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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

MAIN REPORT

JUNE 1999

PACIFIC CONSULTANTS INTERNATIONAL,TOKYO

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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)

PREFACE

In response to a request from the Government of Republic of Bolivia, the Government of Japan decided to conduct a feasibility study on Flood Control in the Northern Rural Region of Santa Cruz and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Hajime Tanaka of Pacific Consultants International Co., Ltd to Bolivia, two times between July 1998 and March 1999. In addition, JICA set up an advisory committee headed by Mr. Shoshiro Horigome, between July 1998 and January 1999 and by Mr. Kenji Kiyomizu, Development Specialist, JICA between February 1999 and March 1999, which examined the Study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of Bolivia and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Bolivia for their close cooperation extended to the Team.

Jun, 1999

Kimio Fujita
President
Japan International Cooperation Agency

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

June, 1999

Mr. Kimio FUJITA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

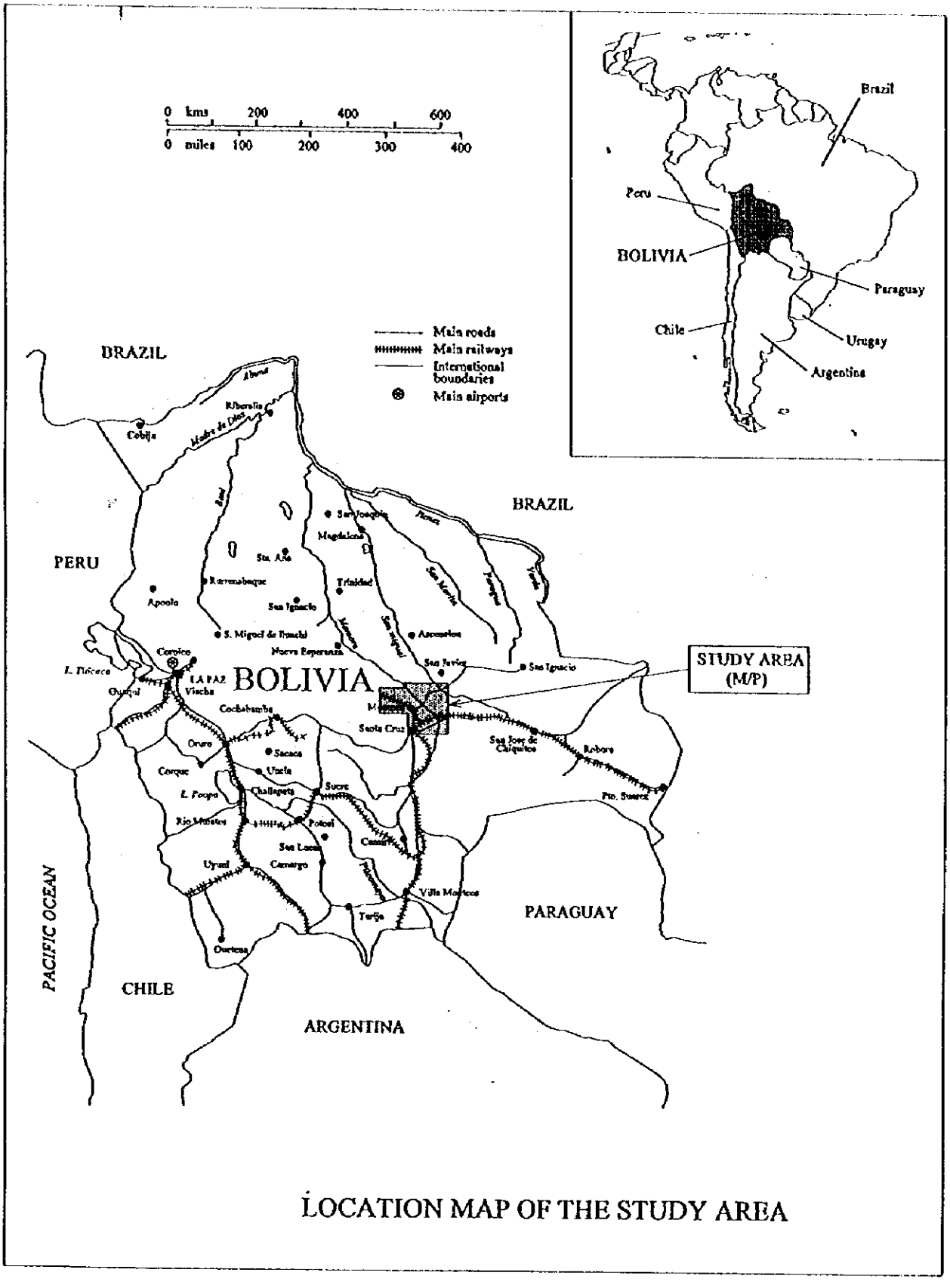
We are pleased to submit the final report entitled the "The Feasibility Study on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia." This report has been prepared by the Study Team in accordance with the contract signed on July 17, 1998 and April 27,1999 between the Japan International Cooperation Agency and Pacific Consultants International.

In the Study, the Study Team based on the analysis of the existing flood and drainage problems in the northern rural region of Santa Cruz, presents the Feasibility Study on the priority projects identified in the Master Plan. The report consists of the Summary, Main Report, Supporting Report, Drawings and Data Book.

All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Advisory Committee, and the Embassy of Japan in Bolivia, and also to the officials concerned of the Government of the Republic of Bolivia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the flood mitigation and drainage improvement and the socio-economic development in the northern rural region of the Santa Cruz.

Yours Faithfully

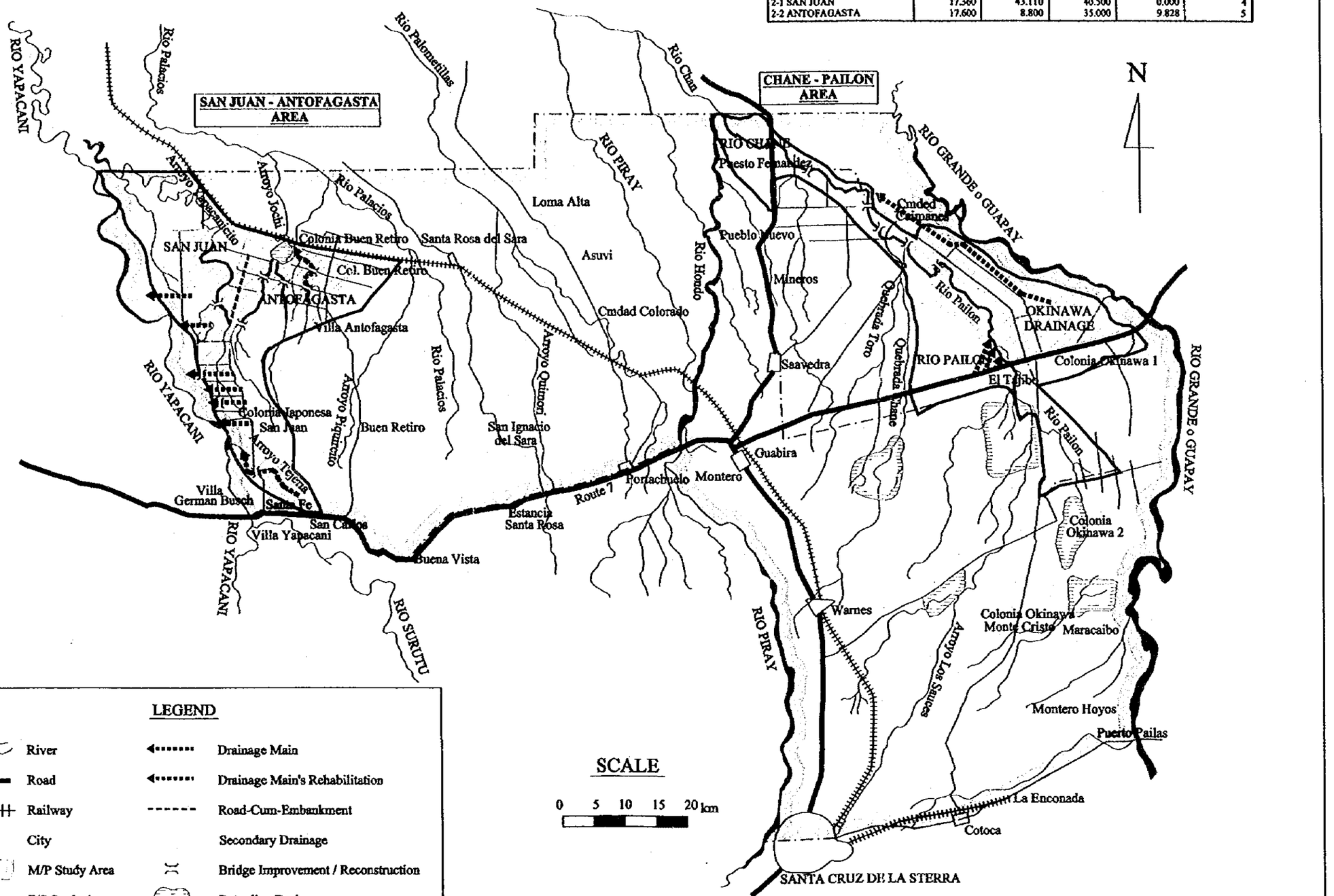
Hajime TANAKA
Team Leader of the Study Team



LOCATION MAP OF THE STUDY AREA

WORK VOLUME OF STRUCTURAL MEASURES

Project / Sub-Project	River Improvement (km)	Main Drainage (km)	Secondary Drainage (km)	Road-Cum-Embankment (km)	Bridge Reconstruction (Nos.)
1. CHANE-PAILON	57.760	32.010	54.000	0.000	7
1-1 CHANE	26.350	0.000	0.000	0.000	4
1-2 PAILON	31.410	10.360	18.500	0.000	2
1-3 OKINAWA DRAINAGE	0.000	21.650	35.500	0.000	1
2. SAN JUAN-ANTOFAGASTA	34.960	51.910	75.500	9.828	9
2-1 SAN JUAN	17.360	43.110	40.500	0.000	4
2-2 ANTOFAGASTA	17.600	8.800	35.000	9.828	5



SUMMARY OF THE PROPOSED PLAN

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

OUTLINE OF THE STUDY

1. Background

The Study has been conducted on the priority area proposed in the Master Plan entitled " The Master Plan Study on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia" (March 1995 to June 1996) by JICA that covers 7,000 sq. km of the northern region of Santa Cruz.

The northern region that has been developed as an important industrial and agricultural production center, has an important role in economic and social terms. However, the area is extremely vulnerable to flood and drainage problems. The annual flood hazard area was estimated to be about 35 % (2,444 sq. km) and the 1992 flood area that was the largest flood in record, was estimated to be 70 % (4,857 sq. km) of the northern region respectively.

The Study area is composed of two areas, i.e., the Chane-Pailon Area (600 sq. km) and the San Juan-Antofagasta Area (607 sq. km), having a population of 192,429 in total according to the 1992 census. The whole area is under the menace of floods and the mitigation of flood problems is an important problem by which the Government is confronted.

2. Proposed Flood Mitigation and Drainage Improvement Measures

2.1 Proposed Structural Measures

The structural measures planned are consisting of river improvement works, drainage improvement works and road-cum embankment. The works are summarized and shown in the following table:

Planned Structural Measures (km)

Area	Improvement (km)		
	River	Drainage	Road-cum Emb.
Chane-Pailon			
Rio Chane area	26.35	0.00	0.00
Rio Pailon area	31.41	10.36	0.00
Okinawa Drainage	0.0	21.65	0.00
Sub total	57.76	32.01	0.00
San Juan - Antofagasta			
San Juan area	17.36	43.11	0.00
Antofagasta area	17.60	8.80	9.83
Sub total	34.96	51.91	9.83
Total	92.72	83.92	9.83

The design criteria decided based on technical and economic aspects in the Master Plan Study, were applied for design of the proposed facilities. They are as follows:

- Flood mitigation facilities : Storm with return period 10 years
  Allowable inundation depth 0.30 m
- Drainage improvement facilities : Storm with return period 5 years
  Allowable inundation depth 0.30 m
- Related public facilities : Storm with return period 50 years

2.2 Proposed Non-structural Measures

Non-structural Measures are planned to be applied for the whole flood hazard area. It is possible for the Study area to effectuate non-structural measures within comparatively a short time and enable the inhabitants to alleviate flood damages to a certain extent, because the structural measure generally requires a long term and a certain amount of investment before completion. The proposed non-structural measures are consisting of the followings:

1) Flood warning and evacuation system based on the 1-day, 3-day and 5-day rainfall at the proposed 4 principal rainfall stations,

2) Flood proofing and flood plain management based on the flood hazard maps and land use zoning maps prepared by the Study,

3) Conservation of the proposed 6 natural retarding basins (123.4 sq. km in total),

4) Conservation of the proposed protection forest along the rivers,

5) Improvement of land use and cropping pattern during the flood season based on the land use zoning maps for the flood hazard areas prepared by the Study.

2.3 Environmental Impact Assessment

The National Secretary of the Natural Resources and Environment, Ministry of Sustainable Development and Planning that is in chargé for the categorization of environmental sheets (Ficha Ambiental), evaluated the proposed projects by the Study as the category III, which does not require Environmental Impact Assessment (EIA), but conceptual EIA.

The flood mitigation and drainage improvement works will improve social and natural environment in general and there may be no significant environmental adverse effects caused by the projects.

2.4 Cost Estimate

The construction cost consists of direct construction cost and indirect construction cost. The direct construction cost is estimated based on the preliminary designs of structures, the market price and currency exchange rate in August 1998.

The indirect construction cost is estimated in the proportional to the direct cost (Unforeseen cost 5 % of direct cost, Overhead charge: 10 %, Profit: 15 %).

The project cost that consists of construction cost, administration cost, engineering service cost and contingency, are estimated and summarized as follows:

Project	Local Bs.	Foreign Bs.	Total Bs.
The Chane - Pailon Area			
Rio Chane	91,434,000	143,193,000	234,627,000
Rio Pailon	143,084,000	231,073,000	374,157,000
Okinawa Drainage	32,120,000	57,680,000	89,800,000
Total	266,638,000	431,946,000	698,584,000
The San Juan - Antofagasta Area			
San Juan	45,724,000	61,826,000	107,550,000
Antofagasta	40,990,000	59,372,000	100,362,000
Total	86,714,000	121,198,000	207,912,000
Grand Total	353,352,000	553,144,000	906,496,000

Note:

- *The labor cost, material cost and the equipment unit cost included the value added tax 13%, based on the market price in August 1998,*
- *Administration cost: 5 % of the construction cost,*
- *Engineering service cost: 10 % of the construction cost*
- *Contingency: 15 % of the construction cost*
- *The currency exchange rate used for currency conversion purpose was US$ 1.0 = Bolivian Bs 5.50 = Japanese Yen 117(August 1998)*

2.5 Institutional Frame

The organizations in charge of flood mitigation are the Department of Santa Cruz, the Civil Defense (CD) and the Operation Center for Departmental Emergency (OCDE), Municipalities, SENAMHI, SEARPI and MUCUCY.

For implementation of the proposed measures, it is planned that the Department of Santa Cruz shall be responsible for implementation of the proposed measures and that the General Coordination Direction (GCD) shall be the implementation organization for the project and take necessary actions for smooth implementation of the proposed measures in order to strengthen the related organizations in function and necessary resources as follows:

- Strategic Planning Division of the General Coordination Direction with the participation of SEARPI, UTD-PLUS, SENAMHI and MUCUCY, in order to conduct general preparation and arrangement for implementation of the projects,
- Infrastructure Development Direction to execute major structural measures,

- Municipalities to execute minor structural and non-structural measures and to conduct O&M activities for both structural and non-structural measures,
- Local groups as public participation to conduct O&M activities for both structural and non-structural measures.

2.6 Project Evaluation

The project has been evaluated from technical, economic, financial, and social and environmental aspects as follows:

(1) Technical Evaluation

The technical aspect of the proposed structural measures is evaluated mainly by reduction of the inundation area. The proposed structural measures will be very effective by reducing the inundation areas of more than 30 cm deep about 279 sq. km in Chane-Pailon area and 197.70 sq. km in San Juan-Antofagasta area during the design 10-year floods. As for the Chane River the water levels without the project are about 60 cm higher than that of with the project in the peak stage for the 10-year flood. In order to avoid any adverse effects, the improvement of the Chane River will be indispensable for the area.

(2) Economic Feasibility

The economic feasibility is evaluated mainly by the Economic Internal Rate of Return (EIRR), of which values higher than10 % is considered to be feasible in consideration of the opportunity cost of capital, estimated to be between 10 % and 12 % in Bolivia. The EIRR is summarized below

Name of Projects		EIRR (%)
-I	Chane-Pailon	12.1
-2	Rio Chane	3.8
-3	Rio Pailon	16.4
-4	Okinawa Drainage	18.4
II.	San Juan-Antofagasta	18.2
-1	San Juan	12.4
-2	Antofagasta	23.4

Besides the benefits produced by the structural measures above, lots of intangible benefits would be produced by the non-structural measures.

(3) Social and Natural Environmental Impacts

The flood mitigation and drainage improvement measures aim basically to improve social and natural environments in the region. The social environment will be improved due to that the structural measures will reduce an interruption of business activities and social communications, and the non-structural measures will promote the good communications among inhabitants.

The result of evaluation is summarized in Table 1.

2.7 Implementation Program

(1) Implementation Organization

The implementation organization for the Project shall be the Department of Santa Cruz. It is proposed that the General Coordination Direction (GCD) shall be the leading implementation organization for the project and take necessary actions, due to the progress of the projects, for smooth implementation of the projects to strengthen the following organizations in function and necessary resources:

- Strategic Planning Division, with the participation of SEARPI, UTD-PLUS, SENAMHI and MACUCY,
- Infrastructure Development Direction,
- Municipalities,
- Local groups.

(2) Implementation Period

The implementation period is to be divided into the following 2 stages:

- Stage-1: Preparatory period (1999 to 2000)
- Stage-2: Implementation period (2001 to 2010)

The Stage-2 is divided to the following two phases;

1) Phase-1: (2001-2005): implementation (or commencement) of the 1st priority works:

a) Structural measure

a. Chane-Pailon area
   - River improvement of the Rio Chane/Rio Pailon,
   - Improvement of Okinawa main drainage,

b. San Juan-Antofagasta area
   - River improvement of the Arroyo Jochi,
   - Development of Road-cum-embankment,
   - Improvement of San Juan drainage (km-13 – 17).

b) Nonstructural measures

Proposed non-structural measures for the whole study area.

2) Phase-2 (2006-2010): Implementation of the 2nd priority works.

a). Chane-Pailon area:

- Drainage improvement related to the Rio Pailon,
- Development of Secondary drainage's,

b). San Juan-Antofagasta area:

- River Improvement of the Arroyo Yapacanicito,
- River improvement of Arroyo Tacuaral,
- Improvement and rehabilitation of drainage

The Implementation Program is shown in Table 2.

3 Conclusion and Recommendation

The proposed flood mitigation and drainage improvement plans for the Feasibility Study have been designed and evaluated from technical, economic, social and environmental aspects. The proposed flood mitigation and drainage improvement

plans are concluded to be feasible in technical, economic, social and environmental terms and to enable the Study area to alleviate flood and drainage problems and to stabilize the area. It is recommended for the Department of Santa Cruz to take immediate actions for the followings:

(1) To implement the structural and non-structural measures proposed in the Study for alleviation of flood and drainage problems, taking immediate action for implementation of the measures proposed to be the 1st priority measures,

(2) To reinforce the existing meteorological and hydrological network for establishment of an effective flood warning system in the northern region of Santa Cruz, including installation of three automatic rain gauges (Saavedra, Trompillo and San Juan de Yapacani) and one water level gauge at Abapo,

(3) To strengthen the General Coordination Directions as the leading implementation organization for the project for early and smooth implementation of the proposed flood mitigation and drainage improvement measures in function and man power,

(4) To take immediate actions to conserve the retarding basins proposed in the Study because of their high efficiency for alleviation of flood problems in the area,

(5) To guide the farmer to follow more appropriate cropping calendars or farming systems due to the existing soil and flood conditions based on the flood hazard area maps and land used zoning maps for alleviation of flood damages in the agricultural crops,

(6) To utilize the coordination committee effectively for the enhancement of public participation in flood mitigation activities.

TABLE 1 PROJECT SUMMARY OF FEASIBILITY STUDY ON FLOOD CONTROL IN THE NORTHERN RURAL REGION OF SANTA CRUZ

AREA / SUB-AREA	FLOOD MITIGATION AND DRAINAGE IMPROVEMENT MEASURES				PROJECT EVALUATION									
	STRUCTURAL MEASURES			NON-STRUCTURAL MEASURES	Technical Efficiency (Reduction of flooded area more than 30 cm depth in 10-year frequency flood : km²)			Economic Efficiency (FIRR : %)			Embironmantal Impact			PROJECT VIABILITY
	Coponent of Structure Measures	Dsitance (km)	Project Cost (1,000 Bs)								Living Environment	Economic Environment	Natural Environment	
1. CHANE-PAILON AREA			**698,584**			**279.00**			**12.1**					
(1) Rio Chane Basin	Improvement of Rio Chane	26.350	234,627		Indispensable for avoiding any adverse effect. More effective with flood control of the Rio Piray.	21.10	A	Not feasible	3.8	C	High	Medium	Negligibly small	High viability for avoiding any adverse effect. A
(2) Rio Pailon Area	Improvement of Rio Pailon	31.680	344,624	- Protection of retarding basin -Flood warning -Flood plain management -Flood evacuation plan -Protected forest -Preparation of flood hazard map	Indispensable as the main stream area. One of the most effective component for the flood mitigation	167.50	A	Highly feasible	16.4	A	High	High	Negligibly small	High viability as the main steram area. A
	Improvement of Rancha Chico Drainage	3.600	8,113		Necessary to mitigating the adverse effect of the bridge construction along Route 9.		B				High	Medium	Negligibly small	Midium viability for avoiding adverse effect of the bridge construction. B
	Improvement of El Chaco Drainage	1.470	1,118		Necessary to mitigating the adverse effect of the bridge construction along Route 9.		B				High	Medium	Negligibly small	Midium viability for avoiding adverse effect of the bridge construction. B
	Improvement of El Empalme II Drainage	5.290	7,304		Necessary to mitigating the adverse effect of the bridge construction along Route 9.		B				High	Medium	Negligibly small	Midium viability for avoiding adverse effect of the bridge construction. B
	Development of Secondary Drainage	18.500	12,998		Necessary to make river and drainage improvement effective.		B				Medium	Medium	Negligibly small	Midium viability to make river and drainage improvement effective. B
(3) Okinawa Drainage Basin	Improvement of Okinawa Main Drainage	21.650	61,891		High necessaity as the major drainage area. It will contribute to mitigate the flood damege of Rio Grande.	90.40	A	Highly feasible	18.4	A	Exclusive High	High	Negligibly small	High viability as the major drainage area for mitigating the flood damege of Rio Grande. A
	Development of Secondary Drainage	35.500	27,909		Necessary to make river and drainage improvement effective.		B				Medium	Medium	Negligibly small	Midium viability to make river and drainage improvement effective. B
2. SAN JUAN-ANTOFAGASTA AREA			**207,912**			**197.70**			**18.2**					
(1) San Juan Area	Improvement of Arroyo Yapacanicito	17.360	37,350		Necessary for improving the northern area of San Juan.	91.60	B	Feasible	12.4	B	Exclusive High	High	Negligibly small	Midium viability as the intensive land use area. B
	Improvement of San Juan Main Drainage (km 13, 17)	7.500	8,474		High necessity as the restoration of the main drainage		A				Exclusive High	High	Negligibly small	High viability as the intensive land use area. A
	Rehabilitation of San Juan Main Drainage (km 11, 15, 24, 28)	27.450	14,136		Necessary to rehabilitate the drainage functions.		B				Exclusive High	Medium	Negligibly small	Midium viability as the intensive land use area. B
	Improvement of Arroyo Tejeria	8.160	8,215		Necessity as the drainage area.		B				Medium	Medium	Negligibly small	Midium viability as the intensive land use area. B
	Development of Secondary Drainage	35.000	33,304		Necessary to make river and drainage improvement effective.		B				Medium	Medium	Negligibly small	Midium viability to make river and drainage improvement effective. B
(2) Antofagasta Area	Improvement of Arroyo Jochi	11.800	25,010		Indispensable to improve flooding condition in the Antofagsta Area	106.10	A	Highly feasible	23.4	A	High	Medium	Negligibly small	High viability as the intensive land use area. A
	Improvement of Arroyo Tacuaral	5.800	18,272		Necessary to improve flooding condition in the Antofagsta Area		B				High	Medium	Negligibly small	Midium viability as the intensive land use area. B
	Development of Road-cum-embankment	9.830	6,071		Indispensable for project phasing in the San Juan - Antofagasta Area .		A				Medium	Medium	Negligibly small	High viability for project phasing. A
	Development of Antofagasta Main Drainage	8.800	21,389		Necessity as the drainage area		B				High	Medium	Negligibly small	Midium viability as the intensive land use area. B
	Development of Secondary Drainage	26.500	35,691		Necessary to make river and drainage improvement effective		B				Medium	Medium	Negligibly small	Midium viability to make river and drainage improvement effective. B

Remarks : Ranking of viability of project components A : High B : Medium C : Low

TABLE 2 IMPLEMENTATION PROGRAM

Project	Priority	Fiscal Year: 1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Stage-1		Stage-2									
				Phase-1					Phase-2				
I Structural Measures													
1. Chane - Pailon Area													
(1) General Coordination and Arrangement													
(2) 1st Priority Components													
- Rio Chane / Rio Pailon	1B												
- Okinawa Main Drainage	1A												
(3) 2nd Priority Components													
- R.Chico / El Chaco / El empalme II	2B												
- Secondary Drainage	2B												
2. San Juan - Antofagasta Area													
(1) General Coordination and Arrangement													
(2) 1st Priority Components													
- Arroyo Jochi	1A												
- Road-cum-embankment	1A												
- San Juan Main Drainage (km 13, 17)	1B												
(3) 2nd Priority Components													
- Arroyo Yapacanicito	2A												
- Arroyo Tacuaral	2A												
- San Juan Main Drainage (km 11, 15, 24, 28)	2B												
- Arroyo Tejeria / Antofagasta Main Drainage	2B												
- Secondary Drainage	2B												
II Non-structural Measures													
(1) General Coordination and Arrangement													
(2) Implementation of Non-structural Measures	1A												

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CHAPTER 9 INSTITUTIONAL ORGANIZATION

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$ = 5.5 Bs.)
¥	:	Japanese Yen

Others

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

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background

This report is the Final Report for the "Feasibility Study on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia" (hereinafter referred to as the Study).

The Study was conducted in accordance with the Scope of Work agreed upon between the Department of Santa Cruz (hereinafter referred to as the Department) and the Japan International Cooperation Agency (hereinafter referred to as JICA) on November 14, 1997. The Study has been conducted since the end of July 1998.

The Department of Santa Cruz, located in the east of the central region of Bolivia, as shown in Figs. 1.1.1 and 1.1.2, covers the area of about 370,000 km^2 or 34% of the country area. The Department has a population of about 1.4 million of which about 80 % is living in the urban area of Santa Cruz, the capital of the Department and the second largest city in the country. The urban area and the northern rural area of Santa Cruz have formed an integrated development area. The Study area is located in the northern rural region of the city of Santa Cruz.

The Department plays a crucial role in the country economic due to its abundant natural resources including crude oil, natural gas, iron ore, and a vast expanse of flat farming land with rich soil and fine climate.

This area has been suffering from the torrential rainfalls and floods almost every year. The extensive flood damages were occurred in 1983 and 1992. In 1983, the floods caused severe damages to the city of Santa Cruz and the area along the Rio Piray. In 1992 the floods caused the severest flood damages to the northern rural region.

Soon after the 1983 flood, the Government of Bolivia established the Servicio de Encauzamiento y Regulation de Aguas del Rio Piray (SEARPI), to deal with the coordination and planning of social and economic development of the Rio Piray basin and in particular with its preservation and reclamation. SEARPI has conducted a Master Plan Study so called the Master Plan for the Management and Training of the Rio Piray (from March 1988 to September 1990) by the EEC assistance.

In 1994, the Government of Bolivia set up a flood control master plan entitled the Master Plan on Flood Control in the Northern Rural Region of Santa Cruz in the Republic of Bolivia by JICA, the official agency responsible for the implementation of technical cooperation programs, from March 1995 to June 1996 that covers about 7,000 km^2 of the northern region of Santa Cruz. According to the Master Plan Study, the northern rural region is extremely vulnerable to flood and drainage problems. The flood hazard areas by the annual floods and by the 1992 floods were estimated to be 2,444 and 4,857 km^2 respectively.

In 1997, the floods caused a wide inundation area in the San Juan - Antofagasta area at the beginning of the year and in the Rio Chane - Pailon area at the end of the year. The damages were reportedly not severe.

In 1997 and 1998, the overflow from the Rio Grande caused the inundation in the Okinawa Drainage basin.

1.2 Review of the Master Plan for Flood Control in 1996 and Proposed Feasibility Study

The Master Plan Study covered the area of about 7,000 km^2 between the Rio Grande and the Rio Yapacani, but the Rio Piray was not included in that study, because she had a master plan prepared in 1990.

The Master Plan Study proposed structural and non-structural measures for the flood mitigation and drainage improvement in the Study Area at the target year 2010. The priority areas which needed a combination of both structural measures and non-structural measures were selected based the following criteria:

- The intensive land use areas such as urban areas and farming areas that were suffering from annual floods,
- The intensive land use areas that were severely affected by the 1992 floods with an inundation depth of more than 50 cm and the period of more than 2 days.

The priority areas identified in the Master Plan were

In eastern part :

The Chane - Pailon Area, consisting of the drainage basin of the Rio Chane and the Okinawa drainage basins.

In western part :

The San Juan - Antofagasta Area, consisting of the drainage basins of the Arroyo Yapacanicito and Arroyo Jochi and Tacuaral.

The structural measures were proposed with the design flood scale of 10-year return period for the flood mitigation facilities and 5-year return period for the drainage improvement.

The measures are composed of

- River improvement,
- Drainage improvement,
- Road-cum embankment.

The non-structural measures were proposed for the whole flood hazard areas. The measures were as follows:

For flood mitigation:

- Flood warning and evacuation system,
- Flood plain management,
- Land use control for retarding basins,
- Preservation of the protected forest along the rivers,
- Land use management.

For drainage improvement:

- Introduction of the water tolerant crops in the poor drainage areas,
- Proper farm land management.

The proposed priority areas for the Feasibility Study in the Master Plan Study are shown in Figs. 1.2.1 and 1.2.2.

The Government of Bolivia realized the importance of the flood damage mitigation in those high priority areas identified in the Master Plan Study and requested the Government of

Japan to conduct the "Feasibility Study for the Flood Control in the Northern Rural Region of Santa Cruz".

1.3 Objectives of the Study

Objectives of this study are:

(1) To conduct a Feasibility Study on the flood control in the Study Area,

(2) To pursue a technology transfer to the counterpart personnel in this field.

1.4 Study Area

The Study Area covers approximately 1,207 km^2 of the northern rural region of Santa Cruz. It consists of Chane - Pailon Area (600 km^2) in the east and San Juan - Antofagasta Area (607 km^2) in the west as shown in Fig. 1.1.2.

1.5 General Approach and Methodology

The Study has been conducted in collaboration with the Department of Santa Cruz and other concerned agencies. Necessary data have been collected for supplementary studies. Field investigation and surveys have been conducted on the existing conditions and the current floods after 1995 in order to obtain supplementary data and information for F/S.

The F/S has been conducted based on the following basic concept:

(1) It is very important to propose effective non-structural measures together with structural measures for flood mitigation that would be possible for early implementation, because of the high productivity and importance of the area. The measures for F/S proposed in the Master Plan were reviewed based on their effectiveness in technical, economical and environmental terms in order to avoid problems for early implementation.

(2) It is necessary to develop GIS database of the basic data and information of the Study Area. In order to formulate effective measures, questionnaire surveys and river cross sectional survey have been conducted.

(3) In order to assess the effects by the proposed measures, the flood simulation models developed in the Master Plan Study were reviewed based on the flood data after the Master Plan Study.

(4) For formulation of effective non-structural measures such as flood warning and evacuation, flood plain management, land use management, the existing conditions and land use of the flood hazard areas were studied based on the database in order to reduce flood damages as much as possible.

(5) In order to minimize adverse effects by the project during the implementation stage, stage-wise implementation programs were studied, because it will take many years to complete the whole-proposed measures.

(6) An effective institutional organization is to be established for implementation of the proposed measures smoothly. The existing institutional organizations might be reinforced in their human resources and their facilities.

(7) Public participation will be based for routine O&M activities for the proposed flood mitigation and drainage improvement measures that will be a base for sustainable development of the study area.

(8) The proposed flood mitigation measures are composed of many types of structural and non-structural measures. The proposed measures were divided to the responsible implementation agencies, i.e., Department level and Municipal level, due to their types and scales of them.

1.6 Supplementary Field Works

The supplementary field works conducted in the Study are

1) Collection of concerned reports, materials and references,
2) Field reconnaissance,
3) Questionnaire survey on
   I. Flood area and conditions,
   II. Flood damages,
   III. Agriculture and land use in the flood hazard area.
4) Survey works, compose of

I. River cross sections along the priority rivers and drainage channels,
II. Soil investigation along the road cum embankment,
III. Environmental impact by the proposed measures.

1.7 Study Schedule

The study schedule consists of 2 phases as follows:

Phase 1 : Basic study and supplementary surveys,
Phase 2 : Plan formulation for the feasibility study.

Phase 1 : Basic Study and Supplementary Surveys

Major works conducted in this phase were:

1) Collection of concerned reports, materials and references,
2) Formulation of concept, approach and methodology,
3) Field reconnaissance,
4) Questionnaire survey on
   I. Flood area and conditions,
   II. Flood damages,
   III. Agriculture and land use in the flood hazard area,
5) Survey works, compose of
   I. River cross sections along the priority rivers and drainage channels,
   II. Soil investigation along the road cum embankment,
   III. Environmental impact by the proposed measures,
6) Formulation of a land use plan,
7) Formulation of structural measures,
8) Formulation of non-structural measures.

Reporting

The reports in this phase were as follows:

1) Inception Report (July 1998)
2) Progress Report (October 1998)

Phase 2 : Plan Formulation for the Feasibility Study

Major works conducted in this phase were

1) Preparation of the flood hazard area and zoning
2) Preliminary design of the proposed structural measures,
3) Formulation of the non-structural measures
4) Preparation of a construction plan,
5) Preparation of an operation and maintenance plan,
6) Project cost estimation,
7) Project evaluation,
8) Preparation of an implementation program for the project,
9) Evaluation of the environmental impact
10) Formulation of the institutional organization.

Reporting

The reports in this phase were as follows:

1)	Draft Final Report	(March 1999)
2)	Final Report	(June 1999)

1.8 Report Layout

This report consists of 4 parts as follows:

(1) Summary

(2) Main Report

(3) Supporting Reports: (A to M)

Supporting A	:	Flood and Flood Damage
Supporting B	:	Meteo-hydrology
Supporting C	:	Preliminary Design
Supporting D	:	Cost Estimate
Supporting E	:	Construction Plan
Supporting F	:	Hydrodynamic Simulation

Supporting G : Environmental Study
Supporting H : Agriculture and Land Use
Supporting I : Socio-economy
Supporting J : Project Evaluation
Supporting K : Questionnaire Survey
Supporting L : Terms of Reference (TOR) for Supplementary Survey
Supporting M : Database

(4) Data Book:
Data Book A : Soil Investigation
Data Book B : Rainfall data
Data Book C : Ficha Ambiental

(5) Data Book - Drawing:
Data Book – Drawing A : Topographic Survey
Data Book – Drawing B : Preliminary Design

FIGURES

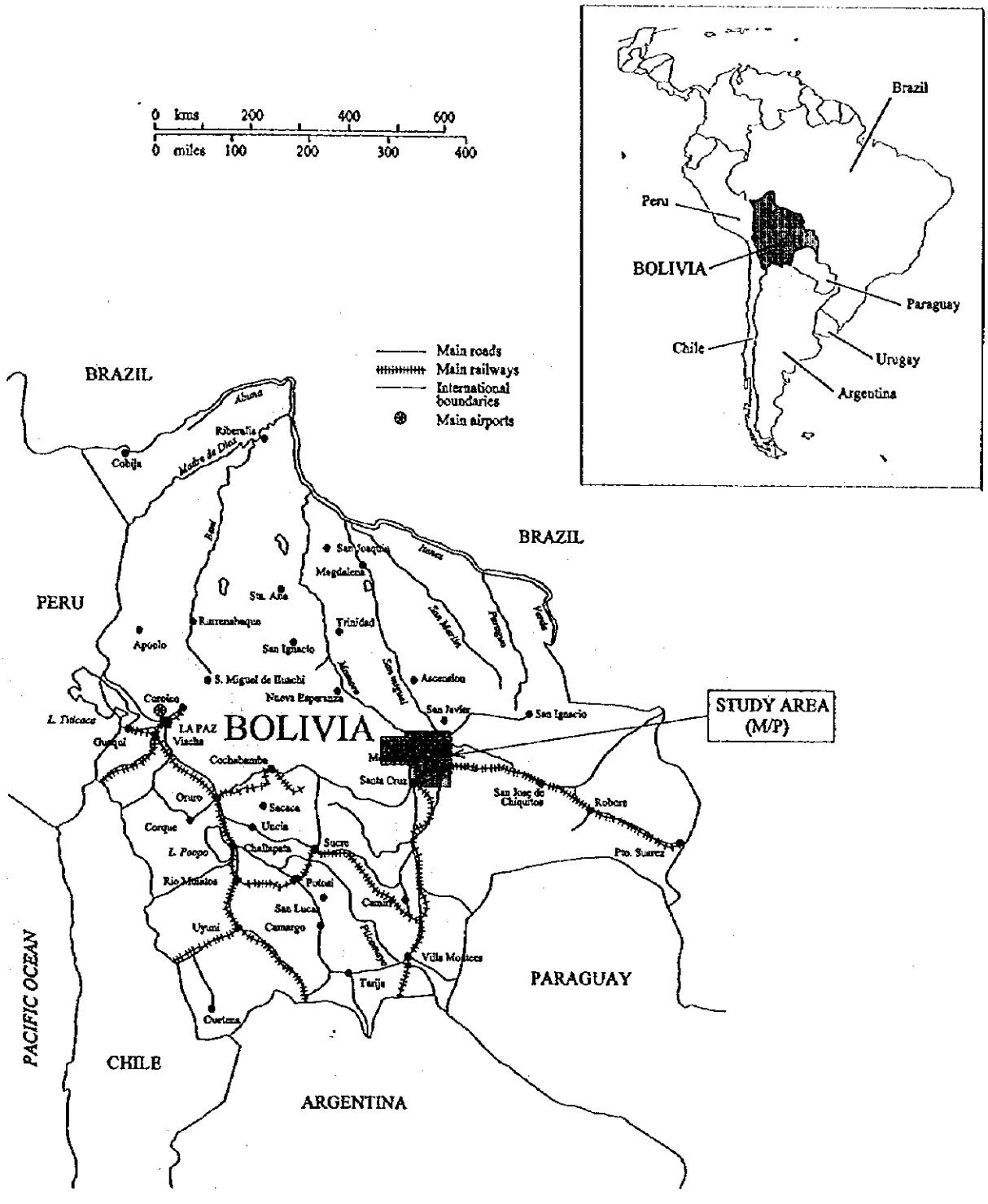

FIG. 1.1.1 LOCATION MAP OF THE STUDY AREA

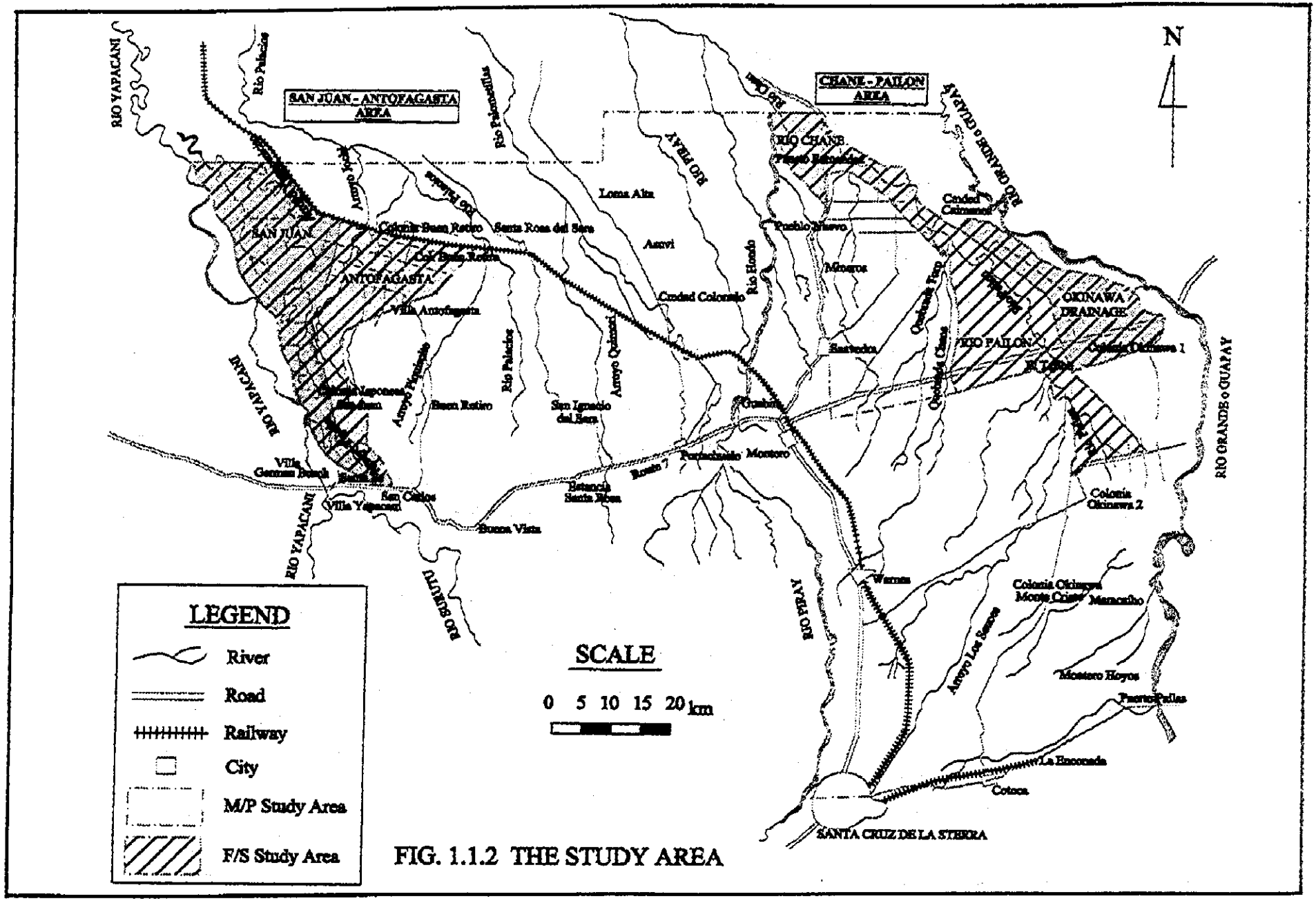

FIG. 1.1.2 THE STUDY AREA

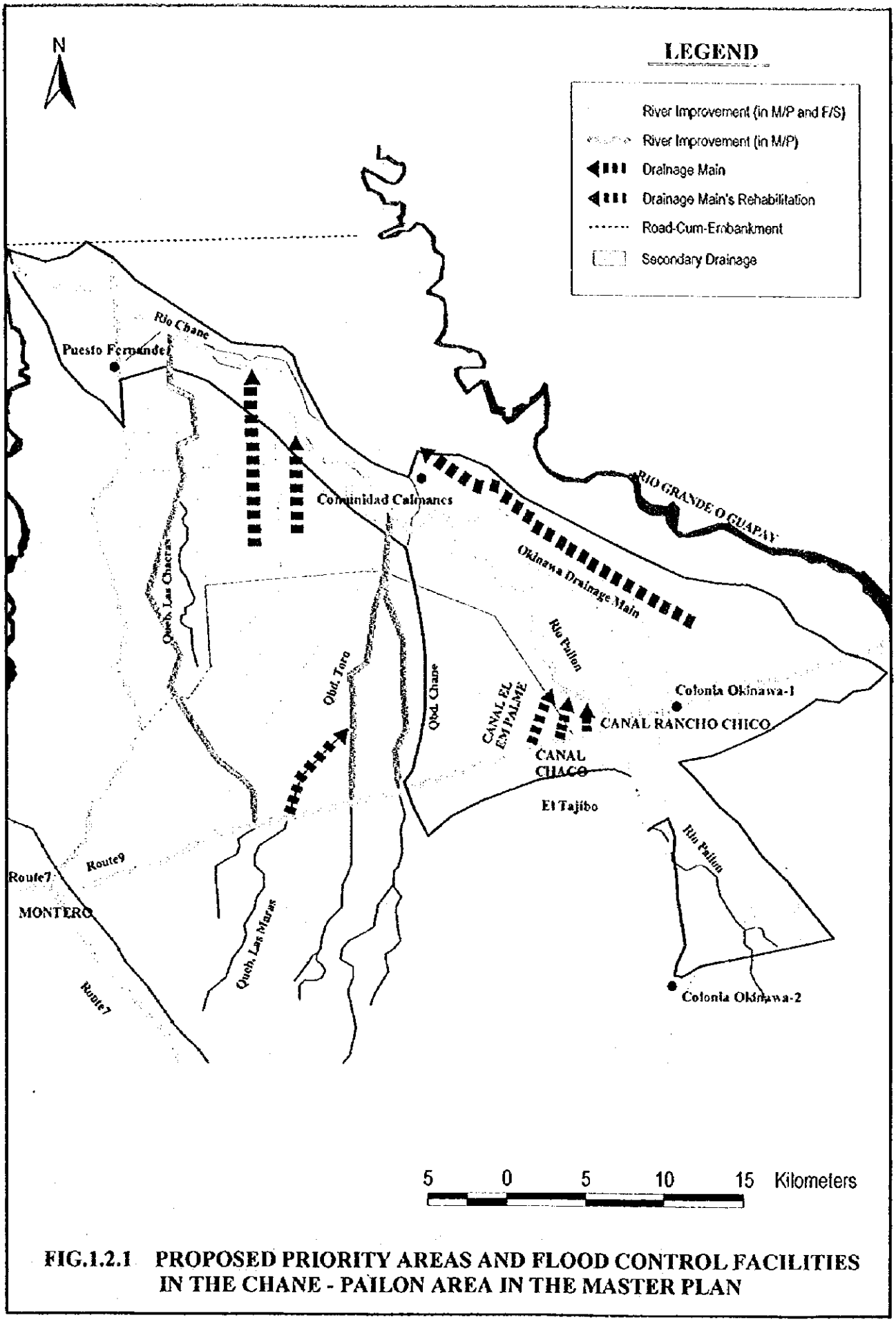

FIG.1.2.1 PROPOSED PRIORITY AREAS AND FLOOD CONTROL FACILITIES IN THE CHANE - PAILON AREA IN THE MASTER PLAN

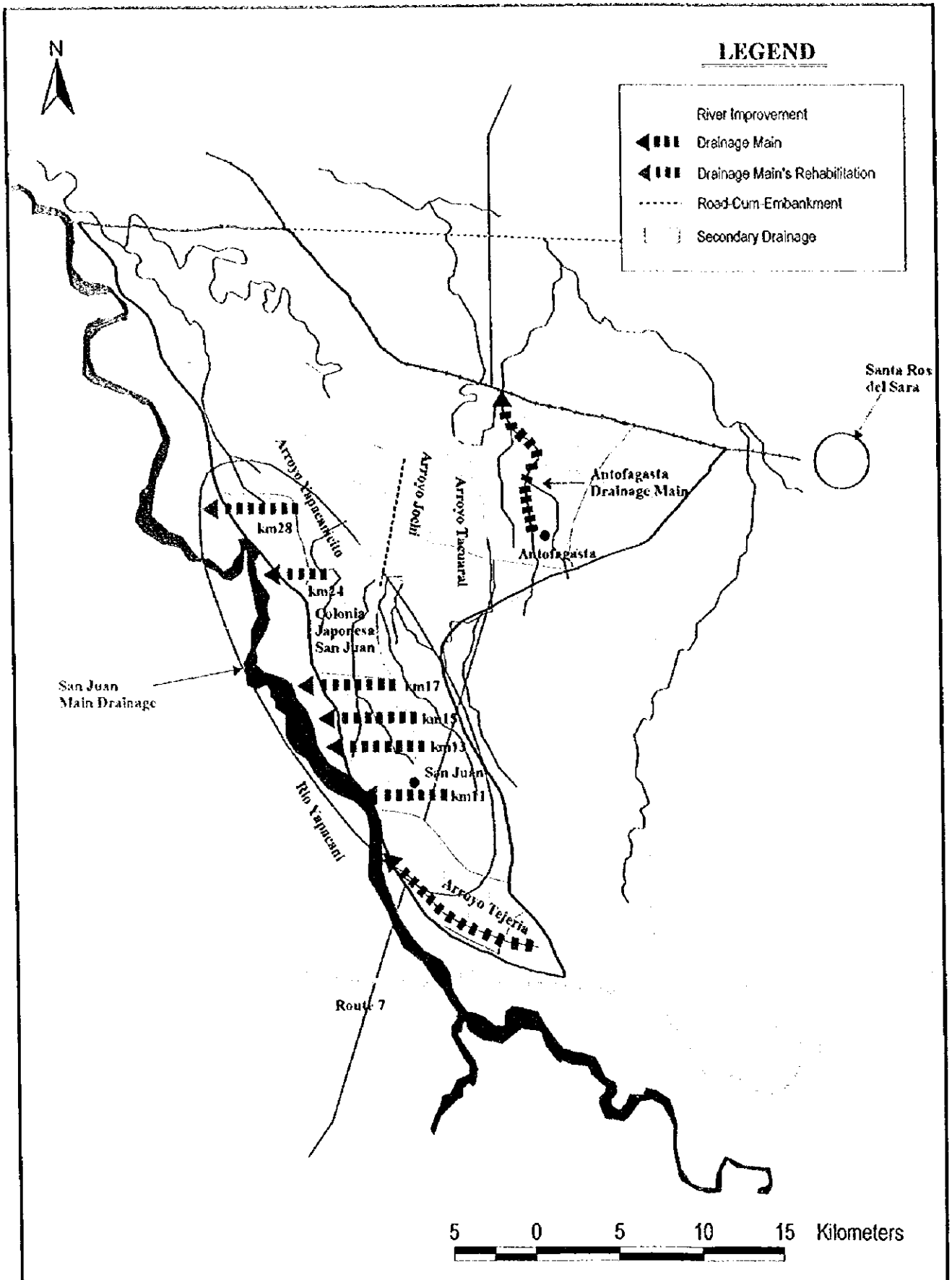

FIG.1.2.2 PROPOSED PRIORITY AREAS AND FLOOD CONTROL FACILITIES IN THE SAN JUAN- ANTOFAGASTA AREA IN THE MASTER PLAN

CHAPTER 2

STUDY AREA

CHAPTER 2 STUDY AREA

2.1 General

The Republic of Bolivia borders the Republic of Brazil to the north and east, the Republics of Paraguay and Argentina to the south and the Republics of Chile and Peru to the west. The country occupies a total land area of 1,098,582 sq. km and has a population of 6,420,792, according to the 1992 Census.

The Study Area is located in the Department of Santa Cruz, which consists of 15 Provinces and 47 Municipal Sections. It has an area of 370,621 km^2 and a population of 1,364,389 according to the 1992 Census. The city of Santa Cruz, which is the capital city of the Department of Santa Cruz, with a population of 697, 278, is a center of political, administrative and economic activities, and the second largest city in the country. The Study area is situated in the northern region of the city of Santa Cruz administratively related to three provinces, i.e., Warnes, Obispo Santistevan and Ichilo.

The Study area (1,207 km^2) is divided into two areas; Chane - Pailon area (600 km^2) and San Juan - Antofagasta area (607 km^2). The former spreads over three Municipalities, i.e., Okinawa Municipality of Warnes Province, Gral. Saavedra and Mineros of Obispo Santistevan Province, and the latter is located in the San Carlos Municipality of Ichilo Province. They are shown in Figs. 2.1.1 (1) and (2).

2.2 Topography

The Rio Chane – Pailon area is located on the alluvial plain of the Rio Piray and partly in the flood plain of the Rio Grande. The Rio Grande formed natural levees in the downstream reach in the Okinawa-I and Okinawa-II and a flood plain along the natural levee in the eastern part of the Okinawa I. The elevation varies from high in the southern area to low in the northeastern area.

San Juan-Antofagasta area is located on the alluvial plain of the Rio Yapacani. The Rio Yapacani and the tributaries created a sand deposition in the northern area at the downstream reach of the river from the National Road No. 7. The Arroyo Yapacanicito, Arroyo Jochi and Tacuaral are formed on the alluvial plain of the Rio Yapacani. The sediment in the Arroyo Yapacanicito, Jochi and Tacuaral varied from clayey sand to clay.

2.3 River System and Characteristics

The river systems and drainage basins in the study area are divided into the eastern and western parts. The eastern part is composed of the Rio Chane basin and the Okinawa drainage basin, and the western part is composed of the Arroyo Tejeria, Arroyo Yapacanicito, Arroyo Jochi and Arroyo Tacuaral basins.

In the Rio Chane basin, the Rio Pailon, the main river, flows from the upstream end of the Study area to the northern part, passes through the National Road No. 9. In the mid-stream reach after the confluence of the Quebrada Chane, the main river thereafter becomes the Rio Chane. The Rio Chane flows northwest wards and meets the Quebrada Las Chacras at the downstream reach and passes through the local road (Montero-San Pedro), which is the end of the study area, then joins 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.

In the San Juan – Antofagasta area, there are 4 main rivers, the Arroyo Tejeria and Yapacanicito belong to the Rio Yapacani basin, and the Arroyo Jochi and Tacuaral belong to the Rio Palacio, which is one of the tributaries of the Rio Yapacani. These rivers flow northwards from the southern part. The Arroyo Tejeria drains the upper part of San Juan area and flows directly into the Rio Yapacani. The Arroyo Yapacanicito drains the most part of the Sun Juan area and joins the Rio Yapacani at the downstream reach outside the study area. The Arroyo Jochi and Tacuaral drain the southern part of Antofagasta. Both rivers flow through the proposed natural retarding basin 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.

2.4 Socio-economy

2.4.1 Population

Population of the Department of Santa Cruz numbered 1,364,389 in 1992, which corresponded to 21 % of the national population (6,420,792). The average annual growth rate of population for the period 1976-1992 was 4.16 %, consisting of 6.21 % in

the urban area and 0.80 % in the rural area. The population density in the same year was 3.68 people/km^2. According to a projection of the National Statistic Institute (Instituto Nacional de Estadistica: INE), it is expected that population of the Department of Santa Cruz will reach 2.348 Million in 2010, growing at the annual rate of 2.62 % on average for the period from 1992 to 2010.

The populations of three Provinces related to the Study Area are as follows:

Population of Provinces in 1992 and 2010

Province	Population		Average Annual Growth Rate % 1992 - 2010
	1992 (Census)	2010 (Projected)	
Warnes	38,285	37,649	-0.09
O. Santistevan	104,660	111,168	0.34
Ichilo	49,484	51,620	0.24

The population density in 1992 was 31 people/km^2 in the Warnes Province, 28 people/km^2 in the Obispo Santistevan Province, and 3.48 people/km^2 in the Ichilo Province. It is expected that the projected population of Provinces in 2010, compared to the 1992 population, will increase by 6.2 % in the Obispo Santistevan Province and 4.3 % in the Ichilo Province, but population in the Warnes Province will decrease somewhat.

The populations of Municipalities in 1992 and 2010 are summarized as follows:

Population of Municipalities in 1992 and 2010

Municipality	Province	Population		Average Annual Growth Rate % 1992 - 2010
		1992 (Census)	2010 (Projected)	
Warnes	Warnes *	38,285	37,649	-0.09
G.A. Saavedra	O. Santistevan	11,639	12,362	0.34
Mineros	O. Santistevan	34,452	36,594	0.34
San Carlos	Ichilo	18,347	19,139	0.24

Note : * : including Okinawa Municipality

2.4.2 GDP and GRDP

The Gross Regional Domestic Product (GRDP) of the Department of Santa Cruz amounted to US$ 1,618 Million in 1995, at the average annual real growth rate of 5.53 % since 1992. Share of the GRDP of the Department of Santa Cruz in the GDP (US$ 5,898 Million) of Bolivia accounted for 27 %, having the highest share among all

Departments. It is expected that this GRDP will amount to approximately US$ 3,800 Million in 2010. The agricultural sector and the manufacturing industrial sector showed a share of 23.4 % and 21.2 % in the GRDP in 1995, respectively.

The per capita GRDP of the Department of Santa Cruz in 1995 indicated US$ 1,042, at the average real growth rate of 1.18 % per annum during the period 1992 - 1995, corresponding to about 1.3 times of the per capita GDP (US$ 796) of Bolivia. It is expected that the per capita GRDP of the Department of Santa Cruz will amount to US$ 1,500 in 2010.

The Department of Santa Cruz, among all departments, is the most developed region on agricultural production and some of grain and industrial products hold an overwhelming majority in production in Bolivia as shown in the following table:

Major Agricultural Productions in the Department of Santa Cruz in 1997
(unit : M.Tons)

Products	Bolivia	Dept. of Santa Cruz	Ratio of Santa Cruz to Bolivia (%)
Rice	255,568	189,910	74.3
Maize	637,929	346,910	54.4
Wheat	131,304	131,254	100.0
Tomatoes	80,001	67,625	84.5
Cotton	22,253	22,110	99.4
Sugar cane	3,962,189	3,247,481	82.0
Sunflower	80,829	80,829	100.0
Soybeans	940,820	921,953	98.0
Cassava	333,638	185,995	55.7

The exports of Bolivia amounted to US$ 1,295.4 Million in 1996, and a dominant export product was a soybean with exports of US$ 200.6 Million. Regarding the production of soybeans, the Dep. Santa Cruz had a share of 98 % in the country. The imports amounted to US$ 1,656.6 Million in the same year, and since 1991 the imports have exceeded the exports every year.

During the period 1991-1996, the average annual inflation rate of the consumer price recorded 10.3 % in the Santa Cruz City. The foreign average exchange rate changed gradually from Bs. 3.91/US$ in 1992 to Bs. 5.08/US$ in 1996. The Bolivian economy was maintaining a comparably stable situation, although it had somewhat an inflationary tendency.

Revenue in the budget of the Central Government of Bolivia amounted to Bs. 9,969 Million in 1997, of which the tax revenue accounted for Bs. 7,310 Million. On the other hand, the budget expenditure amounted to Bs. 11,477 Million in the same year. The expenditure exceeded the revenue in recent years, however, this deficit has been compensated every year by raising the fund from the external and internal credits, etc.

In 1998 the Prefecture's budget of the Dep. Santa Cruz showed an amount of Bs. 729 Million (US$ 139 Million), accounting for 20.9 % of the whole prefecture's budget in Bolivia.

The total public investment in the Department of Santa Cruz in 1997 amounted to US$ 93.3 Million, consisting of US$ 17.9 Million by the Central Government, US$ 29.5 Million by the Department of Santa Cruz, US$ 21.6 Million by Municipalities and US$ 31.0 Million by other public agencies.

The amount (US$ 93.3 Million) of the public investment in the Dep. Santa Cruz in 1997 was distributed to be US$ 4.5 Million (share of 4.8 %) for the production sector, US$ 41.6 Million (share of 44.6 %) for the infrastructure sector, US$ 40.7 Million (share of 43.6 %) for the social sector, and US$ 6.5 Million (share of 7.0 %) for the multipurpose sector.

During the period 1992-1997, the public investment totaled US$ 644.3 Million, at the average rate of US$ 107.4 Million per annum. The ratio of external fund to internal fund was 56 : 44 on average. The external fund of US$ 360.2 Million was composed of a credit of US$ 297.9 Million (82.7 %) and a donation of US$ 62.3 Million (17.3 %).

In 1998, budgets of three Municipalities; Warnes, G. Saavedra and San Carlos, related to the Study Area, are as follows:

Budgets of Municipalities Warnes, G. Saavedra and San Carlos
(unit : Bs. Million)

Description	Warnes	G. Saavedra	San Carlos
(1) Total Budget	19.33	4.18	6.43
(2) Public Investment	15.73	3.79	5.73
Ratio ((2)/(1)) (%)	81	91	89

The public projects with external funds in the Department of Santa Cruz numbered 130 cases in 1997. The total investment amounted to Bs. 64.9 Million, composed of Bs. 49.3 Million (79 %) of the credit projects and Bs. 15.6 Million (21 %) of the donation projects.

Among all public sectors with external funds in 1997, the dominant sectors in invested amount were transport and multipurpose sectors. The major fund sources were FONPLATA (Banco Financiero de Cuenca del Plata), FIDA (Fondo Internacional de Desarrollo Agricola), ALEM (Alemania), and PMA (Programa Mundial de Alimentos).

2.5 Related National and Regional Development Plan

There are 2 development plans related to this study, they are:

- The Departmental Development Plan,
- The Flood Control Plan in the Rio Piray.

(1) The Departmental Development Plan

The plan is formulated for the social, economic and national resources development and the environmental sustainability in the departmental and municipal levels for the year 1998 – 2008. The main strategies for the national resources development and the environmental sustainability guided in the plan are:

- To develop the institutional organization,
- To protect the environmental sustainable areas,
- To protect the soils and rivers from the pollution,
- To promote the public awareness on the environmental conservation,
- To strengthen the law on the environmental conservation.

The target year for the improvement of the soil and water quality was set at the year 2005.

(2) The Flood Control Plan in the Rio Piray Basin

The related project to this study was the flood control plan in the Rio Piray basin, entitled "Master Plan for the Rio Piray Basin Reclamation" formulated in 1991 by the ECC assistance. This project is now being implemented by the SEARPI.

This project proposed the implementation of the Rio Piray into 3 allotments:

- Allotment 1:
  Includes all works for the structural and non-structural measures along the river between the La Belgica Bridge and the Beni Railway crossing.
- Allotment 2:
  Includes all construction works on the right bank of the Rio Piray from the Beni Railway crossing to the confluence of the river with the Rio Chane.

- Allotment 3:
  Includes all construction works on the left bank of the Rio Piray, below the Beni Railway and the works on the right bank below the confluence with the Rio Chane, towards San Pedro.

The agricultural development was also proposed during the implementation of the Allotment 2 and 3.

The project is now being implemented in the Allotment 1. The work in this stage includes the river improvement, the flood warning system and the agricultural development. The project is expected to be completed by the year 2000. The improvement in the Allotment 2 and 3 are expected to be started from the year 2000.

FIGURES

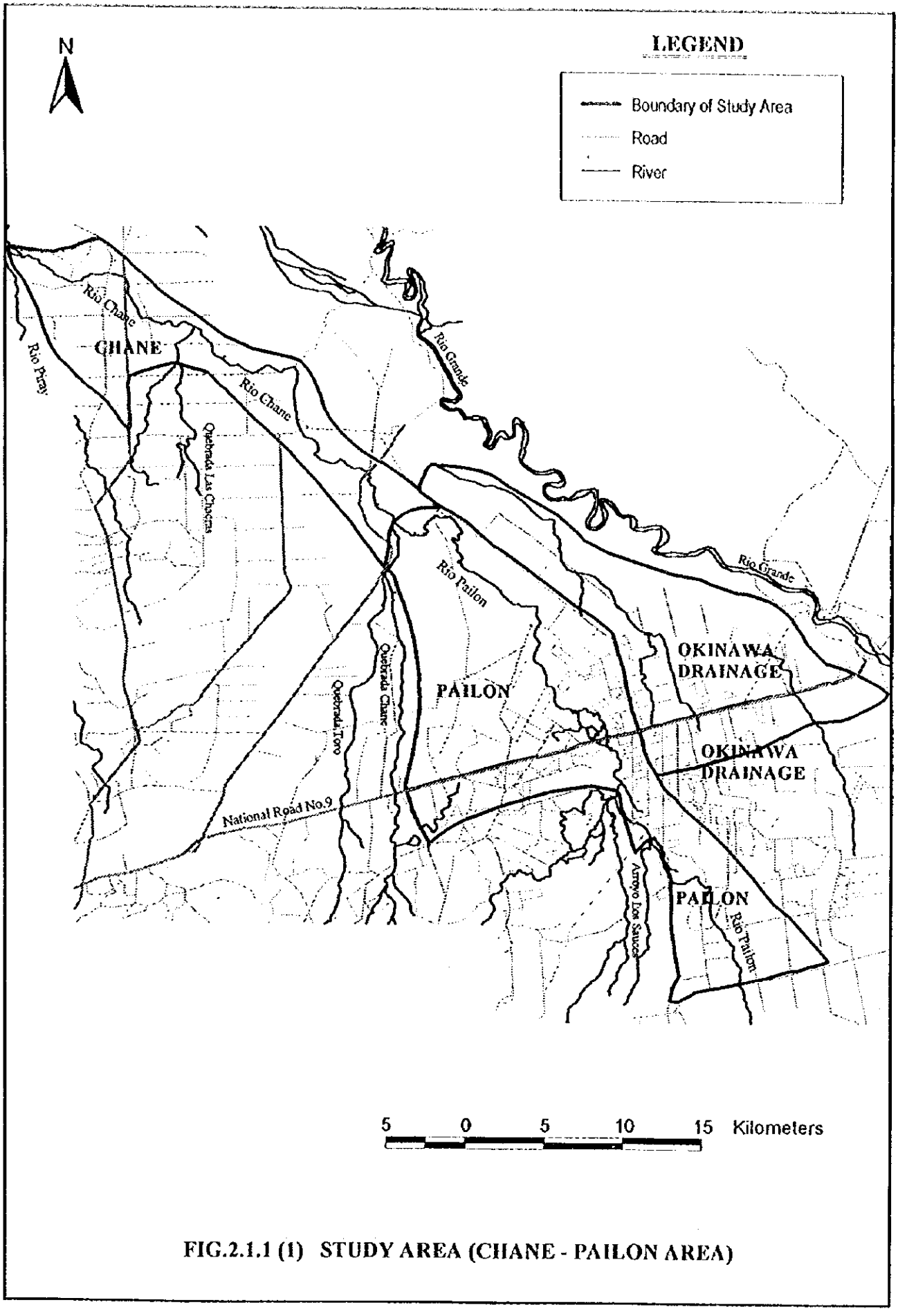

FIG.2.1.1 (1) STUDY AREA (CHANE - PAILON AREA)

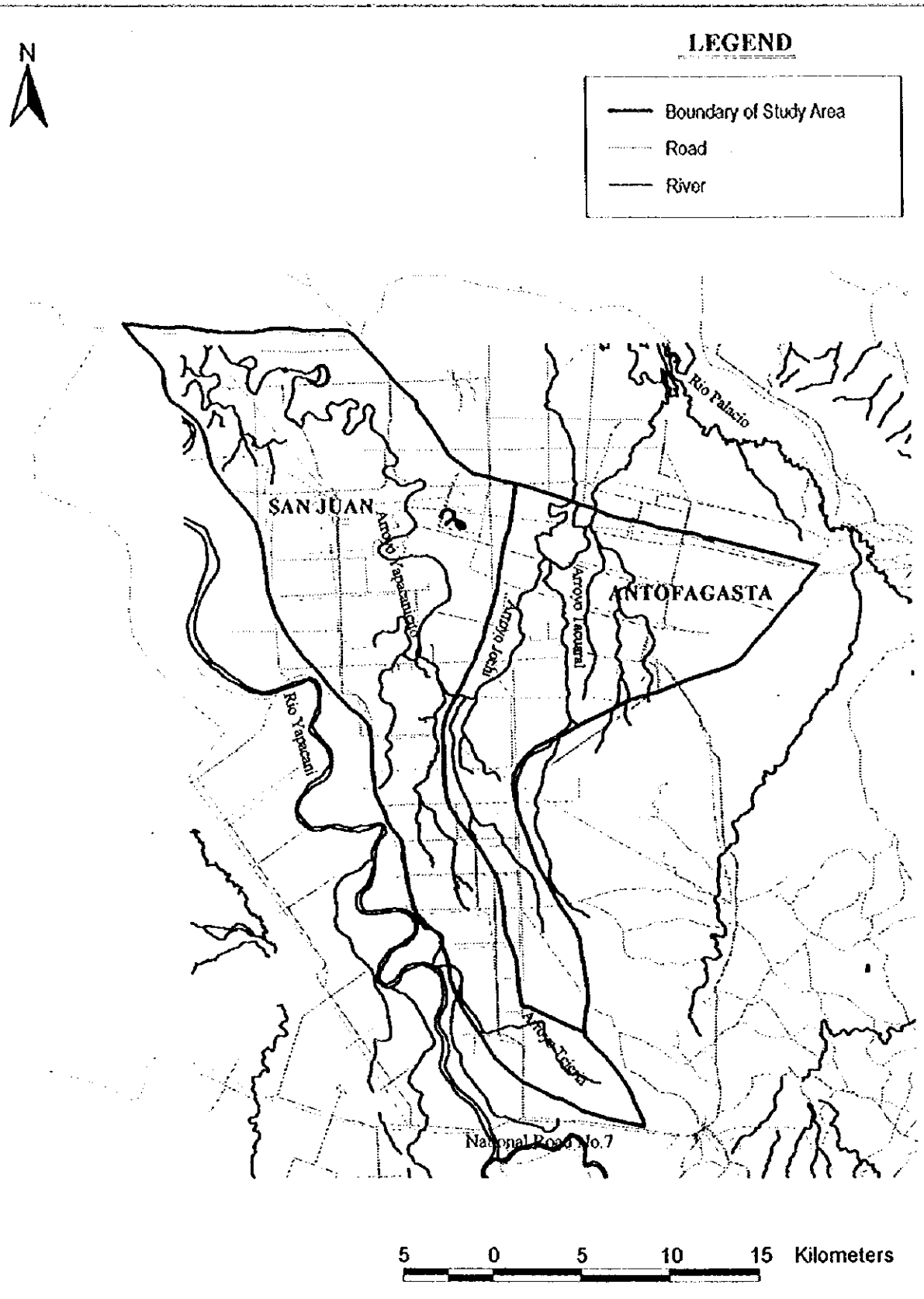

FIG.2.1.1 (2) STUDY AREA (SAN JUAN - ANTOFAGASTA)

CHAPTER 3

FLOOD AND FLOOD DAMAGE SURVEY

CHAPTER 3 FLOOD AND FLOOD DAMAGE SURVEY

3.1 Introduction

The recorded major floods in the Study Area from 1960s to 1995 areas follows:

Eastern area: 1968, 1972, 1983, 1987 and 1992
Western area: 1963, 1966, 1982, 1983 and 1992

The 1992 flood was assessed as the largest flood in recent years in the Study Area.

During the field study from August to September 1998, the floods and flood damages occurred in 1995-1998 were surveyed through the questionnaires to local inhabitants and the interviews to local government officials concerned in the Study Area in order to evaluate the floods after the Master Plan Study stage. The results of the surveys are explained below.

3.2 Flood Survey

3.2.1 1992 Floods by Flood Survey in the M/P

(1) The Chane - Pailon Area

Fig. 3.2.1 shows the inundation area of the Chane - Pailon area during the 1992 Flood in the Master Plan Study which was the largest flood from 1960s through 1995. Almost all of the Chane-Pailon area was inundated.

(2) The San Juan - Antofagasta Area

Fig. 3.2.2 shows the inundation area of the San Juan-Antofagasta area during the 1992 Flood in the Master Plan Study which was the largest flood from 1960s through 1995. All of the San Juan-Antofagasta area was inundated.

3.2.2 Floods in the Chane–Pailon during 1995-1998

The floods occurred in the Chane - Pailon area are listed as follows:

(1) 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.

(2) Floods from the Rio Grande

- Floods occurred in February to March 1997,
- Floods occurred in From February to March 1998.

The largest floods during the period from 1995 to 1998, occurred in the period from the end of November to the beginning of December in 1997.

Fig. 3.2.3 shows the inundation area of the Chane - Pailon Area during the 1997 floods occurred in November to December in 1997 with depth and duration. During the floods, approximately 65 % of the Chane - Pailon Area was considered to be inundated along the river channels i.e. the Rio Chane, Rio Pailon, Queb. Chane, Queb. Las Chacras and the Okinawa Drainage. The situation is summarized as follows:

- The Rio Chane basin was inundated with floodwater over 1.0 meter deep along the main channel,
- About 60 % of the Rio Pailon basin in the Study Area was inundated 0.3 m to 1.0 m deep at the upper reach, but over 1.0 m deep at near the Road No. 9,
- 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.

Fig. 3.2.4 shows the inundation area caused by the floods from Rio Grande occurred in February to March in 1997 with depth and duration. The floodwaters overtopped the left bank of the Rio Grande at two locations, i.e., 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 in the Okinawa Drainage basin. 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.

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 new seven 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.

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

The major floods occurred in the area during the period from 1995 to 1998, are listed 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.

The largest floods during the period from 1995 to 1998 was occurred in December 1996 to February 1997.

Fig. 3.2.5 shows the inundation area caused by the floods occurred in December 1996 to February 1997 with depth and duration. During the floods, the areas along the Rio Yapacani, the Arroyo Yapacanicito, Jochi, Tacuaral and Tejeria were inundated, and the inundation area was estimated to be about 90 % of the San Juan-Antofagasta area.

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

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 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 mostly inundated over 1.0 m deep in the surveyed reach.

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.

3.2.4 Annual Floods

(1) The Chane - Pailon Area

Fig. 3.2.6 shows the inundation area by the Annual Floods in the Chane - Pailon Area. The inundation area is estimated to be 377 km^2 or covers almost 65% of the Chane-Pailon Area.

(2) The San Juan - Antofagasta Area

Fig. 3.2.7 shows the inundation area by the annual floods in the San Juan - Antofagasta Area. The inundation area is estimated to be 424 km^2 or covers approximately 70% of the San Juan-Antofagasta Area.

3.3 Study on 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 Chapter 5.

FIGURES

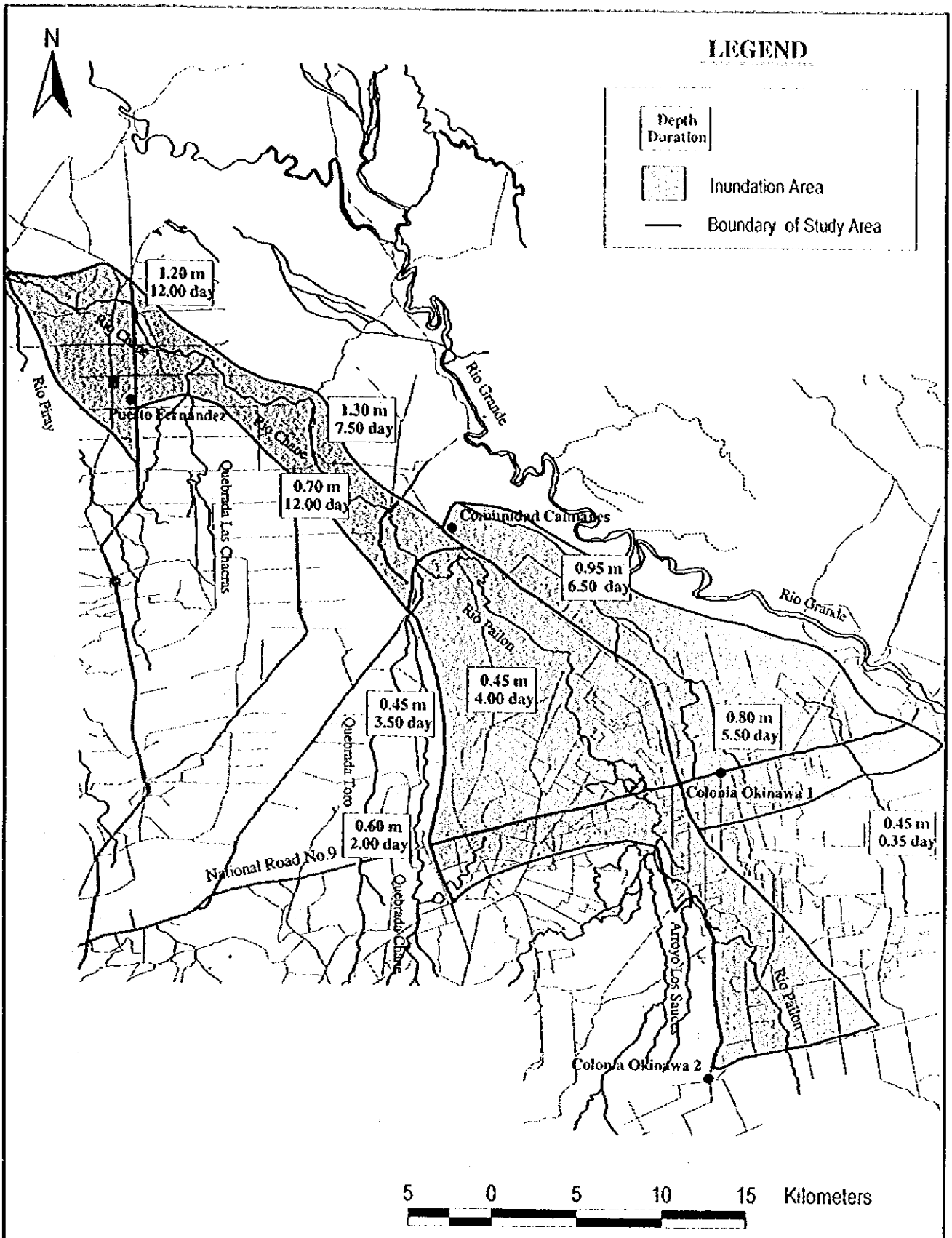

FIG.3.2.1 INUNDATION AREA IN CHANE-PAILON AREA (By 1992 Floods in the Master Plan)

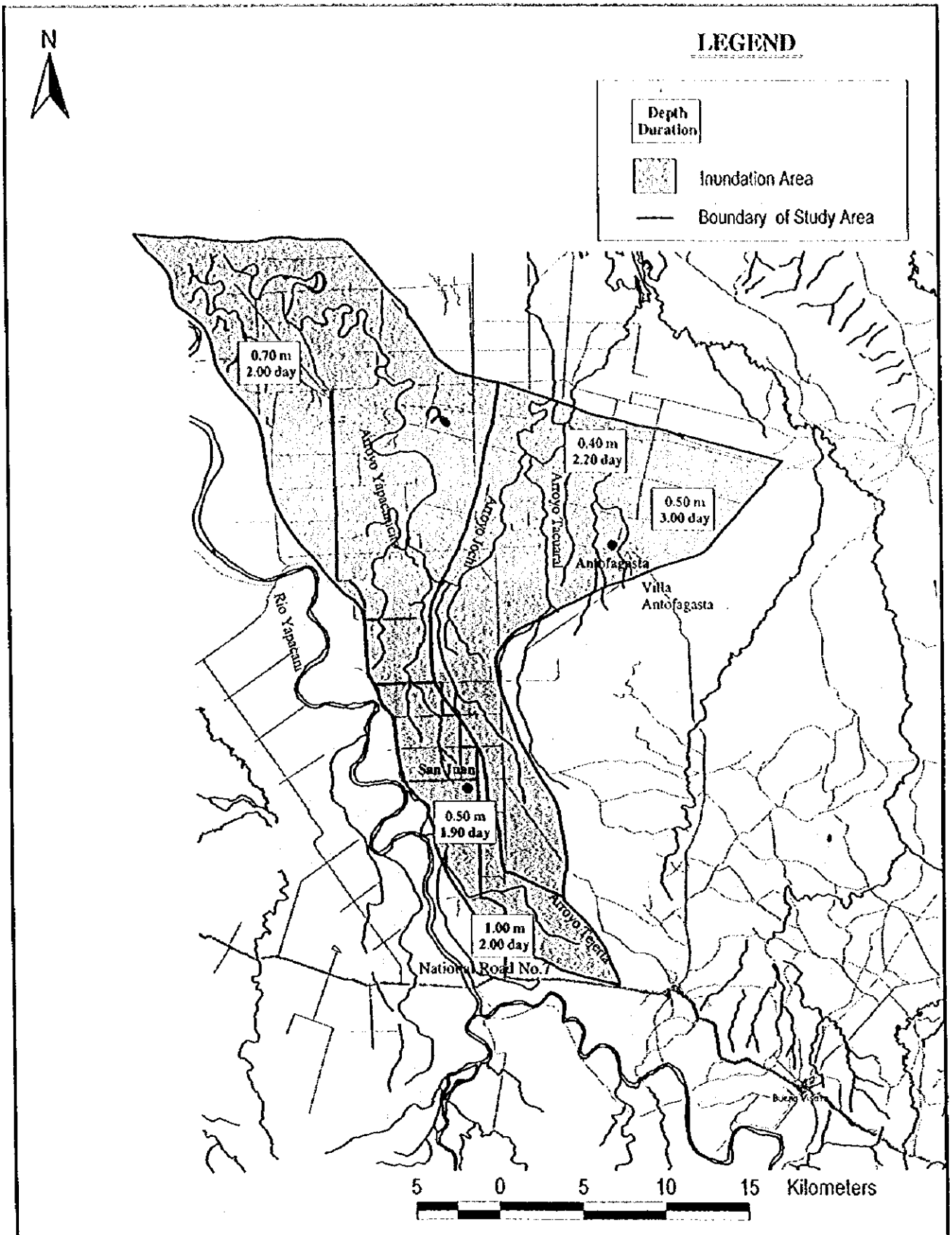

FIG.3.2.2 INUNDATION AREA IN SAN JUAN-ANTOFAGASTA AREA (By 1992 Floods in the Master Plan)

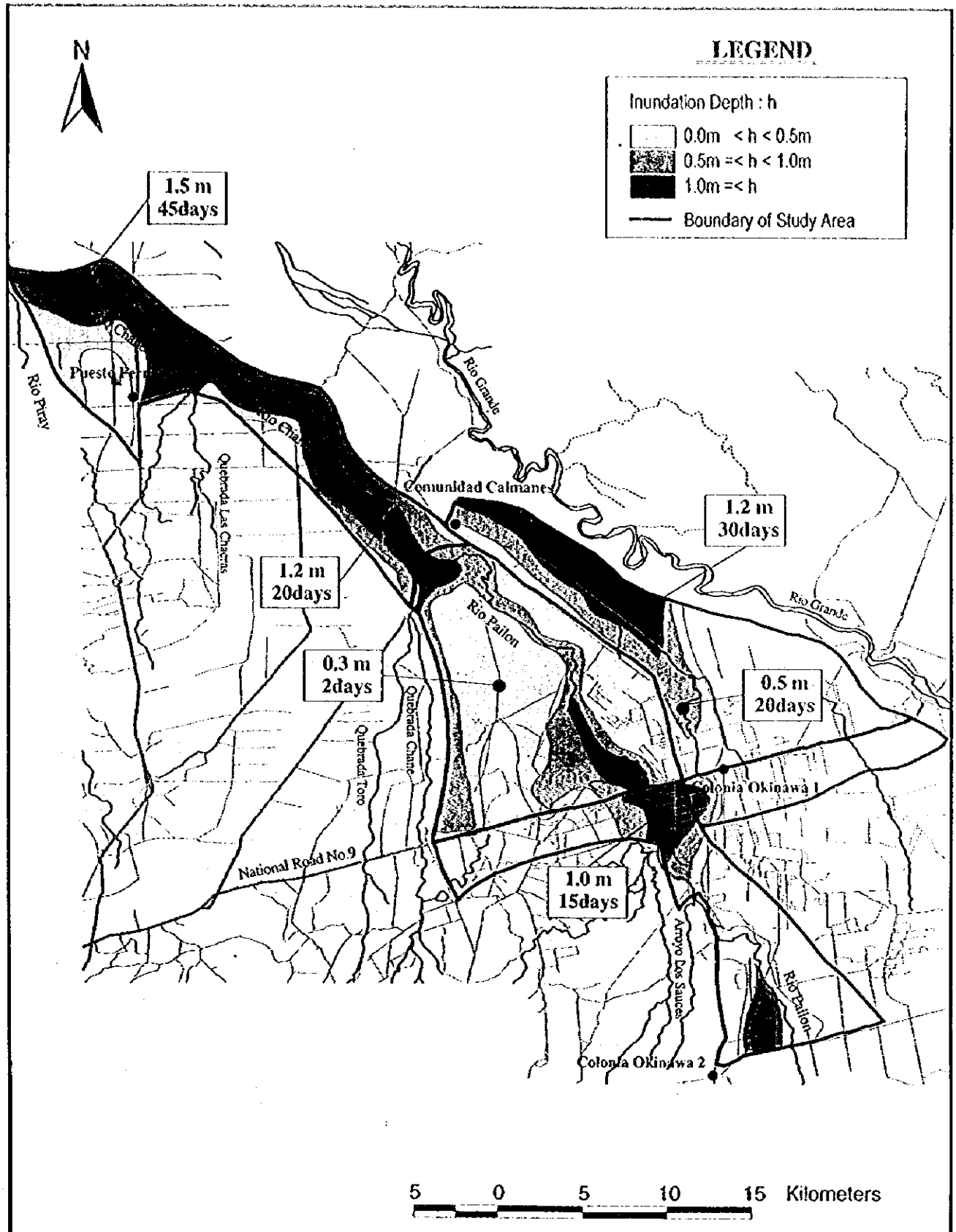

FIG.3.2.3 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during November to December 1997)

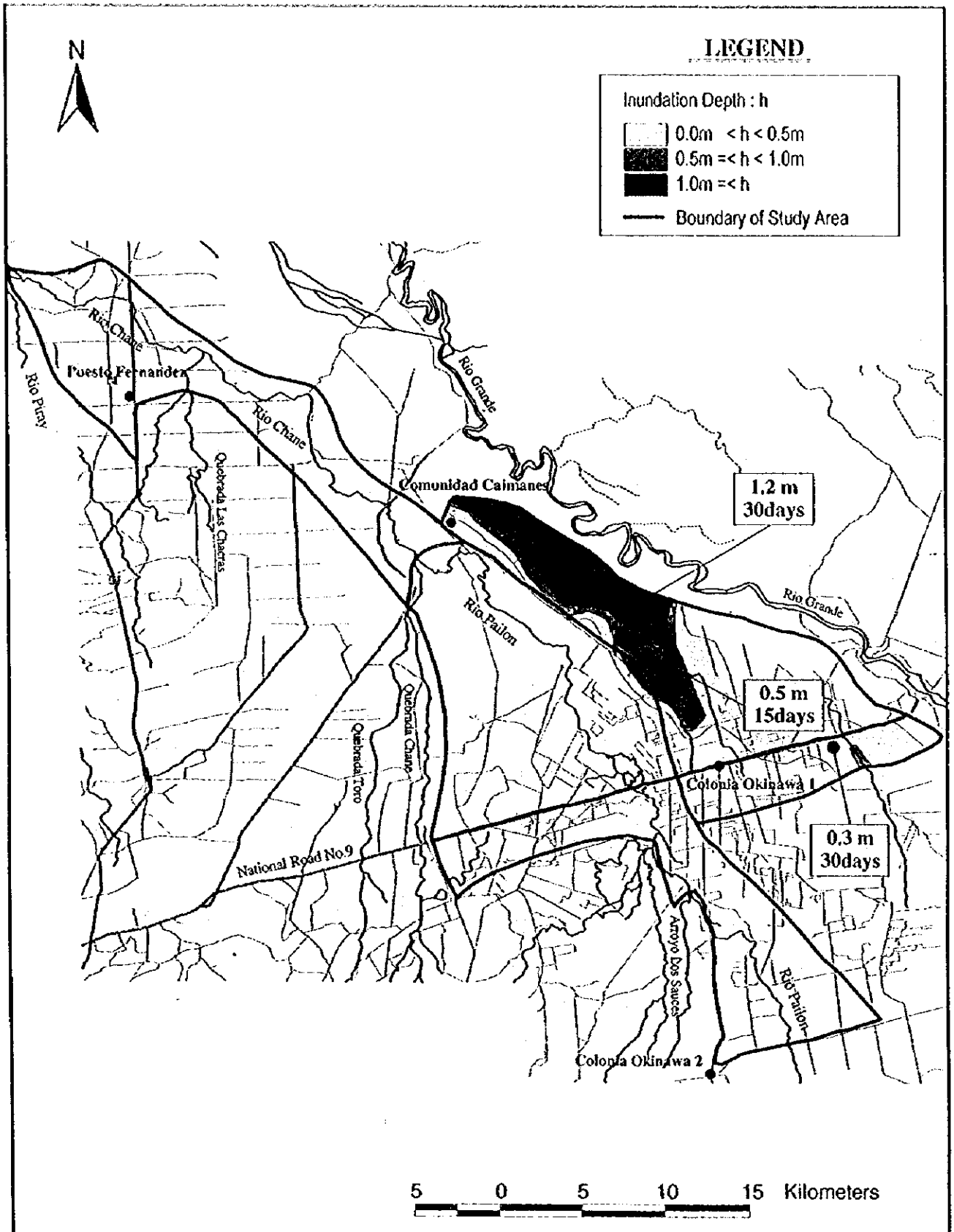

FIG.3.2.4 INUNDATION AREA IN CHANE - PAILON AREA
(By the floods during February to March 1997 from the Rio Grande)

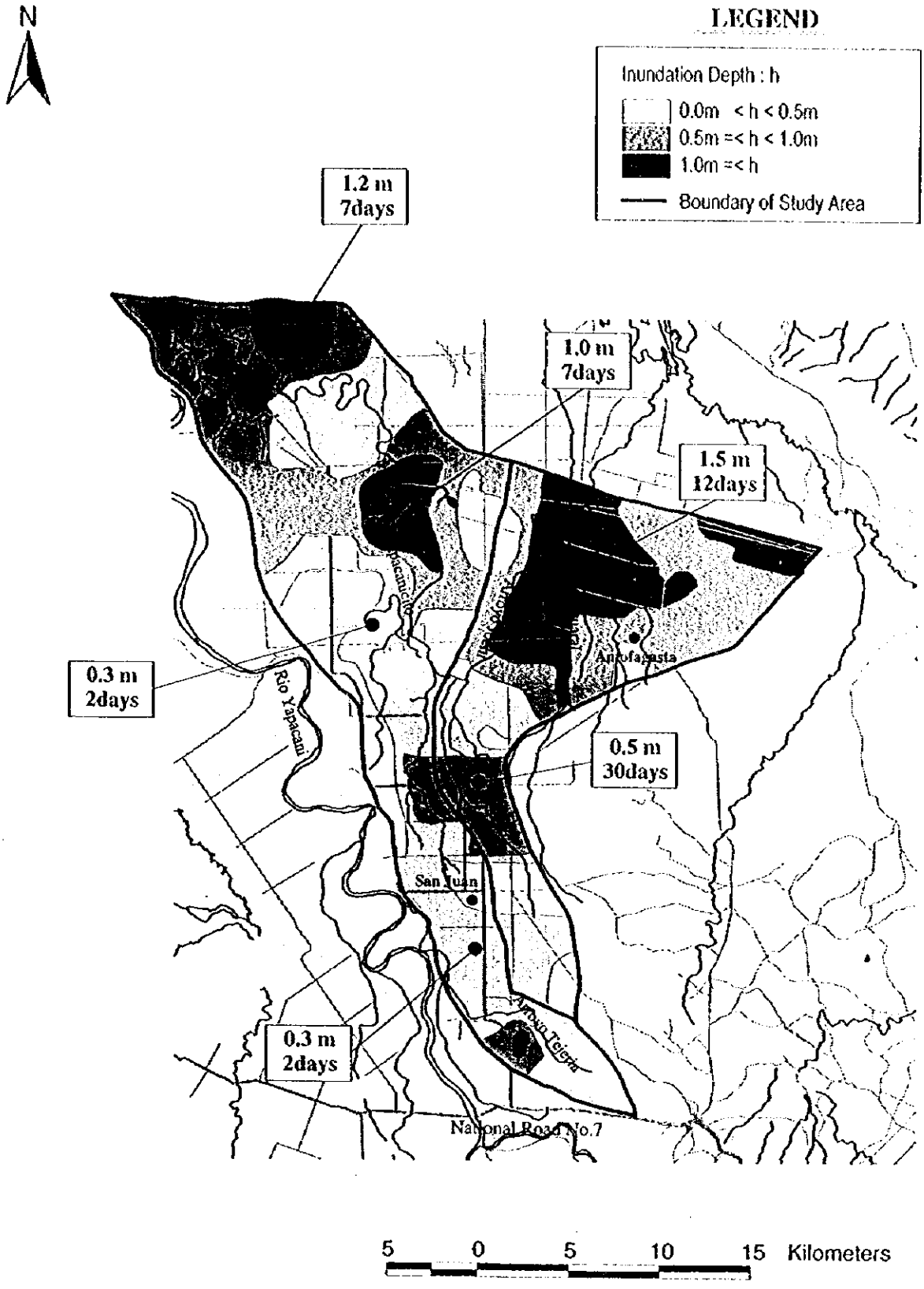

FIG.3.2.5 INUNDATION AREA IN SAN JUAN - ANTOFAGASTA AREA
(By the floods during December 1996 to February 1997)

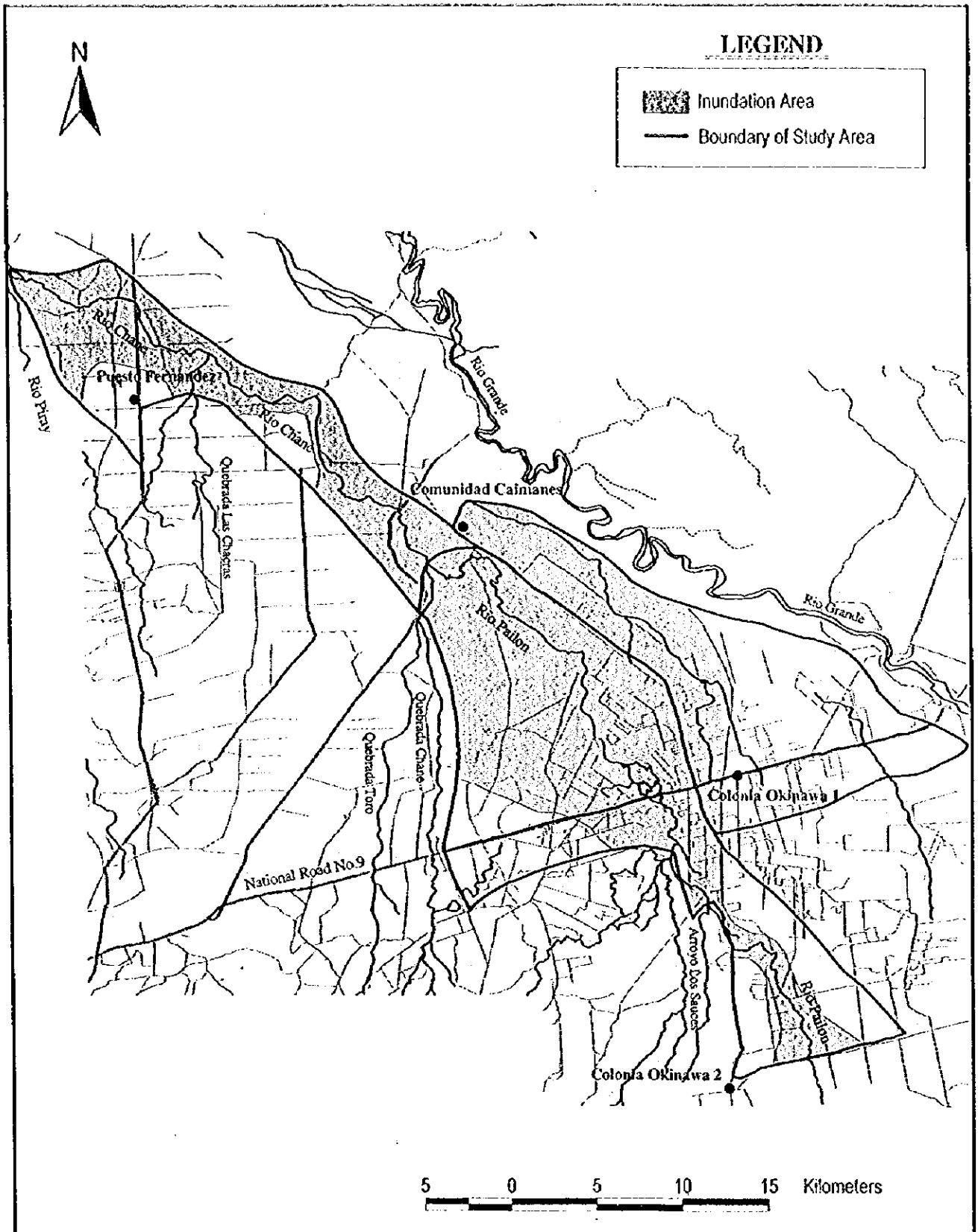

FIG.3.2.6 INUNDATION AREA BY ANNUAL FLOODS IN CHANE-PAILON AREA

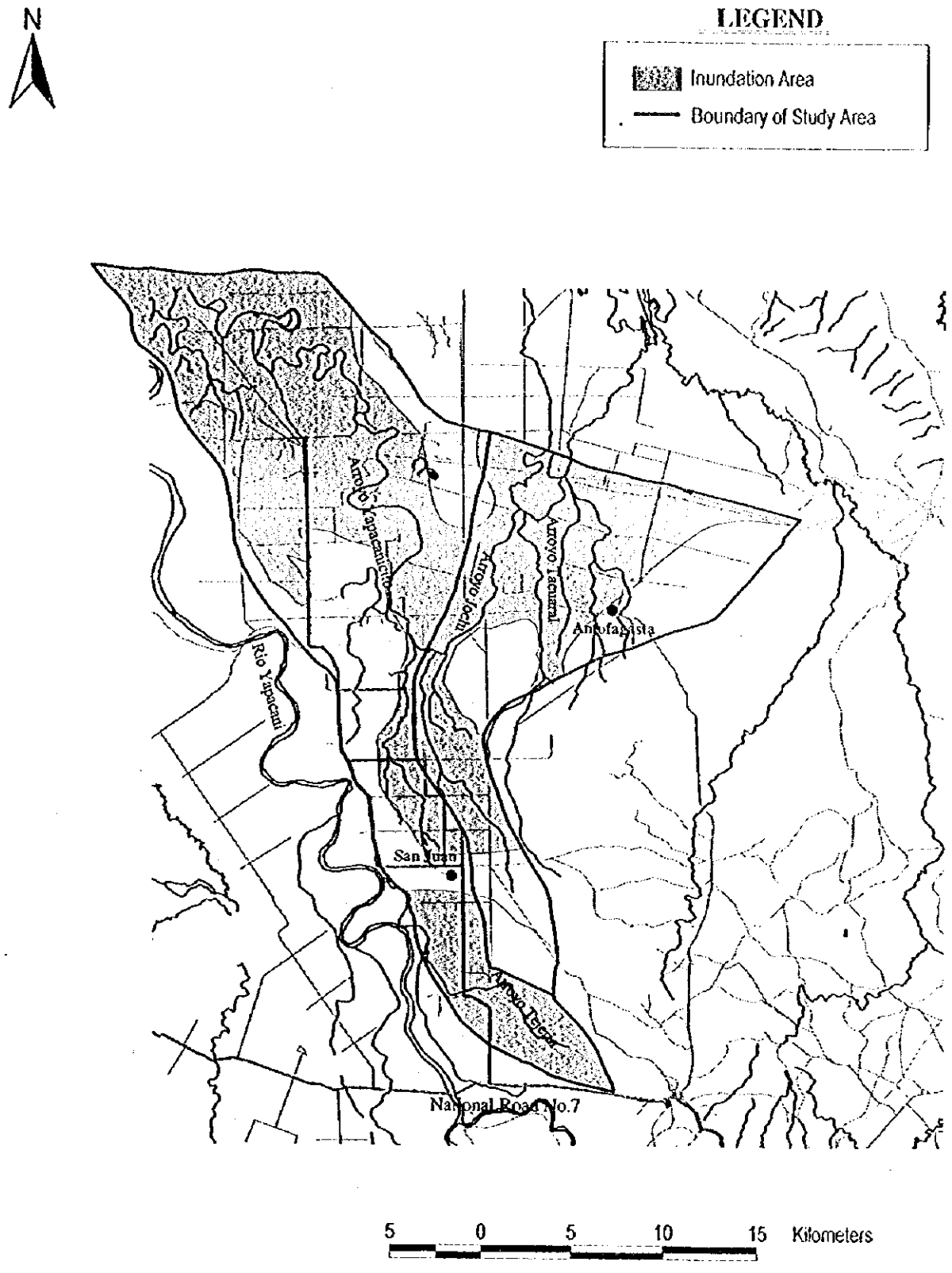

FIG.3.2.7 INUNDATION AREA BY ANNUAL FLOODS IN SAN JUAN-ANTOFAGASTA