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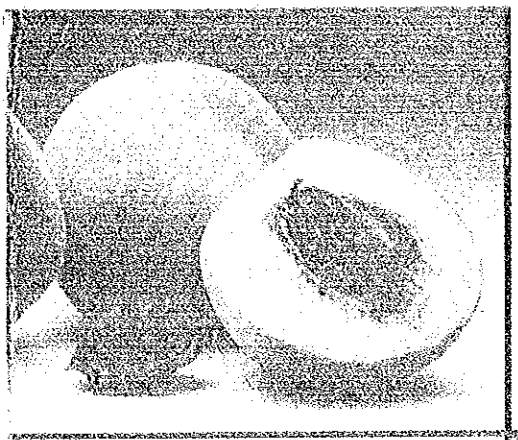

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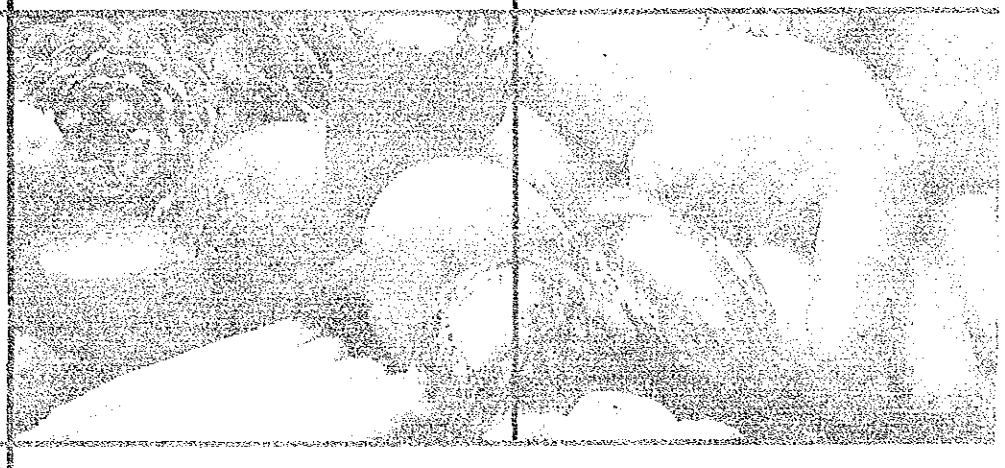
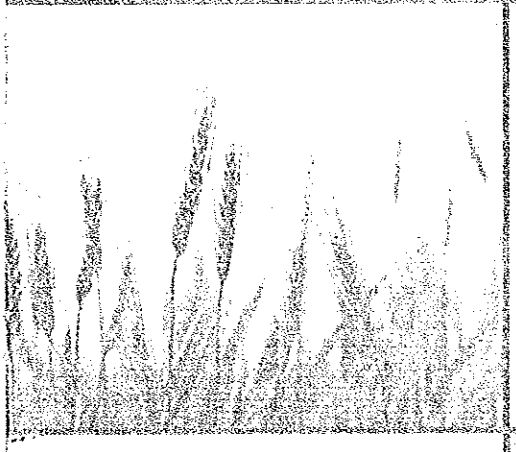


FEASIBILITY STUDY ON MAPOCHO RIVER BASIN AGRICULTURAL DEVELOPMENT PROJECT

VOLUME I: MAIN REPORT

JULY 1986



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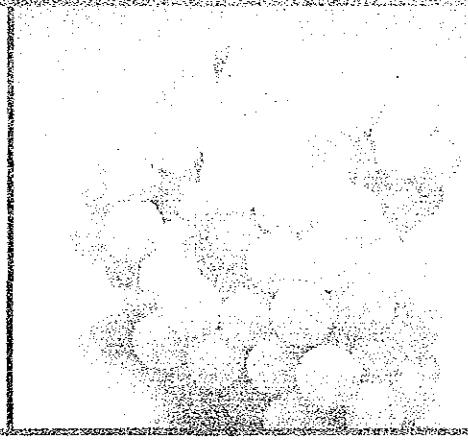

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MINISTRY OF AGRICULTURE

FEASIBILITY STUDY
ON
MAPOCHO RIVER BASIN
AGRICULTURAL DEVELOPMENT PROJECT

VOLUME I :
MAIN REPORT

JULY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

国際協力事業団	
受入月日 '86.10.03	704
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P R E F A C E

It is with great pleasure that I present this Feasibility Study Report on the Mapocho River Basin Agricultural Development Project to the Government of the Republic of Chile.

This report embodies the result of a field survey and detailed analysis in Japan which were carried out from January 1985 to July 1986 by a Japanese survey team sent to Chile by Japan International Cooperation Agency following the request of the Government of Chile to the Government of Japan.

The survey team, headed by Prof. Shoji Kanatsu, had series of close discussions with the officials concerned of the Government of Chile and conducted a wide scope of field survey. After the team returned to Japan, further studies were made and the this report has been prepared.

I hope that this report will be useful as a basic reference for development of the region and contribute to the promotion of friendly relations between our two countries.

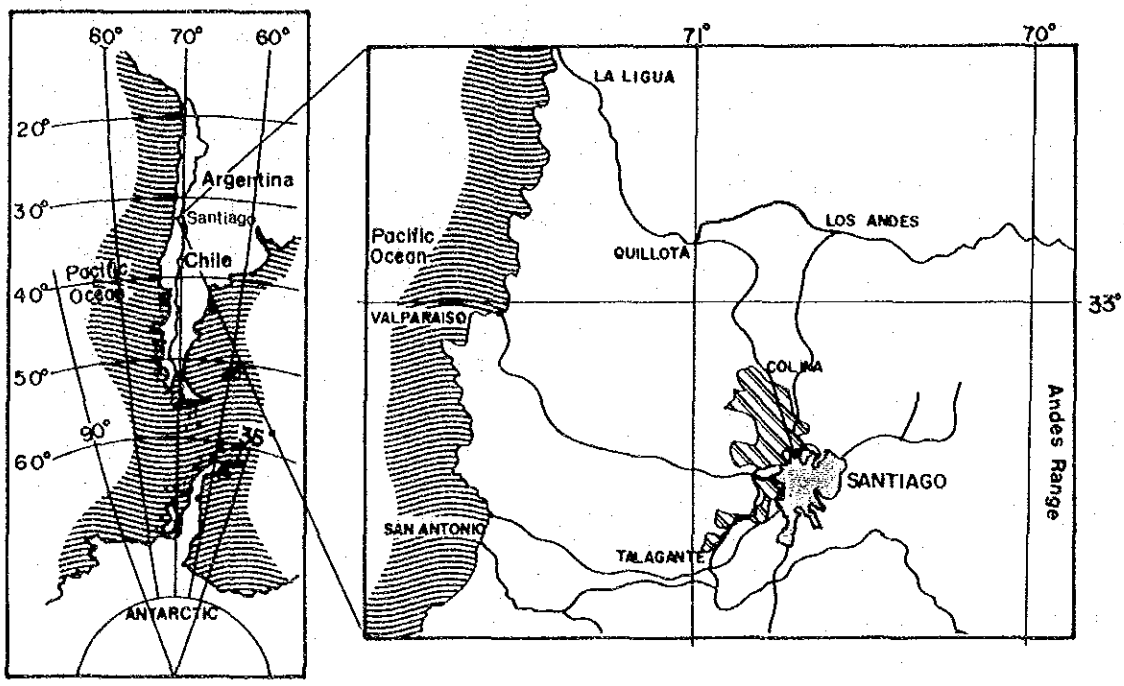
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Chile for their close cooperation extended to the Japanese team.

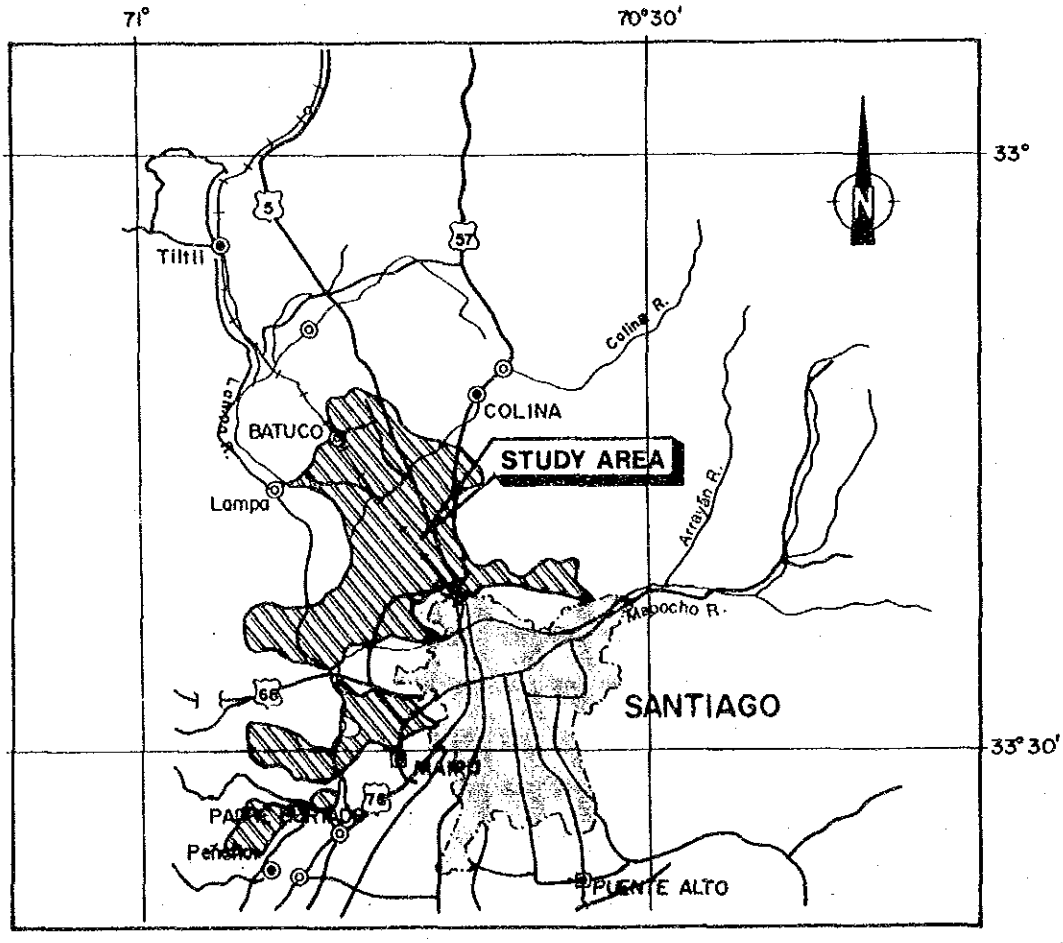
July, 1986

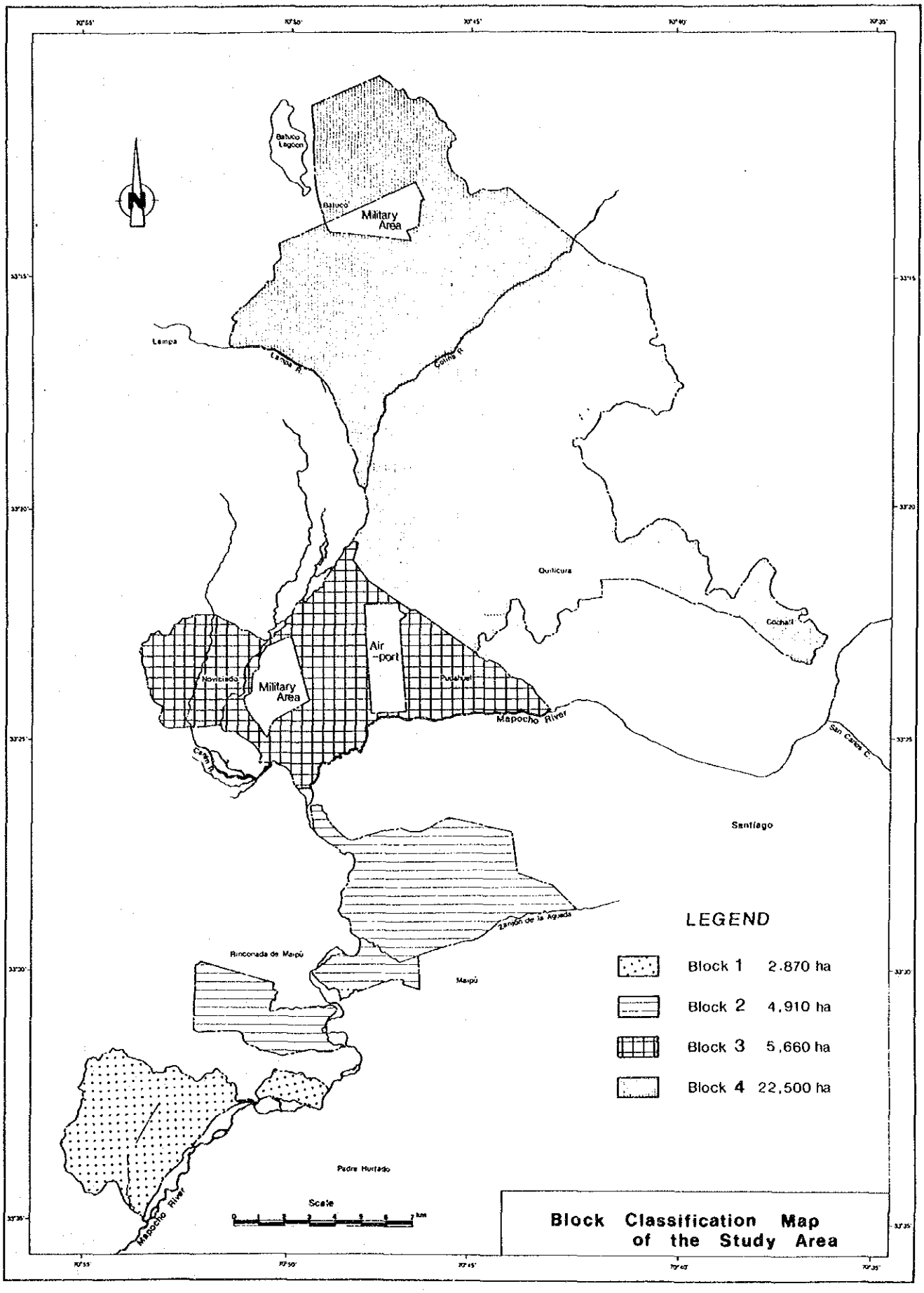
Keisuke Arita

KEISUKE ARITA
President
Japan International Cooperation Agency

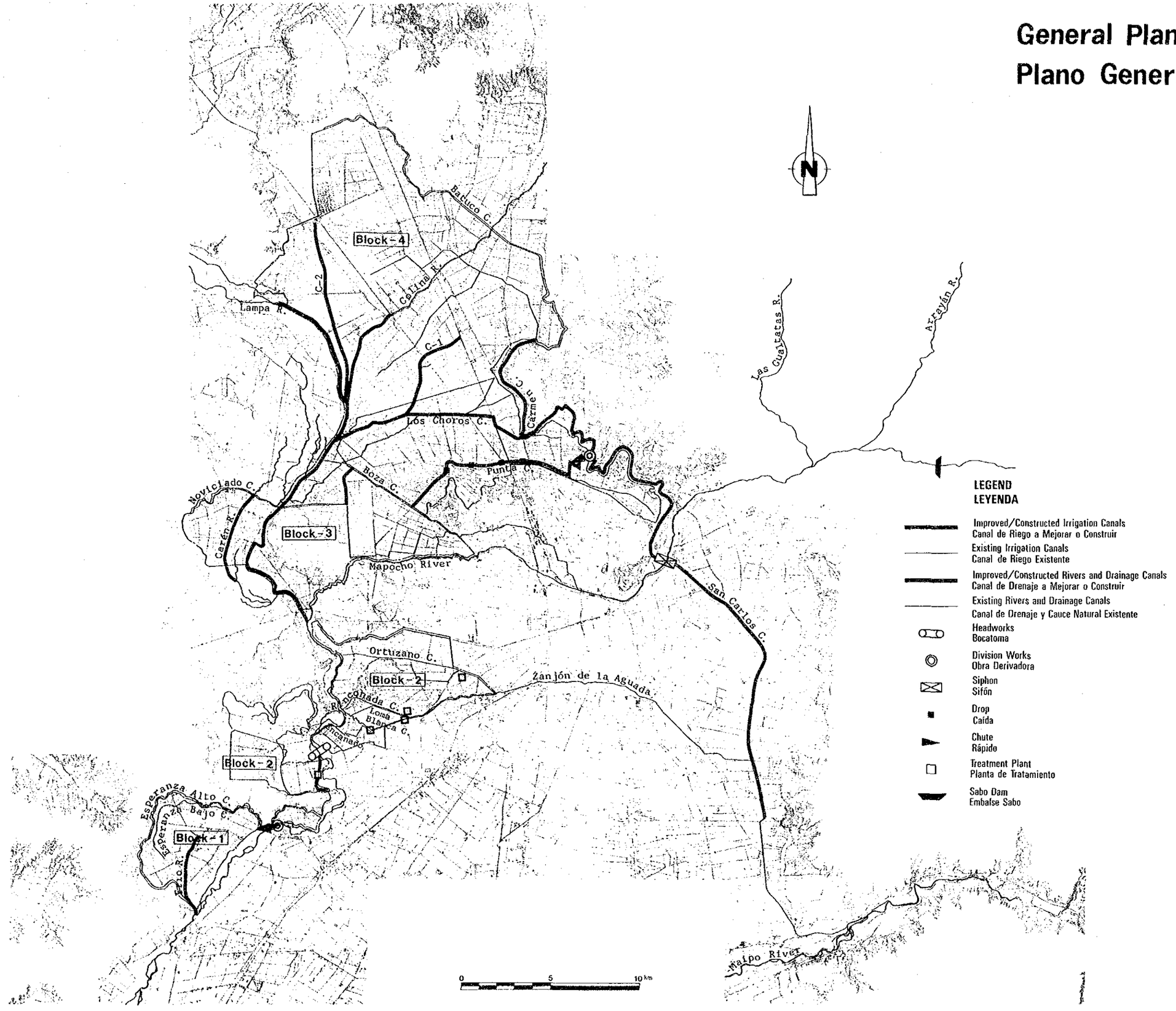
LOCATION MAP OF STUDY AREA






Baluco Lagoon
Baluco
Military Area
Lampa
Lampa R.
Colina R.
Quilicura
Cochaf
Air -port
Military Area
Noviciado
Pudahuel
Mapocho River
San Carlos C.
Santiago
Rinconada de Maipú
Maipú
Padre Hurtado
Mapocho River
LEGEND
Block 1 2.870 ha
Block 2 4,910 ha
Block 3 5,660 ha
Block 4 22,500 ha
Scale
Block Classification Map of the Study Area

General Plan
Plano General



LEGEND
LEYENDA

- Improved/Constructed Irrigation Canals
  Canal de Riego a Mejorar o Construir
- Existing Irrigation Canals
  Canal de Riego Existente
- Improved/Constructed Rivers and Drainage Canals
  Canal de Drenaje a Mejorar o Construir
- Existing Rivers and Drainage Canals
  Canal de Drenaje y Cauce Natural Existente
- Headworks
  Bocatoma
- Division Works
  Obra Derivadora
- Siphon
  Sifón
- Drop
  Caída
- Chute
  Rápido
- Treatment Plant
  Planta de Tratamiento
- Sabo Dam
  Embalse Sabo

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

1. INTRODUCTION

This is a summary of the Feasibility Study on the Mapocho River Basin Agricultural Development Project. The report of this Study consists of the following three volumes:

Volume I: Main Report
Volume II: Appendix
Volume III: Drawings

2. BACKGROUND

2.1 The share of the agricultural sector to the GDP of the Republic of Chile (hereinafter referred to as Chile) was only 9% in 1984. However, the agricultural sector plays an important role for the economy of Chile due to high percentage of labour employment.

2.2 Recently, the production of traditional agricultural products such as wheat has stagnated due to the increase of importation of those items. The balance of international payments has been impressed by the expansion of the importation of foodstuffs such as wheat, maize and sugar. On the other hand, cultivated area and yield of cash products such as vegetables and fruit have increased and exportation of such products is also expanding.

2.3 In order to realize the agricultural policies, the Government has improved the economic measures in connection with customs duties, prices of agricultural products, agricultural credits, etc. and is improving the irrigation/drainage facilities and infrastructures with the financial assistance from WB and IBRD.

2.4 The agricultural area near Santiago city is very important as both fresh-vegetable supply source for the Metropolitan Region and export item (fresh fruit, wine, etc.) production base. However, the following agricultural problems exist in the area and urgent counter-measure are expected:

a. Frequent inundation and insufficient drainage;

b. Shortage of irrigation waters;

c. Irrigation with polluted waters from urban area; and

d. Existence of problem soils

2.5 By eliminating or minimizing these problems, the agriculture in the area near Santiago city will increase the income and improve the living standard mainly of small-scale farmers, and will greatly contribute to the socio-economy of the country in a long run.

2.6 In this connection, the government of Chile in May 1984 requested the Government of Japan to undertake the feasibility study for the Mapocho River Basin Agricultural Development Project (Study). In response to this request, the Government of Japan dispatched a Scope of Work Mission to Chile to study this matter and decided to accept the request. The Scope of Work (S/W) for the Study was discussed and signed by and between both parties on October 4, 1984.

2.7 In accordance with the above S/W, the Government of Japan sent a Study Team to Chile to carry out the feasibility study of the Project between January and December 1985.

3. BRIEF DESCRIPTION OF THE STUDY AREA

3.1 The Study Area (the Area) is mainly agricultural land and other related areas of about 36,000 ha located adjacent to Santiago city along the midstream section of the Mapocho river and downstream section of the Lampa and Colina rivers, which were selected from the First Phase study area of about 61,000 ha.

The Area is divided into four blocks due to present irrigation systems as follows:

Block-1:	2,870 ha
-2:	4,910
-3:	5,660
-4:	22,500
Total Study Area:	35,940 ha

3.2 The Study Area is included in a zone influenced by Mediterranean Climate of Central Chile which is generally mild. Annual rainfall is approximately 400 mm in Santiago city area. Rain falls mainly in winter, with little or none during the summer months. The volume of evaporation in summer is ten times that of winter. The average temperature is approximately 20°C in summer and 10°C in winter, and the temperature range in one day is approximately 15°C. Relative humidity is 55% in summer and increases to 80% in winter, the rainy season.

3.3 The main rivers in the Area are the Mapocho river and its branch streams, the Lampa and Colina rivers. The hydrological characteristics of them are:

a. The discharge of the Mapocho river has two main sources; snowmelt in summer and rainfall in winter. In spite of the fact that rainfall is almost none in summer, the discharge of snowmelt is bigger than that in winter.

b. There is scarce snow in the Lampa river basin. Therefore, the discharge of the Lampa and Colina rivers is only the rainfall in winter and that in summer is very scarce.

Name of River	Catchment Area (km^2)	Stream Length (km)	Altitude of Headwaters (m.A.S.L.)	Annual Mean Discharge (6.7 year return period) (m^3/s)	Flood Flow (6.7 year return period) (m^3/s)
Mapocho	1,370 1/	76	+5,200	12.0 2/	430
Lampa	2,390	78	+2,300	0.38 3/	580
Colina	460	52	+3,700	-	130

1/ Up to the confluence with Lampa river

2/ Rinconada de Maipú Station (A=4,068 km^2)

3/ Polpaico en Chicauma Station (A=1,098 km^2)

3.4 The Area is located in the north of the Central Valley. It presents a flat topography with a slight gradient to the south and southwest. It is formed by fluvial and glaciofluvial sediments, primarily coming from the Mapocho, Lampa and Colina rivers.

3.5 In the Area, the groundwater appears at different levels, the high level is found at flat terrains and the low level at piedmonts. Groundwater is mainly used for domestic purpose. However, it is also used for supplemental irrigation waters in some areas.

3.6 The Area is classified on the basis of the soil suitability classification, topography, flooding extent and actual landuse limit. Of the total Study Area of 35,940 ha, the irrigable, non-irrigable, agricultural facilities and alienated areas are 20,180 ha, 7,680 ha, 860 ha and 7,220 ha, respectively.

Land Suitability Classification

(Unit: ha)

Division	Class	Area				
		Block-1	Block-2	Block-3	Block-4	Total
1 Irrigable Area	I	-	200	240	775	1,215
	II	30	1,800	890	3,850	6,570
	III	1,670	790	1,170	3,020	6,650
	IV	960	130	850	3,805	5,745
	Sub-Total	2,660	2,920	3,150	11,450	20,180
2 Non-irrigable Area	IIIsa[1]	-	-	-	1,845	1,845
	IVsa	-	-	210	3,835	4,045
	V	-	-	-	-	-
	VI	-	300	1,090	250	1,640
	VII	-	30	-	120	150
	Sub-Total	-	330	1,300	6,050	7,680
3 Agricultural Facilities Area		90	200 (30)	120 (20)	450 (60)	860 (110)
Total of Agricultural Land (1 - 3)		2,750	3,450	4,570	17,950	28,720
4 Alienated Area	Urbanized	120	320	270	1,500	2,210
	To be urbanized	-	1,140	610	2,120	3,870
	VIII[2]	-	-	210	930	1,140
	Sub-total	120	1,460	1,090	4,550	7,220
Grand Total (1 - 4)		2,870	4,910	5,660	22,500	35,940

Note: 1. Figures in ( ) are hectarages of the areas to be urbanized, which are included in the agricultural facilities area.

2. 1/ sa: High saline and alkaline concentrated area
2/ Alienated areas of lagoons and swamps

3.7 The quality of the existing irrigation waters used in the Area is summarized below:

Source of Irrigation Water	Water Quality
Maipo River	Usable for irrigation
Mapocho river and Zanjón de la Aguada	Not recommended to use waters for irrigation without treatment due to the contamination with coliform groups and heavy metals.

3.8 In the Area, most of the farmers are small-scale households whose holdings are less than 12 ha. They are the holders of title deeds of the land. There is a fairly large number of holders of very small pieces of land (ie, less than 2 ha). They work with the big land owners as agricultural labourers or ranch hands, and in return, they receive farm land with houses. The farm is utilized mainly for their subsistence agriculture.

3.9 The Area is 35,940 ha in total, of which about 32,590 ha, 91% of the total, are presently used as agricultural land. About 50% of the agricultural land are upland fields and the rest are pastures. Most of the upland fields are ordinary ones and the rest are classified as orchards and vineyards. The Area is located near Santiago city and about 9% of the Area has been urbanized. With the expansion of the urban area, the agricultural land in the Area has been changing rapidly into other land categories.

Present Landuse

(Unit: ha)

Block No.	Agricultural Land							Others 2/	Grand Total
	Upland Field				Pasture	Others 1/	Sub-Total		
	Ordinary Field	Orchard	Vine-yard	Sub-Total					
1	1,690	30	40	1,760	900	90	2,750	120	2,870
2	3,180	120	430	3,730	660	200	4,590	320	4,910
3	2,030	100	170	2,300	2,760	120	5,180	480	5,660
4	7,430	520	650	8,600	11,020	450	20,070	2,430	22,500
Total	14,330	770	1,290	16,390	15,340	860	32,590	3,350	35,940

1/ includes farmhouses, farm roads, secondary and lateral irrigation canals, drainage canals, etc.

2/ includes urban areas, main roads, main canals, rivers, ponds, swamps, garbage disposal areas, etc.

3.10 Agricultural activity in the Area has the characteristics of intensive suburban agriculture. It has the advantage of being situated relatively near the sea ports and next to the airport for export of agro-products. Cereals, vegetables and forage crop are grown in ordinary fields. Vineyards and orchards are also cultivated in the upland field. The rest is covered by natrual pasture.

The planted area of vegetable covers approximately 20% of upland field, which is one of the features of suburban agriculture. Small holders grow more vegetables per holding. Yet, the planted area of vegetable tends to be on the decline. On the other hand, the planted area of wheat, for which the Government gives incentives, and of fruit trees including table grapes, whose export outshines other items, is on the increase.

3.11 If the present single cropping pattern is adopted as the basis of analysis, the present available river water will be sufficient for the supply of water to the existing upland field, except in

Block-1. However, shortage of water will affect also Block-4 because of the present small capacity of the carmen canal. If the proposed double cropping pattern is adopted, the shortage of irrigation waters will occur in Blocks-1,3 and 4.

3.12 The inundation and flood damages in the Area have occured mostly in the following three areas:

"a" Santiago city along the Mapocho river

"b" Areas along the San Carlos canal and Zanjón de la Aguada

"c" Agricultural land along the Lampa and Colina rivers.

The 1982 flood occured due to the snowmelt because of the high temperature in the upper basin in addition to the heavy rain in the watershed, causing the large flood damage mainly in the areas "a" and "b" mentioned above.

On the other hand, the 1984 flood occured due to the heavy rain in the mountainous area of the Lampa river basin, causing the big flood damage in the area "c" mentioned above. Furthermore, the area "c" has inundation damages almost every year due to the topographic demerits, existence of impervious soils and lack of drainage canals.

3.13 The farm roads in the Area have gravel pavement and most of the bridges on the farm roads are wooden made. The density of the farm roads is sufficient except for those in Block-4.

4. PROJECT FORMULATION

4.1 The proposed landuse is prepared based on the result of the land suitability classification as shown in the following table:

Proposed Landuse

(Unit: ha)

Block		Agricultural Land						Others[2/]	Total
		Maximum/Minimum		Average		Others[1/]	Sub-Total		
		Upland Field	Pasture	Upland Field	Pasture				
1	Present	1,760	900	(1,760)	(900)	90	2,750	120	2,870
	Project	2,660	0	2,070	590	90	2,750	120	2,870
2	present	3,730	660	(3,730)	(660)	200	4,590	320	4,910
	Project	2,920	350	2,920	350	150	3,420	1,490	4,910
3	Present	2,300	2,760	(2,300)	(2,760)	120	5,180	480	5,660
	Project	3,150	1,290	3,150	1,290	110	4,550	1,110	5,660
4	present	8,600	11,020	(8,600)	(11,020)	450	20,070	2,430	22,550
	Project	11,450	6,040	11,250	6,240	400	17,890	4,610	22,500
Total	Present	16,390	15,340	(16,390)	(15,340)	860	32,590	3,350	35,940
	Project	20,180	7,680	19,390	8,470	750	28,610	7,330	35,940

1/ includes farmhouses, farm roads, secondary and lateral irrigation canals, drainage canals, etc.

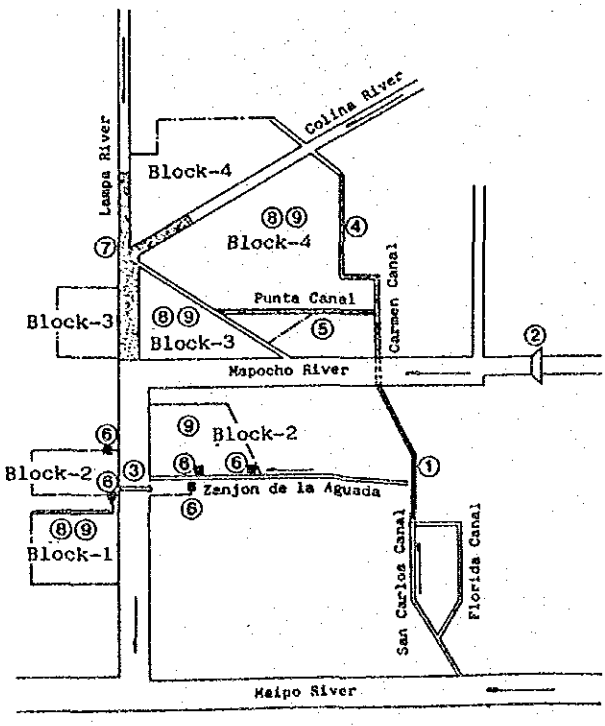
2/ includes urban area, main roads, main canals, rivers, garbage disposal area, etc.

4.2 present agricultural problems and the proposed countermeasures against them are summarized as follows:

present Problems and proposed Countermeasures

Objective Area	Inundation	Shortage of Irritation Water	Contamination of Irrigation Water	Saline/Alkaline Soil	Transportation
Project Area and Surrounding Areas including Santiago City	① ②	-	-	-	-
Block-1	⑧	③	⑥	-	⑨
Block-2	①	-	⑥	-	⑨
Block-3	② ⑦ ⑧	① ④ ⑤	④ ⑤	② ⑦ ⑧	⑨
Block-4	② ⑦ ⑧	① ④	-	② ⑦ ⑧	⑨

① Improvement of San Carlos Canal
② Construction of Sabo Dam
③ Construction of Headworks
④ Improvement of Carmen Canal
⑤ Construction of Punta Canal
⑥ Construction of Lagoon-type Treatment Plants
⑦ Improvement of Lampa and Colina Rivers
⑧ Improvement/Construction of Drainage Canals
⑨ Improvement/Construction of Farm Roads and/or Bridges



4.3 The proposed inundation control scheme is planned, as part of the drainage scheme, based on the flood of 6.7 year return period in coordination with the irrigation planning.

(1) Construction of a Sabo dam in the upper-reach section of the Mapocho river in order to maintain the flow capacity in the downstream section by stopping the sediment from the mountainous areas.

(2) Improvement of the San Carlos canal as the measures to prevent the flooding in Santiago city and its surrounding areas, as well as to increase the usable irrigation water.

(3) Improvement of the Lampa and Colina rivers to prevent the inundation in the Lampa river basin.

(4) Improvement of the Frío and Carén rivers and improvement/construction of drainage canals such as Choros canal as the drainage measures in the Project Area.

The effect of the proposed measures is summarized in the following table.

Inundation Area

Condition	Category of Land	Rainfall	
		July 1984	6.7 year return period
Non-improved	Agricultural Land	3,090 ha	2,700 ha
	Other Area	2,750	2,940
	Out of Project Area	1,940	2,000
	Total	7,780	7,640
Improved with Design Discharge	Agricultural Land	90	0
	Other Area	0	0
	Out of Project Area	90	0
	Total	180	0

4.4 The proposed irrigation scheme is planned based on the available water in 6.7 year return period. The following improvement/ construction works of the existing irrigation facilities are proposed in order to effectively utilize the existing available waters.

(1) For Block-1

a. Construction of Esperanza headworks

b. Construction/improvement of Esperanza canal

(2) For Block-3 and 4

c. Construction of Punta canal and siphon

d. Improvement of Carmen canal

e. Improvement of San Carlos canal

Any new water resources developments, however, are not proposed due to unfeasibility of them at this moment. The effect of the proposed measures is as follows:

Irrigation Area

Block	Present		Project		Increase	
	Irrigation Area (ha)	Available Irrigation Water (m^3/s)	Irrigation Area (ha)	Available Irrigation Water (m^3/s)	Irrigation Area (ha)	Available Irrigation Water (m^3/s)
1	950	1.4	1,190	1.4	240	0
2	2,920	6.6	2,920	7.4	0	0.8
3	2,170	3.2(7.4)	3,150	3.7	980	0.5
4	4,740	7.0(8.2)	10,080	11.9	5,340	4.9
Total	10,780	18.2	17,340	24.4	6,560	6.2

Note: ( ) shows the available waters obtainable from San Carlos canal with existing water rights.

4.5 The transfer of surplus irrigation water rights of the Punta canal to the Carmen canal is indespensable for the success of the proposed irrigation scheme.

4.6 The installation of five aerated lagoon type treatment plants, one for Block-1 and four for Block-2, is proposed in order to secure good irrigation waters.

The quality of the irrigation waters for Blocks-3 and 4 will be improved by changing the intake point of the Punta canal and with a improvement works to be conducted by EMOS, respectively.

4.7 The increase of farm roads in Block-4 and the improvement of existing farm road bridges and construction of some new bridges in all blocks are proposed to improve the transportation conditions of the agricultural products, etc.

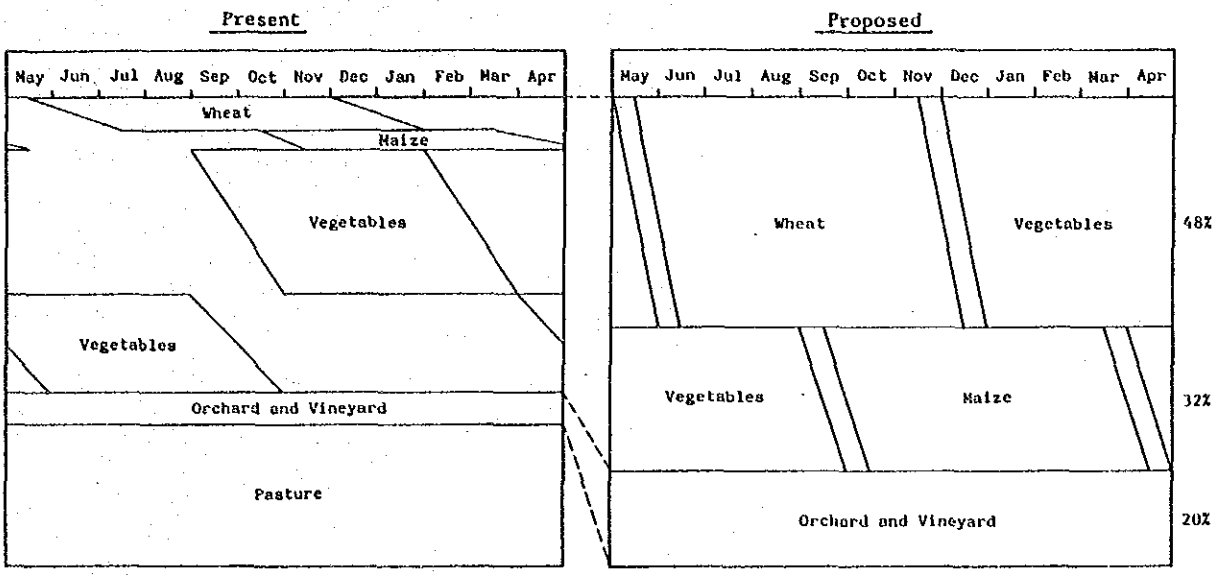
4.8 The planned main facilities are summarized in the following Table:

Summary of Main Facilities Planned

Objective Area	Facilities Planned		
	Facilities	Construction (C) or Improvement (I)	Description
Blocks-2, 3 and 4 and Surrounding Areas including Santiago City	San Carlos Canal	I	17.0 km
	Sabo Dam	C	1 lot (H=18^{m})
Block-1	Esperanza Headworks	C	1 lot (W200^{m} x H1.5^{m})
	Esperanza Irrigation Canal	C and I	C: 1.7 km, I:0.25 km
	Treatment Plant	C	1 location (V=270,000m^{3}/day)
	Frio River	I	5.0 km
	Farm Road Bridge	I	16 units
Block-2	Treatment Plant	C	4 locations (V total = 380,000m^{3}/day)
	Farm Road Bridge	I	18 units
Block-3 and Block-4	Siphon	I	L240^{m} x W2.3^{m} x H2.3^{m}
	Carmen Irrigation Canal	I	27.4 km
	Punta Irrigation Canal	C	14.7 km
	Lampa River	I	24.0 km
	Colina River	I	5.9 km
	Carén River	I	5.8 km
	Choros Canal	I	12.4 km
	C-1 Drainage Canal	C	6.5 km
	C-2 Drainage Canal	C	10.0 km
	Farm Road	C	52.0 km
	Farm Road Bridge	C and I	C: 11 units, I: 25 units

4.9 The farming plan is prepared mainly for the small-scale farmers who hold agricultural land of less than 12 ha, in consideration of the present agricultural conditions in the Project Area.

The proposed cropping pattern is prepared for the average small-scale farmers (in Blocks-2, 3 and 4) as follows:



4.10 By implementing the Project, the net production values in the farmer's level will be increased in the range of 3.2 - 3.8 times the without project situation. The agricultural incomes per farmer will reach 3.1 - 3.7 times the without project situation. The incomes of farm household are expected to increase to the level of 3.1 - 3.5 times, and the expected farmer's economic surplus is anticipated to increase to the range of more than 5.6 - 6.5 times the without project situation level.

5. PROJECT IMPLEMENTATION

5.1 The overall construction period will be sixty (60) months, which consists of eighteen (18) months for detailed design phase and forty-two (42) months for construction phase.

In the course of the detailed design phase, topo-survey and mapping of the Project Area, detailed design including geological

and detailed topographic survey of proposed sites for main structures, preparation of tender documents, etc. will be carried out. Land acquisition, tender evaluation, execution of construction works procurement of equipment for operation and maintenance, etc. are to be envisaged during construction phase.

5.2 The land required for the construction of the facilities and structures such as headworks, treatment plants, new Punta Canal, drainage canals, farm roads, etc. should be acquired by the Chilean Government before the commencement of the respective construction works.

5.3 A contractor will be selected by means of international tendering for the execution of the construction works. The construction machinery and materials are to be procured from domestic and/or international markets under the responsibility of the contractor. Six months are allocated for tendering and tender evaluation.

5.4 In order to facilitate the implementation and operation of the Project, the project-related tasks such as design, construction planning and supervision of construction works should be concentrated to one organization. In this connection, it is advised that the Water Resources Department of the MOP plays the leading role in organizing an executing agency, because irrigation and drainage systems constitute the mainstay of civil engineering works of the Project. Furthermore, with a view that the Project principally aims at the agricultural development, the MOP, in collaboration with the MA, should coordinate the implementation of the Project with other public institutions like: MINVIU, MBN, ODEPA, CNR, EMOS, CONAF, etc. In addition, the participation of the Metropolitan Government is expected with relation to governmental arrangements.

5.5 Consultants should be employed by the Executing Agency for rendering consulting services. The consulting services involve the detailed design in the detailed design phase and evaluation of tendering and supervision of construction works such as their

workmanship, programming and safety control in the construction phase.

5.6 For the purpose that proposed facilities/structures may function adequately after their completion, an agency should be established to take the responsibility of the operation and maintenance of facilities/structures. As the case of the Project Executing Agency, the Water Resources Department of the MOP should undertake this function. For the operation of the Agency, it is requested that the MOP coordinates with such public organization as MA, IRM, EMOS and water users' association, and local farmers.

5.7 The total project cost excluding interest in the course of the construction period is estimated to be Ch$23,335.1 x 10^6 of which the foreign exchange portion represents Ch$ 14,397.1 x 10^6 (62%) and local portion Ch$8,938.0 x 10^6 (38%).

The details of the project cost and construction cost are shown in the following tables.

Project Cost

(Unit: 10^6 Ch$)

	Description	F/C	L/C	Total
1.	Construction Cost	11,093.5	4,749.0	15,842.5
2.	Procurement of O/M Equipment	275.2	-	275.2
3.	Administration Cost	-	88.6	88.6
4.	Consulting Services	888.8	273.6	1,162.4
	Sub Total (1-4)	12,257.5	5,111.2	17,368.7
5.	Physical Contingency	1,225.8	511.1	1,736.9
	Sub Total (1-5)	13,483.3	5,622.3	19,105.6
6.	Economic contingency	913.8	3,315.7	4,229.5
	Total (1-6)	14,397.1 (62%)	8,938.0 (38%)	23,335.1 (100%)

Breakdown of Construction Cost

(Unit: 10^6Ch$)

Block	Irrigation Facilities	Treatment Plants	Drainage Facilities	Farm Roads and Bridges	Total(%)
1	379.7	355.6	34.3	13.5	783.1(5)
2	-	1,064.7	-	12.7	1,077.4(7)
3+4	7,529.0	-	5,956.5	496.5	13,982.0(88)
Total	7,908.7	1,420.3	5,990.8	522.7	15,842.5
(%)	(50)	(9)	(38)	(3)	(100)

Note: The above figures include indirect costs

5.8 Annual operation and maintenance cost and facility replacement cost for entire Project life are Ch$88,747 x 10^3 and Ch$1,434 x 10^6, respectively.

6. PROJECT JUSTIFICATION

6.1 The Project life is 30 years including 5 year construction period (18 months for detailed design and tendering, and 42 months for construction works).

6.2 Benefits of the Project are computed based on the agricultural development benefits, farm road and bridge rehabilitation benefits and flood control benefits, and unquantifiable benefits.

6.3 The EIRR for the total Project is calculated as 15.1% and the ENPV at social discount rate of 12% in 1987 and 10% for succeeding years for the total Project is calculated as Ch$ 7.87 x 10^9 in 1985 price. The B/C at the same discount rate is 1.68.

It is suggested that proposed capital investment to the Project is worthwhile in the context of national economy, as the figure of the EIRR is above the opportunity cost of capital usually found in agricultural sector, the ENPV is positive and the B/C is above 1.00.

6.4 Sensitivity analysis made in respect to Project cost and benefit shows that EIRR changes as follows:

Factors of sensitivity analysis:	EIRR
a. 10% increase in Project cost	14.1%
b. 10% decrease in benefit	14.0%
c. 1 year delay of the construction works	14.2%

The above analysis implies that the economic feasibility of the Project is more sensitive to the reduction of benefits than to increase of costs or delay of construction works.

If food control benefits are included in the total Project benefits, the EIRR will become 16.1%, the ENPV Ch$9.60 x 10^9 and the BV/C 1.83.

6.5 The FIRR is estimated to be 12.0% and the FNPV at a social discount rate of 12% in 1987 and 10% for succeeding years to be Ch$3.33 x 10^9 in 1985 price over a project life of 30 years. The B/C at the same discount rate is 1.24.

It is suggested that the financial situation of the Project is sound, as the figure of the FIRR is above the opportunity cost of capital usually found in agricultural sector, the FNPV is positive and the B/C is above 1.00.

6.6 Annual operation and maintenance costs including depreciation cost of equipment is estimated as Ch$ 5,118/ha. Though the amount ought to be paid by the concerned municipalities which will get indiret benefits from the Project, the farmers can afford to share the cost.

6.7 The implementation of the Project contributes to the following secondary or indirect socio-economic impacts:

a. Development of surrounding areas;
b. Balance in agricultural development policies;
c. Improvement of balance of payments;
d. Creation of employment;
e. Water quality improvement;
f. Flood control;
g. Equilibration of regional difference;
i. Economic impact.

7. CONCLUSION

The economic and financial evaluations have concluded that the implementation of the Project is feasible. The same conclusion has been brought as a result of socio-economic evaluation.

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ABBREVIATIONS

Institutions and Organizations

BCC	Banco Central de Chile	Central Bank of Chile
CIREN	Centro de Información de Recursos Naturales	Natural Resources Information Center
CNR	Comisión Nacional de Riego	National Irrigation Committee
CONICYT	Comisión Nacional de Investigaciones Científicas y Tecnológicas	National Scientific and Tecnological Investigations Committee
COPAGRO	Confederación Nacional de Cooperativas del Agro	National Confederation of Agricultural Cooperation
CONAF	Corporación Nacional Forestal	National Forest Corporation
CORA	Corporación de la Reforma Agraria	Agricultural Reform Corporation
CORFO	Corporación de Fomento de la Producción	Production Promotion Corporation
DGA	Dirección General de Aguas	General Water Administration
DIPROREN	División de Protección de Recursos Naturales	Natural Resources Protection Division
DR	Dirección de Riego	Irrigation Administration
EEC	Comunidad Económica Europea	European Economic Community
EMOS	Empresa Metropolitana de Obras Sanitarias	Sanitary Works Metropolitan Company
EMANI	Empresa Nacional de Minería	National Mining Company
ENAP	Empresa Nacional del Petróleo	National Petroleum Company
ENDESA	Empresa Nacional de Electricidad S. A.	National Electricity Co., Ltd.
FACHI	Fuerza Aérea de Chile	Air Force of Chile
FAO	Organización de las Naciones Unidas para la Agricultura y la Alimentación	Food and Agriculture Organization of the United Nations

FIA	Fundación para la Investigacion Agrícola y Ganadería	Agriculture and Livestock Research Foundation
IBRD	Banco Internacional para Reconstrucción y Desarrollo (BIRD)	International Bank for Reconstruction and Developments
IDB	Banco Interamericano de Desarrollo (BID)	Inter-American Development Bank
IDIEM	Instituto de Investigaciones y Ensayos de Materiales	Institute of Investigation and Test of Materials
IGM	Instituto Geográfico Militar	Military Institute of Geography
IMF	Fondo Monetario Internacional	International Monetary Fund
INACAP	Instituto Nacional del Capacitación Profesional	National Institute of Professional Capacity
INDAP	Instituto de Desarrollo Agropecuario	Institute of Agriculture and Livestock Development
INE	Instituto Nacional de Estadisticas	National Institute of Statistics
INH	Instituto Nacional Hidráulico	National Hydraulic Institute
INIA	Instituto Nacional de Investigaciones Agropecuarias	National Institute of Agriculture and Livestock Investigation
INN	Instituto Nacional de Normalización de Chile	National Institute of Chilean Standard
IRM	Intendencia Región Metropolitana	Metropolitan Region Intendance
ISP	Instituto de Salud Pública de Chile	Chilean Institute of Public Health
JICA	Agencia de Cooperación Internacional de Japón	Japan International Nacionalde Cooperation Agency
LAIA	Asociación Latinoamericana de Integración (ALADI)	Latin American Integration Association
MINVIU	Ministerio de Vivienda y Urbanismo	Ministry of House and Urbanization
MA	Ministerio de Agricultura	Ministry of Agriculture

MBN	Ministerio de Bienes Nacionales	Ministry of National Properties
MOP	Ministerio de Obras Públicas	Ministry of Public Works
NASA	Administración Nacional de Aeronauticas y Espacio	National Aeronautics and Space Administration
ODEPA	Oficina de Planificación Agrícola	Agricultural Planning Office
ODEPLAN	Oficina de Planificación Nacional	National Planning Office
OECF	Fondo de Cooperación Económica a Ultramar de Japón	Overseas Economic Cooperation Fund of Japan
ONEMI	Oficina Nacional de Emergencia	National Emergency Office
PROCHILE	Dirección de Promoción de Exportaciones	Administration of Promotion of Exportation
SAF	Servicio Aerofotogramétrico	Aerophotographic Service
SAG	Servicio Agrícola y Ganadero	Agricultural and Livestock Service
SEREMI	Secretaria Regional Ministerial	Regional Coordinating Agency
SERNAGEOMIN	Servicio Nacional de Geología y Minería	National Service of Geology and Mining
SERPLAC	Secretaría Regional de Planificación	Regional Coordinating Agency of Planning
SNA	Sociedad Nacional de Agricultura	National Society of Agriculture
TTG	Grupos de Technología y Transferencia	Technology and Transfer Groups
UCh	Universidad de Chile	University of Chile
USA	Estados Unidos de America	United States of America
USDA	Agencia de Desarrollo de los Estados Unidos	United States Development Agency
WB	Banco Mundial (BM)	World Bank

Others

BOD	Demanda Bioquímica de Oxigeno (DBO)	Biochemical Oxygen Demand

DO	Oxigeno Disuelto (OD)	Dissolved Oxygen
EC	Conductividad Eléctrica (CE)	Electric Conductivity
ESP	Porcentaje de Sodio Cambiable (PSC)	Exchangeable Sodium Porcentage
pH	Concentración de ion hidrógeno	Hydrogen - ion concentration
SS	Sólido en Suspensión	Suspended Solid

Monetary Unit

Ch$	Peso chileno	Chilean peso
US$	Dólar americano	United States dollar
¥	Yen Japones	Japanese Yen

Economic Terms

B/C	Razón entre Beneficio y Costo	Benefit - Cost Ratio
CIF	Costo de Seguro y Flete	Cost, Insurance and Freight
EIRR	Tasa Interna Económica de Retorno (TIER)	Economic Internal Rate of Return
ENPV	Valor Económico Actual Neto (VEAN)	Economic Net Present Value
FIRR	Tasa Interna Financiera de Retorno (TIFR)	Financial Internal Rate of Return
FNPV	Valor Financiero Actual Neto (VFAN)	Financial Net Present Value
FOB	Franco a Bordo	Free on Board
GDP	Producto Geográfico Bruto (PGB)	Gross Domestic Product
GNP	Producto Geográfico Nacional (PGN)	Gross National Product
IRR	Tasa Interna de Retorno (TIR)	Internal Rate of Return
IVA	Impuesto al Valor Agregado	Added Value Tax
NPV	Valor Actual Neto (VAN)	Net Present Value

Symbol		
(Length)		
mm	milímetro	millimeter
cm	centímetro	centimeter
m	metro	meter
km	kilómetro	kilometer
(Weight)		
g	gramo	gram
kg	kilógramo	kilogram
t (= 1,000 kg)	tonelada	ton
(Area)		
m^2	metro cuadrado	square meter
km^2	kilómetro cuadrado	square kilometer
ha (= 10,000 m^2)	hectárea	hectare
(Volume)		
m^3	metro cúbico	cubic meter
ℓ	litro	liter
(Others)		
ℓ/s	litro por segundo	liter per second
m/s	metro por segundo	meter per second
m^3/s	metro cúbico por segundo	cubic meter per second
t/ha	tonelada por hectárea	ton per hectare
%	por ciento	percent
^oC	centígrado	degrees Centigrade
m.A.S.L. (= EL)	m.s.n.m (metro sobre nivel del mar)	meter above sea level
GL	nivel terrestre (N.T.)	ground level

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Assignment	Name	Charge
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		Mr. Oscar ULLOA	(EMOS)
		Mr. Roberto CORTES M.	(CONAF)
Construction	Mr. Tatsumi TANABE	Mr. Hernan BESOMI T.	(SERPLAC)
		Mr. Ricardo DIAZ	(CONAF)
		Mr. Jaime TORREBLANCA B.	(SEREMI-MOP)
		Mr. Alex GHIO R.	(CONAF)

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		Mr. Ricardo DIAZ	(CONAF)
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		Miss Ximena MONTENEGRO	(ODEPLAN)
		Mr. Jorge PLANELLA O.	(CNR)
		Mr. Osvaldo ALFARO G.	(CONAF)
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		Mr. Galvarino CASTILLO A.	(SEREMI-MA)
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		Mr. Osvaldo ALFARO G.	(CONAF)
		Mr. Jorge MARIN S.	(CONAF)

Other Organizations and Related Persons

- CHILEAN ORGANIZATIONS

CORFO (CIREN)

ENDESA

Facultad de Ciencia Física y Matemática de Universidad de Chile

INIA

SAG

Asociación de Canalista de Maipo

Sociedad del Canal de Maipo

Junta de Vigilancia del Río Maipo

FACHI

NASA

DGA

INH

PROCHILE

Servicio de Impuestos Internos

ONEMI

Cía. Minera Las Condes

Municipalidades de Quilicura, Maipú y Colina

Matadero La Cisterna

Planta Faenadora de Carnes Lo Valledor S.A.

Champion S.A.

SNA

IDIEM

PORGEN Ltda.

- JAPANESE AND INTERNATIONAL ORGANIZATIONS AND PERSONS

Embassy of Japan in Santiago

Ex-Ambassador	Mr. Koichi KOMURA
Ex-Councilar	Mr. Yukio ROKUJO
Councilar	Mr. Tetsuo HANAWA
Secretary	Mr. Takayuki SAHARA

JICA Office in Santiago

Mr. Susumu KATO

FAO Office in Santiago

Mr. Kazuki TAKAMIYA

Main Statesmen and Officials Visited

Name	Post
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Mr. Jorge Prado Aránguiz	Minister of Agriculture
Mr. Jaime de la Sotta	Vice-secretary of Ministry of Agriculture
Mr. Alejandro Espejo Silva	Director of Agricultural Planning Office
Mr. Ivan Castro Poblete	Executive Director of CONAF
Mr. Ricardo Romero Alpe	Technical Director of CONAF
Mr. Eugenio Lobo Parga	General Director of DGA
Mrs. Iris Valenzuela Alarcon	Secretary of SEREMI-MOP

CHAPTER I : INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The share of the agricultural sector to the GDP of the Republic of Chile (hereinafter referred to as Chile) was only 9% in 1984. However, the agricultural sector plays an important role for the economy of Chile due to high percentage of labour employment (510×10^3 persons equivalent to 16% in 1984).

The growth rate of the agricultural sector has been small compared with other sectors in spite of the comparatively good natural conditions due to the following:

a. Mono-cultural socio-economic structure with excessive dependence on the copper mining industries;

b. Policy of the successive Government to preferentially promote mining and manufacturing industries;

c. Failure in agrarian reforms; and

d. Others.

The agricultural production is conducted mainly in the southern areas of central part of Chile where Santiago city is located. Total agricultural land was 16.56×10^6 ha in 1984, 22% of the domain (excluding a claim in Antarctic). The main crops produced are wheat, maize, rice, barley, oat and beans.

Recently, the production of traditional agricultural products such as wheat has stagnated due to the increase of importation of those items. The balance of international payments has been impressed by the expansion of the importation of foodstuffs such as wheat, maize and sugar. On the other hand, cultivated area and yield of cash products such as vegetables and fruit have increased and exportation of such products is also expanding.

However, the increase of production of cash crops does not necessarily bring the increase of employment, and the discharge of population to the urban areas from agricultural areas has continued. This is one of the factors that have increased the population and un-employment in Santiago city.

The Government policies in the agricultural sector are:

i) to introduce profitable crops with effective utilization of limited existing agricultural lands;

ii) to promote the exportation of valuable agricultural products;

iii) to supply cheap agricultural products to domestic markets;

iv) to import insufficient agricultural products ; and

v) to supply surplus fund to other sectors.

In order to realize these agricultural policies, the Government has improved the economic measures in connection with customs duties, prices of agricultural products, agricultural credits, etc. and is improving the irrigation/drainage facilities and infrastructures with the financial assistance from WB and IBRD.

The agricultural area near Santiago city is very important as both fresh-vegetable supply source for the Metropolitan Region and export item (fresh fruit, wine, etc.) production base. However, the following agricultural problems exist in the area and urgent counter-measures are expected:

a. Frequent inundation and insufficient drainage;

b. Shortage of irrigation waters;

c. Irrigation with polluted waters from urban area; and

d. Existence of problem soils

By eliminating or minimizing these problems, the agriculture in the area near Santiago city will increase the income and improve

the living standard of small-scale farmers, and will greatly contribute to the socio-economy of the country in a long run, through realization of the following:

a. Stable supply of fresh vegetables to the Metropolitan Region;

b. Higher productivity of main crops such as wheat and increase of production of export agricultural products;

c. Higher opportunity for employment of jobless persons; and

d. Acquisition of foreign currencies.

In this connection, the Government of Chile in May 1984 requested the Government of Japan to undertake the feasibility study for the Mapocho River Basin Agricultural Development Project (Study), in accordance with the agreement of both governments signed in December 1983. In response to this request, the Government of Japan, through the Japan International Cooperation Agency (JICA), dispatched a Scope of Work Mission headed by Mr. Ryotaro Sudo to Chile from September to October 1984 to study this matter, and decided to accept the request. The Scope of Work (S/W) for the Study was discussed and signed by and between both parties on October 4, 1984.

In accordance with the above-mentioned S/W, JICA sent a Study Team composed of 13 experts (headed by Prof. S. Kanatsu) to Chile from January to March 1985 to conduct the First Phase survey and from August to December 1985 to make the Second Phase feasibility study.

1.2 SCOPE OF THE STUDY

The scope of the Study which is divided into two phases is the following:

a. In the First Phase, water resources development and balance of irrigation waters for the existing agricultural area of

approx. 61,000 ha are to be studied in order to clarify water allocation for agricultural development in the Mapocho river basin.

b. In the Second Phase, a feasibility study is to be carried out for the agricultural development of an area of approx. 36,000 ha, selected from the First Phase study area on the basis of the results of the First Phase study.

1.3 OUTLINE OF THE STUDY

1.3.1 Objective of the Study

The objective of the Study is to formulate an agricultural development project that will realize the following and to evaluate the project from technical and economic view points:

a. Higher productivity and stable supply of agricultural products;

b. Increase of production of high profitable crops;

c. Creation of opportunity for employment;

d. Improvement of living standard of small-scale farmers; and

e. Contribution to the socio-economy of the country.

1.3.2 Outline of the Study

The Study which is consisted of two phases is to be conducted both in Chile for field survey and in Japan for subsequent detailed analysis. The outline of the Study is as follows:

(1) First Phase

1) Field Survey in Chile (Jan. 14 - Mar. 24, 1985)

- Collect comprehensive data/information and conduct basic investigation/survey on the First Phase study area,

focusing on the water resources development as the main subject; and

- Review and roughly assess available data/information in coordination with the results of investigation/survey at the site.

2) Home Office Work in Japan

- Analyse the data/information collected from the field investigation and basic survey;
- Present the basic agricultural development ideas for the First Phase study area, containing the water resources development as the main subject; and
- Select the feasibility study area for the Second Phase from the First Phase study area.

(2) Second Phase

1) Field Survey in Chile (Aug. 2 - Dec. 1, 1985)

- Collect additional data/information and conduct the investigation/survey necessary for the feasibility study of the agricultural development for the selected Second Phase study area; and
- Formulate the framework of the agricultural development plan.

2) Home Office Work in Japan

- Analyse in detail the data/information collected;
- Formulate an optimum agricultural development plan; and
- Conduct the feasibility study of the agricultural development project in the Second Phase study area from the technical and economic view points.

1.4 TECHNICAL COMMITTEE

The flooding over the Mapocho river in June 1984 brought big damages to both Santiago city and the surrounding areas. The Government of Chile established the Metropolitan Overall Flood Control Technical Committee composed of the officials from MA, MOP and MINVIU in order to rapidly cope with the restraction from the damages and to prepare a long-term Mapocho river flood control plan. The Committee has executed some urgent projects including river improvement works. During that time, a desire for comprehensively re-developping the area around the Mapocho river came out.

The Committee decided to positively assist the implementation of the Study by strengthening itself with the cooperation from the agencies concerned. Mr. Lupercio Vasquez F. of SEREMI-MA has general control over the Committee and the regular management of it is made by Mr. Guillermo Nuñez R. of CONAF (Fig 1-4-1).

The Study team of JICA received heartful cooperation and assistance from the officials of the Technical Committee and agencies concerned of the Government of Chile in collection of information/data and site investigation/survey and for smooth and effective operation of the study.

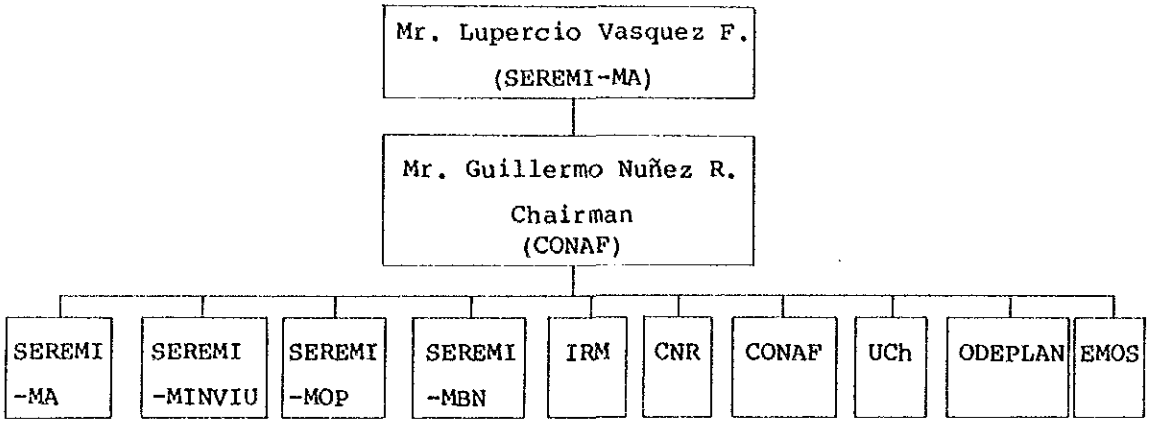


Fig 1-4-1 Technical Committee

CHAPTER 2 : BACKGROUND

CHAPTER 2: BACKGROUND

2.1 BRIEF DESCRIPTION OF THE COUNTRY

Chile is located in the southwestern part of South American Continent and its continental area extends from latitude 17°30' to 56°30' south. The country's territory totals 2,006,626 km^2 including several islands in the Pacific Ocean and also a claim in Antarctic (between longitude 53 to 90° W).

The continental part of Chile is long (over 4,000 km) and narrow (average 190 km wide). The Andes Range extends from north to south in the eastern area as does the Pacific Ocean in the west. The result is steep topographic features and a wide variety of climates both in latitude and altitude. Average annual rainfall is nil in the north, increasing, in general, towards the south up to values of over 5,000 mm.

Total population in June 30, 1985 was estimated to be 12.07×10^6 (INE 1985). Chile is politically divided into 13 regions (Regiones) which in turn are divided into 51 provinces (Provincias) and 335 districts (Comunas).

The greatest wealth of Chile lies in its mineral resources and exports depend largely on its copper production. Over the last years, non-traditional exports such as fish, fruit, timber and some minerals (molybdenum and gold) have greatly increased.

2.2 NATIONAL ECONOMY AND AGRICULTURE

2.2.1 National Economy

(1) Population

The population estimated in the year 1985 was approximately 12.07×10^6, of which 4.77×10^6 (approx. 40%) were

distributed in the Metropolitan Region (INE, 1985). INE estimates that there will be 6.12 x 10^6 inhabitants in the Metropolitan Area of Santiago by the year of 2000 (INE, proyecciones de Población 1970-2000). Annual population growth rate in 1960s was 2.1% and that of 1970 -1984 was 1.7%.

(2) Gross Domestic Product (GDP)

The increase of GDP up to 1981 was mainly the result of the raise of oil price in 1979 and 1980 as well as the policy of laissez-faire in the agricultural and industrial sectors. The country experienced a recession in 1982. The fall of GDP was aggravated by restrictive monetary policies and an overvalued peso. The fall continued into 1983, but such remedical government policies as tariff protection, debt rescheduling schemes and aid to construction industry slowed the decline over the year. 1984 saw a strong recovery of economy and the growth rate of GDP was 6.3%. The growth was remarkable in the sectors of fishery, agriculture and industry. Yet, real GDP in 1984 was still well below the 1981 level (Appendix Tables A-1-1 to 3).

(3) Foreign Trade

Trends of trade deficits due to falling prices of copper and uniform tariff of 10% were reversed during 1982 due to the recession and the devaluation of peso. Imports fell drastically by 44% over the level of the previous year. The level of imports shrank a further 23% in 1983 with the introduction of higher tariffs of 20% in November 1982. The uniform tariff was raised to 35% in September 1984 when peso was further devalued, notwithstanding imports increased. The increase was concentrated in intermediate and capital goods, 20% and 52%, respectively over 1983. Non-food consumer goods increased by 12%, but food decreased by 6%. The level of imports started shrinking again in the first four months of 1985. Although imports of capital goods continued to expand, reflecting positive drive in

investment, consumption goods, especially food, kept decreasing. The Government cut the tariff to 20% in March 1985 (Appendix Tables A-1-4 to 6).

Export earnings have not improved since 1981. The export of copper has been depressed by international market values. The Government's long-term strategy to diversify the export items has been partially successful in the case of fresh fruit exports. Although its record has surpassed others, the value of fruit exports is still small. The Government has shown a strong commitment to export promotion.

Chile is a member of the Latin American Integration Association (LAIA), which consists of ten South American countries and Mexico. As shown in Appendix Table A-1-7, about 15% of its exports and about 26% of its imports stay within LAIA. Among them, Brazil and Argentina are two big trading partners. Chile imports crude oil from Venezuela. USA is by far the biggest trade partner of Chile; about 25% of total flow of goods take place between these two countries. Just above 30% of goods go to the EEC, and less than 20% come from it. Japan is another partner with significant transport volume; around 10% in each direction. Export and import are balanced due to metal ores.

(4) International Accounts

1) Balance of Payments

Hard gained trade surplus against successive peso devaluations, supplemented with a small amount of transfer items, has been offset by the huge amount of service payment on the external debt. This has led to the current account deficit which has been covered by the inflow of capital. With the diminishing inflow of foreign capital, either capital must be raised internally (as in 1984) or foreign exchange reserves are eaten up (as in 1982) (Appendix Table A-1-8).

2) Foreign Debt

Long term public foreign debt at the end of year 1983 reached US$ 6.8 x 10^9, a rise of 44.5% in three years (Appendix Table A-1-9). The fiscal deficit with the current account deficit causes the need of foreign loans. Due to the Government effort in rescheduling the repayment of the principal amount, the debt service ratio has been slightly improved.

(5) Capital Formation and Investment

The level of capital investment as well as formation has been decreasing since 1981, especially foreign investment. In this climate of diminishing investment, it was in the energy section that some of the major items of the public investment were found in 1984 and 1985 (Appendix Tables A-1-8 and 10). The capital investment plan for 1985-1987, in both public and private sectors, indicates that the capital investments in mining, energy and housing sectors will increase and that those for the sectors of agriculture, livestock, forestry and fishery decrease. It is also estimated that the investments in private sectors will increase and that those for public sectors decrease (Appendix Table A-1-11).

On the other hand, the amount of damage caused by the earthquake which hit wide areas from IV to VI Regions including the Metropolitan Region in March 1985 was officially estimated as US$ 1.86 x 10^9. Damages to the ports of Valparaíso and San Antonio amounted to US$ 100 x 10^6. A credit of US$ 18 x 10^6 approved by the World Bank is to be allocated to the reconstruction of ports and other transport facilities. As a part of reconstruction activities, the construction sector grew in 1985; the amount of public investment increased by 52.3% in the housing sector and 40.0% in the public works sector.

(6) Target of Economic Growth Rate and Price Indices

In the latest three year development plan, 1985-1987, the annual growth rate of GDP is set to 2 - 4% in 1985 and 3 - 5% in 1986 and 1987. The variations of price indices for the last five years show that the price index of 1984 was more than 2 times that of 1980 (Appendix Table A-1-12). As a future target, also among the prerequisite conditions for the disbursement of the IMF loan, the annual rate of inflation is to be reduced to 15% by 1987.

2.2.2 Agriculture

There were 3.3 x 10^6 ha of cultivated land and 11.6 x 10^6 ha of pasture in 1983, of which 1.05 x 10^6 ha were covered with 14 basic annual crops (the area further increased by 3% in 1984). The cropping areas slighty increased from agricultural year 1983/84 to 1984/85, occupying 1.08 x 10^6 ha. The production of crops especially oil crops has generally increased (Appendix Table A-1-13). Though Agrarian Reform has produced some 45,000 small holders, the present Government modified the Land Reform Law to remove the restrictions on the size of land holdings. This has allowed private corporations to own farm land with the intention of making the agricultural sector more efficient.

The sectors of agriculture, livestock and forestry contributed 9% of GDP, employing 16% of workforce in 1984. This sector occupies about 20% of total exports and recently is increasing. On the other hand, the ratio against total imports is decreasing. As a result, the trade balance has been converted into the excess of export. The main imported agricultural products are basic crops such as wheat. The total area sown with wheat in 1984-85, for instance, was still 7.3% less than that in 1979-80. Although the area sown did not reach the level of 1979, food production per capita in 1983 was only 1.0% less than that in 1979, according to the FAO Production Yearbook, due to the increase in its productivity. The rate of increase of food production has lagged behind the population growth rate. Ratio of import of wheat to

the total apparent consumption (some was stored for buffer) of the same cereal exceeded 60% in lean years and was around 50% even in bumper years.

The Government has introduced a price incentive policy in the production of wheat and oil crops, along with the reestablishment of the grains and oil crops (beet is another crop to be encouraged) after its laissez-faire policy in agriculture failed. It has also introduced a low cost credit scheme to the agriculture sector since 1982.

Fruit production was revived with Government assistance to one of the promissing non-traditional export crops. US$ 290 x 10^6 of fruits were exported in 1984; an increase of 17.9% on the previous year. Table grapes accounted for about 58% of the value exported, followed by apples, pears, peaches and nectarines.

There were 3.9 x 10^6 cattle, 6.4 x 10^6 sheep and 1.3 x 10^6 pigs in the country in 1983. Although the door has been opened for export since 1981, when Chile was declared free from Foot and Mouth Disease by the Pan-American Health Organization, the export of meat has not been increased. Meat production grew only by 5% overall on the previous year in 1984.

2.3 NATIONAL DEVELOPMENT PLAN IN AGRICULTURAL SECTOR

2.3.1 Basic Considerations

A new three year plan (1985-87), the sixth medium term development plan under the present Government, is an extension of the policies confirmed in the previous plan (1984-86). The principle of non-intervention underlies the development policy except for agricultural tariffs. Major objectives of the plan are generation of investment to produce and export more and to create more employment, while inflation is curbed.

Policies for the development of agricultural sectors expressed in the plan are as follows:

Price Policy

The transparency of the agricultural market is to be guarded and the excessive price fluctuation is to be avoided by mechanisms such as setting limits on price fluctuation.

Tariff Policy

The economic policy of the Government is to reconcile the general system of an open market internationally with moderate and uniform tariffs, except for commodities with prices influenced by external false competitions or which are subjected to large price fluctuations which greatly affect national production.

Commercial Policy

In the field of domestic commerce, priority given in the plan is to create an efficient commercial system. In the field of external commerce, the Government wants to reconcile a free international commerce with an appropriate tariff policy and some means of safeguards, and with stable and realistic exchange rate policies. The Government will promote the increase of agricultural exports. Imports will only be subjected to those controls necessary to safeguard the sanitary condition of products.

Credit Policy

The Government will take care of the flow of credit so that it will be compatible with the necessity of the agricultural sector. The Ministry of Agriculture(MA) through INDAP will continue to maintain its policy of credit assistance to the small farmers.

Tax Policy

The general attitude of the Government is to reduce the direct burden on the income or the savings of the people. This policy will be maintained in the future with the intention of stimulating savings and investment.

Policy of Research and Technical Transfer

The Government will seek to increase the funds for research in the areas of major economic impact. In the field of technical transfer, the Government will continue to give technical assistance to the small and medium sized farmers with the object of increasing the yield and of improving their income, i.e. of raising the level of their life.

Policy of Normalization of Land-ownership

As it is essential to guarantee the title of land-holding for the normal development of this sector, the Government will keep guaranteeing the said titles of deeds with the intention of promoting and facilitating investment on the lands.

Policy of Rural Development

The general object of the policy of rural development is to improve the quality of material life in the rural area by providing the basic social services and creating the sources of employment to eliminate rural-urban migration. The Government will try to improve the rural roads, supply the materials for the construction of rural housing and increase rural electrification.

2.3.2 Financial Aspects of Agricultural Development

The projection of investment to the agro-silvo-livestock sector in the whole country and Metropolitan Region and the summary of targets of the sector are given in Appendix Tables A-1-14 and 15, respectively. The investment is planned to be made in the sub-sectors of fruit culture, livestock, pasture and forestry.

Nearly 95% of the total investment is expected to come from the private sector. All the money from the public sector will go to the sub-sector of forestry. CONAF will stimulate the plantation of trees in private land which needs urgent attention.

In the sub-sector of fruit culture, investment will go to new plantations and replacement of old non-productive trees. In the sub-sector of livestock, the money will be used for the build-up of herds. In the sub-sector of pasture, investment will be made to increase the area of artificial pasture which includes the the improvement of natrual deteriorated pastures. In the sub-sector of forestry, private investment will go to both new plantations and replantation in logged areas.

2.3.3 Agricultural Development Plan

According to the basic strategy envisaged in the development plan, the following actions will be carried out:

- Price and commercialization policies
  - Price limits for wheat and edible oil
  - Support to the cultivation of sugarbeet
    Whenever necessary, a special temporary tariff for the importation of sugar will be established.
  - Support to domestic production of milk
    Fixing of the minimum custom duties will be based on the actual production prices and the subsidies. The Government will give preference to domestic products in relation to imported ones of equal quality. Also the Government will promote the construction of small milk storage centers for small dairy farmers.
  - Support to domestic meat production
    A decision will be taken with respect to the establishment of a classification of meat.
  - Modernization of the agro-market

- Betterment of the wholesale system of perishable products in the Metropolitan Region
- Development of an exchange market of agro-silvo-livestock products
- Study of rules and regulations for commercialization Attention will be paid to the regulation of wheat transaction and meat classification. Regulation of labeling would be another area to be improved.
- Study of an insurance system for prices of agro-products

- Development of forest production

- Development of irrigation

MOP will continue to rationalize the Government shares of water rights with regard to irrigation. Also it will encourage the construction of new irrigation facilities to increase the farmland under irrigation or to improve it by means of a new law and subsidies.

- Measures to protect the domestic production against unfair trade practices

- Measures to develop exports
  - Maintain a high real exchange rate
  - Revision of legal and administrative aspects of export activity
  - Coordination between public and private sectors for the external agro-business negotiations

    The "Comité Agrícola Mixto Público-Privado" will be established to handle the said negotiations efficiently. It will be operated in "Pro-Chile".
  - Distribution of information on international regulations concerning the quality of exporting agro-products

- Issue a certificate of standard of quality for the exporting agro-products
- Sanitary control of exporting agro-products

- Creation and maintenance of a system of information and statistics of the agro-silvo-livestock sector
  This system will be utilized for improving the quality of producers.

- Channel the agricultural credits to the needy producers
  Different lines of credit will be available for operation and investment. A special line of credit for small farmers will also be accessible.

- Research and transfer of technology
  - Research
    The following areas will be given priority: export oriented fruits, improvement of production and quality of the fruits, forest trees (native and introduced) and sanitation of livestocks.
  - Transfer of technology
    Actions will be carried out in two levels, one for small farmers and the other for medium-scale farmers.

- Actions for the conservation of renewable resources

2.4 BRIEF DESCRIPTION OF THE METROPOLITAN REGION

The Metropolitan Region is located in the central part of the country, between latitude 32°80' and 34°35' south and between longitude 69°60' and 71°35' west, in the upstream and mid-stream areas of the Maipo river basin. The eastern end of the Region is defined by the international border with Argentina; the northern and western ends are bounded by the V Region, and the southern end is bounced by the VI Region. The Region occupies 15,600 km^2.

The topography of the Region is distinctly divided into three areas: Andean Range, Central Valley and Coastal Range from the east to the west. The eastern part is located within the Andean Range with many mountains of over 6,000 m A.S.L.; immediately to the west lies the Central Valley (plain area), which extends between the Andean Range and Coastal Range. Due to the altitudinal profile, the climate of the Region ranges from Mediterranean climate in the low areas to high altitude cold climate in the Andes Range. The annual average rainfall ranges between 250 to 350 mm in the Central Valley and increases with altitude.

The main river systems of the Region are the Lampa and Colina rivers in the northern area. The Lampa river drains, after joining with the Colina river, into the Mapocho river that crosses Santiago city from east to west. More to the south, the Maipo river which has its headwaters in the high Andean mountains flows west joining with the Mapocho river and finally drains into the Pacific Ocean.

The Region has an estimated population of about 4.77×10^6 by the end of June 1985 (INE, 1985). The Region is composed of 6 provinces: Santiago Metropolitan Area, Cordillera,Maipo, Talagante, Melipilla and Chacabuco. Santiago city is composed of 17 districts including previously separated ones, such as Puente Alto and San Bernardo, now physically integrated to the rest of the city.

The GDP of the Region was Ch$144 $\times 10^9$ in 1982, about 44% of the total GDP of Chile (INE, 1985). The major production sectors are industry (22%), commerce (25%) and financial services (20%) (BCC; ODEPLAN, 1982). Although forestry, agriculture and livestock are not significant in the gross regional production (only 9%), they present nevertheless an important economic activity due to the wide range of products obtained, the high percentage of national production of some products and the close prosimity to large consumer markets and shipping ports.

The arable area amounts to about 171 x 10^3 ha of which 91% are irrigated (ODEPLAN, 1982); 81 x 10^3 ha consist of annual crops, 40 x 10^3 ha of permanent crops, 27 x 10^3 ha of artificial pastures and 12 x 10^3 ha of fallow areas (INE, 1985).

About 54% of the agricultural farms are smaller than 2 ha, 22% of which correspondend to farms smaller than 0.5 ha. Farms bigger than 10 ha represent 31.7% of the remaining 46% of the total (V Censo Nacional Agropecuario 1975-76). Less than 3% of the Region's labor force is related to agriculture, totaling about 33,000 workers, 52% of which deal with annual crops and the rest with orchards (ODEPA, 1982).

Since Santiago city is the capital of the country, the main Government offices, banks and other important organizations are located there. Most of the economic, cultural, political and other activities are concentrated in Santiago city, and this is accompanied by a migration of people from other regions to the capital.

2.5 PREVIOUS STUDIES AND PLANS

In the Study Area and its surrounding areas, there are many problems caused by the rapid expansion of Santiago city since 1950's. For this, many observations and studies have been conducted and reported by mainly government organizations as follows:

a. Water Resources
   The surveys and analyses have been conducted aggressively by MOP (DGA), CNR, UCh, etc.

b. Inundation and Flood Control
   CONAF has made studies for the upstream sections of the Mapocho river basin, and MOP (DGA), MINVIU and some provincial governments have prepared many proposals for

improvement in the mid-stream and downstream sections based on the hydrological analysis.

c. Agriculture

MA has made a plan of future agriculture through the analysis of statistic data based on the Government policy. INIA has recommended some high-productive crops as a result of surveys and analyses.

d. Water Quality

EMOS, UCh, DIPROREN, etc. are studying water quality improvement schemes based on the observation and analysis of the present conditions of water quality.

e. Socio-economy

ODEPLAN, IRM and MINVIU have made useful studies.

f. Others

BCC and INE have prepared other information and statistic data.

Main Projects concerned for the Study are summarized as follows:

a. "Canal Oriente, Anteproyecto Preliminar" by MOP(DGA)

i. Objective

To supply irrigation waters to the areas north of Santiago and service water to Las Condes area, and to prevent overflowing in the areas east of Santiago.

ii. Outline of the Project

- Irrigation scheme

Objective area	:	31,800 ha
Water Resources	:	36.5 m^3/s from the Mapocho river (15.0 m^3/s for irrigation and 21.5 m^3/s for service water)

Main facilities
- Headworks
- Irrigation canals (123.5 km)
- Siphones
- Tunnels
- Reservoir

- Service water scheme :

Capacity of treatment plants in 2000: 12.8 m^3/s for Nueva Vizcacha and 8.7 m^3/s for Las Condes

- Flood control scheme

Objective area : Small rivers in eastern part of Santiago

Objective flood : 50 m^3/s (1/10 probability)

iii. Project Cost

US$ 17 x 10^6 (1974 price)

b. "Aprovechamiento Multiple de Recursos Hídricos del Maipo Alto" by CNR

i. Objective

To develop agriculture with irrigation, to supply waters for cities and industries and to generate hydraulic powers by developing water resources of the Maipo river

ii. Outline of the Project

- Irrigation scheme

Objective area : 41,385 ha

Water Resources : 40 m^3/s

Canal Length : 375 km

- Service water scheme

Objective population : Approx. 600 x 10^3 in Viña del Mar, Valparaíso, etc.

- Power Generation Scheme

Stations : La Obra and 3 others

Power : 1,184 GWH/year

iii. Project Cost : US$217 x 10^6

c. "Plan Maestro Alcantarillado del Gran Santiago, Periodo 1985 - 2010" by EMOS

i. Objective

To prepare a master plan for sewage and drainage in Great Santiago for 2010

ii. Outline of the Project

- Sewage Scheme

Total tretment capacity: 2.4 x 10^6 m^3/day

Total required treatment plant area: 955 ha

- Drainage scheme

Drainage capacity : 1/2 probability

Drainage pipe : 568 km

iii. Project Cost

Sewage Scheme : 19.5 x 10^9 Ch$

Drainage scheme : 42.5 x 10^9

Total 62.0 x 10^9 Ch$

2.6 RELATED GOVERNMENT INSTITUTIONS AND ORGANIZATIONS

Main public institutions or organizations related to the Project are summarized with their activities in Table 2-6-1.

Table 2-6-1 Related Government Institutions/Organizations

Institution/ Organization	Main Activities
ODEPLAN	• Establishment of national development policies
	• Arrangement among different public institutions
	• Planning, evaluation and study of national development projects
IRM	• Various developments in the Metropolitan Region

Table 2-6-1 - cont'd

Institution/ Organization	Main Activities
IGM	• Topographic maps and aerial photography services
SAG	• Protection and control of various agricultural activities
ODEPA	• Preparation and provision of necessary data and information for planning of agricultural production
	• Planning of agricultural policies and projects
CONAF	• Environmental conservations of vegetation and natural resources
	• Establishment of efficient forest control and utilization
	• Establishment of forest policies
INDAP	• Extension services and agricultural credits for small-scale farmers
INIA	• Agricultural investigation and extension services
INE	• Data collection, analysis and publication of them
	• Execution of censas
CORFO	• Research, data collection and extension services of natural resources
	• Electrification
ONEMI	• Establishment of emergency measures and control of the action
MOP-DGA	• Establishment of water rights, water quality control, collection of hydrological data and publication of them
MOP-DR	• Planning of irrigation projects
	• Maintenance and operation of irrigation facilities
	• Evaluation of water resources

Table 2-6-1 - cont'd

Institution/ Organization	Main Activities
MOP- Sanitary Works Division	• Control of sanitary environment through establishment of sewerage system
MOP- Road Works Division	• Planning, maintenance and operation of roads
MOP- River Defense Section	• Planning, research, construction and control of river protection • Establishment of river protection project, etc.
MBN	• Planning of balanced utilization of national properties
Ministry of Health	• Contamination prevention of water, air and soil
MINVIU	• Planning of urban development
CONICYT	• Establishment of scientific and technological development policies • Control and arrangement of international technical cooperation
"Banco del Estado" and other commercial banks	• Credits for production, transport and export of agricultural products

CHAPTER 3 : THE STUDY AREA

CHAPTER 3: THE STUDY AREA

3.1 LOCATION AND GENERAL FEATURES

3.1.1 Location

The Study Area for the feasibility study is the agricultural land and other related areas of approximately 36,000 ha located adjacent to Santiago city along the mid-stream section of the Mapocho river and the down-stream section of the Lampa and Colina rivers. The extent of the Study Area is approximately 45 Km from north to south and 30 Km from west to east, enclosed by the areas of Batuco, Lampa, Noviciado, Rinconada de Maipů, Padre Hurtado, Maipů, Renca, Quilicura, Conchalí and Colina.

3.1.2 Topography and Geology

The Study Area is located in the Central Valley, which is tectonic relief limited by the Andean Range to the east and the Costal Range to the west. The ground height is between approximately 550 m.A.S.L. for the north and east sectors and 390 m.A.S.L. for the south sector. This presents a slight gradient which diminishes gradually from the piedmont down to the principal river courses, varying from 5% to 0.04% to the south and southwest (Figs A-2-1 and 2).

This morphology is formed during recent period (principally Quaternary) by fluvial and glaciofluvial deposits coming from the Colina and Lampa rivers and Maipo and Mapocho rivers, respectively, moreover by lacustral and talus deposits. These deposits consist of alternations of gravels, sands, silts and clayes coming from principally volcanic and sedimentary rocks of the surrounding higher morphology. In this flat morphologys, there are some volcanic ash hills and monadnocks of igneous rocks (Fig A-2-3).

3.1.3 Meteorology and Hydrology

(1) Location of Gauging Stations

The gauging stations, the observation records of which were used in the Study, were primarily selected by examining the collected hydrological and meteorological data and in consideration of the following:

a. Longer and continuous observation period and least gaps in records;

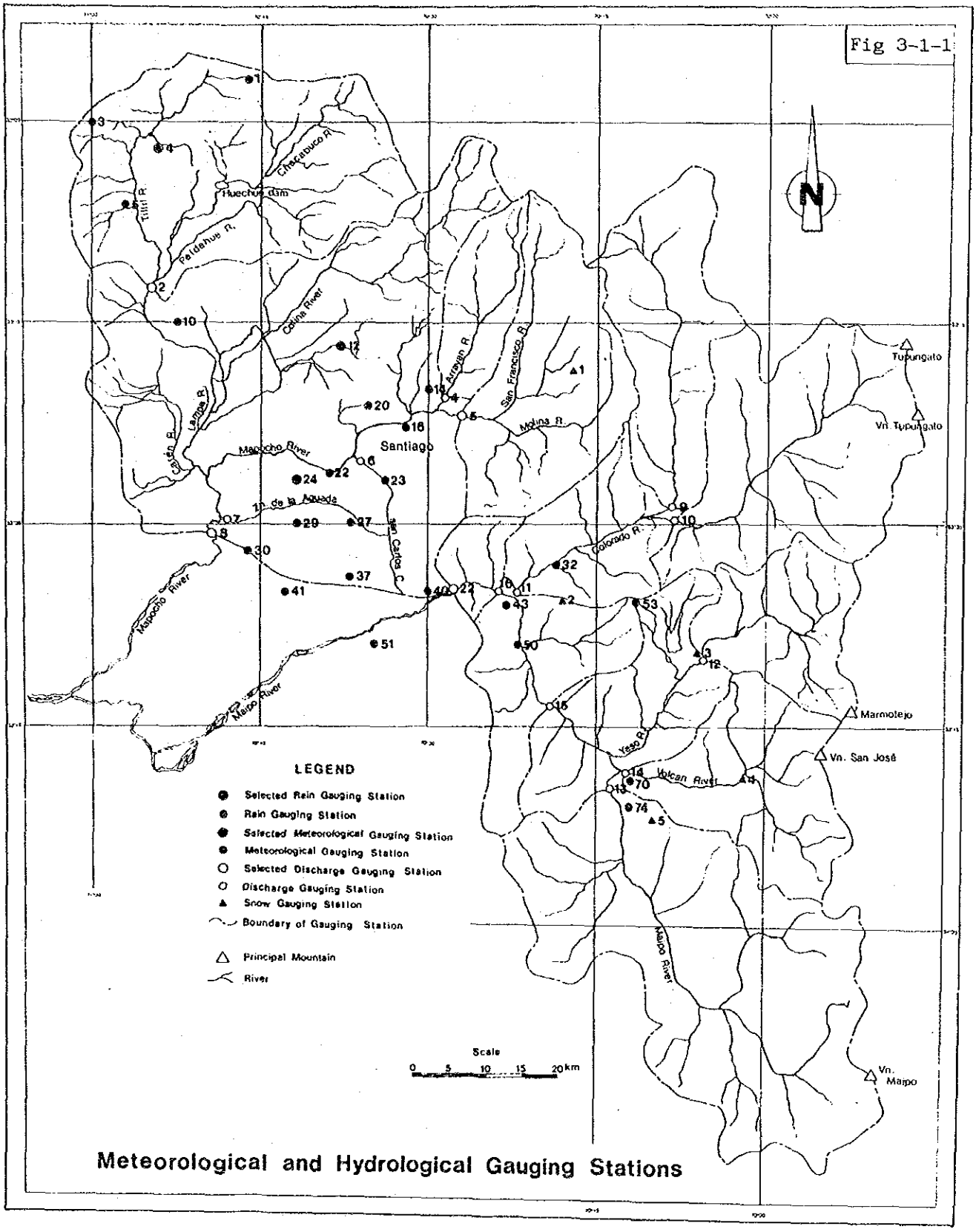
b. Representativeness of the records in the respective river basins; and

c. Coverage of the Study Area.

The selected gauging stations have been listed in order by river basin; ie, Lampa, Mapocho and Maipo (Fig 3-1-1 and Table 3-1-1). The rainfall and meteorological gauge stations for the Mapocho river basin are only located around Santiago city.

(2) Meteorology

The Study Area is included in a zone influenced by Mediterranean Climate of Central Chile which is generally mild. Annual rainfall is approximately 400 mm in Santiago city area. Rain falls mainly in winter, with little or none during the summer months. The volume of evaporation in summer is ten times that of winter. The average temperature is approximately 20°C in summer and 10°C in winter, and the temperature range in one day is approximately 15°C. Relative humidity is 55% in summer and increases to 80% in winter, the rainy season (refer to the Appendix 3 for detail).



Meteorological and Hydrological Gauging Stations

Table 3-1-1 Selected Gauging Stations

River Basin	River Discharge			Rainfall			Meteoro-logical	
	St. No.	Name	Area (Km^2)	St. No.	Name	Altitude (m.A.S.L.)	St. No.	Name
Lampa R. Basin	2	Estero Polpaico en Chicauma	1,098	1	Rincón de los valles	950	4	Rungüe
				4	Rungüe	710		
				5	Tiltil	578		
				10	Batuco Retén	484		
				12	Fundo Valle Hermoso	536		
Mapocho R. Basin	4	Estero Arrayán en la Montosa	219	14	Fundo Huinganal	830	24	Santiago
	5	Mapocho en Los Almendros	620	22	Terraza D.G.A.	600	16	Cerro Calan
	8	Mopocho en Rinconada de Maipú	4,068	23	Tobalaba	640	370	La Platina
				24	Santiago	520		
				29	Los Cerrillos	500		
				37	El Bosque	580		
				41	Sn.Bernardo Seminario	573		
Maipo R. Basin	11	Colorado en Desembo-cadura	1,713	32	Maintenes Planta	1,140	53	El Yeso
	12	Embalse Yeso	353	40	La Obra de Maipo	799		
	14	Volcán en Queltehues	523	43	Río Colorado	910		
	15	Maipo en San Alfonso	2,850	50	San José de Maipo	1,060		
	16	Maipo en Manzano	4,987	53	El Yeso	2,475		
	22	Maipo en La Obra	5,036	70	Quelte-hues Chilectra	1,365		
				74	Las Melosas	1,527		

Note: Refer to Appendix Tables A-3-1 and 2 for details.

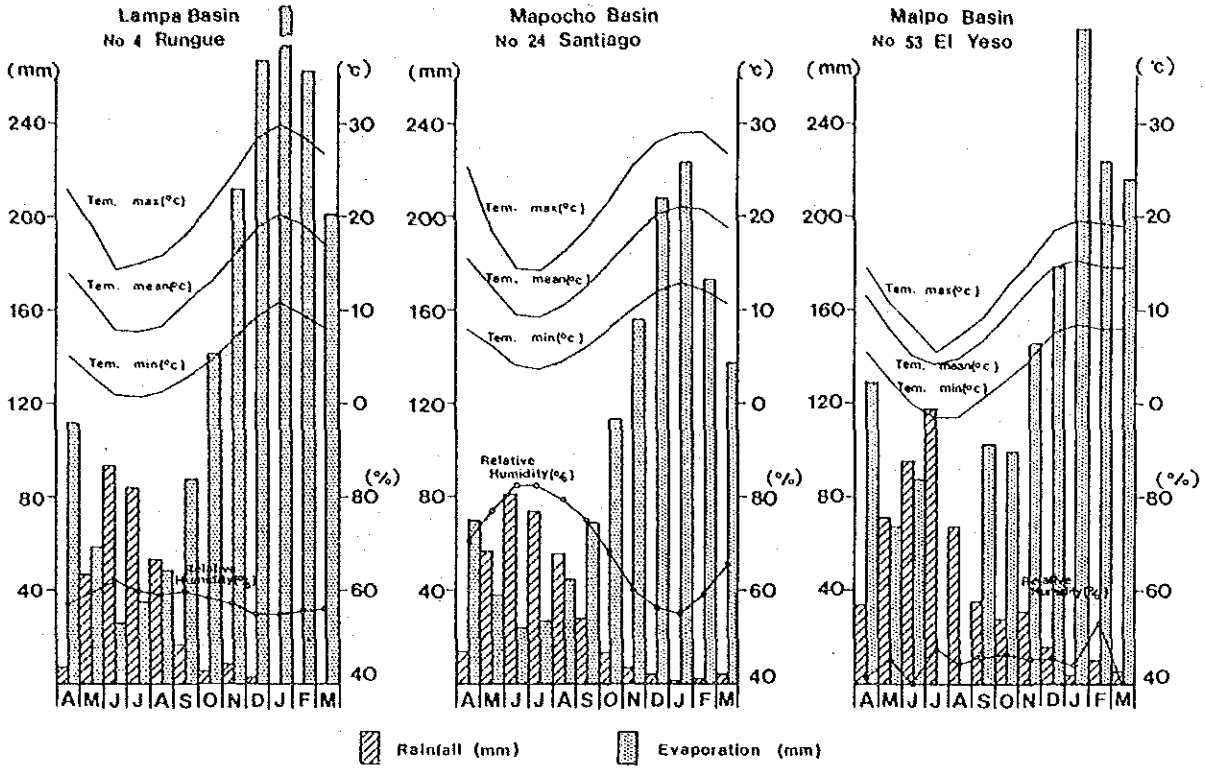


Fig 3-1-2 Meteorological Characteristics

(3) Hydrology

1) Present Condition of Rivers

The main rivers flowing through the Study Area are the Mapocho river and its branches, the Lampa and Colina rivers. Specific features of these rivers are shown in Table 3-1-2.

Table 3-1-2 Specific Features of the Main Rivers

Features		Mapocho R.	Lampa R.	Colina R.
River Rank		Main River	1st Branch	2nd Branch
Catchment Area (km^2)		1,370 1/	2,390	460
Altitude (m.A.S.L.)	Headwaters	EL+5,200m	EL+2,300m	EL+3,700m
	Plain Terrain	EL+470m	EL+470m	EL+480m
Stream Length (km)		76 1/	78	52
Steam Gradient	Headwaters	1/10 - 1/20	1/10 - 1/20	1/10 - 1/20
	Plain Terrain	1/100 - 1/500	1/500 - 1/1000	1/300 - 1/500

1/ show values upto the confluence with the Lampa river

a. Mapocho River

The Mapocho river flows from the Andes Range (altitude of the headwaters is approx. 5,200m A.S.L.) in the east down towards southwest, reaching the northeast edge of Santiago city. Then the Mapocho river crosses the northern part of Santiago city and flows south after meeting the Lampa river at the western part of the Central Valley. The stream gradient of the Mapocho river is very steep; that is, the difference in the altitude for the stream length of 76km is 4,700m.

b. Lampa River

The Lampa river flows down to the south along east edge of the Coastal Range, along the west edge of the Central Valley, and flows into the Mapocho river. It has no clear river channel for about 6km

after passing Lampa town. The river water flows through this section forming many small streams and meets the Colina river. Then, the Lampa river forms a river channel again and flows into the Mapocho river.

c. Colina River

The Colina river flows down from its headwaters, the altitude of which is 3,700m, to the plain of EL+480m with a stream length of 52km.

d. Eastern Part of Santiago

There are many small rivers on the steep western hillside of the Pre-Andes mountains located in the east of Santiago city. The rivers located in the eastern area of Santiago city such as the Apoquindo, San Ramón and Macul rivers are flowing down towards the San Carlos canal. However, the rivers located in the northeast area like San Francisco river are flowing down directly into the Mapocho river.

Main flood discharges flow down through these rivers located in the southeastern area to the San Carlos canal with a high speed due to the steep stream gradient and the short length of these streams (stream gradient: 1/5 - 1/10, length: approx. 15Km), causing flood damage in the area around the canal.

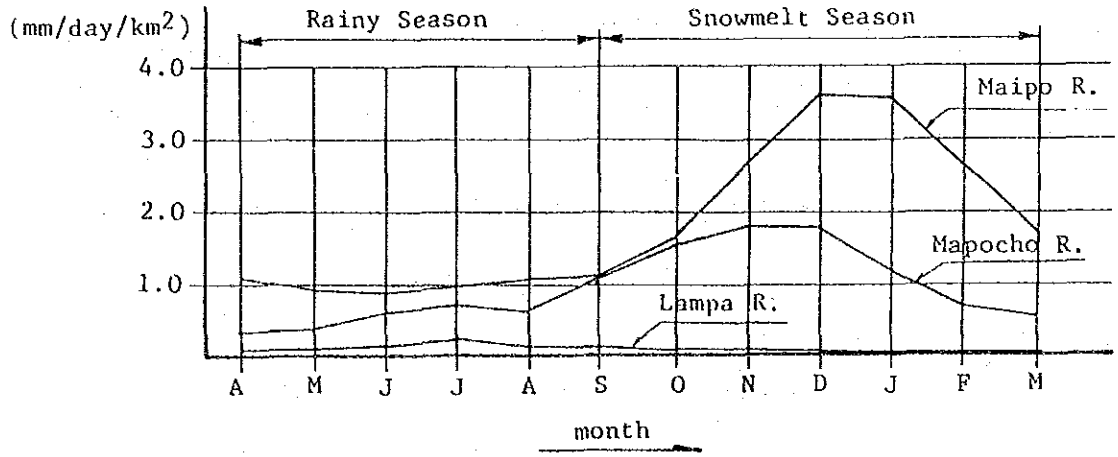
2) Hydrological Characteristics

The most important hydrological characteristics of the Maipo, Mapocho and Lampa river basins are the following (Fig 3-1-3):

a. The Maipo and Mapocho rivers have two main sources: snowmelt in summer and rainfall in winter. In the Maipo and Mapocho river basins, the snow in the headwaters melts in summer with the increase of the

temperature, so that the discharge of both rivers in summer is larger than that in winter, the rainy season, in spite of the fact that rainfall is almost non-existent in summer.

b. In the Lampa river basin, there is little snow because of the low altitude of its headwaters. Therefore, the source of discharge of the Lampa river is only the rainfall in winter; discharge in summer is very low.



Note:

a. Lampa river (Est. Polpaico en Chicauma (N°9), 1943 - 83)
b. Mapocho river (Los Almendros (N° 5), 1948 - 83)
c. Maipo river (El Manzano (N°16), 1947 - 84)

Fig 3-1-3 Monthly Runoff Pattern

3) Selection of Representative Rainfall Gauging Stations

The representative rainfall gauging stations to be used in the irrigation planning were selected from the gauging stations already selected (refer to (1) of this section) for each river basin in consideration of the following:

a. The amount of rainfall in the three river basins is not the same. The highest amount of rainfall was found in

the Maipo river basin, less in the Mapocho and the least in the Lampa;

b. The correlation coefficient of the representative rainfall with the rainfall of all stations in each basin should be larger than 0.9 (Appendix Table A-3-7);

c. The representative gauging station should be located near the Study Area; and

d. The records should cover many years and the gaps in the records should be minimal.

Selected rainfall gauging stations are:
- Fundo Valle Hormoso (No 12) for the Lampa river basin
- Santiago (No 24) for the Mapocho river basin
- Queltehue Chilectra (No 70) for the Maipo river basin

One the other hand, the following rainfall gauging stations where the hourly rainfall records are available were selected for the analysis of the flood control and drainage:
- Rungüe (No 4)
- Santiago (No 24)

(4) Probable Hydrological Values

In order to obtain basic values for planning of irrigation, drainage and flood control schemes, probable hydrological values of rainfall and discharge were calculated. Non-exceedance probable values are used in the irrigation planning and exceedance probable values are for drainage and flood control planning.

Weibull distribution and Gumbel distribution methods were applied in order to obtain accumulated and mean values, and maximum and minimum values, respectively.

1) Non-exceedance values

Probable annual rainfalls and mean discharges were

obtained as non-exceedance values, and are shown in Table 3-1-3 and 4, respectively.

Table 3-1-3 Probable Annual Rainfall

(Unit: mm/year)

Gauging Station	Return Period (Year)			
	2	5	6.7	10
Fundo Valle Hormoso (No 12)	245	170	155	135
Santiago (No.24)	285	198	175	160
Queltehue Chilectra (No 70)	600	445	390	330

Table 3-1-4 Probable Mean Discharge

(Unit: m^3/s)

Item	Gauging Station	Return Period (year)			
		2	5	6.7	30
Annual Mean Discharge	Estero Polpaico en Chicauma (No 2)	0.62	0.42	0.38	0.34
	Mapocho en Los Almendros (No 5)	5.5	3.5	3.1	2.6
	Mapocho en Rinconada de Maipú (No 8)	19.1	13.1	12.0	10.6
	Maipo en La Obra (No 22)	86.0	72.0	69.0	65.0
Mean Discharge in Rainy Season	No 2	0.68	0.39	0.36	0.31
	" 5	3.6	2.4	2.0	1.9
	" 8	22.5	15.7	14.0	12.4
	" 22	48.0	37.0	35.0	32.5
Mean Discharge in Snowmelt Season	" 2	0.47	0.32	0.29	0.26
	" 5	7.3	4.2	3.8	3.3
	" 8	15.7	9.5	8.5	7.2
	" 22	126.7	103.3	100.0	89.2

2) Exceedance values

Probale maximum rainfalls and instantaneous/daily maximum discharges were obtained as exceedance values, and are shown in Table 3-1-5 and 6, respectively.

Table 3-1-5 Probable Maximum Rainfall

(Unit:mm)

Item	Gauging Station	Return Period (year)			
		2	5	6.7	30
Max. Rainfall for 1 day	Estero Arrayán en la Montosa (No 4)	59	92	95	145
	Santiago (No 24)	45	60	62	85
	Queltehues Chilectra (No 70)	80	110	120	170
Max. Rainfall for 2 days	No 4	90	145	155	237
	" 24	55	80	88	120
	" 70	110	181	185	268
Max. Rainfall for 3 days	" 4	92	161	175	274
	" 24	60	90	100	145
	" 70	130	210	228	330

Table 3-1-6 Probable Instantaneous and Daily Maximum Discharge

(Unit: m^3/s)

Item	Gauging Station	Return Period (year)			
		2	5	6.7	30
Instantaneous Max. Discharge	Mapocho en Los Almendros (No 5)	58	148	160	297
	Cerro Calán (No 16)	309	513	540	851
Daily Max. Discharge	No 5	28	59	-	111
	" 16	268	430	-	700

3.1.4 Hydrogeology

(1) General

The study and surrounding areas were divided into two distinctive zones differentiated by properties of the dominant geological formation in each locality as follows: hard rock zone and soft rock zone.

Hard rock zone is made of well-consolidated rocks such as andesites and hard volcanic ash layers distributed in the mountain and hill region and monadnocks. The soft rock zone is covered mainly by clastic material such as fluvial and fluvio-glacial deposits which are generally porous and form permeable layers. Since the hard rock zone is generally poor in water bearing, soft rock zone will be discussed below.

In soft rock zone, psephitic, psammitic and pelitic materials crop out extensively with volcanic ash layers in the Study Area. As a general trend, psephitic and psammitic layers, which have relatively good permeability and water bearing capacity, are predominant in the upstream river courses of main and small rivers. Pelitic layers are dominant in the extensive flat terrains.

In the Study Area, groundwater is used mainly for domestic purposes. However, it is also used for irrigation to supplement surface irrigation waters. Details of groundwater use in each block are described in Appendix 4. In the following sections, the identified hydrogeological layers, their characteristics and distribution are discussed.

(2) Permeable, Semi-permeable and Impermeable Layers

Permeable layers contain stratum water in the soft rock zone. They are distributed in thin beds (< 25m of

thickness) principally composed of gravels, sands and a few silts. Their thickness seems to be large in the high gradient area (> 0.4%) and small in the flat terrains (< 0.4%). Many discontinuous permeable layers appear in the flat terrain and comparatively continuous ones appear in the relatively steep slope area (Appendix Figs A-4-1, 2 and 3). Soft volcanic ash layers seem to be included in this type of layer, too (Appendix Fig A-4-4).

Semi-permeable layers consist of sands and gravels with some portions of silt and clay. These layers are moderate in aquiferous properties and they are generally regarded as permeable layers and hard volcanic ash layers. They do not have a large extension. Impermeable layers consist of silt, clay, compacted conglomerates and hard volcanic ash layers and are mainly distributed in the flat terrains.

(3) Hydrodynamics of Permeable Layers

Using the water level of approximately 160 wells measured from September to October 1985, a regional groundwater level map was drawn (Appendix Fig A-4-5).

In the higher areas of existing main river courses, the old Mapocho river course and talus, the hydraulic gradient is steep (1/200-1/250), but in the lower areas of the flat terrain, it becomes gentle (1/2,000-1/10,000). The change of the gradient is relatively abrupt and the changing zones roughly coincide with changes in geological conditions (principally detrital grading) and ground slope.

The areas with groundwater level being higher than -1.0 m are found extensively in the flat terrain. The areas with higher than -0.5 m very closely coincide with the poor drainage areas with soil problems such as Batuco and the surroundings of Las Cruces river. There are many springs at the foot of river terraces and some spring zones in the flat terrains.

(4) Fluctuation of Groundwater Level

Betweeen 1971 and 1982, the annual decrease of groundwater level in the surrounding area downstream of the Colina river and the western area of Batuco exceeded 5 m (Proyecto Maipo, Estudio Hidrogeológico, 1984). However, we could only detect small increments or stable conditions in the flat terrains.

Seasonal fluctuation is less than 3 m. In the surrounding area downstream of the Colina river, the groundwater levels rises 0.3-0.5 m during winter, especially in rainy years. In the flat terrain, there is little seasonal fluctuation in groundwater levels in summer.

3.1.5 Soil

(1) General

In order to supplement and verify previous soil surveys and studies[1/] related to the Study Area, a soil study was carried out by the Study Team. The soil profile observation constitutes a basic methodology for the soil study. For this purpose, a total of 11 test pits and 26 auger borings were excavated and 71 samples taken from 27 profiles were sent to a laboratory for physical and chemical analyses. Results of the study are presented in Appendix 5 and are shown in Soil Map (Fig 3-1-4).

The parent materials of alluvial deposit, which is prevailing in the Study Area, are fine to medium soils transported by river flows and sedimented in lagoons. The textures of these soils are divided into: 1) heavy clay with high to medium saline/alkaline concentration and 2) loam to clay loam. On the other hand, sandy loam soils

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1/ Estudio de Suelos del Proyecto Maipo, CNR, 1981
Pauta para Estudio de Suelos, SAG, 1981, etc.

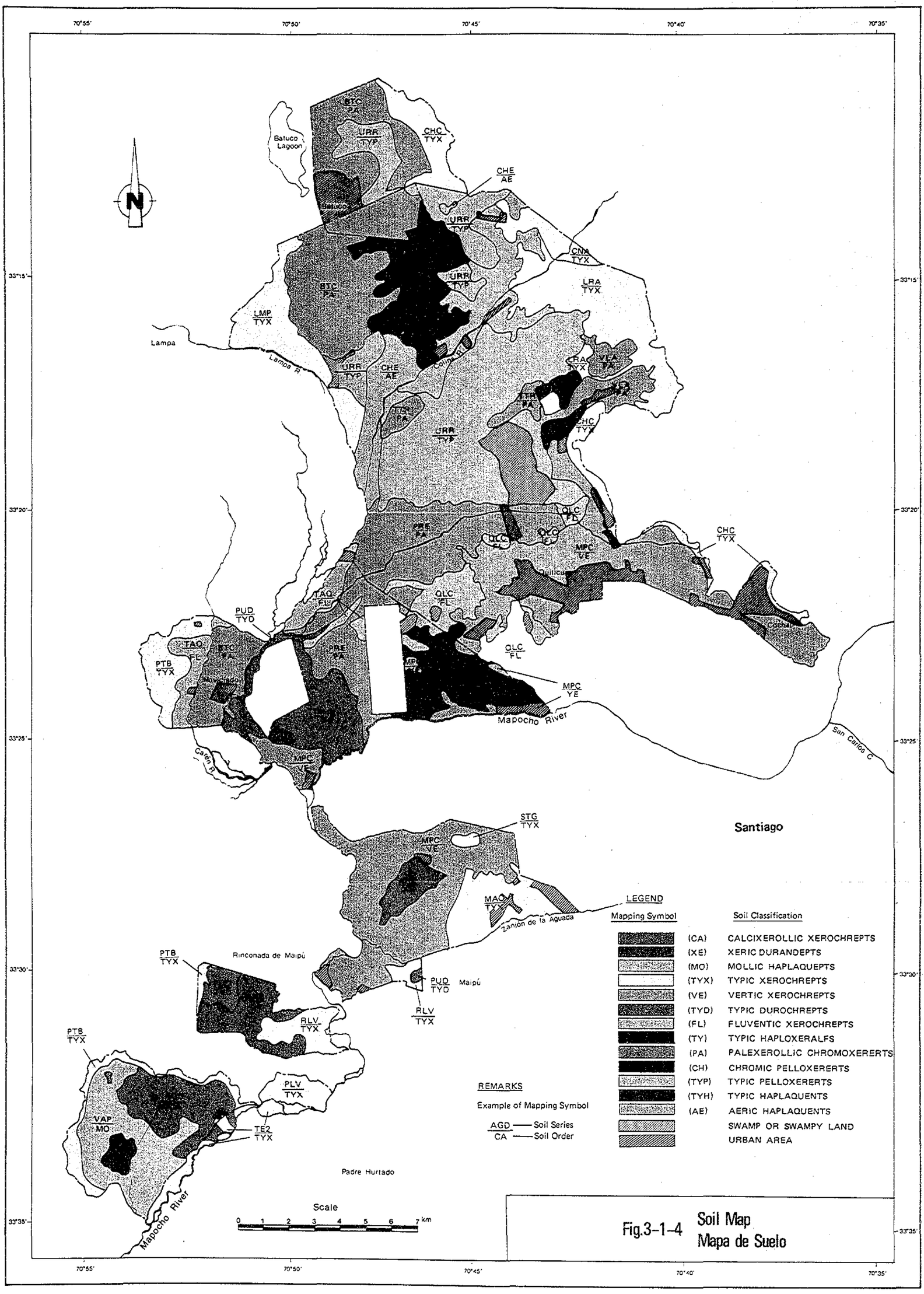


Fig.3-1-4 Soil Map
Mapa de Suelo

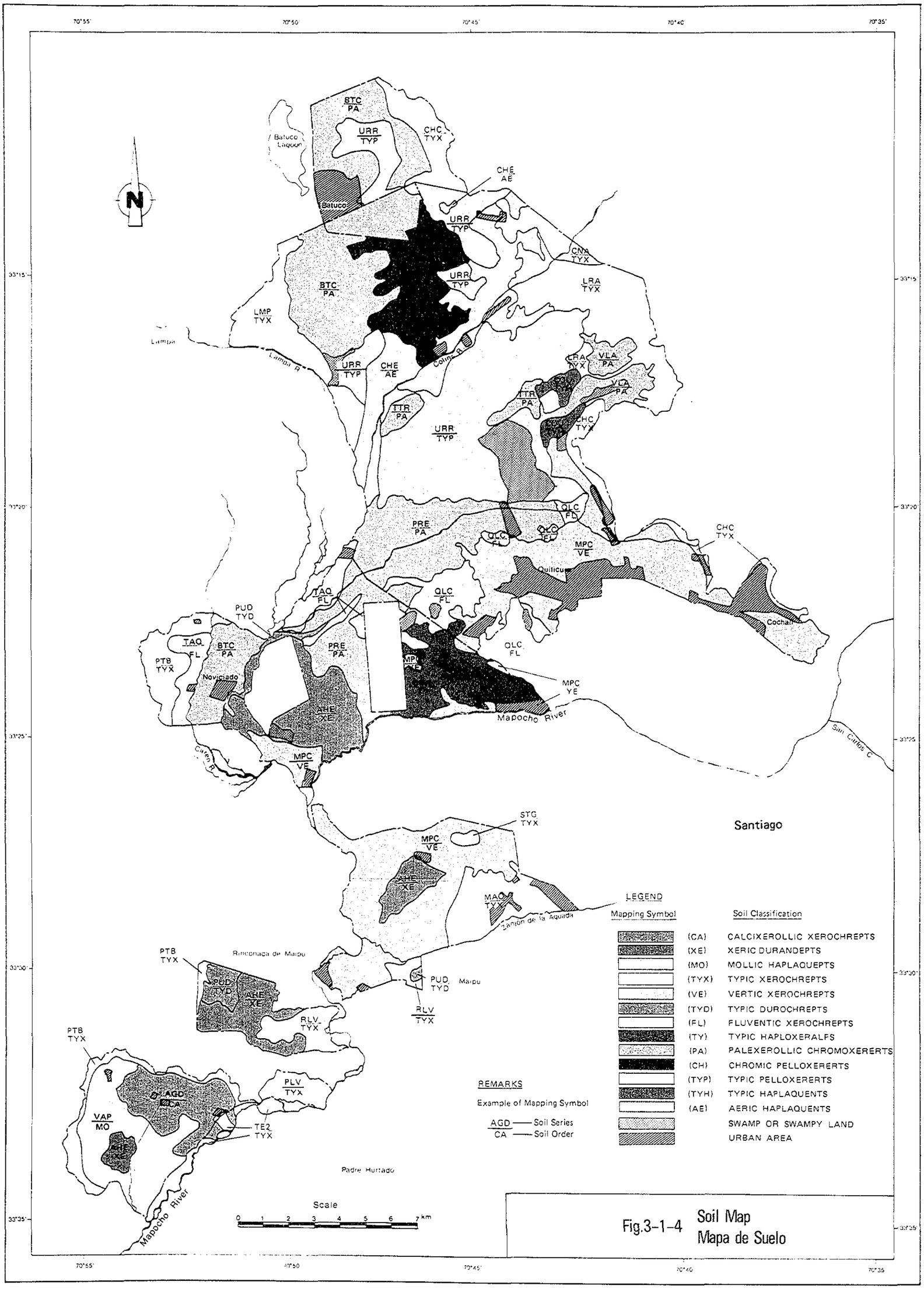


Fig.3-1-4 Soil Map
Mapa de Suelo

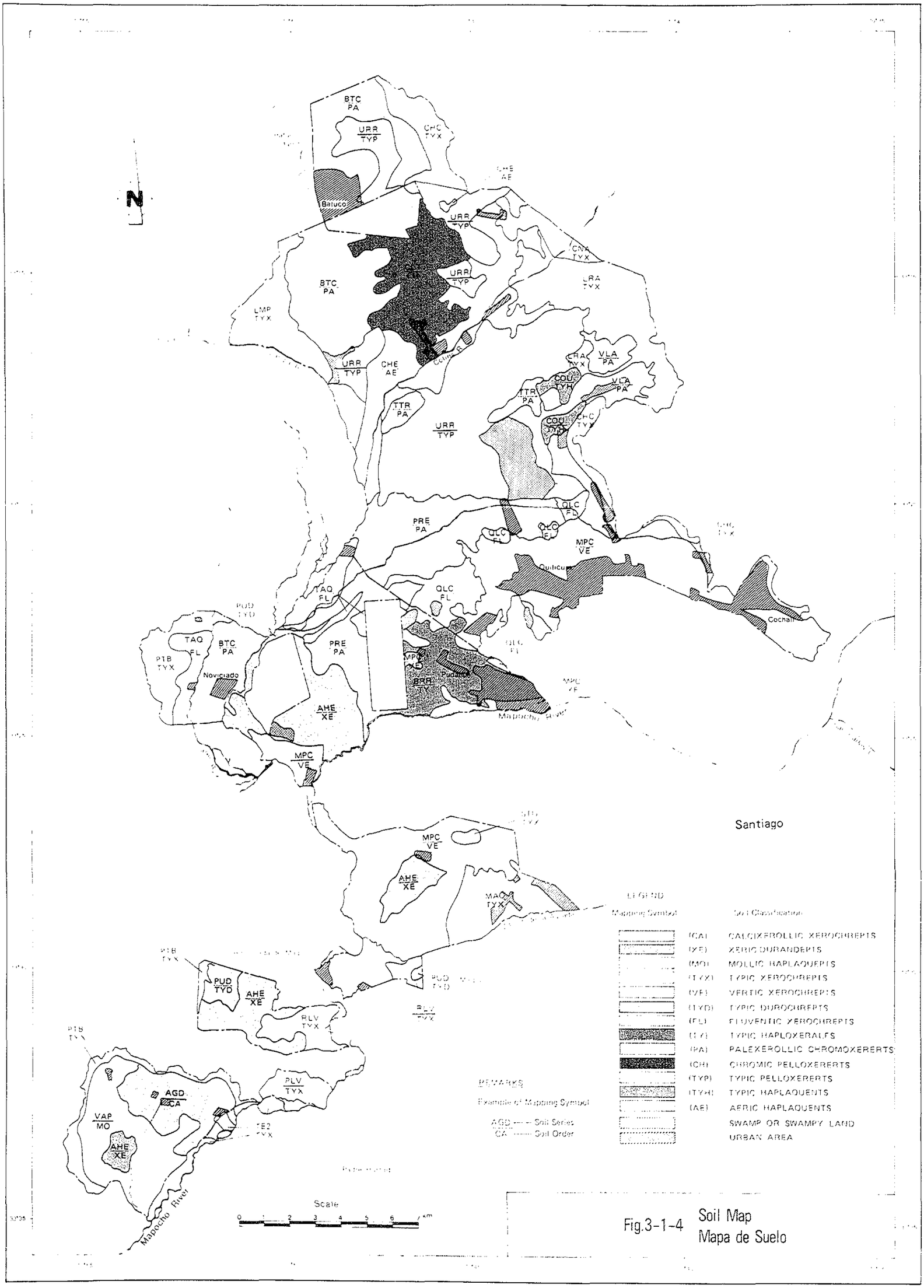


Fig.3-1-4 Soil Map
Mapa de Suelo

originated from volcanic ash are distributed in hilly land within the Study Area.

And, the contaminated soils caused by irrigating polluted water is observed extensively over downstream basin of the Mapocho river.

(2) Soil Property and Classification

Soils within the Study Area are categorized into 25 series and 13 sub-groups (Appendix Table A-5-1). These soils have an effective thickness of layer in the range of 40-90 cm with rare mixture of gravel.

Alluvial soils, loam to clay loam and good to moderate drainage, are distributed along the rivers of Carén, Lampa and Mapocho and in the eastern boundary of the Study Area, with coverage of 15,005 ha (42%). Generally speaking, soils of this type are identified by low saline concentration, though those with high to moderate saline concentration and moderate alkaline saturation are found partially in the south-eastern zone and along the Lampa and Carén rivers. According to the soil classification system employed by the USDA, these soils correspond to Ochrepts and Oxeralfs, which are further divided into 6 sub-groups and 15 series. The soils with developing pan are partially found in the southern part of the Study Area.

Hydromorphyic Alluvial soils are extending along the Colina river, slightly undulating land in the north-eastern part, and flat land at the southern limit of the Study Area (2,960 ha, 8%). These gley soils present generally low saline concentration; nevertheless, those extended in slightly undulating land in the north-eastern part of the Study Area show high saline concentration and alkaline saturation. In the USDA classification system, they belong to Aquepts and Aquents, consisted of 3 sub-groups and 3 series.

Heavy clay alluvial soils are found in the extensive flat land along the Lampa and Colina rivers. Drainage condition of these soils are poor in general and their texture is composed mainly of clay. The average saline concentration and alkaline saturation are moderate to high, though extreamly high concentration is observed in some soils. The coverage of distribution of these soils reaches to 12,030 ha (33%). These soils are corresponding to Oxererts in the USDA classification system accompanied by 3 sub-groups and 6 series.

Soils originating from volcanic ash are distributed in the western hilly area of Alturo Merino Benitez International Airport and southern part of the Study Area. Their texture is sandy loam, drainage is moderate, saline concentration and alkaline saturation are low, and effective thickness of layer is less than 40 cm. They represent Andepts in the USDA classification system. The coverage of distribution of these soils is 1,735 ha (5%).

Table 3-1-7 Characteristic of Soil

Sub-groups		Properties
Fluentic Xerochrepts	(FL)	• Moderate to thick effective soil layer • Loam to clay loam • Good to slightly poor drainage • Low saline concentration • Low alkaline saturation (Saline soil and alkaline soil are partly included)
Typic Xerochrepts	(TYX)	
Calcixerollic Xerochrepts	(CA)	
Typic Durochrepts	(TYD)	
Vertic Xerochiepts	(VE)	
Typic Haploxeralfs	(TY)	
Mollic Haplaquepts	(MO)	• Moderate effective soil layer • Loam to clay loam • Poor to slightly poor drainage • Low saline concentration • Low alkaline saturation (Saline soil and alkaline soil are partly included)
Typic Haplaquents	(TYH)	
Aeric Haplaquents	(AE)	

Sub-groups		Properties
Palexerollic Chromoxererts	(PA)	• Moderate to thick effective soil layer • Clay • Poor to slightly poor drainage • Moderate to high saline concentration • Moderate to high alkaline saturation
Typic Pelloxererts	(TYP)	
Chromic Pelloxererts	(CH)	
Xeric Durandepts	(XE)	• Thin effective soil layer • Sandy loam • Moderate drainage • Low saline concentration and alkaline saturation

(3) Contamination of soil

Contamination of soil in the Study Area is caused by the polluted waters which are conveyed through irrigation canals. According to the results of soil analysis, high contents of copper ions and coliform groups indicate the origin of soil contamination. The contamination of soils is extensively observed over lower basin of the Mapocho river (Appendix Table A-5-6). Soil polluted with high copper ions can be seen in the areas near the confluence of the Lampa and Mapocho rivers and Zanjón de la Aguada and Mapocho river. While neighboring area of the confluence of the Zanjón de la Aguada and Mapocho river is polluted with high coliform groups.

(4) Land Classification

1) *Soil Capability Classification*

Lands within the Study Area were assessed in terms of their capability to produce crops under irrigation. A guideline for this assessment is prepared based on the specification of the SAG (Appendix Table A-5-7). Lands rated in classes I to IV are assessed of the SAG. Lands rated in classes I to IV are assessed to be suitable for upland crop production under irrigation; while lands in classes V to VIII are considered to be unsuitable as shown in Table 3-1-8.

Table 3-1-8 Soil Suitability Classification

Class	Capability for Upland Field	Capability for Orchard
I	None to slight soil limitation for sustained use	
II	Moderate soil limitation for sustained use	
III	Severe soil limitation for sustained use	
IV	Very severe soil limitation for sustained use	
V VI VII VIII	Unsuitable	

Of soils rated in classes III and IV, those with electric conductivity (EC) more than 12 mmhos/cm and exchangeable sodium percentage (ESP) more than 15% are assessed to be unsuitable soils. Although the soils with developed hard pan layer located in the southern part of the Study Area are considered to be marginally suitable (class IV), carefull management or conservation of them is required in their agricultural use.

Unsuitable soils for crop production were assessed principally according to the effective thickness of soil layer and ESP (Appendix Table A-5-7). Soils rated in classes III and IV are observed to have severe or very severe limitation for crop production, because they are represented by slightly poor internal drainage and effective thickness of soil layer in the range of 40-70 cm.

Furthermore, with specification employed by the SAG, soils in classes I to VI are assessed to be suitable for fruits production; in this study, soils rated in classes

IV to VI were assessed with the guideline applied for upland fields in terms of saline concentration.

2) Land Capability Classification

The land classification map is prepared taking account of topography, flooding extent and actual landuse as well as soil capability (Fig 3-1-5).

a. Topography

The topographical factors which constitute constraints on developing agricultural land are:

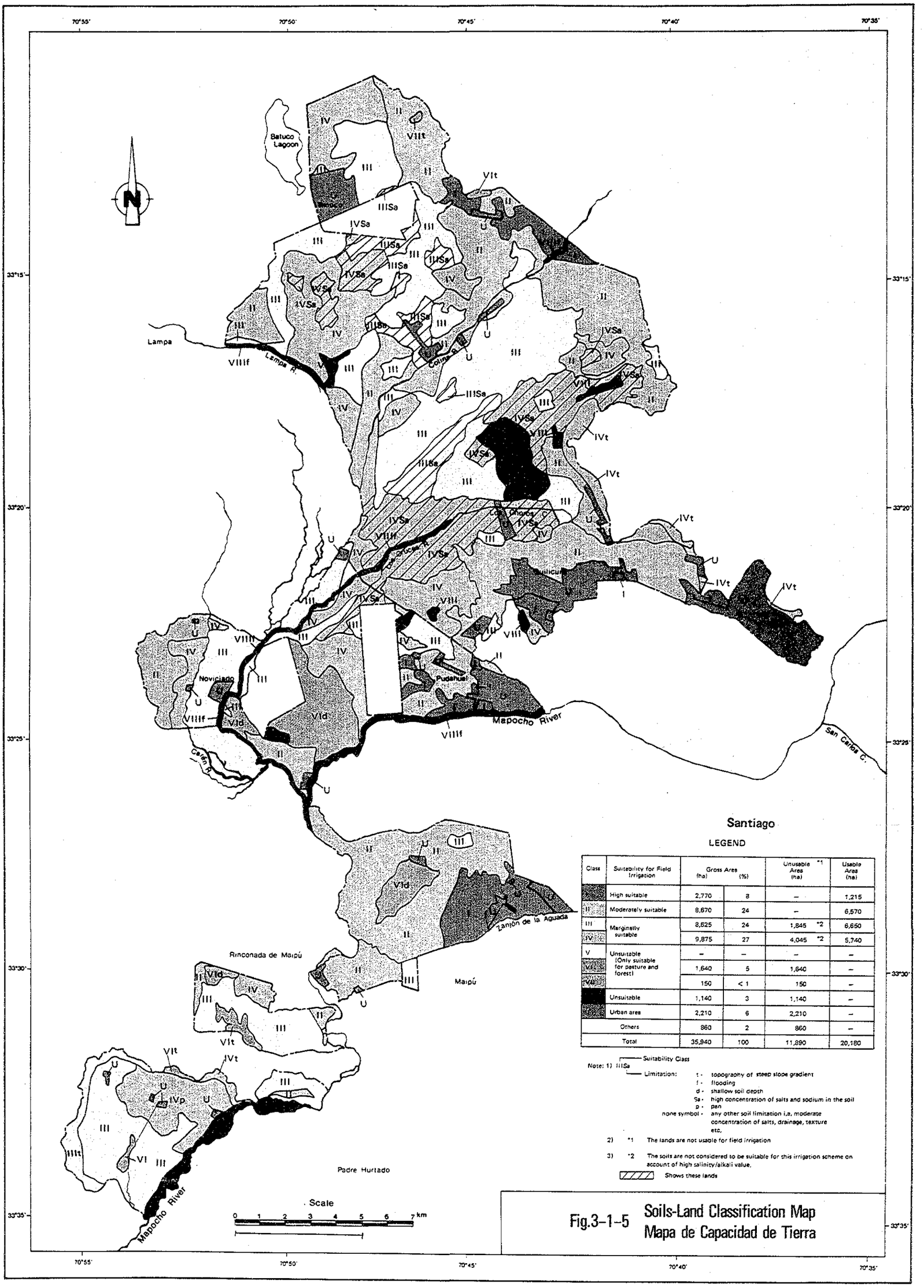
- Land with slope more than 15%, and
- Hilly land with elevation more than about 470 m to which irrigation water will not be conveyed by gravity (Non-irrigable land).

Unsuitable lands in terms of land slope are limited to the circumference of the boundary of the Study Area. These lands are rated in classes VI and VII for the soil capability classification. On the other hand, non-irrigable lands are extended to "Lomas de Pudahuel" located in the north of the confluence of the Mapocho and the Lampa rivers and "Lomas Blancas" located in the north of Maipú district, in Block-2, which are rated in class VI in terms of their effective soil layer being thin.

The greater part of the Study Area corresponds to flat alluvial land with slope less than 2%, which presents no constraint on agricultural development from the viewpoint of topography.

b. Flooding

Some parts of the Study Area is at present subject to frequent flooding and inundation, which may be relaxed to the considerable extent by the countermeasures proposed in the Project.



Santiago

LEGEND

Class	Suitability for Field Irrigation	Gross Area (ha)	(%)	Unusable Area (ha) *1	Usable Area (ha)
I	High suitable	2,770	8	–	1,215
II	Moderately suitable	8,670	24	–	6,570
III	Marginally suitable	8,625	24	1,845 *2	6,650
IV		9,875	27	4,045 *2	5,740
V	Unsuitable (Only suitable for pasture and forest)	–	–	–	–
VI		1,640	5	1,640	–
VII		150	< 1	150	–
VIII	Unsuitable	1,140	3	1,140	–
U	Urban area	2,210	6	2,210	–
	Others	860	2	860	–
	Total	35,940	100	11,890	20,180

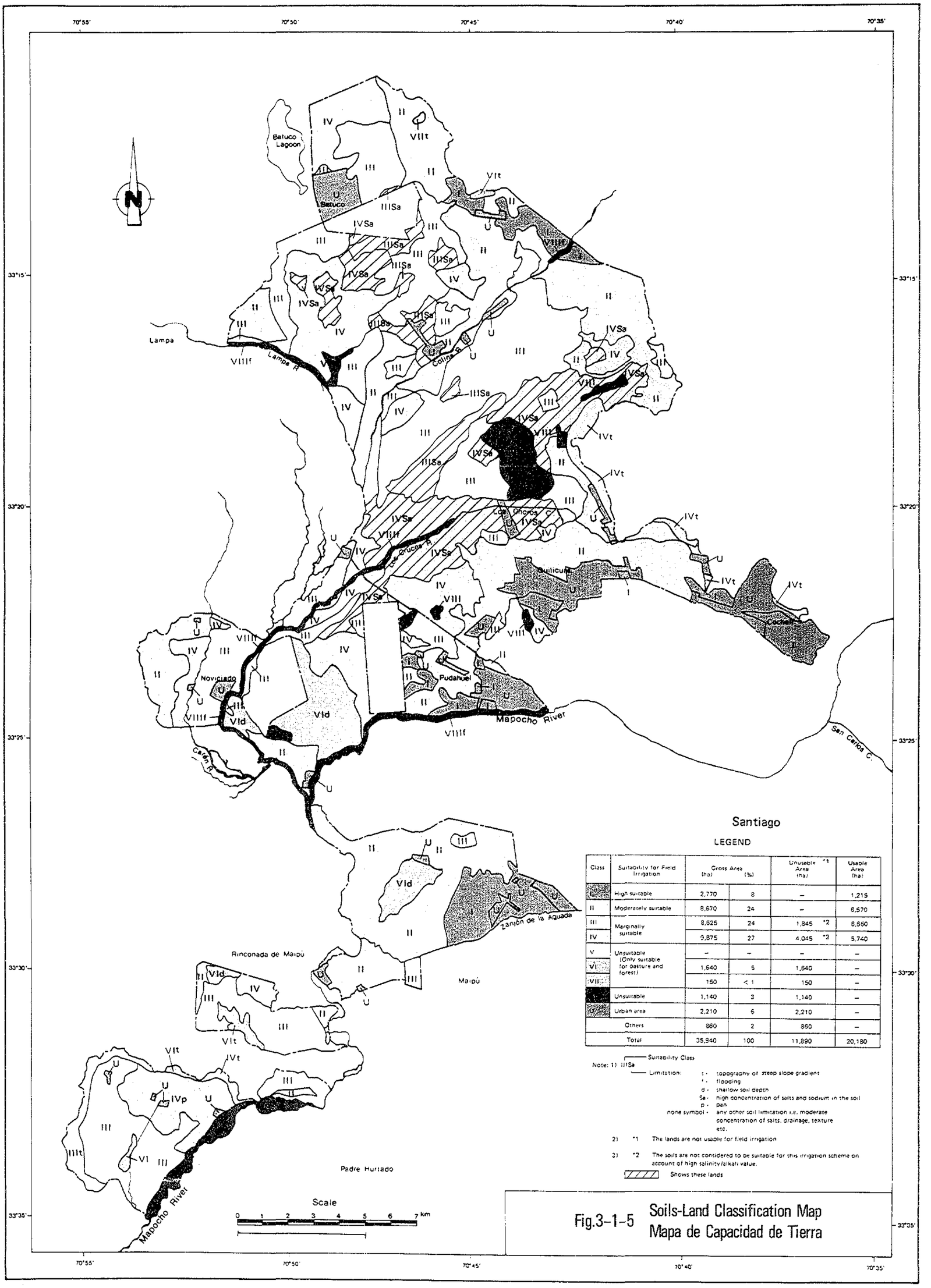
Note: 1) IIISa ← Suitability Class
Limitation: t - topography of steep slope gradient
f - flooding
d - shallow soil depth
Sa - high concentration of salts and sodium in the soil
p - pan
none symbol - any other soil limitation i.a. moderate concentration of salts, drainage, texture etc.

2) *1 The lands are not usable for field irrigation

3) *2 The soils are not considered to be suitable for this irrigation scheme on account of high salinity/alkali value.

Shows these lands

Fig.3-1-5 Soils-Land Classification Map
Mapa de Capacidad de Tierra



Santiago

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V	Unsuitable (Only suitable for pasture and forest)	–	–	–	–
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VIII	Unsuitable	1,140	3	1,140	–
U	Urban area	2,210	6	2,210	–
	Others	860	2	860	–
	Total	35,940	100	11,890	20,180

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Shows these lands

Fig.3-1-5 Soils-Land Classification Map
Mapa de Capacidad de Tierra

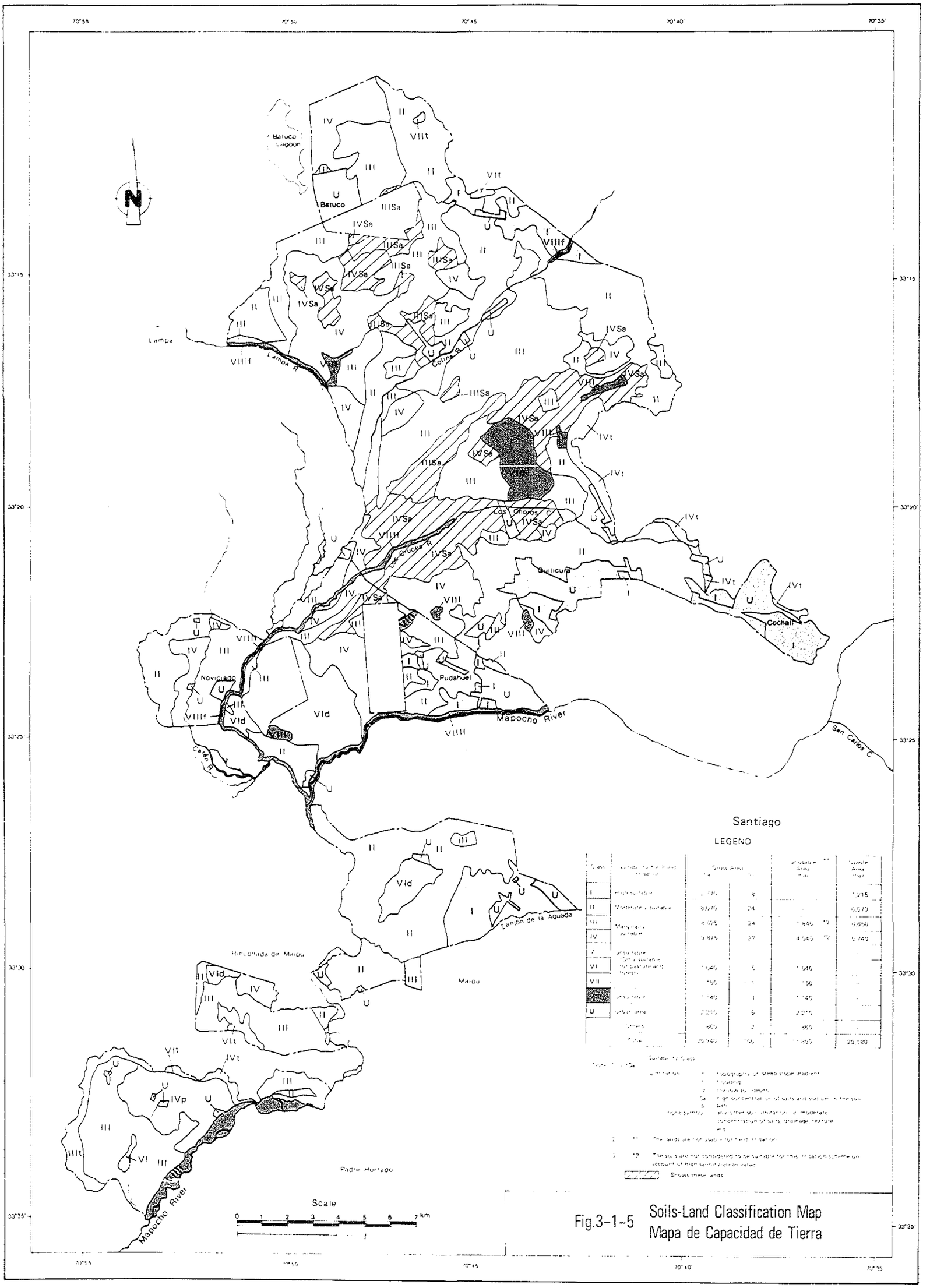

Fig.3-1-5 Soils-Land Classification Map
Mapa de Capacidad de Tierra

Accordingly, the present flooding plain is assessed to be capable land for agricultural production except for apparently low lands in riverside area. Various swamps located over the Study Area are also excluded from agricultural land.

c. Landuse

Neither military base, airport strip nor urban area are included in the Project Area. In addition, the areas to be urbanized in the future (1991) also identified as an alienated land (Fig 4-2-1).

Consequently, the Study Area is classified as shown in Table 3-1-9.

Table 3-1-9 Land Sutability Classification

(Unit: ha)

Division	Class	Area				
		Block-1	Block-2	Block3	Block-4	Total
1 Irrigable Area	I	-	200	240	775	1,215
	II	30	1,800	890	3,850	6,570
	III	1,670	790	1,170	3,020	6,650
	IV	960	130	850	3,805	5,745
	Sub-Total	2,660	2,920	3,150	11,450	20,180
2 Non-irrigable Area	IIIsa1/	-	-	-	1,845	1,845
	IVsa	-	-	210	3,835	4,045
	V	-	-	-	-	-
	VI	-	300	1,090	250	1,640
	VII	-	30	-	120	150
	Sub-Total	-	330	1,300	6,050	7,680
3 Agricultural Facilities Area		90	200 (30)	120 (20)	450 (60)	860 (110)
Total of Agricultural Land (1 - 3)		2,750	3,450	4,570	17,950	28,710
4 Alienated Area	Urbanized	120	320	270	1,500	2,210
	To be urbanized	-	1,140	610	2,120	3,870
	VIII2/	-	-	210	930	1,140
	Sub-total	120	1,460	1,090	4,550	7,220
Grand Total (1 - 4)		2,870	4,910	5,660	22,500	35,940

Note: 1. Figures in ( ) are hectarages of the areas to be urbanized, which are included in the agricultural facilities area.

2. 1/ sa: High saline and alkaline concentrated area
2/ Alienated areas such as lagoons and swamps