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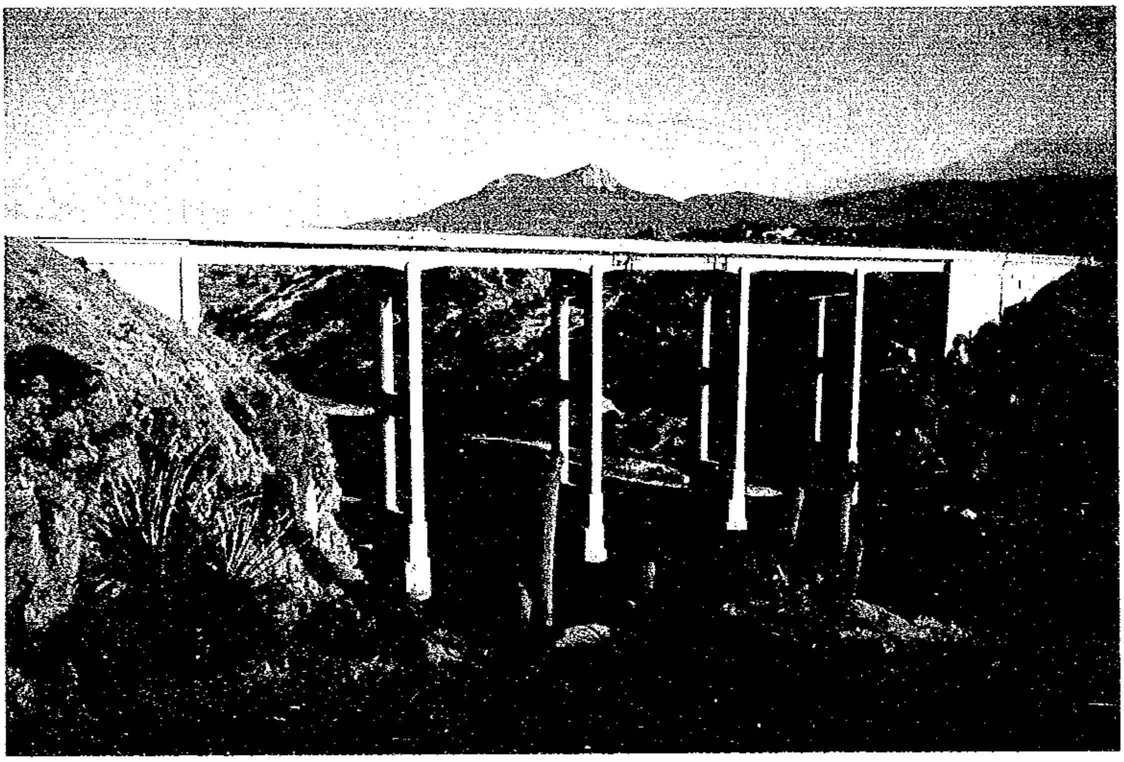
No. 22

The Study on the Rehabilitation and Conservation Program of Bridges in The Republic of Chile



Final Report

March 1993

Japan International Cooperation Agency

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PREFACE

In response to a request from the Government of the Republic of Chile, the Government of Japan decided to conduct the Study on the rehabilitation and Conservation Program of Bridges in the Republic of Chile and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Chile a study team headed by Mr. Katuyuki Hioki, Chodai Co.,Ltd from October, 1991 to February 1993.

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

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

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

March, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President

Japan International Cooperation Agency

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Chapter 1 Introduction

1-1 Survey Background

The coast line of the Republic of Chile is long, running approximately 4,270km north and south. Mountain ranges parallel the coast line, with the Coast Ranges running down the Pacific coast, paralleled by the Andes to the east. Looking east and west, the country is very narrow, with a maximum width of 150km and a minimum width of 80km. 80% of the county is mountainous and high mountains are prominent especially in the northern and central regions.

In order to promote regional economic development and export business, the construction of traffic networks connecting production areas and consumption and shipping areas is urgent. Presently, Chile receives financing from international agencies such as the World Bank and IDB, for developing its road traffic network. The Pan America Highway, which extends north and south, and its adjacent roads are the core of Chile's transportation and traffic network. However, the bridges on these roads are old and present a major obstacle to the development of the road traffic network system.

The construction of bridges in Chile became active in the 1980s and there are now approximately 8,000 bridges. However, earthquakes frequently occur in this country which has more than 55 active volcanoes. In addition to the earthquakes, heavy deterioration of the existing bridges and erosion from fast-flowing rivers from high mountains, such as the Andes, present serious problems in maintaining and managing Chile's bridges.

MOP recently created an inventory of existing bridges on and in close proximity to the Pan America Highway, which is Chile's main road, in order to maintain the functioning of the highway. MOP is planning to establish a bridge maintenance, repair, and management system based on this inventory. In order to activate the efficient maintenance and management of these bridges, it is necessary to summarize and utilize the information which has already been collected individually. Therefore, the establishment of a bridge information system using a data base is also planned. Through this system, a bridge record, inspection record, and repair record, which are presently collected individually, will be systematized and prepared for common use as comprehensive bridge information. By utilizing this method, costs vs effects can be judged rationally.

Given these circumstances, MOP has asked Japan, which has similar topography and geology, and high-technological expertise in the field of bridge earthquake-proofing, for its cooperation and assistance with this plan.

1-2 Survey Outline

1-2-1 Survey Objective

At the request of the Chilean government, a field survey for bridges along the Pan American Highway and the major adjacent routes was conducted throughout Chile, except in the 11th and 12th states. From the field survey, a maintenance, inspection, and repair plan, and related guidelines were created. Additionally, a data base system was constructed using a computer in order to systematically manage all collected information and to perform effective bridge maintenance and management.

The objectives of the field survey can be summarized as follows.

1) To propose a bridge maintenance and management method which is appropriate for Chile.
2) To perform a field survey and collect data related to bridge maintenance and management, and to create a bridge repair plan.
3) To systematize the bridge records and construct a data base.
4) Through this survey, transfer technology related to bridge maintenance, inspection, and management operations to the counterpart engineers in Chile.

1-2-2 Survey Outline

The survey can be divided into the following three themes.

1) Survey of the present bridge situation and determination of a bridge repair plan.
2) Preparation of bridge maintenance and inspection guidelines.
3) The creation of a bridge maintenance and management system.

(1) Present Bridge Situation Survey and Determination of a Bridge Repair Plan

The survey of the present situation regarding bridges in Chile was performed by dividing the survey into a preliminary survey and a detailed survey.

1) Preliminary Survey

The following survey was performed targeting 256 bridges along Route 5 in the 4th to the 10th state, as well as, bridges along other adjacent main roads.

a. Visual observation inspection (deterioration, damage, deformation)
b. Measurement of basic bridge dimensions
c. Photographing bridges

Based on this survey, general bridge structural drawings were created, and a comment chart was created outlining the damage evaluation, structural characteristics, and problems related to bridge maintenance and management.

2) Detailed Inspection Survey

Based on the results of the preliminary survey and its analysis, 10 bridges were targeted for detailed survey. The following surveys were performed.

a. Survey of the deterioration of structural materials such as concrete and steel.
b. Measurement of bridges and related facilities, and a deformation survey.
c. Geological survey

With regard to bridges that traverse rivers, the influence of rivers on bridge structures was surveyed and countermeasures were discussed. A road test was performed for the Peuco Bridge. The purpose of this test was to clarify the characteristics of the Peuco Bridge, to collect data related to the possibility of fatigue failure, and to introduce the latest road test methods to Chilean bridge technicians.

3) Determination of Bridge Repair Plan

Based on the results of the detailed inspection survey, a method of repair was proposed. The proposed method of repair was created based on the following concepts.

a. Priority was given to the recovery of the original functions. Function enhancement was not considered.
b. Design repair based on each member's structural calculations was not performed.
c. Structural damage and the environment surrounding the bridges such as nature and traffic volume were considered.

(2) Creation of Bridge Maintenance and Inspection Guidelines

Bridge maintenance and management is a project to maintain bridge functions, from the completion of bridges to their replacement. In promoting maintenance and management activities, "Bridge Maintenance Repair Guidelines" was created for the technicians in charge of the project. This guideline consists of the following:

1) Definition of terminology used for bridge maintenance and management.
2) Visual inspection survey method
3) Method of evaluating inspection results and standards.
4) Standard repair methods
5) Detailed inspection survey methods
6) Examples of repair methods

(3) Creation of a Bridge Maintenance and Management System

Computers were essential in order to create repair plans scientifically and rationally. In this survey, a system was proposed to evaluate bridge soundness, repair priorities, and to calculate rough estimates for repair costs.

1-3 Survey Organization

The survey was performed in Chile and in Japan. The survey organization consisted of a delegation organized by JICA and its counterpart dispatched from the Chile National Government Agency. The survey was performed through the organization shown in Figure 1-1.

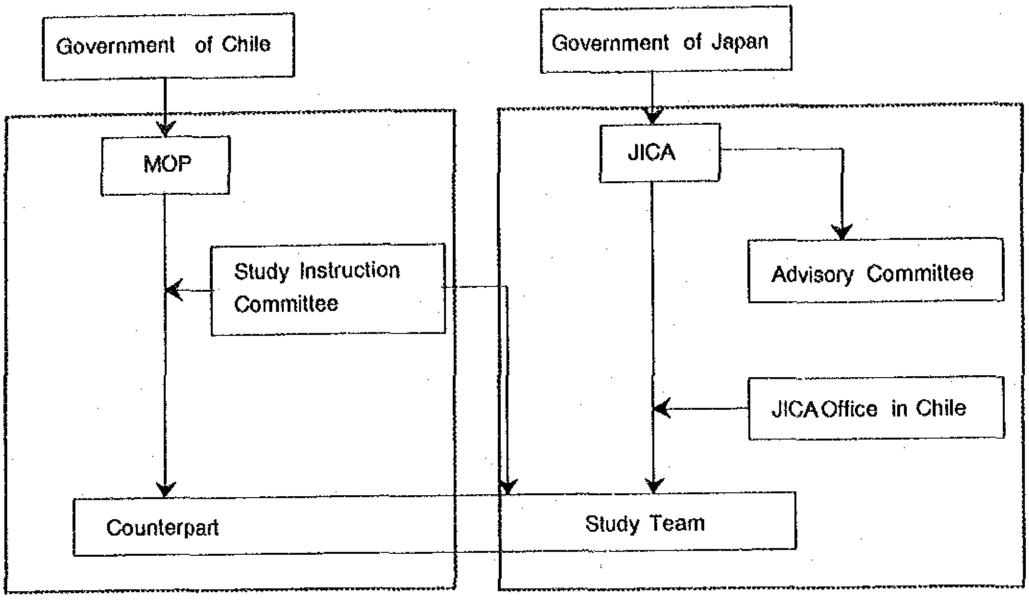


Figure 1-1 Survey Performance Organization

1-4 Organization of MOP

MOP is in charge of the planning, development, maintenance and management of facilities related to public works in Chile. As well, MOP is in charge of roads, road related facilities, ports, airports, and irrigation facilities. The following is an outline of the organization and management of MOP.

1-4-1 Organization of MOP

The government organization in Chile is similar to that in Japan, however, MOP is in charge of a wider range of activities than of the Ministry of Construction. MOP consists of a public works headquarters and a city water headquarters. The public works headquarters consists of the following five bureaus.

(1) Road Bureau
(2) Port Bureau
(3) Airport Bureau
(4) Irrigation Bureau
(5) Construction Bureau

The office for MOP was established in Santiago City, and its Road Bureau is directly in charge of this survey. The Bridge Division, as a part of the Road Bureau, is in charge of the planning, designing, construction, and maintenance and management for all major bridges constructed along all national routes, major local roads, city roads, and others roads. Figure 1-2 shows the organization of the Bridge Division.

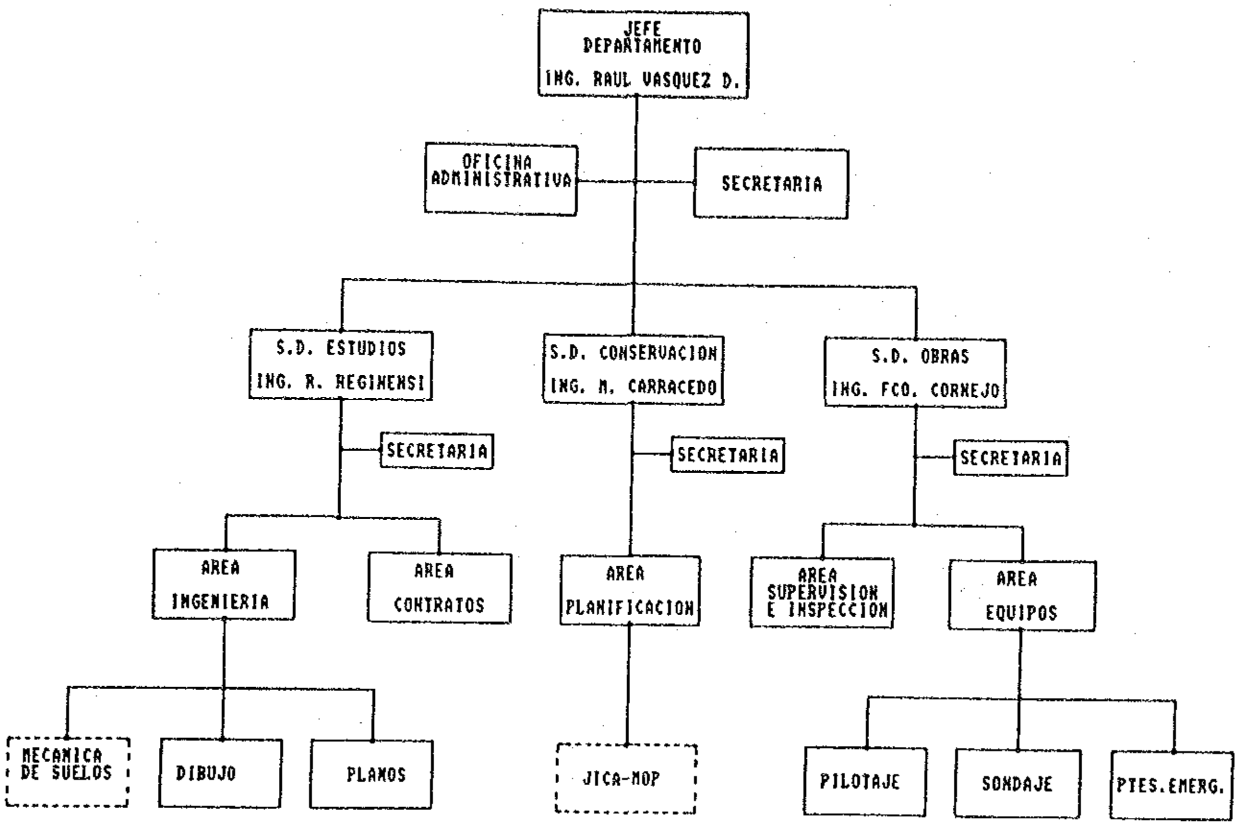


Figure 1-2 Organization Structure of the Bridge Division of the MOP's Road Bureau

1-4-2 Organization of the Local Office of MOP

MOP has established an office in each local area by dividing Chile into eighteen areas. Each office consists of a public works division and a water resource division. The public works division consists of the following six divisions.

(1) Local Road Division
(2) Local Airport Division
(3) Local Construction Division
(4) Local Port Division
(5) Local City Planning Division
(6) Local Irrigation Division

1-4-3 Organization of the Local Road Division

The Local Road Division has a similar structure to MOP's Road Bureau, and consists of the following six sections.

(1) General Affairs Section
(2) Planning Section
(3) Design Section
(4) Contract Section
(5) Local Road Section
(6) Construction Section

The major responsibilities of the Local Road Section are as follows.

(1) Arrangement of inventory data for roads and road related facilities.
(2) Dissemination of information to local branches.
(3) Personnel management of local offices and local branches.
(4) The inspection and reporting of bridges and other structures to the MOP.
(5) Order of small-scale projects

All large-scale projects must be reported to the MOP beforehand. In addition, the director of the Road Division of the local office must explain the project's operation system and management method, and must obtain authorization from MOP.

1-5 Survey Targeted Area

The survey was performed targeting bridges along the major highway Route 5 (Pan American Highway runs through every state) and the adjacent main highways in every state, except for the northern 1st, 2nd, and 3rd states and the southern 11th and 12th states. The survey area is shown in Figure 1-3.

Figure 1-3 Survey Targeted Area

1-6 Present Situation and Problems in Regard to Bridge Maintenance and Management in the Survey Targeted Area

Chile is a thin and long nation that extends over 4,000 kilometers from north to south, and can be roughly divided into 3 areas. The northern area is dry as it receives very little rains, but it is rich in mineral resources. This is an important industrial area that helps support the Chilean economy. The middle area has a mild climate and an abundance of rain. Various industries have been developed in this region and the population density is high. The southern area is cold with heavy rainfall and large forest growth. This is a lumber producing area.

In addition to the weather characteristics of each region, Chile has regional characteristics which must be considered for the maintenance and management of bridges, such as sharp gradients from the mountain areas to the ocean and frequent earthquakes which can cause heavy damage through tsunami. These conditions are similar to those in Japan. Furthermore, large-scale bridge repairs have not been conducted for approximately thirty years because of tight national budgets, consequently, the degree of bridge damage is intense. The following points should also be given special consideration when performing maintenance and management of bridges.

1. Scoured bridge abutments and bridge piers, and washed away banking are often seen as a result of the many rapid rivers.

2. Settlement of substructures due to frequent earthquakes is seen. The problem seems to lie in the selection of the basic form.

3. There are many old bridges. Because of the current increase in the number of heavy vehicles and changes in AASHTO design load, there are many bridges whose load carrying ability is below present day requirements. It is said these bridges comprise approximately 60% of all bridges.

4. As the weather environment for bridges is quite different based on region, careful survey planning in regard to the survey method, survey equipment, and survey period is necessary for the bridge field survey.

5. Because of the similarities in topography and geology, bridge technicians in Chile have a high interest in the latest bridge survey methods, bridge maintenance and management technology, and rational management operation technology being used in Japan.

6. As financial support from international agencies is necessary, the introduction of an operation management system that enables the creation of scientific and rational data and investment planning is highly desirable .

Chapter 2 Bridge Survey

2-1 Bridge Preliminary Survey

2-1-1 Outline of Preliminary Survey

Three teams conducted preliminary surveys targeting 240 bridges. As per agreement, survey bridges included those of a length 10 meters or greater located in the states numbered 4 to 10, and bridges especially required by MOP. Initially, there was a slight difference between the number of targeted bridges proposed by MOP and the actual bridges surveyed. In the end, the number of bridges surveyed by the delegation was 246 located along Route 5 (Tables 2-1 to 2-8), and 10 bridges located on routes other than Route 5 (Table 2-9).

At the beginning of the survey the 3rd state was not targeted. After completion of the survey a detailed survey was also requested by the MOP for the Huasco Bridge. As a result, the number of bridges in the report where visual inspections were performed was 257 bridges, included Huasco Bridge.

Many construction projects to expand the width along Route 5 are presently being carried out at various stages. In some cases it was difficult to assess whether a bridge should be classified as one or two bridges because a completely different bridge was built under the same bridge name, or an old bridge was expanded in width by using a vertical joint to connect to a completely different type of bridge. To combat this confusion when counting the number of bridges, bridges were defined according to the following regulations.

1) When lanes are completely separate with no vertical joints, and the type of bridge is different for each lane. In this situation, the bridge is classified as 1 bridge by adding east or west, or NO. 1 or NO. 2 to the bridge name.

2) Lanes are not completely separate but expanded by using a vertical joint. Lanes are considered to be 1 bridge if the material used is the same (concrete, steel). Lanes are defined as separate bridges when the material used is different (i.e.. the old bridge is steel, and concrete is used for expansion) and the construction year is obviously different.

3) Where completely separate lanes are expanded using different materials or using a different type of construction, each lane is classified as 1 bridge.

4) Both lanes are classified as 1 bridge when the lanes are totally separate, but the year and type of construction and material used are the same, and the substructure is common to both lanes.

2-1-2 Survey Targeted Bridges

Surveyed bridges are shown in the following tables.

Table 2-1 Survey Targeted Bridges in the 4th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	JUAN SOLDADO	503.6	142.5	8.0	11
2	FISCAL	474.1	120.3	7.1	6
3	P.S LA SERENA	473.9	195.4	7.1	13
4	CULEBRON PONIENTE	463.5	40.5	11.5	3
5	CULEBRON ORIENTE	463.5	60.0	6.0	5
6	LANGUNILLAS	442.4	50.0	7.2	6
7	CAMARONES 2	417.0	32.7	6.9	3
8	CAMARONES 1	416.0	56.0	7.0	3
9	ALMENDRO	411.9	24.9	7.0	3
10	QUBRADA SECA	396.7	67.4	7.3	7
11	LIMARI	378.1	198.1	7.1	12
12	LA CEBADA	337.9	20.0	10.0	1
13	EL TENIENTE	335.1	91.6	10.0	6
14	AMOLANAS	310.0	230.2	7.0	13
15	HUENTELAUQUEN	263.0	234.1	7.0	11
16	MILLAHUE	261.5	36.3	7.2	4
17	CHIGUALOCO	244.6	50.0	7.1	4
18	CONCHALI	229.3	55.0	7.1	2
19	P.S. EL NEGRO	218.5	47.7	7.0	7
20	TOTORALILLO	211.1	74.0	7.1	5
21	P.S. PALO COLORADO	202.7	36.5	8.1	3
22	QUILIMARI	200.6	97.2	7.1	5

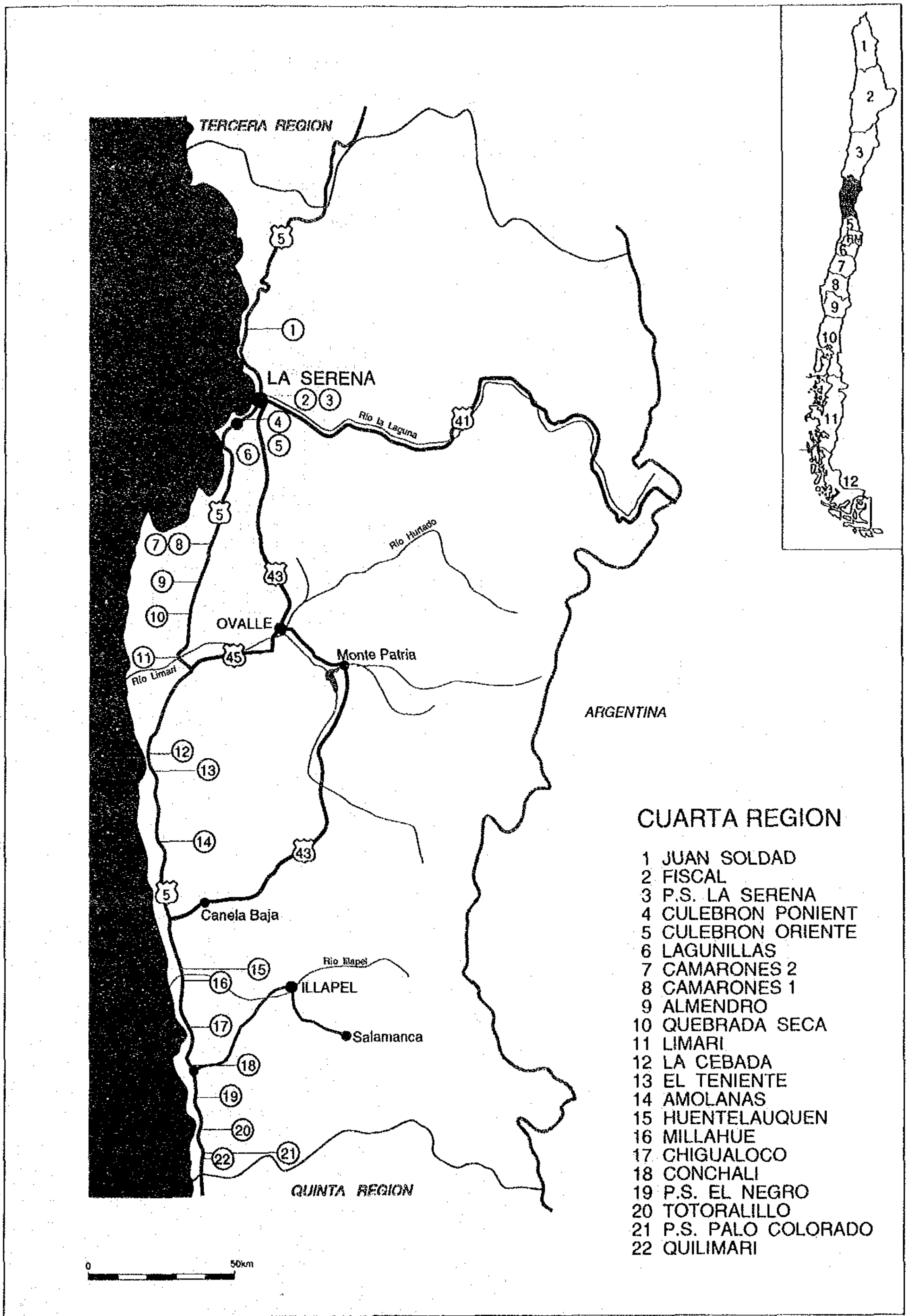


Figure 2-1 Survey Targeted Bridges in the 4th State

Table 2-2 Survey Targeted Bridges in the 5th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	P.S.LOS MOLLES	188.0	18.3	9.0	3
2	EL CHIVATO	185.3	46.9	7.0	3
3	LA BALLENA	180.2	15.0	10.1	2
4	HUAQUEN	171.4	72.6	7.1	5
5	LONGOTOMA No.2	163.2	122.4	7.1	8
6	LONGOTAMA No.1	163.0	14.9	10.1	2
7	PULLALLY	155.2	147.7	8.0	7
8	JAURURO	152.9	24.3	8.1	3
9	TALANQUEN	149.3	12.2	8.0	2
10	QUEBRADILLA	145.9	33.7	8.1	4
11	EL COBRE	123.4	48.0	10.1	6
12	EL MELON	120.3	108.0	8.0	12
13	NOGALES	116.0	112.0	7.0	7
14	EL LITRE	112.6	46.0	8.1	3
15	P.S. EL OLIVO	108.0	45.0	7.1	2
16	ACONCAGUA	100.0	156.0	7.0	7
17	P.S. LA CALAVERA	94.2	97.0	7.0	6
18	LAS VEGAS PONIENTE	88.4	24.1	11.0	1
19	LAS VEGAS ORIENTE	88.4	24.1	11.0	3
20	LOS LOROS	77.8	19.4	14.6	2

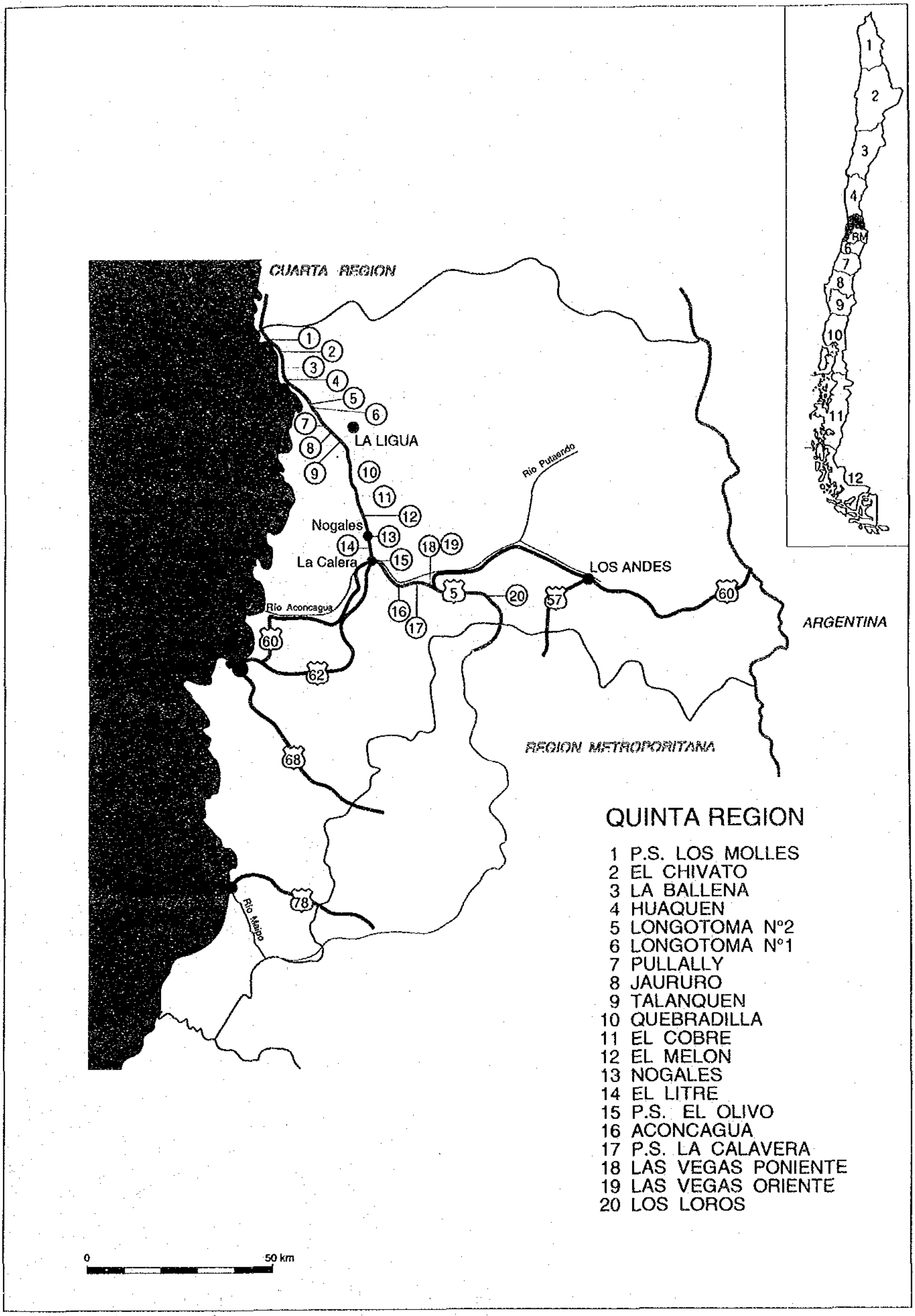


Figure 2-2 Survey Targeted Bridges in the 5th State

Table 2-3 Survey Targeted Bridges in the Capital State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	PEUCO ORIENTE	41.5	16.3	8.0	2
2	PEUCO PONIENTE	41.5	16.3	8.0	2
3	LO PINTO No.1	22.0	13.2	9.1	2
4	LO PINTO No.2	22.0	13.5	12.2	1
5	P.S. LO SIERRA	13.2	22.6	32.1	2
6	P.S. FF.CC. AL SUR No.1	13.7	11.0	35.0	1
7	P.S. FF.CC. AL SUR No.2	13.7	12.0	35.0	1
8	MAIPO	31.1	450.0	17.6	14
9	P.S.FF.CC.PAINE PONIENTE	45.3	34.5	8.1	2
10	P.S.FF.CC.PAINE ORIENTE	45.3	23.0	8.1	3
11	PAINE No.1	48.3	18.4	8.0	1
12	PAINE No.2	48.3	18.4	9.3	1
13	P.S.HOSPITAL ORIENTE	51.2	73.3	8.0	2
14	P.S.HOSPITAL PONIENTE	51.2	73.3	8.0	4

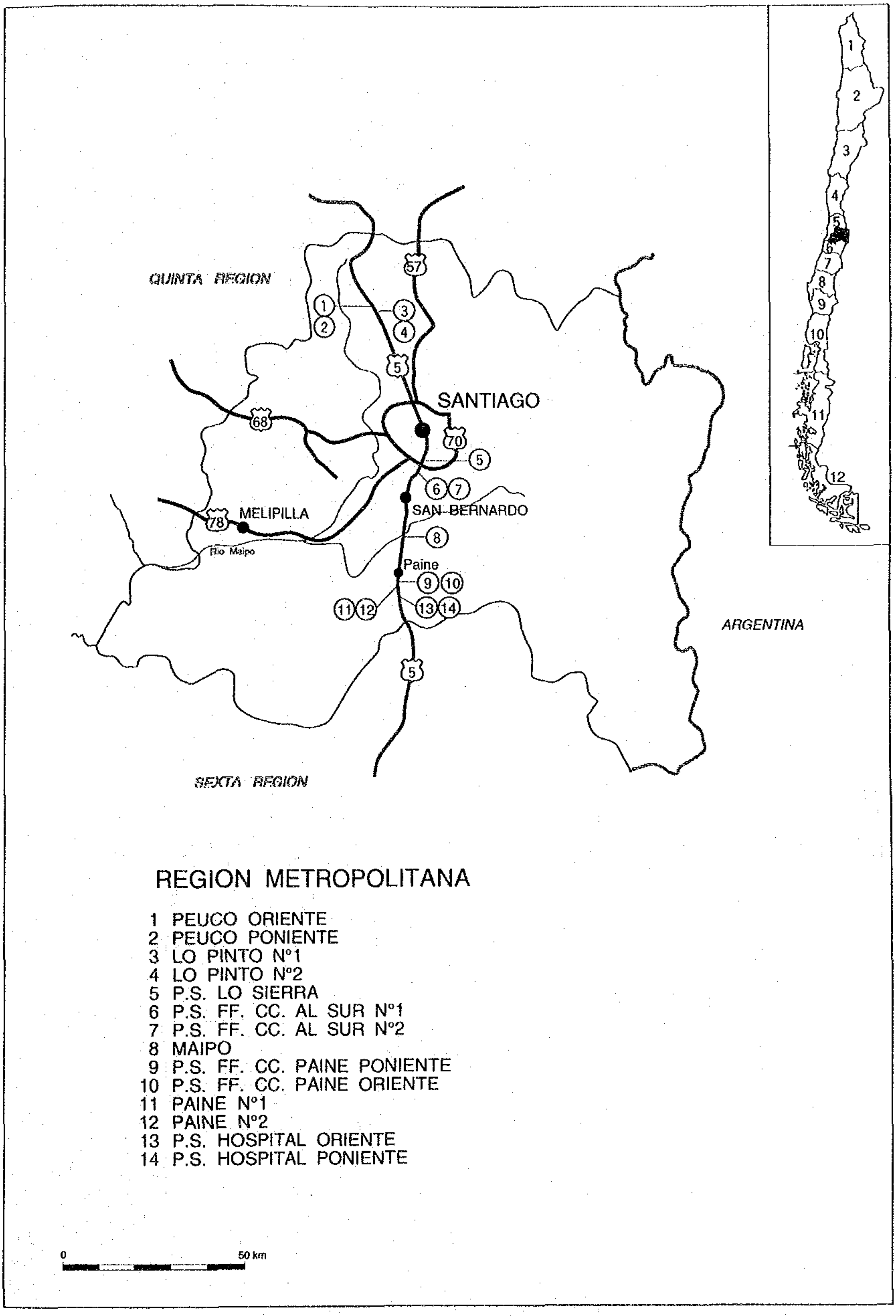
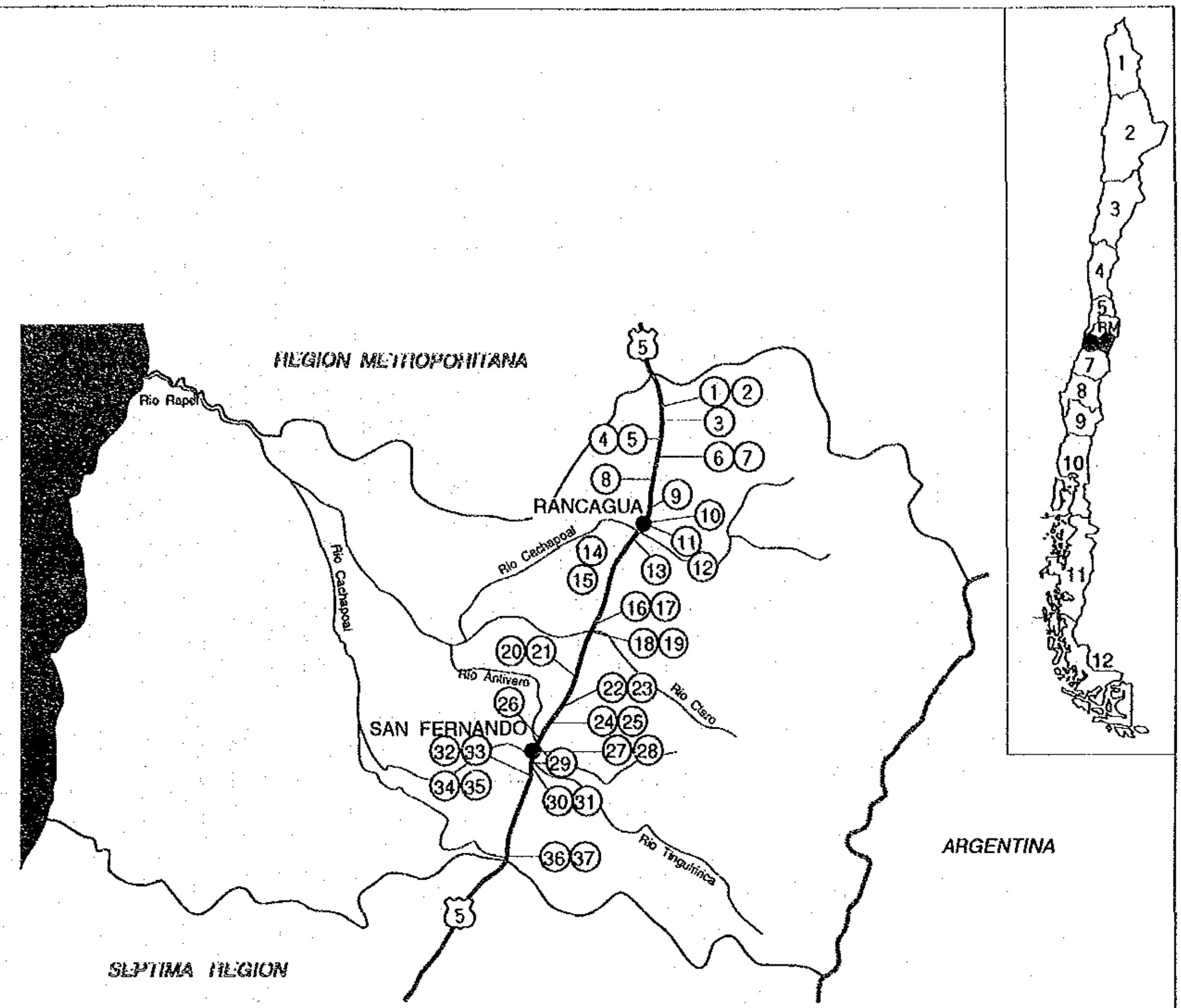


Figure 2-3 Survey Targeted Bridges in the Capital State

Table 2-4 Survey Targeted Bridges in the 6th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	PEUCO ORIENTE	61.9	99.4	8.0	3
2	PEUCO PONIENTE	61.9	92.4	6.0	5
3	TRONCO	66.5	25.3	19.0	3
4	STA BLANCA PONIENTE	71.5	32.4	10.1	3
5	STA BLANCA ORIENTE	71.5	28.3	10.1	5
6	BENITO No.1	74.8	14.5	9.2	2
7	BENITO No.2	74.8	20.0	11.0	2
8	CADENA	80.3	24.8	11.0	3
9	P.S. ALAMEDA	87.3	27.5	21.0	2
10	P.S. MACHALI	87.9	12.5	21.0	1
11	P.S.EL TENIENTE No1	88.9	34.5	8.3	4
12	P.S.EL TENIENTE No2	88.9	34.5	8.0	4
13	CACHAPOAL	91.5	248.4	13.9	9
14	P.S.LOS LIRIOS ORIENTE	96.7	55.4	10.0	2
15	P.S.LOS LIRIOS PONIENTE	96.7	71.3	7.3	5
16	TIPAUME No.1	113.3	39.2	7.9	3
17	TIPAUME No.2	113.3	38.9	10.1	3
18	CLARO No.1	114.5	70.9	10.0	4
19	CLARO No.2	114.5	70.5	10.0	4
20	P.S. PELEQUEN PONIENTE	125.6	24.0	8.0	1
21	P.S. PELEQUEN ORIENTE	125.6	24.0	8.0	1
22	RIGOLEMU ORIENTE	126.3	53.3	7.1	4
23	RIGOLEMU PONIENTE	126.3	51.9	10.1	2
24	CHARQUICAN ORIENTE	133.0	20.0	10.1	1
25	CHARQUICAN PONIENTE	133.0	20.0	10.1	1
26	P.S.SUNFERNANDO	137.8	15.0	16.0	1
27	ANTIVERO ORIENTE	140.2	157.4	8.1	4
28	ANTIVERO PONIENTE	140.2	157.4	8.1	9
29	P.S. TERMAS	140.4	9.7	27.7	1
30	TINGUIRIRICA ORIENTE	143.3	229.8	7.1	6
31	TINGUIRIRICA PONIENTE	143.3	229.8	7.1	11
32	DESCARGA No.1 ORIENTE	144.4	25.3	7.1	2
33	DESCARGA No.1 PONIENTE	144.4	25.3	7.1	2
34	DESCARGA No.2 ORIENTE	144.5	25.5	7.2	2
35	DESCARGA No.2 PONIENTE	144.5	25.5	7.2	4
36	PEOR ES NADA ORIENTE	164.5	78.0	7.0	5
37	PEOR ES NADA PONIENTE	164.5	78.0	7.0	3



SEXTA REGION

1 PEUCO ORIENTE
2 PEUCO PONIENTE
3 TRONCO
4 STA BLANCA PONIENTE
5 STA BLANCA ORIENTE
6 BENITO N°1
7 BENITO N°2
8 CADENA
9 P.S. ALAMEDA
10 P.S. MACHALI
11 P.S. EL TTE. N°1
12 P.S. EL TTE. N°2
13 CACHAPOAL
14 P.S. LOS LIRIOS ORI.
15 P.S. LOS LIRIOS PON.
16 TIPAUME N°1
17 TIPAUME N°2
18 CLARO N°1
19 CLARO N°2
20 P.S. PELEQUEN PON.
21 P.S. PELEQUEN ORI.
22 RIGOLEMU ORI.
23 RIGOLEMU PON.
24 CHARQUICAN ORI.
25 CHARQUICAN PON.
26 P.S. SAN FERNANDO
27 ANTIVERO ORIENTE
28 ANTIVERO PONIENTE
29 P.S. TERMAS
30 TINGUIRIRICA ORI.
31 TINGUIRIRICA PON.
32 DESCARGA N°1 ORI.
33 DESCARGA N°1 PON.
34 DESCARGA N°2 ORI.
35 DESCARGA N°2 PON.
36 PEOR ES NADA ORI.
37 PEOR ES NADA PON.

0 50 km

Figure 2-4 Survey Targeted Bridges in the 6th State

Table 2-5 Survey Targeted Bridges in the 7th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	ENDESA	177.1	24.8	23.5	2
2	TENO	178.0	323.1	7.0	13
3	GUAIQUILLO ORIENTE	194.0	101.8	7.0	5
4	GUAIQUILLO PONIENTE	194.0	148.0	7.0	4
5	P.S. MAQUEHUA ORIENTE	194.6	87.5	7.0	8
6	P.S. MAQUEHUA PONIENTE	194.6	75.5	7.0	3
7	LONTUE ORIENTE	197.0	229.0	6.1	9
8	LONTUE PONIENTE	197.0	238.2	6.1	7
9	PIRIHUIN	200.0	25.7	8.0	5
10	SECO	201.1	25.0	8.0	1
11	CLARO	218.4	117.7	7.3	7
12	CHARGRES	223.4	27.8	8.1	3
13	PANGUE	245.0	133.4	7.1	7
14	LIRCAY No.1	251.3	150.5	6.0	8
15	LIRCAY No.2	251.8	100.0	10.1	3
16	P.S. SAN CLEMENTE	252.8	29.4	8.0	3
17	P.S. LIRCAY	255.8	51.0	7.2	3
18	PIDUCO	257.4	36.7	8.1	4
19	MAULE PONIENTE	269.5	442.8	3.1	8
20	MAULE ORIENTE	269.5	442.8	3.2	8
21	LAS VERTIENTES	270.0	58.0	7.2	4
22	P.S. BOBADILLA	271.8	45.9	7.1	3
23	QUILIPIN	294.9	30.2	8.0	3
24	PUTAGAN	295.7	120.7	6.0	6
25	ANCOA No.1	303.7	94.9	7.1	6
26	ANCOA No.2	304.8	115.4	7.1	7
27	ACHIBUENO	305.5	306.2	7.1	13
28	LIGUAY	316.6	100.6	6.0	5
29	LONGAVI	320.5	319.8	8.0	16
30	HUACARNECO	320.5	20.0	10.1	1
31	PIGUCHEN	320.5	20.3	9.1	3
32	P.S. COPIHUE	331.4	46.7	8.1	3
33	COPIHUE	332.5	24.2	8.0	3
34	COLLIGUAY	335.9	12.7	9.1	2
35	PARRAL	339.0	16.6	9.2	1
36	LA VEGA	347.4	19.1	10.1	3

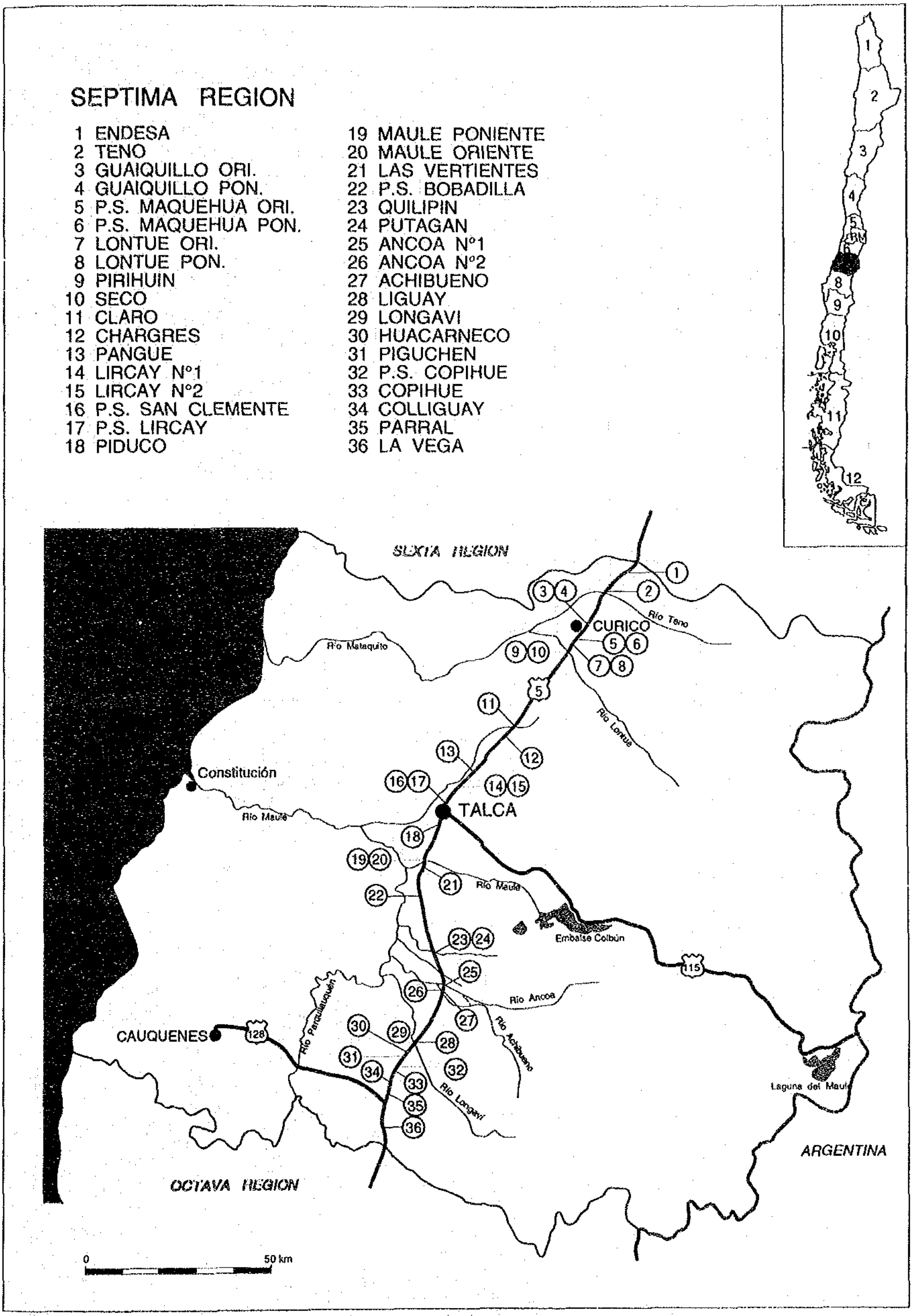


Figure 2-5 Survey Targeted Bridges in the 7th State

Table 2-6 Survey Targeted Bridges in the 8th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	PERQUILAUQUEN	351.6	422.0	6.0	19
2	NIQUEN	359.6	26.3	9.1	4
3	COLLIGUAY	361.7	11.8	6.9	2
4	VIRGUIN	365.8	11.0	6.9	2
5	BULI	369.4	12.3	9.1	2
6	GAONA	373.5	12.2	10.1	2
7	NAVOTAVO	378.2	33.4	8.1	4
8	NINQUIHUE	387.5	20.0	9.3	3
9	MENELHUE	390.5	23.9	8.1	4
10	P.S. IANSA	393.6	11.0	9.0	1
11	NUBLE	397.7	887.2	10.2	23
12	P.S. CHILLAN	405.7	55.6	8.0	1
13	P.S. COCHARCAS	406.9	15.2	16.7	1
14	P.S. CONFLUENCIA	410.0	21.3	8.1	1
15	P.S. SANTA ELISA	410.5	14.1	10.0	1
16	NEBUCO	414.9	156.3	8.1	7
17	LARQUI	425.6	73.3	7.0	5
18	PITE	426.8	19.7	10.1	3
19	GALLIPAVO	429.7	33.6	8.2	4
20	ESPINAL	433.7	20.2	10.1	3
21	PAL-PAL	440.3	29.9	8.0	1
22	DIGUILLIN	444.3	77.7	7.2	4
23	RELBUN	448.3	49.8	7.2	4
24	ITATA	455.3	77.6	7.1	3
25	LAJITA	474.8	30.4	8.0	1
26	BATUCO	483.6	33.0	8.1	4
27	BATUQUITO	484.6	16.7	7.0	3
28	SALTO DEL LAJA	486.4	92.7	10.0	4
29	CALIBORO	488.0	20.5	10.0	3
30	PASO DE PIEDRA	493.5	15.0	6.0	3
31	HUAQUI	501.8	36.6	6.0	3
32	RARINCO	508.1	32.5	6.0	4
33	QUILQUE	514.0	14.1	9.6	2
34	DUQUECO	524.0	124.1	8.1	4
35	BIO BIO	531.8	206.9	6.0	5
36	DESCARGA	531.9	92.0	8.0	10
37	BUREO	545.6	140.4	8.2	5
38	CHUMULCO	551.6	24.0	7.2	3
39	CANAL RIEGO	554.8	10.5	8.1	1

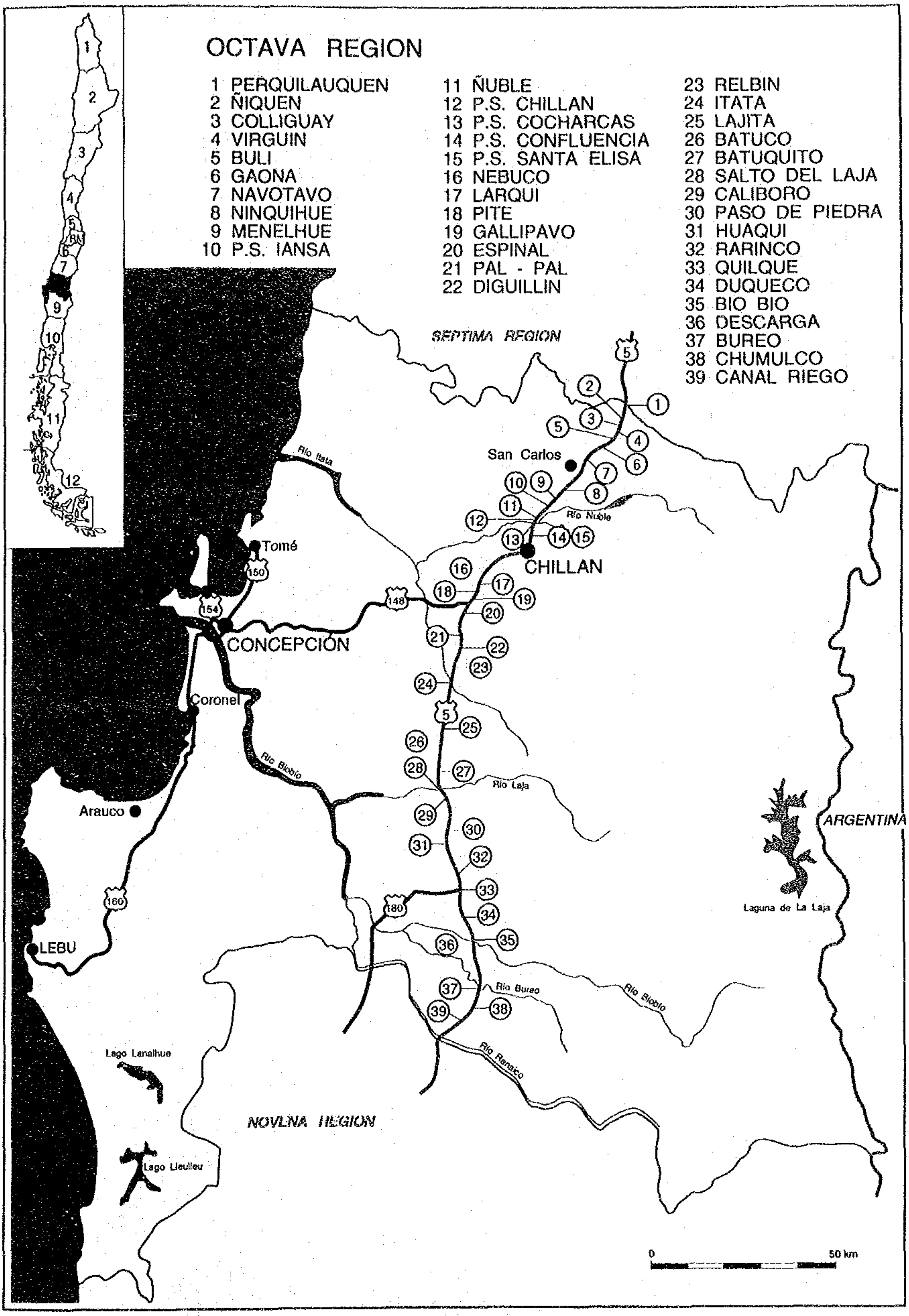


Figure 2-6 Survey Targeted Bridges in the 8th State

Table 2-7 Survey Targeted Bridges in the 9th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	ESPERANZA	561.7	94.3	7.1	5
2	MININCO	564.1	54.4	7.1	3
3	MALLECO	576.7	344.1	18.4	10
4	P.S. PIDIMA	584.5	25.6	8.0	1
5	HUEQUEN	589.0	23.5	8.0	3
6	CHAMICHACO	590.8	16.8	8.8	1
7	DUMO	600.9	29.8	8.0	3
8	COLO	608.2	58.0	8.2	3
9	TRAIGUEN	609.2	30.0	8.0	1
10	TRICAUCO	614.2	20.3	8.0	1
11	CHANCO	618.0	20.3	8.0	1
12	QUINO	619.5	57.8	8.0	1
13	EL SALTO	621.2	20.3	8.0	1
14	P.S. PUA	622.0	26.2	10.0	3
15	QUILLEM	639.5	54.6	8.0	3
16	PUMALAL	665.4	67.0	8.0	3
17	CAUTIN	677.9	140.7	12.0	8
18	METRENCO	687.1	24.0	8.0	2
19	PICHI QUEPE ANTIGUO	689.9	18.5	9.4	1
20	PICHI QUEPE NUEVO	689.9	18.5	8.0	1
21	QUEPE PONIENTE	690.3	80.0	8.0	4
22	QUEPE ORIENTE	690.3	80.0	8.0	4
23	HUILQUILCO	693.3	20.3	8.0	1
24	PELALES	696.6	20.3	8.0	1
25	P.S. FREIRE No.1	699.3	13.5	10.0	1
26	TOLTEN	704.0	392.2	6.0	16
27	CHADA	713.0	24.0	7.4	3
28	DONGUIL	721.0	75.0	10.0	3
29	P.S. LONCOCHE	756.4	133.4	10.0	7
30	LO VASQUEZ No.2	759.5	15.4	10.8	1
31	LO VASQUEZ No.3	759.9	14.9	10.8	2

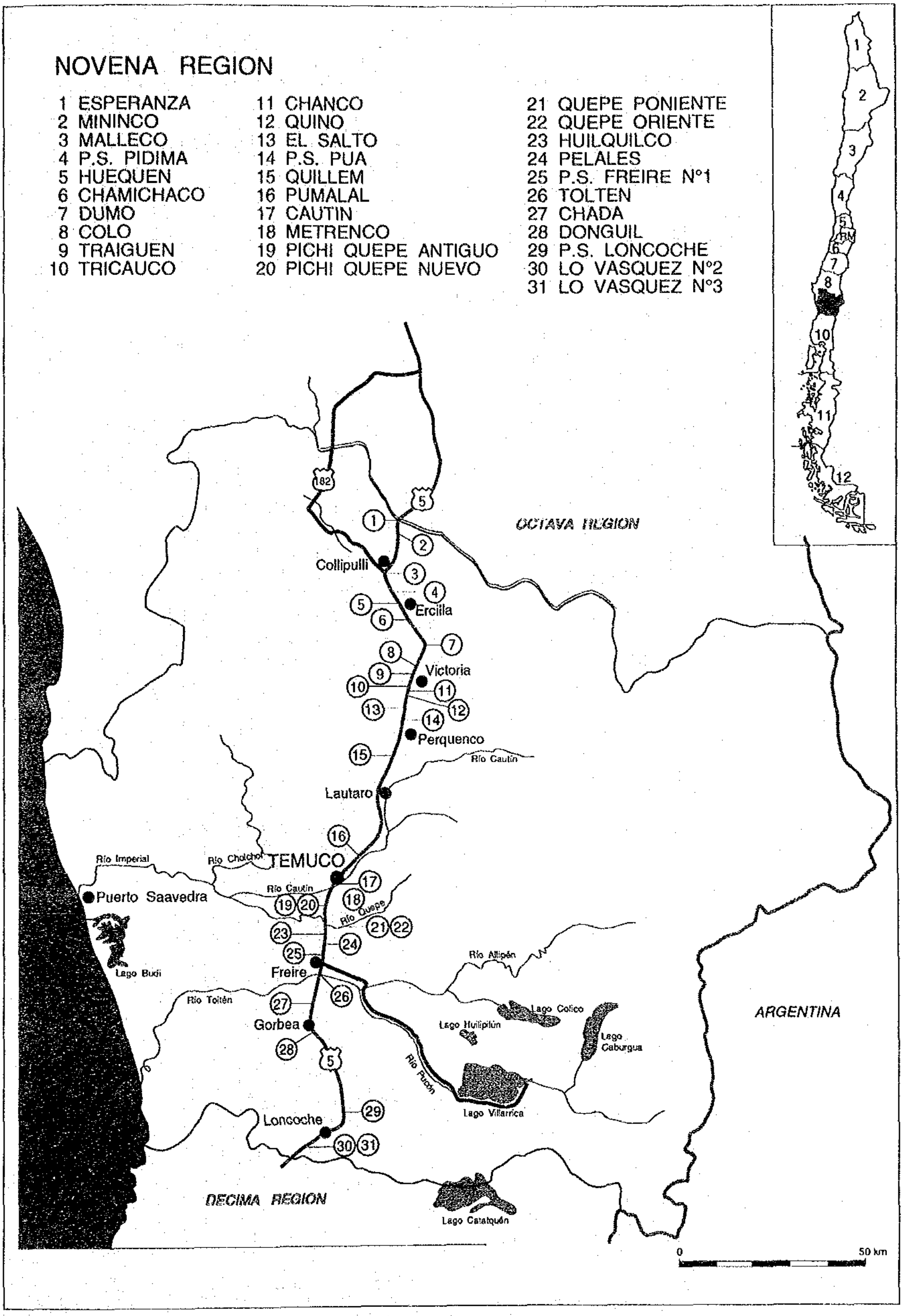


Figure 2-7 Survey Targeted Bridges in the 9th State

Table 2-8 Survey Targeted Bridges in the 10th State

No.	Nombre de puente	Ubic.	Long.	Calz.	Tramos
1	CRUCES	767.9	90.2	6.0	6
2	LELFUCADE No.1	770.8	62.3	7.1	4
3	LELFUCADE No.2	771.4	11.0	10.2	1
4	NEGRO	775.8	130.0	8.1	7
5	RUCACO	787.0	148.1	8.1	8
6	P.S. MAFIL	799.7	27.0	10.0	2
7	RUCAPICHIO	800.7	51.1	10.0	2
8	INAQUE	804.0	70.0	10.0	2
9	MAFIL No.1	808.3	20.6	10.1	1
10	MAFIL No.2	808.5	20.7	10.0	1
11	MAFIL	808.8	50.6	10.1	2
12	HUILLINCO	825.1	60.1	10.1	2
13	SAN PEDRO	831.8	232.3	16.0	5
14	P.S. LOS LAGOS	831.8	12.6	16.0	1
15	HUINA-HUINA	833.5	48.2	8.0	3
16	EL TREBOL	844.5	44.8	10.0	1
17	LLOLLELHUE	869.2	54.4	8.1	2
18	CHOROY	870.6	27.2	8.1	1
19	NISCON	872.5	27.2	8.1	1
20	CUNO-CUNO	873.4	27.1	8.1	1
21	LA POZA	883.3	27.1	8.1	1
22	TRAIGUEN No1	887.1	60.5	8.1	3
23	RIO BUENO	889.2	325.1	8.1	7
24	PILMAIQUEN	895.0	99.7	8.1	3
25	HUITRAL	938.5	24.0	10.0	3
26	PUQUITRE	941.7	20.0	10.0	3
27	DAMAS	949.4	60.0	8.0	2
28	RAHUE	959.4	148.0	8.0	2
29	CHIFIN	973.8	40.0	8.0	3
30	FORRAHUE	977.1	45.0	8.0	3
31	P.S. CASMA	996.9	18.6	10.0	1
32	EL PESCADO	997.7	31.8	9.8	1
33	EL BURRO	1002.9	13.8	10.0	1
34	MAULLIN No.2	1028.6	56.0	8.0	2
35	EL NEGRO	1044.2	20.0	10.0	3
36	ARENAS	1044.4	24.4	9.9	3
37	TAYLOR	1064.2	13.8	10.0	2
38	TRAPEN	1066.0	38.0	8.1	5
39	ARENAS	1068.9	12.2	10.0	2
40	GOMEZ	1077.0	38.8	7.9	5
41	GUAUDA	1077.2	14.2	10.0	2
42	TENIO	1085.0	14.0	10.0	2
43	ASTIL	1087.8	13.5	10.0	2
44	TAMBOR	1088.7	36.1	2.0	4
45	CEBADAL	1089.6	13.5	10.0	2
46	MURROR	1091.4	14.0	10.0	2
47	LOS PALOS	1096.0	13.2	10.0	2
48	TRAPEN BAJO	1097.0	36.0	8.0	4

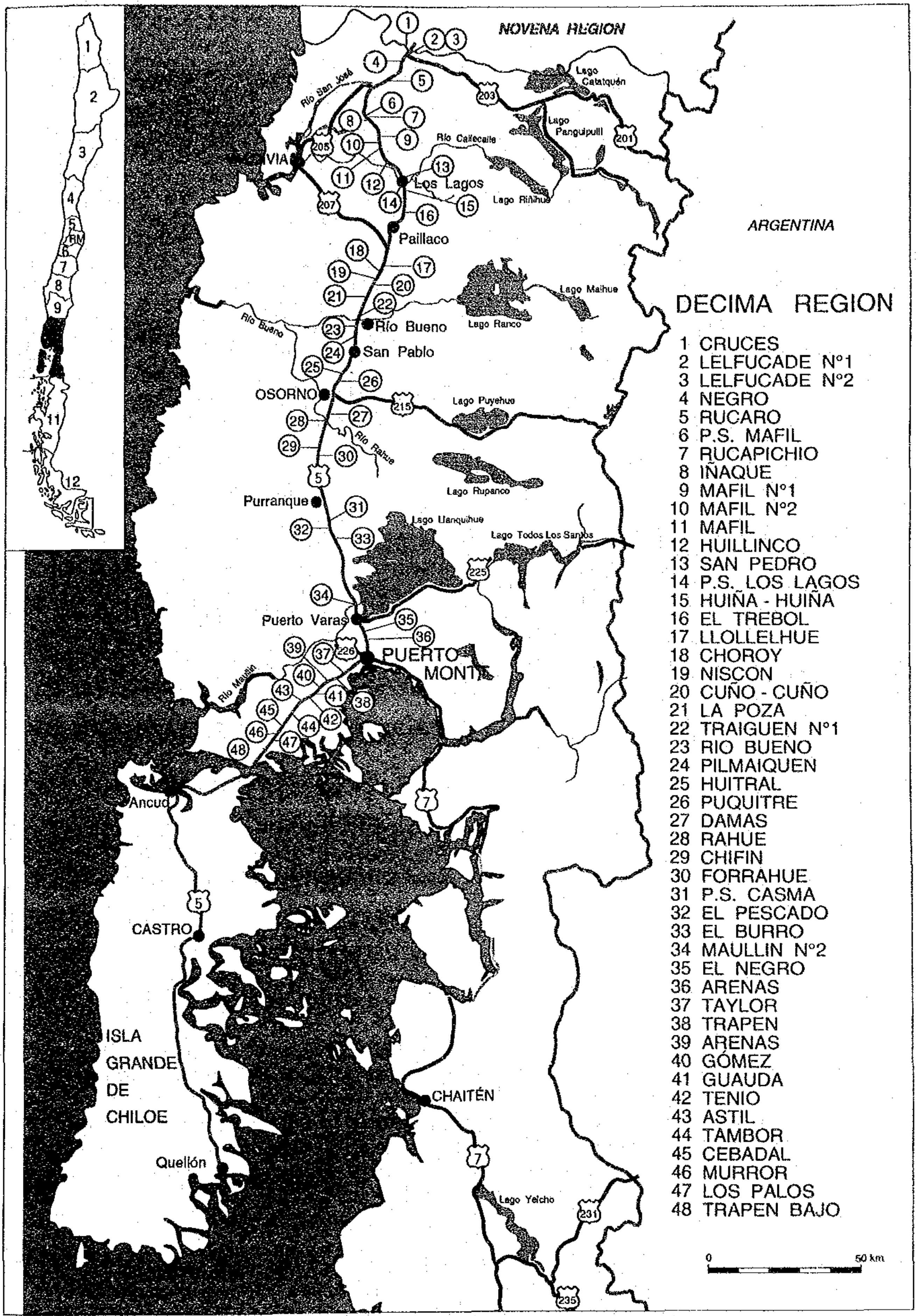


Figure 2-8 Survey Targeted Bridges in the 10th State

Table 2-9 Survey Targeted Bridges on Routes other than Route 5

No	NOMBRE DE PUENTE	REGION	NOTA
1	EL MONTE	RM	
2	ESPERANZA	RM	
3	LONCOMILLA	7	
4	QUEBRADA HONDA	8	CONCEPCION
5	RAMADILLAS	8	
6	QUILLON	8	CONCEPCION
7	BIO BIO ANTIGUO	8	CONCEPCION
8	PICHOY	10	VALDIVIA
9	CAYUMAPU	10	VALDIVIA
10	CRUCES CALLE CALLE	10	VALDIVIA

2-1-3 Field Survey Method

In order to perform the survey along a 2,000 km route, extending north and south, the delegation was divided into 3 survey teams. A survey chart (Table 2-3) was created prior to operation in order to maintain consistency in the types of data obtained from each survey team. Data included estimation of bridge damage, basic bridge size, and specific bridge portions to be photographed. Furthermore, prior to the actual survey, a joint survey was conducted and opinions were exchanged in an effort to minimize differences in the evaluation values between each survey team.

The following survey sheet was prepared for the preliminary survey.

1) Inspection Record

An inspection record (Table 2-10) was created as a means to eliminate differences in inspection parts and evaluation items between surveying teams. The record lists the same items as in the inspection book; as well, these items are basically the same as the evaluation matrix which is used for evaluation of bridge soundness. The essential items were determined during an exchange of opinions after the joint survey.

2) Record of Basic Bridge Measurements

As was expected many old bridges did not have drawings or a record of basic information for input into the data base. In these cases, basic bridge measurements were performed. Measurement records (Figure 2-9 to 2-13) were created showing the elements that would be measured, such as, bridge width and length. Once again efforts were made to minimize inconsistencies in the measuring data, and general structural drawings were made based on this record.

3) Photographic Positioning Instructions

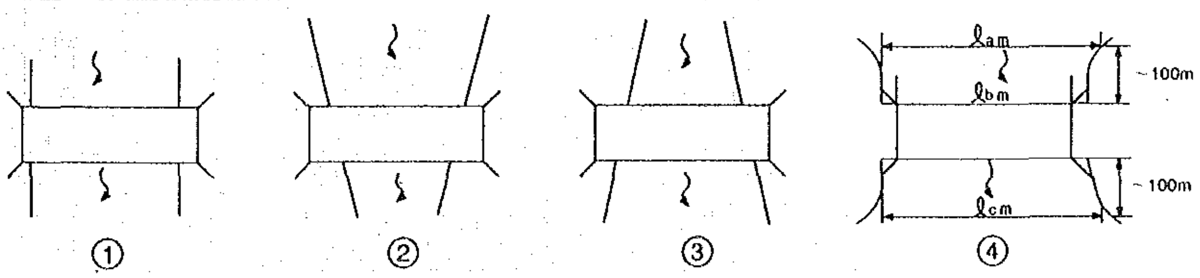
Photographs were an important feature of the inspection data. Reference drawings (Figure 2-14 and 2-15) such as overall structural drawings, bridge surface conditions, main girders, slab, crossbeams, abutments, bridge piers were created, along with drawings of the structures which required special attention and drawings which showed bridge damage. Efforts were made not to ignore any detail. As a general rule, photographs were taken using 1 roll of film (24 exposures) for each bridge, and pictures taken were placed in a photograph record book.

Table 2-10 Inspection Records

CODIGO DEL PUENTE		NOMBRE		NOMBRE DEL CRUCE		NOMBRE DEL RIO	

Lagar de inspeción : Nombre del inspector : Pagina No. de

		TIPO DE DAÑO O DETERIORO Y SU CANTIDAD					
PAVIMENTO	ITEM	1 ALABEO	2 ENSURCADO O CARRILES	3 FISURAMIENTO	4 ASENTAMIENTO	5 OTROS	
	GRADO O CANTID						
BARANDAS	ITEM	1 DEFORMACION	2 OXIDAMIENTO	3 CORROSION	4 FISURAMIENTO	5 ARMADURA AL AIRE	6 OTROS
	GRADO O CANTID						
JUNTAS DE EXPANSION	ITEM	1 SONIDOS EXTRÑOS	2 FILTRACION DE AGUAS	3 DEFORMACION	4 MOVIMIENTOS VERTICALES	5 JUNTAS OBSTRUIDAS	6 OTROS
	GRADO O CANTID						
LOSA	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 DESCASCA RAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES CENCIAS
	GRADO O CANTID						
RIOSTRAS (PTES. DE ACERO)	ITEM	1 OXIDAMIENTO	2 CORROSION	3 DEFORMACION	4 ROTURA DE LAS UNIONES	5 ROTURA DE ARRIOSTRAMIENTOS	6 OTROS
	GRADO O CANTID						
VIGAPRINCIPAL DE ACERO (EN CHERCHAS)	ITEM	1 OXIDAMIENTO	2 CORROSION	3 DEFORMACION	4 PERDIDA DE PERNOS	5 FISURAS EN SOLADURAS	6 OTROS
	GRADO O CANTID						
RIOSTRAS (PTES. CONCRETO)	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 DESCASCA RAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES CENCIAS
	GRADO O CANTID						
VIGA PRINCIPAL DE CONCRETO	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 DESCASCA RAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES CENCIAS
	GRADO O CANTID						
APOYOS	ITEM	1 ROTURA DEL APOYO	2 ROTURA DE ACCESORIOS	3 SALIDA DE ANCLAJES	4 ROTURA DEL DISCO	5 DEFORMACIONES RARAS	6 OTROS
	GRADO O CANTID						
ESTRIBOS	ITEM	1 GRIETAS O DESCASCARAM	2 FISURAS A PARTIR APOYO	3 ROTURA DEL PARAPETO	4 INCLINACIONES	5 SOCAVACIONES	6 OTROS
	GRADO O CANTID						
CEPAS	ITEM	1 GRIETAS O DESCASCARAM	2 FISURAS A PARTIR APOYO	3 DEFORM DE CANTILEVER	4 INCLINACIONES	5 SOCAVACIONES	6 OTROS
	GRADO O CANTID						
PINTURA	ITEM	1 DECOLORACION	2 OXIDAMIENTO	3 AMPOLLAMIENTO	4 DESCASCARAM.	5 OTROS	
	GRADO O CANTID						
ARTICULACIONES DE VIGAS GERBER	ITEM	1 FISURAS EN UNA DIRECCION	2 FISURAMIENTO EN RED	3 AGRIETAMIENTO	4 ARMADURA AL AIRE	5 NIDOS DE PIEDRAS	6 EFLORES CENCIAS
	GRADO O CANTID						
OTROS	ITEM	1 DERRUMBE TALUD,ESTRIBO	2 DAÑOS POR IMPACTO ROCAS	3 DAÑOS EN CABO VIGAS	4 SE EFECTUO REPARACION?	5 OTROS	
	GRADO O CANTID						
COMENTARIOS ESPECIALES	1 EXISTIERON DESBORDAMIENTOS a. SI b. NO c. NO SE SABE			2. EXISTEN EMPRESTITOS DE MATERIAL a. SI b. NO			



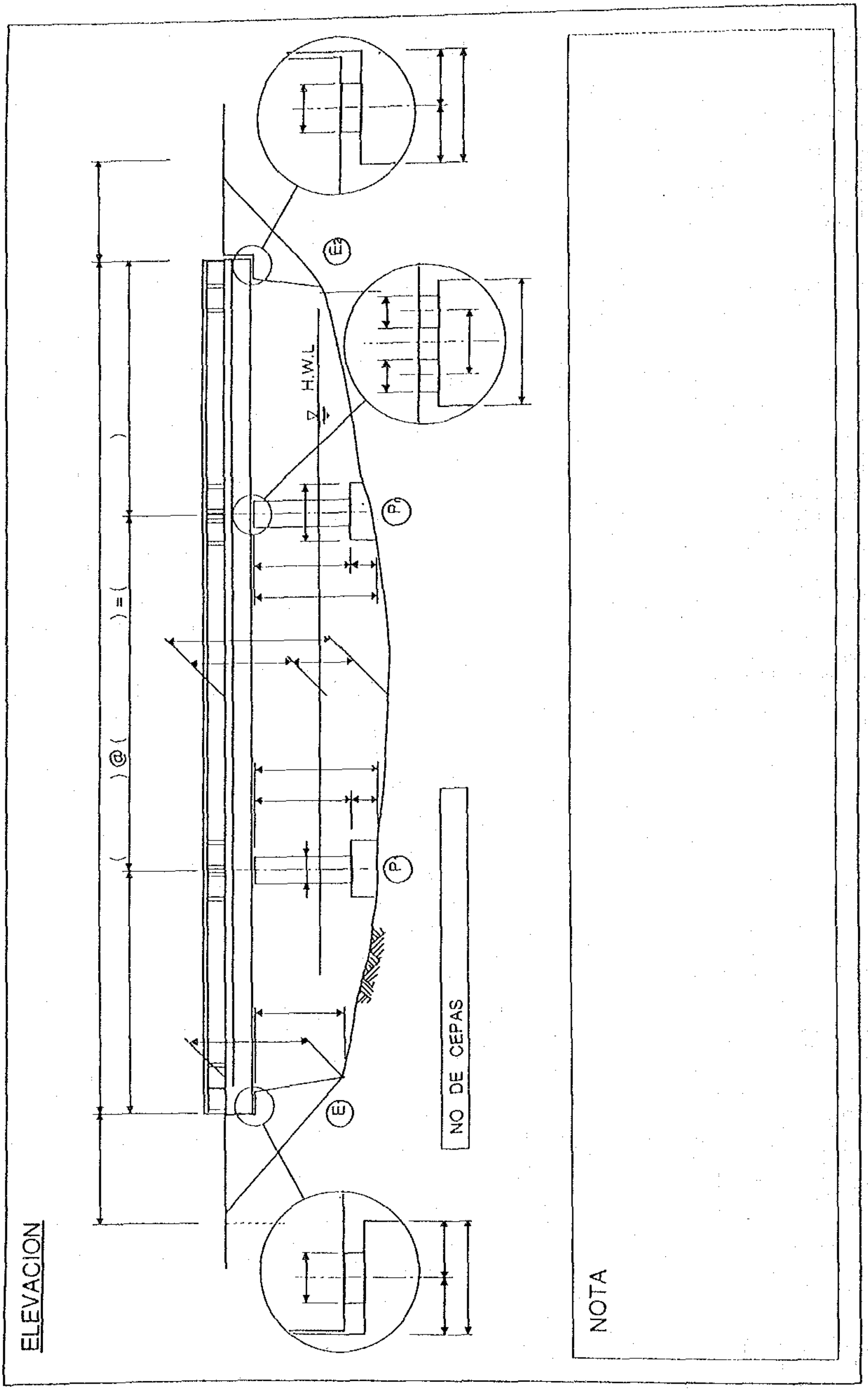


Figure 2-9 Form for Size Measurement (1)

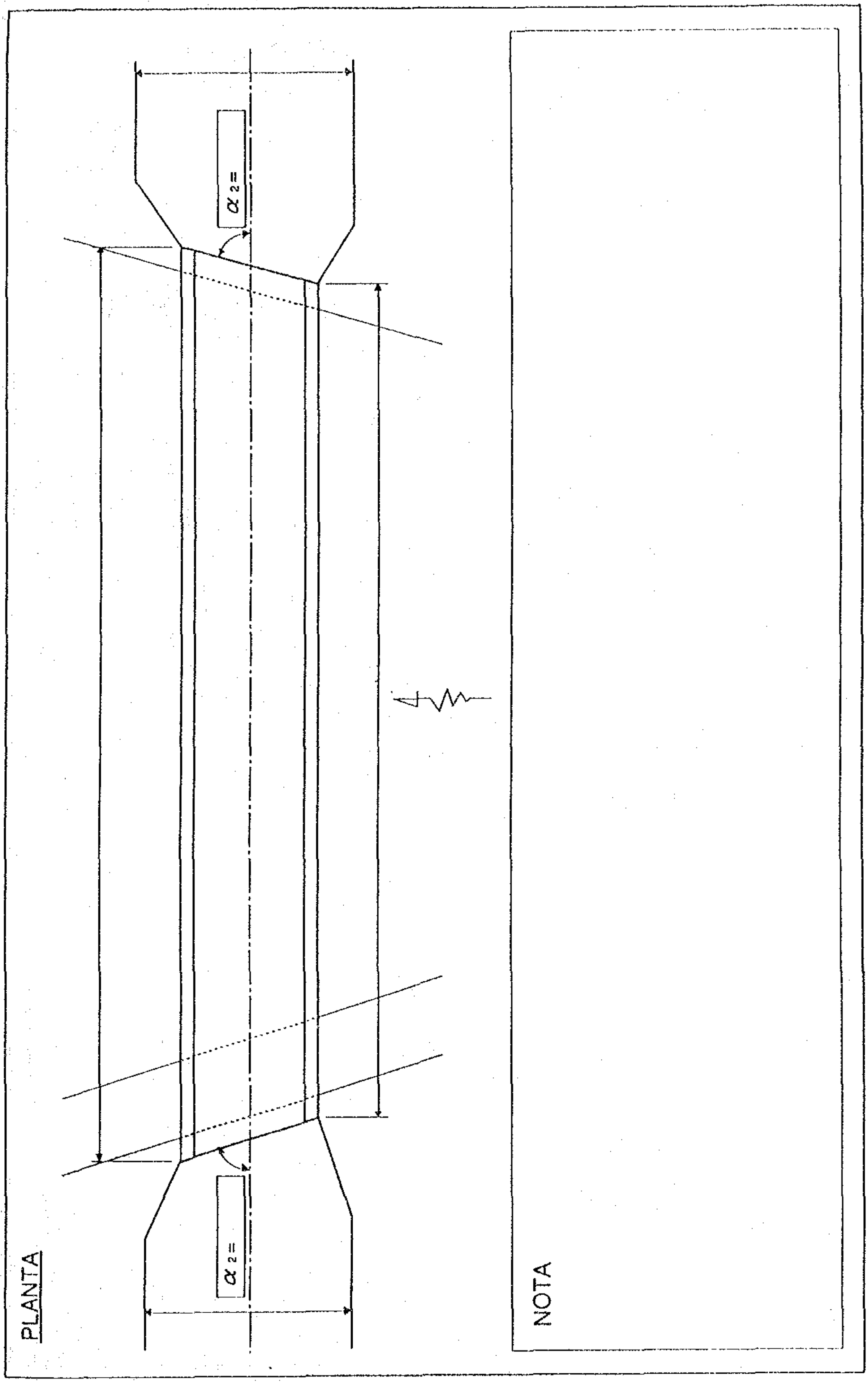
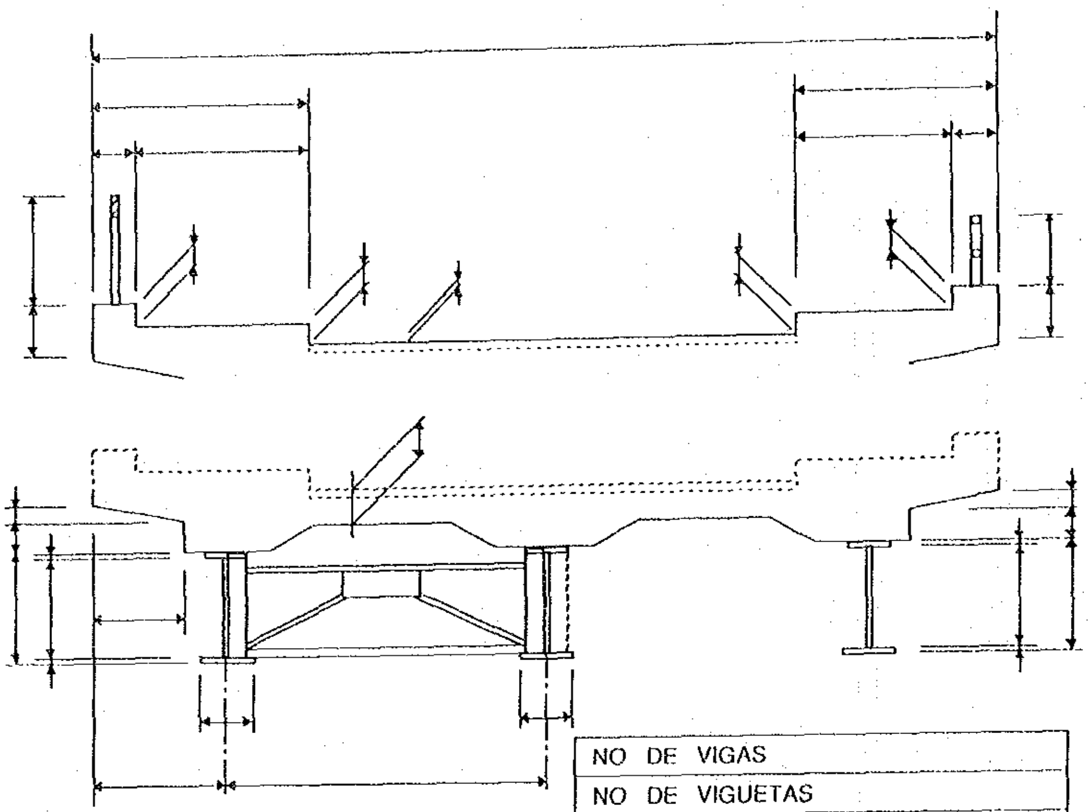


Figure 2-10 Form for Size Measurement (2)

SECTION TRANSVAERSAL - PUENTE METALICO

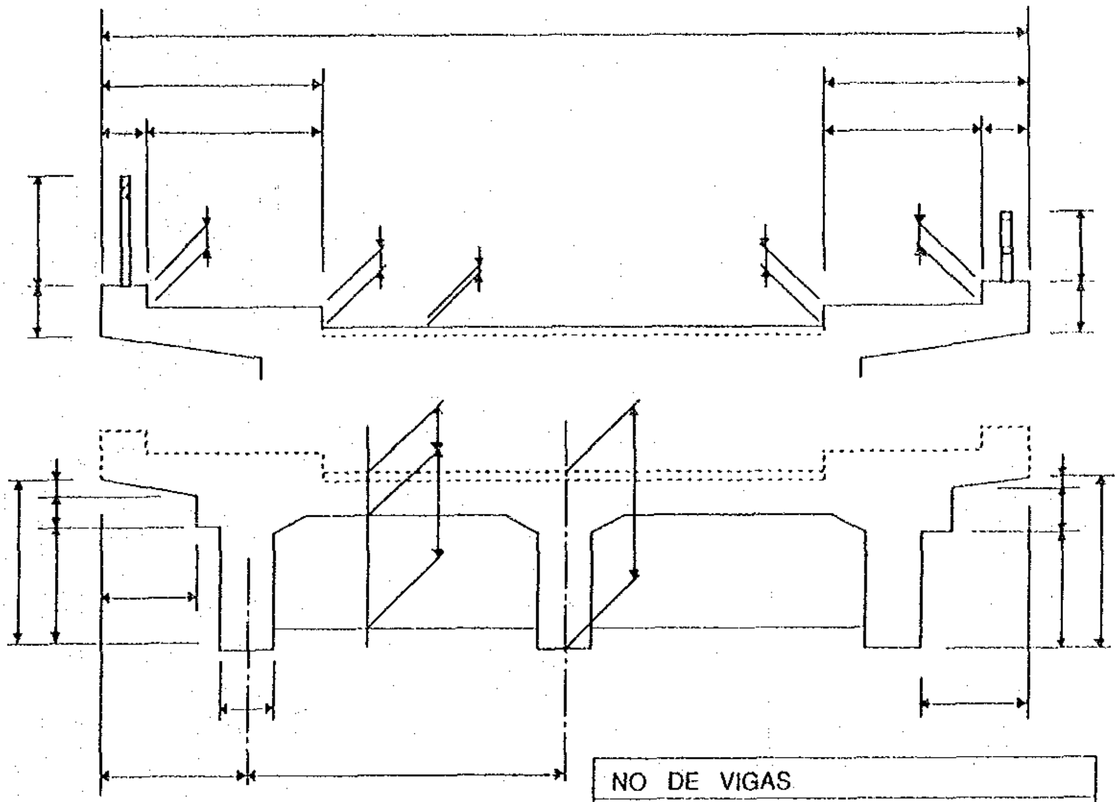


NO DE VIGAS	
NO DE VIGUETAS	
NO DE TRAVESAROS	

NOTA

Figure 2-11 Form for Size Measurement (3)

SECTION TRANSVAERSAL - PUENTE DE HORMIGON

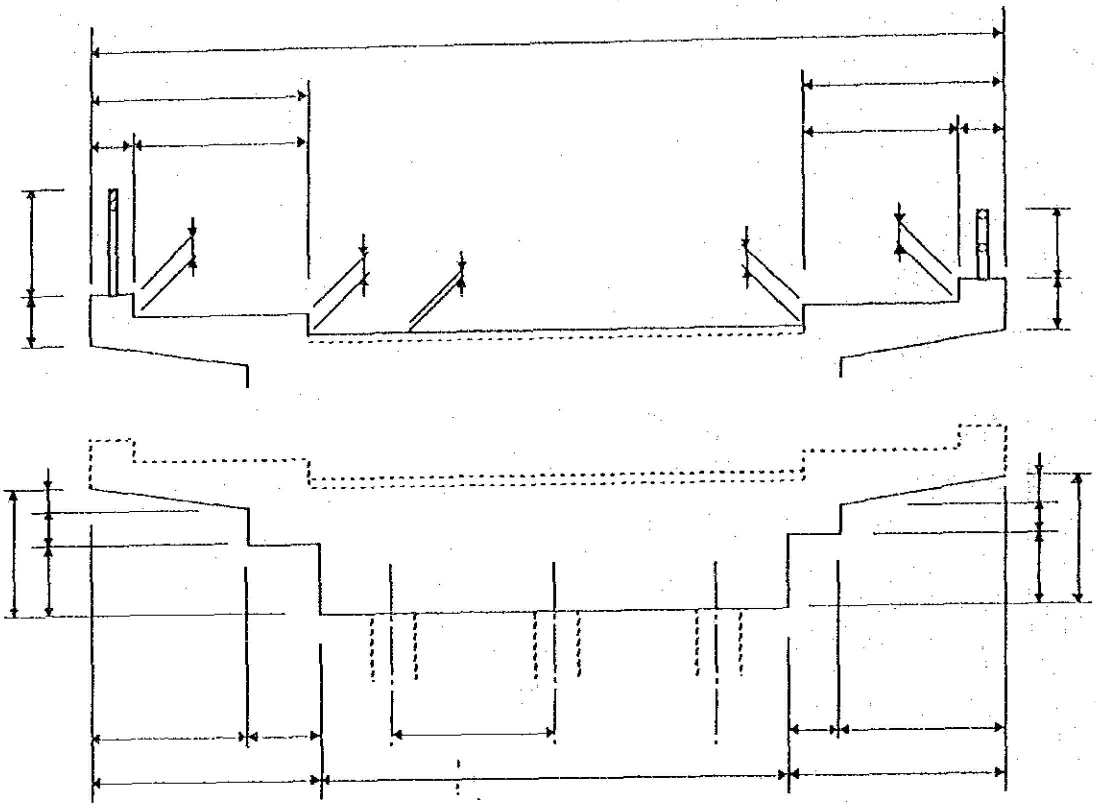


NO DE VIGAS	
NO DE TRAVESAROS	

NOTA

Figure 2-12 Form for Size Measurement (4)

SECTION TRANSVAERSAL - PUENTE LOSA



NOTA

Figure 2-13 Form for Size Measurement (5)

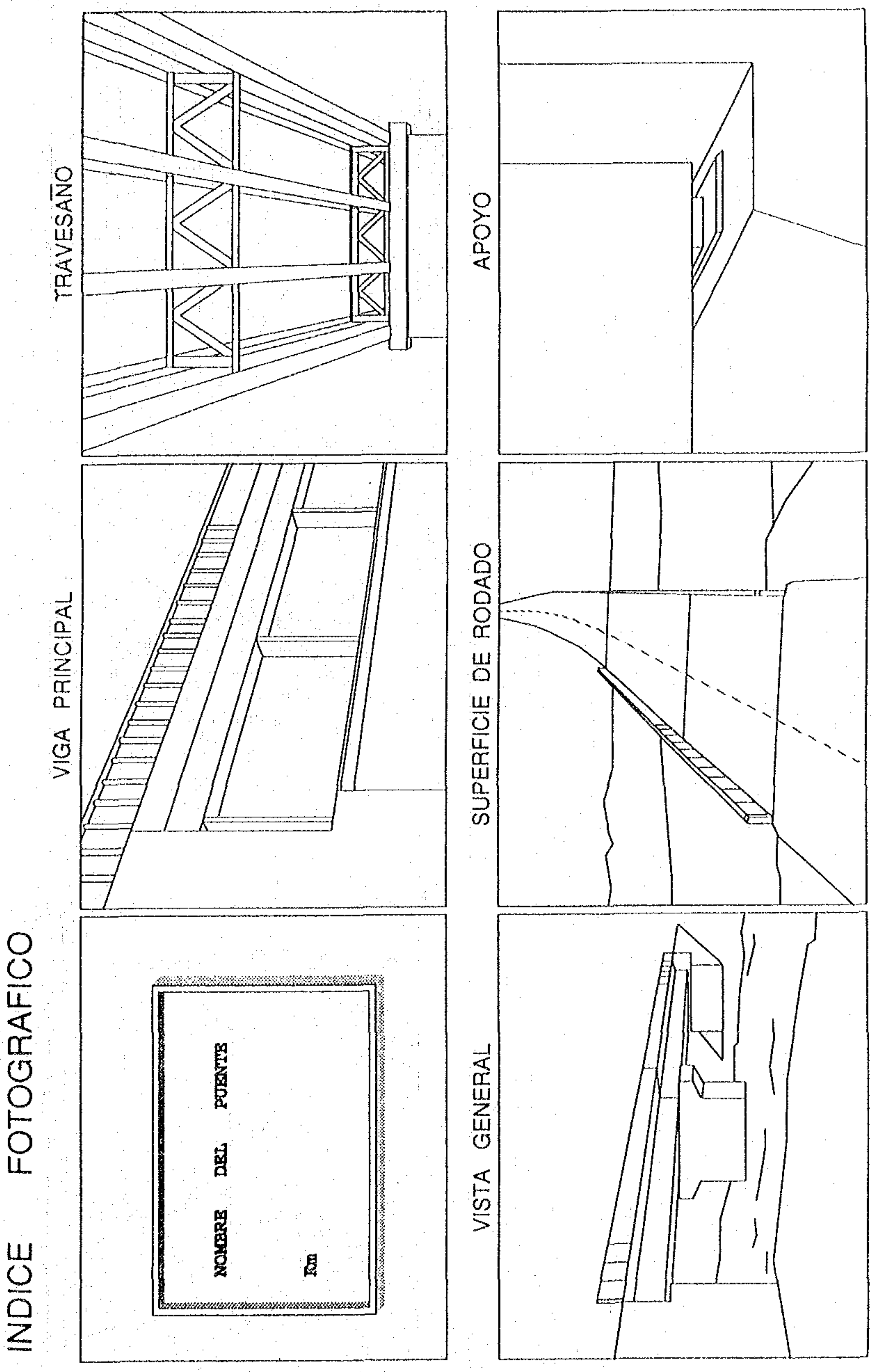


Figure 2-14 Photography Standards (1)

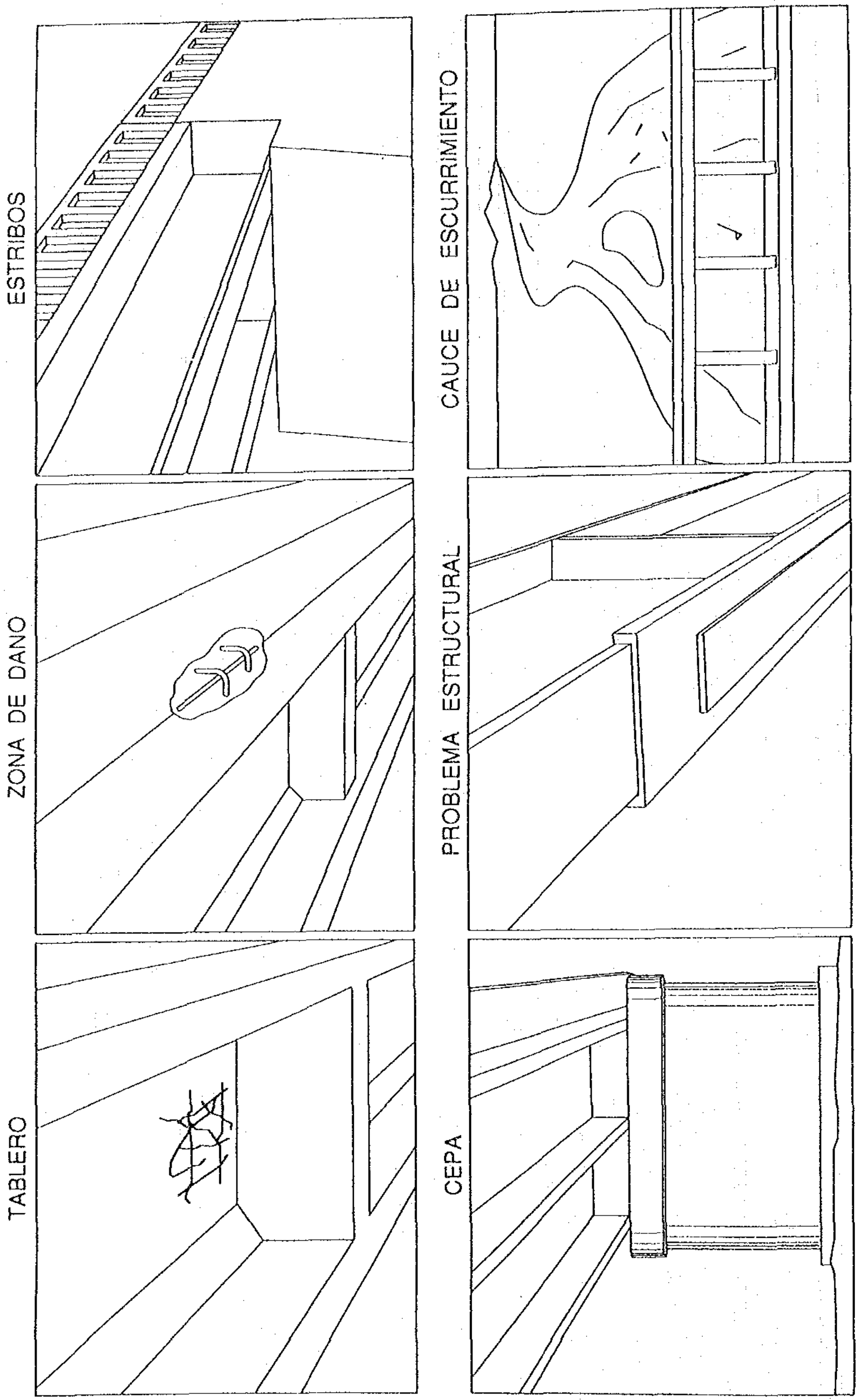


Figure 2-15 Photography Standards (2)

2-1-4 Survey Results

(1) General Bridge Problems in Chile

As a result of visual observation inspections, the following general bridge problems were defined by the surveying teams.

1) Common Problems

a. Bearing

Rubber bearings are now used in the construction of bridges, and satisfactory bearing were almost non-existent for bridges constructed over 10 years ago. As a result, bridge deflection and impact are directly transferred to the substructure and many of the contact points (usually called the base of bearing) between the substructure and upper-structure are now damaged. Movable parts were judged to be immobile, and the Gerver hinge, which is often used in Chile, had an adverse effect on the main body of the bridge.

b. Expansion Joint

Cover plate expansion joints are used for most road bridges in Chile. The cover plate is welded at the construction site and its reliability is suspect. The joint's durability is questionable because most bridge joints were judged by the survey teams to have been damaged after only two years of use. As well, operation accuracy is poor and this has had an adverse affect on the main body of the bridge by creating abnormal sounds and increasing impact effect. (Refer to Figure 2-16)

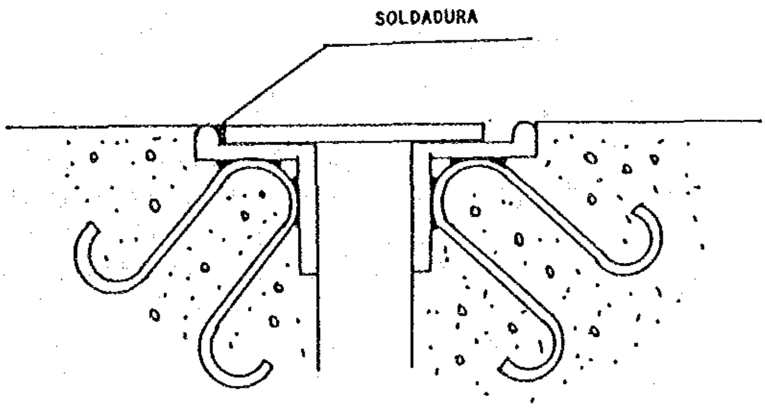


Figure 2-16 Expansion Joint

c. Filling

The protection of fill is extremely poor in the areas where fill touches the bridge. In order to reduce fill pressure, pier-abutment and pier-type abutment bridge bases have often been used. There is however is a high possibility that the fill on the backside of the abutment (approach) will sink as a result of poor compaction and lack of protection of the fill at the front. It is necessary to discuss protection methods for filling. (Refer to Figure 2-17)

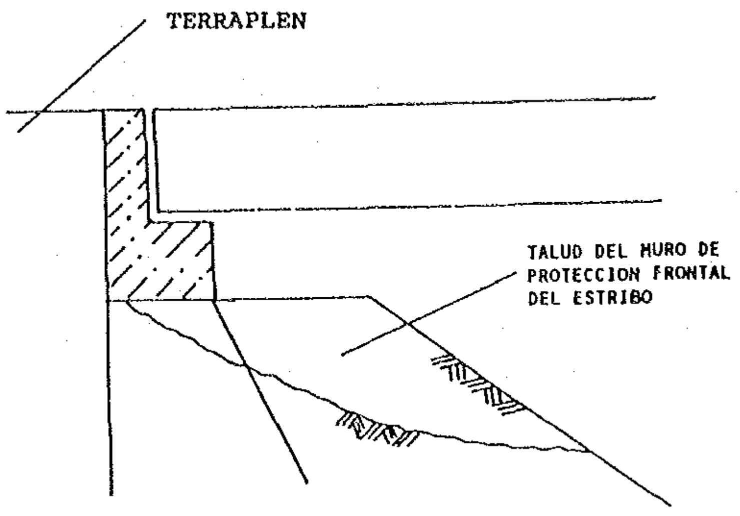


Figure 2-17 Filling

d. Foundation

Certain types of bridge foundations, such as the foundations at the Maipo and Malleco bridges, are often used in Chile even though they should not be used for bridge foundations in countries that experience frequent earthquakes. As was seen at Maule Bridge, problems of scouring were basically a result of the lack of foundation depth. Bridges in dry area tend to endure earthquakes better because of strong ground support. However, in the south, especially for problem bridges in the 10th state, the ground support is poor. Survey of the foundation ground when planning the construction of a bridge is very important.

e. Planning and Design

Bridge design is still analyzed by a bar structural analysis, even for bridges of great width. Grille structural analysis and multidimensional static indeterminate structural analysis are not widely used. This has resulted in the construction of bridge structures that ignore lateral sectional strength by not using supports such as crossbeams. As well, weak points in the structure have been created by using Gerver joints where continuous spans would be more appropriate. The Gerver structure is not being used for bridges currently under construction.

f. Alteration and Renovation Methods

An increase in traffic volume has resulted in a shortage of bridge width in Chile. There are two possibilities for expanding bridges from two lanes to four lanes. One possibility includes using the two old lanes exclusively for oncoming or ongoing traffic, while two lanes are added by constructing a totally separate bridge; the second possibility includes width expansion by creating a vertical joint to make the bridge seem as one. In both situations, the old and new bridge are always different. In the first situation, both bridges are constructed individually and there are few maintenance and control problems as long as the composition of the spans are the same. In the second situation, it is necessary to consider the influence of the new structure on the old structure, control of the expansion joint, and deformation of the vertical joint. (Refer to Figure 2-18)

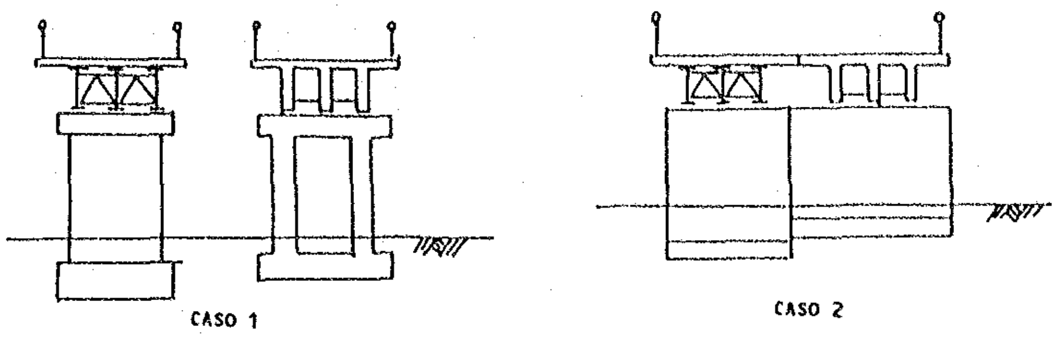


Figure 2-18 Bridge Widening Methods

2) Concrete Bridge Problems

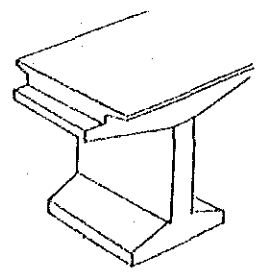
a. Concrete Quality

In general, the quality of concrete was judged to be low. Problems were noticed in the construction of form work, and its resemblance to unfinished concrete. The finish of some bridges presents a problem, such as the treatment of wire for forms and the leaving of corner forms behind.

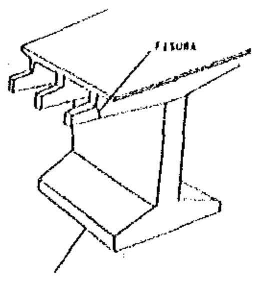
The curing of the concrete was poor, causing honeycombing and the exposure of reinforcement. This contributes to points of weakness in the structure.

b. Continuous Reinforced Concrete Beam Bridges

Gerver hinges have been frequency used on continuous reinforced concrete bridges. One of the problems however is the use of Gerver hinges where there is no necessity. For example, hinges have even been used for beams less than 20 meters in length which creates a major point of weakness. Another problem shown in the figure is the weakness of the hinge structure against shearing. Furthermore, large cracks at a right angle to the bridge axis on the concrete pavement side of the middle support point were observed. (refer to figure 2-19)



Effective Structures against Shear Destruction



Structures used in Chile

Figure 2-19 Problems using the Gerver Hinge

c. Pillars for Reinforced Concrete Arched Bridges

The pillars used for arched bridges are too thin. Rigidity of the pillars is questionable as they are 30 meters in length and only 70 centimeters in thickness, furthermore, there are no middle crossbeams. Pillar elastic deformation does not seem to have been considered and significant bridge damage as a result of pillar thinness was observed in the southern part of the country. (Refer to Figure 2-20)

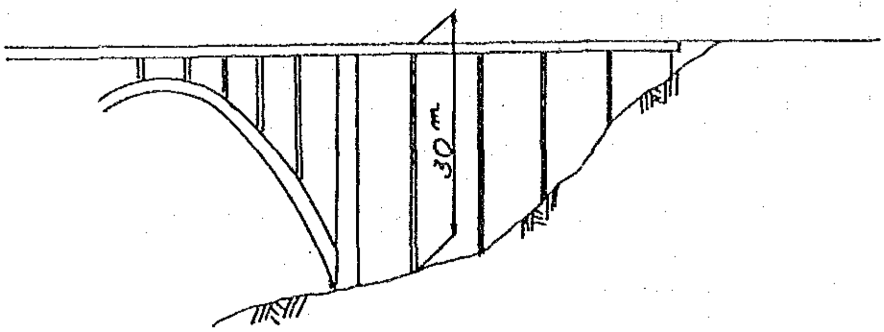


Figure 2-20 Pillars for Arched Bridges

d. Execution of Concrete Work

Treatment of new and old concrete work joints was not performed carefully and weak points in bridge structures were often seen.

3) Steel Bridge Problems

a. Crossbeam Structures

Floor framing was composed of the floor beam only and in rare case, both crossbeams and the floor beam are used. Connection with the main girders was done by on-site welding and was not carefully done. Breaks in the welding and repairs were seen at no less than 10 bridges. (Refer to Figure 2-21)

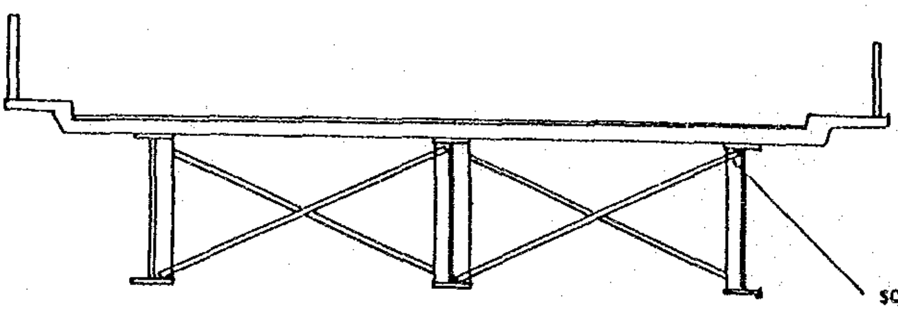


Figure 2-21 Crossbeam Structure

b. Main girders

Cross-section change of the main girders was sudden, which causes a structural problem in regard to fatigue. As well, many girders were loose because of a lack of camber adjustments.

(2) Evaluation of Bridge Damage

Evaluation of damage for bridge members was conducted based on the inspection record shown in Table 2-10. The Analytic Hierarchy Process was used in the evaluation method. The estimation was divided into three steps. In the first step, each member of bridge is evaluated, in the second step the superstructure, substructure and accessories such as expansion joint , pavement and handrail, etc. are evaluated. The comprehensive evaluation for bridge damage is conducted in the third step. The detailed explanation is shown in Section 8-3 in Chapter 8. The estimation of damage is shown in Table 2-11(1)~(5).

Table 2-11(1) Evaluation of Bridge Damage

No.	Bridge Name	Type	State	Floor	Accessory	Super	Sub	Total
130	PS SANTA ELISA	HA-	8	0.098	0.165	0.336	0.557	1.049
128	PS COCHARCAS	HA-	8	0.110	0.151	0.397	0.557	1.105
109	HUACARNECO	HPO	7	0.142	0.260	0.403	0.557	1.221
127	PS CHILLAN	ACE	8	0.082	0.210	0.350	0.668	1.227
215	FORRAHUE	ACE	10	0.077	0.177	0.327	0.758	1.263
224	ARENAS2	HA-	10	0.159	0.189	0.503	0.658	1.350
227	TENIO	LOS	10	0.291	0.158	0.407	0.784	1.350
228	ASTIL	LOS	10	0.258	0.131	0.550	0.758	1.438
94	LIRCAY2	HPO	7	0.134	0.204	0.467	0.789	1.460
129	PS CONFLUENCIA	LOS	8	0.344	0.226	0.636	0.617	1.479
223	TRAPEN	HA-	10	0.168	0.302	0.509	0.707	1.517
212	DAMAS	HPO	10	0.091	0.207	0.348	0.967	1.521
85	PS MAQUEHUAPON	HPO	7	0.100	0.260	0.370	0.895	1.525
229	TAMBOR	LOS	10	0.329	0.156	0.621	0.758	1.535
83	GUAIQUILLOPONI	HPO	7	0.131	0.253	0.399	1.002	1.654
145	PASO DE PIEDRA	LOS	8	0.225	0.190	0.517	0.948	1.655
226	GAUDA	HA-	10	0.183	0.207	0.734	0.758	1.699
174	PICHIQUEPENUEV	MIX	9	0.060	0.227	0.510	0.968	1.705
220	RIONEGRO	LOS	10	0.373	0.182	0.665	0.858	1.705
173	PICHIQUEPEANTI	ACE	9	0.193	0.320	0.508	0.898	1.726
199	PS LOS LAGOS	ACE	10	0.115	0.338	0.490	0.948	1.775
201	EL TREBOL	ACE	10	0.137	0.403	0.582	0.792	1.776
225	GOMEZ	HA-	10	0.185	0.136	0.697	0.949	1.782
216	PS CASMA	ACE	10	0.120	0.219	0.701	0.870	1.791
231	MURROR	LOS	10	0.533	0.386	0.650	0.755	1.791
183	PS LONCOCHE	MIX	9	0.119	0.385	0.645	0.766	1.796
222	TAYLOR	HA-	10	0.153	0.296	0.845	0.660	1.801
196	MAFIL 3	ACE	10	0.169	0.315	0.928	0.557	1.801
182	DONGUIL	ACE	9	0.120	0.289	0.665	0.862	1.816
87	LONTUE PONIENTE	HPO	7	0.167	0.312	0.540	0.966	1.818
206	LA POZA	ACE	10	0.167	0.276	0.733	0.839	1.848
114	PARRAL	HPO	7	0.142	0.344	0.560	0.948	1.852
80	ENDESA	ACE	7	0.155	0.456	0.508	0.898	1.862
89	ESTEROSECO	HPO	7	0.141	0.341	0.506	1.048	1.895
221	ARENAS	LOS	10	0.485	0.217	0.777	0.911	1.905
136	PAL PAL	HPO	8	0.152	0.382	0.518	1.054	1.954
119	VIRGUIN	LOS	8	0.345	0.338	0.637	0.992	1.967
210	HUITRAL	LOS	10	0.564	0.287	0.680	1.014	1.982
118	COLLIGUAY	LOS	8	0.500	0.254	0.792	0.940	1.985
232	LOS PALOS	LOS	10	0.428	0.435	0.623	0.942	1.999
9	EL ALMENDRO	MIX	4	0.286	0.143	0.694	1.171	2.007
217	PESCADO	ACE	10	0.069	0.307	0.748	0.968	2.022
202	LLOLLELHUE	ACE	10	0.231	0.268	0.595	1.174	2.038
115	LA VEGA	HA-	7	0.171	0.452	0.611	0.976	2.039
208	RIOBUENO	HPO	10	0.295	0.302	0.688	1.062	2.052
8	CAMARONES1	MIX	4	0.256	0.143	0.707	1.205	2.055
211	PUQUITRE	LOS	10	0.453	0.304	0.570	1.210	2.083
74	DESCARGA1 ORIE	HA-	6	0.177	0.259	0.654	1.171	2.084
5	CULEBRONORIENT	HA-	4	0.173	0.256	0.673	1.171	2.099
73	TINGUIRIRICAO	HPO	6	0.173	0.256	0.673	1.171	2.099

Table 2-11(2) Evaluation of Bridge Damage

No.	Bridge Name	Type	State	Floor	Accessory	Super	Sub	Total
68	PS SAN FERNANDO	HPO	6	0.173	0.256	0.673	1.171	2.099
63	PS PELEQUENORI	HPO	6	0.173	0.256	0.673	1.171	2.099
69	ANTIVEROORIENT	HPO	6	0.173	0.256	0.673	1.171	2.099
76	DESCARGA2 ORIE	HA-	6	0.195	0.259	0.671	1.171	2.101
47	STA. BLANCA ORI	LOS	6	0.427	0.259	0.672	1.171	2.102
7	CAMARONES2	MIX	4	0.298	0.196	0.746	1.171	2.113
194	MAFIL 1	ACE	10	0.085	0.252	0.933	0.930	2.116
75	DESCARGA1 PONI	HA-	6	0.195	0.278	0.671	1.171	2.120
235	PEUCOPONIENTE	ACE	13	0.169	0.259	0.691	1.171	2.121
121	GAONA	LOS	8	0.521	0.372	0.741	1.039	2.152
12	LA CEBADA	ACE	4	0.159	0.270	0.716	1.171	2.157
19	PS EL NEGRO	LOS	4	0.427	0.327	0.672	1.171	2.170
67	CHARQUICANPONI	HA-	6	0.195	0.333	0.671	1.171	2.175
131	NEBUCO	HAG	8	0.1714	0.313	0.808	1.054	2.175
6	LAGUNILLAS	HA-	4	0.221	0.312	0.697	1.171	2.180
77	DESCARGA2 PONI	LOS	6	0.427	0.272	0.672	1.240	2.184
65	RIGOLEMUPONIEN	ACE	6	0.188	0.279	0.745	1.171	2.195
46	STA. BLANCA PON	HA-	6	0.195	0.324	0.702	1.171	2.197
4	CULEBRONPONIEN	ACE	4	0.174	0.276	0.753	1.171	2.199
62	PS PELEQUENPON	ACE	6	0.205	0.297	0.732	1.171	2.200
218	EL BURRO	ACE	10	0.107	0.380	0.716	1.105	2.201
133	PITE	LOS	8	0.575	0.389	0.926	0.887	2.202
18	CONCHALI	HPO	4	0.191	0.352	0.691	1.171	2.213
246	PS HOSPITAL ORI	HPO	13	0.189	0.357	0.688	1.171	2.216
66	CHARQUICANORIE	HA-	6	0.173	0.376	0.673	1.171	2.219
20	TOTORALILLO	HAG	4	0.125	0.302	0.753	1.171	2.225
207	TRAIGUEN	ACE	10	0.198	0.323	0.996	0.909	2.228
192	RUCAPICHIO	ACE	10	0.128	0.326	0.771	1.138	2.236
153	CHUMULCO	HA-	8	0.201	0.382	0.738	1.118	2.238
96	PS LIRCAY	HAG	7	0.1105	0.321	0.614	1.308	2.244
3	PS LA SERENA	MIX	4	0.389	0.164	0.807	1.276	2.247
126	NUBLE	HPO	8	0.207	0.350	0.782	1.116	2.247
93	LIRCAY 1	HA-	7	0.176	0.342	0.751	1.168	2.262
135	ESPINAL	LOS	8	0.565	0.444	0.682	1.154	2.280
26	HUAQUEN	HA-	5	0.219	0.348	0.774	1.171	2.293
191	PS MAFIL	ACE	10	0.112	0.321	0.776	1.203	2.300
21	PS PALO COLORAD	HA-	4	0.229	0.291	0.804	1.205	2.300
219	MAULLIN	HPO	10	0.173	0.396	0.873	1.042	2.311
193	INAQUE	ACE	10	0.253	0.431	0.960	0.920	2.312
56	PS LIRIOSORIEN	ACE	6	0.174	0.318	0.828	1.171	2.317
37	PS EL OLIVO	ACE	5	0.173	0.285	0.533	1.506	2.323
214	CHIFIN	ACE	10	0.204	0.375	1.012	0.942	2.329
48	BENITOPONIENTE	HA-	6	0.232	0.283	0.890	1.171	2.344
184	LO VASQUEZ 2	HA-	9	0.132	0.338	0.799	1.222	2.359
71	PS LAS TERMAS	LOS	6	0.460	0.266	0.880	1.230	2.366
64	RIGOLEMUORIENT	HAG	6	0.125	0.279	0.925	1.171	2.375
195	MAFIL 2	ACE	10	0.150	0.303	0.943	1.134	2.380
198	SAN PEDRO	ACE	10	0.148	0.328	0.687	1.381	2.396
237	LO PINTO 1 PON.	HA-	13	0.222	0.281	0.715	1.405	2.401
144	CALIBORO	LOS	8	0.395	0.636	0.660	1.205	2.401

Table 2-11(3) Evaluation of Bridge Damage

No.	Bridge Name	Type	State	Floor	Accessory	Super	Sub	Total
78	PEORES NADA PO	HPO	6	0.204	0.344	0.717	1.348	2.408
187	LELFUCADE1	HAG	10	0.2158	0.473	0.797	1.142	2.413
1	JUAN SOLDADO	ARN	4	0.226	0.370	0.702	1.340	2.413
197	HUILLINCO	ACE	10	0.204	0.319	1.149	0.946	2.414
11	LIMARI	ARN	4	0.242	0.310	0.902	1.205	2.417
27	LONGOTOMA2	HA-	5	0.197	0.311	0.797	1.348	2.456
59	TIPAUMEPONIENT	HA-	6	0.232	0.402	0.708	1.348	2.458
204	NISCON	ACE	10	0.172	0.384	0.884	1.192	2.460
113	COLLIGUAY	LOS	7	0.513	0.360	0.863	1.239	2.462
112	COPIHUE	LOS	7	0.472	0.493	0.764	1.208	2.465
61	CLAROPONIENTE	HA-	6	0.334	0.308	0.811	1.348	2.466
230	CEBADAL	LOS	10	0.635	0.418	0.856	1.200	2.473
52	PS MACHALI	ACE	6	0.255	0.392	0.921	1.171	2.483
60	CLARO ORIENTE	HAG	6	0.197	0.319	0.821	1.348	2.488
186	CRUCES	HAG	10	0.1225	0.428	0.824	1.238	2.490
84	PS MAQUEHUAORI	HAG	7	0.2011	0.410	1.034	1.047	2.491
164	TRICAUCO	ACE	9	0.212	0.427	0.952	1.114	2.493
49	BENITOORIENTE	LOS	6	0.674	0.350	0.919	1.233	2.503
13	EL TENIENTE	HAG	4	0.137	0.311	0.807	1.389	2.506
58	TIPAUMEORIENTE	HAG	6	0.125	0.369	0.794	1.348	2.511
209	PILMAIQUEN	HPO	10	0.268	0.437	0.738	1.340	2.515
200	HUINA HUINA	ACE	10	0.210	0.434	1.096	0.987	2.517
53	PS TENIENTEPON	HA-	6	0.282	0.410	0.939	1.171	2.519
243	PS PAINE PONIEN	ACE	13	0.168	0.364	0.993	1.171	2.527
162	COLO	ARS	9	0.800	0.491	0.800	1.239	2.529
163	TRAIGUEN	ACE	9	0.175	0.451	0.962	1.123	2.536
205	CUNOCUNO	ACE	10	0.204	0.405	1.017	1.115	2.537
24	CHIVATO	HAG	5	0.145	0.355	0.883	1.301	2.540
169	QUILLEM	HAG	9	0.21	0.498	0.977	1.070	2.545
16	MILLAHUE	LOS	4	0.574	0.372	0.819	1.361	2.552
190	RUCACO	ACE	10	0.195	0.371	0.946	1.235	2.553
132	LARQUI	HAG	8	0.2012	0.240	0.957	1.358	2.554
242	PS PAINE ORIENT	HA-	13	0.251	0.350	1.035	1.171	2.555
2	FISCAL	HAG	4	0.115	0.350	0.718	1.491	2.559
241	MAIPO	HPO	13	0.222	0.386	0.720	1.453	2.559
50	CADENA	LOS	6	0.553	0.591	0.798	1.171	2.559
247	PS HOSPITAL PON	MIX	13	0.381	0.190	1.075	1.306	2.571
51	PS ALAMEDA	ACE	6	0.249	0.378	0.950	1.250	2.579
120	BULI	LOS	8	0.659	0.341	0.892	1.345	2.579
15	HUENTELAUQUEN	MIX	4	0.420	0.143	1.055	1.382	2.581
154	CANAL RIEGO	ACE	8	0.231	0.363	0.822	1.407	2.592
189	NEGRO	ACE	10	0.184	0.300	1.069	1.238	2.608
57	PS LIRIOSPONIE	HAG	6	0.115	0.336	1.034	1.240	2.610
234	PEUCOORIENTE	LOS	13	0.555	0.275	0.975	1.362	2.612
91	CHAGRES	HA-	7	0.167	0.303	0.813	1.505	2.621
170	PUMALAL	MIX	9	0.145	0.489	1.065	1.070	2.623
36	EL LITRE	ACE	5	0.266	0.323	0.532	1.769	2.625
179	PS FREIRE	LOS	9	0.658	0.464	0.892	1.271	2.626
148	QUILQUE	LOS	8	0.494	0.441	0.780	1.414	2.634
95	PS SAN CLEMENTE	HA-	7	0.310	0.372	1.049	1.217	2.638

Table 2-11(4) Evaluation of Bridge Damage

No.	Bridge Name	Type	State	Floor	Accessory	Super	Sub	Total
180	TOLTEN	ARN	9	0.271	0.514	0.860	1.298	2.672
45	PSTRONCO	LOS	6	0.573	0.293	0.993	1.394	2.680
55	CACHAPOAL	ACE	6	0.173	0.333	0.811	1.542	2.687
81	TENO	HAG	7	0.1477	0.406	1.154	1.130	2.690
92	PANGUE	HAG	7	0.1491	0.350	0.973	1.379	2.702
177	HUILQUILCO	ACE	9	0.176	0.376	1.204	1.133	2.713
125	PSIANSA	LOS	8	0.669	0.388	0.959	1.388	2.735
39	PSLA CALAVERA	MIX	5	0.393	0.259	0.905	1.578	2.742
43	PEUCOPONIENTE	MIX	6	0.379	0.186	0.978	1.579	2.744
82	GUAIQUILLOORIE	HAG	7	0.1536	0.511	0.717	1.532	2.760
86	LONTUEORIENTE	HAG	7	0.1892	0.323	1.014	1.424	2.761
139	ITATA	ARS	8	0.800	0.579	0.800	1.410	2.790
238	PSLO SIERRA	ACE	13	0.221	0.354	0.887	1.551	2.792
10	QUEBRADASECA	LOS	4	0.498	0.262	0.743	1.791	2.796
35	NOGALES	HAG	5	0.155	0.402	0.816	1.584	2.801
41	LAS VEGASOR	MIX	5	0.391	0.132	0.879	1.791	2.801
40	LAS VEGASPO	MIX	5	0.391	0.132	0.879	1.791	2.801
32	QUEBRADILLA	LOS	5	0.506	0.278	0.926	1.598	2.802
111	PSCOPIHUE	HAG	7	0.1375	0.462	0.940	1.407	2.809
79	PEORESNADA OR	HAG	6	0.205	0.398	0.877	1.542	2.817
203	CHOROY	ACE	10	0.191	0.414	0.982	1.428	2.824
185	LO VASQUEZ3	LOS	9	0.653	0.366	0.863	1.595	2.825
30	JAURURO	LOS	5	0.575	0.349	0.996	1.481	2.826
104	ANCOA 1	HAG	7	0.1755	0.441	0.956	1.443	2.839
165	CHANCO	ACE	9	0.304	0.467	1.197	1.200	2.864
107	LIGUAY	HA-	7	0.206	0.504	0.928	1.446	2.878
167	EL SALTO	ACE	9	0.186	0.417	0.975	1.488	2.879
28	LONGOTOMA1	LOS	5	0.732	0.262	1.152	1.469	2.884
103	PUTAGAN	HA-	7	0.218	0.402	0.867	1.625	2.893
54	PSTENIENTEORI	ACE	6	0.308	0.454	1.144	1.297	2.895
147	RARINCO	HA-	8	0.301	0.524	0.842	1.533	2.899
105	ANCOA 2	HAG	7	0.1755	0.445	0.956	1.505	2.905
244	PAINEPONIENTE	ACE	13	0.265	0.412	1.034	1.464	2.911
101	PSBOBADILLA	HAG	7	0.211	0.511	1.230	1.186	2.926
239	FFCCSURLOSA	LOS	13	0.606	0.354	1.027	1.569	2.949
122	NAVOTAVO	LOS	8	0.846	0.406	1.136	1.409	2.951
42	LOSLOROS	LOS	5	0.508	0.299	0.928	1.728	2.956
151	DESCARGA	LOS	8	0.641	0.510	1.001	1.448	2.959
100	LAS VERTIENTES	HAG	7	0.1536	0.527	1.016	1.418	2.961
90	CLARO	ARS	7	1.380	0.271	1.380	1.311	2.962
149	DUQUECO	HPO	8	0.281	0.301	1.003	1.660	2.963
22	QUILIMARI	HAG	4	0.137	0.346	0.805	1.823	2.975
29	PULLALLY	ACE	5	0.225	0.347	0.941	1.688	2.977
88	PIRIHUIN	LOS	7	0.846	0.457	1.219	1.303	2.979
17	CHIGUALOCO	HAG	4	0.191	0.383	1.137	1.465	2.985
158	PSPIDIMA	ACE	9	0.197	0.508	1.080	1.406	2.994
106	ACHIBUENO	HAG	7	0.1997	0.424	0.892	1.681	2.998
102	QUILIPIN	ACE	7	0.163	0.429	0.816	1.755	3.000
175	QUEPEANTIGUO	ACE	9	0.240	0.436	0.961	1.606	3.003
117	NIQUEN	LOS	8	0.795	0.343	1.278	1.387	3.008

Table 2-11(5) Evaluation of Bridge Damage

No.	Bridge Name	Type	State	Floor	Accessory	Super	Sub	Total
31	TALAQUEN	LOS	5	0.448	0.362	0.869	1.781	3.013
44	PEUCOORIENTE	ACE	6	0.249	0.400	1.141	1.473	3.014
25	LA BALLENA	LOS	5	0.550	0.290	0.971	1.761	3.022
155	ESPERANZA	HAG	9	0.2042	0.434	0.982	1.609	3.025
72	TINGUIRIRICAP	HAG	6	0.165	0.371	1.090	1.575	3.037
171	CAUTIN	HAG	9	0.198	0.466	1.095	1.491	3.053
172	METRENCO	HA-	9	0.279	0.440	1.155	1.463	3.059
176	QUEPENUEVO	MIX	9	0.147	0.264	0.942	1.859	3.064
157	MALLECO	ACE	9	0.235	0.460	1.125	1.502	3.088
116	PERQUILAUQUEN	HAG	8	0.1611	0.567	1.156	1.376	3.098
233	TRAPENBAJO	LOS	10	0.852	0.447	1.335	1.341	3.123
33	EL COBRE	LOS	5	0.690	0.295	1.110	1.722	3.127
178	PERALES	ACE	9	0.141	0.456	1.070	1.652	3.177
236	LO PINTO 1 ORI.	LOS	13	0.739	0.349	1.159	1.669	3.177
23	PS LOS MOLLES	LOS	5	0.643	0.389	1.064	1.737	3.190
124	MENELHUE	LOS	8	0.776	0.480	1.229	1.482	3.191
161	DUMO	ARS	9	1.314	0.477	1.314	1.408	3.199
188	LELFUCADE2	ACE	10	0.328	0.493	1.173	1.535	3.201
168	PS PUA	LOS	9	0.858	0.510	1.273	1.438	3.221
240	PS SURACERO	ACE	13	0.254	0.483	1.142	1.601	3.226
181	CHADA	LOS	9	0.813	0.464	1.046	1.717	3.227
140	LAJITA	ACE	8	0.239	0.476	1.278	1.476	3.230
34	EL MELON	LOS	5	0.666	0.329	1.086	1.815	3.230
14	AMOLANAS	ARN	4	0.369	0.419	1.108	1.715	3.242
160	CHAMICHACO	HA-	9	0.364	0.480	1.017	1.750	3.247
38	ACONCAGUA-OCOA	HAG	5	0.149	0.441	1.011	1.804	3.256
108	LONGAVI	ACE	7	0.240	0.504	1.102	1.653	3.260
70	ANTIVEROPONIEN	HAG	6	0.264	0.440	1.287	1.542	3.269
138	RELBUN	HAG	8	0.1995	0.506	1.078	1.742	3.326
156	MININCO	HAG	9	0.1922	0.479	1.343	1.544	3.366
134	GALLIPAVO	LOS	8	0.823	0.505	1.252	1.616	3.373
152	BUREO	HAG	8	0.2528	0.517	1.108	1.794	3.420
110	PIGUCHEN	LOS	7	0.834	0.551	1.215	1.695	3.461
141	BATUCO	LOS	8	0.950	0.493	1.240	1.729	3.462
142	BATUQUITO	LOS	8	0.801	0.524	1.152	1.805	3.481
143	SALTO DEL LAJA	ACE	8	0.310	0.548	1.300	1.662	3.509
150	BIO-BIO	HAG	8	0.2011	0.602	1.118	1.796	3.517
245	PAINE ORIENTE	ACE	13	0.382	0.462	1.039	2.097	3.598
123	NINQUIHUE	LOS	8	0.790	0.468	1.218	1.983	3.669
166	QUINO	ARN	9	0.327	0.488	1.162	2.060	3.710
97	PIDUCO	LOS	7	0.956	0.405	1.371	1.965	3.740
213	RAHUE	ARN	10	0.410	0.414	1.397	1.942	3.754
99	MAULE ORIENTE	ACE	7	0.242	0.465	1.378	1.969	3.812
159	HUEQUEN	LOS	9	0.896	0.512	1.332	2.041	3.885
98	MAULE PONIENTE	MIX	7	0.341	0.586	1.349	2.019	3.954
137	DIGUILLIN	HA-	8	0.323	0.559	1.358	2.050	3.967

2-2 River Surveys

2-2-1 Characteristics of Rivers in Chile

The rivers in Chile are divided broadly into 5 groups: those in the north, those in the central district, those in the south of the central district, those in the lake district and those in the channel district. Rivers in the central district are subdivided into those with a large amount of discharge resulting from the snow melt in spring, and those with the runoff resulting from both the snow melt and rainfall.

Caudales Medios' Mensuales' de los Rios de Chile, published in 1976 by the Water Bureau in the Ministry of Public Works, is a summary of observation results to the year 1970. It is the latest printed data on the river discharges, including the description of the drainage basin areas, the monthly average discharges and the highest recorded discharges.

The following are the characteristics of the 5 river groups:

(1) Rivers in the North

River discharges described below include the runoff from the snow melt. Although the amount of the discharges is not large, it is of much use for human life. There are a large number of dams and pools in the district to prepare for the dry season. Among major dams are Lautaro, Lagunas, Recoleta, Cogoti and Paloma. (Refer to Table 2-12)

There are some hydroelectric power plants in the Los Milles River, a tributary of the Limari River.

Table 2-12 Outline of Rivers in the North

Outline of rivers in the north

River	Drainage area (km^2)	Annual average discharge (m^3/sec)
Copiapó	18.130	3.7
Huasco	11.480	6.7
Elqui	9.020	10.4
Limari	11.670	14.0
Choapa	8.000	27.0
Petorca and La Ligua	4.060	5.4

(2) Rivers in the Central District

Rivers described below are rapid streams with the runoff from the melt snow in summer. The discharges are used for agriculture through irrigation canals. The Aconcagua River has 100 channels to supply water for the land 700,000 ha wide. From this river, water is supplied for the waterworks in Valparíso and Vinã del Mar and also for the Petroleum Development Corporation in Con-Con. The Maipo River, together with its tributary: the Mapocho River, flow through the Metropolitan area, supplying water for the district covering 200,000 ha. In the river, there are dams named El Yeso, Laguna Negra, Vizcachas and Vizcachitas.

There are also hydropower plants, such as Queltehues, El Volcan, Maitenes and Florida, etc.

The Rapel River, which the El Cachapoal River and the El Tinguiririca River flow into, supply water for areas covering 250,000 ha. In the river are 3 hydropower plants: Sauzal, Sausalito and Rapel. The Rapel Power Plant has a dam with an extent of 40 km. (Refer to Table 2-13)

Table 2-13 Outline of rivers in the central district

River	Drainage area (km^2)	Annual average discharge (m^3/sec)
Aconcagua	7.640	40
Maipo	15.000	102
Rapel	13.520	161
Mataquito	6.050	53

(3) Rivers in the South of the Central District

A characteristic of rivers in this district is that they have a large amount of discharge caused by the runoff from the snow melt in spring. These rivers have little discharges in summer. The Maule River has a source in the Lake Maule, which is located at 2,233 m above sea level. It has Colbun-Machicura Complex Hydropower Plant, and also Cipreces and Isla Power plants. The river has a drainage area of 21.690 km2, which is the third largest in Chile.

Among many tributaries of the Maule River are the Claro, Loncomilla, Merado and Reloncavi. The irrigated land along this river is suited for growing grapes. Sunflowers, lapsu and sugar beet (for the oil and sugar industry) are also grown.
The Bíobío River has a drainage area of 23,920 km2, which is the second largest in Chile. It has two hydropower plants: Toro (400,000 kw) and Abanico (136,000 kw). Its main tributary is the Laja River. (Refer to Table 2-14)

Rivers in the south of central district have the runoff from the snow melt and rainfall. The Tolten and the Imperial River belonging in this group, have rapid changes in discharge. Small ships can navigate from the mouth to Carahue in the Imperial, which has the tributary Cautin. The Tolten and its tributary Ajipen River have their sources in Lake Bijarika, which the Pucón, the Maitin and the Karireufu River flow into.

Table 2-14 Outline of rivers in the south of central district

River	Drainage area (km^2)	Annual average discharge (m^3/sec)
Maule	21.690	380
Itata	11.480	140
Bió-Bió	23.920	900

(4) Rivers in the Lake District

This river basin is the most attractive region from the tourist point of view. As there are numerous lakes and marshes in this district, the rivers there have always constant discharges and are surrounded by beautiful scenery. The Valdivia River starts from the City of Valdivia ,where the Calle-Calle and the Cruces Rivers join.

Ships can navigate from there to the mouth of the river at the City of Corral . It joins the Calle-Calle River through the Lakes of Pirehueico, Panquipulli, Calafguen, Rinihue, Tolten, and Lake Ranco in Argentine. The Bueno River has its sources in three large lakes: Ranco, Puyehue and Rupanco. The River allows ships to navigate from Torumao to its mouth.

In addition, this district includes the tributary Rahue River flowing through the City of Osorno and the River Pilmaiquen with a power plant named after it. The Maullín River, which has its source in Lake LLanquihue, has a large amount of discharge despite its short channel. The Petrohue River, a torrent named "Emerald" from the color of the water, rises from Lake Todos Los Santos and flows into Reloncavi, the mouth of the river. (Refer to Table 2-15)

Table 2-15 Outline of the rivers in the lake district

River	Drainage area (km²)	Annual average discharge (m³/sec)
Valdivia	11.280	800
Bueno	14.810	1000
Maullín	4.130	72

(5) Rivers in the Channel District

Rivers in this district, which have sources in the eastern slope of the Andes, flow down as torrents through the steep slopes and empty into the old fjords where there were glaciers in ancient times. The Baker River has the highest discharge in Chile, and allows ships to navigate to the point of 65 km from its mouth. The Cisnes, Bravo, Pascua and Aisen are mountain rivers. (Refer to Table 2-16)

Table 2-16 Rivers in the Channel District

River	Drainage area (km²)	Annual average discharge (m³/sec)
Puelo	3.025	670
Yelcho	3.937	760
Palena	6.968	700
Cisnes	5.512	190
Aysén	11.462	515
Baker	21.483	1,500
Bravo	1.725	150
Pascua	15.340	400
Serrano	8.110	150

2-2-2 Problems of Rivers and Bridge Structures in Chile

The following 4 problems can be pointed out from the results of our site surveys on the bridges on the National Highway No. 5.

1) Considerable scour at parts of piers and abutments

Rivers in Chile have steep slopes and rapid seasonal changes in discharge. The lengths of bridge spans are relatively short and the foundations are shallow. For these reasons, piers and abutments of many bridges are scoured to a considerable degree.

2) Shortage of flow passage section

In order to make the spans shorter, many bridges have approach roads, which are banked at the same level as ground level of the bridges, protruded on the high-water channels. In addition, many bridges have short spans for the economic reasons, with a result that many rivers in the lower reaches have cross-sections much narrower than those in the upper reaches. For these reasons, the flow passage sections of the rivers are conspicuously insufficient.

As a result, in time of flood, the water levels at the bridges will rise higher than those upstream and downstream of the bridge and the flow velocities will increase. This will bring about the increases in the scour at the substructures and the lateral loads caused by the flowing water pressure. This will not only weaken the sustaining power of foundations but also incur the dangers such as subsidence, tilting and collapse.

Furthermore, in cases that the flowing water touch the superstructure, the water levels will rise further. This will bring about the further scouring of the piers and abutments and the deterioration of the superstructures.

3) Insufficient protection of revetment slopes

In many bridges, access roads are protruded on the high-water channels by embankment, and large natural stones are often used to protect the slopes of the approach banks and revetments. In these cases, only those stones which have size and thickness enough to bear the stream power of the rivers serve the purpose of protecting the slopes. Some of them, however, change artificially the stream direction from the upstream portion, resulting in centering the stream power at some parts of the substructures, causing or increasing scours.

At some revetments, which were unable to bear the stream power, slope collapses or erosions have occurred.

4) Insufficient embedding of the foundations of bridge substructures.

In Chile, spread foundations are used in many cases, as most river-bed grounds are made of gravel layers. Whether they use spread or pile foundations, footing depths of substructures are relatively shallow, with a result that the embedment of foundations are notably insufficient. This brings about the early lowering of support strata, tilting and collapse caused by the scour, and is one of the main reasons for insufficient life of functional bridges there.

2-2-3 River Surveys for the Repair of Existing Bridges

River surveys for the repair of existing bridges carry out the research on the following items and are used as reference for the repair design.

Research items in river data:

1) Name of the river where the bridge is to be cross-linked
2) Name of the location where the bridge is to be cross-linked
   (a) The distance from the mouth of the river (km)
3) Highest recorded water level (m)
4) Average width of the river (m)
5) Average slope of the river bed (1/00)
6) Average diameter of grains of the river-bed material (mm)
7) River-bed condition: rock, gravel, sand, silt, or clay
8) Normal line of the levee or plate of the river channel: a rough sketch drawn
9) Picture taken on the bridge in the upstream and downstream directions (used to calculate the grain coefficient)

Note-1: The distance from the river mouth added in the item (2) is used to judge the influence of ebb and flow and waves in the sea on the bridge at the location.

Note-2: The highest recorded water level is used to judge the cross-sectional flow passage capacity of the substructure. The design discharge used to estimate the pier scours may be determined with the assumption of the 1-year probable flood. However, there is no survey data on this value in any bridge. Whilst it is rather easy to obtain the data on the highest recorded water level by investigating the flood traces around the bridge. Accordingly, as the second best measure, it is used as standard data for estimating the existence of pier scours.

Note-3: The average river width is used to examine whether the river width at the location of the bridge is wide or narrow in comparison with those within 1km section upstream and downstream of the bridge. The measurement is made within the range of 10% error using the bridge length as the datum base length. This value is determined using the normal levee line, rough plate sketch of river channel, plate map, etc.

Note-4: The average slope of riverbed corresponds to the average slope of water surface in Manning's flow velocity formula. In the survey this time, the average slope of the land surface in the direction of the river flow is regarded as the average river-bed slope. The average land-surface slope is calculated using the map drawn on a scale of approximately 1 to 25,000. In calculating the flow velocity using Manning's formula, the needed highest recorded discharge can be found from the highest recorded water level and cross-section. This discharge is useful in judging the safety of the flow passage section and the soundness of the span distribution.

Note-5: The average grain diameter of the river-bed materials is recorded by eye-estimation during the survey on the scour depth, water level and pier diameter.

Note-6: River-bed conditions and the pictures taken on the bridge in the upstream and downstream directions are used as reference in finding the roughness coefficient n by using Open-Channel Hydraulics by Prof. Ven Te Chow. The coefficient is needed for the calculation of Manning's formula.

(1) In calculating the largest recorded discharge, the following formula is used.

$Q=A \cdot V$

Q : The highest recorded discharge
A is the flow passage section calculated from the cross-section and the highest recorded water level, which is found from the flood traces and information obtained by inquiry.

$V = 1/n \cdot R^{2/3} \cdot I^{1/2}$

n is determined by comparing the results of the eye-estimation and photographic interpretation of the upstream and downstream parts of the bridge with the values of n in the book by Professor Chow

$R=A/B$

B is the river width.
I is the water surface slope during flood. It is found from the topographic map by estimating the average slope of land surface parallel to the river.

(2) Estimation of the longest scour depth in piers

The analysis of the longest scour depth in piers is extremely difficult, because it is related to various conditions, such as the river conditions, the river-bed conditions, the pier form, the flow velocities, and the discharge. However, if the characteristics of rivers in Japan are taken into account, the following graph as an experimental study will be useful in finding the estimate of the longest scour depth rather easily. (Refer to Figure 2-22)

Z : The longest scour depth
ho : The average water depth at the upstream parts of the piers
D : The pier width (the width of the portion which receives the pressure)
dm : The average grain diameter of gravel (which can be applied to the sand)

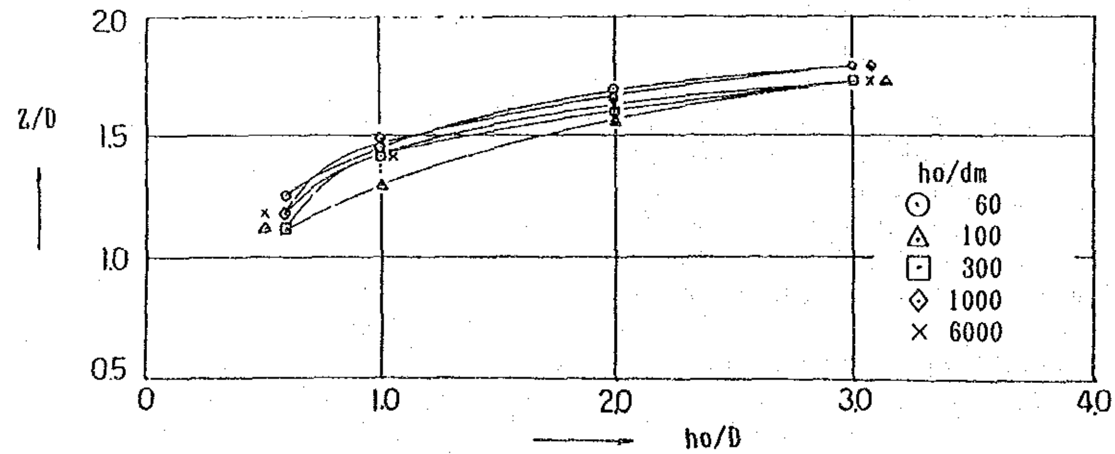


Figure 2-22 The Longest Scour Depth in Piers

Chapter 3 Bridge Detailed Survey

3-1 Bridge Detailed Survey

3-1-1 Outline of Detailed Survey

(1) Selection of Detailed Survey Targeted Bridges

Bridges were targeted for detailed survey based on the following selection standard policies.

1) Bridge for which the degree of damage is severe and repair is urgently required
2) Bridge showing the characteristic damage in Chile
3) Bridges for high economic and social importance
4) Bridge for preparing the typical bridge repair in the technology transfer

As a result of the above selection standards, discussion were held with MOP in regard to the 22 bridges selected by the Study team and the Operation Supervision Committee. Finally, 11 bridges selected, of which 10 bridges are selected for detailed bridge survey and the remaining 1 bridge is for load capacity test as shown in Table 3-1. Table 3-2 shows the situations for bridge damage. The locations of bridge and the structure plans are shown in Figure 3-1, and Figure 3-2 ~ Figure 3-11, respectively.

(2) Surveyed Bridges

Surveyed bridges are shown in Table 3-1.

Table 3-1 Outline of Surveyed Bridge

No.	State	Name of Bridge	Length (m)	Type of Bridge
1	4	AMOLANAS	235.2	3 Span Continuous Reinforced Concrete Arch
2	5	PULLALLY	148.5	3 Span Continuous Plate Girder
3	RM	MAIPO	460.6	Prestressed Concrete Girder
4	RM	PEUCO	99.0	Steel Girder
5	7	CLARO	117.7	7 Span Continuous Brick Arch
6	7	LONCOMILLA	150.0	Prestressed Concrete Girder
7	8	BIO-BIO ANTIGUO	1455.0	Steel Girder (104 continuous)
8	8	RAMADILLAS	210.0	Steel Girder (14 continuous)
9	9	MALLECO	344.1	9 Span Continuous Steel Girder
10	10	PICHOY	80.6	Reinforced Concrete Girder
11	10	CAYUMAPU	49.0	3 Span Continuous Reinforced Concrete Girder

Table 3-2 Situations for Bridge Damage

No	Bridge Name	Situation
1	Amolanas	Damage to the pavement and slab on the side span of the Santiago side was significant as a result of the impact of live loads.
2	Pullally	Deformation of the three continuous spans on the La Serena side was large. The ratio of beam depth to span was small (1/26), and vibration was heavy during vehicle crossing. According to MOP the bridge had a history of collapsing.
3	Maipo	There were no middle crossbeams. There were no lateral pre-stress at the end horizontal beams. The bridge piers were two individual pillars and their resistance to earthquakes was questionable. Part of the foundation was exposed by scouring.
4	Peuco	Two main steel girder bridge. No solid floor beam and damage at the welded parts
5	Claro	Being a monumental structure in Chile, a request was made to restore it. Scouring on the foundation was pronounced.
6	Loncomilla	The depth of the footings for the abutment and bridge pier was insufficient. Therefore, H-shaped steel was exposed to scouring and the bridge pillars were tilting.
7	Bio Bio Antiguo	The bridge collapsed during an earthquake in 1960. Vehicles over eight tons were prohibited from using the bridge. Traffic capacity was insufficient.
8	Ramadillas	The frequency of use by heavy trucks carrying timber was high. Serious cracks have appeared in the abutment concrete.
9	Malleco	The structure was constructed in 1973, but the grid buckled before the opening ceremony. Stiffening material was later added. Although this was a 3 main girder structure, there were no crossbeams to enhance load distribution and deflection was large.
10	Pichoy	The abutment shifted during an earthquake. The abutment width is very narrow and vulnerable to earthquakes. The Gerver hinge was also damaged.
11	Cayumapu	The abutment and bridge pier were significantly tilting as a result of earthquakes.

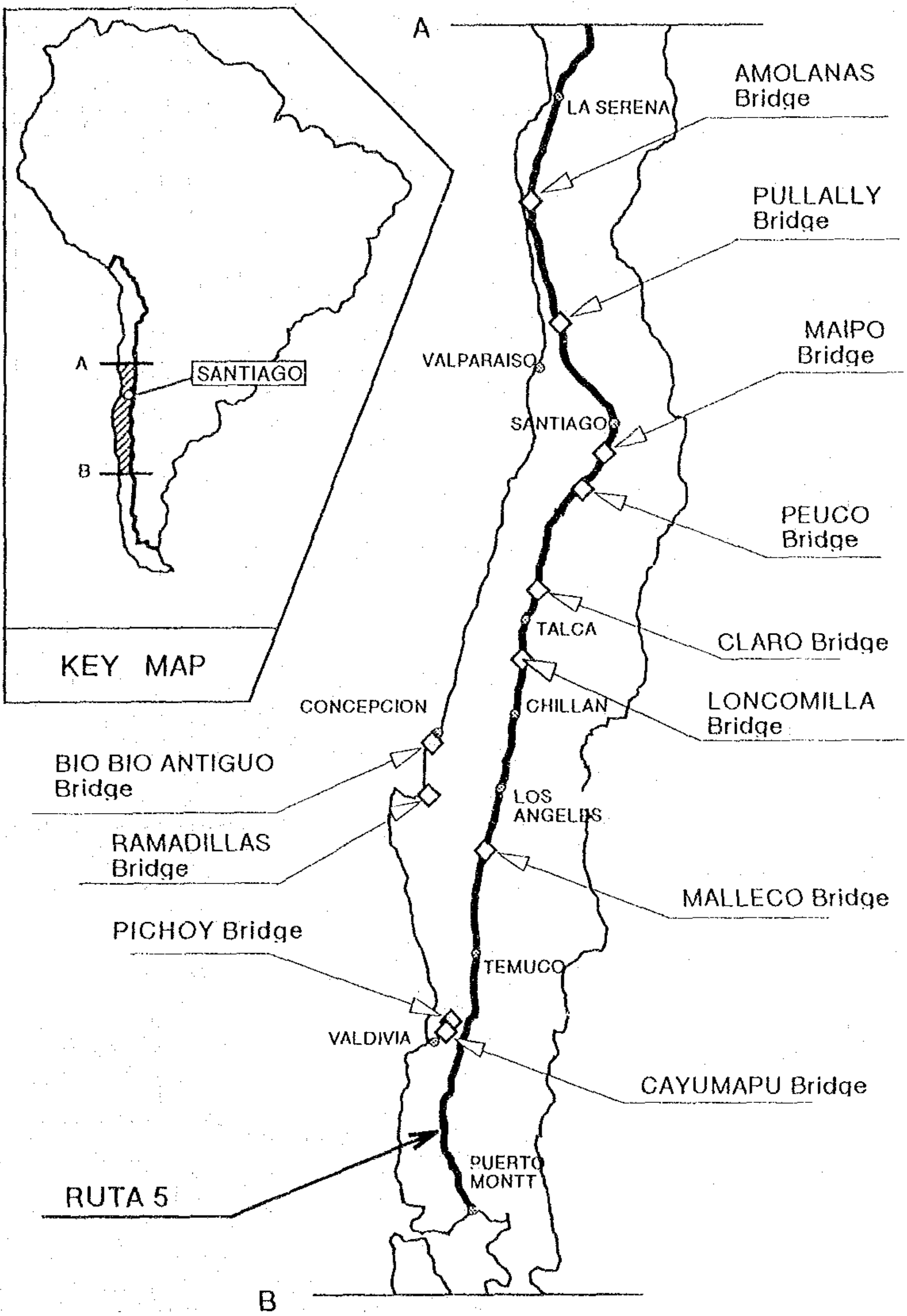


Figure 3-1 Location Map of Surveyed Bridges

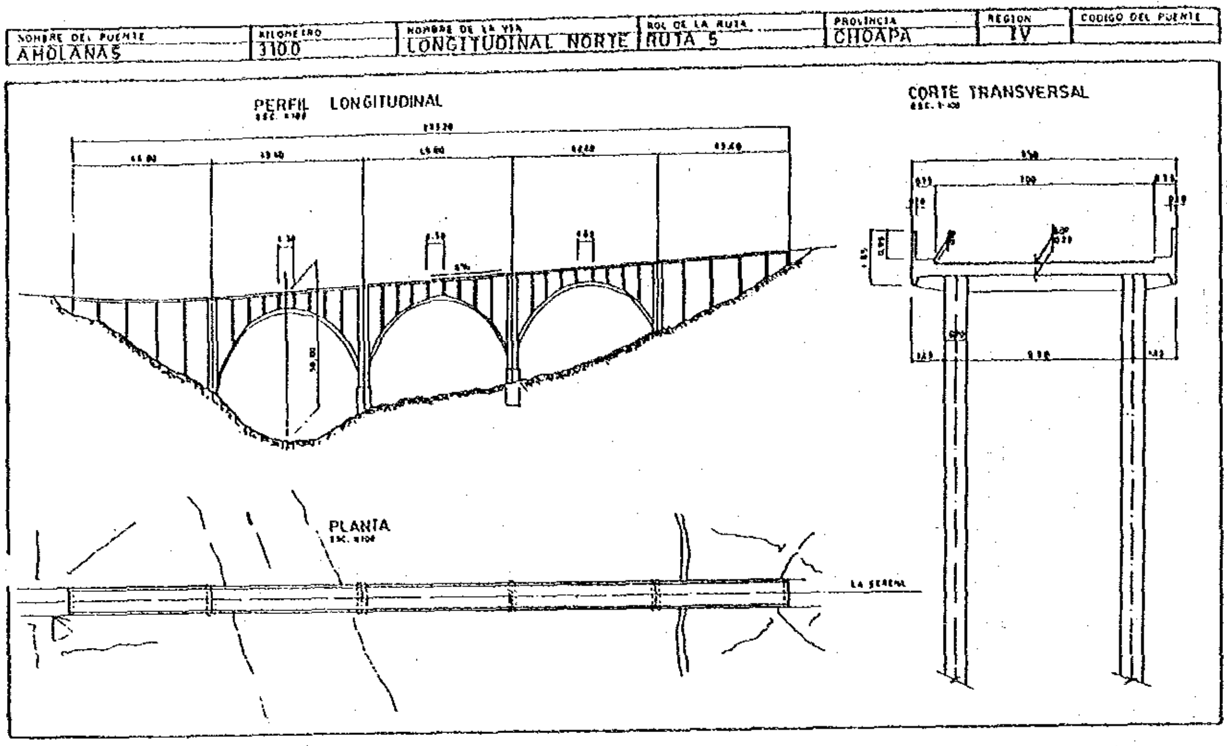


Figure 3-2 AMOLANAS Bridge

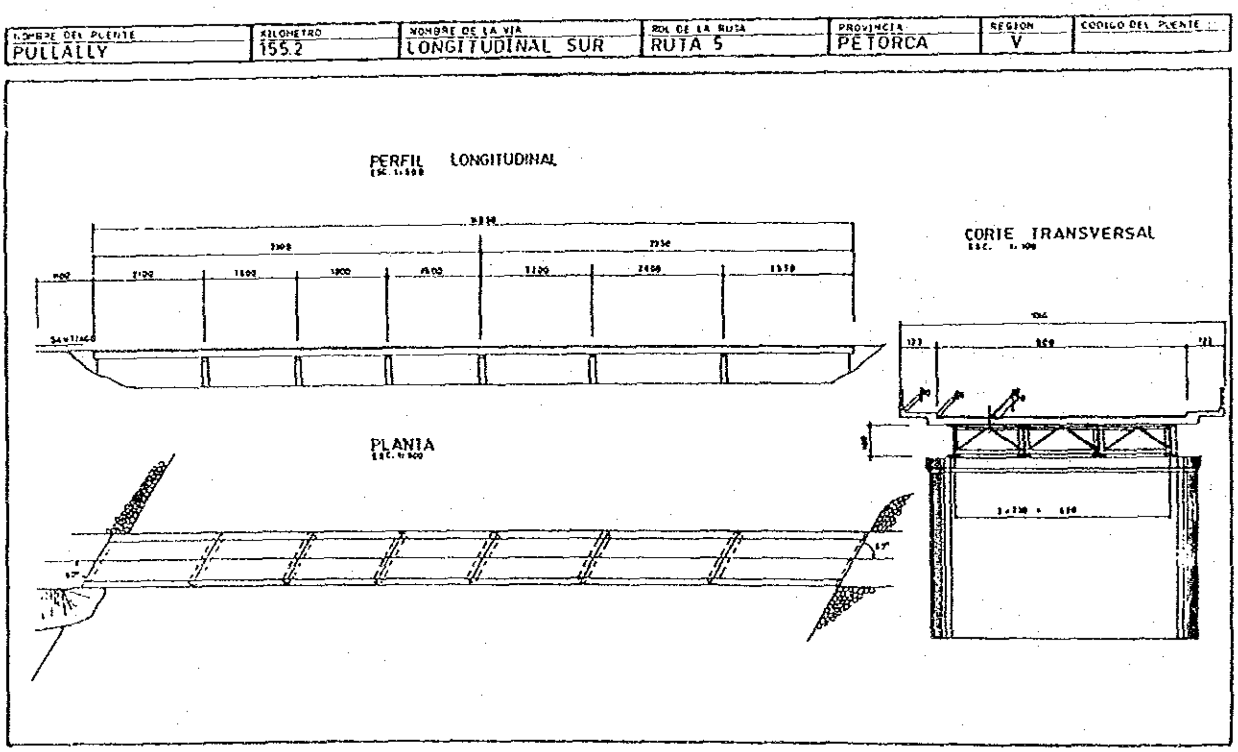


Figure 3-3 PULLALLY Bridge

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA	REGION	CODIGO DEL PUENTE
MAIPO	3U Km	LONGITUDINAL SUR	RUTA 5	TALAGANTE	RM	

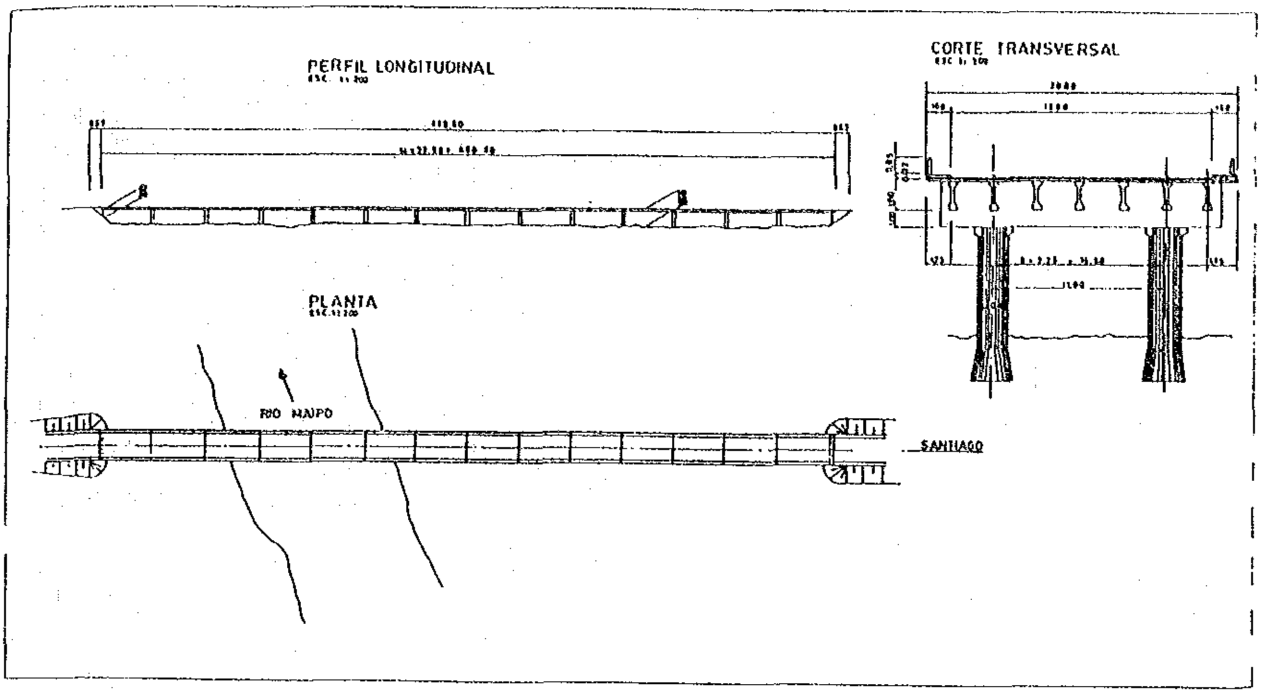


Figure 3-4 MAIPO Bridge

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA	REGION	CODIGO DEL PUENTE
CLARO	2184	LONGITUDINAL SUR	RUTA 5		VII	

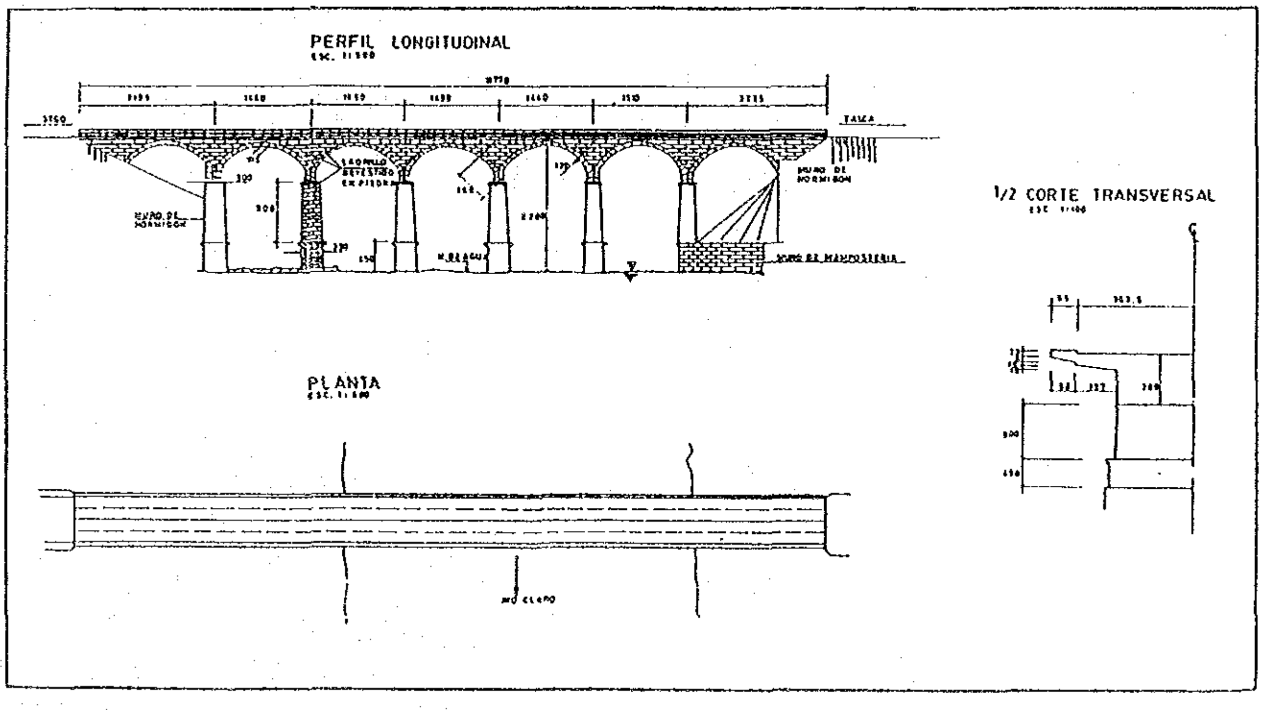


Figure 3-5 CLARO Bridge

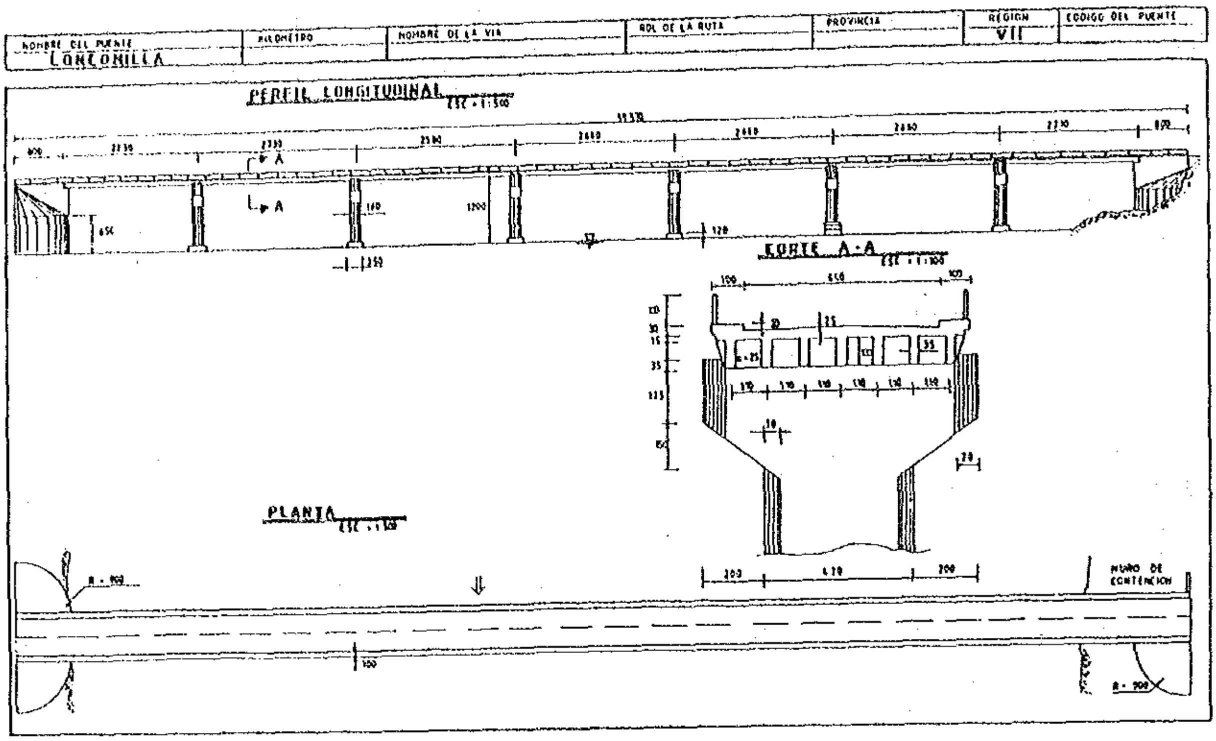


Figure 3-6 LONCOMILLA Bridge

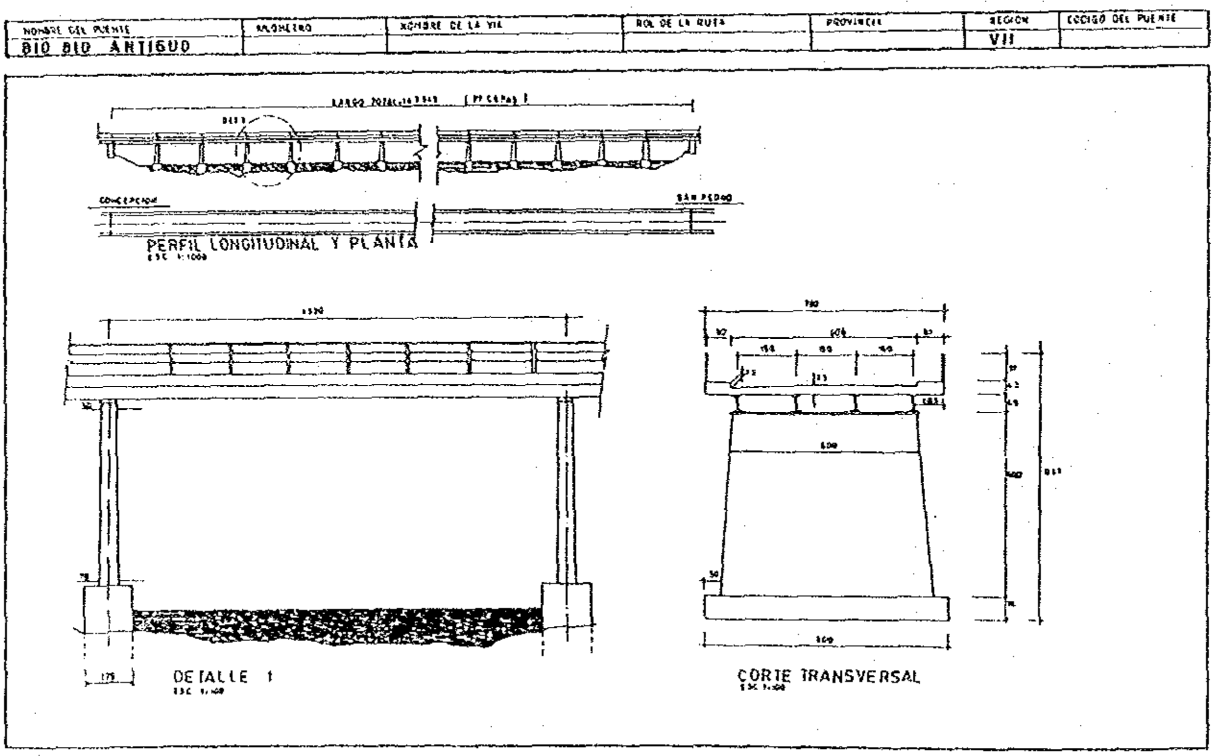


Figure 3-7 BIO BIO ANTIGUO Bridge

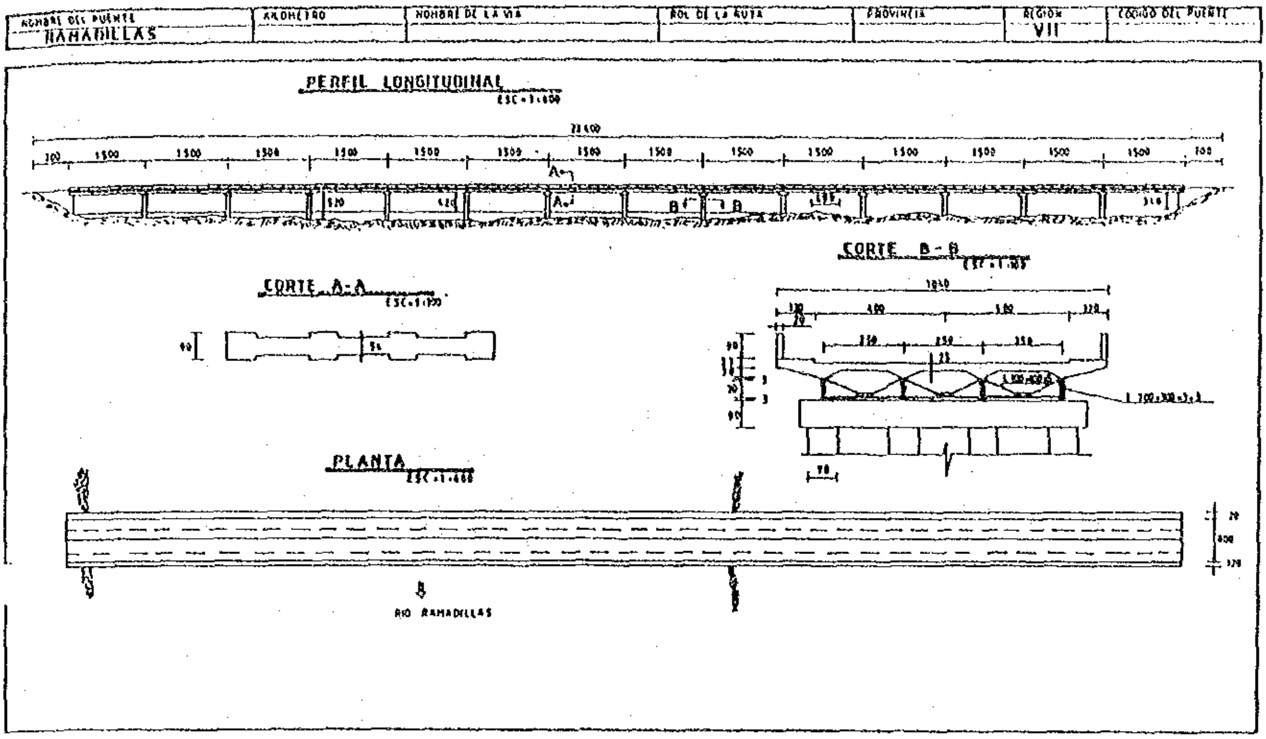


Figure 3-8 RAMADILLAS Bridge

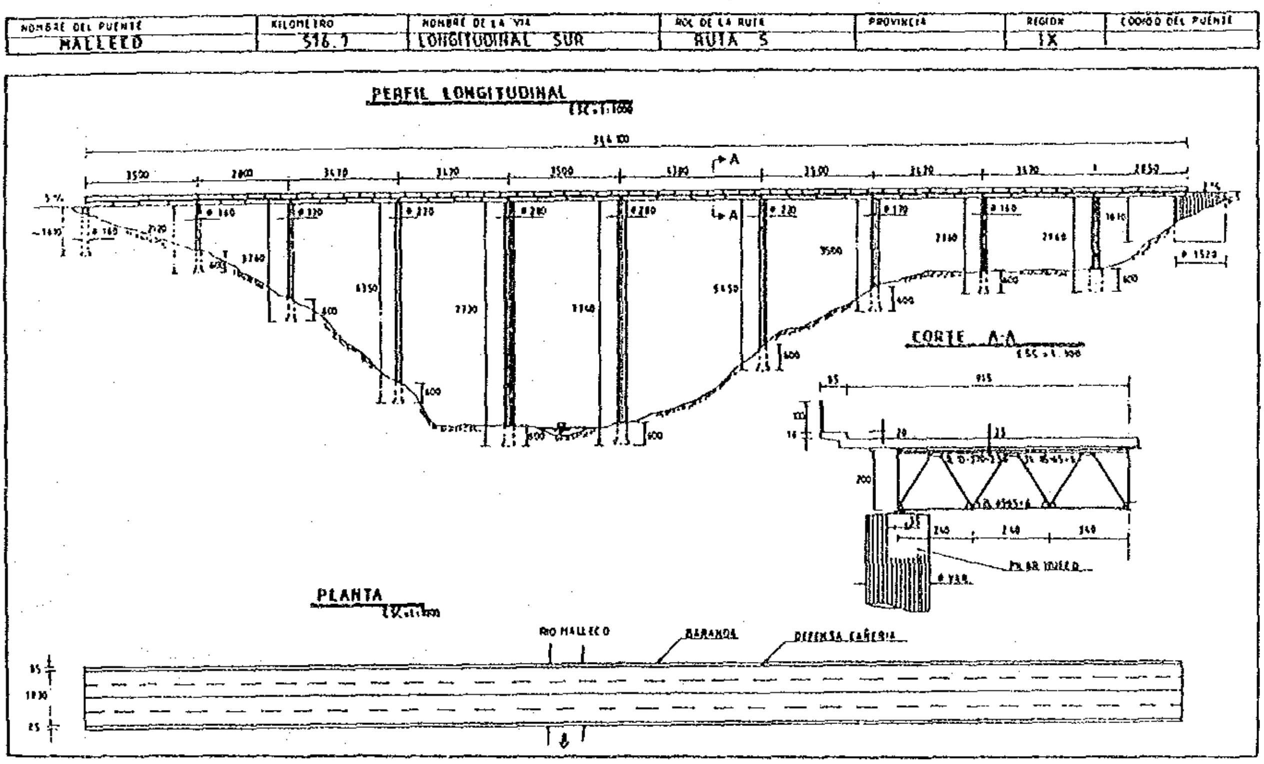


Figure 3-9 MALLECO Bridge

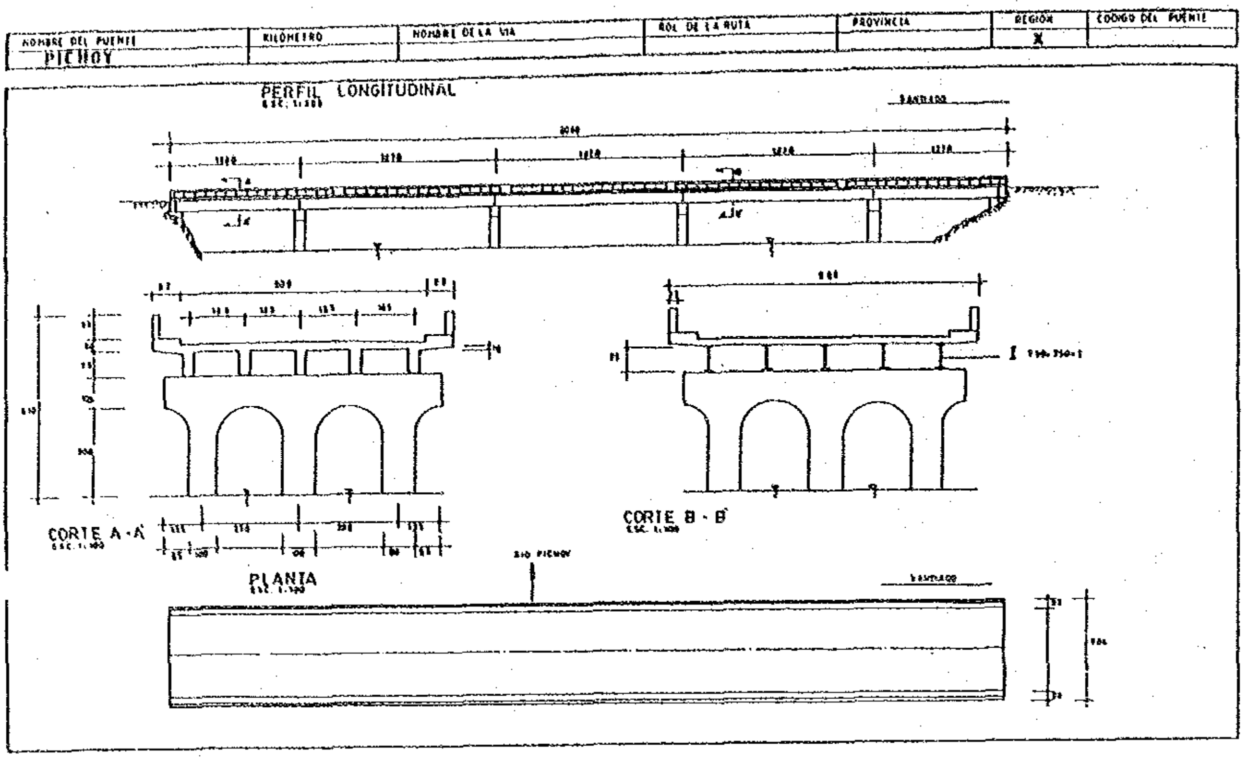


Figure 3-10 PICHOY Bridge

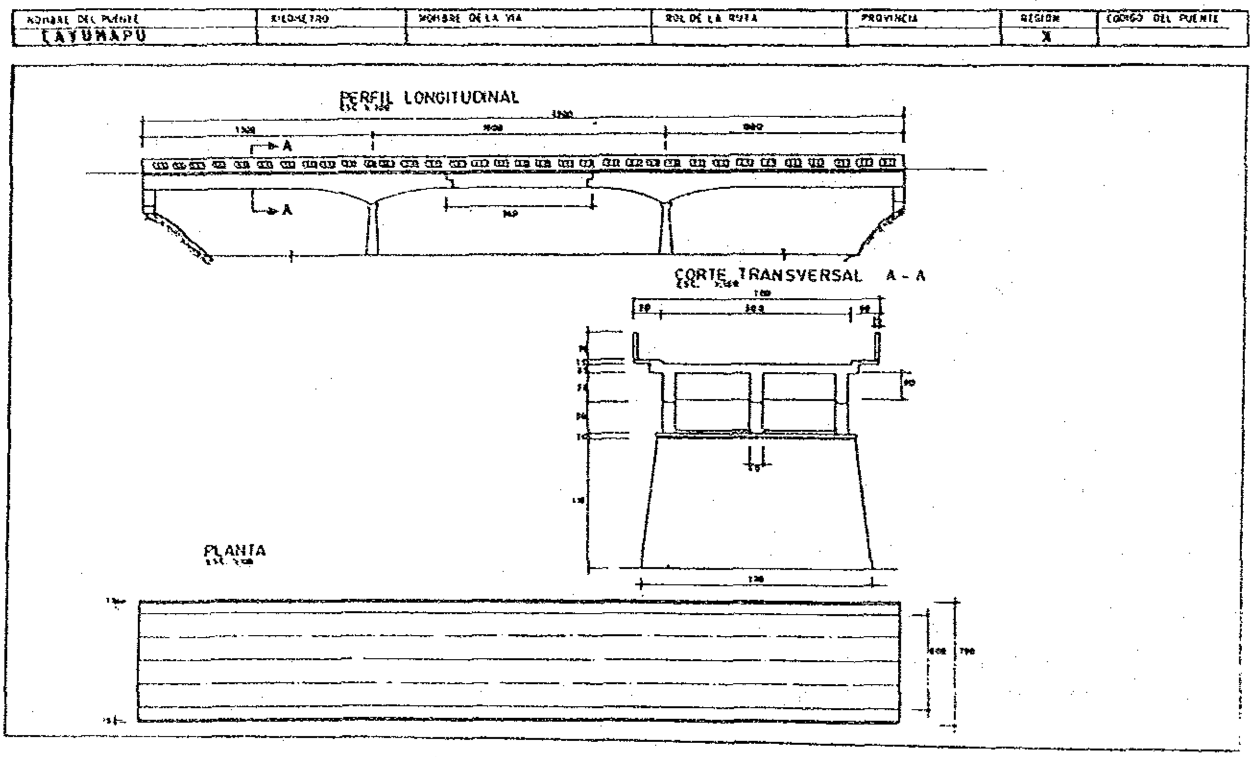


Figure 3-11 CAYUMAPU Bridge

3-1-2 Selection of Detailed Survey Bridges

(1) Selection Method of Candidate Bridges

Ten candidate bridges for detailed survey were selected by the following procedures.

1. Stage I

Field survey performed for bridges in which the length is 10 m or over on Route 5 from 4th State to 10th State, and on main trunk routes other than Route 5 for which detailed surveys were requested by MOP. From the survey by viewing, the data for degree of damage was collected.

2. Stage II

As a result of the Stage I field survey, the Study team selected candidate bridges.

3. Stage III

The Study team discussed with the MOP Bridge Division the selection of candidate bridges .

4. Stage IV

After listening to the reasons for delegation's candidate bridge selection, MOP submitted a request for the detailed survey of these bridges and stated the priority in which the 3 stages were to be surveyed.

5. Stage V

Above discussion, 28 bridges were selected as shown in Table 3-3. Taking into consideration the request from MOP, the Study team finally selected 22 bridges as candidate bridge. Table 3-4 shows those bridges.

Table 3-3 Selection of Candidate Bridges for Detailed Survey

Nº	Bridge Name	REGION	A	B	C	D
1	HUASCO	3			*-1	*
2	AMOLANAS	4	*	*	*-1	*
3	CHIGUALOCO	4		*		*
4	QUILLIMARI	4			*-11	*
5	PULLALLY	5		*	*-111	*
a	EL MONTE	RM	*			
b	ESPERANZA	RM	*			
6	MAIPO	RM		*	*-111	*
7	P.S. EL TENIENTE (Nº1)	6		*		*
8	P.S. EL TENIENTE (Nº2)	6		*		*
9	TENO	7		*	*-1	*
10	CLARO	7		*	*-1	*
c	MAULE ORIENTE	7		*		
11	LONCOMILLA	7	*	*		*
12	QUILLIPIN	7		*		*
d	QUILLON	8	*			
e	QUEBRADA HONDA	8	*			
13	BIO-BIO ANTIGUO	8	*	*	*-1	*
f	SALTO DEL LAJA	8		*		
14	RAMADILLAS	8	*	*	*-11	*
15	MALLECO	9	*	*	*-1	*
16	QUINO	9		*	*-111	*
17	TOLTEN	9	*	*	*-111	*
18	P.S. LONCOCHE	9		*		*
19	PICHOY	10	*	*		*
20	CAYUMAPU	10	*	*		*
21	CRUCES CALLE CALLE	10	*	*	*-11	*
22	RAHUE	10		*	*-11	*

A : Bridge requested for the detailed survey from MOP at the beginning of Study
B : Bridge to be necessary the detailed survey after the preliminary survey
C : Bridge with high priority for the detailed survey requested from MOP according to the "A" and "B"
D : Bridge as the final candidate bridge for the detailed survey

(2) Detailed Survey Bridges Selection

In order to select 10 bridges for the detailed survey, which have typical damage in Chile and include many types of repair, 22 bridges were classified according to the following perspectives.

1) Necessary survey items for the superstructure (see Table 3-4)

a. Load resistance strength
b. Structural analysis
c. Damage degree detailed survey
d. Bridge function survey (traffic volume)

2) Necessary survey items for the substructure (see Table 3-5)

a. Scouring
b. Boring survey
c. Basic form survey
d. Displacement measurement
e. River countermeasures

3) Classification based on type of bridge structure (see Table 3-6)

4) Consideration of the detailed surveys for bridges requested by MOP of Chile.

Table 3-3(C) shows MOP's order of priority for detailed survey. In this table, the bridge marked with"*-I", "*-II" and "*-III" has high priority ranks for the survey requested by MOP, whose marks mean order of priority, i.e., I for the first and II for the second, etc.

Table 3-4 Survey Items for Superstructure

Nº	Bridge Name	REG	A	B	C	D
1	HUASCO	3		*		
2	AMOLANAS	4		*	*	
3	CHIGUALOCO	4			*	
4	QUILLIMARI	4		*		*
5	PULLALLY	5	*	*	*	
6	MAIPO	RM	*	*		
7	P.S. EL TENIENTE (Nº1)	6	*	*	*	
8	P.S. EL TENIENTE (Nº2)	6	*	*	*	
9	TENO	7				*
10	CLARO	7		*		*
11	LONCOMILLA	7				*
12	QUILLIPIN	7				*
13	BIO-BIO ANTIGUO	8	*		*	*
14	RAMADILLAS	8			*	
15	MALLECO	9	*	*	*	
16	QUINO	9			*	
17	TOLTEN	9		*		
18	P.S. LONCHOCHE	9			*	
19	PICHOY	10			*	
20	CAYUMAPU	10			*	
21	CRUCES CALLE-CALLE	10				*
22	RAHUE	10		*		

A : Load Resistance Strength
B : Structure Analysis
C : Damage Degree Detailed Survey
D : Traffic Volume Survey

Table 3-5 Detailed Survey Items for Substructure

Nº	Bridge Name	REG	A	B	C	D	E
1	HASCO	3					
2	AMOLANAS	4					
3	CHIGUALOCO	4					
4	QUILIMARI	4					
5	PULLALLY	5					
6	MAIPO	RM	*	*	*		
7	P.S. EL TENIENTE (Nº1)	6					
8	P.S. EL TENIENTE (Nº2)	6					
9	TENO	7					
10	CLARO	7	*				
11	LONCOMILLA	7	*	*	*	*	*
12	QUILLIPIN	7	*				*
13	BIO BIO ANTIGUO	8	*	*	*		
14	RAMADILLAS	8					
15	MALLECO	9			*	*	
16	QUINO	9					
17	TOLTEN	9			*	*	
18	P.S. LONCHOCHE	9		*	*	*	
19	PICHOY	10		*	*	*	
20	CAYUMAPU	10		*	*	*	
21	CRUCES CALLE-CALLE	10		*		*	
22	RAHUE	10					

A : Scouring
B : Boring Survey
C : Basic Form Survey
D : Hydraulic Survey
E : River Countermeasure

Table 3-6 Classification by Type of Bridge Structure

Nº	Bridge Name	REG	RC	AR	PC	M	OTRA	FUNDA CION.
1	HUASCO	3	*					
2	AMOLANAS	4		*				
3	CHIGUALOCO	4	*					
4	QUILLIMARI	4	*					
5	PULLALLY	5				*		
6	MAIPO	RM			*			*
7	P.S. EL TENIENTE (Nº1)	6	*					
8	P.S. EL TENIENTE (Nº2)	6				*		
9	TENO	7	*					
10	CLARO	7					*	*
11	LONCOMILLA	7			*			*
12	QUILLIPIN	7						
13	BIO-BIO ANTIGUO	8				*		*
14	RAMADILLAS	8				*		
15	MALLECO	9				*		
16	QUINO	9			*			
17	TOLTEN	9			*			
18	P.S. LONCHOCHE	9	*			*		
19	PICHOY	10	*			*		
20	CAYUMAPU	10	*					
21	CRUCES CALLE-CALLE	10	*					
22	RAHUE	10		*				

RC : Reinforcement Concrete Bridge
AR : Reinforcement Concrete Arch Bridge
M : Steel Bridge
PC : Prestress Concrete Bridge
Fundation : Bridge with Problem for Fundation

3-1-3 Method of Detailed Survey

(1) Basic Policy for the Detailed Survey

The following works were conducted in the detailed survey.

1) Measurement by Instrument

The following survey was conducted to measure conditions and deterioration of structure materials.

a. Non-destructive concrete hardness test by Schmidt Concrete Hammer Test
b. Non-Destructive Reinforced Concrete Survey by Profometer
c. Concrete Neutralization Test
d. Steel Hardness Test by Brinell Hardness

2) Survey of Deformation and Measurement of Dimension

Bridges deform by earthquakes, floods and scouring, etc. Differences between dimensions on design drawing and at completion sometimes occur. Therefore, the following surveys were conducted to obtain the present dimension of bridge.

a. Survey for horizontal and vertical displacement, vertical gradient and settlement. survey for vertical alignment of approach road.
b. Survey for scouring and degree of angle for pier
c. Confirmation for depth of foundation of substructure and survey for conditions of scouring on river bed
d. Survey for distribution of cracks in slabs

3) Geological Survey

At present, there is little geological data for bridges in Chile. The geological data is indispensable to conduct measurement against earthquake and scouring. Therefore, of 10 bridges for the detailed survey, 7 bridges exclusive of AMOLANAS, CLARO and RAMADILLAS bridges were surveyed. It is very important to obtain data from the standard penetration test. In this Study, the standard penetration test to find load resistance of foundation, and geological test in laboratory, to determine the type of soils in bridge construction site were conducted.

(2) Measurement

Figures 3-12 to 3-21 show the measurement locations for each bridge. In these figures, the locations where Schmidt Concrete Hammer Test (SCH), and for surveying by Profometer (PRO) and Concrete Neutralization Test (CRO) are indicated.

1) Concrete hardness test by Schmidt Concrete Hammer Test

The 25 non-destructive concrete hardness test (Schmidt Concrete Test Hammer)(SCH) machine used was an NR type. This is a method stipulated by the Japan Materials Academy. A measuring sheet was used for each measuring point. Measurements were performed according to "measurement of 1 location is performed at 20 points with a minimum of 3 centimeter intervals, in a location more than 3 centimeters from the corner." The calculated average for all measuring points represent the measuring points' hardness. Measurements were corrected according to the following method.

a. Angle Correction

$Di = Dmi + \Delta Rmi$

Dmi : value by Schmidt Concrete Test Hammer

ΔRmi : angle correction value

b. Measurement Value Method

Measurement was performed 20 times and an average value +- 20% range was adopted.

Measurement value Di i = 1 - 20

Average value Av = 1/20 Di

Measurement adopted value Dadi 0.8 Av < Dadi < 1.2A

c. Strength Formula

According to the Japan Material Academy formula.

F = 13 * Do - 184(Kg/cm)

d. Concrete Strength Deterioration based on Material

Strength deterioration of concrete over time was based on the following formula.

Fn = F * a a = secular coefficient

2) Non-Destructive Reinforced Concrete Survey Instrument (Profometer)(PRO)

The electromagnetic inducement method non-destructively measures reinforced bar location, reinforced bar diameter, and depth of concrete cover. The following two points were measured using this measuring technique.

1. Confirmation of the location of reinforcement bar and measurement of the concrete covering depth.
2. Confirmation of the location of reinforcement bar (horizontal and vertical directions) in order to conduct the neutralization test.

3) Concrete Neutralization Test

a. Concrete Neutralization

The degree of concrete neutralization was measured in order to determine the bearing force and the durability of the reinforced concrete structure. When concrete is poured it shows strong alkalinity with calcium hydroxide Ca(OH) (Ph value is approximately 12). However, over time, carbonate gases in the air gradually reduce the alkalinity of the concrete.

$$Ca(OH)_2 + CO_2 \dashrightarrow CaCo_3 + H_2O$$

As neutralization of the concrete progresses and the Ph value drops lower than 9, the reinforcement bar encourages the generation of rust, which causes the bar to corrode. Concrete will also expand as the reinforcement bar corrodes, eventually causing crack and breakage in the concrete. Water and air will enter the cracks and promote corrosion, thus further reducing the durability of the reinforced concrete. This phenomena is called concrete neutralization, and it is an important source of information for judging the durability of concrete.

b. Neutralization Test (CAR) Method

The neutralization test was conducted in the following steps.

1. Spray 1% phenolphthalein alcohol liquid on the measuring surface of the concrete.
2. If the sprayed surface turns red, the concrete shows alkalinity.
3. If the sprayed surface turns white, the concrete shows that neutralization has progressed. (Read the Ph value of the "neutralization color change standards chart" for the degree of neutralization.)
4. The depth showing neutralization (depth from the concrete surface) is called "depth of neutralization" and provides an index for concrete neutralization.
5. Remove concrete by drilling and expose the reinforced bar. The degree of rust can be estimated according to the following standards. (Refer to Table 3-7)

Table 3-7 Rust Standards for Reinforced Bar

Rust Display	Rust Conditions of Reinforced Bar
A	Rust is almost nonexistent.
B	Partial pitting is observed.
C	Majority of the bar is covered by red rust.
D	A cross-section is partially lacking at the placing joint of a crack.
E	Expansion strength of the rust layers pushes out the covering concrete.

4) Steel Hardness Test

Steel hardness was measured by equo tip. This test method measures hardness from the degree of repulsion when an impact body made from diamond hits the test specimen. Repulsion is converted into Brinell Hardness and the specimen's harness can be calculated.

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA	REGION	CODIGO DEL PUENTE
AMOLANAS	310.0	LONGITUDINAL NORTE	RUTA 5	CHOAPA	IV	

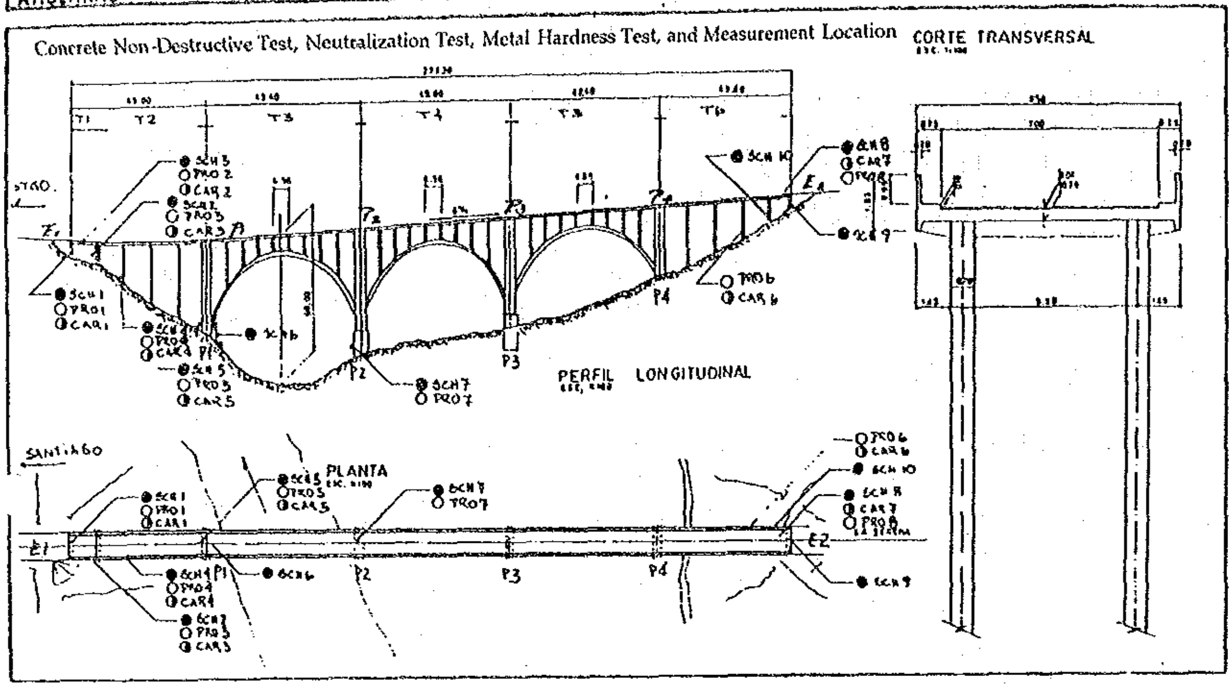


Figure 3-12 Amolanas Bridge Measurement Location

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA	REGION	CODIGO DEL PUENTE
PULLALLY	155.2	LONGITUDINAL SUR	RUTA 5	PETORCA	V	

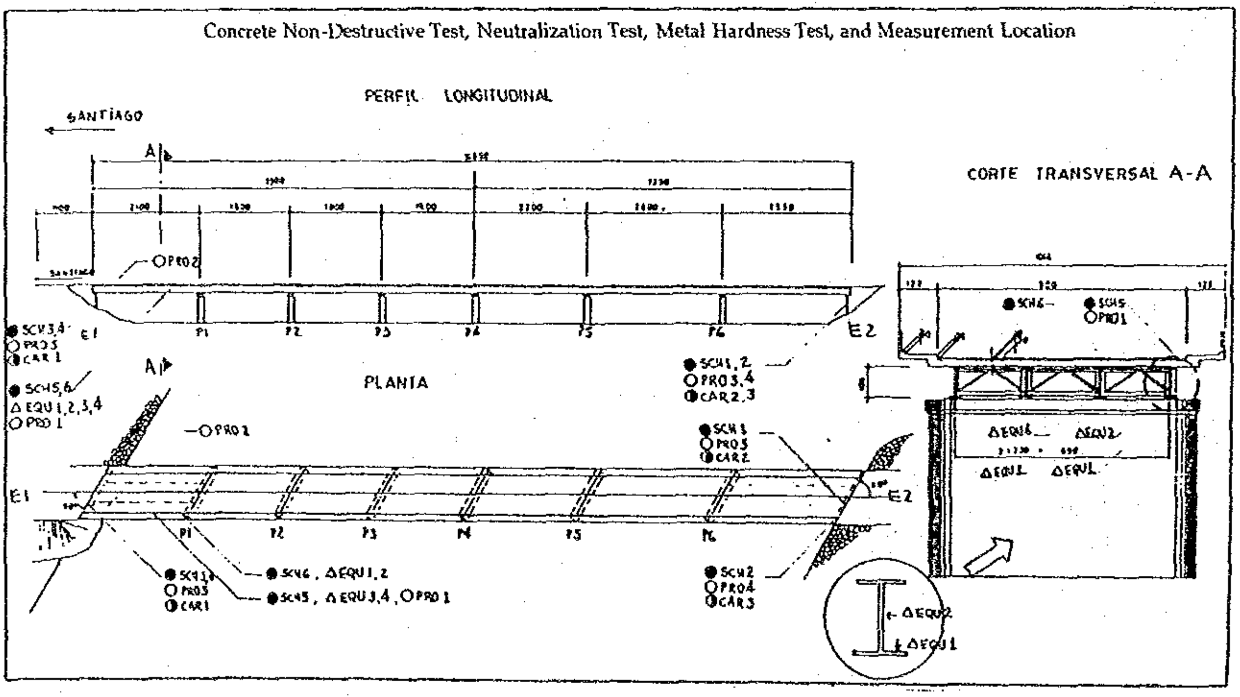


Figure 3-13 Pollally Bridge Measurement Location

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA	REGION	CODIGO DEL PUENTE
MAIPO	311 Km	LONGITUDINAL SUR	RUTA 5	TALAGANTE	RM	

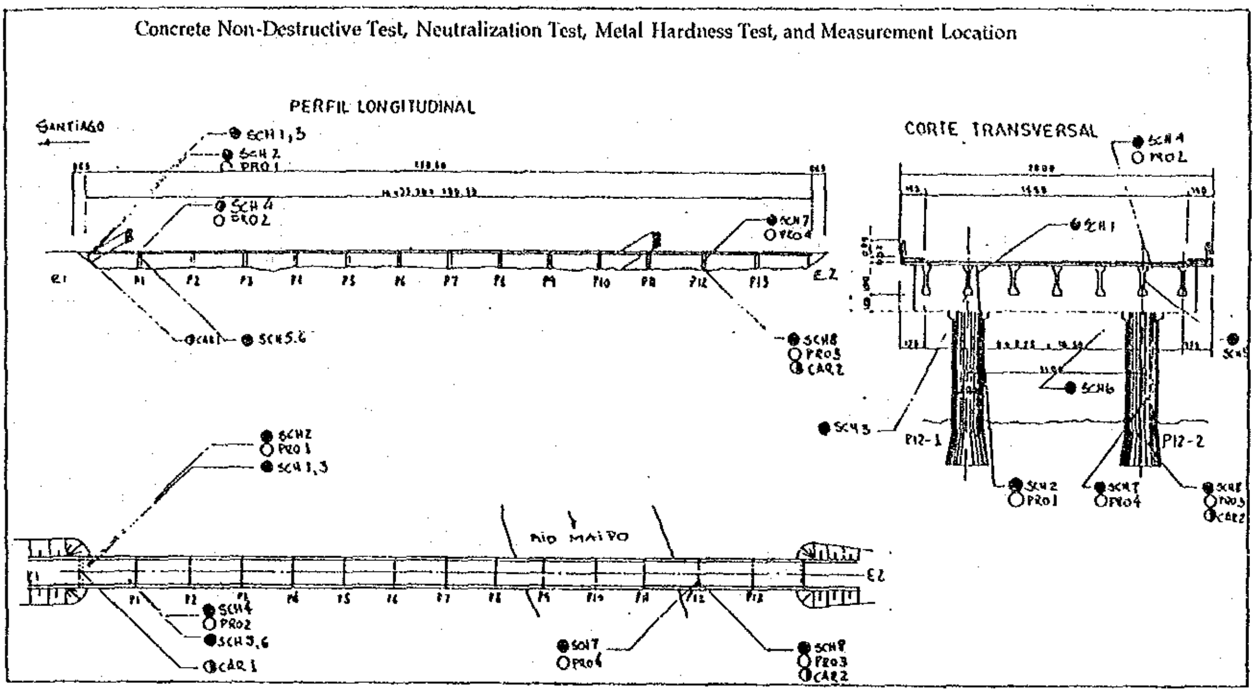


Figure 3-14 Maipo Bridge Measurement Location

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA	REGION	CODIGO DEL PUENTE
CLARO	2186	LONGITUDINAL SUR	RUTA 5		VII	

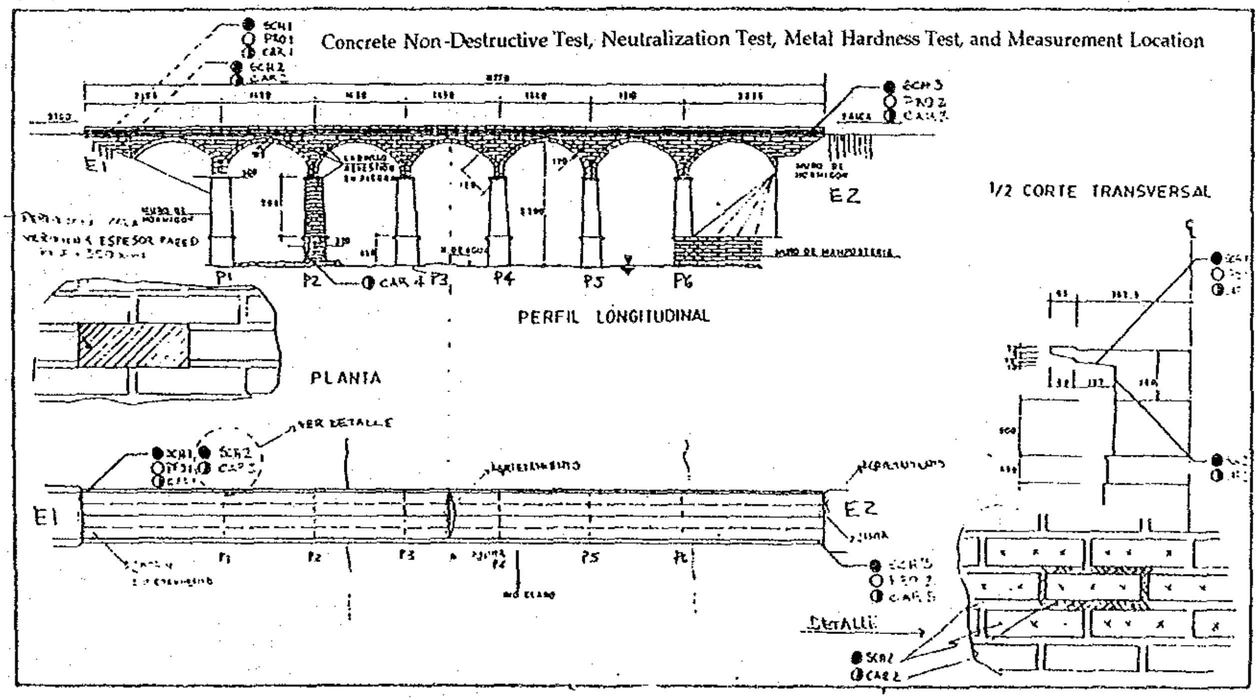


Figure 3-15 Claro Bridge Measurement Location

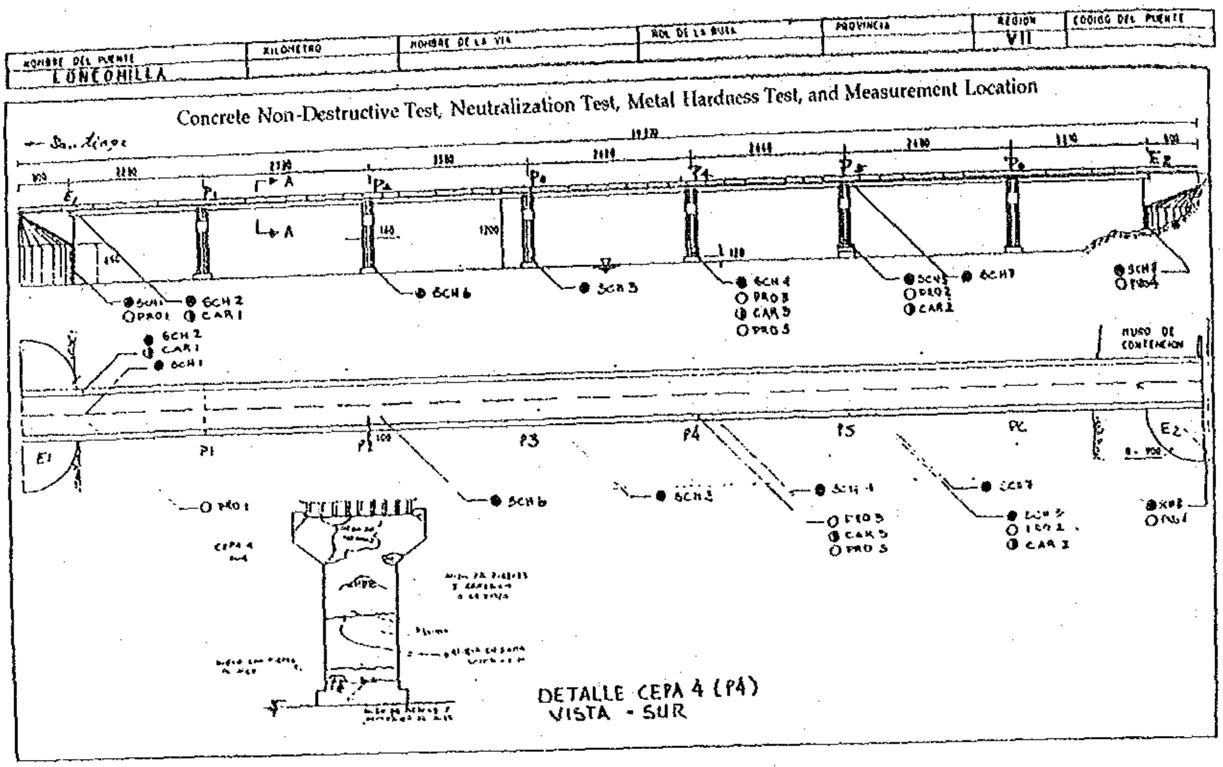


Figure 3-16 Loncomilla Bridge Measurement Location

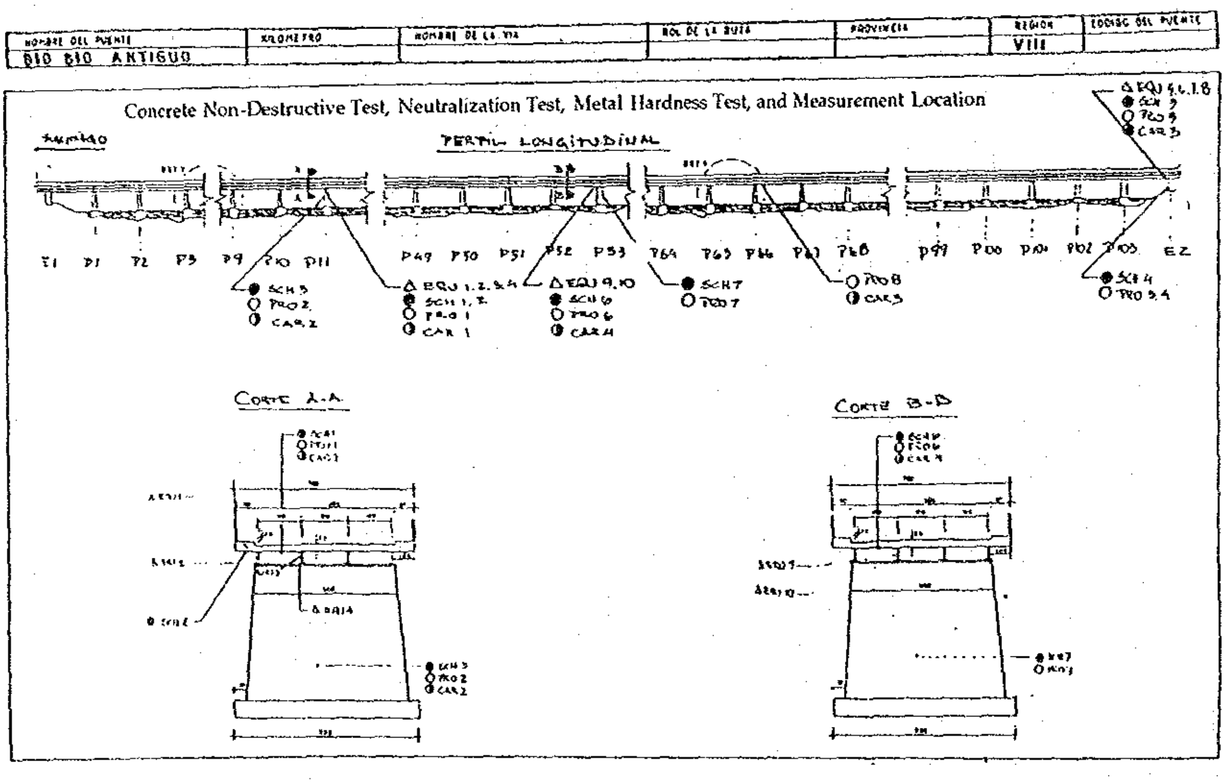


Figure 3-17 Bio Bio Antiguo Bridge Measurement Location

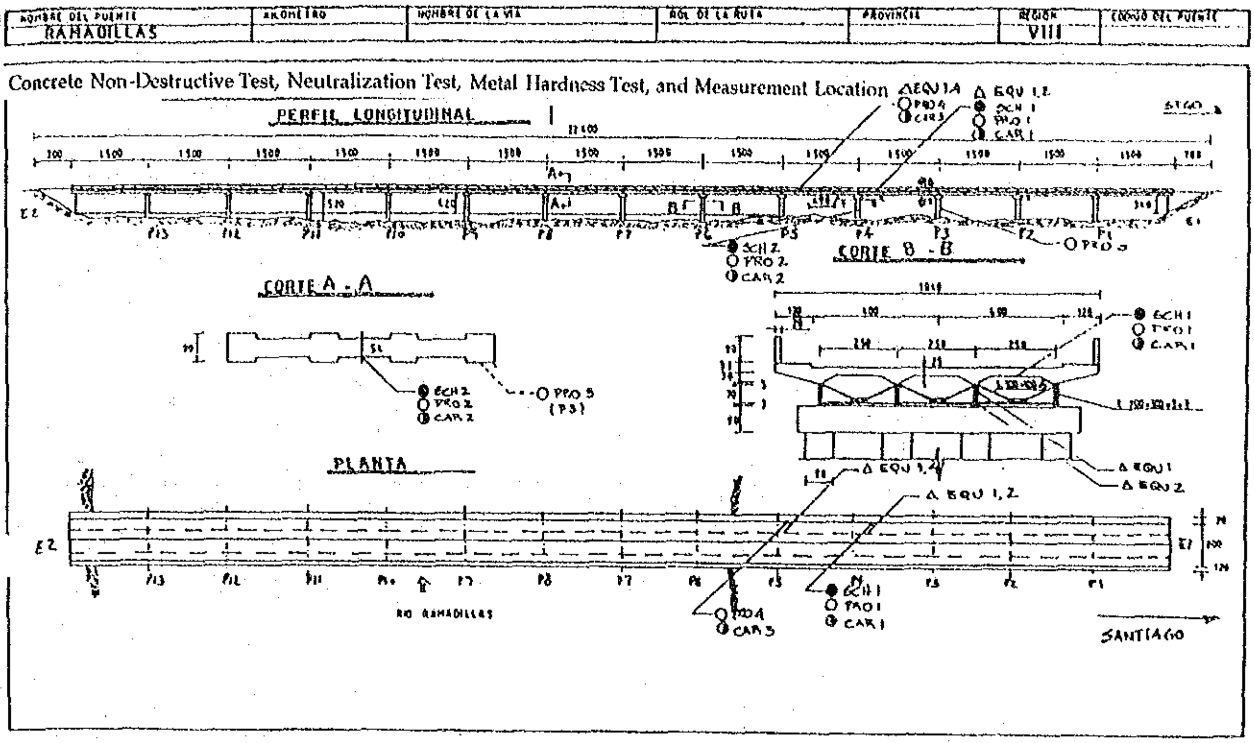


Figure 3-18 Ramadillas Bridge Measurement Location

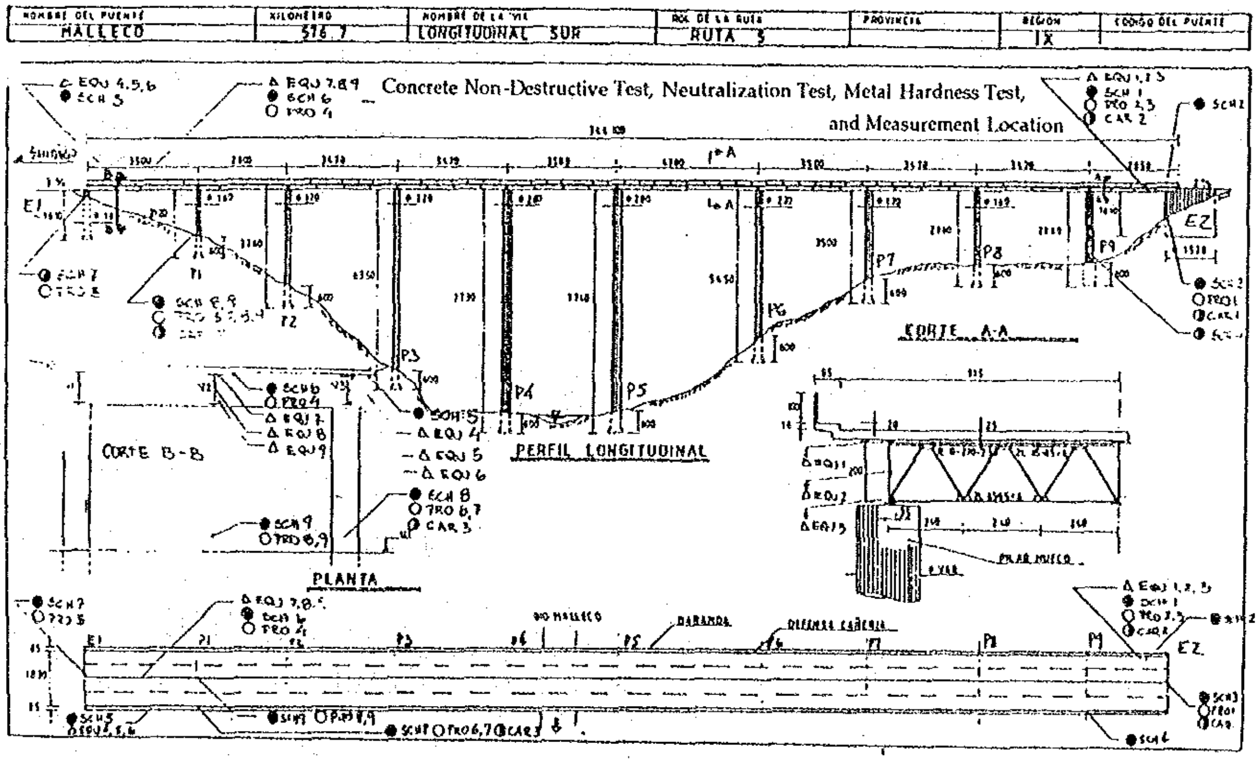


Figure 3-19 Malleco Bridge Measurement Location