2) Forecasting overall traffic growth rate through a growth model (Future river crossing traffic only)

3) Estimation of traffic growth rates by traffic zone applying future economic frame by zone
(Future traffic generation /attraction by zone)

4) Forecasting future vehicle O-D matrix

1. Future river crossing vehicle O-D matrix (daily traffic)
2. Future O-D matrix excluding the river crossing traffic
3. Combination of above vehicle O-D matrix (daily traffic)
4. Future Peak and Off peak hour vehicle O-D matrix

5) Traffic assignment to future road network by alternative bridge plan

1. Peak hour traffic assignment
2. Off peak hour traffic assignment

The process of the forecasting is illustrated in Fig.6-1.

6.2 Establishment of Present O-D Matrix

The present vehicle O-D matrices were prepared combining 2(two) O-D matrix. The one was derived from the results of road side O-D survey conducted by the Study Team and is composed of only river crossing vehicle traffic. The other one was based on O-D data by DICTUC and composed of other O-D components than river crossing traffic. Both O-D matrix above were combined with each other after changing DICTUC's person trip O-D matrix into vehicle O-D matrix in order to obtain complete vehicle O-D matrix covering the whole study area.

6.2.1 Road Traffic Survey for River Crossing Traffic

The Study Team conducted the traffic survey at both ends of Biobio Antiguo bridge and Juan Pablo II bridge. The purpose of the survey was to obtain information on vehicle O-D traffic crossing the river.

(1) Types of Survey and Survey Method

The traffic survey consisted of the following 2(two) types:

1. Roadside Origin-Destination(O-D) Survey
2. Classified Traffic Counting Survey

The roadside O-D survey was based on a interviewing method by stopping vehicles and asking drivers origin/destination places, trip purposes, number of passengers, etc. During the survey time, not only private passenger cars but public buses and trucks were also interviewed.

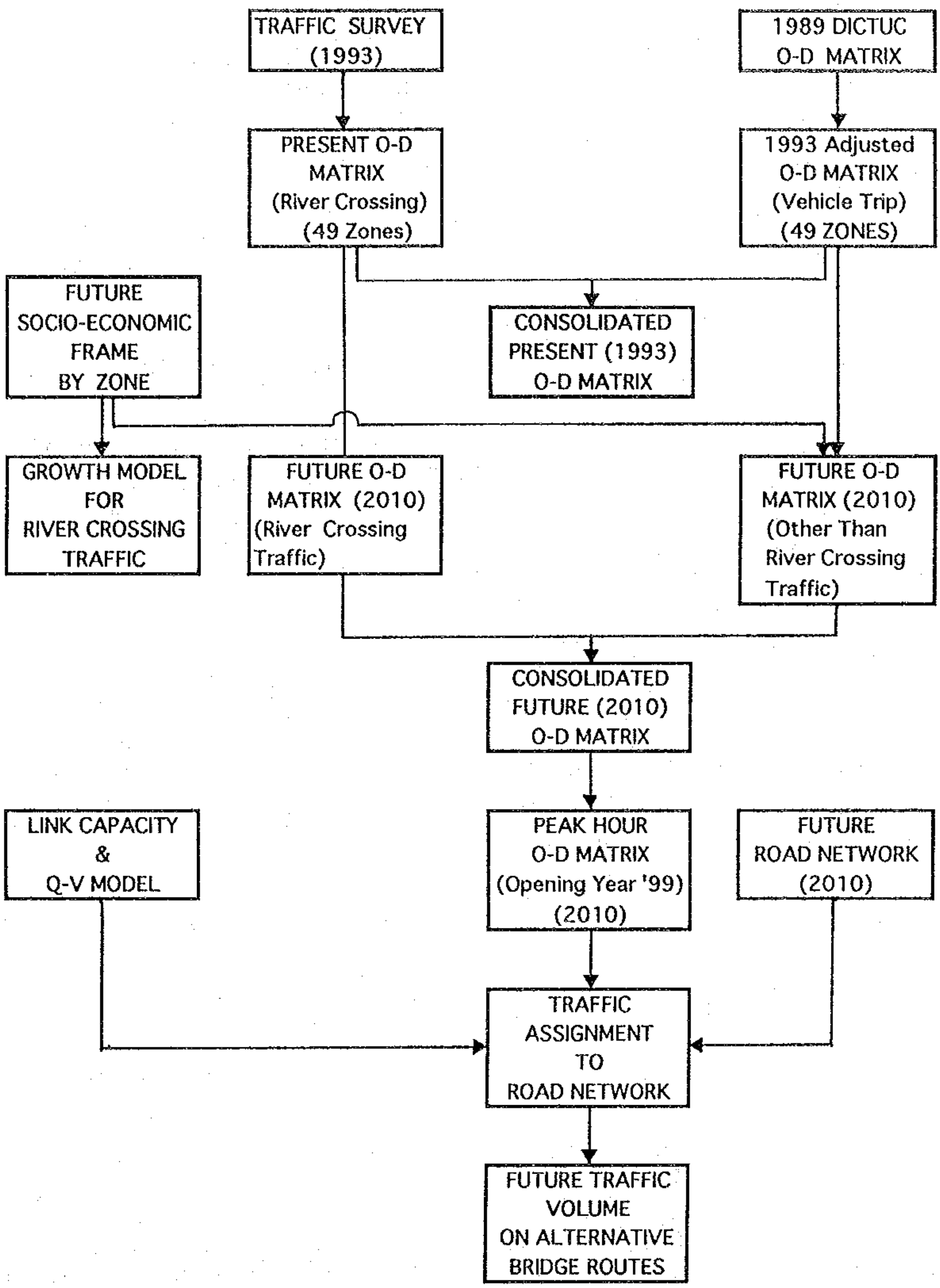


Fig. 6-1 Flow Chart for Future Traffic Forecasting

(2) Survey Stations

The 6(six) stations for the O-D survey and 19 counting stations were selected after a field reconnaissance as shown in Fig.6-2.

(3) Survey Schedule

The roadside O-D survey and traffic counting survey were conducted on 15th and 16th of December 1993 in accordance with the following schedule:

1) 15th December (Wednesday) 1993:

Roadside O-D survey at stations 11-14, 21 and 22:
12 hours (07:00 AM - 19:00)

Traffic counting survey at the same stations of O-D survey:
24 hours (07:00 AM - 07:00 AM next morning)

2) 16th December (Thursday) 1993:

Traffic counting by direction at the intersections of access roads both ends of the 2 bridges:
16 hours (07:00 AM - 23::00)

Although the survey period above was during the students' summer vacation season, the survey schedule took into account the total schedule of this study. Seasonal fluctuation adjustments to vehicle trips in this season (not person trip by trip purpose) were applied in order to obtain the Average Annual Day Traffic (AADT) as explained below.

(4) Survey Items and Survey Form

A survey form for the O-D interviewing is shown in Table 6-1 which includes the following survey items:

1. Vehicle Type
2. Address of origin place
3. Address of destination place
4. Trip purpose
5. Total number of passengers (for passenger vehicles)
6. Capacity- ton (for cargo vehicles)
7. Commodity type (for cargo vehicles)
8. Load condition (for cargo vehicles)

(5) Zone System for Roadside O-D Survey

The zone system for the roadside O-D survey and for the establishment of initial O-D matrix was the same as adopted in socio-economic analysis with 24 zones (Chapter 2 and Chapter 4). The 24 zone system was adopted at first stage in order to get quick and accurate answers from interviewed drivers.

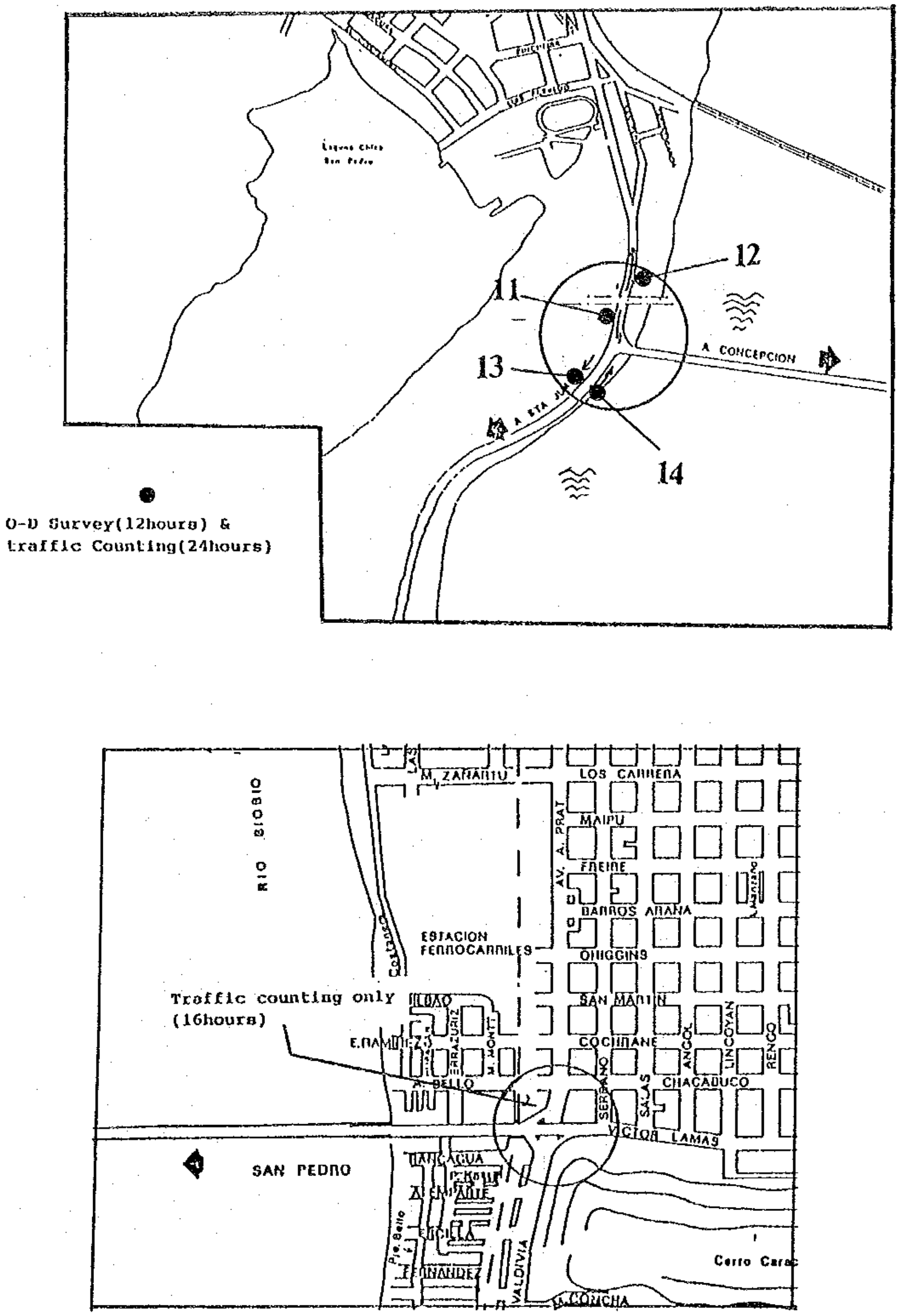
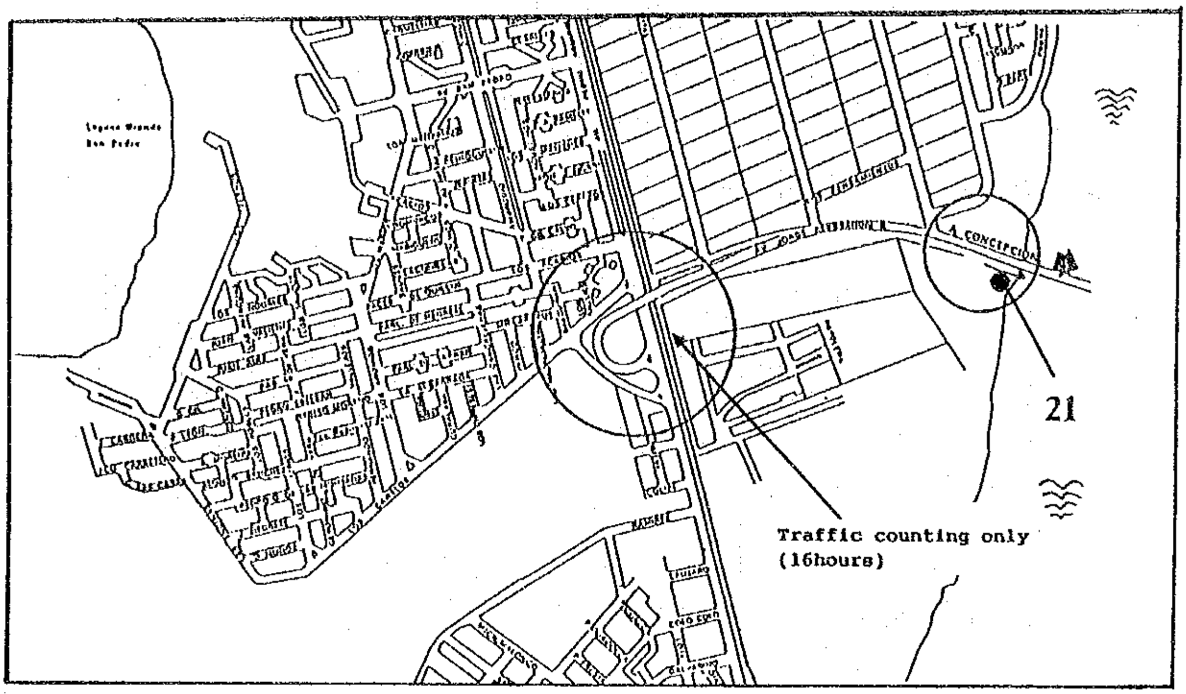


Fig.6-2(1) Location of Traffic Survey Stations



● O-D Survey(12hours) & traffic Counting(24hours)

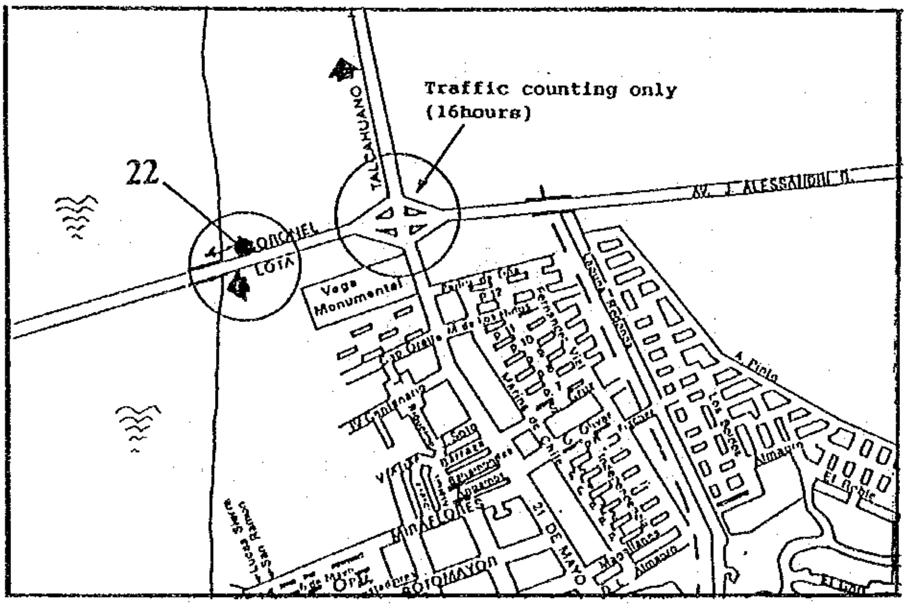


Fig.6-2(2) Location of Traffic Survey Stations

Table 6-1 O-D Interview Form

NUEVO PUENTE BIOBIO
ENCUESTA ORIGEN - DESTINO

Nombre de Encuestador ....

Estación N° [ ]

TURNOS I. 07:00 - 13:00

II. 13:00 - 19:00

TIPO DE VEHICULOS	ORIGEN	DESTINACION	SÓLO PARA PASAJEROS DE AUTOS/WAGON, PICKUP, TAXI/BUS.		SOLO PARA CAMIONES		
			Propósito	N° Pasajeros	Capacidad (Tons.)	Materiales	Clasificación de Carga
1. Autos, Station Wagon, Furgones y Taxi. 2. Taxibus 3. Camioneta (Pickup) 4. Bus Interurbano 5. Camión mediano (2 ejes) 6. Camión Pesado (+ 2 ejes) 7. Trailer	¿De donde viene? Escriba el nombre del lugar de origen antes de esta encuesta. Si el conductor responde solamente "Centro de Concepción", que indique Norte o Sur de calle Carrera.	¿Cuál es su destino? Escriba el nombre del lugar de destino después de esta encuesta. Si el conductor responde solamente "Hacia el centro de Concepción", que indique Norte o Sur de calle Carrera.	1. Trabajo o Negocio. 2. Privado 3. Turismo 4. Otros (No necesita preguntar a Buses ni taxi colectivo)	Cuente el N° de pasajeros incluyendo al chofer y escriba el N° abajo.	Pregunte al chofer por la capacidad de carga en Tons.	1. Agricultura y pescadería. 2. Maderas (logs) 3. Chips (Astilla) 4. Minería. 5. Químicos. 6. Maquinarias. 7. Abarrotes, Vestuario, Papeles. 8. Varios. 9. Vacío.	1. Lleno 2. 3/4 3. 1/2 4. 1/4 5. Vacío.

This initial O-D matrix was divided into smaller zones referring to the DICTUC's zone system because the 24 zone system is considered to be too rough especially in the central area of Concepcion.

The newly divided zone system has 49 zones as illustrated in Fig.6-3 and relationships between 49 zones and DICTUC's zones/ 24 zones are presented in Table 6-2.

(6) Sample Size

The number of sampled vehicles by each survey station is summarized in Table 6-3. Total 14,669 vehicles were collected as samples and an average sampling rate was 32.0%.

6.2.2 Present River Crossing Vehicle O-D Matrix

(1) Types of O-D matrix prepared

The following present vehicle O-D matrices were established in this study:

1. Daily (AADT base) O-D matrix by vehicle type
2. Peak Hour O-D matrix by vehicle type
3. Off Peak Hour O-D matrix by vehicle type

The vehicle type was consolidated into the following 4 categories:

1. Passenger car, Wagon, Pickup
2. Taxibus
3. Bus
4. Truck

Peak and Off peak hour O-D matrices were prepared applying peak hour ratios of total river crossing traffic to the daily O-D matrix(AADT base): Peak hour slots were defined as follows:

1. Morning Peak : 8:00 AM - 10:00 AM
2. Afternoon Peak : 12:00 AM - 2:00 PM
3. Evening Peak : 6:00 PM - 8:00 PM

Peak hour ratios of river crossing traffic in 1993 are shown in Table 6-4. The total 6 hours peak-hour slots were consolidated and applied to daily O-D matrix.

(2) Expansion Factor

Since the roadside O-D interview survey was carried out by random sampling, it is necessary to expand the surveyed sample data, taking the effective sampling rate into consideration. It is obvious that the expansion factor should be calculated by vehicle type and by survey station (by direction). The expansion factors were based on the following equation:

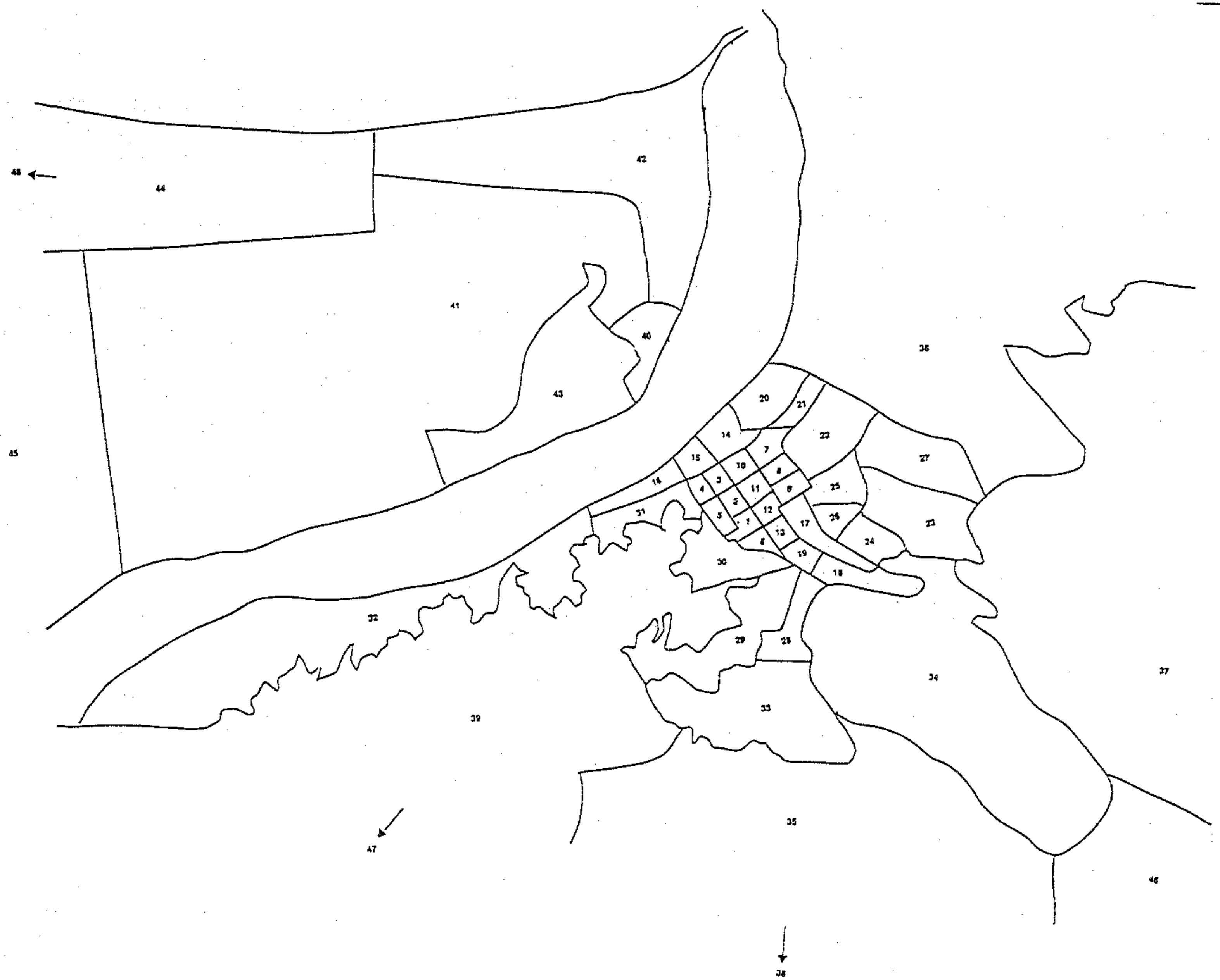


Fig. 6-3 Traffic Zones

Table 6-2 Traffic Zone Code

ZONA DE MARCO ECONOMICO (25 ZONAS)	ZONA DE TRANSITO (49 ZONAS)	ZONA DE DICTUC (113 ZONAS)
1	1	3204
1	2	3205
1	3	3206
1	4	3207
1	5	3208
1	6	3306
2	7	3111
2	8	3112
2	9	3113
2	10	3201
2	11	3202
2	12	3203
2	13	3304
3	14	3109
3	15	3110
4	16	3401
5	17	3108
5	18	3301
5	19	3305
6	20	3101
6	21	3102
6	22	3103
7	23	3104
7	24	3105
7	25	3106
7	26	3107
7	27	3114
8	28	3302
9	29	3307
9	29	3308
9	30	3309
9	30	3310
9	30	3311
9	31	3402
9	31	3403
10	32	3404
10	32	3405
10	32	3406
10	32	5101
10	32	5102
10	32	5103
10	32	5104
10	32	5105
10	32	5106
11	33	3303
11	33	3312
12	34	7102
13	35	7102
14	36	2101
14	36	2102
14	36	2103
14	36	2104
14	36	2105
14	36	2106
14	36	2107
14	36	2108
14	36	2201
14	36	2202
14	36	2301
14	36	2302
14	36	2303
14	36	2304
14	36	2305
14	36	2306
14	36	2307
14	36	2308
14	36	2309
14	36	2310
14	36	2311
14	36	2312
14	36	2313
14	36	2314
14	36	7105
15	37	1101
15	37	1102
15	37	1103
15	37	1104
15	37	1105
15	37	1106
15	37	1201
15	37	1202
15	37	1203
15	37	7101
16	38	7102
17	39	5201
18	40	4104
18	41	4102
18	42	4103
18	42	4201
18	42	4202
18	42	4203
19	43	4101
20	44	6101
20	44	6102
20	44	6103
20	44	6104
20	44	6105
20	44	6106
20	44	6107
20	44	6108
20	44	6109
20	44	6110
20	44	6111
20	44	6112
20	44	6113
20	44	6201
20	44	6202
20	44	6203
20	44	6204
20	44	6205
20	44	6206
20	44	6207
20	44	6208
21	45	7103
22	46	7102
23	47	7102
24	48	7104
25	49	7104

Table 6-3 Sampling Rate of O-D Survey

Puesto Encuestador No.	Relacion de Muestreo	Tipo de Vehiculo			Total
		Autos,Pickup	Buses	Camiones	
St.11	No. de Muestras	3,395	287	13	3,695
	Transito de 24 horas	9,827	1,604	214	11,645
	Relacion de Muestreo(%)	34.5	17.9	6.1	31.7
St.12	No. de Muestras	2,016	70	10	2,096
	Transito de 24 horas	8,554	1,533	235	10,322
	Relacion de Muestreo(%)	23.6	4.6	4.3	20.3
St.13	No. de Muestras	559	46	74	679
	Transito de 24 horas	1,728	111	221	2,060
	Relacion de Muestreo(%)	32.3	41.4	33.5	33.0
St.14	No. de Muestras	678	57	99	834
	Transito de 24 horas	1,924	117	240	2,281
	Relacion de Muestreo(%)	35.2	48.7	41.3	36.6
St.21	No. de Muestras	2,172	768	830	3,770
	Transito de 24 horas	5,882	1,283	1,711	8,876
	Relacion de Muestreo(%)	36.9	59.9	48.5	42.5
St.22	No. de Muestras	2,172	684	739	3,595
	Transito de 24 horas	7,376	1,370	1,840	10,586
	Relacion de Muestreo(%)	29.4	49.9	40.2	34.0
Total	No. de Muestras	10,992	1,912	1,765	14,669
	Transito de 24 horas	35,291	6,018	4,461	45,770
	Relacion de Muestreo(%)	31.1	31.8	39.6	32.0

Table 6-4 Peak Hour Ratio of River Crossing Traffic (Both Ways)

Hora	AUTO PICKUP	%	TAXIBUS	%	BUS	%	CAMION	%	TOTAL	%	PCU	%
07-08	1275	3.86	323	5.82	15	4.86	145	4.08	1758	4.14	2220.47	4.27
08-09	2230	6.76	377	6.80	8	2.65	200	5.63	2815	6.64	3389.34	6.52
09-10	1891	5.73	415	7.48	11	3.43	260	7.32	2576	6.08	3270.18	6.29
10-11	1580	4.79	326	5.87	11	3.46	223	6.28	2139	5.04	2715.61	5.22
11-12	1513	4.58	342	6.16	14	4.52	246	6.93	2115	4.99	2740.69	5.27
12-13	1730	5.24	327	5.90	11	3.62	231	6.51	2299	5.42	2888.90	5.55
13-14	1990	6.03	330	5.95	8	2.62	233	6.56	2561	6.04	3152.30	6.06
14-15	1795	5.44	257	4.63	17	5.55	194	5.46	2263	5.34	2755.84	5.30
15-16	2110	6.39	358	6.46	14	4.65	209	5.89	2691	6.35	3274.09	6.29
16-17	1949	5.91	329	5.94	18	5.93	231	6.51	2528	5.96	3128.25	6.01
17-18	1826	5.53	352	6.35	23	7.45	226	6.36	2427	5.72	3042.35	5.85
18-19	2155	6.53	334	6.02	24	7.96	210	5.91	2723	6.42	3303.45	6.35
19-20	2484	7.53	359	6.47	16	5.24	193	5.44	3052	7.20	3613.55	6.95
20-21	2113	6.40	334	6.02	19	6.21	209	5.89	2675	6.31	3247.17	6.24
21-22	2125	6.44	278	5.02	10	3.15	114	3.21	2527	5.96	2905.24	5.59
22-23	1555	4.71	210	3.79	16	5.31	75	2.11	1856	4.38	2136.99	4.11
23-24	937	2.84	104	1.88	21	6.83	58	1.63	1120	2.64	1307.80	2.51
24-01	638	1.93	39	0.70	7	2.34	46	1.30	730	1.72	835.68	1.61
01-02	352	1.07	13	0.24	4	1.37	35	0.99	404	0.95	471.35	0.91
02-03	214	0.65	6	0.11	0	0.00	19	0.54	239	0.56	271.68	0.52
03-04	120	0.36	1	0.02	0	0.00	17	0.48	138	0.33	164.20	0.32
04-05	80	0.24	0	0.00	0	0.00	29	0.82	109	0.26	152.50	0.29
05-06	126	0.38	8	0.14	2	0.69	49	1.38	185	0.44	267.01	0.51
06-07	215	0.65	124	2.23	37	12.16	99	2.79	475	1.12	758.47	1.46
TOTAL	33003	100.00	5545	100.00	307	100.00	3551	100.00	42406	100.00	52013.10	100.00
Punta(%)		37.81		38.62		25.51		37.37		37.79		37.72
Horas		19-20		9-10		6-7		9-10		19-20		

$$F(i,k) = V(i,k)/S(i,k)$$

Where : F : Expansion Factor
V : Traffic Volume (24 hours)
S : Number of Effective Samples
i : Survey Station (i)
k : Vehicle Type (k)

(3) Adjustments of Weekly and Seasonal Fluctuations in Traffic

The traffic volume by each survey station was the result of counting on specific day of a specific month of the year. The collected data, therefore, included the effects of weekly and seasonal fluctuations. The above fluctuations are adjusted by the following method:

$$AADT = Q * (1/w) * (1/m)$$

Where : AADT: Average Annual Daily Traffic
Q: Traffic Volume counted on a survey day
w: Weekly Fluctuation Factor
= (Daily Traffic)/(Weekly Average Daily Traffic)
m: Monthly(Seasonal) Fluctuation Factor
= (Monthly Average Daily Traffic)/ (Average Annual Daily Traffic)

1) Weekly Fluctuation Factor

The data on weekly traffic fluctuations for the 2(two) bridges (Biobio Antiguo and Juan Pablo II bridge) in November 1992 were available from a report prepared by DICTUC as shown in Table 6-5. The traffic survey carried out on Wednesday and this table indicates that the river crossing traffic volume on Wednesday was at almost the same level with an weekly average and a weekly fluctuation factor defined as above was estimated at 1.01. Therefore, it was decided not to add adjustments to the weekly fluctuations.

2) Seasonal Fluctuation Factor

The data on seasonal vehicle traffic fluctuations are available from the past traffic data by M.O.P which provided, in general, the results of 3(three) "periods" surveys i.e.

1. Verano (Summer) : 17/02/1982 or 14/02/1990
2. Invierno (Winter) : 16/06/1982 or 20/06/1990
3. Primavera (Spring) : 20/10/1982 or 17/10/1990

Traffic data on 2 bridges and of some survey stations in Concepcion and in San Pedro were collected on each of the seasons above, and are as shown in Table 6-7. As the traffic survey was conducted in Summer season (December), seasonal fluctuation factors in 1982 are summarized as follows:

Passenger car, Wagon, Pickup	= 0.94
Bus	= 0.94
Truck	= 1.09

Table 6-5 Seasonal Traffic Fluctuations
1992/11/23-11/29 (24 horas)

Biobío Bridge

	Sur-Norte	Norte-Sur	Total
Domingo	9,272	9,065	18,337
Lunes	12,081	11,787	23,868
Martes	12,241	11,961	24,202
Miércoles*	12,401	12,002	24,403
Jueves	12,246	12,108	24,354
Viernes	13,442	13,038	26,480
Sábado	12,558	12,143	24,701
Promedio Semanal	12,034	11,729	23,764

Juan Pablo II Bridge

	Sur-Norte	Norte-Sur	Total
Domingo	7,581	7,714	15,295
Lunes	7,651	7,910	15,561
Martes	8,450	8,712	17,162
Miércoles*	8,091	8,370	16,461
Jueves	8,157	8,459	16,616
Viernes	8,930	9,092	18,022
Sábado	8,773	9,043	17,816
Promedio Semanal	8,233	8,471	16,705

Two Bridges

	Sur-Norte	Norte-Sur	Total
Domingo	16,853	16,779	33,632
Lunes	19,732	19,697	39,429
Martes	20,691	20,673	41,364
Miércoles*	20,492	20,372	40,864
Jueves	20,403	20,567	40,970
Viernes	22,372	22,130	44,502
Sábado	21,331	21,186	42,517
Promedio Semanal	20,268	20,201	40,468

Note: * Survey Day

Therefore, total traffic volume of car, wagon, Pickup and bus have to be increased by 6.4 % in order to obtain the AADT. Traffic volume of truck, on the other hand, were reduced by 8.3% .

(4) Consolidation of Daily Vehicle O-D Matrix

The vehicle O-D matrices by survey station were consolidated into one O-D matrix. It was found that some samples crossed the river 2 times in one trip using, for example, Juan Pablo II bridge coming from North and crossing Biobio Antiguo bridge to enter South of the central area of Concepcion. These trips were the movements which had both origin and destination in the same side of the river. Therefore, such samples were not included for the establishment of present O-D matrix of river crossing traffic and only the O-D pairs between San Pedro side and Concepcion side were included in forming the components of the river crossing O-D matrix.

The estimated traffic volume, crossing the river, after adjustments for seasonal fluctuations in 1993 and excluding the double crossing river traffic are summarized in Table 6-6.

Table 6-6 Traffic crossing the Biobio River

	Auto, Wagon, Pickup	Taxibus, Bus	Camión	Total
Tránsito Total que Cruza el Río (TMDA)	33.646	6.074	3.258	42.978
Horas punta (6 horas)	12.722	2.302	1.3271	16.351
Fuera de las horas punta	20.924	3.772	1.931	26.627

6.2.3 Present Vehicle O-D matrix Other Than River Crossing

The present vehicle O-D matrices other than river crossing traffic were derived from the DICTUC's O-D matrix prepared in 1989. The following adjustments to the DICTUC's O-D matrix are necessary to consolidate with the river crossing vehicle O-D matrix explained above:

1) Adjustment of the base year from 1989 to 1993

As the base year of DICTUC was 1989, growth rates to the year 1993 were applied to the matrix as shown below:

Private Mode O-D ------ 1.40 (growth rate of car, pickup registration of region VIII, 1989-1993)

Public Mode O-D -------- 1.42 (growth rate of bus registration, 1989-1993)

Truck O-D ------------ 1.23 (growth rate of truck registration, 1989-1993)

Table 6-7 Seasonal Fluctuation Factor

Ano de 1982	Auto de Pasajero					Camion					Bus				
Estacion de Encuesta	Verano	Invierno	Primavera	TMDA	V/TMDA	Verano	Invierno	Primavera	TMDA	V/TMDA	Verano	Invierno	Primavera	TMDA	V/TMDA
55-01	9572	9100	13614	10762	0.89	1302	1099	1331	1244	1.05	1492	1910	1957	1786	0.84
55-02	9348	8875	12648	10290	0.91	1266	1354	1037	1219	1.04	1536	1951	1959	1815	0.85
55-03	1261	1610	2402	1758	0.72	732	310	589	544	1.35	95	144	154	131	0.73
56-01	5904	7499	9621	7675	0.77	2062	2128	1855	2015	1.02	2488	2933	3036	2819	0.88
41-01	5712	4442	4252	4802	1.19	1958	991	1825	1591	1.23	2920	2193	3170	2761	1.06
41-02	5811	4542	5496	5283	1.10	1961	1702	1898	1854	1.06	3313	3063	3752	3376	0.98
41-03	4111	4202	4672	4328	0.95	1988	1500	1640	1709	1.16	1599	1099	1541	1413	1.13
42-01	3537	2650	5690	3959	0.89	1401	1034	1714	1383	1.01	1100	1162	2084	1449	0.76
53-01	2877	2022	2396	2432	1.18	1245	1131	1092	1156	1.08	836	734	738	769	1.09
TOTAL	48133	44942	60791	51289	0.94	13915	11249	12981	12715	1.09	15379	15189	18391	16320	0.94

Ano de 1990	Auto de Pasajero					Camion					Bus				
	Verano	Invierno	Primavera	TMDA	V/TMDA	Verano	Invierno	Primavera	TMDA	V/TMDA	Verano	Invierno	Primavera	TMDA	V/TMDA
48-04	2395	3183	-	2789	0.86	1402	2057	-	1730	0.81	38	69	-	54	0.71
55-01	5026	4512	-	4769	1.05	6056	5132	-	5594	1.08	1506	1507	-	1507	1.00
55-02	5146	3243	-	4195	1.23	5982	4996	-	5489	1.09	1473	1200	-	1337	1.10
55-03	2163	3035	-	2599	0.83	1340	1108	-	1224	1.09	769	895	-	832	0.92
43-01	3757	2303	2569	2876	1.31	3312	2185	3075	2857	1.16	1705	1449	1991	1715	0.99
54-01	3563	2472	2329	2788	1.28	4830	5513	4020	4788	1.01	1790	1779	1575	1715	1.04
119-01	3255	2815	3617	3229	1.01	1738	2263	2558	2186	0.79	4634	5124	5477	5078	0.91
119-02	4307	2774	3269	3450	1.25	2540	2901	2786	2742	0.93	4990	4582	5331	4968	1.00
119-03	5149	5477	4419	5015	1.03	5721	7089	6038	6283	0.91	2079	2465	2214	2253	0.92
119-04	3316	3868	3466	3550	0.93	4727	5126	5029	4961	0.95	195	230	163	196	0.99
TOTAL(43,54,	23347	19709	19669	20908	1.12	22868	25077	23506	23817	0.96	15393	15629	16751	15924	0.97

2) Adjustment of zone numbers from 113 to 49 zones

3) Changing from person trip O-D matrices to vehicle trip O-D matrix applying average occupancy rate.

4) Division of Public mode O-D matrix to Taxibus O-D matrix and large bus O-D matrix

6.2.4 Completed Present Vehicle O-D Matrix

The adjusted DICTUC's O-D matrices above were combined with the river crossing vehicle O-D matrix. The peak hour vehicle O-D matrices were also prepared applying the peak hour ratio to the AADT O-D matrix.

The 49 zone base present O-D matrices by vehicle type are presented in Annex Table A.6-1 and desired lines are shown in Fig.6-4.

6.3 Forecasting Future O-D matrix

6.3.1 Overall Traffic Growth Rates for River Crossing Traffic

(1) Traffic Growth Model

The next step in the forecasting of future traffic is to estimate the growth rates of overall traffic representing the total volume of trips crossing the river in the target year(2010)).

As the historical traffic data crossing the river were available by vehicle type for the past 13 years (1980 - 1993), regression analyses were applied to show the past trends.

The following equations were adopted for the estimation of growth rates applying future socio-economic fram (GRDP and vehicle registration):

Car, Wagon, Pickup : $Q = -11{,}366 + 0.44572*(GRDP) + 0.16450*(VR)$ $(R = 0.8584)$

Buses : $Q = -177.05 + 0.07333*(GRDP) + 0.35683*(VR)$ $(R = 0.7337)$

Trucks : $Q = -1{,}471.9 + 0.08829*(GRDP)$ $(R = 0.9529)$

Where:

Q : Vehicle Traffic Volume of River Crossing Traffic
GRDP : Gross Regional Domestic Product of Region VIII
VR : Vehicle Registration
R : Correlation Coefficient

Fig. 6-4(1) Desired Lines for All Vehicles
(River Crossing Traffic) 1993

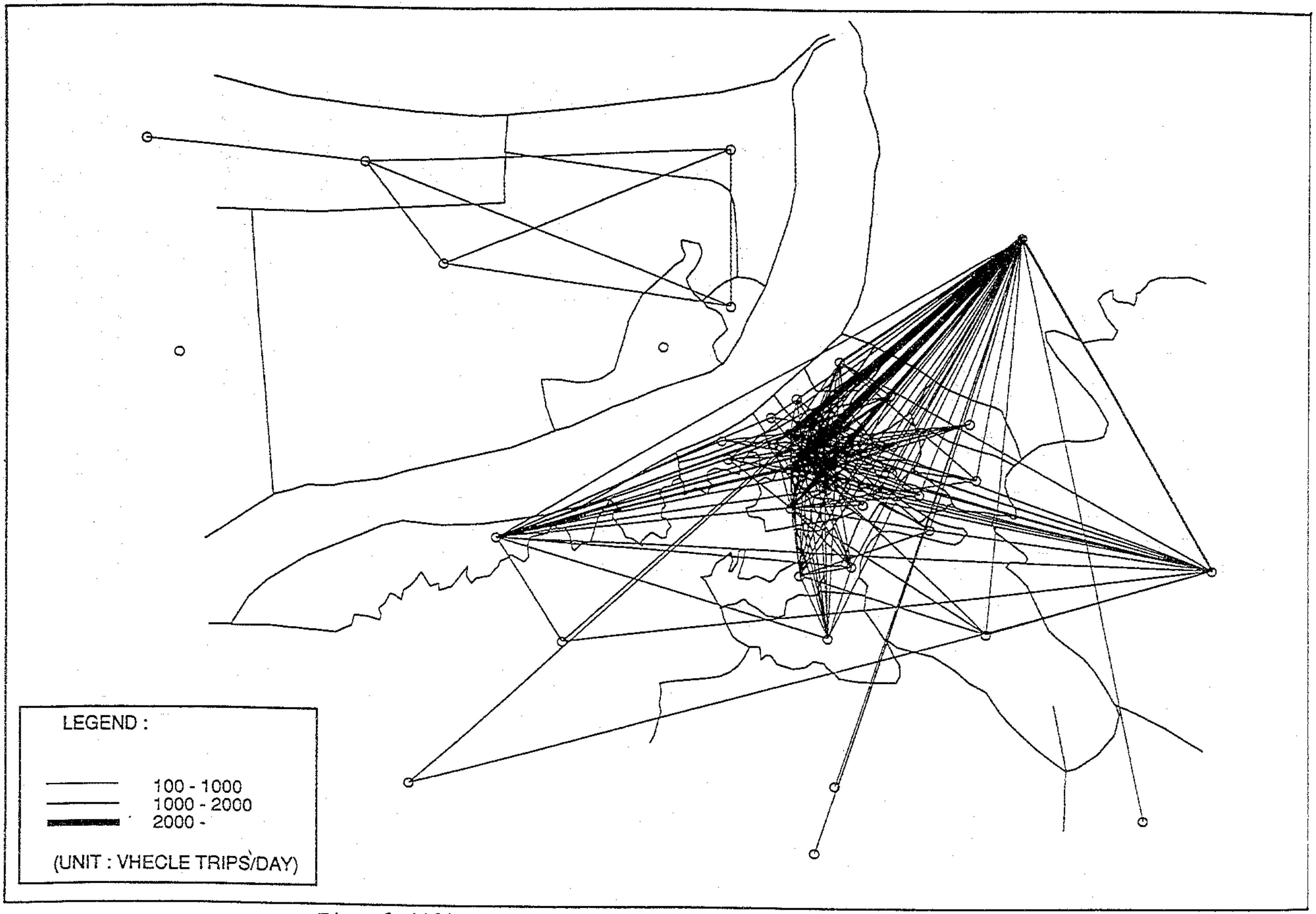


Fig. 6-4(2) Desired Lines for All Vehicles
(Other than River Crossing Traffic) 1993

(2) Results of Forecasting Future River Crossing Traffic

The above equations were applied for forecasting future river crossing traffic through inputting future socio-economic frame and results are summarized in Table 6-8.

Total volume of river crossing traffic will reach to 112,000 vehicles a day in 2010 which is about 2.6 times of 1993 volume. The year 1999 is planned to be an opening year of the new bridge and O-D matrix of 1999 was forecast by linear interpolation of each component in O-D matrix between 1993 and 2010.

Table 6-8 Results of Forecastng Future River Crossing Traffic Volume

Tipo de Vehículo	Tránsito que Cruza el Río(Vehículo/Día)			Tasa de Crecimiento Anual (%) 1993-2010	2010/1993
	1993	1999	2010		
Auto, Wagon, Pickup	33.646	51.000	90.500	6,0	2,69
Taxibus, Bus	6.074	7.700	12.900	4,5	2,12
Camión	3.258	5.000	8.700	5,9	2,67
Total	42.978	63.700	112.100	5,8	2,61

6.3.2 Forecast Future Trip Generation/Attraction by Traffic Zone

Future trip generation and attraction by traffic zone were estimated applying the zonal growth rates of socio-economic indicators to the present trip generation and attraction with the following combinations of indicators:

Car,Wagon,Pickup : Growth rate of vehicle registration by traffic zone

Taxibus,Bus : Growth rate of Population and employment by traffic zone

Truck : Growth rate of vehicle registration by traffic zone

With regard to the river crossing traffic pre-determined in the above section as a Controlled Total Value, the estimated zonal trip generation/attraction were re-adjusted so as to keep consistency with the Controlled Total Value.

6.3.3 Future O-D matrix

A present pattern method was employed to estimate the future trip distribution and the process was iterated to reach the previously determined zonal trip generation/attraction volume.

The future river crossing O-D matrix was combined with the future vehicle O-D matrix derived from DICTUC's O-D matrix after the volume of corresponding O-D pairs of DICTUC base turned into zero. The finalized future O-D matrices of 2010 are presented in Annex Table A.6-2 and desired lines are illustrated in Fig.6-5 and Fig.6-6. The peak hour O-D matrix were prepared using the same peak hour rates in Table 6-4.

6.4 Estimation of Traffic Volume on Alternative Routes

6.4.1 Methodology

The future traffic volume on alternative bridge routes was estimated by assigning the future peak hour time O-D matrix and Off peak hour time O-D matrix to the future road network. The method used for this project traffic assignment is shown in Fig.6-7.

A minimum travel time was adopted as a criterion when selecting possible travel routes for particular O-D pair traffic. Although some public buses have fixed routes at present, the selection of future travel routes in 2010 was based on the minimum travel time. The travel routes of trucks was also based on the same criterion.

The future O-D traffic was divided into 5 steps of 20% O-D traffic and assigning the first 20% O-D traffic to the network, and under the altered conditions by the Q-V Formula (a relationship between traffic volume Q and travel speed V) the second 20% of the O-D traffic was assigned to the network based on minimum time travel routings.

6.4.2 Assigned O-D Matrix

The following O-D matrix were assigned to the future road network:

Year 1999 : Peak hour time O-D matrix by vehicle type
(Opening Year)
Off peak hour time O-D matrix by vehicle type

Year 2010 : the same as above

6.4.3 Future Road Network

The road network for traffic assignment is illustrated in Fig.6-8 in which future road links are included as well. Future road projects adopted in the future network are as follows:

1. Construction of the Costanera (River-side Road)
2. Improvements of the A.Prat Avenue
3. Improvements of Eje 21 DE Mayo
4. Improvements of Los Carrera

The area which will be affected by the new bridge is defined as illustrated in above Fig.6-8 i.e. Concepcion and San Pedro.

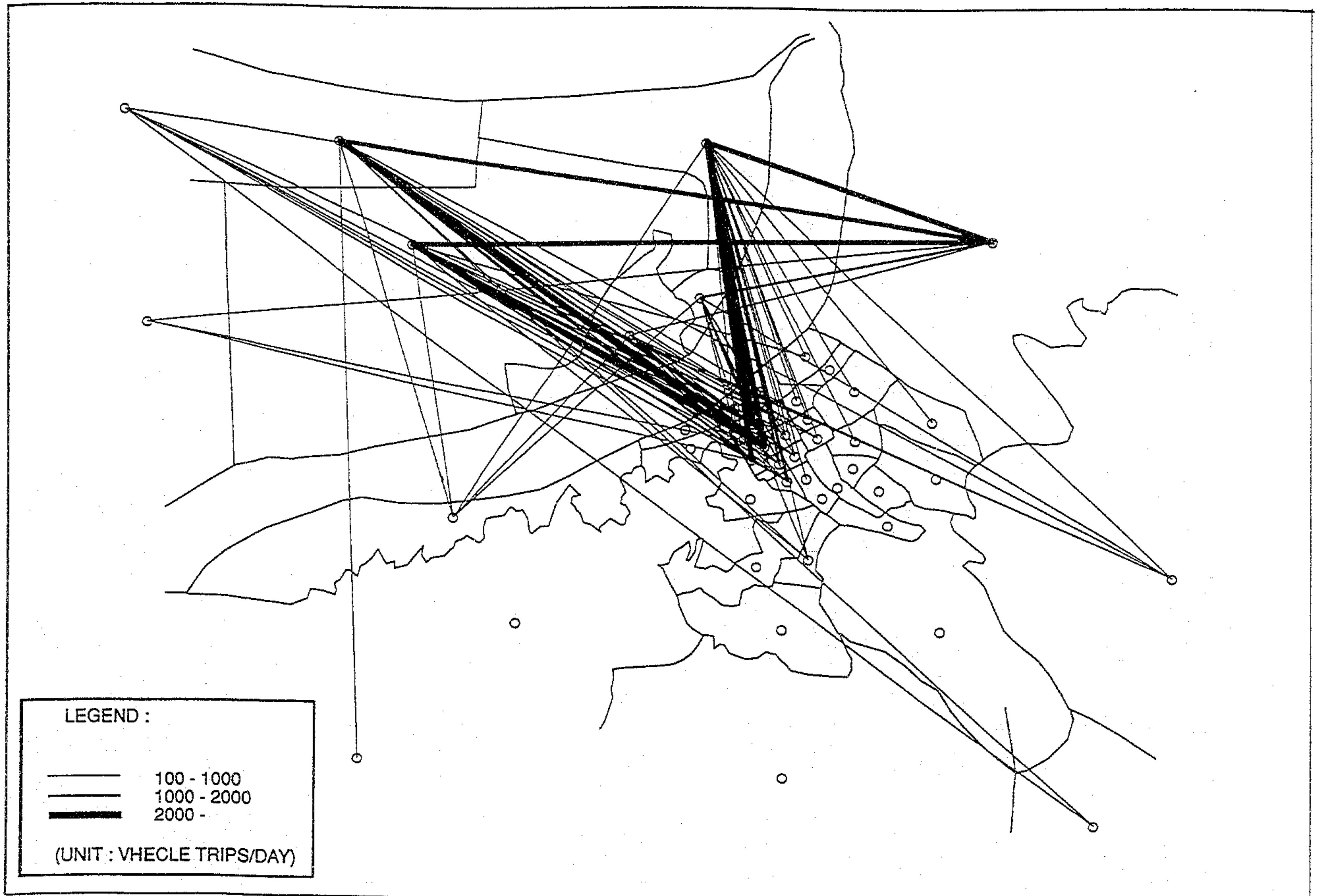


Fig. 6-5(1) Desired Lines for All Vehicles
(River Crossing Traffic) 1999

Fig. 6-5(2) Desired Lines for All Vehicles
(Other than River Crossing Traffic) 1999

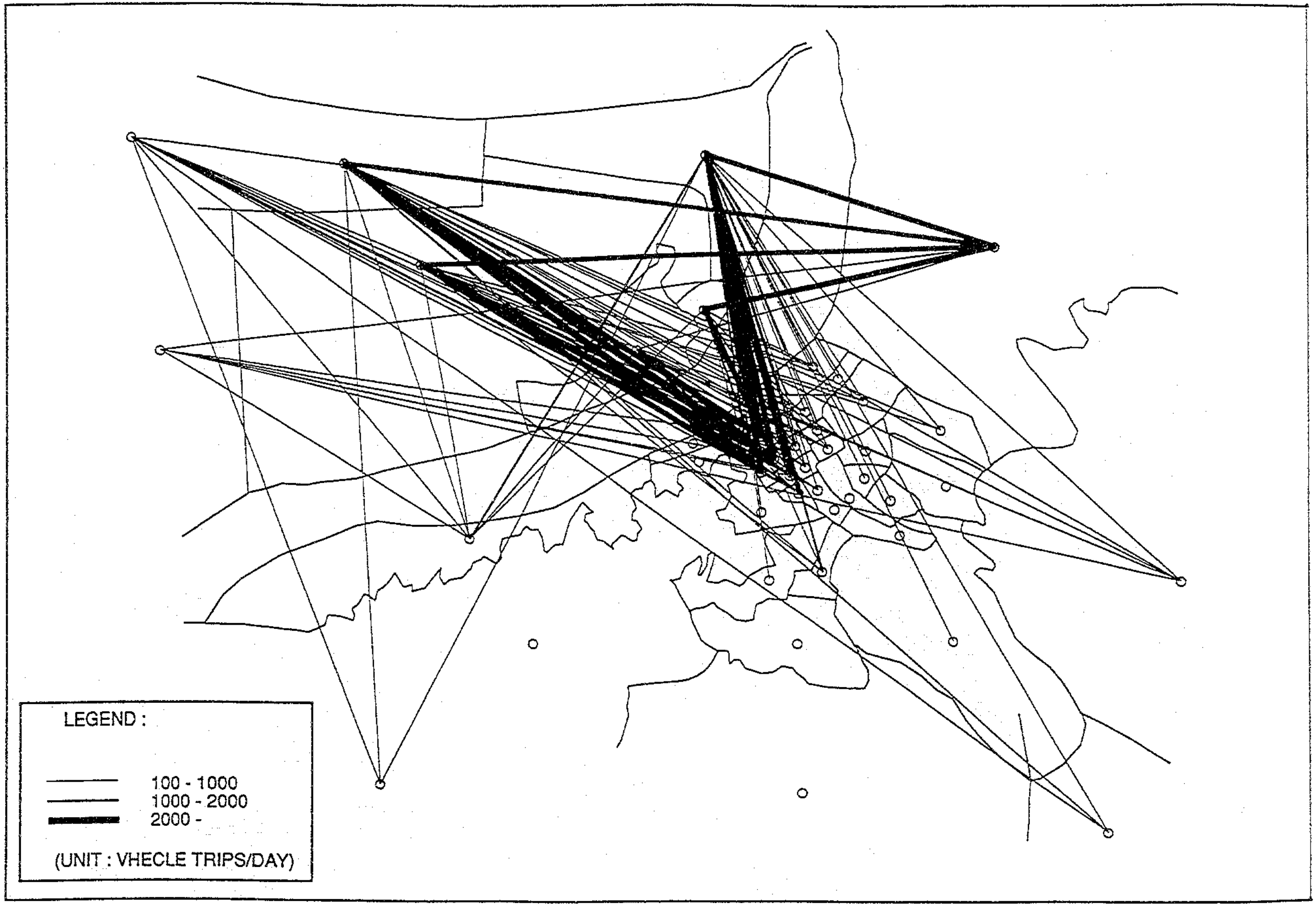


Fig. 6-6(1) Desired Lines for All Vehicles
(River Crossing Traffic) 2010

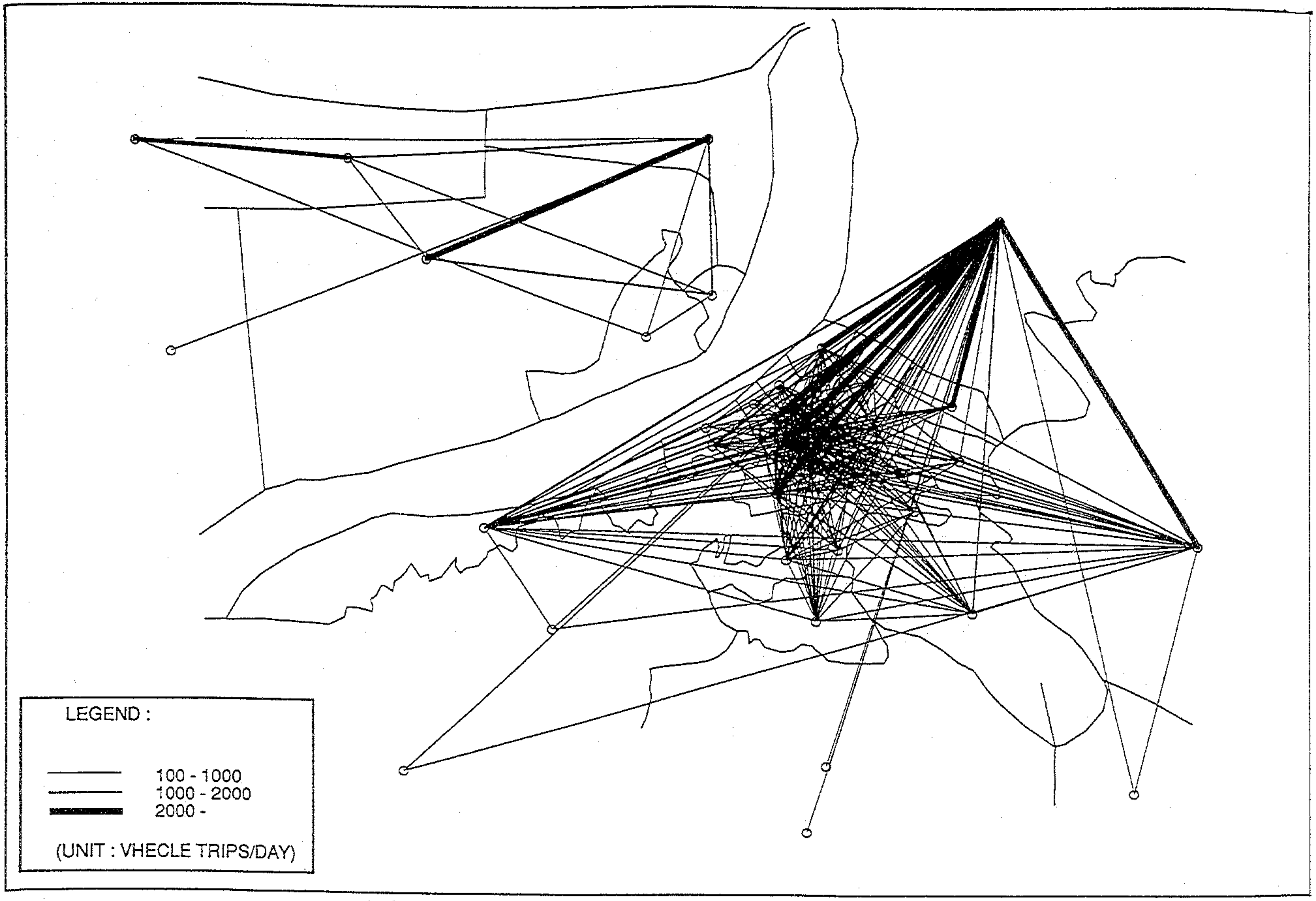


Fig. 6-6(2) Desired Lines for All Vehicles
(Other than River Crossing Traffic) 2010

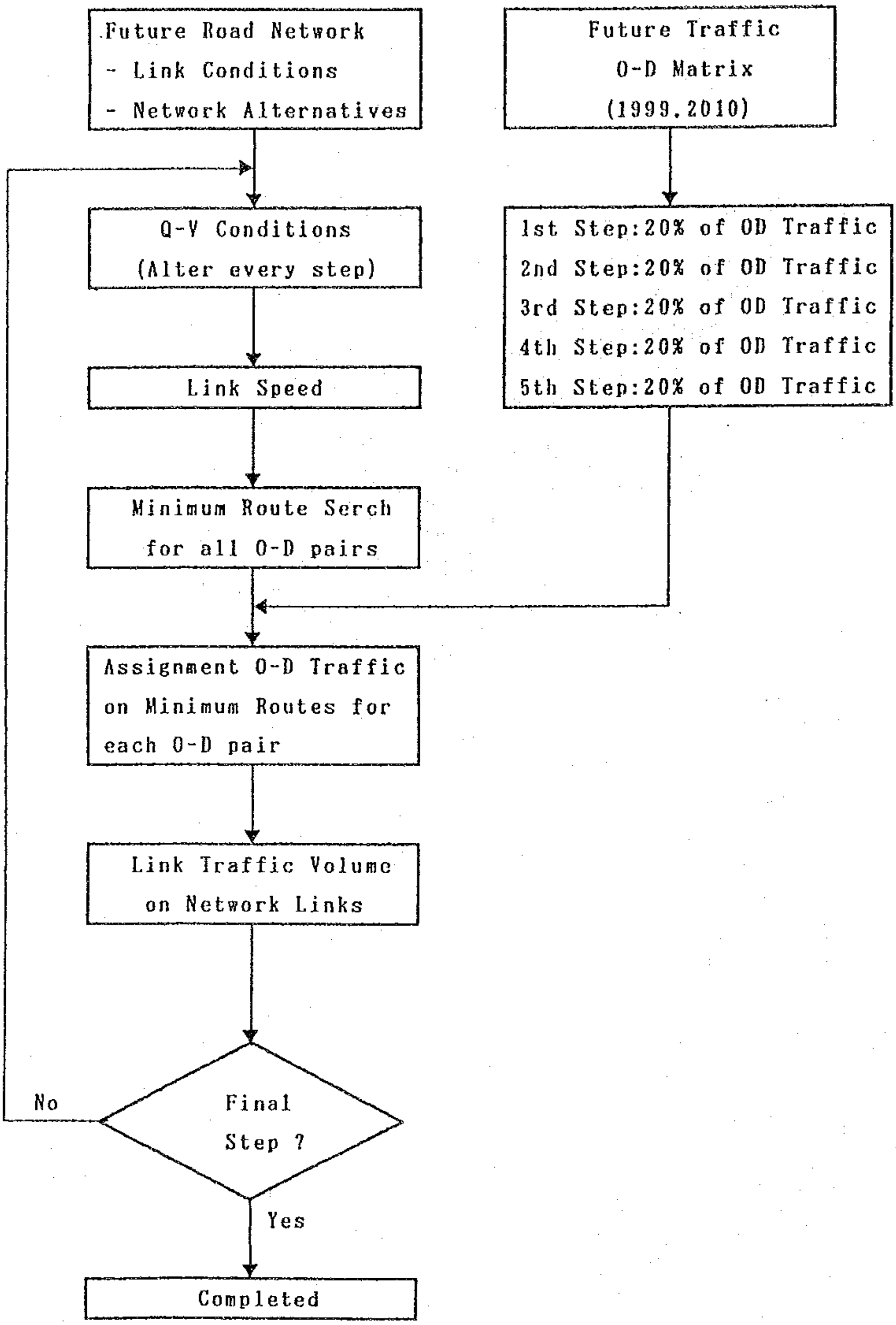


Fig. 6-7 Flow Diagram for Estimating Future Assigned Traffic Volume

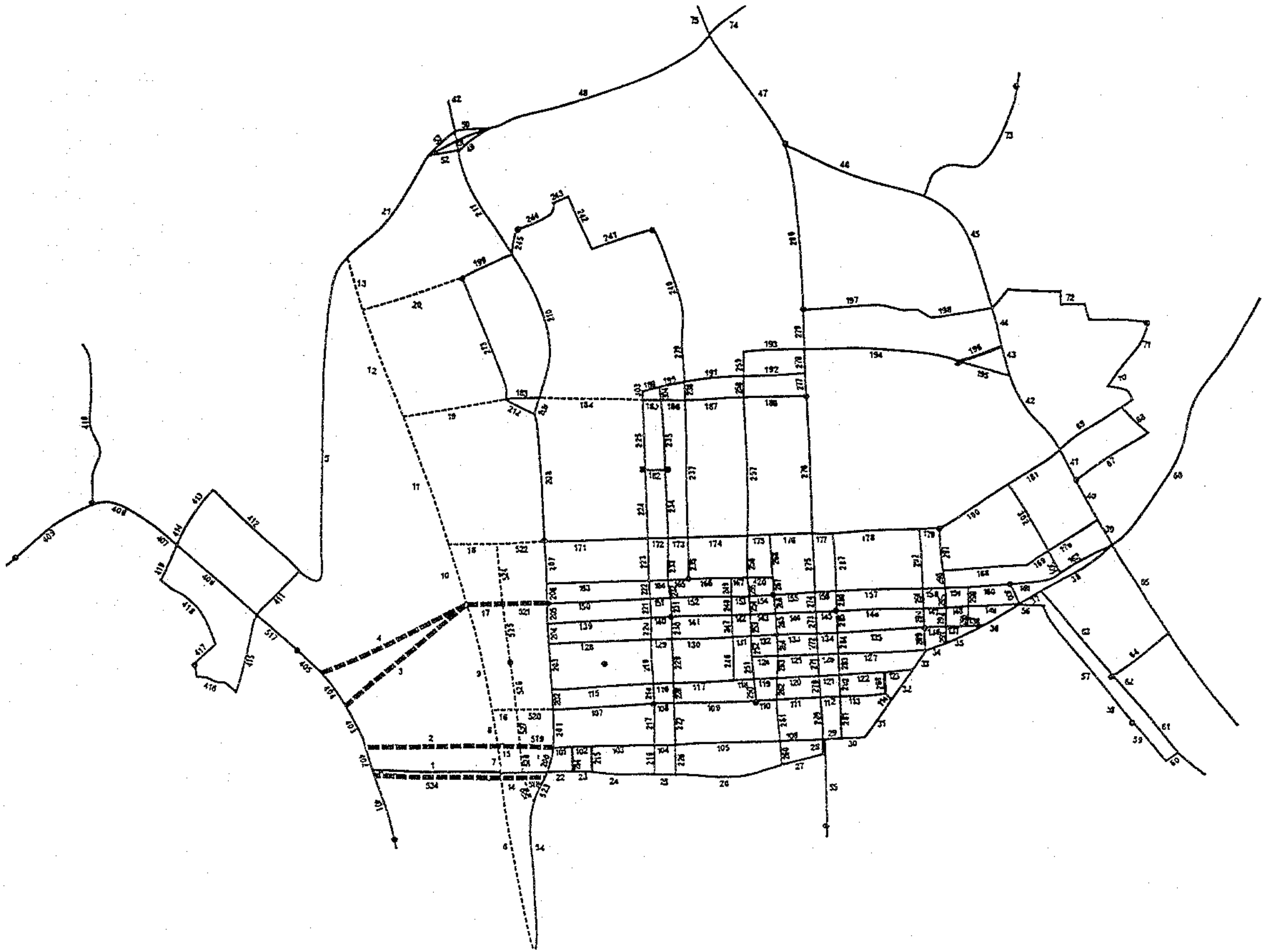


Fig. 6-8 Road Network for Traffic Assignment

6.4.4 Link Conditions

The conditions of each road link in Fig.6-8 are presented in Table 6-10 with information on link length, surface status, one- way or two-way, width, number of lanes, parking, capacity and Q-V number applied.

6.4.5 Q-V Formula and Design Capacity

The so-called Q-V formula adopted for the traffic assignment is shown in Table 6-11 and Fig.6-9. The design capacity (pcu/hour) was calculated based on the Highway Capacity Manual (H.C.M).

6.4.6 Testing the Validity of Assignment Methodology

In order to check the validity of the methodology adopted, the present peak hour O-D matrix was assigned to the present road network and compared with the actual traffic volume on each bridge. Table 6-9 shows the results of the test.

Table 6-9 Comparison of Assigned Traffic Crossing the River (1993, peak houres)

Tipo de Vehiculo	(A) Asignado		(B) Real		(A)/(B)	
	Biobío	Juan Pablo II	Biobío	Juan Pablo II	Biobío	Juan Pablo II
Auto,Wagon,Pickup	6.898	5.586	7.769	5.185	0,89	1,08
Taxibus	1.247	832	1.272	1.006	1,98	0,83
Bus	-	58	-	82	-	0,70
Camión	-	1.077	-	1.217	-	0,88
Total	8.145	7.553	9.041	7.490	0,90	1,01

Above results indicate that the range of errors are not enormous except for the case of bus with a very small traffic volume.

6.4.7 Estimated Future Traffic Volume on Alternative Routes

Results of traffic assignment by alternative bridge route are presented in Table 6-12.

The maximum peak hour traffic volume on the new bridge among the alternatives is estimated at 27,390 vehicles/6 hours in 2010. This volume is equal 5440 pcu/hour and the Design Capacity of new bridge is set at 4280 pcu/hour. Therefore, in this case, the traffic demand will exceed the design capacity of the new bridge in 2010. On the other hand, possible capacity of the new bridge is estimated at 5,640 pcu/hour. Therefore, traffic demand of 5,440 pcu/hour may be handled within the possible capacity but with a low service level.

Table 6-10(1) Link Information Table, 2010

Codigo de Arcos	Distancia (M)	Sentido 0:Ambos 1 y 2: Un sentido	Estado 1:Bueno 2:Regular 3:Malo	Ancho (M)	No. de Pistas	Estacionar 0: SI 1: NO	Capacidad (pcu/hr.)	Codigo de Q-V
1	1500	0	2	8	2	1	1800	35
2	1650	0	1	14	4	1	4280	36
3	1850	0	1	14	4	1	4280	36
4	2300	0	1	14	4	1	4280	36
5	2600	0	1	20	6	1	5900	37
6	1140	0	1	14	4	1	4280	38
7	125	0	1	14	4	1	4280	38
8	254	0	1	14	4	1	4280	38
9	640	0	1	14	4	1	4280	38
10	415	0	1	14	4	1	4280	38
11	750	0	1	14	4	1	4280	38
12	750	0	1	14	4	1	4280	38
13	400	0	1	14	4	1	4280	38
14	270	0	1	14	4	1	4280	36
15	260	0	1	14	4	1	4280	38
16	250	0	1	14	4	1	4280	38
17	280	0	1	14	4	1	4280	38
18	330	0	1	14	4	1	4280	38
19	650	0			2	0	930	4
20	900	0			2	0	930	4
21	830	0	1	18	6	1	5530	34
22	180	1	1	10	3	1	2050	14
23	125	0	1	10	3	1	2050	14
24	379	0	1	10	3	0	1370	11
25	130	0	1	10	3	0	1370	11
26	630	0	1	10	3	0	1370	11
27	247	0	1	10	3	1	2050	14
28	95	0	1	10	3	1	2050	14
29	110	0	1	16	6	1	3640	31
30	140	0	1	16	6	1	3640	31
31	279	0	1	12	4	1	2020	19
32	227	0	1	12	4	1	2020	19
33	134	0	1	12	4	1	2020	19
34	139	0	1	8	2	1	940	4
35	250	0	1	8	2	1	940	4
36	263	0	1	8	2	1	940	4
37	170	0	1	8	2	1	940	4
38	501	1	1	8	2	1	2080	8
39	192	0	1	6	2	1	780	1
40	272	0	1	6	2	1	780	1
41	192	0	1	6	2	1	780	1
42	550	0	1	6	2	1	980	5
43	300	0	1	6	2	1	980	5
44	180	0	1	6	2	1	980	5
45	650	0	1	6	2	1	980	5
46	800	0	1	6	2	1	980	5
47	950	0	1	18	6	1	5530	34
48	1530	0	1	18	6	1	5530	34
49	290	2	1		2	1	2080	8
50	280	1	1		2	1	2080	8
51	112	0	1		4	1	3370	27
52	280	2	1		2	1	2080	8
53	290	2	1		2	1	2080	8
54	890	0	1	12	4	1	3370	27
55	560	0	1	7	2	0	1180	6
56	153	2	12	7	2	0	940	3

Table 6-10(2) Link Information Table,2010

Codigo de Arcos	Distancia (M)	Sentido 0:Ambos 1 y 2: Un sentido	Estado 1:Bueno 2:Regular 3:Malo	Ancho (M)	No. de Pistas	Estacionar 0: SI 1: NO	Capacidad (pcu/hr.)	Codigo de Q-V
57	852	1			2	1	2080	8
58	257	1			2	1	2080	8
59	113	1			2	1	2080	8
60	78	1			2	0	940	3
61	363	1	1	10	4	1	3620	28
62	233	1	1	10	4	1	3620	28
63	700	1	1	10	4	1	3620	28
64	350	0			2	0	1180	6
65	620	0	1	12	4	1	3370	27
66	595	0	1	16	6	1	4780	33
67	470	0			2	0	1180	6
68	220	0			2	0	1180	6
69	445	0	1	8	2	0	1180	6
70	225	0			2	0	1180	6
71	300	0			2	0	1180	6
72	1000	0			2	0	1180	6
73	1140	0			2	0	1180	6
74	2390	0	1	18	6	1	5530	34
75	2080	0	1	18	6	1	5530	34
76	2600	0	1	18	6	1	5530	34
77	1250	0			2	1	980	5
78	2080	0	1	7	2	1	1180	6
79	1400	0	1	7	2	1	1180	6
80	197	0			2	1	980	5
81	192	0			2	1	980	5
82	2080	0	1	7	2	1	940	4
101	130	0	1	16	6	0	2010	29
102	110	0	1	16	6	0	2010	29
103	379	0	1	16	6	0	2010	29
104	130	0	1	16	6	0	2010	29
105	638	0	1	16	6	0	2010	29
106	269	0	1	16	6	0	2010	29
107	609	1	3	7	2	1	1870	7
108	120	1	3	7	2	1	1870	7
109	509	1	3	7	2	1	1870	7
110	140	1	3	7	2	1	1870	7
111	279	1	3	7	2	1	1870	7
112	110	1	3	7	2	1	1870	7
113	269	1	3	7	2	1	1870	7
114	42	0	1	7	2	1	940	4
115	609	2	1	12	4	0	1280	16
116	120	2	1	12	4	0	1280	16
117	389	2	1	12	4	0	1280	16
118	120	2	1	12	4	0	1280	16
119	140	2	1	12	4	1	2570	24
120	259	2	1	12	4	1	2570	24
121	130	2	1	12	4	0	1280	16
122	269	2	1	12	4	0	1280	16
123	170	2	1	12	4	0	1280	16
124	150	1	1	8	2	0	940	3
125	240	1	1	8	2	0	940	3
126	130	1	1	8	2	0	940	3
127	509	1	1	8	2	0	940	3
128	608	2	2	7	2	0	940	3
129	120	2	2	7	2	1	1870	7
130	389	2	2	7	2	1	1870	7

Table 6-10(3) Link Information Table,2010

Codigo de Arcos	Distancia (M)	Sentido 0:Ambos 1 y 2: Un sentido	Estado 1:Bueno 2:Regular 3:Malo	Ancho (M)	No. de Pistas	Estacionar 0: SI 1: NO	Capacidad (pcu/hr.)	Codigo de Q-V
131	110	2	2	7	2	1	1870	7
132	160	2	2	7	2	1	1870	7
133	239	2	2	7	2	1	1870	7
134	130	2	2	7	2	1	1870	7
135	509	2	2	7	2	1	1870	7
136	140	2	2	7	2	1	1870	7
137	140	2	2	7	2	1	1870	7
138	80	2	2	7	2	1	1870	7
139	609	1	2	7	2	0	940	3
140	120	1	2	7	2	1	1870	7
141	379	1	2	7	2	1	1870	7
142	120	1	2	7	2	1	1870	7
143	160	1	2	7	2	1	1870	7
144	239	1	2	7	2	1	1870	7
145	130	1	2	7	2	0	940	3
146	509	1	2	7	2	0	940	3
147	140	1	2	7	2	0	940	3
148	140	1	2	7	2	0	940	3
149	309	1	2	7	2	0	940	3
150	618	0	1	20	6	0	3750	32
151	120	0	1	20	6	0	3750	32
152	379	0	1	20	6	0	3750	32
153	110	0	1	20	6	0	3750	32
154	170	0	1	20	6	0	3750	32
155	240	0	1	20	6	0	3750	32
156	130	0	1	20	6	0	3750	32
157	509	0	1	20	6	0	3750	32
158	140	0	1	20	6	0	3750	32
159	140	0	1	20	6	0	3750	32
160	259	0	1	20	6	0	3750	32
161	315	0	1	20	6	0	3750	26
162	357	0	1	8	2	1	940	4
163	618	1			2	0	940	3
164	120	1			2	0	940	3
165	130	1			2	0	940	3
166	250	1			2	0	940	3
167	110	1			2	0	940	3
168	499	1			2	0	940	3
169	143	1			2	0	940	3
170	368	1			2	0	940	3
171	628	1	3	7	2	1	1870	7
172	120	1	3	7	2	1	1870	7
173	130	1	3	7	2	0	940	3
174	349	1	3	7	2	0	940	3
175	160	1	3	7	2	0	940	3
176	239	1	3	7	2	0	940	3
177	140	0	3	7	2	0	940	4
178	519	0	3	7	2	0	940	4
179	130	0	3	7	2	0	940	4
180	491	2	1	8	2	0	940	3
181	359	2	1	8	2	0	940	3
182	110	0			2	0	1180	6
183	230	0			2	0	1180	6
184	629	0			2	0	1180	6
185	110	0			2	0	1180	6
186	150	0			2	0	1180	6

Table 6-10(4) Link Information Table, 2010

Codigo de Arcos	Distancia (M)	Sentido 0:Ambos 1 y 2: Un sentido	Estado 1:Bueno 2:Regular 3:Malo	Ancho (M)	No. de Pistas	Estacionar 0: SI 1: NO	Capacidad (pcu/hr.)	Codigo de Q-V
187	359	0			2	0	1180	6
188	389	0			2	0	1180	6
189	114	0	3	8	3	0	1530	12
190	155	0	3	8	3	0	1530	12
191	390	0	3	8	3	0	1530	12
192	389	2	3	8	3	0	1140	9
193	389	1	3	6	2	0	860	2
194	1000	0	3	6	2	0	980	5
195	319	0	3	6	2	0	980	5
196	290	0	3	6	2	0	980	5
197	800	0			2	0	1180	6
198	370	0			2	0	1180	6
199	440	0			2	0	1180	6
200	130	0	1	14	4	1	2330	23
201	229	0	1	14	4	1	2330	23
202	130	0	1	14	4	1	2330	23
203	279	0	1	14	4	1	2330	23
204	130	0	1	14	4	1	2330	23
205	130	0	1	14	4	1	2330	23
206	120	0	1	14	4	1	2330	23
207	259	0	1	14	4	1	2330	23
208	768	0	1	14	4	1	2330	23
209	104	0	1	12	4	1	2130	20
210	940	0	1	12	4	1	2130	20
211	720	0	1	12	4	1	2130	20
212	219	0			2	0	940	4
213	789	0			2	0	940	4
214	150	2			2	0	940	3
215	160	1			2	0	940	3
216	179	2	1	8	3	1	1700	13
217	250	2	1	8	3	1	1700	13
218	130	2	1	8	3	1	1700	13
219	269	2	1	8	3	1	1700	13
220	140	2	1	8	3	1	1700	13
221	120	2	1	8	3	1	1700	13
222	110	2	1	8	3	1	1700	13
223	269	2	1	8	3	0	1140	9
224	409	2	1	8	3	0	1140	9
225	419	2	1	8	3	0	1140	9
226	189	1	1	7	2	0	940	3
227	260	1	1	7	2	1	1870	7
228	120	1	1	7	2	1	1870	7
229	269	1	1	7	2	1	1870	7
230	140	1	1	7	2	1	1870	7
231	120	1	1	7	2	1	1870	7
232	110	1	1	7	2	0	940	3
233	269	1	1	7	2	0	940	3
234	409	1	1	7	2	0	940	3
235	419	1	1	7	2	0	940	3
236	269	2	1	7	2	0	940	3
237	828	0	1	7	2	0	940	4
238	120	0	1	7	2	0	940	4
239	290	0	1	7	2	0	1180	6
240	680	0	1	7	2	0	1180	6
241	1930	0			2	0	1180	6
242	360	0			2	0	1180	6

Table 6-10(5) Link Information Table,2010

Codigo de Arcos	Distancia (M)	Sentido 0:Ambos 1 y 2: Un sentido	Estado 1:Bueno 2:Regular 3:Malo	Ancho (M)	No. de Pistas	Estacionar 0: SI 1: NO	Capacidad (pcu/hr.)	Codigo de Q-V
243	120	0			2	0	1180	6
244	300	0			2	0	1180	6
245	250	0			2	0	1180	6
246	259	2	1	7	2	0	740	3
247	140	2	1	7	2	0	940	3
248	120	2	1	7	2	0	940	3
249	120	2	1	7	2	0	940	3
250	140	1	1	7	3	1	1700	13
251	130	1	1	7	3	1	1700	13
252	130	1	1	7	3	1	1700	13
253	140	1	1	7	3	1	1700	13
254	120	1	1	7	3	1	1700	13
255	110	1	1	7	3	1	1700	13
256	259	1	1	7	3	0	1140	9
257	828	1	1	7	3	0	1160	9
258	140	1	1	7	3	0	1140	9
259	150	1	1	7	3	0	1140	9
260	140	2			2	0	940	3
261	250	2			2	0	940	3
262	140	2			2	0	940	3
263	130	2			2	0	940	3
264	140	2			2	0	940	3
265	130	2			2	0	940	3
266	120	2			2	0	940	3
267	112	2			2	0	940	3
268	259	2			2	0	940	3
269	249	2	3	10	3	0	2050	14
270	131	2	3	10	3	0	2050	14
271	140	2	3	10	3	1	1370	11
272	130	2	3	10	3	1	1370	11
273	130	2	3	10	3	1	1370	11
274	130	2	3	10	3	1	1370	11
275	380	2	3	10	4	1	2290	22
276	760	0	3	10	4	1	1900	18
277	155	0	3	10	4	1	1900	18
278	130	0	3	10	4	1	1900	18
279	229	0	3	10	4	1	1900	18
280	850	0	3	10	4	1	1900	18
281	249	1	3	7	2	0	940	3
282	140	1	3	7	2	0	940	3
283	130	1	3	7	2	0	940	3
284	140	1	3	7	2	0	940	3
285	120	1	3	7	2	0	940	3
286	130	1	3	7	2	0	940	3
287	359	1	3	7	2	0	940	3
288	140	1			2	0	940	3
289	150	2	1	9	3	0	1280	10
290	120	2	1	9	3	0	1280	10
291	120	2	1	9	3	0	1280	10
292	369	2	1	9	3	0	1280	10
293	100	1	1	7	2	0	940	3
294	120	1	1	7	2	0	940	3
295	120	1	1	7	2	0	940	3
296	110	1	1	7	2	0	940	3
297	259	1	1	7	2	0	940	3
298	120	2			2	0	940	3

Table 6-10(6) Link Information Table,2010

Codigo de Arcos	Distancia (M)	Sentido 0:Ambos 1 y 2: Un sentido	Estado 1:Bueno 2:Regular 3:Malo	Ancho (M)	No. de Pistas	Estacionar 0: SI 1: NO	Capacidad (pcu/hr.)	Codigo de Q-V
299	120	2			2	0	940	3
300	130	0			2	0	940	4
301	152	2	1	8	2	0	940	3
302	459	2	1	8	2	0	940	3
303	50	2	1	8	3	0	1280	10
304	80	1	1	7	2	0	940	3
305	525	0	1	18	4	1	2700	25
401	542	0	1	8	2	1	1180	41
402	170	0	1	8	2	1	1180	41
403	400	0	1	8	2	1	1180	41
404	500	0	1	8	2	1	1180	41
405	100	0	1	8	2	1	1180	41
406	1550	0	1	12	4	1	3370	27
407	255	0	1	12	4	1	3370	27
408	1125	0	1	12	4	1	3370	27
409	675	0	1	12	4	1	3370	27
410	959	0			2	0	980	5
411	1100	0	1	18	6	0	3690	31
412	1500	0	2	6	2	0	980	5
413	350	0			2	0	1180	6
414	450	0			2	0	1180	6
415	1125	0	1	7	2	0	1180	6
416	688	0	1	7	2	0	1180	6
417	375	0	1	7	2	0	1180	6
418	1125	0	1	7	2	0	1180	6
419	455	0	1	7	2	0	1180	6
420	110	1	1			0	940	3
517	325	0	1	8	2	1	940	4
518	270	0	1	14	4	1	4280	36
519	260	0	1	14	4	1	4280	36
520	260	0	1	14	4	1	4280	38
521	360	0	1	14	4	1	4280	38
522	340	0	1	14	4	1	4280	38
523	250	0	1	12	4	1	3370	27
524	370	0	1	14	4	1	4280	38
525	230	0	1	14	4	1	4280	38
526	440	0	1	14	4	1	4280	38
527	230	0	1	14	4	1	4280	38
528	130	0	1	14	4	1	4280	38
529	320	0	1	14	4	1	4280	38
534	1500	0	1	14	4	1	4280	36

Table 6-11 Q-V Formula

Codigo de Q-V	No. de Pistas	Vmax (km/h)	V1 (km/h)	Vmini (km/h)	Q1 (pcu/hora)	Qmax (pcu/hora)	Capacidad (pcu/hora)
1	2	40	30	10	780	1,400	780
2	2	40	30	10	860	1,500	860
3	2	40	30	10	940	1,600	940
4	2	40	30	10	940	1,600	940
5	2	40	30	10	980	1,700	980
6	2	40	30	10	1,180	2,100	1,180
7	2	40	30	10	1,870	3,300	1,870
8	2	40	30	10	2,080	3,600	2,080
9	3	40	30	10	1,140	2,000	1,140
10	3	40	30	10	1,280	2,200	1,280
11	3	40	30	10	1,370	2,400	1,370
12	3	40	30	10	1,530	2,700	1,530
13	3	40	30	10	1,700	3,000	1,700
14	3	40	30	10	2,050	3,600	2,050
15	4	40	30	10	1,140	2,000	1,140
16	4	40	30	10	1,280	2,200	1,280
17	4	40	30	10	1,660	2,900	1,660
18	4	40	30	10	1,900	3,300	1,900
19	4	40	30	10	2,020	3,500	2,020
20	4	40	30	10	2,130	3,700	2,130
21	4	40	30	10	2,210	3,900	2,210
22	4	40	30	10	2,290	4,000	2,290
23	4	40	30	10	2,330	4,100	2,330
24	4	40	30	10	2,570	4,500	2,570
25	4	40	30	10	2,700	4,700	2,700
26	4	40	30	10	2,800	4,900	2,800
27	4	40	30	10	3,370	5,900	3,370
28	4	40	30	10	3,620	6,300	3,620
29	6	60	45	10	2,010	3,500	2,010
30	6	60	45	10	3,020	5,300	3,020
31	6	60	45	10	3,640	6,400	3,640
32	6	60	45	10	3,750	6,600	3,750
33	6	60	45	10	4,780	8,400	4,780
34	6	60	45	10	5,530	9,700	5,530
35	2	50	40	10	1,800	3,200	1,800
36	4	60	45	10	4,280	7,500	4,280
37	6	60	45	10	5,900	10,300	5,900
38	4	60	45	10	4,280	7,500	4,280
41	2	40	30	10	1,180	2,100	1,180

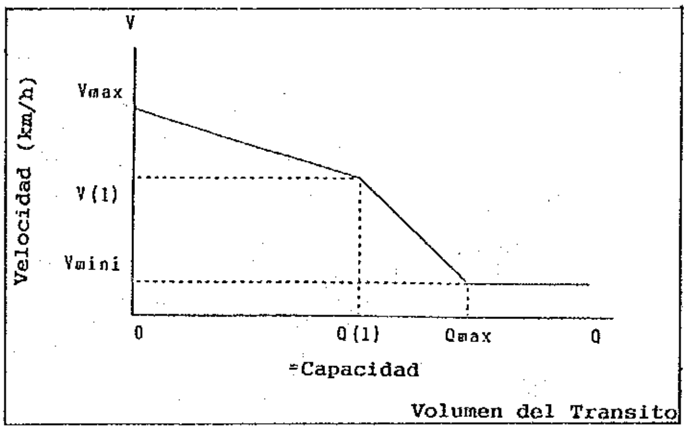


Fig. 6-9 Q - V Formula

Table 6-12(1) Results of Traffic Forecast by Alternative Route
- 2010: All vehicles -

No. del Caso

Alternativa	Puente Viejo Biobio	Costanera	Periodo de Tiempo	Puente Nuevo	Juan Pablo II	Puente Viejo Biobio	Total
0: Sin, 1-4: Con	0: Sin	1: Con		Puente			
0	0	0	Punta	-	41,900	-	41,900
			Fuera de Punta	-	70,500	-	70,500
			Diario	-	112,400	-	112,400
0	1	0	Punta	-	30,100	11,800	41,900
			Fuera de Punta	-	47,000	23,500	70,500
			Diario	-	77,100	35,300	112,400
0	0	1	Punta	-	41,900	-	41,900
			Fuera de Punta	-	70,500	-	70,500
			Diario	-	112,400	-	112,400
0	1	1	Punta	-	30,600	11,400	42,000
			Fuera de Punta	-	51,600	19,000	70,600
			Diario	-	82,200	30,400	112,600
1	0	0	Punta	21,300	20,100	-	41,400
			Fuera de Punta	35,900	34,800	-	70,700
			Diario	57,200	54,900	-	112,100
2	0	0	Punta	21,600	20,300	-	41,900
			Fuera de Punta	36,400	34,200	-	70,600
			Diario	58,000	54,500	-	112,500
3	0	0	Punta	22,400	19,500	-	41,900
			Fuera de Punta	39,000	31,500	-	70,500
			Diario	61,400	51,000	-	112,400
4	0	0	Punta	27,000	14,900	-	41,900
			Fuera de Punta	44,600	25,900	-	70,500
			Diario	71,600	40,800	-	112,400
1	0	1	Punta	20,300	21,600	-	41,900
			Fuera de Punta	30,900	39,600	-	70,500
			Diario	51,200	61,200	-	112,400
2	0	1	Punta	21,400	20,500	-	41,900
			Fuera de Punta	29,200	41,500	-	70,700
			Diario	50,600	62,000	-	112,600
3	0	1	Punta	22,200	19,800	-	42,000
			Fuera de Punta	37,500	33,100	-	70,600
			Diario	59,700	52,900	-	112,600
4	0	1	Punta	23,200	18,800	-	42,000
			Fuera de Punta	42,000	28,500	-	70,500
			Diario	65,200	47,300	-	112,500
1	1	1	Punta	16,700	21,700	3,500	41,900
			Fuera de Punta	30,900	39,600	0	70,500
			Diario	47,600	61,300	3,500	112,400
2	1	1	Punta	18,500	20,500	2,900	41,900
			Fuera de Punta	24,100	42,000	4,600	70,700
			Diario	42,600	62,500	7,500	112,600
3	1	1	Punta	18,300	20,200	3,700	42,200
			Fuera de Punta	31,300	33,800	5,800	70,900
			Diario	49,600	54,000	9,500	113,100
4	1	1	Punta	27,400	11,300	3,300	42,000
			Fuera de Punta	42,600	22,300	5,600	70,500
			Diario	70,000	33,600	8,900	112,500

Table 6-12(2) Results of Traffic Forecast by Alternative Route
- 1999: All vehicles -

No. del Caso

Alternativa: 0: Sin, 1-4: Con
Puente Viejo Biobio: 0: Sin
Costanera: 1: Con

Alternativa	Puente Viejo Biobio	Costanera	Periodo de Tiempo	Puente Nuevo	Juan Pablo II	Puente Viejo Biobio	Total
0	0	0	Punta	-	23,600	-	23,600
			Fuera de Punta	-	40,200	-	40,200
			Diario	-	63,800	-	63,800
0	1	0	Punta	-	15,600	8,100	23,700
			Fuera de Punta	-	21,700	18,500	40,200
			Diario	-	37,300	26,600	63,900
0	0	1	Punta	-	23,600	-	23,600
			Fuera de Punta	-	40,200	-	40,200
			Diario	-	63,800	-	63,800
0	1	1	Punta	-	15,600	8,000	23,600
			Fuera de Punta	-	25,000	15,200	40,200
			Diario	-	40,600	23,200	63,800
1	0	0	Punta	18,600	5,000	-	23,600
			Fuera de Punta	26,100	14,100	-	40,200
			Diario	44,700	19,100	-	63,800
2	0	0	Punta	18,700	4,900	-	23,600
			Fuera de Punta	26,300	13,900	-	40,200
			Diario	45,000	18,800	-	63,800
3	0	0	Punta	19,100	4,500	-	23,600
			Fuera de Punta	27,500	12,700	-	40,200
			Diario	46,600	17,200	-	63,800
4	0	0	Punta	19,100	4,500	-	23,600
			Fuera de Punta	32,600	7,600	-	40,200
			Diario	51,700	12,100	-	63,800
1	0	1	Punta	12,600	11,000	-	23,600
			Fuera de Punta	21,100	19,100	-	40,200
			Diario	33,700	30,100	-	63,800
2	0	1	Punta	13,900	9,700	-	23,600
			Fuera de Punta	23,200	17,000	-	40,200
			Diario	37,100	26,700	-	63,800
3	0	1	Punta	18,800	4,800	-	23,600
			Fuera de Punta	26,600	13,700	-	40,300
			Diario	45,400	18,500	-	63,900
4	0	1	Punta	19,100	4,500	-	23,600
			Fuera de Punta	29,600	10,600	-	40,200
			Diario	48,700	15,100	-	63,800
1	1	1	Punta	12,600	11,000	0	23,600
			Fuera de Punta	21,100	19,100	0	40,200
			Diario	33,700	30,100	0	63,800
2	1	1	Punta	12,300	9,800	1,500	23,600
			Fuera de Punta	20,400	17,200	2,600	40,200
			Diario	32,700	27,000	4,100	63,800
3	1	1	Punta	16,700	4,900	1,900	23,500
			Fuera de Punta	23,500	13,600	3,200	40,300
			Diario	40,200	18,500	5,100	63,800
4	1	1	Punta	17,300	4,400	1,800	23,500
			Fuera de Punta	26,400	10,600	3,200	40,200
			Diario	43,700	15,000	5,000	63,700

(Puente: Puente Nuevo, Juan Pablo II, Puente Viejo Biobio, Total)

CHAPTER 7. NATURAL ENVIRONMENT OF THE STUDY AREA.

7.1 General

Engineering survey has been conducted by the Study Team to obtain the engineering data and information to be used in the preliminary design of the bridge and its connecting roads for the Project.

Survey consisted of meteorological Survey, hydrological survey, geological investigation including soil investigation, seismic survey and topographical survey.

7.2 Climate

This section describes the outline of the climate in the Project area.

7.2.1 Meteorological Observations

There is one meteorological station (CONCEPCION - CARRIEL SUR) in the study area. The location is shown in Fig. 7-1. Table 7-1 shows the climate data including temperature, relative humidity, wind speed and rainfall for the meteorological station.

7.2.2 Temperature

The annual mean temperature of this station shows little variation, ranging from 8.74°C to 16.4°C. The annual maximum and minimum temperature are 35.6°C and -3.8°C, respectively. Both the annual mean maximum and minimum temperatures range from 13.0°C to 22.8°C, and 5.6°C to 10.5°C, respectively.

Monthly mean, monthly maximum, monthly minimum, monthly mean maximum and monthly mean minimum temperature at the meteorological station are shown in Table 7-1.

7.2.3 Relative Humidity

The annual mean relative humidity at 2:00 p.m. of this station ranges from 56% to 77%.

7.2.4 Wind Speed

The annual maximum wind speed and direction of this station ranges from 30 knots/north to 60 knots/north. Maximum wind speed and direction at the meteorological station is shown in Table7-1.

7.2.5 Precipitation

Annual rainfall in this project area ranges from 688.6 mm to 1,528.8 mm. Most rain falls in the winter season (May to September). Only light rain falls in the summer season (October to April) in this area.

Table 7-1 The Monthly Meteorological Data at Concepcion Carriel Sur

Latitude : 36° 46' South
Longitude : 73° 03' West
Elevation : 12 m

Item Mes	Enero	Febr	Marz	Abri	Mayo	Junio	Julio	Agost	Sept	Oct	Nov	Dic	Anual
Temperatura Media en C	16.4	15.7	14.1	12.0	10.8	9.2	8.7	9.1	9.9	11.6	13.8	15.6	12.2
Temperatura Máxima en C	33.2	35.6	32.0	27.0	28.8	22.0	21.7	25.0	25.7	29.6	28.8	33.4	35.6
Temperatura Mínima en C	4.6	3.6	1.6	-1.0	-2.1	-3.2	-3.8	-2.5	-1.4	-0.8	1.6	3.4	-3.8
Temperatura Máxima Media	22.8	22.4	20.9	18.3	15.5	13.4	13.0	13.8	15.1	17.0	19.2	21.4	17.8
Temperatura Mínima Media	10.5	10.1	9.0	7.6	7.5	6.2	5.7	5.6	5.7	6.8	8.4	9.9	7.8
Humedad Relativa Media 14 hrs. en %	56	57	59	64	73	77	75	71	66	64	61	59	65
Velocidad del viento Máxima en nudos	34	35	34	40	50	50	60	40	44	42	40	30	60
Precipitación mm/mes	20.0	14.3	25.3	59.5	189.3	218.3	217.9	152.3	87.9	64.7	40.7	31.5	121.7

Table 7-2 Monthly Average Discharge at Gauging Station on Biobio River (m^3/seg)

Latitude : 36° 46' South
Longitud : 73° 03' West
Elevation : 12.m.
Catchment Área : 21.217 km^2

Año	Enero	Febr	Marzo	Abril	Mayo	Junio	Julio	Agosto	Sept	Oct	Nov	Dic	Anual
1970	-	-	-	-	-	-	-	-	822	999	858	776	-
1971	421	401	212	239	1037	961	2261	1852	1213	1091	917	724	944
1972	403	269	259	284	2106	2805	1489	3053	1700	1657	1490	804	1360
1973	384	241	217	230	710	1194	2113	-	-	-	-	476	-
1974	380	250	229	251	569	1843	1245	1288	1033	1025	786	540	787
1975	244	328	229	474	1180	2004	2070	1093	859	1007	1246	831	964
1976	378	239	222	240	314	1680	927	932	843	1514	984	1356	802
1977	737	214	197	230	1335	1727	2759	1077	1197	1772	1363	807	1118
1978	285	162	164	153	435	834	4312	1130	1466	1428	1380	433	1015
1979	154	127	124	137	466	581	1290	2578	1877	994	1159	950	870
1980	319	332	601	966	2995	-	1451	2118	1252	1075	842	526	-
1981	788	470	345	435	2977	1955	1666	1327	926	735	745	338	1059
1982	217	249	233	262	760	1743	3094	1604	2157	1153	1410	999	1157
1983	525	307	216	365	749	1715	1523	1326	1156	1232	1030	440	882
1984	252	234	249	288	1653	1311	3021	951	1370	1923	1695	921	1156
1985	510	297	265	469	1383	1854	2397	972	1059	1041	1066	411	977
1986	230	217	309	697	1927	3576	1281	2166	1369	1106	1140	992	1251
1987	310	247	282	367	577	1264	2508	2278	1353	1364	868	349	981
1988	266	230	273	300	467	879	1313	1978	1156	996	903	527	774
1989	303	234	229	252	262	1017	1309	1667	1269	953	576	768	737
1990	326	229	284	614	823	1160	1050	1673	1851	922	536	276	812
1991	162	496	587	733	1247	2223	1569	1168	1299	913	880	885	1014
1992	550	-	347	475	2734	3533	1070	618	1280	1184	1156	678	-
1993	410	241	244	537	1915	-	-	-	-	-	-	-	-
Prome	372	273	275	391	1244	1708	1942	1564	1296	1186	1047	687	999

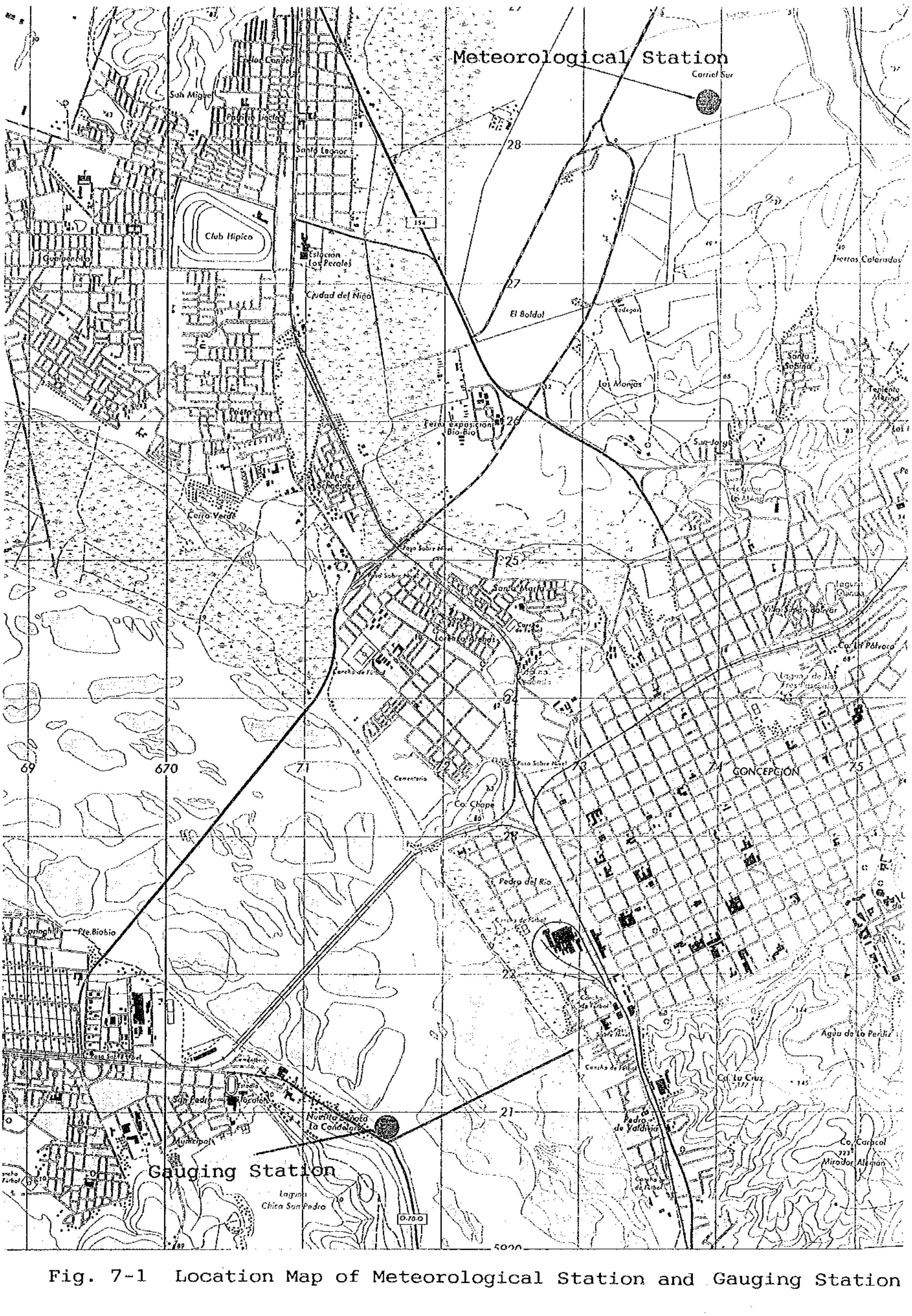


Fig. 7-1 Location Map of Meteorological Station and Gauging Station

7.3 Hydrological Study and Analysis

7.3.1 General

The main objective of the hydrological study is to grasp the hydrological conditions for the bridge design. The hydrological data and information to be used for evaluating the peak flood water level were obtained from MOP and DIRECCION GENERAL DE AERONAUTICA CIVIL, DIRECCION METEOROLOGICA DE CHILE and UNIVERSIDAD DE CHILE (DEPARTAMENTO DE INGENIERIA CIVIL).

7.3.2 Review of Hydrological Data

(1) Hydrological data

Discharge records are available at the gauging station downstream of the existing Biobio Bridge on Biobio river. The gauging station has a water-level recorder and staff gauges. The gauging station's catchment area is 21,217 km2. The location is shown in Fig. 7-1. Table 7-2 shows the monthly average discharge. Table 7-3 shows that the annual peak discharges were observed in the winter season from May to September.

(2) River Condition

The Biobio's catchment area is 24,420 km2 at the river-mouth, between the 36°45' and 38°52' south parallels. It discharges at the west into the Pacific Ocean, and extends to the east up to the ranges of the LOS ANDES at the national frontier with Argentina.

The Biobio flows from southeast to northwest for 356 km until the sea, where the latitude of river mouth is at 36°50' south, south of the HUALPEN Peninsula and north of ARAUCO Gulf. The river begins in the LOS ANDES Ranges at ICALMA and GALLETUE lakes, less than 1,500 m above sea level.

During its course, it meets the many affluent (see Fig 7-2). The most important river is the LAJA river which originates at the LAJA Lake, north east of the river-basin. It flows in a northwesterly direction past CONCEPCION city and turns west to the sea. The width of river at the mouth is about 2 km.

At the mouth of the river, the discharge varies between 124 m^3/sec (December to April) and 13,110 m^3/sec (May to November). The Biobio receives large amounts of water from snow melting in December to April, and from runoff caused by the rainfalls of May to November at the Central Valley and the Coastal Range. The river's discharge grows significantly during May to August and begins to decrease in the months of September, October and November.

Table 7-3 Annual Maximum Flood Record (Peak discharge) and related Water Levels at Gauging Station on Biobio River

Latitude : 36° 50' South
Longitude : 73° 05' West
Elevation : 4 m
Catchment Area : 21.217 km²

Año	Dia	Nivel de aguas (m)	Elevación Nivel de Aguas (m)	Descarga Peak (m^3/s)
1971	Jul.21	3,23	7,23	6.126
1972	May.29	4,46	8,46	13.110
1973	Jul.01	3,01	7,01	5.028
1974	Jun.28	3,05	7,85	9.210
1975	May.29	3,30	7,30	6.398
1976	Jun.20	3,08	7,08	5.436
1977	Jul.10	3,02	7,02	5.022
1978	-	-		-
1979	Ago.31	3,90	7,90	9.503
1980	May.14	3,91	7,91	9.616
1981	May.09	3,44	7,44	7.008
1982	Jul.18	3,33	7,33	6.891
1983	-	-		-
1984	Jul.18	3,36	7,36	6.845
1985	Jul.03	3,61	7,61	7.962
1986	Jun.18	3,92	7,92	9.553
1987	Jul.14	2,98	6,98	5.259
1988	Ago.20	2,73	6,73	4.409
1989	Jun.29	3,66	7,66	7.916
1990	Sep.11	3,07	7,07	5.566
1991	May.31	4,15	8,15	5.059
1992	Jun.06	3,70	7,70	8.087

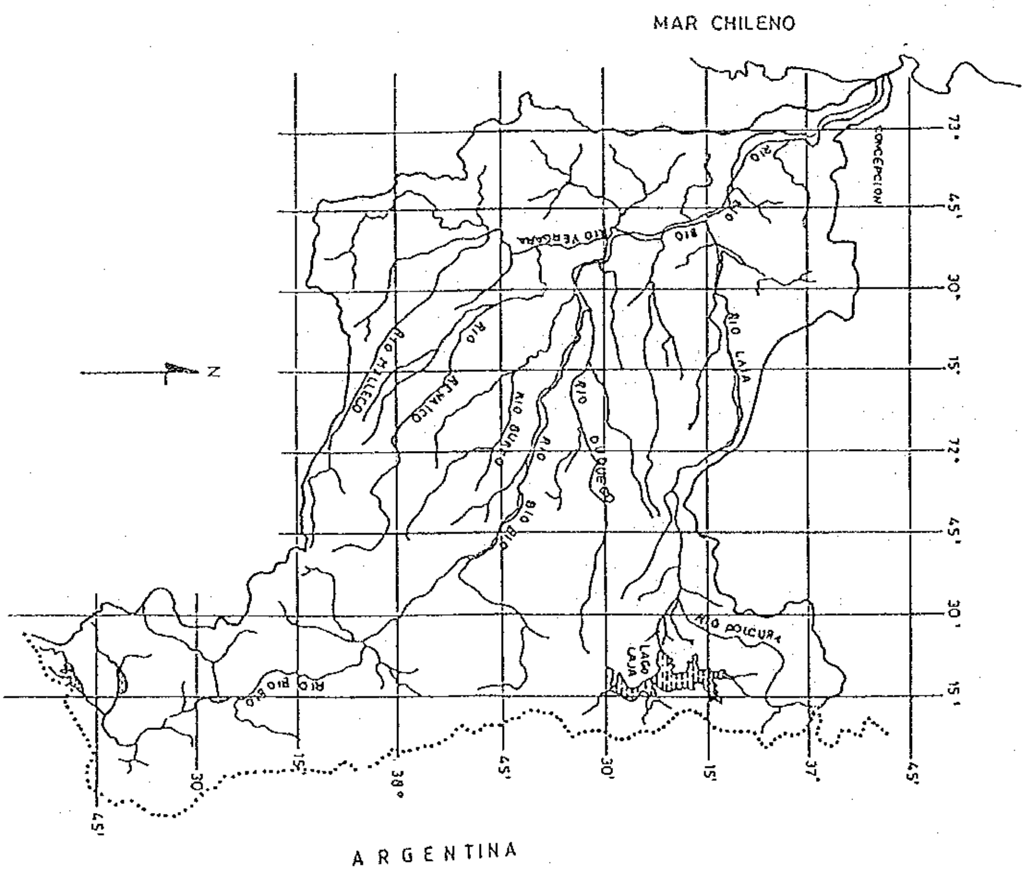


Fig. 7-2 River Basin of Biobio River

7.3.3 Hydrological Analysis

(1) Flood Frequency Analysis

A flood frequency analysis was undertaken by fitting several frequency distributions to predict return period floods at the station. Records of annual maximum flood data at the station are shown in Table 7-3.

Weibull formula was adopted for plotting position formula as follows:

$$P = \frac{m + 1}{N}$$

where, P; probability
N; the number of years of record
m; the rank of the event in order of magnitude

In Chile, Gumbel method is considered to be best fit. The result by Gumbel method is summarized as follows:

Table 7-4 Flood Discharge with Return Period

Return Period (year)	10	20	50	100
Flood Discharge (m^3/s)	11.102	12.605	14.552	16.010

(2) Design Return Period

MOP suggested to apply the largest recorded flood discharge in the past or the 100-year probable flood discharge for bridge design in Chile. The 100-year probable flood discharge calculated by frequency analysis shows nearly equal to the estimated flood discharge on the basis of flood mark of the high water level obtained by field survey.

Based on the above criteria and recorded flood data, design return period to be applied for this study was determined to be the 100-year probable flood discharge.

7.3.4 Hydraulic Calculation and High Water Level

Hydraulic calculation was conducted to determine the design flood water level for the proposed bridge.

The design flood water level is calculated using Manning's uniform flow formula as shown below:

$$v = (1/n) * R^{2/3} * I^{1/2}$$

$$Q = A * v$$

where,
- Q: discharge (m^3/s)
- A: flow area (m^2)
- v: flow velocity (m/s)
- R: hydraulic radius (m)
- I: water surface slope
- n: roughness coefficient

'I' was obtained to be 0.000625 based on collected topographic map. 'n' was estimated on the basis of river bed condition and the existing flood information.Flood water level at proposed bridge is shown in Table 7-3.

7.4 Seismic Survey

The survey was done to obtain the basic data and information to be used for the seismic design of bridge.

The seismic data and information were obtained from MOP and UNIVERSIDAD DE CHILE (DEPARTAMENTO DE INGENIERIA CIVIL). Chile is located in an earthquake-prone area, and the earthquakes of the region of CONCEPCION occur less frequently than in northern Chile.

7.5 Geological and Geotechnical Investigation

7.5.1 General

The survey was done to obtain the basic data for the preliminary design of bridge. The subsurface exploration including rotary drilling, sampling and laboratory tests were conducted at alternative proposed bridge sites. And also the elastic wave exploration tests were conducted at the proposed bridge sites.

The work was subcontracted to a local consultant, ASISTECSA, and carried out under the supervision of the Study Team.

7.5.2 Soil Investigation at Bridge Site

(1) Field Work

The field work including borings, sampling and standard penetration tests was carried out at the proposed bridge sites. The work was conducted near the abutment and pier of proposed bridges as shown in Fig. 7-3.

Table 7-5 List of Boring Sites

Lugar de la Perforación	Marca de la perforación	Profundidad de perforación (mts)
Calle Chacabuco	S-1 S-2 S-5 S-6 S-7	17,0 28,0 18,0 30,0 30,0
Av. Hermanos carrera	S-3 S-4	16,0 21,0
Puente Biobío Antiguo	S-8 S-9	30,0 30,0
Total	9	220,0

The samples were taken for laboratory testing.

Standard penetration tests were conducted at every 1 m depth interval to estimate the bearing capacity of stratum to be used for determination of bridge foundation.

(2) Laboratory Tests

The following laboratory tests were carried out.

1. Grain size analysis
2. Natural moisture contents
3. Specific gravity, dry density
4. Plastic/liquid limits
5. Unconfined compression tests
6. Tri-axial compression tests
7. Consolidation tests

(3) Elastic wave exploration tests

Elastic wave exploration tests by Refraction Method were conducted at the alternative proposed bridge sites.

(4) General Characteristic of soils

Most soils are fine granular, dense or very dense, silty sands (SP or SM). Occasionally, some layers of sandy silt hard to very hard consistency are encountered. Rarely thin layers of gravel,were found. In accordance with generally accepted correlations the Biobio sediments, below 6 m depth, have good bearing capacity, as indicated

Table 7-6 Caracteristic of Soils

Tipo de Suelo	SPT	Ángulo fricción PAI	Densidad Relativa %	Cohesión C(kg/cm2)
Granular SP Granular ML	50 16	40 --	80 --	-- 1

Only one of the four borings along the route of alternative-4 (S-2) shows silty soils and the other 3 (S-5, S-6 and S-7) show uniquely dense sands. In the first 5.6m, of the S-2 boring boulders were detected. They are part of a retaining wall built after the occurrence of two large earthquakes in the area at May,21 and 22, 1960. This structure was built with the purpose to reclaim a 200m to 300m strip of land. Fill materials back of the retaining wall (4 to 6 meters depth) were pumped from the river and deposited without compaction. These will probably liquify during a strong earthquake.

(5) General Comment for the soil mechanism

Geological profiles confirmed by boring results make the following relevant issues :

1. Superficial sediment shows low density. From the surface to 4-6 m depth, soils correspond to recent deposits after periodic changes in this zone during floods.

2. Wave velocity reduction in front of Laguna Chica de San Pedro shows the existence of an ancient interconnection between the pond and the river.

3. High wave velocity reduction in the area of North pier of Alternative route 4 , confirmed the presence of thick stratums of hard consistency silts. This measurement shows the existence of a natural canal that connected Andalien and Biobio rivers during flood in the past century.

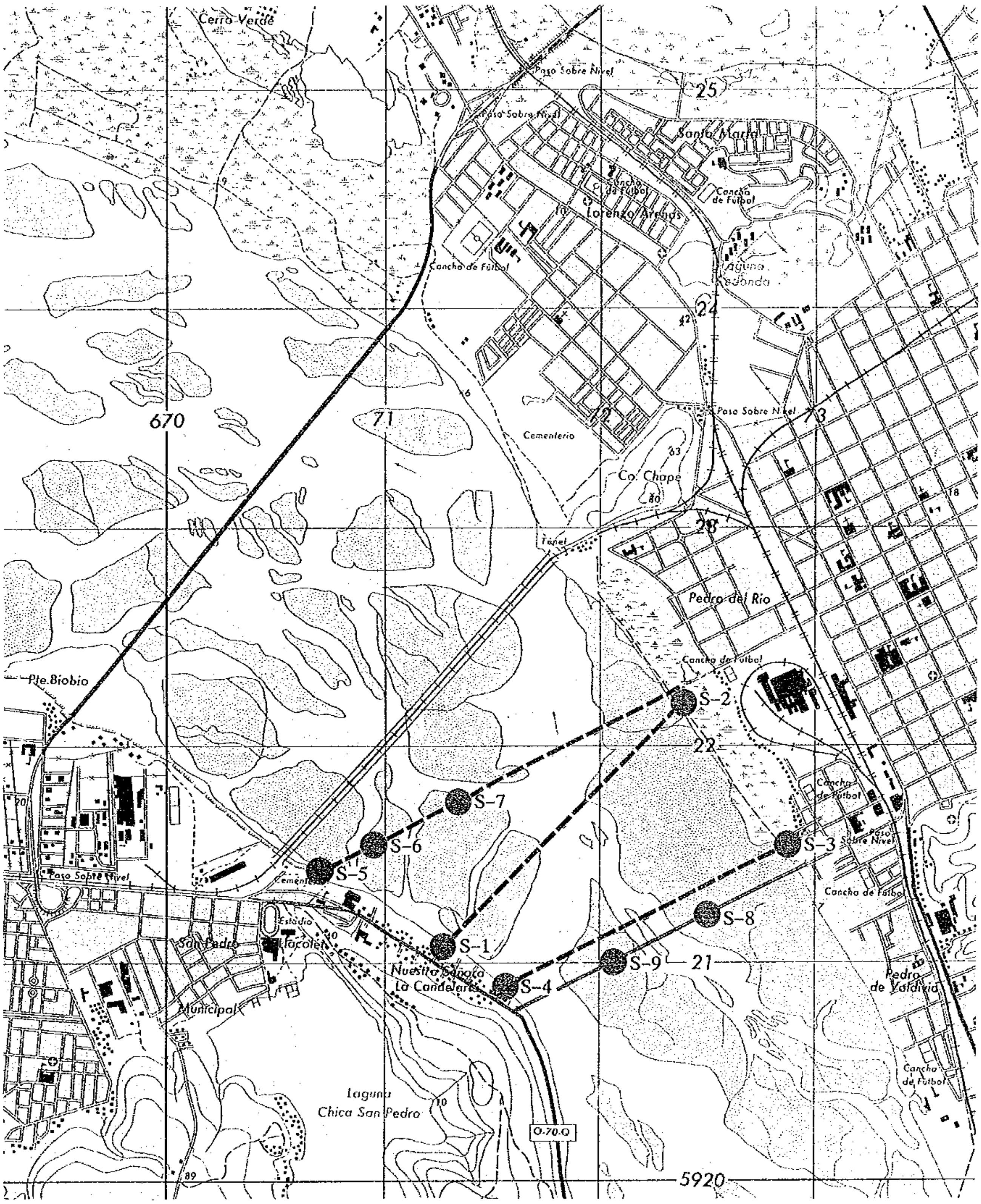


Fig. 7-3 Location Map of Soil Investigation

7.6 Topographic Survey

Provisions were made in the Agreement between the Consultant and JICA to undertake certain topographic surveys in the project area. The Consultant therefore, made arrangements with a local firm to undertake certain surveys and collect other data as necessary in implementing the objectives of the Study.

The specific items of work under this program include the following:

(1) Levelling

Establishment of temporary benchmark and levelling of the streets listed below:

Av. Pedro Aguirre Cerda	1.5 km
Av. Esmeralda	2.0
Av. Chacabuco	1.0
Av. Los Carreras	1.0
Av. Arturo	1.0
Av. Costanera	1.0
	7.5 km

(2) Planimetric Survey

Planimetric survey was carried out for a width of 50 meters along the streets listed below:

Av. Pedro Aguirre Cerda	1.5 km
Av. Esmeralda	2.0
Av. Av. Chacabuco	1.0
Av. Los Carreras	1.0
	5.5 km

(3) Depth of Water and Stream Bed Elevations

Measurement of water depth at 300 m intervals along the bridge, and establishment of stream bed elevations at each pier.

(4) Profile Survey (Levelling)

Levelling was carried out at each pier on both sides of the road for the full length of the bridge.

CHAPTER 8 EXISTING BRIDGES CROSSING BIOBIO RIVER

8.1 Biobio Antiguo Bridge

Very little data regarding this bridge was available at MOP. The Study Team reviewed what was available and to the best of our knowledge, the following information was developed.

The bridge (approximately 1,419 m long) was originally constructed in the 1930's.The deck structural system was timber. The piers were supported on timber piles, however, the pier caps were concrete.

One undated drawing was located showing an integrated construction of a hollow concrete pier of box-type construction with the bottom flange of the box acting as a pier cap over timber piles and the top flange acting as the deck of the bridge. From the results of the discussions, it appears that this plan was never followed.

One other undated plan believed to have been prepared in 1955, shows a 14 cm thick reinforced concrete deck over steel girders spaced at 1.80 m., with an additional concrete topping, 7 cm thick, and one sidewalk. This, arrangement, while substantially reflecting the current actual conditions, is not exactly correct. In actuality, the girders are spaced at 1.90 m., and 2.01 m., and there are two sidewalks. This construction took place in the early 1950's, when the superstructure was rebuilt using structural steel girders, and the deck was rebuilt using reinforced concrete.

It is believed that sometime after the conversion to a concrete deck over steel girders, the pier shafts on the Concepcion side were strengthened by concrete jacketing indicated on an undated drawing which also shows the reinforcement. Twelve steel pipe piles were driven at each pier, and concrete pile cap was placed thereon, forming a perimeter protection to the then existing piers, and leaving the existing piers and their timber pile supports within the perimeter jacket. Additionally, the replacement of 37 piers to cast in-situ piles took place on the San Pedro side, however, the Study Team was unable to ascertain the date of these installations, since no official records could be located.

Other basic data are contained in the recent report prepared by Ministerio de Obras Publicas (MOP), and the Agencia de Cooperacion International del Japon (JICA) in March 1993. This report which contains "Programa de Rehabilitacion y Conservacion de Puentes en la Republica de Chile" covers certain specific bridges, including the Biobio Antiguo Bridge.

A set of plans had been prepared "Planos y Detalles del Estudio Especializado" which includes details of the construction of the Biobio Antiguo Bridge. The information indicated therein is the only existing data regarding the history of this bridge and was collected during the course of that study.

Further strengthening took place due to the damage caused by floods in 1965. These events involved the construction of one span steel girder on the Concepcion side replacing three collapsed spans.

Periodic maintenance was carried out over the years in addition to periodic repairs, however, despite all these efforts, the bridge was posted for restricted loading, and remains restricted till this day for a maximum load of 8 tons.

Refer to Fig. 8-1 for the Biobio Antiguo Bridge. See Table 8-1 for Inspection Sheet.

8.2 Juan Pablo II Bridge and Railway Bridge

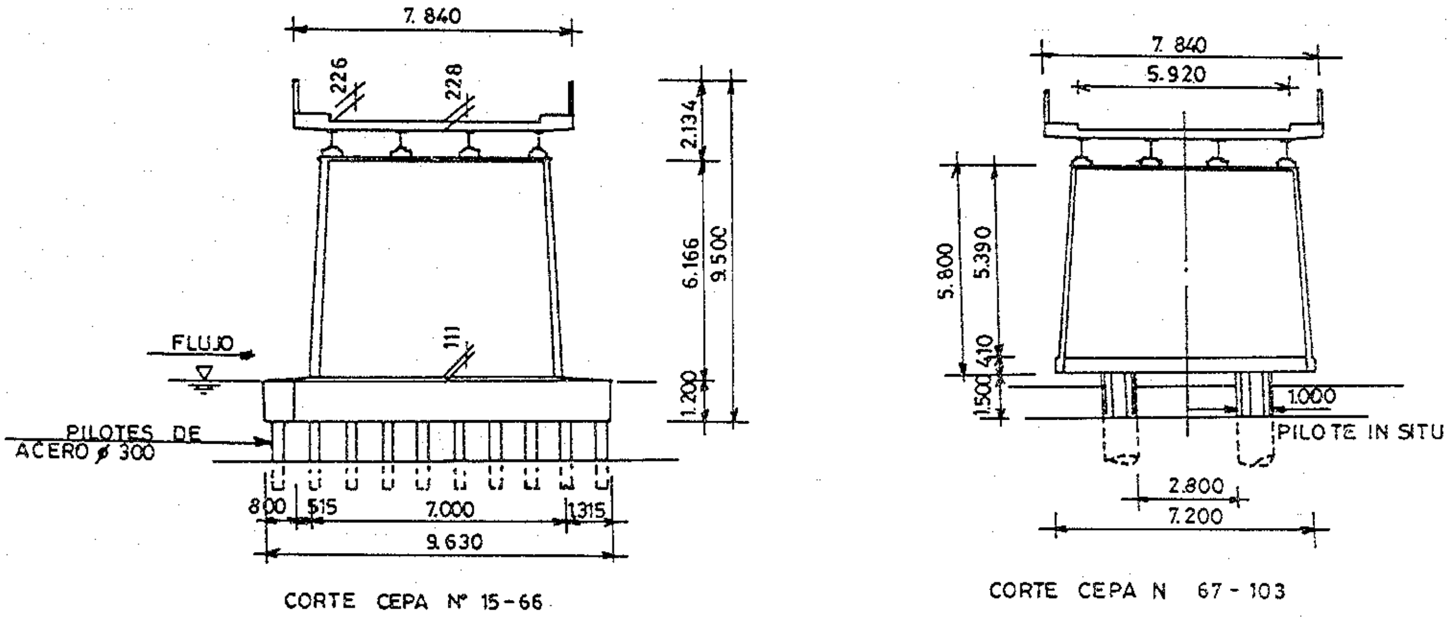
8.2.1 Juan Pablo II Bridge

The Juan Pablo II bridge (2,310 m. long) was constructed in 1960. The bridge uses simple spans (33 m) post-tensioned concrete I-type girders, and special large size pipe (concrete wall) foundation for the piers. We were not able to obtain drawings of this bridge from MOP. No data on subsurface investigation was available to our Study Team. The bridge has 6-lane carriageway. No intermediate diaphragms were noticed, and no positive anchorage between adjacent spans was provided to prevent spans from falling during a major earthquake.

It was noted that one of the methods used to maintain a smooth riding surface was the application of bituminous surface treatment. Such a treatment was placed in 1992, and it is believed that such applications are being provided as routine maintenance. The Study Team calls the attention of the MOP to monitor excessive addition of dead loads to the bridge.

The MOP should examine the construction details of the bridge to determine, whether or not, necessary strengthening is required to resist the action of earthquakes.

Refer to Fig. 8-2 for Cross Section of the Juan Pablo II Bridge. See Table 8-2 for Inspection Sheet.



NOTA: EL ANO 1955 SE REEMPLAZAN PILOTES DE MADERA POR PILOTES DE ACERO

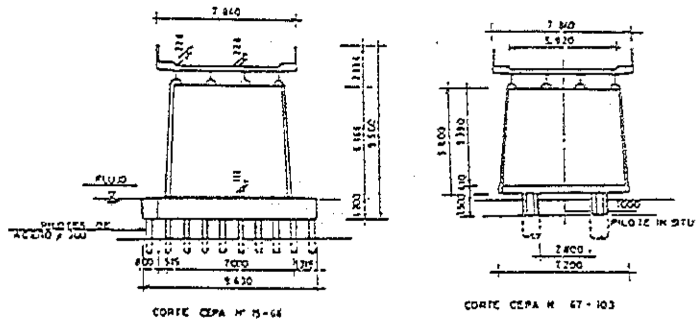
Fig. 8-1 Cross Section of Biobio Antiguo Bridge

Table 8-1 Inspection Sheet - Biobio Antiguo Bridge

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA Y REGION	CODIGO DEL PUENTE

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

COMENTARIOS



NOTAS: EL AÑO 1955 SE REEMPLAZAN PILOTES DE MADERA POR PILOTES DE ACERO

EVALUACION	GRADO DE DETERIORO	SOCAVACION
1	NO EXISTE DAÑO ALGUNO	NO EXISTE SOCAVACION
2	DAÑOS EN UNO O DOS PUNTOS	TENDENCIA A SOCAVAR
3	DAÑOS EN MUCHOS PUNTOS	EXIST. SOCAV. PERO NO HAY PELIGRO
4	MENOS DE LA MITAD DAÑADO	SOCAVACION PELIGROSA
5	CASI TODO DAÑADO	SITUACION DE EMERGENCIA

FECHA INSPECCION	NOMBRE INSPECTOR	
		FIRMA

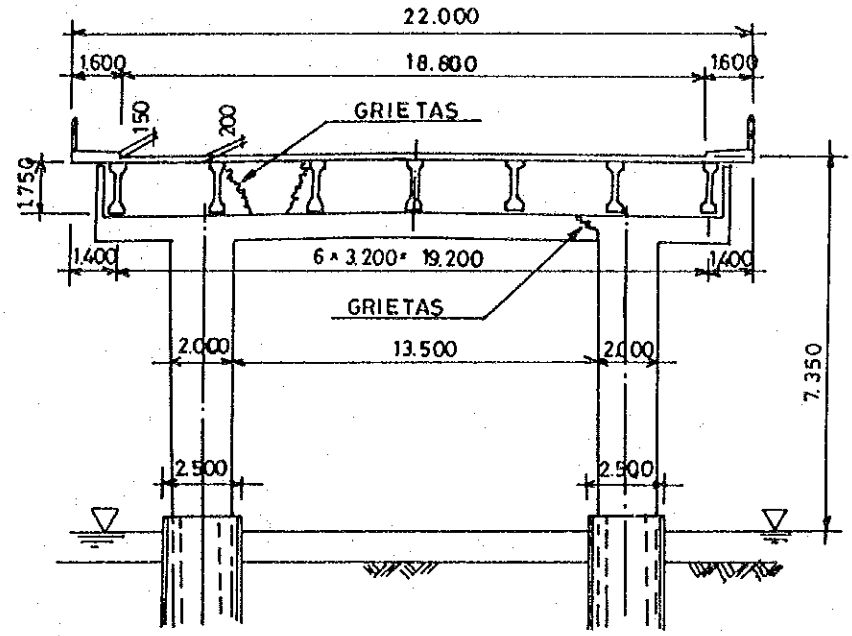


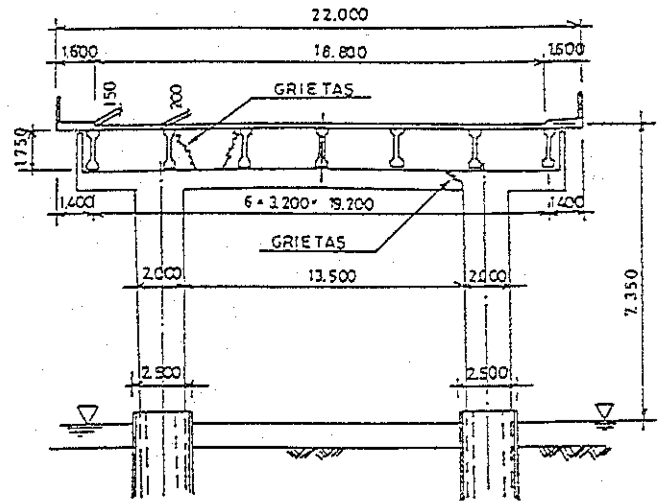
Fig. 8-2 Cross Section of Juan Pablo II Bridge

Table 8-2 Inspection Sheet - Juan Pablo II Bridge

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA Y REGION	CODIGO DEL PUENTE

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

COMENTARIOS



EVALUACION	GRADO DE DETERIORO	SOCAVACION
1	NO EXISTE DAÑO ALGUNO	NO EXISTE SOCAVACION
2	DAÑOS EN UNO O DOS PUNTOS	TENDENCIA A SOCAVAR
3	DAÑOS EN MUCHOS PUNTOS	EXIST. SOCAV. PERO NO HAY PELIGRO
4	MENOS DE LA MITAD DAÑADO	SOCAVACION PELIGROSA
5	CASI TODO DAÑADO	SITUACION DE EMERGENCIA

FECHA INSPECCION	NOMBRE INSPECTOR	
		FIRMA

8.2.2 Railway Bridge

The railway bridge is said to have been constructed in 1877-1890 using steel trusses with pile bent foundation.It has sixty spans of 30.103 m. and 2 spans of 32.314 m. at the Concepcion side. This bridge is still in service. Original plans were made available. Certain repairs appear to have been carried out, especially through bracing or the addition of reinforcement.

At certain locations, it was noted that the steel girder web plates were seriously corroded, with holes present in the web plates.

The Study Team was informed by railway officials that plans are underway to repair the bridge, and we assume that the viability of such repairs has been demonstrated. It is not certain how much corrosion resulted from simple oxidation and how much may be attributed to salt in the air. It appears that corrosion due to salt in the air is not significant.

Refer to Fig. 8-3 for Cross Section of the Railway Bridge.
See Table 8-3 for Inspection Sheet.

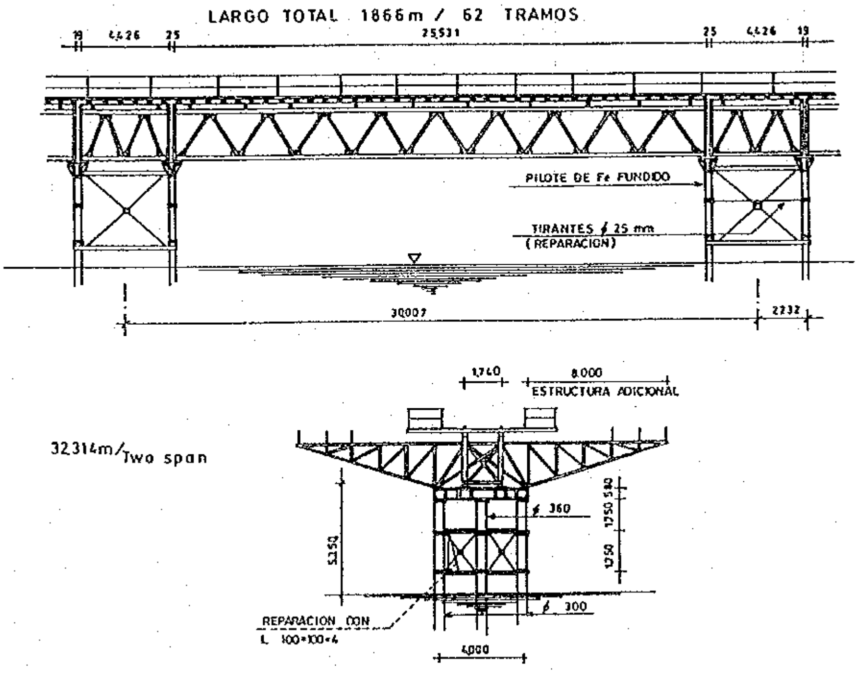


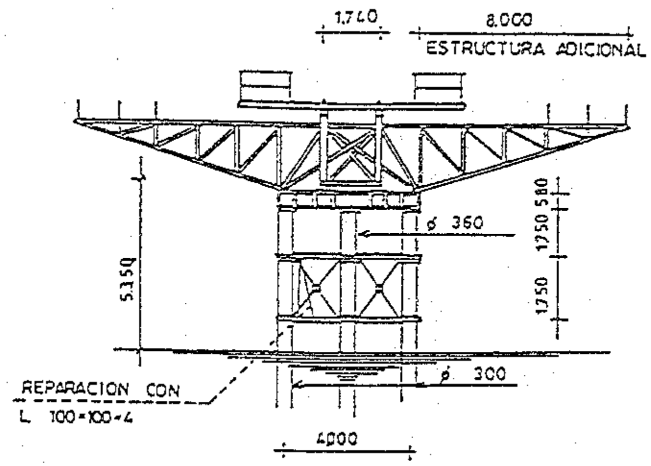
Fig.8-3 Profile and Cross Section of Railway Bridge

Table 8-3 Inspection Sheet - Railway Bridge

NOMBRE DEL PUENTE	KILOMETRO	NOMBRE DE LA VIA	ROL DE LA RUTA	PROVINCIA Y REGION	CODIGO DEL PUENTE

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

COMENTARIOS



EVALUACION	GRADO DE DETERIORO	SOCAVACION
1	NO EXISTE DAÑO ALGUNO	NO EXISTE SOCAVACION
2	DAÑOS EN UNO O DOS PUNTOS	TENDENCIA A SOCAVAR
3	DAÑOS EN MUCHOS PUNTOS	EXIST. SOCAV. PERO NO HAY PELIGRO
4	MENOS DE LA MITAD DAÑADO	SOCAVACION PELIGROSA
5	CASI TODO DAÑADO	SITUACION DE EMERGENCIA

FECHA INSPECCION	NOMBRE INSPECTOR	
		FIRMA

8.3 Results of Site Investigations

Site investigations for Biobio Antiguo bridge were carried out as described below.

8.3.1 Visual observation

(1) General

The Biobio Antiguo bridge was originally constructed with 108 spans with a total bridge length of 1,648.5 m. When the superstructure was rebuilt using structural steel girders, five spans on the Concepcion side were changed to an approach embankment. The river width was reduced to 1,420 m. at the bridge site, and the remaining ten spans at the Concepcion side are now functioning as approach viaducts. The spaces below the bridge at some of these spans are used as temporary shelters or storehouses.

In 1965, two piers and the superstructure of three spans, at the Concepcion side, collapsed due to stream flow pressure resulting from the floods, and the lost spans were replaced with one 45 m steel plate girders span. As a result, the existing bridge crossing the river is composed of one 45 m steel plate girders span, and ninety 15 m steel plate girders spans.

As mentioned in paragraph 8.3.3, a difference of 10 to 20 cm was observed in the elevation of the deck between upstream and downstream side at the piers and at midspan of the girders as well. It is considered that these differences may be caused by settlement or tilting of some piers.

In a similar fashion, due to probable tilting or twisting of piers caused by settlement or lateral movements, the dimension from center to center of bearings of the upstream girder is not the same for the downstream girder.

It was also observed at No. 9 pier that a steel pipe support was introduced to prevent collapse of the pier, and the ends of steel girders between adjacent spans were connected by means of steel bars.

As for the normal maintenance works, minor rehabilitation works such as patching for potholes and overlay on the pavement have been carried out as repairs to damages which have occurred. No repainting of handrails or steel girders has been done since the bridge was originally constructed.

No loss of section attributable to corrosion was noticed. As a result the Study Team recommends either structural steel or prestressed concrete girders for the new bridge depending on economy of cost. Likewise, in the event of using prestressed concrete girders, no additional concrete thickness to protect against corrosion is deemed necessary.

Some debris are still present at the pile caps of the piers, and need to be removed by the MOP. It is suggested that the span length of 15 m is insufficient to avoid creating obstacles in the river bed from debris.

It is noted that vibrations are felt on the deck even when light buses pass on the spans. It is considered that the stiffness of those spans must be insufficient because of the shallow depth of the girders.

In general, the bridge seems to have performed its purpose over the years, however, the Study Team has concluded that the bridge has substantially deteriorated and is nearing the end of its useful life.

The following paragraphs present the findings for each component of the bridge through the visual observation

(2) Deck slab

Visual observation of crack conditions has been carried out at the top and bottom surfaces of the deck slab. These are categorized based on the extent of the deterioration and are classified into four categories. The results are summarized in Table 8-4, and details are shown on Fig.8- 4.

Table 8-4 Surface Cracks in Deck Slab

Tipo de fisuras(4)	Superior(2)		Inferior(3)	
	(m2)	%	(m2)	%
0	7.545	81	9.254	98,90
1	858	9	7	0,07
2	833	9	95	1,00
3	124	1	3	0,03
4	4	0	1	0,00

Note 1. Square meters of deck surface, and percentage of total deck surface affected.
Note 2. "Top" refers to top of 7 cm thick non-structural concrete topping over the structural slab.
Note 3. "Bottom" refers to bottom of the 14 cm thick structural concrete slab.

Note 4. The types of cracks are 0, 1, 2, 3, and 4.
Type 0 - No cracks are evident.
Type 1 - One-directional cracks. There is need to investigate further.
Type 2 - Two-directional cracks. Some level of repair is necessary.
Type 3 - Same as Type 2, with additional cracks within the two directional cracks. Needs immediate repairs.
Type 4 - Same as Type 2, with additional pitting and potholes within the two directional crack pattern. Immediate repairs are necessary.

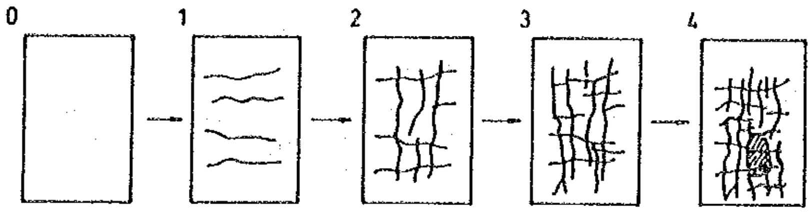


Figure 8-4 Details of the Cracks in the Deck

Cost estimates for the slab cracks repairs, starting with type 2, and including types 3 and 4, are shown in Table 8-10.

It is noted from structural engineering viewpoint that most of the cracks are located at the top of the deck just above the steel girders. Strain marks due to penetration of water from the deck are also found in the vicinity of the girders. It is assumed that the strains are caused by secondary stresses in the deck slab in the longitudinal and transverse directions resulting from unequal deflections between adjacent girders.

For every span, two lines of longitudinal cracks are observed at the middle of the deck parallel to the curbs throughout the bridge.It is assumed that these lines were the original construction joints used during the concrete deck placement, because the superstructure was constructed in the following manner, shown in Fig. 8-5:

1. Erection of one half set of steel girders,
2. Casting of slab 1 concrete in-situ,
3. Construction of the other half set in the same manner,
4. Casting of slab 2.

Therefore the dead load of slab 2 will be carried on the girders through slabs 1 and 3.

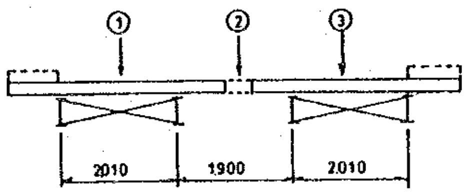


Fig. 8-5 Costruction Method of Superstructure

(3) Steel Girders

1) 15 m spans

The 15 m span lengths are provided using I-shape built-up girders. Each span is composed of four steel girders. Basically, the lower flanges of the girders vary in thickness from 21 to 30 mm using full penetration butt welds. Some of them are provided with cover plates to increase the cross sectional area of the lower flanges.

No intermediate diaphragms were noted. No provision was made to prevent spans from falling through the movements of the piers due to subsiding of the foundation piles or due to lateral movements caused by a major earthquake. Furthermore, the bearing shoes nests, widths of pier caps, are insufficient to prevent collapse from major movements. Some of the girders have lost their bearing supports through lateral movements at the top of the piers.

Both exterior girders of each span are directly exposed to surface water from drainage. Despite this cycle of wetting and drying, and even with no repainting, it was noted that the reduction of thickness for the girders was not significant to affect the cross sectional area of the girders.

There are no cracks at the haunch between the steel girders and concrete decks, making it likely that the superstructure, as a composite girder, is carrying the live load and dead load of the pavement.

2) 45 m span bridge

For the replaced spans, I-shape built-up girders were provided. The span is separated into two longitudinal segments at the center line of the bridge by means of a longitudinal expansion joint. The span is thus composed of two segments of superstructures, each supported on two steel girders. These two girders are connected by cross frames and lateral bracings, and carry the loadings similar to a box girder.

The field inspection examined the welding and noted that the lateral bracings are connected to the lower flanges directly by fillet welds in transverse direction to the longitudinal axis of the girders. It is noted that such a practice adversely affects the strength of the girder because of fatigue stresses in the lower flanges which are tension members. It was noted, however, that such work was carried out under emergency conditions.

(4) Expansion Joints

L-shape steel members are provided for expansion joints at both ends of deck between adjacent spans. These are functioning as protection for the edge of concrete deck rather than expansion joints. Although the expansion joints were repaired by the MOP in the past, most of them were damaged or lost at present because of weakness of the anchorage system. Impact load from dips due to broken expansion joints is adversely affecting the life of the structure.

Expansion joints are important components of the bridge from traffic viewpoint. They can also be some of the weak points of bridge construction if not used properly. Provision for rehabilitation should be given to the expansion joints to conserve the bridge, smooth the traffic service, and contribute to traffic safety.

(5) Piers

It is noted that the concrete piers supporting the superstructure have been in use since the bridge was originally constructed except for the replaced span, where steel framed piers are provided.

The concrete piers are highly deteriorated. In several piers, the concrete cover has become loose and spalled due to corrosion of the reinforcement bars. Progress of the neutralization of the concrete is indicated in the following paragraph. However, it appears that the piers were able to maintain their carrying capacity because of the mass concrete.

In connection with the rehabilitation of the piers, widening at the top of piers is one of the most important elements urgently needed for countermeasure against earthquake effects.

(6) Steel piles

The foundations of the piers were originally constructed using timber piles, while steel piles were provided later for strengthening of the foundations. The tops of the steel piles were capped with pile cap, and the old pier caps were skirted or jacketed with concrete. No evidence was found to positively anchor the new pile caps with the old piers' foundations.

Therefore, vertical forces will be carried on the steel piles only if part of the load is transferred through friction between the old concrete and the new foundation. It is therefore not logical to expect the two foundations to work as a group. The new foundations can only carry lateral forces resulting from earthquake motion or dynamic water pressure.

(7) Concrete piles

Two, 1 m diameter reinforced concrete piles were used as the foundations for each of the first 37 piers at the San Pedro side. It appears that these piles might have been constructed originally to support the piers which in turn supported the timber deck bridge, which were built as inverted fink girder trusses.

The Study Team was unable to obtain any drawings for this installation, so that it is difficult to know the depth of penetration of the piles and evaluate their stability and resistance to earthquake action.

The piers and piles are connected by means of fill concrete. The spaces between the base of piers and tops of piles varies, and is approximately 14 cm, filled with concrete. Laitance on the tops of the piles prevented the bonding of the fill concrete. This fill concrete is in poor condition, and in many cases is broken up and/or missing. Rehabilitation for these areas should be taken into consideration.

8.3.2 Non Destructive Inspection

(1) Concrete Hardness Test

Concrete hardness tests for the deck slab and piers, (Refer to Table A.8-1 in the Appendix and Table 8-5). Refer to Fig. 8-6 for Location of Concrete Hardness and Carbonation Tests. Concrete hardness tests were carried out by the use of Schmidt Hammer for the purpose of estimating the concrete strength.

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

Table 8-5 Neutralization Test and Schmidt Hammer Test

Elemento, Ubicacion	Ensayo de Carbonatación			Ensayo de Schmidt	
	Carbonat. (mm)	PH	Estado del hierro	Losa	Cepa
				kgf/cm²	kgf/cm²
P20	2	11	C		207
Losa 1	7	11	-	273	
P35	15	10,5	C		245
Losa 2	18	10	C	262	
P45	25	10,5	D		215
Losa 3	28	10	B	279	
P60	30	10,5	C		155
Losa 4	26	10,5	D	273	
P88	16	10	-		169

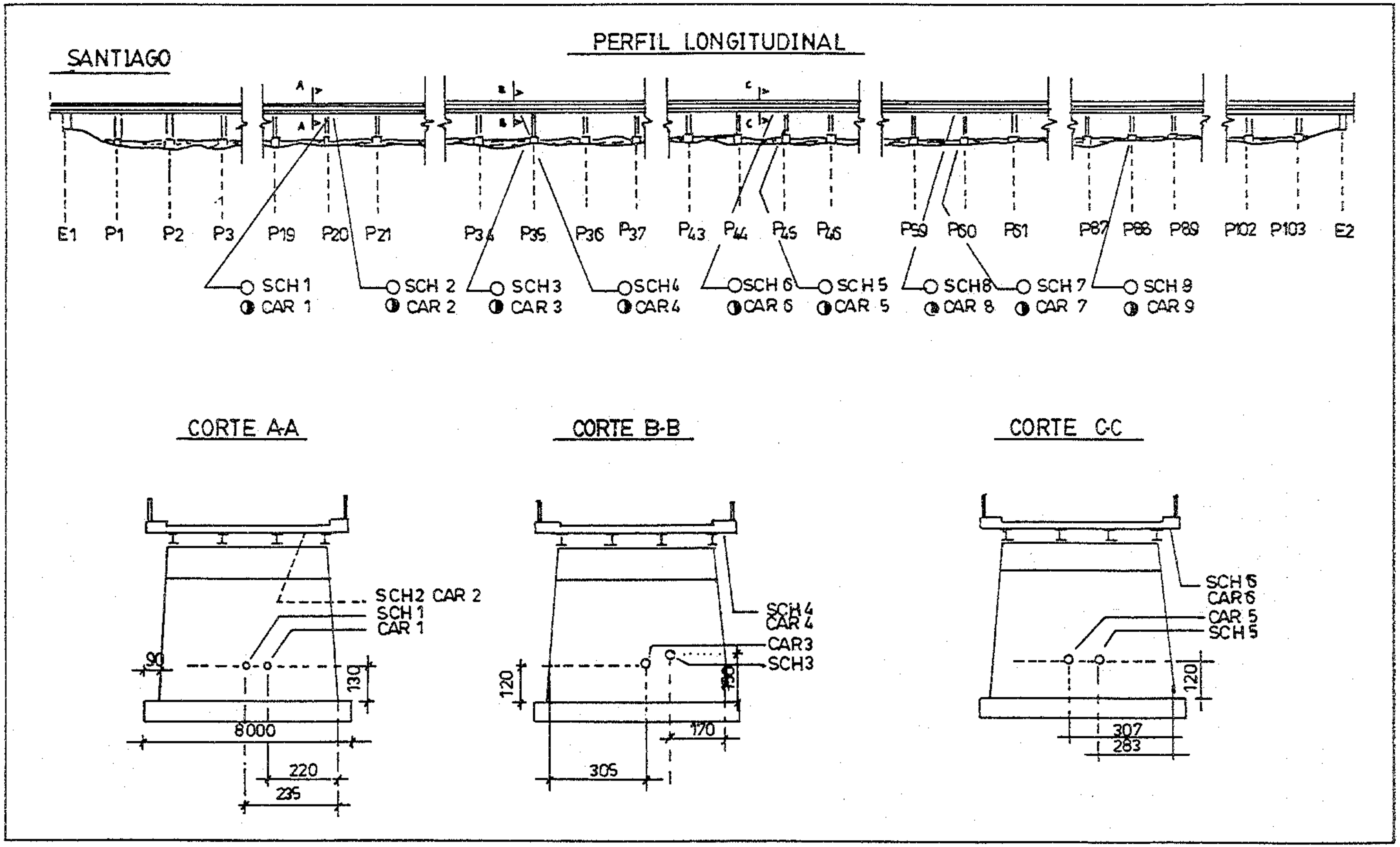


Fig. 8-6(1) Location of Concrete Hardness and Neutralization Tests

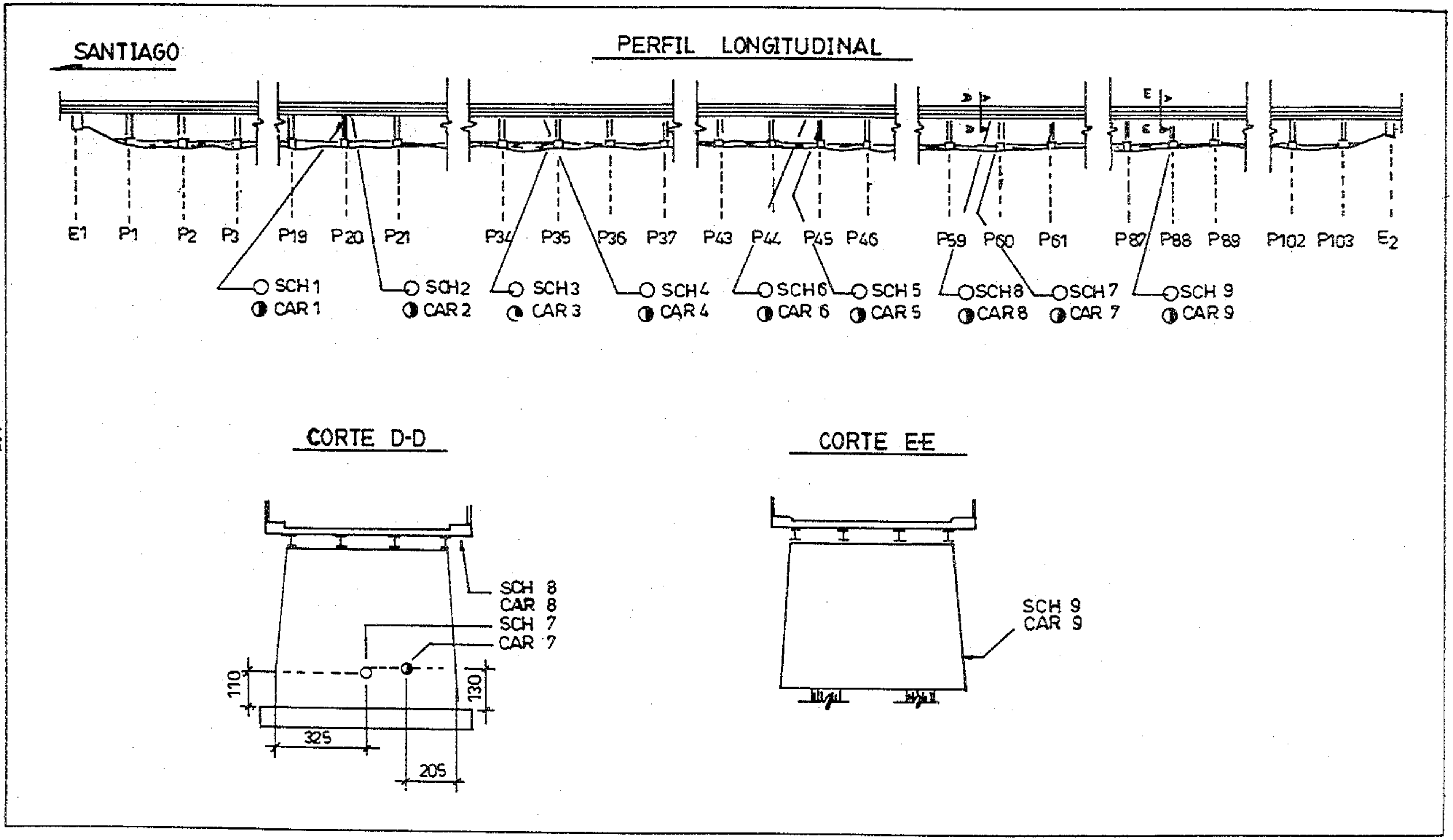


Fig. 8-6(2) Location of Concrete Hardness and Neutralization Tests

1) Angle Correction

Di = Dmi + Rmi

Di : Basic value or basic hardness
Dmi : value by Schmidt Concrete Test Hammer
Rmi : angle correction value

2) Measurement Value Method

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

Measurement value Di i = 1 to 20

Average value Av = 1/20 Di

Measurement adopted value Dadi, 0.8 Av < Dadi < 1.2 Av

3) Strength Formula

According to the Japan Material Academy formula.

F =(13 x Do) - 184 (kg/cm2)

where "F" is compressive strength and Do is the adopted average value

4) Concrete Strength Deterioration based on Concrete Age

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

Fn = F x a,

where:Fn= compressive strength corrected by secular coefficient and

a = secular coefficient.

Table 8-6 Values of "a" related to age of concrete.

Vida (dias)	10	20	28	50	100	150	200	300	500	1000	3000	38anos
a	1,55	1,12	1,00	0,87	0,78	0,74	0,72	0,70	0,67	0,65	0,63	0,60

According to the values in Table 8-5, it is indicated that the strength of the concrete in the pier shows low values (below 200 kgf/cm2), whereas the sidewalk concrete slab shows satisfactory values. We were unable to conduct tests under the structural slab due to the continuous movement of vehicular traffic.

(2) Concrete Neutralization test

1) Concrete Neutralization Test

Tests to determine the degree of deterioration of the concrete were carried out. Refer to Table 8-6 and Fig. 8-6 for location of the neutralization tests carried out for the deck slab and piers respectively.

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.

$$Ca\ (OH)2 + CO2 \text{ --------> } Ca\ CO3 + H2O$$

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 phenomenon is called concrete neutralization, and it is an important source of information for judging the durability of concrete.

2) 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 reinforcement bar. The degree of rust can be estimated according to the following standards. (Refer to Table 8-7).

Table 8-7 Rust Standard for Reinforcement Bars

Grado de Oxidación	Estado de oxidación de la armadura
A	Casi no existe oxidación
B	Se verifica oxidación parcial
C	Gran parte de la armadura está oxidada
D	Existen partes muy afectadas, con grietas o pérdida parcial del fierro
E	Estado de corrosión y expansión del hierro. Expulsa el recubrimiento de hormigon

It is concluded (see Table 8-5) that the concrete deterioration has progressed to the reinforcing steel, and as a result rusting of the reinforcement steel will be progressing in the future. Additionally, the outer 3 cm of the concrete is considered deteriorated.

8.3.3 Settlement survey

Settlement survey was carried out by levelling at the side walk to compare deck elevations with those taken during the previous investigation "Programa de Rehabilitacion y Conservacion de Puentes en la Republica de Chile" carried out by MOP/JICA in 1992/1993. The elevations taken at certain locations in the previous investigation indicated substantial differences from those in the current investigation especially between upstream and downstream points on the deck, by as much as 20 cm transversely, as well as longitudinally. The aim of the new survey is to correlate the old and the new information and determine if pile settlements have taken place. (Refer to Fig. 8-7).

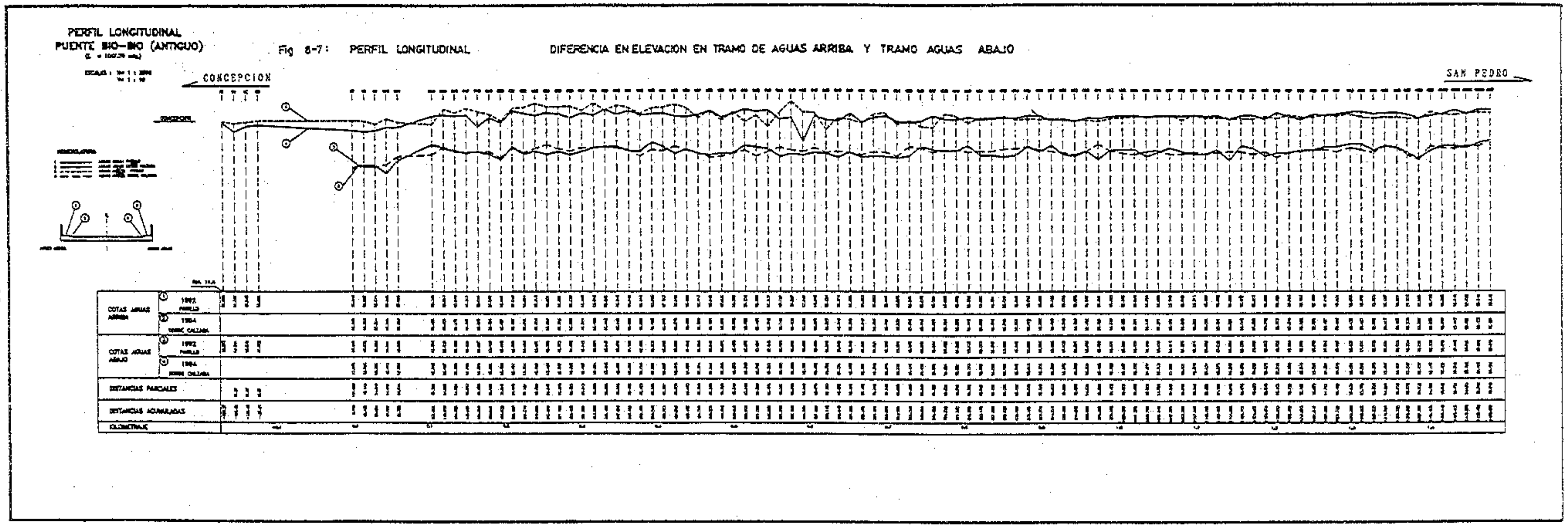


Fig. 8-7 Longitudinal Profile Showing Difference in Elevation of Upstream and Downstream Points on the Deck

8.4 Preliminary Structural Evaluation

8.4.1 Stability of Existing Bridge

(1) Superstructure

1) Structural Steel Girders

The stability of the existing bridge may be examined by calculation using service load design method and AASHTO loading. The calculations are carried out for the deck slab, steel girders and foundations. Steel girder strength was calculated as a non-composite section for dead loads, and in composite action with the deck slab for live loads and other loads. The computations were carried out using two cases of Live Loads (HS20-44 and HS15-44).

The yield strength and the allowable stress of the steel girder for (36A) steel are 2,400 kg/cm2 and 1,320 kg/cm2 respectively. Additional calculations were also carried out for 8-ton loading, currently being used as the load restriction on the bridge. The stress levels of the main girder are tabulated in Table 8-8. It is our understanding that shear connectors (steel coils) were used by welding to the top flanges of the girders, however, no drawings or evidence was available to verify the presence of shear connectors so that composite action can be assured.

Table 8-8 Stress Levels in the Steel Girders and Concrete Slab

Carga Viva			HS-20	HS-15	8 ton
Sección no-compuesta	Platabanda Superior	fd (kgf/cm^2)	-1.885	-1.885	-1.885
		fl (kgf/cm^2)	-1.885	-1.885	-1.885
		Total	-3.770	-3.299	-2.639
	Platabanda Inferior	fd (kgf/cm^2)	+1.242	+1.242	+1.242
		fl (kgf/cm^2)	+2.484	+2.174	+1.739
		Total	+2.484	+2.174	+1.739
Sección no-compuesta	Platabanda Superior	fd (kgf/cm^2)	-1.249	-1.249	-1.249
		fl (kgf/cm^2)	-365	-274	-146
		Total	-1.614	-1.523	-1.395
	Platabanda Inferior	fd (kgf/cm^2)	+1.204	+1.204	+1.204
		fl (kgf/cm^2)	+797	+598	+319
		Total	+2.001	+1.802	+1.523
Losa de hormigón (en acción compuesta de viga)		fd (kgf/cm^2)	-15,4	-15,4	-15,4
		fl (kgf/cm^2)	-45,0	-34,0	-18,0
		Total	-60,4	-49,4	-33,4

Legend: fd = Unit stress due to dead loads.
fl = Unit stress due to live load including impact
\+ = Denotes tension
\- = Denotes compression

It is noted that a critical condition is currently prevailing. Under the 8 ton loading, the fiber stress in the steel of the main girder due to dead load alone (1,885 Kg/cm2) is higher than the allowable stress of 1,320. Furthermore, under the same 8 ton load, the combined dead and live load stress in the steel girder (1,523 Kg/cm2 for composite. and 2,639 for non-composite) substantially exceed the permissible unit stress of 1,320 Kg/cm2.

It appears that the stability is generated by the combined action of the girders and the deck slab, and as a result the long range service of the bridge is dependent on the progress of the deterioration, particularly the cracks in the deck slab.

When the cracks increase, as the bridge deteriorates with age, the girders will function as non-composite sections, reaching yield stress levels and potential collapse. It is also noted that these stress levels have not taken into account any other normal bridge loadings, particularly seismic loads.

2) Reinforced Concrete Deck Slab

Table 8-9 below, shows the stresses in the concrete of the deck slab under the same bridge loading indicated above.

Table 8-9 Stress in Deck Slab

(Unidad: kg/cm^2)

Carga viva	HS-20	HS-15	8 ton
Tensión en la barra	+5.773	+3.747	+2.521
Tensión admisible, fa	+1.352	+1.352	+1.352
Tensión de fluencia, fy	+2.700	+2.700	+2.700
Tensión en el hormigón	-115	-75	-50
Tensión admisible del hormigón	-70	-70	-70

"+" denotes tension. "-" denotes compression.

From the above table, it is indicated that in all cases the tensile stresses of the reinforcing steel in the deck exceed the yield stress of the steel except for the case of the 8-ton live loading.

The calculation of the reinforcement bar stresses were done based on the data from the drawing prepared by MOP in 1955. The drawing was prepared when the timber deck was being replaced by concrete slab. The drawing shows that the 12 mm dia. bars were arranged at 80 mm center to center intervals. The Study Team could not confirm that the actual reinforcement bar arrangement in the existing slab is the same as shown on the drawing.

It is noted that the concrete compressive stresses under restricted loading are well within the allowable value. Furthermore, the Schmidt Hammer tests showed results (262 to 279 kg/cm2, see Table 8-5). The concrete stress is close or higher than the design allowable strength.

3) Depth to Span Ratio of Steel Girders

All bridge codes as well as other structural codes have limitations regarding the depth of the structural supports. These restrictions are made to control deflections as well as to reduce vibrations. It is noted that in the case of the existing bridge, the depth/span ratio is 44/1530 or 1/34.77. This condition contributes to higher deflections in the future particularly when the deck deteriorates further.

The limitations of the AASHTO Specifications are 1/25 when the combined depths of the girder and slab are used, and 1/30 when the girder depth is taken alone. These two parameters for the existing bridge are 1/25.08 and 1/34.77 respectively.

(2) Substructure

The stability of the pier with cast-in-situ concrete piles is verified as follows:

Load from Superstructure Rd = 70 tons
Rh = 7 tons
Allowable capacity of pile = 230 tons per pile
Modulus of Elasticity = 2.5 x (10)6 tons/sq m.
Moment of Inertia = 0.049 m4

Table 8-10 External Force on Piers

	V	H	Ml	Mt
Superestructura	70,0	7,0	40,6	46,2
Pirotes	80,9	8,1	21,8	21,8
Total	150,9	15,1	62,4	68,0

donde, V: Carga vertical (ton)
H: Carga horizontal debido a sísmos (ton)
Ml: Momento longitudinal debido a sísmos (ton.m)
Mt: Momento transversal debido a sísmos (ton.m)

Table 8-11 Load on Piles

	Longitudinal	Transversal	Admisible
Reacción vertical (t)	75,5	98,4	230
Momento en el pilote (t.m)	45,7	18,6	(Nota 1)
Desplazamiento (mm)	6,3	2,2	15

Note (1) : The allowable moment on the pile is not calculated because the details of reinforcement in the piles cannot be investigated. Due to the small computed displacement, it is assumed that the pile is sufficiently strong. Therefore the stability of the pier appears adequate.

8.4.2 Load Carrying Capacity

The load carrying capacity of BioBio Antiguo bridge can be calculated by the following formula based on AASHTO.

P = RF*Po
RF = (fa-fd)/fl

where:

P = Load carrying capacity (ton)
Po = Basic live loading of 13.6 ton (HS15). and 18.1 ton (HS20)

fd= Stress due to dead load (kg/cm2)
fa= Allowable stress of girder (kg/cm2)
fl= Stress due to live load including impact load (kg/cm2)

P = 18.1 (1,320-1,204)/797 = 2.63 ton +18.1 (H20-44)
P = 13.6 (1,320-1,204)/598 = 2.64 ton +13.6 (H15-44)
P = 8.0 (1,320-1,204)/319 = 2.91 ton + 8.0 (8 ton)

The values for RF are 0.145, 0.194 and 0.364 respectively.

According to the "Manual for Inspection and Maintenance of Bridges, AASHTO 1978, a bridge shall require traffic control such as weight or speed limitations of vehicles if RF is below 1.0. The bridge, however shall be closed to traffic in the event the load carrying capacity is below 3 tons.

The Study Team is of the opinion that the stresses in the steel girders are in between those under composite and non-composite action.

A thorough evaluation of the carrying capacity of the bridge can only be obtained after taking into account the stresses, the design conditions, actual traffic of the bridge and its actual physical condition.

The load carrying capacity of this bridge is below 3 tons, suggesting the need for the MOP to take countermeasures related to safety. See paragraph 8.7 "Recommendations Regarding the Existing Bridge".