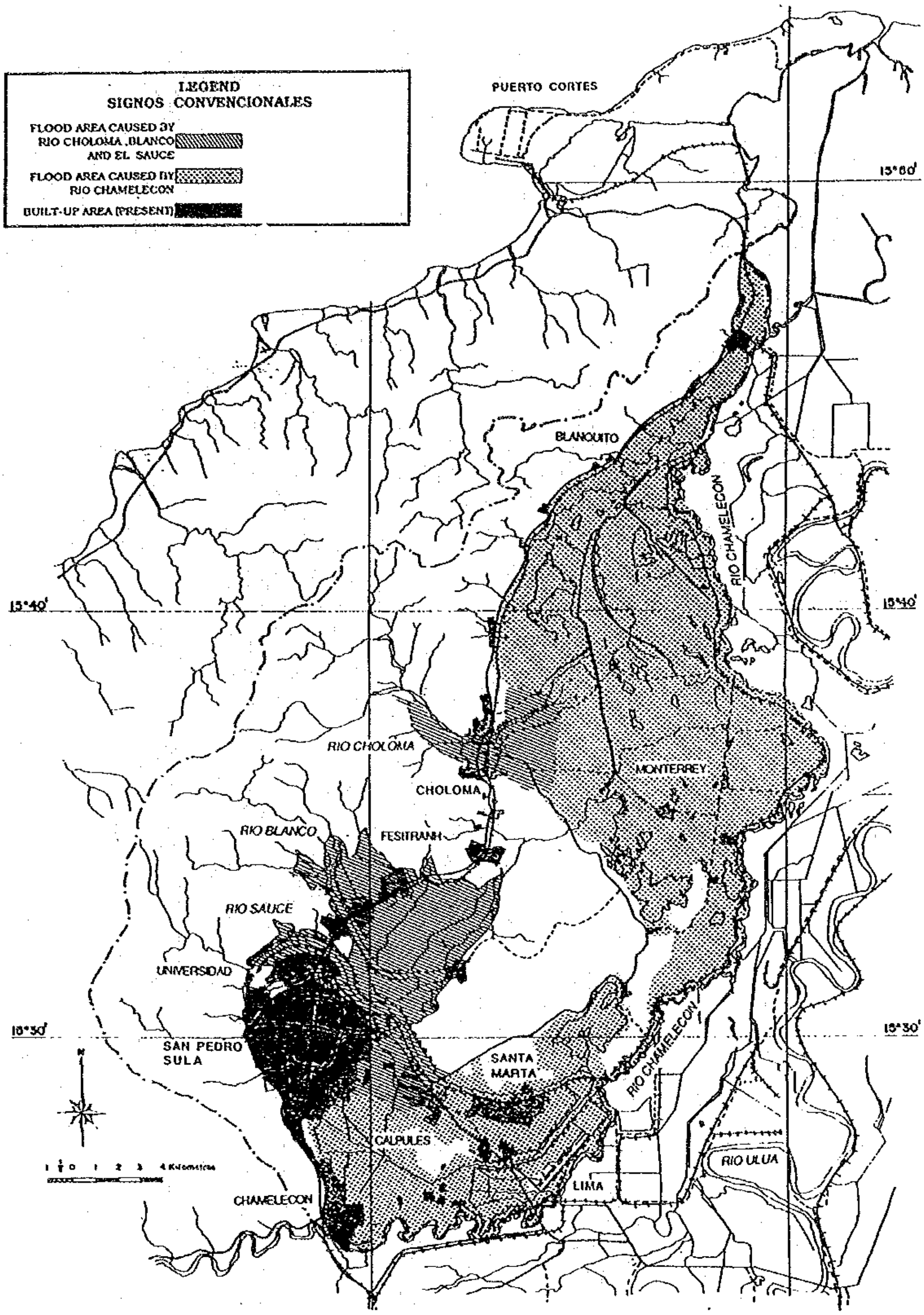


FIG. 5.3 FLOOD MAP OF 1974

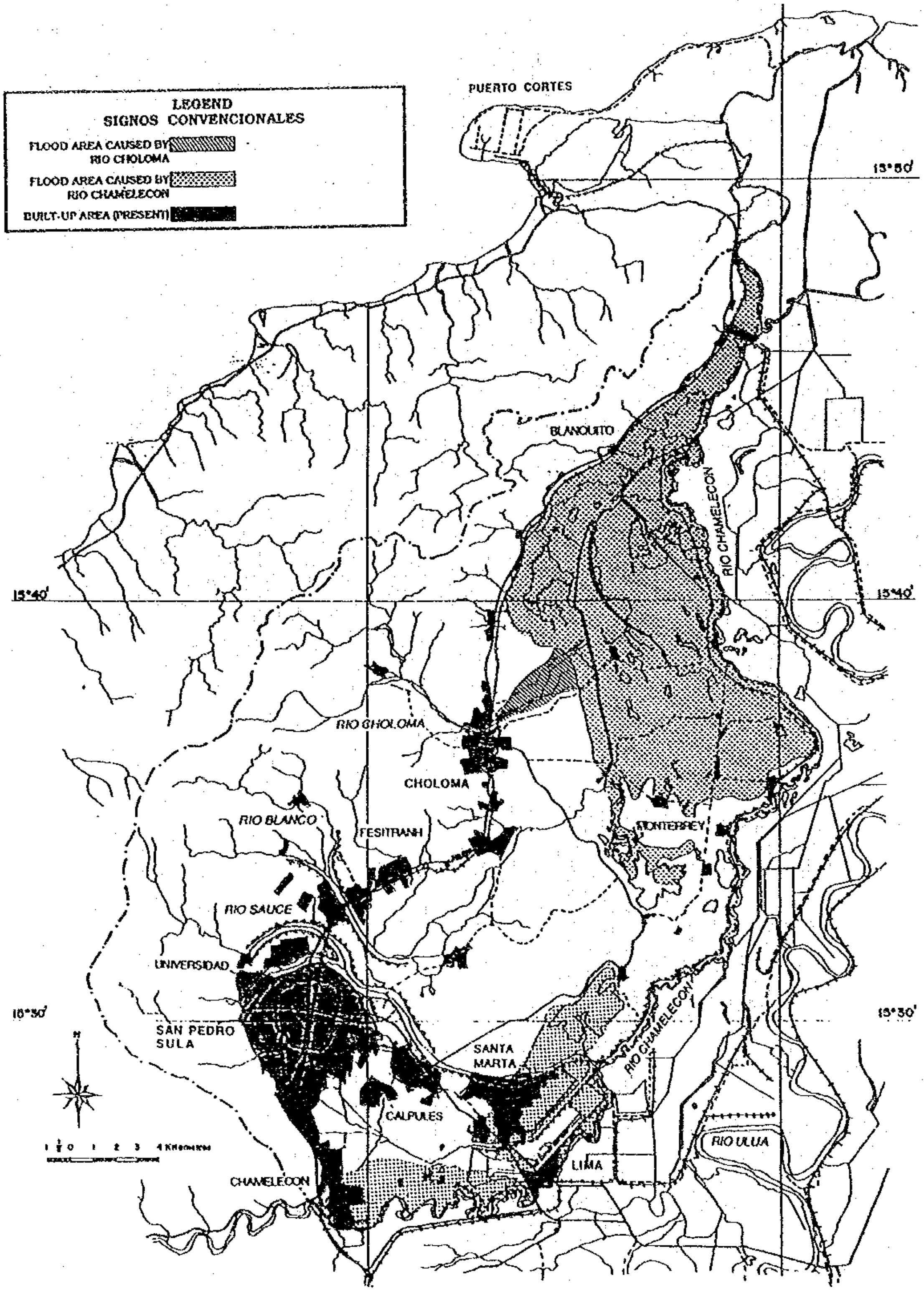


FIG. 5.4 FLOOD MAP OF 1990

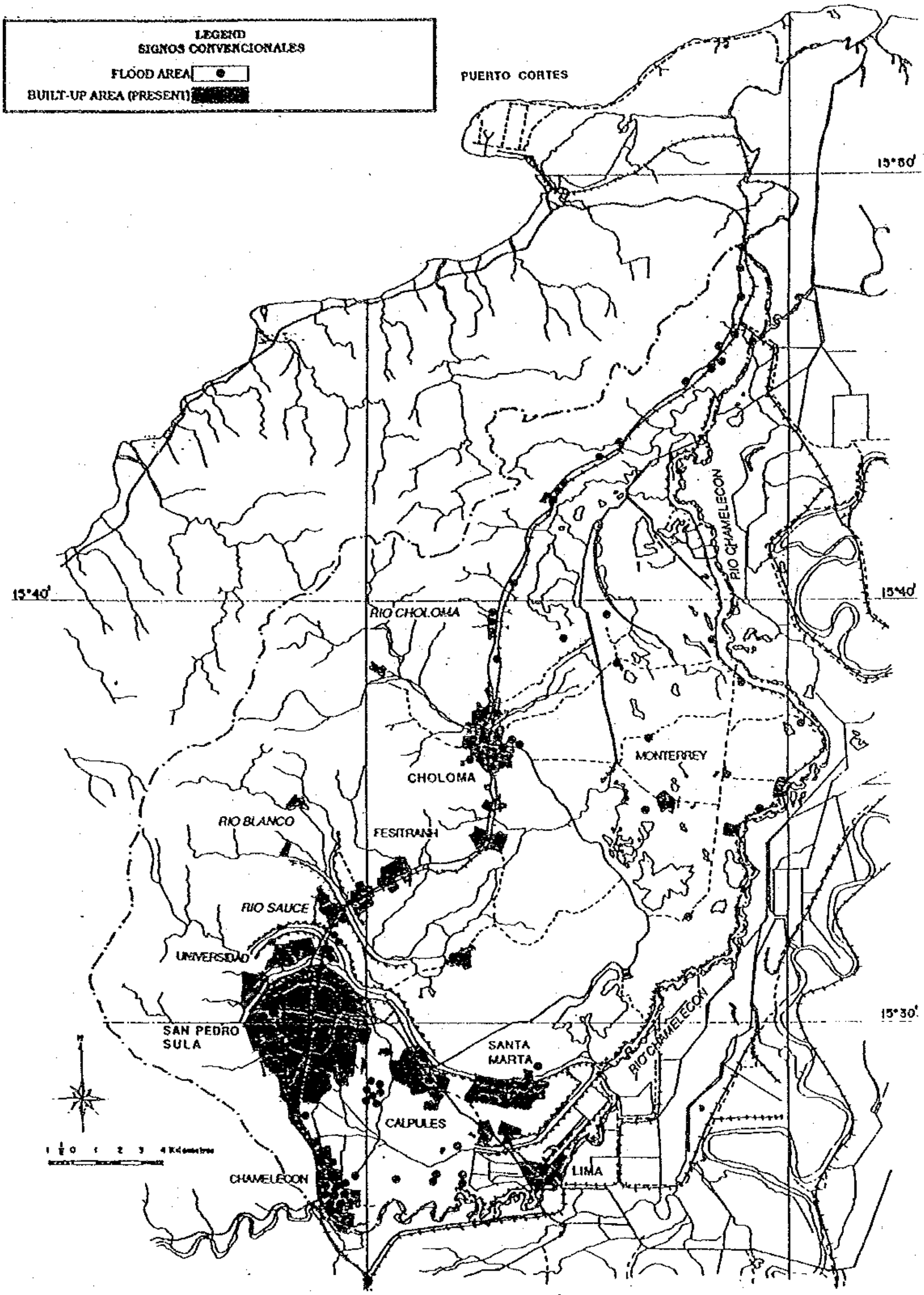
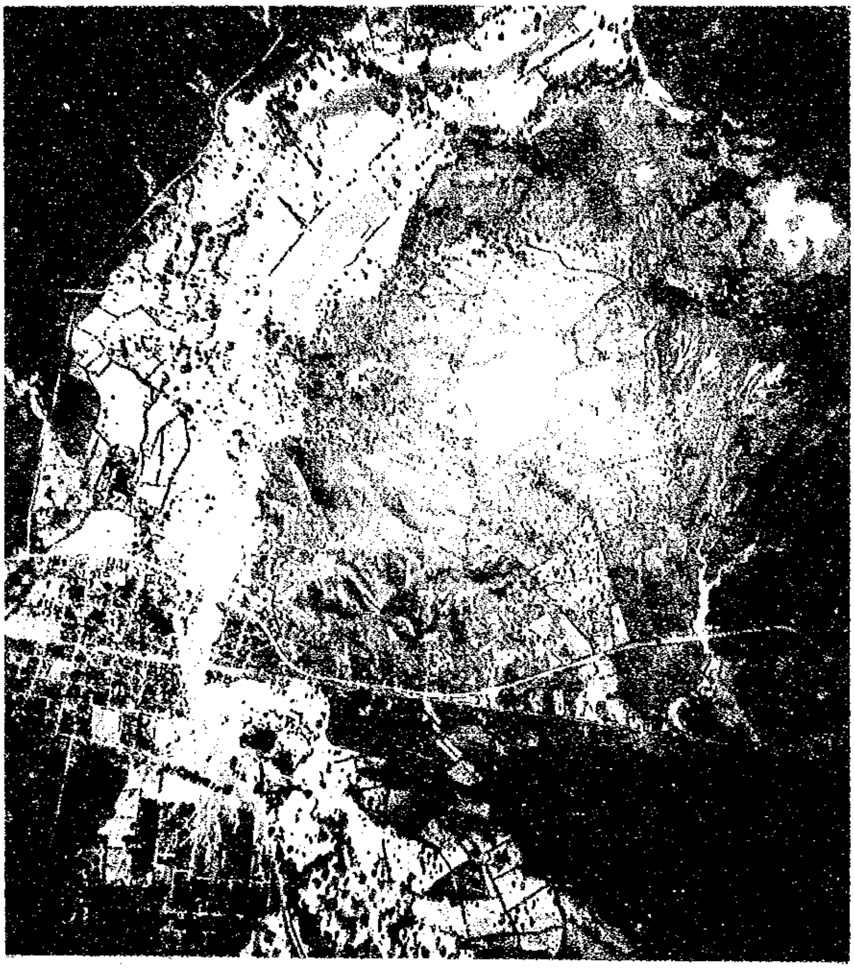


FIG. 5.5 ANNUAL FLOOD MAP



HUGE AMOUNT OF SEDIMENT DISCHARGE OF THE RIO CHOLOMA BY THE FLOOD OF HURRICANE "FIFI" IN 1974

CHAPTER 6
SEDIMENT YIELD STUDY

CHAPTER 6 SEDIMENT YIELD STUDY

6.1 General

In 1974 the hurricane Fifi caused extensive hillslope collapses in the Merendon mountains and the most severe sedimentary damages to the study area, especially in the Rio Choloma and the Rio Blanco basins. Since then the sediment runoffs have been affecting the drainage system downstream in the Sula Valley.

In order to devise adequate erosion control plan, various physical properties of the river basin, such as forest conditions and geological conditions, must be understood, and values for sediment yield and discharge within the basin must be estimated through the sediment yield study.

This sediment yield study was conducted using aerial photo-interpretation, topographic map analysis, field observations of past floods, and the amount of sediment yields were estimated for a scale of the hurricane Fifi.

6.2 River Systems in the Mountain Areas

6.2.1 Topography and Geography

(1) Rio Choloma

The Rio Choloma basin is composed of the Rio Jutosa, the Rio Majaine, the Rio Ocotillo and their respective branches. The altitude of the Rio Choloma basin where the national road bridge is crossing, is about 40 meters, while the highest altitude is the Cerro El Mogoton, at 1,320 meters in the Rio La Jutosa basin.

The Rio La Jutosa and the Rio Majaine are composed of migmatite and granitic rocks. Collapses are often seen in the upper reach of the Rio Majaine and a greater scale in the uppermost of the Rio La Jutosa basin. Steep mountainous terrain is found within the mid and upper basins of both rivers. Terraces including debris flow and flood terraces are formed in the mid reaches of both these rivers. Sediment deposits mostly composed of sand and gravel are widely distributed in the riverbeds and along the channels.

The Rio del Ocotillo is mostly composed of metamorphic rocks such as gneiss and schist. The lower basin is formed from steep slopes, but the mid and upper basins are low relief surfaces developing from an aging mountain system. Boulders with a maximum diameter of two(2) meters can be observed to be intermingled in the riverbed deposits of the lower basin of the Rio del Ocotillo, while the mid and upper basins have a gentle gradient of 3~5 degrees, mainly composed of sand and gravel.

There is one check dam (Takemoto dam) in the Rio La Jutosa, which was completed in 1984 and filled by the debris in August, 1992.

A flood plain (low terrace) of 1.2 km maximum width was formed in the Rio Choloma downstream basin from confluence with the Rio Majaine and the Rio La Jutosa, where thick overflow deposits of sand and gravel accumulate, and provides the downstream with a large amount of sediments when floods occur.

(2) Rio Blanco Basin

The Rio Blanco basin is composed of the Rio del Zapotal, the Rio Chiquito, the Rio de Armenta and their tributaries. The altitude, where the national road bridge crosses the Rio Blanco, is 75 meters, while the highest altitude is 1749 meters at the Cerro El Mogote, in the Rio Zapotal Basin.

The geology in this basin is mainly composed of metamorphic rocks (chiefly migmatite) and granitic rocks. The mid and upper basin is steep, mountainous terrain. Most hillslope collapses occurred at the steep slopes in the upper basin.

In the Rio del Zapotal basin riverbed deposits are widely distributed, almost in all river channels. The riverbed of the Rio del Zapotal contains sand, gravel and boulders, and considerable wasting of the channels can be observed. Erosion of the flood terraces at two(2)-three(3) meters above the existing riverbed is very noticeable and a great volume of sediments can be estimated during floods.

Alluvial fans of sand and gravel are formed in the lower basin, where a river course of unstable braided stream is formed, probably containing considerable sediment yield accompanying river bank erosion during floods. Channel deposits are distributed in some parts of the mid basin of the Rio de Armenta where boulders intermingled with sediments are observed in the river channel.

(3) Rio El Sauce Basin

The Rio El Sauce basin is composed of the Rio Santa Ana, the Rio Piedras and their tributaries.

The Rio Santa Ana consists of steep mature slopes and is mostly of metamorphic rock such as migmatite and schist. The altitude of the Rio Santa Ana basin where the national road bridge crosses the Rio Santa Ana is about 60 meters, while the highest point, a peak near the Cerro El Mogote, is 1720 meters. Most of Hillslope collapses occur in the steep slopes of the uppermost river basin. Channel deposits are observed in some parts of the mid reach of the river and the right bank tributaries. Boulders of two(2) meters in diameter mixed with riverbed sediments are observed in the river course from the valley exit to about the mid of the alluvial fan.

The Rio Piedras is surrounded by the main stream channel, plus its two tributaries, the Quebrada Santa Ana and Quebrada de Palmeras, which enter the main channel in the plain. The area where the national road bridge crosses the Rio Piedras is about 70 meters, while the highest point is the Cerro de la Virtudis, at 1,711 meters above mean sea level.

The mountain basin consists of steep and mature slopes. The geology in this basin mostly contains metamorphic rocks such as migmatite and schist. The riverbed from the valley exit to about 4 km upstream, is about 4 degrees and flood terraces of 1-1.5 meters above the riverbed, are existing along the river course. Subsequent floods have left numerous traces of erosion in these terraces. There has probably been a considerable amount of sediment discharged to downstream.

6.2.2 Stream Order Analysis

The stream channel network of each river basin is subdivided into individual lengths of channel, or channel segments, according to a hierarchy of orders of magnitude, assigning a sequence of numbers to the orders. The stream channel network of each pilot river system was subdivided based on the topographic maps of 1:50,000. The results are shown in *Figs* 6.1 (1)~(4) and 6.2 (1)~(4).

In this study the streams of second order are decided as the minimum segment for analysis.

6.3 Sediment Runoff by the Hurricane Fifi

6.3.1 Hill Slope Collapse

The hurricane Fifi of 1974 caused numerous hillslope collapses and extensive sedimentary damages. Aerial photo interpretations, topographic map analyses and field surveys have been conducted in order to investigate the sediment yield and discharge from the Rio Choloma and Rio Blanco basins.

A sample area of 16.4 square km was selected from the region where color aerial photographs (1:20,000) were taken immediately after the hurricane Fifi. The sample area was selected in the Rio Choloma basin and composed of two regions. One region was selected along the right bank of the Rio Choloma, consisting of gentle valleys which had comparatively small-scale collapses and the other was the Rio La Jutosa basin, where most of the collapse activities occurred, consisting of steep slopes and higher relief energy.

In the sample area the collapse conditions were photographically examined based on the color aerial photos (1:20,000) and also black and white aerial photos (1:20,000) taken in 1975. The hillslope collapses, likely occurred in the hurricane Fifi, were identified and shown in *Fig.* 6.3.

The sediment yield during the hurricane Fifi was estimated based on the likely hillslope collapse areas and supplementary information obtained through site investigations partly in the sample area. The major findings are summarized as follows:

- The total hillside landslide areas cover 9.68 % of the sample area.
- The depth of the collapse in the sample area of the Rio Choloma was tens of centimeters, while it was about 1 ~ 2 meters in the sample area of the Rio La Jutosa basin. The collapsed depth of slope areas was estimated about 1 meter in average.
- Most of the collapsed slope materials seem to have already been discharged downstream as debris flows or sediment flows. and very few unstable deposits were believed to be remaining on the hillslope.

6.3.2 River Bed Fluctuation

Riverbed fluctuation accompanying sediment deposition and discharge in both the Rio Choloma and the Rio Blanco was estimated using aerial photographs taken in 1954, 1974 and 1975. However, for the upper basin tributaries of the Rio Choloma and Rio Blanco, it could not be examined, because no aerial photos are available for these areas.

By studying the basic form elements of fluvial erosion landscape such as river channels alluvial plains, flood terraces, and alluvial fans, the land surface previously affected by sedimentation could be approximated. The thickness of the overflowing sediments was estimated by referring to buried conditions of vegetation and man-made structures such as houses, as well as landscape data obtained from the 1954 aerial photos.

The riverbed fluctuations during the hurricane Fifi, identified through aerial photo readings and field investigation, are explained below:

- The occurrence of debris flows was observed in nearly all the first and second order basins.

- The sediment deposition areas identified along the Rio Choloma and the Rio Blanco basins are shown in *Figs.* 6.4 (1) and (2).

They are explained as follows:

(Choloma Basin)

Rio Choloma (the reach downstream of the confluence with the Rio La Jutosa)

The sediment discharged from the Rio Majaine, the Rio La Jutosa and their tributaries such as the Qda. Guana, were thickly deposited in the flood plain extending from the confluence with the Rio La Jutosa to the vicinity of the Choloma railroad bridge, and in the river course till a few kilometers downstream from the railroad bridge. Thin sediment deposits were identified in a wide area from the railroad bridge to the Canal San Roque.

Rio Majaine

Sedimentation area identified was the reach at immediate upstream from the confluence with the Qda. del Ocotillo. Most of the sedimentation occurred in the reach between the confluence with the Qda. del Ocotillo and immediate downstream of the confluence with the Rio La Jutosa. Debris flow deposits were observed at upstream from the confluence with the Qda. del Ocotillo.

Rio La Jutosa

Sedimentation was identified in the vicinity of the confluence with the Qda. la Danta. Debris flow deposits were observed at upstream of the old debris flow terrace near the confluence with the Rio Choloma. Most of the sedimentation were identified in the same area as the debris flow deposits.

(Rio Blanco Basin)

Rio del Zapotal

Sedimentation was identified at the river course slightly upstream from the exit of the valley. Discharged sediment flowed downwards and deposited along an old river course near the head of the alluvial fan located at the valley exit, but at the mid alluvial fan it flowed over the river course and formed a fan like deposits.

The overflowed sediments converged with the sediments discharged from the Rio de Armenta, flowed further downstream and thickly deposited in a wide area extending to the vicinity of the national road bridge. Thick sediment deposits were also identified for several kilometers along a river course existed at the time. Together with the sediment discharged from the Rio de Armenta, the sedimentation area was expanded to another 5 - 6 kilometers downstream from the national road bridge to Laguna El Carmen.

Rio Chiquito

Sedimentation was identified at the river course slightly upstream from the valley exit. It flowed and deposited along the river course until it was blocked by the sediment deposits from the Rio del Zapotal, and then it changed direction, flowing down southeast along the river course existed at that time, and formed thick fan like deposits. Thin sedimentation was identified in a wide area down to the national road.

Rio de Armenta

It is identified that the sediment converged with the sediment discharged from the Qda. de Peno, deposited thickly from the head of the alluvial fan at the valley exit up to the vicinity of the confluence with the Rio del Zapotal. A part of the sediment deposited in the flat area that is located between river courses in the southern part of the alluvial fan.

6.3.3 Sediment Balance

The sediment balance of the hurricane Fifi in the Rio Choloma basin was estimated and shown in *Fig.* 6.5. The respective sediment volumes were derived as follow:

1) Produced Sediment Volume from Collapsed Area (Vfc)

$$Vfc = A \times Cr \times Cd \times Dr$$

where,

A	:	Mountain slope area,
Cr	:	Ratio of collapsed area (9.68 %),
Cd	:	Average collapsed depth (1.0 meter),
Dr	:	Discharge ratio of collapsed mass deposits (100 %).

2) Eroded Sediment Volume of the River Course (Vfe)

Vfe is equal to the unstable riverbed deposits in the streams of primary, secondary and some of tertiary order. Some third order valleys were omitted from the Vfe calculations, because they were classified as the reaches of sedimentation based on aerial photo interpretation and site surveys. The values of unstable riverbed deposits were based on the results of the unstable deposits related to sediment yield.

3) Supplied Sediment Volume (Vfs)

$$Vfs = Vfc + Vfe$$

4) Accumulated Sediment Volume (Vfa)

The net volume of sediment deposited in the Rio Choloma basin during the 1974 flood is estimated to be 6,545,500 cubic meters. This amount of sediments has been discharged downstream by the subsequent floods, but in a lesser intensity. This has caused aggradation and blockage of river courses and drainage channels downstream.

6.4 Unstable Deposits Related to Sediment Yield

Unstable alluvial deposits that are the sources of sediment yield, such as collapses, talus cones, terraces, landslides, alluvial fans, alluvial cones and river course deposits in stream channels, were recognized in the study area, through aerial photos of 1:10,000 taken in 1989 and 1:40,000 in 1992 The results of this study are shown in *Figs*. 6.6 (1)~(5).

Although some landslides have been identified in the southern part of the Rio Piedras basin, but not common in the study area, they unlikely yielded sediment in the hurricane Fifi.

6.4.1 Past Collapse Areas

A total of 646 collapse sites were recognized in the study area, through the aerial photo interpretation. These collapse areas were laid down on a 1;20,000 topographic map and measured. Although all the collapsed areas over 150 square meters or more might have been recognized, those collapsed areas that were covered by vegetation and those steep bank failures of small-medium size that were difficult to be recognized, might not have been identified. According to the field survey, it was decided that the average collapsed depth in the existing collapse areas was 1 meter, and the ratio of the remaining was 10 percent. The remaining collapsed materials were estimated and shown in *Table* 6.1.

Photo-interpretation indicate that collapse areas are mostly distributed in the both upper basins of the Rio Choloma and the Rio Blanco, and in the northern uppermost basins of the Rio Santa Ana. While only a few such areas exist in the Rio Piedras basin and the mid-lower basin of the Rio Santa Ana. In those basins of Rio Choloma, Rio Blanco and Rio Santa Ana, the ratio of collapsed areas is between 0.41~0.55 percentage, while in the Rio Piedras basin the ratio is 0.07 percent. The ratio in the mid-lower basin of the Rio Santa Ana is 0.22 percent. The ratios indicate more than 0.51 percent in the area be of granitic rocks, but less than 0.3 percent in the area be of metamorphic rocks. The occupied ratio of existing collapsed area are shown in *Table* 6.2.

6.4.2 Unstable Riverbed Deposits (Vbu)

In the hurricane Fifi, the sediment yields in the streams of first and second order were discharged mostly as debris flows and sediment flows, while the sediment yields in the streams of third through fifth order were transported as bed load.

Accordingly the whole existing unstable deposits in the streams of first and second order were estimated as unstable riverbed deposits, while in the streams of third through fifth order, the amount likely produced by secondary erosion, was estimated as the unstable riverbed deposits, but not including the reaches identified as sedimentation areas. The amount of Vbu is estimated as follows:

- The sediment yield from the streams of first and second order, was estimated by their stream lengths and widths, and thickness of deposits were estimated based on the followings:

	Stream of First Order	Stream of Second Order
Width	3.0~5.0 meters	3.0~7.0 meters
Thickness	0.5~1.5 meters	0.8~1.5 meters

- The sediment yields from the streams of third through fifth order were estimated based on the depth of secondary erosion which was decided at 1.0 to 2.0 meters through field surveys.

The results of the calculations are shown in *Table* 6.3.

6.4.3 Unstable Deposits along the River Course (Vcu)

The unstable alluvial deposits along the streams such as terrace deposits, talus deposits, and alluvial fan deposits, would easily undergo lateral erosion during floods. Those reaches were decided as the potential areas of sediment yield. The volume of unstable deposits along the river course was derived from the following equation;

$$Vcu = Lu \times Wu \times Tu$$

where,

Vcu : Unstable deposits along the river course,
Lu : Length of unstable deposit area along the river,
Wu : Width of unstable deposits area,

Tu : Thickness of unstable deposits.

Lu and Wu were derived based on the distribution map of existing unstable sediments. Tu was estimated from field surveys and photo analysis. The results of the calculation, the unstable deposits along the river course in each of the four (4) pilot river basins, are shown in *Table* 6.4.

TABLES

TABLE 6.1 EXISTING COLLAPSES

C.P	River Basin Name, Stream Order and Number / Nombre del Rio, Orden de La Corriente y Numero de Cuenca	Drainage Area		Collapse / Derrumbamiento			
		Drainage Area (DA) km²	Mountain Slope Area (A) km²	Collapsed Slope Area (Ca) m²	Occupied Ratio (Cr) %	Volume (Vc) m³	Residual Volume (Vru) m³
①	Rio Majaine 5-1-1	34.63	33.49	163730	0.48	163730	16373
②	Rio La Jutosa 4-3	20.39	18.29	67320	0.36	67320	6732
	Remains	16.62	10.04	25710	0.26	25710	2571
△	Rio Choloma Basin	71.64	61.82	256760	0.41	256760	25676
①	Rio del Zapotal 4-1-1	17.92	17.92	165750	0.92	165750	16575
②	Rio de Armenta 3-3-1	9.02	9.02	47450	0.52	47450	4745
③	Rio Chiquito 3-5, 3-6	7.47	6.98	2700	0.03	2700	270
	Remains	9.49	5.29	3100	0.06	3100	310
△	Rio Blanco Baisin	43.90	39.21	219000	0.55	219000	21900
①	Rio Santa Ana 4-1-1	22.39	22.39	125630	0.56	125630	12563
	Remains	15.24	6.20	5250	0.08	5250	525
△	Rio Santa Ana Basin	37.63	28.59	130880	0.46	130880	13088
①	Rio Piedras 3-1-2	20.09	20.09	16400	0.08	16400	1640
	Remains	10.78	6.68	1200	0.02	1200	120
△	Rio Piedras Basin	30.87	26.77	17600	0.07	17600	1760

Note/Nota :

Average collapsed depth / Profundidad promedio de derrumbamiento=1.0m

Residual ratio of collapsed mass deposits on the slope / Porcentaje remanente de derrumbamiento=10%

C.P, △ : Design control point / Punto de control de diseño

① : Sub-control point & Number / Punto de sub-control y numer

Remains : Remains of drainage area / Restos en area de cuenca

DA : Area de cuenca

A : Area de montañosa

Ca : Collapsed slopa Area / Area de cuesta derrumbada

Cr : Radio ocupado (=Ca/A×100)

Vc : Volume of collapsed mass deposits / Volumen de depositos masa de derrumbamiento (=Ca×1.0m)

Vru : Residual unstable deposits of existing past collapsed area (=Vc×10%)
Depositos residuales inestables existentes del area derrumbada anteriormente

TABLE 6.2 OCCUPIED RATIO OF EXISTING COLLAPSED AREA

Drainage Basin Control point	D.A km²	A km²	Ca ×10³ m²	Rr %
① Rio Majaine	34.63	33.49	163.73	0.48
② Rio La Jutosa	20.39	18.29	67.32	0.36
Remains	16.62	10.04	25.71	0.26
△ Rio Choroma Total	71.64	61.82	256.76	0.41
① Rio del Zapotal	17.92	17.92	165.75	0.92
② Rio de Armenta	9.02	9.02	47.45	0.52
③ Rio Chiquito	7.47	6.98	2.70	0.03
Remains	9.49	5.29	3.10	0.06
△ Rio Blanco Total	43.90	39.21	219.00	0.55
Rio Santa Ana	9.44	9.44	89.45	0.95
① Rio Santa Ana	12.95	12.95	36.18	0.28
Remains	15.24	6.20	5.25	0.08
△ Rio Santa Ana Total	37.63	28.59	130.88	0.46
① Rio Piedras	20.09	20.09	16.40	0.08
Remains	10.78	6.68	1.20	0.02
△ Rio Piedras Total	30.87	26.77	17.60	0.07

Note/Nota :

Drainage basin : Cuenca de drenaje
△ : Design control point / Punto de control para diseño
① : Sub-control point and Number / Punt de sub-control y Numero
Remains : Remains of drainage area / Restos en area de cuenca
D.A : Drainage area / Area de cuenca
A : Mountain slope area / Area de momtañosa
Ca : Collapsed slope area / Area colapsada
Rr : Ratio of collapsed slope area / Porcentaje de area de colapsos (= Ca/A×100)

TABLE 6.3 RIVERBED DEPOSITS

C.P	River Basin Name , Stream Order and Number Nombre del Rio , Orden de La Corriente y Numero de Cuenca	Drainage Area (DA) km²	Riverbed Deposits (Vbu) m³
①	Rio Majaine 5-1-1	34.63	483535
②	Rio La Jutosa 4-3	20.39	352345
	Remains	16.62	149315
△	Rio Choloma Baisn	71.64	985195
①	Rio del Zapotal 4-1-1	17.92	212305
②	Rio de Armenta 3-3-1	9.02	88520
③	Rio Chiquito 3-5,3-6	7.47	105020
	Remains	9.49	32680
△	Rio Blanco Basin	43.90	438525
①	Rio Santa Ana 4-1-1	22.39	325740
	Remains	15.24	92775
△	Rio Santa Ana Basin	37.63	418515
①	Rio Piedras 3-1-2	20.09	266820
	Remains	10.78	60540
△	Rio Piedras Basin	30.87	327360

Note/Nota :

C.P, △ : Design control point / Punto de control de diseño
① : Sub-control point & number / Punto de sub-control y numero
Remains : Remains of drainage area / Restos en area de cuenca
DA : Area de cuenca
Vbu : Unstable riverbed deposits
Depositos inestables en el lecho del rio

TABLE 6.4 VOLUME OF UNSTABLE DEPOSITS

C.P	River Basin Name , Stream Order and Number Nombre del Rio , Orden de La Corriente y Numero de Cuenca	DA km²	Vru x10³ m³	Vbu x10³ m³	Vcu x10³ m³
①	Rio Majaine 5-1-1	34.63	16.8	483.6	1644.4
②	Rio La Jutosa 4-3	20.39	6.8	352.2	4760.4
	Remains	16.62	2.5	149.3	7168.1
△	Rio Choloma Basin	71.64	26.1	985.1	13572.9
①	Rio del Zapotal 4-1-1	17.92	16.5	212.2	725.5
②	Rio de Armenta 3-3-1	9.02	4.8	88.5	97.5
③	Rio Chiquito 3-5,3-6	7.47	0.3	105.1	112.8
	Remains	9.49	0.4	32.7	6370.1
△	Rio Blanco Baisin	43.90	22.0	438.5	7305.9
①	Rio Santa Ana 4-1-1	22.39	12.5	325.9	157.2
	Remains	15.24	0.5	92.9	472.5
△	Rio Santa Ana Basin	37.63	13.0	418.8	629.7
①	Rio Piedras 3-1-2	20.09	1.6	266.8	878.7
	Remains	10.78	0.2	60.6	798.1
△	Rio Piedras Basin	30.87	1.8	327.4	1676.8

Note/Nota :
C.P, △ : Design control point / Punto de control de diseño
① : Sub-control point & number / Punto de sub-control y numero
Remains : Remains of drainage area / Restos en area de cuenca
DA : Drainage area / Area de cuenca
Vru : Residual unstable deposits of existing past collapsed area
Depositos residuales inestables existentes del area derrumbada anteriormente
Vbu : Unstable riverbed deposits
Depositos inestables en el lecho del rio
Vcu : Unstable deposits along the river course
Depositos inestables a lo largo del curso del rio

FIGURES

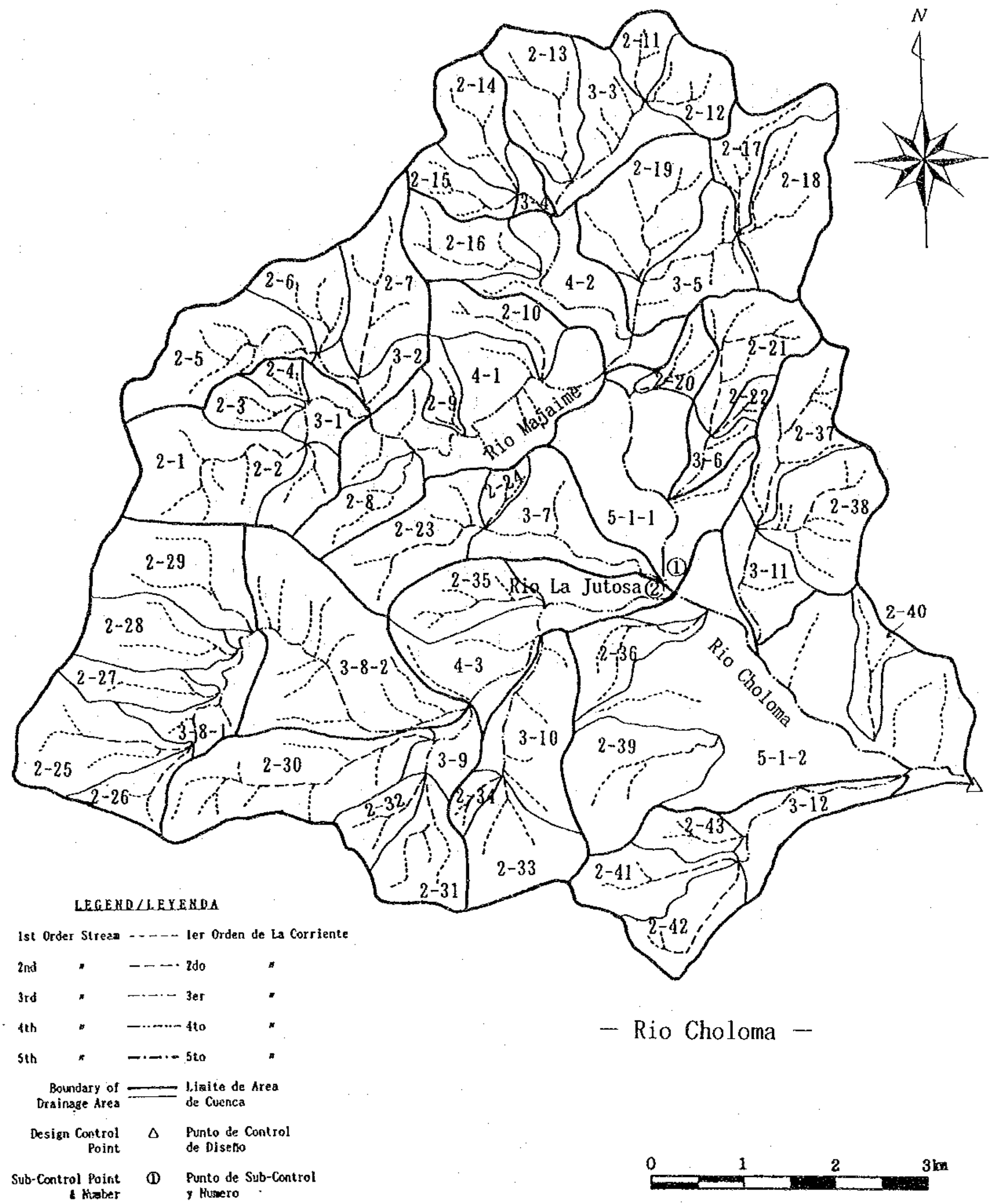


FIG. 6.1 (1) STREAM ORDER (RIO CHOLOMA)

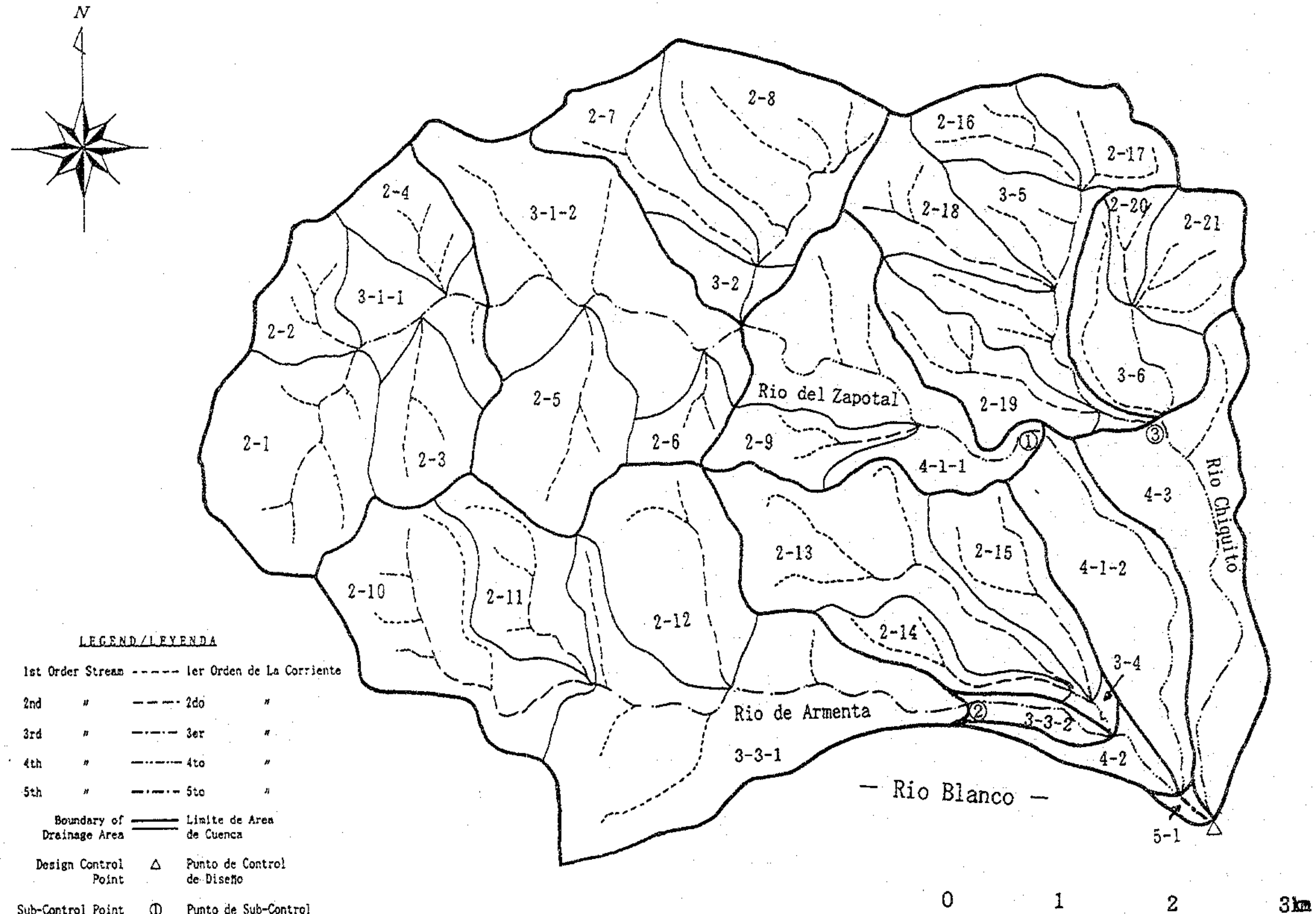
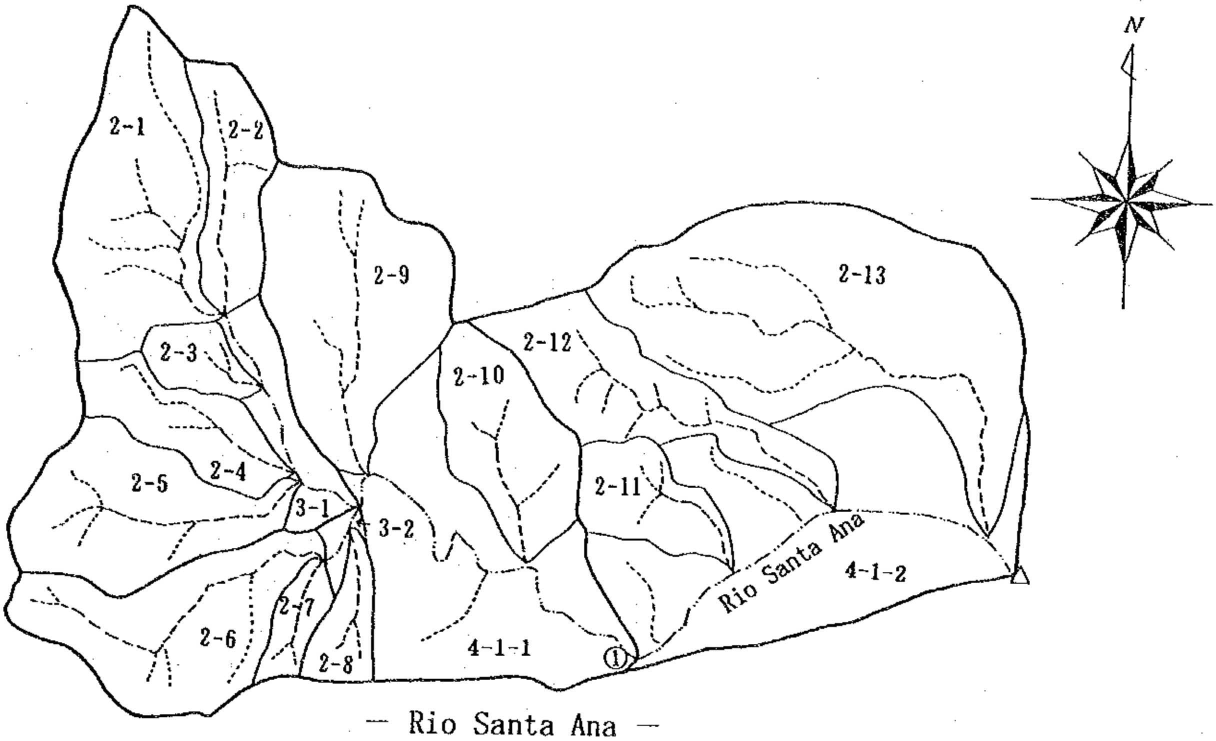


FIG. 6.1 (2) STREAM ORDER (RIO BLANCO)



— Rio Santa Ana —

FIG. 6.1 (3) STREAM ORDER (RIO SANTA ANA)

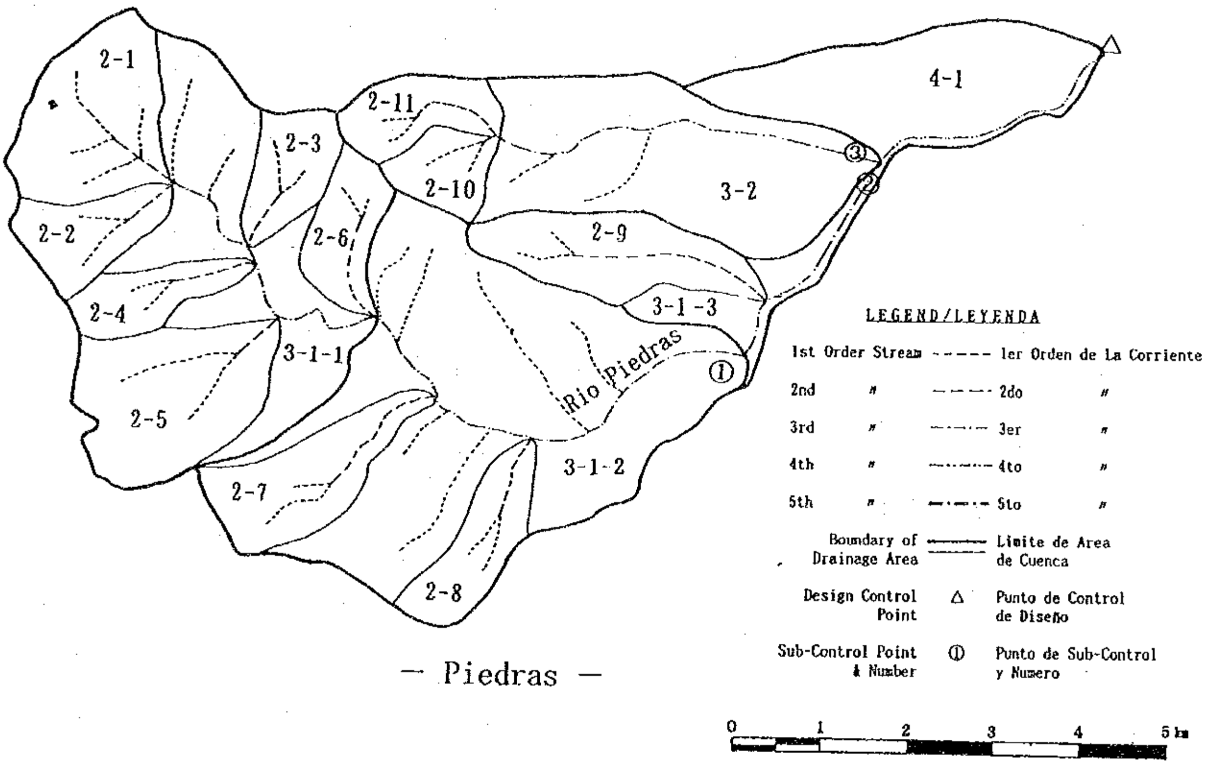


FIG. 6.1 (4) STREAM ORDER (RIO PIEDRAS)

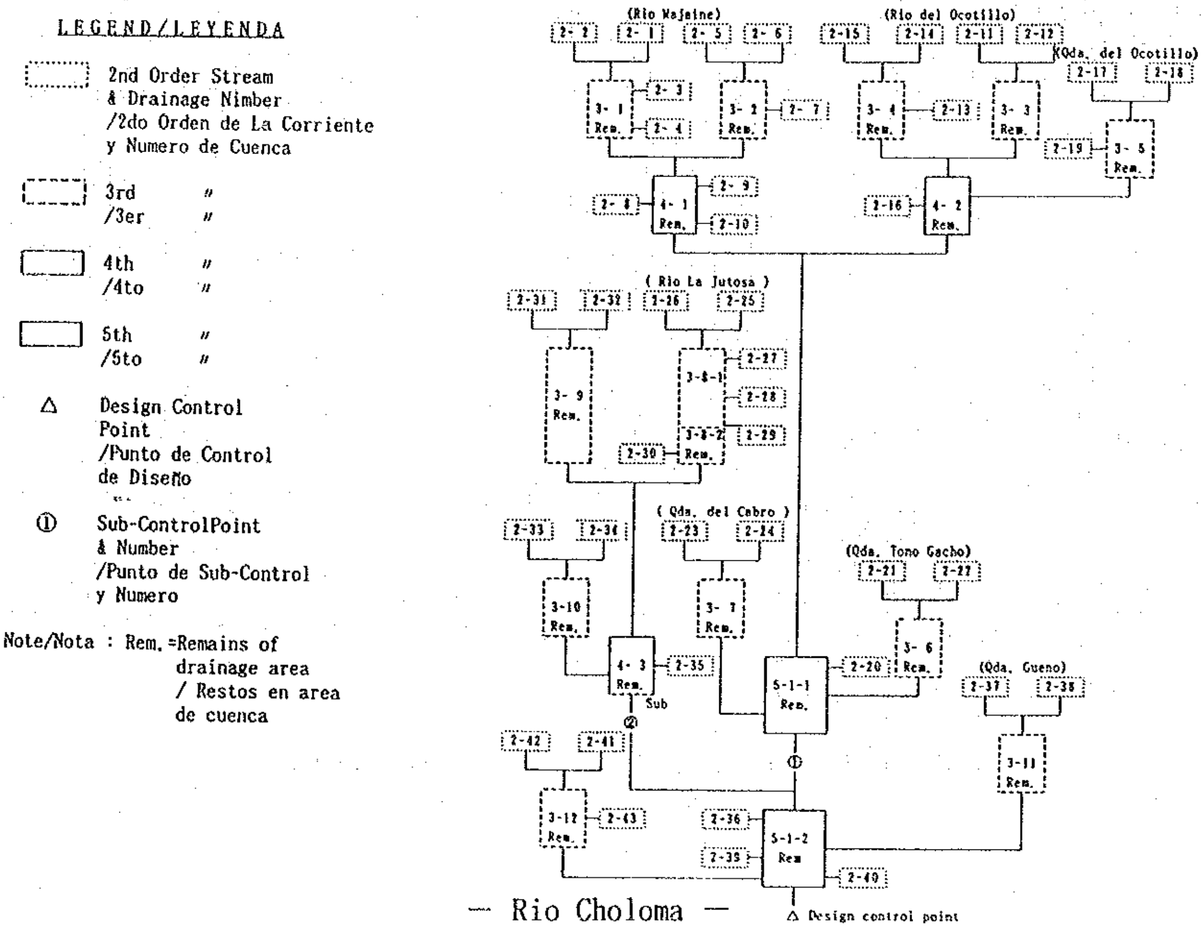


FIG. 6.2 (1) RIVER SYSTEM (RIO CHOLOMA)

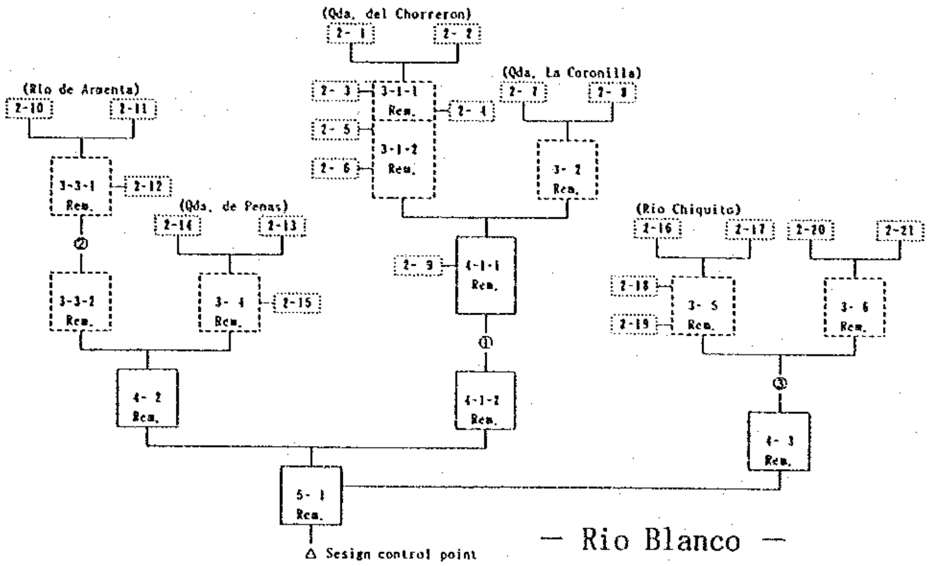


FIG. 6.2 (2) RIVER SYSTEM (RIO BLANCO)

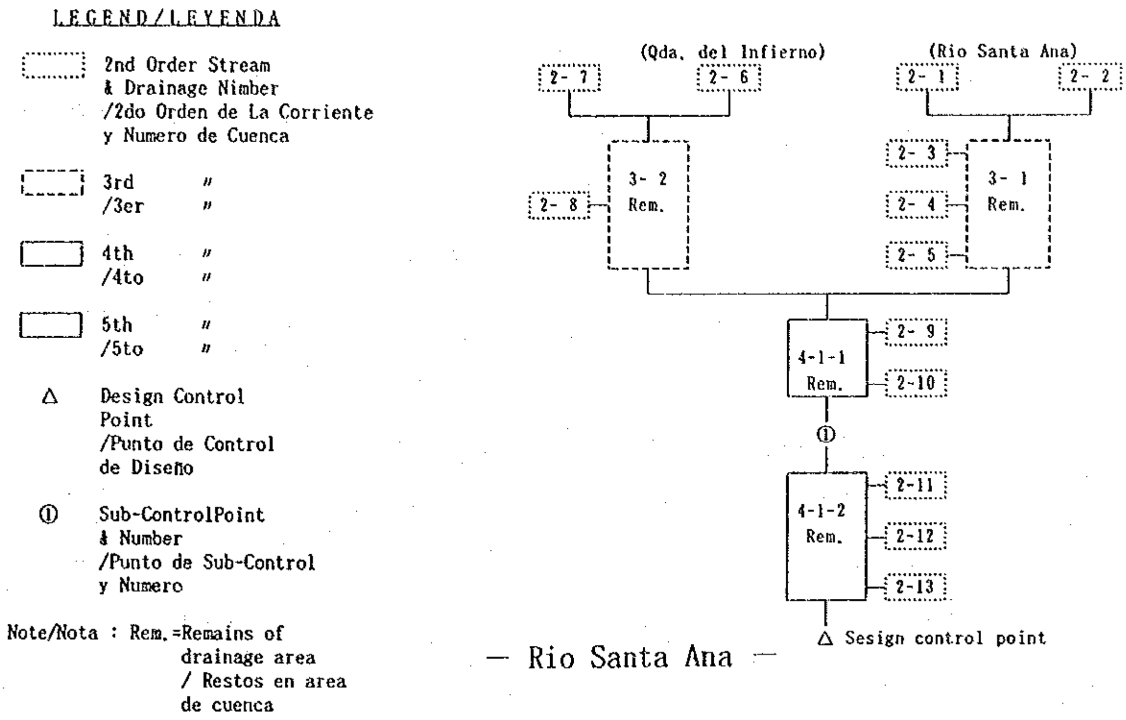


FIG. 6.2 (3) RIVER SYSTEM (RIO SANTA ANA)

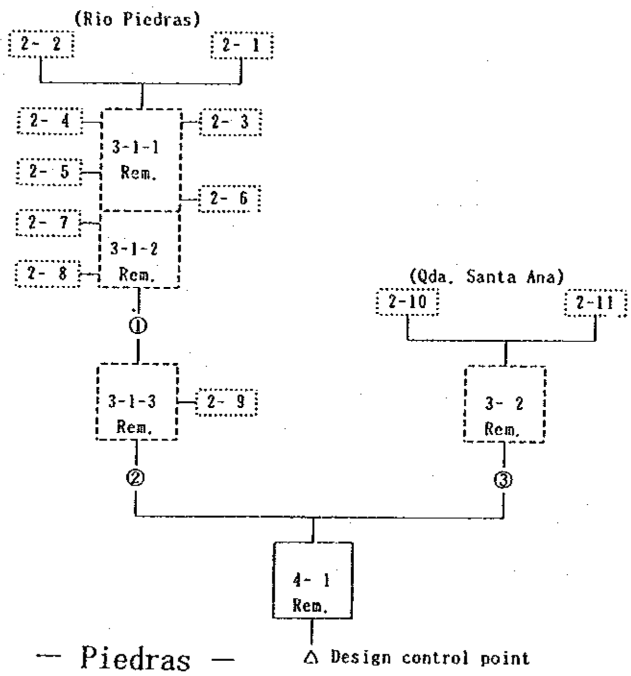


FIG. 6.2 (4) RIVER SYSTEM (RIO PIEDRAS)

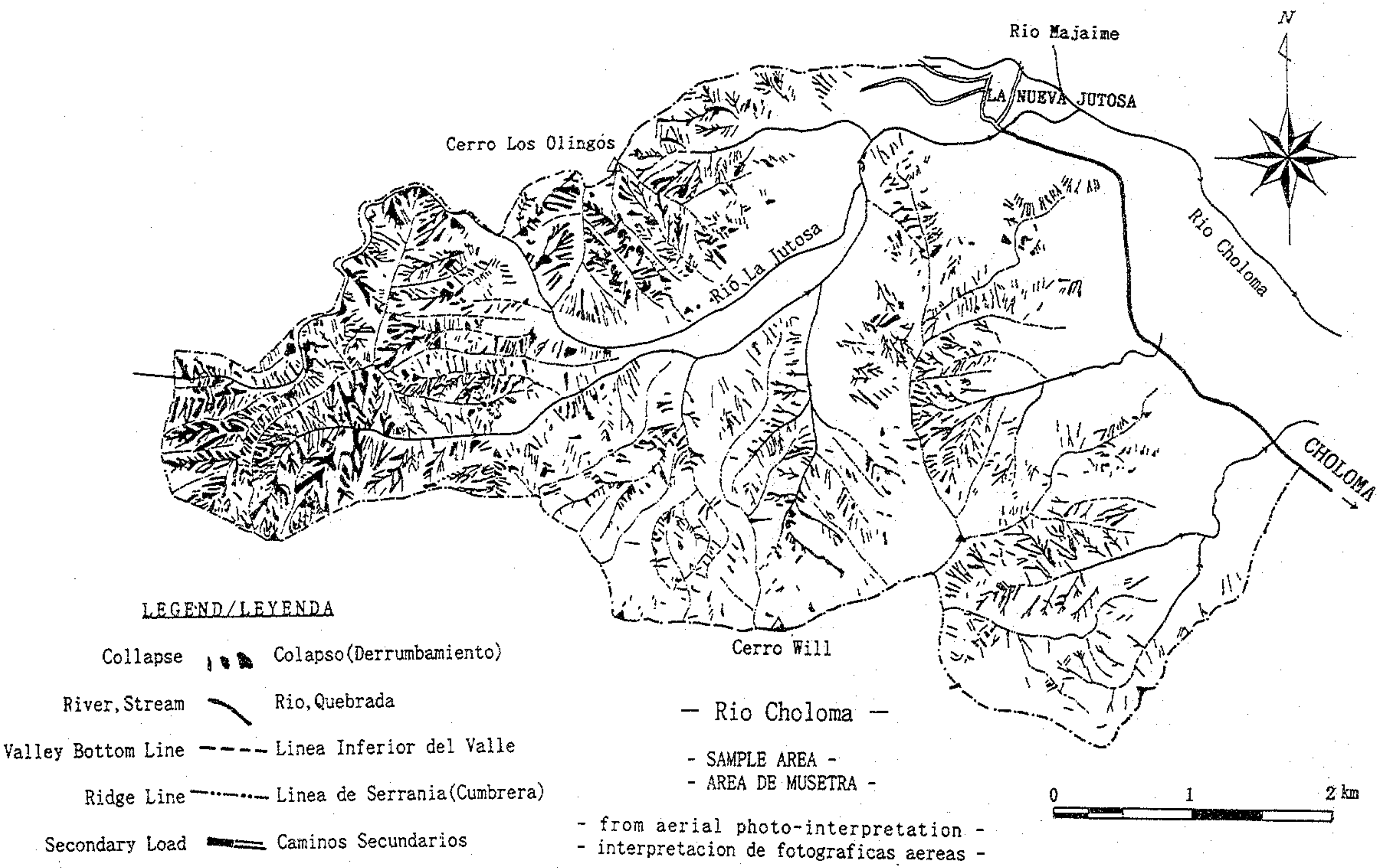


FIG. 6.3 HILL SLOPE COLLAPSES IN 1974

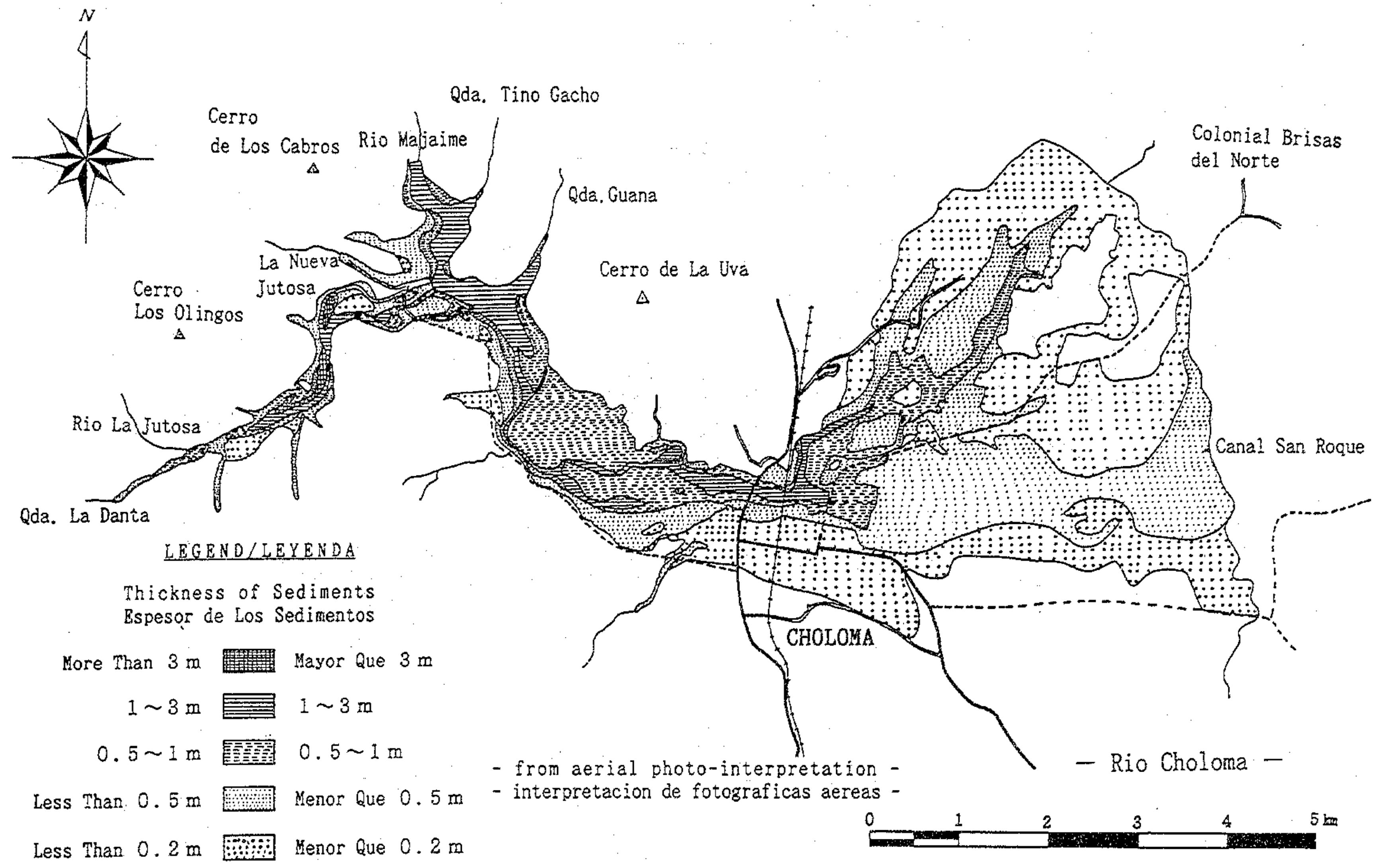
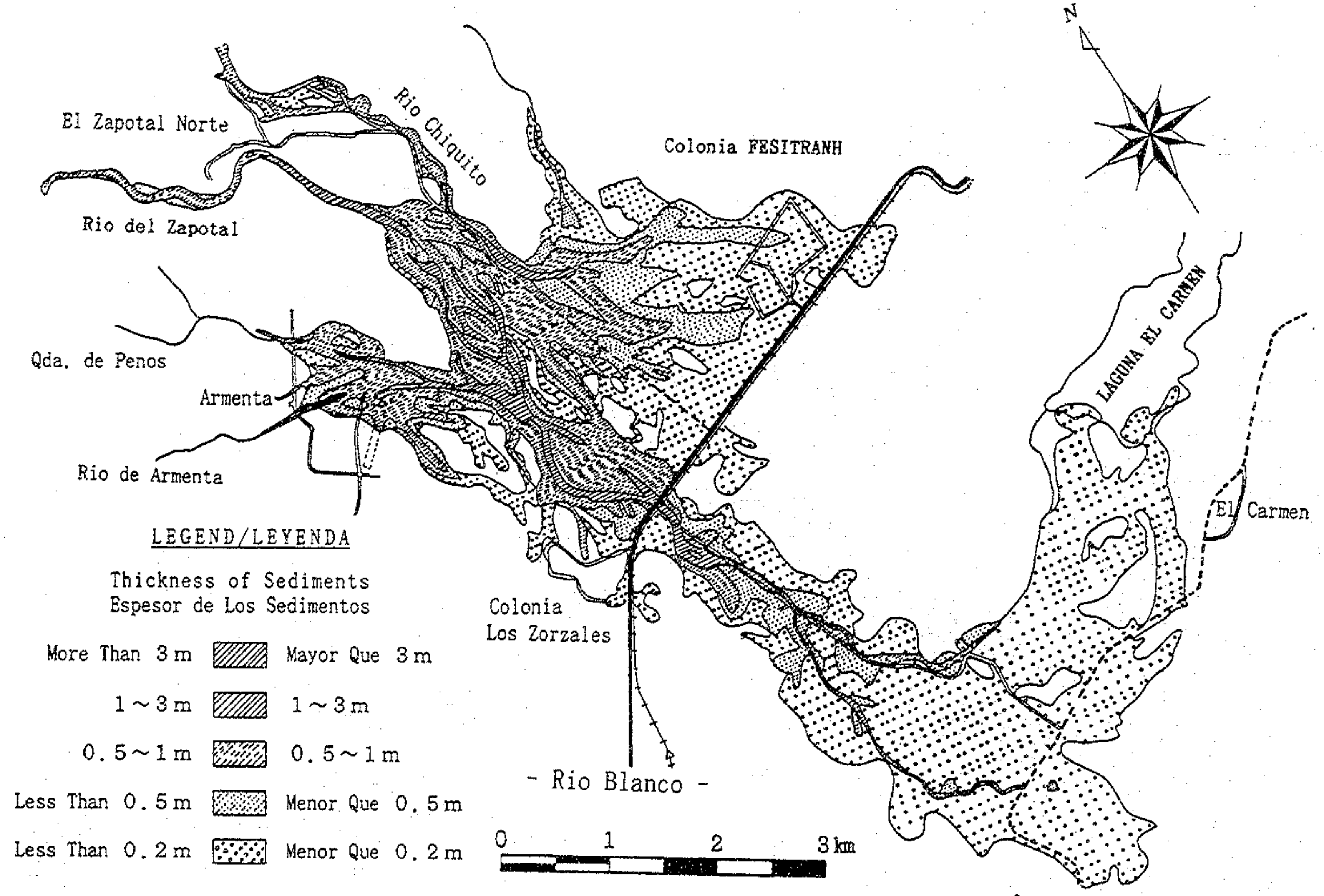
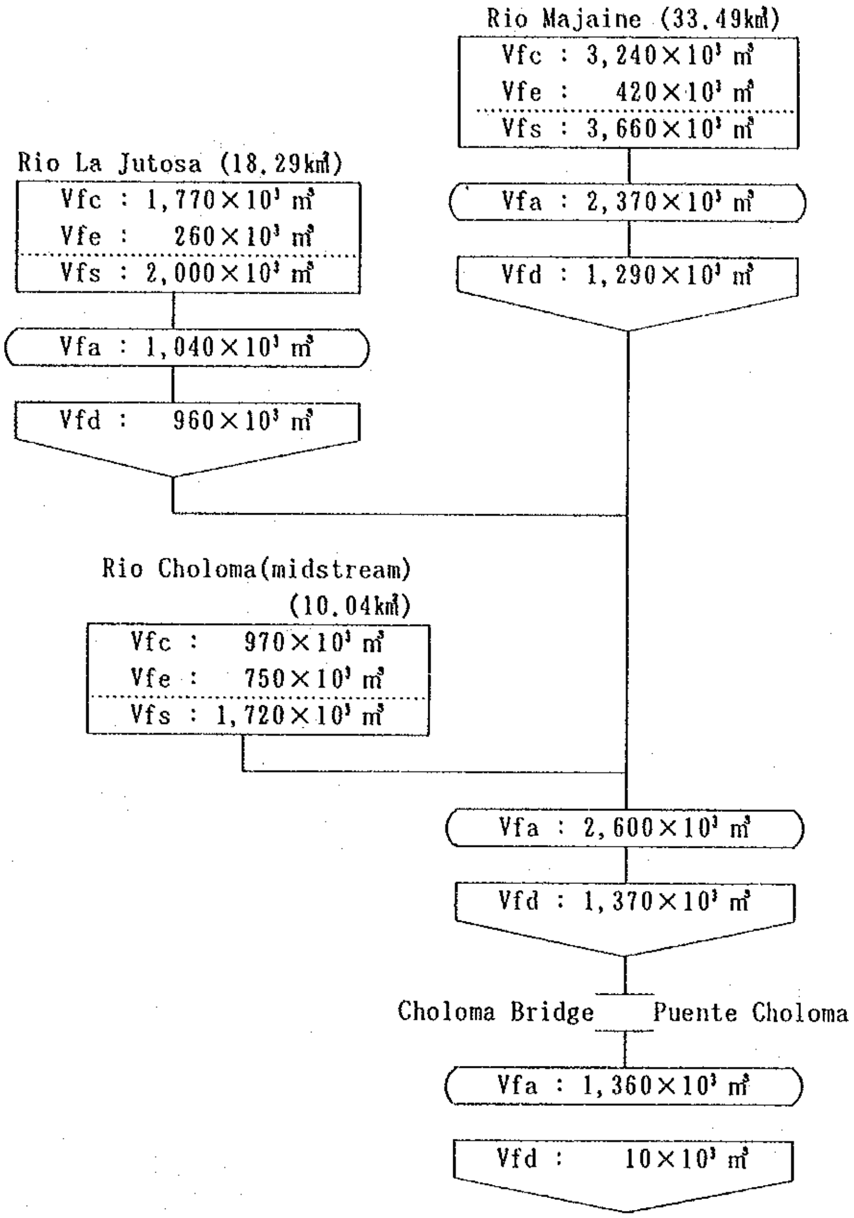


FIG. 6.4 (1) THICKNESS OF SEDIMENTS (RIO CHOLOMA 1974 FLOOD)



- from aerial photo-interpretation -
- interpretacion de fotograficas aereas -

FIG. 6.4 (2) THICKNESS OF SEDIMENTS (RIO BLANCO 1974 FLOOD)



Vfc : Produced sediment volume from collapsed area
/ Volumen de sedimentos producido por colapsada

Vfe : Eroded sediment volume of the river course
/ Volumen de sedimentos erosionada en el curse del rio

Vfs : Supplied sediment volume
/ Volumen de sedimentos suministrado(=Vfc+Vfe)

Vfa : Accumulated sediment volume
/ Volumen de sedimentos acumulado

Vfd : Sediment discharge volume
/ Volumen de descarge de sedimentos(=Vfs+Vfd)

(km^2) : Mountain slope area / Area de montañosa

FIG. 6.5 SEDIMENT BALANCE AT THE RIO CHOLOMA BASIN (1974 FLOOD)

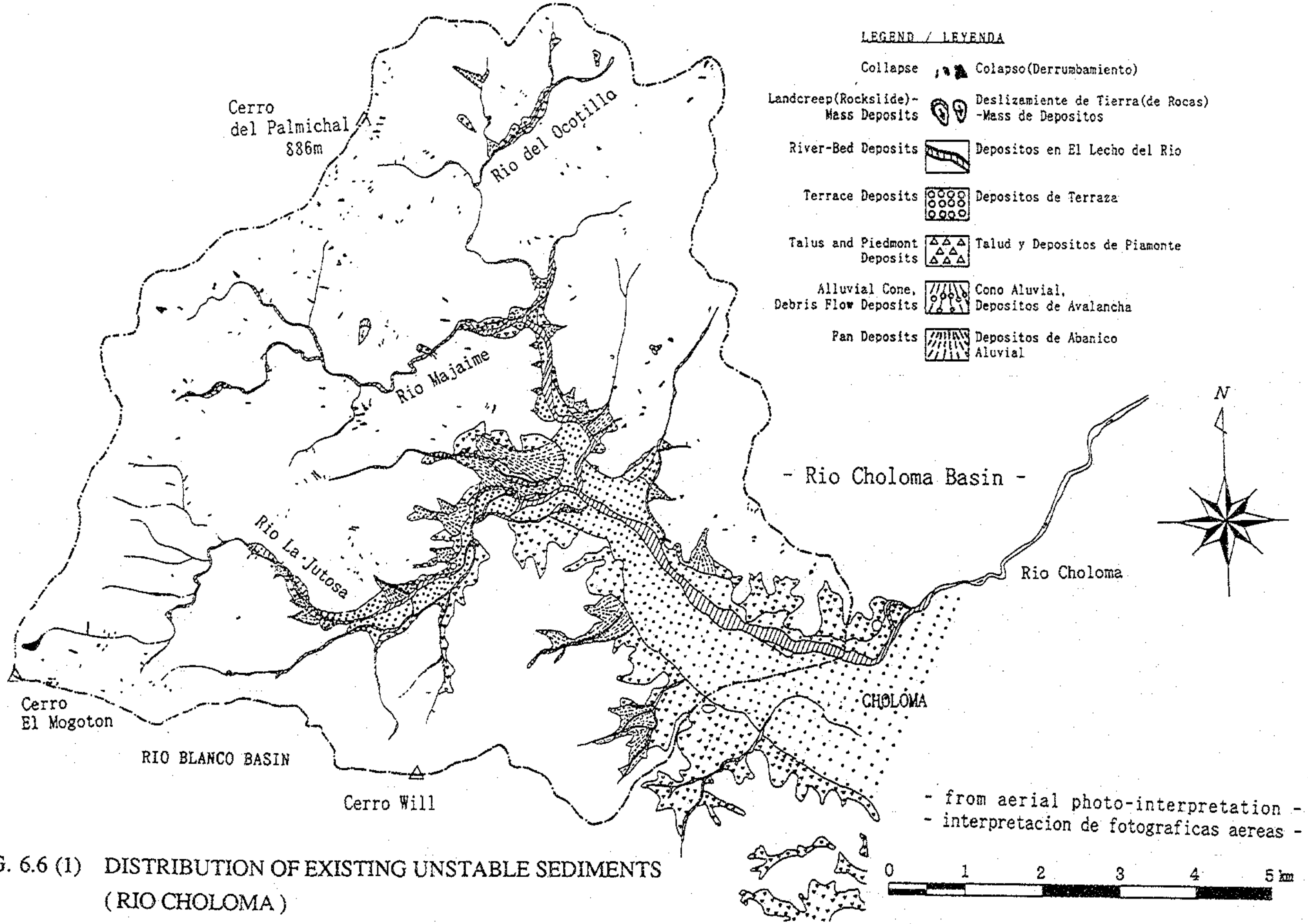


FIG. 6.6 (1) DISTRIBUTION OF EXISTING UNSTABLE SEDIMENTS (RIO CHOLOMA)

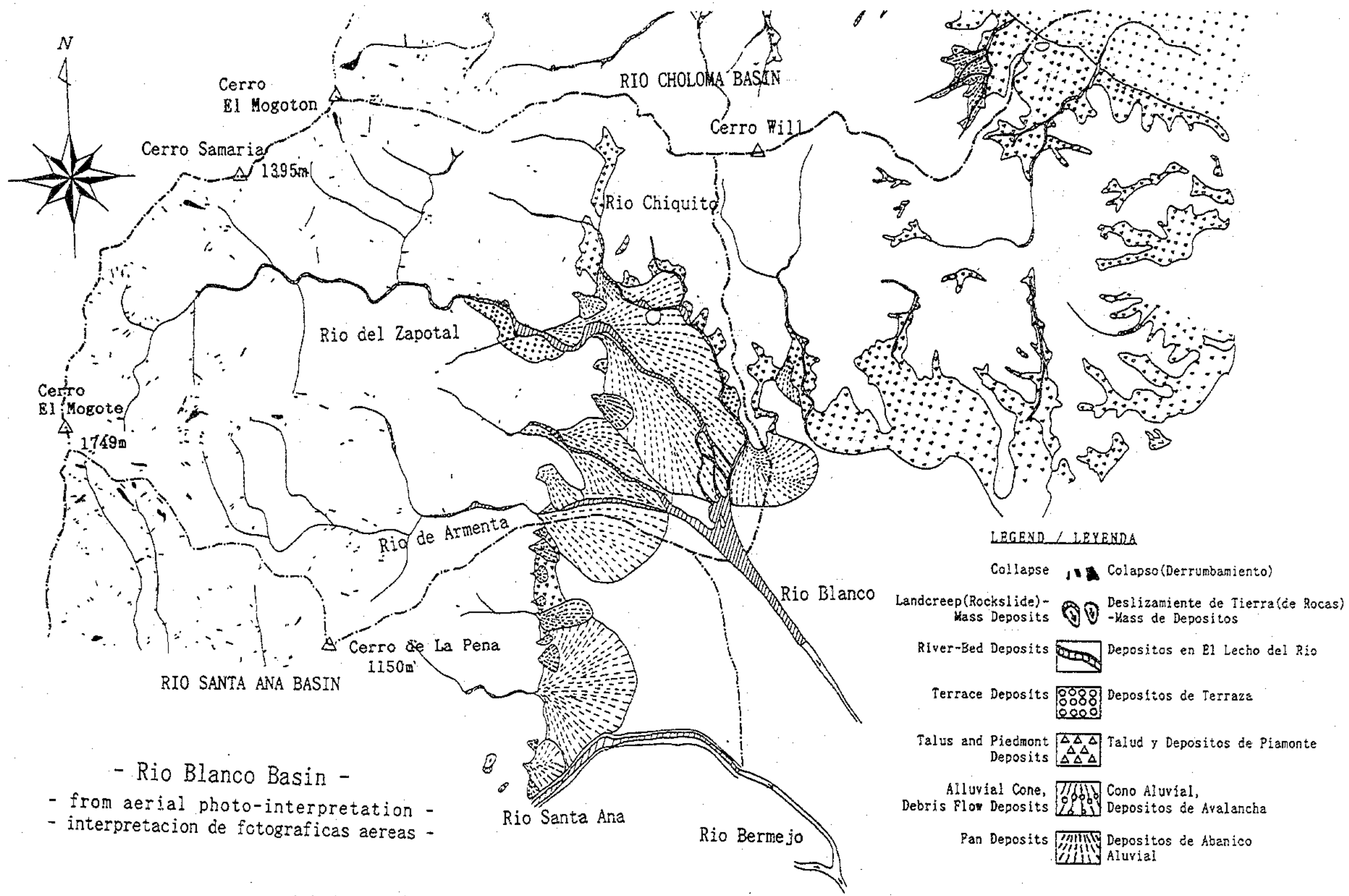


FIG. 6.6 (2) DISTRIBUTION OF EXISTING UNSTABLE SEDIMENTS
(RIO BLANCO)

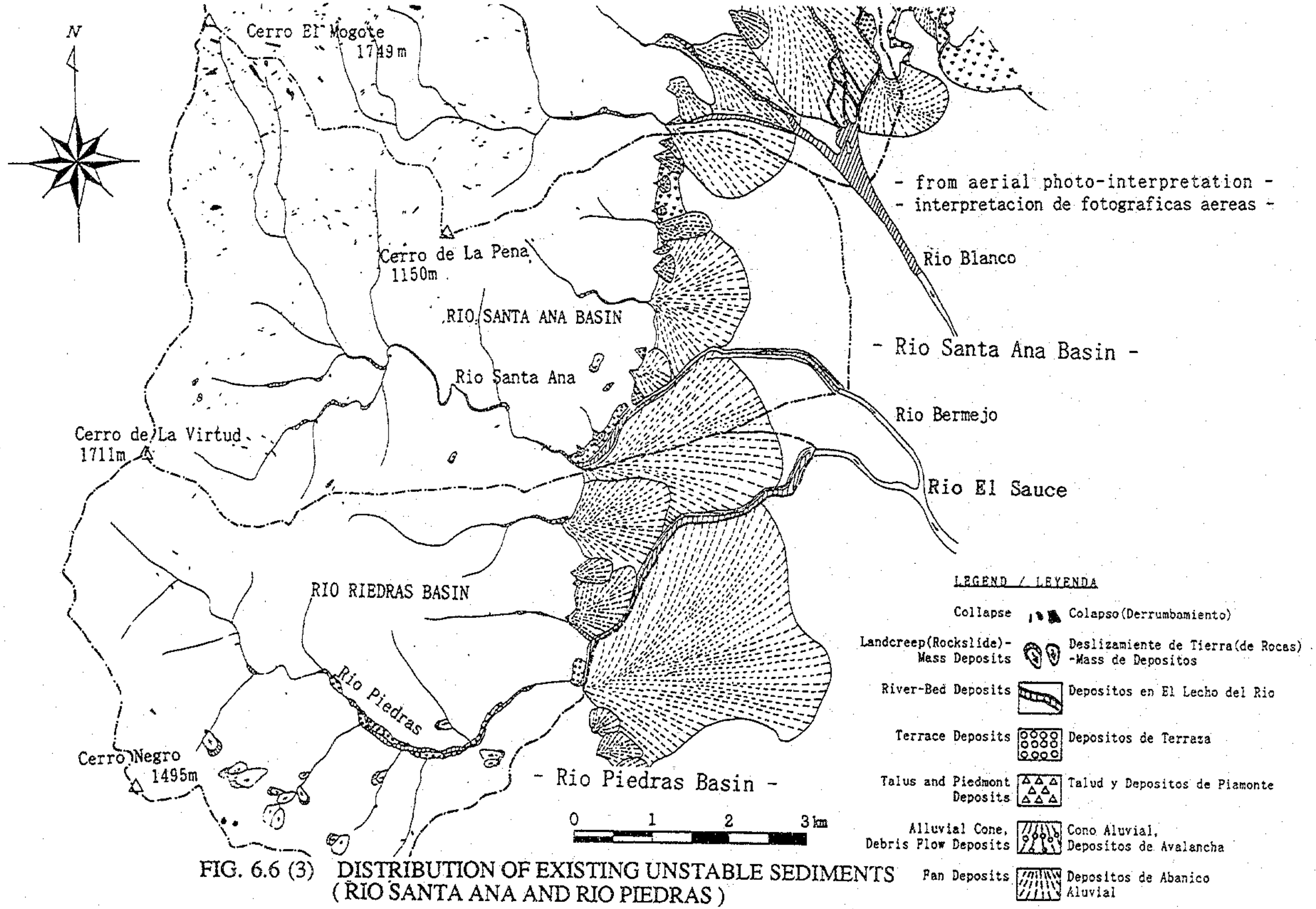


FIG. 6.6 (3) DISTRIBUTION OF EXISTING UNSTABLE SEDIMENTS (RIO SANTA ANA AND RIO PIEDRAS)

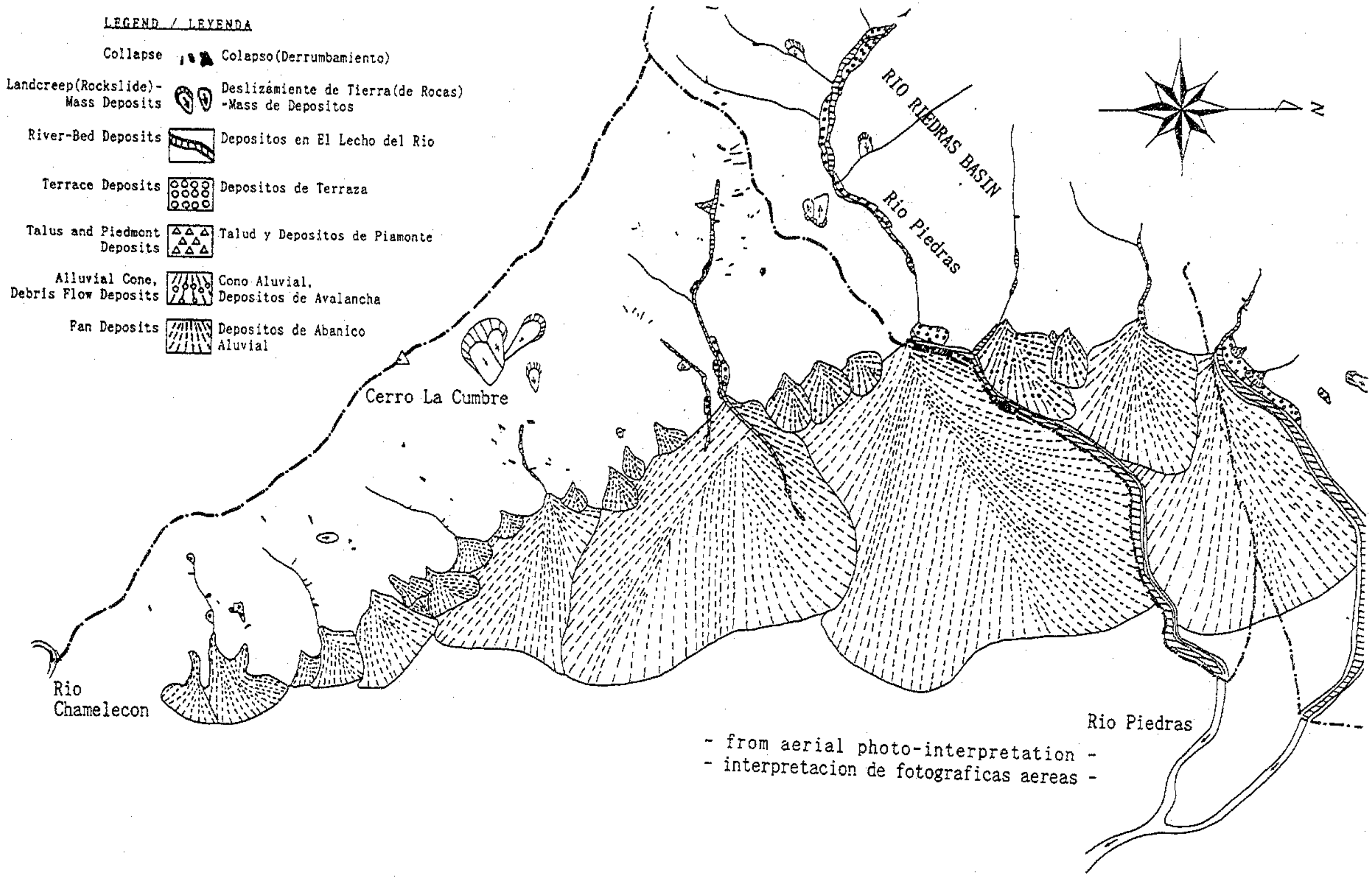


FIG. 6.6 (4) DISTRIBUTION OF EXISTING UNSTABLE SEDIMENTS
(SOUTHERN PART OF THE STUDY AREA)

0 1 2 3 km

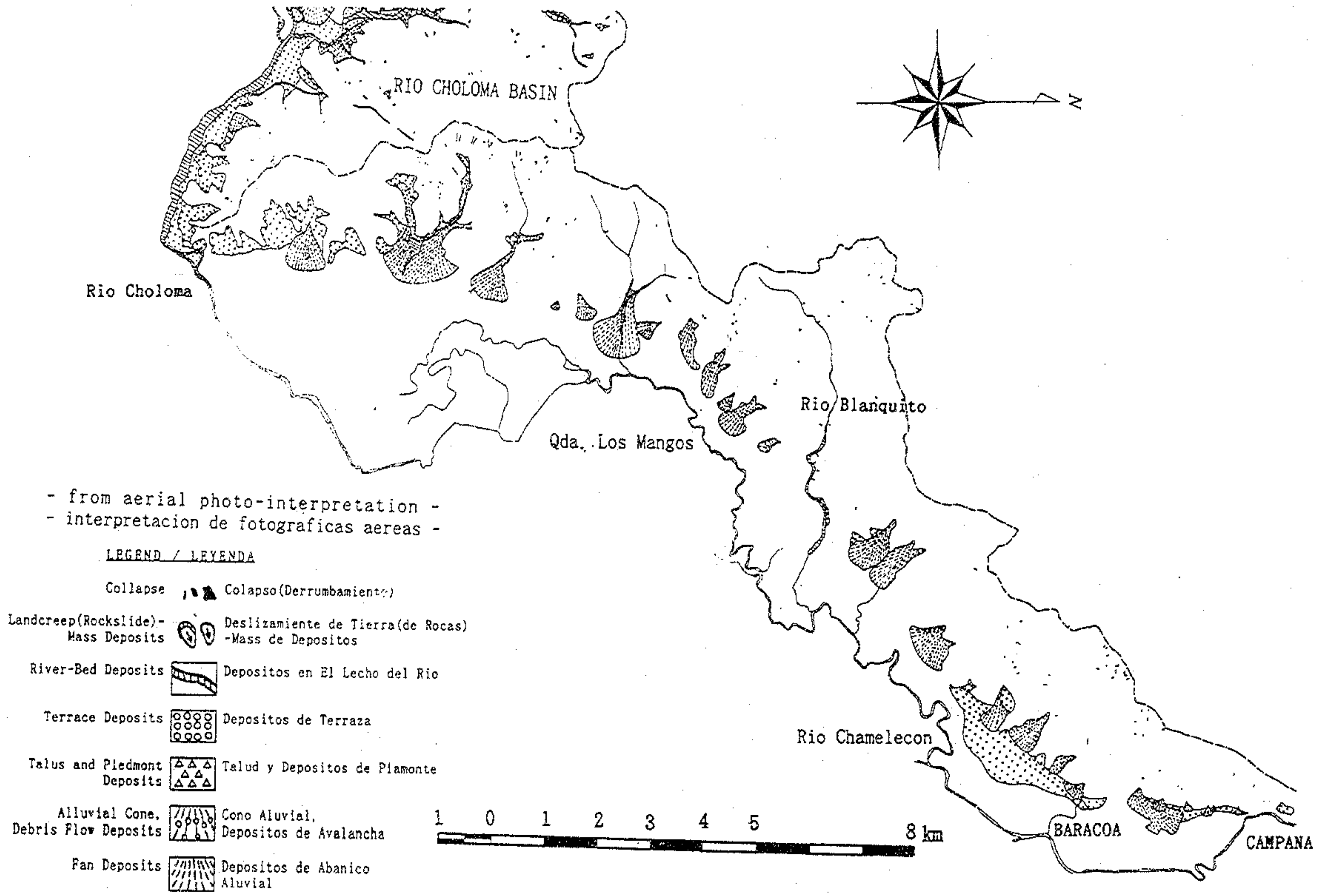
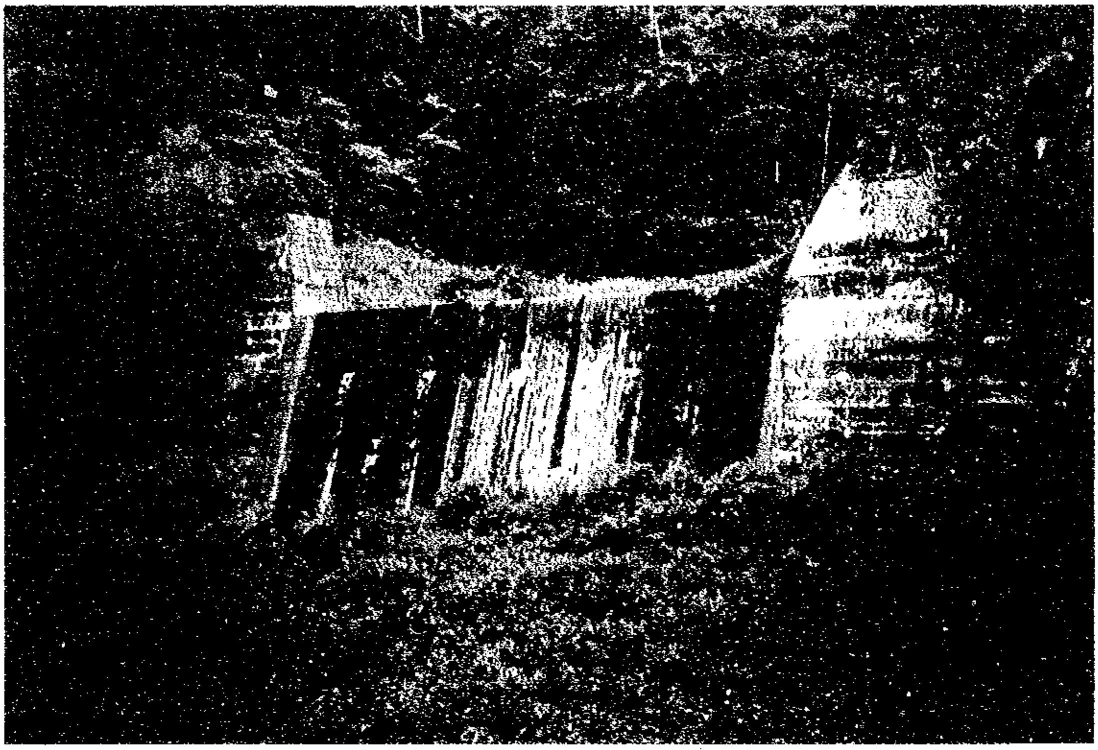


FIG. 6.6 (5) DISTRIBUTION OF EXISTING UNSTABLE SEDIMENTS
(NORTHERN PART OF THE STUDY AREA)



TAKEMOTO CHECK DAM IN THE RIO LA JUTOSA (1993)

CHAPTER 7
EROSION AND SEDIMENT CONTROL MEASURES

CHAPTER 7 EROSION AND SEDIMENT CONTROL MEASURES

7.1 General

In this chapter the sediment balance in and after the hurricane Fifi has been studied for the pilot river basins based on the result of the sediment yield study in Chapter 6. On the basis of the sediment balance for each pilot river basin, optimum countermeasures are proposed in order to mitigate sediment disaster from the study area..

A series of sediment control structures were planned by SECOPT for the Rio Choloma basin and one (1) check dam (Takemoto Dam) was constructed at the Rio La Jutosa in 1984. The check dam is effectively located at the reach of debris flows. For the other basins neither authorized plan nor facility exists for mitigation of erosion and sediment control.

According to the result of sediment yield study, the study area has a high potential of sediment disaster and will surely require urgent countermeasures.

7.2 Basic Concept

7.2.1 Planning Area

The three river basins of the Rio Choloma, the Rio Blanco and the Rio El Sauce are decided as the planning areas for erosion and sediment control measures. The Rio El Sauce is divided into two (2) basins of the Rio Santa Ana and the Rio Piedras.

7.2.2 Design Scale of Sediment Discharge

The hurricane Fifi caused the most severe sediment disaster in the study area. The sediment discharge was mostly due to debris flows that occurred in the upper basins. In general, for designing purposes the largest amount of sediment discharge on record is adopted as the design scale of sediment yield, because sediment discharge by debris flows totally depends on the presence of debris flows and also it is difficult to estimate the magnitude of sediment discharge at an intermediate stage. In this study the scale of the sediment yield caused by the hurricane Fifi is adopted as the design scale of sediment yield.

7.2.3 Design Control Point

For each river basin one design control point and its sub-control points are decided for sediment control planning. The design control points are decided as follows:

(1) Rio Choloma

The design control point is planned at the national road bridge. The riverbed slope is about 1/140 at the design control point, but a severe sediment deposit occurred at the reach between the confluence with the Rio La Jutosa and the national road bridge during the hurricane Fifi of 1974. Moreover Choloma urban area is expanding towards downstream along the river course and considered as the major conservation area from sediment disaster.

The sub-control points are planned at the confluence with the Rio La Jutosa and at the confluence with the Rio Majaine, which are considered as the control points of debris flows.

(2) Rio Blanco

The design control point is planned at the national road bridge. In the hurricane Fifi a heavy sediment deposit occurred in the reach between the valley exit of the Rio del Zapotal (1/25) and the confluence with the Rio Chiquito(1/140). The design control point is planned in order to protect the urban area at downstream from sediment disaster.

The sub-control points are selected at the valley exit of the Rio de Armenta, at the Rio del Zapotal and at the Rio Chiquito, where debris flows likely start to overflow due to their topographic features.

(3) Rio El Sauce

The Rio El Sauce is divided into the two river basins, i.e., the Rio Santa Ana and the Rio Piedras. The design control point is planned for each river as follows:

The two design control points are planned at where the rivers are crossing the national road bridge (Rio Santa Ana: 1/140, Rio Piedras: 1/120). The sub-control points are selected at each valley exit of the rivers (Rio Santa Ana: 1/30, Rio Piedras: 1/20), which are assessed as the lower end of debris flows from the upper reaches, and the confluence with the Qda. Santa Ana to estimate the sediment discharge from the tributary.

Those design control points and sub-control points are shown in *Fig.* 7.1.

7.3 Design Sediment Yield and Discharge

7.3.1 Design Sediment Yield (V10)

The design sediment yield is the volume of sediments resulting from the new and expanding collapse of hillside and river banks from the remaining unsound sediments of existing past collapsed areas on slopes, and from the sediments that has been deposited on river courses which are also subject to secondary erosion.

The design sediment yield is the basis on which the volume of design excess sediments can be calculated and is the determining factor of basic planning for erosion control. It is estimated based on current survey data, past sediment discharge such as debris flow phenomena data, similar site data, and others.

In this respect, the design sediment yield was defined as a sum of the following four (4) volumes of sediments based on the wasting conditions caused by the hurricane Fifi and the current state of unstable sediments (*Fig.* 7.2).

$$(V10)=V1 + V2 + V3 + V4$$

where,

V1 : Sediment yield of newly and expanding collapsed area,
V2 : Remaining collapsed sediment yield of existing past collapse,
V3 : Sediment yield of surrounding riverbed area,
V4 : Sediment yield due to river bank erosion.

1) Sediment Yield of Newly and Expanding Collapsed Area

a) The Rio Choloma and Rio Blanco basins

The V1 is estimated as follows:

$$V1 = a1 \times d1$$

$$a1 = A \times r1$$

where,

a1 : Newly collapsed area (square meter),
d1 : Average collapsed depth of slope (1.0 meter),
A : Mountain area,
r1 : Ratio of collapsed area (9.68 percent).

b) The Rio Santa Ana and Rio Piedras basins

Since there are no available aerial photographs of these river basins, taken immediately after the hurricane Fifi, hence there is no information on their newly and expanding collapsed areas at that time.

However the potentials of sediment yield by collapse in the river basins are assessed to be lower than the Rio Choloma or the Rio Blanco, because there are no reports of distinctive sediment disaster by debris flows during and after the hurricane Fifi. Moreover their geological conditions and forest conditions seem to be more stable than the Rio Choloma or the Rio Blanco basins.

The values of V1 for the Rio Santa Ana and the Rio Piedras are estimated as follows:

$$V1 = Lo \times Wo \times do$$

where,

- Lo : Zero order valley length,
- Wo : Zero order valley width,
- do : Thickness of zero order valley deposits.

The values of V1 for the basins are estimated and shown in *Table* 7.1.

The volumes of V2 and V3 are decided based on the values of Vru and Vbu respectively that are the result of the sediment yield study.

$$V4 = (Wf - Wo) \times Lz \times Hb$$

where,

- Wf : Riverbed width during flood is derived from the regime theory,
- Wo : Riverbed width obtained from photo-interpretation and field surveys,
- Lz : Zone length derived from unstable sediment distribution map,
- Hb : Height of river bank estimated from aerial photo analysis and field survey.

The regime theory;

$$Wf = \alpha \cdot q^{0.5}$$

where,

- α : Coefficient (*Fig.* 7.3),

q : Discharge Volume (*Table* 7.2).

The results of the calculation are summarized and shown in *Tables* 7.3 and 7.4.

7.3.2 Design Sediment Discharge (V30)

The design sediment discharge is defined as the sediment amount transported by debris flow and bed load to the design control point from the upper reach. The sediments that is temporarily deposited in a river channel, which is a part of the design sediment yield from the upper reach, is referred to as the amount of naturally controlled sediment discharge. The design sediment discharge is estimated as follows:

(V30) = (V10) - (V20)

where,

V30 : Design sediment discharge,
V10 : Design sediment yield,
V20 : Naturally controlled sediment discharge.

The volume of V20 is estimated at the reach where the river bed slope is less than 15 degrees (1/4), because the debris flow is supposed to occur from the stream channel steeper than 20 degrees (1/3), but to begin to deposit to the stream channel of 15 degrees (1/4). The volume is estimated through field investigation, photo interpretation and topographic conditions as follows:

V20 = Ie x b x d

where, Ie : Storage section length,
b : Storage section width,
d : Deposit thickness (debris deposits height or flood terrace height).

7.3.3 Design Allowable Sediment Discharge (V40)

The design allowable sediment discharge should be a value that does not lead to any abnormal variation to the channel bed at downstream. It is decided to be 10 % of the design sediment discharge.

The value of 10 % is normally applied in erosion and sediment control works in Japan.

7.3.4 Design Excess Sediment Discharge (V50)

The design amount of excess sediment discharge is the sediment amount to be dealt with through the execution of erosion and sediment control facilities and estimated as follows:

(V50) = (V30) - (V40)

The results of calculation are shown in *Table* 7.5 and the proposed sediment balance for each river basin is shown in *Table* 7.6.

7.4 Erosion Control Facility Plan

7.4.1 Basic Concept

Erosion and sediment control facilities will be planned to reduce the excessive sediment discharge to the allowable sediment discharge at the design control point, by reducing the sediment yield and discharge and controlling the sediment discharge with optimum facilities such as hillside works, check dams, consolidation dams and channel works.

The basic concepts for planning erosion and sediment control facilities are summarized as follows:

a) A number of hillslope collapses were observed in the photographs taken soon after the 1974 floods due to the hurricane Fifi, but most of them have already recovered. Now there are not many hillslope collapses, but a severe flood will likely cause a number of new hillslope collapses. In a sediment yield area the basic countermeasures such as check dams and hillside works, can be considered as the direct measures for reducing the producing and discharging of new sediments.

b) Deposition of debris flows is identified at the reach where the riverbed slope is about 1/30, while sedimentation area by bed load is observed in the lower reach. The sediment in those areas should be consolidated or regulated by direct measures such as check dams and consolidation works.

c) Sediment discharge to downstream have been produced from the deposit area of the 1974 floods. The sediment deposits should be consolidated by the direct measures such as consolidation dams and channel works.

1) Check Dam

It is planned for controlling sediment discharge, consolidation of riverbed and banks and controlling debris flows. The facility is planned as follows:

- Dam sites were selected on the topographic maps and decided through field investigation.

- Dam height was decided as 14 meters, considering the construction cost and method.

- Required facilities were planned based on the topographic conditions.

- Effect of a facility was assessed based on the amount of sediments to be controlled or to be retained by the facility.

- Sedimentation slope upstream of a check dam is decided as 1/2 of the existing channel slope.

2) Consolidation dam

It is planned at where a river channel needs consolidation works or improvement works. The effect of the facility is assessed based on the amount of sediments to be controlled or to be retained by a series of consolidation dams proposed for the design river reach, because a series of consolidation dams are planned for consolidation of the deformed river section.

3) Channel Work

It is composed of consolidation dams, riverbed girdles and revetment. The effect of the facilities is assessed on the same way as that of the consolidation dam

4) Sand Retarding Area

It is planned for retarding the sediment discharged from the upper stream during a flood and that would discharge gradually after the flood. The effect of the facility is assessed as a part of the controlled sediment discharge along river courses.

5) Training Levee

It is planned for training the flow direction of sediment flows and flood flows to the downstream channel.

7.4.2 Facility Location Plan

1) The Rio Choloma Basin

In this basin 10 check dams, 3 series of consolidation dams and 1 sediment retarding area with a training levee are planned to cope with the design sediment amount. The locations of the proposed facilities are shown in *Figs.* 7.4 (1) and 7.5 (1), the details of them are shown in *Table* 7.7 (1). They are explained as follows:

a) Rio Choloma

- A sediment retarding area is planned at the reach between the design control point and the confluence with the Rio La Jutosa. Also a training dike is planned at the sediment retarding area for protecting Choloma city area from floods.

  Since the reach has a riverbed slope from 1/100 to 1/140 and a meandering channel that may cause bank erosion, considered as the main source of sediment flow to the downstream area, a series of consolidation dams is planned to stabilize unstable sediment deposits in the reach.

b) Rio Majaine

- One (1) series of consolidation dams is proposed at the reach (1/50 ~1/60) between the confluence with the Rio del Ocotillo and the junction with the Rio La Jutosa for stabilizing the unstable sediments, because the river channel has a considerable amount of unstable fine materials and likely produces a major part of the sediment discharge downstream.

- Four (4) check dams are planned for the Rio Majaine and three check dams for the Rio del Ocotillo at the upper reaches of the proposed consolidation dams.

c) Rio La Jutosa

Although the Takemoto dam is considered to be effective in catching sediment discharge like debris flows, two (2) more check dams are planned at the reaches downstream from Takemoto dam where the riverbed slope ranges from 1/24 to 1/17. Also one (1) check dam is planned at the reach (1/10)of the Qda. Danta, a major tributary.

One (1) series of consolidation dams is planned at the reach downstream of the Rio La Jutosa in order to stabilize the sediments deposited by the hurricane Fifi.

2) Rio Blanco Basin

Nine (9) check dams, one (1) series of consolidation works and eight (8) training levees are planned to cope with the design sediment amount. The location of those facilities is shown in *Figs* 7.4 (2) and 7.5 (2), and the details of them are shown in *Table* 7.7 (2). They are explained as follows:

a) Alluvial fan area

- At the design control point one (1) consolidation dam is planned in order to stabilize the river course of the Rio Blanco and also channel works are planned in the reach downstream.

- Training levees are planned at the alluvial fan downstream of the sub-control points in order to train flood flow into the Rio Blanco.

- In the downstream area of the Rio Chiquito, consolidation works are planned to stabilize the river course.

- In the valley exit of the Rio Armenta, training levees are planned to train flood flow to the river course.

- One (1) series of consolidation dams is planned for the Rio Zapotal at the head of alluvial fan in order to retain the existing unsound materials in the river course and train the direction of flood flows.

b) Mountain area

- Five(5) check dams are planned for the Rio Zapotal and four(4) check dams for the Rio de Armenta. They are planned at the upper reaches of the sub-control points in order to control the sediment discharge.

3) Rio Santa Ana

Seven(7) check dams along with channel works are planned to cope with the design sediment amount. The location of facilities is shown in *Figs.* 7.4 (3) and 7.5 (3) and their details are shown in *Table* 7.7 (3). They are explained as follows:

a) Plain area

- Channel improvement works including consolidation dams are planned at the river course (riverbed slope: 1/20~1/100) between the design control point and the sub-control point, because the river course does not seem to be stabilized.

b) Mountainous area

- Seven(7) check dams are planned at the upper reach (1/20~1/11) of the sub-control point.