FIGURES

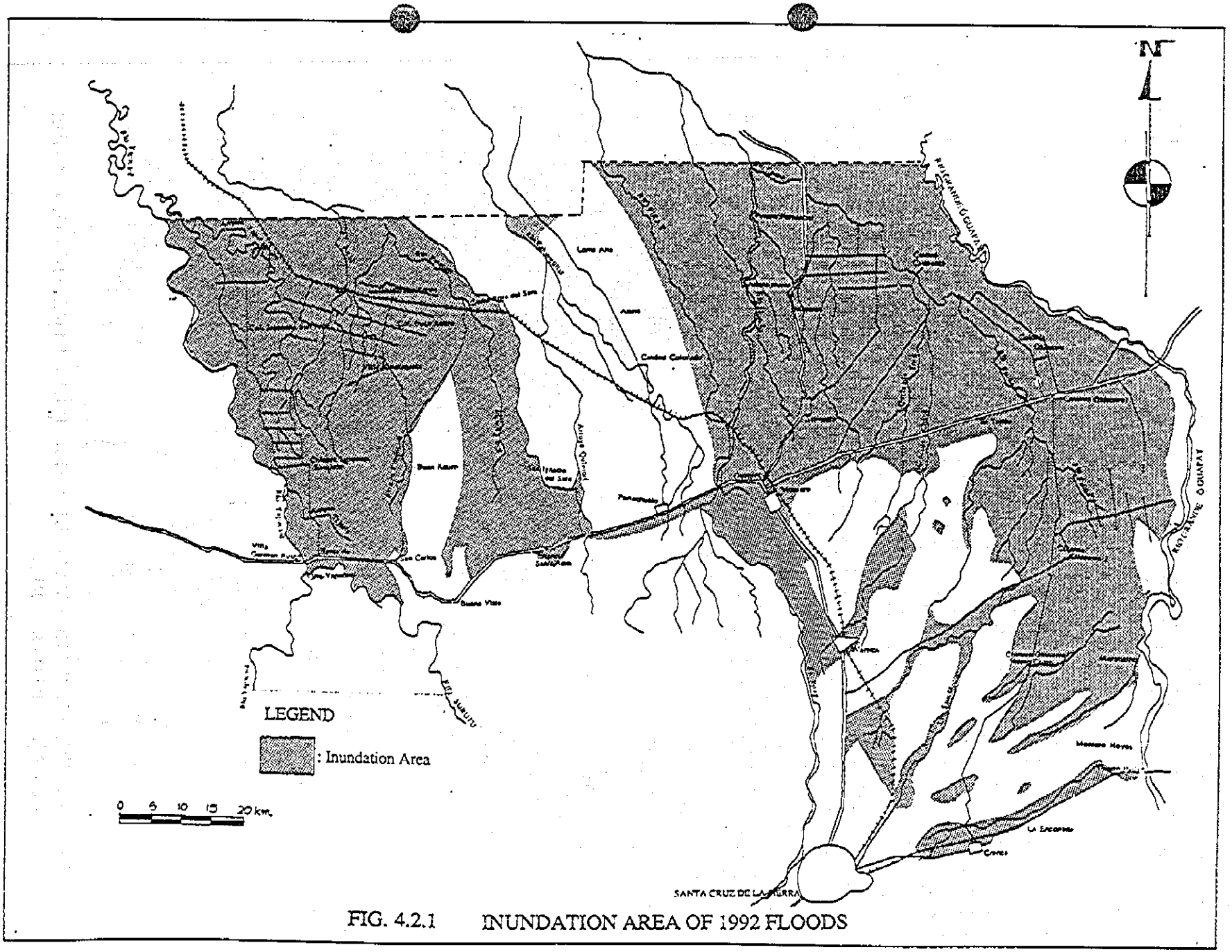


FIG. 4.2.1 INUNDATION AREA OF 1992 FLOODS

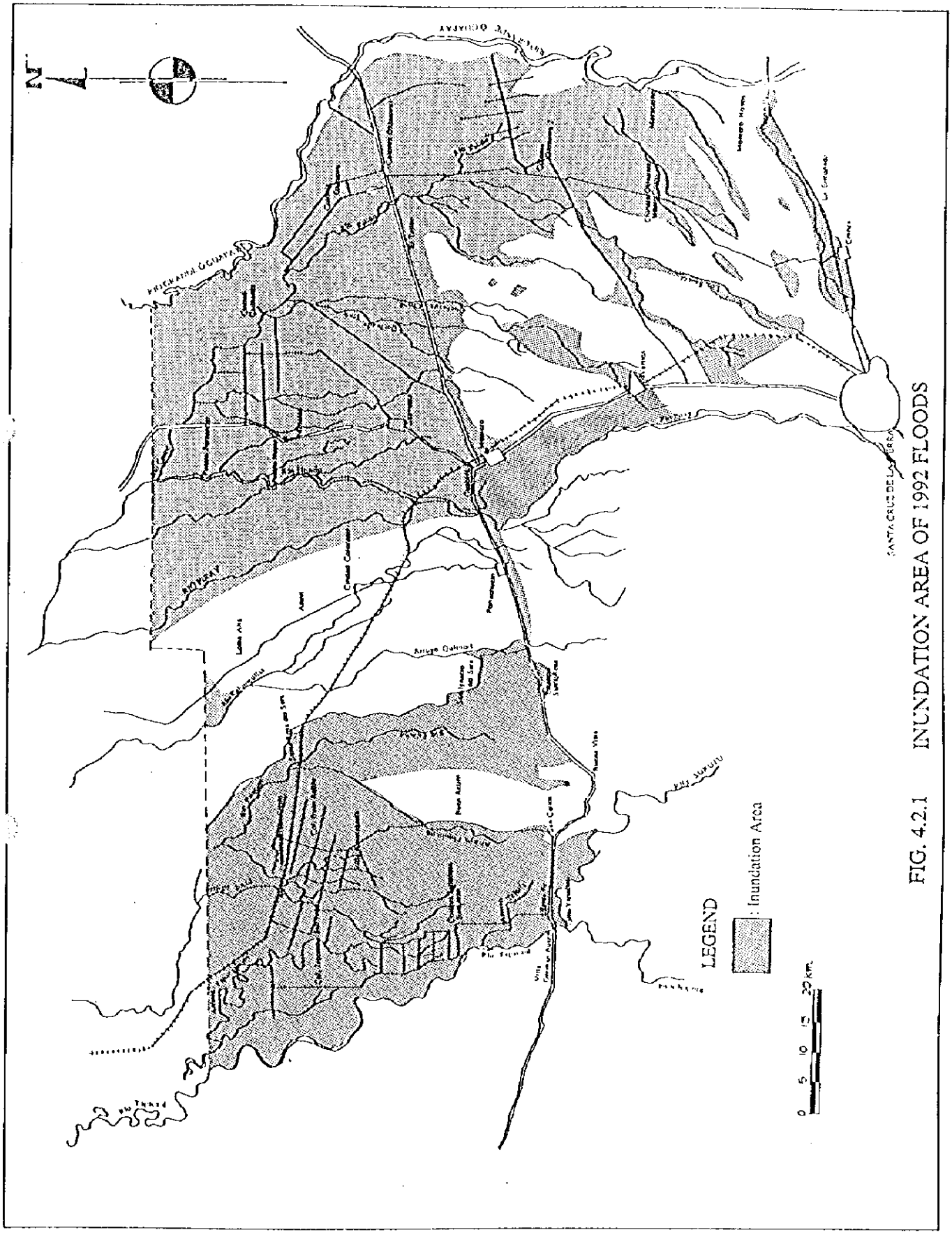


FIG. 4.2.1 INUNDATION AREA OF 1992 FLOODS

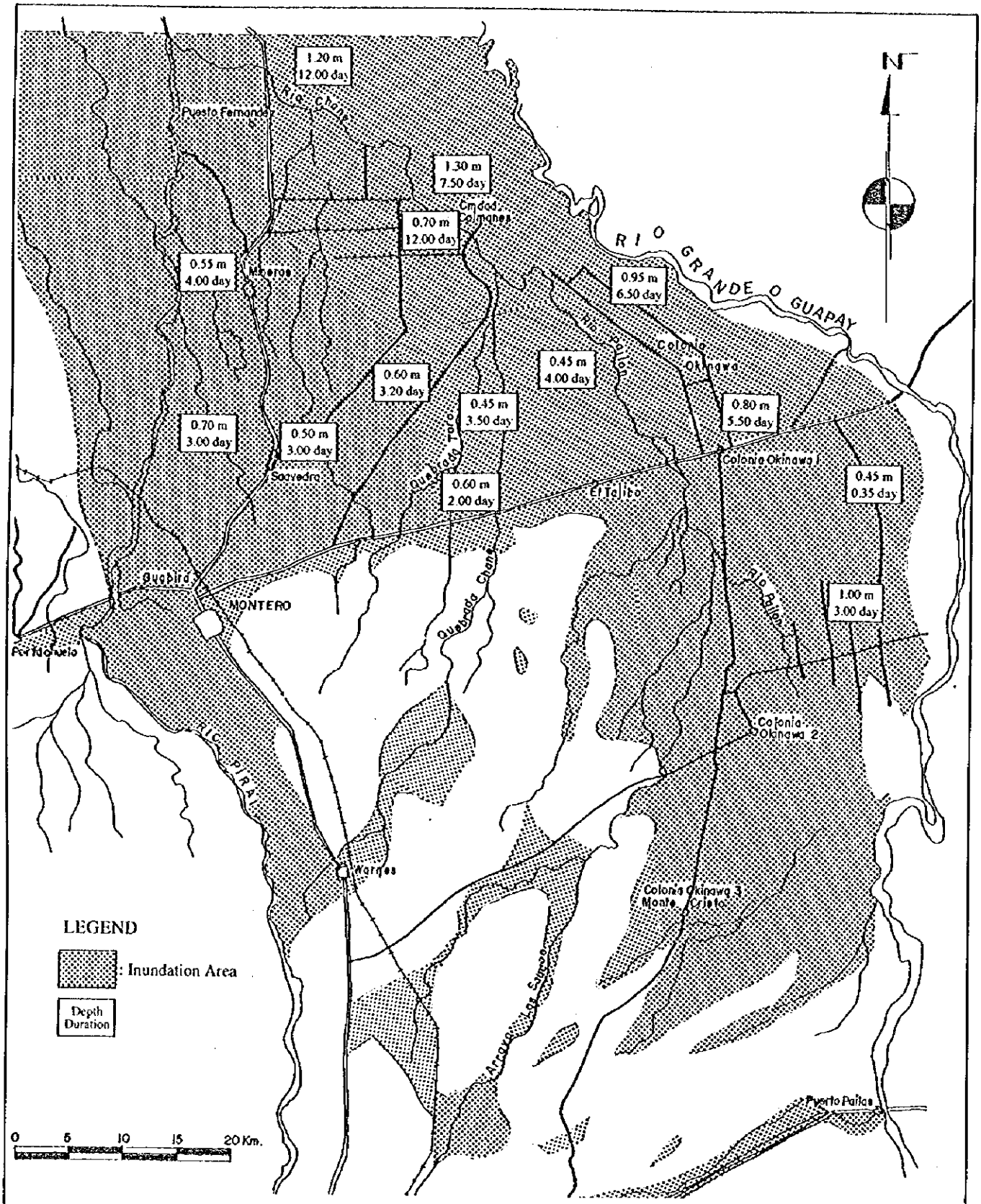


FIG. 4.2.2 INUNDATION AREA WITH DEPTH AND DURATION OF 1992 FLOODS - CHANE - PAILON AREA

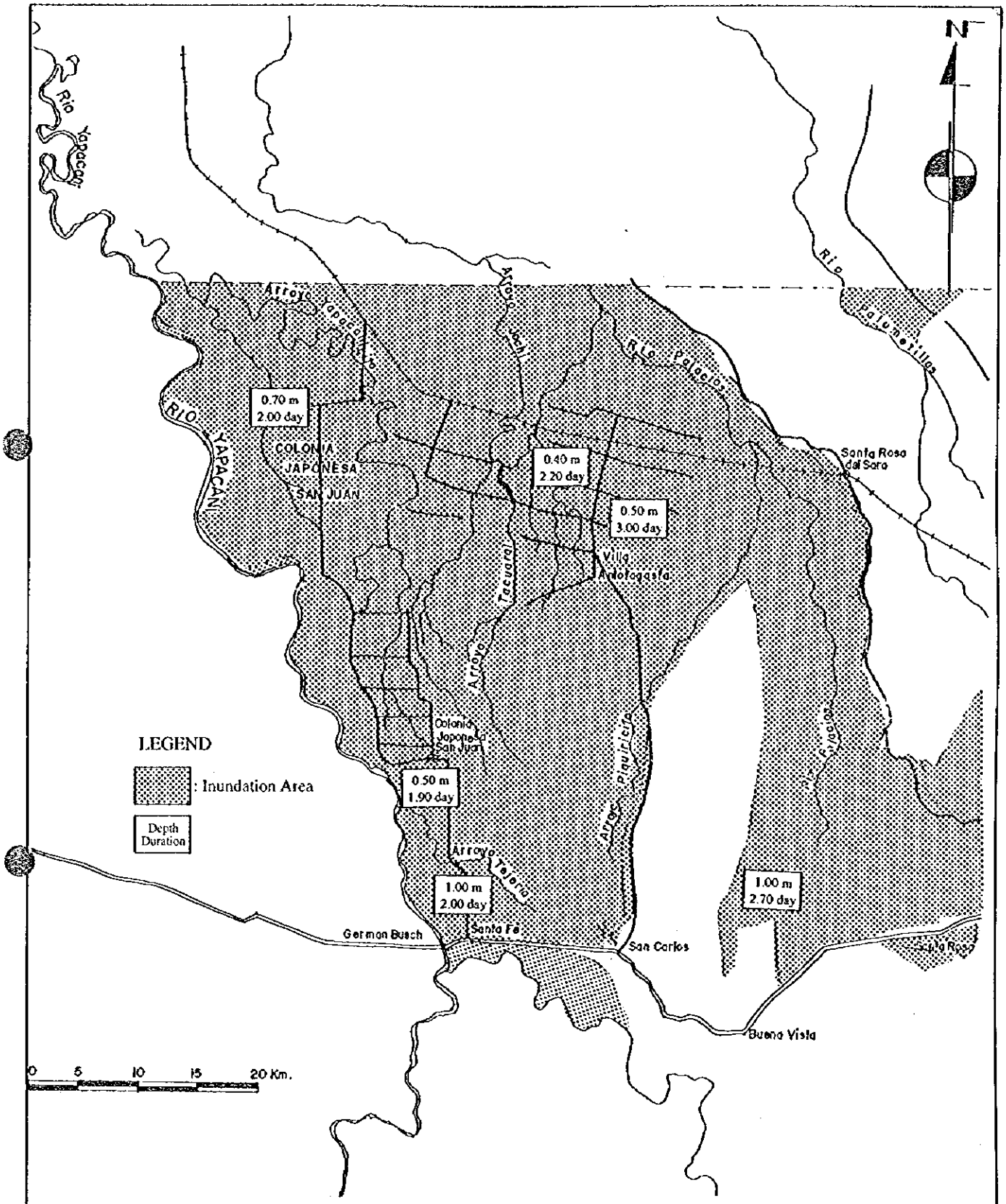


FIG. 4.2.3 INUNDATION AREA WITH DEPTH AND DURATION OF 1992 FLOODS - SAN JUAN - ANTOFAGASTA AREA

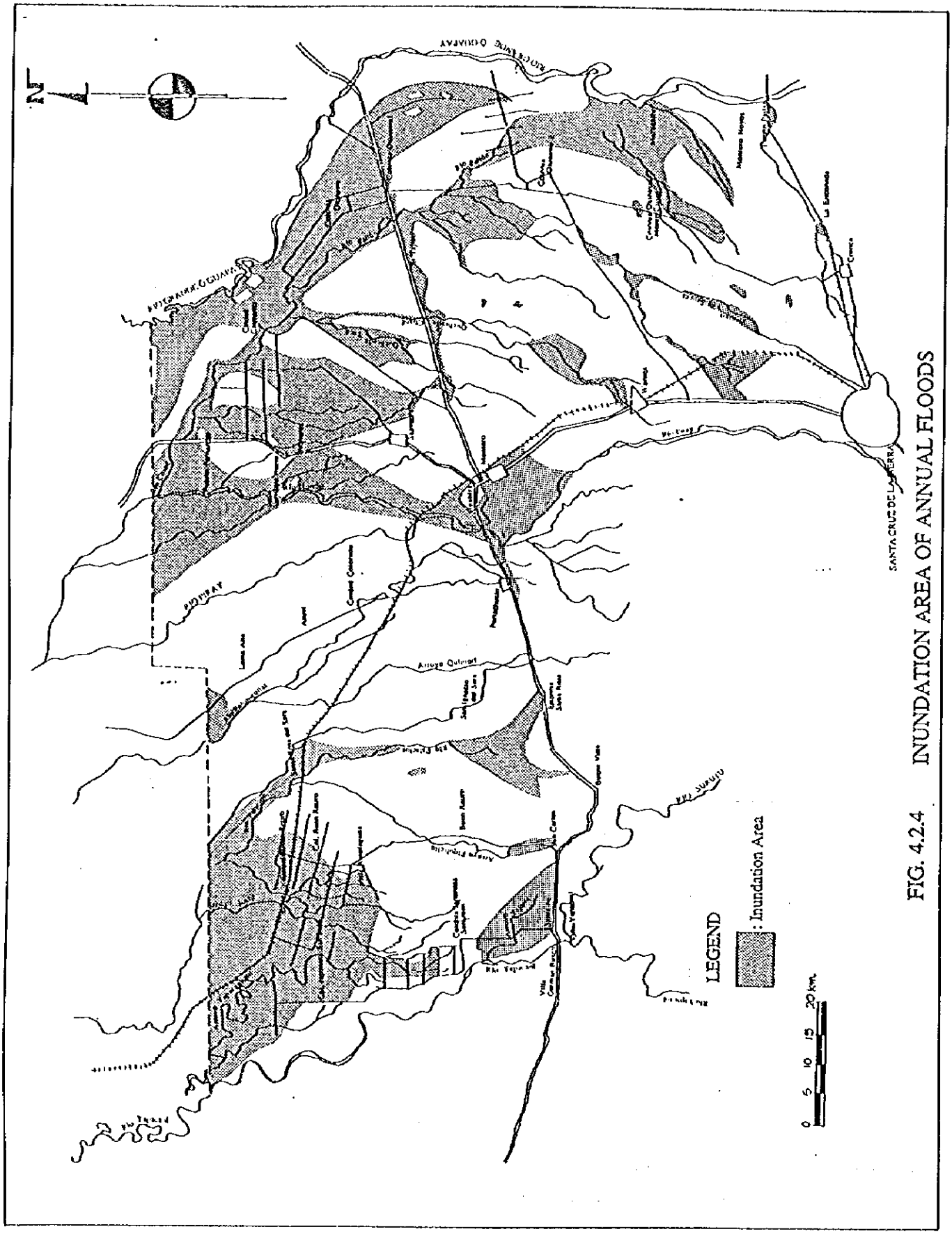


FIG. 4.2.4 INUNDATION AREA OF ANNUAL FLOODS

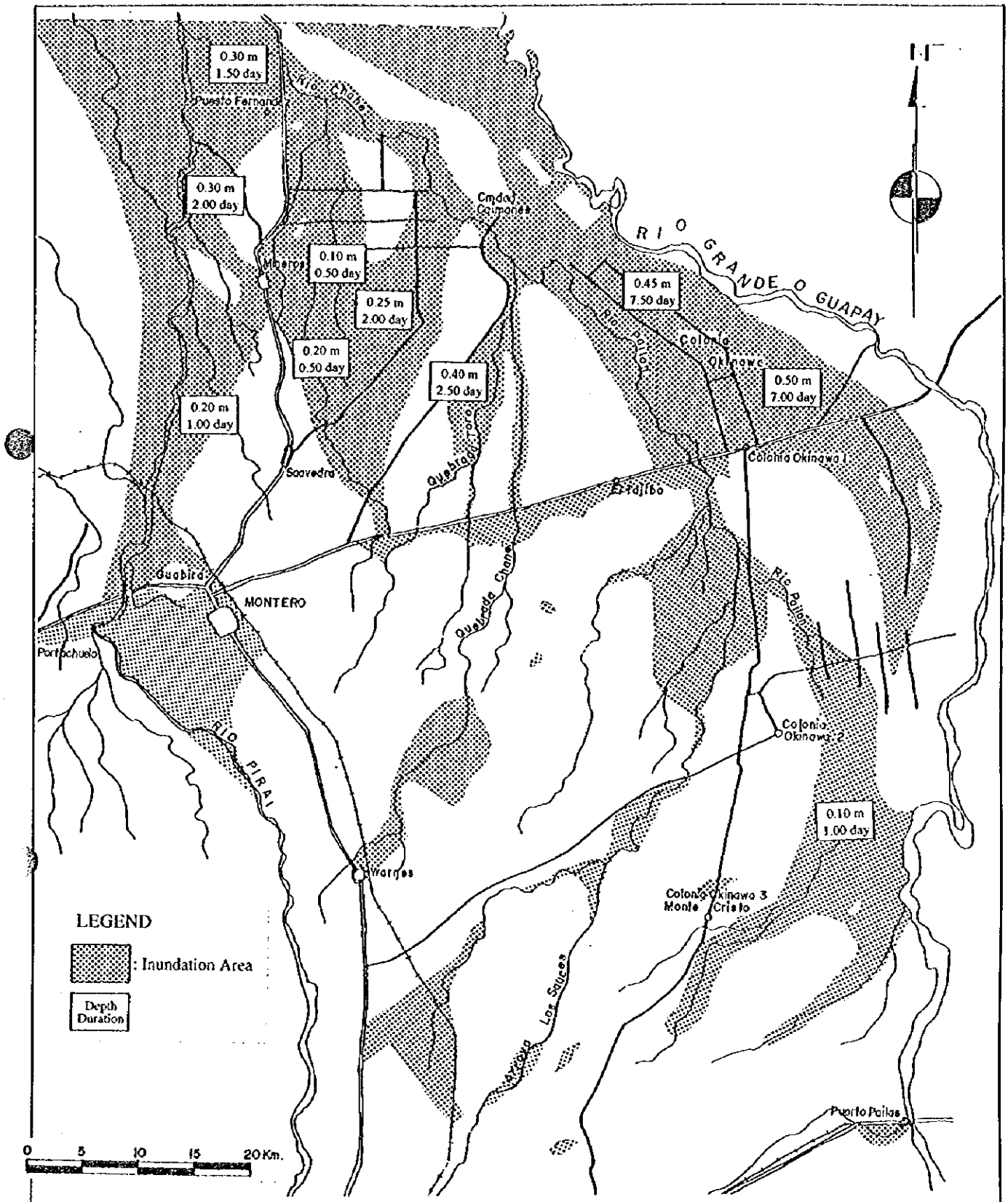


FIG. 4.2.5 INUNDATION AREA WITH DEPTH AND DURATION OF ANNUAL FLOODS - CHANE - PAILON AREA

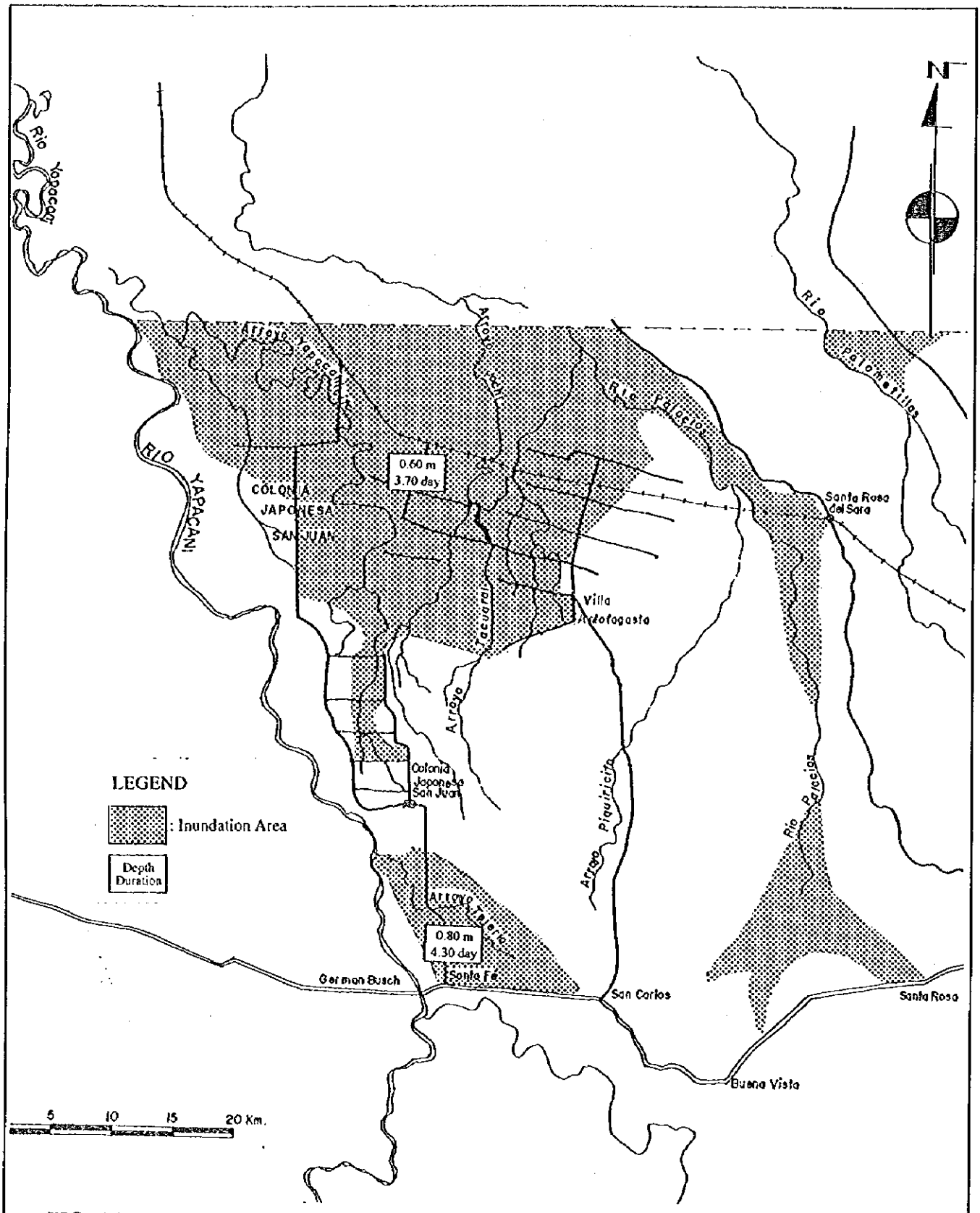


FIG. 4.2.6 INUNDATION AREA WITH DEPTH AND DURATION OF ANNUAL FLOODS - SAN JUAN - ANTOFAGASTA AREA

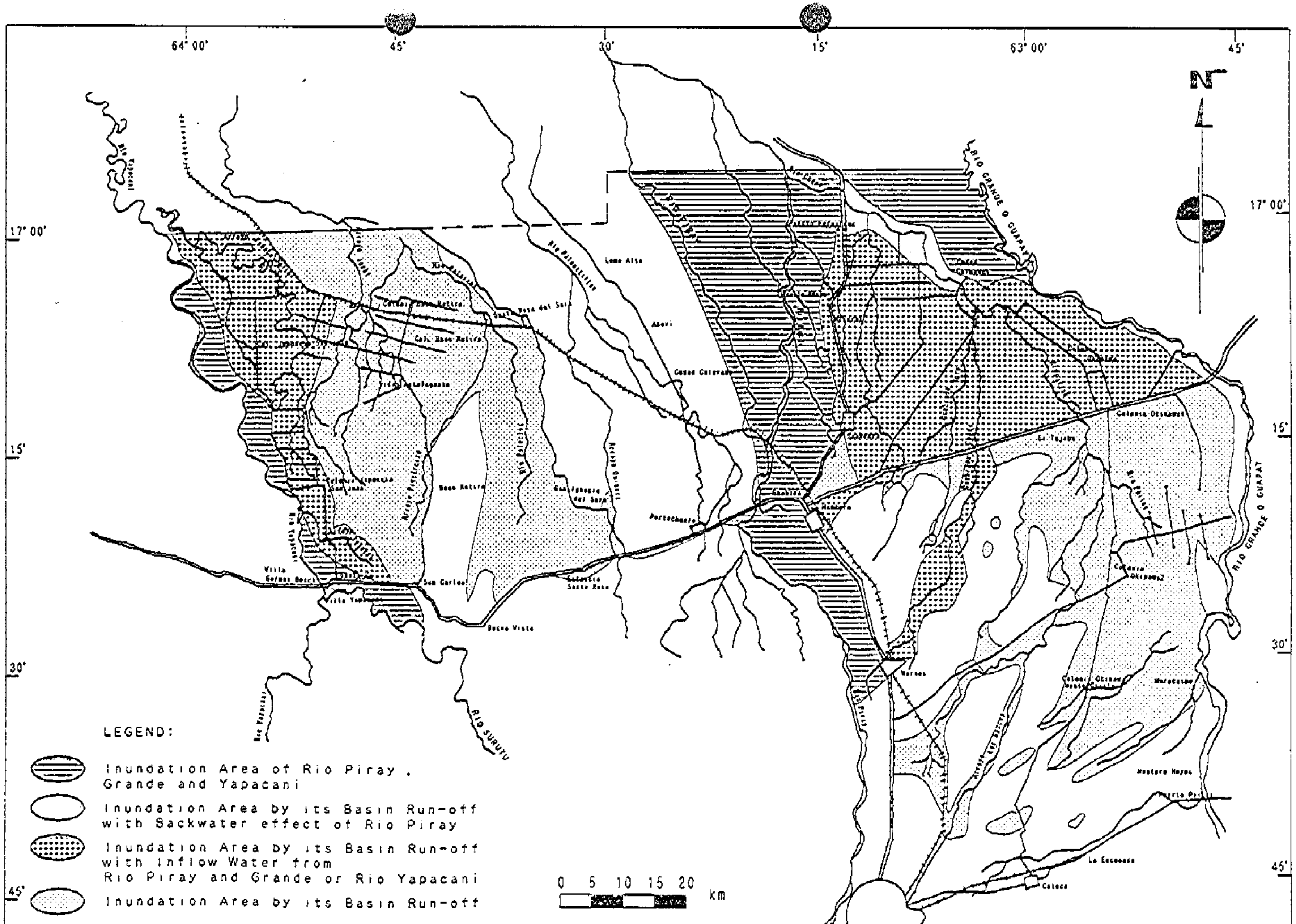


FIG.4.3.1 CAUSES OF FLOOD IN THE STUDY AREA (1992 FLOODS)

CHAPTER 5
HYDROLOGY

CHAPTER 5 HYDROLOGY

5.1 River System and Drainage Basin

The study area is bounded by the Río Grande in the east, Río Piray in the center and the Río Yapacani in the west. Catchment areas of the Río Grande, Río Piray and Río Yapacani are about 106,000 km^2, 10,660 km^2 and 9,960 km^2 respectively. *Fig. 5.1.1* shows the river system and drainage basins with their catchment areas in the study area. Major rivers in the study area are as follows;

Central Part:	Río Piray main stream and others
Eastern Part:	Río Chané, Río Pailón, Arroyo Los Sauces, Quebrada Chané, Quebrada El Toro, Quebrada Las Chacras and others
Western Part:	Río Palometillas, Río Palacios, Arroyo Tacuaral, Arroyo Jochi, Arroyo Yapacanicito, Arroyo Tejeria and others

5.2 Meteo-hydrological Observation Network

Fig. 5.2.1 shows the meteo-hydrological observation network in and around the study area.

(1) Rainfall Gauging Stations

There are 34 number of the rainfall stations in the study area as shown in *Table 5.2.1 (1)*. They are the stations of SENAMI, SEARPI, CETABOL - JICA, CAICO, CAISY and others. Among these stations, Santa Cruz - Trompillo and Viru Viru Aeropuerto are the general meteorological stations.

(2) Water Level and Discharge Gauging Stations

Table 5.2.1 (2) and *(3)* shows the existing water level and discharge gauging stations in and around the study area. There exists only four water level and discharge gauging stations in the study area. The existing stations are as follows;

Río Piray:	Puente Eisenhower
	La Belgica
Río Grande:	no gauging station
Río Yapacani:	Puente Yapacani of National Road No.7
Río Chané and its tributaries:	no gauging station

Tributary of Río Palacios:	Río Palometillas at National Road No.7
Other rivers:	no gauging station

Along the Río Grande, there are abandoned stations at Puerto Pailas and Abapó. Abapó locates about 150 km upstream from Puerto Pailas.

5.3 Available Data

(1) Daily Rainfall Data

Table 5.2.1 (1) shows the collected daily rainfall data. Number of the rainfall gauging stations that have daily rainfall data older than 1975 or 1976 is ten stations. Among the ten stations, following four stations were selected as the principal stations for the study because they have rather long record of rainfall data.

5806 Santa Cruz - Trompillo	:	52 years record
61NP Saavedra	:	44 years record
Colonia San Juan de Yapacani	:	35 years record
Okinawa II	:	26 years record

(2) Hourly Rainfall Data

Available hourly rainfall data relating to the above principal stations are listed in below;

25NP Santa Cruz - Oficina	:	1973 - 1994 (21 years record)
61NP Saavedra	:	1951 - 1994 (44 years record)
Okinawa II	:	1986 - 1994 (8 years record)

As the Santa Cruz - Oficina and Saavedra have rather long record, these data were used to analyze hourly rainfall pattern.

(3) Daily Water Level and Discharge Data

Collected daily water level and discharge data are listed in *Table 5.2.1 (2)* and *(3)*. Water level and discharge of the Río Grande are not observed now. Water level measurements of the Río Yapacani and right tributary of the Río Palacios (station: Río Palometillas) have been started since 1994.

5.4 General Meteorological Condition

Table 5.4.1 shows the general meteorological condition in the study area. There are dry season and wet season in the study area. Dry season is from April to October and rainy season is from October to March. Transition seasons are March – April and September – October. Average annual rainfalls of the western, southern, northern and eastern parts are 1898 mm, 1356 mm, 1301 mm and 1274 mm respectively.

5.5 Rainfall Analysis

5.5.1 Rainfall in 1992 Floods and 1983 Floods

Fig. 5.5.1 and *Fig. 5.5.2* show the daily rainfall of January 1992 Floods and March 1983 Floods respectively. Characteristics of the rainfall of 1992 Floods and 1983 Floods are described below.

(1) Rainfall of 1992 Floods

The rainfall recorded in the year 1992 was 2 to 2.5 times of the annual average year. The rainfalls recorded in January, February and December were 2 to 3 times of average monthly rainfalls. Those of April and May in 1992 were 2 to 4 times of average monthly rainfall. Hence, the study area was in a rather saturated condition during rainy season of 1992. Furthermore, run-off rate and run-off coefficient during storm rainfall were rather high in 1992.

As for the recorded daily rainfall of 1992 Floods, continuous rainfall with duration of about 4 to 6 days was observed in the whole area. Furthermore, heavy rainfall concentrated in three days were recorded at all four principal stations. Therefore, the rainfall of 1992 Floods is characterized as continuous heavy rainfall with duration of three days. The amount of the continuous rainfall and daily maximum rainfall were as follows;

Station	Continuous Rainfall	Daily Maximum Rainfall
Saavedra	453.6 mm	220.4 mm (January 14)
Okinawa II	374.0 mm	194.0 mm (January 15)
Colonia San Juan de Yapacani	293.3 mm	196.5 mm (January 15)
Santa Cruz - Trompillo	168.1 mm	57.1 mm (January 13)

(2) Rainfall of 1983 Floods

Amount of rainfall of 1983 Floods was small. Hence, it could be concluded that the rainfall in the study area was not the major reason for the floods.

5.5.2 Frequency Analysis

(1) Probable Maximum Rainfall

Probable maximum daily rainfalls were calculated by using the data of annual maximum one day to seven day rainfall of the four principal stations. Gumbel Method was used for the analysis was. *Table 5.5.1* shows the summary of probable maximum daily rainfalls.

(2) Return Periods of 1992 Floods and 1983 Floods

1) 1992 Floods

Return periods of the storm rainfall of 1992 Floods were assessed as follows;

Station	Return Period
Santa Cruz - Trompillo:	2 to 5 year
Saavedra:	over 100 year
Okinawa II:	50 to 100 year
Colonia San Juan de Yapacani:	5 to 10 year

2) 1983 Floods

The return periods of the four principal stations were less than two year.

Summary of return periods of January 1992 Floods and March 1983 Floods are shown in the Supporting Report A.

(3) Rainfall Intensity Curves

Frequency analysis by Gumbel Method was conducted using the annual maximum hourly rainfall of Saavedra and Santa Cruz - Oficina. Rainfall intensity curves of these two stations were made as shown in *Fig. 5.5.3* and *Fig. 5.5.4*.

5.5.3 Design Rainfall

Design rainfalls of the four principal stations of Saavedra, Santa Cruz, Okinawa II and Colonia San Juan de Yapacani were made. The design rainfall is three day continuous rainfall with post peak.

Rainfall intensity curves of Saavedra and Santa Cruz were used for making their own design rainfalls. The rainfall pattern of Saavedra was also applied for making the design hyetograph of Okinawa II and Colonia San Juan de Yapacani. This is because the correlation of annual maximum one day rainfall of these two stations with Saavedra are higher than those of these two stations with Santa Cruz.

Fig. 5.5.5 shows the design rainfalls of ten year return period for Saavedra, Santa Cruz, Okinawa II and Colonia San Juan de Yapacani. Design rainfalls with return periods of 2, 5, 10, 20, 30, 50 and 100 year could be referred to the Supporting Report A.

5.6 Rainfall Runoff Analysis

Rainfall runoff analysis was conducted for Río Chané Basin and Arroyo Yapacanicito-Jochi-Tacuaral-Tejeria Basin. Unit Hydrograph Method by U.S. Soil Conservation Service (SCS) was applied for the rainfall runoff analysis. Procedure of the analysis by SCS Unit Hydrograph Method is illustrated in the Supporting Report A. *Fig. 5.6.1* and *Fig. 5.6.2* show sub-catchments and runoff points and *Table 5.6.1* shows the SCS parameters of the runoff points.

5.6.1 Río Chané Basin

(1) Design Rainfall

Design rainfalls with return periods of 2,5,10,20,30,50 and 100 year of Santa Cruz, Okinawa II and Saavedra were used for the runoff analysis.

(2) Runoff Discharge

The calculated peak runoff discharges are shown in *Fig. 5.6.3*. At the major points, the peak runoff discharges are as follows;

Probable Peak Runoff Discharge (m^3/s)

	Return Period (Year)		
	10-Year	20-Year	50-Year
Río Chané (downstream)	1270	1510	1820
Río Chané (upstream)	1200	1420	1700
Río Pailón (at Road 9)	1340	1580	1890
Qda Chané (at Road 9)	390	460	540

Fig. 5.6.5 (1) shows the calculated specific discharges of Río Chané Basin. Specific discharges at the most downstream of Río Chané are about 0.2 to 0.8 $m^3/s/km^2$. These specific discharges coincide with the tendency of the specific discharges of the Río Piray that was calculated by SEARPI.

5.6.2 Arroyo Yapacanicito-Jochi-Tacuaral-Tejeria Basins

(1) Design Rainfall

Design rainfalls with return periods 2, 5, 10, 20, 30, 50 and 100 year of Col. San Juan de Yapacani were used for the runoff analysis.

(2) Runoff Discharge

Fig. 5.6.4 shows the calculated peak runoff discharge of each runoff point. *Fig. 5.6.5 (2)* shows the calculated specific discharges. At the major runoff points, the probable runoff discharges are calculated as follows;

Probable Runoff Discharge (m^3/s)

	Return Period (Year)		
	10-Year	20-Year	50-Year
A. Yapacanicito (downstream)	540	630	740
A. Yapacanicito (upstream)	220	250	290
A. Jochi (mid-stream)	270	310	360
A. Tacuaral (mid-stream)	330	380	440
A. Tejeria (downstream)	210	240	280

Tendency of specific discharges of this basin is almost same as that of the Río Chané basin.

5.7 Flood Analysis

Flood analysis was conducted for the Río Chané Basin and Arroyo Yapacanicito-Jochi-Tacuaral Basin. The aim of the flood analysis is to evaluate the hydraulic effect of flood mitigation and drainage improvement measures in these areas.

5.7.1 Hydraulic Models

Hydraulic models were made for Río Chané Basin and Arroyo Yapacanicito-Jochi-Tacuaral Basin. Model structures are composed of river and drainage systems as shown in *Fig. 5.7.1* and *Fig. 5.7.2*. Inundation areas and retarding basins are included in the river systems.

Rainfall runoff of each sub-catchment is calculated by SCS method and assuming lateral inflow. Hydraulic calculation was done by un-steady flow method. The hydraulic models were calibrated by comparing the simulated flood conditions with actual flood conditions of 1992 Floods.

5.7.2 Simulations of Río Chané Basin

Simulations of Río Chané Basin for without project condition as well as with project conditions were conducted. Without project conditions include the JICA's seven bridge project. With project conditions are composed of Alternative I and Alternative II of flood mitigation and drainage improvements. The simulated inundation areas with depth for 2, 5, 10, 20 and 50 year floods are shown in *Table 5.7.1* to *Table 5.7.3*. *Fig. 5.7.3* and *Fig. 5.7.4* show those information for 10 year floods. *Fig. 5.7.5* shows the simulated peak discharge of the Alternative I.

Inundation conditions of Río Pailón, Quebrada Chané, Chané - Chacras and Okinawa Drainage will be very much improved by either of Alternative I or Alternative II.

However, in spite of the river improvement along the Río Chané, flood water level of Río Chané will slightly increase by Alternative I. This will be caused by the increasing of flood discharge from the upstream basins due to the river and drainage improvements as well as the backwater effect of the Río Piray. Furthermore, as the river improvement of Río Chané is not included in the Alternative II, the flood water level along the Río Chané will increase. The amount of increase in flood water level for Río Chané by Alternative II will be 0.5 m to 0.9 m for 10 year floods.

5.7.3 Simulation of San Juan - Antofagasta

Results of the simulation for San Juan - Antofagasta are shown in *Table 5.7.4* to *Table 5.7.6* and *Fig. 5.7.6* to *Fig. 5.7.7*. *Fig. 5.7.8* shows the simulated peak discharge of the Alternative I.

Inundation conditions of San Juan - Antofagasta will be very much improved by either Alternative I or Alternative II for the reaches in which river and drainage improvement will be done.

5.8 Drought Analysis

Eastern part of the study area has a problem of drought. In this study, analysis for drought rainfall was conducted. *Table 5.8.1* shows the summary of probable drought rainfall by log-normal distribution for Santa Cruz-Trompillo, Saavedra, Okinawa II and Colonia San Juan de Yapacani.

In recent years, 1988, 1994 and 1995 are classified as drought years. Drought scale of four month rainfall for the four (4) rainfall stations are as follows;

	Drought Scale (4 Month Rainfall)		
Station	1st.	2nd	3rd.
SC-Trompillo	1994	1988	1995
	(49.4)	(34.4)	(18.9)
Saavedra	1988	1995	1993
	(>200)	(31.9)	(3.5)
Okinawa II	1995	1988	1993
	(16.5)	(12.8)	(5.7)
Col. San Juan de Yapacani	1988	1995	1993
	(>200)	(145.6)	(28.6)

Remarks: values in parenthesis are return periods of drought.

According to the analysis, it can be concluded that the recent drought scales are rather high.

TABLES

TABLE 5.2.1 LIST OF HYDROLOGICAL GAUGING STATIONS AND COLLECTED DATA (1/2)

1. LIST OF RAINFALL GAUGING STATIONS AND COLLECTED DAILY RAINFALL DATA

Station No.	Station Name	Location		Elevation	Observation Started						Data Collected					
		Latitude	Longitude		Manual			Automatic			Beginning			End		
				(El. m)	Day	Mon.	Year	Day	Mon.	Year	Day	Mon.	Year	Day	Mon.	Year
1. DATA FROM SEARPI																
09NP	San Pedro de Terevinto	17° 43' 05''	63° 26'	450	6	10	1988	-	-	-	6	10	1988	31	12	1994
20NP	Villa Diego	17° 35' 27''	63° 31' 25''	380	1	5	1988	-	-	-	1	5	1988	31	12	1994
22NP	Montero - Ciudad	-	-	-	1	2	1973	-	-	-	1	1	1989	31	12	1994
23NP	Patuju	-	-	-	1	1	1959	-	-	-	1	1	1989	31	12	1994
25NP	Santa Cruz-Oficina	17° 47'	63° 10'	416	11	11	1975	11	11	1975	11	11	1975	31	12	1994
28NP	Perotó	17° 29'	63° 10' 42''	350	1	5	1988	-	-	-	1	5	1988	31	12	1994
50NP	Viru Viru-Aeropuerto	17° 38' 51''	63° 07' 55''	360	1	8	1984	-	-	-	1	8	1984	31	12	1994
51NP	Warnes	17° 30'	63° 08'	330	16	2	1976	16	2	1976	16	2	1976	31	12	1994
52NP	San Isidro	17° 27'	63° 31'	332	8	11	1975	8	11	1975	8	11	1975	31	12	1994
55NP	Portachuelo	17° 21'	63° 24'	289	1	11	1975	-	-	-	1	11	1975	31	12	1994
56NP	La Belgica-Ingenio	17° 33'	63° 13'	378	1	2	1954	-	-	-	1	2	1954	31	12	1994
57NP	La Belgica-Puente	17° 32'	63° 13'	348	1	10	1977	-	-	-	1	10	1977	31	12	1994
58NP	Terevinto	17° 43'	63° 23'	425	1	9	1977	13	10	1986	1	9	1977	31	12	1994
59NP	Puente Eisenhower	17° 19'	63° 19'	277	1	10	1978	-	-	-	1	10	1977	31	12	1994
60NP	Gabetas	17° 20' 35''	63° 21' 25''	280	1	10	1981	-	-	-	1	10	1981	31	12	1994
61NP	Saavedra	17° 14'	63° 10'	320	1	8	1951	10	8	1951	1	8	1951	31	12	1994
62NP	Mineros (Unagro)	17° 06'	63° 14'	245	1	11	1975	-	-	-	1	11	1975	31	12	1994
5806	Santa Cruz-Trompillo	17° 47'	63° 10'	437	1	1	1943	-	-	-	1	1	1943	31	12	1994
5807	SantaCruz-Universidad	17° 46' 38''	63° 11'	725	18	1	1971	-	-	-	1	2	1971	31	12	1994
2. DATA FROM SENAMHI																
	Algodonera Boliviana	17° 33'	63° 09'	345			1958	-	-	-	-	-	-	-	-	-
	Algonodera Sta. Clara	17° 35'	63° 05'	344			1963	-	-	-	-	-	-	-	-	-
	Buen Retiro	17° 13'	63° 03'	275			1978	-	-	-	-	-	-	-	-	-
	Chocuete	17° 27'	63° 06'	313			1974	-	-	-	-	-	-	-	-	-
	Est. Exp. Vallecito	17° 46'	63° 09'	398				-	-	-	-	-	-	-	-	-
	Guapilo	17° 46'	63° 04'	325			1975	-	-	-	-	-	-	-	-	-
	Ingenio Esperanza	17° 18'	63° 03'	368			1944	-	-	-	-	-	-	-	-	-
	La Victoria	17° 36'	63° 03'	344			1969	-	-	-	-	-	-	-	-	-
	Okinawa I	17° 13'	62° 53'	252			1966	-	-	-	1	1	1977	31	12	1994
	Okinawa III	17° 32'	62° 55'	300			1963	-	-	-	-	-	-	-	-	-
	Puerto Paitas	17° 39'	62° 47'	280			1977	-	-	-	1	1	1977	31	12	1994
	Puesto Fernandez	17° 00'	63° 14'	230			1977	-	-	-	-	-	-	-	-	-
3. DATA FROM CETABOL - JICA																
	Okinawa II	17° 23'	62° 54'	280			1969				1	1	1969	31	12	1994
4. DATA FROM CAISY																
	Col. San Juan de Yapacar	17° 15'	63° 50'	350		1	1960	-	-	-	1	1	1960	31	12	1994
5. DATA FROM SPERNR																
13PY	Buena Vista	17° 27'	63° 40'	379	2	11	1990	-	-	-	2	11	1990	31	12	1993

Notes; SEARPI: Sevicio Encauzamiento de Aguas y Regularizacion del Rio Pirai
SENAMHI: Servicio Nacional de Meteorologia e Hidrologia
CETABOL-JICA: Centro Tecnologico Agropecuario en Bolivia-JICA
CAISY: Cooperativa Agropecuaria Integral San Juan de Yapacani Ltda.
SPERNR: Subproyecto de Proteccion de Etnias y Recursos Naturales Renovables

TABLE 5.2.1 LIST OF HYDROLOGICAL GAUGING STATIONS AND COLLECTED DATA (2/2)

2. LIST OF WATER LEVEL GAUGING STATIONS AND COLLECTED DATA

Station No.	Station Name	Location		Catchment Area	Elevation	Observation Started						Data Collected					
						Manual			Automatic			Beginning			End		
		Latitude	Longitude	(km2)	(El. m)	Day	Mon.	Year	Day	Mon.	Year	Day	Mon.	Year	Day	Mon.	Year
1. WATER LEVEL DATA OF THE RIO PIRAY																	
0506	Angostura	18° 09' 59"	63° 34' 05"	1417.7	620.0	1	1	1976	-	-	-	1	10	1977	31	12	1994
0510	La Belgica	17° 32'	63° 13'	2815.3	348.0	1	10	1977	-	-	-						
0505	Bermejo	18° 06'	63° 38'	477.4	1000.0	1	11	1975	-	-	-	1	10	1976	31	12	1994
0504	Colorado	18° 08'	63° 08'	102.3	1020.0							1	1	1981	31	12	1994
0512	Eisenhower	17° 19'	63° 19'	4010.0	279.5	1	10	1977	-	-	-	1	10	1977	31	12	1994
0520	Espejos	17° 58' 30"	63° 34' 17"	236.0	496.7	1	4	1981	-	-	-	27	11	1976	31	12	1994
0530	San Pedro de Terevinto	17° 43' 05"	63° 26'	165.0	450.0	6	10	1988	-	-	-	6	10	1988	25	11	1993
2. WATER LEVEL DATA OF THE RIO GRANDE																	
0401	Puente Abapo			60600.0								1	9	1971	31	3	1974
0402	Puerto Pailas	17° 40'	62° 47'	74500.0								1	10	1971	23	3	1974
3. WATER LEVEL DATA OF THE RIO YAPACANI																	
0041I	Rio Yapacani (Puente)	17° 24'	63° 43'	5970.0	283.0	25	7	1994	-	-	-	25	7	1994	31	12	1994
4. WATER LEVEL DATA OF THE TRIBUTARY OF RIO PALACIOS																	
0031I	Rio Palometillas (Puente)	17° 23'	63° 32'	261.5	290.0	20	7	1994	-	-	-	20	7	1994	31	12	1994

3. LIST OF DISCHARGE GAUGING STATIONS AND COLLECTED DATA

Station No.	Station Name	Location		Catchment Area	Elevation	Observation Started						Data Collected					
						Manual			Automatic			Beginning			End		
		Latitude	Longitude	(km2)	(El. m)	Day	Mon.	Year	Day	Mon.	Year	Day	Mon.	Year	Day	Mon.	Year
1. DISCHARGE DATA OF THE RIO PIRAY																	
0506	Angostura	18° 09' 59"	63° 34' 05"	1417.7	620							24	12	1975	31	12	1993
0510	La Belgica	17° 32'	63° 13'	2815.3	348							1	4	1976	31	12	1991
0505	Bermejo	18° 06'	63° 38'	477.4	1000							17	1	1976	31	12	1993
0504	Colorado	18° 08'	63° 08'	102.3	1020							10	9	1981	31	12	1993
0512	Eisenhower	17° 19'	63° 19'	4010.0	279.5							4	2	1977	31	12	1991
0520	Espejos	17° 58' 30"	63° 34' 17"	236.0	496.7							27	11	1976	31	12	1993
0530	San Pedro de Terevinto	17° 43' 05"	63° 26'	165.0	450							6	10	1988	25	11	1993
2. DISCHARGE DATA OF THE RIO GRANDE																	
0401	Puente Abapo			60600.0								1	1	1964	30	9	1981
0402	Puerto Pailas	17° 40'	62° 47'	74500.0								13	6	1971	31	3	1974
3. DISCHARGE DATA OF THE RIO YAPACANI																	
0041I	Rio Yapacani (Puente)	17° 24'	63° 43'	5970.0	283.0	15	9	1993	-	-	-	15	9	1993	23	11	1994
4. DISCHARGE DATA OF TRIBUTARY OF THE RIO PALACIOS																	
0031I	Rio Palometillas (Puente)	17° 23'	63° 32'	261.5	290	2	7	1991	-	-	-	2	7	1991	8	12	1994

TABLE 5.4.1 METEO-HYDROLOGICAL CONDITION IN THE STUDY AREA

Station		MONTH												Annual
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
1. MONTHLY AVERAGE TEMPERATURE													(Unit : °C)	Average
5806 SC - Trompillo	Max.	30.4	30.5	30.1	28.5	26.0	23.9	24.6	27.4	29.2	30.5	30.8	30.8	28.6
	Mean	26.4	26.3	25.8	24.2	22.0	20.3	20.2	22.6	24.5	26.0	26.8	26.7	24.3
	Min.	21.4	21.4	20.8	19.0	17.4	16.5	15.3	16.5	18.4	19.8	20.7	21.3	18.5
61NP Saavedra	Max.	30.4	30.4	30.4	29.0	27.0	25.3	25.9	28.5	30.2	30.9	30.4	30.1	29.0
	Mean	26.0	25.2	24.9	23.4	21.6	19.9	20.2	21.3	23.9	25.2	24.4	25.3	23.4
	Min.	21.5	21.3	20.6	18.9	17.2	15.4	14.5	15.6	17.8	19.5	19.8	20.7	18.6
Okinawa 2	Max.	30.6	30.8	30.8	29.5	26.8	25.3	25.6	28.5	29.5	31.4	31.3	30.9	29.7
	Mean	26.0	25.7	25.4	24.2	21.6	19.9	19.6	21.8	23.3	25.6	26.1	26.1	23.8
	Min.	21.7	21.2	20.8	19.4	17.2	15.5	14.1	15.9	17.4	19.6	20.7	21.5	18.7
Col. San Juan de Yapacani	Max.	30.6	30.8	30.9	29.7	27.0	25.4	25.9	27.7	28.8	30.7	30.7	30.6	29.1
	Mean	26.3	26.4	26.2	24.7	22.5	20.8	20.6	21.8	23.1	25.2	25.6	26.3	24.1
	Min.	22.0	21.9	21.6	19.7	18.0	16.3	15.3	16.0	17.5	19.7	20.8	21.9	19.2
Data : SC-Trompillo (Jan. 1943 - Dec. 1992), Saavedra (Jan. 1952 - Dec. 1994) Okinawa 2 (Apr. 1981 - Dec. 1994), Col. San Juan de Yapacani (Jan. 1973 - Dec. 1994)														
2. MONTHLY AVERAGE RELATIVE HUMIDITY													(Unit : %)	Average
5806 SC - Trompillo		75.0	75.0	75.0	74.0	76.0	76.0	69.0	61.0	60.0	64.0	67.0	71.0	70.3
61NP Saavedra		75.0	76.0	73.0	72.0	73.0	71.0	63.0	56.0	56.0	61.0	66.0	73.0	68.0
Okinawa 2		83.2	82.0	82.6	81.7	81.2	79.0	73.4	69.0	68.5	70.9	75.7	79.5	74.8
Col. San Juan de Yapacani		80.1	79.7	77.8	77.3	78.2	78.4	73.7	69.8	69.2	70.3	74.0	78.5	75.6
Data : SC-Trompillo (Jan. 1943 - Dec. 1992), Saavedra (Jan. 1956 - Dec. 1992) Okinawa 2 (Apr. 1981 - Dec. 1994), Col. San Juan de Yapacani (Jan. 1973 - Dec. 1994)														
3. MONTHLY AVERAGE RAINFALL AND RAINY DAYS													(Unit : mm)	
													(Unit : day)	Total
5806 SC - Trompillo		181.5	137.3	126.0	104.3	90.0	75.2	61.8	42.9	70.9	99.3	130.1	181.9	1301.2
		13	12	11	9	10	8	6	4	5	7	9	12	108
61NP Saavedra		224.1	161.4	114.0	84.5	83.5	69.3	45.2	48.2	71.9	106.5	147.1	200.4	1356.1
		13	11	10	7	8	5	4	4	5	7	9	12	94
Okinawa 2		200.8	166.1	109.4	82.9	88.8	58.3	48.4	52.1	66.8	101.5	122.6	176.5	1274.2
		11	10	8	6	6	5	3	3	4	6	7	10	77
Col. San Juan de Yapacani		301.7	239.4	180.3	122.7	156.9	97.4	69.2	77.9	83.9	134.0	161.3	272.7	1897.5
		17	15	13	10	10	8	6	5	6	9	10	15	125
Data : SC-Trompillo (Jan. 1943 - Dec. 1994), Saavedra (Jan. 1952 - Dec. 1994) Okinawa 2 (Jan. 1969 - Dec. 1994), Col. San Juan de Yapacani (Jan. 1960 - Dec. 1994)														
4. MONTHLY AVERAGE WIND SPEED AND DIRECTION												(Unit : knot, 1 knot = 0.514 m/s)		Average
5806 SC - Trompillo		NW-09	NW-09	NW-08	NW-08	NW-09	NW-11	NW-11	NW-11	NW-11	NW-10	NW-10	NW-09	NW-10
61NP Saavedra		N-07	N-07	N-07	S-08	S-10	N-11	N-12	N-11	S-11	N-10	N-09	N-08	N-09
Data : SC-Trompillo (Jan. 1943 - Dec. 1994), Saavedra (Feb. 1979 - Dec. 1992)														
5. MONTHLY AVERAGE EVAPORATION													(Unit : mm)	Total
SC-Universidad		121.5	108.2	110.6	90.7	74.0	63.2	76.5	96.1	116.7	137.2	133.0	126.5	1254.1
Col. San Juan de Yapacani		88.0	77.4	95.5	94.1	75.4	65.5	90.4	105.4	114.7	123.1	111.8	93.9	1142.0
Data : SC-Universidad (1971 - 1994), Col. San Juan de Yapacani (Jan. 1974 - Sep. 1984)														

TABLE 5.5.1 SUMMARY OF PROBABLE MAXIMUM RAINFALL BY GUMBEL METHOD

(Unit : mm)

Return Period (Year)	Probable Maximum Rainfall						
	1 Day	2 Day	3 Day	4 Day	5 Day	6 Day	7 Day
1. 5806 SANTA CRUZ TROMPILLO							
200	292.7	328.2	342.0	357.4	373.1	383.9	388.9
100	265.6	298.7	311.7	326.3	341.2	351.7	357.0
50	238.5	269.1	281.3	295.1	309.3	319.5	325.0
40	229.7	259.5	271.5	285.0	299.0	309.0	314.7
30	218.3	247.2	258.7	272.0	285.6	295.6	301.3
20	202.2	229.6	240.7	253.4	266.6	276.4	282.3
10	174.2	199.1	209.4	221.3	233.7	243.2	249.3
5	145.0	167.3	176.7	187.7	199.4	208.5	214.9
2	100.9	119.3	127.4	137.1	147.5	156.2	162.9
2. 61NP SAAVEDRA							
200	256.9	321.1	369.7	402.1	417.5	452.9	458.8
100	235.1	292.7	336.0	364.7	379.8	411.5	417.3
50	213.2	264.2	302.3	327.2	341.9	369.9	375.6
40	206.1	255.0	291.3	315.1	329.6	356.4	362.1
30	197.0	243.1	277.2	299.4	313.8	339.0	344.7
20	184.0	226.2	257.2	277.2	291.4	314.4	319.9
10	161.4	196.8	222.4	238.6	252.3	271.5	276.9
5	137.9	166.2	186.1	198.3	211.6	226.8	232.1
2	102.4	120.0	131.3	137.4	150.2	159.2	164.4
3. OKINAWA II							
200	266.3	296.2	332.6	345.7	391.3	391.4	416.9
100	243.2	271.2	304.3	316.6	357.3	358.9	382.0
50	220.1	246.1	275.9	287.4	323.2	326.2	346.9
40	212.6	238.0	266.7	278.0	312.2	315.6	335.6
30	202.9	227.5	254.8	265.8	297.9	302.0	320.9
20	189.2	212.6	237.9	248.5	277.7	282.6	300.1
10	165.3	186.7	208.6	218.5	242.5	248.9	263.9
5	140.4	159.7	178.1	187.1	205.9	213.7	226.2
2	102.8	119.0	131.9	139.8	150.5	160.7	169.3
4. COL. SAN JUAN DE YAPACANI							
200	352.4	417.6	440.7	445.8	459.2	471.1	522.5
100	322.4	381.7	404.0	410.7	423.8	435.4	481.0
50	292.2	345.7	367.1	375.4	388.4	399.6	439.2
40	282.4	334.1	355.2	364.0	376.9	388.0	425.8
30	269.8	319.0	339.8	349.3	362.1	373.1	408.3
20	251.9	297.7	317.9	328.4	341.0	351.8	383.6
10	220.8	260.6	279.9	292.0	304.4	314.9	340.6
5	188.3	221.9	240.3	254.1	266.3	276.4	295.7
2	139.3	163.5	180.5	196.9	208.7	218.2	228.0

TABLE 5.6.1 RUNOFF POINTS AND SCS PARAMETERS OF THE RIO CHANE BASIN AND ARROYO YAPACANICITO-JOCHI-TACUARAL-TEJERIA BASINS

1. CHACHMENT CHARACTERISTICS FOR RUNOFF POINTS OF THE RIO CHANE BASIN

Point Code	Sub-catchments	Chach-ment Area (km^2)	Hydraulic Length (km)	Grand Slope (%)	SCS Curve Number (CN)	CBR method Lag Time (hr)	CBR method Velocity (m/sec)
P-1	A-1_11,B-1_3,C-1_8,D-1	2519.1	132700.0	0.133	82	36.6	1.01
P-2	A-2_11,B-1_3,C-1_8,D-1	2455.7	120200.0	0.139	82	33.4	1.00
P-2-1	A-2_11,C-1_8,D-1	2231.5	120200.0	0.139	82	33.4	1.00
P-2-2	B-1_3	224.3	50500.0	0.152	82	16.5	0.85
P-3	A-3_11,C-1_8,D-1	2032.8	98200.0	0.118	82	30.4	0.90
P-3-1	D-1,A-3_11	1563.5	98200.0	0.164	82	26.8	1.02
P-3-2	C-1_8	469.3	58500.0	0.198	82	16.7	0.97
P-4	D-1,A-4_11	1398.8	75200.0	0.193	82	20.5	1.02
P-5	D-1,A-5_11	1338.7	71000.0	0.200	82	19.3	1.02
P-5-1	D-1,A-5_10	1063.3	71000.0	0.200	82	19.3	1.02
P-5-2	A-11	275.5	42000.0	0.231	82	12.2	0.96
P-6	D-1,A-6_10	1047.5	67000.0	0.209	82	18.2	1.02
P-6-1	D-1,A-6	456.7	55000.0	0.173	82	16.8	0.91
P-6-2	A-7_9	524.7	67000.0	0.209	82	18.2	1.02
P-6-3	A-10	66.1	28000.0	0.207	82	9.3	0.83
P-7	A-8,A-9	412.0	39000.0	0.223	82	11.7	0.93
P-7-1	A - 8	270.1	39000.0	0.223	82	11.7	0.93
P-7-2	A - 9	141.9	32000.0	0.225	82	10.0	0.89
P-8	B-2,B-3	217.5	48000.0	0.156	82	15.7	0.85
P-9	B - 3	64.0	16000.0	0.213	82	6.0	0.74
P-10	C-2_8	466.1	54500.0	0.202	82	15.7	0.96
P-10-1	C-4_8	233.7	44000.0	0.205	82	13.3	0.92
P-10-2	C-2,C-3	232.4	54500.0	0.202	82	15.7	0.96
P-11	C - 3	197.4	40000.0	0.225	82	11.9	0.94
P-12	C-5_8	194.9	32500.0	0.228	82	10.1	0.90
P-12-1	C-7,C-8	62.4	28000.0	0.211	82	9.3	0.84
P-12-2	C-5,C-6	132.5	32500.0	0.228	82	10.1	0.90
P-13	C - 6	121.2	28000.0	0.243	82	8.8	0.89
P-14	C - 8	38.4	21000.0	0.219	82	7.3	0.80
P-15	D - 1	244.8	33000.0	0.188	83	11.0	0.83

2. CHACHMENT CHARACTERISTICS FOR RUNOFF POINTS OF THE YAPACANICITO-JOCHI-TACUARAL-TEJERIA BASIN

River	Point Code	Sub-catchments	Chach-ment Area (km^2)	Hydraulic Length (km)	Grand Slope (%)	SCS Curve Number (CN)	CBR method Lag Time (hr)	CBR method Velocity (m/sec)
Yapacanicito	P_Y1	Y1_1, Y1_2, Y1_3, Y1_4, Y2_1, Y2_2	370.7	61.4	0.099	80	22.7	0.75
	P_Y2	Y1_2, Y1_3, Y1_4, Y2_1, Y2_2	303.9	51.1	0.108	80	19.0	0.75
	P_Y2_1	Y1_2, Y1_3, Y1_4	229.2	51.1	0.108	81	19.0	0.75
	P_Y3	Y1_3, Y1_4	130.8	31.5	0.145	83	11.7	0.75
	P_Y4	Y1_4	34.9	11.8	0.200	83	4.9	0.67
	P_Y2_2	Y2_1, Y2_2	74.7	25.9	0.058	81	14.3	0.50
	P_Y5	Y2_2	11.9	6.5	0.083	82	4.3	0.42
Jochi	P_J1	J_1, J_2, J_3, J_4	148.0	46.8	0.096	80	18.6	0.70
	P_J2	J_2, J_3, J_4	106.4	33.2	0.106	81	13.8	0.67
	P_J3	J_3, J_4	94.6	31.1	0.108	82	13.0	0.67
	P_J4	J_4	18.3	5.0	0.120	82	3.1	0.46
Tacuaral	P_T1	T_1, T_2, T_3, T_4	252.8	49.7	0.121	80	17.8	0.77
	P_T2	T_2, T_3, T_4	214.6	39.5	0.140	80	14.1	0.78
	P_T2_1	T_2	88.2	26.0	0.100	80	11.7	0.62
	P_T3	T_3, T_4	126.4	37.7	0.142	80	13.6	0.77
	P_T4	T_4	49.4	13.2	0.200	81	5.3	0.69
Tejeria	P_TJ1	TJ_1	43.6	17.0	0.180	82	6.7	0.70

TABLE 5.7.1 INUNDATION AREA AND DEPTH OF CHANE - PAILON
WITHOUT FLOOD MITIGATION AND DRAINAGE IMPROVEMENT

Target Area	Distance (km)	Potential Inundation Area (km2)	Inundation Depth (m) Return Period (Year)					Inundation Area (km2) Return Period (Year)				
			2	5	10	20	50	2	5	10	20	50
A. DOWNSTREAM OF ROUTE 9	**185.80**	**845.1**	**0.68**	**0.90**	**1.06**	**1.19**	**1.36**	**601.3**	**725.6**	**779.7**	**799.2**	**820.7**
B. UPSTREAM OF ROUTE 9	**24.40**	**179.1**	**0.19**	**0.28**	**0.37**	**0.46**	**0.58**	**49.5**	**68.5**	**83.3**	**97.3**	**115.7**
1. RIO CHANE	35.00	107.4	0.88	1.18	1.39	1.57	1.81	93.3	106.0	107.4	107.4	107.4
1-1 Jct. Río Piray - Jct. Qda. Chacras	12.50	63.4	1.24	1.57	1.72	1.86	2.03	63.4	63.4	63.4	63.4	63.4
1-2 Jct. Qda. Chacras - Jct. Qda. Chané	22.50	44.0	0.68	0.97	1.20	1.41	1.69	29.9	42.7	44.0	44.0	44.0
2. RIO PAILON	42.90	260.5	0.58	0.77	0.93	1.07	1.27	170.4	182.6	190.0	197.7	209.3
2-1 Jct. Río Chané - Route 9	23.50	164.7	0.97	1.26	1.49	1.69	1.96	159.8	164.7	164.7	164.7	164.7
2-2 Route 9 - Jct. A. Sauces	8.00	50.8	0.13	0.22	0.32	0.42	0.56	6.6	11.2	16.3	21.3	28.4
2-3 Jct. A. Sauces - Okinawa II	11.40	45.0	0.09	0.15	0.20	0.26	0.36	4.1	6.8	9.0	11.7	16.2
3. QDA. CHANE	43.30	159.5	0.33	0.50	0.63	0.75	0.88	56.9	81.1	100.7	112.4	123.2
3-1 Qda. Chané: Jct. Río Chané - Route 9	18.00	38.2	0.17	0.39	0.56	0.70	0.85	6.5	14.9	21.4	26.7	32.5
3-2 Qda. Chané: Upstream of Route 9	1.00	22.0	0.68	0.86	0.96	1.05	1.16	15.0	18.9	21.1	22.0	22.0
3-3 Qda. Toro: Jct. Qda. Chané - Route 9	15.50	50.1	0.67	0.83	0.96	1.09	1.24	33.6	41.6	48.1	50.1	50.1
3-4 Qda. Toro: Upstream of Route 9	1.00	18.0	0.05	0.17	0.26	0.39	0.56	0.9	3.1	4.7	7.0	10.1
3-5 Qda. Maras: Jct. Qda. Toro - Route 9	6.80	23.9	0.04	0.08	0.15	0.17	0.22	1.0	1.9	3.6	4.1	5.3
3-6 Qda. Maras: Upsream of Route 9	1.00	7.3	0.00	0.10	0.24	0.33	0.45	0.0	0.7	1.7	2.4	3.3
4. CHANE - CHACRAS	63.00	318.9	0.73	0.93	1.07	1.18	1.32	233.1	296.8	318.9	318.9	318.9
4-1 Qda. Chacras: Jct. Río Chané - Route 9	36.00	160.2	0.73	0.93	1.07	1.18	1.32	117.0	149.0	160.2	160.2	160.2
4-2 Qda. Chacras: Upstream of Route 9	1.00	4.0	0.80	1.05	1.19	1.33	1.49	3.2	4.0	4.0	4.0	4.0
4-3 Chané Drainage	26.00	154.7	0.73	0.93	1.07	1.18	1.32	112.9	143.9	154.7	154.7	154.7
5. OKINAWA DRAINAGE	26.00	177.9	0.55	0.73	0.85	0.93	1.07	97.1	127.5	146.1	160.2	177.6
5-1 Downstream of Route 9	25.00	145.9	0.53	0.71	0.82	0.90	1.04	77.3	103.6	119.6	131.3	145.9
5-2 Upstream of Route 9	1.00	32.0	0.97	1.30	1.50	1.68	1.90	19.8	23.9	26.5	28.8	31.7

TABLE 5.7.2 INUNDATION AREA AND DEPTH OF CHANE - PAILON
WITH FLOOD MITIGATION AND DRAINAGE IMPROVEMENT (ALTERNATIVE I)

Target Area	Distance (km)	Potential Inundation Area (km2)	Inundation Depth (m) Return Period (Year)					Inundation Area (km2) Return Period (Year)				
			2	5	10	20	50	2	5	10	20	50
A. DOWNSTREAM OF ROUTE 9	**185.80**	**845.1**	**0.17**	**0.33**	**0.51**	**0.67**	**0.83**	**106.6**	**196.8**	**325.5**	**443.7**	**554.4**
B. UPSTREAM OF ROUTE 9	**24.40**	**179.1**	**0.06**	**0.23**	**0.32**	**0.41**	**0.52**	**26.5**	**53.4**	**67.4**	**82.5**	**100.8**
1. RIO CHANE	35.00	107.4	0.78	1.21	1.45	1.67	1.93	84.5	103.4	107.4	107.4	107.4
1-1 Jct. Río Piray - Jct. Qda. Chacras	12.50	63.4	1.33	1.76	1.91	2.16	2.50	63.4	63.4	63.4	63.4	63.4
1-2 Jct. Qda. Chacras - Jct. Qda. Chané	22.50	44.0	0.48	0.91	1.19	1.40	1.61	21.1	40.0	44.0	44.0	44.0
2. RIO PAILON	42.90	260.5	0.04	0.14	0.27	0.42	0.59	11.6	36.9	72.2	115.1	162.5
2-1 Jct. Río Chané - Route 9	23.50	164.7	0.05	0.09	0.26	0.47	0.70	8.2	14.8	42.8	77.4	115.3
2-2 Route 9 - Jct. A. Sauces	8.00	50.8	0.04	0.31	0.41	0.52	0.62	2.0	15.7	20.8	26.4	31.5
2-3 Jct. A. Sauces - Okinawa II	11.40	45.0	0.03	0.14	0.19	0.25	0.35	1.4	6.3	8.6	11.3	15.8
3. QDA. CHANE	43.30	159.5	0.06	0.14	0.26	0.35	0.44	14.4	28.2	46.6	59.5	75.9
3-1 Qda. Chané: Jct. Río Chané - Route 9	18.00	38.2	0.00	0.05	0.14	0.23	0.31	0.0	1.9	5.3	8.8	11.8
3-2 Qda. Chané: Upstream of Route 9	1.00	22.0	0.19	0.38	0.43	0.49	0.58	4.2	8.4	9.5	10.8	12.8
3-3 Qda. Toro: Jct. Qda. Chané - Route 9	15.50	50.1	0.16	0.29	0.46	0.56	0.70	8.0	14.5	23.1	28.1	35.1
3-4 Qda. Toro: Upstream of Route 9	1.00	18.0	0.12	0.15	0.23	0.32	0.46	2.2	2.7	4.1	5.8	8.3
3-5 Qda. Maras: Jct. Qda. Toro - Route 9	6.80	23.9	0.00	0.01	0.13	0.16	0.20	0.0	0.2	3.1	3.8	4.8
3-6 Qda. Maras: Upsream of Route 9	1.00	7.3	0.00	0.06	0.21	0.32	0.43	0.0	0.4	1.5	2.3	3.1
4. CHANE - CHACRAS	63.00	318.9	0.00	0.09	0.29	0.48	0.63	0.0	28.7	92.5	153.1	200.9
4-1 Qda. Chacras: Jct. Río Chané - Route 9	36.00	160.2	0.00	0.09	0.29	0.48	0.63	0.0	14.4	46.5	76.9	100.9
4-2 Qda. Chacras: Upstream of Route 9	1.00	4.0	0.00	0.09	0.29	0.48	0.63	0.0	0.4	1.2	1.9	2.5
4-3 Chané Drainage	26.00	154.7	0.00	0.09	0.29	0.48	0.63	0.0	13.9	44.9	74.2	97.4
5. OKINAWA DRAINAGE	26.00	177.9	0.06	0.26	0.39	0.49	0.60	22.6	53.1	74.2	91.1	108.6
5-1 Downstream of Route 9	25.00	145.9	0.04	0.23	0.36	0.46	0.56	5.8	33.6	52.5	67.1	81.7
5-2 Upstream of Route 9	1.00	32.0	0.60	0.94	1.13	1.31	1.53	16.8	19.5	21.7	24.0	26.9

TABLE 5.7.3 INUNDATION AREA AND DEPTH OF CHANE - PAILON
WITH FLOOD MITIGATION AND DRAINAGE IMPROVEMENT (ALTERNATIVE II)

Target Area	Distance (km)	Potential Inundation Area (km2)	Inundation Depth (m) Return Period (Year) 2	5	10	20	50	Inundation Area (km2) Return Period (Year) 2	5	10	20	50
A. DOWNSTREAM OF ROUTE 9	**185.80**	**845.1**	**0.31**	**0.46**	**0.64**	**0.80**	**0.96**	**106.6**	**196.8**	**325.5**	**443.7**	**554.4**
B. UPSTREAM OF ROUTE 9	**24.40**	**179.1**	**0.06**	**0.23**	**0.32**	**0.41**	**0.52**	**26.5**	**53.4**	**67.4**	**82.5**	**100.8**
1. RIO CHANE	35.00	107.4	1.49	1.93	2.14	2.33	2.59	84.5	103.4	107.4	107.4	107.4
1-1 Jct. Río Piray - Jct. Qda. Chacras	12.50	63.4	1.68	2.10	2.29	2.46	2.65	63.4	63.4	63.4	63.4	63.4
1-2 Jct. Qda. Chacras - Jct. Qda. Chané	22.50	44.0	1.38	1.83	2.06	2.26	2.56	21.1	40.0	44.0	44.0	44.0
2. RIO PAILON	42.90	260.5	0.04	0.14	0.27	0.42	0.59	11.6	36.9	72.2	115.1	162.5
2-1 Jct. Río Chané - Route 9	23.50	164.7	0.05	0.09	0.26	0.47	0.70	8.2	14.8	42.8	77.4	115.3
2-2 Route 9 - Jct. A. Sauces	8.00	50.8	0.04	0.31	0.41	0.52	0.62	2.0	15.7	20.8	26.4	31.5
2-3 Jct. A. Sauces - Okinawa II	11.40	45.0	0.03	0.14	0.19	0.25	0.35	1.4	6.3	8.6	11.3	15.8
3. QDA. CHANE	43.30	159.5	0.06	0.14	0.26	0.35	0.44	14.4	28.2	46.6	59.5	75.9
3-1 Qda. Chané: Jct. Río Chané - Route 9	18.00	38.2	0.00	0.05	0.14	0.23	0.31	0.0	1.9	5.3	8.8	11.8
3-2 Qda. Chané: Upstream of Route 9	1.00	22.0	0.19	0.38	0.43	0.49	0.58	4.2	8.4	9.5	10.8	12.8
3-3 Qda. Toro: Jct. Qda. Chané - Route 9	15.50	50.1	0.16	0.29	0.46	0.56	0.70	8.0	14.5	23.1	28.1	35.1
3-4 Qda. Toro: Upstream of Route 9	1.00	18.0	0.12	0.15	0.23	0.32	0.46	2.2	2.7	4.1	5.8	8.3
3-5 Qda. Maras: Jct. Qda. Toro - Route 9	6.80	23.9	0.00	0.01	0.13	0.16	0.20	0.0	0.2	3.1	3.8	4.8
3-6 Qda. Maras: Upsream of Route 9	1.00	7.3	0.00	0.06	0.21	0.32	0.43	0.0	0.4	1.5	2.3	3.1
4. CHANE - CHACRAS	63.00	318.9	0.00	0.09	0.29	0.48	0.63	0.0	28.7	92.5	153.1	200.9
4-1 Qda. Chacras: Jct. Río Chané - Route 9	36.00	160.2	0.00	0.09	0.29	0.48	0.63	0.0	14.4	46.5	76.9	100.9
4-2 Qda. Chacras: Upstream of Route 9	1.00	4.0	0.00	0.09	0.29	0.48	0.63	0.0	0.4	1.2	1.9	2.5
4-3 Chané Drainage	26.00	154.7	0.00	0.09	0.29	0.48	0.63	0.0	13.9	44.9	74.2	97.4
5. OKINAWA DRAINAGE	26.00	177.9	0.06	0.26	0.39	0.49	0.60	22.6	53.1	74.2	91.1	108.6
5-1 Downstream of Route 9	25.00	145.9	0.04	0.23	0.36	0.46	0.56	5.8	33.6	52.5	67.1	81.7
5-2 Upstream of Route 9	1.00	32.0	0.60	0.94	1.13	1.31	1.53	16.8	19.5	21.7	24.0	26.9

TABLE 5.7.4 INUNDATION AREA AND DEPTH OF SAN JUAN - ANTOFAGASTA
WITHOUT FLOOD MITIGATION AND DRAINAGE IMPROVEMENT

Target Area	Distance (km)	Potential Inundation Area (km2)	Inundation Depth (m) Return Period (Year)					Inundation Area (km2) Return Period (Year)				
			2	5	10	20	50	2	5	10	20	50
A. WHOLE AREA	**111.40**	**663.1**	**0.29**	**0.42**	**0.48**	**0.53**	**0.59**	**315.8**	**419.5**	**464.2**	**495.0**	**533.4**
1. SAN JUAN	63.20	355.1	0.48	0.69	0.79	0.88	0.97	187.8	259.4	283.4	297.6	315.8
1-1 Arroyo Yapacanicito: Downstream	32.40	165.0	0.77	0.97	1.07	1.16	1.25	127.1	160.1	165.0	165.0	165.0
1-2 Arroyo Yapacanicito: Mid-stream	21.30	96.0	0.24	0.47	0.59	0.68	0.78	23.0	45.1	56.6	65.3	74.9
1-3 San Juan Drainage Main: km 24 - km 28		15.5	0.49	0.50	0.50	0.50	0.54	7.6	7.8	7.8	7.8	8.4
1-4 San Juan Drainage Main: km 17 - km 9		35.0	0.32	0.59	0.69	0.75	0.83	11.2	20.7	24.2	26.3	29.1
1-5 Arroyo Tejeria: Downstream of Road Main	7.50	14.0	0.06	0.26	0.40	0.54	0.68	0.8	3.6	5.6	7.6	9.5
1-6 Arroyo Tejeria: Upstream of Road Main	2.00	29.6	0.61	0.75	0.82	0.87	0.98	18.1	22.2	24.3	25.8	29.0
2. ANTOFAGASTA	48.20	308.0	0.37	0.50	0.59	0.66	0.74	128.0	160.1	180.8	197.4	217.6
2-1 Arroyo Jochi: Mid-stream	7.00	76.0	0.16	0.26	0.32	0.37	0.41	12.2	19.8	24.3	28.1	31.2
2-2 Arroyo Joch: Upstream	18.60	24.0	0.31	0.47	0.60	0.70	0.81	7.4	11.3	14.4	16.8	19.4
2-3 Arroyo Tacuaral: Mid-stream	6.20	159.0	0.54	0.63	0.69	0.74	0.81	85.9	100.2	109.7	117.7	128.8
2-4 Arroyo Tacuaral: Upstream	16.40	49.0	0.46	0.59	0.66	0.71	0.78	22.5	28.9	32.3	34.8	38.2

TABLE 5.7.5 INUNDATION AREA AND DEPTH OF SAN JUAN - ANTOFAGASTA
WITH FLOOD MITIGATION AND DRAINAGE IMPROVEMENT (ALTERNATIVE I)

Target Area	Distance (km)	Potential Inundation Area (km2)	Inundation Depth (m) Return Period (Year)					Inundation Area (km2) Return Period (Year)				
			2	5	10	20	50	2	5	10	20	50
A. WHOLE AREA	**111.40**	**663.1**	**0.21**	**0.30**	**0.37**	**0.43**	**0.51**	**160.2**	**223.7**	**253.9**	**285.8**	**326.4**
1. SAN JUAN	63.20	355.1	0.35	0.49	0.60	0.71	0.83	133.7	182.4	202.0	223.6	250.3
1-1 Arroyo Yapacanicito: Downstream	32.40	165.0	0.81	1.01	1.13	1.22	1.32	133.7	165.0	165.0	165.0	165.0
1-2 Arroyo Yapacanicito: Mid-stream	21.30	96.0	0.00	0.04	0.11	0.21	0.32	0.0	3.8	10.6	20.2	30.7
1-3 San Juan Drainage Main: km 24 - km 28		15.5	0.00	0.13	0.21	0.28	0.41	0.0	2.0	3.3	4.4	6.4
1-4 San Juan Drainage Main: km 17 - km 9		35.0	0.00	0.23	0.38	0.51	0.70	0.0	8.1	13.3	17.9	24.5
1-5 Arroyo Tejeria: Downstream of Road Main	7.50	14.0	0.00	0.10	0.26	0.45	0.63	0.0	1.4	3.7	6.3	8.9
1-6 Arroyo Tejeria: Upstream of Road Main	2.00	29.6	0.00	0.07	0.21	0.33	0.50	0.0	2.1	6.2	9.9	14.9
2. ANTOFAGASTA	48.20	308.0	0.25	0.37	0.45	0.51	0.59	26.6	41.3	51.9	62.2	76.1
2-1 Arroyo Jochi: Mid-stream	7.00	76.0	0.00	0.06	0.12	0.17	0.21	0.0	4.6	9.1	12.9	16.0
2-2 Arroyo Joch: Upstream	18.60	24.0	0.31	0.47	0.60	0.70	0.81	7.4	11.3	14.4	16.8	19.4
2-3 Arroyo Tacuaral: Mid-stream	6.20	159.0	0.00	0.00	0.00	0.01	0.04	0.0	0.0	0.0	1.6	6.4
2-4 Arroyo Tacuaral: Upstream	16.40	49.0	0.39	0.52	0.58	0.63	0.70	19.1	25.5	28.4	30.9	34.3

TABLE 5.7.6 INUNDATION AREA AND DEPTH OF SAN JUAN - ANTOFAGASTA
WITH FLOOD MITIGATION AND DRAINAGE IMPROVEMENT (ALTERNATIVE II)

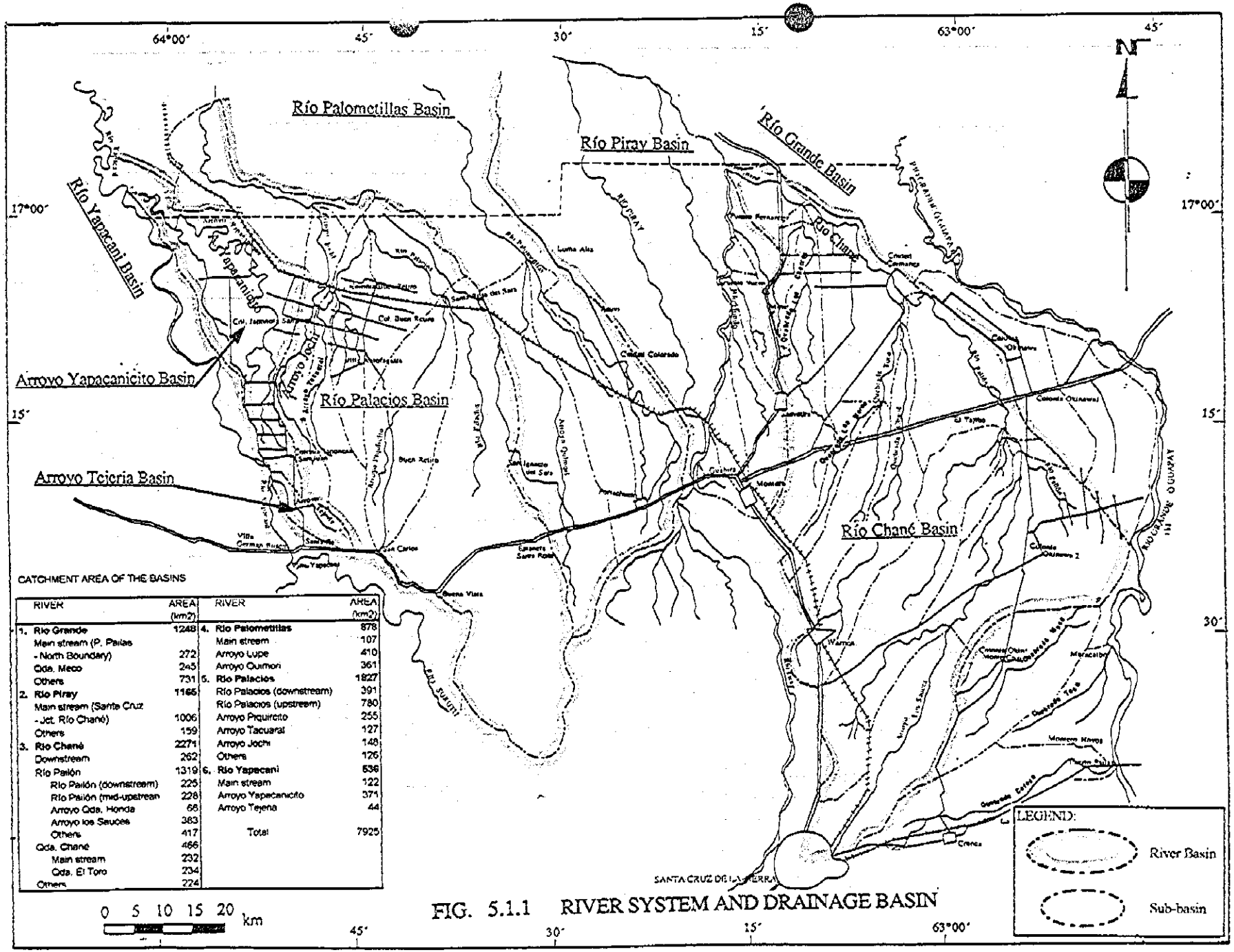
Target Area	Distance (km)	Potential Inundation Area (km2)	Inundation Depth (m) Return Period (Year)					Inundation Area (km2) Return Period (Year)				
			2	5	10	20	50	2	5	10	20	50
A. WHOLE AREA	**111.40**	**663.1**	**0.22**	**0.31**	**0.38**	**0.44**	**0.50**	**161.9**	**228.1**	**258.2**	**286.9**	**322.5**
1. SAN JUAN	63.20	355.1	0.35	0.51	0.62	0.72	0.82	135.3	186.8	206.2	224.7	246.5
1-1 Arroyo Yapacanicito: Downstream	32.40	165.0	0.82	1.03	1.15	1.24	1.33	135.3	165.0	165.0	165.0	165.0
1-2 Arroyo Yapacanicito: Mid-stream	21.30	96.0	0.00	0.11	0.19	0.26	0.34	0.0	10.6	18.2	25.0	32.6
1-3 San Juan Drainage Main: km 24 - km 28		15.5	0.00	0.13	0.21	0.28	0.36	0.0	2.0	3.2	4.3	5.6
1-4 San Juan Drainage Main: km 17 - km 9		35.0	0.00	0.16	0.28	0.41	0.56	0.0	5.8	9.9	14.3	19.4
1-5 Arroyo Tejeria: Downstream of Road Main	7.50	14.0	0.00	0.10	0.26	0.45	0.63	0.0	1.4	3.7	6.3	8.9
1-6 Arroyo Tejeria: Upstream of Road Main	2.00	29.6	0.00	0.07	0.21	0.33	0.50	0.0	2.1	6.2	9.9	14.9
2. ANTOFAGASTA	48.20	308.0	0.25	0.37	0.45	0.51	0.59	26.6	41.3	51.9	62.2	76.1
2-1 Arroyo Jochi: Mid-stream	7.00	76.0	0.00	0.06	0.12	0.17	0.21	0.0	4.6	9.1	12.9	16.0
2-2 Arroyo Joch: Upstream	18.60	24.0	0.31	0.47	0.60	0.70	0.81	7.4	11.3	14.4	16.8	19.4
2-3 Arroyo Tacuaral: Mid-stream	6.20	159.0	0.00	0.00	0.00	0.01	0.04	0.0	0.0	0.0	1.6	6.4
2-4 Arroyo Tacuaral: Upstream	16.40	49.0	0.39	0.52	0.58	0.63	0.70	19.1	25.5	28.4	30.9	34.3

TABLE 5.8.1 SUMMARY OF PROBABLE MONTHLY DROUGHT RAINFALL BY LOG-NORMAL DISTRIBUTION

(Unit : mm)

Return Period	Probable Monthly Rainfall for Drought						Annual
(Year)	1 Month	2 Month	3 Month	4 Month	5 Month	6 Month	Rainfall
1. 5806 SANTA CRUZ TROMPILLO							
200	0.1	2.7	21.2	48.2	75.0	117.1	623.9
100	0.1	3.5	24.7	54.8	84.8	130.2	667.6
50	0.1	4.7	29.3	63.2	97.3	146.7	720.3
20	0.3	7.3	37.7	78.1	119.0	174.6	805.1
10	0.5	10.7	47.0	93.9	142.1	203.5	887.6
5	1.1	17.0	61.5	117.7	176.4	245.4	1000.1
2	5.1	41.1	103.0	181.1	266.7	350.8	1256.0
2. 6INP SAAVEDRA							
200	0.0	0.3	15.1	37.3	65.4	104.5	629.6
100	0.0	0.4	17.9	42.7	73.9	116.5	675.9
50	0.0	0.7	21.6	49.6	84.7	131.7	731.7
20	0.1	1.4	28.4	62.0	103.3	157.5	822.0
10	0.2	2.6	36.2	75.3	123.0	184.3	910.4
5	0.4	5.6	48.8	95.5	152.4	223.3	1031.5
2	2.6	24.1	85.9	150.3	229.1	322.1	1309.2
3. OKINAWA II							
200	0.0	0.3	0.4	10.4	29.0	49.7	499.5
100	0.0	0.5	0.7	13.4	35.1	59.0	544.3
50	0.0	0.8	1.2	17.9	43.5	71.3	599.2
20	0.0	1.7	2.8	27.0	59.7	94.2	689.7
10	0.1	3.2	5.6	38.9	78.7	120.3	780.3
5	0.2	7.0	13.4	60.8	110.3	162.2	907.5
2	1.3	31.1	70.3	142.2	210.4	287.1	1210.6
4. COL. SAN JUAN DE YAPACANI							
200	0.3	10.7	23.0	54.2	78.1	154.3	900.4
100	0.4	12.9	27.5	62.6	90.0	172.3	964.6
50	0.6	15.7	33.5	73.5	105.4	194.9	1041.9
20	1.1	21.1	44.8	93.1	132.9	233.5	1166.4
10	1.9	27.4	57.9	114.6	162.9	273.6	1288.0
5	3.8	37.6	79.0	147.8	208.9	332.1	1453.9
2	13.4	68.9	143.2	239.9	335.7	480.8	1832.3

FIGURES



RIVER	AREA (km2)	RIVER	AREA (km2)
1. Río Grande	1248	4. Río Palometillas	878
Main stream (P. Pailas - North Boundary)	272	Main stream	107
Qda. Meco	245	Arroyo Lupe	410
Others	731	Arroyo Quimon	361
2. Río Piray	1165	5. Río Palacios	1827
Main stream (Santa Cruz - Jct. Río Chané)	1006	Río Palacios (downstream)	391
Others	159	Río Palacios (upstream)	780
3. Río Chané	2271	Arroyo Piquircito	255
Downstream	262	Arroyo Tacuaral	127
Río Pailón	1319	Arroyo Jochi	148
Río Pailón (downstream)	225	Others	126
Río Pailón (mid-upstream	228	6. Río Yapacani	536
Arroyo Qda. Honda	66	Main stream	122
Arroyo los Sauces	363	Arroyo Yapacanicito	371
Others	417	Arroyo Tejena	44
Qda. Chané	466		
Main stream	232	Total	7925
Qda. El Toro	234		
Others	224		

FIG. 5.1.1 RIVER SYSTEM AND DRAINAGE BASIN

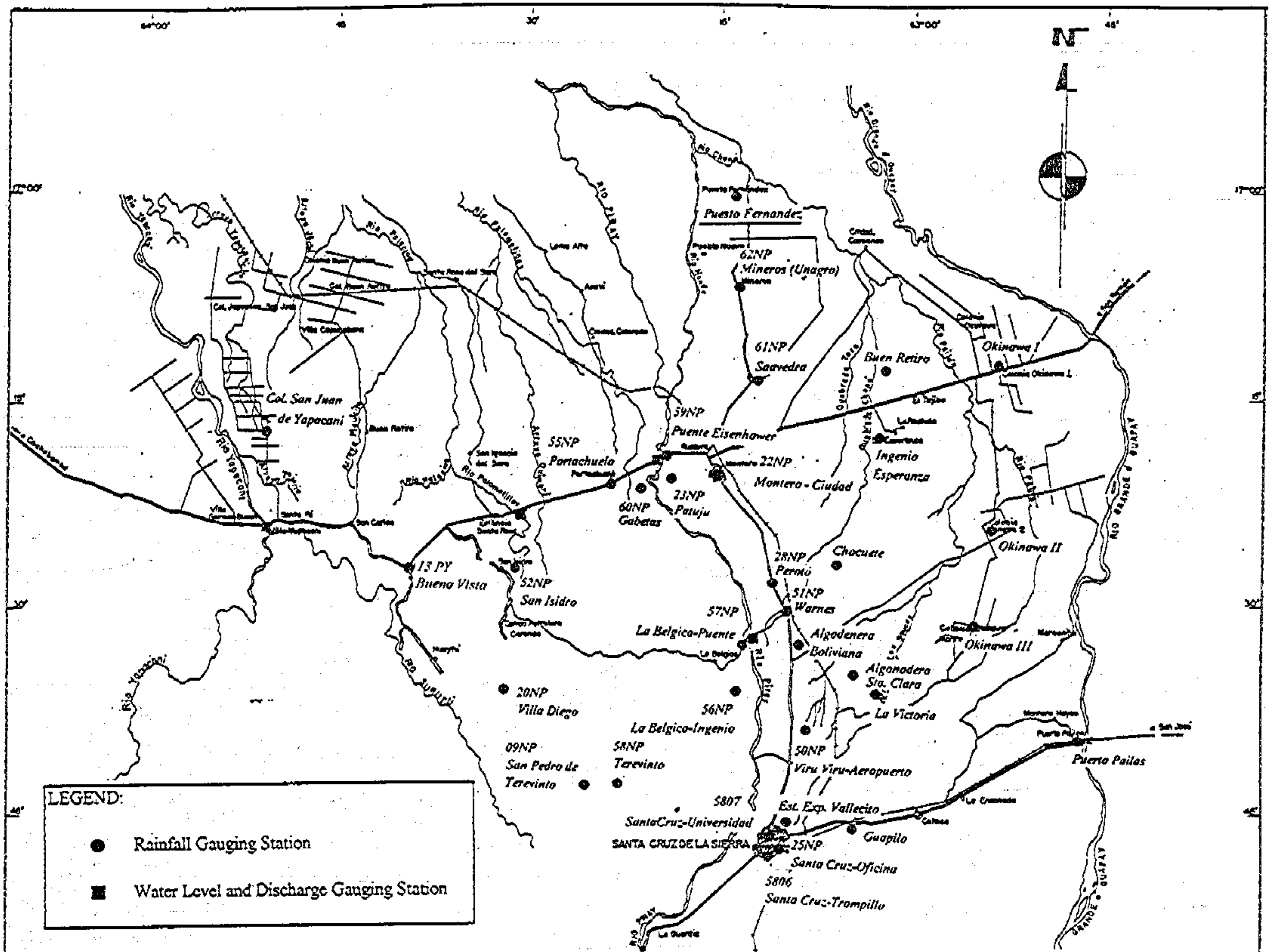


FIG. 5.2.1 NETWORK FOR METEO-HYDROLOGICAL OBSERVATION

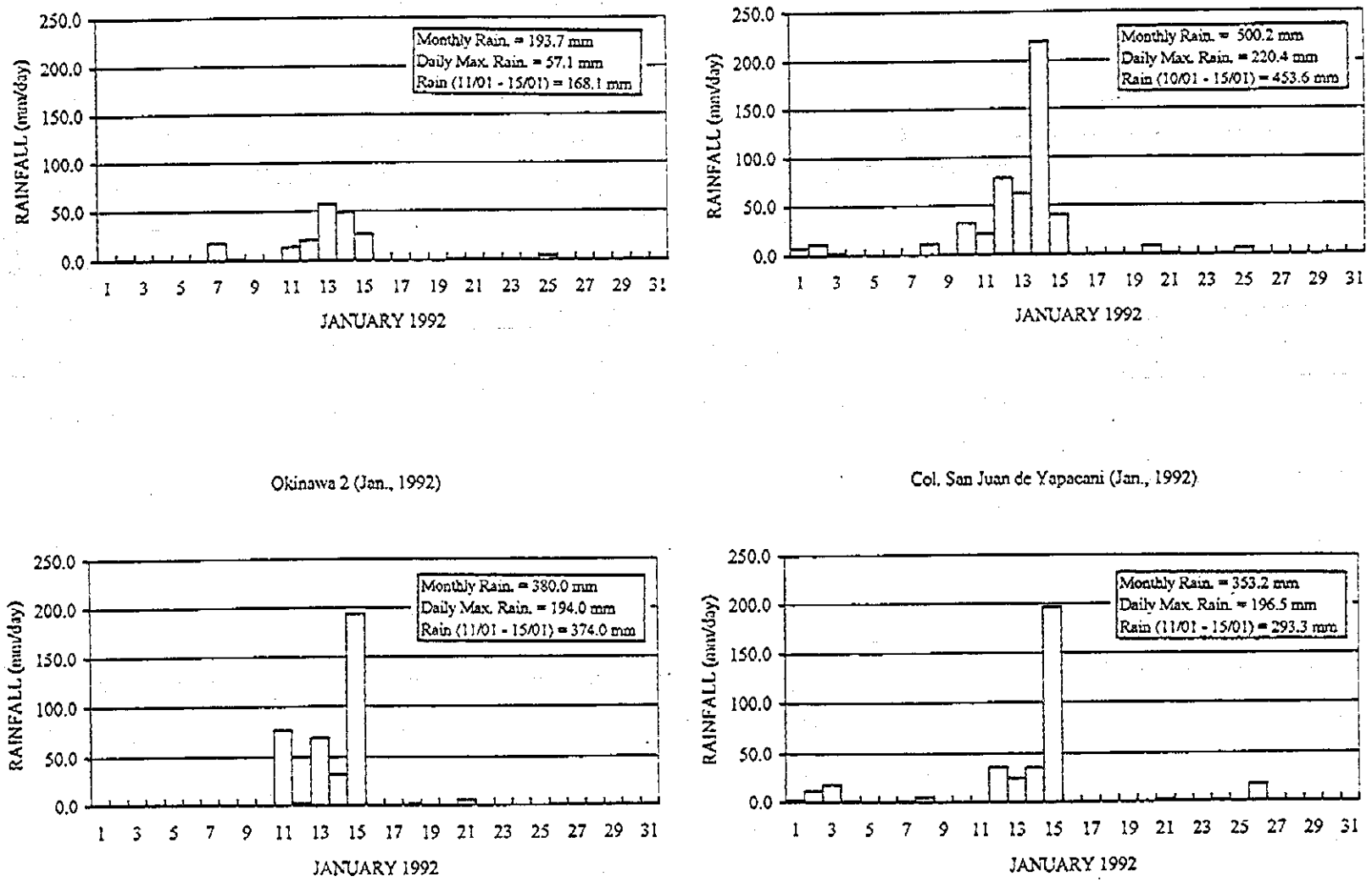


FIG. 5.5.1 DAILY RAINFALL IN JANUARY 1992

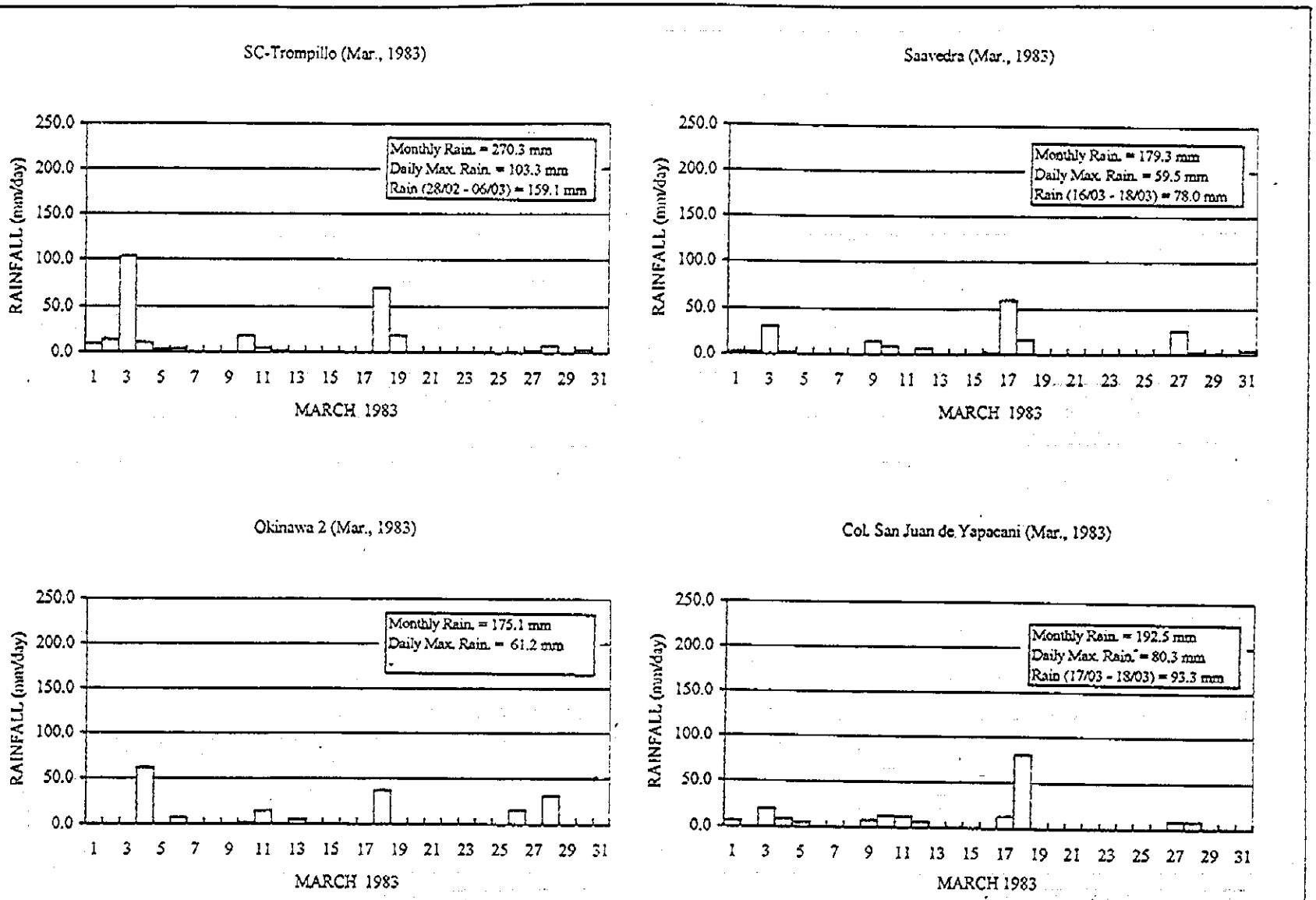
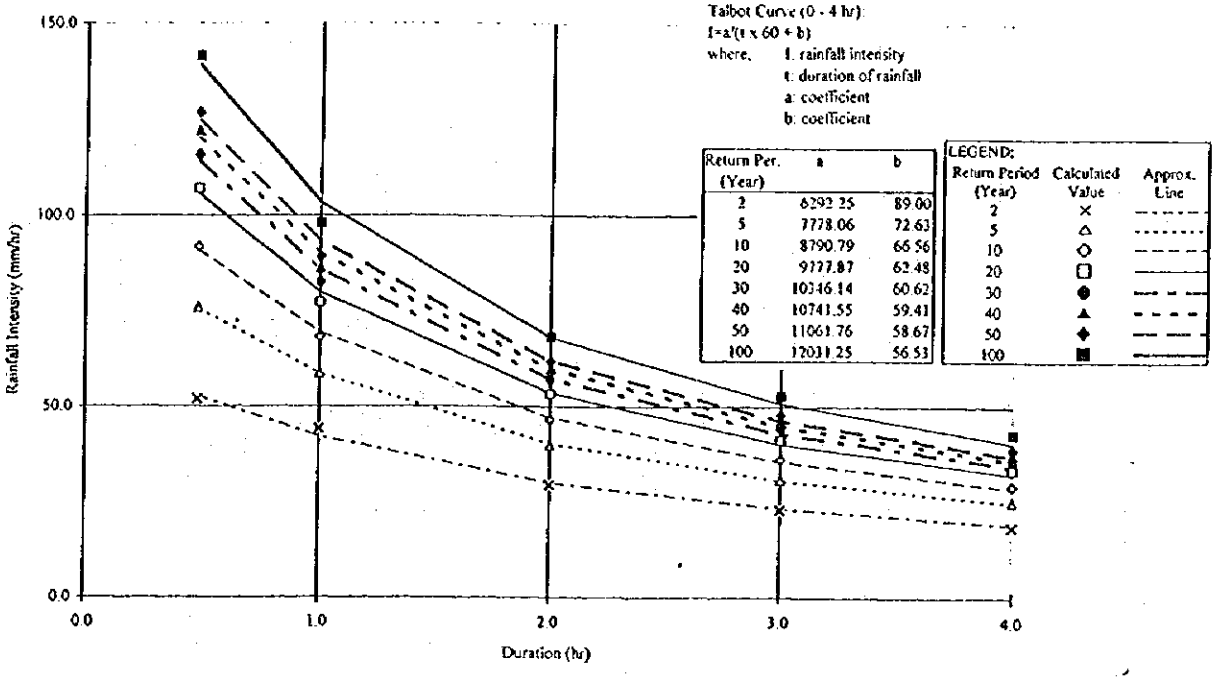


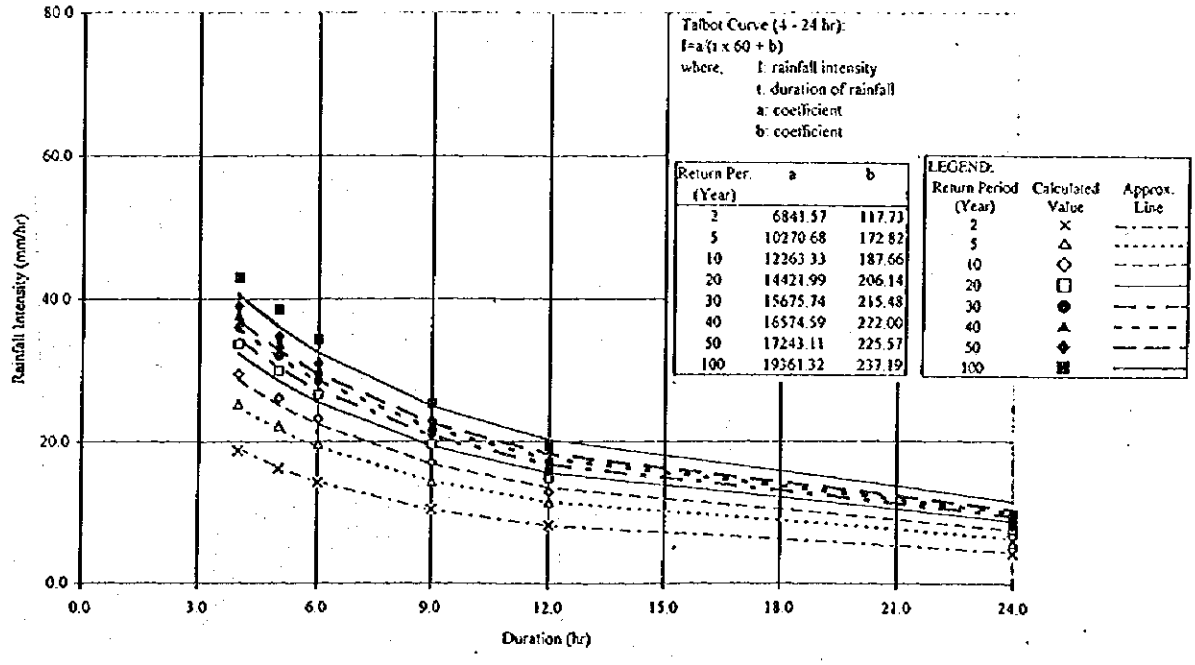
FIG. 5.5.2 DAILY RAINFALL IN MARCH 1983

RAINFALL INTENSITY - DURATION CURVE (0 - 4 HRS)
STATION: SAAVEDRA



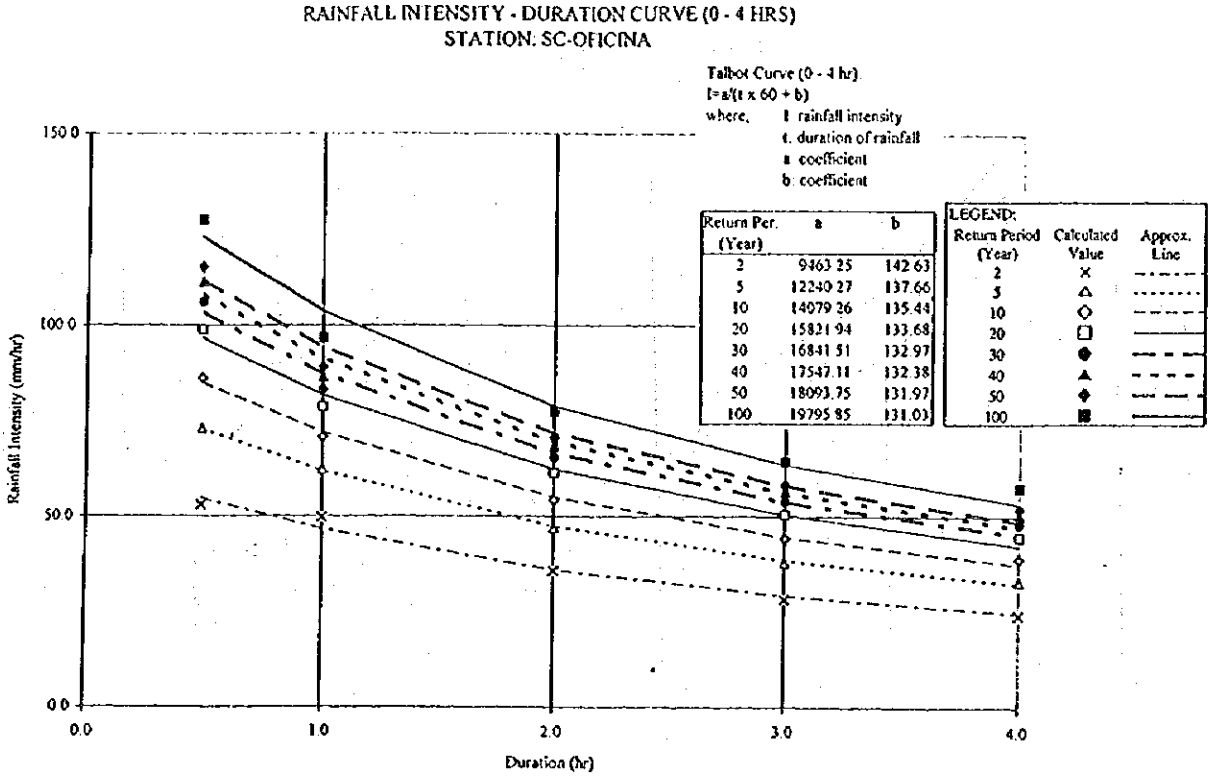
Return Per. (Year)	a	b
2	6292.25	89.00
5	7778.06	72.63
10	8790.79	65.56
20	9777.87	62.48
30	10346.14	60.62
40	10741.55	59.41
50	11061.76	58.67
100	12031.25	56.53

RAINFALL INTENSITY - DURATION CURVE (4 - 24 HRS)
STATION: SAAVEDRA



Return Per. (Year)	a	b
2	6841.57	117.73
5	10270.68	172.82
10	12263.33	187.66
20	14421.99	206.14
30	15675.74	215.48
40	16574.59	222.00
50	17243.11	225.57
100	19361.32	237.19

FIG. 5.5.3 RAINFALL INTENSITY CURVES OF SAAVEDRA



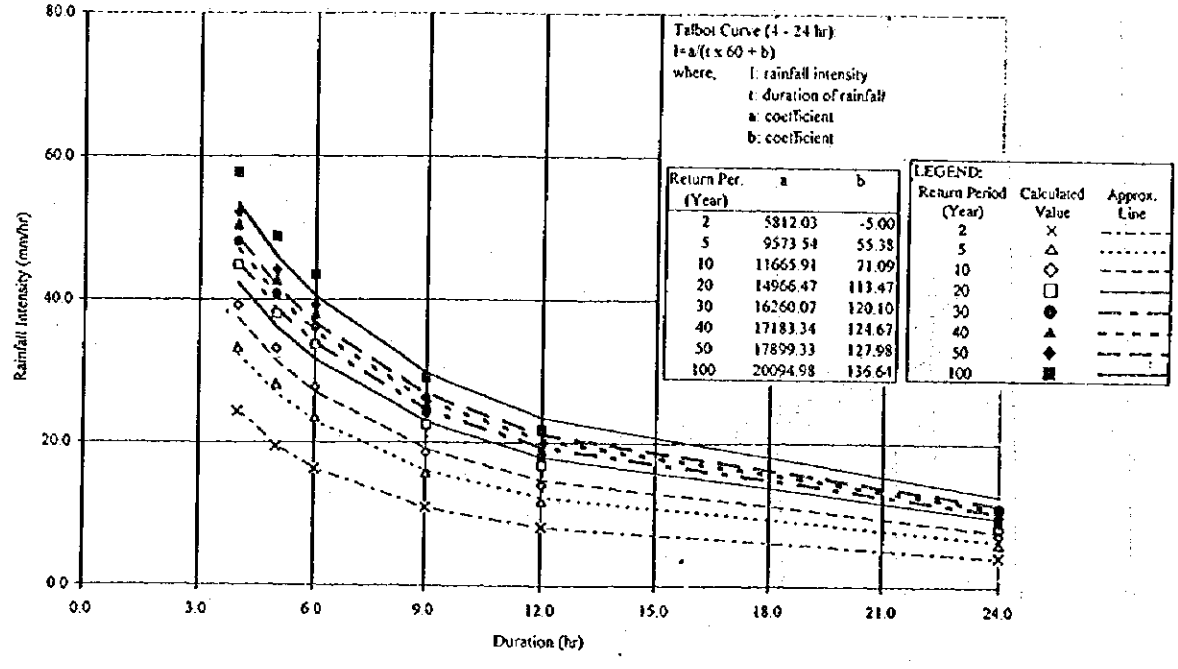
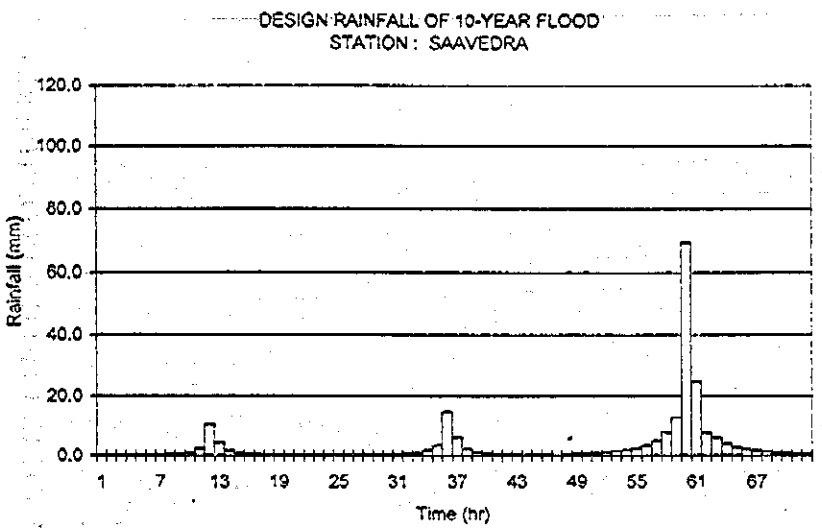
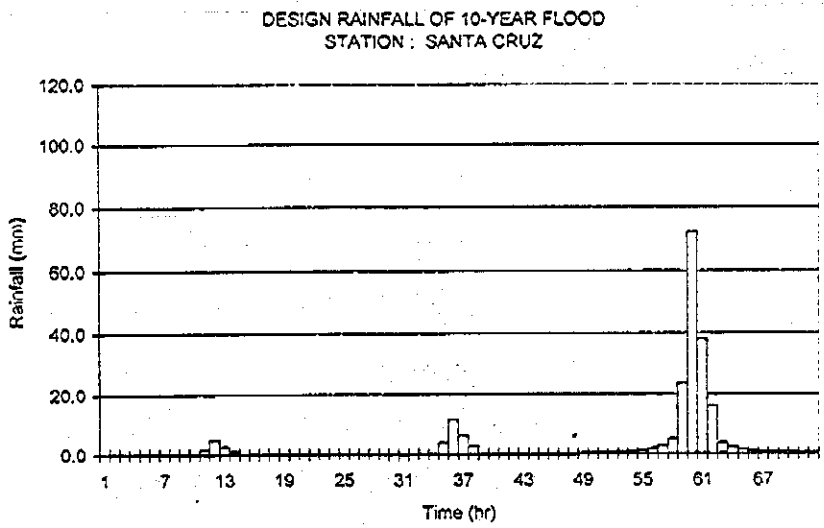
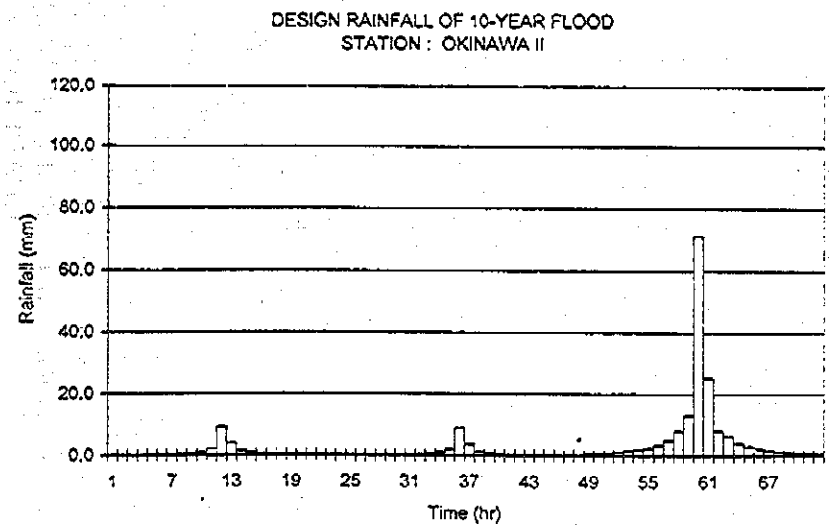


FIG. 5.5.4 RAINFALL INTENSITY CURVES OF SANTA CRUZ - OFICINA







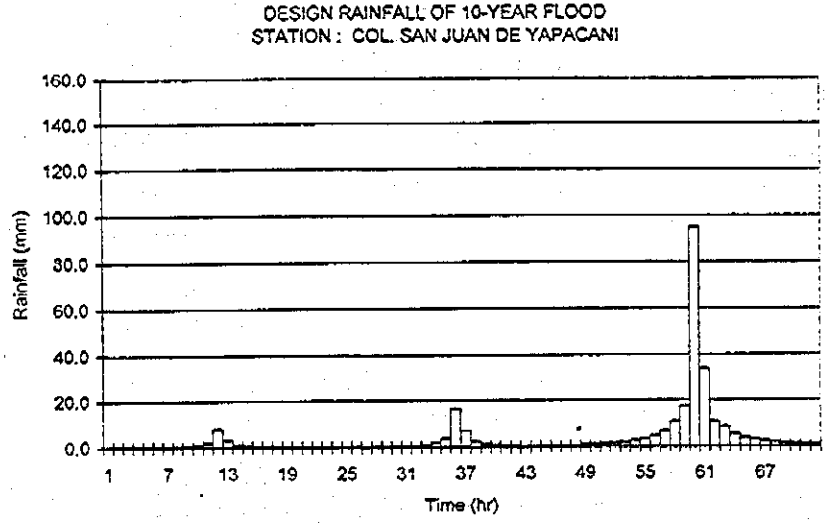


FIG. 5.5.5 DESIGN RAINFALLS FOR 10-YEAR RETURN PERIOD

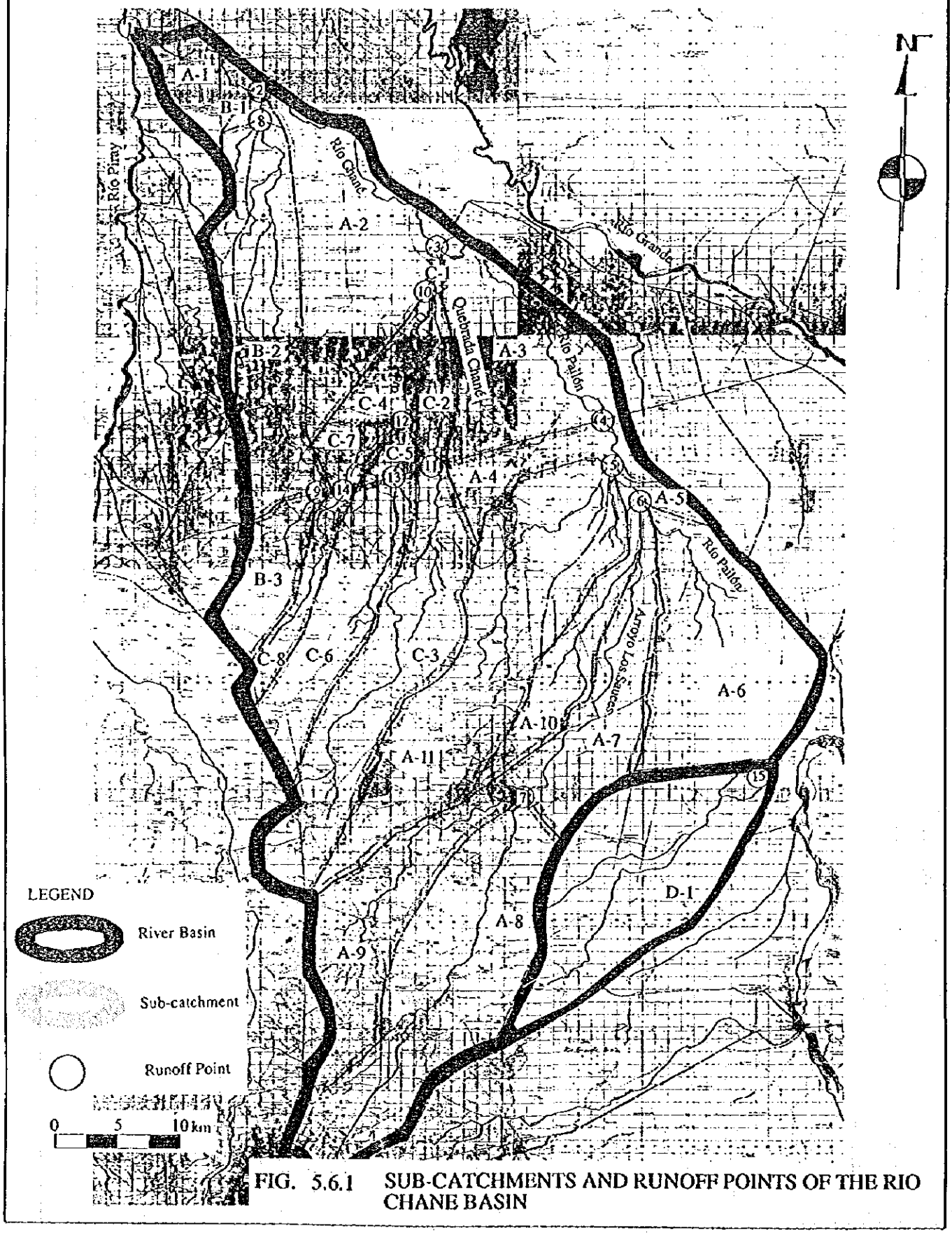


FIG. 5.6.1 SUB-CATCHMENTS AND RUNOFF POINTS OF THE RIO CHANE BASIN

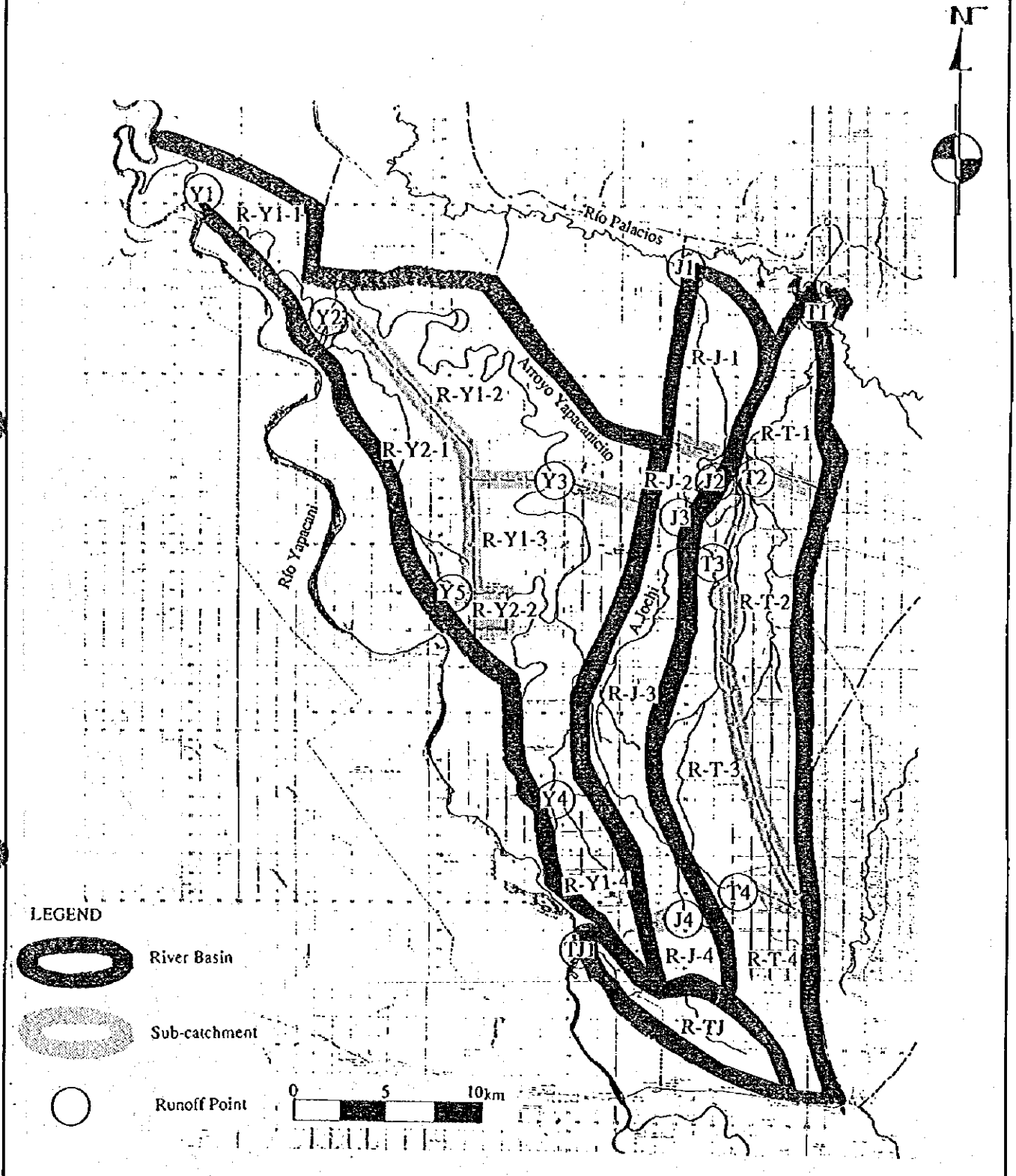


FIG. 5.6.2 SUB-CATCHMENTS AND RUNOFF POINTS OF THE ARROYO YAPACANICITO-JOCHI-TACUARAL-TEJERIA BASINS

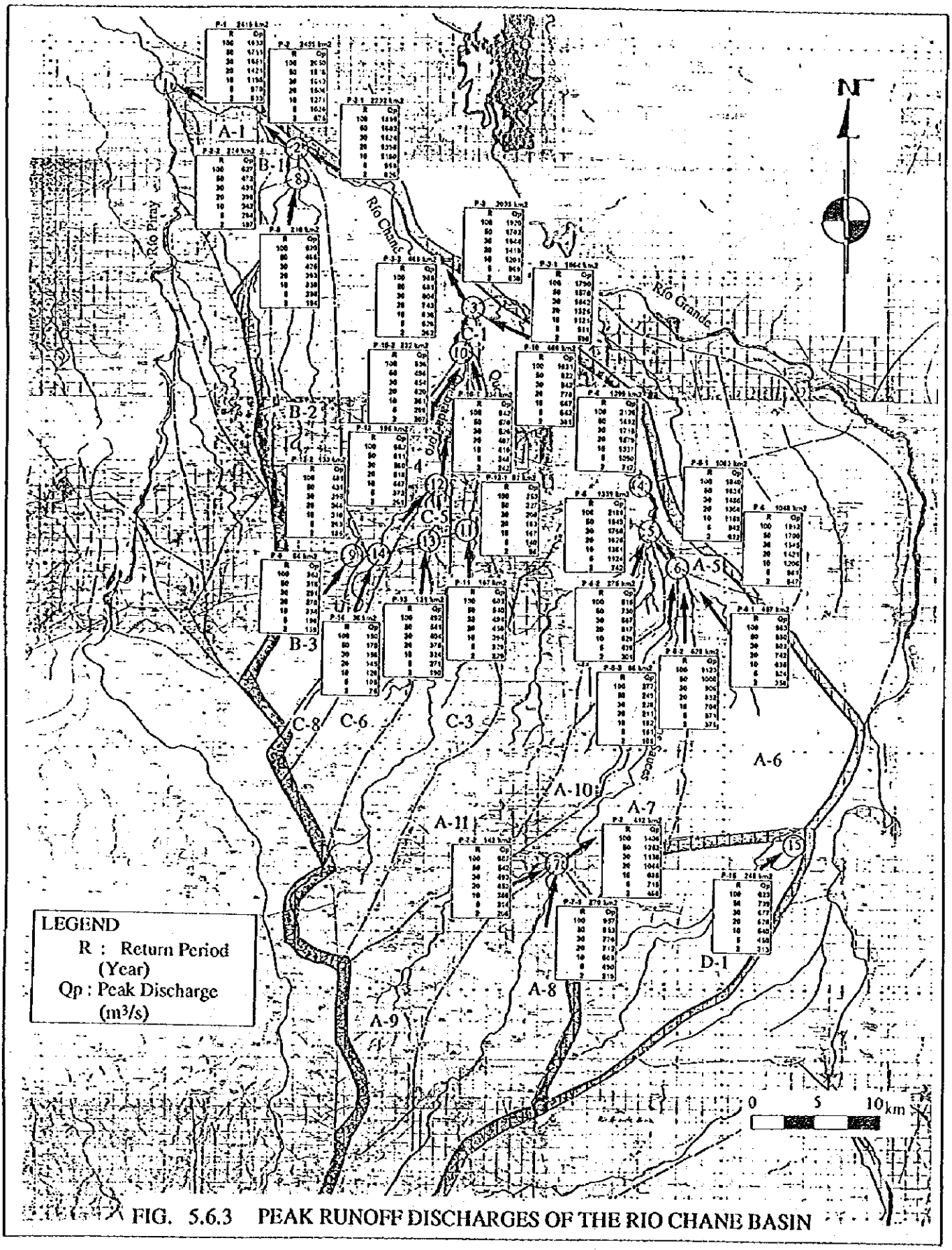


FIG. 5.6.3 PEAK RUNOFF DISCHARGES OF THE RIO CHANE BASIN

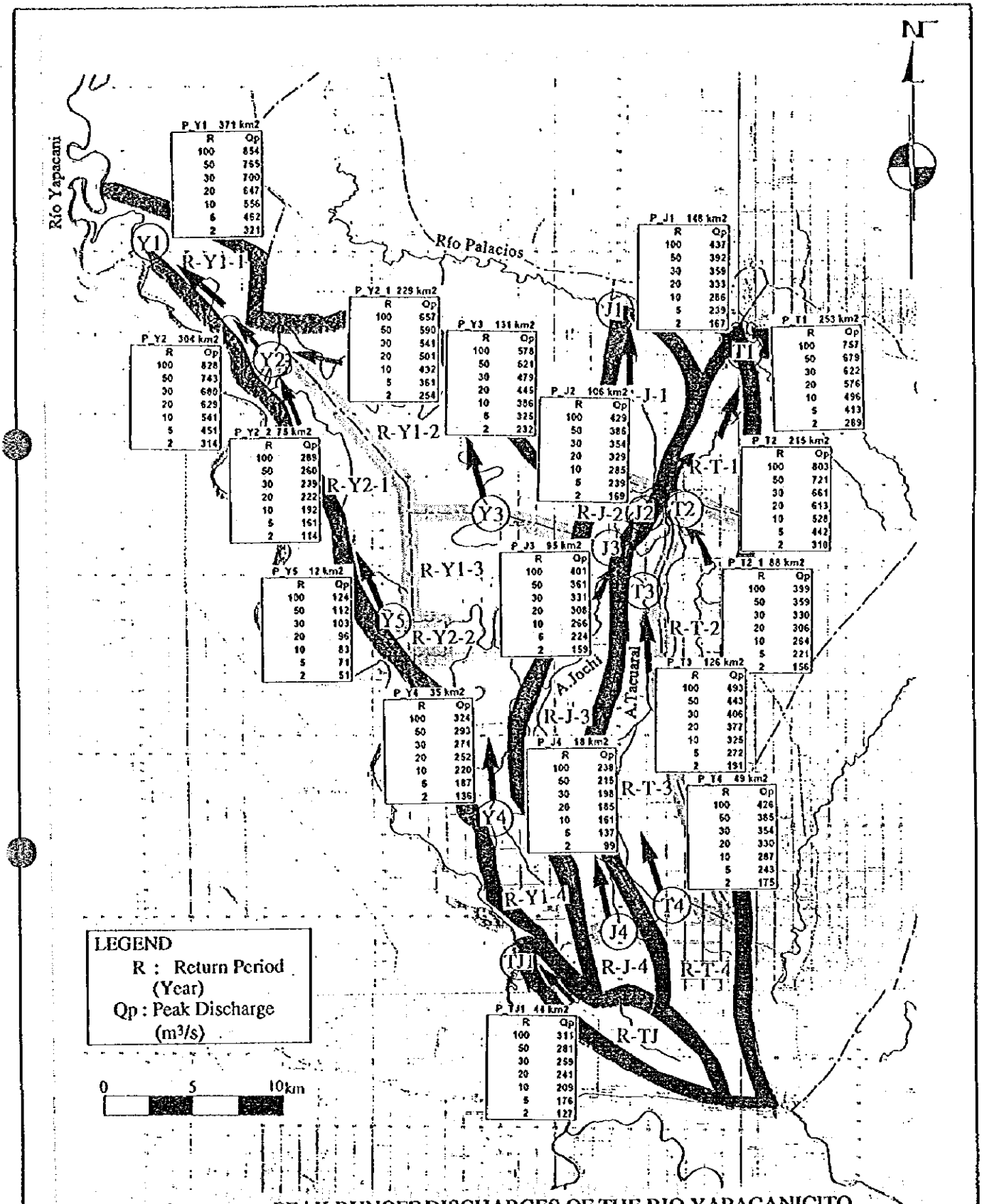
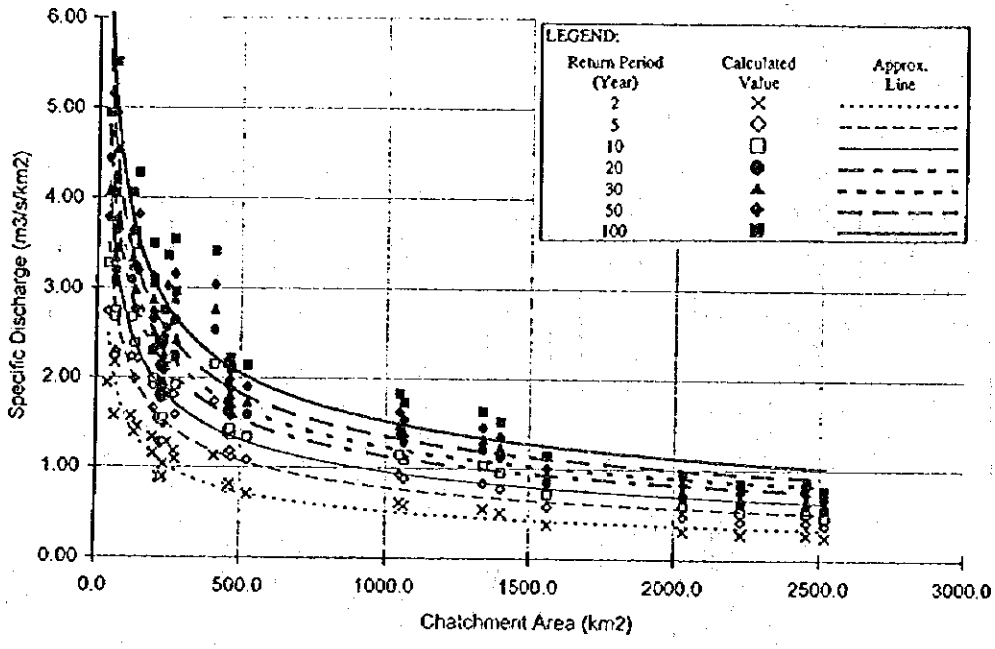


FIG. 5.6.4 PEAK RUNOFF DISCHARGES OF THE RIO YAPACANICITO-JOCHI-TACUARAL-TEJERIA BASINS

SPECIFIC DISCHARGE OF THE RIO CHANE BASIN



SPECIFIC DISCHARGE OF THE ARROYO YAPACANICITO-JOCHI-TACUARAL-TEJERIA BASINS

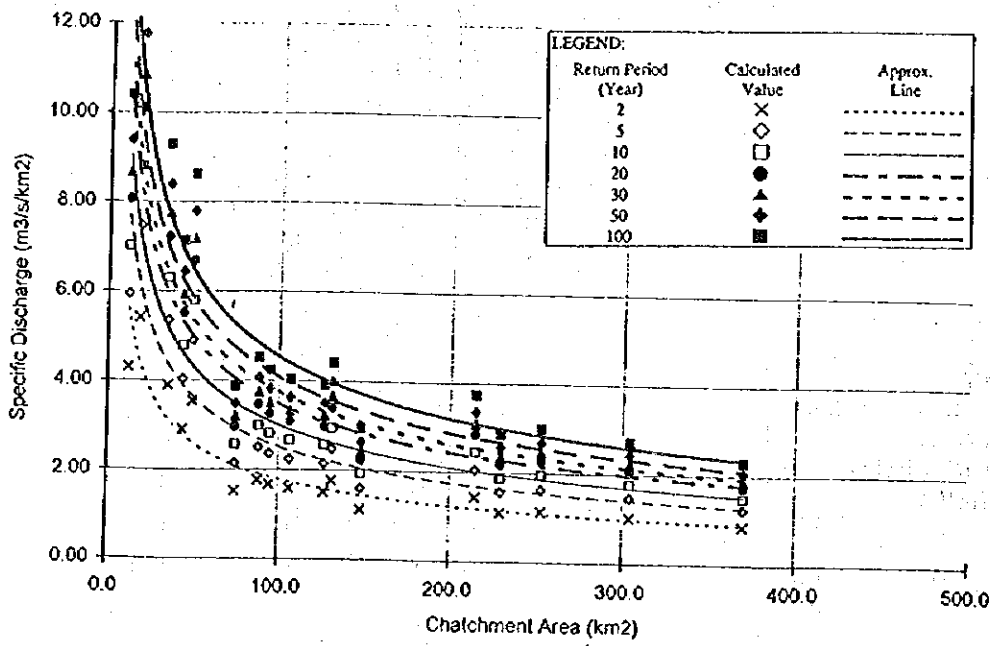


FIG. 5.6.5 SPECIFIC DISCHARGES OF THE RIO CHANE BASIN AND ARROYO YAPACANICITO-JOCHI-TACUARAL-TEJERIA BASINS

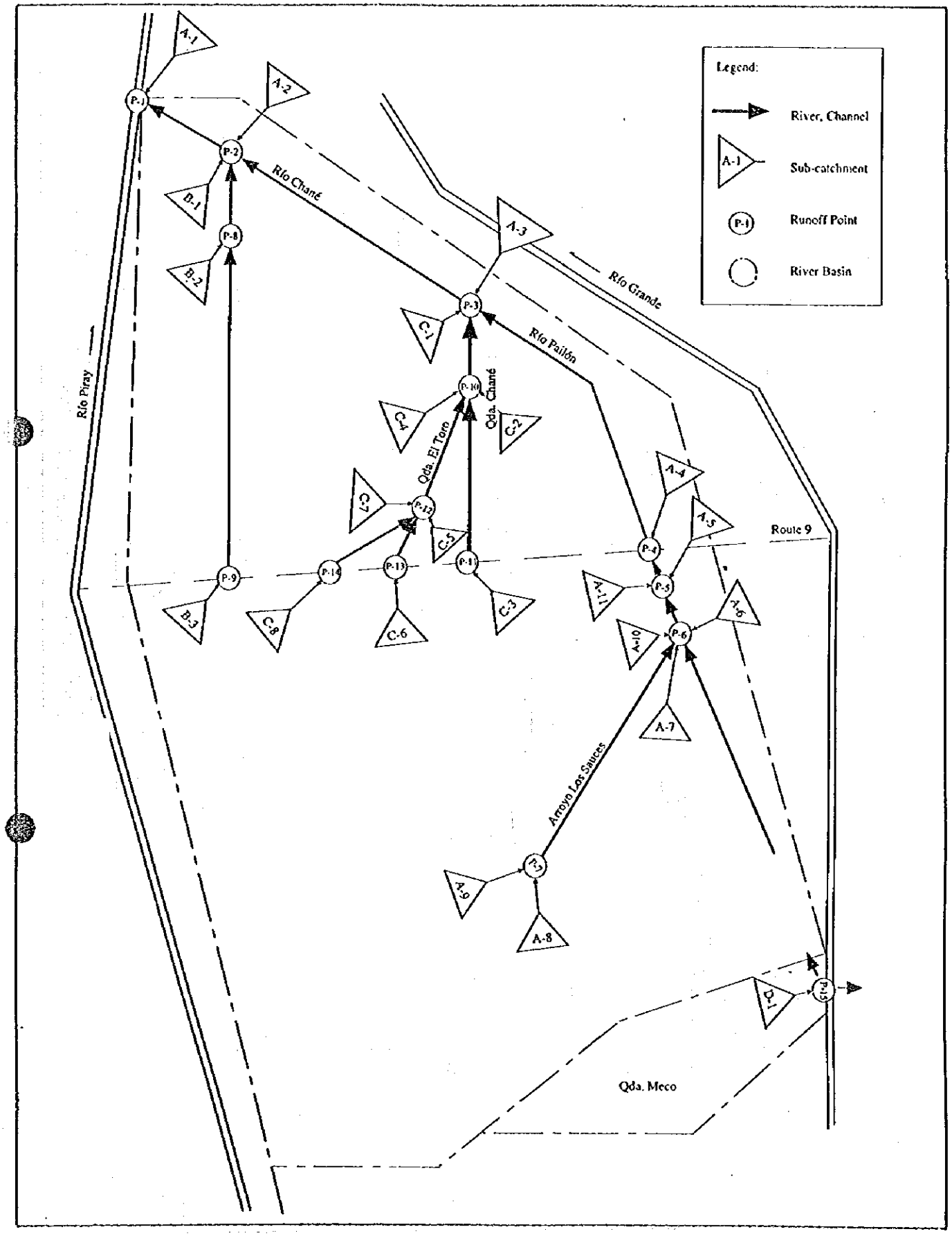


FIG. 5.7.1 MODEL STRUCTURE OF FLOOD ANALYSIS FOR THE RIO CHANE BASIN

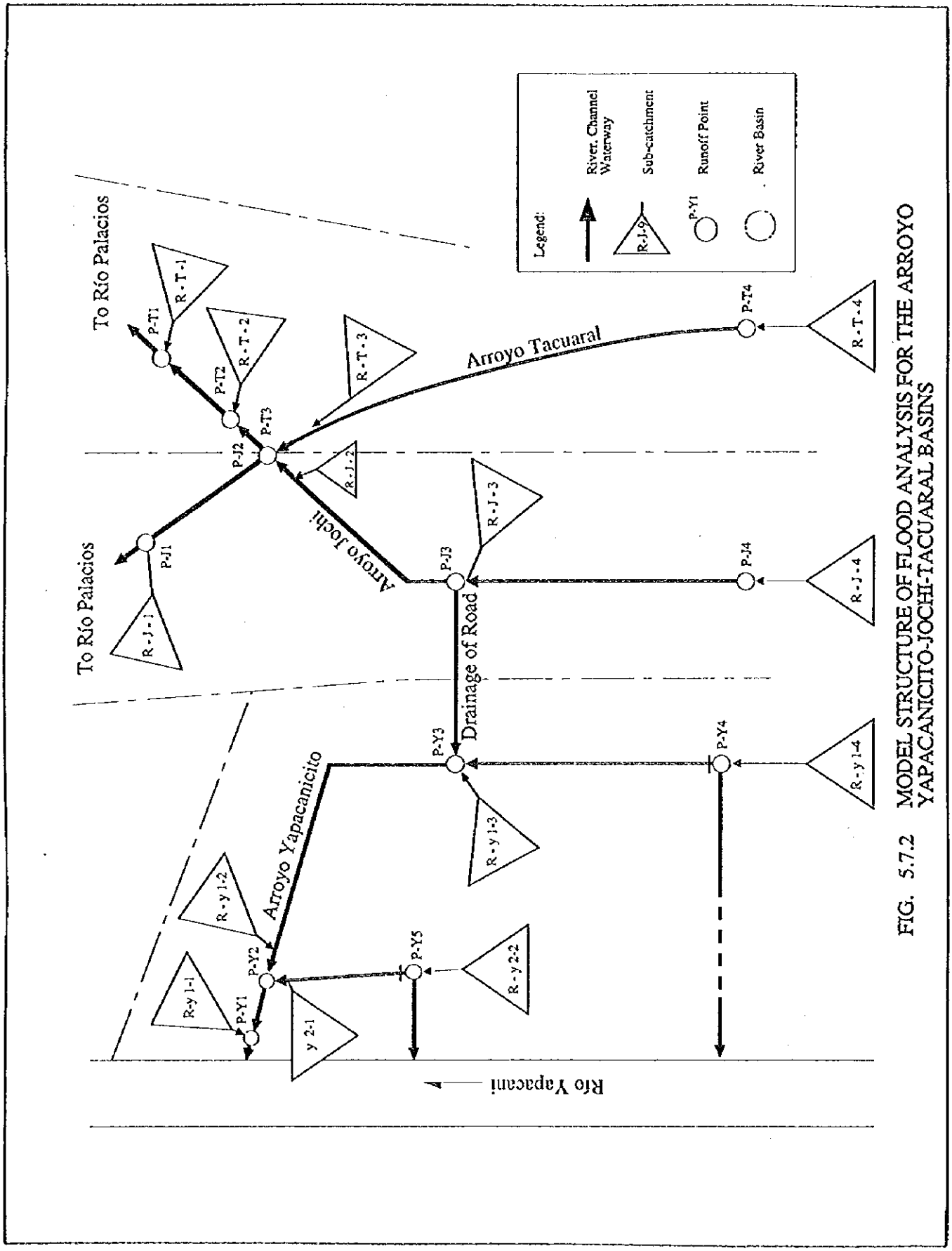


FIG. 5.7.2 MODEL STRUCTURE OF FLOOD ANALYSIS FOR THE ARROYO YAPACANICITO-JOCHI-TACUARAL BASINS

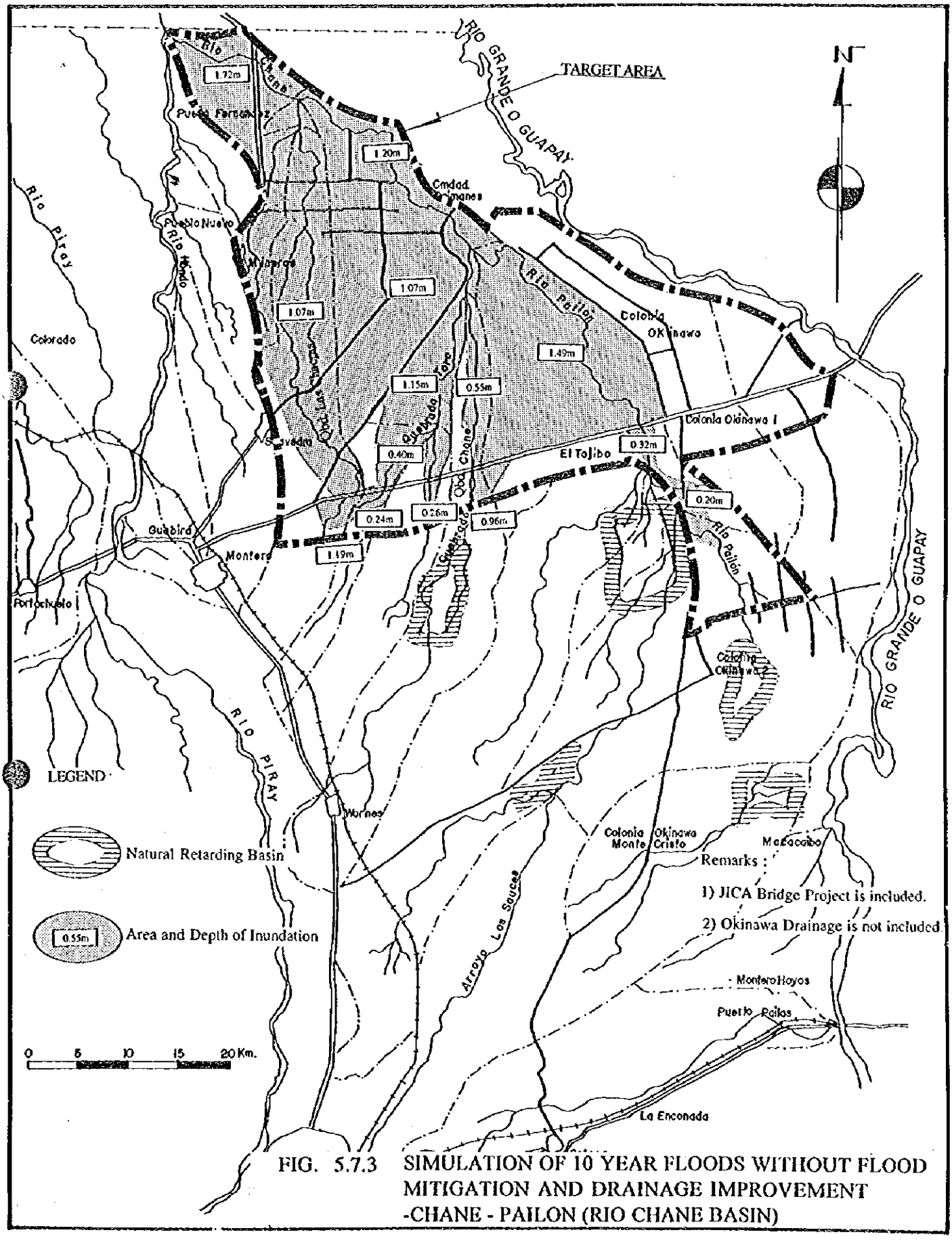


FIG. 5.7.3 SIMULATION OF 10 YEAR FLOODS WITHOUT FLOOD MITIGATION AND DRAINAGE IMPROVEMENT -CHANE - PAILON (RIO CHANE BASIN)

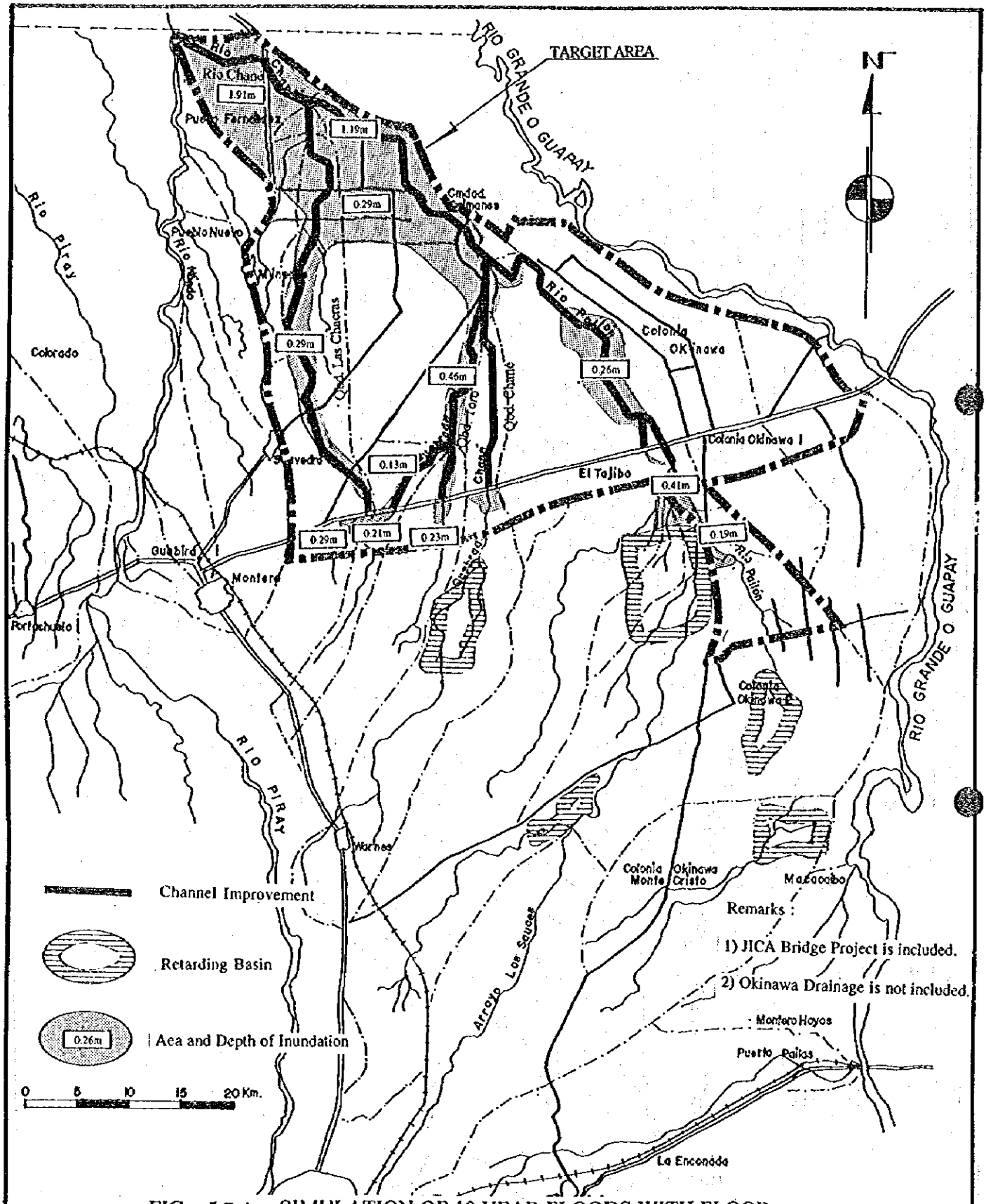


FIG. 5.7.4 SIMULATION OF 10 YEAR FLOODS WITH FLOOD MITIGATION AND DRAINAGE IMPROVEMENT (ALTERNATIVE 1) -CHANE - PAILON (RIO CHANE BASIN)

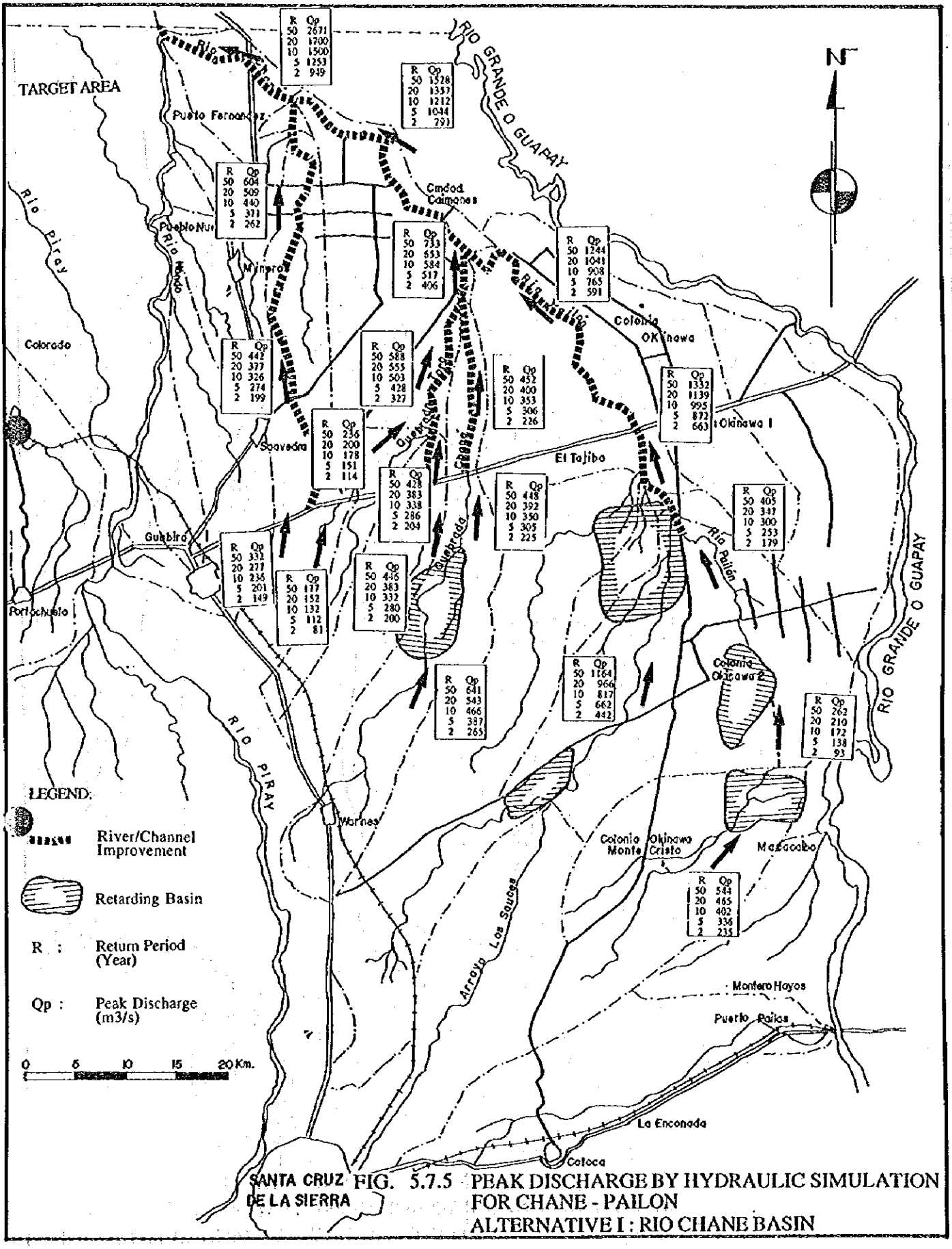


FIG. 5.7.5 PEAK DISCHARGE BY HYDRAULIC SIMULATION FOR CHANE - PAILON ALTERNATIVE I : RIO CHANE BASIN

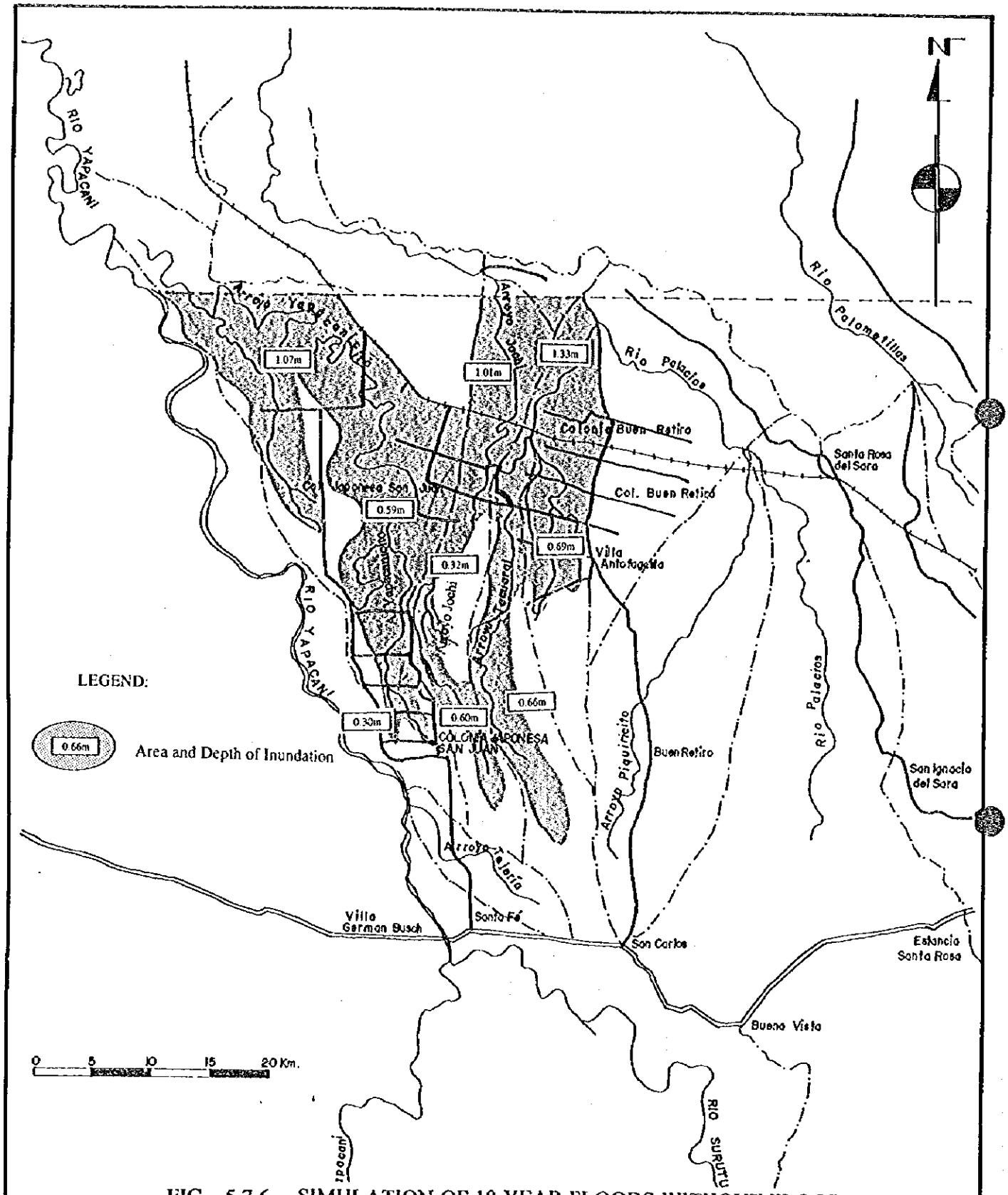


FIG. 5.7.6 SIMULATION OF 10 YEAR FLOODS WITHOUT FLOOD MITIGATION AND DRAINAGE IMPROVEMENT -SAN JUAN - ANTOFAGASTA (ARROYO YAPACANICITO-JOCHI-TACUARAL BASIN)

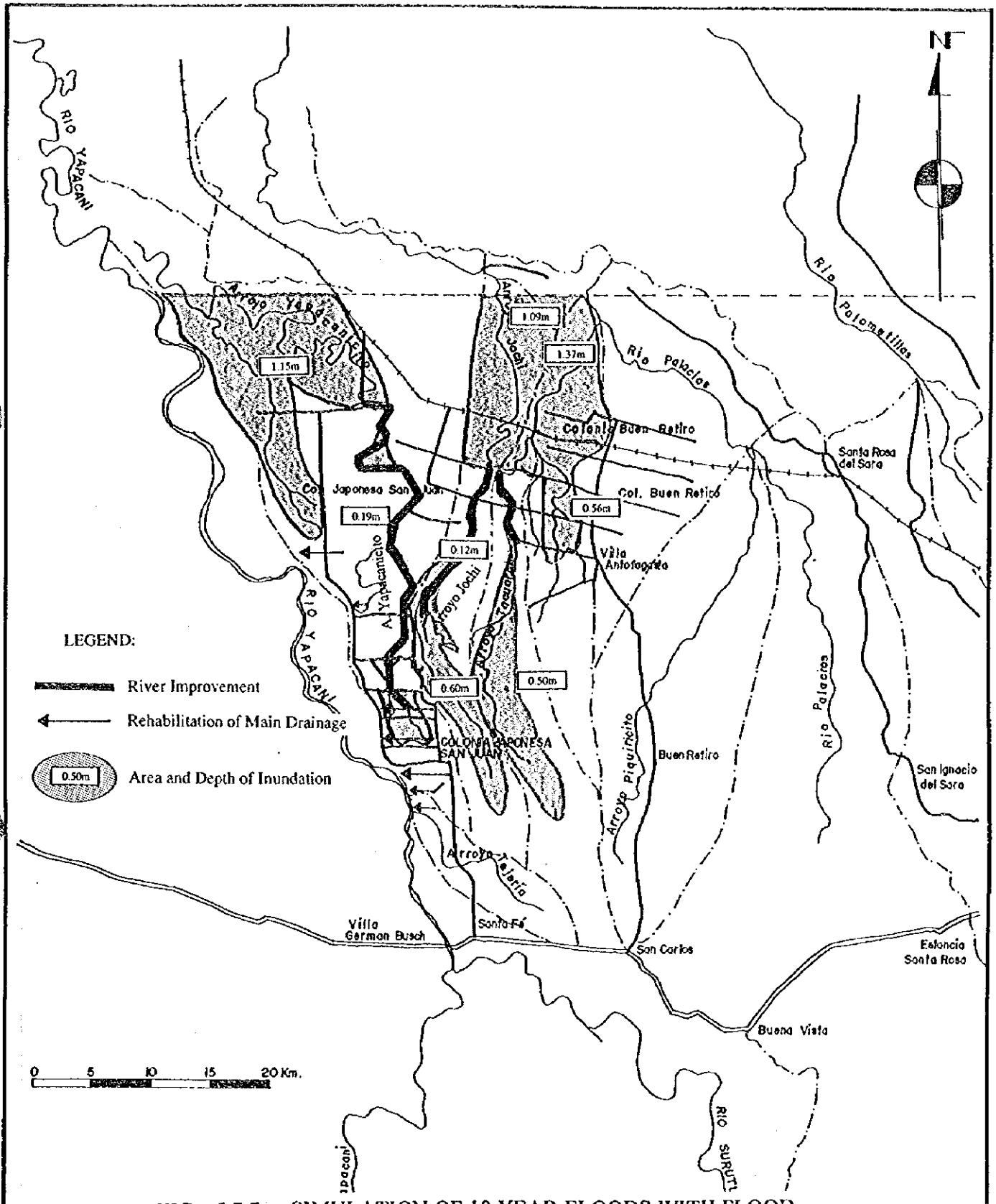


FIG. 5.7.7 SIMULATION OF 10 YEAR FLOODS WITH FLOOD MITIGATION AND DRAINAGE IMPROVEMENT (ALTERNATIVE I) -SAN JUAN - ANTOFAGASTA (ARROYO YAPACANICITO-JOCHI-TACUARAL BASIN)

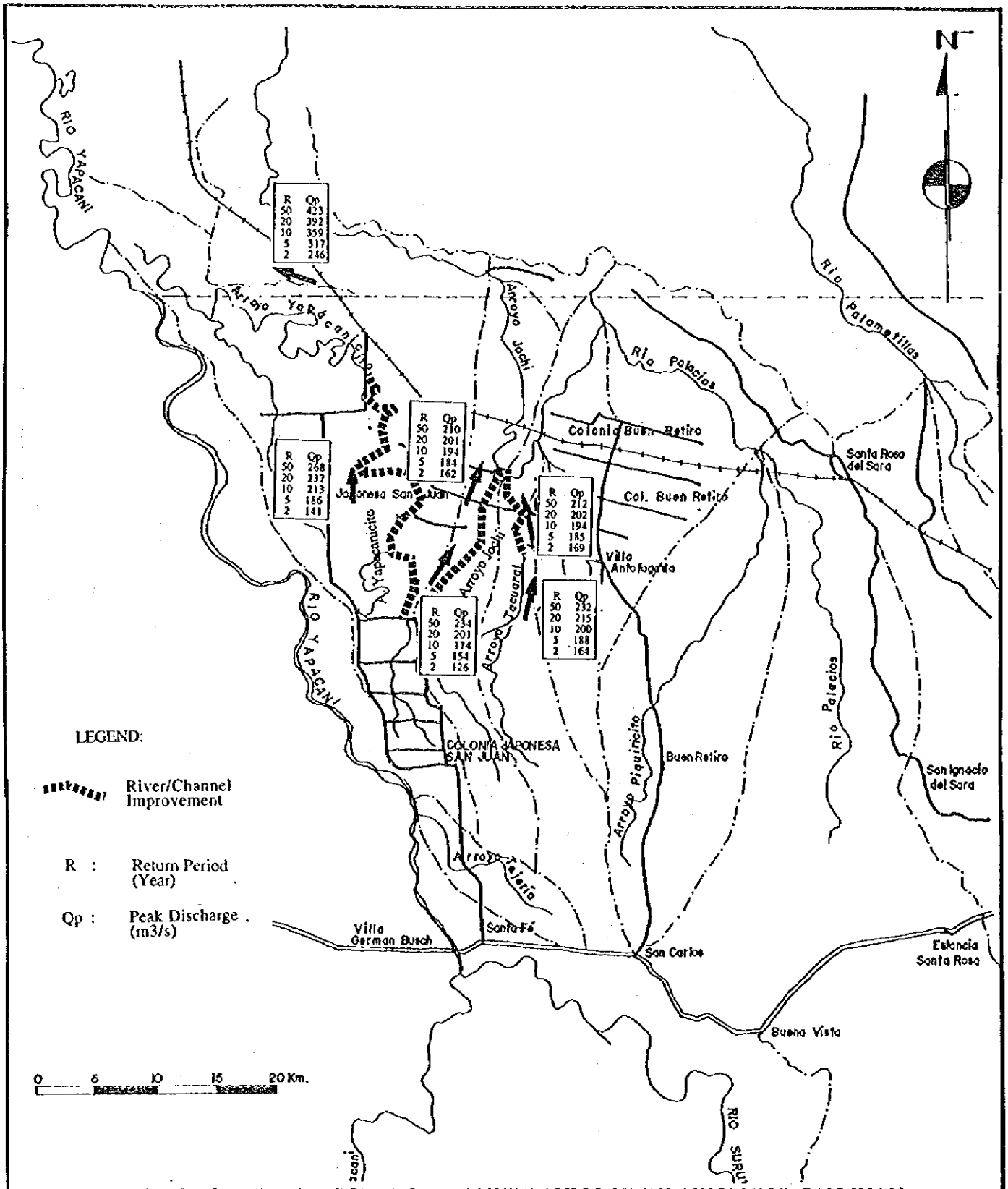


FIG. 5.7.8 PEAK DISCHARGE BY HYDRAULIC SIMULATION FOR SAN JUAN - ANTOFAGASTA - ALTERNATIVE I: ARROYO YAPACANICITO-JOCHI-TACUARAL BASIN

CHAPTER 6
REGIONAL DEVELOPMENT

CHAPTER 6 REGIONAL DEVELOPMENT

6.1 General

Recent development of the study area has started in 1954 when the national road from Cochabamba to Santa Cruz was completed. The population of the Department of Santa Cruz has increased rapidly by migrants from both Altiplano and abroad since 1954. The current population of the Department reached 1.36 million according to the 1992 Census and the city of Santa Cruz has become the second largest city in the country.

The study area stands in a fertile agricultural area and most part of the study area was developed by the first half of 1980s. Currently the development area has been expanding to areas beyond the study area, toward the east side of the Rio Grande, the west side of the Rio Yapacani and the north side of the Rio Chane.

6.2 Development Policy

6.2.1 National Development Policy

The Republic of Bolivia has undertaken "A new Policy for the National Development" with emphasis on Sustainable Development. According to the General Plan for Social and Economic Development (PGDES), formulated by the Ministry of Sustainable Development and Environment, sustainable development is defined as follows:

> "Sustainable development seeks to improve the living standards of all the Bolivians, through a productive change, which require a rational utilization of the human, natural, physical and financial resources, and the institutional and cultural assets, without endangering the fulfillment of needs of the future generation and within the nature's capacity and in a context of social equity and governability."

The sustainable development is based on the following four fundamental pillars:

1) Economic Growth:

A productive transformation that will entitle the country to tackle the tough requirements of competitiveness derived from technological development.

2) Social Equity:

Reduction of social differences and creation of opportunities for citizen's participation in society and the decision-making process, apart from the acknowledgment of cultural diversity and the surmounting of all type of discrimination.

3) Rational Use of Natural Resources:

Conservation of renewable resources, without affecting its regenerative capacity, and the integral profit of non-renewable resources, as well as the preservation of the environment.

4) Governability:

Improvement of the decision-making effectiveness, and the legitimacy of the State and the political system before civil society, in order to perfect democracy.

The objectives and policies of the PGDES are listed as follows:

- A change of the conditions of international insertion,
- Productive transformation,
- Equal opportunities for all the population,
- Improvement of democracy,
- Rational use of natural resources and preservation of the environment,
- A harmonious relation between population and renewable natural resources.

6.2.2 Regional Development Plan

The Regional Development Plan has been prepared by CORDECRUZ in June 1995 based on the objectives and policies of the PGDES. The current Development Plan of the Department has a temporary horizon at medium and long term (up to 10 years). The plan is explained as follows:

(1) Role of the Department

The role of the Department is summarized as follows:

a. To contribute in a significant way to the supply of domestic market with consumption goods, raw materials, intermediate goods, and energy resources.

b. To be the main region for non-traditional exports of the country, at medium term.

c. To contribute absorbing, through the generation of employment, demographic surplus from the depressed regions of the country, which have few development perspectives.

d. To contribute to the expansion and dynamism of the national internal market.

(2) Plan for the land use of the Department (PLUS)

The Plan for the Land Use of the Department of Santa Cruz (PLUS) prepared by CORDECRUZ in 1995 with the target year of 2005, is shown in *Figs. 6.2.1* and *6.2.2*. They are summarized as follows:

Largest units of use	Area (,000km^2)	Share(%)
-Intensive agricultural & cattle raising use	29.6	8
-Limited agricultural & cattle raising use	14.8	4
-Extensive cattle raising use	111.0	30
-Forests for forest use	118.4	32
-Protection and conservation	95.5	25
-Others	3.7	1

Source: CORDECRUZ

(3) Goals and Objectives

The annual national economic growth for the next decade shall be maintained at a rate of 5 % of the GDP for the next decade through an accelerated expansion and greater export diversification. The Department should take an important role to achieve the goals of the national economic growth. The key issue is acceleration of exports of the regional products by stimulating the potential of the Department that includes vast natural resources.

Within this framework, the main sectors that will promote regional economic growth through export acceleration at a short and mid term will be the followings:

a. Mining (the beginning of Precambrian mining),
b. Hydrocarbon (butane exploitation potential),
c. Agriculture/livestock and agroindustrial development,
d. Wood industry,
e. Services related to foreign commerce and transit trade,

f. Manufacturing industries (access to neighboring countries, import raw materials industrialization or assembling of imported parts as spare parts for re-exportation, etc.),

g. Tourism.

(4) Specific policies for the priority sectors

1) Transportation Sector

- Establishment of minimum indispensable access for export,
- Strengthening of the organization for maintenance of roads,
- Establishment of minimum road networks at secondary and tertiary levels,
- Improvement of the existing roads.

2) Agriculture sector

- Encouragement of technological development through research, extension and organizational improvement,
- Improvement of secondary road networks,
- Provision of various measures to get more easy credit, especially for small and medium-scale producers,
- Improvement of farmers' capability and technical level through governmental supporting services.

3) Forestry sector

- Reforestation of the deforested and abandoned areas.

4) Industry sector

- Provision of incentives for investors, such as tax free for the capital,
- Provisions of various measures to get more easy credit,
- Improvement of human capability and technical level through governmental supporting services,
- Promotion of small scale industries and handicrafts.

5) Hydrocarbon sector

- Increase the production of liquid gas for domestic consumption,
- Completion of the gas pipeline (Santa Cruz - Brazil).

6) Mining sector

- Investigation and development of potential areas of mining,
- Strengthening of the governmental supporting to the mining enterprises,
- Conservation of the natural resources in the mining areas,
- Conservation of the native people in the mining areas,
- Provision of infrastructure in the mining areas.

6.3 Population and Settlement

6.3.1 Urban and Rural Development

(1) City of Santa Cruz

The city of Santa Cruz is located in the center of the most dynamic part of the national central development axis of La Paz - Cochabamba - Santa Cruz that has generated an important growth of economic activities especially in the fields of commercial, financial, agriculture and livestock, and industrial sectors, supported by a strong demographic growth.

The city of Santa Cruz has developed rapidly since 1950s. The past population of the city are shown below:

Year	Population	Rate of Increase (%)
1900	15,874	-
1950	42,746	1.99
1976	254,682	7.23
1992	697,278	6.50

The city of the Santa Cruz has prepared "The City Development Master Plan" in 1993. According to the Master Plan, the population of the city of Santa Cruz will become 1.7 millions (by low forecast) to 2.1 millions (by high forecast) in the year of 2010. Accordingly the city boundary of Santa Cruz will be expanded from 5,631 to 62,500 ha in 2010.

The city of Santa Cruz is drained partly to the Rio Chane basin, partly to the Rio Grande and Rio Pirai basins. The expansion of the urban area will affect the runoff of

the Rio Chane basin, because the urban area is located in the upper reach of the Rio Chane.

(2) Other cities in the study area

There are twelve (12) cities that have population more than 2,000 within the study area, other than the city of Santa Cruz. Among them the city of Montero is the largest one, having a population of 57,027, followed with the city of Mineros having 11,181 and the city of Warnes having 10,866 in 1992 as shown in *Table 6.3.1.*

The total urban population was 119,177 in 1992, as shown in *Table 6.3.2.* There are eight (8) municipalities, established by the law of popular participation. In addition to the above municipalities, Santa Fe de Yapacani and Okinawa I are scheduled to become new municipalities.

The acreage of the city areas will be expanded by 2.0 to 2.5 times of the existing urban areas by the year of 2010 according to the estimation based on the municipal maps, their past trends and their population forecasts.

(3) Major Colonies

There are five (5) major colonies in the study area. They are shown in *Fig. 6.3.1* and listed as follows:

1) Okinawa,
2) Aroma,
3) Puesto Fernandez,
4) San Juan,
5) Antofagasta.

These colonies, covering an area of 1,334 ha (19 % of the Study Area), are relatively well developed with basic facilities such as roads and agroindustrial industrial facilities. They play an important role for the production of soybeans, rice, livestock and sugarcane in the study area. Especially the colonia Okinawa and the Colonia San Juan are well organized as economic and social units.

(4) Expansion of the Colonies in the surrounding

In line with the "Export corridor development policy," which is shown in *Fig. 6.3.2*, a number of new large colonies have been developed in the eastern side of the Rio

Grande since 1970s. They have been developed as national and Mennonite colonies. They are shown in *Fig. 6.3.3.*

6.4 Basic Infrastructures

6.4.1 Road Condition of the Study Area

(1) Fundamental Roads in the Region

The total length of road in the Department is 6,974 km that accounts for 15.1 % of the total road length in the country. The Department's road length consists of 1,830 km of fundamental road, 1,368 km of complement road and 3,776 km of district road.

The fundamental road in the Department is relatively developed and well maintained. The city of Santa Cruz acts as the transportation hub in the Department. There are two routes connecting Santa Cruz to Cochabamba. One is the route No. 4 (500 km), opened in 1954 and the other is the route No. 7 (470 km), opened in 1989. The route No. 4 also extends to the Puerto Suares through Cotoca.

Another fundamental road is the route No. 9 extends towards both the northern region and the southern region of the city of Santa Cruz. The northern part of 500 km connects Santa Cruz - Guaira - Rio Grande - San Ramon - Ascencion de Guarayos toward Trinidad in the Department of Beni and the southern part of 460 km connects Santa Cruz - Abapo - Ipati - Boyuibe - Yacuiba in the Department of Tarija. *Fig. 6.4.1* shows the existing major road network of the study area. These roads will have an important function as an essential part of the "Export Corridor connecting the Pacific to the Atlantic" in the future.

(2) Road conditions in the study area

The road length by surface types according to the road map prepared by the Study Team, using the aerial photographs taken in May 1995, is summarized as follows:

a. Asphalt road:	187 km (8%)
b. Gravel road:	808 km (34%)
c. Earth road:	1,354 km (58%)
Total length:	2,349 km (100%)

The fundamental roads have been mostly paved, except the road between Guabira and Okinawa I/the Rio Grande that is to be paved within 2 years along with the construction of seven bridges by JICA.

The rest of the roads are categorized as district road. These roads are mostly not paved or graveled except those of Colonia Okinawa, San Juan and Puesto Fernandez, located at north of Mineros.

The construction and maintenance of district roads have to be carried out mostly by the communities or producers by their own financial resources. Those costs are serious financial problems to the local communities such as the Colonia Okinawa, the Colonia San Juan and the Sugarcane Factories-producer's Association.

6.4.2 Accessibility of the Secondary Roads

(1) Accessible Road Length

The accessibility of each secondary road in the Study Area has been surveyed during the Study. The most part of the earth road is not accessible when it rains for 2 days or more than 50 mm continuously, because of the weak road bed, poor drainage facilities and poor maintenance. The accessible all-weather secondary road throughout a year is less than 40 % of the total length. The following table shows the accessible road length (*Figs. 6.4.2* and *6.4.3*):

Surface condition	Nonnal Year	1992 Flood Year
Good road	935 km (40 %)	846 km (36 %)
Bad road	1,317 km (56 %)	540 km (32 %)
Very bad road	97 km (4 %)	940 km (41 %)

Note:

1. Good: Accessible throughout a year,
2. Bad: Not accessible at least more than one month,
3. Very bad: Not accessible at least more than five months.

The secondary roads play an important role for the transportation of regional products to markets and factories. The poor accessibility of the secondary road is a serious constraint to the transportation of agricultural crops, especially during harvest time.

(2) Transportation and Harvest Periods

Summer soybeans, rice and cotton are the major crops harvested in the rainy season, and sugar cane and winter soybeans are the major crops harvested in the dry season. The harvest calendars of the major crops in the study area were surveyed and shown in *Table 6.4.1*.

The required number of trucks for transportation of the harvest crops were estimated and shown in *Table 6.4.2*. The transportation of sugar cane products occupies the share of 77 % of the product-tons. The transportation period of sugarcane is basically from May to October.

(3) Secondary Road by Canton / Sub-zone

The condition of the secondary roads was assessed on the road density, accessibility, number of dependant inhabitants, land use pattern, etc., and shown in *Fig. 6.4.4*.

6.4.3 Improvement of Secondary Road

The stages of the regional development and the road network development in the Study Area are illustrated in *Fig. 6.4.5* and summarized as the following four stages:

a. 1950s-60s: Exploitation of the Virgin Land (rice, cattle and sugar cane)
b. 1970s-80s: Development of the Large-scale Colonies (sugar cane, cotton and diversification),
c. Now: Expansion to the Surroundings (soybeans),
d. Future: Expansion and Integration.

The Study Area requires to facilitate the central function of various services, such as technical and financial supports, transportation and storage facilities, agro-industrial and manufacturing factories in order to serve the huge hinterland.

In short term, the following parts of the secondary road network should be up-graded or improved from earth surface to gravel or asphalt in order to facilitate a smooth traffic flow to the related productive and populated areas. (*Fig. 6.4.6*):

- From the north end of Okinawa-2 to the north of Warnes (26 km),
- From Okinawa-3 to the industrial park of the city of Santa Cruz (34 km),
- From Okinawa-3 to Cotoca (25 km),
- From Okinawa-3 to Monte Hoyos (16 km).

In mid to long term, the following parts of the secondary road network should be improved or reconstructed:

- From the north end of Okinawa-2 to Mineros (24 km),
- From Mineros to Loma Alta (28 km),
- From Loma Alta to Santa Rosa del Sara (14 km),
- From Santa Rosa del Sara to Antofagasta (18 km),
- From Antofagasta to Colonia San Juan (8 km).

6.5 Inventory of the Agroindustries

The existing agroindustrial factories are mostly located along the fundamental roads (Cotoca - Santa Cruz - Warnes - Montero - Portachuelo). The agroindustrial factories and the industrial parks in the Study Area were surveyed and shown in the *Table 6.5.1* and *Fig. 6.5.1*.

6.6 Flood Mitigation Area

The important facilities, as well as the productive agricultural and livestock fields, shall be protected from floods. They are shown in *Fig. 6.6.1* and summarized as follows:

1) Municipalities and other urban areas, including the future expansion areas,
2) Large scale and well established colonies,
3) Regional main roads and important infrastructure, including agroindustrial factories.

TABLES

TABLE 6.3.1 EXITING AND FUTURE POPULATION OF THE URBAN AREAS IN THE STUDY AREA

Name of urban area	Total Population		Increase	Municipality	Population	Increase	Estimated Population			Assumed Increase Ratio			
	1992	1976	ratio(76-92)		1950	ratio(50-76)	2000	2005	2010	'92-2000	2000-05	2005-10	'92-2010
1 Santa Cruz	697,278	254,682	6.5%	#	42,746	7.1%	1,098,623	1,415,403	1,767,905	5.8%	5.2%	4.5%	5.3%
2 Montero	57,027	28,686	4.4%	#	2,713	9.5%	75,154	87,428	99,559	3.5%	3.1%	2.6%	3.1%
3 Mineros	11,181	6,230	3.7%	#	-		14,140	16,081	17,959	3.0%	2.6%	2.2%	2.7%
4 Warnes	10,866	4,288	6.0%	#	1,581	3.9%	15,795	19,392	23,132	4.8%	4.2%	3.6%	4.3%
5 Portachuelo	9,453	7,059	1.8%	#	2,456	4.1%	10,627	11,330	11,970	1.5%	1.3%	1.1%	1.3%
6 Cotoca	9,229	2,107	9.7%	#	910	3.3%	16,752	23,245	30,818	7.7%	6.8%	5.8%	6.9%
7 Santa Fe de Yapacani	4,029	1,671	5.7%	(#)	-		5,740	6,970	8,235	4.5%	4.0%	3.4%	4.1%
8 San Carlos	3,223	2,021	3.0%	#	-		3,887	4,306	4,703	2.4%	2.1%	1.8%	2.1%
9 Puesto Fernandez	3,196	1,632	4.3%		-		4,186	4,854	5,512	3.4%	3.0%	2.6%	3.1%
10 Santa Rosa del Sara	3,125	2,626	1.1%	#	-		3,350	3,481	3,596	0.9%	0.8%	0.7%	0.8%
11 Saavedra	2,918	2,243	1.7%	#	-		3,242	3,435	3,609	1.3%	1.2%	1.0%	1.2%
12 Okinawa I	2,586	1,006	6.1%	(#)	-		3,781	4,657	5,570	4.9%	4.3%	3.6%	4.4%
13 San Juan de Yapacani	2,344	1,268	3.9%		-		3,000	3,434	3,857	3.1%	2.7%	2.3%	2.8%
TOTAL	816,455	315,519	6.1%	-	50,406		1,258,278	1,604,014	1,986,424	5.6%	5.0%	4.4%	5.1%
TOTAL(excluded Santa Cruz)	119,177	60,837	4.3%	-	7,660		159,655	188,611	218,519	3.7%	3.4%	3.0%	3.4%

Source; Census and JICA estimations

Notes; (#) will be designated for new municipality

The forecast is made that Santa Cruz will have the increase ratios at 90 % up to 2000, 80 % up to 2005 and 70 % up to 2015 of the past increase ratio of 5.8 %(1976-1992), and

The other cities will have the increase ratios at 80 % up to 2000, 70 % up to 2005 and 60 % up to 2015 of the past increase ratio of each cities(1976-1992)

TABLE 6.3.2 THE EXISTING AND FUTURE POPULATION OF THE STUDY AREA BY CANTONS

No.	(Province) Name of Cantons	Population in 1992			Area	Density(p/km2)		Futrure Population			
		Total	Urban	Rural	(km2)	Total	Rural	2000	2010	Urban	Rural
(A. IBAZES)		20,370	9,229	11,141	615	33	18	27,893	41,959	30,818	11,141
1	PALMER DEL ORATORIO	1,928	0	1,928	154	13	13	1,928	1,928	0	1,928
2	COTOCA	14,723	9,229	5,494	295	50	19	22,246	36,312	30,818	5,494
3	MONTERO HOYOS	3,719	0	3,719	166	22	22	3,719	3,719	0	3,719
(WARNES)		38,285	13,452	24,833	2,161	18	11	44,409	53,535	28,702	24,833
4	LOS CHACOS	15,241	2,586	12,655	1340	11	9	16,436	18,225	5,570	12,655
5	WARNES	13,117	10,866	2,251	173	76	13	18,046	25,383	23,132	2,251
6	TOCOMECHI	2,704	0	2,704	151	18	18	2,704	2,704	0	2,704
7	JUAN LATINO	818	0	818	43	19	19	818	818	0	818
8	AZUSAQUI	3,150	0	3,150	151	21	21	3,150	3,150	0	3,150
9	CHUCHIO	3,255	0	3,255	303	11	11	3,255	3,255	0	3,255
(ICHILO)		22,065	9,596	12,469	1,550	14	8	25,096	29,264	16,795	12,469
10	BUENA VISTA	1,229	0	1,229	75	16	16	1,229	1,229	0	1,229
11	SAN JAVIER	325	0	325	54	6	6	325	325	0	325
12	SAN CARLOS*1)	20,511	9,596	10,915	1,421	14	8	23,542	27,710	16,795	10,915
(SARA)		21,684	12,578	9,106	1,182	18	8	23,083	24,672	15,566	9,106
13	PALOMETAS	2,920	0	2,920	366	8	8	2,920	2,920	0	2,920
14	PORTACHUELO	10,584	9,453	1,131	272	39	4	11,758	13,101	11,970	1,131
15	SAN IGNACIO DE SARA	1,859	0	1,859	166	11	11	1,859	1,859	0	1,859
16	SANTA ROSA DEL SARA	6,321	3,125	3,196	378	17	8	6,546	6,792	3,596	3,196
(O. SANTISTEVAN)		95,358	74,322	21,036	1,659	57	13	117,758	147,675	126,639	21,036
17	GRAL A. SAAVEDRA	11,639	2,918	8,721	504	23	17	11,963	12,330	3,609	8,721
18	MONTERO	58,569	57,027	1,542	275	213	6	76,696	101,101	99,559	1,542
19	MINEROS*2)	25,150	14,377	10,773	880	29	12	29,099	34,244	23,471	10,773
STUDY AREA TOTAL		197,762	119,177	78,585	7,167	28	11	238,239	297,105	218,520	78,585

Notes; *1) San Carlos, Santa Fe and San Juan and *2) Mineros and P. Fernandez

Source; Census and JICA Estimation

TABLE 6.4.1 TRANSPORTATION AND HARVEST PERIODS

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Seasons	Rain season			Dry season						Rain season		
Heavy rains in the Past	23%	8%	8%	8%	15%	8%	4%	4%	0%	4%	12%	12%
Rain fall(m/m) 1974-'84	227	176	132	99	105	75	56	55	73	110	140	208
Rain days(1974-'84 av.)	14	12	11	8	9	7	5	4	14	7	9	12
1992 data(mm/month)												
Santa Cruz	194	314	115	414	184	133	47	100	234	71	149	296
La Belgica	343	335	138	392	207	82	28	90	210	123	128	477
Saavedra	500	340	182	349	191	62	25	124	239	68	138	490
Mineros	391	348	242	331	208	46	14	91	282	68	162	364
Okinawa II	380	393	98	291	194	52	4	80	215	50	140	362
Portachuelo	361	445	128	371	232	102	21	84	243	118	90	436
San Ishidro	463	432	202	512	283	141	53	147	244	119	185	539
San Juan	353	474	265	421	334	180	48	119	182	87	146	555
Total average	373	385	171	385	229	100	30	104	231	88	142	440
SUMMER CROPS												
Maize				(Manual)								
Rice	(Spring)		(Summer)									Rice
Cotton										Cotton		
Potatos							(Winter)				(Winter)	
WINTER CROPS												
Sorghum			(Summer)					(Winter)				
Wheat								(V.Misoter.)				
Sanflower												
Soy beans				(Summer)					(Winter)			
Col. San Juan	Rice										Soy beans	
				Soy beans								
Col. Okinawa			Soy beans/Rice					Soy beans				
Sugar Mill Factories					Sugar Cane							

TABLE 6.4.2 AGRICULTURAL PRODUCTION AND TRANSPORTATION LOAD

Major crops	Santa Cruz Department					Study Area				
	Harvest(ton)	share	No. of trucks	Area(ha)	ton/ha	Harvest(ton)	share	No. of trucks	Area(ha)	ton/ha
Cotton seed	133,000	4%	17,733	19,000	7.0	2,589	0%	345	5,090	1
Rice	193,000	6%	25,733	96,500	2.0	138,700	7%	18,493	69,350	2
Maize	270,300	8%	36,040	85,000	3.2	42,830	2%	5,711	11,900	4
Soy beans(W)	133,500	4%	17,800	89,000	1.5	132,000	6%	17,600	88,000	2
Soy beans(S)	592,900	17%	79,053	242,000	2.5	135,491	6%	18,065	57,265	2
Sugar cane	1,844,000	53%	245,867	64,354	28.7	1,647,036	77%	219,605	57,468	29
Others	326,243	9%	43,499	161,050	2.0	30,115	1%	4,015	22,840	1
TOTAL	3,492,943	100%	465,726	756,904	4.6	2,128,761	100%	283,835	311,913	7

Notes; Average traffic volume will be 1,280 trucks for the Department and 780 trucks in the Study Area per day.
Average traffic volume of sugarcane transport will be more than 1,360 trucks during harvest-delivery period(May-October)in the Study Area.
Tons of truck is set at 7.5 tons

Source: JICA Study Team

TABLE 6.5.1 NUMBER OF AGROINDUSTRIAL FACTORIES IN THE STUDY AREA

Agro-Industries	Santa Cruz *1)	Cotoca	Warnes	Montero	Portachuelo	Minero	Santa Fe	San Carlos	San Juan	Santa Rosa	Buena Vista	Saavedra	Okinawa	Total
Beverage factory	0	0	0	2	0	0	0	0	0	0	0	0	0	2
Cheese factory	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Chocolate factory	0	0	0	0	0	0	0	0	0	1	3	0	0	4
Coffe Mill	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Corn mills	0	0	0	3	0	0	0	0	0	0	0	0	0	3
Cotton gin	1	0	2	4	0	0	0	0	0	0	0	0	0	7
Edible oil	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Feeding animal	1	0	0	0	1	0	0	0	0	0	0	0	0	2
Grain collector	1	1	2	1	0	1	0	0	0	0	1	0	0	7
Milk factory	0	1	2	0	0	0	0	0	0	0	0	0	0	3
Milk Collecting Place	0	1	3	2	1	1	0	1	0	0	0	1	6	16
Noodle factory	0	0	0	3	0	0	0	0	0	0	0	0	0	3
Pig farm	6	0	1	0	1	1	0	0	0	0	0	0	0	9
Poultry farms	0	1	10	0	0	0	0	60	118	0	0	0	0	189
Rice mill/peeler	1	0	2	60	12	3	4	6	15	0	5	0	1	109
Saw mill	9	0	1	4	0	0	0	8	0	0	4	0	0	26
Seed factory	0	0	2	2	0	0	0	0	0	0	0	0	0	4
Slaugther house	1	2	1	2	1	0	0	0	0	0	1	0	0	8
Sugar mill	0	0	0	1	0	1	0	0	0	0	0	0	0	2
TOTAL	20	6	27	84	16	7	4	75	133	1	16	1	7	397

Note: *1) Santa Cruz agro-industries located in km 5 from SCZ to Warnes

Source: Guia Rural 1995- Plan de Desarrollo GTZ 1994-1999, and each municipalities