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DIRECTORATE GENERAL OF WATER
MINISTRY OF PUBLIC WORKS
THE REPUBLIC OF CHILE

THE STUDY
ON
THE DEVELOPMENT OF WATER RESOURCES
IN
NORTHERN CHILE

SUPPORTING REPORT A : SURFACE WATER

MARCH 1995

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO

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Chapter I SURFACE WATER OF SAN JOSE RIVER BASIN

1.1 General

San José River basin located in the Region I in northern Chile has a drainage basin area of about 3,187 km^2 covering the sub-basins of Laco and Tignamar rivers. The drainage basin area is shown in Fig. A, 1.1 and Table A, 1.1.

1.1.1 Climate and Precipitation

Information on climate in the basin is obtained from Arica Oficina and Azapa weather stations in the downstream of the basin. Maximum monthly average temperature is in December at 36.4 °C and minimum one is in August at 18.5 °C. Humidity does not vary much throughout a year lying within a range of 60 - 80 %.

Precipitation is observed regularly by DGA and Meteorological Department. Most of the stations are distributed in the upstream of the basin as shown in Fig. A, 1.2.

Most of the precipitation fall in the upstream mountain areas with an altitude of higher than 3,000 m. On the other hand, the lower reaches including Arica city and Azapa valley receive no rainfall throughout the year. Average annual precipitation regionally varies from zero in Arica city to 200 mm in the uppermost mountain area as shown in Fig. A,1.2.

1.1.2 River System

San José River originates from the Andes mountains with an elevation of 4,000 - 5,000 m. It flows westwards, joining the main tributaries of Tignamar, Seco and Laco, through the Azapa valley to the Pacific Ocean at Arica city. The river is called as San José River after the confluence of the above main tributaries.

The river runoff is caused by the rainfall and snow melt in the Andes mountains. The indigenous flow rate of the San José River is small. Hence, the Lauca River, flowing toward Bolivia across the border, was diverted to increase the flow rate of San José River in 1962.

The diverted water is discharged at Central Chapiquina located in the upstream tributary (Laco River) of San José River through the Central Chapiquina hydropower station with the maximum output of 10.2 MW.

The water after joining that of the above mentioned tributaries, flows down in the San José main river to the irrigation dam/intake of the Azapa Irrigation Canal.

The irrigation dam/intake called as "Bocatoma" is located 40 km upstream from the river mouth. It usually draws the whole river flow to irrigate approximately 3,200 ha of farmland in Azapa Valley. Only flood water spills over the Bocatoma.

For the river system, see Fig. A, 1.1. Flow model of San José River is shown in Fig. A, 1.3 along the discharge observation stations.

1.2 Surface Flow Rate

1.2.1 Flow Rate at Major Stations

Daily water level is observed at DGA's observation stations by automatic recorder. Flow rate at each station is generally calculated by so called "Discharge Rating Curve" or "H-Q Curve" which is a calibration curve of water level and flow rate. Major observation stations are as follows;

River	Location	Observation Period
Lauca Canal	Bocatoma Lauca	1979 - Present
	Central Chapiquina	1967 - Present
San José	Ausipar	1967 - 1972
	Antes Bocatoma	1974 - 1984
	Acueducto Azapa	1963 - Present

Their locations are shown in Fig. A, 1.3.

Observation at Ausipar and Antes Bocatoma have ceased since 1973 and 1985 respectively because the stations were damaged by the river floods. However, observation at Ausipar started again in 1993.

Average monthly flow rate of these stations are shown in Table A, 1.2 and Table A, 1.3. Monthly fluctuation of the flow rate at each station is shown in Fig. A.1.4. Monthly maximum, minimum and average flow rates in the recorded years are shown in Table A, 1.4. Recorded monthly flow rates in the past are shown in Appendix A, 1.1.

Ausipar and Antes Bocatoma stations are closely located with a distance of approximately 7 km. Water use and loss between both stations are considered negligibly small. Hence, the discharge data of both stations are combined.

Yearly average flow rate at Central Chapiquina is estimated at 0.796 m^3/s. On the other hand, that at Ausipar/Antes Bocatoma is estimated to be 1.101 m^3/s. The balance of 0.305 m^3/s is considered as the indigenous flow of the San José River. The Lauca diversion water shares approximately 70 % of the total water of San José River.

Flow rate at Acueducto Azapa (irrigation water intake rate) has increased in recent years. Average flow rates during the periods of 1963 - 1975 and 1976 - 1990 were 0.296 m^3/s and 0.646 m^3/s respectively.

Usually, all the river water is used or infiltrates into underground in the Azapa Valley. Only flood water is discharged to the sea. Flood flow rate to the sea has been observed at Puente Saucache by DGA. The observed monthly average flood flow rates in the past are also shown in Appendix A, 1.1. However, it should be noted that the observation was conducted on ad hoc basis and as a result, the observed data do not include all the floods occurred during the observation period.

1.2.2 Supplementary Observation

1) Objective

The purpose of the supplementary observation is to check the water balance along the San José River, especially to examine the water loss between upstream and downstream stations.

2) Location

Observation points are as follows:

(1) Ausipar AU-1
(2) Downstream of Tignamar River TG-1
(3) Acueducto Azapa AQ-1

For location, see Fig. A, 1.3.

3) Observation Method

The measurement was conducted by JICA Study Team & DGA. River conditions during measurement are shown in Appendix A, 1.2. Flow velocity was measured by a propeller current meter across the river section at a length interval of about 1/10 of the river width. Flow rate was calculated as the product of average velocity times cross sectional area

$$Q = \sum_{i=1}^{m} V_i \times A_i$$

where Q = flow rate (m^3/s),
V = flow velocity (m/s),
A = cross sectional area of the river (m^2) and
m = number of sub-cross sections.

4) Date of Observation

Observations were carried out on 12th June, 8th October and 29th November 1993.

5) Results of Observation

Flow rate at each point is shown in Table A, 1.5. In the table, the flow rate at Central Chapiquina is the one discharged from the hydropower station. It was obtained from the electric company.

(1) First observation

The Seco and Laco (upstream section of Central Chapiquina hydropower station) were almost dried up at the observation time. Hence, only Tignamar River was observed to estimate the indigenous flow rate of San José River. At that time, there was no overflow from the Bocatoma and all the water at Antes Bocatoma was drawn by the irrigation intake. Further, no water was drawn at Sr. Aguero irrigation intake located between Ausipar and Antes Bocatoma stations.

The total flow rate of Tignamar and Lauca diversion is 0.587 m^3/s. It is in a well agreement with the flow rates of 0.554 m^3/s at Ausipar and 0.549 m^3/s at Antes Bocatoma (equal to Acueducto Azapa). This would mean there is no significant infiltration into

underground and other water losses in the upstream reaches of Bocatoma.

(2) Second Observation

The second observation was carried out to further examine the water loss between Ausipar and Antes Bocatoma. All the river water at Antes Bocatoma was drawn by the Azapa irrigation intake with no overflow from Bocatoma at the observation time.

The flow rate at Ausipar and Antes Bocatoma (equal to Acueducto Azapa) were 0.717 m^3/s and 0.562 m^3/s respectively. The difference is large equivalent to 28 % of the flow rate at Antes Bocatoma. This difference may mainly be due to the water extraction at Sr. Aguero irrigation intake and observation error. However, the extracted water volume was not observed at that time.

(3) Third Observation

A further detailed observation was executed to confirm the water balance between Ausipar and Antes Bocatoma stations. At that time, some water was drawn from Sr. Aguero intake for irrigation use and a little amount of overflow was observed at Bocatoma.

The water balance between the stations was as small as 0.047 m^3/s.

Flow rate at Ausipar	:	0.780 m^3/s
Water withdrawal at Sr. Aguero	:	-0.061 m^3/s
Overflow at Bocatoma	:	-0.004 m^3/s
Flow rate at Acueducto Azapa	:	-0.668 m^3/s
Balance	:	0.047 m^3/s

From the above observations, it is concluded that there is no significant infiltration loss in the upstream reaches of Antes Bocatoma.

(4) Conclusion

(i) There is some water loss between Ausipar and Antes Bocatoma stations. Major portion of this water loss is caused by the water extraction at Sr. Aguero irrigation

intake. No significant infiltration and other losses are identified.

(ii) The water loss between both stations in considered not large. Hence, the discharge data at both stations are collectively used with no modification for evaluation of the surface water potential of San José River.

The observed discharge differences between both stations are as follows.

Observation	(1) Ausipar (l/s)	(2) Antes Bocatoma (l/s)	((1)-(2))/(2) (%)
1st	554	549	1
2nd	717	562	28
3rd	780	672	16
Average	684	594	15

The surface water potential of the River is to be evaluated by the data at Antes Bocatoma. However, the period of the available data is limited to 1974-1984 (11 years). On the other hand, the data at Ausipar is available for the period of 1967-1972 (6 years). Therefore, these data were combined with no correction of the data at Ausipar to evaluated the surface water potential based on as much data as possible. However, the flow rate of the River was calculated by weighting the data at both stations according to their recorded periods.

As a result, the error (overestimate) of the estimated surface water potential of the River is considered as small as 5% (=15% x $\frac{6}{17}$) at most.

1.2.3 Calculation of Runoff Coefficient

The surface runoff coefficient of San José River at Antes Bocatoma was estimated by comparing the average indigenous flow rate of San José River at Antes Bocatoma with average annual precipitation of the drainage basin of Antes Bocatoma.

The average annual indigenous flow rate was obtained by deducting the flow rate at Central Chapiquiña from the flow rate at Antes Bocatoma. The average annual precipitation of the basin was estimated based on the isohyetal map of annual precipitation prepared by DGA in 1987 as shown in Fig. A, 1.2.

The differences among the average annual precipitations at the DGA stations in the whole study area for the periods until 1987 and until present time are negligibly small. The average difference is approximately 5%.

Therefore, the isohyetal map of DGA - 1987 was used in this study without any modification.

The run-off coefficient of San José River at Antes Bocatoma is estimated to be 0.068 as shown in Table A, 1.6. This means that 6.8 % of the precipitation runs off into the river as surface water. The remaining 93.2 % is mainly lost by evaporation.

1.3 Surface Water Quality

1.3.1 Water Quality at Major Stations

Water quality is observed by DGA. Water quality samples are taken from the river and analyzed in the DGA laboratory. The observation stations are as follows;

River	Location	Observation Period
Lauca Canal	Sifon N1	1959 - Present
San José	Ausipar	1969 - 1981
	Bocatoma	1967 - 1987
	Acueducto Azapa	1970 - Present
	Saucache	1972 - 1977

The analyzed water quality elements are as follows;

(1) Health Significance : As, $N\text{-}NO_3$, $N\text{-}NO_2$, $N\text{-}NH_3$

(2) Aesthetic Quality : Cl^-, Cu, Fe, Na, P, SO_4, pH

(3) Others : HCO_3, CO_3, Ca, Mg, K, B, E.C.

Average water quality at each station are shown in Table A, 1.7 and A, 1.8. Average monthly data in the past are shown in Appendix A, 1.3.

1.3.2 Evaluation of Water Quality

Permissible drinking water quality of Chile is shown partly as follows;

	pH	Cl^- (mg/l)	SO_4 (mg/l)	Mg (mg/l)	As (mg/l)	Cu (mg/l)	Fe (mg/l)	N-NO_3 (mg/l)
Permissible Values	6.0-8.5	250	250	125	0.05	1.0	0.3	10.0

Water Quality Standard is referred in Appendix A, 5.

Water quality of San José River is generally good. However, As and Fe exceed the permissible limit at almost all the stations. The average concentration of As and Fe at the above five (5) stations are 0.09 mg/l and 0.82 mg/l respectively.

1.4 Evaluation of Surface Water Development Potential

The river water is usually all consumed or infiltrates into underground in Azapa Valley and resultingly, no water flows down to the sea. Only flood water is discharged to the sea. This flood water discharging to the sea is the surface water potential which can be further developed.

The flood flowing to the sea was measured at Puente Saucache by DGA during 1971 to 1989. The observed flood hydrograph is shown in Fig. A, 1.5. However, this hydrograph records do not include all the actual floods during the observation period. Because the DGA observation was conducted on ad hoc basis.

Hence, flood flow at Puente Saucache is estimated from that at Antes Bocatoma. The observed flood flow rates at both stations at the same day in the past are plotted as shown in Fig. A, 1.6.

Relation between the flood flow rates at both stations is expressed as follows;

$$Q_{Saucache} = 0.712 Q_{Antes\ Bocatoma} - 0.577$$

or $$Q_{Antes\ Bocatoma} = 1.404 Q_{Saucache} + 0.810$$

where Correlation Coefficient (r) = 0.7120

Q = flow rate (m^3/s),

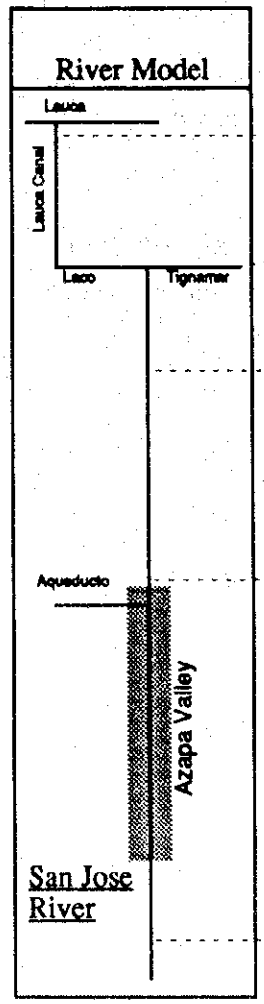
a, b = constant

Flood flow rates at Puente Saucache during 1976 to 1984 are estimated from the observed flood flow rates at Antes Bocatoma based on the above equation. The results are shown in Appendix A, 1.4.

Yearly flood flow volume to the sea during 1976 to 1984 is calculated as shown in Table A, 1.9. It ranges from 0 m^3 in 1983 to 16,936,933 m^3 in 1976 with an average of 4,708,652 m^3.

The above average yearly flood flow volume to the sea of 4,708,652 m^3/year (= 0.149 m^3/s) is considered to be the theoretically maximum surface water potential which can be further developed in San José River Basin.

Table A, 1.1 Drainage Basin and Sub-Basin Areas in San José River Basin
<Cuenca de Drenaje y Area Sub-cuenca en Cuenca del Rio San Jose>



River	Tributaries	Location	Sub-Basin (km2)	Total Basin (km2)
	Laco		259.4	259.4
	Tignamar		593.7	853.1
San Jose		Ausipar	340.9	1,194.0
San Jose		Antes Bocatoma	84.1	1,278.1
San Jose		River Mouth	1,908.8	3,186.9

Table A, 1.2 Average Surface Flow Rate observed by DGA at Major Stations in San Jose River Basin

<Nivel de Flujo de Superficie Promedio Meansual Observado por DGA en las Principales Estaciones de la Cuenca del Rio San Jose>

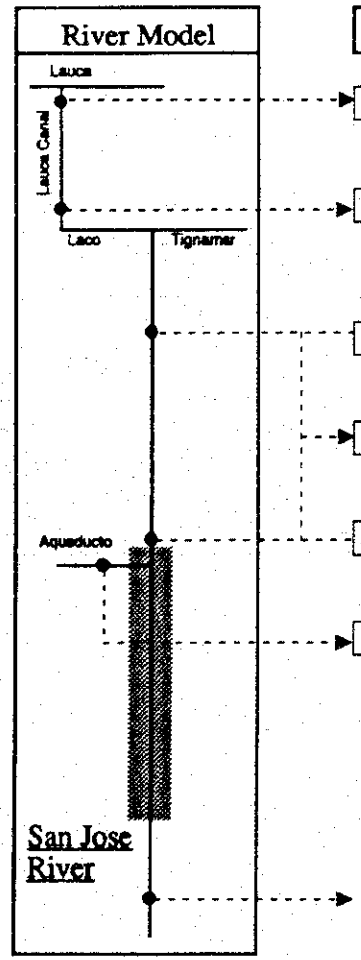
Unit : m^3 /s

River	Location	Obs. Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVG
Lauca	Bocatoma Lauca	1979-1992	1.050	1.050	1.071	0.905	0.926	0.895	0.893	0.899	0.933	1.003	1.018	0.943	0.965
Canal	Central Chapiquina	1967-1993	0.879	0.877	0.874	0.752	0.757	0.752	0.791	0.784	0.778	0.769	0.770	0.767	0.796
San Jose	Ausipar	1967-1972	2.325	1.604	0.947	0.565	0.890	0.833	0.773	0.705	0.586	0.506	0.506	0.652	0.907
	Antes Bocatoma	1974-1984	1.333	2.558	2.137	0.980	1.010	1.030	0.965	0.879	0.843	0.788	0.802	0.929	1.188
	Ausipar & Antes Bocatoma		1.638	2.272	1.740	0.876	0.970	0.959	0.901	0.825	0.769	0.694	0.717	0.850	1.101
	Acueducto Azapa	1963-1990	0.504	0.362	0.380	0.475	0.546	0.520	0.545	0.517	0.486	0.472	0.501	0.536	0.487

Note : Average flow rate at Ausipar & Antes Bocatoma is calculated by weighted average of the recorded years

Table A, 1.3 Average Surface Flow Rate in San José River Basin
<Nivel de Flujo de Superficie Promedio en la Cuenca del Rio San Jose>
(Recorded period of the stations are different but range from 1967 to 1992)

Unit : m^3/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVG
Bocatoma Lauca	1.050	1.050	1.071	0.905	0.926	0.895	0.893	0.899	0.933	1.003	1.018	0.943	0.965
Central Chapiquina Hydropower Station	0.879	0.877	0.874	0.752	0.757	0.752	0.791	0.784	0.778	0.769	0.770	0.767	0.796
Ausipar	2.325	1.604	0.947	0.565	0.890	0.833	0.773	0.705	0.586	0.506	0.506	0.652	0.907
Ausipar & Antes Bocatoma Azapa	1.638	2.272	1.740	0.876	0.970	0.959	0.901	0.825	0.769	0.694	0.717	0.850	1.101
Antes Bocatoma Azapa	1.333	2.558	2.137	0.980	1.010	1.030	0.965	0.879	0.843	0.788	0.802	0.929	1.188
Aqueducto Azapa en Bocatoma	0.504	0.362	0.380	0.475	0.546	0.520	0.545	0.517	0.486	0.472	0.501	0.536	0.487

Puente Saucache, but not regular observation, only during flood period

Table A, 1.4 Average, Maximum and Minimum Surface Flow Rate in San José River Basin

<Promedio, Tasa de Flujo de Superficie Maximo y Minimo en la Cuenca del Rio San José>

(Max. and Min. are the maximum and minimum of average values in a month of the recorded years, not instantaneous values)

Unit : m^3/s

River	Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
San Jose	Bocatoma Lauca	Max.	1.485	1.374	1.584	1.546	1.396	1.203	1.188	1.290	1.350	1.452	1.776	1.528	1.431
		Avg.	1.050	1.050	1.071	0.905	0.926	0.895	0.893	0.899	0.933	1.003	1.018	0.943	0.965
		Min.	0.691	0.678	0.520	0.442	0.466	0.552	0.575	0.639	0.579	0.619	0.615	0.531	0.576
	Central Chapiquina	Max.	1.260	1.215	1.231	1.121	1.079	1.067	1.065	1.190	1.190	1.240	1.124	1.193	1.165
		Avg.	0.879	0.877	0.874	0.752	0.757	0.752	0.791	0.784	0.778	0.769	0.770	0.767	0.796
		Min.	0.450	0.450	0.465	0.384	0.370	0.200	0.480	0.520	0.500	0.430	0.380	0.460	0.424
	Ausipar	Max.	6.700	3.170	2.250	1.070	1.300	1.050	1.030	0.796	0.664	0.644	0.622	0.935	1.686
		Avg.	2.330	1.610	0.948	0.564	0.891	0.833	0.773	0.705	0.586	0.506	0.506	0.652	0.909
		Min.	0.604	0.718	0.120	0.117	0.547	0.663	0.494	0.553	0.463	0.391	0.349	0.508	0.461
	Antes Bocatoma Azapa	Max.	2.720	7.220	5.360	2.110	2.040	1.670	1.500	1.420	1.280	1.070	1.030	1.540	2.413
		Avg.	1.330	2.560	2.140	0.980	1.010	1.030	0.964	0.879	0.842	0.788	0.802	0.929	1.188
		Min.	0.551	0.620	0.540	0.398	0.259	0.357	0.407	0.443	0.475	0.414	0.467	0.489	0.452
	Ausipar & Antes Bocatoma	Max.	6.700	7.220	5.360	2.110	2.040	1.670	1.500	1.420	1.280	1.070	1.030	1.540	2.745
		Avg.	1.638	2.272	1.740	0.876	0.970	0.959	0.901	0.825	0.769	0.694	0.717	0.850	1.101
		Min.	0.551	0.620	0.120	0.117	0.259	0.357	0.407	0.443	0.463	0.391	0.349	0.489	0.381
	Acueducto Azapa en Bocatoma	Max.	0.943	0.976	1.010	1.030	1.090	1.040	1.040	0.863	0.817	0.889	0.942	1.000	0.970
		Avg.	0.504	0.362	0.380	0.475	0.546	0.520	0.545	0.517	0.486	0.472	0.501	0.536	0.487
		Min.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A, 1.5 Surface Flow Rate observed on 12 June, 8 October and 29 November 1993 in San Jose River Basin

<Nivel de Flujo de Superficie Observado entre el 12 de Junio y 10 de Octobre y 29 de Noviembre de 1993 en la Cuenca del Rio San Jose>

River	Location/ Quebrada	Average Velocity (m/s)	Cross-section Area (m2)	Flow Rate (m3/s)	Remarks
Observation on 12th June 1993					Flow Pattern
Canal Lauca	Central Chapiquina	-	-	Data from DGA 0.557	
Tignamar	-	0.51	0.059	0.030	
San Jose	Ausipar	0.54	1.021	0.554	
	Sr. Aguero Intake	-	-	0.000	
	Acueducto Azapa	1.40	0.391	0.549	
	Bocatoma	-	-	0.000	
Observation on 8th October 1993					
San Jose	Ausipar	0.68	1.056	0.717	
	Sr. Aguero Intake			not observed	
	Acueducto Azapa	1.41	0.400	0.562	
	Bocatoma			0.000	
Observation on 29th November 1993					
San Jose	Ausipar	0.64	1.213	0.780	
	Sr. Aguero Intake	-	-	0.061	
	Acueducto Azapa	1.49	0.450	0.668	
	Bocatoma	-	-	0.004	

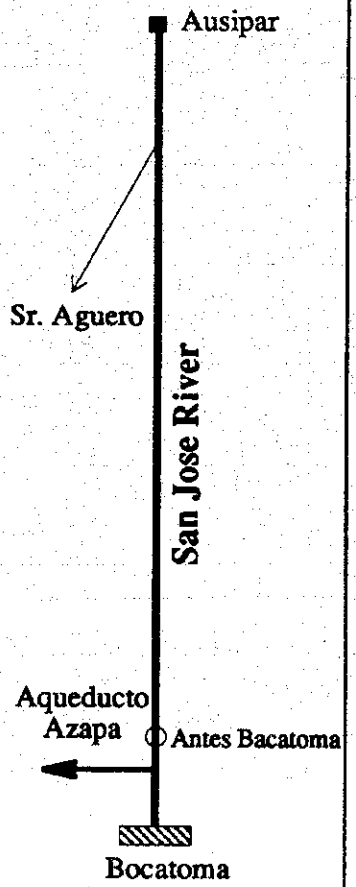


Table A, 1.6 Average Runoff Coefficient in San José River Basin
<Coeficientes de Escorrentias Promedios en la Cuenca de Rio San José>

Location : **Antes Bocatoma**

Rainfall Range (mm)	Average Rainfall R (mm)	Total River Basin (km2)	Upstream Basin of A. Bocatoma A (km2)	Average R*A (mm.km2)	Upstream Avg. Rainfall R (mm) (R*A/A)	Flow Rate at A.Bocatoma Q (m3/s)	Runoff Coefficient f (= Q/R*A)	Upstream Average Altitude H (m, msl)
0.0 - 10.0	5.0	1,940.72	31.92	159.59		0.305		
10.0 - 50.0	30.0	296.08	296.08	8,882.40		(C.Chapiquina		
50.0 - 100.0	75.0	218.80	218.80	16,410.00		- A.Bocatoma)		
100.0 - 150.0	125.0	372.50	372.50	46,563.00				
150.0 - 200.0	175.0	234.94	234.94	41,113.80				
200.0 - 250.0	225.0	123.86	123.86	27,868.78				
250.0 - 300.0	275.0	0.00	-	-				
300.0 - 350.0	325.0	0.00	-	-				
> 350.0	-	0.00	-	-		(m3/year)		
		3,186.90	1,278.10	140,997.58	110.32	9,618,480	0.068	3,464

Note : - Average basin rainfall is calculated from Average Annual Precipitation Map (Isohyetal Map) by DGA in 1987
- Flow rate at Antes Bocatoma is the indigeneous flow rate of San Jose River excluding the diversion water from Lauca Canal. That is the difference of the average flow rate of Ausipar/Antes Bocatoma and average flow rate of Central Chapiquina (1.101 - 0.796 = 0.305 m3/s).
- Upstream average altitude of Antes Bocatoma is obtained by averaging the altitude of the rainfall stations located in the upstream basin of Antes Bocatoma

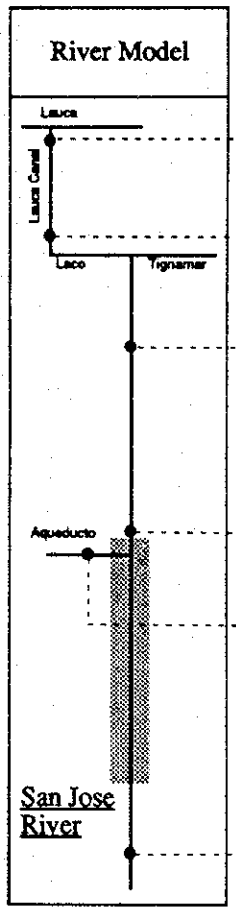
Table A, 1.7 Average Water Quality Observed by DGA in San José River Basin

<Calidad Promedio de Agua Observada por DGA en la Cuenca del Rio San José>

River	Location	pH	E.C (mh/cm)	CO_3 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	B (mg/l)	As (mg/l)	Cu (mg/l)	Fe (mg/l)	$N\text{-}NO_3$ (mg/l)	$N\text{-}NO_2$ (mg/l)	P (mg/l)	$N\text{-}NH_3$ (mg/l)
San Jose	Canal Lauca	7.97	676	5.725	232.5	41	101	34.3	35.8	7.8	55.3	1.41	0.087	0.059	0.27	0.092	0.003	0.166	0.117
	Ausipar	7.93	801	2.695	243.8	55	134	55.2	35.9	8.2	68.4	1.02	0.078	0.015	0.80	0.227			
	Bocatoma	7.94	756	1.601	191.8	50	135	55.4	31.4	7.0	60.5	1.60	0.080	0.015	1.40	0.126	0.007	0.075	0.062
	Acueducto	7.93	811	6.045	207.4	53	155	54.3	34.1	8.2	67.5	1.68	0.118	0.061	0.83	0.135	0.004	0.133	0.073
	Saucache	7.47	634	0.100	172.8	56	130	77.3	15.8	6.3	47.3	1.13	0.085	0.112	0.82	0.402	0.005		0.000
Permissible Value		6.0 - 8.5				250	250		125.0				0.050	1.000	0.30	10.000			

Table A, 1.8 Average Water Quality and Surface Flow Rate in San Jose River Basin
<Calidad Promedio del Agua y Nivel de Flujo en la Cuenca del Rio San Jose>

(Recorded period of the stations are different but range from 1967 to 1992)



River Model	pH	E.C (mh/cm)	CO_3 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	B (mg/l)	As (mg/l)	Cu (mg/l)	Fe (mg/l)	$N\text{-}NO_3$ (mg/l)	$N\text{-}NO_2$ (mg/l)	P (mg/l)	$N\text{-}NH_3$ (mg/l)	Q (m^3/s)
Bocatoma Lauca	7.97	676	5.725	232.5	41	101	34.3	35.8	7.8	55.3	1.41	0.087	0.059	0.268	0.092	0.003	0.166	0.117	0.965
Central Chapiquina Hydropower Station																			
Auspar	7.93	801	2.695	243.8	55	134	55.2	35.9	8.2	68.4	1.02	0.078	0.015	0.797	0.227				0.907
Antes Bocatoma Azapa	7.94	756	1.601	191.8	50	135	55.4	31.4	7.0	60.5	1.60	0.080	0.015	1.399	0.126	0.007	0.075	0.062	1.188
Aqueducto Azapa en Bocatoma	7.93	811	6.045	207.4	53	155	54.3	34.1	8.2	67.5	1.68	0.118	0.061	0.829	0.135	0.004	0.133	0.073	0.487
Puente Saucache	7.47	634	0.100	172.8	56	130	77.3	15.8	6.3	47.3	1.13	0.085	0.112	0.824	0.402	0.005		0.000	-

Table A, 1.9 Flood Water Volume at Saucache and Antes Bocatoma

<Volumen de Inundación en Saucache y Antes Bocatoma>

Year	Number of Flooding days	Total Water Volume at Saucache (m3)	Total Water Volume at Antes Bocatoma (m3)	Ratio (%)
1976	75	16,936,933	55,585,958	30.47 %
1977	33	16,799,754	45,549,302	36.88 %
1978	2	276,096	25,753,162	1.07 %
1979	17	1,826,638	31,185,216	5.86 %
1980	6	642,474	22,796,899	2.82 %
1981	5	984,932	17,212,694	5.72 %
1982	1	60,877	16,775,683	0.36 %
1983	No Flood	0	12,398,659	0.00 %
1984	26	4,850,161	15,255,821	31.79 %
Average for 9 consecutive years		4,708,652	26,945,933	17.47 %

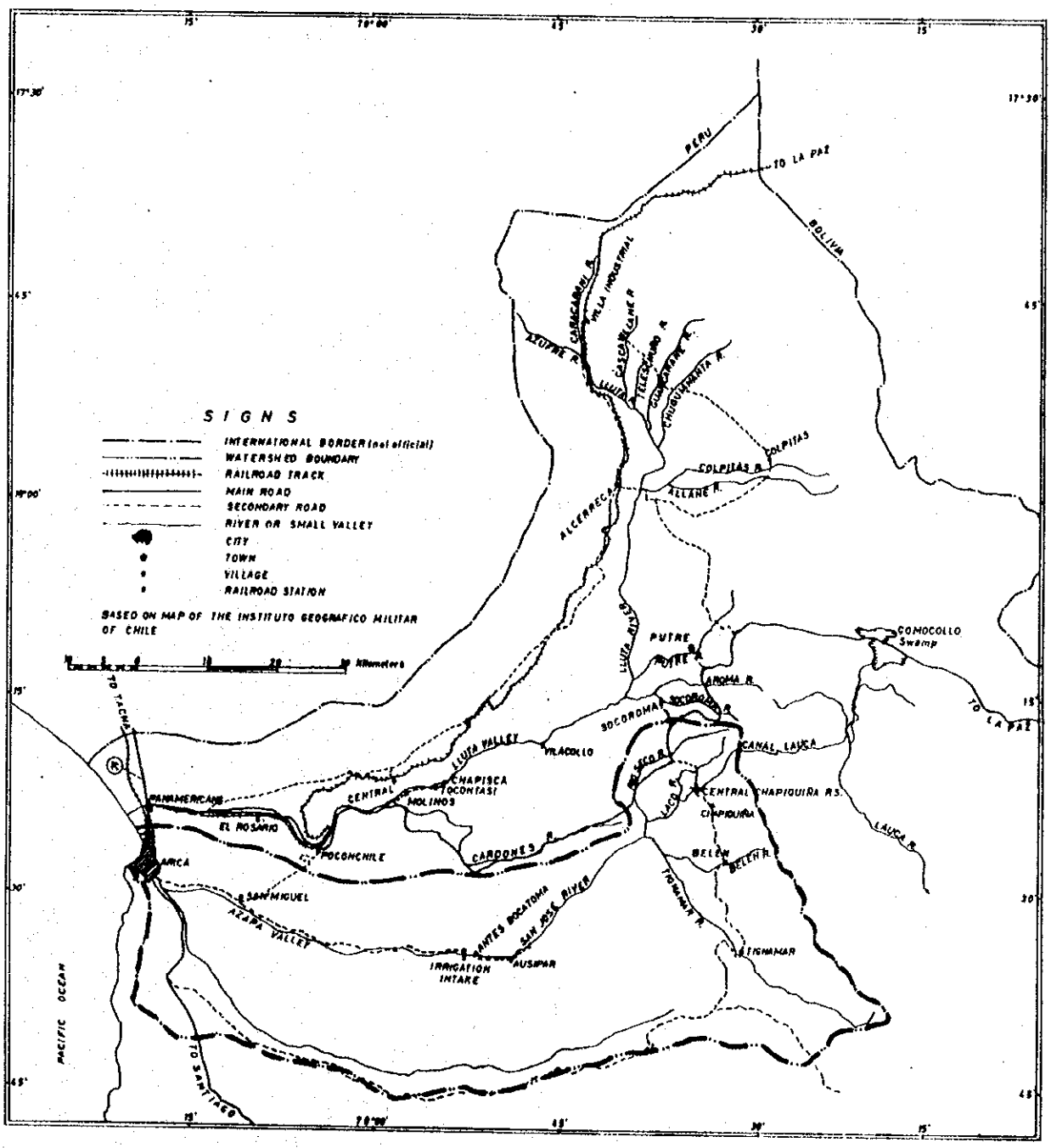


Fig. A, 1.1 River System of San José River Basin

<Systema Fluvial de la Cuenca del Rio San José>

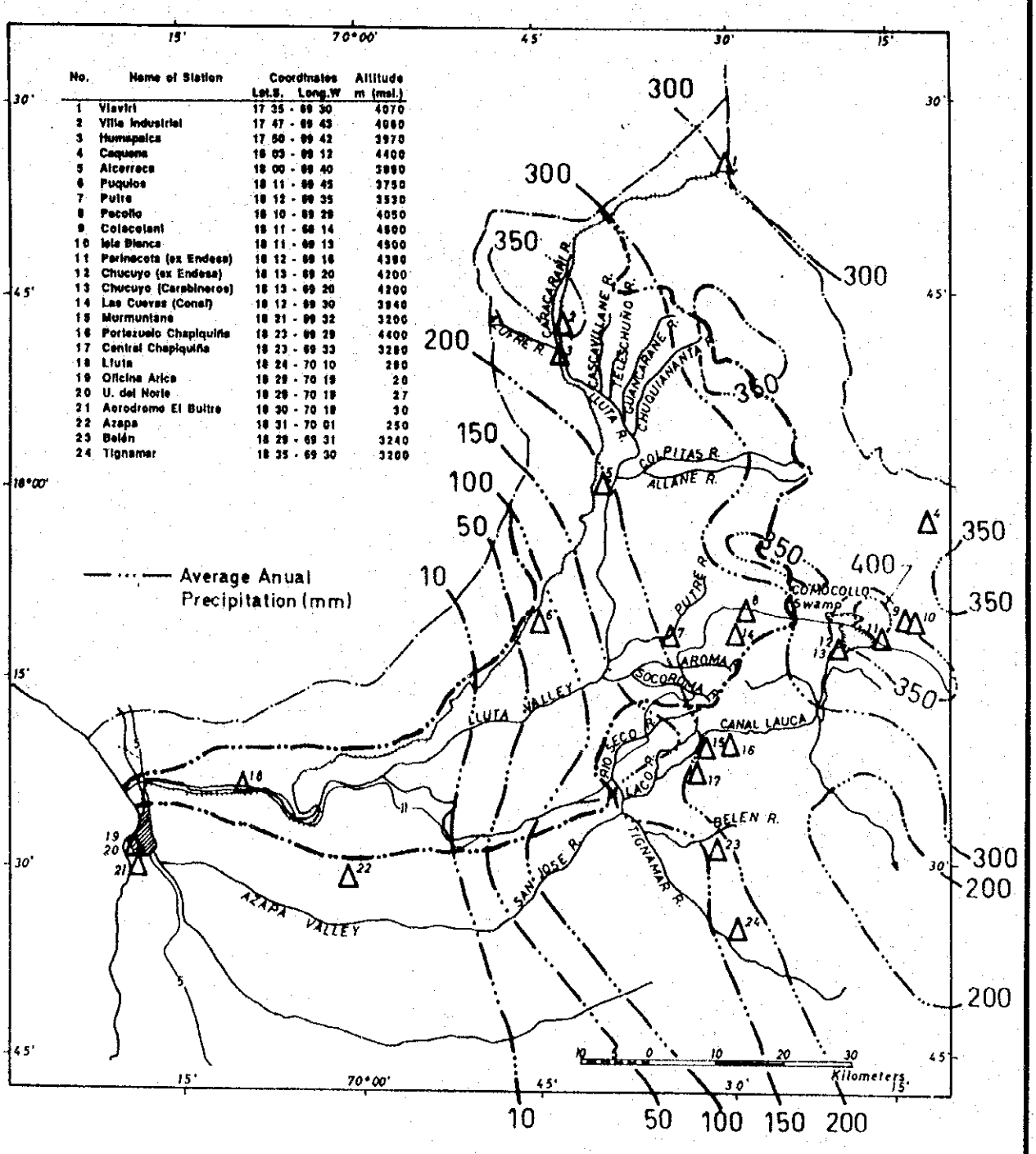
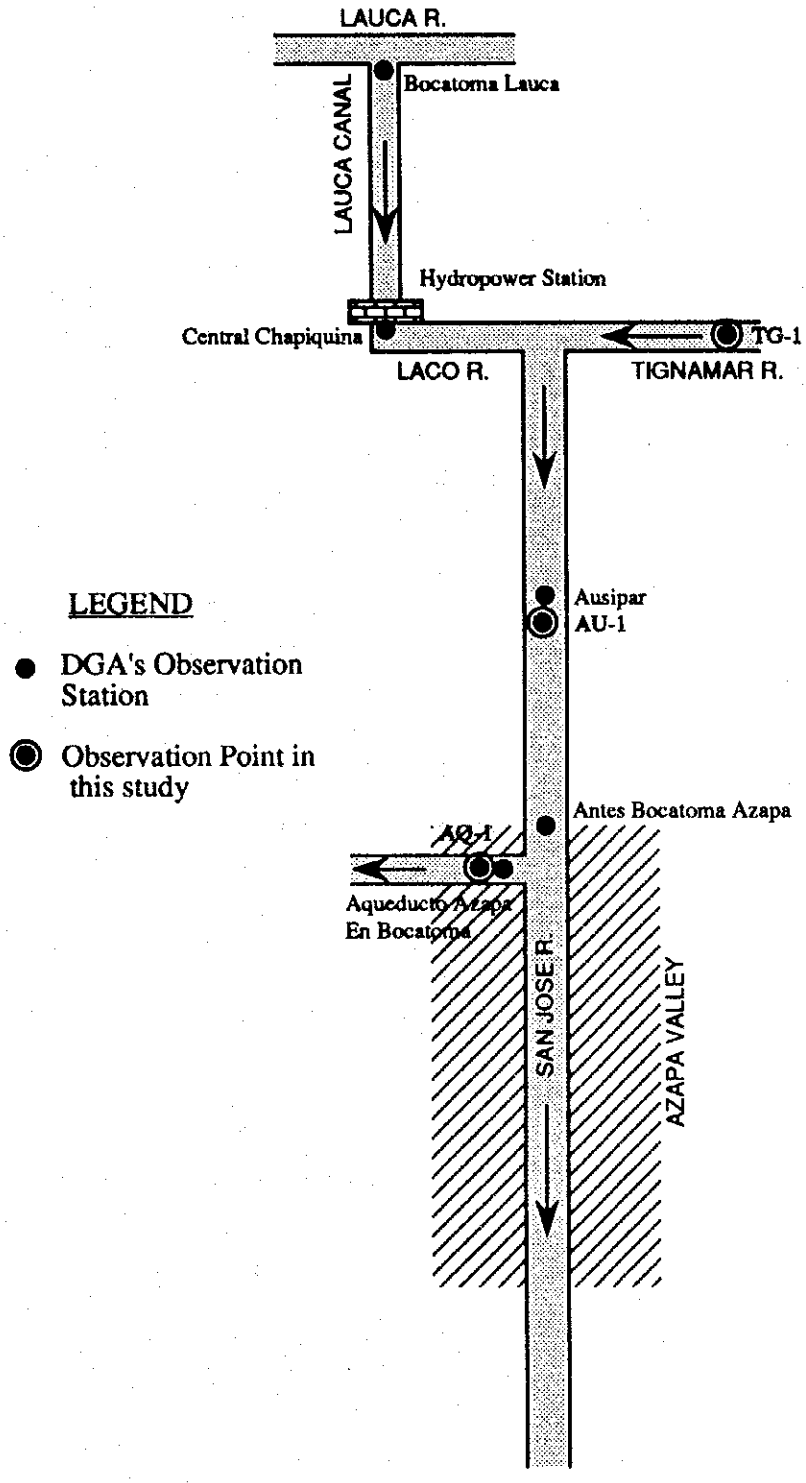


Fig. A, 1.2 Average Precipitation (Isohyetal Map) in San José River Basin

<Precipitacion Promedio en Mapa de Isoyeta en la Cuenca del Río San José>



Flow Model in San Jose River Basin

Fig. A, 1.3 Flow Model in San José River Basin

<Modelo de Flujo en la Cuenca del Rio San José>

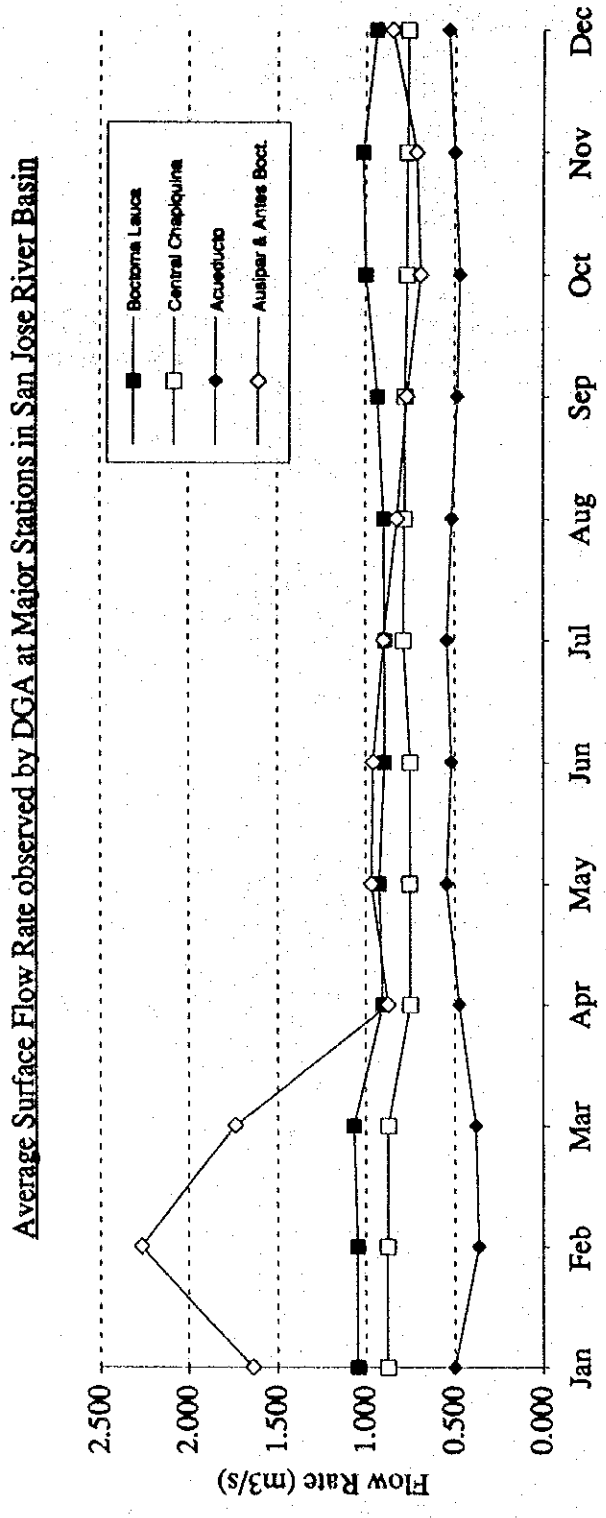


Fig. A, 1.4 Average Surface Flow Rate in San José River Basin

<Nivel de Flujo de Superficie Premedio Meansual de la Cuenca del Rio San José>

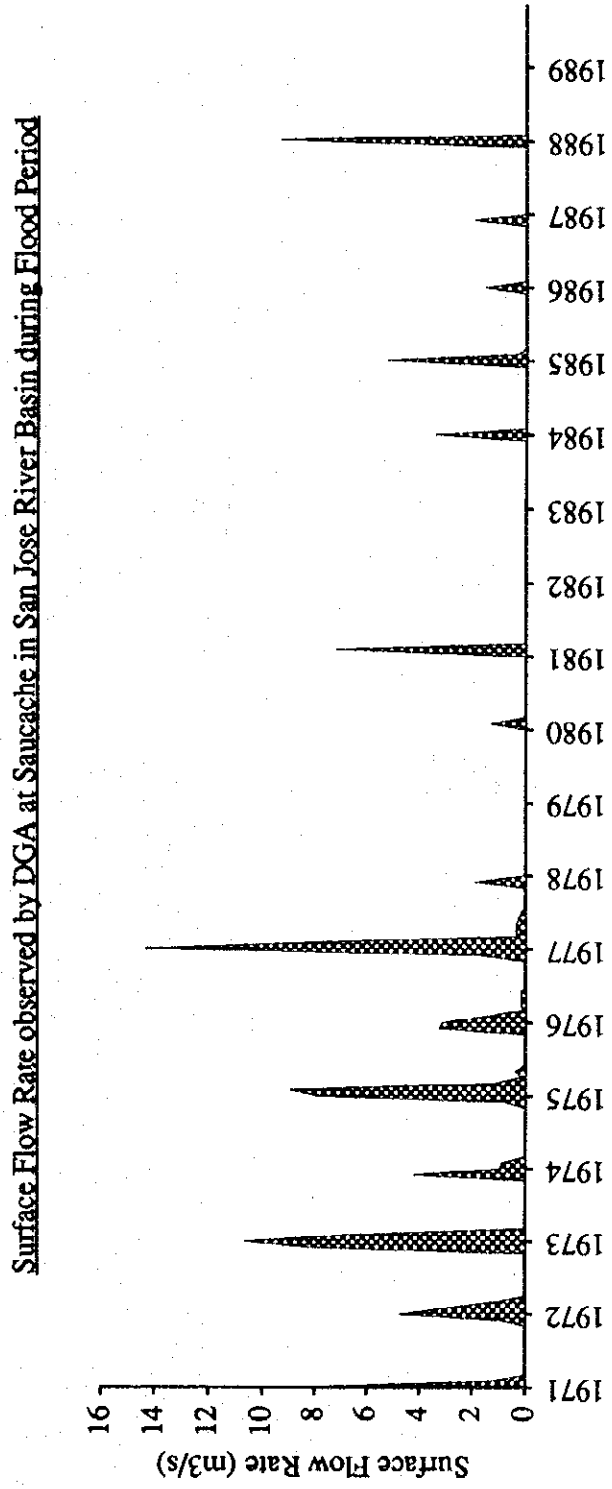


Fig. A, 1.5 Surface Flow Rate at Saucache during Flood Period

<Nivel de Flujo de Superficie en Saucache durante el Periodo de Avenidas>

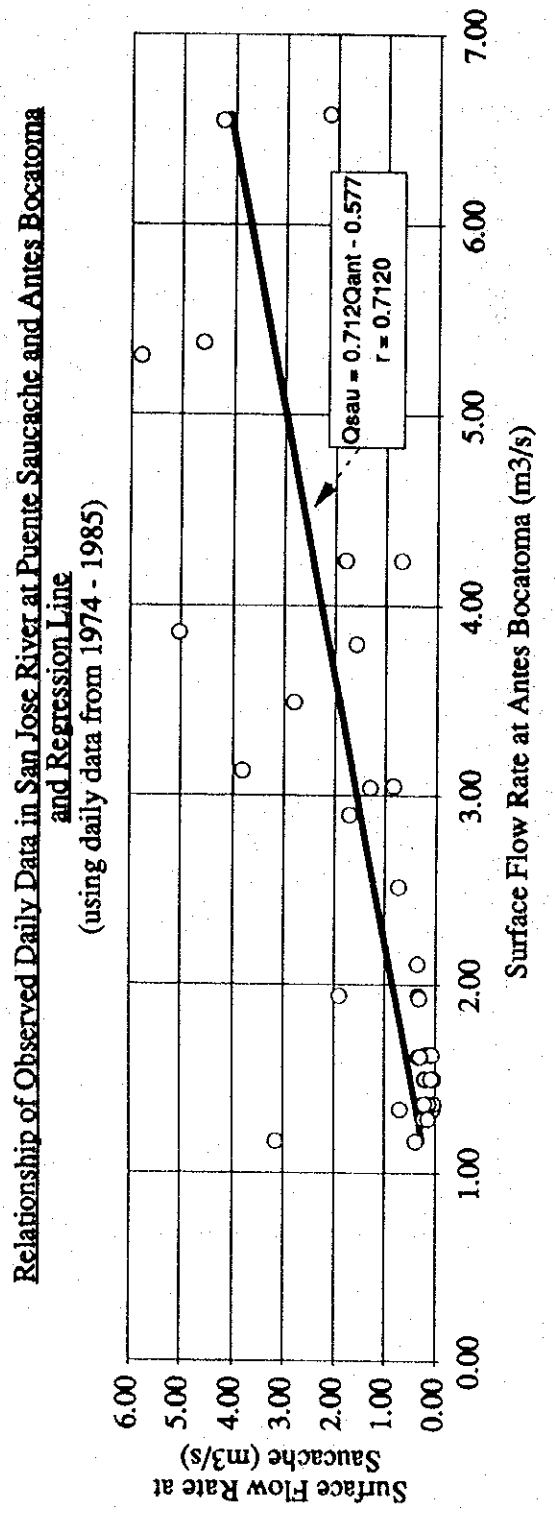


Fig. A, 1.6 Relationship of Observed Data at Saucache and Antes Bocatoma and Regression line
<Relacion de Datos Observado en Saucache y Antes Bocatoma y Linea de Regresion>

Chapter II SURFACE WATER OF LLUTA RIVER BASIN

2.1 General

Lluta River basin located in the Region I in northern Chile has a drainage basin area of about 3,378 km^2 covering the sub-basins of Azufre, Caracarani, Cascavillane, Teleschuno, Guancarane, Chuquiananta, Colpitas, Allane, Putre, Aroma and Socoroma rivers. The drainage basin area is shown in Fig. A, 2.1 and Table A, 2.1.

2.1.1 Climate and Precipitation

Information on climate in the basin is obtained from Lluta, Pacollo and Putre weather stations. Average temperature is different between lower and upper basin. In lower basin (Lluta and Pacollo), Maximum monthly average temperature is in January at 34.6 °C and minimum monthly average temperature is in June at 10.1 °C while those of upper basin (Putre) are 29.2 °C and 2.5 °C in the same period. Humidity does not vary much throughout a year lying within a range of 60 - 80 %.
Precipitation is observed regularly by DGA and Meteorological Department. Most of the stations are distributed in the upstream of the basin as shown in Fig. A, 2.2.

Most of the precipitation fall in the upstream mountain areas with an altitude of higher than 3,000 m. On the other hand, the lower reaches receive almost no rainfall throughout the year. Average annual precipitation regionally varies from zero in the lower most reaches to 350 mm at Villa Industrial station located in the upstream highland.

More than 90 % of the precipitation in the basin concentrates during the four (4) months of December and March.

2.1.2 River System

Lluta River, the main river in the basin, flows westwards to Pacific Ocean in the north of San José River basin and is named after the confluence of several tributaries. Main tributaries are Azufre, Caracarani, Cascavillane, Teleschuno, Guancarane, Chuquiananta, Colpitas, Allane, Putre, Aroma and Socoroma. Flow originates from the

mountain areas in the north and north-east. In the north, Caracarani River, a main tributary, flows southwards, joins Azufre, Cascavillane, Teleschuno, Guancarane and Chuquiananta rivers in between Humapalca and Alcerreca. In the north-east, Colpitas and Allane River flow eastwards and meet Caracarani at Alcerreca. Lluta River, named after this confluence, combines with Putre, Aroma and Socoroma River at Putre, flows through Lluta Valley and down to Pacific Ocean at Arica city.

Several tributaries and Quebradas in the basin are not taken into consideration in the flow model because flow rates are negligibly small based on data and information from DGA. Flow model is shown in Fig. A, 2.3.

2.2 Surface Flow Rate

2.2.1 Flow Rate at Major Stations

Daily water level is observed at DGA's observation stations by automatic recorder. Flow rate at each station is generally calculated by so called "Discharge Rating Curve" or "H-Q Curve" which is a calibration curve of water level and flow rate. Major observation stations are as follows;

River	Location	Observation Period
Caracarani	Humapalca	1973 - Present
	Alcerreca	1961 - 1984
Colpitas	Alcerreca	1961 - Present
Lluta	Alcerreca	1961 - Present
	Tocontasi	1946 - 1985
	Chapisca	1987 - Present
	Panamericana	1969 - Present

Data at Tocontasi and Chapisca are combined together in the analysis because the station at Chapisca is a new re-located station of that at Tocontasi.

Monthly average surface flow rate at these stations are shown in Table A, 2.2. Fluctuation of these flows throughout the year are shown in Fig. A.2.4. Recorded monthly flow rates are shown in Appendix A, 2.1.

At Azufre River, there is no permanent observation station. Observation has been done since 1985 up to the present occasionally at about once in a month by measuring velocity and cross sectional area, not by H-Q curve.

Therefore, average monthly flow rate of Azufre River is calculated from the correlation with flow rate of Caracarani River at Humapalca as shown in Fig. A, 2.5. Relationship between these two points is obtained as follows;

$$Q_{Caracarani} = 1.40Q_{Azufre} + 0.261$$

where Correlation Coefficient (r) = 0.7053

Monthly average surface flow rate at Azufre River in Humapalca are shown in Table A, 2.3.

Yearly average flow rate at Tocontasi/Chapisca of Lluta River is 2.216 m^3/s. This flow rate is distributed to the upstream tributaries as shown below.

River	Flow Rate (m^3/s)	Portion
Caracarani	0.378	17 %
Azufre	0.084	4 %
Cascavillane + Teleschuno + Guancarane + Chuquiananta	0.396	18 %
Colpitas	0.521	24 %
Putre + Aroma + Socoroma	0.331	15 %
Unknown	0.509	23 %
Lluta	2.216	100 %

Unknown flow is the balance of Lluta River at Alcerreca (1.885 m^3/s) and Caracarani River at Alcerreca (0.855 m^3/s) plus Colpitas River at Alcerreca (0.521 m^3/s).

Exceedance probability of the surface flow rate was calculated by Hazen Method to evaluate drought flow rate.

Exceedance probability in Hazen Method is defined as follows;

$$P(x_j) = \frac{2j - 1}{(2N)} \quad \text{and} \quad F(x_j) = 1 - P(x_j)$$

where $P(x_j)$ = Exceedance Probability
x = variable (flow rate)
j = order of x_j counted from the largest sample
N = size of sample

Flow rates with 80 % and 90 % exceedance probability are calculated for the respective stations of Lluta River and its tributaries as shown in Table A, 2.4. Monthly variation of these probable flow rates are shown in Appendix A, 2.2.

Flow rate in Caracarani at Humapalca and Alcerreca, Colpitas at Alcerreca and Lluta at Chapisca & Tocontasi and Panamericana are analyzed as shown in Table A, 2.4 and monthly fluctuations are shown in Appendix A, 2.2.

2.2.2 Calculation of Runoff Coefficient

The surface runoff coefficients of Lluta River at Alcerreca and Tocontasi were estimated by comparing the average indigenous flow rates at these stations with the average annual precipitation in their upstream basin.

The average annual indigenous flow rates in these stations were obtained from the regular observation of DGA. The average annual precipitation in their upstream basin were estimated based on the isohyetal map of annual precipitation prepared by DGA in 1987 as shown in Fig. A, 2.2.

Runoff coefficient is found to be 0.186 at Alcerreca and 0.143 at Tocontasi as shown in Table A, 2.5 and A, 2.6. This can be interpreted that about 18.6 % of rainfall flows through rivers in the upstream and 14.3 % in the midstream as surface flow.

2.3 Surface Water Quality

2.3.1 Water Quality at Major Stations

Water quality is observed regularly by DGA. Water quality samples are taken from the river and analyzed in the laboratory. The observation stations are as follows;

River	Location	Observation Period
Caracarani	Humapalca	1967 - 1985
	Alcerreca	1967 - 1989
Azufre	Humapalca	1967 - 1984
Colpitas	Alcerreca	1967 - 1989
Lluta	Alcerreca	1967 - 1985
	Tocontasi	1967 - 1987
	Poconchile	1968 - 1985
	Panamericana	1967 - 1989

The items of the analysis are classified as follows;

(1) Health Significance : As, $N\text{-}NO_3$, $N\text{-}NO_2$, $N\text{-}NH_3$

(2) Aesthetic Quality : Cl^-, Cu, Fe, Na, P, SO_4, pH

(3) Others : HCO_3, CO_3, Ca, Mg, K, B, E.C.

Results of the examination are shown in Table A, 2.7 and A, 2.8. Average monthly data are shown in Appendix A, 2.3

2.3.2 Evaluation of Water Quality

Water of Lluta River and tributaries are much contaminated by the pollutants mainly originating from natural contamination sources.

The worst two (2) rivers in terms of the health significance are

Number 1 Azufre River at Humapalca

Number 2 Colpitas River at Alcerreca

Information on water quality of the other main tributaries including Cascavillane, Teleschuno, Guancarane, Chuquiananta, Putre, Aroma and

Socoroma, were obtained from the supplementary observation in this study as explained in the following section.

2.4 Supplementary Observation

2.4.1 Simultaneous Observation in the Upstream Tributaries

1) Objective

The purposes of the supplementary observation are to measure flow rates in the tributaries which are not regularly observed by DGA, to check flow balance and the examine water quality in the Lluta River.

2) Location

Observation points are located as follows:

Location	Code	Latitude	Longitude
1. Azufre	AZ-1	17° 50′	69° 43′
2. Caracarani, before confluence with Azufre	CR-1	17° 50′	69° 42′
3. Cascavillane	CV-1	17° 51′	69° 39′
4. Teleschuno, Queb. Teleschuno	TL-1	17° 51′	69° 38′
5. Teleschuno, Queb. Gualluma	TL-2	17° 51′	69° 38′
6. Guancarane	GC-1	17° 51′	69° 36′
7. Chuquiananta	CQ-1	17° 52′	69° 35′
8. Colpitas	CP-1	17° 57′	69° 28′
9. Allane	AL-1	17° 59′	69° 28′
10. Putre, Queb. Llancomane	PT-1	18° 10′	69° 31′
11. Putre, Queb. Pacollo	PT-2	18° 10′	69° 30′
12. Putre, Queb. Taipicahua	PT-3	18° 11′	69° 30′
13. Putre, Queb. Jurase	PT-4	18° 12′	69° 30′
14. Putre, Queb. Lluscuma	PT-5	18° 12′	69° 30′
15. Aroma	AR-1	18° 14′	69° 33′
16. Socoroma	SR-1	18° 16′	69° 31′
17. Chapisca	TC-1	18° 23′	69° 55′

Locations of these points are shown in Fig. A, 2.3 and A, 2.6.

3) Observation Method

The measurement was conducted by JICA Study Team & DGA. River conditions during the measurement are shown in Appendix A, 2.4. The items of measurement are as follows;

(1) Flow Rate

Flow velocity was measured by a propeller current meter across the river section at a length interval of about 1/10th of the river width. Flow rate was calculated as the product of average velocity times cross sectional area

$$Q = \sum_{i=1}^{m} V_i \times A_i$$

where Q = flow rate (m^3/s),
V = flow velocity (m/s),
A = cross sectional area of the river (m^2) and
m = number of sub-cross sections.

(2) Water Quality

Samples were taken from the checking points and analyzed mostly in the DGA laboratory following the standard method of water quality analysis. However, pH, EC, Temperature, Turbidity and DO were analyzed in situ. Items of the analysis are classified as follows;

(i) Health Significance : As, Cd, Cr, CN, F, Pb, NO_3

(ii) Aesthetic Quality : Al, Cl^-, Cu, $CaCO_3$, Fe, Mn, Na, SO_4, TDS, Zn, pH

(iii) Others : HCO_3, CO_3, Ca, Mg, K, B, E.C. Temperature, Turbidity, DO

4) Date of Observation

Observation was carried out on 1st - 3rd June 1993.

5) Results of Observation

(1) Surface Flow Rate

Flow rate at each point is shown in Table A, 2.9.

Results of flow rates measured in Azufre (0.076 m^3/s) and Caracarani River (0.394 m^3/s) at Humapalca show a good agreement with the calculated flow rate in Caracarani from the correlation as mentioned previously (0.367 m^3/s). The difference is about 7 %.

Balance of flow are as follows;

River	Flow Rate (m^3/s)	Portion
Caracarani	0.394	33%
Azufre	0.076	6%
Cascavillane + Teleschuno + Guancarane + Chuquiananta	0.334	29 %
Colpitas + Allane	0.231	19%
Putre	0.315	27%
Aroma	0.033	3%
Socoroma	0.012	1%
Unknown	-0.211	-15%
Total	1.184	100%

Unknown flow from this balance is -15 % of flow in Lluta River at Alcerreca. This contradicts the unknown flow from average monthly balance (23 %). It may be attributed mainly to the error of measurement.

Major water sources of Lluta River are Caracarani (33 %), Cascavillane+Teleschuno+Guancarane+Chuquiananta (29 %) and Putre River (27 %). These sources contribute about 89 % to Lluta River.

(2) Water Quality

Results of the examination is shown in Table A, 2.10. Classification as acceptable and unacceptable rivers in water

quality of the tributaries of Lluta River according to Water Quality Standard, shown in Appendix A, 5, is as follows;

River	Flow Rate (m^3/s)	Portion
Unacceptable		
Azufre	0.076	6 %
Colpitas	0.211	17%
Cascavillane	0.082	7%
Allane	0.020	2%
Putre : Pacollo	0.017	2%
Putre : Jurase	0.009	1%
Sub-total	0.415	35%
Acceptable		
Teleschuno	0.007	1%
Guancarane	0.168	15%
Chuquiananta	0.077	7%
Caracarani	0.394	33%
Putre : Llancomane	0.043	4%
Putre : Taipicahua	0.184	16%
Aroma	0.033	3%
Socoroma	0.012	1%
Sub-total	0.918	80%
Putre : Lluscuma	0.062	6%
Unknown	-0.211	-15%
Total at Chapisca	1.184	100%

It should be noted that water quality at Lluscuma was not observed.

2.4.2 Intensive Observation in the Contaminated Tributaries

1) Objective

From the result of water quality examinations mentioned above, Azufre and Colpitas Rivers are the most contaminated tributaries of Lluta River. However, contaminated sources of these rivers need to be observed intensively for water potential development. Identification of the definite contaminated sources of these rivers is the purpose of this observation.

2) Location

Observation points are shown in Fig. A, 2.7 for Azufre River and Fig. A, 2.8 for Colpitas River.

3) Observation Method

The measurement was conducted by DGA in cooperation with JICA Study Team. Observation items and method are the same as that of the simultaneous observation in Section 2.4.1.

4) Date of Observation

Observation was carried out in the middle of November 1993 and took about 2 weeks.

5) Results of Observation

Flow rate and water quality in these tributaries are shown in Table A, 2.11 and A, 2.12(1) to 2.12(6).

Conclusions drawn from the observation result are as follows;

Azufre River (refer to Table A, 2.12(7) and Fig. A, 2.7)

(1) Flow Rate

- The location, so called Agua Calientes is considered as the original water source of Azufre River with the springs AV-1, AV-2, AV-3, AV-4, AV-5, AV-6 and AV-7.

- There was no flow at A-6 and A-7 because water infiltrated into underground from A-8 and emerged to surface again at A-5A. Hence, flow rate and water quality were not measured at A-6 and A-7.

- Flow rate at A-5A is higher than A-3 because water partly infiltrates into underground again along the river course between these 2 points.

- Flow rate at A-1 (Lluta) approximately equals A-3 (Azufre)+ A-4 (Caracarani)

A-1 (100%) = A-3 (30%) + A-4 (70%)

(2) Water Quality

- Azufre River is contaminated from its original source at Agua Calientes at AV-1, AV-2 and AV-7. Although flow rates of these points are apparently low, in wet season the pollutants will be washed out to the stream.

- Water quality at A-8 is worse than at A-10 although the tributary at A-11 is comparatively clean. This may be because pollutant source is from the river bed along the stream, not from the tributary.

- Water quality becomes better from A-8 to A-5A.

- Another contaminated source is at A-5B.

Colpitas River (refer to Table A, 2.12(8) and Fig. A, 2.8)

(1) Flow Rate

- Flow originates from the mountains in the east outside the study drainage basin with several tributaries flowing into 2 main tributaries.

- Main tributaries are Colpitas and Allane Rivers with the portion of Allane (C-4) 58 % and Colpitas (C-5) 42 %.

(2) Water Quality

- Contaminated source is the whole upstream part of Colpitas River at C-11A, C-11B, C-10, C-6 and C-5.

- Although Allane River is comparatively clean, water quality is still higher than the standard limit.

- Small tributaries between C-3 and confluence of C-4 (Allane) and C-5 (Colpitas) at CV-1 to CV-5 also discharge a large amount of pollutants to the river.

(Note)

The Boron concentration of 5.56 mg/l at C1 point observed in November, 1993 is considered to have some error because that:

(i) This concentration of 5.56 mg/l is very low compared to the average concentration of 9.85 mg/l in the past. The Boron concentrations at C1, C2 and C3 points observed in November, 1993 are compared to their average concentrations in the past (1967-1989) as follows.

Sampling Point	Nov. 1993	Average in Past
C1 (Caracarani Alcerreca)	3.87 mg/l	5.8 mg/l
C2 (Colpitas Alcerreca)	22.61	21.55 mg/l
C3 (Lluta Alcerreca)	5.56	9.85 mg/l

(ii) The pollution loads (g/s) of Boron at C2 and C3 points observed in November, 1993 are considered nearly correct in comparison with the pollution loads in their upstream reaches.

(iii) If the concentration of Boron at C1 point observed in November, 1993 is replaced by the average concentration in the past, the pollution loads of Boron among C1, C2 and C3 points are roughly balanced as follows.

C2 + C3 = 2.183 g/s + 7.823 g/s = 10.006 g/s
C1 = 9.180 g/s

Flow balance in the Lluta River is re-calculated based on the assumption that contaminated sources at A-8 point in Azufre River (whose share is 65 % of total flow in Azufre River) and C-10 point in Colpitas River (whose share is 67 % of total flow in Colpitas River) are evaporated. Comparison of the flow balance with and without evaporation at these points are as follows;

River	Flow Rate (m^3/s) (without evaporation of A-8 and C-10)		Flow Rate (m^3/s) (with evaporation of A-8 and C-10)	
Unacceptable				
Azufre	0.076	6 %	0.027	3 %
			(35 % of Azufre)	
Colpitas	0.211	17%	0.070	7 %
			(33 % of Colpitas)	
Cascavillane	0.082	7 %	0.082	8 %
Allane	0.020	2 %	0.020	2 %
Putre : Pacollo	0.017	2 %	0.017	2 %
Putre : Jurase	0.009	1 %	0.009	1 %
Sub-total	0.415	35%	0.225	23 %
Acceptable				
Teleschuno	0.007	1 %	0.007	1 %
Guancarane	0.168	15%	0.168	17 %
Chuquiananta	0.077	7 %	0.077	8 %
Caracarani	0.394	33%	0.394	40 %
Putre : Llancomane	0.043	4 %	0.043	4 %
Putre : Taipicahua	0.184	16%	0.184	18 %
Aroma	0.033	3 %	0.033	3 %
Socoroma	0.012	1 %	0.012	1 %
Sub-total	0.918	80 %	0.918	92 %
Putre : Lluscuma	0.062	6 %	0.062	6 %
Unknown	-0.211	-15 %	-0.211	-21 %
Total at Chapisca	1.184	100 %	0.994	100 %

After evaporation of the contaminated sources in Azufre and Colpitas Rivers, portion of flow rate in Lluta River which water quality is acceptable increases from 80 % to 92 %.

2.5 Evaluation of Surface Water Development Potential

Evaluation of surface water potential in Lluta River basin is done by considering the water potential to be stored by a dam or reservoir before flowing to the sea. Tocontasi & Chapisca is selected for the analysis instead of Panamericana due to the insufficient recorded years at Panamericana.

Accumulated water volume from 1946 to 1990 at Tocontasi & Chapisca is plotted with the assumed amount of water release at this station as shown in Fig. A, 2.9. From this mass curve, approximate slope of the observed data is in between flow rate of 2.0 and 3.0 m^3/s. This means that water release from Tocontasi should be less than 3.0 m^3/s in order to maintain the storage. Monthly volume storage is calculated as shown in Fig. A, 2.10. Inflow is the actual recorded flow rate and outflow is the assumed water release from this station.

Storage volume of the dam is determined by accumulating the balance of inflow and outflow. Outflow of 1.5 and 2.0 m^3/s are selected for the calculation. From this calculation, maximum and minimum accumulated volume storages are listed in Table A, 2.13 and A, 2.14. Rising period means the period that volume storage is in the minimum stage, the following actual flow is higher than the water release (1.5 or 2.0 m^3/s) and the volume storage is gradually increasing. The reverse condition implies for decreasing period.

Probability of nonexceedance (F(x)) is used to find out the return period year of the volume storage. The results are shown in Table A, 2.15 and A, 2.16.

The required volume storage is determined from the maximum storage volume during decreasing period to ensure the condition of no empty storage. It can be briefly summarized that

For return period of 10 years;

Storage volume = 15,375,456 m^3, if water release = 2.0 m^3/s

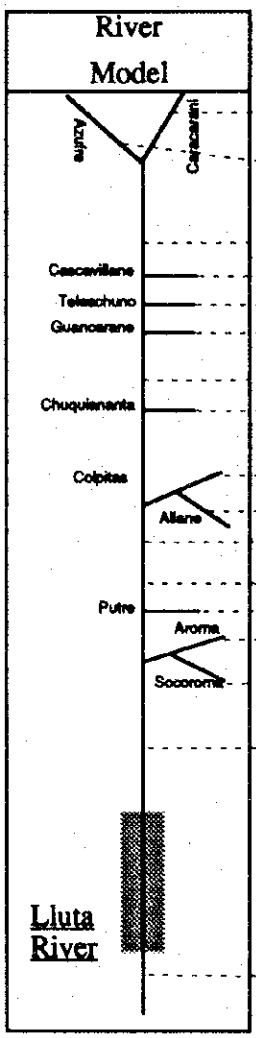
Storage volume = 5,086,848 m^3, if water release = 1.5 m^3/s

For return period of 5 years;

Storage volume = 12,913,171 m^3, if water release = 2.0 m^3/s

Storage volume = 3,361997 m^3, if water release = 1.5 m^3/s

Table A, 2.1 Drainage Basin and Sub-Basin Areas in Lluta River Basin
<Cuenca de Drenaje y Area Sub-cuenca en Cuenca del Rio Lluta>



River	Tributaries	Location	Sub-Basin (km2)	Total Basin (km2)
	Caracarani	Humapalca	141.3	141.3
	Azufre	Humapalca	37.3	178.6
Lluta		Humapalca	90.7	269.3
	Cascavillane		28.2	297.5
	Teleschuno		40.8	338.2
	Guancarane		101.1	439.4
Lluta			123.1	562.5
	Chuquiananta		142.1	704.6
	Colpitas		218.6	923.2
	Allane		245.6	1,168.8
Lluta		Alcerreca	-	1,168.8
Lluta			485.2	1,654.1
	Putre		304.3	1,958.3
	Aroma		70.5	2,028.9
	Socoroma		50.5	2,079.3
Lluta		Tocontasi	470.7	2,550.0
Lluta		River Mouth	828.0	3,378.0

Table A, 2.2 Average Surface Flow Rate Observed by DGA at Major Stations in Lluta River Basin

<Nivel de Flujo de Superficie Promedio Meansual Observado por DGA en las Principales Estaciones de la Cuenca del Rio Lluta>

Unit : m^3 /s

River	Location	Obs. Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVG
Caracarani	Humapalca	1973-1990	0.698	0.625	0.475	0.317	0.303	0.303	0.426	0.321	0.268	0.268	0.242	0.295	0.378
	Alcerreca	1961-1984	0.965	1.343	1.022	0.864	0.760	0.796	0.861	0.828	0.761	0.677	0.637	0.752	0.855
Colpitas	Alcerreca	1961-1990	0.705	0.812	0.668	0.580	0.469	0.452	0.442	0.423	0.407	0.411	0.419	0.465	0.521
Lluta	Alcerreca	1961-1990	2.939	3.832	3.088	1.795	1.512	1.531	1.498	1.386	1.406	1.146	1.137	1.351	1.885
	Tocontasi	1946-1985	2.940	4.590	4.410	1.770	1.790	1.840	1.980	1.760	1.560	1.340	1.290	1.490	2.230
	Chapisca	1987-1990	2.250	6.060	1.950	1.670	1.490	1.530	1.500	1.390	1.440	1.230	1.130	1.260	1.908
	Avg.(Tocontasi+Chapisca)		2.887	4.741	4.222	1.759	1.809	1.802	1.937	1.746	1.542	1.332	1.307	1.508	2.216
	Panamericana	1969-1990	2.807	6.104	2.321	0.839	0.751	1.128	1.023	0.566	0.339	0.208	0.164	0.371	1.385

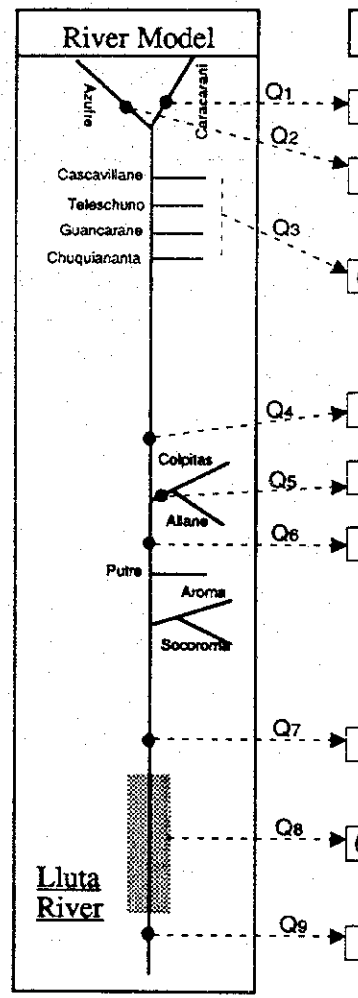
Note : Average flow rate in Tocontasi and Chapisca is calculated by weighted average of the recorded years

Table A, 2.3 Average Surface Flow Rate in Lluta River Basin

<Nivel de Flujo de Superficie Promedio en la Cuenca del Rio Lluta>

(Recorded period of the stations are different but range from 1946 to 1990)

Unit : m^3/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVG
Q_1 Humapalca	0.698	0.625	0.475	0.317	0.303	0.303	0.426	0.321	0.268	0.268	0.242	0.295	0.378
Q_2 Humapalca (Data in Azufre River are interpolated from the Correlation with Caracarani River in Alcerreca)	*0.312*	*0.260*	*0.153*	*0.040*	*0.030*	*0.030*	*0.118*	*0.043*	*0.005*	*0.005*	*0.000*	*0.024*	*0.084*
Q_3 Calculated from Flow Balance ($Q_3 = Q_4 - Q_2 - Q_1$)	*0.000*	*0.458*	*0.395*	*0.507*	*0.426*	*0.463*	*0.318*	*0.464*	*0.487*	*0.404*	*0.395*	*0.432*	*0.396*
Q_4 Caracarani in Alcerreca	0.965	1.343	1.022	0.864	0.760	0.796	0.861	0.828	0.761	0.677	0.637	0.752	0.855
Q_5 Colpitas	0.705	0.812	0.668	0.580	0.469	0.452	0.442	0.423	0.407	0.411	0.419	0.465	0.521
Q_6 Lluta in Alcerreca	2.939	3.832	3.088	1.795	1.512	1.531	1.498	1.386	1.406	1.146	1.137	1.351	1.885
Q_7 Tocontasi & Chapisca	2.887	4.741	4.222	1.759	1.809	1.802	1.937	1.746	1.542	1.332	1.307	1.508	2.216
Q_8 Agricultural Consumption, calculated from Flow Balance ($Q_8 = Q_7 - Q_9$)	*0.080*	*0.000*	*1.900*	*0.921*	*1.058*	*0.674*	*0.915*	*1.180*	*1.203*	*1.124*	*1.143*	*1.137*	*0.831*
Q_9 Panamericana	2.807	6.104	2.321	0.839	0.751	1.128	1.023	0.566	0.339	0.208	0.164	0.371	1.385

Table A, 2.4 Average and Probable Surface Flow Rate at Major Stations in Lluta River Basin

<Nivel Promedio y Flujo Probable de Superficie en las Estaciones Principales en la Cuenca del Rio Lluta>

Unit : m^3/s

River	Location	Probability Exceedance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVG
Caracarani	Humapalca	Average	0.698	0.625	0.475	0.317	0.303	0.303	0.426	0.321	0.268	0.268	0.242	0.295	0.378
		90%	0.258	0.066	0.256	0.255	0.257	0.243	0.240	0.211	0.218	0.182	0.140	0.142	0.206
		80%	0.315	0.167	0.289	0.257	0.268	0.244	0.254	0.244	0.233	0.201	0.185	0.192	0.237
	Alcerreca	Average	0.965	1.343	1.022	0.864	0.760	0.796	0.861	0.828	0.761	0.677	0.637	0.752	0.855
		90%	0.579	0.436	0.368	0.567	0.659	0.559	0.739	0.688	0.619	0.521	0.424	0.514	0.556
		80%	0.710	0.565	0.535	0.617	0.692	0.734	0.784	0.736	0.633	0.528	0.522	0.579	0.636
Colpitas	Alcerreca	Average	0.705	0.812	0.668	0.580	0.469	0.452	0.442	0.423	0.407	0.411	0.419	0.465	0.521
		90%	0.402	0.412	0.394	0.371	0.288	0.296	0.271	0.264	0.289	0.270	0.282	0.333	0.323
		80%	0.453	0.437	0.446	0.433	0.372	0.365	0.304	0.356	0.344	0.353	0.332	0.355	0.379
Lluta	Tocontasi & Chapisca	Average	2.887	4.741	4.222	1.759	1.809	1.802	1.937	1.746	1.542	1.332	1.307	1.508	2.216
		90%	1.250	1.502	1.320	1.260	1.215	1.309	1.554	1.328	1.228	1.094	1.037	1.018	1.260
		80%	1.614	1.813	1.830	1.400	1.444	1.521	1.589	1.470	1.302	1.168	1.089	1.091	1.444
	Pan-americana	Average	2.807	6.104	2.321	0.839	0.751	1.128	1.023	0.566	0.339	0.208	0.164	0.371	1.385
		90%	0.393	0.246	0.382	0.098	0.159	0.565	0.696	0.253	0.096	0.049	0.069	0.072	0.256
		80%	0.611	0.433	0.517	0.164	0.297	0.710	0.786	0.317	0.125	0.067	0.078	0.082	0.349

Table A, 2.5 Average Runoff Coefficient in Lluta River Basin
<Coeficientes de Escorrentia Promedios en la Cuenca de Rio Lluta>

Location : **Lluta River at Alcerreca**

Rainfall Range (mm)	Average Rainfall R (mm)	Total River Basin (km2)	Upstream Basin of Alcerreca A (km2)	Average R*A (mm.km2)	Upstream Avg. Rainfall R (mm) (R*A/A)	Flow Rate at Alcerreca Q (m3/s)	Runoff Coefficient f (= Q/R*A)	Upstream Average Altitude H (m, msl)
0.0 - 10.0	5.0	967.13	-	-		1.885		
10.0 - 50.0	30.0	165.60	-	-				
50.0 - 100.0	75.0	256.90	-	-				
100.0 - 150.0	125.0	270.38	-	-				
150.0 - 200.0	175.0	345.60	-	-				
200.0 - 300.0	250.0	1,089.04	885.44	221,360.00				
300.0 - 350.0	325.0	158.80	158.80	51,610.00				
350.0 - 400.0	375.0	124.56	124.56	46,710.00		(m3/year)		
		3,378.00	1,168.80	319,680.00	273.51	59,445,360	0.186	4,007

Note : - Average basin rainfall is calculated from Average Annual Precipitation Map (Isohyetal Map) by DGA in 1987
- Flow rate is obtained from monthly data observed by DGA
- Upstream average altitude of the station is obtained by averaging the altitude of the rainfall stations located in the upstream basin of that station

Table A, 2.6 Average Runoff Coefficient in Lluta River Basin
<Coeficientes de Escorrentia Promedios en la Cuenca de Rio Lluta>

Location : **Lluta River at Tocontasi**

Rainfall Range (mm)	Average Rainfall R (mm)	Total River Basin (km2)	Upstream Basin of Tocontasi A (km2)	Average R*A (mm.km2)	Upstream Avg. Rainfall R (mm) (R*A/A)	Flow Rate at Tocontasi Q (m3/s)	Runoff Coefficient f (= Q/R*A)	Upstream Average Altitude H (m, msl)
0.0 - 10.0	5.0	967.13	139.13	695.63		2.216		
10.0 - 50.0	30.0	165.60	165.60	4,968.00				
50.0 - 100.0	75.0	256.90	256.90	19,267.50				
100.0 - 150.0	125.0	270.38	270.38	33,796.88				
150.0 - 200.0	175.0	345.60	345.60	60,480.00				
200.0 - 300.0	250.0	1,089.04	1,089.04	272,260.00				
300.0 - 350.0	325.0	158.80	158.80	51,610.00				
350.0 - 400.0	375.0	124.56	124.56	46,710.00		(m3/year)		
		3,378.00	2,550.00	489,788.00	192.07	69,883,776	0.143	3,899

Note :
- Average basin rainfall is calculated from Average Annual Precipitation Map (Isohyetal Map) by DGA in 1987
- Flow rate is obtained from monthly data observed by DGA
- Upstream average altitude of the station is obtained by averaging the altitude of the rainfall stations located in the upstream basin of that station

Table A, 2.7 Average Water Quality Observed by DGA in Lluta River Basin

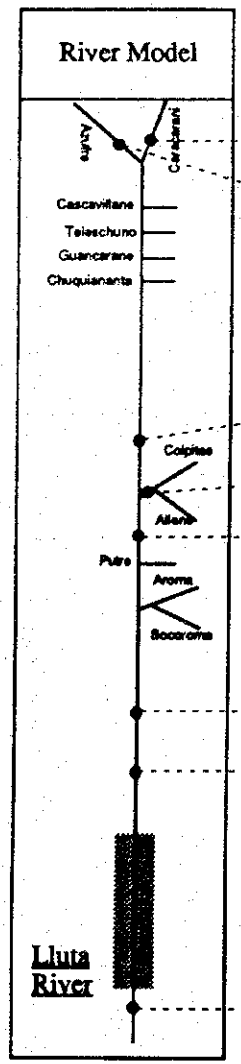
<Calidad Promedio de Agua Observada por DGA en la Cuenca del Rio Lluta>

River	Location	pH	E.C (mh/cm)	CO_3 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	B (mg/l)	As (mg/l)	Cu (mg/l)	Fe (mg/l)	$N\text{-}NO_3$ (mg/l)	$N\text{-}NO_2$ (mg/l)	P (mg/l)	$N\text{-}NH_3$ (mg/l)
Caracarani	Humapalca	7.80	1,475	3.644	213.4	165	285	71.6	47.1	20.4	155.6	3.23	0.120	0.029	1.17	0.150	0.003	0.130	0.033
Azufre	Humapalca	2.11	9,243	0.000	0.0	1,377	2,111	174.1	190.5	139.8	314.2	19.05	1.246	0.215	61.94	3.628	0.069	-	0.230
Caracarani	Alcerreca	5.72	1,357	0.000	42.4	219	305	61.2	35.8	23.7	129.5	5.81	0.140	0.055	4.79	0.090	0.000	0.081	0.118
Colpitas	Alcerreca	7.53	2,375	0.725	132.6	545	223	70.8	29.3	60.4	350.2	21.55	0.465	0.014	1.41	0.124	0.001	0.164	0.037
Lluta	Alcerreca	6.28	1,734	0.378	58.9	309	284	65.5	36.7	35.6	193.7	9.85	0.209	0.031	4.83	0.188	0.000	0.000	-
	Tocontasi	6.89	1,728	0.686	56.6	323	310	92.5	36.7	28.5	198.9	10.69	0.305	0.106	3.82	0.209	0.003	0.055	0.092
	Poconchile	7.05	2,049	0.000	55.8	411	373	125.6	41.2	33.9	231.8	11.17	0.173	0.000	-	-	-	-	-
	Panamericana	7.43	3,895	0.000	89.1	704	751	269.4	81.9	53.0	428.6	16.84	0.124	0.075	2.37	0.431	0.015	0.046	0.211
Permissible Value		6.0 - 8.5				250	250		125.0				0.050	1.000	0.30	10.000			

Table A, 2.8 Average Water Quality and Surface Flow Rate in Lluta River Basin

<Calidad Promedio del Agua y Nivel de Flujo en la Cuenca del Rio Lluta>

(Recorded period of the stations are different but range from 1946 to 1990)



	pH	E.C (mh/cm)	CO_3 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	B (mg/l)	As (mg/l)	Cu (mg/l)	Fe (mg/l)	$N\text{-}NO_3$ (mg/l)	$N\text{-}NO_2$ (mg/l)	P (mg/l)	$N\text{-}NH_3$ (mg/l)	Q (m^3/s)
Humapalca	7.80	1,475	3.644	213.4	165	285	71.6	47.1	20.4	155.6	3.23	0.120	0.029	1.168	0.150	0.003	0.130	0.033	0.378
Humapalca	2.11	9,243	0.000	0.0	1,377	2,111	174.1	190.5	139.8	314.2	19.05	1.246	0.215	61.94	3.628	0.069	-	0.230	0.084
Caracarani in Alcerreca	5.72	1,357	0.000	42.4	219	305	61.2	35.8	23.7	129.5	5.81	0.140	0.055	4.788	0.090	0.000	0.081	0.118	0.855
Colpitas	7.53	2,375	0.725	132.6	545	223	70.8	29.3	60.4	350.2	21.55	0.465	0.014	1.414	0.124	0.001	0.164	0.037	0.521
Lluta in Alcerreca	6.28	1,734	0.378	58.9	309	284	65.5	36.7	35.6	193.7	9.85	0.209	0.031	4.825	0.188	0.000	0.000	-	1.885
Tocontasi & Chapisca	6.89	1,728	0.686	56.6	323	310	92.5	36.7	28.5	198.9	10.69	0.305	0.106	3.817	0.209	0.003	0.055	0.092	2.216
Poconchile	7.05	2,049	0.000	55.8	411	373	125.6	41.2	33.9	231.8	11.17	0.173	0.000	-	-	-	-	-	-
Panamericana	7.43	3,895	0.000	89.1	704	751	269.4	81.9	53.0	428.6	16.84	0.124	0.075	2.371	0.431	0.015	0.046	0.211	1.385

Table A, 2.9 Surface Flow Rate observed on 1st - 3rd June 1993 in Lluta River Basin
<Nivel de Flujo de Superficie Observado entre el 1 - 3 de Junio de 1993 en la Cuenca del Rio Lluta>

River	Location/ Quebrada	Code No.	Average Velocity (m/s)	Cross-section Area (m2)	Flow Rate (m3/s)	Remarks
Azufre	Humapalca	AZ-1	0.54	0.141	0.076	
Caracarani	Humapalca	CR-1	0.47	0.838	0.394	
Cascavillane	-	CV-1	0.59	0.139	0.082	
Teleschuno	Qda. Teleschuno	TL-1	0.27	0.026	0.007	
	Qda. Gualluma	TL-2	no flow	-	-	Total Q = 0.334
Guancarane	-	GC-1	0.33	0.509	0.168	
Chuquiananta	-	CQ-1	0.37	0.208	0.077	
Colpitas	-	CP-1	0.38	0.555	0.211	
Allane	-	AL-1	0.28	0.071	0.020	
Putre	Qda. Llancomane	PT-1	0.68	0.063	0.043	DGA calls "Llancoma"
	Qda. Pacollo	PT-2	0.37	0.046	0.017	
	Qda. Taipicahua	PT-3	0.52	0.354	0.184	Total Q = 0.315
	Qda. Jurase	PT-4	0.40	0.023	0.009	
	Canal Lluscuma	PT-5	0.53	0.117	0.062	
Aroma	-	AR-1	0.58	0.057	0.033	DGA calls "Socoroma"
Socoroma	-	SR-1	0.29	0.041	0.012	DGA calls "Colallaque"
Lluta	Chapisca	LT-1	0.69	1.716	1.184	

Table A, 2.10 (1) Water Quality Observed on 1st - 3rd June 1993 in Lluta River Basin
<Calidad de Agua Observado entre el 1-3 de Junio 1993 en la Cuenca del Rio Lluta>

River	Code	Health Significance						
		As (mg/l)	Cd (mg/l)	Cr (mg/l)	CN (mg/l)	F (mg/l)	Pb (mg/l)	NO3 (mg/l)
Azufre	AZ-1	4.308	0.160	0.10		2.002	2.40	0.190
Caracarani	CR-1	0.085	0.002	0.03	0.00	0.350	0.02	0.509
Cascavillane	CV-1	0.421	0.002	0.03	0.00	0.140	0.02	0.000
Teleschuno	TL-1	0.000	0.000	0.02	0.00	0.180	0.02	0.000
Guancarane	GC-1	0.018	0.003	0.03	0.00	0.150	0.03	0.000
Chuquiananta	CQ-1	0.000	0.002	0.04	0.00	0.240	0.02	0.137
Colpitas	CP-1	1.058	0.002	0.04	0.00	0.350	0.02	0.563
Allane	AL-1	0.175	0.009	0.03	0.00	0.290	0.04	0.000
Putre : Llancomane	PT-1	0.093	0.001	0.02	0.00	0.260	0.00	0.000
Putre : Pacollo	PT-2	0.149	0.001	0.01	0.00	0.310	0.01	0.000
Putre : Taipicahua	PT-3	0.033	0.002	0.01	0.00	0.220	0.01	0.000
Putre : Jurase	PT-4	0.128	0.001	0.03	0.00	0.210	0.00	0.244
Aroma	AR-1	0.000	0.002	0.02	0.00	0.950	0.00	0.297
Socoroma	SR-1	0.000	0.003	0.02	0.00	0.950	0.02	0.190
Lluta at Chapisca	TC-1	0.270	0.009	0.03	0.00	0.760	0.07	3.291

Table A, 2.10 (2) Water Quality Observed on 1st - 3rd June 1993 in Lluta River Basin

<Calidad de Agua Observado entre el 1-3 de Junio 1993 en la Cuenca del Rio Lluta>

River	Code	Aesthetic Quality										
		pH	CaCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	Na (mg/l)	Zn (mg/l)	Al (mg/l)	Cu (mg/l)	Fe (mg/l)	Mn (mg/l)	TDS (mg/l)
Azufre	AZ-1	3.04	451.5	327.0	716.0	156.4	15.300	240.0	0.105	82.24	11.45	1,935
Caracarani	CR-1	6.30	446.5	151.7	370.0	156.0	0.010	0.3	0.021	0.26	0.08	1,328
Cascavillane	CV-1	6.70	70.5	8.9	80.7	29.7	0.019	0.9	0.200	10.30	0.30	212
Teleschuno	TL-1	6.32	61.0	5.3	60.0	17.5	0.008	0.1	0.015	0.17	0.03	151
Guancarane	GC-1	7.30	28.0	16.3	17.3	17.5	0.005	0.2	0.015	0.31	0.03	94
Chuquiananta	CQ-1	7.80	202.0	6.4	165.2	19.6	0.010	0.9	0.015	0.31	0.05	362
Colpitas	CP-1	6.70	332.4	873.5	254.5	589.0	0.034	0.9	0.030	2.54	0.45	2,452
Allane	AL-1	7.18	146.0	145.0	77.3	132.9	0.010	0.1	0.018	0.74	0.18	768
Putre : Llancomane	PT-1	7.79	103.0	20.2	89.5	25.0	0.007	0.3	0.013	0.90	0.03	276
Putre : Pacollo	PT-2	8.15	127.5	95.7	78.8	80.0	0.005	0.0	0.011	0.07	0.02	495
Putre : Taipicahua	PT-3	4.57	33.0	15.0	26.0	16.6	0.004	0.1	0.010	0.14	0.03	113
Putre : Jurase	PT-4	4.24	757.0	222.3	1129.0	303.6	0.061	5.3	0.037	2.72	0.87	2,018
Aroma	AR-1	3.31	184.0	5.3	374.6	15.2	0.148	22.3	0.024	10.10	0.93	625
Socoroma	SR-1	4.03	0.0	6.7	393.8	20.2	0.121	11.2	0.016	0.37	1.56	650
Lluta at Chapisca	TC-1	5.37	443.5	400.0	402.0	234.6	0.567	9.1	0.027	2.55	0.86	1,700

Table A, 2.10 (3) Water Quality Observed on 1st - 3rd June 1993 in Lluta River Basin
<Calidad de Agua Observado entre el 1-3 de Junio 1993 en la Cuenca del Rio Lluta>

River	Code	Others									
		Temp (C)	EC (mh/cm)	CO3 (mg/l)	HCO3 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Turbidity (mg/l)	DO (mg/l)	B (mg/l)
Azufre	AZ-1	9.0	2,522	0.00	0.00	99.50	49.50	36.50	25	1.90	25.72
Caracarani	CR-1	1.9	1,700	0.00	220.00	96.20	50.20	21.80	12	2.40	2.30
Cascavillane	CV-1	4.4	300	0.00	46.40	18.60	5.90	4.10	116	2.30	0.48
Teleschuno	TL-1	8.7	200	0.00	33.00	18.00	3.90	3.10	15	7.40	0.17
Guancarane	GC-1	-	100	0.00	40.20	6.70	2.80	3.30	16	8.00	0.23
Chuquiananta	CQ-1	6.5	500	0.00	78.10	44.50	22.10	5.20	14	8.80	0.00
Colpitas	CP-1	7.8	3,900	0.00	179.40	96.50	3.00	59.50	38	7.80	14.10
Allane	AL-1	6.1	1,000	0.00	175.10	36.90	13.10	10.40	14	7.90	4.74
Putre : Llancomane	PT-1	1.9	400	0.00	44.50	28.90	7.60	5.30	34	2.20	0.85
Putre : Pacollo	PT-2	11.5	700	0.00	133.00	31.00	12.20	19.00	9	6.40	4.17
Putre : Taipicahua	PT-3	0.0	167	0.00	36.00	9.10	2.60	3.90	13	2.00	0.91
Putre : Jurase	PT-4	6.8	2,500	0.00	9.70	303.50	9.50	14.50	17	8.10	8.26
Aroma	AR-1	3.0	800	0.00	0.00	45.00	17.40	5.90	15	2.10	0.34
Socoroma	SR-1	1.8	800	0.00	0.00	83.10	22.00	4.70	16	2.60	0.28
Lluta at Chapisca	TC-1	-	2,100	0.00	7.90	116.00	35.00	37.80	46	9.40	12.22

Table A, 2.11 Surface Flow Rate Observed in Azufre and Colpitas Rivers

<Nivel de Flujo de Superficie Observado en Rio Azufre y Colpitas>

Observation Period : November 1993

Code No.	Latitude	Logitude	Average Velocity (m/s)	Cross-section Area (m2)	Flow Rate (m3/s)	Remarks
Azufre River						
A-1	17°50'37"	69°42'16"	0.560	0.432	0.242	
A-2	17°50'37"	69°42'16"	-	-	0.000	measured by volume
A-3	17°50'17"	69°42'27"	0.448	0.164	0.074	
A-4	17°50'18"	69°42'23"	0.240	0.721	0.173	
A-5A	17°49'01"	69°44'22"	0.707	0.169	0.119	
A-5B	17°49'01"	69°44'22"	-	-	0.000	measured by volume
A-8	17°45'46"	69°48'09"	0.532	0.090	0.048	
A-10	17°45'20"	69°49'09"	0.377	0.128	0.048	
A-11	17°45'24"	69°49'07"	0.187	0.034	0.006	
A-12	17°43'25"	69°49'16"	0.248	0.055	0.014	
A-13	17°43'36"	69°49'03"	0.493	0.080	0.039	
AV-1	17°43'06"	69°49'19"	0.063	0.037	0.002	
AV-2	17°43'08"	69°49'16"	-	-	0.003	measured by volume
AV-3	17°43'21"	69°49'20"	-	-	0.000	measured by volume
AV-4	17°43'22"	69°49'20"	-	-	0.001	measured by volume
AV-5	17°43'22"	69°49'20"	-	-	0.001	measured by volume
Colpitas River						
C-1	17°59'59"	69°37'50"	0.490	1.901	0.932	
C-2	17°59'39"	69°37'48"	0.418	1.350	0.564	
C-3	17°59'45"	69°37'40"	0.540	0.640	0.346	
C-4	17°59'22"	69°35'35"	0.569	0.270	0.154	
C-5	17°59'21"	69°35'35"	0.241	0.457	0.110	
C-6	17°58'15"	69°34'03"	0.245	0.289	0.071	
C-9	17°58'51"	69°27'31"	0.191	0.029	0.006	
C-10	17°58'10"	69°27'14"	0.377	0.195	0.074	
C-11A	17°57'25"	69°25'36"	0.226	0.076	0.017	
C-11B	17°57'25"	69°25'36"	0.124	0.030	0.004	
C-12	17°59'01"	69°26'14"	0.086	0.029	0.002	
C-14	17°58'59"	69°27'31"	-	-	0.001	measured by volume
CV-1	17°59'24"	69°35'38"	-	-	0.002	measured by volume
CV-2	17°59'42"	69°36'22"	-	-	0.001	measured by volume
CV-3	17°59'42"	69°36'22"	-	-	0.002	measured by volume
CV-4	17°59'48"	69°36'58"	-	-	0.000	measured by volume
CV-5	17°59'24"	69°36'01"	-	-	0.004	measured by volume

Note : The observation points located in the map but not shown here dried up during the observation period

Table A, 2.12 (1) Water Quality Observed in Azufre River
<Calidad de Agua Observado en Rio Azufre>

Observation Period : November 1993

River/Quebrada	Code	Health Significance						
		As (mg/l)	Cd (mg/l)	Cr (mg/l)	CN (mg/l)	F (mg/l)	Pb (mg/l)	NO3 (mg/l)
Lluta	A-1	1.739	-	-	-	-	-	-
Qda. Chadonasa	A-2	0.010	-	-	-	-	-	-
Azufre	A-3	5.212	-	-	-	-	-	-
Caracarani	A-4	0.166	-	-	-	-	-	-
Azufre	A-5A	0.006	-	-	-	-	-	-
Qda. Quenuavichiucha	A-5B	5.434	-	-	-	-	-	-
Azufre	A-8	6.753	-	-	-	-	-	-
Azufre	A-10	3.189	-	-	-	-	-	-
Azufre	A-11	2.327	-	-	-	-	-	-
Azufre-Agua Caliente	A-12	-	-	-	-	-	-	-
Azufre-Agua Caliente	A-13	1.513	-	-	-	-	-	-
Azufre-Agua Caliente	AV-1	4.759	-	-	-	-	-	-
Azufre-Agua Caliente	AV-2	4.663	-	-	-	-	-	-
Azufre-Agua Caliente	AV-3	0.000	-	-	-	-	-	-
Azufre-Agua Caliente	AV-4	0.000	-	-	-	-	-	-
Azufre-Agua Caliente	AV-5	0.013	-	-	-	-	-	-
Azufre-Agua Caliente	AV-6	0.193	-	-	-	-	-	-
Azufre-Agua Caliente	AV-7	0.785	-	-	-	-	-	-
Azufre-Agua Caliente	AV-8	0.032	-	-	-	-	-	-

Table A, 2.12 (2) Water Quality Observed in Azufre River
<Calidad de Agua Observado en Rio Azufre>

Observation Period : November 1993

River/Quebrada	Code	Aesthetic Quality										
		pH	CaCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	Na (mg/l)	Zn (mg/l)	Al (mg/l)	Cu (mg/l)	Fe (mg/l)	Mn (mg/l)	TDS (mg/l)
Lluta	A-1	2.96	-	661.9	1,200.8	257.6	-	-	-	-	-	-
Qda. Chadonasa	A-2	2.60	-	211.3	396.2	119.6	-	-	-	-	-	-
Azufre	A-3	2.84	-	1,683.5	3,194.0	466.0	-	-	-	-	-	-
Caracarani	A-4	5.11	-	173.4	300.2	172.5	-	-	-	-	-	-
Azufre	A-5A	3.23	-	1,196.8	1,248.8	322.0	-	-	-	-	-	-
Qda. Quenuavichiucha	A-5B	2.81	-	1,745.9	3,784.8	420.9	-	-	-	-	-	-
Azufre	A-8	3.01	-	2044.4	3938.5	506.0	-	-	-	-	-	-
Azufre	A-10	3.76	-	967.8	2,233.4	306.4	-	-	-	-	-	-
Azufre	A-11	3.60	-	786.3	1,248.8	151.8	-	-	-	-	-	-
Azufre-Agua Caliente	A-12	-	-	-	-	-	-	-	-	-	-	-
Azufre-Agua Caliente	A-13	2.18	-	352.0	1,858.8	262.2	-	-	-	-	-	-
Azufre-Agua Caliente	AV-1	4.10	-	506.2	2,497.6	414.0	-	-	-	-	-	-
Azufre-Agua Caliente	AV-2	2.94	-	459.4	2,497.6	368.0	-	-	-	-	-	-
Azufre-Agua Caliente	AV-3	7.17	-	11.3	33.1	11.3	-	-	-	-	-	-
Azufre-Agua Caliente	AV-4	7.22	-	13.5	30.3	11.7	-	-	-	-	-	-
Azufre-Agua Caliente	AV-5	7.19	-	42.5	100.9	19.3	-	-	-	-	-	-
Azufre-Agua Caliente	AV-6	1.65	-	156.0	1,508.1	248.4	-	-	-	-	-	-
Azufre-Agua Caliente	AV-7	1.89	-	377.9	1,469.7	240.4	-	-	-	-	-	-
Azufre-Agua Caliente	AV-8	6.00	-	72.3	165.2	72.5	-	-	-	-	-	-

Table A, 2.12 (3) Water Quality Observed in Azufre River
<Calidad de Agua Observado en Rio Azufre>

Observation Period : November 1993

River/Quebrada	Code	Others									
		Temp (C)	EC (mh/cm)	CO3 (mg/l)	HCO3 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Turbidity (mg/l)	DO (mg/l)	B (mg/l)
Lluta	A-1	-	6,200	0.00	0.00	153.90	84.00	68.00	-	2.90	8.93
Qda. Chadonasa	A-2	-	1,700	0.00	0.00	90.00	56.50	29.00	-	3.60	3.13
Azufre	A-3	-	18,800	0.00	0.00	285.00	160.00	190.00	-	2.80	27.87
Caracarani	A-4	-	1,800	0.00	298.40	77.60	47.10	27.00	-	5.40	2.46
Azufre	A-5A	-	19,500	0.00	0.00	410.00	180.00	90.00	-	3.40	6.82
Qda. Quenuavichiucha	A-5B	-	5,300	0.00	0.00	322.00	170.00	156.00	-	1.80	27.87
Azufre	A-8	-	24,700	0.00	0.00	330.10	175.00	210.00	-	4.30	28.93
Azufre	A-10	-	10,600	0.00	0.00	259.90	125.00	160.00	-	3.60	7.03
Azufre	A-11	-	10,800	0.00	0.00	145.10	65.10	50.10	-	3.50	9.56
Azufre-Agua Caliente	A-12	-	-	-	-	-	-	-	-	-	-
Azufre-Agua Caliente	A-13	-	5,700	0.00	0.00	220.00	103.00	104.90	-	3.90	9.77
Azufre-Agua Caliente	AV-1	-	9,400	0.00	0.00	185.00	90.00	100.10	-	2.60	12.08
Azufre-Agua Caliente	AV-2	-	9,100	0.00	0.00	195.00	90.00	109.90	-	1.80	11.03
Azufre-Agua Caliente	AV-3	-	200	0.00	24.40	9.40	5.50	5.10	-	3.10	0.00
Azufre-Agua Caliente	AV-4	-	100	0.00	28.10	10.20	5.70	5.10	-	2.80	0.00
Azufre-Agua Caliente	AV-5	-	400	0.00	70.20	42.30	17.60	6.70	-	2.00	0.03
Azufre-Agua Caliente	AV-6	-	4,500	0.00	0.00	218.00	104.00	126.30	-	4.50	2.33
Azufre-Agua Caliente	AV-7	-	5,600	0.00	0.00	181.00	88.00	116.90	-	4.80	11.87
Azufre-Agua Caliente	AV-8	-	1,000	0.00	167.20	59.90	29.60	12.90	-	2.50	0.84

Table A, 2.12 (4) Water Quality Observed in Colpitas River
<Calidad de Agua Observado en Rio Colpitas>

Observation Period : November 1993

River/Quebrada	Code	Health Significance						
		As (mg/l)	Cd (mg/l)	Cr (mg/l)	CN (mg/l)	F (mg/l)	Pb (mg/l)	NO3 (mg/l)
Lluta : after confluence	C-1	0.520	-	-	-	-	-	-
Lluta : before confluenc	C-2	0.299	-	-	-	-	-	-
Colpitas	C-3	0.674	-	-	-	-	-	-
Colpitas	C-3-4	0.679	-	-	-	-	-	-
Allane	C-4	0.459	-	-	-	-	-	-
Colpitas	C-5	0.998	-	-	-	-	-	-
Colpitas	C-6	1.692	-	-	-	-	-	-
Allane	C-9	0.341	-	-	-	-	-	-
Colpitas	C-10	2.081	-	-	-	-	-	-
Colpitas	C-11A	0.810	-	-	-	-	-	-
Colpitas	C-11B	4.489	-	-	-	-	-	-
Allane	C-12	0.444	-	-	-	-	-	-
Qda. Curaguara	C-14	0.098	-	-	-	-	-	-
Colpitas	CV-1	-	-	-	-	-	-	-
Colpitas	CV-2	0.853	-	-	-	-	-	-
Colpitas	CV-2'	0.565	-	-	-	-	-	-
Colpitas	CV-3	0.913	-	-	-	-	-	-
Colpitas	CV-4	1.719	-	-	-	-	-	-
Colpitas	CV-4'	0.587	-	-	-	-	-	-
Colpitas	CV-5	0.578	-	-	-	-	-	-

Table A, 2.12 (5) Water Quality Observed in Colpitas River
<Calidad de Agua Observado en Rio Colpitas>

Observation Period : November 1993

River/Quebrada	Code	Aesthetic Quality										
		pH	CaCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	Na (mg/l)	Zn (mg/l)	Al (mg/l)	Cu (mg/l)	Fe (mg/l)	Mn (mg/l)	TDS (mg/l)
Lluta : after confluence	C-1	5.21	-	408.4	665.2	165.6	-	-	-	-	-	-
Lluta : before confluenc	C-2	3.20	-	366.2	665.2	161.0	-	-	-	-	-	-
Colpitas	C-3	6.76	-	607.6	240.2	370.3	-	-	-	-	-	-
Colpitas	C-3-4	6.69	-	651.9	252.6	425.5	-	-	-	-	-	-
Allane	C-4	6.93	-	426.8	206.6	271.4	-	-	-	-	-	-
Colpitas	C-5	6.77	-	1,099.7	342.0	731.4	-	-	-	-	-	-
Colpitas	C-6	6.68	-	1,760.1	396.7	1,196.0	-	-	-	-	-	-
Allane	C-9	7.13	-	149.6	235.4	138.0	-	-	-	-	-	-
Colpitas	C-10	7.95	-	1,648.1	377.0	1,127.0	-	-	-	-	-	-
Colpitas	C-11A	7.88	-	478.6	147.0	312.8	-	-	-	-	-	-
Colpitas	C-11B	7.67	-	4,485.8	259.4	2,829.0	-	-	-	-	-	-
Allane	C-12	7.23	-	375.4	90.3	317.4	-	-	-	-	-	-
Qda. Curaguara	C-14	8.10	-	142.2	48.5	100.7	-	-	-	-	-	-
Colpitas	CV-1	6.62	-	-	-	-	-	-	-	-	-	-
Colpitas	CV-2	6.08	-	1,773.6	307.4	966.0	-	-	-	-	-	-
Colpitas	CV-2'	6.76	-	570.0	206.6	377.2	-	-	-	-	-	-
Colpitas	CV-3	6.70	-	2,070.3	270.4	1,081.0	-	-	-	-	-	-
Colpitas	CV-4	7.28	-	1,081.2	195.0	538.2	-	-	-	-	-	-
Colpitas	CV-4'	6.80	-	582.8	241.1	381.8	-	-	-	-	-	-
Colpitas	CV-5	5.68	-	573.2	206.6	331.2	-	-	-	-	-	-

Table A, 2.12 (6) Water Quality Observed in Colpitas River
<Calidad de Agua Observado en Rio Colpitas>

Observation Period : November 1993

River/Quebrada	Code	Others									
		Temp (C)	EC (mh/cm)	CO3 (mg/l)	HCO3 (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Turbidity (mg/l)	DO (mg/l)	B (mg/l)
Lluta : after confluence	C-1	-	2,200	0.00	0.00	110.40	48.00	38.00	-	2.60	* 5.56
Lluta : before confluenc	C-2	-	2,500	0.00	0.00	93.60	47.60	41.10	-	3.10	3.87
Colpitas	C-3	-	2,500	0.00	378.30	79.60	23.40	71.60	-	3.90	22.61
Colpitas	C-3-4	-	2,500	0.00	148.30	84.00	21.00	70.00	-	3.30	24.67
Allane	C-4	-	2,300	0.00	134.20	68.00	21.00	70.00	-	3.70	12.67
Colpitas	C-5	-	3,700	0.00	191.60	117.00	21.00	75.90	-	3.10	72.00
Colpitas	C-6	-	5,900	0.00	251.40	216.00	24.00	120.00	-	3.10	133.05
Allane	C-9	-	900	0.00	124.50	59.10	19.00	16.40	-	3.40	6.05
Colpitas	C-10	-	5,800	0.00	251.40	140.10	22.00	120.00	-	4.30	61.79
Colpitas	C-11A	-	1,500	0.00	140.30	53.10	12.70	45.40	-	4.90	20.88
Colpitas	C-11B	-	2,000	0.00	609.00	148.10	25.30	204.90	-	8.10	181.47
Allane	C-12	-	1,800	0.00	299.00	20.40	23.00	13.70	-	4.70	16.18
Qda. Curaguara	C-14	-	500	0.00	146.40	30.70	11.30	11.30	-	4.60	4.60
Colpitas	CV-1	-	2,200	-	-	-	-	-	-	3.50	-
Colpitas	CV-2	-	8,700	0.00	184.30	114.00	58.00	380.10	-	4.10	83.58
Colpitas	CV-2'	-	2,800	0.00	158.60	78.00	22.00	77.00	-	3.30	19.94
Colpitas	CV-3	-	9,600	0.00	130.60	110.00	60.00	450.00	-	4.40	93.05
Colpitas	CV-4	-	4,200	0.00	83.00	76.00	36.00	206.50	-	5.80	26.67
Colpitas	CV-4'	-	2,700	0.00	140.30	80.00	22.00	70.00	-	3.80	19.73
Colpitas	CV-5	-	3,600	0.00	218.40	88.20	34.10	70.00	-	4.80	15.73

* Boron at C-1 may include some error (refer to page II-12).

Table A, 2.12(7) Water Quality Observed in Azufre River

<Calidad de Agua Observado en Rio Azufre>

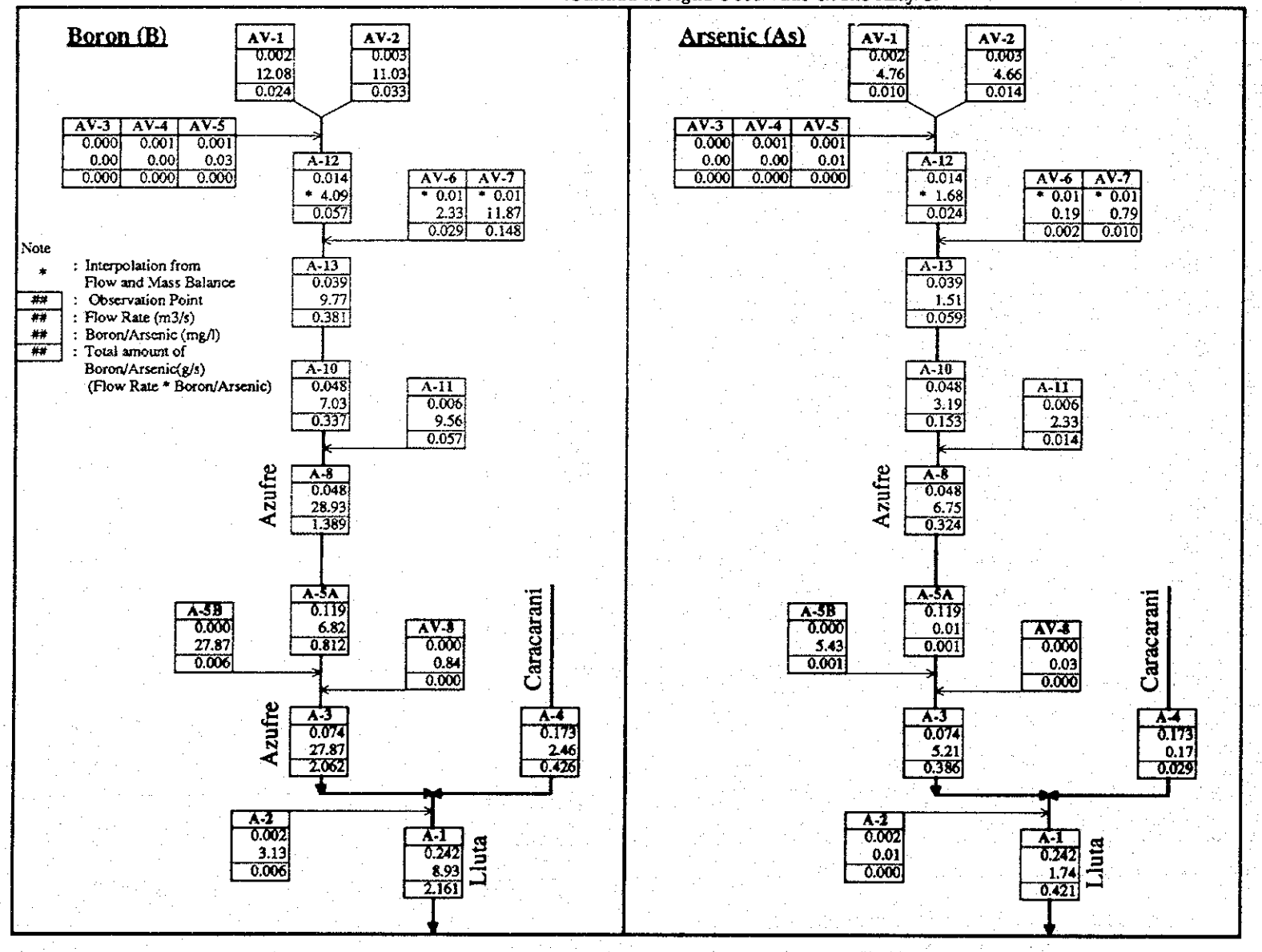
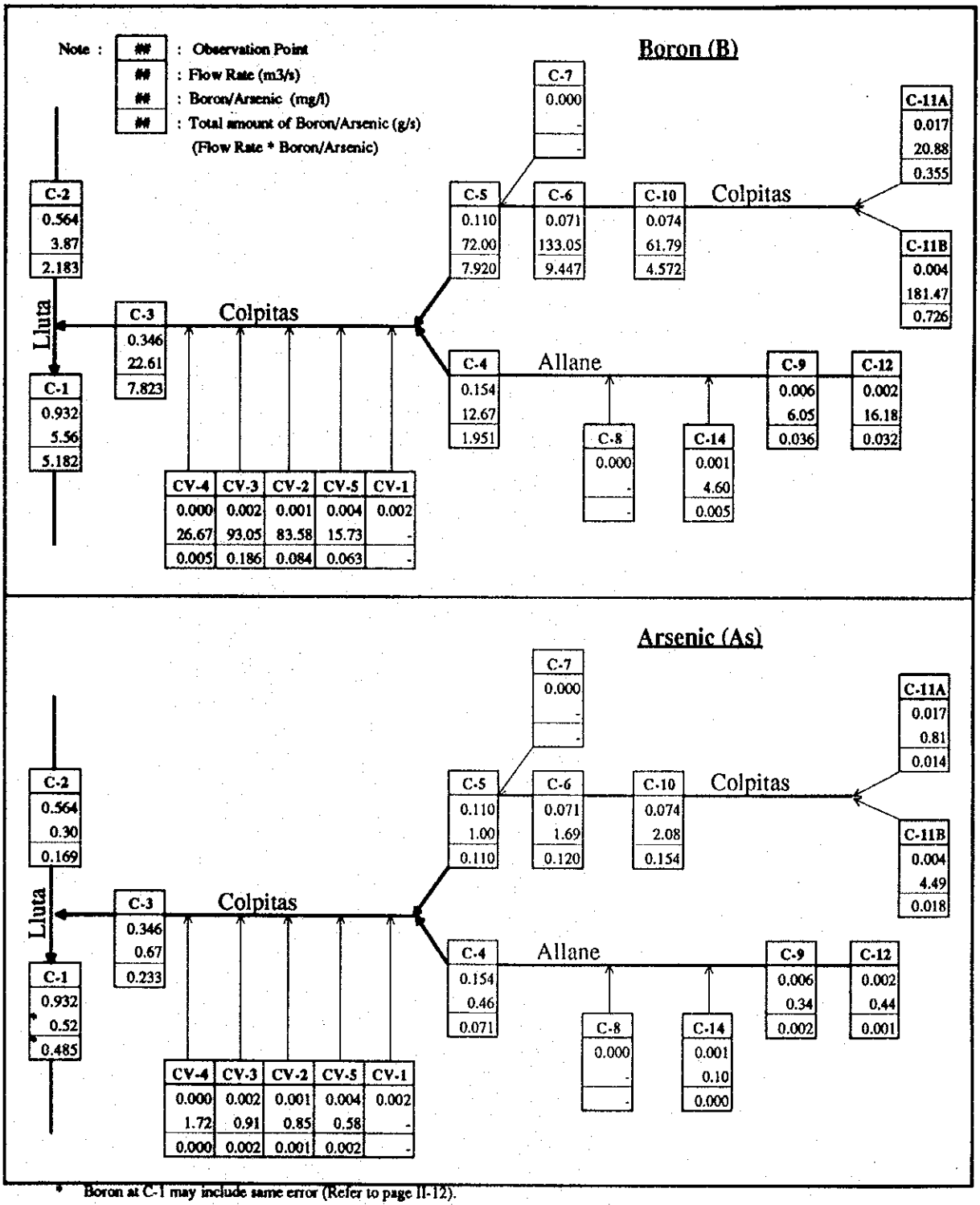


Table A, 2.12(8) Water Quality Observed in Colpitas River
<Calidad de Agua Observado en Rio Colpitas>



* Boron at C-1 may include same error (Refer to page II-12).

Table A, 2.13 (1) Storage Volume at Tocontasi & Chapisca
<Volumen de Almacenamiento en Tocontasi y Chapisca>
(Inflow = Qobs, Outflow = 2.0 m3/s)

("Rising" or "Decreasing" refers to the period that storage volume changes from Max. to Min. or Min. to Max. in a cycle)

Year	Month	Max or Min Vol.Storage (m3)	Necessary Storage Volume (m3)	
			Rising Period	Decreasing Period
1946	Mar	14,785,027		
1946	Dec	2,643,408		-12,141,619
1947	Jan	2,938,032	294,624	
1947	Nov	-14,799,024		-17,737,056
1947	Dec	-14,209,776	589,248	
1948	Jan	-14,531,184		-321,408
1948	Mar	-163,728	14,367,456	
1948	Dec	-6,769,872		-6,606,144
1949	Jul	54,428,976	61,198,848	
1950	Feb	45,225,302		-9,203,674
1950	Mar	46,135,958	910,656	
1950	Dec	37,162,886		-8,973,072
1951	Mar	41,656,550	4,493,664	
1951	Dec	30,039,206		-11,617,344
1952	Sep	65,290,406	35,251,200	
1952	Dec	63,048,326		-2,242,080
1953	Mar	121,415,846	58,367,520	
1953	Nov	115,947,850		-5,467,997
1954	Mar	149,035,680	33,087,830	
1954	Dec	140,115,917		-8,919,763
1955	Mar	154,900,944	14,785,027	
1955	Nov	147,653,971		-7,246,973
1956	Feb	152,459,539	4,805,568	
1957	Jan	139,546,368		-12,913,171
1957	Mar	147,299,126	7,752,758	
1957	Nov	138,138,307		-9,160,819
1958	Mar	155,880,288	17,741,981	
1958	Apr	155,260,800		-619,488
1958	Sep	159,470,208	4,209,408	
1959	Jan	153,392,832		-6,077,376
1959	Mar	165,831,581	12,438,749	
1959	Dec	156,911,818		-8,919,763
1960	Mar	171,696,845	14,785,027	
1960	Dec	162,777,082		-8,919,763
1961	Mar	177,562,109	14,785,027	
1961	Dec	167,705,251		-9,856,858
1962	Mar	181,874,074	14,168,822	
1962	May	180,772,474		-1,101,600
1962	Jun	180,927,994	155,520	
1962	Dec	175,086,490		-5,841,504
1963	Sep	200,148,538	25,062,048	
1963	Dec	196,962,883		-3,185,654
1964	Jan	199,309,162	2,346,278	
1964	Jul	194,988,730		-4,320,432
1964	Sep	195,597,850	609,120	
1964	Dec	193,132,858		-2,464,992
1965	Apr	208,391,962	15,259,104	
1965	Jun	203,493,946		-4,898,016
1966	Feb	214,959,226	11,465,280	
1966	May	212,992,762		-1,966,464
1966	Jun	213,718,522	725,760	
1967	Jan	200,009,434		-13,709,088
1967	Mar	209,154,874	9,145,440	

Table A, 2.13 (2) Storage Volume at Tocontasi & Chapisca
<Volumen de Almacenamiento en Tocontasi y Chapisca>
(Inflow = Qobs, Outflow = 2.0 m3/s)

("Rising" or "Decreasing" refers to the period that storage volume changes from Max. to Min. or Min. to Max. in a cycle)

Year	Month	Max or Min Vol.Storage (m3)	Necessary Storage Volume (m3)	
			Rising Period	Decreasing Period
1968	Jan	198,850,205		-10,304,669
1968	Mar	214,821,763	15,971,558	
1968	Dec	200,488,867		-14,332,896
1969	Mar	215,273,894	14,785,027	
1969	Dec	205,346,794		-9,927,101
1970	Jan	206,471,722	1,124,928	
1970	Feb	206,036,266		-435,456
1970	Mar	206,464,810	428,544	
1970	Dec	188,014,954		-18,449,856
1971	Mar	197,097,322	9,082,368	
1971	Dec	181,334,506		-15,762,816
1972	Mar	229,287,370	47,952,864	
1972	Apr	228,667,882		-619,488
1972	Aug	233,586,634	4,918,752	
1972	Dec	227,860,819		-5,725,814
1973	Mar	242,645,846	14,785,027	
1973	Dec	232,069,018		-10,576,829
1974	Mar	249,701,530	17,632,512	
1974	Jul	247,759,258		-1,942,272
1974	Aug	250,250,170	2,490,912	
1974	Dec	241,617,773		-8,632,397
1975	Mar	254,860,042	13,242,269	
1975	Jun	253,386,058		-1,473,984
1975	Jul	253,787,818	401,760	
1975	Nov	248,017,162		-5,770,656
1976	Mar	289,566,058	41,548,896	
1976	Apr	288,946,570		-619,488
1976	May	288,973,354	26,784	
1976	Dec	281,317,450		-7,655,904
1977	Jun	301,375,382	20,057,933	
1977	Dec	294,631,430		-6,743,952
1978	Feb	300,529,094	5,897,664	
1978	Dec	285,463,526		-15,065,568
1979	Jan	286,963,430	1,499,904	
1979	Feb	284,810,342		-2,153,088
1979	Mar	288,560,102	3,749,760	
1979	Dec	279,049,709		-9,510,394
1980	Mar	293,834,736	14,785,027	
1981	Jan	279,601,286		-14,233,450
1981	Mar	315,178,214	35,576,928	
1982	Jan	303,011,021		-12,167,194
1982	Feb	303,228,749	217,728	
1983	Dec	255,530,938		-47,697,811
1984	Mar	268,585,718	13,054,781	
1985	Jan	255,816,662		-12,769,056
1985	Mar	269,181,965	13,365,302	
1985	Nov	261,650,650		-7,531,315
1986	Mar	276,837,437	15,186,787	
1986	Dec	267,917,674		-8,919,763
1987	Mar	282,702,701	14,785,027	
1987	Dec	272,600,208		-10,102,493
1988	Mar	304,944,912	32,344,704	
1988	Dec	294,030,000		-10,914,912
1989	Mar	304,503,494	10,473,494	

Table A, 2.14 (1) Storage Volume at Tocontasi & Chapisca
<Volumen de Almacenamiento en Tocontasi y Chapisca>
(Inflow = Qobs, Outflow = 1.5 m3/s)

("Rising" or "Decreasing" refers to the period that storage volume changes from Max. to Min. or Min. to Max. in a cycle)

Year	Month	Max or Min Vol.Storage (m3)	Necessary Storage Volume (m3)	
			Rising Period	Decreasing Period
1946	Jun	20,857,392		
1946	Dec	18,411,408		-2,445,984
1947	Jan	20,045,232	1,633,824	
1947	Jun	18,444,240		-1,600,992
1947	Jul	18,631,728	187,488	
1947	Nov	15,397,776		-3,233,952
1948	Aug	40,491,792	25,094,016	
1948	Nov	39,677,040		-814,752
1949	Sep	111,623,702	71,946,662	
1949	Dec	110,070,230		-1,553,472
1950	Sep	117,367,142	7,296,912	
1950	Dec	116,002,886		-1,364,256
1951	Sep	126,607,622	10,604,736	
1951	Dec	124,647,206		-1,960,416
1954	Sep	283,149,475	158,502,269	
1954	Dec	282,027,917		-1,121,558
1955	Sep	304,782,739	22,754,822	
1955	Nov	303,994,771		-787,968
1956	Sep	316,969,632	12,974,861	
1957	Jan	314,333,568		-2,636,064
1957	Aug	327,830,371	13,496,803	
1957	Nov	326,015,107		-1,815,264
1958	Oct	361,336,896	35,321,789	
1959	Jan	359,716,032		-1,620,864
1959	Sep	378,785,376	19,069,344	
1959	Dec	377,663,818		-1,121,558
1960	Sep	400,418,640	22,754,822	
1960	Dec	399,297,082		-1,121,558
1961	Aug	422,015,962	22,718,880	
1961	Dec	419,993,251		-2,022,710
1962	Sep	443,995,258	24,002,006	
1962	Nov	443,062,138		-933,120
1963	Nov	480,869,914	37,807,776	
1963	Dec	480,786,883		-83,030
1964	Mar	486,014,602	5,227,718	
1964	Apr	485,470,282		-544,320
1964	Oct	491,751,130	6,280,848	
1964	Nov	491,466,010		-285,120
1965	Apr	513,167,962	21,701,952	
1965	Jun	510,905,146		-2,262,816
1966	Jul	537,567,322	26,662,176	
1967	Jan	532,476,634		-5,090,688
1967	Sep	548,252,669	15,776,035	
1967	Dec	545,746,205		-2,506,464
1968	Apr	566,772,163	21,025,958	
1968	Jun	562,376,995		-4,395,168
1968	Sep	564,274,426	1,897,430	
1968	Dec	563,152,867		-1,121,558
1969	Sep	585,858,442	22,705,574	
1969	Dec	583,778,794		-2,079,648
1970	Mar	588,784,810	5,006,016	
1970	Jun	587,164,810		-1,620,000

Table A, 2.14 (2) Storage Volume at Tocontasi & Chapisca

<Volumen de Almacenamiento en Tocontasi y Chapisca>

(Inflow = Qobs, Outflow = 1.5 m3/s)

("Rising" or "Decreasing" refers to the period that storage volume changes from Max. to Min. or Min. to Max. in a cycle)

Year	Month	Max or Min Vol.Storage (m3)	Necessary Storage Volume (m3)	
			Rising Period	Decreasing Period
1970	Jul	587,298,730	133,920	
1970	Dec	582,214,954		-5,083,776
1971	Mar	595,185,322	12,970,368	
1971	May	594,790,474		-394,848
1971	Jul	595,186,186	395,712	
1971	Dec	591,302,506		-3,883,680
1972	Sep	654,959,434	63,656,928	
1972	Dec	653,596,819		-1,362,614
1973	Sep	676,351,642	22,754,822	
1973	Dec	673,573,018		-2,778,624
1974	Aug	702,251,770	28,678,752	
1974	Dec	698,889,773		-3,361,997
1975	Aug	720,861,034	21,971,261	
1975	Nov	719,717,962		-1,143,072
1976	Sep	772,977,514	53,259,552	
1976	Dec	770,125,450		-2,852,064
1977	Sep	800,947,526	30,822,077	
1977	Dec	799,207,430		-1,740,096
1978	Feb	807,653,894	8,446,464	
1978	Mar	807,225,350		-428,544
1978	Aug	808,509,254	1,283,904	
1978	Dec	805,807,526		-2,701,728
1979	Jan	808,646,630	2,839,104	
1979	Feb	807,703,142		-943,488
1979	Mar	812,792,102	5,088,960	
1979	Apr	812,688,422		-103,680
1979	Oct	816,381,677	3,693,254	
1979	Dec	815,161,709		-1,219,968
1980	Aug	836,281,757	21,120,048	
1980	Dec	832,391,942		-3,889,814
1981	Sep	874,268,813	41,876,870	
1981	Dec	871,676,813		-2,592,000
1982	Feb	873,425,549	1,748,736	
1982	Apr	872,787,917		-637,632
1982	Jul	873,475,661	687,744	
1982	Nov	864,403,834		-9,071,827
1982	Dec	864,805,594	401,760	
1983	Dec	854,714,938		-10,090,656
1984	Aug	873,605,174	18,890,237	
1984	Oct	872,573,558		-1,031,616
1984	Nov	872,884,598	311,040	
1985	Jan	872,107,862		-776,736
1985	Sep	891,538,618	19,430,755	
1985	Nov	891,031,450		-507,168
1986	Sep	915,527,232	24,495,782	
1986	Dec	914,405,674		-1,121,558
1987	Sep	937,214,928	22,809,254	
1987	Dec	934,856,208		-2,358,720
1988	Aug	972,892,944	38,036,736	
1988	Nov	972,027,216		-865,728
1989	May	987,793,747	15,766,531	
1990	May	977,468,688		-10,325,059
1990	Sep	979,512,912	2,044,224	

Table A, 2.15 Probability of Storage Volume at Tocontasi & Chapisca

<Probabilidad de Volumen de Almacenamiento en Tocontasi y Chapisca>

(Inflow = Qobs, Outflow = 2.0 m3/s)

("Rising" or "Decreasing" refers to the period that storage volume changes from Max. to Min. or Min. to Max. in a cycle)

Order	Necessary Storage Volume (m3)		Weibull Probability		
	Rising Period	Decreasing Period	T (Year)	P(x) (%)	F(x) (%)
1	61,198,848	-47,697,811	45.000	2.22	97.78
2	58,367,520	-18,449,856	22.500	4.44	95.56
3	47,952,864	-17,737,056	15.000	6.67	93.33
4	41,548,896	-15,762,816	11.250	8.89	91.11
5	35,576,928	-15,065,568	9.000	11.11	88.89
6	35,251,200	-14,332,896	7.500	13.33	86.67
7	33,087,830	-14,233,450	6.429	15.56	84.44
8	32,344,704	-13,709,088	5.625	17.78	82.22
9	25,062,048	-12,913,171	5.000	20.00	80.00
10	20,057,933	-12,769,056	4.500	22.22	77.78
11	17,741,981	-12,167,194	4.091	24.44	75.56
12	17,632,512	-12,141,619	3.750	26.67	73.33
13	15,971,558	-11,617,344	3.462	28.89	71.11
14	15,259,104	-10,914,912	3.214	31.11	68.89
15	15,186,787	-10,576,829	3.000	33.33	66.67
16	14,785,027	-10,304,669	2.813	35.56	64.44
17	14,785,027	-10,102,493	2.647	37.78	62.22
18	14,785,027	-9,927,101	2.500	40.00	60.00
19	14,785,027	-9,856,858	2.368	42.22	57.78
20	14,785,027	-9,510,394	2.250	44.44	55.56
21	14,785,027	-9,203,674	2.143	46.67	53.33
22	14,785,027	-9,160,819	2.045	48.89	51.11
23	14,367,456	-8,973,072	1.957	51.11	48.89
24	14,168,822	-8,919,763	1.875	53.33	46.67
25	13,365,302	-8,919,763	1.800	55.56	44.44
26	13,242,269	-8,919,763	1.731	57.78	42.22
27	13,054,781	-8,919,763	1.667	60.00	40.00
28	12,438,749	-8,632,397	1.607	62.22	37.78
29	11,465,280	-7,655,904	1.552	64.44	35.56
30	10,473,494	-7,531,315	1.500	66.67	33.33
31	9,145,440	-7,246,973	1.452	68.89	31.11
32	9,082,368	-6,743,952	1.406	71.11	28.89
33	7,752,758	-6,606,144	1.364	73.33	26.67
34	5,897,664	-6,077,376	1.324	75.56	24.44
35	4,918,752	-5,841,504	1.286	77.78	22.22
36	4,805,568	-5,770,656	1.250	80.00	20.00
37	4,493,664	-5,725,814	1.216	82.22	17.78
38	4,209,408	-5,467,997	1.184	84.44	15.56
39	3,749,760	-4,898,016	1.154	86.67	13.33
40	2,490,912	-4,320,432	1.125	88.89	11.11
41	2,346,278	-3,185,654	1.098	91.11	8.89
42	1,499,904	-2,464,992	1.071	93.33	6.67
43	1,124,928	-2,242,080	1.047	95.56	4.44
44	910,656	-2,153,088	1.023	97.78	2.22

Table A, 2.16 Probability of Storage Volume at Tocontasi & Chapisca

<Probabilidad de Volumen de Almacenamiento en Tocontasi y Chapisca>

(Inflow = Qobs, Outflow = 1.5 m3/s)

("Rising" or "Decreasing" refers to the period that storage volume changes from Max. to Min. or Min. to Max. in a cycle)

Order	Necessary Storage Volume (m3)		Weibull Probability		
	Rising Period	Decreasing Period	T (Year)	P(x) (%)	F(x) (%)
1	158,502,269	-10,325,059	45.000	2.22	97.78
2	71,946,662	-10,090,656	22.500	4.44	95.56
3	63,656,928	-9,071,827	15.000	6.67	93.33
4	53,259,552	-5,090,688	11.250	8.89	91.11
5	41,876,870	-5,083,776	9.000	11.11	88.89
6	38,036,736	-4,395,168	7.500	13.33	86.67
7	37,807,776	-3,889,814	6.429	15.56	84.44
8	35,321,789	-3,883,680	5.625	17.78	82.22
9	30,822,077	-3,361,997	5.000	20.00	80.00
10	28,678,752	-3,233,952	4.500	22.22	77.78
11	26,662,176	-2,852,064	4.091	24.44	75.56
12	25,094,016	-2,778,624	3.750	26.67	73.33
13	24,495,782	-2,701,728	3.462	28.89	71.11
14	24,002,006	-2,636,064	3.214	31.11	68.89
15	22,809,254	-2,592,000	3.000	33.33	66.67
16	22,754,822	-2,506,464	2.813	35.56	64.44
17	22,754,822	-2,445,984	2.647	37.78	62.22
18	22,754,822	-2,358,720	2.500	40.00	60.00
19	22,718,880	-2,262,816	2.368	42.22	57.78
20	22,705,574	-2,079,648	2.250	44.44	55.56
21	21,971,261	-2,022,710	2.143	46.67	53.33
22	21,701,952	-1,960,416	2.045	48.89	51.11
23	21,120,048	-1,815,264	1.957	51.11	48.89
24	21,025,958	-1,740,096	1.875	53.33	46.67
25	19,430,755	-1,620,864	1.800	55.56	44.44
26	19,069,344	-1,620,000	1.731	57.78	42.22
27	18,890,237	-1,600,992	1.667	60.00	40.00
28	15,776,035	-1,553,472	1.607	62.22	37.78
29	15,766,531	-1,364,256	1.552	64.44	35.56
30	13,496,803	-1,362,614	1.500	66.67	33.33
31	12,974,861	-1,219,968	1.452	68.89	31.11
32	12,970,368	-1,143,072	1.406	71.11	28.89
33	10,604,736	-1,121,558	1.364	73.33	26.67
34	8,446,464	-1,121,558	1.324	75.56	24.44
35	7,296,912	-1,121,558	1.286	77.78	22.22
36	6,280,848	-1,121,558	1.250	80.00	20.00
37	5,227,718	-1,121,558	1.216	82.22	17.78
38	5,088,960	-1,031,616	1.184	84.44	15.56
39	5,006,016	-943,488	1.154	86.67	13.33
40	3,693,254	-933,120	1.125	88.89	11.11
41	2,839,104	-865,728	1.098	91.11	8.89
42	2,044,224	-814,752	1.071	93.33	6.67
43	1,897,430	-787,968	1.047	95.56	4.44
44	1,748,736	-776,736	1.023	97.78	2.22

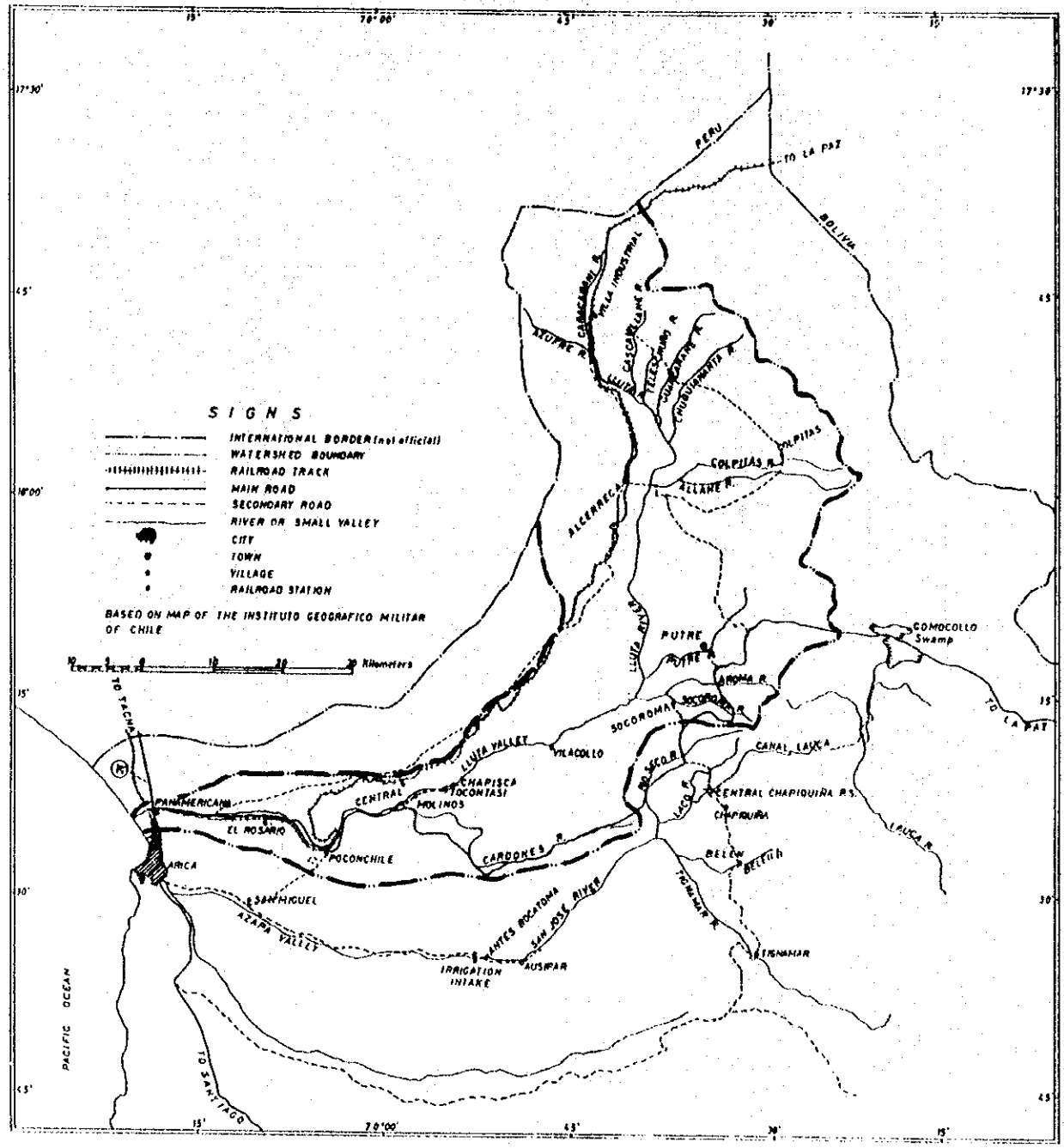


Fig. A, 2.1 River System of Lluta River Basin

<Systema Fluvial de la Cuenca del Rio Lluta>

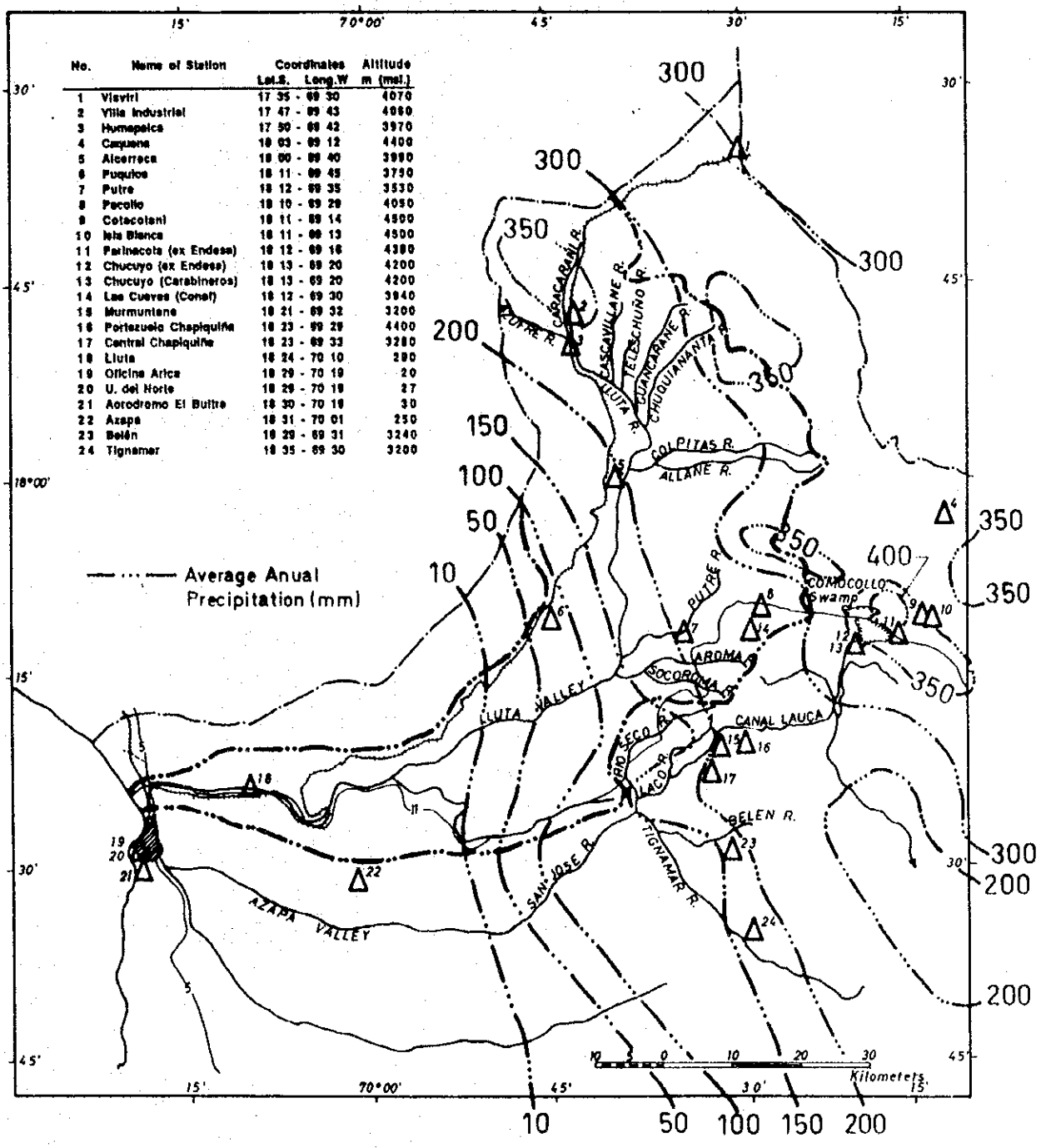
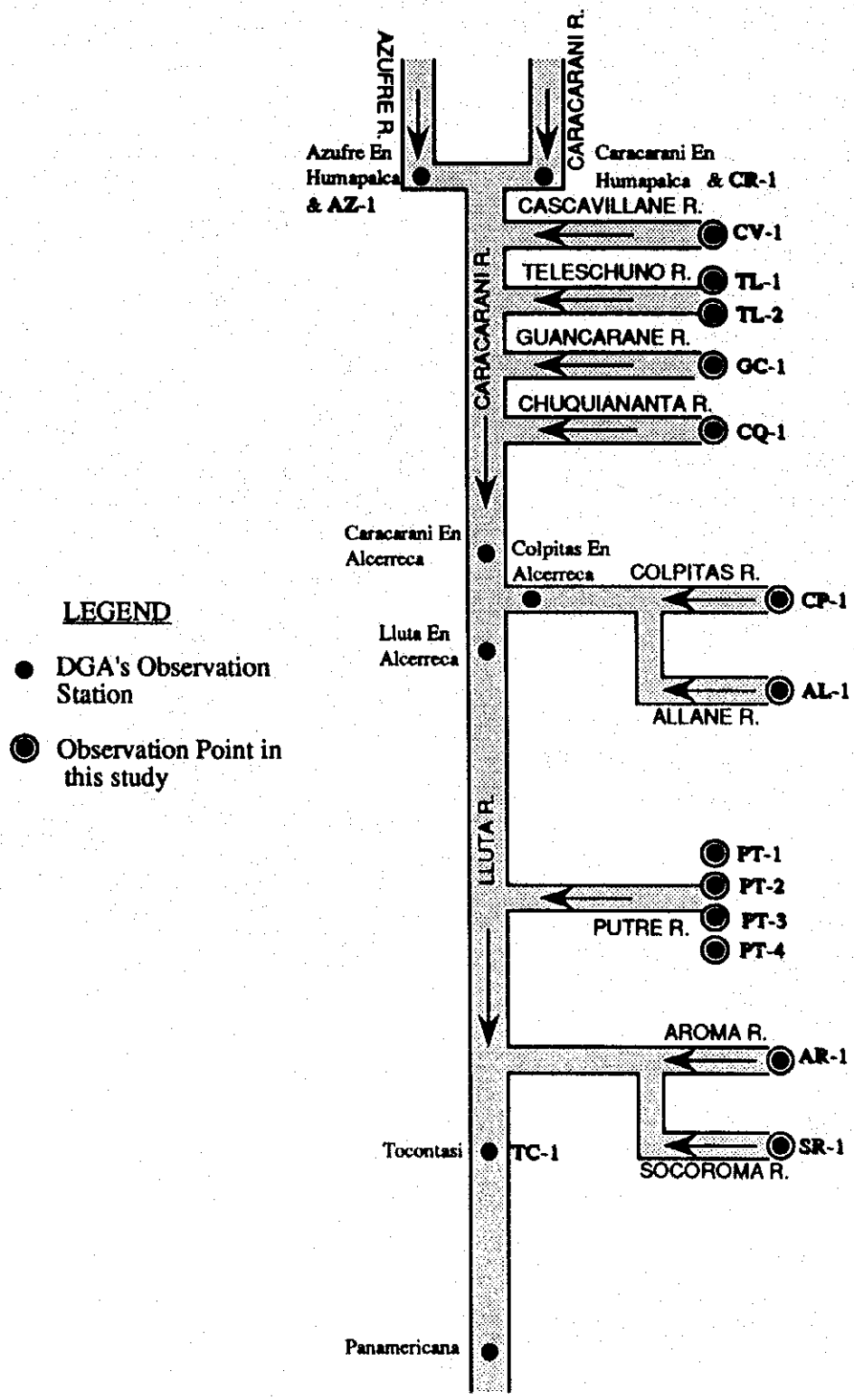


Fig. A, 2.2 Average Precipitation (Isohyetal Map) in Lluta River Basin

<Precipitacion Promedio en Mapa de Isoyeta en la Cuenca del Rio Lluta>



Flow Model in Lluta River Basin

Fig. A, 2.3 Flow Model in Lluta River Basin

<Modelo de Flujo en la Cuenca del Rio Lluta>

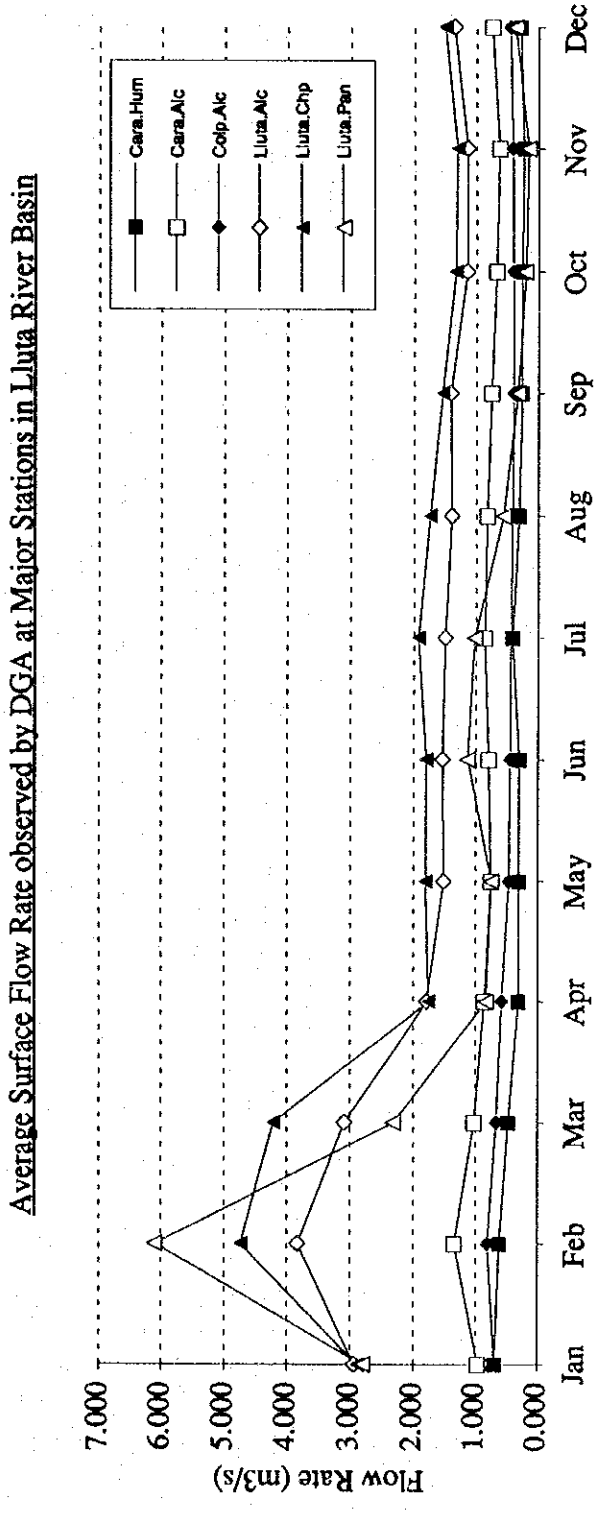


Fig. A, 2.4 Average Surface Flow Rate in Lluta River Basin

<Nivel de Flujo de Superficie Premedio Meansual de la Cuenca del Rio Lluta>

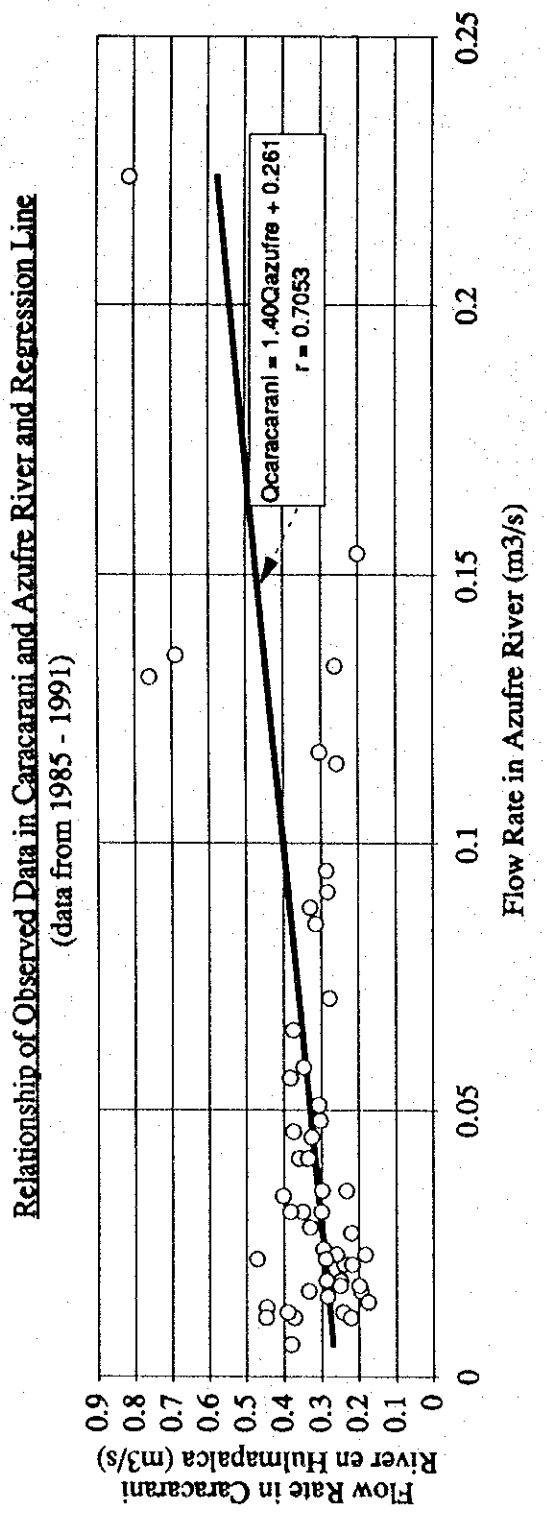


Fig. A, 2.5 Relationship of Observed Data in Caracarani and Azufre River and Regression Line

<Relacion de Datos Observado en Rio Caracarani y Azufre y Linea de Regresion>

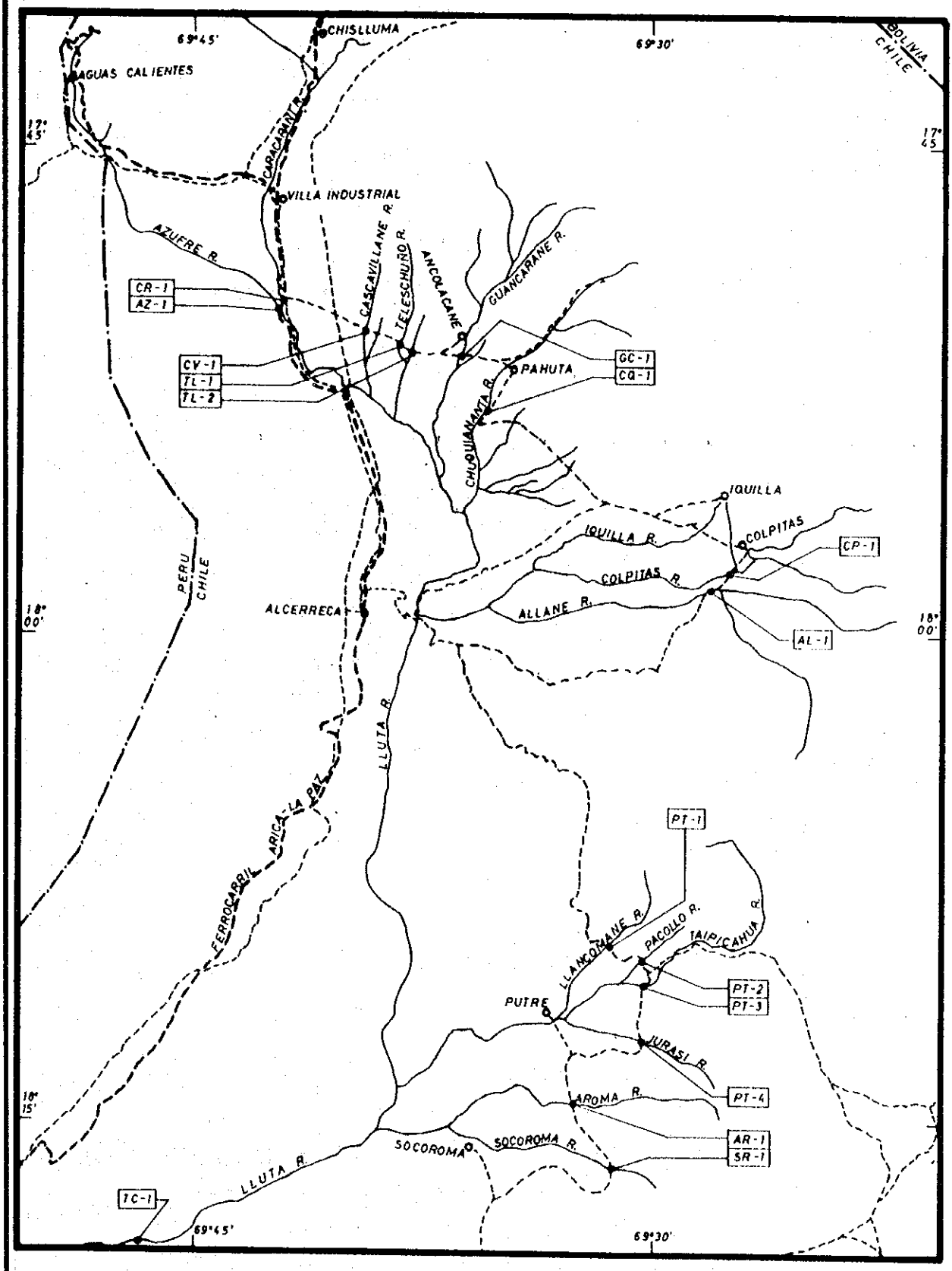


Fig. A, 2.6 Location of Observation Points on 1st - 3rd June 1993 in Lluta River Basin

<Ubicacion de Los Puntos de Observacion el 1 - 3 Junio 1993 en la Cuenca del Rio

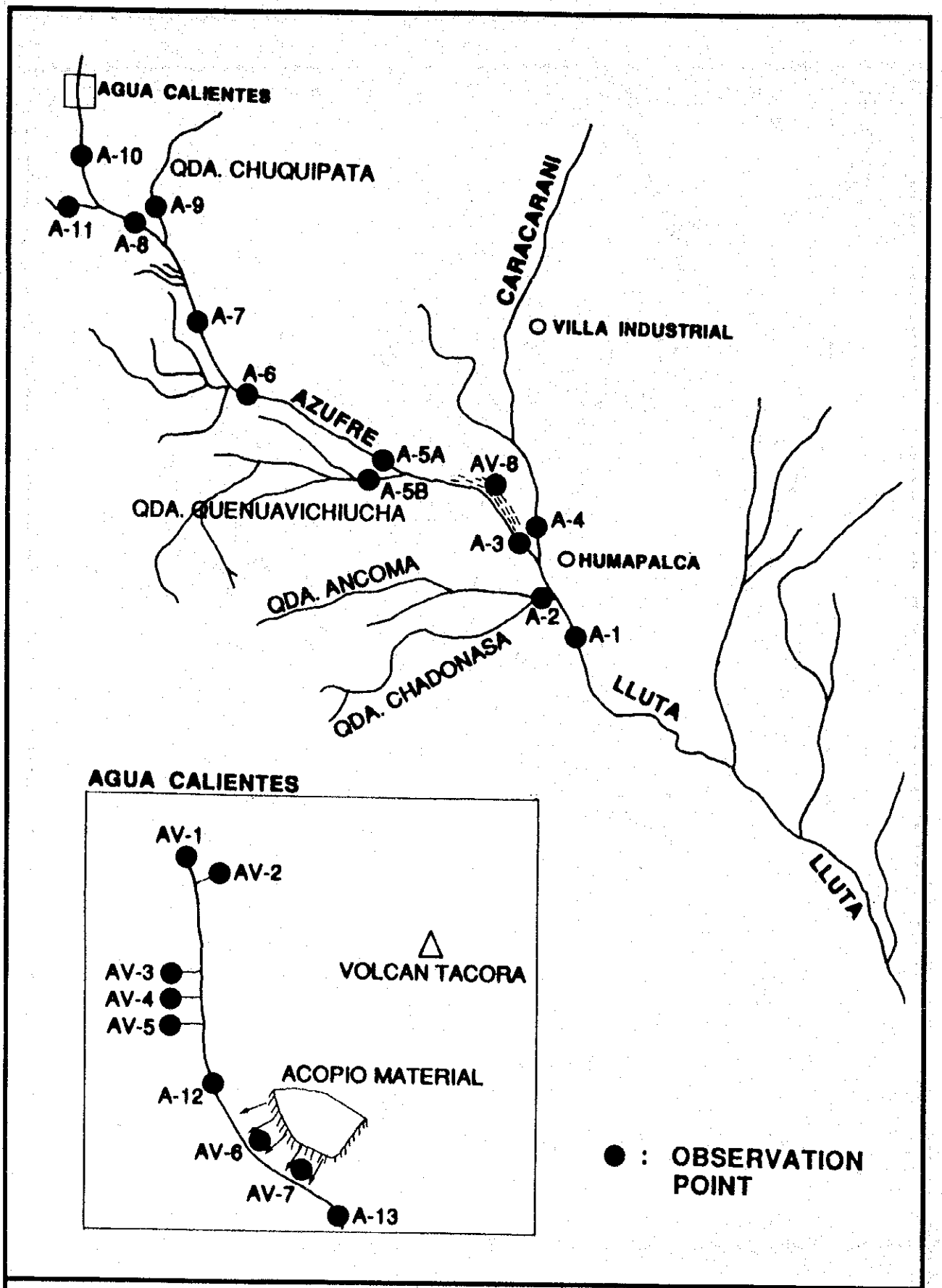


Fig. A, 2.7 Location of Observation Points in Azufre River Basin in November 1993

<Mapa de Ubicacion de Los Puntos el Noviembre 1993 en la Cuenca del Rio Azufre>

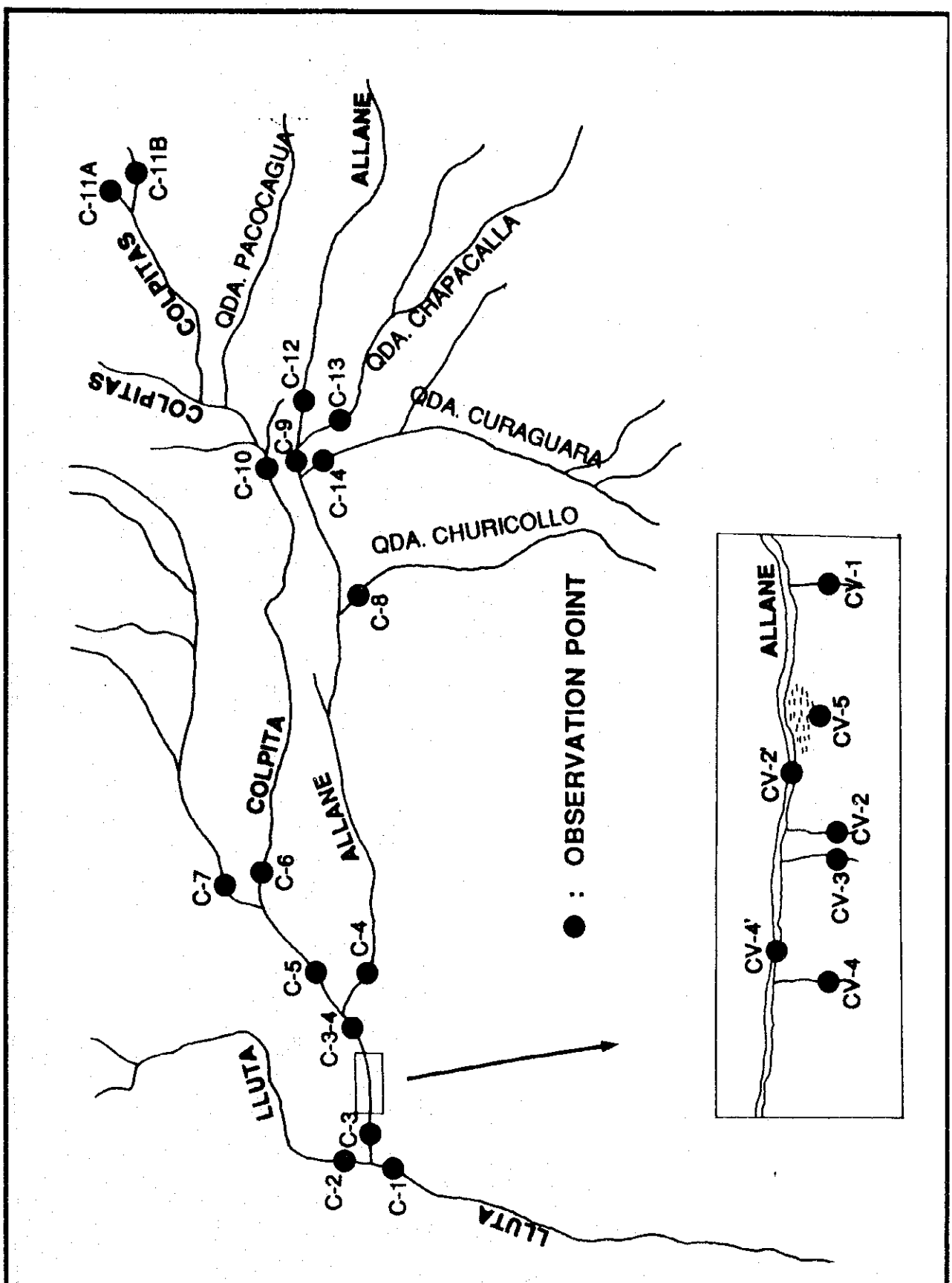


Fig. A, 2.8 Location of Observation Points in Colpitas River Basin in November 1993

<Mapa de Ubicacion de Los Puntos el Noviembre 1993 en la Cuenca del Rio Colpitas>

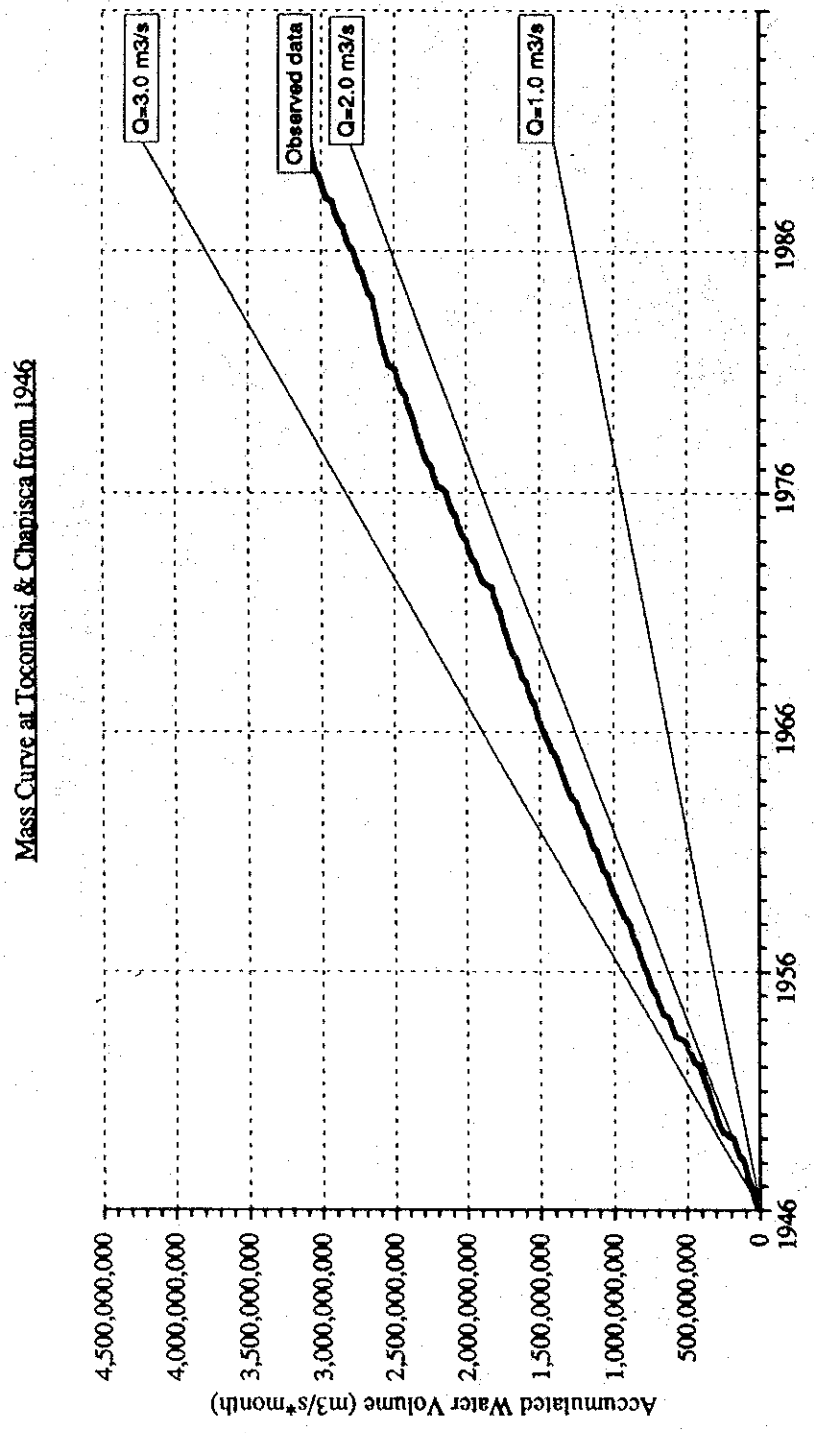


Fig. A, 2.9 Mass Curve at Tocontasi & Chapisca from 1946

<Curva de Mase en Tocontasi y Chapisca desde 1946>

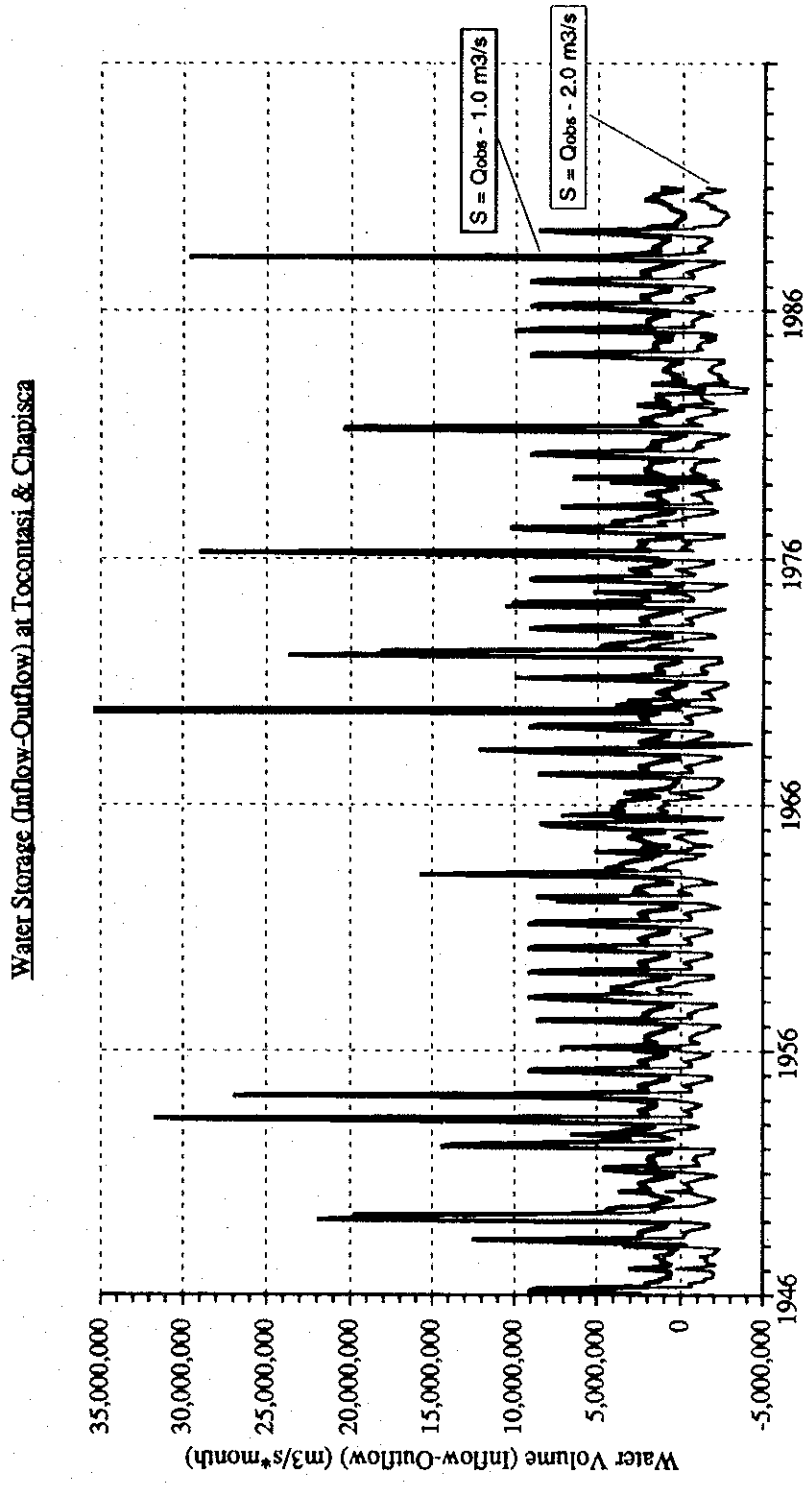


Fig. A, 2.10 Water Storage (Inflow - Outflow) at Tocontasi & Chapisca

<Almacenamiento de Agua (Entrada - Salida) en Tocontasi y Chapisca>

Chapter III SURFACE WATER OF PAMPA DEL TAMARUGAL BASIN

3.1 General

Pampa del Tamarugal basin located in the Region I in northern Chile has a total drainage basin area of 18,005 km^2, covers the river basin of 7,435 km^2 and residual basin of 10,570 km^2. Drainage basin area is shown in Fig. A, 3.1 and Table A, 3.1.

3.1.1 Climate and Precipitation

Information on climate in the basin is obtained from Pampa Lirima (Pueblo Nuevo) weather station in the upstream of the basin. Maximum monthly average temperature is in March at 22.4 °C and minimum one is in June at 10.0 °C. Humidity does not vary much throughout a year lying within a range of 35 - 55 %.

Precipitation is observed regularly by DGA and Meteorological Department. Most of the stations are distributed in the upstream of the basin as shown in Fig. A, 3.2.

Most of the precipitation fall in the upstream mountain areas with an altitude of higher than 3,000 m. However, in downstream of the rivers in the middle part of the basin, precipitation is almost nil. Average annual precipitation regionally varies from zero in the Pampa areas to 200 mm in the highest mountain areas as shown in Fig. A,3.2.

3.1.2 River System

Main rivers in the basin are Aroma, Tarapaca, Quipisca, Juan Morales (or Sagasca), Quisma (or Pica), Chacarilla and Ramada rivers. All the rivers originate in the east and flow westwards to the Pampa areas. In downstream, all flows infiltrate to underground and the river courses disappear.

Although there are several rivers in the basin, only above mentioned seven (7) rivers are not dried-up according to the information obtained from DGA. Flow model is shown in Fig., A, 3.3.

3.2 Surface Flow Rate

3.2.1 Flow Rate at Major Stations

Daily water levels are observed at DGA's observation stations by automatic recorders. Flow rate at each stations is generally calculated by so called "Discharge Rating Curve" or "H-Q Curve" which is a calibration curve of water level and flow rate. Data of other basins are also used for the calculation since a few station is available in Pampa del Tamarugal. Major observation stations are as follows;

River	Location	Observation Period
Tarapacá	Mina San Juan	1984 - 1990
Coscaya	Saitoco	1985 - 1990
	Pampa Lirima	1977 - 1989
Camarones	Conanoxa	-
Oda. Camiña	Altusa	-
Roa	Lequena	-

Average, maximum and minimum surface flow rate of these stations in the recorded years are shown in Table A, 3.2, fluctuation of these flows throughout a year are shown in Fig. A.3.4 and recorded monthly flow rates are shown in Appendix A, 3.1.

Information on flow rate in recent years is limited to only in Tarapacá River basin, a main river in the basin, and Coscaya River, a tributary of Tarapacá River in the south. Average total flow rate of Tarapacá is 0.303 m^3/s. All this water amount infiltrates into underground in the downstream Pampa areas.

Averaged surface flow rates of other basins are as follows;

Camarones	: 0.52 m^3/s
Camiña	: 0.61 m^3/s
Loa (Lequeña)	: 0.53 m^3/s
Loa (Desp. Junta)	: 1.07 m^3/s

3.2.2 Calculation of Runoff Coefficient

Average yearly rainfall contour map prepared by DGA in 1987, as shown in Fig. A, 3.2, is used to calculate the surface runoff coefficient which in this case is the ratio of the average indigenous flow rate of

Tarapacá River at Mina San Juan, the only available observed data in the basin, with average annual precipitation in its upstream basin. Runoff coefficient is found to be 0.054 as shown in Table A, 3.3. This can be interpreted that about 5.4 % of rainfall flows through rivers as surface flow in the upstream of Tarapacá River basin. The remaining 94.6 % is mainly lost by evaporation.

3.3 Surface Water Quality

3.3.1 Water Quality at Major Stations

Water quality is observed at DGA's observation stations. Water samples are taken from the river and analyzed in the laboratory. Observation stations are as follows;

River	Location	Observation Period
Tarapaca	Mocha	1970 - 1981
	Pachica	1970 - 1987
Coscaya	Pampa Lirima	1975 - 1989

The items of the analysis are classified as follows;

(1) Health Significance : As, $N\text{-}NO_3$, $N\text{-}NO_2$, $N\text{-}NH_3$

(2) Aesthetic Quality : Cl^-, Cu, Fe, Na, P, SO_4, pH

(3) Others : HCO_3, CO_3, Ca, Mg, K, B, E.C.

Results of the examination are shown in Table A, 3.4. Average monthly data are shown in Appendix A, 3.2.

3.3.2 Evaluation of Water Quality

Permissible drinking water quality of Chile is shown partly as follows;

	pH	Cl^- (mg/l)	SO_4 (mg/l)	Mg (mg/l)	As (mg/l)	Cu (mg/l)	Fe (mg/l)	$N\text{-}NO_3$ (mg/l)
Permissible Values	6.0-8.5	250	250	125	0.05	1.0	0.3	10.0

Water Quality Standard is referred in Appendix A, 5.