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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**

**SUMMARY**

JUNE 1999

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**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)



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## 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.

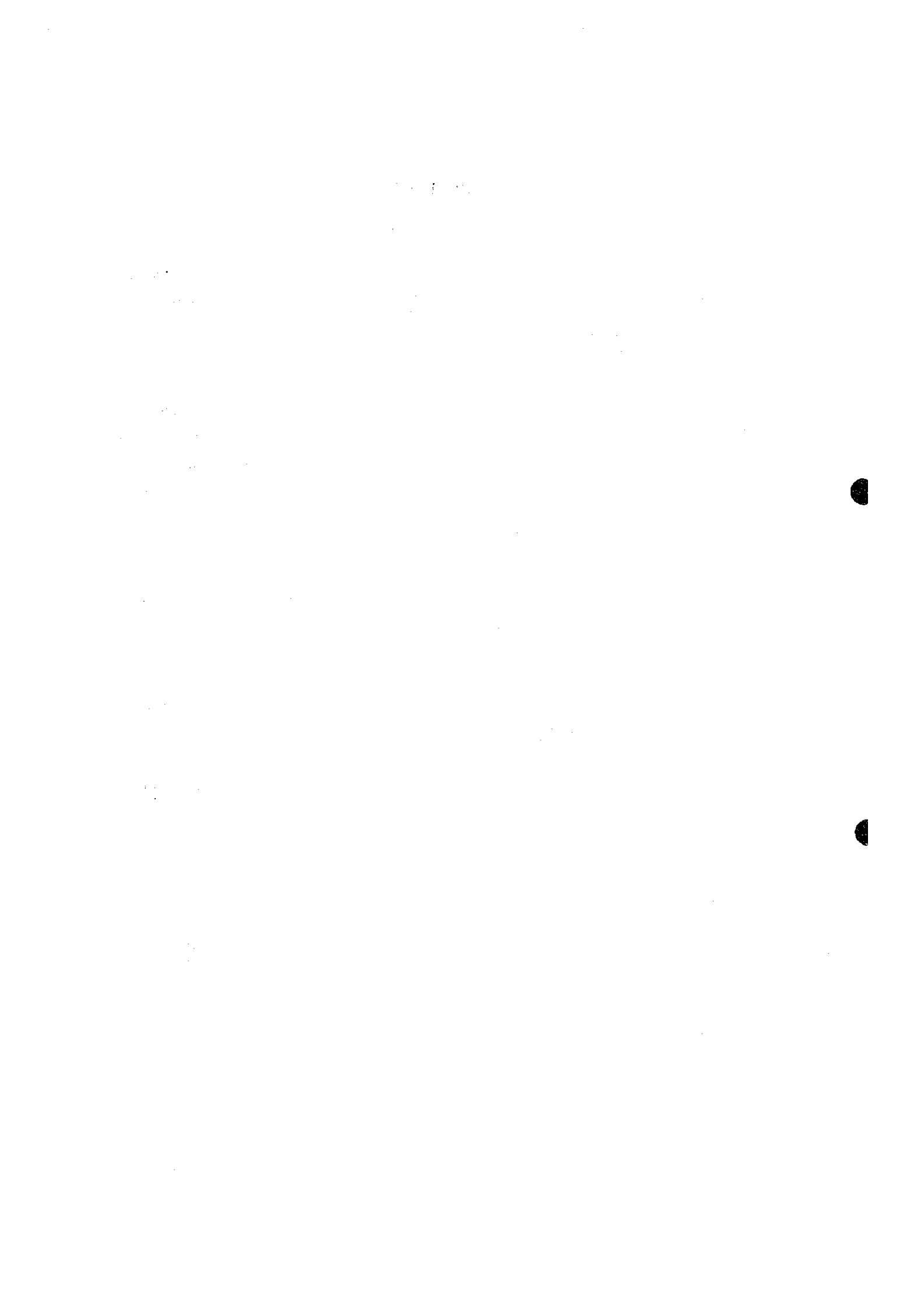
Jun, 1999



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Kimio Fujita  
President

Japan International Cooperation Agency



THE FEASIBILITY STUDY  
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June, 1999

Mr. Kimio FUJITA  
President  
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

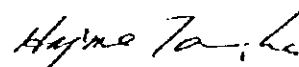
Dear Sir,

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.

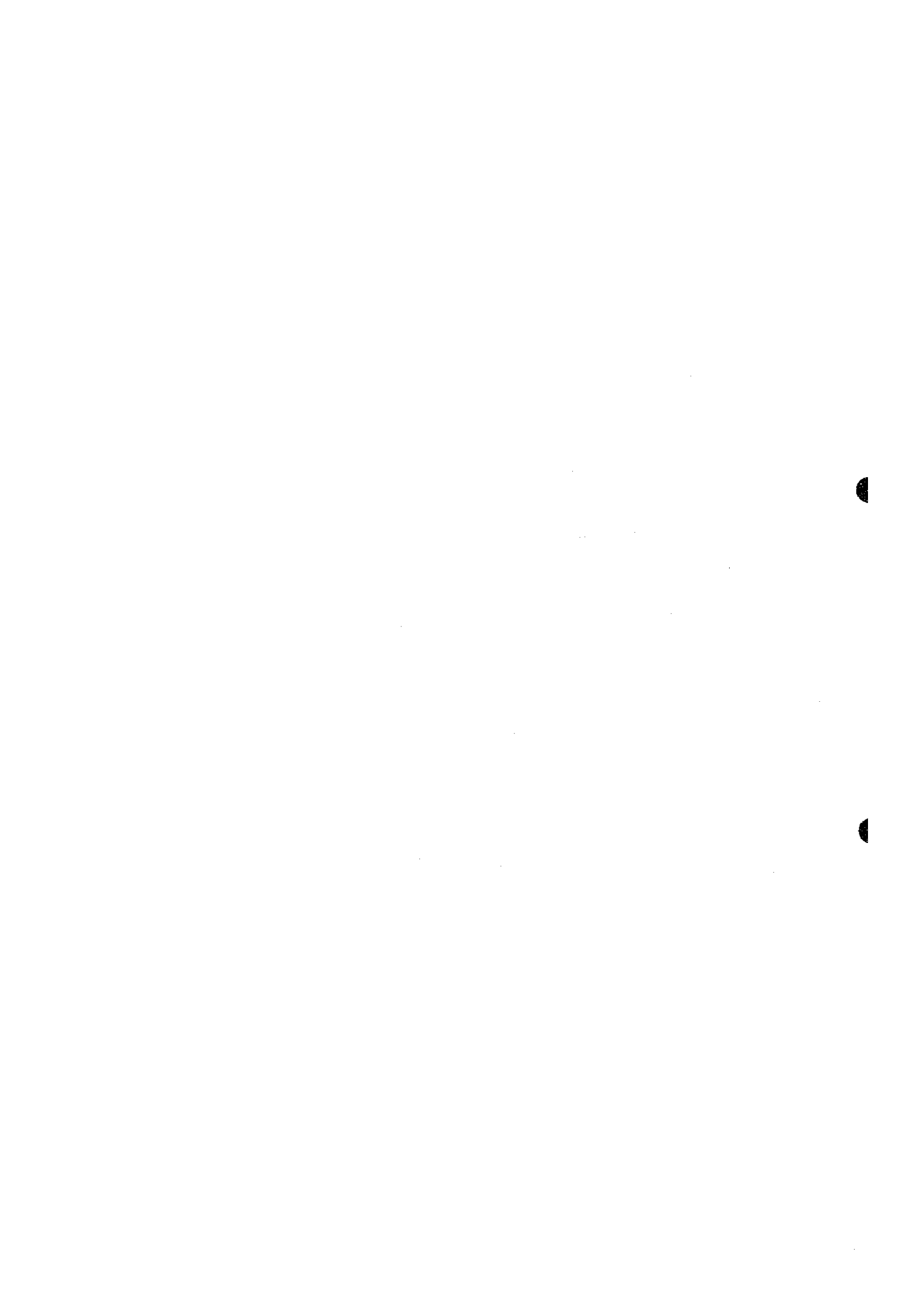
All members of the Study Team wish to express sincere appreciation to the personnel of your Agency, Advisory Committee, and the Embassy of Japan in Bolivia, and also to the officials concerned of the Government of the Republic of Bolivia for their assistance extended to the Study Team. The Study Team 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

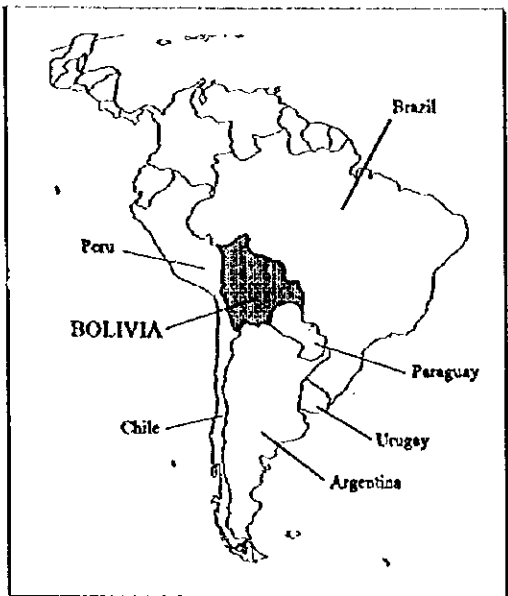
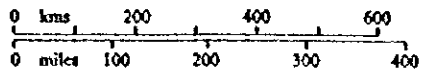


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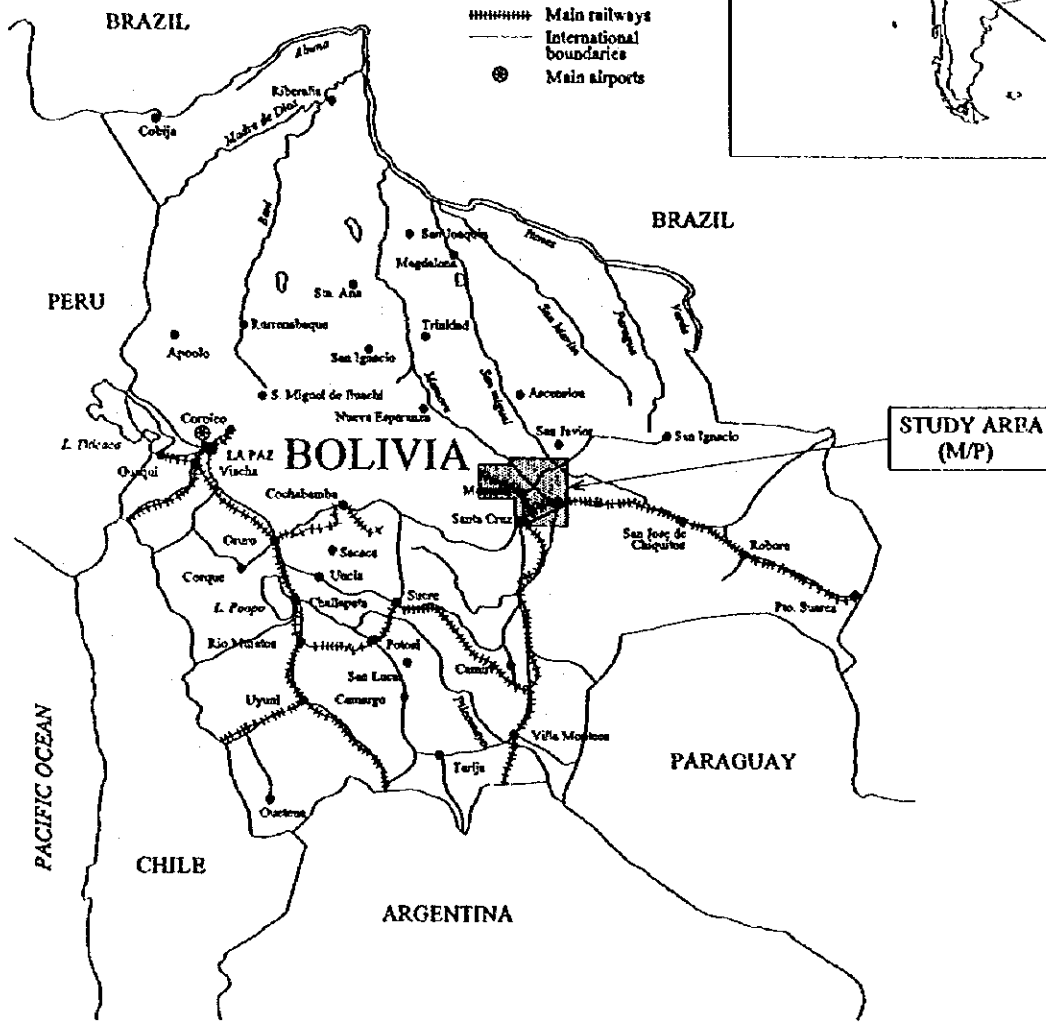
Hajime TANAKA  
Team Leader of the Study Team







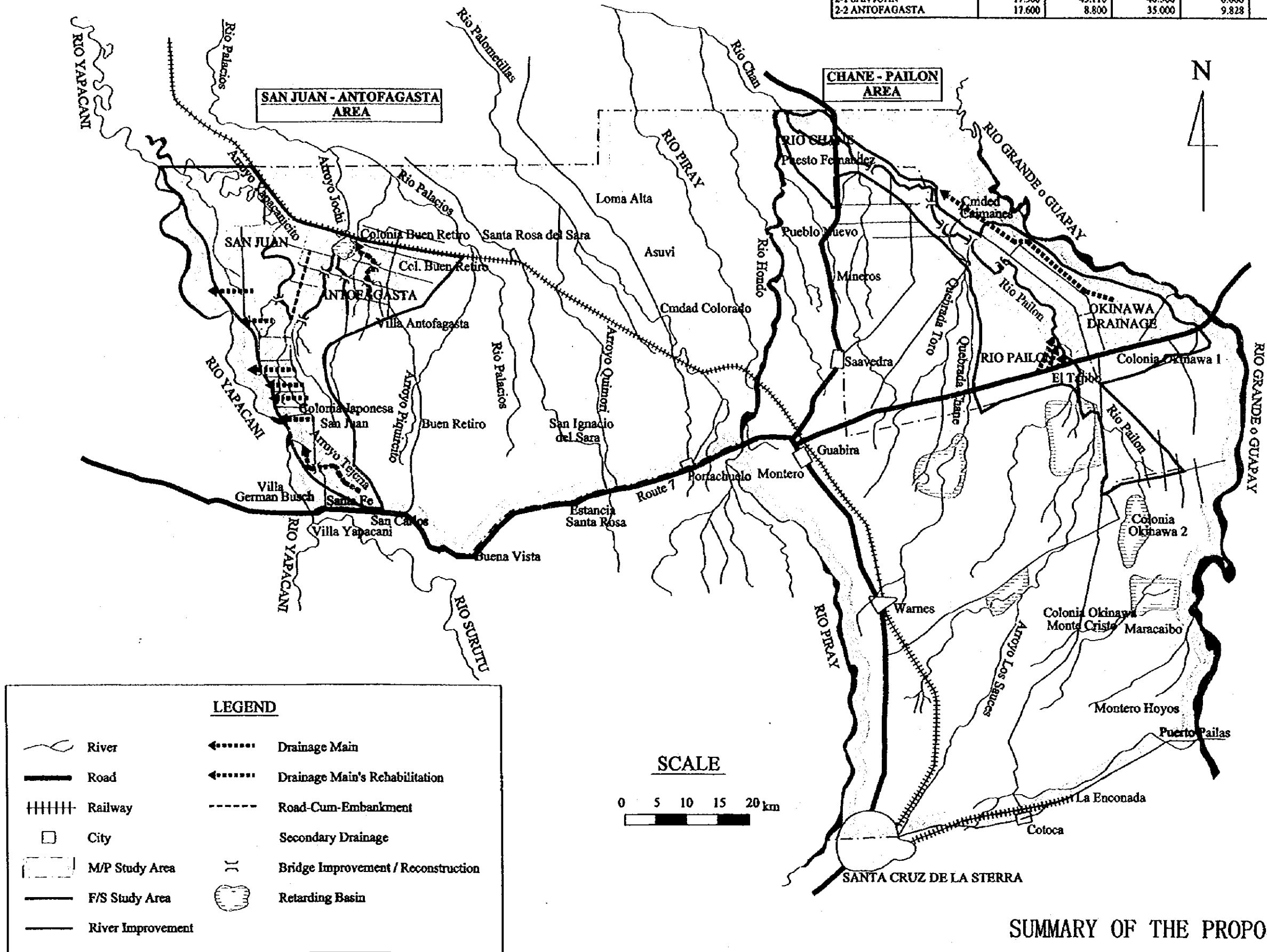
- Main roads
- ==== Main railways
- - - - International boundaries
- Main airports



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.
<b>Chane-Pailon</b>			
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
<b>San Juan - Antofagasta</b>			
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
<b>Total</b>	<b>92.72</b>	<b>83.92</b>	<b>9.83</b>

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

*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 than 10 % 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

	<u>Name of Projects</u>	<u>EIRR (%)</u>
-1	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 1<sup>st</sup> 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 2<sup>nd</sup> 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 1<sup>st</sup> 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 : km <sup>2</sup> )			Economic Efficiency (EIRR : %)		Embrionmental Impact			PROJECT VIABILITY		
	Component of Structure Measures	Dsitance (km)	Project Cost (1,000 Bs)		Living Environment	Economic Environment	Natural Environment								
<b>1. CHANE-PAILON AREA</b>				698,584	279.00			12.1							
(1) Rio Chane Basin	Improvement of Rio Chane	26,350	234,627	- Protection of retarding basin - Flood warning - Flood plain management - Flood evacuation plan - Protected forest - Preparation of flood hazard map	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		Indispensable as the main stream area. One of the most effective component for the flood mitigation.		A	Highly feasible	16.4	A	High	High	Negligibly small	High viability as the main stream area.	A
	Improvement of Rancho 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.	167.50	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 necessity as the major drainage area. It will contribute to mitigate the flood damage 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 damage 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	
<b>2. SAN JUAN-ANTOFAGASTA AREA</b>				207,912	197.70			18.2							
(1) San Juan Area	Improvement of Arroyo Yapacanicito	17,360	37,350	- Protection of retarding basin - Flood warning - Flood plain management - Flood evacuation plan	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	- Protected forest - Preparation of flood hazard map	Indispensable to improve flooding condition in the Antofagasta 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 Antofagasta 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						
<b>I Structural Measures</b>													
<b>1. Chane - Pailon Area</b>													
(1) General Coordination and Arrangement													
(2) 1 <sup>st</sup> Priority Components													
- Rio Chane / Rio Pailon	1B												
- Okinawa Main Drainage	1A												
(3) 2 <sup>nd</sup> Priority Components													
- R. Chico / El Chaco / El empalme II	2B												
- Secondary Drainage	2B												
<b>2. San Juan - Antofagasta Area</b>													
(1) General Coordination and Arrangement													
(2) 1 <sup>st</sup> Priority Components													
- Arroyo Jochi	1A												
- Road-cum-embankment	1A												
- San Juan Main Drainage (km 13, 17)	1B												
(3) 2 <sup>nd</sup> 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												
<b>II Non-structural Measures</b>													
(1) General Coordination and Arrangement													
(2) Implementation of Non-structural Measures	1A												



***FINAL REPORT***

***SUMMARY***



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

**SUMMARY**

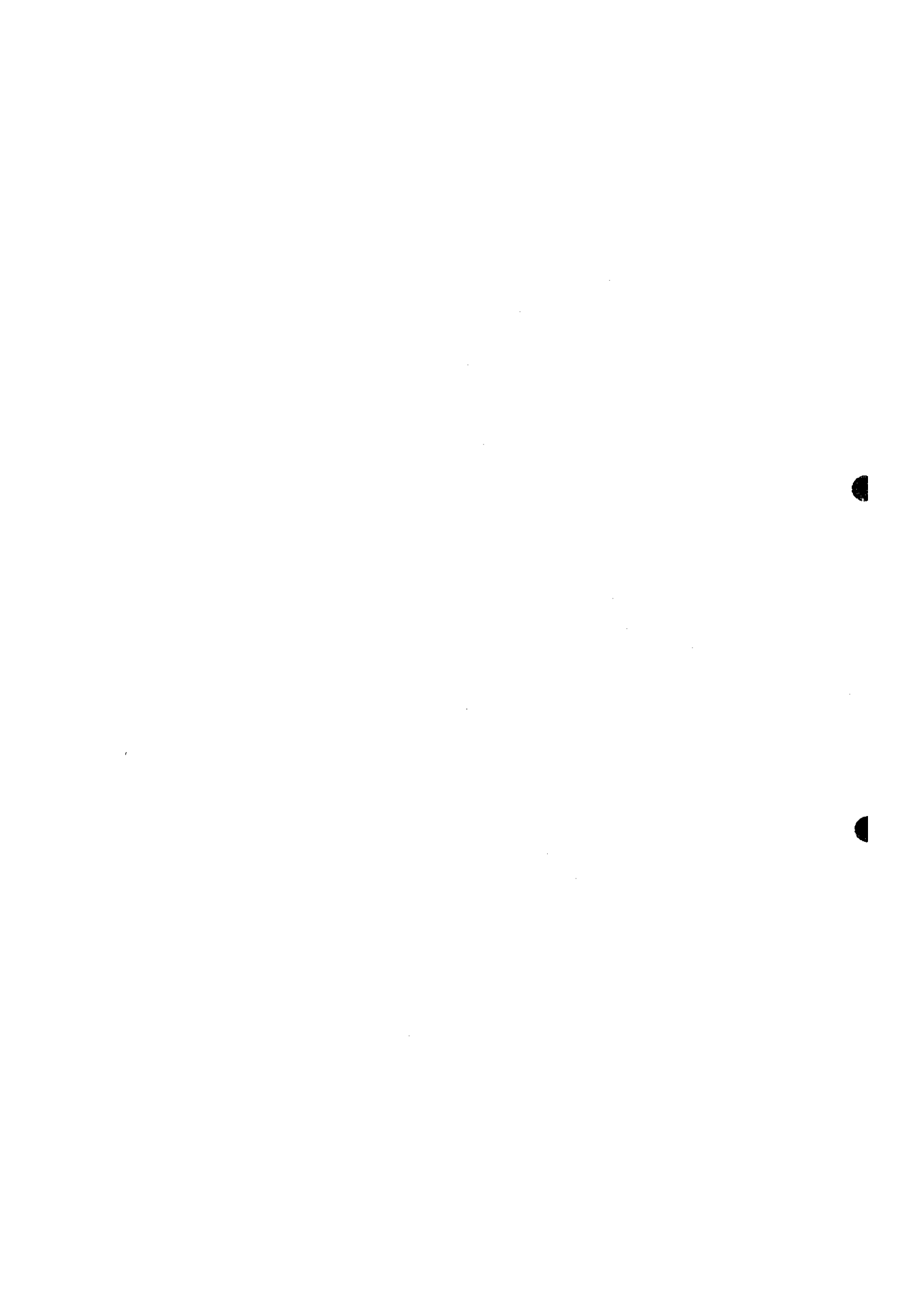
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## SUMMARY

This is a summary of 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 has been conducted on the areas 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 (refer Fig. 1).

According to the Master Plan Study, 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 objectives of the Study are:

- 1) To conduct a Feasibility Study on the flood control for 1,207 sq. km of the Northern Rural Region of Santa Cruz, consisting of the Chane - Pailon and San Juan - Antofagasta areas,
- 2) To pursue a technology transfer to the counterpart personnel through the Study.

The Study commenced at the end of July 1998 and confirmed the proposed measures for the Study based on the supplementary data and the field works from August through October 1998, and prepared a Draft Final Report for the Study in Japan from November 1998 to March 1999. The Draft Final Report was explained to the GOB in March 1999 and the Final Report has been compiled after giving consideration to the comments from the GOB on the Draft Final Report. This summary report outlines the Final Report as follows:

### 1. Approach and Basic Concept of the Study

The Study has been conducted in collaboration with the Department of Santa Cruz and other concerned agencies. During the Study supplementary data and information have been collected and studied together with supplementary field investigation and surveys, including questionnaire surveys, river cross sectional survey and geological survey in the Study Area based on the following concepts:

- 1) 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,
- 2) To develop a GIS database of the basic data and information of the Study Area in order to formulate effective measures,
- 3) To review the flood simulation models developed in the Master Plan based on the floods occurred after the Master Plan in order to assess the effects of the flood mitigation measures proposed in the Study,
- (4) To study on the present land use and the land classification in the flood hazard area in order to alleviate flood damages as much as possible,
- (5) To prepare phased implementation programs in order to minimize adverse effects caused by the project, because of a long term required for the whole-proposed measures to be done,
- (6) To propose reinforcement of the existing organizations as effective implementation organizations for the projects in their human resources and their facilities,
- (7) To consider the utilization of public participation for routine OM activities for the proposed flood mitigation and drainage improvement measures,
- (8) To divide the responsibilities for implementation of the proposed measures among the responsible implementation agencies, i.e., Department level and Municipal level, due to their types and scales.

## 2. Study Area

- (1) The Study Area consists of two areas i.e., the Chane - Pailon area (600 sq. km) and the San Juan - Antofagasta area (607 sq. km) in the northern region of Santa Cruz. The Study Area, having a population of 192,429 (1992 census) in total, is administratively related to the three Provinces of Warnes, Obispo Santistevan and Ichilo.
- (2) The river and drainage basins in the Study Area are divided into the eastern and western parts. The eastern part is composed of the Rio Chane and the Okinawa

drainage basins, and the western part is composed of the Arroyo Tejeria, Arroyo Yapacanicito, Arroyo Jochi and Arroyo Tacuaral basins.

- (3) The average annual real growth rate of Gross Regional Domestic Product (GRDP) of the Department of Santa Cruz is 5.53 % since 1992. Share of the GRDP of the Department of Santa Cruz in the GDP of Bolivia accounted for 27 %, which is the highest value among all the Departments.
- (4) 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\$ 53.8 Million by the Department of Santa Cruz, US\$ 21.6 Million by Municipalities.

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 productive 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.

### **3. Agriculture and Land Use**

- (1) The agricultural sector in Santa Cruz plays an important role not only in the regional economy but also in the national economy, which contributes to 23 % of the total GRDP and 39 % of the agricultural GDP. The sector of the department much contributes to foreign currency earning because more than 90 % of industrial crops: soybean, sugarcane, cotton, sunflower etc., were produced in the department and they contributed 18 % of the total export earnings in 1995.
- (2) The main agricultural products in the Study Area are soybean, rice and wheat, which shared 12 %, 43 % and 41 % of the total production of the Department in 1997/1998. During 1994 – 1998, the share of soybean decreased from 19 % to 12 %, but that of rice and wheat increased from 33 % to 43 % and from 25 % to 41 % respectively. However, the production was fluctuated because their yields in summer, especially soybean, were much affected by floods.
- (3) The land use in the Study Area is shown in Figs. 2 and 3. The land use is characterized as follows:

- Forest distributes mainly along the river and in the unarable land with poor drainage,
- Grazing land distributes mainly in the unarable land of low fertility and/or severe inundation areas,
- Sugar cane distributes in the arable land with severe flood, where flood depth is more than 50 cm in the 1997/98 floods,
- Upland distributes in the arable land with less severe flood.

(4) The land potentiality is studied based on the land classification by Bolivia in the Study Area and classified by the Study into the five categories as follows:

#### LAND CLASSIFICATION CATEGORY

Category	Land Classification	Criteria
1	I - III	Land suited for crop cultivation
2	IV	Land marginally suited for crop cultivation
3	V	Land suited for grazing
4	VI - VII	Land marginally suited for grazing
5	VIII	Land unsuited for any agricultural activity

Source: UTD-PLUS of the Department

In Chane-Pailon area about 60 % of the area is classified to be Category-1, but in San Juan – Antofagasta area a wide area is classified to be Category-3 to -5 (refer Table 1 and Figs. 4 and 5).

#### 4. Floods after the Master Plan

##### (1) Floods caused by the Rio Chane and the Tributaries

The floods caused by the Rio Chane and her tributaries were occurred yearly, but large floods were in the period from the end of November to the beginning of December in 1997 and assessed to be probable floods once in 5- to 20- year based on the rainfall data.



### Characteristics of floods after 1995

Flood period	Inundation Area		Probable Rainfall Period	Measured Rainfall					
	(km <sup>2</sup> )	%		Saavedra		CETABOL		Trompillo	
				(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

The inundation areas of the floods of Nov.-Dec, 1997 and the floods of 1992 are shown in Figs 6 and 7.

#### (2) Floods by the Rio Grande

The floods by the Rio Grande were occurred successively in 1997 and 1998 as follows:

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

Both of the floods inundated over about 15% of the Study Area (refer Fig. 8). However, the scales of floods are not assessed yet because of no available data for hydrological analysis.

#### (3) Floods in San Juan - Antofagasta Area

The floods in San Juan – Antofagasta Area were also occurred yearly and caused mainly by the runoff from their own basins. Among the floods after 1995, the largest flood was occurred in January to February 1997, which is assessed to be a scale of once in 10- to 20-year, which seems to be larger than the 1992 floods (5-10-year) in the area.

### Characteristics of floods after 1995

Flood period	Inundation Area		Probable Rainfall Period	Measured Rainfall	
	(km <sup>2</sup> )	%		San Juan de Yapacani	
				(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

The inundation areas of the floods of Jan.-Feb. 1997 and the floods of 1992 are shown in Figs 9 and 10.

#### (4) Hydrodynamic Model

In this study, the hydrodynamic model developed in the Master Plan Study was updated by using the new cross sections of the newly constructed bridges along the national road No.9 after the Master Plan and the river cross sections surveyed during the Study.

The hydrodynamic model was formulated with the same basis as in the Master Plan Study. The models were set up for the river basins in the Study Area as follows and shown in Figs 11 and 12:

- The Chane – Pailon Area : The Rio Chane-Pailon and Okinawa Drainage basins,
- The San Juan – Antofagasta Area : The Arroyo Yapacanicito, Jochi and Tacuaral basins.

#### 5. Proposed Flood Mitigation and Drainage Improvement Measures

The flood hazard area is classified by the cause of floods in the following four categories:

- | <u>Category</u> | <u>Causes of Floods</u>  |
|-----------------|--|
| -1:             | Inundation area caused by floods from the major river such as the Rio Grande, Rio Piray, or Rio Yapacani,                  |
| -2:             | Inundation area caused by floods from the own basin with the backwater effect of the Rio Piray, like the Rio Chane and her |

- tributaries,
- 3: Inundation area caused by floods from the own basin with floods from the major rivers,
  - 4: Inundation area caused only by floods from the own basin.

The proposed measures are composed of the structural and non-structural measures.

## 5.1 Proposed Structural Measures

### (1) The River and Drainage Improvement

The river and drainage improvement works aim to increase the flow capacity of the rivers and drainage canals by increasing the width and depth and by stabilizing the cross sections. The road-cum embankment aims mainly to prevent the overflow to the next basin and also to use as an evacuation road during floods. The proposed structural measures are summarized in the following table and their locations are shown in Figs. 13 and 14.

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	0.00	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

### (2) Design Criteria

The design criteria that were decided based on the technical and economical aspects in the Master Plan Study, were applied. They are as follows:

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

The design discharges are shown in Fig 15 and the inundation areas with and without the projects are shown in Figs. 16 – 19.

## 5.2 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 to reduce flood damages to some extent because in general the structural measure requires a long term and a certain amount of investment before completion.. The proposed non-structural measures are explained below:

### (1) Flood Warning and Evacuation System

#### a) The existing flood warning system

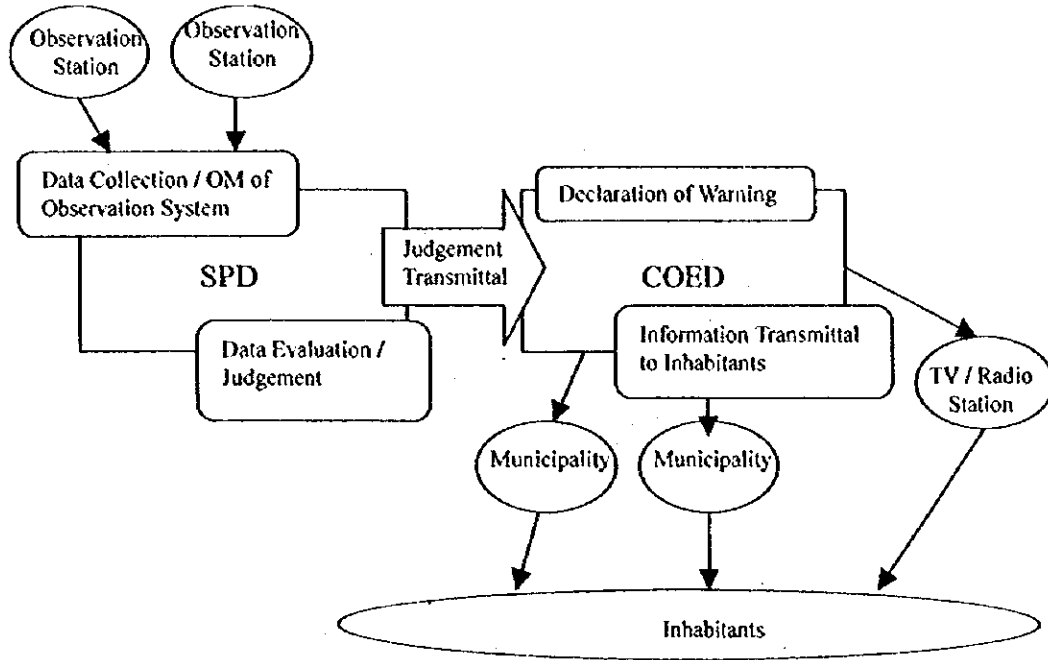
At present, there is one flood warning system established against the floods from the Rio Piray that is the "Emergency Action Plan for the Rio Piray Basin", established by the Department of Santa Cruz to protect people in and around the City of Santa Cruz and along the river from the floods from the Rio Piray. In the plan, SEARPI and the Civil Defense are defined as the core of the system as follows:

- SEARPI : To observe water levels at five stations and decide three alert levels based on the river stages,  
To transmit the emergency information to the Prefecto who is the president of the Civil Defense,
- Civil Defense : To inform flood warning to the people through the media,  
To organize the activities for support, help and evacuation.

#### b) Flood warning plan

In this Study the existing flood warning system that is applied to the limited areas, is planned to be expanded to the Study area. It is planned that the Strategic Planning Division of the General Coordination Direction of the Department shall take responsibilities in observation of hydrological data, evaluation of the observed data, decision of an alert level and transmission of the alert level to the Operation Center of Departmental Emergency

(OCDE). The OECD shall give a warning to the inhabitants in the flood hazard area through the Municipalities. The proposed warning system is illustrated as follow:



**SCHEME OF PROPOSED FLOOD WARNING SYSTEM**

**c) Principal observation station**

For the flood warning system in the Study Area, it is proposed that the alert levels shall be decided based on the rainfall data from the principal rainfall stations selected in the Master Plan Study. They are as follows:

- Saavedra (daily rainfall data is collected at present)
- CETABOL (hourly rainfall data is collected at present)
- Trompillo (daily rainfall data is collected at present)
- San Juan de Yapacani (daily rainfall data is collected at present)

However, the rain gauges except that of CETABOL shall be replaced to be capable of hourly rainfall data because the hourly rainfall data is preferable for effective flood warning. The existing observation stations are shown in Fig. 20.

**d) Alert level**

The alert levels for flood warning have been studied based on the past data and proposed as follows:

- Alert Level 1 : for rainfall with return period 2 years
- Alert Level 2 : for rainfall with return period 5 years
- Alert Level 3 : for rainfall with return period 10 years

Proposed Rainfall Amount for Warning

Rainfall	Warning Level	Chane - Pailon			San Juan - Antofagasta S.J. Yapacani
		Saavedra	CETABOL	Trompillo	
1 Day	1	90	90	90	125
	2	120	125	125	165
	3	145	145	155	195
3 Day	1	120	115	110	160
	2	165	160	155	215
	3	200	200	185	250
5 Day	1	135	135	130	190
	2	190	185	175	240
	3	225	215	205	275

Against the floods from the Rio Grande, flood warning is proposed to be based on the water levels at the upper reach because still no flood analysis has been conducted in the basin and it is necessary to set a new river gauging station at Abapo for the flood warning system (refer Fig, 21).

e) Evacuation

For evacuation of inhabitants in the flood hazard areas, it is necessary to provide them information available refuges and evacuation routs in the Study Area (refer Figs. 22-24). The proposed refuge areas are selected and shown below:

Area	Refuge Area
Chane-1 (down stream)	Puerto Fernandes
Chane-2 (mid-stream)	Saavedra
Pailon	Okinawa I
Okinawa	Okinawa I
San Juan	San Juan
Antofagasta-1 (west)	San Juan
Antofagasta-2 (east)	San Carlos

The major public facilities in the proposed refuge area were not inundated in the 1992 floods and the 1997/98 floods. However, floods affected some of the evacuation routes locally, so it is necessary to level up the road surface level.

**(2) Flood Proofing and Flood Plain Management**

The flood plain management is to utilize the information of potential flood hazard area and effective land use. For the purposes publication of the flood hazard area maps and the land use zoning maps prepared by the Study, is necessary in order to reduce flood damages by themselves, improving their land uses and farming systems in the possible flood hazard area.

**(3) Land Use Control for Retarding Basins**

In the Master Plan Study, five retarding basins were proposed in Chane – Pailon area and one in Antofagasta area. The five retarding basins are located in the upper reaches of the Rio Pailon, the Quebrada Chane and the Arroyo Los Sauces and the other one is located in the middle reaches of the Arroyo Jochi and Tacuaral (refer Fig. 25).

They contribute to lower the burden of the lower reaches by reducing the peak discharges. It is indispensable for the basins to conserve the retarding basins because their effects are considered in formulation of the river improvement plan. The proposed six retarding areas cover 123.4 sq. km, including one swamp area at the Antofagasta Area (7.2 sq. km) as follows:

No.	Related River	Area (sq. km)	Present Land Use	Land Class
1	Rio Pailon	51.4	Primary Forest, Secondary Forest, Idle Land	V
2	Rio Pailon	10.6	Secondary Forest	V
3	Quebrada Chane	17.5	Primary Forest, Secondary Forest, Grazing Land	III, V
4	Arroyo Los Sauces	12.9	Primary Forest	V
5	Quebrada Meco	23.8	Secondary Forest	III
6	Arroyo Jochi, Arroyo Tacuaral	7.2	Primary Forest, Swamp Forest	V
Total		123.4		

It is necessary to prohibit the development activities such as land reclamation in the area in order to conserve the retarding basins. At present, there is the New Forest Law (Nueva Ley Forestal No.1700, 1996) as a legal background concerning land use control in and around the river, swamp and marsh areas. In those areas, the landowner does have a land property title but no right to use the land in accordance with the Law. However, the Law concentrates upon the permanent flood area and it is not sufficient to cover the proposed retarding basins, where are usually temporary flood areas. Hence, it is necessary to designate the areas as protected areas by the Department as soon as possible.

**(4) Conservation of the Protection Forest**

The conservation of protection forests along the river channels is very effective for conservation of the river channels and also for protection of the natural environment along the rivers. The proposed protection forest areas are as follows:

River	Proposed Protection Forest
<b>Chane-Pailon Area</b> Rio Chane and Rio Pailon  Rio Grande	100 m wide of both sides of the river channels  1,000 m wide of both sides of the river channel
<b>San Juan-Antofagasta Area</b> Arroyo Yapacanicito, Arroyo Jochi and Arroyo Tacuaral  Rio Yapacani	20 m wide of both side of the river channels  1,000 m wide of both side of the river channel

**(5) Improvement of Land Use in the Flood Hazard Area**

The land use in the flood hazard area shall be based on the flood conditions and the land use zoning considered the land classification. An optimum land use and farming method during the flood season (or in summer) were studied and shown in Figs. 26 and 27. The flood hazard area is divided as follow:

- Chane-Pailon area: 6 zones,
- San Juan-antofagasta area: 4 zones



## **6. Environmental Impact Assessment**

- (1) According to the regulation, all projects or activities, irrespective of public or private, require an environmental sheet (Ficha Ambiental) and must be classified as an instrument of categorization of the EIA before the implementation of projects. The categorization is as follows:

Category I	:	Require integrated EIA
Category II	:	Require specific EIA
Category III	:	Require no EIA but advisable conceptual EIA
Category IV	:	Require no EIA

The National Secretary of the Natural Resources and Environment, Ministry of Sustainable Development and Planning, is in charge of the categorization. After the decentralization, the environmental unit of the departmental office has been responsible for it since 1997. However, the Ministry evaluates only the project implemented by the department in order to avoid the same organization responsible both for the implementation and for the evaluation.

- (2) The Ministry evaluated the project proposed in the Study as category III, which does not require environmental Impact Assessment (EIA). According to the results, however, Program of Prevention and Mitigation (Programa de Prevencion y Mitigacion: PPM) and Plan of Environmental Application and Follow (Plan de Aplicacion y Seguiment Ambiental: PASA) regulated by articles from 29 to 32, regulation of prevention and control of environment, shall be prepared and get permission for the implementation from the Ministry during a final design stage.
- (3) 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.

## **7. Cost Estimate**

### **(1) Construction Cost**

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 and calculated based on the market price and currency exchange rate

in August 1998. The indirect construction cost is estimated in the proportional to the direct construction cost as follows:

- 1) Unforeseen cost (5% of direct cost)
- 2) Overhead charge (10% of direct cost)
- 3) Profit (15% of direct cost)

**(2) Project Cost**

The project costs 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.
<b>The Chane - Pailon Area</b>			
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
<b>Total</b>	<b>266,638,000</b>	<b>431,946,000</b>	<b>698,584,000</b>
<b>The San Juan - Antofagasta Area</b>			
San Juan	45,724,000	61,826,000	107,550,000
Antofagasta	40,990,000	59,372,000	100,362,000
<b>Total</b>	<b>86,714,000</b>	<b>121,198,000</b>	<b>207,912,000</b>
<b>Grand Total</b>	<b>353,352,000</b>	<b>553,144,000</b>	<b>906,496,000</b>

*Note:*

- The cost was calculated based on the market price in August 1998,
- The labor cost, material cost and the equipment unit cost included the value added tax 13%,
- 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  
 $US\$ 1.0 = Bolivian Bs 5.50 = Japanese Yen 117$

### (3) Operation and Maintenance

The operation and maintenance cost is considered as the cost for the routine operation and maintenance. The cost is estimated at 1.0 % of the construction cost, which is usually applied for the river improvement works.

### (4) Construction Plan

The basic conditions for the construction plan are based on the followings:

- The proposed construction works are to be completed within ten (10) years from 2001,
- The urgent works are to be commenced within five (5) years from 2001,

Based on the preliminary design of the river and drainage improvement works, the major quantities of works for the projects are summarized as follows:

	Chane - Pailon			San Juan - Antofagasta	
	Rio Chane	Rio Pailon	Okinawa Drainage	San Juan	Antofagasta
<b>River Improvement(km)</b>	26.35	31.41	21.65	17.36	17.60
Soil Excavation (1,000m <sup>3</sup> )	5,638	9,196	0	652	640
Bridge Construction	4	1	0	1	3
<b>Road-cum-embankment (km)</b>					9.8
Soil Filling (1,000m <sup>3</sup> )					37
<b>Drainage Improvement (km)</b>	0	10.36	21.65	43.11	8.80
Soil Excavation (1,000m <sup>3</sup> )	0	398	1,838	235	389
Bridge Construction	0	1	1	3	2
<b>Secondary Drainage</b>					
Soil Excavation (1,000m <sup>3</sup> )	0	416	799	998	755
Culvert Construction	0	9	17	18	21

## **8. Institutional Frame**

### **(1) General**

The organizations related to flood mitigation are the Department of Santa Cruz, the Civil Defense and the Operation Center for Departmental Emergency, Municipalities, SENAMHI, SEARPI and MACUCY. The organization of the Department of Santa Cruz has been reformed since January 1999 due to the decentralization (refer to Fig. 28).

### **(2) Implementation Organization**

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

- Strategic Planning Division of the GCD 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.

### **(3) Flood Warning**

Meteorological and hydrological data are basic and essential data for execution of flood mitigation measures. The Department of Santa Cruz together with SENAMHI shall take necessary actions for installation (or replacement) of rain gauges and river gauges required for the proposed flood warning system, and also shall have functions to collect data and to decide alert levels for flood warning and to inform the alert level to the COED. The COED shall transmit the alert level to the people through the municipalities in the anticipated flood hazard areas.

#### **(4) Operation and Maintenance**

Proper operation and maintenance (OM) activities are required to gain the expected benefits with the implementation of the proposed flood mitigation and drainage improvement measures and shall be carried out by the implementation organization and the related municipalities. The OM organization is planned as follows:

- The OM activities of flood mitigation measures shall be conducted by the implementation organization of the project with the assistance of the related municipalities and local participants,
- The OM activities for the drainage facilities shall be conducted by the related municipalities and local participants,
- Crews of local participants shall conduct the field level routine activities.

### **9. Project Evaluation**

The project has been evaluated from technical, economic, financial, and social and environmental aspects. The result of evaluation is summarized in Table 2.

#### **(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 km<sup>2</sup> in Chane - Pailon area and 197.70 km<sup>2</sup> in San Juan - Antofagasta area during the design 10-year floods. As for the Chane River the water levels without projects are about 60 cm higher than that of with projects in the peak stage for the 10-year floods. In order to avoid any adverse effects, the improvement of the Chane River will be indispensable.

#### **(2) Economic Feasibility**

The economic feasibility is evaluated mainly by the Economic Internal Rate of Return (EIRR), of which values higher than 10 % 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
-1	Rio Chane	3.8
-2	Rio Pailon	16.4
-3	Okinawa Drainage	18.4
II.	San Juan-Antofagasta	18.2
-1	San Juan	12.4
-2	Antofagasta	23.4

The Chane - Pailon project, which contains three areas of the Rio Chane, the Rio Pailon and the Okinawa drainage, and the San Juan – Antofagasta project are economically feasible, indicating EIRR of 12.1 % and 18.2 % respectively. Accordingly, the said two projects is expected to contribute to a promotion of economic development in the region. Besides the benefits produced by the structural measures above, lots of intangible benefits would be produced from the non-structural measures.

### (3) Social and Natural Environmental Impacts

The flood mitigation and drainage improvement 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.

## 10. Financial Aspects

- (1) The investment amount of US\$ 93.3 Million in 1997, was maintained by US\$ 45.5 Million (48.8 %) of the internal fund and US\$ 47.8 Million (51.2 %) of the external fund. The ratio of internal fund to external fund was approximately 44 : 56 on average for the period 1992-1997. The external fund in 1997, US\$ 47.8 Million, was composed of a credit of US\$ 31.6 Million (66.1 %) and a donation of US\$ 16.2 Million (33.9 %).
- (2) The public investment budget of Municipalities of Warnes, G. Saavedra and San Carlos in 1998 was Bs. 25.3 Million in total for 12 projects. Among the 12

projects, the maximum cost per project was Bs. 8.4 Million for the construction and maintenance of local roads.

- (3) After completion of the construction works, the annual OM cost for facilities of the project is estimated at Bs. 6.8 Million at the 1998 constant price. The operation and maintenance of the project will be commenced partly in 2005 and fully in 2011, and it is expected that GRDP of the Department of Santa Cruz in 2010 will become twice as much that in 1998. Under these conditions, it seems that the operation and maintenance to be conducted by the Municipalities will not be so difficult in the financial aspect.

## **11. 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:

#### **1) Planning stage**

Strategic Planning Division of GCD, with the participation of SEARPI, UTD-PLUS, SENAMHI and MACUCY.

#### **2) Implementation stage**

Infrastructure Development Direction and municipalities.

#### **3) O&M stage**

Department of Santa Cruz, municipalities and local groups.

### **(2) Implementation Period**

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

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

#### **1) Stage-1: Preparatory period**

The GCD shall reinforce the Strategic Planning Division for the preparatory works. The GCD and the Strategic Planning Division shall carry out the tasks for implementation of the projects. The major tasks to be conducted in this stage are listed as follows:

- To organize a committee made up by SEARPI, UTD-PLUS, SENAMHI and MACUCY under the direction of the GCD to promote the projects proposed in the Study for an early implementation,
- To reinforce necessary staff to the organizations,
- To prepare a training program for staff,
- To arrange for installation (or replacement) of the proposed rain gauges and river gauges to support the proposed flood warning system,
- To establish the function of collecting hydrological data and making decision of alert levels for flood warning and informing the alert level to the CD and COED,
- To support the COED to arrange an information network for the regional flood warning system, including Municipalities,
- To support financial arrangement for implementation of the project,
- To prepare for execution of non-structural measures, i.e., flood warning and evacuation system, flood plain management, land uses control,
- To support the establishment of a committee of municipality level to promote public participation for alleviation of flood damages and for OM activities.

2) Stage-2: Implementation of proposed measures

The proposed measure shall be executed by different agencies due to the types and the scales. The GCD shall take the leading role for implementation of the projects and take actions to arrange an implementation organization for each project and support the Infrastructure Development Direction and the Municipalities as execution agencies to execute the projects smoothly. The major tasks in this stage shall be as follows:

- Institutional arrangement for execution of the proposed works,
- Execution of non-structural measures,
- Execution of the proposed structural measures, i.e., D/D, construction,
- Establishment of public participation for O&M activities.



### (3) Project Component and Priority

The priority ranking of each component was evaluated from technical, economic and other potential effects. The proposed works were ranked to be the four orders of 1<sup>st</sup> A, 1<sup>st</sup> B, 2<sup>nd</sup> A and 2<sup>nd</sup> B. The proposed components and their priorities are listed as follows:

#### (I) Structural Measures of Flood Mitigation Priority Order

- 1) Chane – Pailon Area
  - Improvement of Rio Chane 1<sup>st</sup> B
  - Improvement of Rio Pailon 1<sup>st</sup> B
  
- 2) San Juan – Antofagasta Area
  - Improvement of Arroyo Yapacanicito 2<sup>nd</sup> A
  - Improvement of Arroyo Jochi 1<sup>st</sup> A
  - Improvement of Arroyo Tacuaral 2<sup>nd</sup> A
  - Development of Road-cum-embankment 1<sup>st</sup> A

#### (II) Structural Measures of Drainage Improvement Priority Order

- 1) Chane – Pailon Area
  - Improvement of Rancho Chico Drainage 2<sup>nd</sup> B
  - Improvement of El Chaco Drainage 2<sup>nd</sup> B
  - Improvement of El Empalme II Drainage 2<sup>nd</sup> B
  - Improvement of Okinawa Main Drainage 1<sup>st</sup> A
  - Development of Secondary Drainage 2<sup>nd</sup> B
  
- 2) San Juan – Antofagasta Area
  - Improvement of San Juan Main Drainage
    - (km 13 and 17) 1<sup>st</sup> B
  - Rehabilitation of San Juan Main Drainage
    - (km 11, 15, 24 and 28) 2<sup>nd</sup> A
  - Improvement of Arroyo Tejeria 2<sup>nd</sup> B
  - Development of Antofagasta Main Drainage 2<sup>nd</sup> B
  - Development of Secondary Drainage 2<sup>nd</sup> B

#### (III) Non-structural Measures Priority Order

- Flood Warning System 1<sup>st</sup> A

- Flood Plain Management 1<sup>st</sup> A
- Conservation of Retarding Basins 1<sup>st</sup> A
- Flood Evacuation Plan 1<sup>st</sup> A
- Conservation of Protected Forest 1<sup>st</sup> A
- Flood Hazard Map 1<sup>st</sup> A

#### **(4) Implementation Schedule**

##### **1) Structural Measures**

The construction works of the river and drainage improvement are planned to be executed in 2 phases in the Stage-2. The 1<sup>st</sup> priority components are to be constructed or commenced in the Phase-1 from year 2001 to 2005 and the 2<sup>nd</sup> priority components are to be constructed in the Phase-2 from year 2006 to 2010 basically (refer Table 3).

##### **2) Non-structural Measures**

The non-structural measures shall be implemented as soon as possible, since they are important and effective for mitigation of flood damages and not require the financial arrangement like the structure measures. The following activities are required to set up as soon as possible.

- Improvement of the observation network of rain gauges / river gauges and set up to establish an function of flood warning in the Strategic Planning Division,
- Publication of flood hazard areas and required non-structure measures,
- Designation of the retarding basin areas to be protected and the protected areas by the Department under the existing regulation,
- Arrangement of human resources and budget allocation for the activities of the non-structural measures.

## **12 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 1<sup>st</sup> 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 to the agricultural crops,
6. To utilize the coordination committee effectively for enhancement of public participation in flood mitigation activities.

**TABLES**

TABLE 1(1) SUMMARY OF LAND CLASSIFICATION

Area	Class	II	III	IV	V	VI	VII	Total
Chané-Pailon	Km2	155.7	201.7	31.2	400.0	7.1	4.0	599.6
	%	26.0	33.6	5.2	66.7	1.2	0.7	100.0
San Juan- Antofagasta	Km2	0.0	221.9	285.7	99.8	0.0	0.0	607.3
	%	0.0	36.5	47.0	16.4	0.0	0.0	100.0

Source: Departmental Office

TABLE 1(2) ZONING CATEGORY AND RECOMMENDED LAND USE

Zone	Flood Depth	Soil Classification	Existing Land Use	Recommended Land Use	
				Summer(Flood season)	Winter
1	No flood	II-02,III-01, 06,07,IV08	Upland crop,	Any crops	Any crops
2	50 cm >	II-02,III-01, 06,07,IV08	Upland crop, Sugar cane ,Forest,	Water tolerant crops such as rice	Any crops
3	50 cm <	II-02,III-01, 06,07,IV08	Upland crop, Sugar cane, Grazing land	Crop rotation keeping away from flood season	Any crops
4	No flood	IV-07	Grazing land, Upland crop	Perennial crop, Grazing land	Perennial crop, Grazing land
5	50 cm >	IV-07	Grazing, Forest, Upland crop	Grazing land	Grazing land
6	-	V-02,V-10,11,17, VI-09,05, VII-05	Forest, Grazing, Sugar cane	Grazing land, Forest	Grazing land, Forest

Source: Study Team