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THE REPUBLIC OF VENEZUELA
MINISTRY OF ENVIRONMENT
AND NATURAL RESOURCES
DGSPROA - LNH

JAPAN INTERNATIONAL
COOPERATION AGENCY

STUDY
ON
COMPREHENSIVE IMPROVEMENT
OF
THE APURE RIVER BASIN

FINAL REPORT

VOLUME I

EXECUTIVE SUMMARY

NOVEMBER 1993

NIPPON KOEI CO., LTD.
NIKKEN CONSULTANTS, INC.
KOKUSAI KOGYO CO., LTD.
TOKYO, JAPAN

This report consist of the following five volumes.

VOLUME I : EXECUTIVE SUMMARY

VOLUME II : MAIN REPORT

VOLUME III : SUPPORTING REPORT

- PART-A : TOPOGRAPHIC SURVEY
- PART-B : GEOLOGICAL AND GEOMORPHOLOGICAL STUDIES
- PART-C : AGRICULTURE AND LAND USE SURVEY
- PART-D : HYDROLOGICAL AND HYDRAULIC STUDIES
- PART-E : STUDY ON CHANNEL STABILIZATION FOR NAVIGATION
- PART-F : STUDY ON FLOOD MANAGEMENT
- PART-G : CONSTRUCTION PLAN AND COST ESTIMATE
- PART-H : SOCIO-ECONOMY AND PRELIMINARY PROJECT EVALUATION
- PART-I : ENVIRONMENTAL SURVEY

VOLUME IV : DATA BOOK I

VOLUME V : DATA BOOK II

The cost estimate was made based on February 1993 price level and expresses in Bolivares according to the following exchange rate.

US$ 1.00 = Bs. 82.00 = ¥ 119.72

(As of February 17, 1993)

PREFACE

In response to a request from the Government of the Republic of Venezuela, the Government of Japan decided to conduct Study on Comprehensive Improvement of The Apure River Basin and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Venezuela a study team headed by Mr. Yoichi Takeuchi, Nippon Koei Co., Ltd., and composed of members from Nippon Koei Co., Ltd., Nikken Consultants, Inc. and Kokusai Kogyo Co., Ltd. four times between March 1992 and October 1993.

The team held discussions with the officials concerned of the Government of Venezuela, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Venezuela for their close cooperation extended to the team.

November 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

November 1993

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Yanagiya

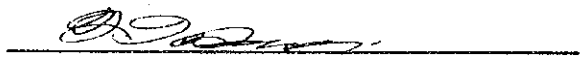
Letter of Transmittal

We are pleased to submit herewith the Final Report of Study on Comprehensive Improvement of The Apure River Basin. This Report deals with formulation of the basic concepts and measures for stabilization of the river channel for navigation and mitigation of the flood damages at master plan level.

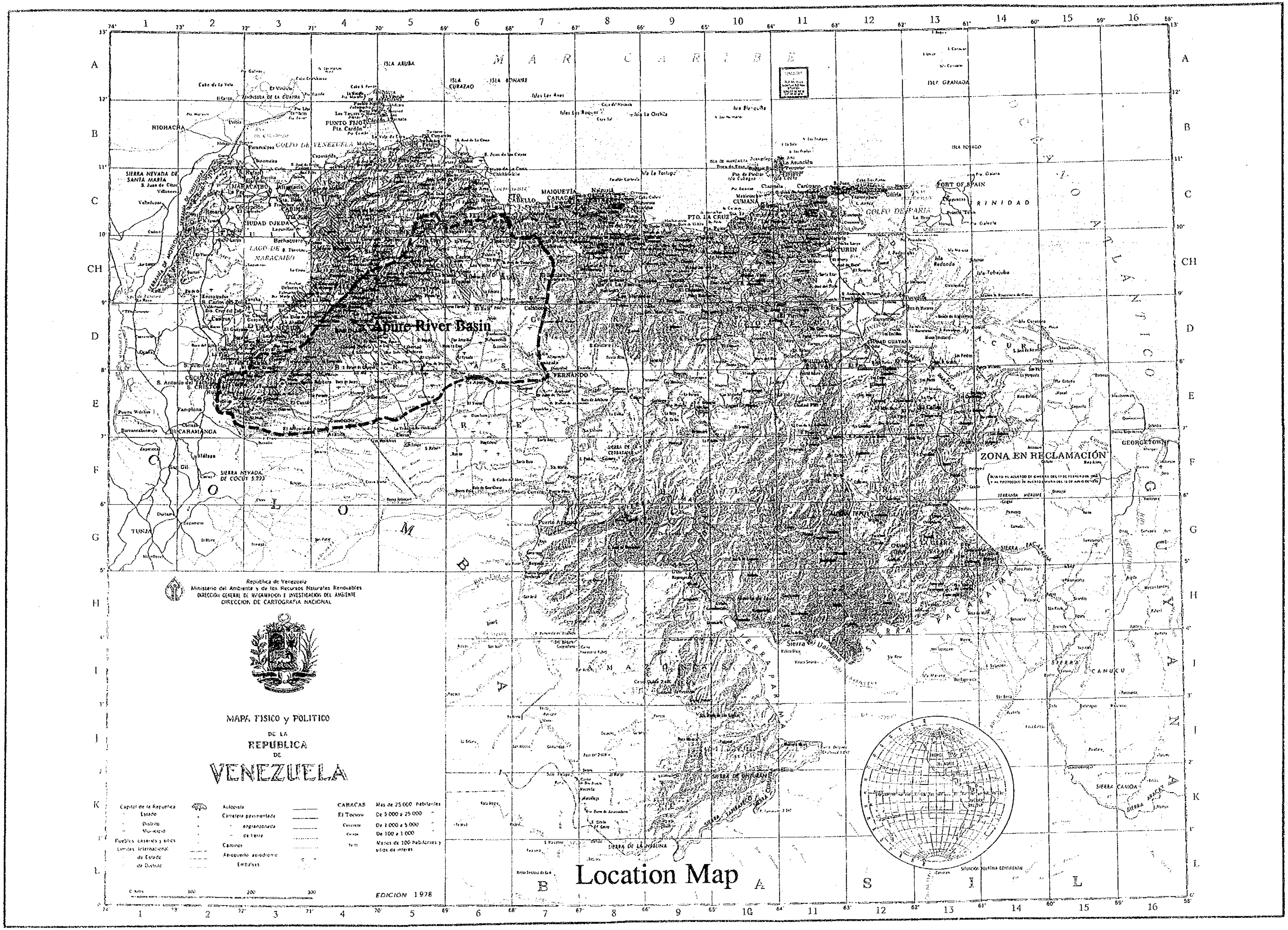
The Report consists of five (5) volumes, Executive Summary, Main Report, Supporting Report, Data Book I and Data Book II. Main outputs presented in the Report are channel stabilization plan for navigation and flood management plan. The former proposes several measures to stabilize the channel such as derivation channel, anabranch treatment, alignment normalization, etc., while the latter proposes dike construction along the river channel to mitigate flood damages in the protection area selected.

We would like to express our grateful acknowledgment to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction and Embassy of Japan in Venezuela, and also to officials and individuals of the Government of Venezuela for their assistance and advice extended to the Study Team. We sincerely hope that the results of this study would contribute to the improvement of the Study Area.

Very truly yours,



Yoichi Takeuchi
Team Leader
Study on Comprehensive Improvement
of The Apure River Basin


Apure River Basin
MAR CARIBE
ZONA EN RECLAMACIÓN
República de Venezuela
Ministerio del Ambiente y de los Recursos Naturales Renovables
Dirección General de Información e Investigación del Ambiente
Dirección de Cartografía Nacional
MAPA FISICO y POLITICO
DE LA
REPUBLICA
DE
VENEZUELA
EDICION 1978
Location Map

STUDY ON COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN

OUTLINE OF THE STUDY

INTRODUCTION

1. OBJECTIVE OF THE STUDY: Objective of the Study is to formulate the basic concepts and measures for the comprehensive improvement of the Apure river basin for the stabilization of river channels and the mitigation of flood damages. In the course of the Study technology transfer is performed.

2. STUDY PERIOD: Total period of the Study was twenty one (21) months from the commencement in March 1992 to the submission of the final report in November 1993 dividing into four (4) phases, each of which consists of filed survey in Venezuela and home work in Japan.

3. STUDY AREA: The study area covers:

   1) River reaches of the main Apure river from the confluence with the Orinoco river to Guasdualito and the Portuguesa river from San Fernando to El Baul for the Study of channel stabilization;
   2) Area bounded by the Apure, Masparro and Portuguesa rivers for the study of flood damage mitigation; and
   3) Whole Apure river basin for the hydrological study related to the Study.

4. APURE RIVER: The Apure river which is one of the largest tributaries of the Orinoco river originates at the northwest point of the Andes mountains in Venezuela near the border to Colombia. The catchment area is 111,800 km^2 at San Fernando. Length of the main Apure river is 681 km from the confluence of the Orinoco river to Remolino bridge near Guasdualito. Major tributaries of the Apure are the Portuguesa, Masparro, Paguey, Canagua, Suripa, Caparo, Uribante, and Sarare rivers from the Merida mountains; and the Guaritico river from the plain area on right bank.

STUDY ON CHANNEL STABILIZATION PLAN

5. CHANNEL STABILIZATION MEASURES FOR NAVIGATION: In order to improve channel capacity for navigation, the following two principal measures were considered.

   1) Flow Improvement:
      Derivation channel by use of released water from hydro-power plant
   2) Channel Improvement:
      a. Treatment of anabranches by submerged and closing dikes
      b. Normalization of channel alignment by realignment and cut-off channel works
      c. Improvement of channel section by island treatment, channel dredging, river training and temporary channel improvement works

6. SHORT-TERM PLAN: The short-term plan aims to accomplish the following physical target:

1) Apure river: To attain eight (8) month navigation from river mouth to San Fernando port and seven (7) month navigation from San Fernando port to Santos Luzardo port.
2) Portuguesa river: To attain eight (8) month navigation from San Fernando port to El Baul port.

The short-term plan includes the following works:

1) Derivation channel works: Caparo-Uribante Viejo derivation channel under water release of La Vueltosa power station at the initial development stage.
2) Anabranch treatment works: Chirel site and Bravo/Garzas site
3) Alignment normalization works: For critical bends with Rc<320 m for the Apure river and Rc<150 m for the Portuguesa river
4) Channel section improvement works

7. MID-TERM PLAN: The mid-term plan aims to accomplish the following physical target:

1) Apure river: To attain nine (9) month navigation from river mouth to San Fernando port and eight (8) month navigation from San Fernando port to Santos Luzardo port.
2) Portuguesa river: To attain nine (9) month navigation from San Fernando port to El Baul port

The mid-term plan includes the following works:

1) Flow improvement by Caparo-Uribante Viejo derivation channel under water release of La Vueltosa power station at the final development stage.
2) Alignment normalization works: For critical bends with Rc<560 m for the Apure river and Rc<240 m for the Portuguesa river.
3) Channel section improvement works

8. COST ESTIMATE: The cost required for the implementation of the project was estimated in US$ by using the prevailing exchange rate in February, 1993 as follows:

1)	Short-Term Plan	:	US$ 53,705,000
2)	Mid-Term Plan	:	US$ 74,587,000
3)	STP + MTP	:	US$ 128,293,000

9. ECONOMIC EVALUATION: The benefit of fluvial navigation was estimated for reduction of the transportation cost in comparison with the land transportation, for the extended navigation period by the channel stabilization works. Since navigation master plan has not been prepared yet, some economic considerations on the channel stabilization plan were made based on cargo data prepared provisionally by PROA.

Plan	EIRR(%)	B/C	B-C (US$ 1,000)
1) Short-Term Plan	17.7	1.72	38,677
2) STP + MTP	13.7	1.46	46,666

STUDY ON FLOOD MANAGEMENT PLAN

10. STUDY AREA: The area subject to the present flood management study is 21,200 km^2 bounded by the Apure river in south, Portuguesa river in north and east and local road route 2 in west. The study area is vast and presently mostly in natural conditions, so that consideration from environmental aspect is important.

11. PROTECTION AREA: The protection area was selected applying the criteria that it should have possibility of solution of drainage problems and land use assignment in the future. Consequently, the following four (4) areas were selected.

1) Area "A" : Area extending on the right bank side of Caño Igues
2) Area "B" : Area extending on the right bank side of the Guanare river
3) Area "C" : Area extending on the left bank side of the Apure river
4) Area "D" : San Fernando city and its surrounding area

Area "D" was selected for the reason that the flood management works for Areas "A", "B" and "C" in the upstream may influence to the area and therefore increase of safety degree against flood will be necessary to protect San Fernando city from flood.

12. PROPOSED PLAN: For the above protection areas, several alternative plans such as dike, dam, retarding basin, etc. were formulated and studied from engineering and environmental aspects. As a result, the following plans were selected.

1) Area "A" : Dike on the right bank of the Portuguesa river (Plan A1)
2) Area "B" : Dike on the right bank of the Guanare river (Plan B1)
3) Area "C" : Dike on the left bank of the Apure river (Plan C1) or Apure type module (Plan C3)
4) Area "D" : No plan was proposed because of no influence by the above plans.

The proposed flood management plan for the entire study area is integrated one of the said Plans A1, B1 and C1 (or C3) as no mutual interference is observed.

13. LONG-TERM PLAN: The long-term plan aims to accomplish the entire flood management plan consisting of the following works.

1) Construction of dike on the right bank of Portuguesa river (187 km long)
2) Construction of dike on the right bank of Guanare river (145 km long)
3) Construction of dike on the left bank of Apure river (155 km long)

14. SHORT-TERM PLAN: The short-term plan aims at implementation of the following priority works and effective works in the long term plan.

1) Partial dike for Portuguesa river (103 km long) from national road route 8 to Nueva Florida in relation with railway project.
2) Partial dike for Guanare river (25 km long) to connect existing roads to use them as road dike.

15. COST ESTIMATE: The project cost required for implementation of the proposed flood management plan was estimated in US$ by using the prevailing exchange rate in February, 1993 as follows:

1) Plan A1: US$ 34,185,000
2) Plan B1: US$ 25,553,000
3) Plan C1: US$ 34,110,000
4) Overall: US$ 93,848,000

16. ECONOMIC EVALUATION: The benefits produced by the implementation of the proposed flood management plan are flood reduction benefit and land enhancement benefit. Based on the project cost and benefits estimated, economic internal rate of return (EIRR) and benefit-cost ratio (B/C) for respective plans are as follows:

Plan	EIRR (%)	B/C	B-C (US$1,000)
Plan A1	11.0	1.39	9,124
Plan B1	11.0	1.45	7,295
Plan C1	6.6	0.82	-5,212
Overall	9.2	1.15	7,614

IMPLEMENTATION SCHEDULE

17. IMPLEMENTATION SCHEDULE: The short-term plan shall be implemented first and then the mid-term plan and long term plan. The sequence of project works would be as follows:

(1) Channel Stabilization Plan
1) Project Preparation: 1st to 5th year
2) Short-Term Plan: 1st to 7th year
3) Mid-Term Plan: 6th to 17th year

(2) Flood Management Plan
1) Project Preparation: 1st to 5th year
2) Short-Term Plan: 2nd to 10th year
3) Long-Term Plan: 8th to 20th year

STUDY ON COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN

FINAL REPORT

VOLUME I : EXECUTIVE SUMMARY

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I. INTRODUCTION

1.1 BACKGROUND: Upon request of the Government of Venezuela, Government of Japan decided to render technical cooperation to the Study on Comprehensive Improvement of the Apure River Basin (the Study) through its executing agency, Japan International Cooperation Agency (JICA).

1.2 OBJECTIVE OF STUDY: Objective of the Study is to formulate the basic concepts and measures for the comprehensive improvement of the Apure river basin for the stabilization of river channels and the mitigation of flood damages. In the course of the Study technology transfer is performed.

1.3 SCOPE OF STUDY (Fig. 1): The Study shall cover:

1) River reaches of the main Apure river from the confluence with the Orinoco river to Guasdualito and the Portuguesa river from San Fernando to El Baul for the Study of channel stabilization;
2) Area bounded by the Apure, Masparro and Portuguesa rivers for the study of flood damage mitigation; and
3) Whole Apure river basin for the hydrological study related to the Study.

1.4 STUDY WORKS (Fig. 2): Total period of the Study was scheduled for twenty one (21) months from the commencement in March 1992 to the submission of the final report in November 1993. The study period is divided into four (4) phases, each of which consists of filed survey in Venezuela and home work in Japan. The Study work was implemented effectively in collaboration with MARNR and JICA Study Team. Various agencies of MARNR are related to the Study, i.e., PROA, LNH, DHM, DC, DPRH, DEP, DPC and GVS. PROA and LNH jointly function as a leading agency of MARNR for the Study.

II. STUDY AREA

2.1 LOCATION (Fig. 1): The study area covers the Apure river basin which is one of the largest tributary of the Orinoco. The area is located in 7°N to 10°N and 66°W to 73°W. The basin is bounded by the coastal mountains (Cordillera de la Costa) on the north and the Andes mountains (Los Andes) on the west. A vast plain called as Venezuelan Llanos extends between the Orinoco river and the Andes/coastal mountains. The Apure river basin administratively covers all of Barinas, Portuguesa and Cojedes provinces; a part of Tachira and Apure provinces; and small portions of Merida, Trujillo, Lara, Yaracuy, Carabobo and Guarico provinces.

2.2 GEOLOGY: The Mesozoic rocks and tertiary rocks contact with many over-thrust faults in the piedmont. Along the Caribe Fault, many earthquakes have happened as well as the Bocono Fault. Since the Cretaceous, the Andes and the Coastal Mountains have been affected by up-lift crustal movement. On the other hand, the Apure basin has been affected by subsidence. Consequently, the Mesozoic and Tertiary formations deposit thickly in the basin. These formations are presently covered with Quaternary formations.

2.3 METEOROLOGY: Climate of the study area falls mostly under the tropical sabana climate by Koppen's classification. Rainfall is most distinctive to the climate of the study area. The annual rainfall ranges from 1,200 mm to 1,600 mm in the plain area and amounts to 2,800 mm in the mountainous area. Rainy season of the study area is from April to November. The maximum temperature is observed in March and minimum in July, although the variation is slight. In the plain area monthly average temperature ranges from 25°C to 29°C throughout the year.

2.4 APURE RIVER: The Apure river originates at the northwest point of the Andes mountains in Venezuela near the border to Colombia. The catchment area is 111,800 km^2 at San Fernando. Length of the main Apure river is 681 km from the confluence of the Orinoco river to Remolino bridge near Guasdualito. Major tributaries of the Apure are the Portuguesa, Masparro, Paguey, Canagua, Suripa, Caparo, Uribante, and Sarare rivers from the Merida mountains; and the Guaritico river from the plain area on right bank.

2.5 BASIN AREA: Areas of the basin and sub-basins at major points of interest are presented below:

1)	Main Apure River		:	111,800 km^2 at San Fernando
	a)	Remolino Br.	:	8,400 km^2
	b)	Bruzual	:	40,000 km^2
	c)	El Saman	:	48,000 km^2
	d)	San Fernando	:	111,800 km^2
2)	Portuguesa River		:	54,600 km^2 at junction with Apure river
	a)	El Baul	:	13,200 km^2
	b)	El Jobalito	:	23,300 km^2
	c)	Camaguan	:	54,400 km^2

Drainage areas of the main Apure (57,200 km^2) and the Portuguesa (54,600 km^2) are almost equal at their confluence, although their river features are quite different. River channel of the main Apure is wider and braided in places, while that of the Portuguesa is narrower and meandering.

III. SURVEY AND INVESTIGATION

3.1 TOPOGRAPHIC SURVEY: The topographic survey was carried out twice in May to July 1992 and January to March 1993 for the Apure and Portuguesa rivers. The survey consist of the following:

1) Channel cross section survey: 191 sections in total
2) Leveling survey: 430 km in total

3.2 MATERIAL INVESTIGATION: The following material investigations were conducted in the Apure and Portuguesa rivers and their tributaries and in the Orinoco river.

1) River bed material investigation: 39 sites for Apure and Portuguesa rivers and tributaries and for Orinoco river
2) Bore hole drilling: 13 sites for Apure and Portuguesa rivers
3) Test pitting: 13 sites for Apure and Portuguesa rivers
4) Laboratory test: 5 kinds of tests

3.3 HYDROLOGICAL INVESTIGATION: The following hydrological investigations were conducted during the study period:

1) Data collection and review
2) Inundation observation
3) Discharge measurement
4) Sediment observation
5) Water level observation
6) Water quality test

3.4 AGRICULTURAL AND LAND USE SURVEY: Present agronomic conditions of the area, existing and future agricultural development plans, present and proposed land use, etc. were surveyed.

3.5 SOCIO-ECONOMIC SURVEY: Socio-economic conditions of the study area such as population, labor force, gross domestic product, price index, and foreign exchange rate were surveyed.

3.6 ENVIRONMENTAL SURVEY: Present environmental conditions of the study area, institutional setup and distribution of objects to be conserved were surveyed. Also, workshop on environment was held to hear opinions from environmental experts and personnel concerned.

IV. BASIC STUDIES

4.1 GEOMORPHOLOGICAL STUDY: As basic data for the study mainly on flood management, the contour map with contour line of 5 m intervals was prepared based on the survey points in the existing topographic map with scale of 1/100,000 and with contour lines of 20 m intervals. Also, the flood prone area map was prepared mainly by interpretation of satellite images referring available inundation data.

4.2 FLOOD ANALYSIS: Flood analysis consists of hydrological flood runoff analysis and hydraulic flood inundation analysis. The flood inundation analysis was introduced to cope with hydraulic conditions that the area for flood management has vast inundation and the ordinary hydrological flood runoff calculation method is not

proper to grasp the effect of flood management plan. The study area for flood management is subject to the flood inundation analysis and the remaining area of the Apure river basin is subject to the flood runoff analysis.

4.3 RAINFALL ANALYSIS: Duration of design rainfall is 8 months of rainy season considering long-term inundation of the study area. Rainfall pattern is that in 1981 which is the recorded maximum in the Portuguesa river basin. Sixty one (61) representative stations were selected for estimation of probable basin mean rainfall by Thiessen polygon method. The probable 10-year and 50-year basin mean 8-months rainfall calculated by Gumbel method are as follows:

(Unit : mm)

Return Period	Apure R. Basin	Portuguesa R. Basin	Whole Basin (*)
10-Year	1,942	1,576	1,742
50-Year	2,184	1,808	1,958
1981 (Actual)	2,004	1,623	1,818

Note : * upstream from San Fernando

4.4 FLOOD RUNOFF ANALYSIS: A storage function method was employed for flood runoff calculation. For construction of flood runoff model, the Apure river basin was divided into 107 sub-basins and 17 channels. The probable flood runoff was calculated based on the probable basin mean rainfall under the following three conditions excluding flood inundation analysis area.

- Without dam
- With existing dams
- With existing and proposed dams

Calibration of constants was made for the floods in 1976 and 1981.

4.5 FLOOD INUNDATION ANALYSIS: A pond model method was employed for flood inundation analysis. The whole study area of flood management is subject to flood inundation analysis. For flood inundation calculation, the objective area was divided into 495 mesh blocks. A mesh block has a size of 10 km x 10 km in principle. The flood inundation calculation was made for alternative flood management plans. The probable flood runoff with existing dams and probable rainfall in the objective area are inflows to the inundation analysis area. Calibration of constants was made for the floods in 1976 and 1981.

4.6 ANNUAL RUNOFF RATIO: Average annual runoff ratio of the main Apure river varies from 0.84 at Remolino bridge to 0.41 at San Fernando, decreasing toward downstream. The runoff ratio of the Portuguesa river varies from 0.14 at El Baul to 0.20 at Camaguán, increasing slightly toward downstream. Runoff ratio of the Portuguesa river is remarkably small. This may come from smaller basin rainfall and losses due to evaporation and possibly groundwater movement.

4.7 WATER LEVEL: Water level of the Apure river forms single cycle hydrograph in a year with peak in August and bottom in March or April. Its daily and monthly fluctuations are slight. For example, difference between the highest and lowest water levels in a year is about 6 to 7 m at San Fernando and 4 m at Bruzual, while the fluctuation in a month in flood season is only 0.5 m or less.

4.8 CHANNEL FLOW ANALYSIS: Channel flow models were constructed for the evaluation of navigability and analyses of channel flow features. River sections surveyed in March 1992 by PROA were used for the Apure river, supplementing some sections with INC sounding results. Forty nine (49) sections were incorporated with the channel flow model for the entire stretch of 681 km from river mouth at the confluence with the Orinoco river to Remolino bridge.

Regarding the Portuguesa river, thirty nine (39) sections surveyed in October 1989 by PROA were used over the stretch of about 249 km from river mouth at the confluence with the Apure river to El Baul port. All of these section are the sounding result surveyed from water surface and are not related to the MSL-datum. In order to construct channel flow model for the evaluation of navigation capacity under various channel discharges, river elevation of bed profile were assumed and channel roughness were estimated.

4.9 EXTENT OF INFLUENCE OF ORINOCO RIVER: According to the channel flow analysis, the hydraulic influence of the Orinoco river extends up to 94 km from river mouth (near Danta Flaca about 29 km downstream from Arichuna). The Apure river channel downstream from Arichuna is deemed to be formed under the influence of the Orinoco river.

4.10 BANKFUL CHANNEL CAPACITY: Bankful channel capacity of the Apure river was estimated by the channel flow model and is summarized below.

Stretches (from mouth)	Bankful Capacity(m^3/s) Average	Minimum	Remarks
0 - 70 km	2,290	2,210	Lowest reaches
70 - 130 km	2,480	1,750	Anabranch reaches
	(1,760)	(1,110)	(Main Apure only)
130 - 195 km	4,140	2,990	Between anabranches
195 - 275 km	3,150	3,150	Anabranch reaches
	(1,380)	(1,380)	(Main Apure only)
275 - 450 km	3,380	2,500	El Samán - Bruzual
450 - 520 km	2,080	1,800	Bruzual - Suripa R.
520 - 680 km	910	600	Suripa -Guasdualito

4.11 ANNUAL SEDIMENT TRANSPORT: Annual sediment transport capacity was estimated, as an average for each river stretch, as presented below.

Stretches	Annual Sediment Load (mil. m^3/yr)	Stretch Length (km)	Approximate Channel Width (m)
River mouth to San Fernando	14.7	167.3	340
San Fernando to El Samán	15.2	180.8	342
El Samán to Bruzual	14.5	94.1	522
Bruzual to Suripa River	13.0	81.4	501
Suripa R. to Remolino Bridge	14.3	139.8	265

V. STUDY ON CHANNEL STABILIZATION PLAN

V.1 Previous Studies and Works

5.1 CHANNEL IMPROVEMENT WORKS: Improvement of the Apure river initiated in 1960s together with water resources development. Channel improvement works implemented so far are mostly for protection of towns, public facilities and agricultural lands from flood water and bank erosion. Recently, studies and works of the Apure river as navigation channel are started.

5.2 WORKS BY PROA: Construction of four (4) fluvial ports have been planned and the works are ongoing.

1) San Fernando port : constructed
2) El Baul port : under construction
3) Nutrias port/Bruzual : constructed
4) Santos Luzardo port : constructed

Studies and designs of some channel improvement works are also being implemented. Master plan study for the fluvial navigation of the Orinoco-Apure system is scheduled to be conducted soon separately.

V.2 Characteristics of Channel

5.3 GENERAL CHANNEL FEATURES (Fig. 3): Principal features of the Apure river are presented for respective stretches as follows:

1) Stretch-A1 (Apure river from river mouth to San Fernando port): Ground slope is 1/8,500. Large scale anabranches develop in this stretch. River is not braided. Average river width is 257 m ranging from 120 m to 600 m for the main Apure and 340 m ranging from 135 m to 600 m including anabranches.
2) Stretches-A2 (San Fernando port to confluence of Portuguesa river) and A3.1 (Confluence of Portuguesa river to Apurito): Ground slope is 1/7,200. Large scale anabranches develop in this stretch. River is not braided. Average river width is 251 m ranging from 100 m to 560 m for the main Apure and 342 m ranging from 250 m to 560 m including anabranches.

3) Stretch-A3.2 (Apurito to Nutrias port): Ground slope is 1/5,000. River is braided and average river width is 522 m fluctuating much from 200 m to 880 m.

4) Stretch-A4.1 (Nutrias port to confluence of Suripa river): Ground slope is 1/4,200. There are several confluence of tributaries. River is braided and average river width is 501 m fluctuating much from 220 m to 800 m.

5) Stretch-A4.2 (Confluence of Suripa river to Santos Luzardo port): Ground slope of 1/2,500. There is no confluence of major tributaries and channel is not braided. Average river width is 265 m ranging from 100 m to 370 m.

5.4 HISTORICAL VARIATION: According to the study on the topographic maps of the year 1988 (scale 1/10,000) and those of the year 1960 to 1966 (scale 1/25,000), variations of left and right banks were very active in the Stretches-A3.2 and A4.1.

5.5 VARIATION THROUGH FLOOD SEASON: Channel characteristics of sections surveyed in June/July of 1992 and January/February of 1993 were compared. Changes in river section during a flood season are outlined as follows:

1) River channels in Camaguán site are deep and narrow with width-depth ratio (B/hm) of 19, while Guasdualito and Bruzual sites are relatively flat with width-depth ratios of 72 and 82, respectively.

2) Regarding the changes of the maximum channel depth, channel width and river bank shifting, changes in Guasdualito and Bruzual are remarkable. The channels in Camaguán site are stable comparing with those of other two sites.

3) The maximum values of the depth ratio (hmax/hm) are around 3.5, 3.0 and 2.0 for Guasdualito, Bruzual and Camaguán sites, respectively.

4) The depth ratios of Guasdualito site and Bruzual site have similar increasing tendency if the maximum depth takes place closer to river bank. But, that of Camaguán site is quite different from other sites, having no significant tendency for the place of the maximum depth.

5) Significant changes of depth ratios in 1992 and 1993 sections are not observed for Guasdualito and Camaguán sites. For Bruzual site, the upper limit of depth ratio in 1992 is almost half of that of 1993. This might be caused by filling-up due to low flows.

V.3 Evaluation of Channel Capacity for Navigation

5.6 CRITERIA: Navigability of river channel was examined for water depth, width and radius of curvature of channel adopting the criteria presented below.

1) Channel Size Criteria:

	Items	Apure River	Portuguesa River
a)	Water Depth	≥ 2.00 m	≥ 1.70 m
b)	Channel Width	≥ 80 m	≥ 30 m
c)	Radius of Curvature	≥ 560 m	≥ 240 m

2) Channel Flow Criteria: Ordinal daily discharge was adopted as criteria for navigable period. The ordinal daily discharge is defined as the daily discharges ranking from the annual minimum based on the average flow duration at stream gauging stations such as San Fernando, El Samán, Bruzual and Remolino bridge along the main Apure river; and Camaguán, El Jobalito and El Baul along the Portuguesa river.

5.7 EVALUATION OF APURE RIVER (Fig. 4): Making use of the channel flow model, and large scale topographic maps as available, critical sections for navigation were evaluated as follows:

1) Critical Depth (Dc < 2.00 m):

Navigation Months	No. of Critical Sections			
	St-A1 (Sect)(%)	St-A2 (Sect)(%)	St-A3 (Sect)(%)	St-A4 (Sect)(%)
12	43 (9.4)	24 (15.2)	367 (23.2)	423 (29.1)
11	25 (5.5)	18 (11.4)	331 (20.9)	359 (24.7)
10	21 (4.6)	17 (10.8)	272 (17.2)	289 (19.9)
9	11 (2.4)	13 (8.2)	214 (13.5)	192 (13.2)
8	3 (0.7)	6 (3.8)	148 (9.4)	95 (6.5)
7	1 (0.2)	3 (1.9)	38 (2.4)	45 (3.1)
6	0 (0)	1 (0.6)	6 (0.4)	26 (1.8)
5	0 (0)	0 (0)	0 (0)	18 (1.2)
Total Sections	(458)	(158)	(1581)	(1455)

Note: Sections in the lowest stretch of 95.74 km of St-A1 is not included because of no section data

2) Critical Width (Wc < 80 m):

Navigation Months	No. of Critical Sections			
	St-A1 (Sect)(%)	St-A2 (Sect)(%)	St-A3 (Sect)(%)	St-A4 (Sect)(%)
12	6 (55)	0 (0)	9 (56)	12 (71)
11	4 (36)	0 (0)	9 (56)	9 (53)
10	1 (9)	0 (0)	7 (44)	5 (29)
9	1 (9)	0 (0)	4 (25)	2 (12)
8	0 (0)	0 (0)	1 (6)	0 (0)
7	0 (0)	0 (0)	1 (6)	0 (0)
6	0 (0)	0 (0)	1 (6)	0 (0)
Total Sections	(11)	(3)	(16)	(17)

3) Critical Radius of Curvature (Rc < 560 m):

Radius	No. of Critical Bends			
	St-A1	St-A2	St-A3	St-A4
Rc < 560 m (site) (km/site)	12 (14)	0 (-)	16 (16)	12 (18)
Rc < 320 m (site)	6	0	5	5
Channnel Length (km)	167.3	24.9	250.0	221.2

4) Summary: Shortage of water depth is the principal problem of the Apure river. Judging from the critical water depth, navigable months of the Apure river were evaluated as follows, assuming that existing critical sections less than 1.0 % were navigable with minor improvement. For the navigation longer than nine (9) months, channel width also become critical:

- Stretch : St-A1 St-A2 St-A3 St-A4
- Navigable month : 8 6 6 4

5.8 EVALUATION OF PORTUGUESA RIVER (Fig. 5): In the similar manner as the Apure river, critical sections for navigation were evaluated as follows:

1) Critical Depth (Dc < 1.70 m):

Navigation Months	No. of Critical Sections St-P1 (Sect)(%)	St-P2 (Sect)(%)
12	3 (10)	0 (0)
11	1 (3)	0 (0)
10	1 (3)	0 (0)
9	1 (3)	0 (0)
8	0 (0)	0 (0)
Total Sections	(31)	(8)

2) Critical Width (Wc < 30 m):

Navigation Months	No. of Critical Sections St-P1 (Sect)(%)	St-P2 (Sect)(%)
12	15 (48)	8 (100)
11	9 (29)	8 (100)
10	7 (23)	5 (63)
9	3 (10)	3 (38)
8	0 (0)	1 (13)
Total Sections	(31)	(8)

3) Critical Radius of Curvature (Rc < 240 m):

Radius	No. of Critical Bends St-P1	St-P2
Rc < 240 m (site) (km/site)	27 (8)	5 (7)
Rc < 150 m (site)	5	2
Channel length (km)	214.8	33.7

4) Summary: Shortage of channel width and radius of curvature are the principal problems of the Portuguesa river. Judging from the critical channel width, navigable months of the existing Portuguesa river were evaluated to be eight (8) months for St-P1 and seven (7) months for St-P2. The critical channel sections increase abruptly for the navigation longer than nine (9) months.

V.4 Channel Stabilization Measures for Navigation

5.9 PRINCIPLES OF CHANNEL STABILIZATION (Fig. 6): In order to improve channel capacity for navigation, two (2) principal measures were considered, i.e., (1) flow improvement to increase channel discharge and (2) channel improvement to provide enough channel section. Efforts were made to incorporate ideas and schemes studied by PROA and other authorities concerned of MARNR.

5.10 FLOW IMPROVEMENT: Based on the results of evaluation of effects of possible measures, the following principles for the formulation of channel stabilization plan were derived:

1) Flow improvement of upper Apure: Caparo-Uribante Viejo derivation channel will be taken up. Works related to dams will not be included, since new dams are not proposed but the released water from the power generation will be used.
2) Flow improvement of middle Apure: Bocono-Masparro derivation channel will be discarded, since its hydraulic effects are low in the initial stage, and moreover, it will get lower in future due to the increase of irrigation water demand.
3) Flow improvement of upper Portuguesa: The Cojedes-El Frasco derivation channel will not be considered for the present study, but might be incorporated in future for the enhancement of navigation capacity based on the navigation master plan after examining the economic viability.

5.11 CHANNEL IMPROVEMENT: Based on the results of evaluation of effects the following principles for the formulation of channel stabilization plan were derived:

1) Treatment of anabranches at Chirel site and Bravo/Garzas site will be taken up for the plan, since the treatment of Chirel site would be effective for stabilization of the bifurcation, and the treatment of Bravo/Garzas site would also be effective for flow improvement of the main Apure river. These

measures, however, needs further studies and investigation on channels, facilities and environment.

2) Normalization of channel alignment: Realignment and cut-off channel will be the principal measures for the sections of critical radius of curvature in the meandering reaches.

3) Improvement of channel section: The island treatment and channel dredging would be the principal measures. The other improvement works of channel section such as river training and temporary works are expected to be adopted gradually depending on the progress of development of measures, accumulating the technology and experience through hydraulic model tests in laboratory and prototype tests in the Apure river.

V.5 Formulation of Channel Stabilization Plan

5.12 ARRANGEMENT OF STAGED PLANS (Figs. 7 and 8): Three (3) stages of plans were considered for the channel stabilization plan, i.e., short-term plan, mid-term plan and long-term plan. The physical targets of staged plans were set in consideration of the existing navigable months and the limit of channel improvement works at the present stage. The limit of channel improvement works was assumed to be 10 % of the total channel length, and is considered to be the physical target of the mid-term plan. The physical target of the short-term plan was set in-between as an immediate works. The physical target of the long-term plan shall be discussed in line with the navigation master plan to be prepared.

(1) Short-term Plan

1) Derivation channel works: Flow improvement by Caparo-Uribante Viejo derivation channel under water release of La Vueltosa power station at the initial development stage.

2) Anabranch treatment works: Chirel site and Bravo/Garzas site

3) Alignment normalization works: For critical bends with Rc<320 m for the Apure river and Rc<150 m for the Portuguesa river

4) Channel section improvement works: For 8 month navigation for St-A1, A2, P1 and P2, and 7 month navigation for St-A3 and A4.

(2) Mid-term Plan

1) Derivation channel works: Flow improvement by Caparo-Uribante Viejo derivation channel under water release of La Vueltosa power station at the final development stage.

2) Alignment normalization works: For critical bends with Rc<560 m for the Apure river and Rc<240 m for the Portuguesa river.

3) Channel section improvement works: For 9 month navigation for St-A1, A2, P1 and P2, and 8 month navigation for St-A3 and A4.

(3) Long-term Plan: Not studied in the present study.

5.13 COST ESTIMATE: The project cost required for the implementation of the project was estimated in US$ by using the prevailing exchange rate in February, 1993. The project cost estimated is as follows:

	Work item	STP (US$1,000)	MTP (US$1,000)	STP+MTP (US$1,000)
1)	Construction cost	40,013	55,576	95,589
	a) Preparatory works	3,737	5,053	8,690
	b) Derivation channel	3,020	0	3,020
	c) Anabranch treatment	1,029	0	1,029
	d) Alignment normalization	20,941	27,813	48,754
	e) Channel section improvement	10,326	21,239	31,565
	f) Miscellaneous works	1,060	1,471	2,531
2)	Land acquisition	5	2	7
3)	Administration cost	2,001	2,780	4,781
4)	Engineering services cost	6,803	9,448	16,251
5)	Physical contingency	4,883	6,781	11,664
6)	Total	53,705	74,587	128,293

5.14 ECONOMIC CONSIDERATION: The fluvial navigation has the advantages of the low-cost and massive load transportation. The benefit of fluvial navigation was estimated for reduction of the transportation cost in comparison with the land transportation, for the extended navigation period by the channel stabilization works. Since navigation master plan has not been prepared yet, some economic considerations were made based on the cargo data and transportation costs prepared provisionally by PROA.

	Plan	EIRR(%)	B/C*	B-C (US$1,000)*
1)	Short-Term plan	17.7	1.72	38,677
2)	Mid-Term Plan	13.7	1.46	46,666

* B/C and B-C: for 8 % of annual discount rate

5.15 ENVIRONMENTAL CONSIDERATIONS: The channel stabilization for navigation would be attained by flow improvement and channel improvement. The channel improvement includes works of anabranch treatment, alignment normalization, channel section improvement, and bank protection. The changes in river and surrounding areas would be more or less brought about from the implementation of the channel stabilization works. Among them, changes in anabranches downstream of the closing and submerged dike, and sites for disposal of dredged materials would be important. Further intensive study and investigation would be necessary at the design stage on the following aspects, but not limited to:

1) Existing water use
2) Existing ecological condition
3) Identification of objects to be conserved

Based on the study and investigation, the plan and design should be revised, if necessary, to conserve the ecological system and compensate the right of resident people.

VI. STUDY ON FLOOD MANAGEMENT PLAN

VI.1 Study Area

6.1 STUDY AREA (Fig. 1): The area subject to the present flood management study is 21,200 km^2 bounded by the Apure river in south, Portuguesa river in north and east and local road route 2 in west. The study area is vast and presently mostly in natural conditions, so that environmental aspect should be carefully considered. A drastic change of hydraulic conditions of the area resulting from implementation of the flood management works will give strong impact to the environment of the area.

Major rivers in the study are the Apure and Portuguesa rivers mentioned above and also the Guanare river which runs through the center part of the study area. Besides that, a lot of small streams called "Caño" run in the study area. The study area administratively belongs to three states, that is, Barinas, Portuguesa and Cojedes. In the study area, the Arismendi district is known as a center of Apure depression which is the lowest zone of western llanos (flatland).

VI.2 Present Conditions of The Study Area

6.2 HYDRAULIC CHARACTERISTICS (Figs. 9 to 11): The habitual inundation area is widely distributed in the study area and causes of inundation are classified into flooding of river, local rainfall and repress by river flooding. The total inundation area comes to 11,200 km^2 which corresponds to 53% of the study area. The inundation caused by flooding of river is distributed along the Portuguesa, Guanare and Apure rivers which are major rivers in the study area.

The possibility of solution of drainage problems in the study area is roughly classified into three categories according to the study by MARNR. The areas of low and almost no possibilities occupy a half of the study area. The areas with possibility are distributed in upper and middle basins and partly on the left bank area of the Apure river, while most of the lower basins have almost no possibility of solution of drainage problems.

The present discharge capacities of the rivers in and around the study area are fairly small for their catchment areas as follows:

	River	Catchment Area (km^2)	Base Point	Capacity (m^3/s)
1.	Apure	111,800	San Femando	6,900
2.	Apure	40,000	Bruzual	3,800
3.	Portuguesa	23,300	El Jobalito	600
4.	Portuguesa	54,400	Camaguan	1,200
5.	Guanare	4,200	Arismendi	200
6.	Guanare	10,800	La Union	140

6.3 EXISTING AND PROPOSED RIVER DIKES (Fig. 12): Seven (7) dikes have been constructed so far in parallel with the river course and one (1) dike included in the railway project has been planned on the right bank of the Portuguesa river.

6.4 EXISTING AND PROPOSED DAMS (Table 1 and Fig. 13): In the Portuguesa river basin to which the study area belong, seven (7) dams have been constructed so far and two (2) more dams are scheduled to be constructed. Total area of dam basins is 10,960 km^2. Total effective storage and total flood control capacity are 6,325 x 10^6 m^3 and 797 x 10^6 m^3, respectively.

6.5 EXISTING FLOODWAY AND PROPOSED DIVERSION CHANNEL (Fig. 14): A floodway from the Portuguesa river to the Apurito river exists at Hato Gorrin 6 km north from San Fernando crossing Camaguan-San Fernando road dike in order to drain flooding water. It has a width of 400 m, but is narrowed by bridge of 120 m long and does not have low water channel. The length is 10 km and design discharge is 190 m^3/s for 50-year probable flood.

A diversion channel is proposed by MARNR at Sombrerito about 3 km north from the existing floodway. It has a width of 400 m and low water channel of 60 m wide, but is narrowed by bridge of 85 m long. The length is 18 km and design discharge is 440 m^3/s for 50-year probable flood.

6.6 EXISTING AND PROPOSED PROJECT (Fig. 12 and 15): Only Guanare-Masparro agricultural development project situated in the higher part of the area is on-going in the area. On the other hand, there are two proposed projects. One is extension of the Guanare-Masparro Project under consideration and the other is a railway project mentioned before, which is scheduled to be implemented near future.

6.7 EXISTING LAND USE PLAN (Fig. 15): Zoning plans of Barinas, Portuguesa and Cojedes states have been prepared by MARNR, which aim to picture the future development of the respective states till the year 2010. The proposed land use is mostly for agriculture use (cattle breeding). The areas to be preserved for agricultural use are classified into three categories of high, medium and low priorities. On the other hand, flood plain occupies 27% of the study area (about 5,700 km^2) and the areas without any assignment of land use 29% of the study area (about 6,000 km^2).

VI.3 Basic Concept for Flood Management Planning

6.8 BASIC CONSIDERATION: In order to mitigate the inundation, increase of discharge capacities of the rivers in the area will be primary consideration. However, it will incur concentration of flood flow to San Fernando funnel, and large increase of discharge capacity of the funnel is not expectable. Therefore, improvement method which incur flood concentration to San Fernando will not be appropriate for the present study. Also, the flood inundation contributes to the life of inhabitants in the area as water resources though it causes damages. Consideration from environmental aspect is important as the study area is presently mostly in the natural conditions. Therefore, the flood management plan to be proposed in this study will be of change of inundation condition and runoff regulation by retarding.

6.9 PROCEDURE OF PLANNING: The proposed flood management plan will be formulated by the following procedure.

1) Selection of protection area
2) Selection of design scale of the plan
3) Selection of possible measures
4) Formulation of alternative plans
5) Study on alternative plans
6) Environmental consideration
7) Determination of proposed flood management plan

6.10 PROTECTION AREA (Fig. 16): The protection area was selected applying the criteria that it should have possibility of solution of drainage problems and land use assignment in the future. Consequently, the following four (4) areas were selected.

1) Area "A" : Area extending on the right bank side of Caño Igues
2) Area "B" : Area extending on the right bank side of the Guanare river
3) Area "C" : Area extending on the left bank side of the Apure river
4) Area "D" : San Fernando city and its surrounding area

Area "D" was selected for the reason that the flood management works for Areas "A", "B" and "C" in the upstream may influence to the area and therefore increase of safety degree against flood will be necessary to protect San Fernando city from flood.

6.11 DESIGN SCALE OF THE PLAN: The return period of 10 years was employed as design scale of the plan, which is commonly applied to the rural area in Venezuela. The design rainfall with 10-year return period corresponds to 96% of rainfall in 1981 which is the largest rainfall recorded in the study area.

6.12 POSSIBLE MEASURES: The possible measures for the present flood management planning will be as follows:

1) Dike
2) Diversion Channel
3) Retarding basin (natural and artificial)
4) Dam
5) Widening and deepening of present river channel

VI.4 Preliminary Study for Flood Management Plan

6.13 POSSIBILITY OF DIKES ON BOTH RIVER BANKS: In order to know the influence by confining the flood runoff water in the river channel, flood runoff calculation for the flood in 1981 was carried out.

According to the calculation result, the peak runoff at Camaguan on the Portuguesa river reaches 6,800 m^3/s for the channel width of 10 km in the downstream reaches. Considering the present discharge capacity of the Apure river at San Fernando (bankful - 6,900 m^3/s) and also difficulty of increase of the capacity, the flood management plan to confine the runoff water in the river channel is not appropriate. Therefore, it may be better to apply one side dike so as to softly regulate the flood flow. Fortunately, the study area has a gentle slope from north to south and also from west to east. It is convenient topography to apply one side dike.

6.14 EFFECT OF DAMS (Fig. 13): Existing six (6) dams except Bocono-Tucupido dam and proposed (2) dams have almost no effect for mitigation of inundation in the study area because of their locations far from the study area and insufficient storage capacity to the total runoff of the Portuguesa river basin. The total effective storage capacity and flood control capacity of eight (8) dams are 9% and 1% of the total runoff.

6.15 APPLICABILITY OF APURE TYPE MODULE (Fig. 18): Water resources conservation in the study area is another important aspect as well as flood management. Apure type module is one of the possible measures for the said purpose and it has a capacity to store almost 90% of the 10-year probable rainfall in the subject module area.

The Apure type module has an advantage of storage of water for dry season and produce benefit though the land use is limited to cattle breeding, so that it should be introduced for development purpose.

6.16 POSSIBILITY OF WIDENING AND DEEPENING OF PRESENT RIVER CHANNEL: The widening and deepening of the present river channels are common method to increase capacity of river channel, but they are not employed for the present study by the reasons below.

- Flood concentration to the downstream
- Breaking of stability of the channel resulting from loss of river bank forests in some reaches.
- Influence to navigation by decrease of water depth in dry season

VI.5 Formulation of Alternative Plans

6.17 ALTERNATIVE PLANS FOR AREA "A" (Fig. 19): Possible measures to protect Area "A" were selected as follows:

a) Dike against flooding and
b) Dam for flood peak cut.

However, as dam plan was discarded because there exist no proposed and feasible dams effective for protection of the Area "A".

Considering that the inundation in and around the protection area is mainly caused by flooding of the Portuguesa river and Caño Igues, the following three (3) alternative plans were formulated. Extent of dike in each plan is from national road route 5 to confluence of the Portuguesa river and Caño Igues so as to cover the extent of Area "A".

1) Plan A1: Dike on the right bank of the Portuguesa river (187 km long)
2) Plan A2: Dike on the right bank of Caño Igues (190 km long)
3) Plan A3: Dike on the right bank of the Portuguesa river and left bank of Caño Igues (185 km long)

6.18 ALTERNATIVE PLANS FOR AREA "B" (Fig. 19): Possible measures to protect Area "B" were selected as follows:

a) Dike against flooding,
b) Dam for flood peak cut and
c) Improvement of existing river channels.

However, dam plan was discarded because there exist no proposed and feasible dams effective for protection of the Area "B" other than existing Bocono-Tucupido dam.

To prevent the flooding of the Guanare river and also to mitigate the inundation in the area, the following three alternative plans were formulated.

1) Plan B1: Dike on the right bank of Guanare river (145 km long)
2) Plan B2: Dike on the right bank of Guanare river (145 km long) and improvement of Guanare Viejo river (95 km long)

By the improvement capacity of Guanare Viejo river, this plan is divided into the following two cases.

Plan B2A: Proposed width and depth of Guanare Viejo river are 25 m and 3 m, respectively..
(about 100 m^3/s in capacity)

Plan B2B: Proposed width and depth of Guanare Viejo river are 50 m and 3 m, respectively.
(about 200 m^3/s in capacity)

6.19 ALTERNATIVE PLANS FOR AREA "C" (Fig. 19): Possible measure to protect Area "C" was selected as follows:

a) Dike against flooding and
b) Apure type module to protect some specific locations

To prevent the flooding from the Apure river, the following three alternative plans were formulated.

1) Plan C1: Dike on the left bank of Apure river from Puerto Nutrias to Samanal (155 km long)
2) Plan C2: Dike on the left bank of Apure river from Puerto Nutrias to Apurito (105 km long)
3) Plan C3: Apure type modules in areas other than wetlands subject to environmental conservation

6.20 ALTERNATIVE PLANS FOR AREA "D" (Fig. 19): The purpose of the flood management of Area "D" is to cope with expected influence by flood management plans for Area "A", "B" and "C" and then to increase safety degree against flood. Possible measures were selected as follows:

a) Widening of the present Apure river channel,
b) Diversion channel to alleviate burden of Apure river,
c) Retarding basin to regulate flood concentration to San Fernando funnel,
d) Heightening of existing dike surrounding San Fernando and
e) Lowering of water level of downstream stretch from San Fernando.

Among them, measures a) and e) were discarded due to difficulty and small effect, respectively. Measure d) should be employed when other measures are not effective because it does not mean improvement of the hydraulic condition in the area.

Regarding the measures b) and c), the following three (3) alternative plans were formulated.

1) Plan D1: Diversion channel from Portuguesa to Apurito rivers

This plan is divided into the following two (2) cases.

Plan D1A : Improvement of existing floodway
Plan D1B : Improvement of existing floodway and proposed diversion channel

Improved floodway and proposed diversion channel have the same dimension, that is, total width of 400 m and low water channel of 60 m wide.

2) Plan D2: Retarding basin by Apure type module

VI.6 Study on Alternative Plans

6.21 HYDRAULIC STUDY (Table 2): Effects and influences of respective alternative plans are hydraulically studied by the pond model method and the maximum inundation depth by block, difference from present conditions and major changes of inundations by respective plans were obtained. Based on the results, plan proposed for each area was selected.

6.22 PROPOSED PLAN FOR AREA "A" (Fig. 20): Among the alternative plans, Plan A1 was selected mainly because of economic advantage. Plans A2 and A3 have smaller increase of inundation depth on the left bank of the Portuguesa river than Plan A1, but they reversely much decrease the protectable area (about 30%), that is, the benefit. On the other hand, Plan A1 increases inundation depth on the left bank of the Portuguesa river by 40 ~ 50 cm at maximum for the present condition, however inundation area may not extend due to topographic condition and also no serious environmental impact is expected according to the preliminary investigation. This plan will have economic effect by using the dike as road connecting national roads route 5 and route 8.

6.23 PROPOSED PLAN FOR AREA "B" (Fig. 20): Among the alternative plans, Plan B1 was selected because effect of improvement of existing channel in Plans B2A and B2B is as small as 3 ~ 6 cm in decrease of inundation depth though it lasts for longer period and also the cost is 2 to 3 times higher than Plan B. Prevention of flooding of the Guanare river is essential for the present flood management plan though the decrease of inundation depth of the area is about 5 cm. This plan has advantages of economic effect by using the dike as road and also to utilize existing roads of 120 km long in total as dike.

6.24 PROPOSED PLAN FOR AREA "C" (Fig. 20): Both Plans C1 and C2 increase the water level of the Apure river by about 1 m for the present condition, but influence does not reach San Fernando. In case of Plan C2, overflow of 0.5 ~ 1 m in depth still occurs in the reaches downstream from Apurito because of influence of the said water level increase and influence to the area. Among Plans C1 and C3, the

the proposed plan should be determined based on more detail study and therefore both of Plans C1 and C3 remain as the proposed plan in the present study.

6.25 AREA "D": No plan was selected because of small effects of respective alternative plan and also no influence to the area by the flood management plan for Areas A, B and C in the upstream. Heightening of dikes surrounding the area will be economical, if necessary. Diversion channels of Plans D1A and D1B lower the water level of the Apure river at San Fernando by about 10 ~ 20 cm. Effect of Apure type module of Plan D2 is seen in decrease of the inundation depth in the lowest area of about 10 cm.

6.26 ENVIRONMENTAL CONSIDERATION: The study area is mostly in natural condition at present, so that consideration from environmental aspect is important. According to the preliminary study, no significant environmental impact is expected though the further detailed environmental impact analysis has to be made for final conclusion.

In the areas protected by the dikes on the right banks of Portuguesa and Guanare rivers (Areas "A" and "B", respectively), human intervention has already caused physical impact on nature and therefore the proposed dikes will not cause major ecological impact, but instead they will promote consolidation of existing incipient farming development by protecting them from flooding of rivers.

On the other hand, Area "C" protected by the dike on the left bank of the Apure river has much less human intervention than Areas "A" and "B". Therefore, the environmental impact by the dike should be analyzed before dike construction. If the dike construction is not allowed from the environmental viewpoint, plan to protect the specific areas by such as module should be considered as alternative for the continuous river dike.

VI.7 Proposed Flood Management Plan

6.27 PROPOSED FLOOD MANAGEMENT PLAN (Fig. 20): The flood management plan to be proposed is formulated by integration of the following component plans proposed for respective protection areas.

Plan A1 for Area "A" (Dike for Portuguesa river)
Plan B1 for Area "B" (Dike for Guanare river)
Plan C1 or C3 for Area "C" (Dike for Apure river or Apure type module)

As no significant change occurs in inundation by integration of the respective component plans comparing with the result of hydraulic study for each plan, this plan was adopted as the proposed flood management plan.

6.28 PRELIMINARY FACILITY DESIGN (Fig. 21): The dike was designed as road-dike. It has a crest width of 10 m and is paved with asphalt. Height is more than 2 m. The dike is provided with sluiceways at the points where the existing streams cross the dike to secure the existing water supply and drainage routes. In order to alleviate environmental impact, the round-shaped borrow pit with gentle bank slope is proposed on the river side as well as continuous borrow pit on land side.

6.29 COST ESTIMATE: The project cost required for implementation of the proposed flood management plan was estimated in US$ by using the prevailing exchange rate in February, 1993. The project cost estimated is summarized below:

Work item	Plan A1 (US$1,000)	Plan B1 (US$1,000)	Plan C1 (US$1,000)	Overall (US$1,000)
1) Construction cost	25,312	18,916	25,284	69,512
a) Preparatory works	2,240	1,674	2,238	6,152
b) Foundation excavation	960	740	790	2,490
c) Dike embankment	19,400	14,500	19,925	53,825
d) Vegetation cover	1,240	900	1,060	3,200
e) Sluiceway	800	600	600	2,000
f) Miscellaneous works	672	502	671	1,845
2) Land acquisition	187	145	155	487
3) Administration cost	1,275	953	1,272	3,500
4) Engineering services cost	4,303	3,216	4,298	11,817
5) Physical contingency	3,108	2,323	3,101	8,532
6) Total	34,185	25,553	34,110	93,848

6.30 ECONOMIC CONSIDERATION: The benefits produced by the implementation of the proposed flood management plan are flood reduction benefit and land

enhancement benefit. Based on the project cost and benefits estimated, economic internal rate of return (EIRR) and benefit-cost ratio (B/C) for respective plans are as follows:

Plan	Annual Benefit (US$ 1,000)	EIRR (%)	B/C*	B-C* (US$ 1,000)
A1	4,482	11.0	1.39	9,124
B1	3,473	11.0	1.45	7,295
C1	4,042	6.6	0.82	-5,212
Overall	11,286	9.2	1.15	7,614

* B/C and B-C: for 8 % of annual discount rate

VII. FORMULATION OF MASTER PLAN

7.1 ARRANGEMENT OF PLANS: The Study on comprehensive improvement of the Apure River Basin includes two component plans, i.e., channel stabilization and flood management plans. These plans could be formulated independently, since derivation channel and anabranch treatment works for channel stabilization are designed principally so as not to give radical changes to flood flows, while flood management plan does not intend to make substantial drainage of inundation water and widening of river channel and, therefore, no influence to channel stabilization for navigation is expected. In addition, objectives, problems and basis of planning of these two plans are different. These component plans had better to be treated separately in promoting the project.

7.2 CHANNEL STABILIZATION PLAN:

(1) Short-Term Plan (STP)

The short-term plan aims to accomplish the following physical target:

1) Apure river: To attain eight (8) month navigation from river mouth to San Fernando port (St-A1) and seven (7) month navigation from San Fernando port to Santos Luzardo port (St-A2, A3 and A4).
2) Portuguesa river: To attain eight (8) month navigation from San Fernando port to El Baul port (St-A2, P1 and P2).

The short-term plan includes the following works:

1) Derivation channel works: Flow improvement by Caparo-Uribante Viejo derivation channel under water release of La Vueltosa power station at the initial development stage.
2) Anabranch treatment works: Chirel site and Bravo/Garzas site
3) Alignment normalization works: For critical bends with Rc<320 m for the Apure river and Rc<150 m for the Portuguesa river
4) Channel section improvement works: For 8 month navigation for St-A1, A2, P1 and P2, and 7 month navigation for St-A3 and A4.

(2) Mid-Term Plan (MTP)

The mid-term plan aims to accomplish the following physical target:

1) Apure river: To attain nine (9) month navigation from river mouth to San Fernando port (St-A1) and eight (8) month navigation from San Fernando port to Santos Luzardo port (St-A2, A3 and A4).
2) Portuguesa river: To attain nine (9) month navigation from San Fernando port to El Baul port (St-A2, P1 and P2).

The mid-term plan includes the following works:

1) Derivation channel works: Flow improvement by Caparo-Uribante Viejo derivation channel under water release of La Vueltosa power station at the final development stage.
2) Alignment normalization works: For critical bends with Rc<560 m for the Apure river and Rc<240 m for the Portuguesa river.
3) Channel section improvement works: For 9 month navigation for St-A1, A2, P1 and P2, and 8 month navigation for St-A3 and A4.

7.3 FLOOD MANAGEMENT PLAN

(1) Long-Term Plan

The target of the long-term plan is to accomplish the entire flood management plan proposed. The long-term plan largely consists of the following works.

1) Construction of dike on the right bank of Portuguesa river (187 km long)
2) Construction of dike on the right bank of Guanare river (145 km long)

3) Construction of dike on the left bank of Apure river (155 km long) or Apure type module (some specific locations)

The order of implementation in the long-term plan is determined taking into account the economic and environmental viewpoints as follows:

Order of Implementation	Works
1st	Construction of dike for Portuguesa river
2nd	Construction of dike for Guanare river
3rd	Construction of dike for Apure river or Apure type module

(2) Short-Term Plan

The short-term plan aims at implementation of the priority works and effective works in the long term plan. In the proposed flood management plan, the following two works are taken up as the short-term plan.

1) Partial dike for Portuguesa river (103 km long) from national road route 8 to Nueva Florida in relation with railway project.
2) Partial dike for Guanare river (25 km long) to connect existing roads to use them as road dike.

7.4 IMPLEMENTATION SCHEDULE:

(1) Channel Stabilization Plan (Fig. 22)

The short-term plan shall be implemented first and then the mid-term plan depending on the increase of the cargo to be transported and the economic viability. The implementation schedule was tentatively proposed and shall be revised in line with the navigation master plan to be prepared. The sequence of project works would be as follows:

1) Project Preparation: 1st to 5th year
   a) Navigation master plan study
   b) Feasibility study
   c) Financing

2) Short-Term Plan:
   a) Preparation: 1st to 2nd year
   b) Detailed design: 1st to 2nd year
   c) Construction works: 3rd to 7th year

3) Mid-Term Plan:
   a) Preparation: 6th to 7th year
   b) Detailed design: 6th to 7th year
   c) Construction works: 8th to 17th year

4) Long-Term Plan: Not scheduled (After 18th year)

(2) Flood Management Plan (Fig. 22)

The short-term plan shall be implemented first and then the long-term plan. The sequence of project works for flood management would be as follows:

1) Preparatory Period: 1st to 5th year
   a) Feasibility study
   b) Financing

2) Short-Term Plan: 2nd to 10th year
   a) Preparation : 2nd to 3rd year
   b) Detailed design : 4th to 5th year
   c) Partial dike for the Portuguesa river for railway project (103 km long) : 6th to 8th year
   d) Partial dike for the Guanare river (25 km long) : 9th to 10th year

3) Long-Term Plan: 8th to 20th year
   a) Preparation : 9th to 10th year
   b) Detailed design : 9th to 10th year
   c) Dike for the Portuguesa river (Remaining 84 km long) : 11th to 12th year
   d) Dike for the Guanare river (Remaining 120 km long) : 13th to 16th year
   e) Dike for the Apure river (155 km long) or
      Apure type module (some specific locations : 17th to 20th year

VIII. CONCLUSION AND RECOMMENDATION

8.1 CHANNEL STABILIZATION PLAN:

(1) Conclusion

The study on channel stabilization plan is concluded as follows:

1) Considering the expected quantity of cargo, radical channel improvement over the entire stretches would not be practical from the economic standpoint. Channel improvement for navigation for the Apure and Portuguesa rivers should be planned and designed considering the characteristics of existing river to the maximum extent.

2) Shortage of water depth is the principal problem for the fluvial navigation of the Apure river. Navigable months of the Apure river were evaluated to be 8 months for downstream reaches of San Fernando and 6 months for the upstream reaches. As for the Portuguesa river, the shortage of channel width and radius of curvature are the principal problems. Navigable months of the existing Portuguesa river were evaluated to be eight (8) months for downstream reaches of the Cojedes river junction and seven (7) months for the upstream reaches.

3) Three (3) stages of plans were considered for the channel stabilization plan for the fluvial navigation, i.e., short-term plan, mid-term plan and long-term plan and long-term plan. Physical targets of staged plans were set as follows:

   a) Short-term plan: Eight (8) months navigation for the stretches from the Orinoco river via San Fernando port upto El Baul port and seven (7) months navigation for the stretches from San Fernando port via Nutrias port upto Santos Luzardo port.
   b) Mid-term plan: Navigable months will be enhanced by one (1) month from the short-term plan for respective stretches. The plan requires the channel improvement of about 10% of the total length.
   c) Long-term plan was not discussed in detail.

4) The plan was evaluated economically to be viable according to the preliminary study.

(2) Recommendation

For further studies on the prepared channel stabilization plan, the followings are recommended:

1) To implement study on navigation master plan as soon as possible. The master plan will be the basis of all the activities related to the fluvial navigation including channel stabilization. The review of economic viability and implementation program should be included in the study on the navigation master plan.

2) To conduct further geomorphologic and hydraulic studies on the channel stabilization measures, especially for the derivation channel works and anabranch treatment works.

3) To develop channel improvement measures applicable to the Apure and Portuguesa rivers by means of hydraulic model tests in laboratory and prototype tests infield.

8.2 FLOOD MANAGEMENT PLAN:

(1) Conclusion

The proposed flood management plan consists of dike on the right bank of Portuguesa river for Area "A", dike on the right bank of Guanare river for Area "B" and dike on the left bank of Apure river or Apure type module (some specific locations) for Area "C". According to the economic evaluation except the Apure type module, economic viabilities of dike plans for Areas "A" and "B" are sufficient, while that of dike plan for Area "C" is relatively low.

Therefore, it is concluded that the dike constructions for Portuguesa river and Guanare river may proceed to further study paying much attention to the environmental aspect. However, as the flood control and management are closely related to lives of peoples living there, implementation of the flood control and management works cannot be decided from the economic viewpoint only. The flood management in Area "C" should be planned based on more detailed environmental investigation and impact study, so that dike construction on the left bank should be evaluated from the environmental aspect before its construction.

(2) Recommendation

For the further study on the proposed flood management plan, the followings are recommended.

1) To systematically accumulate basic data and information such as those on the hydrology, hydraulics, topography, geology, geomorphology, etc.

2) To establish more concrete regional development plan of the subject area and basin plan of the subject basin taking into account environmental aspect.

3) To conform the flood management and control plans to the said regional development and basin plan.

TABLES

Table 1 PRINCIPAL FEATURES OF DAMS IN THE PORTUGUESA RIVER BASIN

Dam	Status	Owner	Function	Catchment Area (km2)	Gross Storage (mil m3)	Effective Capacity (mil m3)	Flood Control Capacity (mil m3)	Spillway Capacity (m3/s)
1. Bocono-Tucupido	Constructed	CADAFE/MARNR	P, I, W, F	2,020	3,485	2,595	249	687
2. Guaremal	Constructed	-	F	-	4	(Filled up with sediment)		
3. Las Majaguas	Constructed	MARNR	I, F	100	304	303	41	60
4. Cabuy	Constructed	MARNR	I	44	11	10	4	80
5. Pao Cachinche	Constructed	INOS	I,W	940	170	165	67	760
6. Pao La Balsa	Constructed	INOS	I,W	2,700	394	369	56	60
7. Tisnados	Constructed	MARNR	I,F	1,480	870	820	229	486
8. Yacambu	Under Construction	MARNR	I,W,F	335	435	313	26	480
9. Las Palmas	Under Bidding	MARNR	P,I,W,F	4,325	1,920	1,750	125	170

Note : - Data are not available.

P - Power generation
I - Irrigation
W - Water supply
F - Flood control

As of March 1993

Table 2 MAXIMUM INUNDATION DEPTH BY BLOCK (10-YEAR RETURN PERIOD) (1/2)

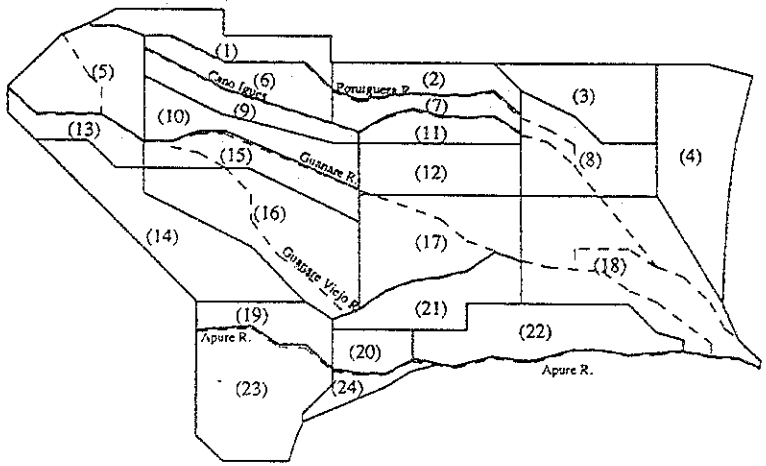
Block No.	Present Condition	A1		B1		B2A		B2B		C1		C2	
		Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference
1	0.25	0.25		0.25		0.25		0.25		0.25		0.25	
2	0.35	0.77	0.42	0.35		0.35		0.35		0.35		0.35	
3	0.10	0.10		0.10		0.10		0.10		0.10		0.10	
4	0.13	0.13		0.13		0.13		0.13		0.13		0.13	
5	0.05	0.05		0.06	0.01	0.06	0.01	0.06	0.01	0.05		0.05	
6	0.12	0.12		0.12		0.12		0.12		0.12		0.12	
7	0.24	0.10	-0.14	0.24		0.24		0.24		0.24		0.24	
8	0.29	0.41	0.12	0.30	0.01	0.29		0.29		0.29		0.29	
9	0.18	0.18		0.20	0.02	0.19	0.01	0.19	0.01	0.18		0.18	
10	0.17	0.17		0.24	0.07	0.24	0.07	0.24	0.07	0.17		0.17	
11	0.37	0.17	-0.20	0.37		0.37		0.37		0.37		0.37	
12	0.52	0.40	-0.12	0.53	0.01	0.53	0.01	0.53	0.01	0.52		0.52	
13	0.07	0.07		0.06	-0.01	0.06	-0.01	0.06	-0.01	0.07		0.07	
14	0.08	0.08		0.08		0.08		0.08		0.08		0.08	
15	0.14	0.14		0.14		0.12	-0.02	0.12	-0.02	0.14		0.14	
16	0.30	0.30		0.25	-0.05	0.23	-0.07	0.20	-0.10	0.30		0.30	
17	0.49	0.45	-0.04	0.49		0.48	-0.01	0.48	-0.01	0.49		0.49	
18	1.77	1.74	-0.03	1.78	0.01	1.78	0.01	1.78	0.01	1.77		1.77	
19	0.13	0.13		0.13		0.13		0.13		0.13		0.13	
20	0.41	0.41		0.41		0.41		0.42	0.01	0.13	-0.28	0.13	-0.28
21	0.50	0.50		0.47	-0.03	0.52	0.02	0.54	0.04	0.36	-0.14	0.36	-0.14
22	0.07	0.07		0.07		0.07		0.07		0.07		0.09	0.02
23	0.31	0.31		0.31		0.31		0.31		0.31		0.31	
24	1.28	1.28		1.28		1.28		1.28		1.90	0.62	1.90	0.62

Note :

A1	Dike for Portuguesa river (right bank)
B1	Dike for Guanare river (right bank)
B2A	Dike for Guanare river (right bank)+improvement of Guanare Viejo river
B2B	Dike for Guanare river (right bank)+improvement of Guanare Viejo river
C1	Dike for Apure river (left bank)
C2	Dike for Apure river (left bank-shortened)
D1A	Diversion channel by improvement of existing floodway
D1B	D1A + new diversion channel
D2	Retarding basin applying Apure type module
Overall	Plan A1+Plan B1+Plan C1

Table 2 MAXIMUM INUNDATION DEPTH BY BLOCK (10-YEAR RETURN PERIOD) (2/2)

Block No.	D1A Depth	D1A Difference	D1B Depth	D1B Difference	D2 Depth	D2 Difference	Overall Depth	Overall Difference
1	0.25		0.25		0.25		0.25	
2	0.35		0.35		0.56	0.21	0.77	0.42
3	0.10		0.10		0.10		0.10	
4	0.13		0.13		0.13		0.13	
5	0.05		0.05		0.05		0.06	0.01
6	0.12		0.12		0.11	-0.01	0.11	-0.01
7	0.24		0.24		0.62	0.38	0.10	-0.14
8	0.29		0.29		0.40	0.11	0.41	0.12
9	0.18		0.18		0.18		0.18	
10	0.17		0.17		0.17		0.24	0.07
11	0.37		0.37		0.51	0.14	0.17	-0.20
12	0.52		0.52		0.56	0.04	0.41	-0.11
13	0.07		0.07		0.07		0.06	-0.01
14	0.08		0.08		0.08		0.08	
15	0.14		0.14		0.14		0.14	
16	0.30		0.30		0.30		0.25	-0.05
17	0.49		0.49		0.40	-0.09	0.41	-0.08
18	1.77		1.77		1.67	-0.10	1.74	-0.03
19	0.13		0.13		0.17	0.04	0.13	
20	0.41		0.41		0.41		0.13	-0.28
21	0.50		0.50		0.43	-0.07	0.31	-0.19
22	0.07		0.07		0.43	0.36	0.07	
23	0.31		0.31		0.30	-0.01	0.31	
24	1.28		1.28		1.90	0.62	1.90	0.62



Note :

A1	Dike for Portuguesa river (right bank)
B1	Dike for Guanare river (right bank)
B2A	Dike for Guanare river (right bank)+improvement of Guanare Viejo river
B2B	Dike for Guanare river (right bank)+improvement of Guanare Viejo river
C1	Dike for Apure river (left bank)
C2	Dike for Apure river (left bank-shortened)
D1A	Diversion channel by improvement of existing floodway
D1B	D1A + new diversion channel
D2	Retarding basin applying Apure type module
Overall	Plan A1+Plan B1+Plan C1

FIGURES

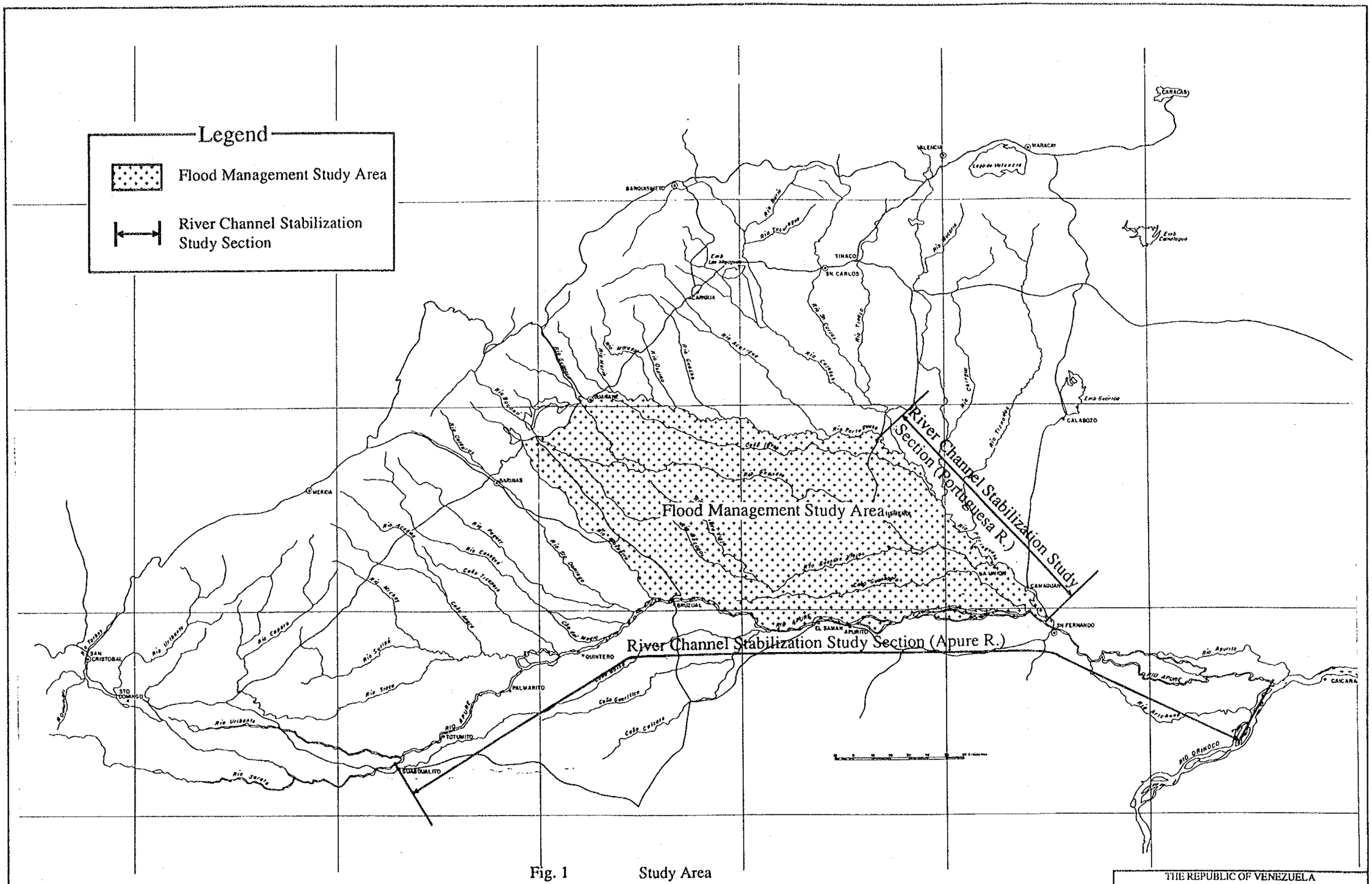


Fig. 1 Study Area

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

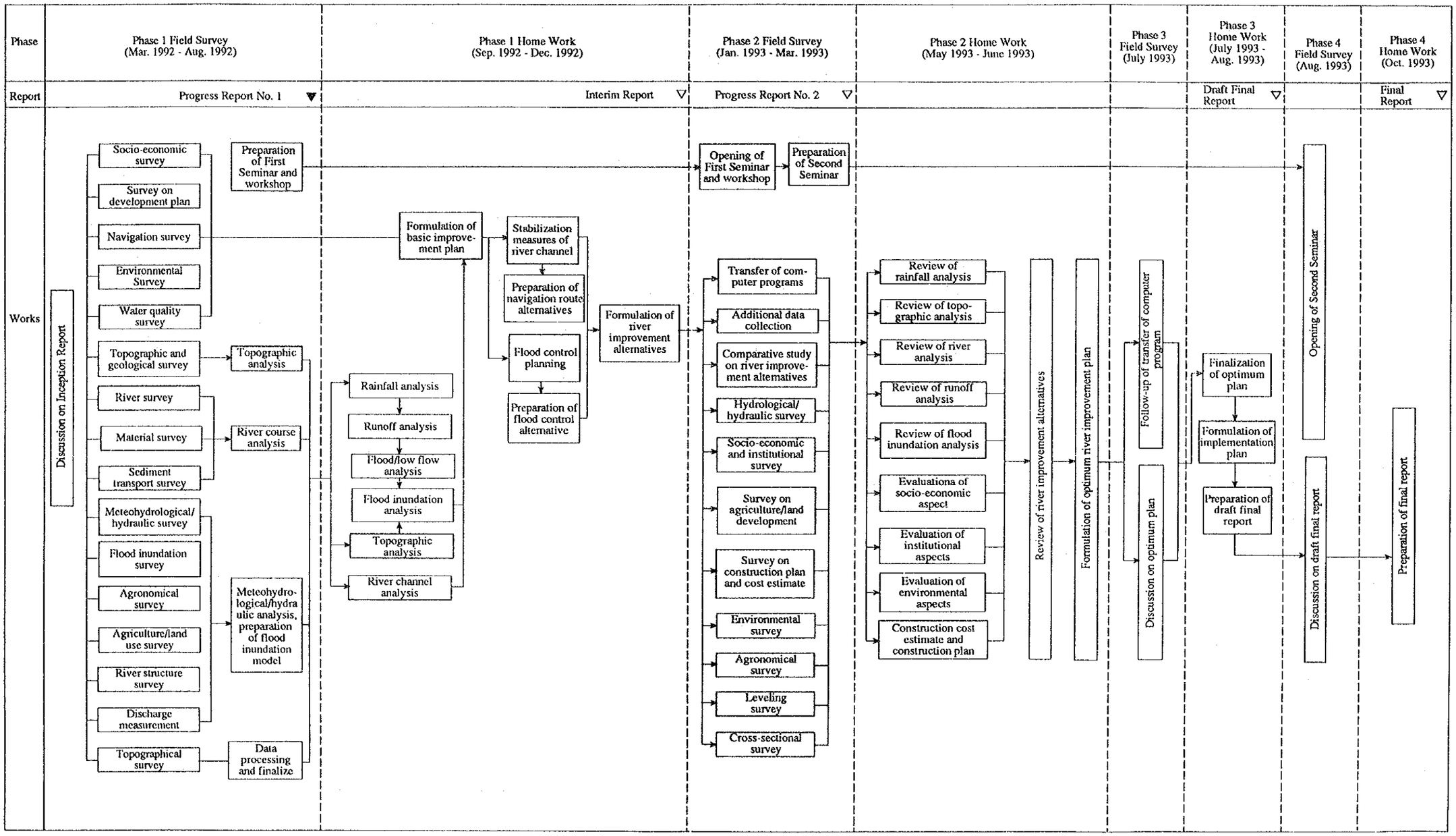


Fig. 2 Overall Work Flow of Study

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

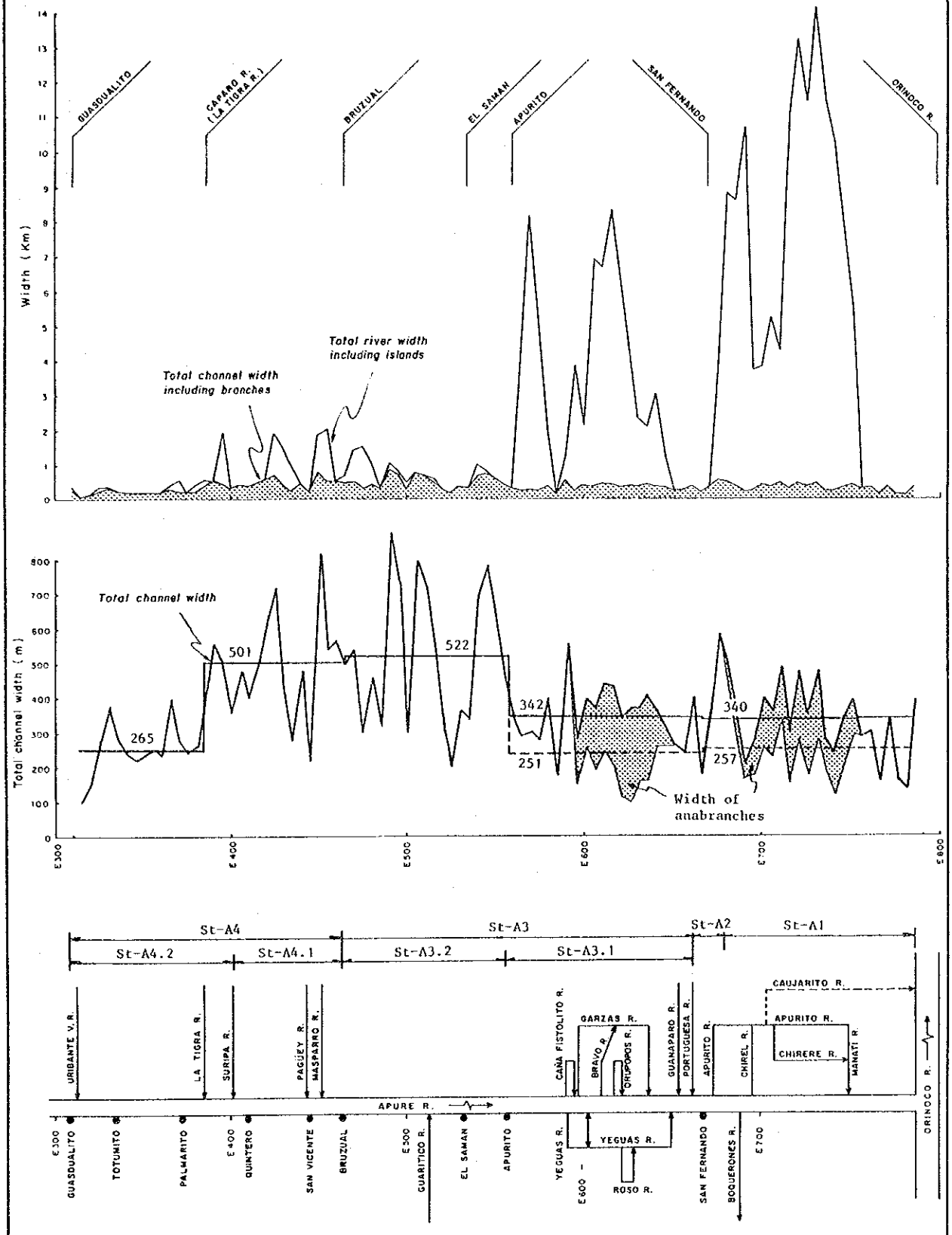


Fig. 3 Ground Feature of Apure River (1/2)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

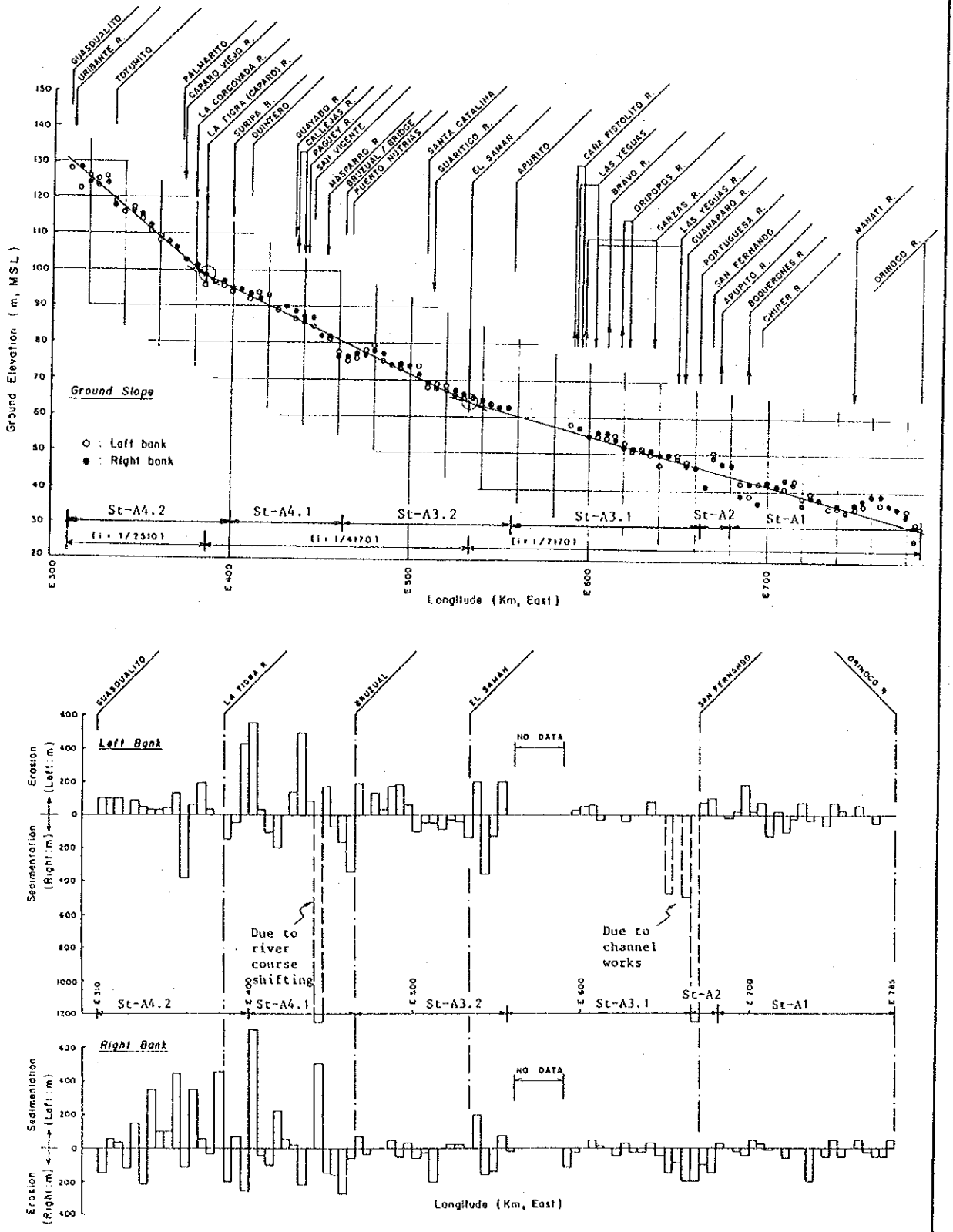


Fig. 3 Ground Feature of Apure River (2/2)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
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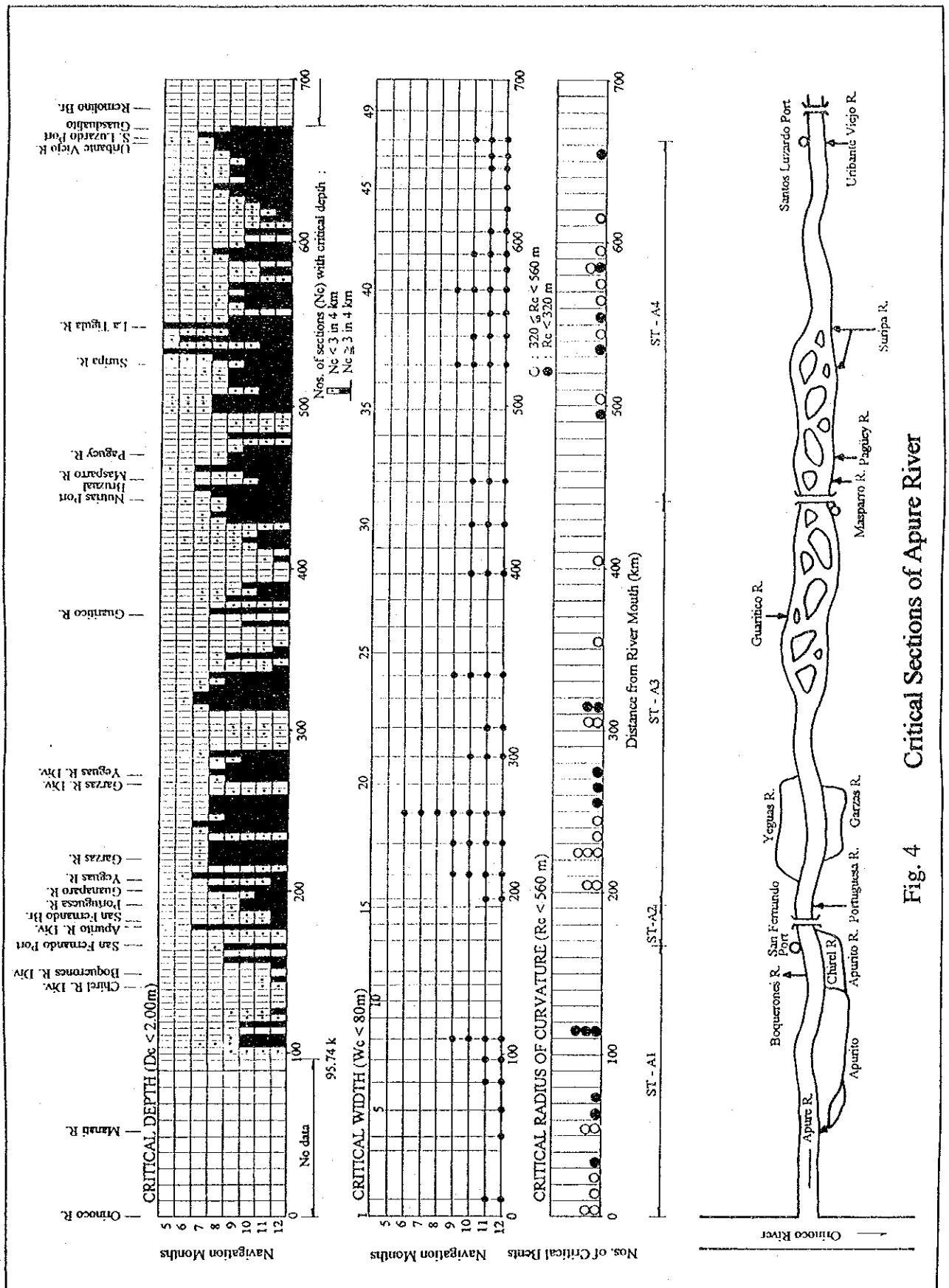

Fig. 4 Critical Sections of Apure River

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
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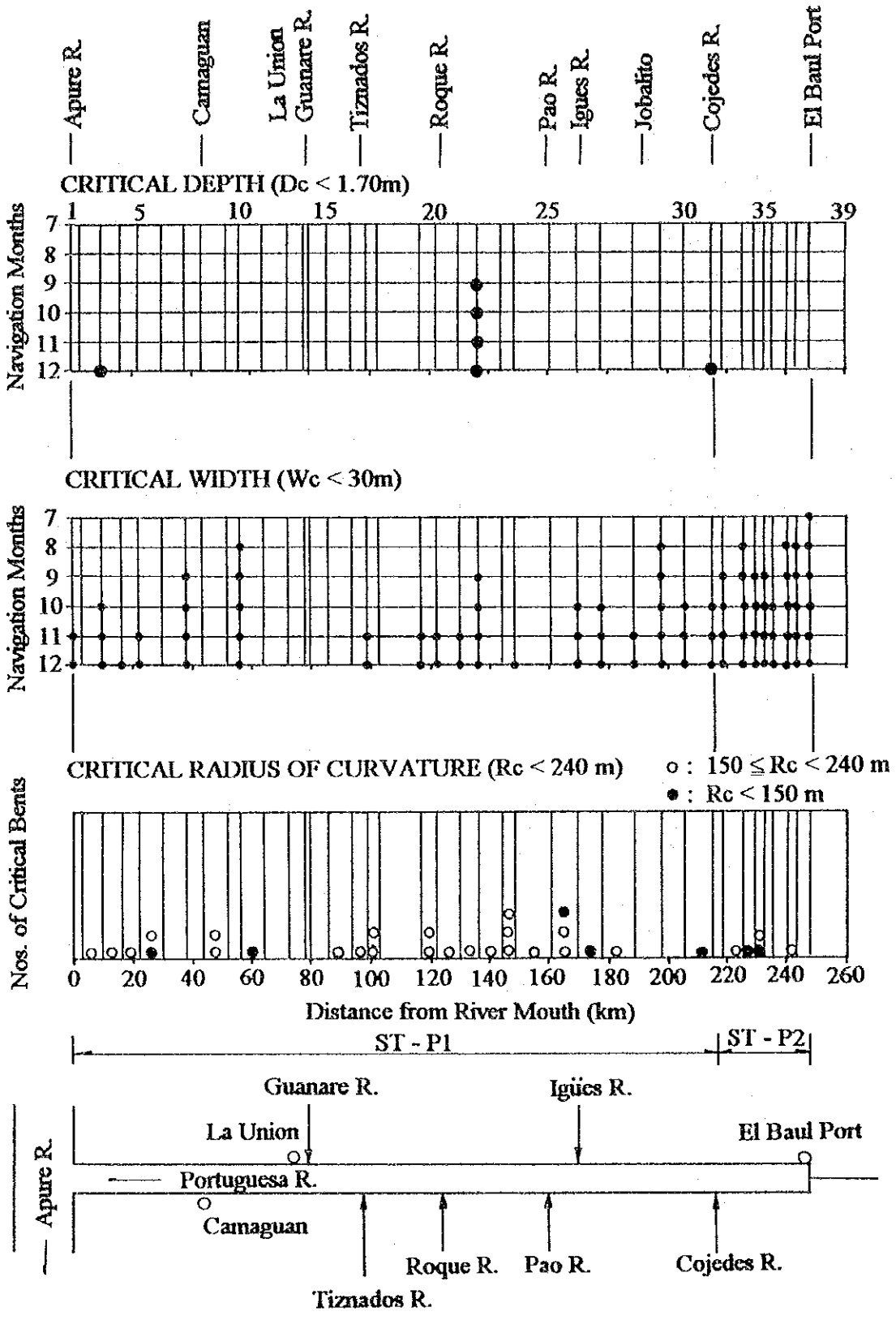

Fig. 5 Critical Sections of Portuguesa River

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

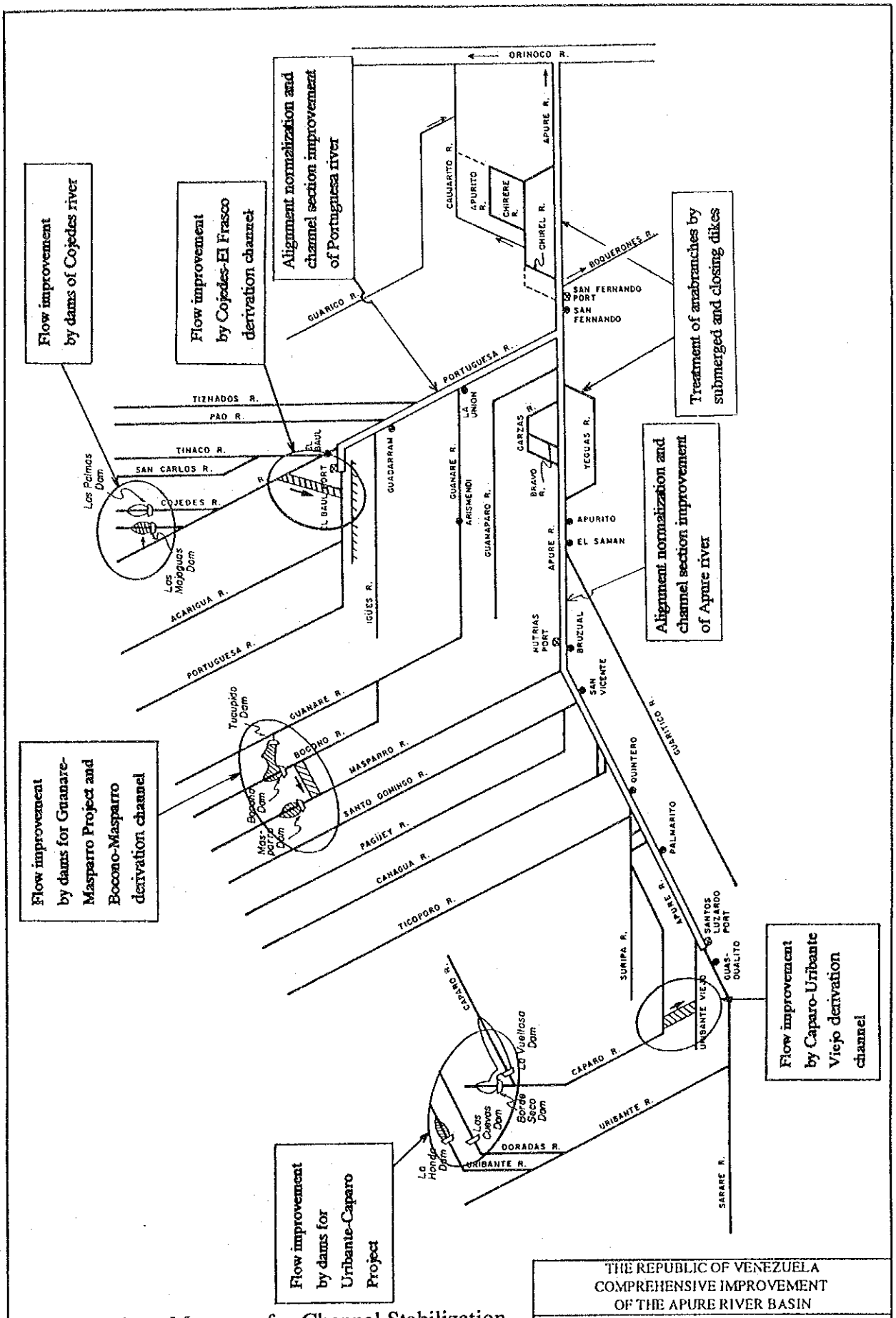

Fig. 6 Measures for Channel Stabilization

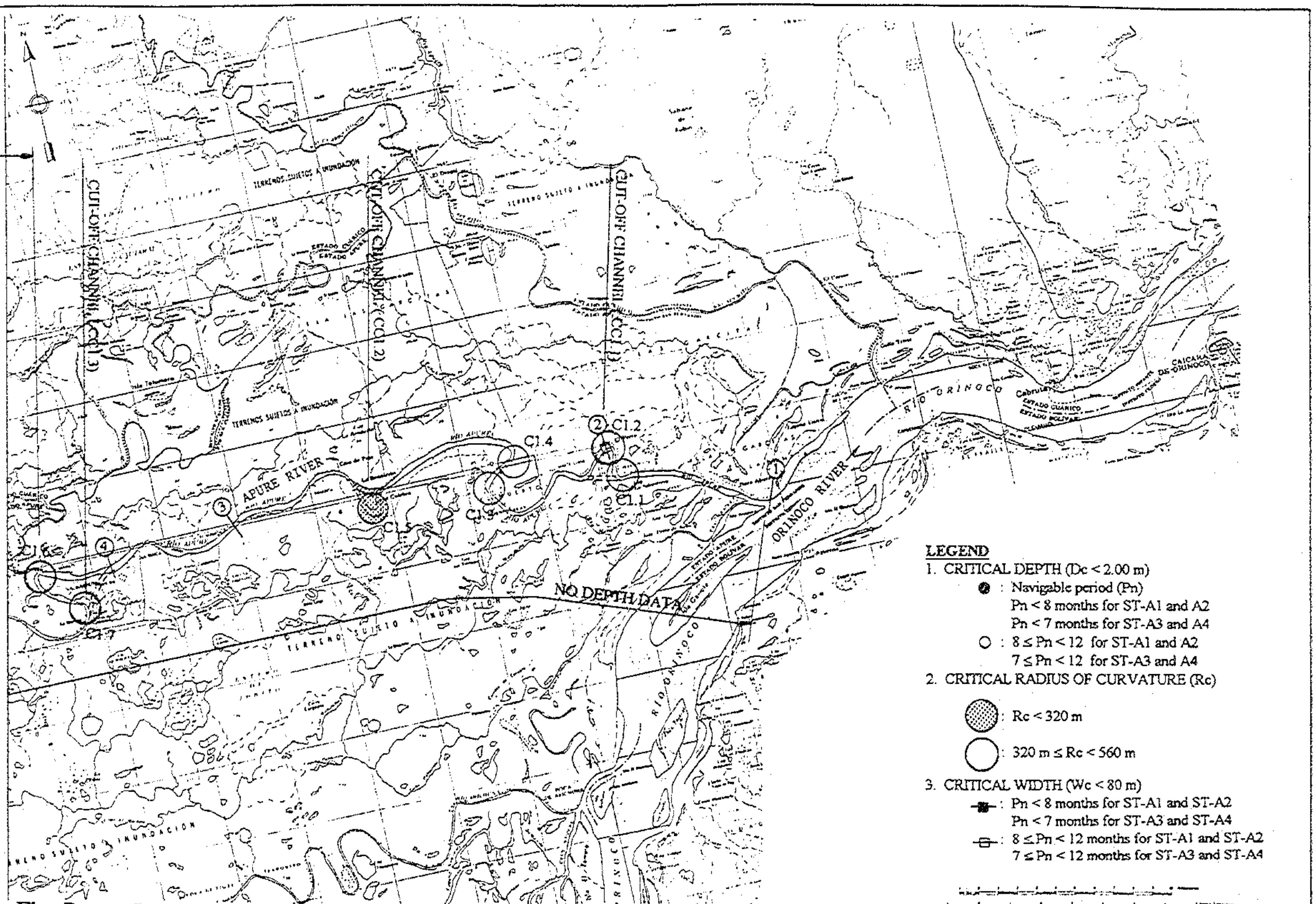

Fig. 7 Location of Critical Sections and Measures : Apure River (1/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

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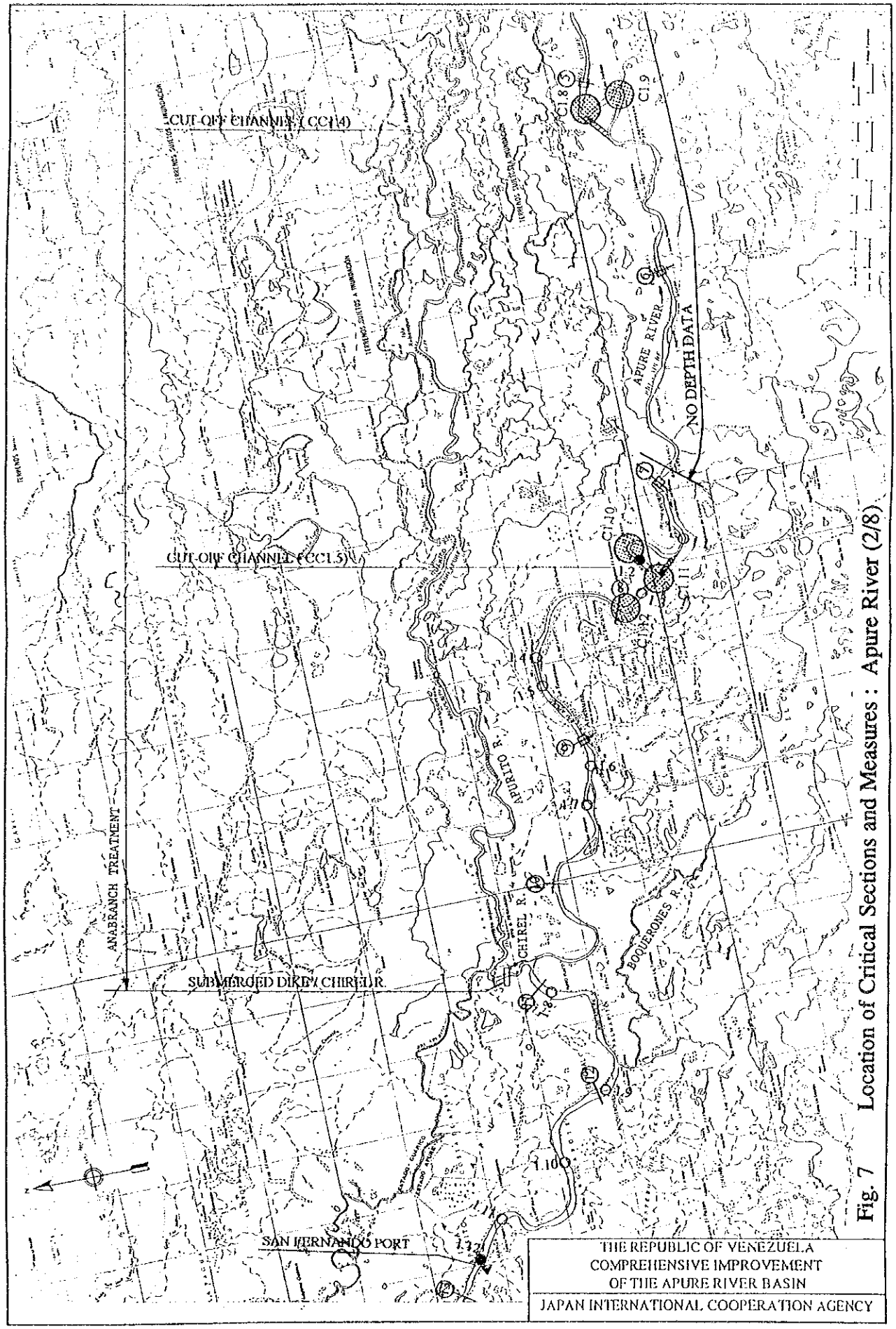

Fig. 7 Location of Critical Sections and Measures : Apure River (2/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

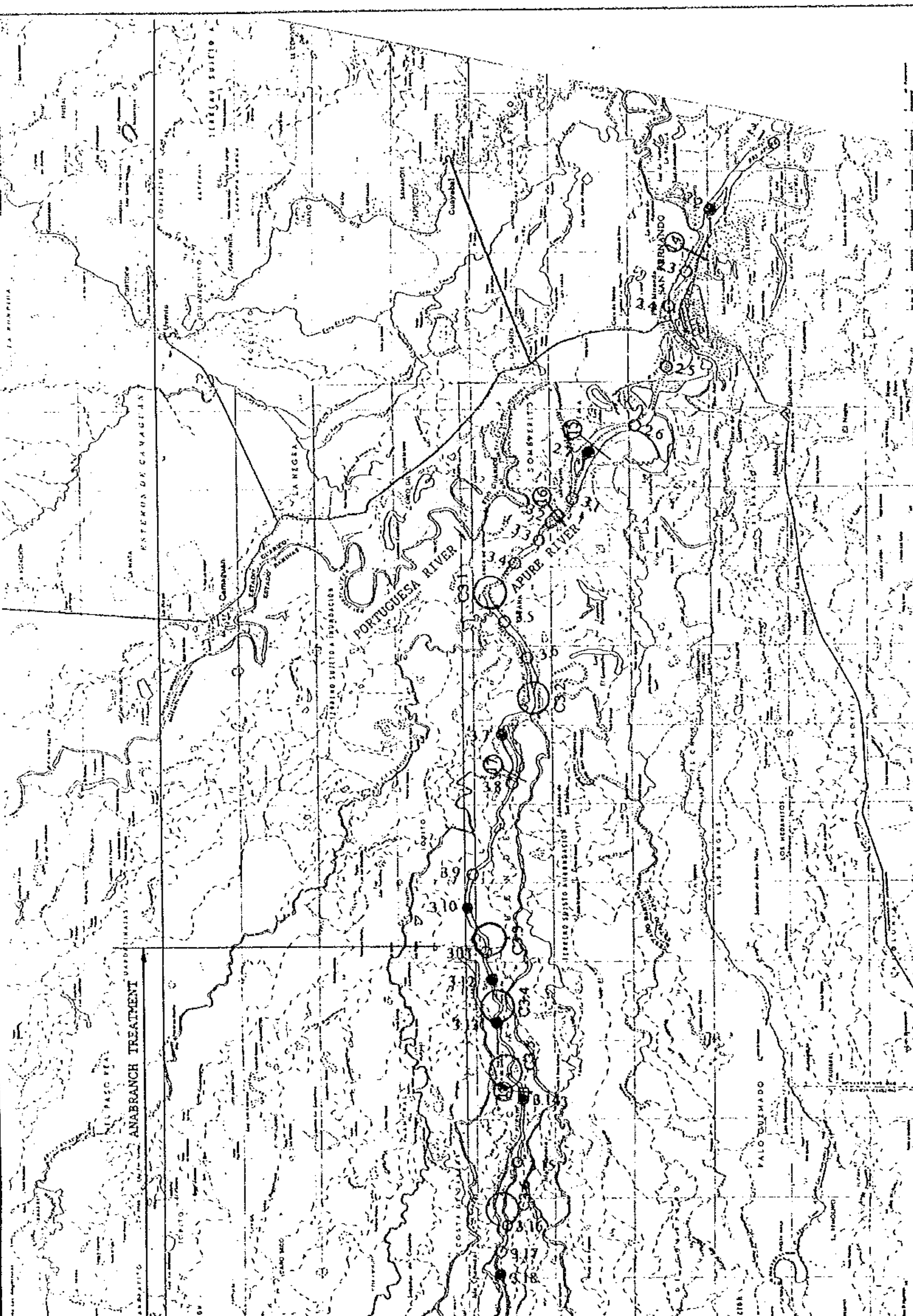

Fig. 7 Location of Critical Sections and Measures : Apure River (3/8)

THE REPUBLIC OF VENEZUELA
COMPREHENSIVE IMPROVEMENT
OF THE APURE RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

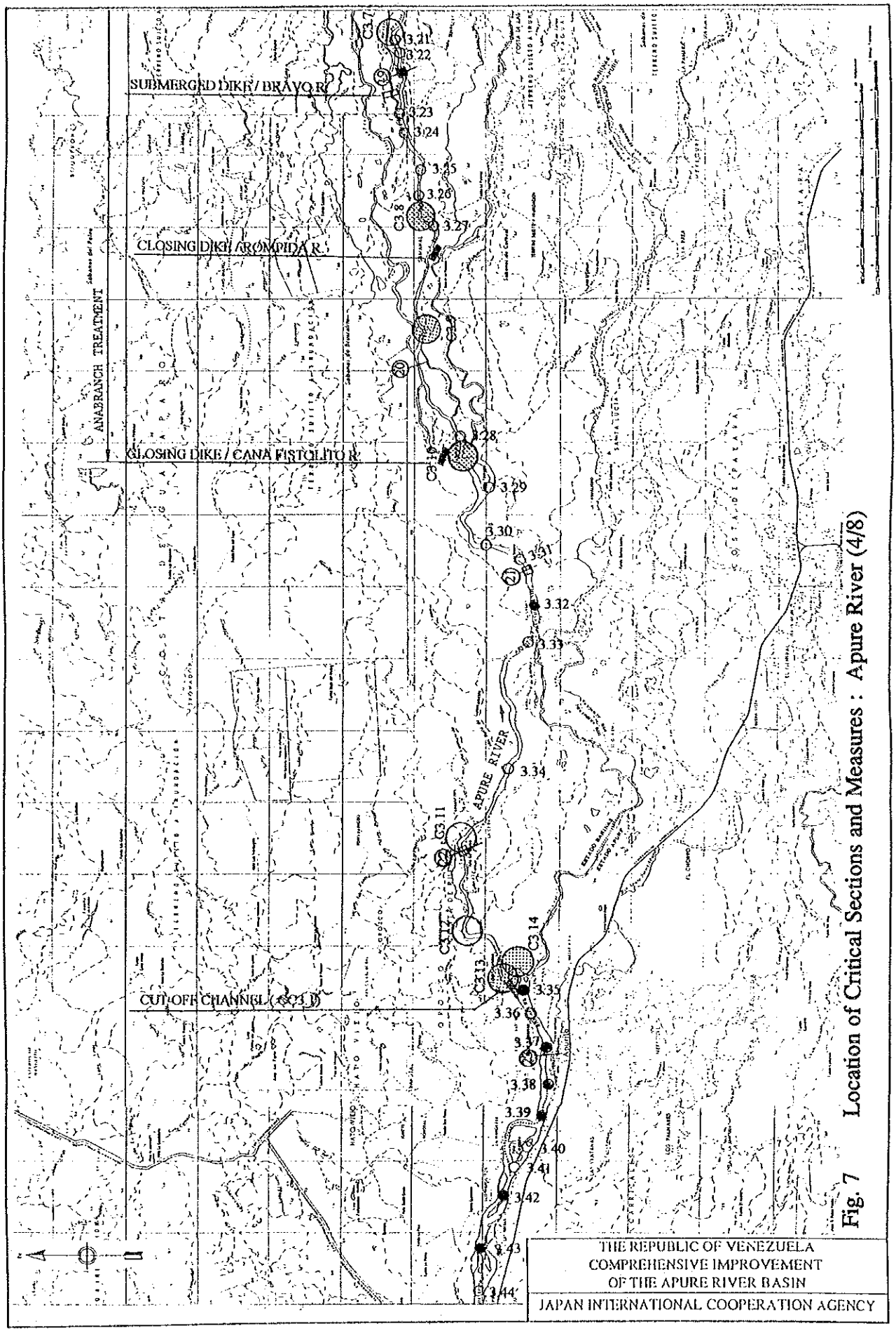

Fig. 7 Location of Critical Sections and Measures : Apure River (4/8)

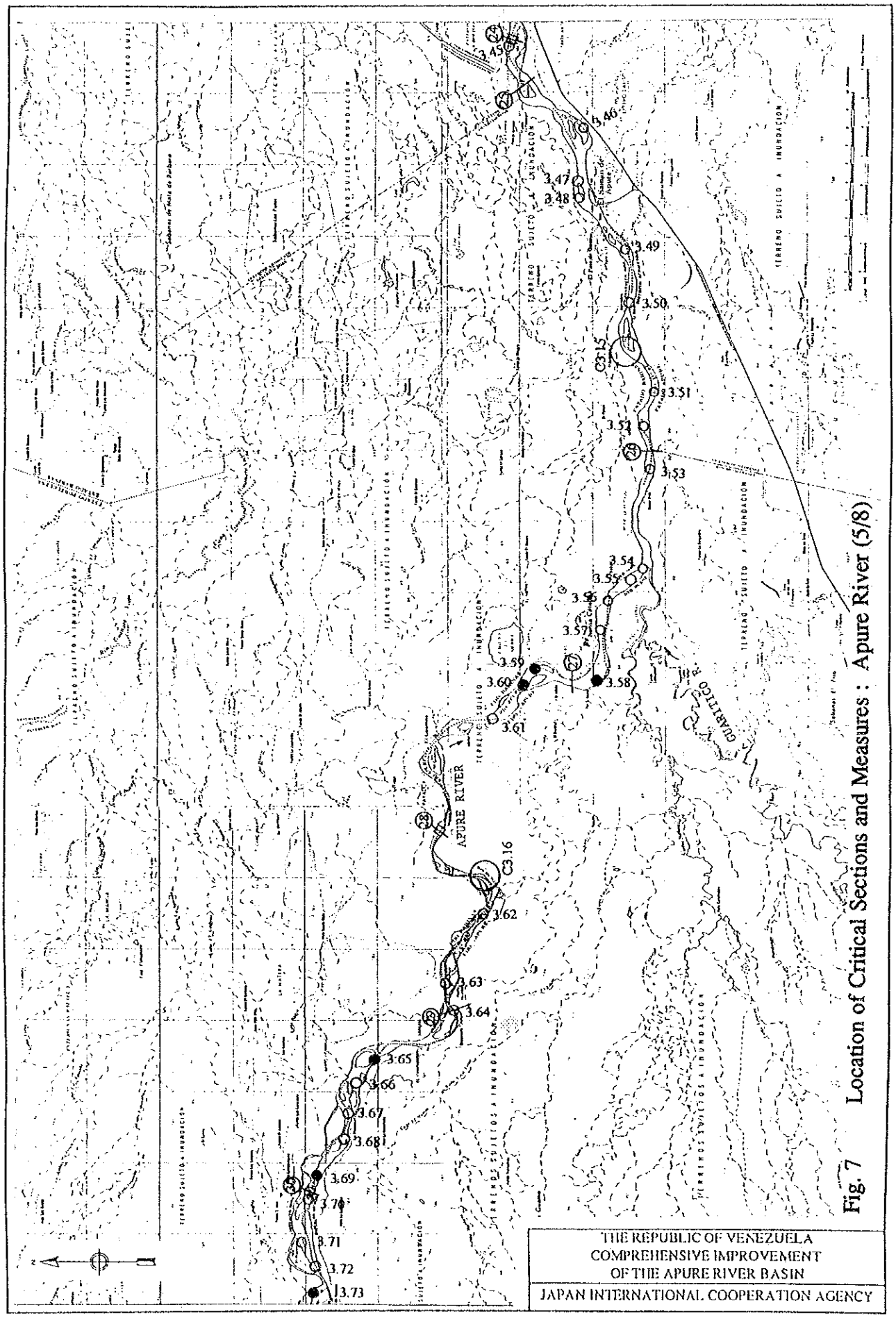

Fig. 7 Location of Critical Sections and Measures : Apure River (5/8)

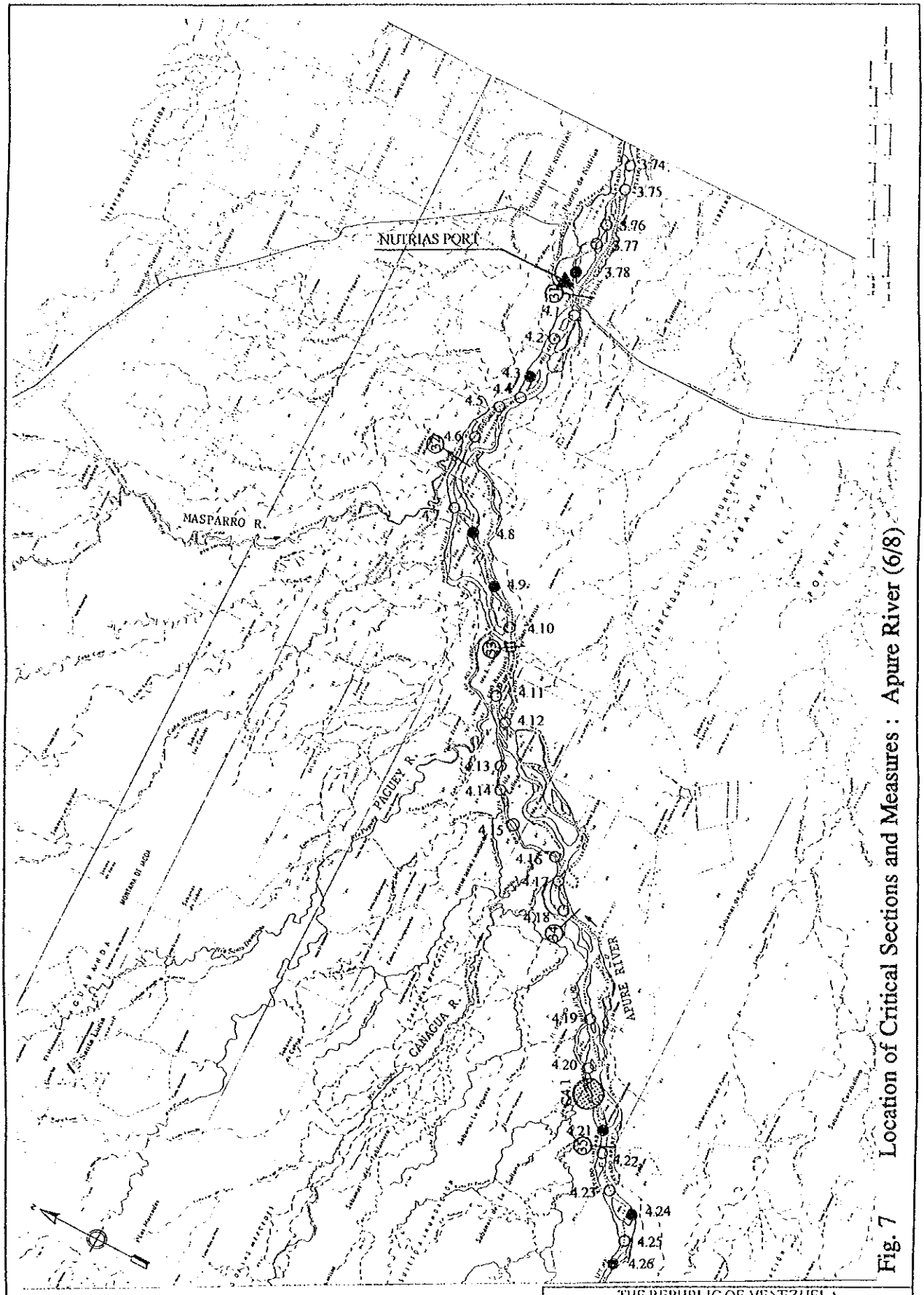

Fig. 7 Location of Critical Sections and Measures : Apure River (6/8)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

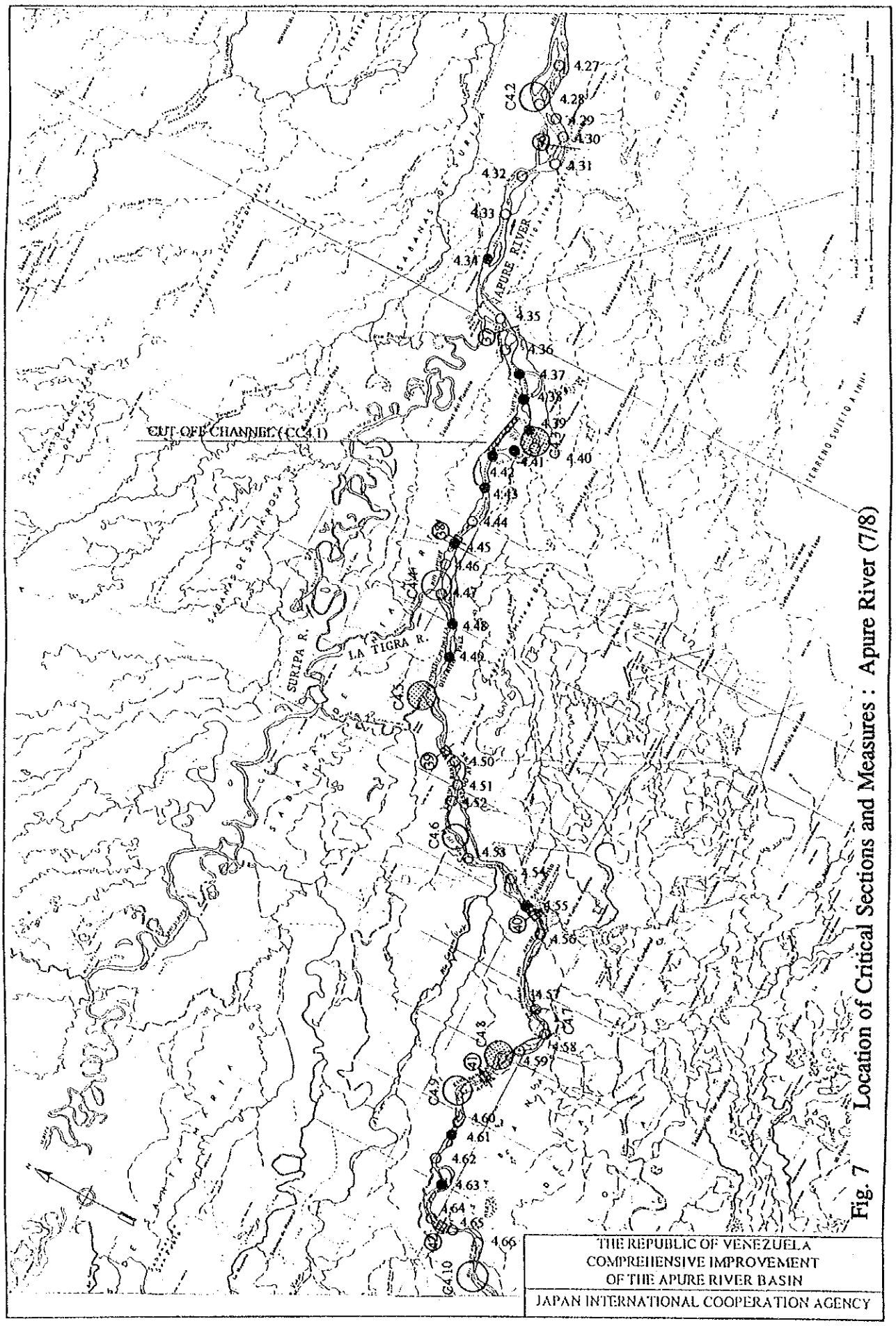

Fig. 7 Location of Critical Sections and Measures : Apure River (7/8)

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

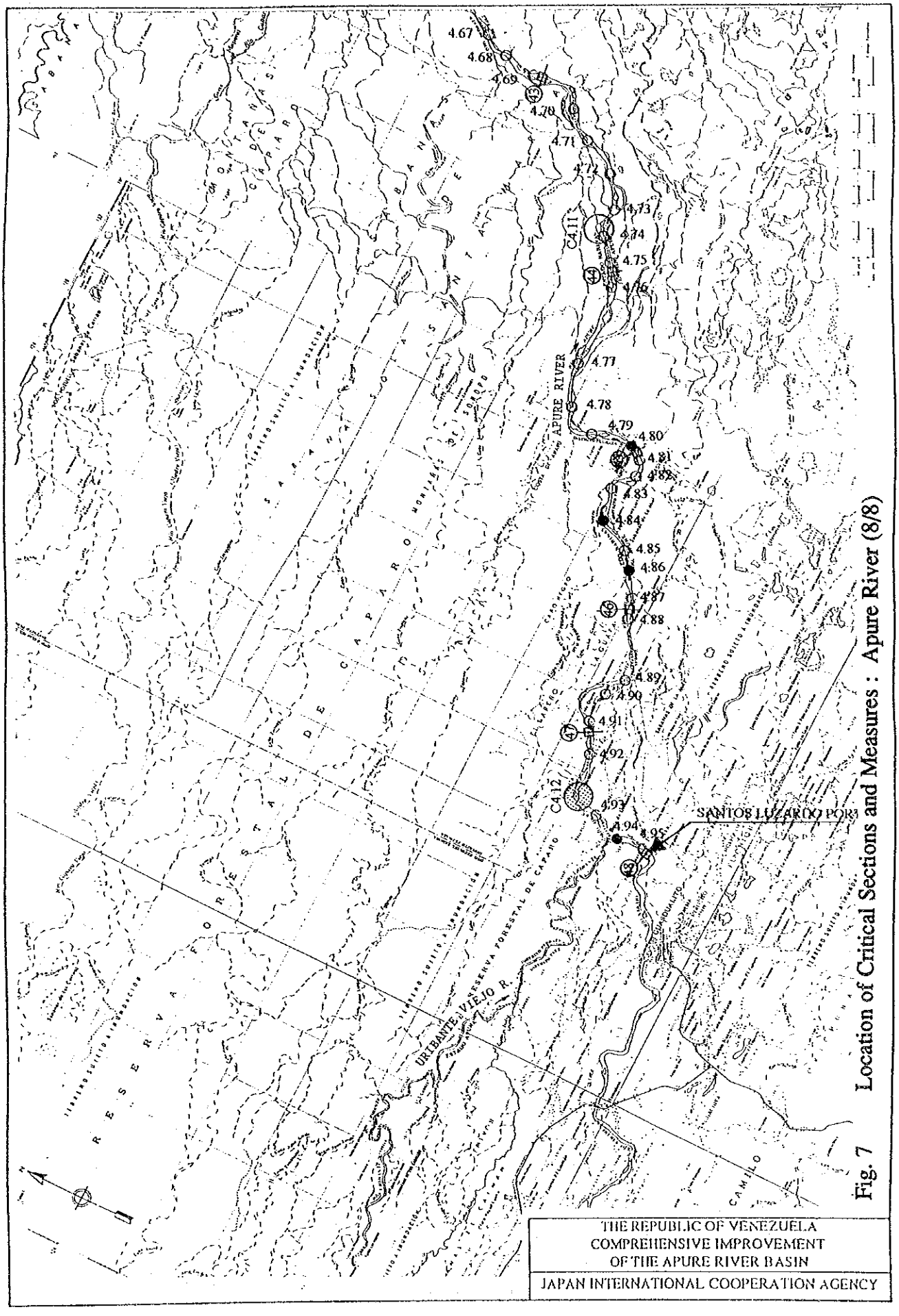

Fig. 7 Location of Critical Sections and Measures : Apure River (8/8)

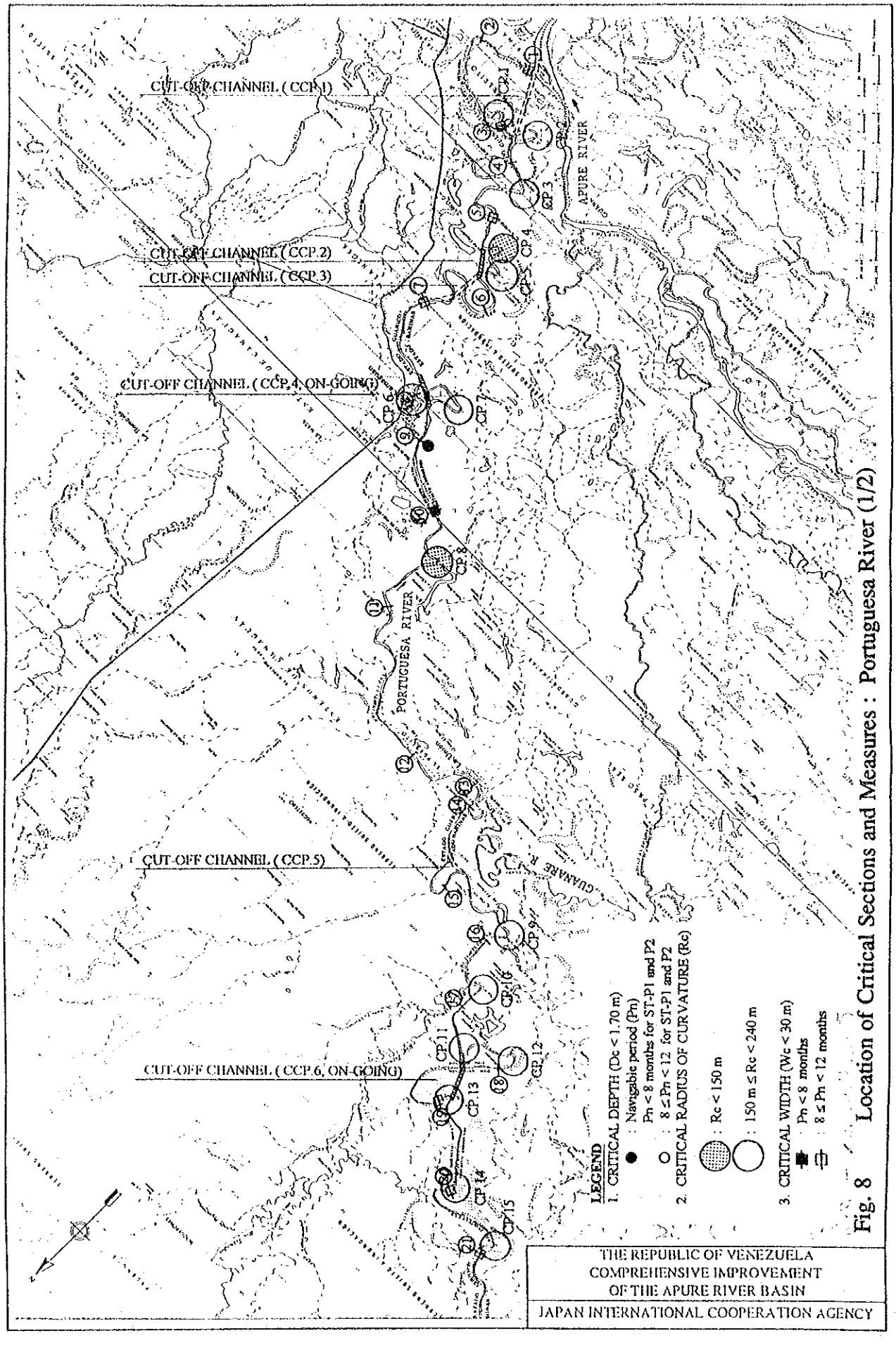

Fig. 8 Location of Critical Sections and Measures : Portuguesa River (1/2)

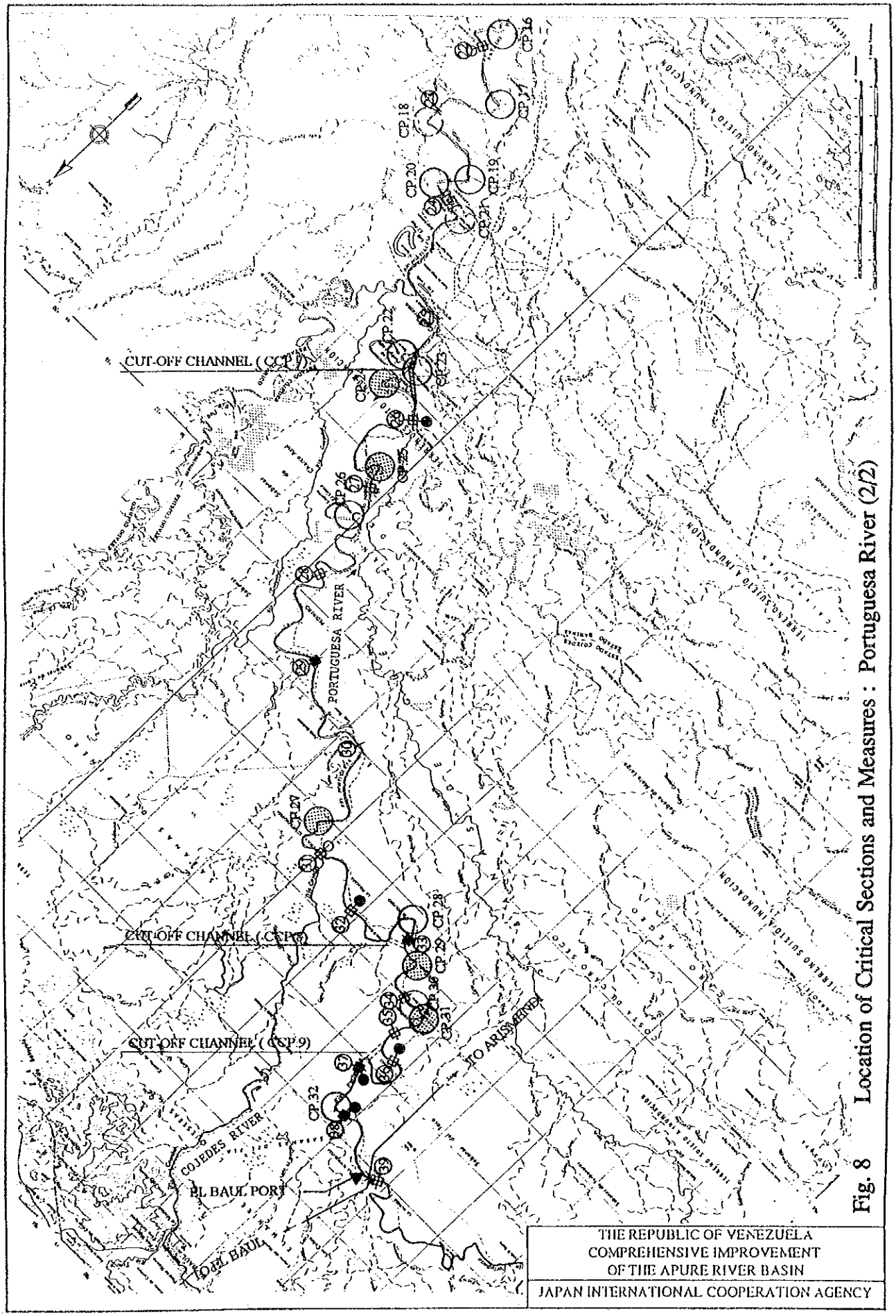

Fig. 8 Location of Critical Sections and Measures : Portuguesa River (2/2)

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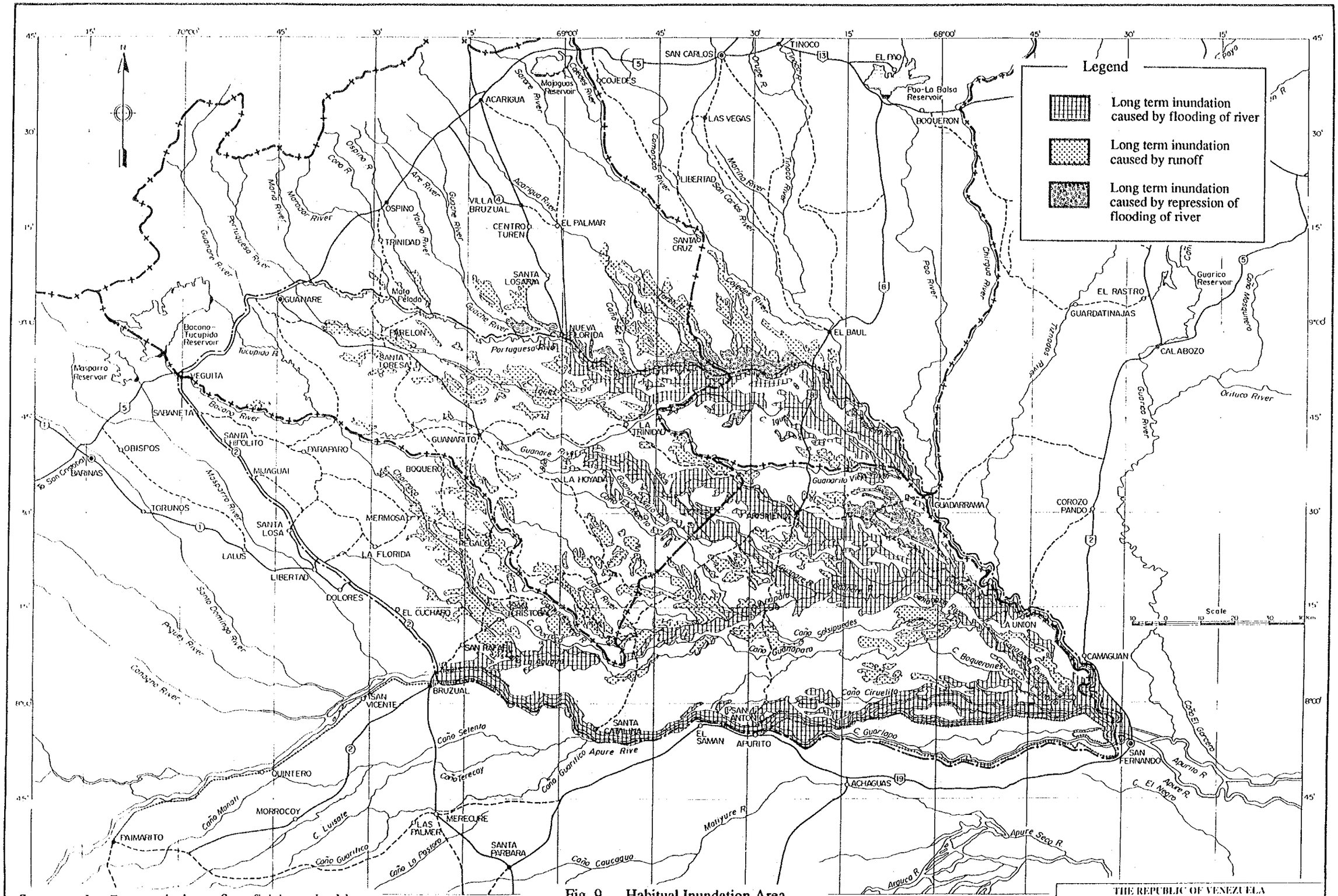
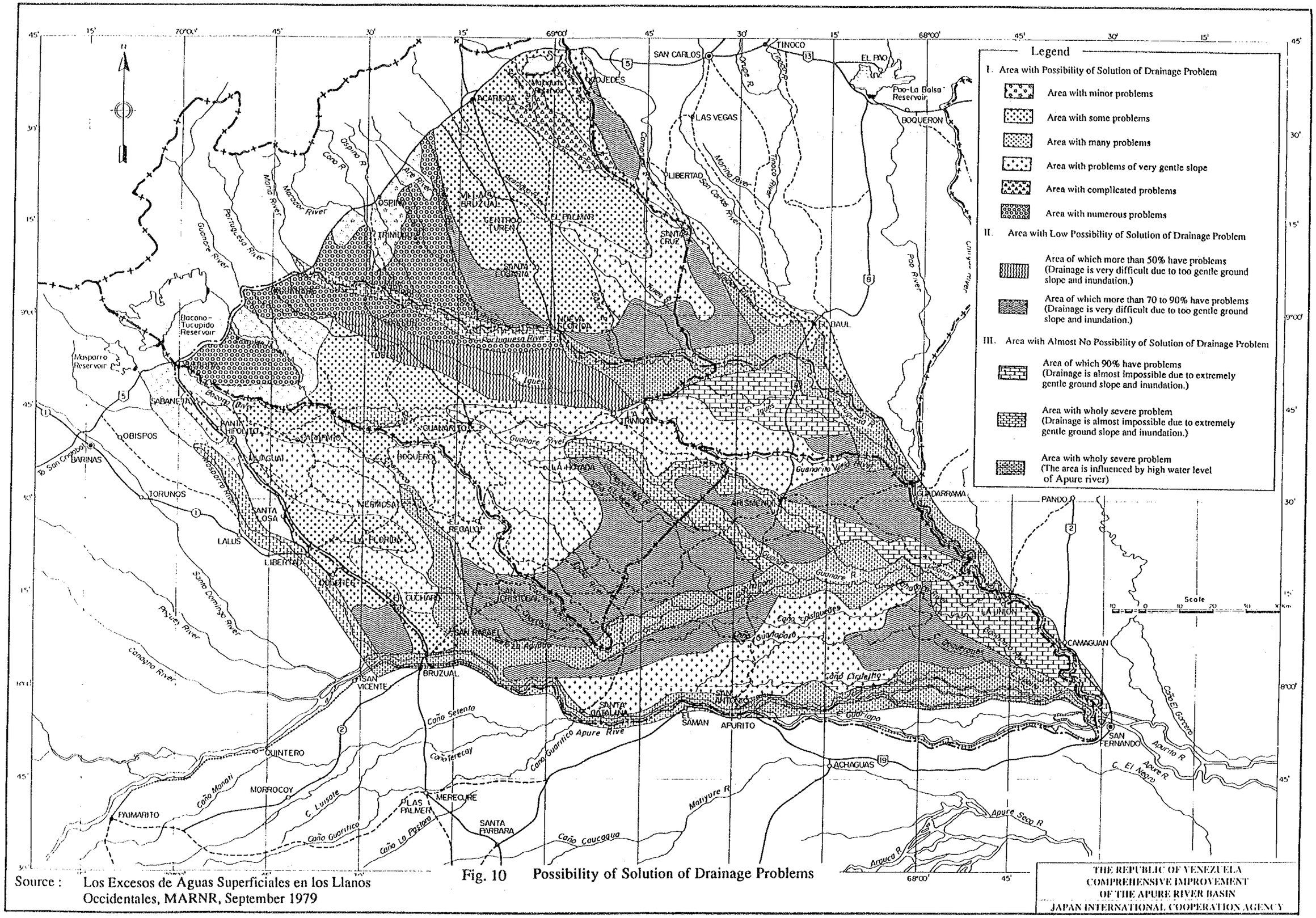


Source : Los Excesos de Aguas Superficiales en los Llanos Occidentales, MARNR, September 1979

Fig. 9 Habitual Inundation Area



Source : Los Excesos de Aguas Superficiales en los Llanos Occidentales, MARNR, September 1979

Fig. 10 Possibility of Solution of Drainage Problems

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