社会開発調査部報告書

No. 52

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

MINISTRY OF SUSTAINABLE DEVELOPMENT AND PLANNING
DEPARTMENT OF SANTA CRUZ
REPUBLIC OF BOLIVIA

THE FEASIBILITY STUDY ON FLOOD CONTROL IN THE NORTHERN RURAL REGION OF SANTA CRUZ IN THE REPUBLIC OF BOLIVIA

FINAL REPORT

SUPPORTING REPORT

JUNE 1999

PACIFIC CONSULTANTS INTERNATIONAL,TOKYO

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

MINISTRY OF SUSTAINABLE DEVELOPMENT AND PLANNING
DEPARTMENT OF SANTA CRUZ
REPUBLIC OF BOLIVIA

THE FEASIBILITY STUDY ON FLOOD CONTROL IN THE NORTHERN RURAL REGION OF SANTA CRUZ IN THE REPUBLIC OF BOLIVIA

FINAL REPORT

SUPPORTING REPORT

JUNE 1999

PACIFIC CONSULTANTS INTERNATIONAL,TOKYO

The cost estimate was made based on prevailing market price in August 1998 and expresses in Bolivianos according to the following exchange rate.

US$ 1.00 = Bs. 5.50 = Yen 117.00

(As of August, 1998)

TABLE OF CONTENTS

ABBREVIATION

ALEM:	Alemania
B/C:	Benefit-Cost Ratio
BID:	Interamerican Development Bank (Banco Interamericano de Desarrollo)
CAICO:	The Okinawa Colony Integrated Agriculture and Livestock Cooperation (Cooperativa Agropecuaria Integral Colnias Okinawa Ltda.)
CAISY:	San Juan of Yapacani Integrated Agriculture and Livestock Cooperation (Cooperativa Agropecuaria Integral San Juan de Yapacani Ltda.)
CAF:	Andian Development Cooperation (Corporacion Andina de Fomento)
CAO:	Oriental Chamber of Agriculture and Livestock (Camara Agropecuaria del Oriente)
CDDC:	Department Civil Defence Committee
CETABOL:	Agriculture and Livestock Technical Center in Bolivia (Centro Tecnologico gropecuario en Bolivia)
CIF:	Cost, Insurance and Freight
CIPCA:	Investigation and Promotion Center for Farmer (Centro de Investigation y Promocion del Campesino)
COD:	Joint Operation Center
COED:	Department Emergency Operation Center of Civil Defense (Centro Operativo de Emergencia Departamental)
CORDECRUZ:	Santa Cruz Regional Development Corporation (Coroiracion regional de Desarrollo de Santa Cruz)
DHI:	International Hydrological Decade
EDEN:	National Demographic Investigation (Encuesta Demografica Nacional)
EEC:	European Economic Community
EIA:	Environmental Impact Assessment
EIRR:	Economic Internal Rate of Return
ENDSA:	National Investigation of Demographic and Health (Encuesta Nacional de Demografia y Salud)
ENPV:	National Investigation of Population and housing (Encuesta Nacional de Poblacion and Vivienda)
F.A.:	Environmental Sheet (Ficha Ambiente)
FIDA:	Fondo Internacional de Desarrollo Agricola

FIS:	Social Investment Fund (Fondo de Inversion Social)
FNDR:	National Fund for Rural Development (Dondo Nacional de Desarrollo Rural)
FOB:	Free on Board
FONPLATA:	Banco Financiero de Cuenca del Plata
F/S:	Feasibility Study
GDP:	Gross Domestic Product
GIS:	Geological Information System
GOB:	The Government of Bolivia
GOJ:	Government of Japan
GRDP:	Gross Regional Domestic Product
IDA:	International Development Asociation (Asociacion Internaciional de Desarrollo)
INE:	National Statistic Institute (Instituto Nacional de Estadistica)
JICA:	Japan International Cooperation Agency (Agencia de Cooperacion Internacional del Japon)
MACUCY:	Chimore-Ichilo-Yapacani Valley Management (Manejo de Cuencas Chimore-Ichilo-Yapacani)
MDN:	Ministry of National Defense (Ministerio de Defensa Nacional)
MDSP:	Ministry of Sustainable Development and Planning (Ministerio de Desarrollo Sostenible y Planificacion)
M/S:	Master Plan
NGO:	Non Government Organization.
NPV:	Net Present Value
O M Cost:	Operation and Maintenance Cost
OMM:	World Meteorological Organization
OTB:	Territorial Base Organization
PMA:	Programa Mundial de Alimentos
SEARPI:	Servicio Encauzamiento de Aguas y Regulaizacion del Rio Piraii
SENAMHI:	National Service of Meteorology and Hydrology (Servicio Nacional de Meteorologia y Hidrologia)
SNC:	National Road Service (Servicio Nacional de Caminos)
US:	United State

CONVERSION FACTOR

Length

Cm	:	Centimeter
m	:	Meter
Km	:	Kilometer

Area, Volume and Weight

cm^2	:	Square Centimeter
m^2	:	Square Meter
Km^2	:	Square Kilometer
Ha	:	Hectare
l	:	Liter
m^3	:	Cubic Meter
Kg	:	Kilogram
Ton	:	Ton
lb	:	Pound = 453.6g
qq	:	Quintal = 100 lb = 45.3 Kg
Fanega	:	Fanega = 177 Kg

Currency

US$	:	United States Dollar
Bs.	:	Bolivianos (1 US$ = 5.50 Bs.)
¥	:	Japanese Yen (1 US$ = 117 ¥)

Others

T/ha	:	Ton per Hectare
mm	:	Millimeter
%	:	Percent
°C	:	Degree in Centigrade
Kw	:	Kilowatt
A	:	Ampere

SUPPORTING REPORT A

FLOOD AND FLOOD DAMAGES

TABLE OF CONTENTS

LIST OF FIGURES

SUPPORTING REPORT A FLOOD AND FLOOD DAMAGES

1. Introduction

The flood and flood damage surveys were conducted through the questionnaires to local inhabitants and interviews to the local government officials concerned in the Study Area in order to assess the major recent floods occurred from 1995 to 1998.

The 1992 flood was clarified in the Master Plan Study as the largest floods recorded in the Study Area. In this survey, it was apparent that 1997 flood was recorded as the largest floods in recent years from 1995 to 1998.

2. Flood Survey

2.1 1992 Floods by the Flood Survey in the Master Plan Study

2.1.1 The Chane - Pailon Area

Fig. A.2.1 shows the inundation area of the Chane - Pailon Area during the 1992 Floods in the Master Plan Study which was the largest flood from 1960s through 1995. Almost all of the Chane - Pailon Area was inundated.

2.1.2 The San Juan-Antofagasta Area

Fig. A.2.2 shows the inundation area of the San Juan - Antofagasta Area during the 1992 Floods in the Master Plan Study which was the largest flood from 1960s through 1995. All of the San Juan - Antofagasta Area was inundated.

2.2 Floods by the Flood Survey in the Feasibility Study

In the Feasibility Study, the survey was conducted from August through September 1998. 136 samples in the Chane – Pailon area and 105 samples in the San Juan – Antofagasta area were taken in the survey. The location of the samples in the survey are shown in Fig. A.2.3.

2.2.1 Floods in the Chane – Pailon Area during 1995-1998

The floods occurred from 1995 to 1998 are summarized as follows:

(i) Floods from the Rio Chane and her tributaries

- Floods occurred in December 1995 to February 1996,
- Floods occurred in December 1996 to February 1997,
- Floods occurred in November to December 1997.

(ii) Floods from the Rio Grande

- Floods occurred in February to March 1997
- Floods occurred in February to March 1998

From 1995 to 1998, the largest flood was occurred in the period from the end of November to the beginning of December in 1997.

(1) Floods occurred in November to December 1997

Fig. A.2.4 shows the inundation area of each flood with average depth and duration. During the floods, approximately 65 % of the Chane - Pailon area along the river channel was inundated, i.e. Rio Chane, Rio Pailon, Queb. Chane, Queb. Las Chacras and Okinawa Drainage. The situation is summarized as follows:

a. The Rio Chane area was inundated with floodwater over 1.0 meter deep along the main channel.
b. About 60 % of the Rio Pailon basin in the Study Area was inundated 0.3m to 1.0m deep at the upper reach, but over 1.0 m deep at near the Road No.9.
c. Whole area along the Okinawa Drainage area was inundated 0.3 m to 0.5 m deep at the upstream, but over 1.0 m deep at the downstream.

(2) Other Floods in the Chane - Pailon area

1) Floods occurred in December 1995 to February 1996
Fig. A.2.5 shows the inundation areas together with average depth and duration. The inundation area covered about 20% of the Study Area.
2) Floods occurred in December 1996 to February 1997
Fig. A.2.6 shows the inundation area with average depth and duration. The inundation area was about 30% of the Study Area.

(3) Floods caused by the Rio Grande

1) Floods occurred in February to March 1997

Fig. A.2.7 shows the inundation area with average depth and duration. The locations, from where the floodwater overtopped the riverbank of the Rio Grande, were at the northwestern side of the Mercedes Communidad and at the southwestern side of the Colonia Okinawa 2.

The floodwater from the southwestern side of the Colonia Okinawa 2, flew over the National Road No.9 and inundated along the Okinawa Drainage. The floodwater inundated over about 15% of the Study Area, about 0.5 m deep at the upper reach and over 1.0 m at the lower reach.

2) Floods during February to March 1998

Fig. A.2.8 shows the inundation area with average depth and duration. The inundation depth at the upper reach and lower reach were about 0.3 m and over 1.0 m respectively. The inundation area was about 15 % of the Study Area.

In addition, it was evident that the flood condition in the southern part of the National Road No.9 was alleviated after the construction of several new bridges along the Road No.9 by the financial assistance of the Government of Japan. This was attributed to the improvement of the water conveyance at the crossing points of the Road No.9 and river channels after the construction.

2.2.3 Floods in the San Juan – Antofagasta Area during 1995 - 1998

In the San Juan – Antofagasta area, the major floods occurred during the period from 1995 to 1998, are summarized as follows:

- Floods occurred in December 1994 to February 1995
- Floods occurred in December 1995 to February 1996
- Floods occurred in December 1996 to February 1997
- Floods occurred in December 1997 to February 1998

According to the survey, it became clear that the floods occurred in December 1996 to February 1997 were the largest floods among those occurred from 1995 to 1998.

The floods were caused mainly by the runoff from their own basins and partly by the inflow from the Rio Yapacani.

(1) Floods during December 1996 to February 1997

Fig. A.2.9 shows the inundation area with average depth and duration. During the floods, the areas along the Rio Yapacani, the Arroyo Yapacanicito, Jochi, Tacuaral and Tejeria were inundated. The floodwater inundated about 90 % of the San Juan - Antofagasta area.

Most of the Arroyo Yapacanicito basin was inundated 0.3 to 0.5 m deep at the upper reach, but 1.0 m deep at the lower reach.

Almost whole area of the Arroyo Jochi and Arroyo Tacuaral basins was inundated. The Arroyo Jochi basin was inundated with floodwater of 0.3 to 0.7 m deep at the upper reach and over 1.0 m at the lower reach near the railway embankment. The Arroyo Tacuaral basin was inundated with floodwater of over 1.0 m deep at the upstream.

As for the inundation area along the Rio Yapacani, it is said that the floods of the Rio Yapacani have been limited to the low-lying area along the river at 30 to 40 km in the north from the National Road No.7.

(2) Other Floods

1) Floods during December 1994 to February 1995
Fig. A.2.10 shows the inundation area with average depth and duration. Approximately 55% of the Study Area was inundated.

2) Floods during December 1995 to February in 1996
Fig. A.2.11 shows the inundation area with average depth and duration. The floodwater inundated over about 65% of the Study Area.

3) Floods during December 1997 to February in 1998
Fig. A.2.12 shows the inundation area with average depth and duration. The inundation area covered about 75% of the Study Area.

3. Annual Floods

The survey also revealed the inundation area by the annual floods in the Study Area as follows:

3.1 The Chane - Pailon Area

Fig. A.3.1 shows the inundation area by the annual floods in the Chane-Pailon Area. The inundation area was estimated to be 377 km^2 and covered almost 65% of the Chane-Pailon Area.

3.2 The San Juan - Antofagasta Area

Fig. A.3.2 shows the inundation area by the annual floods in the San Juan - Antofagasta area. The inundation area was found to be 424 km^2 and covered approximately 70% of the San Juan - Antofagasta Area.

4. Study on the Flood Damage

The assets are composed of general assets, agricultural crops, public facilities and others. The general assets are composed of buildings and household effects.

(1) Buildings

The average appraisal values of buildings in the Study Area are shown in the table below.

Kind of Buildings	Residence			Shop	Factory
	High Class	Medium Class	Low Class		
Construction Cost (Bs.)	313,300	133,600	6,900	69,400	255,800

(2) Household Effects

The average appraisal values of buildings in the Study Area are shown in the table below.

Kind of Buildings	Residence		
	High Class	Medium Class	Low Class
Household Effects (Bs.)	125,300	68,600	14,100

The agriculture situation is mentioned in the Supporting Report H.

FIGURES

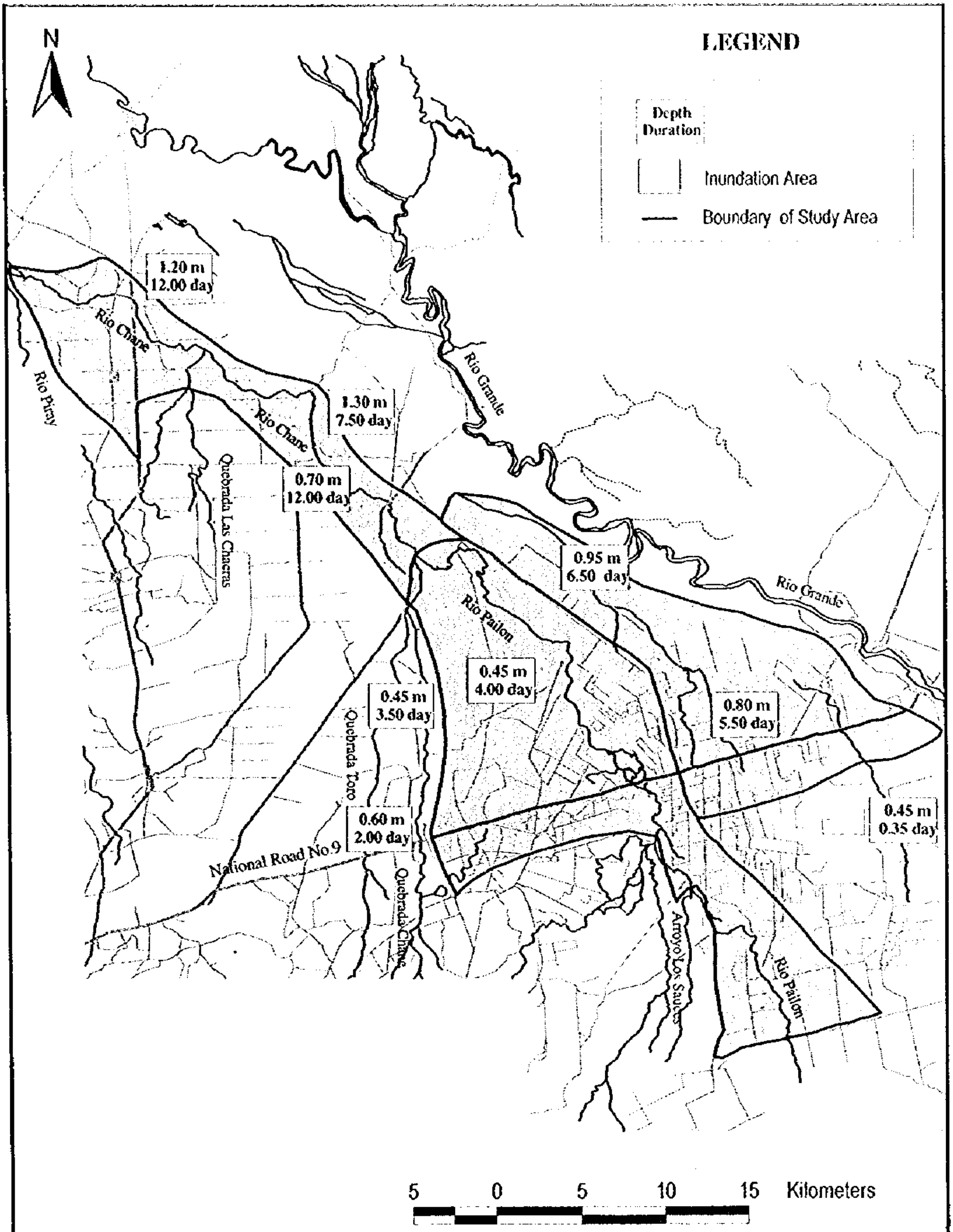

FIG.A.2.1 INUNDATION AREA IN CHANE-PAILON AREA
(By 1992 Floods in the Master Plan)

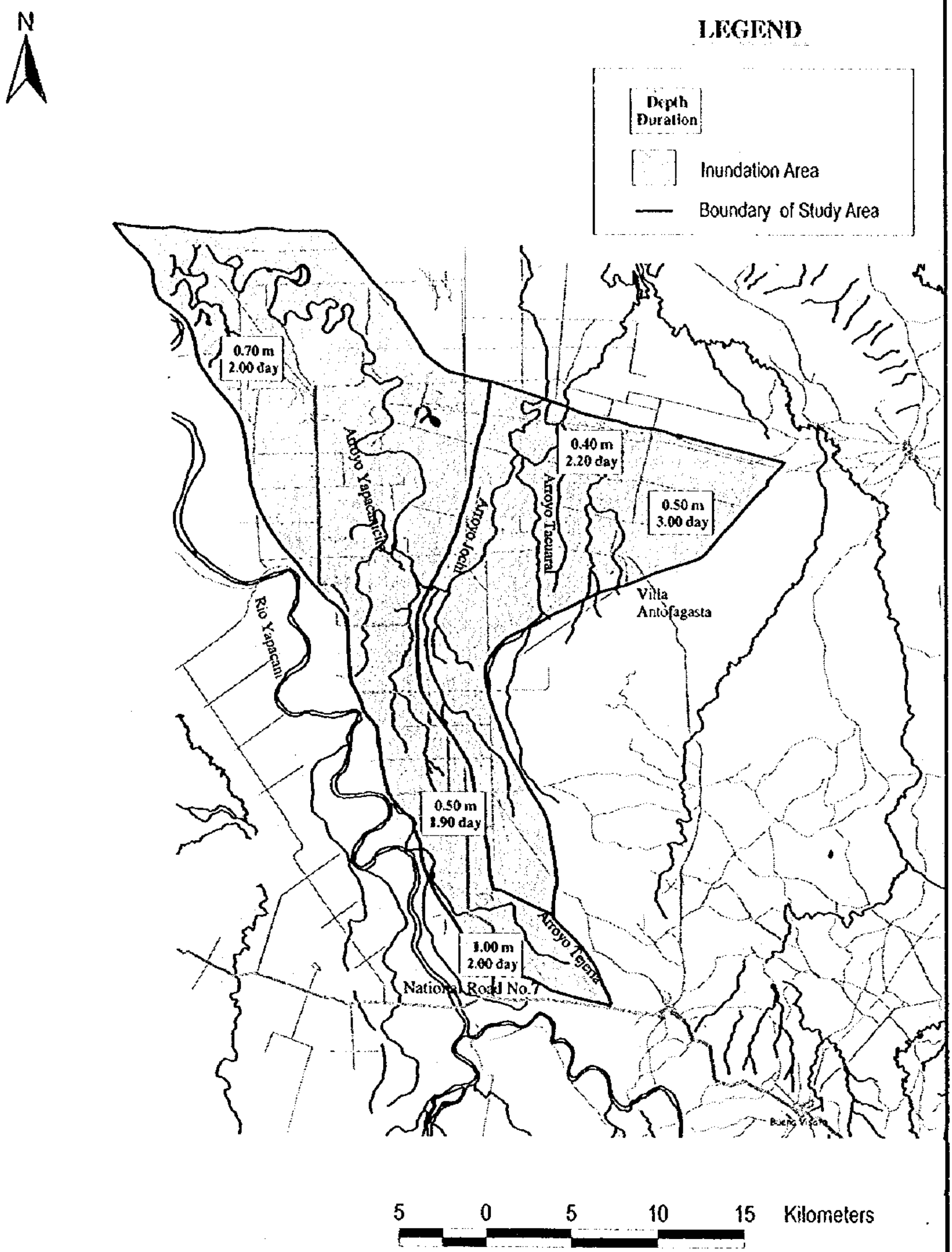

FIG.A.2.2 INUNDATION AREA IN SAN JUAN-ANTOFAGASTA AREA
(By 1992 Floods in the Master Plan)

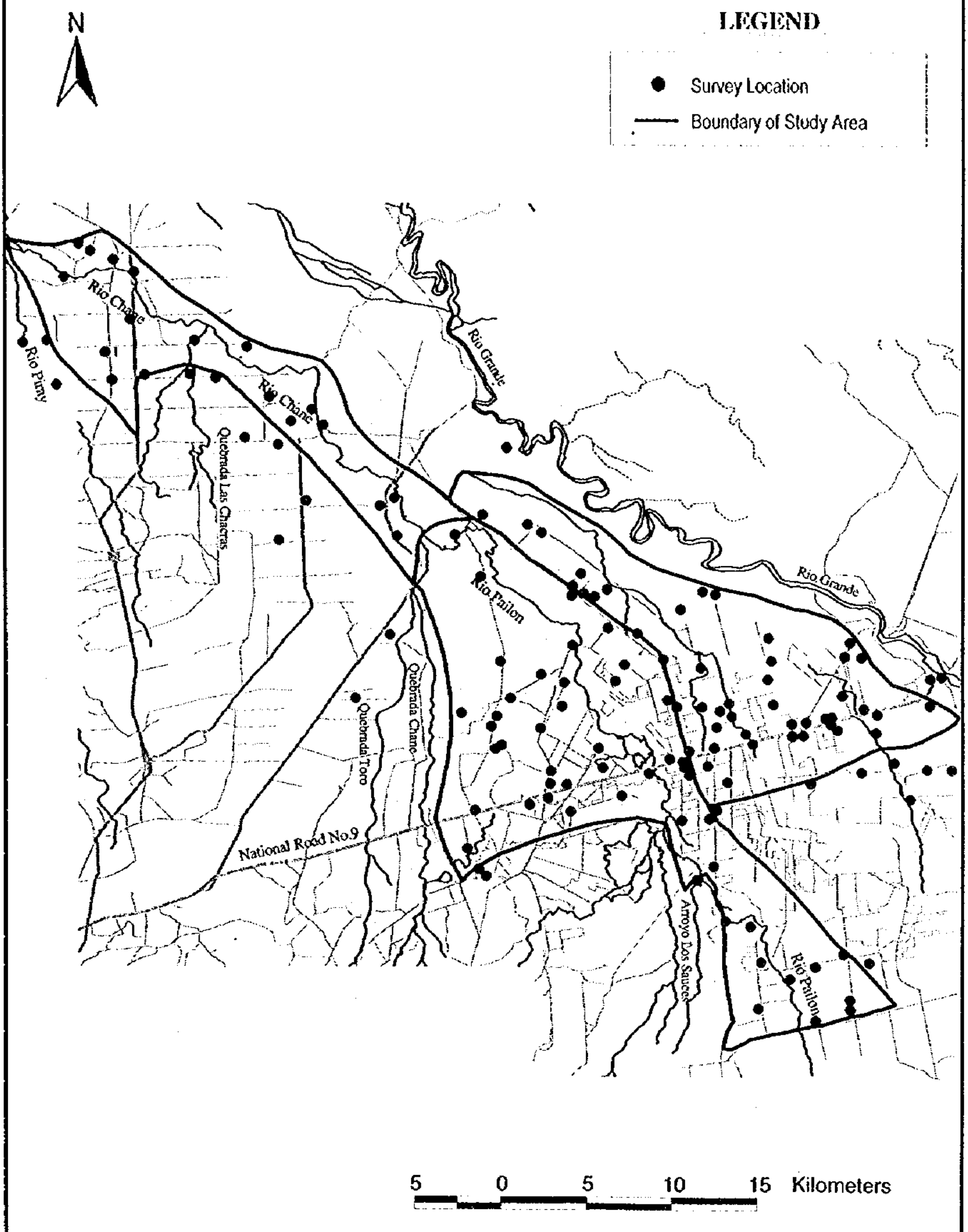

FIG.A.2.3(a) LOCATION OF FLOOD SURVEY IN CHANE - PAILON AREA

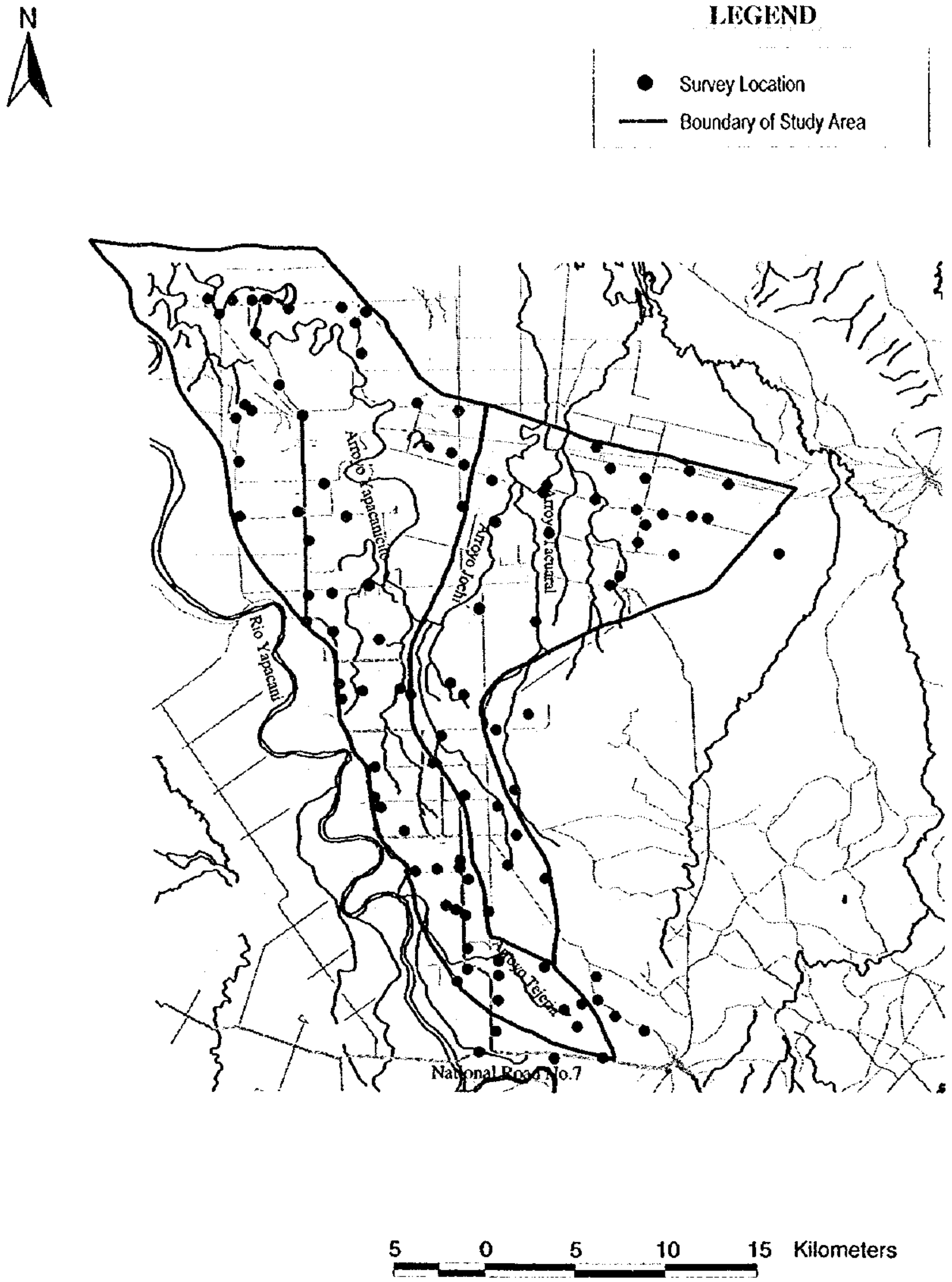

FIG.A.2.3(b) LOCATION OF FLOOD SURVEY IN SAN JUAN - ANTOFAGASTA AREA

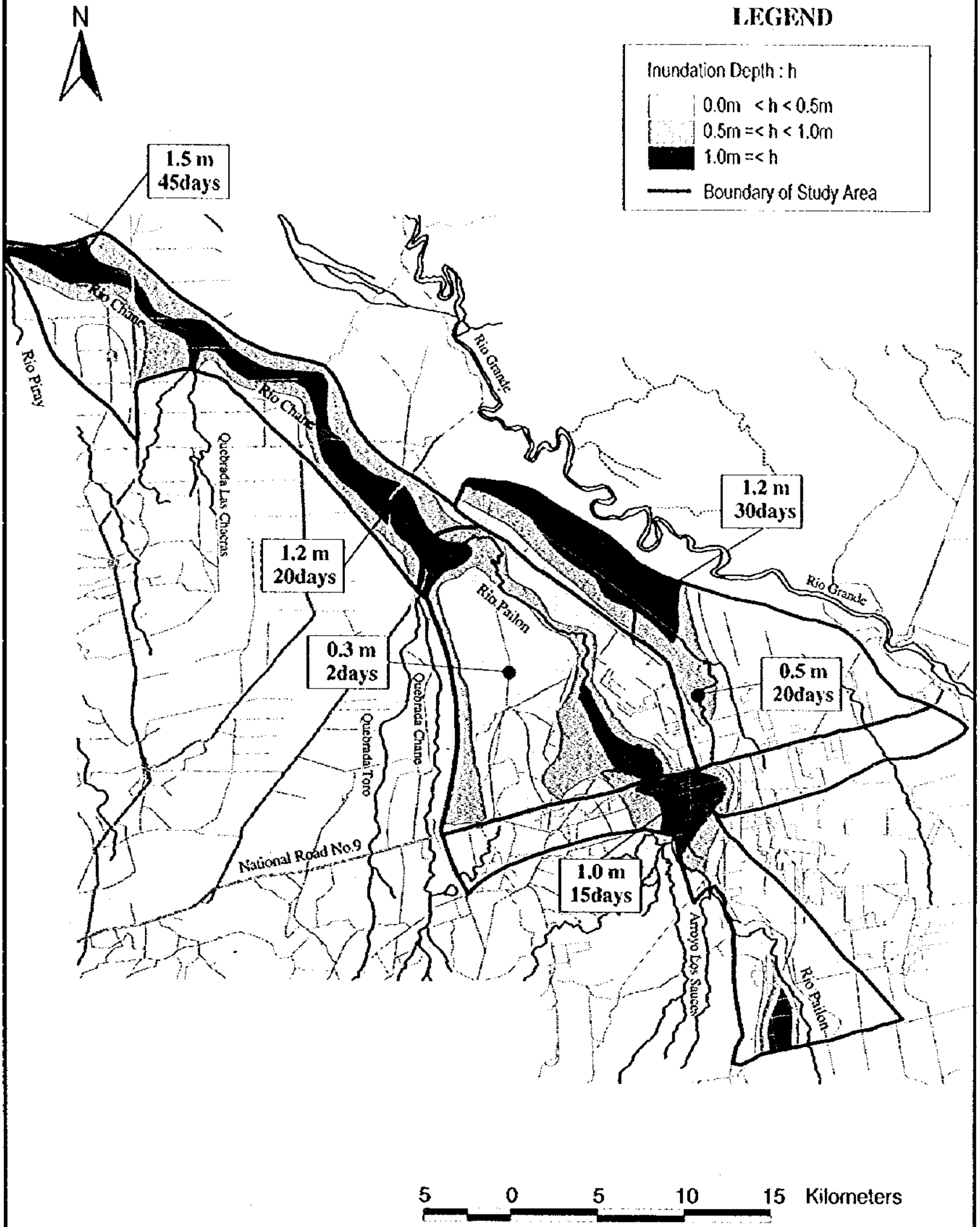

FIG.A.2.4 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during November to December 1997)

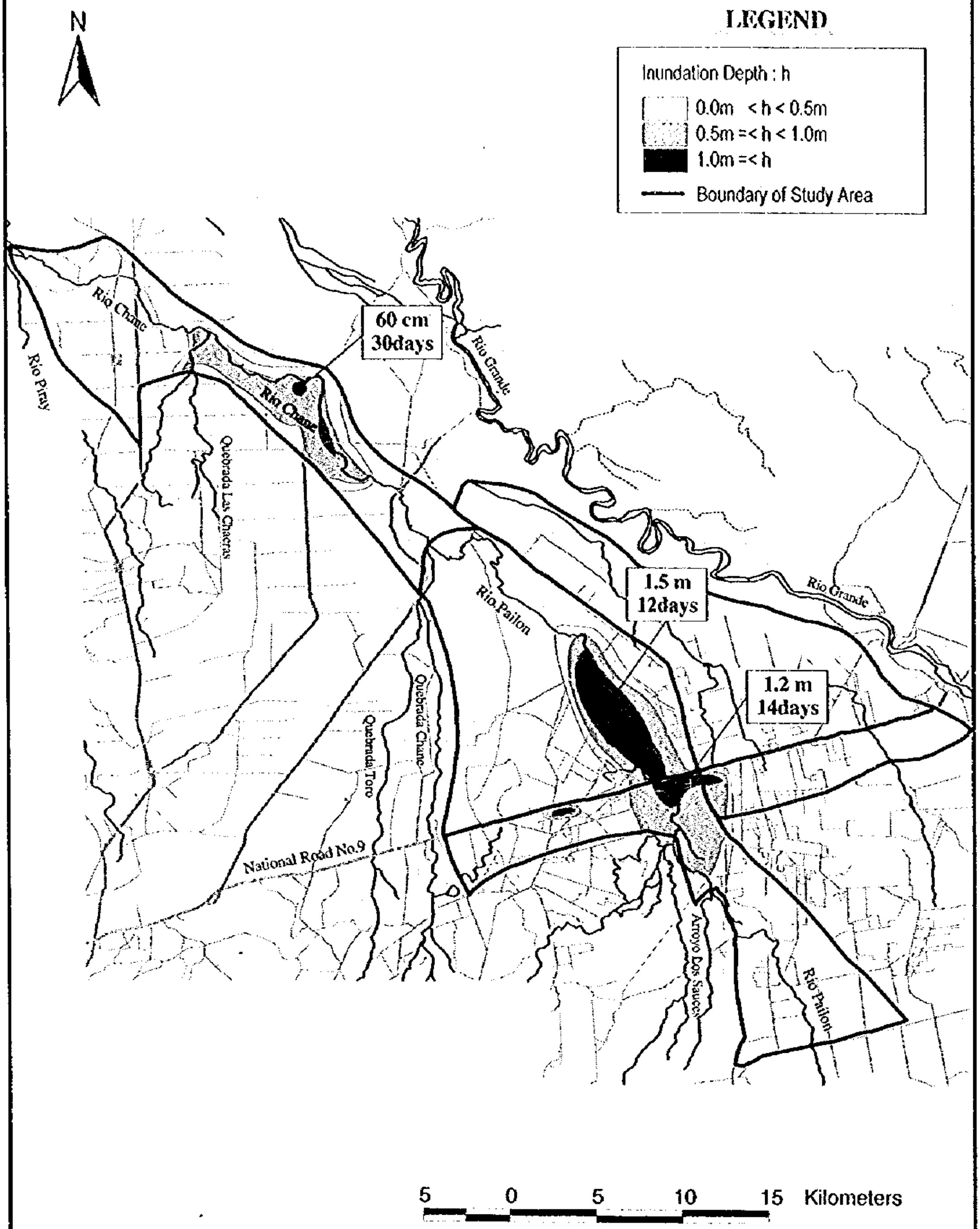

FIG.A.2.5 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during December 1995 to February 1996)

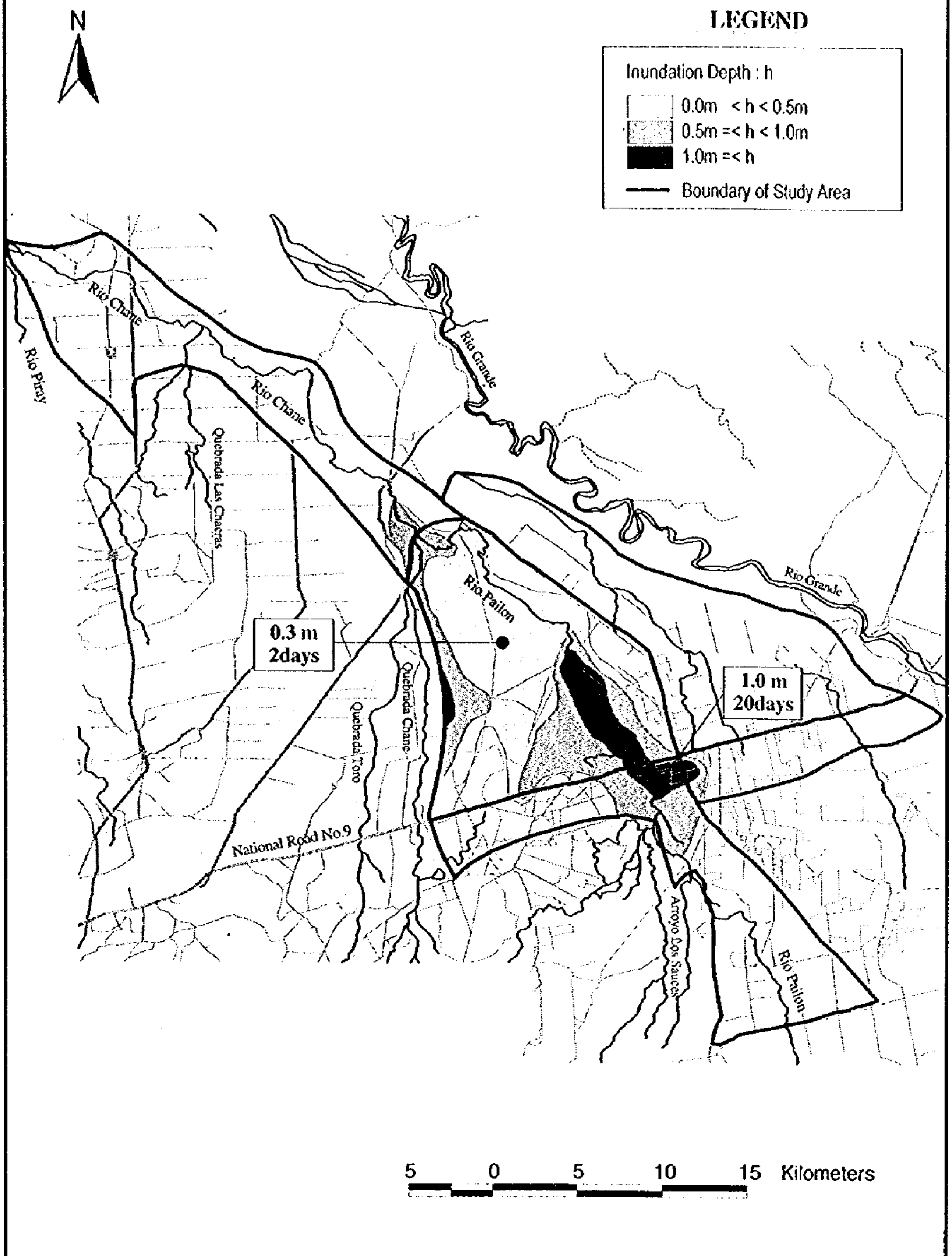

FIG.A.2.6 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during December1996 to February 1997)

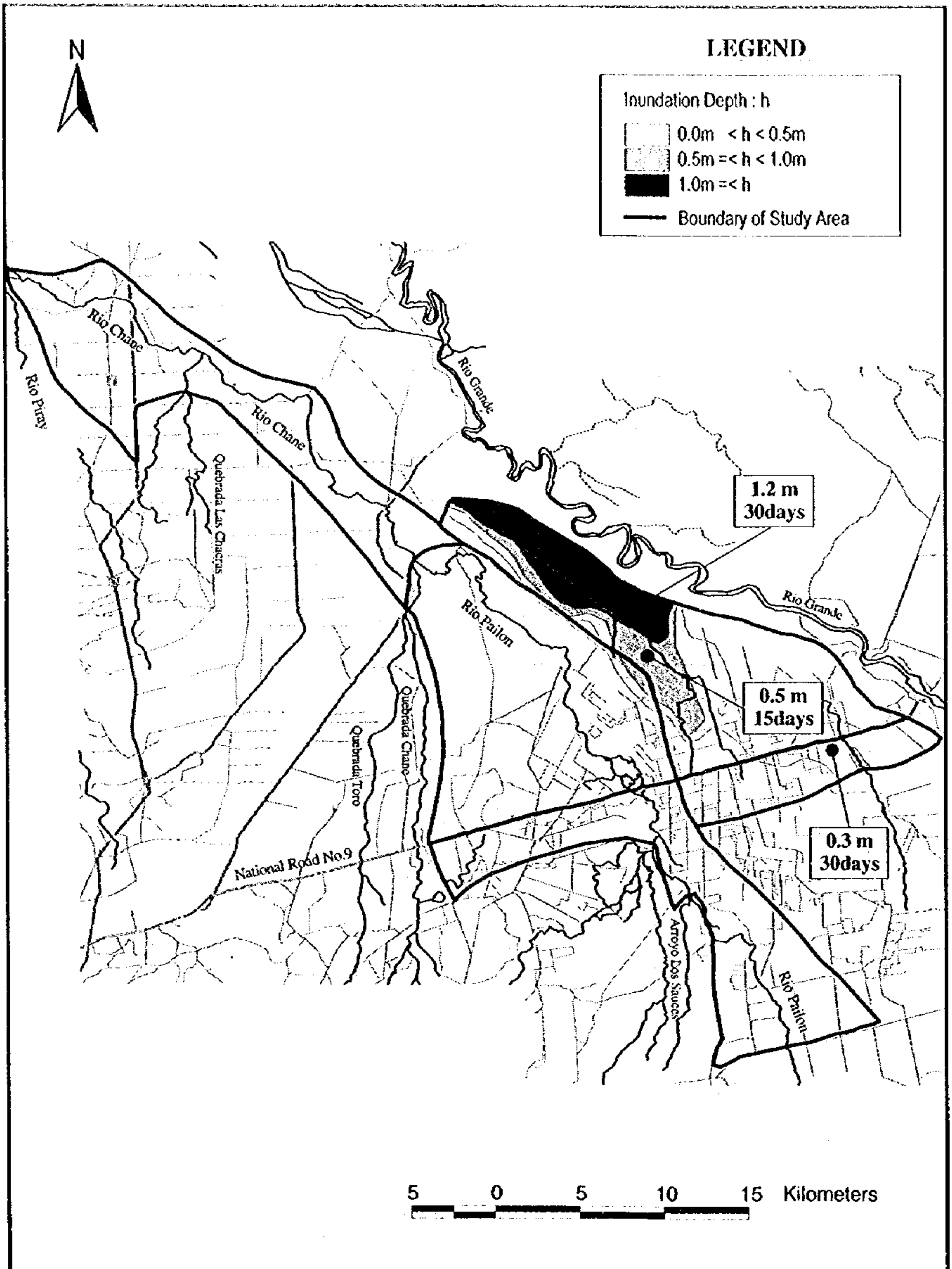

FIG.A.2.7 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during February to March 1997 from the Rio Grande)

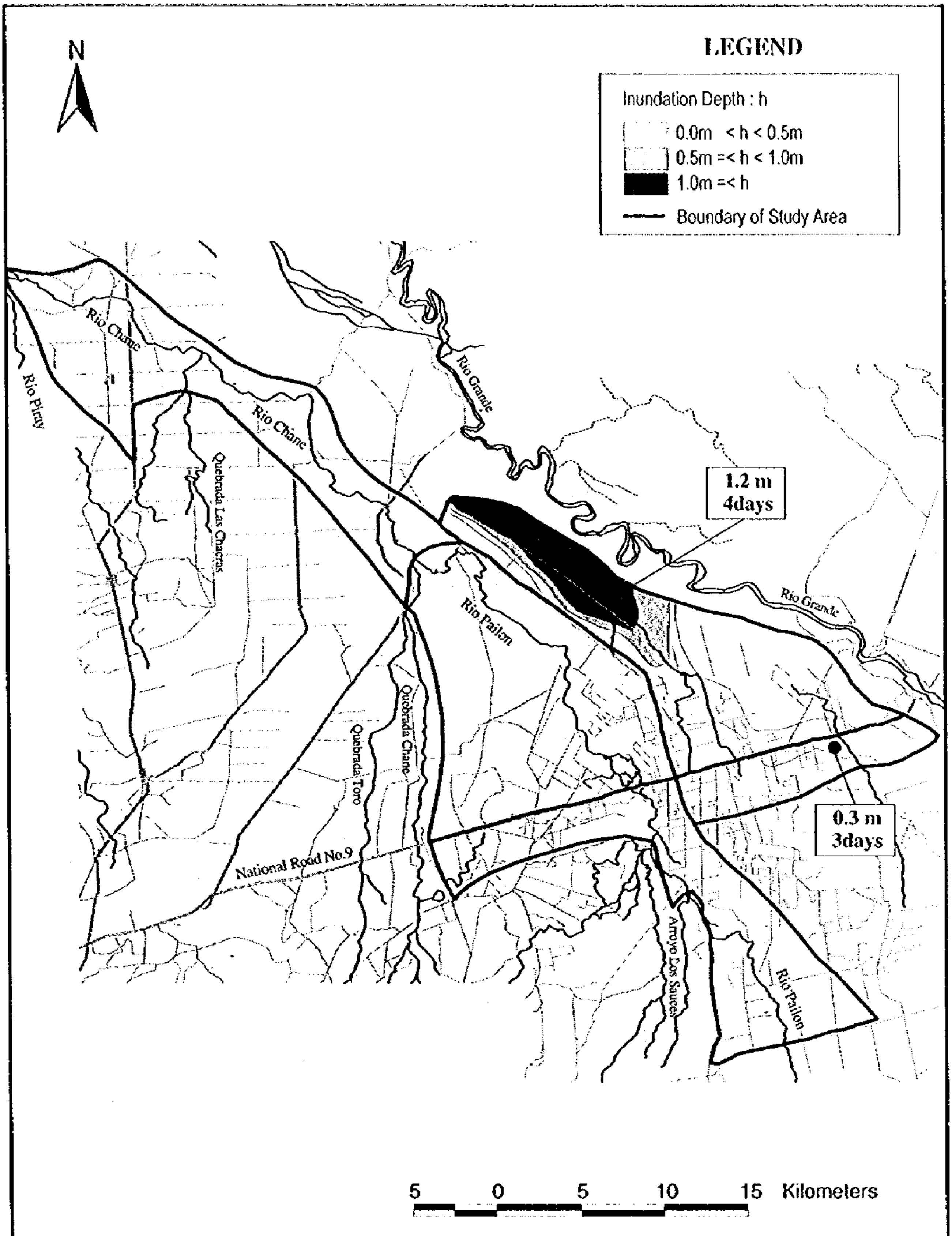

FIG.A.2.8 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during February to March 1998 from the Rio Grande)

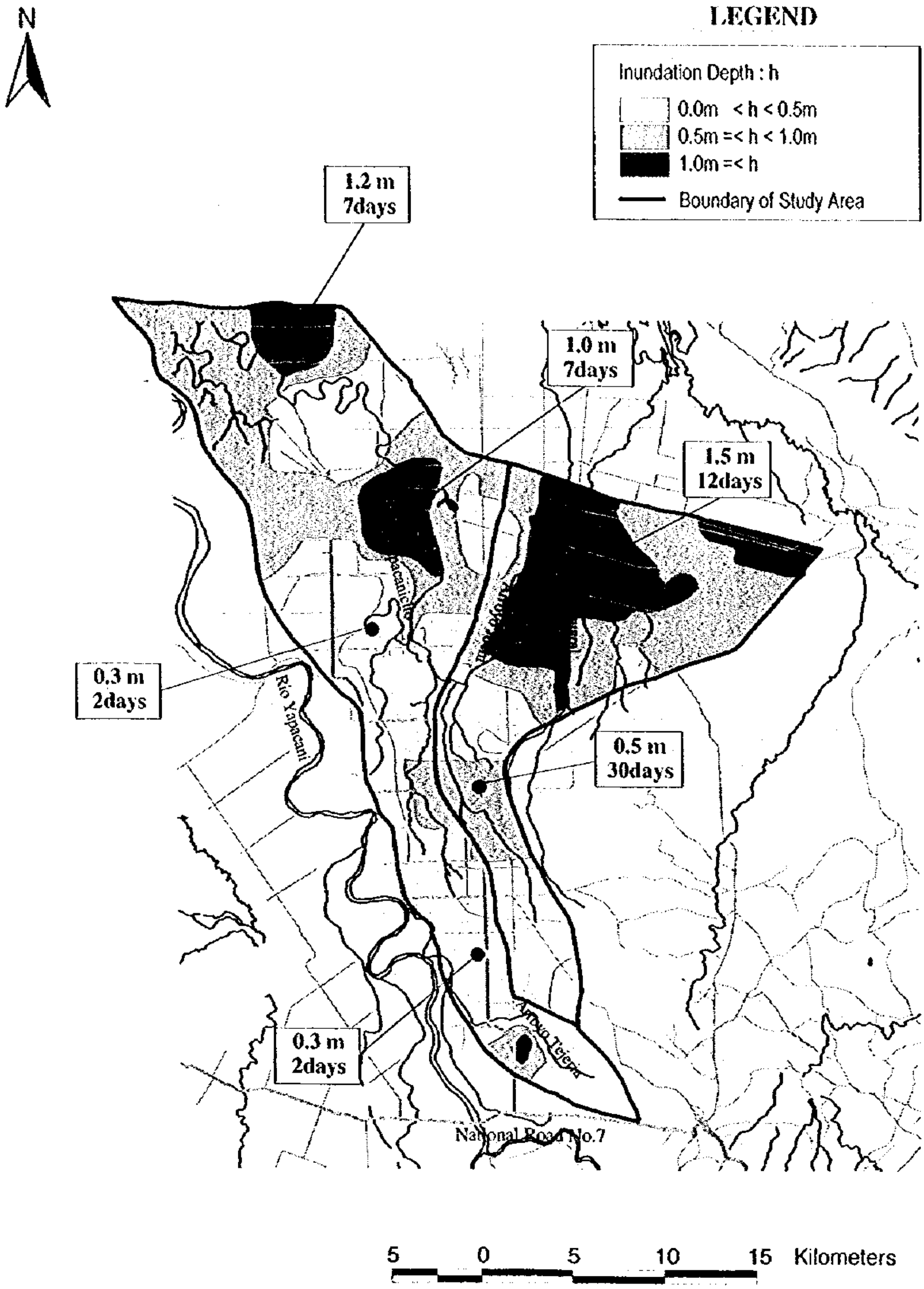

FIG.A.2.9 INUNDATION AREA IN SAN JUAN - ANTOFAGASTA AREA (By the floods during December 1996 to February 1997)

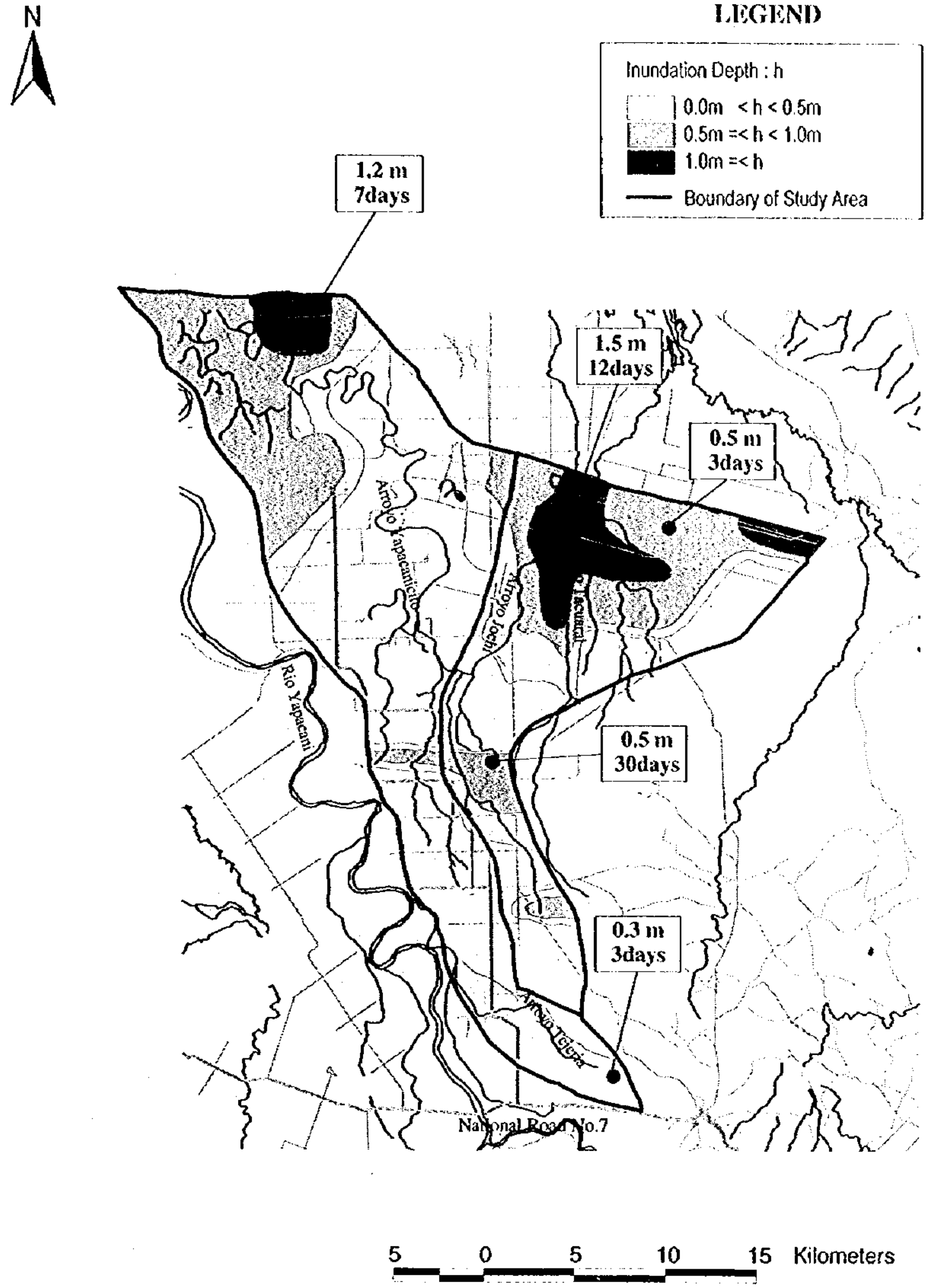

FIG.A.2.10 INUNDATION AREA IN SAN JUAN - ANTOFAGASTA AREA (By the floods during December 1994 to February 1995)

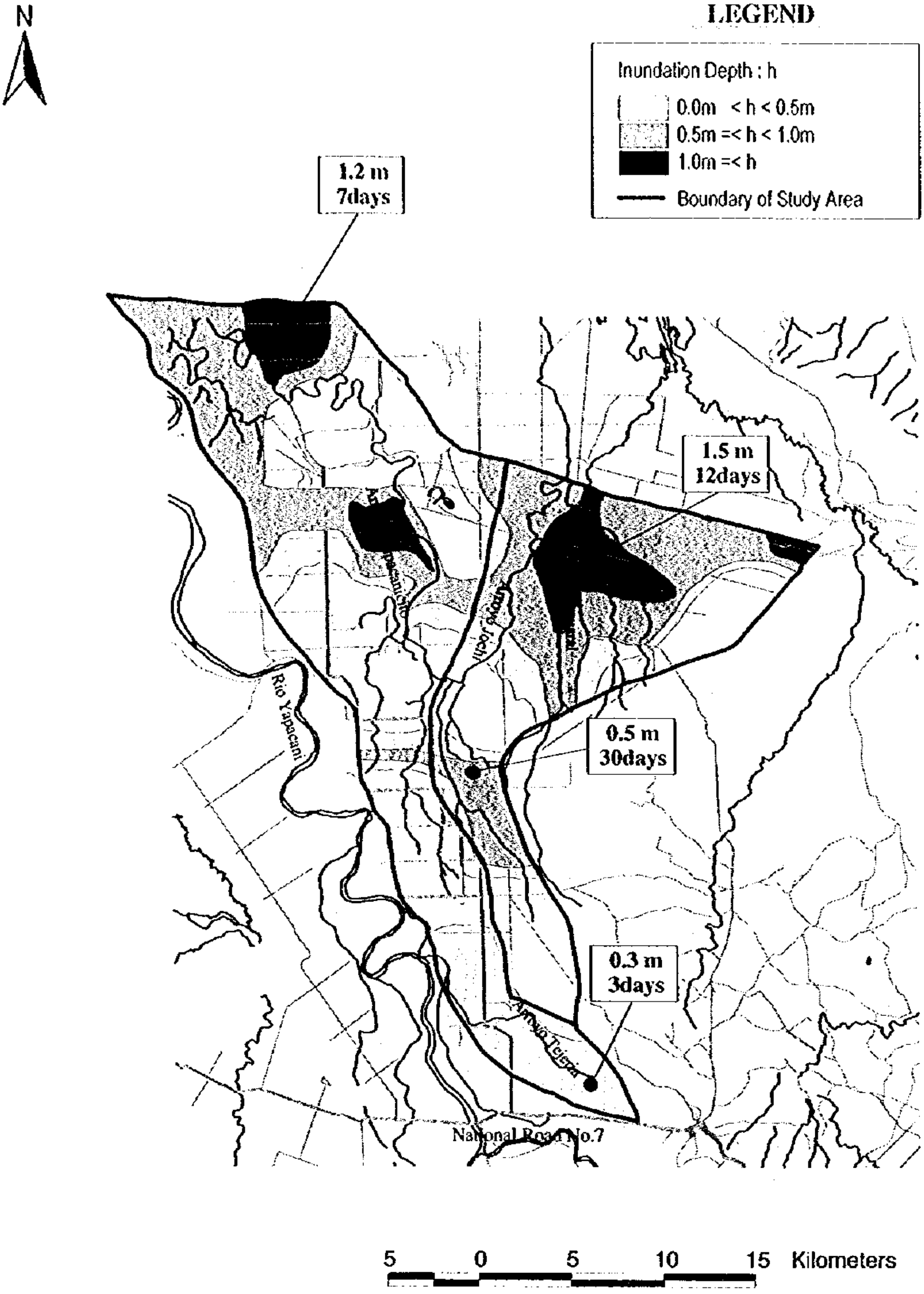

FIG.A.2.11 INUNDATION AREA IN SAN JUAN - ANTOFAGASTA AREA
(By the floods during December 1995 to February 1996)

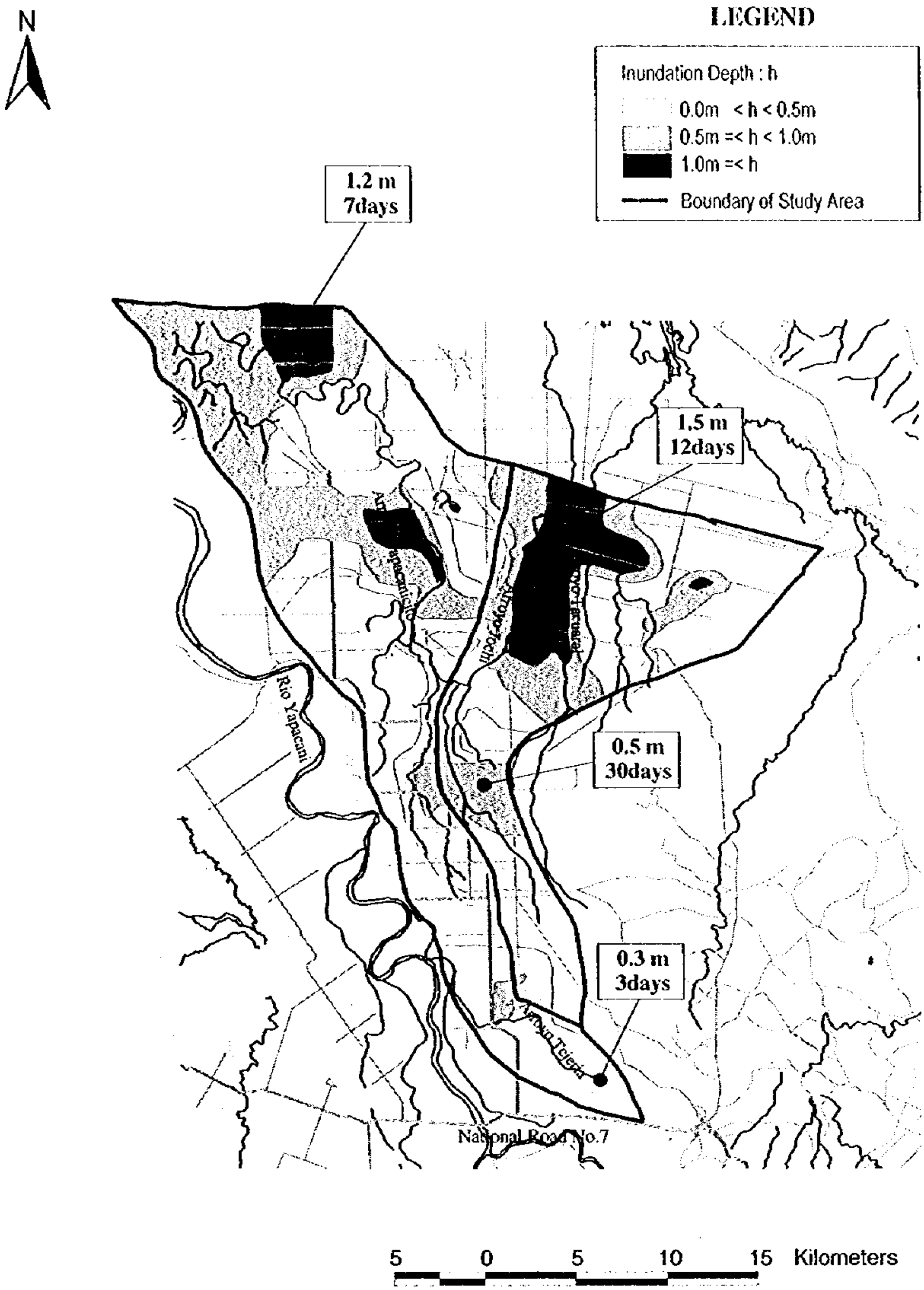

FIG.A.2.12 INUNDATION AREA IN SAN JUAN - ANTOFAGASTA AREA (By the floods during December 1997 to February 1998)

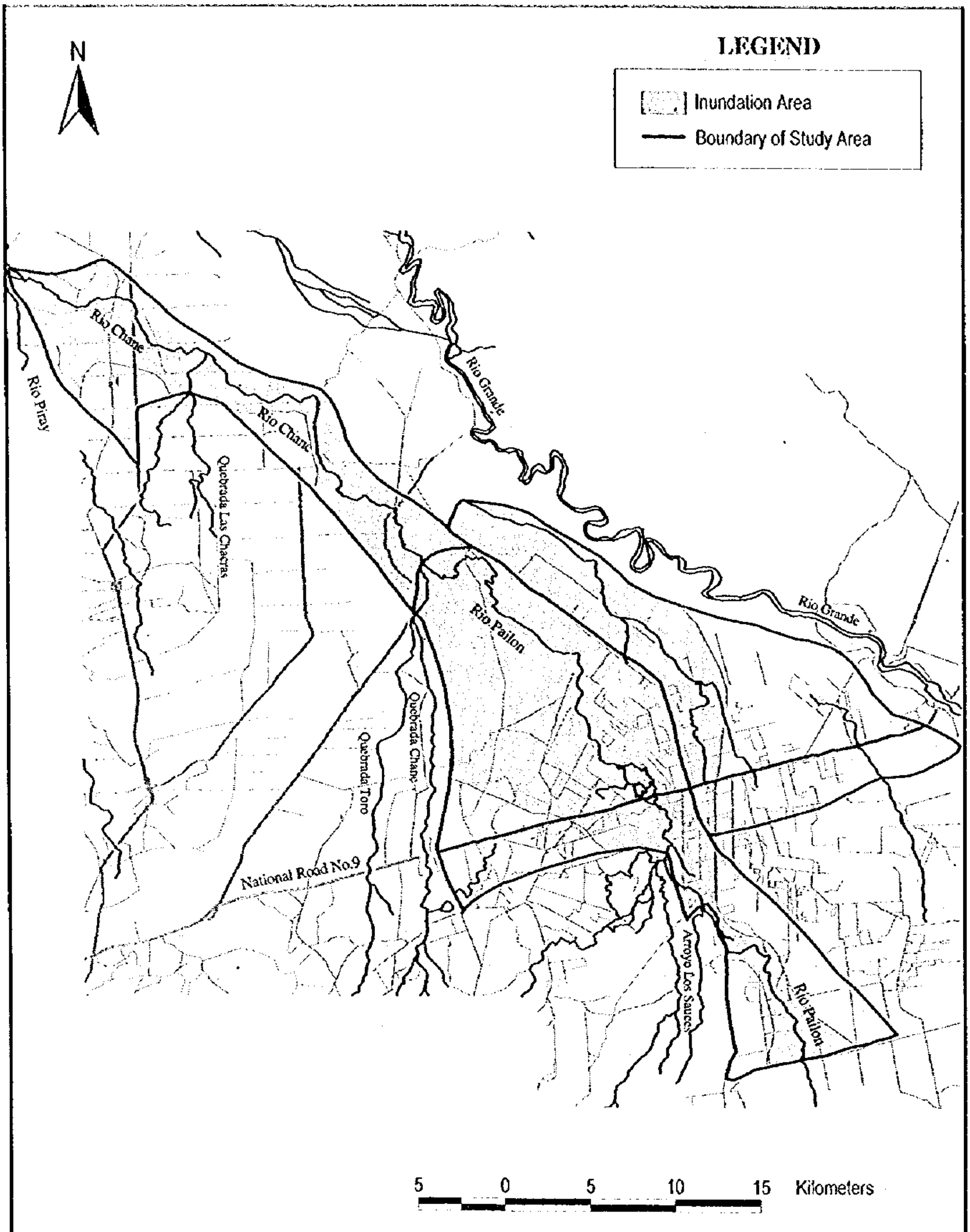

FIG.A.3.1 INUNDATION AREA BY ANNUAL FLOODS IN CHANE-PAILON AREA

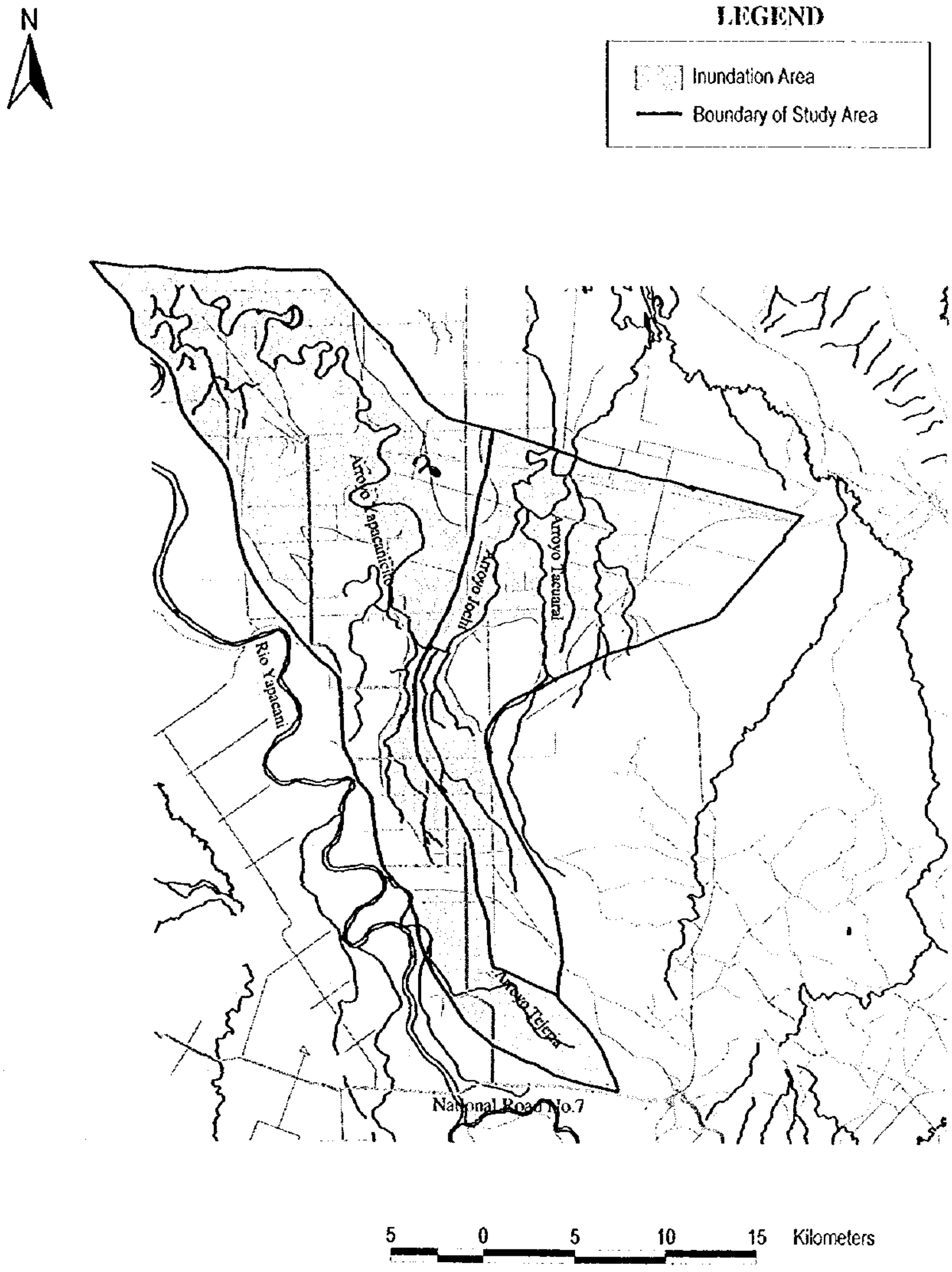

FIG.A.3.2 INUNDATION AREA BY ANNUAL FLOODS IN SAN JUAN-ANTOFAGASTA

SUPPORTING REPORT B

METEO-HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

SUPPORTING REPORT B METEO- HYDROLOGY

SUPPORTING REPORT B METEO - HYDROLOGY

1. Introduction

Meteorological and hydrological condition in the Study Area were reviewed and studied to obtain the basin characteristics on climate, rainfall and others. The hydrological condition was also used for the further analysis.

The hydrological analysis was conducted in this study in order to clarify and update the hydrological condition causing floods after the Master Plan Study in 1996. The results were used in the flood analysis for the calculation of the inundation depth and areas and the design of rivers.

This supporting report describes the general meteorological and hydrological condition, characteristics of the current storms causing floods in the study area, selection of design rainfall and rainfall-runoff analyses of the current storms and design storms. At last, a flood forecasting and warning system by rainfalls is also proposed as a non-structural measure for the flood damage mitigation.

2. Meteorological Condition

Data on the meteorological condition were obtained from the measurement stations in the Study Area and vicinity as shown in Table B.2.1 and B.2.2. The meteorological condition can be summarized as follows:

Average annual maximum temperature	=	28.9 °C	
Average annual mean temperature	=	23.9 °C	
Average annual minimum temperature	=	19.0 °C	
Average annual humidity	=	72.8 %	
Average annual wind speed at Trompillo	=	NW-10	knot
Saavedra	=	N-09	knot
Average annual evaporation	=	1,198 %	

3. River System

The Study Area covers the areas in the eastern part so called the Rio Chane – Pailon area and the western part so called the San Juan – Antofagasta area. The Rio Chane – Pailon area is composed of 2 main river basin: the Rio Chane – Pailon basin and the Okinawa Drainage basin. The study area is approximately 600 km^2 but the drainage area is approximately 2,217 km^2. The San Juan – Antofagasta area is composed of 4 main river basins and some main drainage. The 4 main river basins are the Arroyo Yapacanicito basin, the Arroyo Tejeria basin, the Arroyo Jochi basin and the Arroyo Tacuaral basin and the main drainage are the Arroyo Antofagasta basin and the San Juan drainage basin. The Study Area is approximately 607 km^2 but the drainage area is approximately 689 km^2.

A summary of the drainage area is shown as follows:

River	Area (km^2)
Downstream	262.0
Rio Pailon	1,319.0
- downstream	225.0
- midstream	228.0
- other QDA	866.0
QDA Chane	466.0
- mainstream	232.0
- QDA El Toro	234.0
Other	224.0
Total	2,271.0
Okinawa Drainage	381.5

The San Juan - Antofagasta Area

River/Arroyo	Area (km^2)
Arroyo Jochi	148.0
Arroyo Tacuaral	127.0
Arroyo Yapacanicito	370.7
Arroyo Tejeria	43.6
Total	689.3

Note : The Arroyo Antofagasta is included in the Arroyo Tacuaral
The San Juan drainage is included in the Arroyo Yapacanicito

3.1 River System in the Rio Chane – Pailon Area

In the Rio Chane – Pailon area, the Rio Chane and Rio Pailon, the main river, flows from the upstream end of the Study Area, passes through the National Road No. 9. In the mid-stream reach, the main river thereafter is named the Rio Chane after the confluence of the Rio Pailon and the Quebrada Chane. The Rio Chane flows northwards and meets the Quebrada Chacras at the downstream reach and passes through a local road bridge, which is the end of the Study Area, then discharges to the Rio Piray outside the study area.

The slopes of the river in the upstream vary from 1/600 to 1/1,600, while those in the mid-stream and downstream vary from 1/1,900 to 1/2,800. The widths vary from about 10 to 15 m in the upstream to 30 – 75 m in the downstream.

3.2 River System in the San Juan – Antofagasta Area

In the San Juan – Antofagasta area, there are 4 main rivers, the Arroyo Yapacanicito, Tejeria, Jochi and Tacuaral. These rivers flow northwards from the southern part with small tributaries. The Arroyo Yapacanicito and Tejeria originate from combination of the tributaries and the drainage canals in the upstream reach of the Study Area and joins the Rio Yapacani at the downstream reach outside the Study Area and at the upstream of the urban area of San Juan respectively. The Arroyo Jochi and Tacuaral also originate from the tributaries and drainage canals in the upstream reach in the southern part. Both rivers flow through a natural retarding basin located in the mid-stream reach and then join the Rio Palacios in the northern part outside the study area.

The river slopes vary from 1/600 to 1/1,250, while the widths vary from about 15 to 70 m. for all the rivers.

4. Available Hydrological Data

Available hydrological data on rainfall and discharge/water level were obtained from 28 gauging stations distributing in the Study Area and vicinity. These stations are operated by the SEARPI, SENAMHI, CETABOL, AASANA and MACUCY as shown in Table B.4.1. A summary of these stations in the Study Area is as follows:

Area/River	Number of Gauging Stations		Sources of Acquired Data
	Rainfall	Discharge/ Water Level	
The Chane - Pailon Area	15		SEARPI, SENAMHI, CETABOL, AASANA
The San Juan - Antofagasta Area	2		CETABOL, MACUCY
Rio Piray		7	SEARPI
Rio Grande		2	SEARPI
Rio Yapacani		1	MACUCY
Rio Palometillas		1	MACUCY
Total	17	11	

Data on monthly average rainfalls were illustrated in the Master Plan Study – Supporting Report A, 1996. The average annual rainfall from the main stations is as follows:

Average annual rainfall

Station	Annual Rainfall (mm)
5806 Santa Cruz - Trompillo	1,301.2
56NP La Belgica - Ingenio	1,417.0
61NP Saavedra	1,356.1
62NP Mineros (Unagro)	1,556.0
Okinawa II	1,274.2
55NP Portachuelo	1,639.0
52NP San Isidro	2,066.0
Col. San Juan de Yapacani	1,897.5

4.1 Available Hydrological Data in the Chane – Pailon Area

Data from 5 main stations: Saavedra, CETABOL-JICA, Warnes, Puerto Pailas and Santa Cruz/Trompillo stations were used in the hydrological analysis. Location of these stations is shown in Figure B.4.1. However, data from the Warnes and Puerto Pailas stations were used for the analysis of the current flood situation only because of their short observation records.

Some other stations including the Viru-Viru Aeropuerto, Montero and Peroto stations had only short observation records and were considered not reliable for the analysis. The Vallecito, Santa Cruz/Universidad and Santa Cruz/Oficina were represented by Santa Cruz/Trompillo, which had the longest observation record in the region. Therefore, the Santa Cruz/Trompillo and the Saavedra stations were considered as the principal stations in the Santa Cruz area and the Chane - Pailon area respectively.

4.2 Available Hydrological Data in the San Juan – Antofagasta Area

There are only 2 rainfall gauging stations in this area: the San Juan de Yapacani and Buena Vista stations as shown in Figure B.4.1. However, only the data the San Juan de Yapacani were used in the analysis because the Buena Vista station was considered not a representative station.

4.3 Available Hydrological Data in the Rio Grande Basin

Although the Rio Grande Basin was not in the Study Area, data from the Abapo station in this basin was considered and used as a main station for the flood warning system. Location of the basin and this station is shown in Figure B.4.2.

5. Rainfall Analysis

5.1 Rainfall Analysis in the Rio Chane – Pailon Area

Monthly and annual rainfall data until 1994 were illustrated in the Master Plan Study – Supporting Report A, 1996. The later data were collected in the Study as shown in Data Book – B. The current rainfalls causing floods in this area are summarized as follows:

(1) Rainfall in 1983

Rainfall in 1983 was pretty much higher than the average except in June, August, September and December. The peak monthly rainfalls at the major stations are as follows:

Saavedra	:	302.3 mm	(January)
CETABOL	:	240.2 mm	(January)
Santa Cruz – Trompillo	:	395.3 mm	(January)

(2) Rainfall in 1992

Rainfall in 1992 was considered very extensive. The average monthly rainfall during rainy season was much higher than the average at the order of 2 – 3 times. The peak monthly rainfalls are as follows:

Saavedra	:	500.2 mm	(January)
CETABOL	:	393.0 mm	(February)
Santa Cruz – Trompillo	:	413.5 mm	(April)

(3) Rainfall during December 1995 to January 1996

Rainfall in this period was considered pretty extensive. Data from major stations are as follows:

Saavedra	:	203.4 mm	(December)
CETABOL	:	134.6 mm	(December)
Santa Cruz – Trompillo	:	141.9 mm	(January)

(4) Rainfall during December 1996 to February 1997

Rainfall during this period was considered not extensive compared to the average in Saavedra and CETABOL. However, heavy rainfall was found in Santa Cruz – Trompillo. Measured rainfalls are as follows:

Saavedra	:	131.1 mm	(January)
CETABOL	:	96.6 mm	(December)
Santa Cruz – Trompillo	:	186.4mm	(January)

(5) Rainfall at the end of 1997

Rainfall during this period was the most extensive rainfall after 1995. These rainfalls are as follows:

Saavedra	:	286.3 mm	(December)
CETABOL	:	219.6 mm	(December)
Santa Cruz – Trompillo	:	182.4 mm	(December)

5.2 Rainfall Analysis in the San Juan – Antofagasta Area

Monthly and annual rainfall data until 1994 were also illustrated in the Master Plan Study – Supporting Report A, 1996. The later data were also collected in the Study as shown in Data Book – B. The current rainfalls causing floods in this area are summarized as follows:

(1) Rainfall in 1983

Rainfall in 1983 was pretty much higher than the average except in February, August, September and December. The peak monthly rainfall at the major stations is as follows:

Col. San Juan de Yapacani : 361.7 mm (January)

(2) Rainfall in 1992

Rainfall in 1992 was also considered very extensive in this area. The average monthly rainfall during rainy season was much higher than the average at the order of 1.5 – 4 times. The peak monthly rainfall is as follows:

Col. San Juan de Yapacani : 473.7 mm (February)

(3) Rainfall in 1996

Rainfall in this year was considered pretty extensive. The peak monthly rainfall is as follows:

Col. San Juan de Yapacani : 245.0 mm (February)

(4) Rainfall in 1997

Rainfall in this year was considered the most extensive after 1995, same as in the Chane – Pailon Area. The peak monthly rainfall is as follows:

Col. San Juan de Yapacani : 443.0 mm (February)

(5) Rainfall in 1998

Rainfall in this year was considered not extensive. The peak monthly rainfall is:
Col. San Juan de Yapacani : 145.0 mm (February)

6. Frequency Analysis

Frequency analysis for the annual maximum rainfall based on the Gumbel Method in the Master Plan Study in 1996 was used in this study. The analysis was conducted in the main rainfall stations including Saavedra, CETABOL, Santa Cruz – Trompillo and Col. San Juan de Yapacani to calculate the return period of the maximum consecutive rainfall in 1 day until 7 days. The result is shown in Table B.6.1. The probable maximum rainfall in one day is shown in Table B.6.2.

Return period of major rainfalls causing floods in the Chane – Pailon Area and the San Juan – Antofagasta Area are summarized as follows:

Return period of the major rainfalls causing floods

Date/Period of Floods	Return period (year)			
	The Chane - Pailon Area			The San Juan - Antofagasta Area
	Saavedra	CETABOL	Santa Cruz - Trompillo	San Juan de Yapacani
March 1983	< 2 years	< 2 years	< 2 years	< 2 years
January 1992	> 100 years	50 - 100 years	2 - 5 years	5 - 10 years
Dec/1995 - Feb/1996	2 - 5 years	2 years	2 years	-
January 1996	-	-	-	2 - 5 years
Dec/1996 - Feb/1997	2 years	2 years	2 - 5 years	-
January 1997	-	-	-	10 - 20 years
November 1997	10 - 20 years	5 - 10 years	3 - 5 years	-
January 1998	-	-	-	< 2 years

7. Design Rainfall

The design rainfall for the Study was set up in the Master Plan Study in 1996 by considering the rainfalls of the four principal stations of Saavedra, Santa Cruz, Okinawa II (CETABOL) and Colonia San Juan de Yapacani.

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 hydrograph of Okinawa II and Colonia San Juan de Yapacani. This is because the correlation of the annual maximum one day rainfall of these two stations with Saavedra are higher than those of these two stations with Santa Cruz.

Correlation of these stations is shown in Figure B.7.1 and B.7.2. The design rainfalls in these stations are shown in Table B.7.1 and Figure B.7.3.

8. Rainfall Runoff Analysis

The rainfall runoff analysis was conducted by using the Unit Hydrograph Method developed by the U.S. Soil Conservation Service (SCS). The analysis was done during the rainfall periods those caused major floods in the Study Area recently as follows:

The Chane - Pailon area	:	November 30th - December 5th,	1997
		March 24th - 29th,	1998
The San Juan - Antofagasta area	:	January 30th - February 6th,	1997

The Study Area was divided in sub-basins, shown in Figure B.8.1 and B.8.2, for the rainfall runoff model. The necessary parameters in the model were decided based on the calibration as shown in Table B.8.1, and the results are shown in Figure B.8.3, B.8.4 and B.8.5. The runoff characteristics at each time period were different due to the rainfall pattern.

Rainfall runoff analysis for return period 2, 5, 10, 20 and 50 years was then conducted for both areas as shown in Figure B.8.6. These were used in the hydrodynamic simulation and the structural measures in the latter section.

9. Flood Analysis

From the rainfall runoff analysis and flood damage survey, it can be summarized that the floods in the Study Area were caused by

The Chane – Pailon Area:

- Extensive rainfall in Saavedra, CETABOL and Santa Cruz Trompillo,
- Overflow from the Rio Grande

The San Juan – Antofagasta Area:

- Extensive rainfall in San Juan de Yapacani

9.1 Flood Analysis in the Chane – Pailon Area

The characteristics of floods after 1995 clarified by the flood damage survey in 1998 and the rainfall runoff analysis are as follows:

Characteristics of floods after 1995

Flood period	Inundation Area		Probable Rainfall Period	Measured Rainfall					
				Saavedra		CETABOL		Trompillo	
	(km²)	%		(mm)	R.P. (yrs)	(mm)	R.P. (yrs)	(mm)	R.P. (yrs)
Dec/95 - Feb/96	112.7	18.8	4 - 20 Jan/96	203.4	2 - 5	134.6	2	141.9	2
Dec/96 - Feb/97	170.9	28.5	30 Jan - 6 Feb/97	131.1	2	96.6	2	186.4	2 - 5
Nov - Dec/97	370.3	61.8	30 Nov - 5 Dec/97	286.3	10 - 20	219.6	5 - 10	182.4	2 - 5
Feb - Mar/97	98.2	16.4	No data						
Feb - Mar/98	83.5	13.9	No data						

Note : 1). % is the ratio of inundation area to the Study Area
2). R.P. = Return Period

9.2 Flood Analysis in the San Juan – Antofagasta Area

The characteristics of floods after 1995 clarified from the same sources are as follows:

Characteristics of floods after 1995

Flood period	Inundation Area		Probable Rainfall Period	Measured Rainfall	
				San Juan de Yapacani	
	(km²)	%		(mm)	R.P. (yrs)
Jan - Feb 1995	323.7	53.3	No data		
Jan - Feb 1996	405.1	66.7	2 - 8 Feb 96	245.3	2 - 5
Jan - Feb 1997	560.1	92.2	30 Jan - 6 Feb 97	443.0	10 - 20
Jan - Feb 1998	450.5	74.2	28 Jan - 2 Feb 98	156.0	<2

Note : 1). % is the ratio of inundation area to the Study Area
2). R.P. = Return Period

9.3 Overflow from the Rio Grande

Inundation in the Chane – Pailon Area during February – March in 1997 and 1998 was caused apparently by the overflow from the Rio Grande according to the flood damage survey.

Due to the insufficient data in the Rio Grande basin, the rainfall runoff analysis could not be conducted. The information of the flow condition in the Rio Grande was obtained from the water level/discharge observation stations at the Abapo Bridge and Puerto Pailas Bridge.

The relationship between the water level at the Abapo Bridge and the Okinawa Drainage could not be verified clearly. However, during the flood in the Okinawa Drainage from January to March 1998 as reported by the flood damage survey, the rainfall was found to be not extensive but the inundation area in the Okinawa Drainage was remarkably wide. Therefore, it was summarized that the cause of flood was from the overflow from the Rio Grande. The water depth during that period, at the Abapo Bridge 9.2 m, at the Puerto Pailas Bridge 4.0 m and at the Okinawa I 3.0m, somehow showed a relationship among these stations. Rainfall in the Rio Grande basin during that period is shown in Figure B.9.1.

10. Flood Warning System

10.1 Measurement Stations

The flood warning system is proposed hereinafter from the hydrological point of view. The rainfall and water level/discharge gauging stations to be used and set up for the system are proposed as follows:

Existing Rainfall Gauging Station	:	Saavedra
		CETABOL
		Santa Cruz - Trompillo
		San Juan de Yapacani
Water level Gauging Station	:	Abapo Bridge

The rainfall gauging stations should be improved for the hourly measurement. The water level/discharge gauging station at the Abapo Bridge should also be set up for the hourly measurement for the warning of floods from the Rio Grande.

10.2 Warning Criteria

From the current floods and inundation condition, the warning system should be divided into 3 levels based on the rainfall return period as follows:

Alert Level 1	:	Warning for rainfall at return period 2 years,
Alert Level 2	:	Warning for rainfall at return period 5 years,
Alert Level 3	:	Warning for rainfall at return period 10 years.

From the Master Plan Study and the flood damage survey, it was found that 3-day rainfall always caused flooding. However, the warning system herein is proposed to use 1-day, 3-day and 5-day rainfall for the judgement. The magnitude of rainfalls for warning should be as follows:

Rainfall	Return Period (year)	Chane - Pailon			San Juan - Antofagasta
		Saavedra	CETABOL	Trompillo	S.J. Yapacani
1 Day	Calculated rainfall				
	2	104.8	102.8	100.3	139.6
	5	141.9	140.4	144.4	187.8
	10	166.4	165.3	173.7	219.7
	Proposed magnitude to be used for warning system				
	2	90.0	90.0	90.0	125.0
	5	120.0	125.0	125.0	165.0
	10	145.0	145.0	155.0	195.0
3 Day	Calculated rainfall				
	2	134.1	131.9	126.3	182.1
	5	188.7	178.1	175.4	241.6
	10	224.9	208.6	207.9	231.1
	Proposed magnitude for flood warning system				
	2	120.0	115.0	110.0	160.0
	5	165.0	160.0	155.0	215.0
	10	200.0	200.0	185.0	250.0
5 Day	Calculated rainfall				
	2	152	150.5	145.7	212.3
	5	212.2	205.9	197.7	270.9
	10	252.1	242.5	232.1	309.7
	Proposed magnitude to be used for warning system				
	2	135.0	135.0	130.0	190.0
	5	190.0	185.0	175.0	240.0
	10	225.0	215.0	205.0	275.0

TABLES

TABLE B.2.1(1) EXISTING MEASUREMENT STATIONS IN THE GRANDE RIVER BASIN

	Station	Latitude	Long	Elevation (m)	Province	Period	Measurement Type
					YAPACANI BASIN		
1	Buen Retiro	17 ° 17 '	63 ° 43 '	275	Ichilo	1978-1998	Rainfall
2	Buena Vista				Ichilo		Rainfall
3	Col. San Juan de Yapacani	17 ° 24 '	63 ° 50 '	285	Ichilo	1959-1998	Rainfall, Temperature and Humidity
4	Puente Yapacani	17 ° 24 '	63 ° 43 '	283	Ichilo	1994-1998	Water Level
					PIRAI BASIN		
1	Angostura	18 o 10 '	63 o 34 '	700	Andres Ibanez	1947-1998	Rainfall, Suspended Solid and Water Level
2	Bermejo	18 o 06 '	63 o 38 '	1000	Florida	1975-1998	Rainfall, Suspended Solid and Water Level
3	Ing. La Belgica	17 o 33 '	63 o 13 '	348	Andres Ibanez	1954-1998	Rainfall, Temperature, Humidity, Suspended Solid and Water Level
4	Gabetas						Rainfall
5	La Guardia	17 o 52 '	63 o 19 '	470	Andres Ibanez	1977-1998	Rainfall
6	Mairana	18 o 06 '	63 o 57 '	1350	Florida	1947-1998	Rainfall, Temperature, Wind and Humidity
7	Mataral	18 o 07 '	64 o 13 '	1400	Florida	1966-1998	Rainfall
8	Montero	17 o 20 '	63 o 23 '	317	O Santiestevan	1945-1998	Rainfall
9	El Patuju	17 o 20 '	63 o 19 '	292	O Santiestevan	1959-1998	Rainfall
10	Pampa Grande	18 o 05 '	64 o 06 '	1300	Florida	1977-1998	Rainfall
11	Portachelo	17 o 21 '	63 o 24 '	289	Sara	1976-1998	Rainfall
12	P. Eisenhower	17 o 19 '	63 o 19 '	277	O Santiestevan	1977-1998	Rainfall, Suspended Solid and Water Level
13	Quirusillas	18 o 20 '	63 o 57 '	1500	Florida	1966-1998	Rainfall
14	San Luis	17 o 33 '	63 o 09 '	345	Warnes	1972-1998	Rainfall
15	Samaipata	18 o 10 '	63 o 57 '	1650	Florida	1964-1998	Rainfall
16	San Juan del Rosario	18 o 18 '	63 o 48 '	1700	Florida	1976-1998	Rainfall
17	Trigal	18 o 18 '	64 o 09 '	1500	Vallegrande	1966-1998	Rainfall
18	Terevinto	17 o 43 '	63 o 23 '	425	Andres Ibanez	1977-1998	Rainfall, Water Level
19	Puente Palometillas	17 o 23 '	63 o 32 '	290	Ichilo	1994-1998	Water Level

TABLE B.2.1(2) EXISTING MEASUREMENT STATIONS IN THE GRANDE RIVER BASIN

	Station	Latitude	Long	Elevation (m)	Province	Period	Measurement Type
					CHANE BASIN		
1	CETABOL	17 o 25 '	62 o 54 '	283	Warnes	1970-1998	Rainfall, Temperature, Evaporation and Humidity
2	Cotoca	17 o 45 '	62 o 59 '	359	Andres Ibanez	1976-1998	Rainfall
3	Mineros	17 o 06 '	63 o 14 '	245	O Santiestevan	1976-1998	Rainfall
4	Okinawa I	17 o 13 '	62 o 53 '	252	Warnes	1966-1998	Rainfall and Temperature
5	General Saavedra	17 o 14 '	63 o 10 '	320	O Santiestevan	1952-1998	Rainfall, Temperature, Humidity and Nebulosity
6	Aerop. Trompillo	17 o 47 '	63 o 10 '	437	Andres Ibanez	1943-1998	Rainfall, Temperature, Wind, Pressure and Humidity
7	Viru Viru	17 o 39 '	63 o 08 '	360	Andres Ibanez	1985-1998	Rainfall, Temperature, Wind, Pressure and Humidity
8	Warnes	17 o 30 '	63 o 08 '	330	Warnes	1976-1998	Rainfall
9	Peroto	17 o 29 '	63 o 11 '	350	O Santiestevan	1988-1998	Rainfall
10	Sta Cruz - Oficina	17 o 47 '	63 o 10 '	416	Andres Ibanez	1975-1998	Rainfall
11	Sta Cruz - Universidad	17 o 47 '	63 o 11 '	725	Andres Ibanez	1971-1998	Rainfall
12	Est. Exp. Vallecito	17 o 46 '	63 o 09 '	398	Andres Ibanez	1995-1998	Rainfall, Temperature, Evaporation, Humidity and Insolation
					RIO GRANDE BASIN		
1	Cochabamba	o '	o '		Cochabamba		Rainfall
2	Comarapa	17 o 53 '	64 o 53 '	1814	M.M.Caballero	1963-1998	Rainfall, Temperature and Humidity
3	Moro Moro	18 o 21 '	64 o 19 '	2340	Vallegrande	1970-1998	Rainfall
4	Monteagudo	o '	o '		Chuquisaca		Rainfall
5	Saipina	18 o 05 '	64 o 35 '	1360	M.M.Caballero	1964-1998	Rainfall
6	San Isidro	17 o 27 '	63 o 31 '	332	Ichilo	1976-1998	Rainfall
7	Sta Rosa (Florida)	17 o 53 '	64 o 18 '	1500	Florida	1966-1998	Rainfall
8	Sucre	o '	o '		Chuquisaca		Rainfall
9	Vallegrande	18 o 28 '	64 o 07 '	1980	Vallegrande	1943-1998	Rainfall, Temperature, Wind and Humidity
10	P. Pailas	17 o 39 '	62 o 47 '	280	Andres Ibanez	1977-1998	Rainfall

TABLE B.2.2 METEOROLOGICAL CONDITIONS IN THE STUDY AREA

Station		Month												Annual
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
MONTHLY AVERAGE TEMPERATURE (°C)														
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	19.0
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
CETABOL-JICA	Max	30.49	30.48	30.71	29.24	26.7	25.0	25.73	28.41	29.58	31.19	31.0	30.77	29.1
	Mean	26.06	25.58	25.47	24.19	21.54	19.86	20.0	21.92	23.54	25.57	25.86	26.0	23.8
	Min	21.73	21.15	20.89	19.36	17.09	15.39	14.35	16.0	17.67	19.71	20.55	21.5	18.8
San Juan de Yapacani	Max	30.5	30.6	30.9	29.6	27.0	25.3	26.1	27.7	28.8	30.6	30.6	30.5	29.0
	Mean	26.3	26.3	26.2	24.7	22.4	20.8	20.8	21.9	23.2	25.2	25.6	26.2	24.1
	Min	22.1	22.0	21.6	19.8	17.9	16.3	15.5	16.1	17.6	19.8	20.8	21.9	19.3
MONTHLY AVERAGE RELATIVE HUMIDITY (%)														
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	67.9
CETABOL-JICA		82.32	81.34	81.17	80.26	80.2	77.62	72.0	68.7	68.33	71.34	75.61	79.25	76.5
San Juan de Yapacani		80.94	80.0	78.4	77.83	78.59	79.0	74.63	71.17	70.31	71.45	74.88	79.41	76.4
MONTHLY AVERAGE RAINFALL (mm)														
5806 SC/Trompillo		180.4	137.6	125.3	103.5	86.76	73.81	59.75	42.19	69.76	101.8	131.1	182.1	1294.0
61NP Saavedra		222.7	164.7	113.3	89.36	80.12	68.38	43.2	48.51	74.37	110.1	151.1	200.7	1366.598
CETABOL-JICA		193.7	164.7	110.7	85.36	81.0	56.86	44.7	50.39	69.65	102.3	124.7	175.4	1259.5
San Juan de Yapacani		308.2	252.2	178.6	134.0	144.7	94.2	64.9	78.5	84.6	135.3	162.4	276.2	1913.8
MONTHLY AVERAGE WIND SPEED AND DIRECTION (knot)														
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)														
MONTHLY AVERAGE EVAPORATION (%)														
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
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 B.4.1(1) AVAILABLE DATA

Rainfall

No	St No	Station Name	Latitud	Longitud	Elevation (m)	Year (43–97)
Okinawa / Chane-Pailon (SEARPI, SENAMHI, CETABOL and AASANA)						
1	22NP	Montero	17°20'	63°23'	317	
2	25NP	Sta Cruz-Oficina	17°47'	63°10'	416	
3	28NP	Peroto	17°29'	63°10'42"	350	
4	50NP	Viru-Viru Aeropuerto	17°38'51"	63°07'55"	360	
5	51NP	Warnes	17°30'	63°08'	330	
6	61NP	Saavedra	17°14'	63°10'	320	
7	62NP	Mineros	17°06'	63°14'	245	
8	5806	Sta Cruz-Trompillo	17°47'	63°10'	437	
9	5807	Sta Cruz-Universidad	17°46'38"	63°11'	725	
10		Est. Exp. Vallecito	17°46'	63°09'	398	
11		Okinawa 1	17°13'	62°53'	252	
12		Puerto Pailas	17°39'	62°47'	280	
13		CETABOL-JICA	17°23'	62°54'	280	
14		Vallegrande				
15		Camiri				
San Juan de Yapacani / Antofaganta (CETABOL and MACUCY)						
1		San Juan de Yapacani	17°15'	63°50'	350	
2	13PY	Buena Vista	17°27'	63°40'	379	

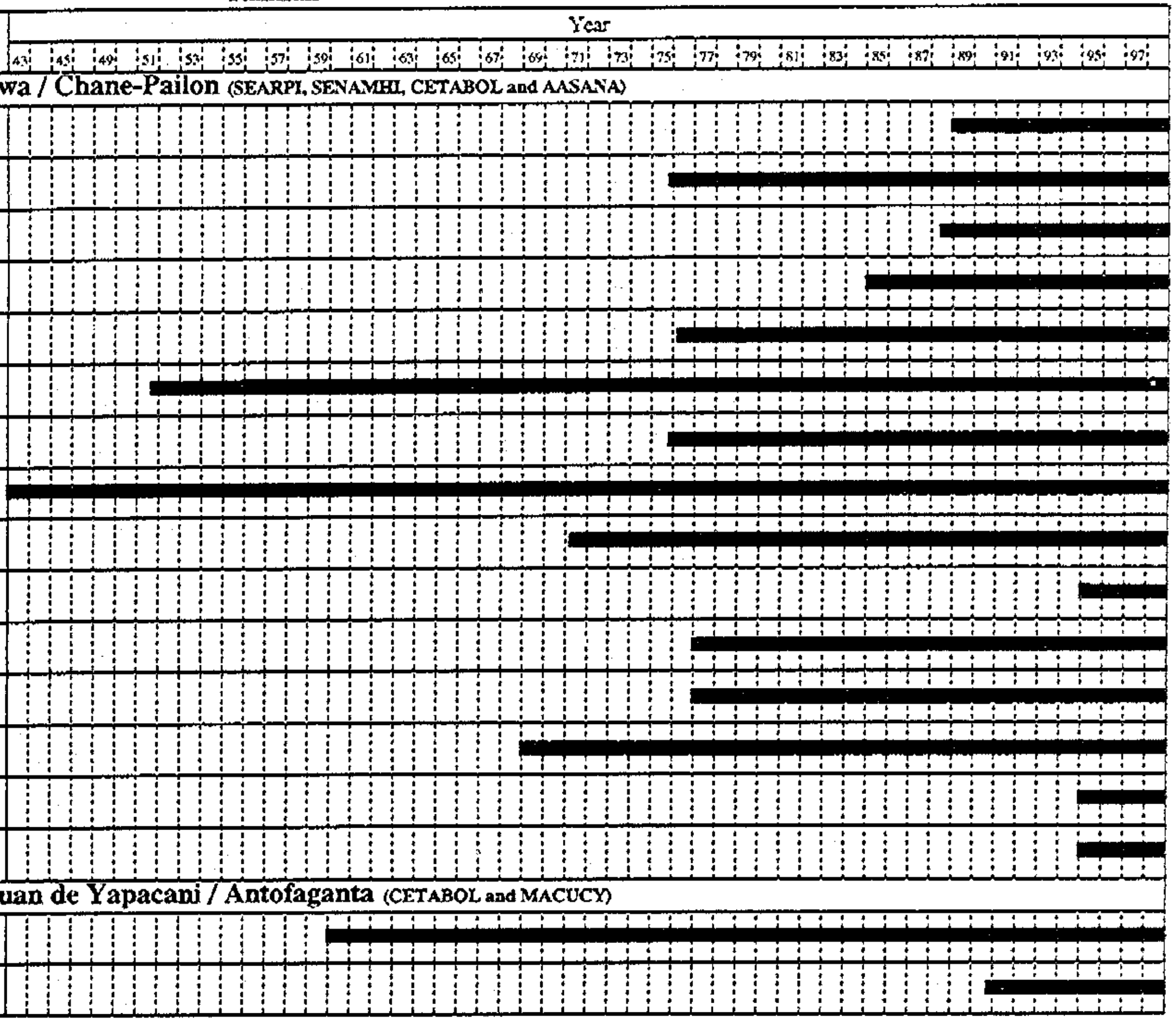

TABLE B.4.1(2) AVAILABLE DATA

Discharge / Water Level

No	St No	Station Name	Latitud	Longitud	Elevation (m)
Rio Pirai (SEARPI)					
1	506	Angostura	18°09'59"	63°34'05"	620
2	510	La Belgica	17°32'	63°13'	348
3	505	Bermejo	18°06'	63°38'	1000
4	504	Colorado	18°08'	63°08'	1020
5	512	P. Eisenhower	17°19'	63°19'	279
6	520	Espejos	17°58'30"	63°34'17"	497
7	530	San Pedro Terevinto	17°43'05"	63°26'	450
Rio Grande (SEARPI)					
1	401	P. Abapo			440
2	402	Puerto Pailas	17°40'	62°47'	280
Rio Yapacani (MACUCY)					
1	004H	Puente Yapacani	17°24'	63°43'	283
Rio Palometillas (MACUCY)					
1	003H	Puente Palometillas	17°23'	63°32'	290

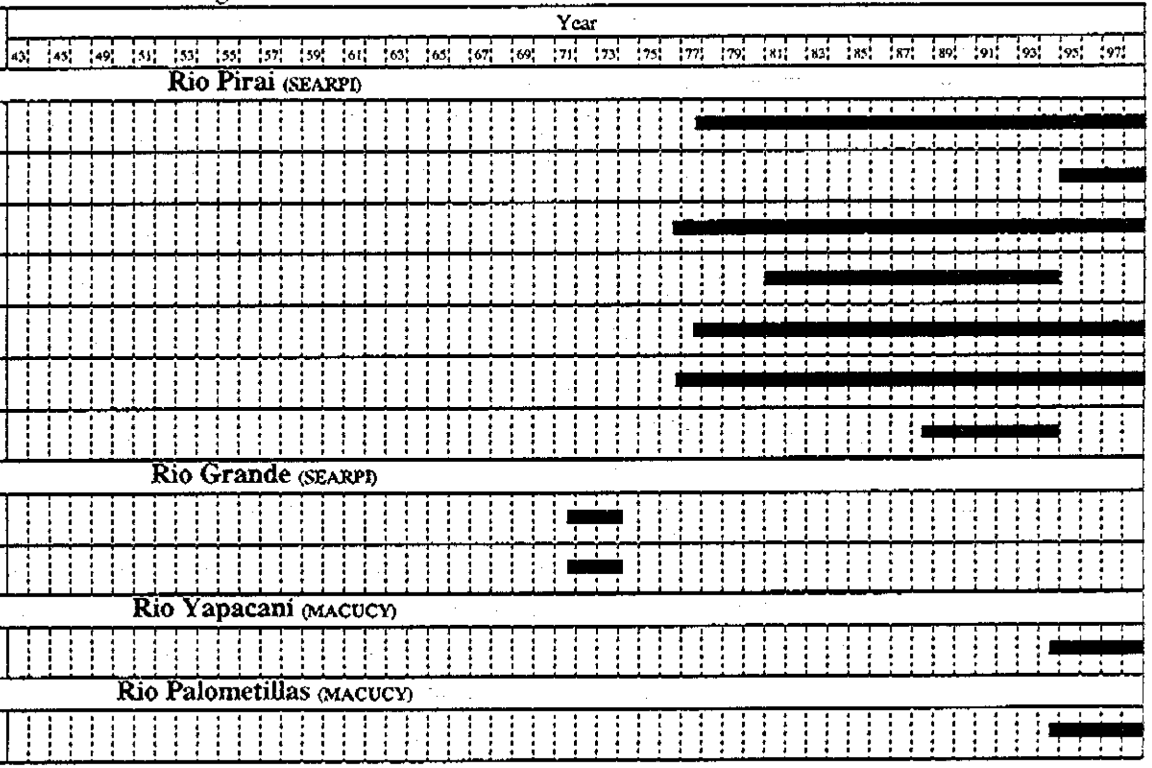

TABLE B.6.1(1) ANNUAL MAXIMUM RAINFALL BY GUMBEL DISTRIBUTION

Station Name 5806 SANTA CRUZ - TROMPILLO

	1 Day Max.		2 Day Max.	3 Day Max.	4 Day Max.	5 Day Max.	6 Day Max.	7 Day Max.
n		54	54	54	54	54	54	54
Sx		48.2	52.3	53.6	55.2	56.7	57.5	57.3
Sy		1.2	1.2	1.2	1.2	1.2	1.2	1.2
y'		0.6	0.6	0.6	0.6	0.6	0.6	0.6
1/a		39.0	42.3	43.3	44.6	45.9	46.5	46.3
x'		108.3	127.0	135.3	144.9	155.1	163.8	170.3
x0		86.0	102.8	110.5	119.3	128.9	137.2	143.8
T	y	x	x	x	x	x	x	x
200	5.3	292.4	326.7	339.9	355.6	371.8	383.4	389.1
100	4.6	265.3	297.3	309.7	324.5	339.8	351.0	356.9
50	3.9	238.1	267.8	279.5	293.4	307.8	318.6	324.5
40	3.7	229.3	258.2	269.7	283.3	297.5	308.1	314.1
30	3.4	217.9	245.9	257.1	270.3	284.1	294.5	300.5
20	3.0	201.8	228.4	239.1	251.8	265.1	275.3	281.4
10	2.3	173.7	198.0	207.9	219.7	232.1	241.8	248.0
5	1.5	144.4	166.2	175.4	186.2	197.7	206.9	213.3
2	0.4	100.3	118.3	126.3	135.7	145.7	154.3	160.8

Station Name 61NP SAAVEDRA

	1Day Max.		2 Day Max.	3 Day Max.	4 Day Max.	5 Day Max.	6 Day Max	7 Day Max.
n		47	47	47	47	47	47	47
Sx		40.3	50.9	59.3	65.2	65.5	71.6	71.6
Sy		1.2	1.2	1.2	1.2	1.2	1.2	1.2
y'		0.6	0.6	0.6	0.6	0.6	0.6	0.6
1/a		32.7	41.4	48.2	53.0	53.2	58.1	58.2
x'		111.6	131.2	144.0	150.8	162.9	172.5	177.5
x0		92.9	107.6	116.5	120.5	132.5	139.2	144.2
T	y	x	x	x	x	x	x	x
200	5.3	266.0	326.6	371.6	401.0	414.0	447.0	452.2
100	4.6	243.2	297.8	338.1	364.2	377.1	406.6	411.8
50	3.9	220.4	268.9	304.5	327.2	339.9	366.0	371.2
40	3.7	213.0	259.6	293.6	315.3	327.9	352.9	358.0
30	3.4	203.5	247.5	279.5	299.8	312.4	335.9	341.0
20	3.0	189.9	230.4	259.6	277.9	290.4	311.8	317.0
10	2.3	166.4	200.6	224.9	239.7	252.1	270.0	275.1
5	1.5	141.9	169.6	188.7	200.0	212.2	226.4	231.5
2	0.4	104.8	122.7	134.1	140.0	152.0	160.5	165.5

Station Name Okinawa 2 (CETABOL - JICA)

	1Day Max.		2 Day Max.	3 Day Max.	4 Day Max.	5 Day Max.	6 Day Max	7 Day Max.
n		25	25	25	25	25	25	25
Sx		39.7	43.1	48.8	50.0	58.5	56.1	60.2
Sy		1.2	1.2	1.2	1.2	1.2	1.2	1.2
y'		0.6	0.6	0.6	0.6	0.6	0.6	0.6
1/a		33.2	36.0	40.7	41.8	48.8	46.8	50.2
x'		109.6	126.3	140.2	148.3	160.5	170.2	179.5
x0		90.7	105.8	117.0	124.5	132.6	143.5	150.8
T	y	x	x	x	x	x	x	x
200	5.3	266.3	296.2	332.6	345.7	391.3	391.4	416.9
100	4.6	243.2	271.2	304.3	316.6	357.3	358.9	382.0
50	3.9	220.1	246.1	275.9	287.4	323.2	326.2	346.9
40	3.7	212.6	238.0	266.7	278.0	312.2	315.6	335.6
30	3.4	202.9	227.5	254.8	265.8	297.9	302.0	320.9
20	3.0	189.2	212.6	237.9	248.5	277.7	282.6	300.1
10	2.3	165.3	186.7	208.6	218.5	242.5	248.9	263.9
5	1.5	140.4	159.7	178.1	187.1	205.9	213.7	226.2
2	0.4	102.8	119.0	131.9	139.8	150.5	160.7	169.3

TABLE B.6.1(2) ANNUAL MAXIMUM RAINFALL BY GUMBEL DISTRIBUTION

Station Name Puerto Pailas

	1Day Max.		2 Day Max.	3 Day Max.	4 Day Max.	5 Day Max.	6 Day Max	7 Day Max.
n		20	20	20	20	20	20	20
Sx		29.6	31.6	34.1	49.0	51.5	51.8	53.6
Sy		1.2	1.2	1.2	1.2	1.2	1.2	1.2
y'		0.6	0.6	0.6	0.6	0.6	0.6	0.6
1/a		25.0	26.7	28.8	41.4	43.5	43.8	45.3
x'		84.8	100.7	106.9	120.7	125.6	132.8	142.0
x0		70.6	85.5	90.5	97.1	100.8	107.9	116.2
T	y	x	x	x	x	x	x	x
200	5.3	203.0	226.9	243.0	316.4	331.3	340.0	356.3
100	4.6	185.6	208.4	223.0	287.6	301.0	309.5	324.8
50	3.9	168.1	189.7	202.9	258.7	270.6	278.9	293.1
40	3.7	162.5	183.7	196.4	249.3	260.8	269.0	282.9
30	3.4	155.2	175.9	188.0	237.3	248.1	256.2	269.6
20	3.0	144.8	164.8	176.1	220.1	230.1	238.1	250.9
10	2.3	126.9	145.6	155.3	190.3	198.7	206.5	218.2
5	1.5	108.1	125.5	133.7	159.2	166.1	173.6	184.2
2	0.4	79.8	95.3	101.1	112.3	116.7	123.9	132.8

Station Name Colonia San Juan de Yapacani (JICA/CAISY)

	1Day Max.		2 Day Max.	3 Day Max.	4 Day Max.	5 Day Max.	6 Day Max	7 Day Max.	8 Day Max.
n		37	37	37	37	37	37	37	32
Sx		51.9	62.9	64.2	63.6	63.1	63.2	73.7	75.449
Sy		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.213
y'		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5709
1/a		42.5	51.5	52.6	52.1	51.7	51.8	60.3	62.2
x'		148.3	176.4	192.8	212.1	222.9	232.4	244.1	246.29
x0		124.0	146.9	162.8	182.3	193.4	202.8	209.6	210.78
T	y	x	x	x	x	x	x	x	x
200	5.3	349.1	419.9	441.2	458.2	467.1	477.0	529.2	540.18
100	4.6	319.6	384.0	404.6	422.0	431.1	441.0	487.2	496.91
50	3.9	289.9	348.0	367.9	385.6	395.0	404.8	445.1	453.48
40	3.7	280.3	336.4	356.0	373.8	383.4	393.1	431.4	439.44
30	3.4	267.9	321.3	340.7	358.6	368.3	378.0	413.8	421.28
20	3.0	250.3	300.0	318.9	337.1	346.9	356.6	388.8	395.53
10	2.3	219.7	262.9	281.1	299.6	309.7	319.3	345.4	350.76
5	1.5	187.8	224.2	241.6	260.5	270.9	280.5	300.1	304.07
2	0.4	139.6	165.8	182.1	201.4	212.3	221.8	231.7	233.58

TABLE B.6.2 PROBABLE MAXIMUM RAINFALL WITHIN 24 HOURS BY GUMBEL METHOD

STATION: SAAVEDRA

(Unit:mm)

Duration	Return Period(Year)							
(hr)	2	5	10	20	30	40	50	100
0.5	26.0	37.9	45.9	53.5	57.9	61.0	63.3	70.7
1.0	44.2	58.6	68.1	77.3	82.5	86.2	89.1	98
2.0	59.1	79.8	93.5	106.7	114.3	119.6	123.8	136.6
3.0	69.1	93.0	108.9	124.1	132.9	139.0	143.8	158.6
4.0	74.9	100.9	118.1	134.6	144.1	150.8	156.0	172
5.0	81.3	111.0	130.7	149.6	160.4	168.1	174.0	192.3
6.0	85.8	118.0	139.2	159.6	171.3	179.6	186.0	205.8
9.0	94.2	130.0	153.7	176.4	189.5	198.7	205.8	227.8
12.0	99.2	137.5	155.2	177.9	191.0	200.2	207.3	229.3
24.0	102.4	137.9	161.4	184.0	197.0	206.1	213.2	235.1

STATION: SANTA CRUZ-OFICINA

(Unit:mm)

Duration	Return Period(Year)							
(hr)	2	5	10	20	30	40	50	100
0.5	26.5	36.5	43.1	49.4	53	55.6	57.6	63.7
1.0	49.8	62.3	70.7	78.6	83.2	86.5	89	96.7
2.0	71.7	94.0	108.8	122.9	131.1	136.8	141.3	155
3.0	85.0	113.9	133.0	151.3	161.9	169.3	175	192.8
4.0	97.3	133.0	156.7	179.4	192.5	201.7	208.8	230.9
5.0	97.5	140.7	165.7	189.7	203.5	213.2	220.8	244
6.0	97.7	140.9	166.1	201.9	216.8	227.3	235.4	260.4
9.0	98.2	141.6	167.5	202.0	217.1	227.7	235.9	261.3
12.0	98.7	142.3	168.8	202.0	217.3	228.1	236.4	262.1
24.0	100.9	145.0	174.2	202.2	218.3	229.7	238.5	265.6

TABLE B.7.1(1) RAINFALL VALUES FOR EACH RETURN PERIOD

Saavedra (unit: mm)

Time		Return Period (Year)					
		2	5	10	20	30	50
1st Day	1	0.0	0.1	0.1	0.1	0.1	0.1
	2	0.0	0.1	0.1	0.1	0.1	0.1
	3	0.1	0.1	0.1	0.1	0.2	0.2
	4	0.1	0.1	0.1	0.2	0.2	0.2
	5	0.1	0.1	0.2	0.2	0.2	0.3
	6	0.1	0.2	0.2	0.3	0.3	0.4
	7	0.1	0.3	0.3	0.4	0.4	0.5
	8	0.2	0.4	0.5	0.6	0.6	0.7
	9	0.3	0.5	0.7	0.9	0.9	1.0
	10	0.5	0.9	1.2	1.5	1.6	1.8
	11	1.1	1.9	2.5	3.0	3.3	3.7
	12	4.7	8.2	10.6	12.8	14.1	15.7
	13	2.0	3.5	4.5	5.4	6.0	6.7
	14	0.7	1.2	1.6	1.9	2.1	2.4
	15	0.4	0.7	0.9	1.1	1.2	1.3
	16	0.2	0.4	0.6	0.7	0.7	0.8
	17	0.2	0.3	0.4	0.5	0.5	0.6
	18	0.1	0.2	0.3	0.3	0.4	0.4
	19	0.1	0.2	0.2	0.3	0.3	0.3
	20	0.1	0.1	0.2	0.2	0.2	0.2
	21	0.1	0.1	0.1	0.2	0.2	0.2
	22	0.0	0.1	0.1	0.1	0.1	0.2
	23	0.0	0.1	0.1	0.1	0.1	0.1
	24	0.0	0.1	0.1	0.1	0.1	0.1
Sub-total		11.3	19.9	25.6	31.0	34.1	38.1
2nd Day	1	0.1	0.1	0.1	0.1	0.2	0.2
	2	0.1	0.1	0.1	0.2	0.2	0.2
	3	0.1	0.1	0.2	0.2	0.2	0.2
	4	0.1	0.2	0.2	0.2	0.3	0.3
	5	0.1	0.2	0.3	0.3	0.3	0.4
	6	0.2	0.3	0.3	0.4	0.4	0.5
	7	0.2	0.4	0.4	0.5	0.6	0.6
	8	0.3	0.5	0.6	0.8	0.8	0.9
	9	0.5	0.8	1.0	1.2	1.3	1.4
	10	0.8	1.3	1.7	2.0	2.2	2.4
	11	1.7	2.8	3.4	4.1	4.5	5.0
	12	7.3	11.7	14.6	17.4	19.0	21.0
	13	3.1	5.0	6.2	7.4	8.1	9.0
	14	1.1	1.7	2.2	2.6	2.8	3.2
	15	0.5	1.0	1.2	1.5	1.6	1.8
	16	0.4	0.6	0.8	0.9	1.0	1.1
	17	0.3	0.4	0.5	0.6	0.7	0.8
	18	0.2	0.3	0.4	0.5	0.5	0.6
	19	0.1	0.2	0.3	0.3	0.4	0.4
	20	0.1	0.2	0.2	0.3	0.3	0.3
	21	0.1	0.1	0.2	0.2	0.2	0.3
	22	0.1	0.1	0.2	0.2	0.2	0.2
	23	0.1	0.1	0.1	0.2	0.2	0.2
	24	0.1	0.1	0.1	0.1	0.1	0.2
Sub-total		17.6	28.3	35.4	42.2	46.1	51.0
3rd Day	1	0.3	0.6	0.7	0.8	0.9	1.0
	2	0.4	0.6	0.8	1.0	1.1	1.2
	3	0.5	0.8	1.0	1.2	1.3	1.4
	4	0.6	0.9	1.2	1.4	1.5	1.7
	5	0.7	1.2	1.5	1.7	1.9	2.1
	6	1.0	1.5	1.9	2.2	2.4	2.7
	7	1.3	2.0	2.4	2.9	3.1	3.5
	8	1.8	2.7	3.3	3.9	4.3	4.7
	9	2.8	4.0	4.9	5.7	6.1	6.7
	10	4.8	6.5	7.8	8.9	9.5	10.3
	11	10.0	11.6	12.7	13.8	14.4	15.2
	12	42.2	58.7	69.4	79.8	85.8	93.2
	13	18.0	22.1	24.8	27.3	28.8	30.6
	14	6.3	7.2	7.7	8.3	8.7	9.1
	15	3.6	5.1	6.1	7.0	7.5	8.2
	16	2.2	3.3	4.0	4.7	5.1	5.5
	17	1.5	2.3	2.8	3.3	3.6	4.0
	18	1.1	1.7	2.1	2.5	2.7	3.0
	19	0.8	1.3	1.6	1.9	2.1	2.4
	20	0.7	1.1	1.3	1.6	1.7	1.9
	21	0.5	0.9	1.1	1.3	1.4	1.6
	22	0.4	0.7	0.9	1.1	1.2	1.3
	23	0.4	0.6	0.7	0.9	1.0	1.1
	24	0.3	0.5	0.6	0.8	0.8	0.9
Sub-total		102.4	137.9	161.4	184.0	197.0	213.2
TOTAL		131.3	186.1	222.4	257.2	277.2	302.3

Trompillo (unit: mm)

Time		Return Period (Year)					
		2	5	10	20	30	50
1st Day	1	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0
	7	0.0	0.0	0.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.0	0.0	0.0
	10	0.0	0.0	0.0	0.1	0.1	0.1
	11	1.3	1.5	1.6	1.8	1.8	1.9
	12	3.7	4.4	4.8	5.1	5.3	5.6
	13	2.0	2.4	2.6	2.8	2.9	3.1
	14	0.9	1.0	1.1	1.2	1.2	1.3
	15	0.0	0.0	0.0	0.0	0.0	0.0
	16	0.0	0.0	0.0	0.0	0.0	0.0
	17	0.0	0.0	0.0	0.0	0.0	0.0
	18	0.0	0.0	0.0	0.0	0.0	0.0
	19	0.0	0.0	0.0	0.0	0.0	0.0
	20	0.0	0.0	0.0	0.0	0.0	0.0
	21	0.0	0.0	0.0	0.0	0.0	0.0
	22	0.0	0.0	0.0	0.0	0.0	0.0
	23	0.0	0.0	0.0	0.0	0.0	0.0
	24	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total		8.1	9.4	10.3	11.1	11.5	12.2
2nd Day	1	0.0	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0
	6	0.0	0.0	0.0	0.0	0.0	0.0
	7	0.0	0.0	0.0	0.0	0.0	0.0
	8	0.0	0.0	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.1	0.1	0.1	0.1
	10	0.1	0.1	0.1	0.1	0.1	0.1
	11	2.9	3.5	3.9	4.3	4.6	4.8
	12	8.5	10.3	11.5	12.7	13.4	14.2
	13	4.6	5.6	6.3	6.9	7.3	7.7
	14	2.0	2.4	2.7	3.0	3.1	3.3
	15	0.1	0.1	0.1	0.1	0.1	0.1
	16	0.0	0.0	0.0	0.0	0.0	0.1
	17	0.0	0.0	0.0	0.0	0.0	0.0
	18	0.0	0.0	0.0	0.0	0.0	0.0
	19	0.0	0.0	0.0	0.0	0.0	0.0
	20	0.0	0.0	0.0	0.0	0.0	0.0
	21	0.0	0.0	0.0	0.0	0.0	0.0
	22	0.0	0.0	0.0	0.0	0.0	0.0
	23	0.0	0.0	0.0	0.0	0.0	0.0
	24	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total		18.4	22.3	24.9	27.4	28.9	30.6
3rd Day	1	0.0	0.2	0.3	0.4	0.5	0.6
	2	0.0	0.2	0.3	0.5	0.6	0.7
	3	0.0	0.3	0.4	0.6	0.7	0.8
	4	0.0	0.3	0.5	0.7	0.9	1.0
	5	0.0	0.4	0.6	0.9	1.1	1.3
	6	0.1	0.5	0.8	1.2	1.4	1.6
	7	0.1	0.7	1.2	1.6	1.9	2.2
	8	0.1	1.1	1.7	2.3	2.7	3.7
	9	0.2	1.7	2.7	3.6	4.1	4.7
	10	0.5	3.2	4.9	6.2	7.0	8.1
	11	15.9	20.6	23.7	26.6	28.3	30.4
	12	46.7	61.9	72.1	81.7	87.3	94.2
	13	25.4	33.1	38.2	43.0	45.9	49.4
	14	10.9	14.0	16.1	18.0	19.2	20.6
	15	0.3	2.3	3.6	4.6	5.2	6.1
	16	0.2	1.3	2.1	2.8	3.3	3.8
	17	0.1	0.9	1.4	1.9	2.2	2.6
	18	0.1	0.6	1.0	1.4	1.6	1.9
	19	0.1	0.5	0.7	1.1	1.2	1.4
	20	0.0	0.3	0.6	0.8	1.0	1.1
	21	0.0	0.3	0.5	0.7	0.8	0.9
	22	0.0	0.2	0.4	0.5	0.6	0.8
	23	0.0	0.2	0.3	0.5	0.5	0.6
	24	0.0	0.2	0.3	0.4	0.5	0.5
Sub-total		100.9	145.0	174.2	202.2	218.3	238.5
TOTAL		127.4	176.7	209.4	240.7	258.7	251.3

TABLE B.7.1(2) RAINFALL VALUES FOR EACH RETURN PERIOD

CETABOL (unit: mm)

Time		Return Period (Year) 2	5	10	20	30	50
1st Day	1	0.0	0.1	0.1	0.1	0.1	0.1
	2	0.1	0.1	0.1	0.1	0.1	0.1
	3	0.1	0.1	0.1	0.1	0.1	0.1
	4	0.1	0.1	0.1	0.1	0.2	0.2
	5	0.1	0.1	0.2	0.2	0.2	0.2
	6	0.1	0.2	0.2	0.2	0.3	0.3
	7	0.2	0.2	0.3	0.3	0.3	0.4
	8	0.2	0.3	0.4	0.5	0.5	0.5
	9	0.4	0.5	0.6	0.7	0.7	0.8
	10	0.6	0.9	1.0	1.2	1.3	1.4
	11	1.3	1.8	2.1	2.5	2.7	2.9
	12	5.3	7.6	9.0	10.4	11.3	12.3
	13	2.3	3.2	3.8	4.4	4.8	5.2
	14	0.8	1.1	1.4	1.6	1.7	1.8
	15	0.5	0.6	0.8	0.9	1.0	1.1
	16	0.3	0.4	0.5	0.6	0.6	0.7
	17	0.2	0.3	0.3	0.4	0.4	0.4
	18	0.1	0.2	0.2	0.3	0.3	0.3
	19	0.1	0.2	0.2	0.2	0.2	0.2
	20	0.1	0.1	0.1	0.2	0.2	0.2
	21	0.1	0.1	0.1	0.1	0.1	0.2
	22	0.1	0.1	0.1	0.1	0.1	0.1
	23	0.0	0.1	0.1	0.1	0.1	0.1
	24	0.0	0.1	0.1	0.1	0.1	0.1
Sub-total		12.9	18.4	21.9	25.3	27.3	29.8
2nd Day	1	0.1	0.1	0.1	0.1	0.1	0.1
	2	0.1	0.1	0.1	0.1	0.1	0.1
	3	0.1	0.1	0.1	0.1	0.1	0.1
	4	0.1	0.1	0.1	0.1	0.1	0.1
	5	0.1	0.1	0.2	0.2	0.2	0.2
	6	0.2	0.2	0.2	0.2	0.2	0.2
	7	0.2	0.2	0.3	0.3	0.3	0.3
	8	0.3	0.3	0.4	0.4	0.4	0.5
	9	0.4	0.5	0.6	0.6	0.7	0.7
	10	0.8	0.9	1.0	1.1	1.2	1.2
	11	1.6	1.9	2.1	2.3	2.4	2.5
	12	6.7	8.0	8.8	9.7	10.1	10.7
	13	2.8	3.4	3.8	4.1	4.3	4.6
	14	1.0	1.2	1.3	1.4	1.5	1.6
	15	0.6	0.7	0.8	0.8	0.9	0.9
	16	0.4	0.4	0.5	0.5	0.5	0.6
	17	0.2	0.3	0.3	0.3	0.4	0.4
	18	0.2	0.2	0.2	0.3	0.3	0.3
	19	0.1	0.2	0.2	0.2	0.2	0.2
	20	0.1	0.1	0.1	0.2	0.2	0.2
	21	0.1	0.1	0.1	0.1	0.1	0.1
	22	0.1	0.1	0.1	0.1	0.1	0.1
	23	0.1	0.1	0.1	0.1	0.1	0.1
	24	0.0	0.1	0.1	0.1	0.1	0.1
Sub-total		16.2	19.3	21.4	23.4	24.6	26.0
3rd Day	1	0.3	0.6	0.7	0.9	0.9	1.0
	2	0.4	0.7	0.8	1.0	1.1	1.2
	3	0.5	0.8	1.0	1.2	1.3	1.5
	4	0.6	1.0	1.2	1.4	1.6	1.8
	5	0.7	1.2	1.5	1.8	2.0	2.2
	6	1.0	1.5	1.9	2.3	2.5	2.7
	7	1.3	2.0	2.5	3.0	3.2	3.6
	8	1.8	2.8	3.4	4.0	4.4	4.8
	9	2.8	4.1	5.0	5.8	6.3	6.9
	10	4.9	6.7	8.0	9.2	9.8	10.6
	11	10.0	11.8	13.0	14.2	14.9	15.7
	12	42.4	59.7	71.1	82.1	88.4	96.2
	13	18.1	22.5	25.4	28.1	29.6	31.6
	14	6.4	7.3	7.9	8.6	8.9	9.4
	15	3.6	5.2	6.2	7.2	7.8	8.5
	16	2.3	3.4	4.1	4.8	5.2	5.7
	17	1.5	2.4	2.9	3.4	3.7	4.1
	18	1.1	1.7	2.2	2.6	2.8	3.1
	19	0.8	1.3	1.7	2.0	2.2	2.4
	20	0.7	1.1	1.3	1.6	1.8	2.0
	21	0.5	0.9	1.1	1.3	1.4	1.6
	22	0.4	0.7	0.9	1.1	1.2	1.3
	23	0.4	0.6	0.8	0.9	1.0	1.1
	24	0.3	0.5	0.7	0.8	0.9	1.0
Sub-total		102.8	140.4	165.3	189.2	202.9	220.1
TOTAL		131.9	178.1	208.6	237.9	254.8	275.9

San Juan de Yapacani (unit: mm)

Time		Return Period (Year) 2	5	10	20	30	50
1st Day	1	0.1	0.1	0.1	0.1	0.1	0.1
	2	0.1	0.1	0.1	0.1	0.1	0.1
	3	0.1	0.1	0.1	0.1	0.1	0.1
	4	0.1	0.1	0.1	0.1	0.1	0.1
	5	0.1	0.1	0.1	0.1	0.2	0.2
	6	0.2	0.2	0.2	0.2	0.2	0.2
	7	0.2	0.2	0.2	0.3	0.3	0.3
	8	0.3	0.3	0.3	0.4	0.4	0.4
	9	0.5	0.5	0.5	0.6	0.6	0.6
	10	0.8	0.9	0.9	1.0	1.0	1.0
	11	1.7	1.8	1.9	2.0	2.0	2.1
	12	7.0	7.6	8.0	8.3	8.6	8.8
	13	3.0	3.2	3.4	3.5	3.7	3.8
	14	1.1	1.1	1.2	1.2	1.3	1.3
	15	0.6	0.6	0.7	0.7	0.7	0.8
	16	0.4	0.4	0.4	0.4	0.5	0.5
	17	0.3	0.3	0.3	0.3	0.3	0.3
	18	0.2	0.2	0.2	0.2	0.2	0.2
	19	0.1	0.2	0.2	0.2	0.2	0.2
	20	0.1	0.1	0.1	0.1	0.1	0.1
	21	0.1	0.1	0.1	0.1	0.1	0.1
	22	0.1	0.1	0.1	0.1	0.1	0.1
	23	0.1	0.1	0.1	0.1	0.1	0.1
	24	0.1	0.1	0.1	0.1	0.1	0.1
Sub-total		17.0	18.4	19.3	20.2	20.8	21.4
2nd Day	1	0.1	0.1	0.1	0.1	0.2	0.2
	2	0.1	0.1	0.2	0.2	0.2	0.2
	3	0.1	0.2	0.2	0.2	0.2	0.3
	4	0.1	0.2	0.2	0.3	0.3	0.3
	5	0.2	0.2	0.3	0.3	0.4	0.4
	6	0.2	0.3	0.4	0.4	0.5	0.5
	7	0.3	0.4	0.5	0.6	0.6	0.7
	8	0.4	0.6	0.7	0.8	0.9	1.0
	9	0.7	0.9	1.1	1.3	1.3	1.5
	10	1.1	1.6	1.9	2.2	2.3	2.5
	11	2.4	3.3	3.9	4.5	4.8	5.2
	12	10.0	13.9	16.4	18.9	20.3	22.1
	13	4.2	5.9	7.0	8.0	8.6	9.4
	14	1.5	2.1	2.5	2.8	3.0	3.3
	15	0.9	1.2	1.4	1.6	1.7	1.9
	16	0.5	0.7	0.9	1.0	1.1	1.2
	17	0.4	0.5	0.6	0.7	0.7	0.8
	18	0.3	0.4	0.4	0.5	0.5	0.6
	19	0.2	0.3	0.3	0.4	0.4	0.4
	20	0.2	0.2	0.3	0.3	0.3	0.3
	21	0.1	0.2	0.2	0.2	0.3	0.3
	22	0.1	0.1	0.2	0.2	0.2	0.2
	23	0.1	0.1	0.1	0.2	0.2	0.2
	24	0.1	0.1	0.1	0.1	0.1	0.2
Sub-total		24.2	33.6	39.8	45.8	49.2	53.5
3rd Day	1	0.5	0.8	0.9	1.1	1.3	1.4
	2	0.5	0.9	1.1	1.3	1.5	1.6
	3	0.7	1.1	1.3	1.6	1.7	1.9
	4	0.8	1.3	1.6	1.9	2.1	2.3
	5	1.0	1.6	2.0	2.4	2.6	2.9
	6	1.3	2.1	2.5	3.0	3.3	3.6
	7	1.8	2.7	3.3	3.9	4.3	4.7
	8	2.5	3.7	4.6	5.4	5.8	6.4
	9	3.8	5.5	6.7	7.8	8.4	9.1
	10	6.6	8.9	10.7	12.2	13.0	14.1
	11	13.6	15.8	17.4	18.9	19.8	20.9
	12	57.4	80.1	95.0	109.3	117.5	127.7
	13	24.5	30.2	33.9	37.4	39.4	42.0
	14	8.6	9.8	10.6	11.4	11.9	12.5
	15	4.9	6.9	8.3	9.6	10.3	11.2
	16	3.1	4.5	5.5	6.4	6.9	7.6
	17	2.1	3.2	3.9	4.6	5.0	5.5
	18	1.5	2.3	2.9	3.4	3.7	4.1
	19	1.1	1.8	2.2	2.7	2.9	3.2
	20	0.9	1.4	1.8	2.1	2.3	2.6
	21	0.7	1.2	1.5	1.7	1.9	2.1
	22	0.6	1.0	1.2	1.5	1.6	1.8
	23	0.5	0.8	1.0	1.2	1.4	1.5
	24	0.4	0.7	0.9	1.1	1.2	1.3
Sub-total		139.3	188.3	220.8	251.9	269.8	292.2
TOTAL		180.5	240.3	279.9	317.9	339.8	367.1

TABLE B.8.1 PARAMETERS FOR THE RUNOFF ANALYSIS

Point Code	Sub-Catchment	Area (km2)	Hydraulic Length (km)	Grand Slope (%)	SCS Curve Number (CN)	CBR Method	
						Lag Time (h)	Velocity (m/s)
			OKINAWA/CHANE-PAILON/OKINAWA DRAINAGE				
1	A-1～11,B-1～3,C-1～8,D-1	2519.1	132700	0.133	82	36.6	1.01
2	A-2～11,B-1～3,C-1～8,D-1	2455.7	120200	0.139	82	33.4	1.00
3	A-3～11,C-1～8,D-1	2032.8	98200	0.118	82	30.4	0.90
4	A-4～11,D-1	1398.8	75200	0.193	82	20.5	1.02
5	A-5～11,D-1	1338.7	71000	0.200	82	19.3	1.02
6	A-6～10,D-1	1047.5	67000	0.209	82	18.2	1.02
7	A-8～9	412.0	39000	0.223	82	11.7	0.93
8	B-2～3	217.5	48000	0.156	82	15.7	0.85
9	B-3	64.0	16000	0.213	82	6.0	0.74
10	C-2～8	466.1	54500	0.202	82	15.7	0.96
11	C-3	197.4	40000	0.225	82	11.9	0.94
12	C-5～8	194.9	32500	0.228	82	10.1	0.90
13	C-6	121.2	28000	0.243	82	8.8	0.89
14	C-8	38.4	21000	0.219	82	7.3	0.80
15	D-1	244.8	33000	0.188	83	11.0	0.83
E-1	E-1	70.0	15500	0.060	82	9.5	0.97
E-2	E-2	75.9	15000	0.030	82	8.0	0.97
E-3	E-3	235.6	23500	0.040	82	11.0	0.92
			SAN JUAN/ANTOFAGASTA				
Y1	Y1-1～1-4,Y2-1～2-2	370.7	61.4	0.099	80	22.7	0.75
Y2	Y1-2～1-4,Y2-1～2-2	303.9	51.1	0.108	80	19.0	0.75
Y3	Y1-3～1-4	130.8	31.5	0.145	83	11.7	0.75
Y4	Y1-4	34.9	11.8	0.200	83	4.9	0.67
Y5	Y2-2	11.9	6.5	0.083	82	4.3	0.42
J1	J-1～4	148.0	46.8	0.096	80	18.6	0.70
J2	J-2～4	106.4	33.2	0.106	81	13.8	0.67
J3	J-3～4	94.6	31.1	0.108	82	13.0	0.67
J4	J-4	18.3	5.0	0.120	82	3.1	0.46
T1	T-1～4	252.8	49.7	0.121	80	17.8	0.77
T2	T-2～4	214.6	39.5	0.140	80	14.1	0.78
T3	T-3～4	126.4	37.7	0.142	80	13.6	0.77
T4	T-4	49.4	13.2	0.200	81	5.3	0.69
TJ1	TJ-1	43.6	17.0	0.180	82	6.7	0.70

FIGURES

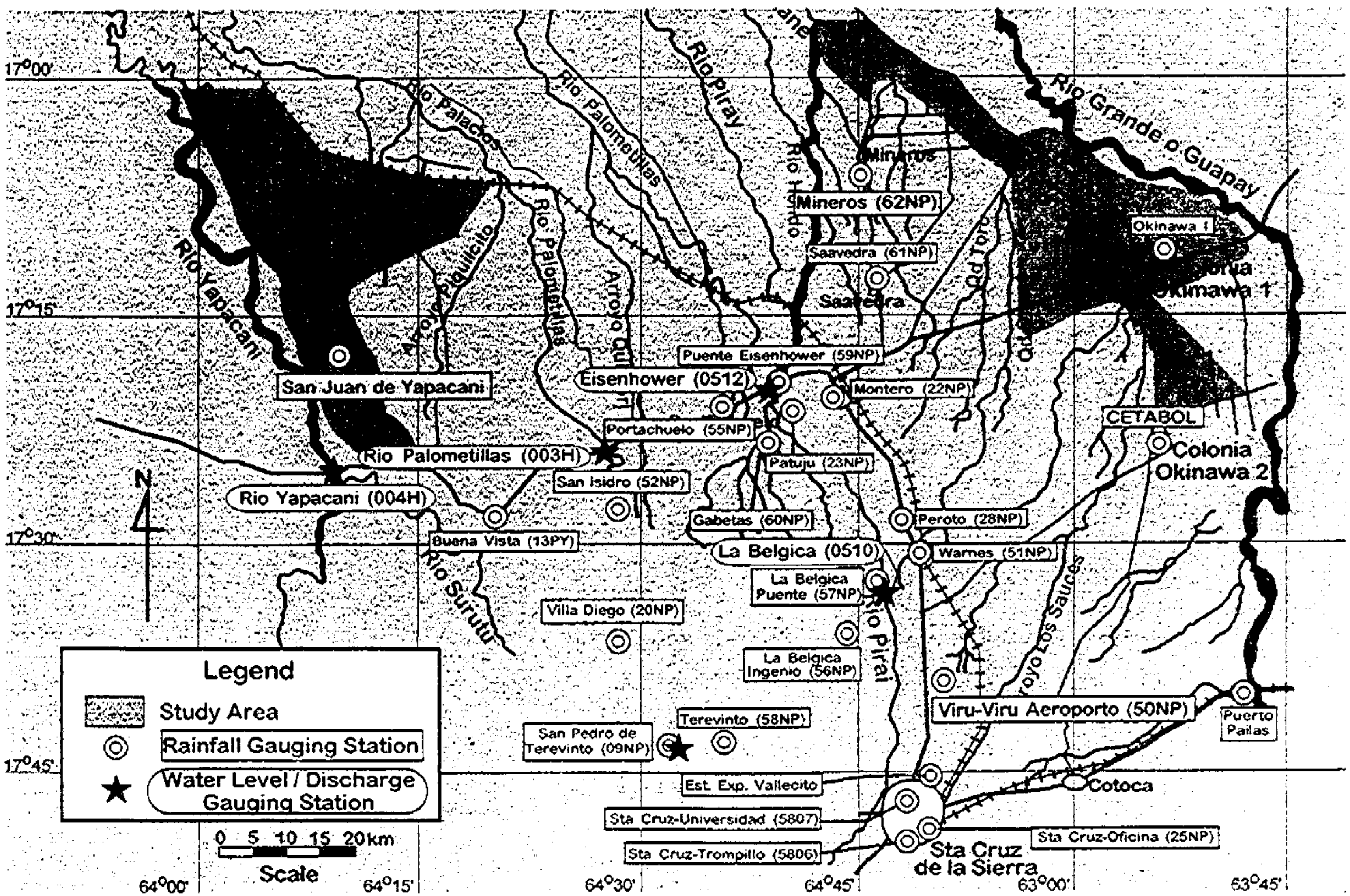

FIG.B.4.1 EXISTING MEASUREMENT STATION

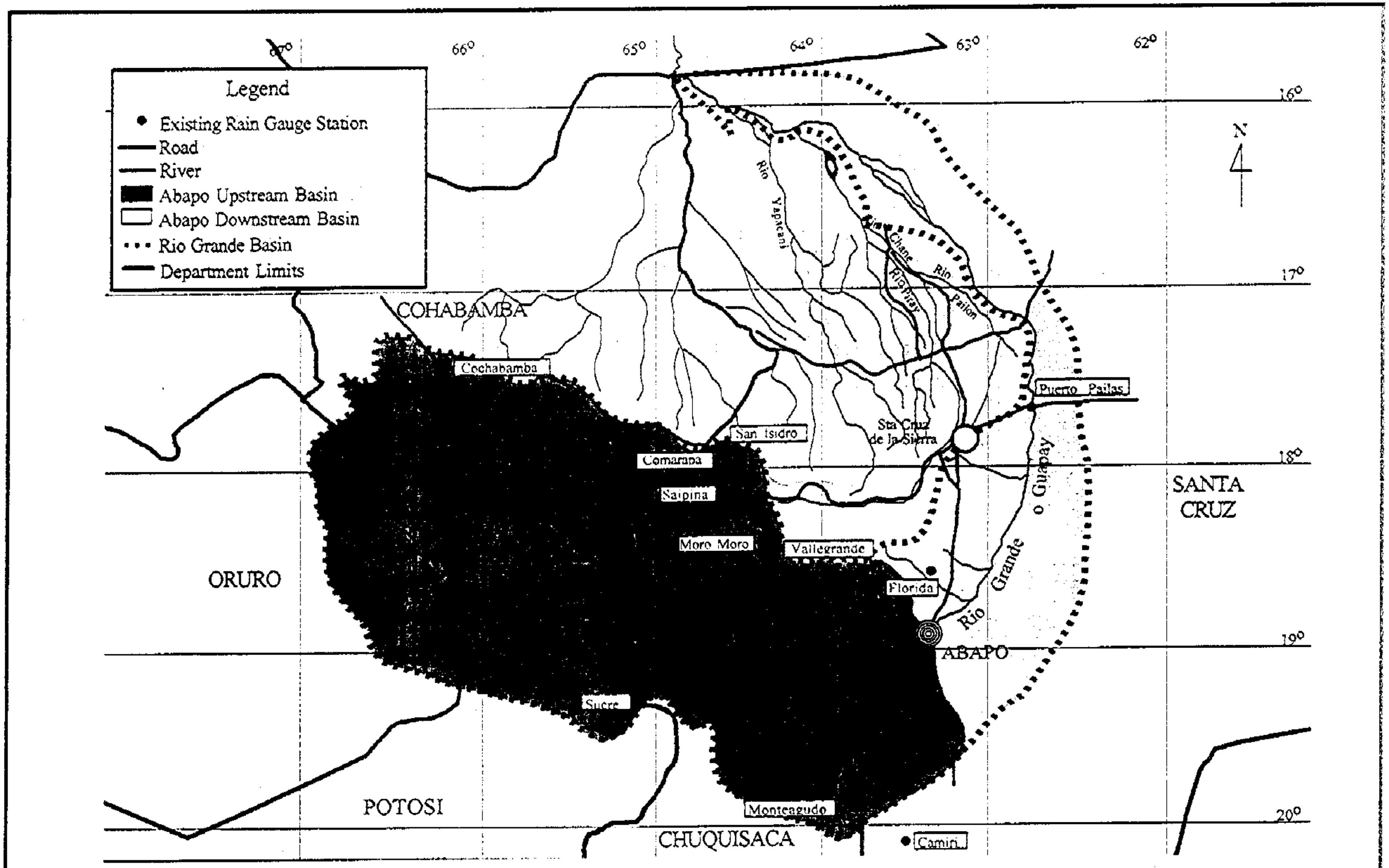

FIG.B.4.2 RIO GRANDE BASIN

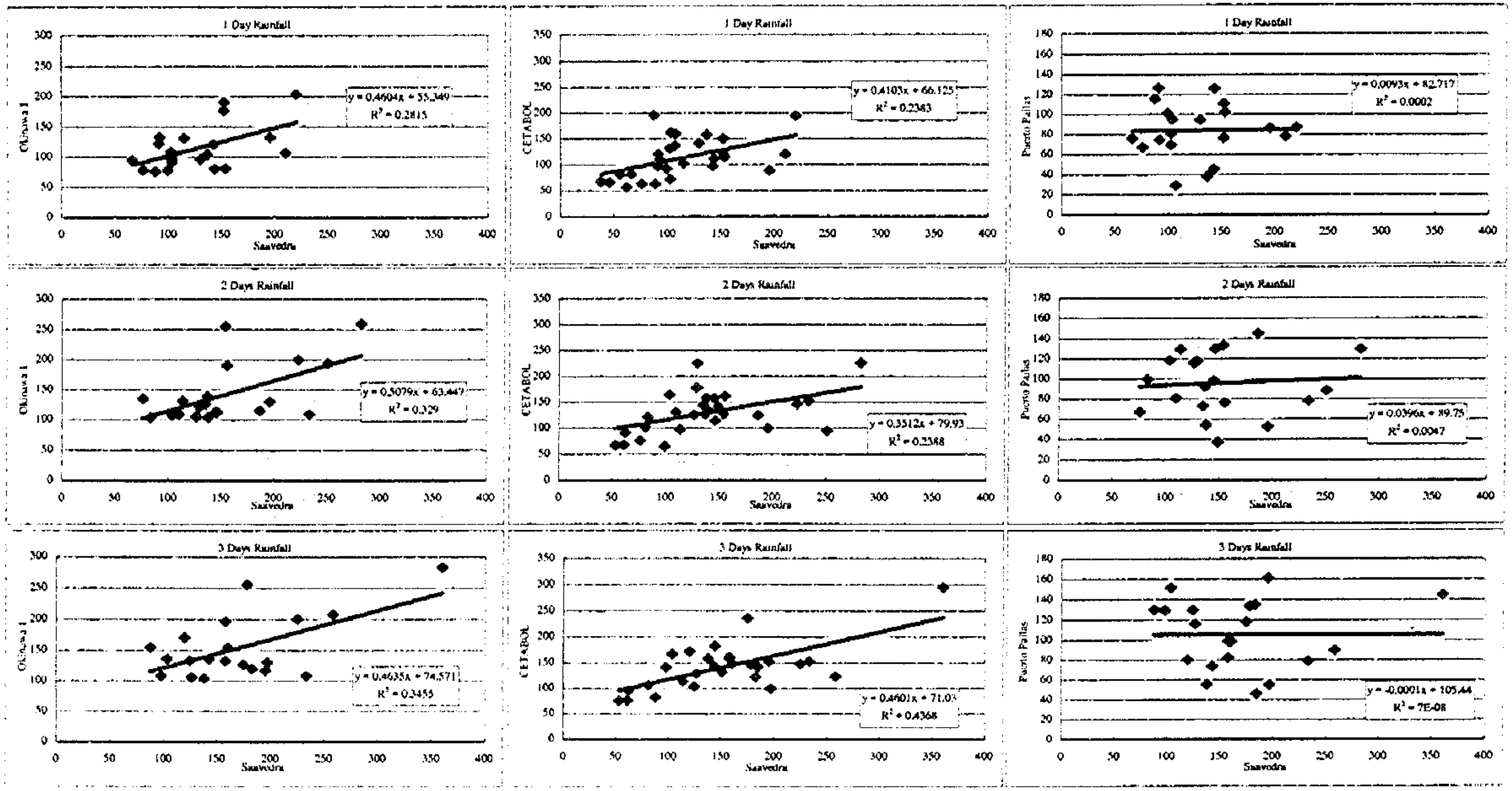

FIG.B.7.1(1) RAIN GAUGES CORRELATION

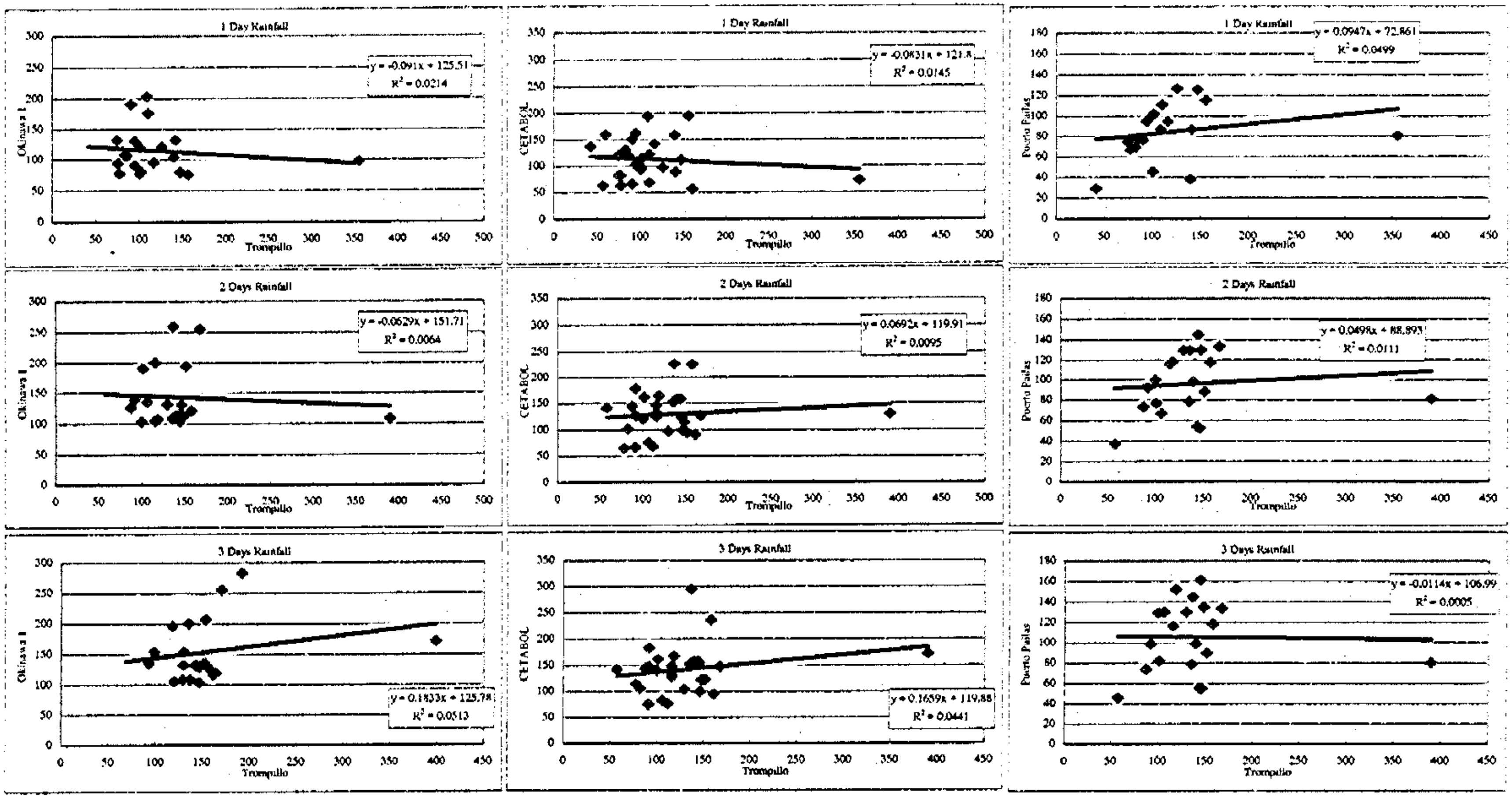

FIG.B.7.1(2) RAIN GAUGES CORRELATION

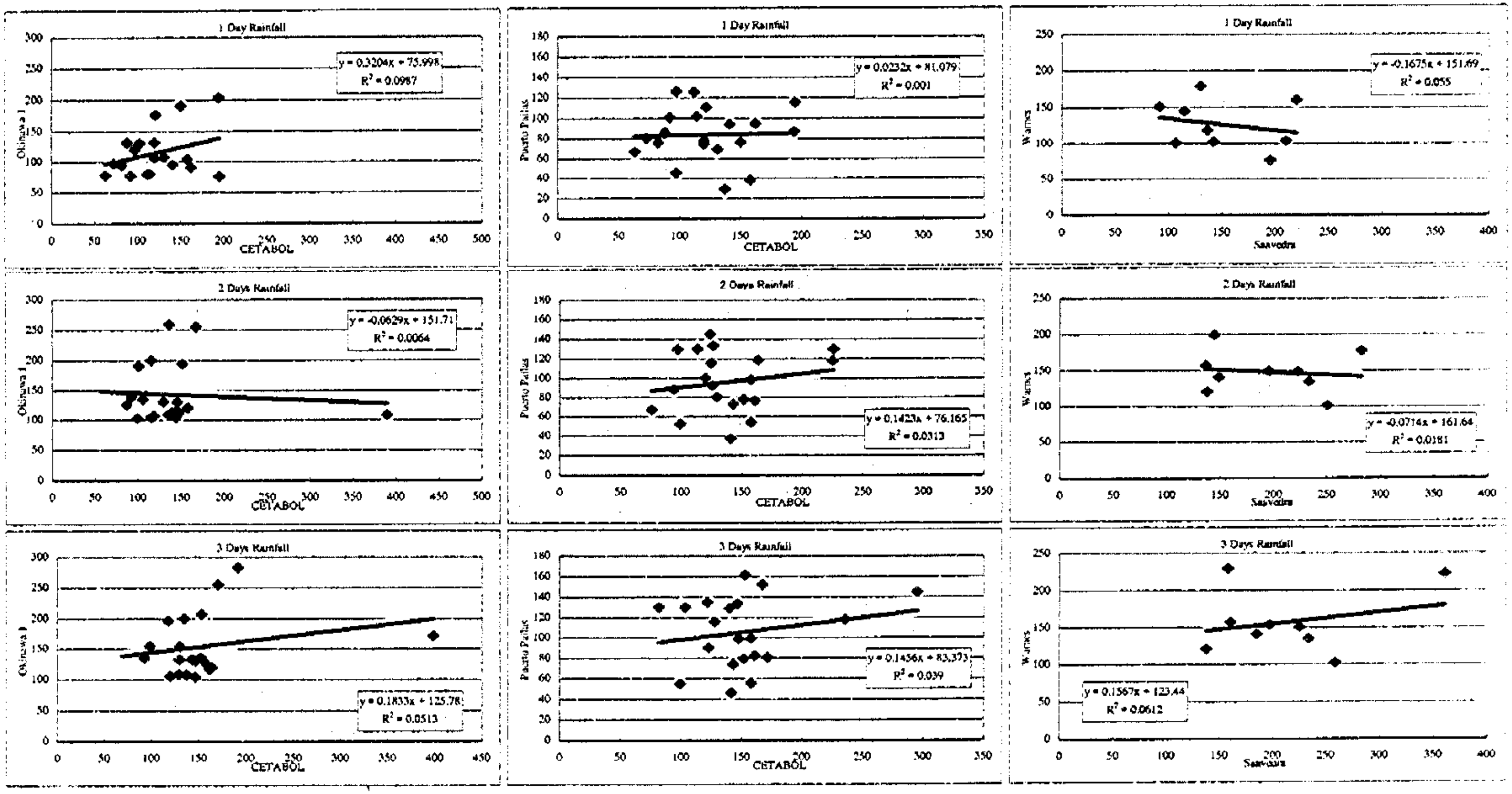

FIG.B.7.1(3) RAIN GAUGES CORRELATION

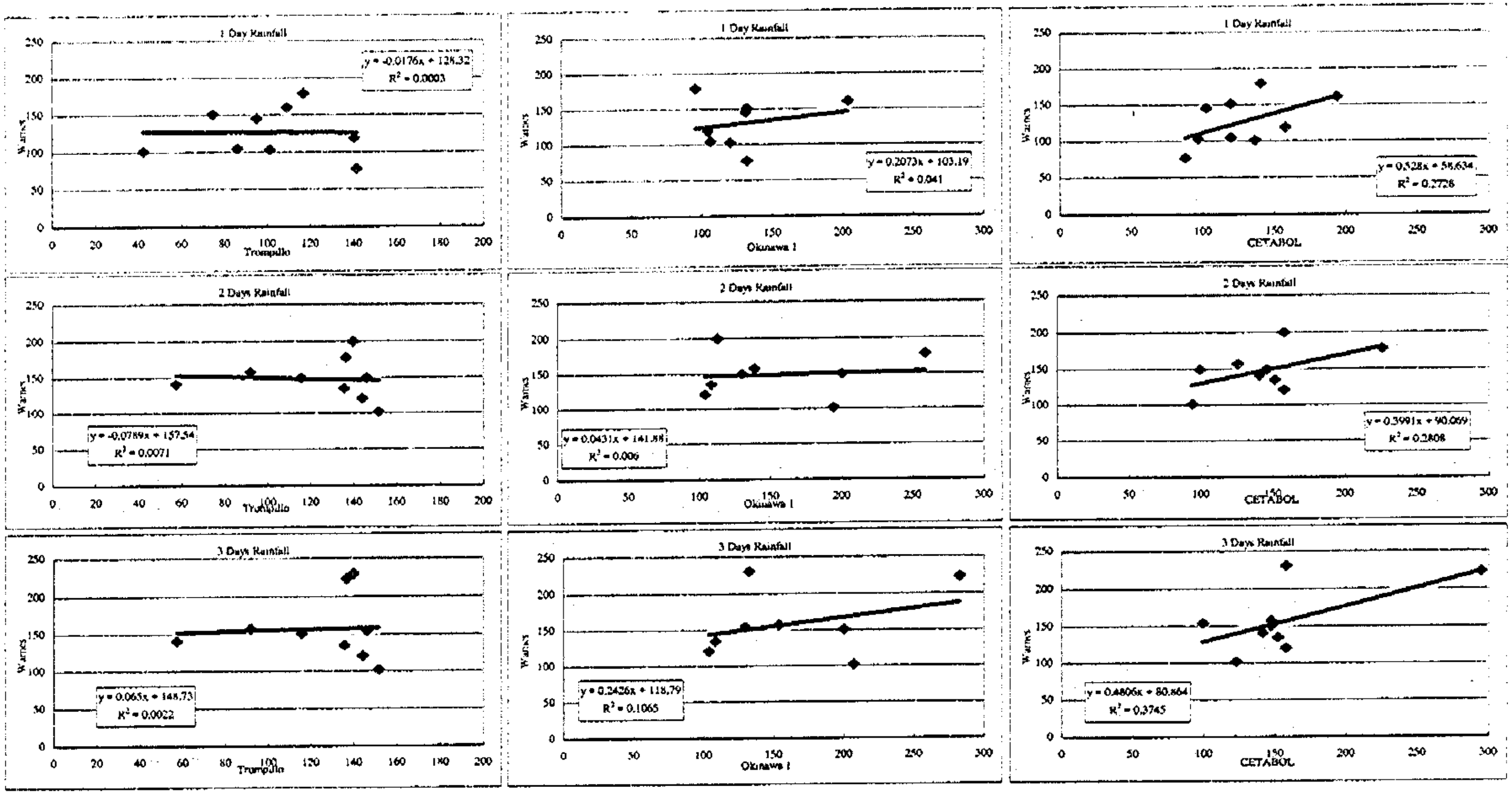

FIG.B.7.1(4) RAIN GAUGES CORRELATION

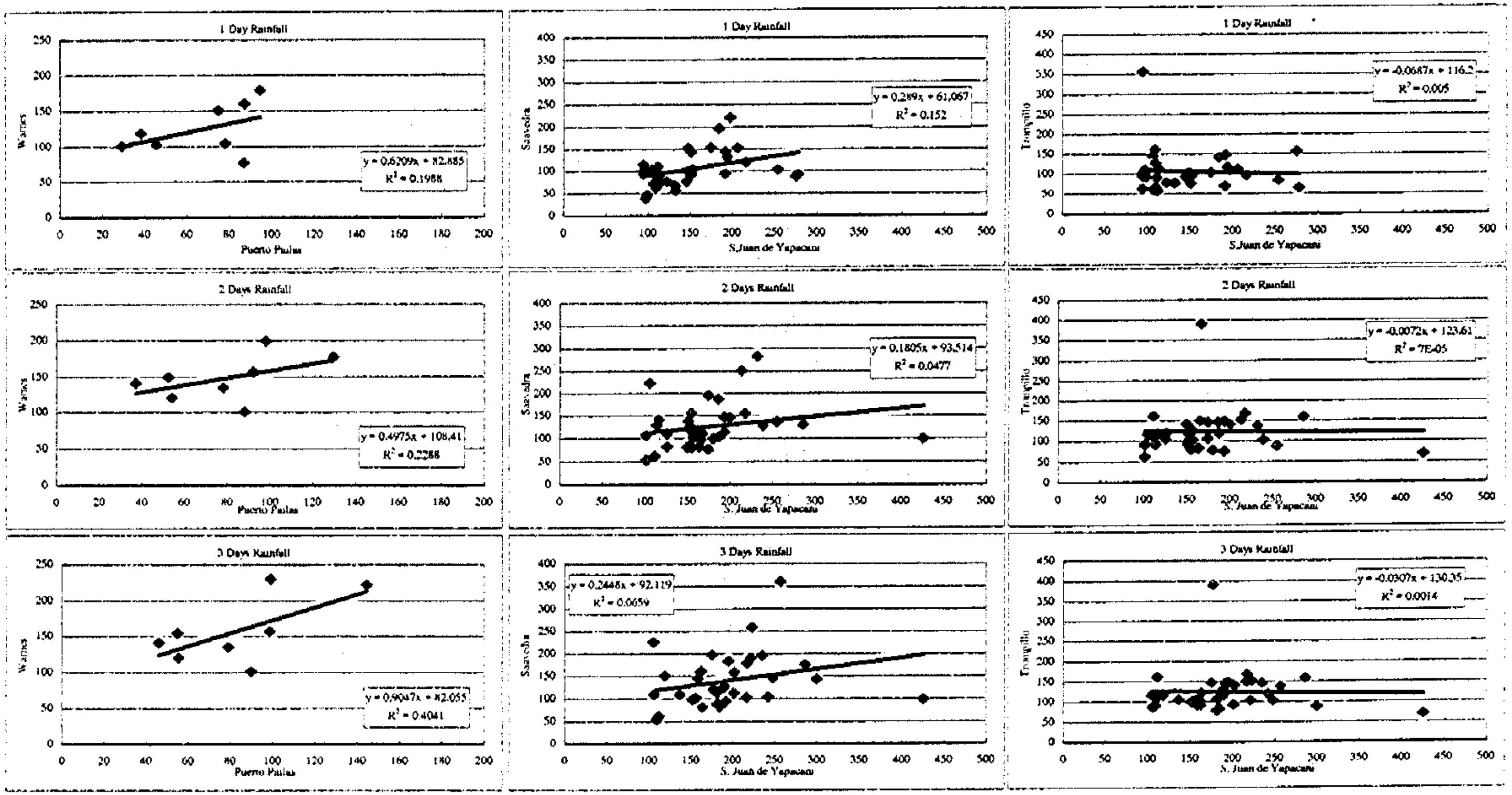

FIG.B.7.1(5) RAIN GAUGES CORRELATION

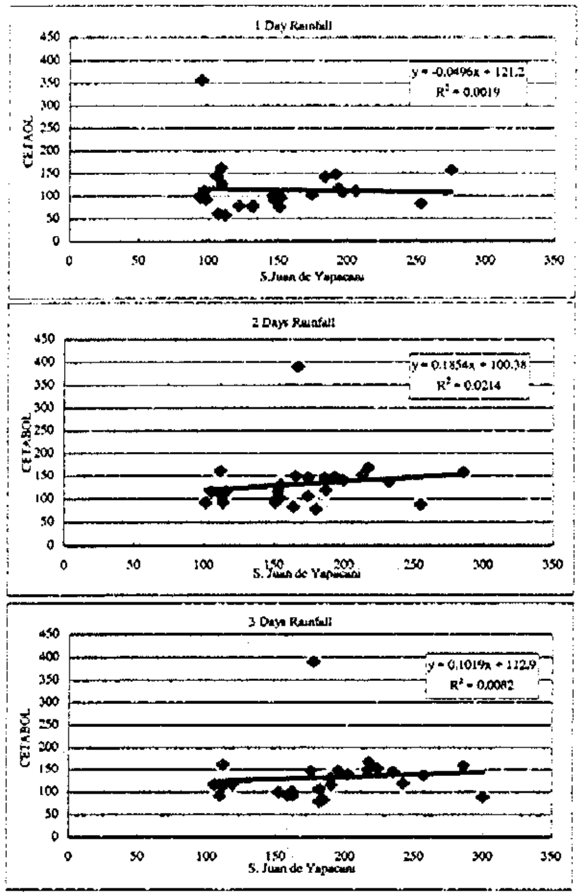

FIG.B.7.1(6) RAIN GAUGES CORRELATION

1 Day Rainfall

Stations	Saavedra	Warnes	Trompillo	Okinawa 1	CETABOL	Puerto Pailas
Saavedra		6%		28%	24%	
Warnes	6%			4%	27%	20%
Trompillo		0%		2%	1%	5%
Okinawa 1	28%	4%	2%		10%	
CETABOL	24%	27%	1%	10%		0%
Puerto Pailas	0%	20%	5%		0%	

Some Correlation
Small Correlation
No Correlation
Not Considered

2 Days Rainfall

Stations	Saavedra	Warnes	Trompillo	Okinawa 1	CETABOL	Puerto Pailas
Saavedra		2%		33%	24%	0%
Warnes	2%		1%	1%	28%	20%
Trompillo		1%		0%	1%	1%
Okinawa 1	33%	1%	0%		0%	
CETABOL	24%	28%	1%	0%		3%
Puerto Pailas	0%	20%	1%		3%	

Some Correlation
Small Correlation
No Correlation
Not Considered

3 Days Rainfall

Stations	Saavedra	Warnes	Trompillo	Okinawa 1	CETABOL	Puerto Pailas
Saavedra		6%		35%	44%	0%
Warnes	6%		2%	11%	37%	40%
Trompillo		2%		5%	4%	0%
Okinawa 1	35%	11%	5%		5%	
CETABOL	44%	37%	4%	5%		4%
Puerto Pailas	0%	40%	0%		4%	

Some Correlation
Small Correlation
No Correlation
Not Considered

FIG.B.7.2 CORRELATION BETWEEN MEASUREMENT STATIONS

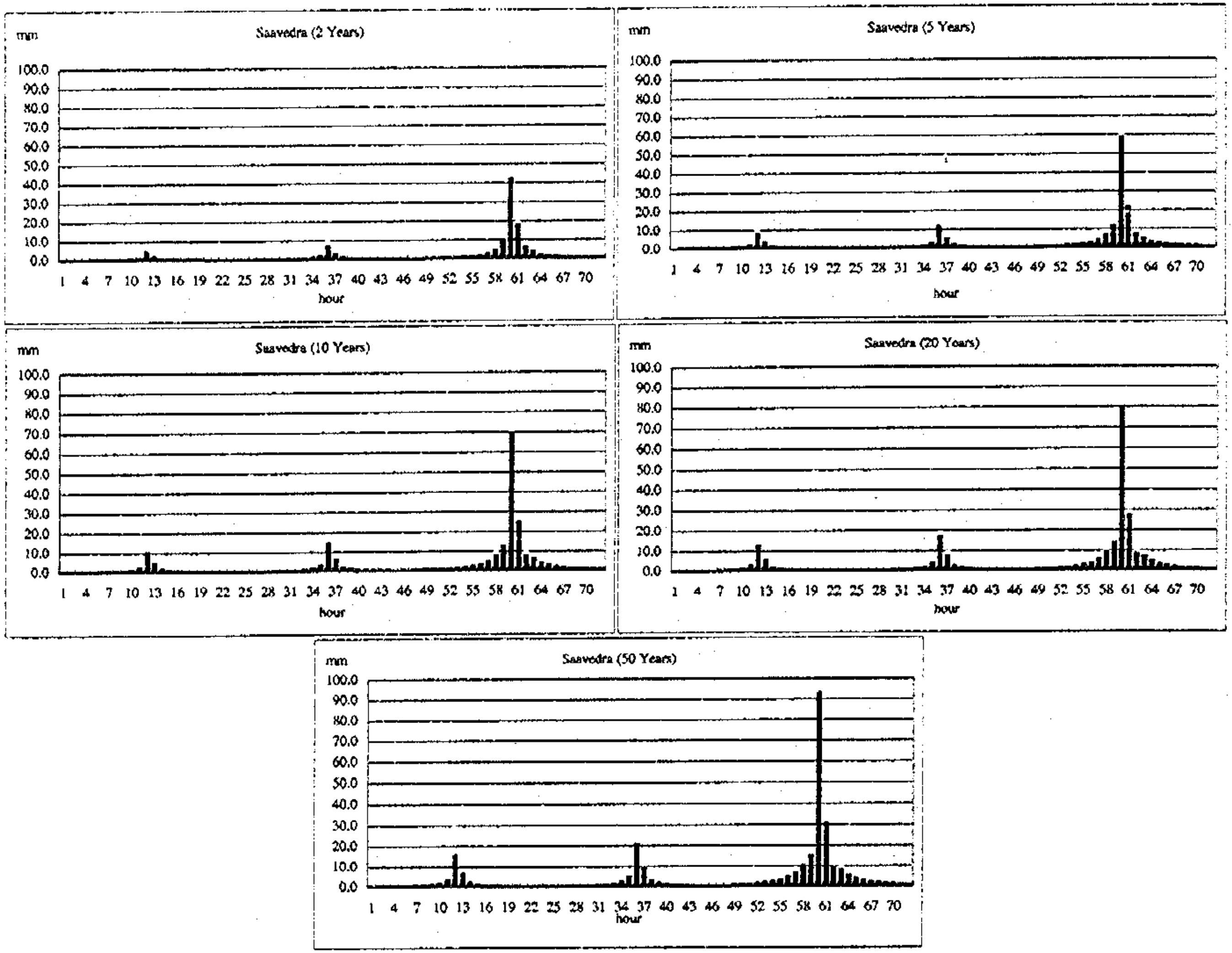

FIG.B.7.3(1) DESIGNED RAINFALL FOR SAAVEDRA

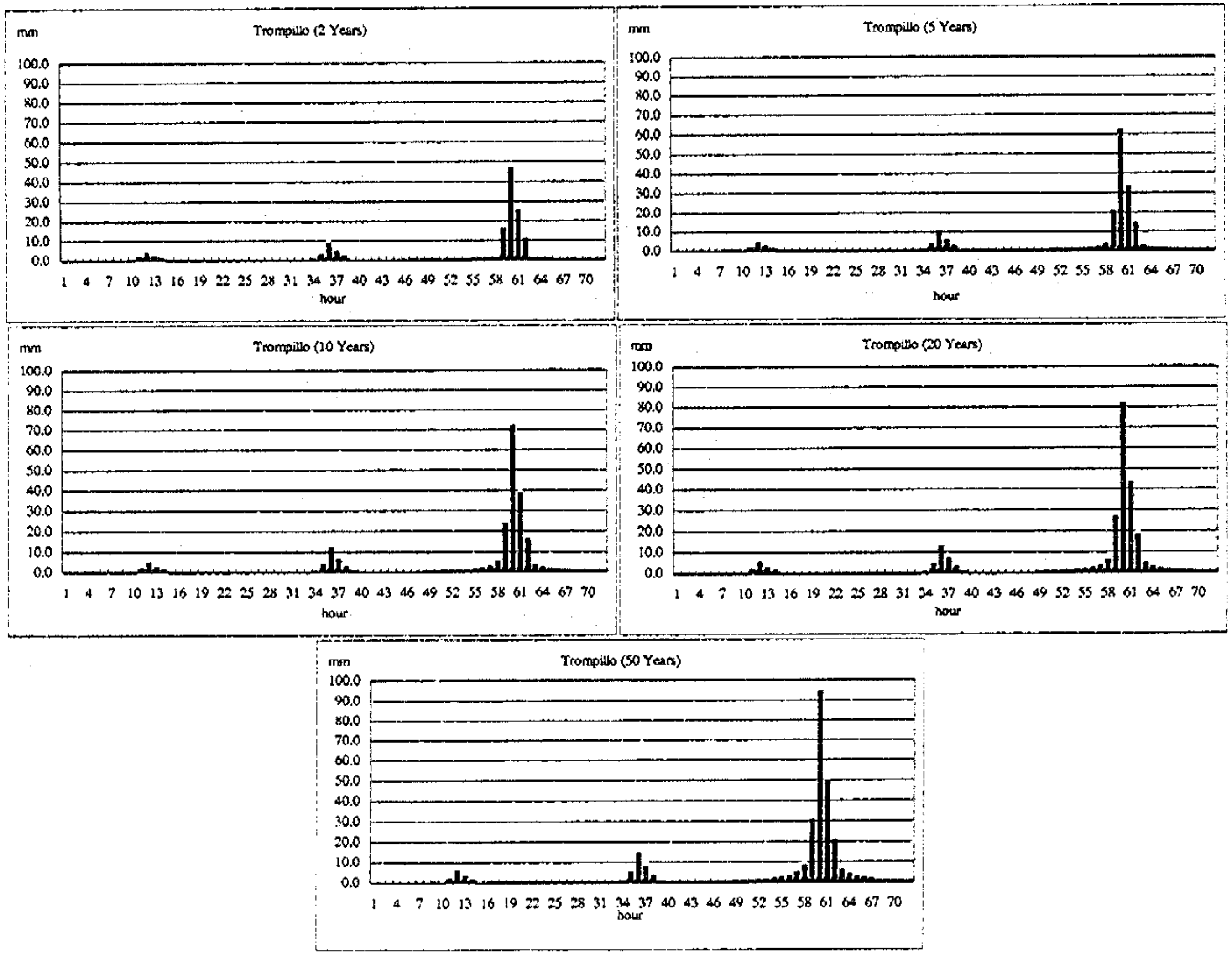

FIG.B.7.3(2) DESIGNED RAINFALL FOR TROMPILLO

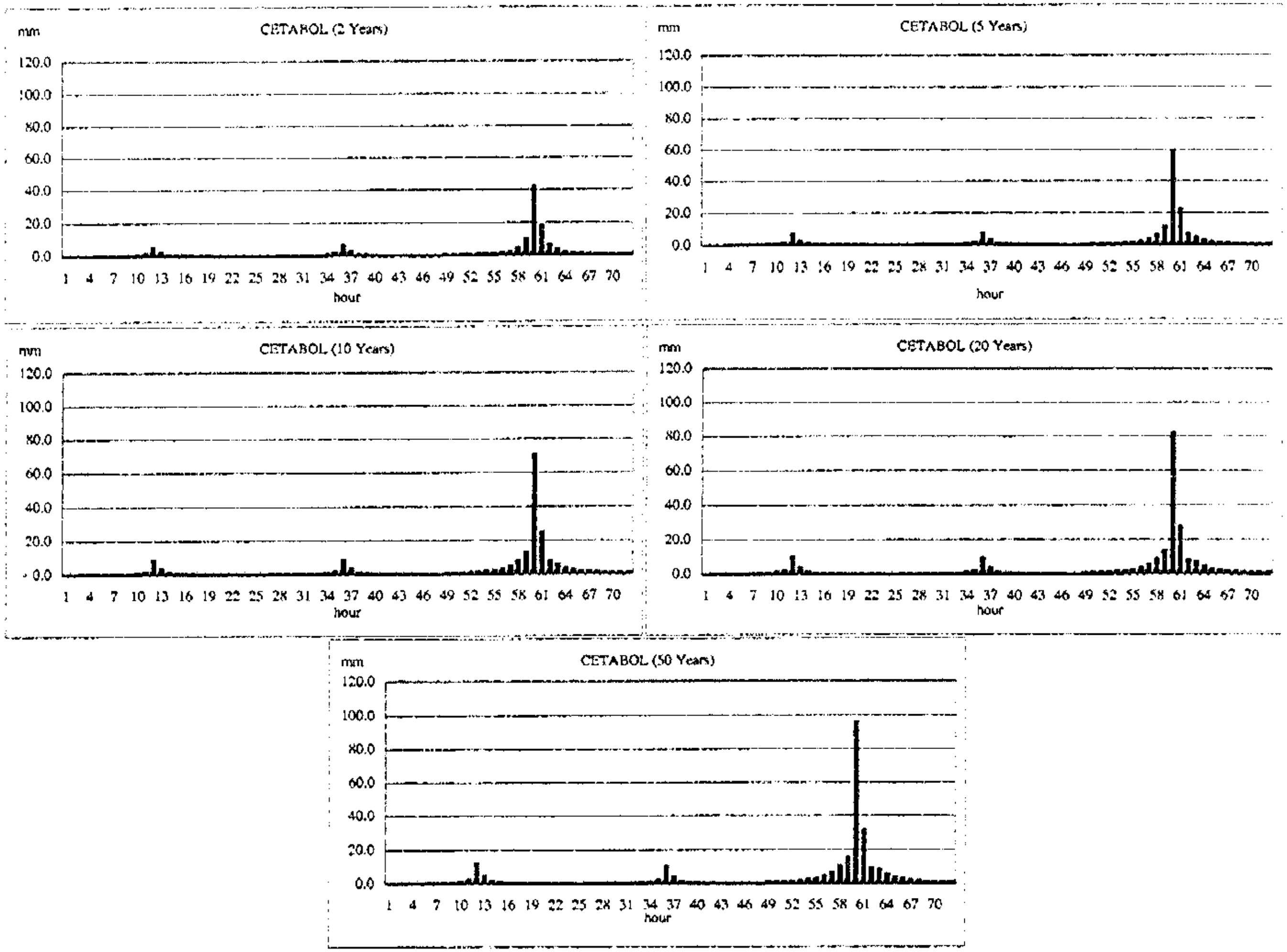

FIG.B.7.3(3) DESIGNED RAINFALL FOR CETABOL