APPENDIXES

APPENDIXES

Appendix-1 Planning of Upper Lluta Alternative to Arica Water Supply

(Note): This Appendix preliminarily deals with the water source of the Lluta river upstream, for the purpose of informational reference to readers.

Water Source

The surface water from the tributaries in the upstream of the Lluta river might be identified as a supplementary source for the Arica water supply scheme. The Lluta river rises at an elevation of more than +4,000 m MSL. Many creeks join to form the upstream of the Lluta river. The quality of water in the Lluta river is not within the limits of the Chilean Drinking Water Standards (NCH409). The water is contaminated with arsenic (As), boron (B) and iron (Fe).

Among many streams in the Upper Lluta river catchment, two tributaries (Guancarane and Caracarani), with less contamination by As, B and Fe, are identified as suitable for extracting water for the Arica water supply. These two streams might be able to be developed.

However, the existing water demand and supply balance of Lower Lluta River is tight. The water extraction from the upper tributaries will fringe the existing river water rights for agricultural uses in the Lower Lluta Valley.

The monthly drought discharge with the exceeding probabilities of 80% (design probability for irrigation) at Tocontasi/Chapisca station are estimated as follows.

	Jan. ~ Sep.	Oct.	Nov.	Dec.
80% Drought Discharge (l/s)	1,302~1,830	1,168	1,089	1,091

For details, see Supporting Report A, Table A, 2.4.

On the other hand, the following river water rights are granted to the agricultural uses in the downstream reaches of Tocontasi/Chapisca station as of 1993.

Legally authorized river water rights : 284.50 l/s
Custom river water rights : 2,558.15 acción
(maximum quantity : 2,558.15 x 0.75 = 1,918.61 l/s)

For details of the water rights, see Supporting Report C, Appendix C.3.

From the above discussions, the surface water development of the upper tributaries is considered difficult.

However, the actual water demand is smaller than the total amount of the existing water rights. Because the river water is repeatedly used between Tocontasi/Chapisca and river mouth. The irrigation water extracted from the upstream intakes is not all really consumed but its considerable portion is returned to the river for re-use in the downstream. The existing average real irrigation water consumption in the downstream reaches of Tocontasi/Chapisca is estimated to be approximately 900 l/s (see Supporting Report C).

In this Upper Lluta development study, the river water requirement at Tocontasi/Chapisca for the irrigation in the downstream is preliminarily assumed to be 1,000 l/s, considering 10% allowance to the real irrigation water consumption.

If this assumption would be accepted by the concerned water right owerners, some surface water of the two upper tributaries could be extracted during the period of January to September, however, no water could be developed for the remaining driest period of October to December.

The drought discharge with a 90% probability of the Caracarani and Guancarane rivers are estimated as follows.

	Jan.~Sep.	Oct.	Nov.	Dec.
Caracarani (Humapalca)(l/s)	211~258	182	140	142
Guancarane (l/s)	90~110	78	60	61
Total (l/s)	301~368	260	200	203

From the above discussions, 270 l/s (considering 10% allowance to the available water of 301 l/s) could be extracted from the upper tributaries ; 190 l/s from Caracarani and 80 l/s from Guancarane, during the period of nine months (Jan. - Sep.).

This development can supply 202 l/s to Arica city throughout the year by combining with the existing water supply system of Azapa Valley as follows.

	Jan.~Sep.	Oct.~Dec.	Average
Upper Lluta	270 l/s	0	202 l/s
Azapa Valley	435 l/s	705	503 *

* : Existing water supply of Azapa Valley

However, the water intake rate is hardly sufficient to meet the future water requirement. But, this source can be considered as a potential supplementary source.

Water Quality

According to the water quality analysis, following constituents are observed to be present in the water. The concentration of each constituent and the permissible limits of the same, are listed below:

Item	As (mg/l)	B(mg/l)	Fe (mg/l)	TDS (mg/l)
- Caracarani (at Humapalca)	0.120	3.23	1.17	1,328
- Guancarane	0.018	0.23	0.31	94
Expected level in the above two combined water	0.09	2.34	0.92	962
Permissible limit (NCH 409)	0.05		0.30	1,000

Therefore, the construction of a treatment plant is necessary for treating the water to an acceptable level. The treatment plant will be located in the Lower Lluta area in the Arica territory.

Treatment Process

The surface water contains As, Fe and turbidity. Therefore, an aeration to oxidize Fe++ ions and the chemical precipitation followed by the filtration for the removal of oxidized Fe ions, turbidity and excessive As, are recommended for treating the raw water from the two streams. For the flow diagram of the treatment plant, see Fig. DA 1-5.

Transmission Pipeline

The Caracarani river intake (q= 190 l/sec; WL=+4,040 m) is located near Villa Industrial; and the Guancarane river intake (q= 80 l/sec; WL=+4,040 m) near Ancolacane. The raw water transmission pipeline from the two sources to the Lluta Treatment Plant is of ductile cast iron pipes (DIP), 131.7 km long in total and the diameters vary from 500-300 mm. The Caracarani water flows by gravity to a junction tank (WL=+3,940 m) to be located near Alcerreca. The Guancarane water also flows by gravity to the same junction tank. The water then flows by gravity from the junction tank (GL=+3,940 m) to the Lluta treatment plant (Gl+=131 m). As the water sources are located at a fairly high altitude, 30 break-pressure tanks are required along the main for the purpose of reducing the operating pressure within the water mains to acceptable levels.

The transmission route follows the gravel-paved road used for maintenance of the above-ground oil pipeline, which runs from Bolivia to the Arica port, via mountainous desert areas. This road runs parallel with the railway line, which connects the Arica harbor, Chile, and Bolivia.

The route of the pipeline is shown in Fig. DA 1-1. The longitudinal profile is shown in Fig. DA 1-2 to Fig. DA 1-4. The hydraulic calculation is described in Table DA 1-1.

Water Pollution Control of Lluta River

This surface water development of Caracarani and Guancarane rivers will aggravate the water quality of Lower Lluta River to some extent due to the reduction of the clean water. The annual average content of Boron (B) at Tocontasi/Chapisca will increase by 8%.

Therefore, it will be necessary to reduce the pollution loads, especially, Boron (B) of Azufre River and/or Colpitas River to compensate for the above-mentioned adverse effects on the water quality of Lower Lluta River.

For this purpose, the following two (2) works are proposed.

(1) Construction of a bypass channel in the downstream reaches of Azufre River to remove the pollutants springing from the river bed.

(2) Construction of an evaporation pond in the upstream reaches of Colpitas River to evaporate a certain portion of the contaminated river water.

For the construction plans of the bypass channel and evaporation pond, see the following sections <Note-1> and <Note-2>.

Construction Cost

Cost estimation is summarized below:

Item	Amount (Peso:$)
(A) Intake facilities	$135,000,000
(B) Transmission pipeline	$16,159,869,000
(C) Tanks	$240,669,000
(D) Treatment plant	$4,919,427,000
(E) Bypass channel work of Azufre River	$177,820,000
(F) Evaporation pond	$297,211,000
	Total = $ 21,929,996,000

For more details, see Table DA 1-2.

Table DA1-1 Hydraulic Calculations for Transmission Pipelines, Upper Lluta Alternative to Arica Water Supply

Transmission Pipeline
from Caracarani/Guancarane Rivers to Lluta Treatment Plant

Total Pipe Length: (22,900 + 94,300) + 14,500
= 117,200 + 14,500 = 131,700 m

From Caracarani River to Lluta Treatment Plant
Total Length: L= 117,200 m

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Point (Accumulated Distance)	Altitude above Sea Level	Distance between Two Points	Flow Q	Pipe Dia.	V	I	H	Dynamic Water Level
(m)	(+m)	(m)	(l/s)	(mm)	(m/s)	(x10*-3)	(m)	(+m)
0	+4,040	0						+4,040
(Garacarani River Intake near Villa Industrial: Intake = 190 l/sec)								
22,900	+3,940	22,900	190	450	1.19	2.96	67.78	+3,972.22
(Junction Tank: LWL=+3,940; Mixed with Guarantee water of 80 l/sec)								
27,150	+3,920	4,250	270	500	1.38	3.40	14.45	+3,925.55
(Alcerreca: Without Tank)								
31,900	+3,850	4,750	270	400	2.14	10.07	47.83	+3,877.72
(Tank: LWL=+3,850								
47,100	+3,750	15,200	270	450	1.70	5.68	86.34	+3,763.66
(Tank: LWL=3,750)								
58,000	+3,600	10,900	270	450	1.70	5.68	61.91	+3,688.09
(Tank: LWL=+3,600)								
61,500	+3,400	3,500	270	350	2.81	19.3	67.55	+3,532.45
(Tank: LWL=+3,400)								
64,800	+3,200	3,300	"	"	"	"	63.69	+3,336.31
(Tank: LWL=+3,200)								
65,600	+3,000	800	"	"	"	"	15.44	+3,184.56
(Tank: LWL=+3,000)								
68,400	+2,800	2,800	"	"	"	"	54.04	+2,945.96
(Tank: LWL=+2,800)								
70,000	+2,600	1,600	"	"	"	"	30.88	+2,769.12
(Tank: LWL=2,600)								
73,000	+2,400	3,000	"	"	"	"	57.90	+2,542.10
(Tank: LWL=+2,400)								
75,500	+2,200	2,500	"	"	"	"	48.25	+2,351.75
(Tank: LWL=+2,200)								
76,300	+2,000	800	"	"	"	"	15.44	+2,184.56
(Tank: LWL=+2,000)								
78,500	+1,800	2,200	"	"	"	"	42.46	+1,957.54
(Tank: LWL=+1,800)								
81,500	+1,600	3,000	"	"	"	"	57.90	+1,742.10
(Tank: LWL=+1,600)								
85,300	+1,400	3,800	"	"	"	"	73.34	+1,526.66
(Tank: LWL=+1,400)								

(1) Point (Accumulated Distance) (m)	(2) Altitude above Sea Level (+m)	(3) Distance between Two Points (m)	(4) Flow Q (l/s)	(5) Pipe Dia. (mm)	(6) V (m/s)	(7) I (x10*-3)	(8) H (m)	(9) Dynamic Water Level (+m)
90,100 (Tank: LWL=+1,200)	+1,200	4,800	270	350	2.81	19.3	92.64	+1,307.36
98,700 (Tank: LWL=+1,000)	+1,000	8,600	"	"	"	"	165.98	+1,034.02
103,300 (Tank: LWL=+800)	+800	4,600	"	"	"	"	88.78	+911.22
106,600 (Tank: LWL=+600)	+600	3,300	"	"	"	"	63.69	+736.31
111,100 (Tank: LWL=+400)	+400	4,500	"	"	"	"	86.85	+513.15
111,500 (Tank: LWL=+250)	+25-	400	"	"	"	"	7.72	+392.28
117,200 {Lluta Treatment Plant: GL=+131, WL (Receiving Tank)=+135}	+131	5,700	"	"	"	"	110.00	+140.00

From Guancarane River to Junction Tank / Alcerreca
Total Length: L= 14,500 m

(1) Point (Accumulated Distance) (m)	(2) Altitude above Sea Level (+m)	(3) Distance between Two Points (m)	(4) Flow Q (l/s)	(5) Pipe Dia. (mm)	(6) V (m/s)	(7) I (x10*-3)	(8) H (m)	(9) Dynamic Water Level (+m)
0 (Garacarani River Intake near Ancolacane: Intake = 80 l/sec)	+4,040	0						+4,040
14,500 (Junction Tank: LWL=+3,940; Mixed with Guarantee water of 190 l/sec)	+3,940	14,500	80	300	1.13	4.31	62.50	+3,977.50

Total Length of Pipes
(Upper Lluta Alternative)

Diameter	Distance
500 mm DIP	4,250 m
450 mm DIP	49,000 m
400 mm DIP	4,750 m
350 mm DIP	59,200 m
300 mm DIP	14,500 m
Total =	131,700 m

Table DA1-2 Construction Cost for Upper Lluta Alternative - Arica Water Supply System (Water Source: Surface Water from Upper Lluta River)

Summary

	Item	Amount (Peso:$)
(A)	Intake Facilities.. (at Guancarane River and Caracarani River)	$135,000,00
(B)	Transmission Pipeline .... (from two after sources to Lluta Treatment Plant)	$16,159,869,000
(C)	Tanks .... (Transmission/Break-pressure/Distribution Tanks))	$240,669,000
(D)	Treatment Plant (at Lluta) .... (Q=270 l/sec)	$4,919,427,000
Sub Total (A+B+C+D)...		$21,454,965,000
(E)	Bypass channel work of Azufre River..............................	$177,820,000
(F)	Evaporation pond work of Colpitas River	$297,211,000
Grand Total (A+B+C+D+E+F)... (Upper Lluta Alternative)		$21,929,996,000

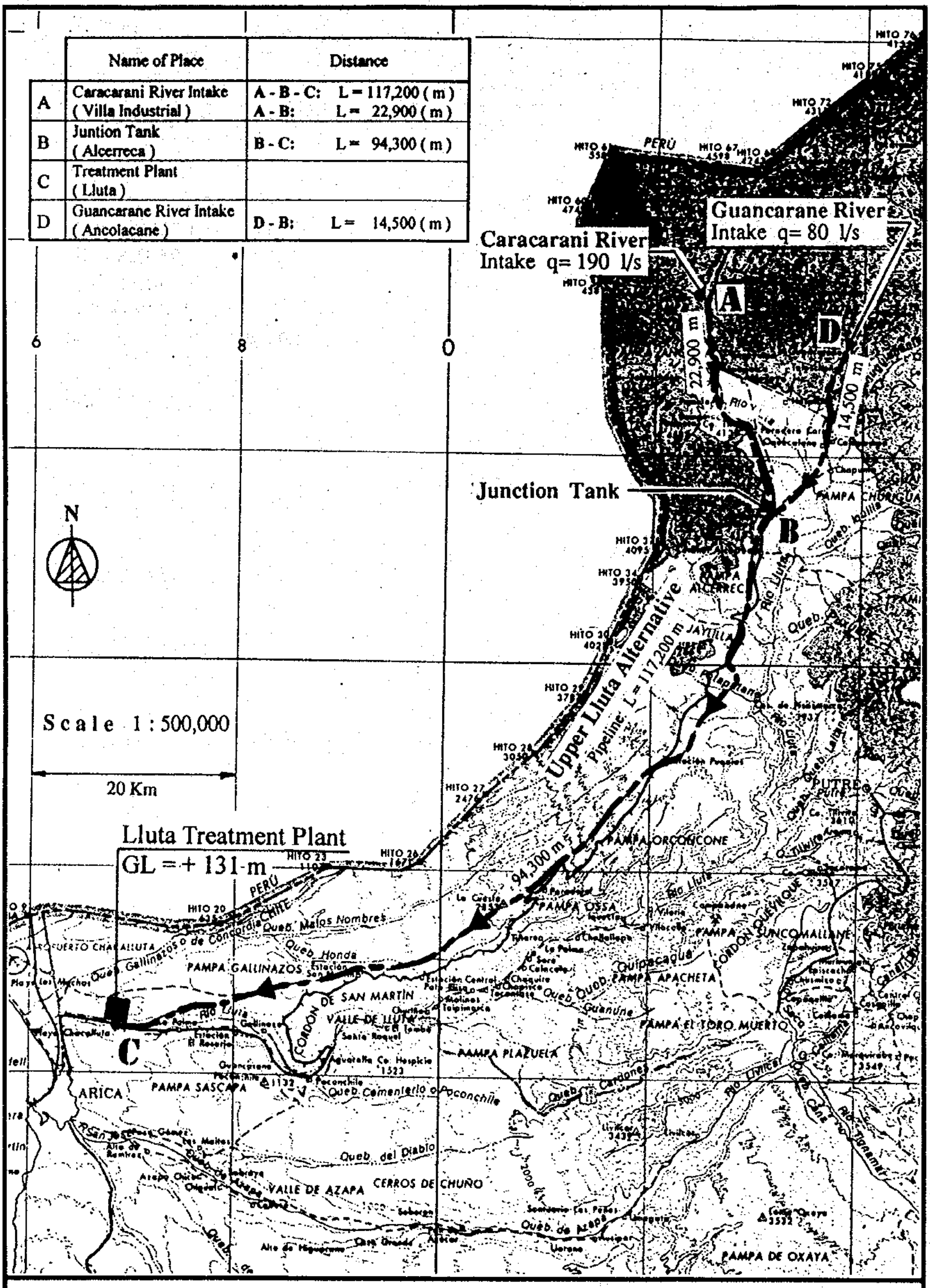
(Note): - Cost : as of March 1994
- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994):
  US$1.00 = Chile Peso: $435.00
  US$1.00 = Japanese Yen: ¥110.00
  Japanese Yen 1.00 = Chile Peso: $3.955

Table DA1-2' Cost Estimation for Upper Lluta Alternative - Arica Water Supply System
(Water Source: Surface Water from Upper Lluta River)

(Note): - Cost : as of March 1994
- Cost without Value Added Tax (IVA)
- Foreign exchange rate (as of March 1994):
US$1.00 = Chile Peso: $435.00
US$1.00 = Japanese Yen: \110.00
Japanese Yen 1.00 = Chile Peso: $3.955

Item		Q'ty	Unit Price ($)	Amount ($)
(A)	Intake Facilities			
1.	Guarantee River intake	1 lot		10,000,000
2.	Intake canal for the above	500 m	100,000	50,000,000
3.	Caracarani River intake	1 lot	2,200,000	15,000,000
4.	Intake canal for the above	500 m	120,000	60,000,000
Total of (A)				$135,000,000
(B)	Transmission Pipeline (from two after water sources) (Materials and Installation cost)			
1.	500 mm DIP	4,250 m	167,677	712,627,000
2.	450 mm "	49,000 m	144,568	7,083,832,000
3.	400 mm "	4,750 m	122,701	582,830,000
4.	350 mm "	59,200 m	103,565	6,131,048,000
5.	300 mm "	14,500 m	83,146	1,205,617,000
			Sub Total =	$15,715,954,000
6.	Pressure reducing valve: 450 mm (with strainer)	1 No.	34,250,000	34,250,000
7.	Pressure reducing valve: 350 mm	17 Nos.	21,745,000	369,665,000
8.	Road crossing work	2 sites	2,000,000	4,000,000
9.	Railway crossing work	8 sites	2,000,000	16,000,000
10.	River crossing work	2 sites	10,000,000	20,000,000
Total of (B)				$16,159,869,000
(C)	Tanks (RC: Reinforced Concrete)			
1.	1,000 m^3 tank (Junction tank near Alcerreca)	1 No.	43,709,000	43,709,000
2.	162 m^3 tank (Break-pressure tank)	20 Nos.	9,848,000	196,960,000
Total of (C)				$240,669,000

	Item	Q'ty	Unit Price ($)	Amount ($)
(D)	Treatment Plant (at Chilloma) (Capacity: Q= 270 l/sec = 23,330 m^3/day)			
1.	Civil works	1 lot	43,709,000	1,250,629,000
2.	Building works	1 lot		760,186,000
3.	Mechanical equipment	1 lot		1,790,116,000
4.	Electric equipment	1 lot		1,103,496,000
5.	Land acquisition	5 ha	3,000,000	15,000,000
Total of (D)				$4,919,427,000
Total of (A+B+C+D)				$21,454,965,000
(E)	Azufre River Bypass channel work --> (See <Note-1>)			
1.	Diversion canal (500w x 400h; masonry)	5,000 m	35,564	177,820,000
Total of (E)				177,820,000
(F)	Colpitas River Evaporation pond work --> (See <Note-2>)			
1.	Diversion canal (300w x 250h; masonry)	900 m	20,966	18,869,000
2.	Soil bank construction (h= 1.5 m = 5.0 m; L= 4,000 m)	131,666 m^3	2,114	278,342,000
Total of (F)				$297,211,000
Grand Total (A+B+C+D+E+F) (Upper Lluta Alternative)				$21,929,996,000



	Name of Place	Distance
A	Caracarani River Intake (Villa Industrial)	A - B - C: L = 117,200 (m) A - B: L = 22,900 (m)
B	Juntion Tank (Alcerreca)	B - C: L = 94,300 (m)
C	Treatment Plant (Lluta)	
D	Guancarane River Intake (Ancolacane)	D - B: L = 14,500 (m)

Fig. DA1 - 1 Upper Lluta Alternative to Arica Water Supply
< Alternativa Alto Lluta al Abastecimiento de Agua de Arica >

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE | JICA

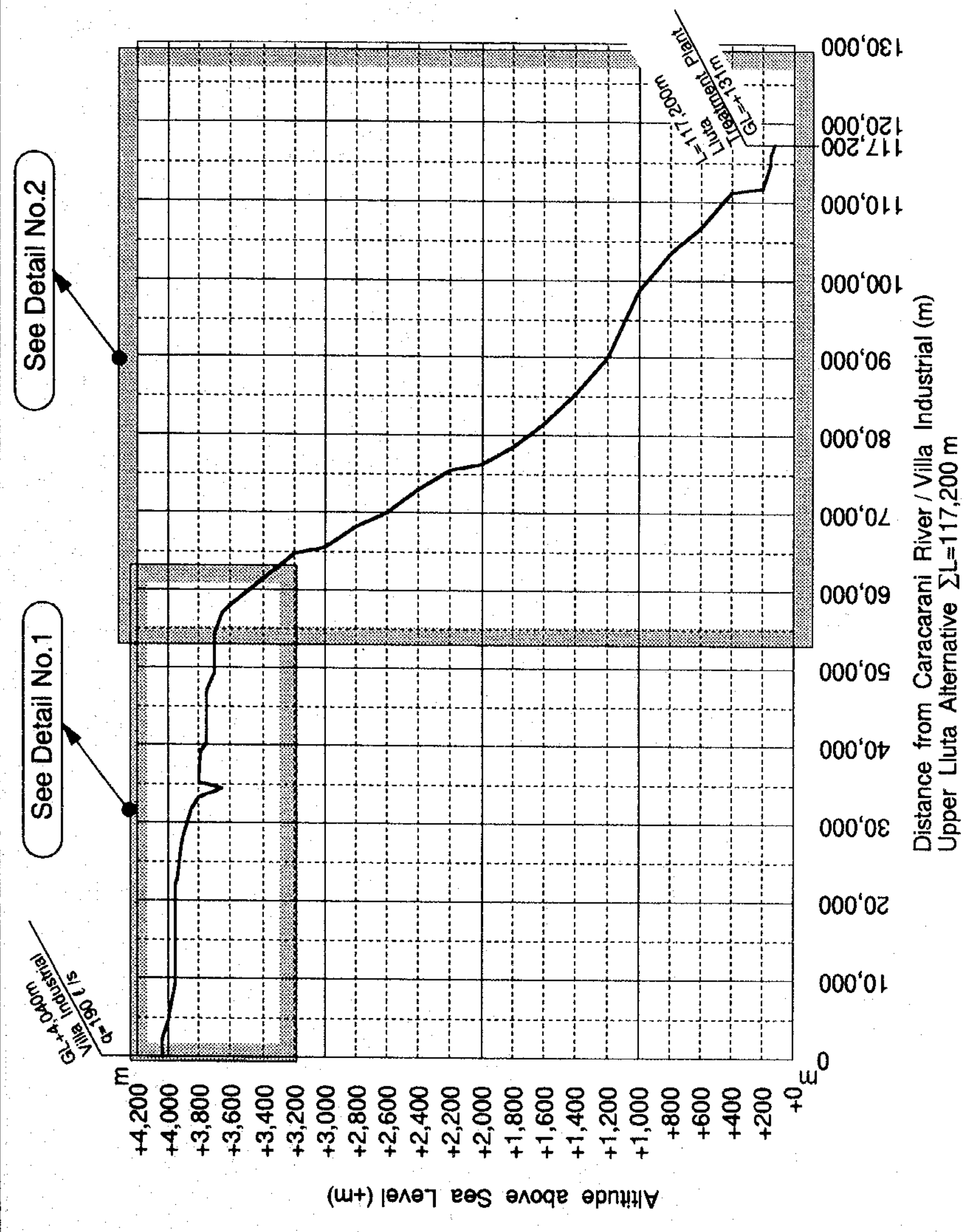


Fig. DA1 - 2 Longitudinal Profile of Transmission Pipeline for Upper Lluta Alternative to Arica Water Supply

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< Perfil Longitudinal de la Cañeria de Conduccio'n para la Alternative Alto Lluta al Abastecimiento de Agua de Arica >

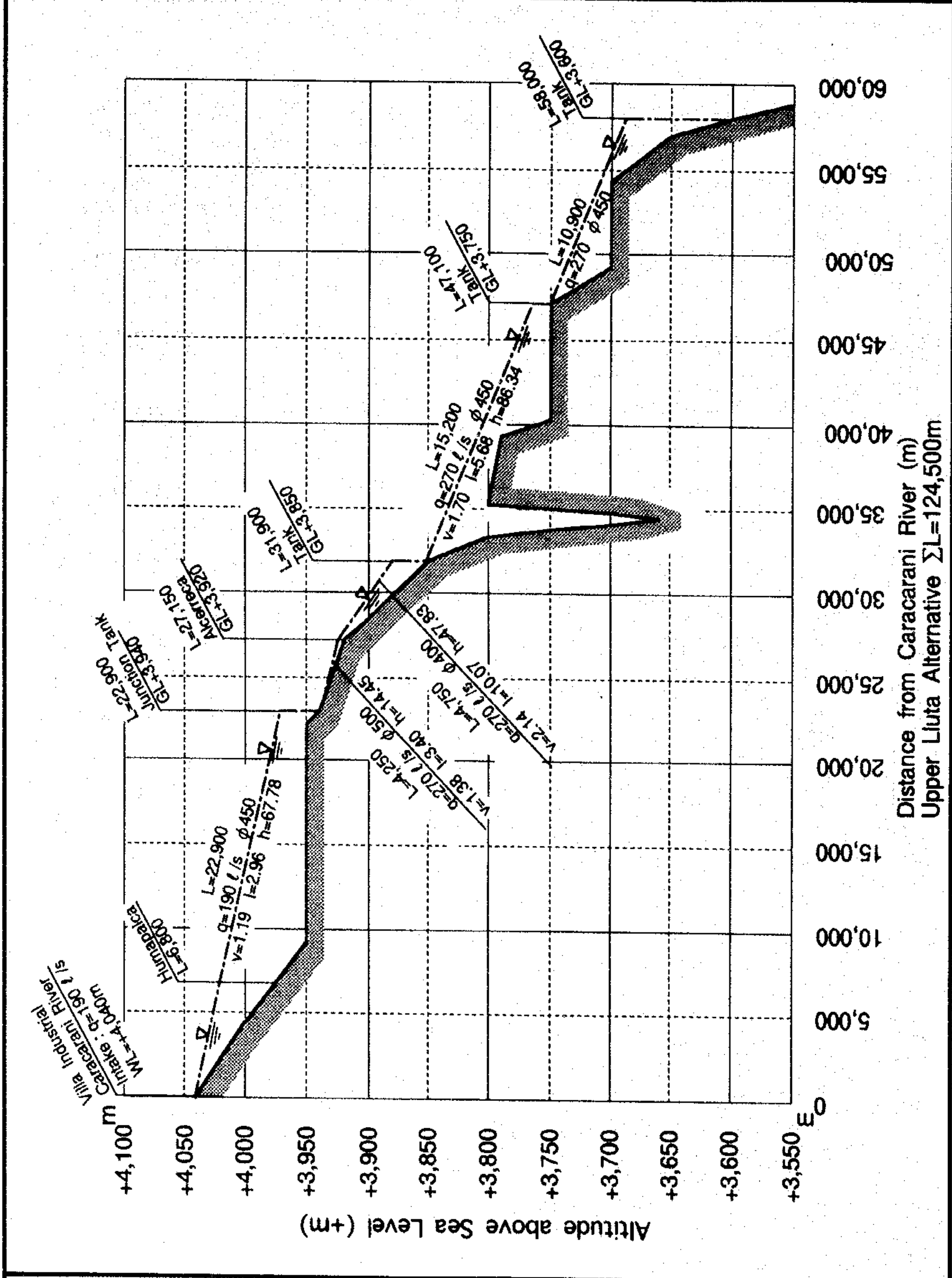

Fig. DA1 - 3 Longitudinal Profile of Transmission Pipeline for Upper Lluta Alternative - Detail No. 1 to Arica Water Supply

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< Perfil Longitudinal de la Cañeria de Conduccio'n para la Alternative Alto Lluta - Detalle No.1 al Abastecimiento de Agua de Arica >

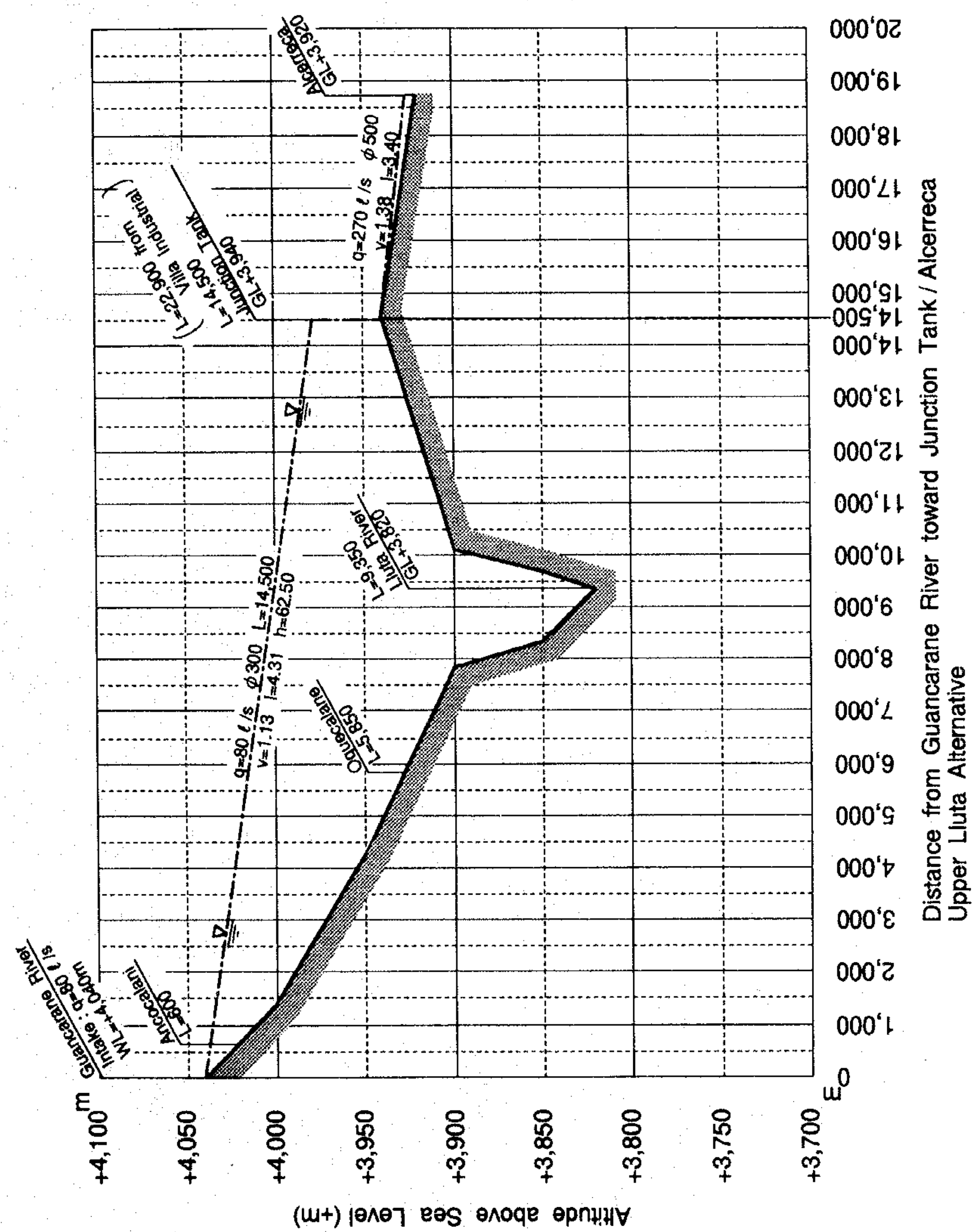


Fig. DA1 - 3' Longitudinal Profile of Transmission Pipeline for Upper Lluta Alternative - Detail No. 1' to Arica Water Supply

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE	JICA

< Perfil Longitudinal de la Cañeria de Conduccio'n para la Alternative Alto Lluta - Detalle No.1' al Abastecimiento de Agua de Ari

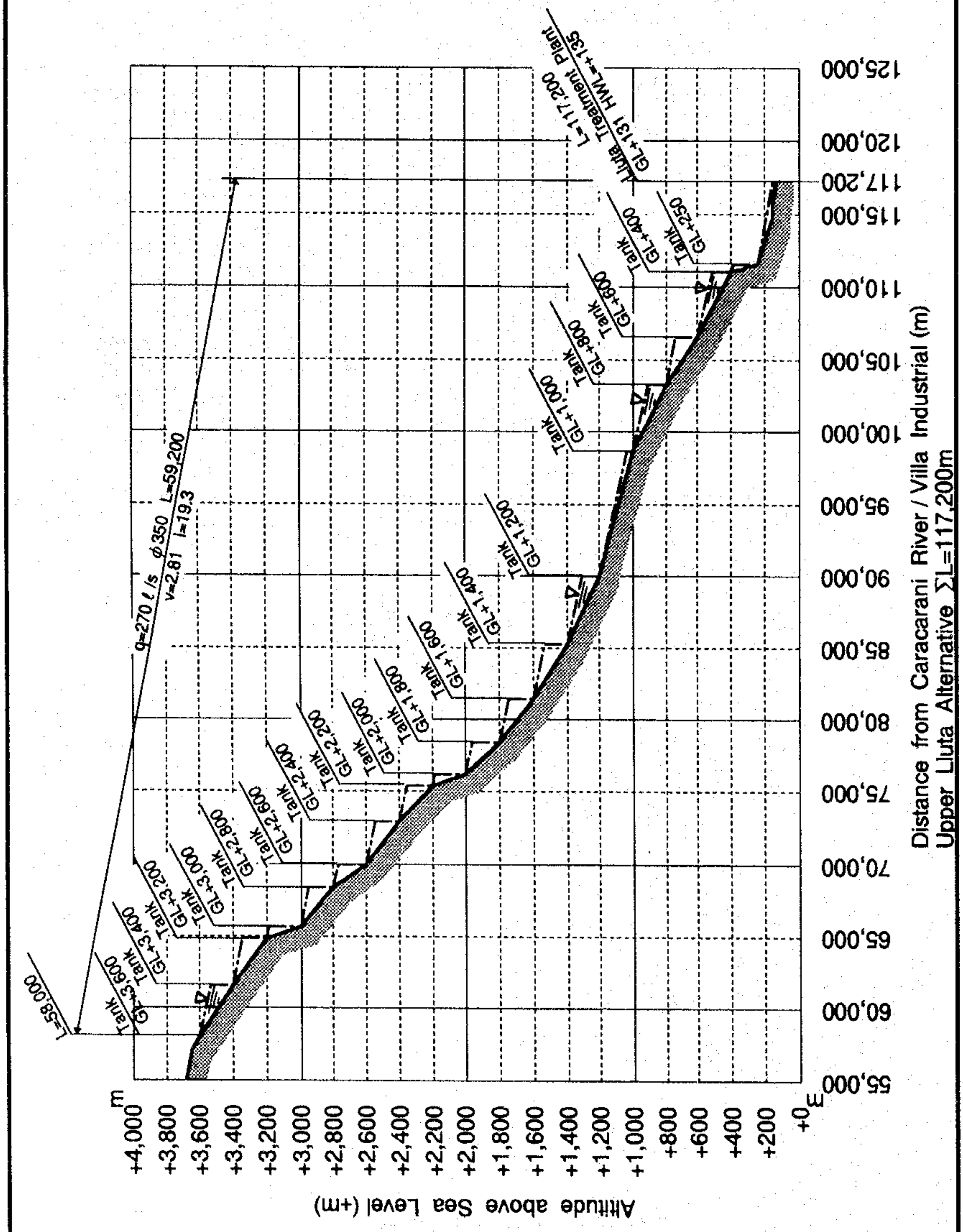


Fig. DA1 - 4 Longitudinal Profile of Transmission Pipeline for Upper Lluta Alternative - Detail No.2 to Arica Water Supply

< Perfil Longitudinal de la Cañeria de Conduccio'n para la Alternative Alto Lluta Detalle No.2 al Abastecimiento de Agua de Arica >

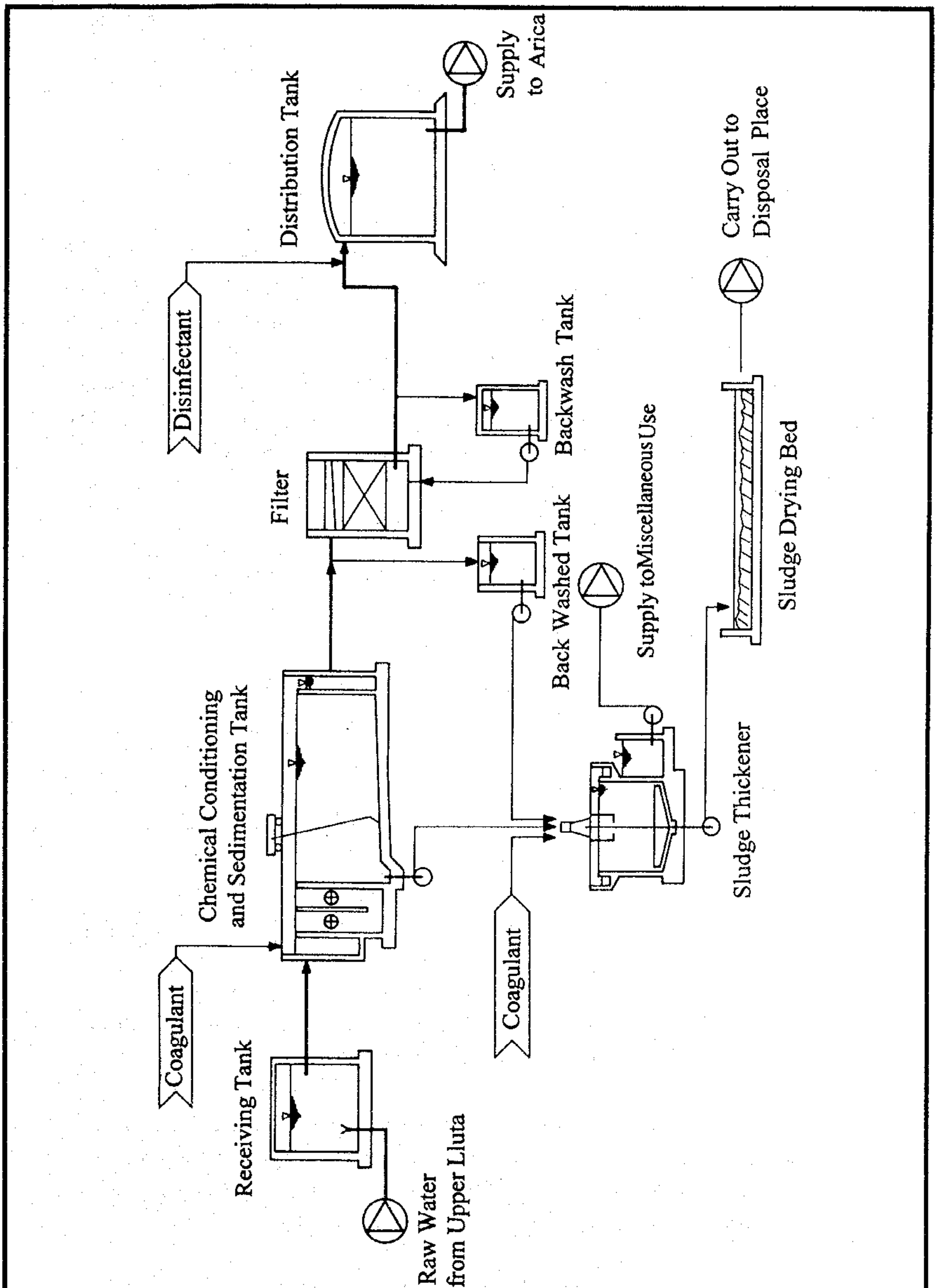


Fig. DA1-5 Flow Diagram of Treatment Plant for Upper Lluta River Water

< Diagrama Flujo en Planta Tratamiento para Curso Superior Rio Lluta >

< Note - 1 > Bypass Channel Work of Azufre River

1.1 Introduction

The Azufre River is one of the main contamination sources of the Lluta River with regard to arsenic (As) and (B) boron contents. Azufre River is contaminated from its origin at Aguas Calientes. However, it becomes comparatively clean after infiltration into the underground at A-8, and becomes worse again between A-5A and A-3 after emerged. The largest contamination sources were found between observation points A-5A and A-3 by detailed water quality observation and field survey, conducted by DGA and the Study Team. Therefore, removal of the pollutants emerging between the two points is considered essential for reduction of arsenic (As) and boron (B) contents of the Azufre River.

For the results of the detailed water quality observation, see Supporting Report A.

1.2 Results of Survey

The flow rate and pollution loads by river section are shown below.

River Section	A-8	A-5A	A-3
Flow Rate (l/s)	48	119	74
As Content (mg/l)	6.75	0.01	5.21
As Load (g/s)	0.324 (83.9%)	0.001 (0.3%)	0.386 (100%)
B Content (mg/l)	28.93	6.82	27.87
B Load (g/s)	1.389 (67.4%)	0.812 (39.4%)	2.062 (100%)

The river bed between these observation points consists mainly of volcanic materials, especially tuff breccia. The tuff breccia is altered by hydrothermal solution which is derived from the volcanic activity.

From these facts it may be inferred that there exist contamination sources of hydrothermal solution in the river bed. Therefore, it is one of the prospective method for reduction of arsenic (As) and boron (B) of the Azufre river to bypass the existing river channel between two (2) observation points.

In planning the bypass channel, it is required to allow the flood water pass through the channel. The maximum flow rate is estimated to be 350 l/sec based on the data during 27 years, from 1961 to 1988, observed by DGA. Therefore, this maximum flow rate is adopted for the planning.

1.2 Contents of Work

The work is aimed to make a bypass channel of the Azufre River between observation points A-5A and A-3 for reduction of arsenic (As) and boron (B) contents, mainly B content. For this purpose, following bypass channel is planned.

Location	: Between A-5A and A-3.
Length of channel	: 5,000 m
Gradient	: 1/100

The location of the bypass channel is shown in Fig. DA 1-6.

B load in the Lluta River is reduced by this work as shown below.

	Existing		After bypassing	
Azufre River		(%)		(%)
Flow rate (l/sec)	84*	100	84	100
B content (mg/l)	19.05	100	7.62	40
B load (mg/sec)	1,600	100	640	40
Lower Lluta River		(%)		(%)
Flow rate (l/sec)	2,216*	100	2,216	100
B content (mg/l)	10.69	100	10.26	96
B load (mg/sec)	23,689	100	22,729	96

* : Data from 1946 to 1990.

2.3 Planning of Facilities

Maximum rate and average flow rates are 350 l/sec and 160 l/sec respectively. It is required that the bypass channel should allow the flood water to pass through. Therefore, the channel should have a flow capacity of 350 l/sec.

Dimensions of bypass channel are as follows;

Flow rate (Q) = 350 l/sec
Length (L) = 5,000 m
Width (W) = 0.60 m

Depth of the water (H) = 0.31 m

$$V = \frac{1}{n} \times R^{2/3} \times I^{1/2} \text{ ---- (Manning Formula)}$$

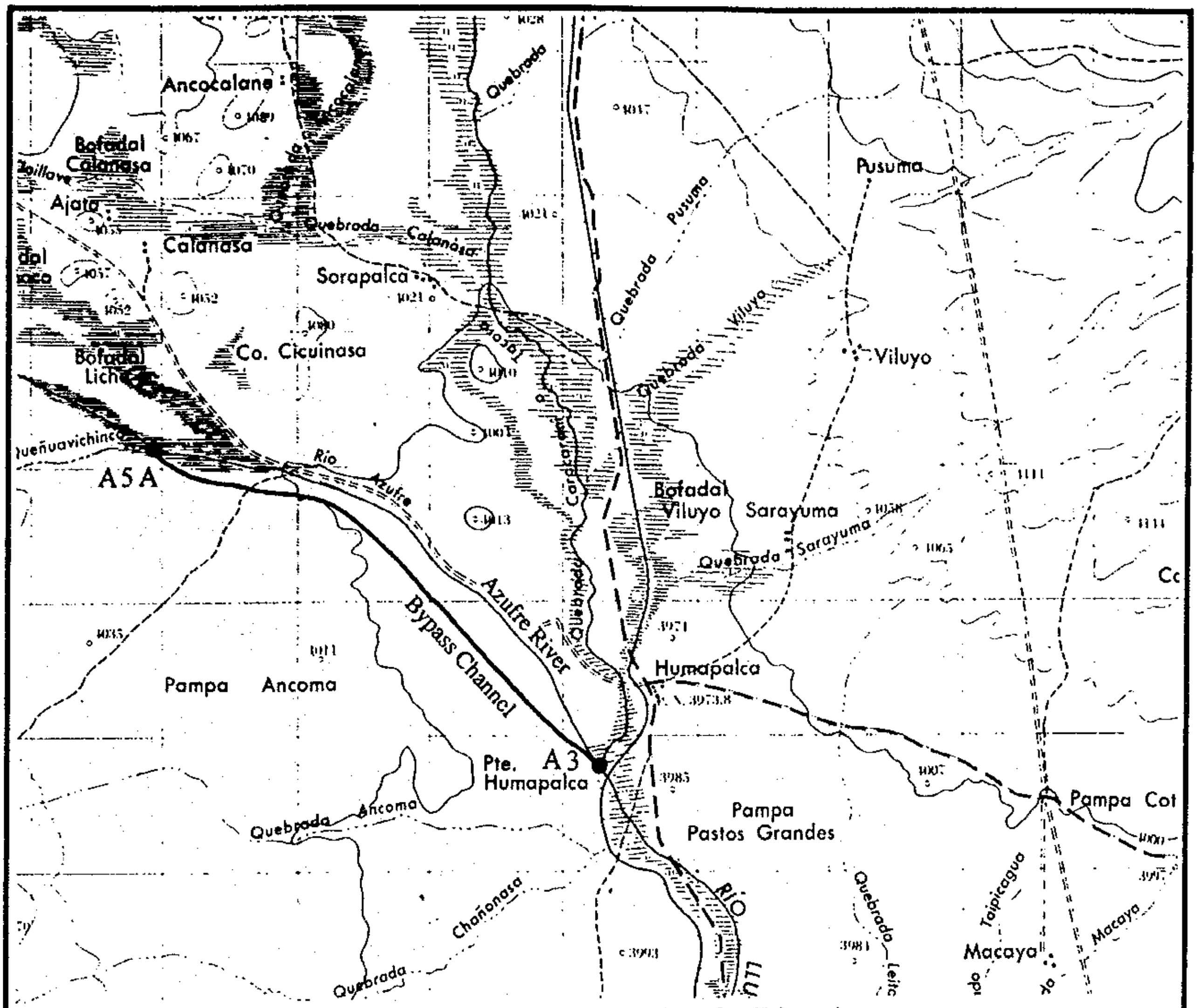
$$R = \frac{W \times H}{W + 2H}$$

where, V : Velocity (m/sec)
R : Hydraulic radius (m)
I : Hydraulic gradient
W : Width of section
H : Water depth (m)
n : Roughness coefficient

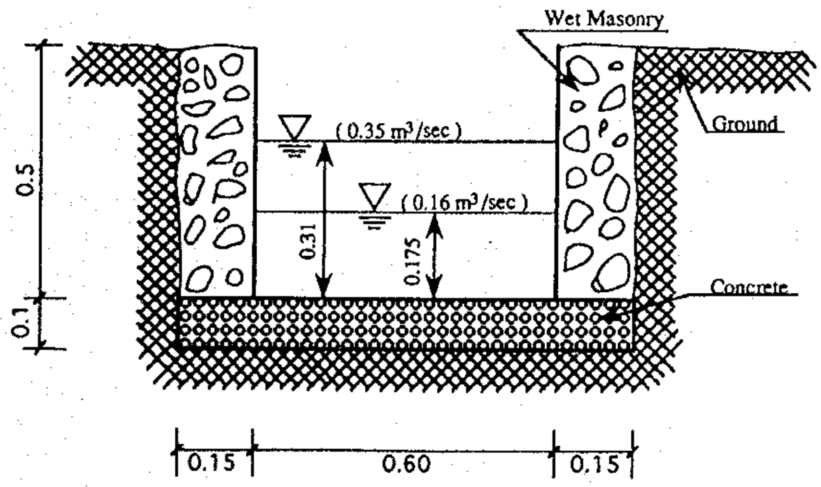
Then,

$$V = (1/0.015) \times [0.6 \times 0.31/\{0.6 + (0.31 \times 2)\}]^{2/3} \times (1/100)^{1/2}$$
$$= 1.90 \text{ m/sec}$$

Typical section of the bypass channel is shown in Fig. DA1-6.



Location of Bypass Channel (Azufre River)



Typical Section of Bypass Channel

Fig. DAI - 6 Location and Typical Section of Bypass Channel (Azufre River)

< Ubicación y Sección Típica del Canal de Derivación (Río Azufre) >

< Note - 2 > Evaporation Work of Colpitas River

2.1 Introduction

The Colpitas River is one of the contamination sources of the Lluta River in arsenic (As) and boron (B) contents. The major portion of arsenic (As) and boron (B) contents originates from the upper basin of the C-10 observation point. Shares of the pollution load of arsenic (As) and boron (B) contents to the total load of the Colpitas River are 66.1 % and 58.4 % respectively. Therefore, it is considered as one of the prospective work to construct evaporation ponds for reduction of arsenic (As) and boron (B) of the Colpitas River.

2.2 Contents of Work

The evaporation ponds are planned to evaporate 20 % of the average flow rate of the river and to pass through to the downstream 80 % of the flow. Three (3) evaporation ponds including intakes are planned for this purpose. The location of the ponds are near the Colpitas Village as shown in Fig. DA1-7.

Boron (B) load in the Lluta River is reduced by this work as shown below.

	Present		After evaporation	
Upper Colpitas R.		(%)		(%)
Flow rate (l/sec)	111	100	89	80
B content (mg/l)	59.12	100	59.12	-
B load (mg/s)	6,562	100	5,262	80
Lower Lluta R.		(%)		(%)
Flow rate (l/sec)	2,216	100	2,194	95
B content (mg/l)	10.69	100	10.20	95
B load (mg/s)	23,689	100	22,379	95

2.3 Planning of Facilities

1) Water quantity required to be evaporated

The work is planned to evaporate 20% of surface flow of the Upper Colpitas River.

Then,

$$Q = (q1 - q2)\ l/sec. \times 86{,}400\ sec. \times 10^{-3}$$
$$= (111 - 89) \times 86{,}400 \times 10^{-3} = 1{,}900.8\ (m^3/day)$$

where, q1 : Flow rate of the Upper Colpitas River (l/sec)
q2 : Flow rate to the downstream after evaporation (l/sec)

2) Area of evaporation ponds required

$$S = Q / (E \times 10^{-3} / 365)$$
$$= 1{,}900.8 / (1{,}000 \times 10^{-3} / 365) = 693{,}792\ m^2 \fallingdotseq 70\ (ha)$$

where, S : Area of evaporation ponds (m^2)
E : Evaporation Rate (mm/year)

Area required for the evaporation pond is 70 ha. The proposed area is gently sloped. If one (1) pond is planned for evaporation, it requires high bank, more than 20 m high. Therefore, three (3) ponds are planned considering the slope condition as shown in Fig. DA1-7.

3) Diversion channel

A diversion channel is planned for each evaporation pond, three (3) in total.

Dimensions of diversion channel are as follows;

Flow rate(Q_1)/3 = 7.33 l/sec
Length (L) = 900 m (= 300 m x 3 sites)
Width (W) = 0.25 m
Height (H) = 0.3 m
Depth of the water (D) = 0.075 m

$$V = \frac{1}{n} \times R^{2/3} \times I^{1/2} \text{ - - - - (Manning Formula)}$$

$$R = \frac{W \times H}{W + 2H}$$

where,

V	: Velocity (m/sec)
R	: Hydraulic radius (m)
I	: Hydraulic gradient
n	: Roughness coefficient

Then,

$$V = (1 / 0.015) \times [0.01875 / \{0.25 + (0.075 * 2)\}]^{2/3} \times (1/300)^{1/2}$$
$$= 0.5 \text{ m/sec} > 0.3 \text{ m/sec, OK}$$

The Structures of the evaporation pond is shown in Fig. DA 1-8.

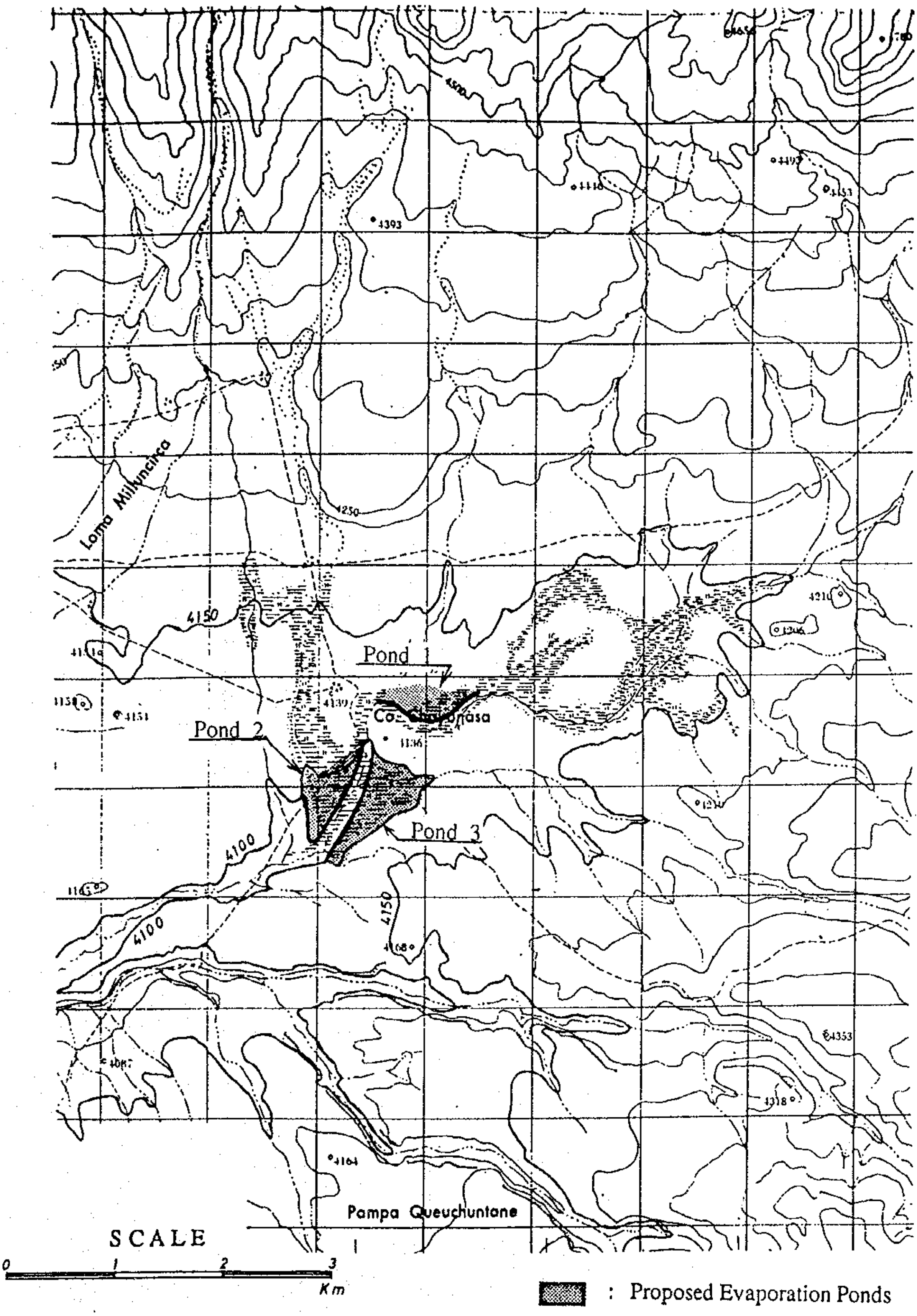
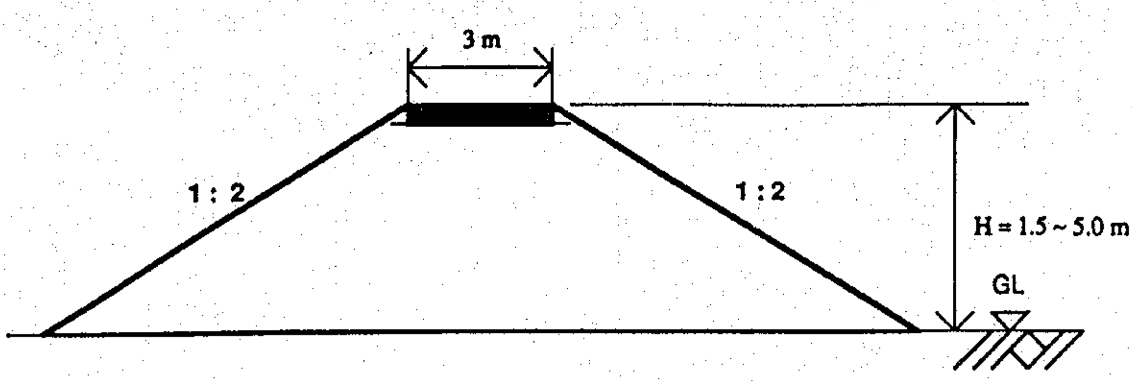
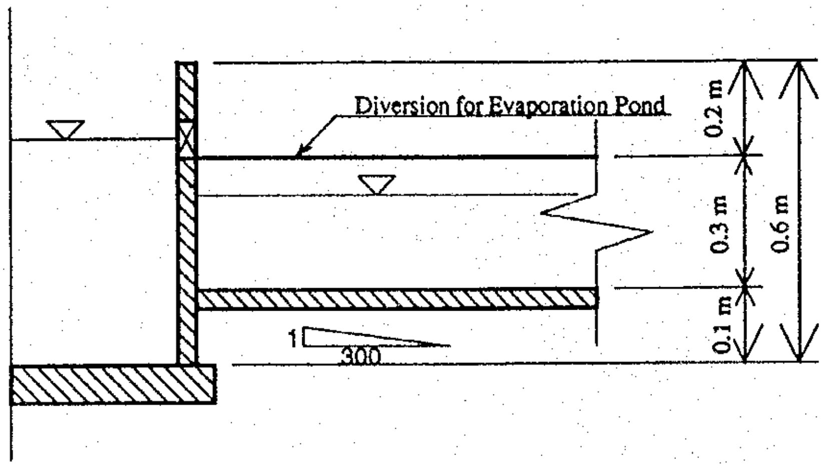


Fig. DAI-7 Location of Evaporation Ponds for Upper Colpitas River (Scale 1 : 50000)

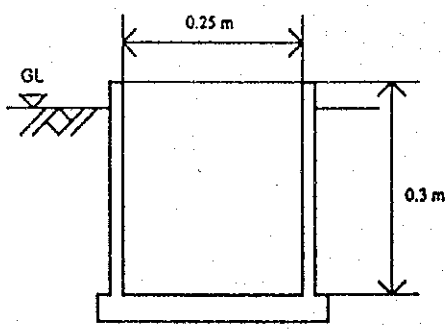
< Ubicación de los Embalses de Evaporación para el Curso Superior del Río Colpitas >



[Typical Section of the Bank for Evaporation Ponds]



[Intake Weir of Diversion]



[Typical Section of the Diversion for Evaporation Ponds]

Fig. DAI-8 Typical Section of Bank and Diversion for Evaporation Ponds

< Sección Típica del Pretil y Desvío para los Embalses de Evaporación >

Appendix-2 Desalination Technology for Lower Lluta Groundwater to Arica Water Supply

Introduction

The Lower Lluta groundwater contains high concentrations of Total Dissolved Solids (TDS), about 3,000 ppm. The concentration of Boron (B) in the raw water is also high.

Ions such as Chloride, Nitrate, Sulfate, Sodium and Potassium do not form insoluble precipitates in association with common ions. Particularly, all the ions which form insoluble salts with these, in order to treat in conventional treatment processes, are either extremely expensive or toxic. Their removal, therefore, needs desalination processes, such as Reverse Osmosis (RO), Electrodialysis (EDR) or Multi-Stage Flash (MSF) method.

Treatment Methods

Three types of desalination methods considered for the treatment of raw water are described below:

1) Reverse Osmosis (RO)
2) Electrodialysis (EDR)
3) Multi-Stage Flash (MSF)

In Reverse Osmosis method, a passage of water is forced through a membrane against the natural osmotic pressure. This is accomplished by applying counter pressure against the osmotic pressure. Only the desalted water passes through the RO membrane.

Electrodialysis method is based on the principle of ion-exchange. Cations pass selectively through cation membranes and anions pass through anion membranes. When DC voltage is applied to these membranes, ions in dilute chambers are transferred to concentrate chambers. Thus, the raw water is desalinated.

InMulti-Stage Flash method, the raw water flows through a heated pipe. The water is heated initially by steam and then by boilers. The desalination is achieved by generating steam from the raw water and the condensation of steam by the sudden reduction of the vapor pressure.

Both RO and EDR plants have about 70-80 % recovery rate, but the recovery rate in MSF is very low. Desalination plants produce a highly concentrated brine solution. RO plants have a bleed which carries away the salt ions left behind by the desalted water passing through the semi-permeable RO membrane. Electrodialysis plants similarly produce side streams in which salt ions are concentrated, after their removal from the process flow stream through selective ion permeable membranes. The power consumption by these two desalination techniques is much less than that by the Multi-Stage Flash system.

In early days, Multi-Stage Flash system was used to remove TDS in groundwater, but it is not popular nowadays due to high operational cost, less productivity and high rate of wastewater production. This method is therefore not considered for treating Lower Lluta groundwater.

Conclusion

Either Reverse Osmosis or Electrodialysis plant is therefore recommended to be installed at the Lluta Treatment works. Both these desalination processes are expensive than the conventional water treatment processes. As there is not much difference between the two methods, in terms of the productivity and efficiency, the balance between capital expenditure and running costs needs to be considered for the final selection of the most suitable desalination method. Therefore, the selection of RO or EDR method for Lower Lluta water primarily depends on economic considerations.

Table DA2-1 Comparison of Desalination Methods

Item	Desalination Method (A) Reverse Osmosis (RO)	(B) Electro-dialysis (EDR)	(C) Multi-Stage Flash (MSF)
1) Treatment process	Raw water → Sand filter → Check filter → RO unit → Disinfection → Treated water	Raw water → Sand filter → EDR unit → Ion exchanger → Disinfection → Treated water	Raw water → Sand filter → MSF unit → Disinfection → Treated water
2) Special features	- Less-energy consumption than (C) - Developed in USA and Japan - Good for middle-sized plants - Suitable for desalination of sea water and river/ground water - High rate of water recovery	- Less-energy consumption than (C) - Rte of TDS removal is almost same as (A) - Good for small/middle sized plants - Suitable for desalination of sea water and river/ground water - Used for table salt manufacturing - High rate of water recovery	- High reliability - Good for large-scale plants for sea water desalination - Not suitable for river/ground water - High energy consumption - High rate of TDS removal - Very low rate of water recovery
3) Application to large-scale facility	- Applicable by increasing the number of units - Standard capacity of each unit = 3,000 - 3,500 m^3/d - Plants with capacity above 50,000 m^3/d exist in Middle-East	- Applicable by increasing the number of units - Standard capacity of each unit = 3,000 m^3/d	- 450,000 m^3/d capacity plants exist in the world for sea water desalination - The larger the plant, the cheaper is the unit cost of construction and operation
4) Productivity	70-80% of water recovery	70-80% of water recovery	About 10% of water recovery
5) Electric power consumption	About 1.5 kwh/m^3	About 1.5 kwh/m^3	About 5 kwh/m^3
6) Development and application	- Since 1965 - For both brackish and sea water - 2,000,000 m^3/d capacity plants are in operation in the world - 25% of desalination plants in the world are of this type	- Since 1969 - For brackish water and table salt manufacturing - More than 2,000 plant exist in the world	- Developed in old days - For sea water - 70% of sea water desalination plants in the world are of this type - Majority are in Middle-East

Item	Desalination Method		
	(A) Reverse Osmosis (RO)	(B) Electro-dialysis (EDR)	(C) Multi-Stage Flash (MSF)
7) Maintenance of equipment	- Membrane	- Membrane	- Boiler
8) Environmental concerns	- Disposal of concentrated saline water into sea	- Disposal of concentrated saline water into sea	- Disposal of concentrated saline water into sea - Air-pollution due to boiler operation
9) Construction cost	About US$1,000 per m^3/day for desalination equipment	About US$1,000 per m^3/day for desalination equipment	About 5-10 times expensive than (A) or (B)
10) Running cost	US$0.40-0.60 per m^3 of treated water	US$0.40-0.60 per m^3 of treated water	-
11) Overall judgment	Recommended	Recommended	Not recommended due to high energy consumption and high construction cost

Appendix-3: Comparative Study on Investment Timing for Installation of Transmission Pipelines

Objective

It is required to increase the yearly water demand. The water supply facilities could be constructed in one step or in two/three steps. The construction of facilities such as deep wells in the water source field and filters in the treatment plant, and installation of pumps etc. could be carried out in a stepwise manner as the water demand increases. For the pipeline construction work the following, two alternatives were considered for cost comparison:

a) One-time investment, or

b) Stepwise investment.

The cost analysis for the pipeline along Route No.1, from the collection tank at the La Tirana (Pampa-North) water source to the tank at L=64,600 m (Alternative (1) for Iquique), was carried out. The longitudinal profile of the pipeline is divided into four spans in the following analysis.

Span-1: Pumping pipeline: 40,400 m long, from the collection tank at La Tirana to the tank at the highest peak (L=40,400 m)

Span-2: Gravity pipeline: 1,700 m long, from the tank at the highest peak to the tank at L=42,100 m

Span-3: Gravity pipeline: 11,650 m long, from the tank at L=42,100 to the tank at L=53,750 m

Span-4: Gravity pipeline: 10,850 m long, from the tank at L=53,750 to the tank at L=64,600 m

The analysis was carried out under the following conditions.

- Method	:	Present value
- Discount rate	:	12% per annum
- Year of calculation	:	50 years after the first investment
- Years of first investment	:	1997 and 1998, 50% in each year
- Years of second investment	:	2004 and 2005, 50% in each year

Cost Analysis for Span-1

Alternative (A): One-time investment
Installation of 900 mm dia. pipeline, in 1997 and 1998

Alternative (B): Two-steps investment
First-step: Installation of 700 mm dia. pipeline, in 1997 and 1998, and
Second-step: Installation of an additional 700 mm dia. pipeline, in 2004 and 2005

Note:

- Pipe Installation Cost

Alternative (A)

900 dia.: 40,400 m x 379,366 $/m	=	$ 15,326,386,000 (1997/98)
	=	($ 7,663,193,000 x 2)

Alternative(B)

700 dia.: 40,400 m x 266,537 $/m	=	$ 10,768,094,000 (1997/98)
	=	($ 5,384,047,000 x 2)
700 dia.: 40,400 m x 266,537 $/m	=	$ 10,768,094,000 (2004/05)
	=	($ 5,384,047,000 x 2)
Total	=	$ 21,536,188,000

- Pipeline repair cost = 2% of the investment cost per annum (including labor cost)

- Electricity cost: Power consumption cost for transmission pumps

Calculations

Calculation for the Alternatives (A) and (B) for Span-1 is given in the attached sheets.

Analysis

Alternative	Total Cost
Alternative (A) (One-time investment)	$ 12,773,169,556 (100%)
Alternative (B) (Two-steps investment)	$ 13,001,836,829 (102%)

According to the above analysis, it can be seen that the cost incurred in the Alternative (A) is almost same as that in the Alternative (B).

Cost Analysis for Span-2

Alternative (A): One-time investment
Installation of 600 mm dia. pipeline, in 1997 and 1998

Alternative (B): Two-steps investment
First-step: Installation of 400 mm dia. pipeline, in 1997 and 1998, and
Second-step: Installation of an additional 400 mm dia. pipeline, in 2004 and 2005

Note:

- Pipe Installation Cost

Alternative (A)

600 dia.: 1,700 m x 206,377 $/m	=	$ 350,840,000 (1997/98)
	=	($ 175,420,000 x 2)

Alternative(B)

400 dia.: 1,700 m x 113,741 $/m	=	$ 193,360,000 (1997/98)
	=	($ 96,680,000 x 2)
400 dia.: 1,700 m x 113,741 $/m	=	$ 193,360,000 (2004/05)
	=	($ 96,680,000 x 2)
Total	=	$ 386,720,000

- Pipeline repair cost = 2% of the investment cost per annum (including labor cost)

- Electricity cost: Not required, as the flow is by gravity

Calculations

Calculation for the Alternatives (A) and (B) for Span-2 is given in the attached sheets.

Analysis

Alternative	Total Cost
Alternative (A) (One-time investment)	$ 273,375,350 (125%)
Alternative (B) (Two-steps investment)	$ 218,781,657 (100%)

According to the above analysis, in Span-2, Alternative (B) is more economical than Alternative (A).

Cost Analysis for Span-3

Alternative (A): One-time investment
Installation of 700 mm dia. pipeline, in 1997 and 1998

Alternative (B): Two-steps investment
First-step: Installation of 500 mm dia. pipeline, in 1997 and 1998, and
Second-step: Installation of an additional 500 mm dia. pipeline, in 2004 and 2005

Note:

- Pipe Installation Cost

Alternative (A)
700 dia.: 11,650 m x 266,537 $/m = $ 3,105,156,000 (1997/98)
= ($ 1,552,578,000 x 2)

Alternative(B)

500 dia.: 11,650 m x 157,154 $/m	=	$ 1,830,844,000 (1997/98)
	=	($ 915,422,000 x 2)
500 dia.: 11,650 m x 157,154 $/m	=	$ 1,830,844,000 (2004/05)
	=	($ 915,422,000 x 2)
Total	=	$ 3,661,688,000
- Pipeline repair cost	=	2% of the investment cost per - Electricity cost: Not required, as the flow is by gravity

Calculations

Calculation for the Alternatives (A) and (B) for Span-3 is given in the attached sheets.

Analysis

Alternative	Total Cost
Alternative (A) (One-time investment)	$ 2,419,544,826 (117%)
Alternative (B) (Two-steps investment)	$ 2,071,55,909 (100%)

According to the above analysis, in Span-3, Alternative (B) is more economical than Alternative (A).

Cost Analysis for Span-4

Alternative (A): One-time investment
Installation of 600 mm dia. pipeline, in 1997 and 1998

Alternative (B): Two-steps investment
First-step: Installation of 400 mm dia. pipeline, in 1997 and 1998, and
Second-step: Installation of an additional 400 mm dia. pipeline, in 2004 and 2005

Note:

- Pipe Installation Cost

Alternative (A)

600 dia.: 10,850 m x 206,377 $/m	=	$ 2,239,190,000 (1997/98)
	=	($ 1,119,595,000 x 2)

Alternative(B)

400 dia.: 10,850 m x 113,741 $/m	=	$ 1,234,090,000 (1997/98)
	=	($ 617,045,000 x 2)
400 dia.: 10,850 m x 113,741 $/m	=	$ 1,234,090,000 (2004/05)
	=	($ 617,045,000 x 2)
Total	=	$ 2,468,180,000

- Pipeline repair cost = 2% of the investment cost per annum (including labor cost)

- Electricity cost: Not required, as the flow is by gravity

Calculations

Calculation for the Alternatives (A) and (B) for Span-4 is given in the attached sheets.

Analysis

Alternative	Total Cost
Alternative (A) (One-time investment)	$ 1,744,782,091 (125%)
Alternative (B) (Two-steps investment)	$ 1,396,339,755 (100%)

According to the above analysis, in Span-4, Alternative (B) is more economical than Alternative (A).

Discussion

Except in the case of Span-1, in all other cases the Alternative (B) is more economical thanthe Alternative (A). Also, the Alternative(B)has following advantages:

- Magnitude of the initial investment budget for Alternative (B) is smaller than the Alternative (A). The initial budget for Alternative (A) is about 50% bigger than that for the Alternative (B).

- Double pipeline system is securer than a single pipeline. Therefore, Alternative (B) is better than Alternative (A)

Conclusion

It is recommended that the two-steps investment (Alternative B) be taken up, in all spans.

Span 1A

COST ANALYSIS

Span - 1 Pumping Pipeline from La Tirana Water Source to Santa Laura Tank (L=40,400 m)
(Pampa-North Route to Iquique)
Alternative (A) : One - time Investment (900 mm pipe x 1 line)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	7,663,193,000	0	0	7,663,193,000	5,454,509,413
4	1998	7,663,193,000	0	0	7,663,193,000	4,870,097,690
5	1999		306,527,720	89,729,875	396,257,595	224,847,201
6	2000		306,527,720	96,358,813	402,886,533	204,114,856
7	2001		306,527,720	104,741,702	411,269,422	186,037,400
8	2002		306,527,720	113,173,684	419,701,404	169,510,358
9	2003		306,527,720	121,556,914	428,084,634	154,371,611
10	2004		306,527,720	129,940,169	436,467,889	140,530,979
11	2005		306,527,720	138,323,399	444,851,119	127,884,067
12	2006		306,527,720	150,020,940	456,548,660	117,184,670
13	2007		306,527,720	161,718,457	468,246,177	107,309,939
14	2008		306,527,720	173,415,998	479,943,718	98,205,994
15	2009		306,527,720	185,113,539	491,641,259	89,821,020
16	2010		306,527,720	196,811,080	503,338,800	82,105,462
17	2011		306,527,720	210,019,547	516,547,267	75,232,186
18	2012		306,527,720	223,228,038	529,755,758	68,889,222
19	2013		306,527,720	236,436,505	542,964,225	63,041,826
20	2014		306,527,720	253,608,471	560,136,191	58,067,507
21	2015		306,527,720	262,805,638	569,333,358	52,697,275
22	2016		306,527,720	262,805,638	569,333,358	47,051,138
23	2017		306,527,720	262,805,638	569,333,358	42,009,945
24	2018		306,527,720	262,805,638	569,333,358	37,508,879
25	2019		306,527,720	262,805,638	569,333,358	33,490,071
26	2020		306,527,720	262,805,638	569,333,358	29,901,849
27	2021		306,527,720	262,805,638	569,333,358	26,698,079
28	2022		306,527,720	262,805,638	569,333,358	23,837,571
29	2023		306,527,720	262,805,638	569,333,358	21,283,545
30	2024		306,527,720	262,805,638	569,333,358	19,003,165
31	2025		306,527,720	262,805,638	569,333,358	16,967,112
32	2026		306,527,720	262,805,638	569,333,358	15,149,207
33	2027		306,527,720	262,805,638	569,333,358	13,526,078
34	2028		306,527,720	262,805,638	569,333,358	12,076,855
35	2029		306,527,720	262,805,638	569,333,358	10,782,906
36	2030		306,527,720	262,805,638	569,333,358	9,627,595
37	2031		306,527,720	262,805,638	569,333,358	8,596,067
38	2032		306,527,720	262,805,638	569,333,358	7,675,060
39	2033		306,527,720	262,805,638	569,333,358	6,852,732
40	2034		306,527,720	262,805,638	569,333,358	6,118,511
41	2035		306,527,720	262,805,638	569,333,358	5,462,956
42	2036		306,527,720	262,805,638	569,333,358	4,877,639
43	2037		306,527,720	262,805,638	569,333,358	4,355,035
44	2038		306,527,720	262,805,638	569,333,358	3,888,424
45	2039		306,527,720	262,805,638	569,333,358	3,471,807
46	2040		306,527,720	262,805,638	569,333,358	3,099,828
47	2041		306,527,720	262,805,638	569,333,358	2,767,704
48	2042		306,527,720	262,805,638	569,333,358	2,471,164
49	2043		306,527,720	262,805,638	569,333,358	2,206,396
50	2044		306,527,720	262,805,638	569,333,358	1,969,997
51	2045		306,527,720	262,805,638	569,333,358	1,758,926
52	2046		306,527,720	262,805,638	569,333,358	1,570,469
53	2047		306,527,720	262,805,638	569,333,358	1,402,205
54	2048		306,527,720	262,805,638	569,333,358	1,251,969
					TOTAL of [5] = $	12,773,169,556

Span 1B

COST ANALYSIS

Span - 1 Pumping Pipeline from La Tirana Water Source to Santa Laura Tank (L=40,400 m)
(Pampa-North Route to Iquique)

Alternative (B) : Two - Steps Investment (700 mm pipe x 2 lines)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	5,384,047,000	0	0	5,384,047,000	3,832,258,308
4	1998	5,384,047,000	0	0	5,384,047,000	3,421,659,203
5	1999		215,361,880	88,348,893	303,710,773	172,333,649
6	2000		215,361,880	94,875,808	310,237,688	157,176,068
7	2001		215,361,880	103,129,682	318,491,562	144,069,408
8	2002		215,361,880	111,431,891	326,793,771	131,986,523
9	2003		215,361,880	119,686,100	335,047,980	120,821,661
10	2004	5,384,047,000	215,361,880	127,940,333	5,727,349,213	1,844,053,163
11	2005	5,384,047,000	215,361,880	136,194,542	5,735,603,422	1,648,848,926
12	2006		430,723,760	147,712,052	578,435,812	148,470,066
13	2007		430,723,760	159,229,540	589,953,300	135,202,070
14	2008		430,723,760	170,747,050	601,470,810	123,072,845
15	2009		430,723,760	182,264,561	612,988,321	111,990,674
16	2010		430,723,760	193,782,072	624,505,832	101,870,429
17	2011		430,723,760	206,787,254	637,511,014	92,849,872
18	2012		430,723,760	219,792,461	650,516,221	84,592,863
19	2013		430,723,760	232,797,643	663,521,403	77,039,332
20	2014		430,723,760	249,705,326	680,429,086	70,537,882
21	2015		430,723,760	258,760,945	689,484,705	63,818,437
22	2016		430,723,760	258,760,945	689,484,705	56,980,747
23	2017		430,723,760	258,760,945	689,484,705	50,875,667
24	2018		430,723,760	258,760,945	689,484,705	45,424,703
25	2019		430,723,760	258,760,945	689,484,705	40,557,770
26	2020		430,723,760	258,760,945	689,484,705	36,212,295
27	2021		430,723,760	258,760,945	689,484,705	32,332,406
28	2022		430,723,760	258,760,945	689,484,705	28,868,220
29	2023		430,723,760	258,760,945	689,484,705	25,775,196
30	2024		430,723,760	258,760,945	689,484,705	23,013,568
31	2025		430,723,760	258,760,945	689,484,705	20,547,829
32	2026		430,723,760	258,760,945	689,484,705	18,346,275
33	2027		430,723,760	258,760,945	689,484,705	16,380,603
34	2028		430,723,760	258,760,945	689,484,705	14,625,539
35	2029		430,723,760	258,760,945	689,484,705	13,058,517
36	2030		430,723,760	258,760,945	689,484,705	11,659,390
37	2031		430,723,760	258,760,945	689,484,705	10,410,169
38	2032		430,723,760	258,760,945	689,484,705	9,294,794
39	2033		430,723,760	258,760,945	689,484,705	8,298,923
40	2034		430,723,760	258,760,945	689,484,705	7,409,753
41	2035		430,723,760	258,760,945	689,484,705	6,615,851
42	2036		430,723,760	258,760,945	689,484,705	5,907,010
43	2037		430,723,760	258,760,945	689,484,705	5,274,116
44	2038		430,723,760	258,760,945	689,484,705	4,709,032
45	2039		430,723,760	258,760,945	689,484,705	4,204,493
46	2040		430,723,760	258,760,945	689,484,705	3,754,011
47	2041		430,723,760	258,760,945	689,484,705	3,351,796
48	2042		430,723,760	258,760,945	689,484,705	2,992,675
49	2043		430,723,760	258,760,945	689,484,705	2,672,031
50	2044		430,723,760	258,760,945	689,484,705	2,385,742
51	2045		430,723,760	258,760,945	689,484,705	2,130,127
52	2046		430,723,760	258,760,945	689,484,705	1,901,899
53	2047		430,723,760	258,760,945	689,484,705	1,698,124
54	2048		430,723,760	258,760,945	689,484,705	1,516,182
					TOTAL of [5] = $	13,001,836,829

Span 2A

COST ANALYSIS

Span - 2 Gravity - Flow Pipeline from Santa Laura Tank to La Isla Tank (L=1,700 m)
(Pampa-North Route to Iquique)
Alternative (A) : One - time Investment (600 mm pipe x 1 line)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	175,420,000	0	0	175,420,000	124,860,491
4	1998	175,420,000	0	0	175,420,000	111,482,581
5	1999		7,016,800	0	7,016,800	3,981,521
6	2000		7,016,800	0	7,016,800	3,554,929
7	2001		7,016,800	0	7,016,800	3,174,044
8	2002		7,016,800	0	7,016,800	2,833,968
9	2003		7,016,800	0	7,016,800	2,530,328
10	2004		7,016,800	0	7,016,800	2,259,222
11	2005		7,016,800	0	7,016,800	2,017,162
12	2006		7,016,800	0	7,016,800	1,801,038
13	2007		7,016,800	0	7,016,800	1,608,069
14	2008		7,016,800	0	7,016,800	1,435,776
15	2009		7,016,800	0	7,016,800	1,281,943
16	2010		7,016,800	0	7,016,800	1,144,592
17	2011		7,016,800	0	7,016,800	1,021,957
18	2012		7,016,800	0	7,016,800	912,462
19	2013		7,016,800	0	7,016,800	814,698
20	2014		7,016,800	0	7,016,800	727,409
21	2015		7,016,800	0	7,016,800	649,472
22	2016		7,016,800	0	7,016,800	579,886
23	2017		7,016,800	0	7,016,800	517,755
24	2018		7,016,800	0	7,016,800	462,282
25	2019		7,016,800	0	7,016,800	412,751
26	2020		7,016,800	0	7,016,800	368,528
27	2021		7,016,800	0	7,016,800	329,043
28	2022		7,016,800	0	7,016,800	293,788
29	2023		7,016,800	0	7,016,800	262,311
30	2024		7,016,800	0	7,016,800	234,206
31	2025		7,016,800	0	7,016,800	209,113
32	2026		7,016,800	0	7,016,800	186,708
33	2027		7,016,800	0	7,016,800	166,703
34	2028		7,016,800	0	7,016,800	148,842
35	2029		7,016,800	0	7,016,800	132,895
36	2030		7,016,800	0	7,016,800	118,656
37	2031		7,016,800	0	7,016,800	105,943
38	2032		7,016,800	0	7,016,800	94,592
39	2033		7,016,800	0	7,016,800	84,457
40	2034		7,016,800	0	7,016,800	75,408
41	2035		7,016,800	0	7,016,800	67,329
42	2036		7,016,800	0	7,016,800	60,115
43	2037		7,016,800	0	7,016,800	53,674
44	2038		7,016,800	0	7,016,800	47,923
45	2039		7,016,800	0	7,016,800	42,789
46	2040		7,016,800	0	7,016,800	38,204
47	2041		7,016,800	0	7,016,800	34,111
48	2042		7,016,800	0	7,016,800	30,456
49	2043		7,016,800	0	7,016,800	27,193
50	2044		7,016,800	0	7,016,800	24,279
51	2045		7,016,800	0	7,016,800	21,678
52	2046		7,016,800	0	7,016,800	19,355
53	2047		7,016,800	0	7,016,800	17,282
54	2048		7,016,800	0	7,016,800	15,430
					TOTAL of [5] = $	273,375,350

Span 2B

COST ANALYSIS

Span - 2 Gravity - Flow Pipeline from Santa Laura Tank to La Isla Tank (L=1,700 m)
(Pampa-North Route to Iquique)
Alternative (B) : Two - Steps Investment (400 mm pipe x 2 lines)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	96,680,000	0	0	96,680,000	68,814,914
4	1998	96,680,000	0	0	96,680,000	61,441,888
5	1999		3,867,200	0	3,867,200	2,194,353
6	2000		3,867,200	0	3,867,200	1,959,244
7	2001		3,867,200	0	3,867,200	1,749,325
8	2002		3,867,200	0	3,867,200	1,561,897
9	2003		3,867,200	0	3,867,200	1,394,551
10	2004	96,680,000	3,867,200	0	100,547,200	32,373,507
11	2005	96,680,000	3,867,200	0	100,547,200	28,904,917
12	2006		7,734,400	0	7,734,400	1,985,228
13	2007		7,734,400	0	7,734,400	1,772,525
14	2008		7,734,400	0	7,734,400	1,582,611
15	2009		7,734,400	0	7,734,400	1,413,046
16	2010		7,734,400	0	7,734,400	1,261,648
17	2011		7,734,400	0	7,734,400	1,126,472
18	2012		7,734,400	0	7,734,400	1,005,778
19	2013		7,734,400	0	7,734,400	898,016
20	2014		7,734,400	0	7,734,400	801,800
21	2015		7,734,400	0	7,734,400	715,893
22	2016		7,734,400	0	7,734,400	639,190
23	2017		7,734,400	0	7,734,400	570,706
24	2018		7,734,400	0	7,734,400	509,559
25	2019		7,734,400	0	7,734,400	454,963
26	2020		7,734,400	0	7,734,400	406,217
27	2021		7,734,400	0	7,734,400	362,694
28	2022		7,734,400	0	7,734,400	323,834
29	2023		7,734,400	0	7,734,400	289,137
30	2024		7,734,400	0	7,734,400	258,158
31	2025		7,734,400	0	7,734,400	230,498
32	2026		7,734,400	0	7,734,400	205,802
33	2027		7,734,400	0	7,734,400	183,752
34	2028		7,734,400	0	7,734,400	164,064
35	2029		7,734,400	0	7,734,400	146,486
36	2030		7,734,400	0	7,734,400	130,791
37	2031		7,734,400	0	7,734,400	116,778
38	2032		7,734,400	0	7,734,400	104,266
39	2033		7,734,400	0	7,734,400	93,094
40	2034		7,734,400	0	7,734,400	83,120
41	2035		7,734,400	0	7,734,400	74,214
42	2036		7,734,400	0	7,734,400	66,263
43	2037		7,734,400	0	7,734,400	59,163
44	2038		7,734,400	0	7,734,400	52,824
45	2039		7,734,400	0	7,734,400	47,165
46	2040		7,734,400	0	7,734,400	42,111
47	2041		7,734,400	0	7,734,400	37,599
48	2042		7,734,400	0	7,734,400	33,571
49	2043		7,734,400	0	7,734,400	29,974
50	2044		7,734,400	0	7,734,400	26,762
51	2045		7,734,400	0	7,734,400	23,895
52	2046		7,734,400	0	7,734,400	21,335
53	2047		7,734,400	0	7,734,400	19,049
54	2048		7,734,400	0	7,734,400	17,008
					TOTAL of [5] = $	218,781,657

Span 3A

COST ANALYSIS

Span - 3 Gravity - Flow Pipeline from La Isla Tank to El Toro 1 Tank (L=11,650 m)
(Pampa-North Route to Iquique)
Alternative (A) : One - time Investment (700 mm pipe x 1 line)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	1,552,578,000	0	0	1,552,578,000	1,105,094,354
4	1998	1,552,578,000	0	0	1,552,578,000	986,691,387
5	1999		62,103,120	0	62,103,120	35,238,978
6	2000		62,103,120	0	62,103,120	31,463,373
7	2001		62,103,120	0	62,103,120	28,092,298
8	2002		62,103,120	0	62,103,120	25,082,409
9	2003		62,103,120	0	62,103,120	22,395,008
10	2004		62,103,120	0	62,103,120	19,995,543
11	2005		62,103,120	0	62,103,120	17,853,163
12	2006		62,103,120	0	62,103,120	15,940,324
13	2007		62,103,120	0	62,103,120	14,232,432
14	2008		62,103,120	0	62,103,120	12,707,529
15	2009		62,103,120	0	62,103,120	11,346,008
16	2010		62,103,120	0	62,103,120	10,130,364
17	2011		62,103,120	0	62,103,120	9,044,968
18	2012		62,103,120	0	62,103,120	8,075,864
19	2013		62,103,120	0	62,103,120	7,210,593
20	2014		62,103,120	0	62,103,120	6,438,030
21	2015		62,103,120	0	62,103,120	5,748,241
22	2016		62,103,120	0	62,103,120	5,132,358
23	2017		62,103,120	0	62,103,120	4,582,462
24	2018		62,103,120	0	62,103,120	4,091,484
25	2019		62,103,120	0	62,103,120	3,653,111
26	2020		62,103,120	0	62,103,120	3,261,706
27	2021		62,103,120	0	62,103,120	2,912,238
28	2022		62,103,120	0	62,103,120	2,600,212
29	2023		62,103,120	0	62,103,120	2,321,618
30	2024		62,103,120	0	62,103,120	2,072,873
31	2025		62,103,120	0	62,103,120	1,850,780
32	2026		62,103,120	0	62,103,120	1,652,482
33	2027		62,103,120	0	62,103,120	1,475,430
34	2028		62,103,120	0	62,103,120	1,317,348
35	2029		62,103,120	0	62,103,120	1,176,204
36	2030		62,103,120	0	62,103,120	1,050,182
37	2031		62,103,120	0	62,103,120	937,663
38	2032		62,103,120	0	62,103,120	837,199
39	2033		62,103,120	0	62,103,120	747,499
40	2034		62,103,120	0	62,103,120	667,410
41	2035		62,103,120	0	62,103,120	595,902
42	2036		62,103,120	0	62,103,120	532,055
43	2037		62,103,120	0	62,103,120	475,049
44	2038		62,103,120	0	62,103,120	424,151
45	2039		62,103,120	0	62,103,120	378,706
46	2040		62,103,120	0	62,103,120	338,131
47	2041		62,103,120	0	62,103,120	301,902
48	2042		62,103,120	0	62,103,120	269,556
49	2043		62,103,120	0	62,103,120	240,675
50	2044		62,103,120	0	62,103,120	214,888
51	2045		62,103,120	0	62,103,120	191,864
52	2046		62,103,120	0	62,103,120	171,307
53	2047		62,103,120	0	62,103,120	152,953
54	2048		62,103,120	0	62,103,120	136,565
					TOTAL of [5] = $	2,419,544,826

Span 3B

COST ANALYSIS

Span - 3 Gravity - Flow Pipeline from La Isla Tank to El Toro 1 Tank (L=11,650 m)
(Pampa-North Route to Iquique)

Alternative (B) : Two - Steps Investment (500 mm pipe x 2 lines)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	915,422,000	0	0	915,422,000	651,579,298
4	1998	915,422,000	0	0	915,422,000	581,767,230
5	1999		36,616,880	0	36,616,880	20,777,401
6	2000		36,616,880	0	36,616,880	18,551,251
7	2001		36,616,880	0	36,616,880	16,563,617
8	2002		36,616,880	0	36,616,880	14,788,944
9	2003		36,616,880	0	36,616,880	13,204,414
10	2004	915,422,000	36,616,880	0	952,038,880	306,531,040
11	2005	915,422,000	36,616,880	0	952,038,880	273,688,428
12	2006		73,233,760	0	73,233,760	18,797,282
13	2007		73,233,760	0	73,233,760	16,783,288
14	2008		73,233,760	0	73,233,760	14,985,078
15	2009		73,233,760	0	73,233,760	13,379,534
16	2010		73,233,760	0	73,233,760	11,946,013
17	2011		73,233,760	0	73,233,760	10,666,083
18	2012		73,233,760	0	73,233,760	9,523,288
19	2013		73,233,760	0	73,233,760	8,502,936
20	2014		73,233,760	0	73,233,760	7,591,907
21	2015		73,233,760	0	73,233,760	6,778,488
22	2016		73,233,760	0	73,233,760	6,052,222
23	2017		73,233,760	0	73,233,760	5,403,769
24	2018		73,233,760	0	73,233,760	4,824,794
25	2019		73,233,760	0	73,233,760	4,307,852
26	2020		73,233,760	0	73,233,760	3,846,296
27	2021		73,233,760	0	73,233,760	3,434,193
28	2022		73,233,760	0	73,233,760	3,066,244
29	2023		73,233,760	0	73,233,760	2,737,718
30	2024		73,233,760	0	73,233,760	2,444,391
31	2025		73,233,760	0	73,233,760	2,182,492
32	2026		73,233,760	0	73,233,760	1,948,653
33	2027		73,233,760	0	73,233,760	1,739,869
34	2028		73,233,760	0	73,233,760	1,553,455
35	2029		73,233,760	0	73,233,760	1,387,013
36	2030		73,233,760	0	73,233,760	1,238,404
37	2031		73,233,760	0	73,233,760	1,105,718
38	2032		73,233,760	0	73,233,760	987,248
39	2033		73,233,760	0	73,233,760	881,472
40	2034		73,233,760	0	73,233,760	787,028
41	2035		73,233,760	0	73,233,760	702,704
42	2036		73,233,760	0	73,233,760	627,414
43	2037		73,233,760	0	73,233,760	560,191
44	2038		73,233,760	0	73,233,760	500,171
45	2039		73,233,760	0	73,233,760	446,581
46	2040		73,233,760	0	73,233,760	398,733
47	2041		73,233,760	0	73,233,760	356,012
48	2042		73,233,760	0	73,233,760	317,868
49	2043		73,233,760	0	73,233,760	283,810
50	2044		73,233,760	0	73,233,760	253,402
51	2045		73,233,760	0	73,233,760	226,252
52	2046		73,233,760	0	73,233,760	202,011
53	2047		73,233,760	0	73,233,760	180,367
54	2048		73,233,760	0	73,233,760	161,042
					TOTAL of [5] = $	2,071,550,909

Span 4A

COST ANALYSIS

Span - 4 Gravity - Flow Pipeline from El Toro 1 Tank to Alto Hospicio (L=7,450 m)
(Pampa-North Route to Iquique)
Alternative (A) : One - time Investment (600 mm pipe x 1 line)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	1,119,595,000	0	0	1,119,595,000	796,905,607
4	1998	1,119,595,000	0	0	1,119,595,000	711,522,863
5	1999		44,783,800	0	44,783,800	25,411,531
6	2000		44,783,800	0	44,783,800	22,688,867
7	2001		44,783,800	0	44,783,800	20,257,917
8	2002		44,783,800	0	44,783,800	18,087,426
9	2003		44,783,800	0	44,783,800	16,149,487
10	2004		44,783,800	0	44,783,800	14,419,185
11	2005		44,783,800	0	44,783,800	12,874,272
12	2006		44,783,800	0	44,783,800	11,494,886
13	2007		44,783,800	0	44,783,800	10,263,291
14	2008		44,783,800	0	44,783,800	9,163,653
15	2009		44,783,800	0	44,783,800	8,181,833
16	2010		44,783,800	0	44,783,800	7,305,208
17	2011		44,783,800	0	44,783,800	6,522,507
18	2012		44,783,800	0	44,783,800	5,823,667
19	2013		44,783,800	0	44,783,800	5,199,703
20	2014		44,783,800	0	44,783,800	4,642,592
21	2015		44,783,800	0	44,783,800	4,145,171
22	2016		44,783,800	0	44,783,800	3,701,046
23	2017		44,783,800	0	44,783,800	3,304,505
24	2018		44,783,800	0	44,783,800	2,950,451
25	2019		44,783,800	0	44,783,800	2,634,331
26	2020		44,783,800	0	44,783,800	2,352,081
27	2021		44,783,800	0	44,783,800	2,100,073
28	2022		44,783,800	0	44,783,800	1,875,065
29	2023		44,783,800	0	44,783,800	1,674,165
30	2024		44,783,800	0	44,783,800	1,494,790
31	2025		44,783,800	0	44,783,800	1,334,634
32	2026		44,783,800	0	44,783,800	1,191,638
33	2027		44,783,800	0	44,783,800	1,063,962
34	2028		44,783,800	0	44,783,800	949,966
35	2029		44,783,800	0	44,783,800	848,184
36	2030		44,783,800	0	44,783,800	757,307
37	2031		44,783,800	0	44,783,800	676,167
38	2032		44,783,800	0	44,783,800	603,721
39	2033		44,783,800	0	44,783,800	539,036
40	2034		44,783,800	0	44,783,800	481,282
41	2035		44,783,800	0	44,783,800	429,716
42	2036		44,783,800	0	44,783,800	383,675
43	2037		44,783,800	0	44,783,800	342,567
44	2038		44,783,800	0	44,783,800	305,864
45	2039		44,783,800	0	44,783,800	273,093
46	2040		44,783,800	0	44,783,800	243,833
47	2041		44,783,800	0	44,783,800	217,708
48	2042		44,783,800	0	44,783,800	194,382
49	2043		44,783,800	0	44,783,800	173,555
50	2044		44,783,800	0	44,783,800	154,960
51	2045		44,783,800	0	44,783,800	138,357
52	2046		44,783,800	0	44,783,800	123,533
53	2047		44,783,800	0	44,783,800	110,298
54	2048		44,783,800	0	44,783,800	98,480
					TOTAL of [5] = $	1,744,782,091

Span 4B

COST ANALYSIS

Span - 4 Gravity - Flow Pipeline from El Toro 1 Tank to Alto Hospicio (L=7,450 m)
(Pampa-North Route to Iquique)
Alternative (B) : Two - Steps Investment (400 mm pipe x 2 lines)

(Unit : $ = Chilean Peso)

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Electricity Cost	[4]=[1]+[2]+[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost
0	1994	0	0	0	0	0
1	1995	0	0	0	0	0
2	1996	0	0	0	0	0
3	1997	617,045,000	0	0	617,045,000	439,200,443
4	1998	617,045,000	0	0	617,045,000	392,143,253
5	1999		24,681,800	0	24,681,800	14,005,116
6	2000		24,681,800	0	24,681,800	12,504,568
7	2001		24,681,800	0	24,681,800	11,164,793
8	2002		24,681,800	0	24,681,800	9,968,565
9	2003		24,681,800	0	24,681,800	8,900,505
10	2004	617,045,000	24,681,800	0	641,726,800	206,618,855
11	2005	617,045,000	24,681,800	0	641,726,800	184,481,120
12	2006		49,363,600	0	49,363,600	12,670,407
13	2007		49,363,600	0	49,363,600	11,312,863
14	2008		49,363,600	0	49,363,600	10,100,771
15	2009		49,363,600	0	49,363,600	9,018,545
16	2010		49,363,600	0	49,363,600	8,052,272
17	2011		49,363,600	0	49,363,600	7,189,529
18	2012		49,363,600	0	49,363,600	6,419,222
19	2013		49,363,600	0	49,363,600	5,731,448
20	2014		49,363,600	0	49,363,600	5,117,365
21	2015		49,363,600	0	49,363,600	4,569,076
22	2016		49,363,600	0	49,363,600	4,079,532
23	2017		49,363,600	0	49,363,600	3,642,439
24	2018		49,363,600	0	49,363,600	3,252,178
25	2019		49,363,600	0	49,363,600	2,903,730
26	2020		49,363,600	0	49,363,600	2,592,616
27	2021		49,363,600	0	49,363,600	2,314,836
28	2022		49,363,600	0	49,363,600	2,066,818
29	2023		49,363,600	0	49,363,600	1,845,373
30	2024		49,363,600	0	49,363,600	1,647,654
31	2025		49,363,600	0	49,363,600	1,471,120
32	2026		49,363,600	0	49,363,600	1,313,500
33	2027		49,363,600	0	49,363,600	1,172,768
34	2028		49,363,600	0	49,363,600	1,047,114
35	2029		49,363,600	0	49,363,600	934,923
36	2030		49,363,600	0	49,363,600	834,753
37	2031		49,363,600	0	49,363,600	745,315
38	2032		49,363,600	0	49,363,600	665,460
39	2033		49,363,600	0	49,363,600	594,161
40	2034		49,363,600	0	49,363,600	530,501
41	2035		49,363,600	0	49,363,600	473,661
42	2036		49,363,600	0	49,363,600	422,912
43	2037		49,363,600	0	49,363,600	377,600
44	2038		49,363,600	0	49,363,600	337,143
45	2039		49,363,600	0	49,363,600	301,020
46	2040		49,363,600	0	49,363,600	268,768
47	2041		49,363,600	0	49,363,600	239,972
48	2042		49,363,600	0	49,363,600	214,260
49	2043		49,363,600	0	49,363,600	191,304
50	2044		49,363,600	0	49,363,600	170,807
51	2045		49,363,600	0	49,363,600	152,506
52	2046		49,363,600	0	49,363,600	136,166
53	2047		49,363,600	0	49,363,600	121,577
54	2048		49,363,600	0	49,363,600	108,551
					TOTAL of [5] = $	1,396,339,755

Appendix-4 Planning of Hydropower Plants for Iquique

Introduction

As for the Iquique water supply scheme, transmission pipeline routes sometimes follow a steep terrain and there exists an effective residual pressure. As a result possibility exists for the construction of hydropower plants along the pipelines, for generating electric power. However, the water supply shall be the first priority, and the construction of hydropower plants is viable as an option.

The amount of power that could be generated would be almost sufficient to operate the intake facilities and transmission pumps (about 2,770 kw in total). But the power plants and the pump facilities which require power may not have been located in a convenient manner such that the generated power is readily available for the above facilities. However, this problem can be overcome by selling the generated power to the public electric power authority and buying power when and where necessary.

Location of the Hydropower Plants

The transmission pipeline from La Tirana in Pampa-North up to Iquique has got two steep terrains for generating electric power. One is located about 4,000 meters upstream of the Alto Hospicio Tanks and the other one is in the site of Cavancha distribution tanks. Locations and hydraulic profiles of the pipeline for generating electricity are described in Fig. DA4-1.

Design Conditions and Main Specifications of Equipment

Design conditions and main specifications of hydropower plants are shown below. The pipe diameter and construction year is selected based on the total cost analysis (See Tables DA4-2 (1/8) to DA4-2 (8/8). Their summary is shown below.

Construction Year		Alto Hospicio Pipeline	Alto Hospicio Power Plant	Cavancha Pipeline	Cavancha Power Plant
1st Stage	Diameter	500 mm		400 mm	
	Construction Year	1998	2005	1998	2005
2nd Stage	Diameter	500 mm		400 mm	
	Construction Year	2005	2015	2005	2015

Item	Unit	Installation Place & Section of Subjects			
		Alto Hospicio (El Toro 1 Tank to Alto Hospicio)		Cavancha (Alto Hospicio to Cavancha)	
		1 st Stage	2 nd Sage	1 st Stage	2 nd Stage
Water Rate (Max)	l/sec	369	332	369	332
Water Rate (Ave)	l/sec	284	255	284	255
Top of Altitude	+m	+975	+975	+545	+545
Bottom of Altitude	+m	+567	+567	+114	+114
Total Head	m	408	408	431	431
Length of Pipe	m	6,850	6,850	3,000	3,000
Diameter of Pipe	m	0.5	0.5	0.4	0.4
Friction Loss	m	41.52	34.15	53.86	44.30
Velocity	m/sec	1.88	1.69	2.94	2.64
Coefficient of Friction	---	0.0168	0.0171	0.0163	0.0166
Effective Residual Head	m	366.48	373.85	377.14	386.70
Wall Thickness of Pipes and Pipeline Distance	mm m	6.0 1,750	6.0 1,750	6.0 460	6.0 460
	mm m	7.9 1,700	7.9 1,700	9.5 460	9.5 460
	mm m	12.7 1,700	12.7 1,700	12.7 460	12.7 460
	mm m	15.1 1,700	15.1 1,700	15.1 1,620	15.1 1,620
Power Generating Capacity (Max)	kw	1022.97	938.91	1052.71	971.18

The drawings of layout and main section of hydropower plants are shown in Figs. DA4-2 to DA4-5.

The type of turbine is selected by a reference. (See Fig. DA4-6)

Design Calculation of Main Equipment

Power generating capacity is calculated by the following formula :

$$Pg = 9.8 \times Q \times H \times (f \times g)$$

where

Pg	: Power generating capacity (kw)		
Q	: Flow rate (m^3/sec)		
H	: Effective Head (m)		
f	: Efficiency of the Hydro-Turbine	=	83 %
g	: Efficiency of the Generator	=	93 %

Wall thickness and design maximum pressure of steel pipe (pen stock) are calculated by the following formula and the calculation results are shown in the table below :

$$P = 2Pa \times (k / 100) \times (t - E) / D$$

where

P	: Maximum pressure of steel pipe (kg/cm^2)		
Pa	: Permissible tension stress of steel pipe	=	1,150 (kg/cm^2)
k	: Efficiency of welding	=	90 %
t	: Thickness of steel pipe (cm)		
E	: Thickness of steel pipe for corrosion (cm)		
D	: Diameter of steel pipe (cm)		

Thickness of Pipe (mm)	Maximum Pressure to Each Pipe Diameter (kg/cm^2)					
	400 mm	(80% Value)	500 mm	(80% Value)	600 mm	(80% Value)
6	20.70	16.56	16.56	13.25	13.80	11.04
7.1	26.39	21.11	21.11	16.89	17.60	14.08
7.9	30.53	24.43	24.43	19.54	20.36	16.28
9.5	38.81	31.05	31.05	24.84	25.88	20.70
10.3	42.95	34.36	34.36	27.49	28.64	22.91
12.7	55.37	44.30	44.30	35.44	36.92	29.53
15.1	67.79	54.23	54.23	43.39	45.20	36.16
20.6	96.26	77.00	77.00	61.60	64.17	51.34
26.2	125.24	100.19	100.19	80.15	83.49	66.79

Gravity flow pipeline from the hydropower plant to Alto Hospicio Tanks is calculated by the following formula and results of calculation are shown in the table below:

(1) Water Flow Rate : q (l /sec)

q^1 = 369 (l /sec)

q^2 = 332 (l /sec)

Where

q^1 : Daily maximum flow of 1st Stage

q^2 : Daily maximum flow of 2nd Stage

(2) Selection of the Pipe Diameter

[Manning Formula]

$$Q = A * V = (1/n) * R^{2/3} * I^{1/2} * A$$
$$= (1/n) * (D/4)^{2/3} * I^{1/2} * (\pi D^2/4)$$
$$= (0.312/n) * I^{1/2} * D^{8/3}$$

Therefore,

$$D = [(n * Q)/(0.312 * I^{1/2})]^{3/8}$$
$$I = [(n * Q)/(0.312 * D^{8/3})]^2$$

Where

Q : Flow Rate (m^3/sec)

A : Sectimal Area of the Pipe (mm)

V : Flow Velocity (m/sec)

n : Roughness Coefficient

R : Hydraulic radius (m)

I : Hydraulic Gradient
D : Pipe Diameter (m)
L : Length of Pipe (m)
hl : Friction Loss (m)
HP : Elevation of Hydropower Plant (m)
AT : Elevation of High Water Level of Alto Hospicio Tanks (m)

[Selection of Pipe Diameter]

The diameters of the gravity flow pipelines are as follows.

1 st Stage : 600 mm
2 nd Stage : 600 mm

Stage	D (m)	D' (m)	n (---)	Q (m3/sec)	I-1 (---)	I-2 (---)	I-3 (---)
1 st	0.5	0.3031	0.013	0.369	0.1375	0.0159	0.0095
	0.6	0.3031	0.013	0.369	0.1375	0.0159	0.0036
2 nd	0.5	0.2914	0.013	0.332	0.1375	0.0159	0.0077
	0.6	0.2914	0.013	0.332	0.1375	0.0159	0.0029

V (m/sec)	L (m)	hl (m)	HP (m)	AT (m)
1.8803	4,000	38.12	593	550
1.3057	4,000	14.42	567	550
1.6917	4,000	30.86	585	550
1.1748	4,000	11.67	564	550

I-1 : Grade of Ground
I-2 : Grade of Pipeline
I-3 : Hydraulic Gradient

[Material of Pipeline]

Pipe material of the gravity flow pipeline is Ductile Cast Iron Pipe as well as the transmission pipelines.

Construction Cost

The cost estimation of equipment and pipelines for hydropower plants are summarized below.

[Unit : Chilean Peso]

Construction Stage	Construction Year	Alto Hospicio	Cavancha
1 st Stage	1998	1,926,270,133	481,438,500
	2005	1,120,125,000	1,152,750,000
2 nd Stage	2005	1,926,270,133	481,438,500
	2015	1,022,250,000	1,065,750,000
Total		5,994,915,266	3,181,377,000

The detail of the cost estimation is given in Table DA4-1.

Revenue

Revenue is expected from the power generated, after the construction of the above plants. The revenue of each year is given in cost analysis in Tables DA4-2 (1/8) to (8/8).

Table DA4-1 Construction Cost of Hydropower Plant

[Alto Hospicio Hydropower Plant]

[Unit : $ = Chilean Peso]

Item	1 st Stage Specification	1 st Stage Unit Cost	1 st Stage Amount	2 nd Stage Specification	2 nd Stage Unit Cost	2 nd Stage Amount
1. Pipeline			1,926,270,133			1,926,270,133
(1) Materials			1,740,337,000			1,740,337,000
-1 Steel Pipe (Dia 500mm)	6.0mm * 1,750 m	74,300	130,025,000	6.0mm * 1,750 m	74,300	130,025,000
	7.9mm * 1,700 m	97,400	165,580,000	7.9mm * 1,700 m	97,400	165,580,000
	12.7mm * 1,700 m	117,000	198,900,000	12.7mm * 1,700 m	117,000	198,900,000
	15.1mm * 1,700 m	155,000	263,500,000	15.1mm * 1,700 m	155,000	263,500,000
-2 Mortar Lining (500mm)	6,850 m	30,000	205,500,000	6,850 m	30,000	205,500,000
-3 Ductile Pipe (600mm)	9.0mm * 4,000 m	194,208	776,832,000	9.0mm * 4,000 m	194,208	776,832,000
(2) Installation			185,933,133			185,933,133
-1 Welding (Steel 500mm)	1,989	7,640	15,197,233	1,989	7,640	15,197,233
-2 Instllation (500mm)	6,850 m	14,894	102,023,900	6,850 m	14,894	102,023,900
-3 Instllation (600mm)	4,000 m	17,178	68,712,000	4,000 m	17,178	68,712,000
2. Hydropower Plant		2,500 US$/kw	1,120,125,000		2,500 US$/kw	1,022,250,000
-1 Equipment	Max 1,030 kw		1,064,118,750	Max 940 kw		971,137,500
-2 Building & Civil			56,006,250			51,112,500
TOTAL			3,046,395,133			2,948,520,133

[Cavancha Hydropower Plant]

Item	1 st Stage Specification	1 st Stage Unit Cost	1 st Stage Amount	2 nd Stage Specification	2 nd Stage Unit Cost	2 nd Stage Amount
1. Pipeline			481,438,500			481,438,500
(1) Materials	Dia 400 mm		363,112,000	Dia 400 mm		363,112,000
-1 Steel Pipe	6.0mm * 460 m	59,200	27,232,000	6.0mm * 460 m	59,200	27,232,000
	9.5mm * 460 m	93,000	42,780,000	9.5mm * 460 m	93,000	42,780,000
	12.7mm * 460 m	123,000	56,580,000	12.7mm * 460 m	123,000	56,580,000
	15.1mm * 1,620 m	146,000	236,520,000	15.1mm * 1,620 m	146,000	236,520,000
-2 Mortar Lining	3,000 m	25,000	75,000,000	3,000 m	25,000	75,000,000
(2) Installation			118,326,500			118,326,500
-1 Welding	550	6,290	3,459,500	550	6,290	3,459,500
-2 Instllation	3,000 m	38,289	114,867,000	3,000 m	38,289	114,867,000
2. Hydropower Plant		2,500 US$/kw	1,152,750,000		2,500 US$/kw	1,065,750,000
-1 Equipment	Max 1,060 kw		1,095,112,500	Max 980 kw		1,012,462,500
-2 Building & Civil			57,637,500			53,287,500
TOTAL			1,634,188,500			1,547,188,500

Table DA4-2 Cost Analysis (1/8)

Alto Hospicio Hydropower Plant

Case-1. Diameter : 500 mm [Unit : $ = Chilean Peso]

Construction Year Pipe : 1 st Stage--1998, 2nd Stage- 2005

Hydropower Plant : 1 st Stage--1998, 2nd Stage- 2005

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	454
1	1995	0	0	0	0	0	184.5	239.9	512
2	1996	0	0	0	0	0	193.5	251.6	537
3	1997	0	0	0	0	0	202.7	263.5	562
4	1998	3,046,395,133	0	0	3,046,395,133	1,936,039,181	212.2	275.9	588
5	1999	0	60,927,903	125,422,768	-64,494,865	-36,596,119	221.8	288.4	615
6	2000	0	60,927,903	130,945,893	-70,017,990	-35,473,293	231.6	301.1	642
7	2001	0	60,927,903	136,599,485	-75,671,582	-34,229,981	241.6	314.1	670
8	2002	0	60,927,903	142,383,545	-81,455,642	-32,898,568	251.8	327.4	698
9	2003	0	60,927,903	146,384,548	-85,456,646	-30,816,523	258.9	336.6	718
10	2004	0	60,927,903	154,299,577	-93,371,675	-30,063,180	272.9	354.8	757
11	2005	2,948,520,133	60,927,903	160,475,040	2,848,972,996	819,011,658	283.8	369.0	787
12	2006	0	119,898,305	173,304,345	-53,406,040	-13,708,000	306.5	398.5	850
13	2007	0	119,898,305	186,481,564	-66,583,258	-15,259,164	329.8	428.8	914
14	2008	0	119,898,305	200,050,185	-80,151,879	-16,400,663	353.8	460.0	981
15	2009	0	119,898,305	213,879,741	-93,981,436	-17,170,057	378.3	491.8	1,049
16	2010	0	119,898,305	228,187,678	-108,289,373	-17,664,342	403.6	524.7	1,119
17	2011	0	119,898,305	242,669,572	-122,771,267	-17,880,940	429.2	558.0	1,190
18	2012	0	119,898,305	257,586,358	-137,688,052	-17,904,898	455.6	592.3	1,263
19	2013	0	119,898,305	272,894,546	-152,996,240	-17,763,900	482.7	627.5	1,338
20	2014	0	119,898,305	288,637,625	-168,739,320	-17,492,659	510.5	663.7	1,415
21	2015	0	119,898,305	304,859,086	-184,960,781	-17,119,898	539.2	701.0	1,495
22	2016	0	119,898,305	304,859,086	-184,960,781	-15,285,623	539.2	701.0	1,495
23	2017	0	119,898,305	304,859,086	-184,960,781	-13,647,878	539.2	701.0	1,495
24	2018	0	119,898,305	304,859,086	-184,960,781	-12,185,605	539.2	701.0	1,495
25	2019	0	119,898,305	304,859,086	-184,960,781	-10,880,005	539.2	701.0	1,495
26	2020	0	119,898,305	304,859,086	-184,960,781	-9,714,290	539.2	701.0	1,495
27	2021	0	119,898,305	304,859,086	-184,960,781	-8,673,473	539.2	701.0	1,495
28	2022	0	119,898,305	304,859,086	-184,960,781	-7,744,172	539.2	701.0	1,495
29	2023	0	119,898,305	304,859,086	-184,960,781	-6,914,440	539.2	701.0	1,495
30	2024	0	119,898,305	304,859,086	-184,960,781	-6,173,607	539.2	701.0	1,495
31	2025	0	119,898,305	304,859,086	-184,960,781	-5,512,149	539.2	701.0	1,495
32	2026	0	119,898,305	304,859,086	-184,960,781	-4,921,562	539.2	701.0	1,495
33	2027	0	119,898,305	304,859,086	-184,960,781	-4,394,251	539.2	701.0	1,495
34	2028	0	119,898,305	304,859,086	-184,960,781	-3,923,439	539.2	701.0	1,495
35	2029	0	119,898,305	304,859,086	-184,960,781	-3,503,070	539.2	701.0	1,495
36	2030	0	119,898,305	304,859,086	-184,960,781	-3,127,741	539.2	701.0	1,495
37	2031	0	119,898,305	304,859,086	-184,960,781	-2,792,626	539.2	701.0	1,495
38	2032	0	119,898,305	304,859,086	-184,960,781	-2,493,416	539.2	701.0	1,495
39	2033	0	119,898,305	304,859,086	-184,960,781	-2,226,265	539.2	701.0	1,495
40	2034	0	119,898,305	304,859,086	-184,960,781	-1,987,736	539.2	701.0	1,495
41	2035	0	119,898,305	304,859,086	-184,960,781	-1,774,764	539.2	701.0	1,495
42	2036	0	119,898,305	304,859,086	-184,960,781	-1,584,611	539.2	701.0	1,495
43	2037	0	119,898,305	304,859,086	-184,960,781	-1,414,831	539.2	701.0	1,495
44	2038	0	119,898,305	304,859,086	-184,960,781	-1,263,242	539.2	701.0	1,495
45	2039	0	119,898,305	304,859,086	-184,960,781	-1,127,895	539.2	701.0	1,495
46	2040	0	119,898,305	304,859,086	-184,960,781	-1,007,049	539.2	701.0	1,495
47	2041	0	119,898,305	304,859,086	-184,960,781	-899,151	539.2	701.0	1,495
48	2042	0	119,898,305	304,859,086	-184,960,781	-802,813	539.2	701.0	1,495
49	2043	0	119,898,305	304,859,086	-184,960,781	-716,798	539.2	701.0	1,495
50	2044	0	119,898,305	304,859,086	-184,960,781	-639,998	539.2	701.0	1,495
51	2045	0	119,898,305	304,859,086	-184,960,781	-571,427	539.2	701.0	1,495
52	2046	0	119,898,305	304,859,086	-184,960,781	-510,202	539.2	701.0	1,495
53	2047	0	119,898,305	304,859,086	-184,960,781	-455,538	539.2	701.0	1,495
54	2048	0	119,898,305	304,859,086	-184,960,781	-406,730	539.2	701.0	1,495
TOTAL		5,994,915,266	5,582,122,447	13,425,411,391	-1,848,373,678	2,247,332,254			

Table DA4-2 Cost Analysis (2/8)

Alto Hospicio Hydropower Plant (Unit : $ = Chilean Peso)
Case-2. Diameter : 500 mm
Construction Year Pipe : 1 st Stage--1998, 2nd Stage- 2005
Hydropower Plant : 1 st Stage--2005, 2nd Stage- 2015

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	454
1	1995	0	0	0	0	0	184.5	239.9	512
2	1996	0	0	0	0	0	193.5	251.6	537
3	1997	0	0	0	0	0	202.7	263.5	562
4	1998	1,926,270,133	0	0	1,926,270,133	1,224,179,493	212.2	275.9	588
5	1999	0	38,525,403	0	38,525,403	21,860,348	221.8	288.4	615
6	2000	0	38,525,403	0	38,525,403	19,518,168	231.6	301.1	642
7	2001	0	38,525,403	0	38,525,403	17,426,936	241.6	314.1	670
8	2002	0	38,525,403	0	38,525,403	15,559,764	251.8	327.4	698
9	2003	0	38,525,403	0	38,525,403	13,892,646	258.9	336.6	718
10	2004	0	38,525,403	0	38,525,403	12,404,149	272.9	354.8	757
11	2005	3,046,395,133	38,525,403	0	3,084,920,536	886,840,937	283.8	369.0	787
12	2006	0	99,453,305	173,304,345	-73,851,040	-18,955,722	306.5	398.5	850
13	2007	0	99,453,305	190,536,418	-91,083,113	-20,873,899	329.8	428.8	914
14	2008	0	99,453,305	190,536,418	-91,083,113	-18,637,410	353.8	460.0	981
15	2009	0	99,453,305	190,536,418	-91,083,113	-16,640,544	378.3	491.8	1,049
16	2010	0	99,453,305	190,536,418	-91,083,113	-14,857,629	403.6	524.7	1,119
17	2011	0	99,453,305	190,536,418	-91,083,113	-13,265,740	429.2	558.0	1,190
18	2012	0	99,453,305	190,536,418	-91,083,113	-11,844,411	455.6	592.3	1,263
19	2013	0	99,453,305	190,536,418	-91,083,113	-10,575,367	482.7	627.5	1,338
20	2014	0	99,453,305	190,536,418	-91,083,113	-9,442,292	510.5	663.7	1,415
21	2015	1,022,250,000	99,453,305	190,536,418	931,166,887	86,188,445	539.2	701.0	1,495
22	2016	0	119,898,305	304,859,086	-184,960,781	-15,285,623	539.2	701.0	1,495
23	2017	0	119,898,305	304,859,086	-184,960,781	-13,647,878	539.2	701.0	1,495
24	2018	0	119,898,305	304,859,086	-184,960,781	-12,185,605	539.2	701.0	1,495
25	2019	0	119,898,305	304,859,086	-184,960,781	-10,880,005	539.2	701.0	1,495
26	2020	0	119,898,305	304,859,086	-184,960,781	-9,714,290	539.2	701.0	1,495
27	2021	0	119,898,305	304,859,086	-184,960,781	-8,673,473	539.2	701.0	1,495
28	2022	0	119,898,305	304,859,086	-184,960,781	-7,744,172	539.2	701.0	1,495
29	2023	0	119,898,305	304,859,086	-184,960,781	-6,914,440	539.2	701.0	1,495
30	2024	0	119,898,305	304,859,086	-184,960,781	-6,173,607	539.2	701.0	1,495
31	2025	0	119,898,305	304,859,086	-184,960,781	-5,512,149	539.2	701.0	1,495
32	2026	0	119,898,305	304,859,086	-184,960,781	-4,921,562	539.2	701.0	1,495
33	2027	0	119,898,305	304,859,086	-184,960,781	-4,394,251	539.2	701.0	1,495
34	2028	0	119,898,305	304,859,086	-184,960,781	-3,923,439	539.2	701.0	1,495
35	2029	0	119,898,305	304,859,086	-184,960,781	-3,503,070	539.2	701.0	1,495
36	2030	0	119,898,305	304,859,086	-184,960,781	-3,127,741	539.2	701.0	1,495
37	2031	0	119,898,305	304,859,086	-184,960,781	-2,792,626	539.2	701.0	1,495
38	2032	0	119,898,305	304,859,086	-184,960,781	-2,493,416	539.2	701.0	1,495
39	2033	0	119,898,305	304,859,086	-184,960,781	-2,226,265	539.2	701.0	1,495
40	2034	0	119,898,305	304,859,086	-184,960,781	-1,987,736	539.2	701.0	1,495
41	2035	0	119,898,305	304,859,086	-184,960,781	-1,774,764	539.2	701.0	1,495
42	2036	0	119,898,305	304,859,086	-184,960,781	-1,584,611	539.2	701.0	1,495
43	2037	0	119,898,305	304,859,086	-184,960,781	-1,414,831	539.2	701.0	1,495
44	2038	0	119,898,305	304,859,086	-184,960,781	-1,263,242	539.2	701.0	1,495
45	2039	0	119,898,305	304,859,086	-184,960,781	-1,127,895	539.2	701.0	1,495
46	2040	0	119,898,305	304,859,086	-184,960,781	-1,007,049	539.2	701.0	1,495
47	2041	0	119,898,305	304,859,086	-184,960,781	-899,151	539.2	701.0	1,495
48	2042	0	119,898,305	304,859,086	-184,960,781	-802,813	539.2	701.0	1,495
49	2043	0	119,898,305	304,859,086	-184,960,781	-716,798	539.2	701.0	1,495
50	2044	0	119,898,305	304,859,086	-184,960,781	-639,998	539.2	701.0	1,495
51	2045	0	119,898,305	304,859,086	-184,960,781	-571,427	539.2	701.0	1,495
52	2046	0	119,898,305	304,859,086	-184,960,781	-510,202	539.2	701.0	1,495
53	2047	0	119,898,305	304,859,086	-184,960,781	-455,538	539.2	701.0	1,495
54	2048	0	119,898,305	304,859,086	-184,960,781	-406,730	539.2	701.0	1,495
TOTAL		5,994,915,266	5,220,854,947	11,948,481,948	-732,711,735	2,023,501,475			

Table DA4-2 Cost Analysis (3/8)

Alto Hospicio Hydropower Plant
Case-3. Diameter : 600 mm [Unit : $ = Chilean Peso]

Construction Year Pipe : 1 st Stage–1998, 2nd Stage- 2005
Hydropower Plant : 1 st Stage–1998, 2nd Stage- 2005

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	485
1	1995	0	0	0	0	0	184.5	239.9	546
2	1996	0	0	0	0	0	193.5	251.6	572
3	1997	0	0	0	0	0	202.7	263.5	599
4	1998	3,475,891,267	0	0	3,475,891,267	2,208,991,739	212.2	275.9	628
5	1999	0	69,517,825	133,780,179	-64,262,354	-36,464,185	221.8	288.4	656
6	2000	0	69,517,825	139,671,331	-70,153,506	-35,541,949	231.6	301.1	685
7	2001	0	69,517,825	145,701,644	-76,183,819	-34,461,691	241.6	314.1	714
8	2002	0	69,517,825	151,871,119	-82,353,293	-33,261,114	251.8	327.4	745
9	2003	0	69,517,825	156,138,725	-86,620,900	-31,236,365	258.9	336.6	766
10	2004	0	69,517,825	164,581,163	-95,063,338	-30,607,851	272.9	354.8	807
11	2005	3,356,266,267	69,517,825	171,168,121	3,254,615,971	935,624,320	283.8	369.0	839
12	2006	0	136,643,151	184,852,293	-48,209,143	-12,374,086	306.5	398.5	906
13	2007	0	136,643,151	198,907,562	-62,264,411	-14,269,396	329.8	428.8	975
14	2008	0	136,643,151	213,380,313	-76,737,163	-15,701,944	353.8	460.0	1,046
15	2009	0	136,643,151	228,131,387	-91,488,237	-16,714,559	378.3	491.8	1,119
16	2010	0	136,643,151	243,392,718	-106,749,568	-17,413,167	403.6	524.7	1,193
17	2011	0	136,643,151	258,839,598	-122,196,447	-17,797,221	429.2	558.0	1,269
18	2012	0	136,643,151	274,750,347	-138,107,196	-17,959,403	455.6	592.3	1,347
19	2013	0	136,643,151	291,078,580	-154,435,429	-17,931,000	482.7	627.5	1,427
20	2014	0	136,643,151	307,870,683	-171,227,532	-17,750,604	510.5	663.7	1,510
21	2015	0	136,643,151	325,173,043	-188,529,892	-17,450,254	539.2	701.0	1,595
22	2016	0	136,643,151	325,173,043	-188,529,892	-15,580,584	539.2	701.0	1,595
23	2017	0	136,643,151	325,173,043	-188,529,892	-13,911,235	539.2	701.0	1,595
24	2018	0	136,643,151	325,173,043	-188,529,892	-12,420,746	539.2	701.0	1,595
25	2019	0	136,643,151	325,173,043	-188,529,892	-11,089,952	539.2	701.0	1,595
26	2020	0	136,643,151	325,173,043	-188,529,892	-9,901,743	539.2	701.0	1,595
27	2021	0	136,643,151	325,173,043	-188,529,892	-8,840,842	539.2	701.0	1,595
28	2022	0	136,643,151	325,173,043	-188,529,892	-7,893,609	539.2	701.0	1,595
29	2023	0	136,643,151	325,173,043	-188,529,892	-7,047,865	539.2	701.0	1,595
30	2024	0	136,643,151	325,173,043	-188,529,892	-6,292,736	539.2	701.0	1,595
31	2025	0	136,643,151	325,173,043	-188,529,892	-5,618,515	539.2	701.0	1,595
32	2026	0	136,643,151	325,173,043	-188,529,892	-5,016,531	539.2	701.0	1,595
33	2027	0	136,643,151	325,173,043	-188,529,892	-4,479,045	539.2	701.0	1,595
34	2028	0	136,643,151	325,173,043	-188,529,892	-3,999,148	539.2	701.0	1,595
35	2029	0	136,643,151	325,173,043	-188,529,892	-3,570,668	539.2	701.0	1,595
36	2030	0	136,643,151	325,173,043	-188,529,892	-3,188,096	539.2	701.0	1,595
37	2031	0	136,643,151	325,173,043	-188,529,892	-2,846,514	539.2	701.0	1,595
38	2032	0	136,643,151	325,173,043	-188,529,892	-2,541,531	539.2	701.0	1,595
39	2033	0	136,643,151	325,173,043	-188,529,892	-2,269,224	539.2	701.0	1,595
40	2034	0	136,643,151	325,173,043	-188,529,892	-2,026,093	539.2	701.0	1,595
41	2035	0	136,643,151	325,173,043	-188,529,892	-1,809,011	539.2	701.0	1,595
42	2036	0	136,643,151	325,173,043	-188,529,892	-1,615,189	539.2	701.0	1,595
43	2037	0	136,643,151	325,173,043	-188,529,892	-1,442,133	539.2	701.0	1,595
44	2038	0	136,643,151	325,173,043	-188,529,892	-1,287,619	539.2	701.0	1,595
45	2039	0	136,643,151	325,173,043	-188,529,892	-1,149,659	539.2	701.0	1,595
46	2040	0	136,643,151	325,173,043	-188,529,892	-1,026,482	539.2	701.0	1,595
47	2041	0	136,643,151	325,173,043	-188,529,892	-916,501	539.2	701.0	1,595
48	2042	0	136,643,151	325,173,043	-188,529,892	-818,305	539.2	701.0	1,595
49	2043	0	136,643,151	325,173,043	-188,529,892	-730,629	539.2	701.0	1,595
50	2044	0	136,643,151	325,173,043	-188,529,892	-652,348	539.2	701.0	1,595
51	2045	0	136,643,151	325,173,043	-188,529,892	-582,453	539.2	701.0	1,595
52	2046	0	136,643,151	325,173,043	-188,529,892	-520,048	539.2	701.0	1,595
53	2047	0	136,643,151	325,173,043	-188,529,892	-464,328	539.2	701.0	1,595
54	2048	0	136,643,151	325,173,043	-188,529,892	-414,579	539.2	701.0	1,595
TOTAL		6,832,157,534	6,362,280,257	14,319,999,217	-1,125,561,426	2,635,717,313			

Table DA4-2 Cost Analysis (4/8)

Alto Hospicio Hydropower Plant [Unit : $ = Chilean Peso]
Case-4. Diameter : 600 mm
Construction Year Pipe : 1 st Stage--1998, 2nd Stage- 2005
Hydropower Plant : 1 st Stage--2005, 2nd Stage- 2015

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	485
1	1995	0	0	0	0	0	184.5	239.9	546
2	1996	0	0	0	0	0	193.5	251.6	572
3	1997	0	0	0	0	0	202.7	263.5	599
4	1998	2,279,641,267	0	0	2,279,641,267	1,448,753,237	212.2	275.9	628
5	1999	0	45,592,825	0	45,592,825	25,870,594	221.8	288.4	656
6	2000	0	45,592,825	0	45,592,825	23,098,744	231.6	301.1	685
7	2001	0	45,592,825	0	45,592,825	20,623,879	241.6	314.1	714
8	2002	0	45,592,825	0	45,592,825	18,414,177	251.8	327.4	745
9	2003	0	45,592,825	0	45,592,825	16,441,230	258.9	336.6	766
10	2004	0	45,592,825	0	45,592,825	14,679,670	272.9	354.8	807
11	2005	3,475,891,267	45,592,825	0	3,521,484,092	1,012,342,528	283.8	369.0	839
12	2006	0	115,110,651	184,852,293	-69,741,643	-17,900,943	306.5	398.5	906
13	2007	0	115,110,651	190,536,418	-75,425,768	-17,285,639	329.8	428.8	975
14	2008	0	115,110,651	190,536,418	-75,425,768	-15,433,606	353.8	460.0	1,046
15	2009	0	115,110,651	190,536,418	-75,425,768	-13,780,006	378.3	491.8	1,119
16	2010	0	115,110,651	190,536,418	-75,425,768	-12,303,577	403.6	524.7	1,193
17	2011	0	115,110,651	190,536,418	-75,425,768	-10,985,336	429.2	558.0	1,269
18	2012	0	115,110,651	190,536,418	-75,425,768	-9,808,336	455.6	592.3	1,347
19	2013	0	115,110,651	190,536,418	-75,425,768	-8,757,443	482.7	627.5	1,427
20	2014	0	115,110,651	190,536,418	-75,425,768	-7,819,145	510.5	663.7	1,510
21	2015	1,076,625,000	115,110,651	190,536,418	1,001,199,232	92,670,612	539.2	701.0	1,595
22	2016	0	136,643,151	325,173,043	-188,529,892	-15,580,584	539.2	701.0	1,595
23	2017	0	136,643,151	325,173,043	-188,529,892	-13,911,235	539.2	701.0	1,595
24	2018	0	136,643,151	325,173,043	-188,529,892	-12,420,746	539.2	701.0	1,595
25	2019	0	136,643,151	325,173,043	-188,529,892	-11,089,952	539.2	701.0	1,595
26	2020	0	136,643,151	325,173,043	-188,529,892	-9,901,743	539.2	701.0	1,595
27	2021	0	136,643,151	325,173,043	-188,529,892	-8,840,842	539.2	701.0	1,595
28	2022	0	136,643,151	325,173,043	-188,529,892	-7,893,609	539.2	701.0	1,595
29	2023	0	136,643,151	325,173,043	-188,529,892	-7,047,865	539.2	701.0	1,595
30	2024	0	136,643,151	325,173,043	-188,529,892	-6,292,736	539.2	701.0	1,595
31	2025	0	136,643,151	325,173,043	-188,529,892	-5,618,515	539.2	701.0	1,595
32	2026	0	136,643,151	325,173,043	-188,529,892	-5,016,531	539.2	701.0	1,595
33	2027	0	136,643,151	325,173,043	-188,529,892	-4,479,045	539.2	701.0	1,595
34	2028	0	136,643,151	325,173,043	-188,529,892	-3,999,148	539.2	701.0	1,595
35	2029	0	136,643,151	325,173,043	-188,529,892	-3,570,668	539.2	701.0	1,595
36	2030	0	136,643,151	325,173,043	-188,529,892	-3,188,096	539.2	701.0	1,595
37	2031	0	136,643,151	325,173,043	-188,529,892	-2,846,514	539.2	701.0	1,595
38	2032	0	136,643,151	325,173,043	-188,529,892	-2,541,531	539.2	701.0	1,595
39	2033	0	136,643,151	325,173,043	-188,529,892	-2,269,224	539.2	701.0	1,595
40	2034	0	136,643,151	325,173,043	-188,529,892	-2,026,093	539.2	701.0	1,595
41	2035	0	136,643,151	325,173,043	-188,529,892	-1,809,011	539.2	701.0	1,595
42	2036	0	136,643,151	325,173,043	-188,529,892	-1,615,189	539.2	701.0	1,595
43	2037	0	136,643,151	325,173,043	-188,529,892	-1,442,133	539.2	701.0	1,595
44	2038	0	136,643,151	325,173,043	-188,529,892	-1,287,619	539.2	701.0	1,595
45	2039	0	136,643,151	325,173,043	-188,529,892	-1,149,659	539.2	701.0	1,595
46	2040	0	136,643,151	325,173,043	-188,529,892	-1,026,482	539.2	701.0	1,595
47	2041	0	136,643,151	325,173,043	-188,529,892	-916,501	539.2	701.0	1,595
48	2042	0	136,643,151	325,173,043	-188,529,892	-818,305	539.2	701.0	1,595
49	2043	0	136,643,151	325,173,043	-188,529,892	-730,629	539.2	701.0	1,595
50	2044	0	136,643,151	325,173,043	-188,529,892	-652,348	539.2	701.0	1,595
51	2045	0	136,643,151	325,173,043	-188,529,892	-582,453	539.2	701.0	1,595
52	2046	0	136,643,151	325,173,043	-188,529,892	-520,048	539.2	701.0	1,595
53	2047	0	136,643,151	325,173,043	-188,529,892	-464,328	539.2	701.0	1,595
54	2048	0	136,643,151	325,173,043	-188,529,892	-414,579	539.2	701.0	1,595
TOTAL		6,832,157,534	5,979,480,257	12,630,390,470	181,247,321	2,416,856,682			

Table DA4-2 Cost Analysis (5/8)

Cavancha Hydropower Plant

Case-5. Diameter : 400 mm [Unit : $ = Chilean Peso]

Construction Year — Pipe : 1 st Stage--1998, 2nd Stage- 2005

Hydropower Plant : 1 st Stage--1998, 2nd Stage- 2005

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	468
1	1995	0	0	0	0	0	184.5	239.9	526
2	1996	0	0	0	0	0	193.5	251.6	552
3	1997	0	0	0	0	0	202.7	263.5	578
4	1998	1,634,188,500	0	0	1,634,188,500	1,038,556,335	212.2	275.9	605
5	1999	0	32,683,770	129,071,007	-96,387,237	-54,692,707	221.8	288.4	633
6	2000	0	32,683,770	134,754,786	-102,071,016	-51,712,353	231.6	301.1	661
7	2001	0	32,683,770	140,572,827	-107,889,057	-48,803,530	241.6	314.1	689
8	2002	0	32,683,770	146,525,131	-113,841,361	-45,978,616	251.8	327.4	718
9	2003	0	32,683,770	150,642,514	-117,958,744	-42,537,106	258.9	336.6	739
10	2004	0	32,683,770	158,787,772	-126,104,002	-40,602,114	272.9	354.8	779
11	2005	1,547,188,500	32,683,770	165,142,863	1,414,729,407	406,700,898	283.8	369.0	810
12	2006	0	63,627,540	178,345,341	-114,717,801	-29,445,202	306.5	398.5	875
13	2007	0	63,627,540	191,905,853	-128,278,313	-29,398,078	329.8	428.8	941
14	2008	0	63,627,540	205,869,152	-142,241,612	-29,105,452	353.8	460.0	1,009
15	2009	0	63,627,540	220,100,976	-156,473,436	-28,587,112	378.3	491.8	1,079
16	2010	0	63,627,540	234,825,095	-171,197,555	-27,926,030	403.6	524.7	1,151
17	2011	0	63,627,540	249,728,232	-186,100,692	-27,104,513	429.2	558.0	1,225
18	2012	0	63,627,540	265,078,910	-201,451,370	-26,196,654	455.6	592.3	1,300
19	2013	0	63,627,540	280,832,375	-217,204,835	-25,218,953	482.7	627.5	1,377
20	2014	0	63,627,540	297,033,383	-233,405,843	-24,196,429	510.5	663.7	1,457
21	2015	0	63,627,540	313,726,685	-250,099,145	-23,149,080	539.2	701.0	1,538
22	2016	0	63,627,540	313,726,685	-250,099,145	-20,668,821	539.2	701.0	1,538
23	2017	0	63,627,540	313,726,685	-250,099,145	-18,454,305	539.2	701.0	1,538
24	2018	0	63,627,540	313,726,685	-250,099,145	-16,477,058	539.2	701.0	1,538
25	2019	0	63,627,540	313,726,685	-250,099,145	-14,711,659	539.2	701.0	1,538
26	2020	0	63,627,540	313,726,685	-250,099,145	-13,135,410	539.2	701.0	1,538
27	2021	0	63,627,540	313,726,685	-250,099,145	-11,728,044	539.2	701.0	1,538
28	2022	0	63,627,540	313,726,685	-250,099,145	-10,471,468	539.2	701.0	1,538
29	2023	0	63,627,540	313,726,685	-250,099,145	-9,349,525	539.2	701.0	1,538
30	2024	0	63,627,540	313,726,685	-250,099,145	-8,347,790	539.2	701.0	1,538
31	2025	0	63,627,540	313,726,685	-250,099,145	-7,453,384	539.2	701.0	1,538
32	2026	0	63,627,540	313,726,685	-250,099,145	-6,654,807	539.2	701.0	1,538
33	2027	0	63,627,540	313,726,685	-250,099,145	-5,941,792	539.2	701.0	1,538
34	2028	0	63,627,540	313,726,685	-250,099,145	-5,305,172	539.2	701.0	1,538
35	2029	0	63,627,540	313,726,685	-250,099,145	-4,736,760	539.2	701.0	1,538
36	2030	0	63,627,540	313,726,685	-250,099,145	-4,229,250	539.2	701.0	1,538
37	2031	0	63,627,540	313,726,685	-250,099,145	-3,776,116	539.2	701.0	1,538
38	2032	0	63,627,540	313,726,685	-250,099,145	-3,371,532	539.2	701.0	1,538
39	2033	0	63,627,540	313,726,685	-250,099,145	-3,010,297	539.2	701.0	1,538
40	2034	0	63,627,540	313,726,685	-250,099,145	-2,687,765	539.2	701.0	1,538
41	2035	0	63,627,540	313,726,685	-250,099,145	-2,399,790	539.2	701.0	1,538
42	2036	0	63,627,540	313,726,685	-250,099,145	-2,142,670	539.2	701.0	1,538
43	2037	0	63,627,540	313,726,685	-250,099,145	-1,913,098	539.2	701.0	1,538
44	2038	0	63,627,540	313,726,685	-250,099,145	-1,708,123	539.2	701.0	1,538
45	2039	0	63,627,540	313,726,685	-250,099,145	-1,525,110	539.2	701.0	1,538
46	2040	0	63,627,540	313,726,685	-250,099,145	-1,361,705	539.2	701.0	1,538
47	2041	0	63,627,540	313,726,685	-250,099,145	-1,215,808	539.2	701.0	1,538
48	2042	0	63,627,540	313,726,685	-250,099,145	-1,085,543	539.2	701.0	1,538
49	2043	0	63,627,540	313,726,685	-250,099,145	-969,235	539.2	701.0	1,538
50	2044	0	63,627,540	313,726,685	-250,099,145	-865,388	539.2	701.0	1,538
51	2045	0	63,627,540	313,726,685	-250,099,145	-772,668	539.2	701.0	1,538
52	2046	0	63,627,540	313,726,685	-250,099,145	-689,882	539.2	701.0	1,538
53	2047	0	63,627,540	313,726,685	-250,099,145	-615,966	539.2	701.0	1,538
54	2048	0	63,627,540	313,726,685	-250,099,145	-549,970	539.2	701.0	1,538
TOTAL		3,181,377,000	2,964,770,610	13,815,923,521	-7,669,775,911	702,277,390			

Table DA4-2 Cost Analysis (6/8)

Cavancha Hydropower Plant

Case-6 Diameter : 400 mm [Unit : $ = Chilean Peso]

Construction Year Pipe : 1 st Stage--1998, 2nd Stage- 2005

Hydropower Plant : 1 st Stage--2005, 2nd Stage- 2015

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/[1+0.12]^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kwh)
0	1994	0	0	0	0	0	163.9	213.1	468
1	1995	0	0	0	0	0	184.5	239.9	526
2	1996	0	0	0	0	0	193.5	251.6	552
3	1997	0	0	0	0	0	202.7	263.5	578
4	1998	481,438,500	0	0	481,438,500	305,962,870	212.2	275.9	605
5	1999	0	9,628,770	0	9,628,770	5,463,623	221.8	288.4	633
6	2000	0	9,628,770	0	9,628,770	4,878,235	231.6	301.1	661
7	2001	0	9,628,770	0	9,628,770	4,355,567	241.6	314.1	689
8	2002	0	9,628,770	0	9,628,770	3,888,899	251.8	327.4	718
9	2003	0	9,628,770	0	9,628,770	3,472,231	258.9	336.6	739
10	2004	0	9,628,770	0	9,628,770	3,100,206	272.9	354.8	779
11	2005	1,634,188,500	9,628,770	0	1,643,817,270	472,558,185	283.8	369.0	810
12	2006	0	42,312,540	178,345,341	-136,032,801	-34,916,232	306.5	398.5	875
13	2007	0	42,312,540	190,536,418	-148,223,878	-33,969,087	329.8	428.8	941
14	2008	0	42,312,540	190,536,418	-148,223,878	-30,329,542	353.8	460.0	1,009
15	2009	0	42,312,540	190,536,418	-148,223,878	-27,079,948	378.3	491.8	1,079
16	2010	0	42,312,540	190,536,418	-148,223,878	-24,178,525	403.6	524.7	1,151
17	2011	0	42,312,540	190,536,418	-148,223,878	-21,587,969	429.2	558.0	1,225
18	2012	0	42,312,540	190,536,418	-148,223,878	-19,274,972	455.6	592.3	1,300
19	2013	0	42,312,540	190,536,418	-148,223,878	-17,209,797	482.7	627.5	1,377
20	2014	0	42,312,540	190,536,418	-148,223,878	-15,365,890	510.5	663.7	1,457
21	2015	1,065,750,000	42,312,540	190,536,418	917,526,122	84,925,862	539.2	701.0	1,538
22	2016	0	63,627,540	313,726,685	-250,099,145	-20,668,821	539.2	701.0	1,538
23	2017	0	63,627,540	313,726,685	-250,099,145	-18,454,305	539.2	701.0	1,538
24	2018	0	63,627,540	313,726,685	-250,099,145	-16,477,058	539.2	701.0	1,538
25	2019	0	63,627,540	313,726,685	-250,099,145	-14,711,659	539.2	701.0	1,538
26	2020	0	63,627,540	313,726,685	-250,099,145	-13,135,410	539.2	701.0	1,538
27	2021	0	63,627,540	313,726,685	-250,099,145	-11,728,044	539.2	701.0	1,538
28	2022	0	63,627,540	313,726,685	-250,099,145	-10,471,468	539.2	701.0	1,538
29	2023	0	63,627,540	313,726,685	-250,099,145	-9,349,525	539.2	701.0	1,538
30	2024	0	63,627,540	313,726,685	-250,099,145	-8,347,790	539.2	701.0	1,538
31	2025	0	63,627,540	313,726,685	-250,099,145	-7,453,384	539.2	701.0	1,538
32	2026	0	63,627,540	313,726,685	-250,099,145	-6,654,807	539.2	701.0	1,538
33	2027	0	63,627,540	313,726,685	-250,099,145	-5,941,792	539.2	701.0	1,538
34	2028	0	63,627,540	313,726,685	-250,099,145	-5,305,172	539.2	701.0	1,538
35	2029	0	63,627,540	313,726,685	-250,099,145	-4,736,760	539.2	701.0	1,538
36	2030	0	63,627,540	313,726,685	-250,099,145	-4,229,250	539.2	701.0	1,538
37	2031	0	63,627,540	313,726,685	-250,099,145	-3,776,116	539.2	701.0	1,538
38	2032	0	63,627,540	313,726,685	-250,099,145	-3,371,532	539.2	701.0	1,538
39	2033	0	63,627,540	313,726,685	-250,099,145	-3,010,297	539.2	701.0	1,538
40	2034	0	63,627,540	313,726,685	-250,099,145	-2,687,765	539.2	701.0	1,538
41	2035	0	63,627,540	313,726,685	-250,099,145	-2,399,790	539.2	701.0	1,538
42	2036	0	63,627,540	313,726,685	-250,099,145	-2,142,670	539.2	701.0	1,538
43	2037	0	63,627,540	313,726,685	-250,099,145	-1,913,098	539.2	701.0	1,538
44	2038	0	63,627,540	313,726,685	-250,099,145	-1,708,123	539.2	701.0	1,538
45	2039	0	63,627,540	313,726,685	-250,099,145	-1,525,110	539.2	701.0	1,538
46	2040	0	63,627,540	313,726,685	-250,099,145	-1,361,705	539.2	701.0	1,538
47	2041	0	63,627,540	313,726,685	-250,099,145	-1,215,808	539.2	701.0	1,538
48	2042	0	63,627,540	313,726,685	-250,099,145	-1,085,543	539.2	701.0	1,538
49	2043	0	63,627,540	313,726,685	-250,099,145	-969,235	539.2	701.0	1,538
50	2044	0	63,627,540	313,726,685	-250,099,145	-865,388	539.2	701.0	1,538
51	2045	0	63,627,540	313,726,685	-250,099,145	-772,668	539.2	701.0	1,538
52	2046	0	63,627,540	313,726,685	-250,099,145	-689,882	539.2	701.0	1,538
53	2047	0	63,627,540	313,726,685	-250,099,145	-615,966	539.2	701.0	1,538
54	2048	0	63,627,540	313,726,685	-250,099,145	-549,970	539.2	701.0	1,538
TOTAL		3,181,377,000	2,590,235,610	12,246,153,727	-6,474,541,117	476,367,798			

Table DA4-2 Cost Analysis (7/8)

Cavancha Hydropower Plant

Case-7. Diameter : 500 mm   (Unit : $ = Chilean Peso)

Construction Year   Pipe : 1 st Stage--1998, 2nd Stage- 2005

Hydropower Plant : 1 st Stage--1998, 2nd Stage- 2005

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	512
1	1995	0	0	0	0	0	184.5	239.9	576
2	1996	0	0	0	0	0	193.5	251.6	604
3	1997	0	0	0	0	0	202.7	263.5	633
4	1998	1,857,126,000	0	0	1,857,126,000	1,180,237,147	212.2	275.9	663
5	1999	0	37,142,520	141,281,999	-104,139,479	-59,091,537	221.8	288.4	693
6	2000	0	37,142,520	147,503,502	-110,360,982	-55,912,308	231.6	301.1	723
7	2001	0	37,142,520	153,871,969	-116,729,449	-52,802,475	241.6	314.1	755
8	2002	0	37,142,520	160,387,401	-123,244,881	-49,776,541	251.8	327.4	786
9	2003	0	37,142,520	164,894,317	-127,751,797	-46,068,579	258.9	336.6	809
10	2004	0	37,142,520	173,810,171	-136,667,651	-44,003,326	272.9	354.8	852
11	2005	1,737,501,000	37,142,520	180,766,497	1,593,877,023	458,201,557	283.8	369.0	886
12	2006	0	71,892,540	195,218,019	-123,325,479	-31,654,579	306.5	398.5	957
13	2007	0	71,892,540	210,061,447	-138,168,907	-31,664,747	329.8	428.8	1,030
14	2008	0	71,892,540	225,345,769	-153,453,229	-31,399,571	353.8	460.0	1,105
15	2009	0	71,892,540	240,924,020	-169,031,480	-30,881,419	378.3	491.8	1,181
16	2010	0	71,892,540	257,041,141	-185,148,601	-30,201,747	403.6	524.7	1,260
17	2011	0	71,892,540	273,354,215	-201,461,675	-29,341,753	429.2	558.0	1,340
18	2012	0	71,892,540	290,157,171	-218,264,631	-28,383,043	455.6	592.3	1,423
19	2013	0	71,892,540	307,401,021	-235,508,481	-27,344,131	482.7	627.5	1,507
20	2014	0	71,892,540	325,134,754	-253,242,214	-26,252,801	510.5	663.7	1,594
21	2015	0	71,892,540	343,407,356	-271,514,816	-25,131,306	539.2	701.0	1,684
22	2016	0	71,892,540	343,407,356	-271,514,816	-22,438,666	539.2	701.0	1,684
23	2017	0	71,892,540	343,407,356	-271,514,816	-20,034,523	539.2	701.0	1,684
24	2018	0	71,892,540	343,407,356	-271,514,816	-17,887,967	539.2	701.0	1,684
25	2019	0	71,892,540	343,407,356	-271,514,816	-15,971,399	539.2	701.0	1,684
26	2020	0	71,892,540	343,407,356	-271,514,816	-14,260,178	539.2	701.0	1,684
27	2021	0	71,892,540	343,407,356	-271,514,816	-12,732,302	539.2	701.0	1,684
28	2022	0	71,892,540	343,407,356	-271,514,816	-11,368,127	539.2	701.0	1,684
29	2023	0	71,892,540	343,407,356	-271,514,816	-10,150,113	539.2	701.0	1,684
30	2024	0	71,892,540	343,407,356	-271,514,816	-9,062,601	539.2	701.0	1,684
31	2025	0	71,892,540	343,407,356	-271,514,816	-8,091,608	539.2	701.0	1,684
32	2026	0	71,892,540	343,407,356	-271,514,816	-7,224,650	539.2	701.0	1,684
33	2027	0	71,892,540	343,407,356	-271,514,816	-6,450,580	539.2	701.0	1,684
34	2028	0	71,892,540	343,407,356	-271,514,816	-5,759,447	539.2	701.0	1,684
35	2029	0	71,892,540	343,407,356	-271,514,816	-5,142,363	539.2	701.0	1,684
36	2030	0	71,892,540	343,407,356	-271,514,816	-4,591,396	539.2	701.0	1,684
37	2031	0	71,892,540	343,407,356	-271,514,816	-4,099,460	539.2	701.0	1,684
38	2032	0	71,892,540	343,407,356	-271,514,816	-3,660,232	539.2	701.0	1,684
39	2033	0	71,892,540	343,407,356	-271,514,816	-3,268,065	539.2	701.0	1,684
40	2034	0	71,892,540	343,407,356	-271,514,816	-2,917,915	539.2	701.0	1,684
41	2035	0	71,892,540	343,407,356	-271,514,816	-2,605,281	539.2	701.0	1,684
42	2036	0	71,892,540	343,407,356	-271,514,816	-2,326,144	539.2	701.0	1,684
43	2037	0	71,892,540	343,407,356	-271,514,816	-2,076,914	539.2	701.0	1,684
44	2038	0	71,892,540	343,407,356	-271,514,816	-1,854,388	539.2	701.0	1,684
45	2039	0	71,892,540	343,407,356	-271,514,816	-1,655,703	539.2	701.0	1,684
46	2040	0	71,892,540	343,407,356	-271,514,816	-1,478,307	539.2	701.0	1,684
47	2041	0	71,892,540	343,407,356	-271,514,816	-1,319,917	539.2	701.0	1,684
48	2042	0	71,892,540	343,407,356	-271,514,816	-1,178,497	539.2	701.0	1,684
49	2043	0	71,892,540	343,407,356	-271,514,816	-1,052,229	539.2	701.0	1,684
50	2044	0	71,892,540	343,407,356	-271,514,816	-939,491	539.2	701.0	1,684
51	2045	0	71,892,540	343,407,356	-271,514,816	-838,831	539.2	701.0	1,684
52	2046	0	71,892,540	343,407,356	-271,514,816	-748,956	539.2	701.0	1,684
53	2047	0	71,892,540	343,407,356	-271,514,816	-668,711	539.2	701.0	1,684
54	2048	0	71,892,540	343,407,356	-271,514,816	-597,063	539.2	701.0	1,684
TOTAL		3,594,627,000	3,351,376,860	15,123,003,522	-8,176,999,662	834,076,818			

Table DA4-2 Cost Analysis (8/8)

Cavancha Hydropower Plant
Case-8 Diameter : 500 mm [Unit : $ = Chilean Peso]
Construction Year Pipe : 1 st Stage--1998, 2nd Stage- 2005
Hydropower Plant : 1 st Stage--2005, 2nd Stage- 2015

n No. of Year	Year	[1] Investment Cost	[2]=[1] x 2.0% Repair Cost	[3] Revenue by Electricity Generated	[4]=[1]+[2]-[3] Total Cost	[5]=[4]/(1+0.12)^n Discounted Cost	Water Rate Daily Average (l/sec)	Water Rate Daily Max (l/sec)	Generated Power (kw/h)
0	1994	0	0	0	0	0	163.9	213.1	512
1	1995	0	0	0	0	0	184.5	239.9	576
2	1996	0	0	0	0	0	193.5	251.6	604
3	1997	0	0	0	0	0	202.7	263.5	633
4	1998	595,626,000	0	0	595,626,000	378,531,091	212.2	275.9	663
5	1999	0	11,912,520	0	11,912,520	6,759,484	221.8	288.4	693
6	2000	0	11,912,520	0	11,912,520	6,035,253	231.6	301.1	723
7	2001	0	11,912,520	0	11,912,520	5,388,619	241.6	314.1	755
8	2002	0	11,912,520	0	11,912,520	4,811,267	251.8	327.4	786
9	2003	0	11,912,520	0	11,912,520	4,295,774	258.9	336.6	809
10	2004	0	11,912,520	0	11,912,520	3,835,513	272.9	354.8	852
11	2005	1,857,126,000	11,912,520	0	1,869,038,520	537,303,912	283.8	369.0	886
12	2006	0	49,055,040	195,218,019	-146,162,979	-37,516,396	306.5	398.5	957
13	2007	0	49,055,040	190,536,418	-141,481,378	-32,423,880	329.8	428.8	1,030
14	2008	0	49,055,040	190,536,418	-141,481,378	-28,949,893	353.8	460.0	1,105
15	2009	0	49,055,040	190,536,418	-141,481,378	-25,848,119	378.3	491.8	1,181
16	2010	0	49,055,040	190,536,418	-141,481,378	-23,078,678	403.6	524.7	1,260
17	2011	0	49,055,040	190,536,418	-141,481,378	-20,605,962	429.2	558.0	1,340
18	2012	0	49,055,040	190,536,418	-141,481,378	-18,398,180	455.6	592.3	1,423
19	2013	0	49,055,040	190,536,418	-141,481,378	-16,426,947	482.7	627.5	1,507
20	2014	0	49,055,040	190,536,418	-141,481,378	-14,666,917	510.5	663.7	1,594
21	2015	1,141,875,000	49,055,040	190,536,418	1,000,393,622	92,596,045	539.2	701.0	1,684
22	2016	0	71,892,540	343,407,356	-271,514,816	-22,438,666	539.2	701.0	1,684
23	2017	0	71,892,540	343,407,356	-271,514,816	-20,034,523	539.2	701.0	1,684
24	2018	0	71,892,540	343,407,356	-271,514,816	-17,887,967	539.2	701.0	1,684
25	2019	0	71,892,540	343,407,356	-271,514,816	-15,971,399	539.2	701.0	1,684
26	2020	0	71,892,540	343,407,356	-271,514,816	-14,260,178	539.2	701.0	1,684
27	2021	0	71,892,540	343,407,356	-271,514,816	-12,732,302	539.2	701.0	1,684
28	2022	0	71,892,540	343,407,356	-271,514,816	-11,368,127	539.2	701.0	1,684
29	2023	0	71,892,540	343,407,356	-271,514,816	-10,150,113	539.2	701.0	1,684
30	2024	0	71,892,540	343,407,356	-271,514,816	-9,062,601	539.2	701.0	1,684
31	2025	0	71,892,540	343,407,356	-271,514,816	-8,091,608	539.2	701.0	1,684
32	2026	0	71,892,540	343,407,356	-271,514,816	-7,224,650	539.2	701.0	1,684
33	2027	0	71,892,540	343,407,356	-271,514,816	-6,450,580	539.2	701.0	1,684
34	2028	0	71,892,540	343,407,356	-271,514,816	-5,759,447	539.2	701.0	1,684
35	2029	0	71,892,540	343,407,356	-271,514,816	-5,142,363	539.2	701.0	1,684
36	2030	0	71,892,540	343,407,356	-271,514,816	-4,591,396	539.2	701.0	1,684
37	2031	0	71,892,540	343,407,356	-271,514,816	-4,099,460	539.2	701.0	1,684
38	2032	0	71,892,540	343,407,356	-271,514,816	-3,660,232	539.2	701.0	1,684
39	2033	0	71,892,540	343,407,356	-271,514,816	-3,268,065	539.2	701.0	1,684
40	2034	0	71,892,540	343,407,356	-271,514,816	-2,917,915	539.2	701.0	1,684
41	2035	0	71,892,540	343,407,356	-271,514,816	-2,605,281	539.2	701.0	1,684
42	2036	0	71,892,540	343,407,356	-271,514,816	-2,326,144	539.2	701.0	1,684
43	2037	0	71,892,540	343,407,356	-271,514,816	-2,076,914	539.2	701.0	1,684
44	2038	0	71,892,540	343,407,356	-271,514,816	-1,854,388	539.2	701.0	1,684
45	2039	0	71,892,540	343,407,356	-271,514,816	-1,655,703	539.2	701.0	1,684
46	2040	0	71,892,540	343,407,356	-271,514,816	-1,478,307	539.2	701.0	1,684
47	2041	0	71,892,540	343,407,356	-271,514,816	-1,319,917	539.2	701.0	1,684
48	2042	0	71,892,540	343,407,356	-271,514,816	-1,178,497	539.2	701.0	1,684
49	2043	0	71,892,540	343,407,356	-271,514,816	-1,052,229	539.2	701.0	1,684
50	2044	0	71,892,540	343,407,356	-271,514,816	-939,491	539.2	701.0	1,684
51	2045	0	71,892,540	343,407,356	-271,514,816	-838,831	539.2	701.0	1,684
52	2046	0	71,892,540	343,407,356	-271,514,816	-748,956	539.2	701.0	1,684
53	2047	0	71,892,540	343,407,356	-271,514,816	-668,711	539.2	701.0	1,684
54	2048	0	71,892,540	343,407,356	-271,514,816	-597,063	539.2	701.0	1,684
TOTAL		3,594,627,000	2,946,391,860	13,242,488,537	-6,701,469,677	617,189,963			

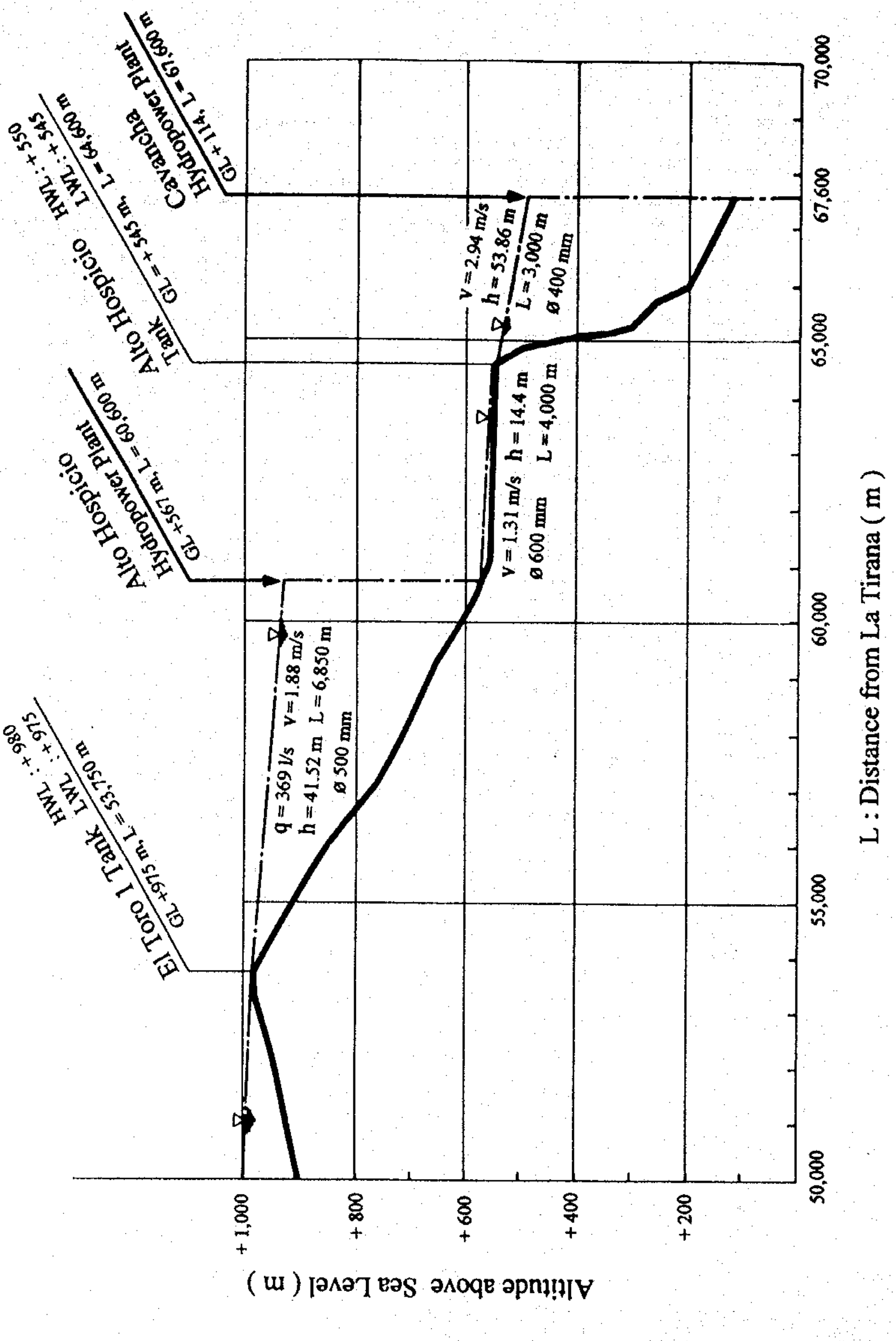


Fig.DA4-1 Location and Hydraulic Profile of Hydropower Plants

< Localización y Perfil Hidráulico de Central Hidroeléctrica >

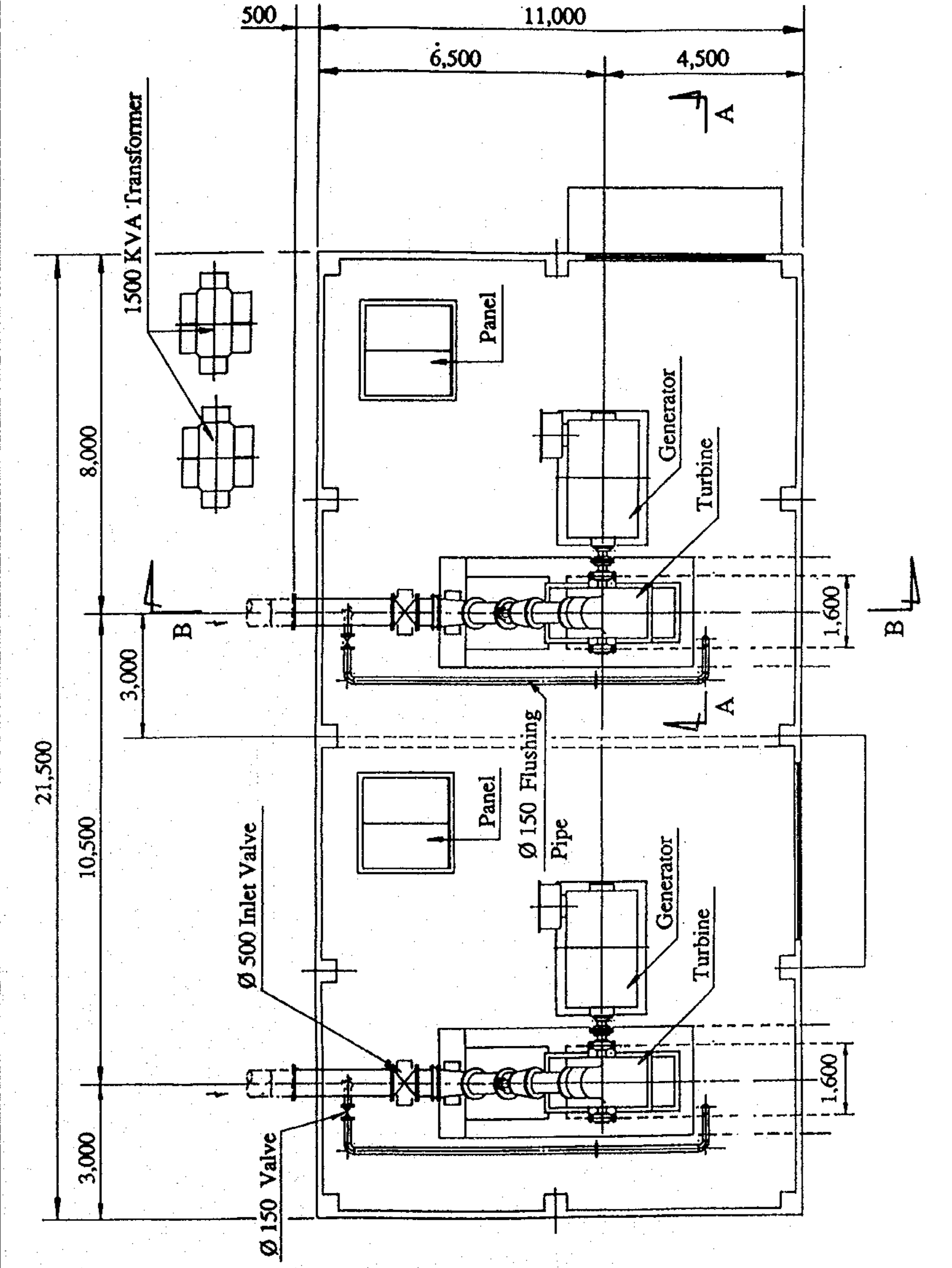
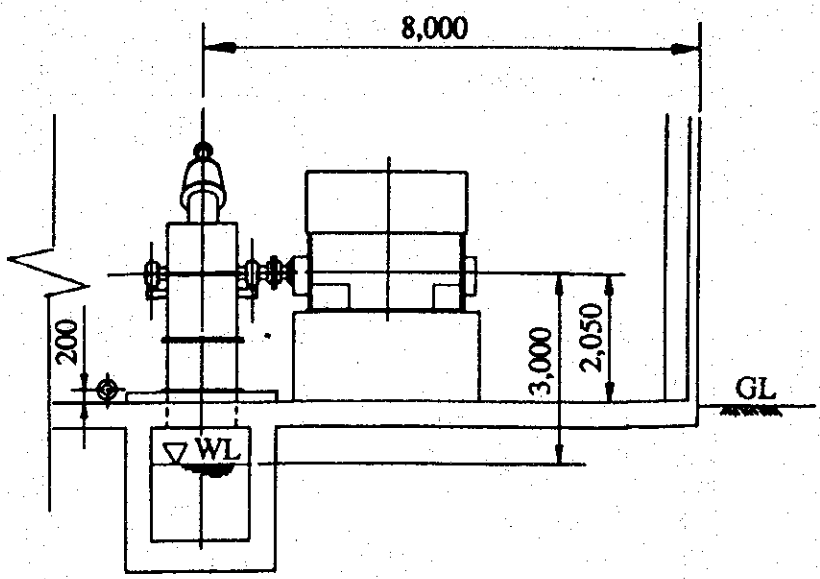
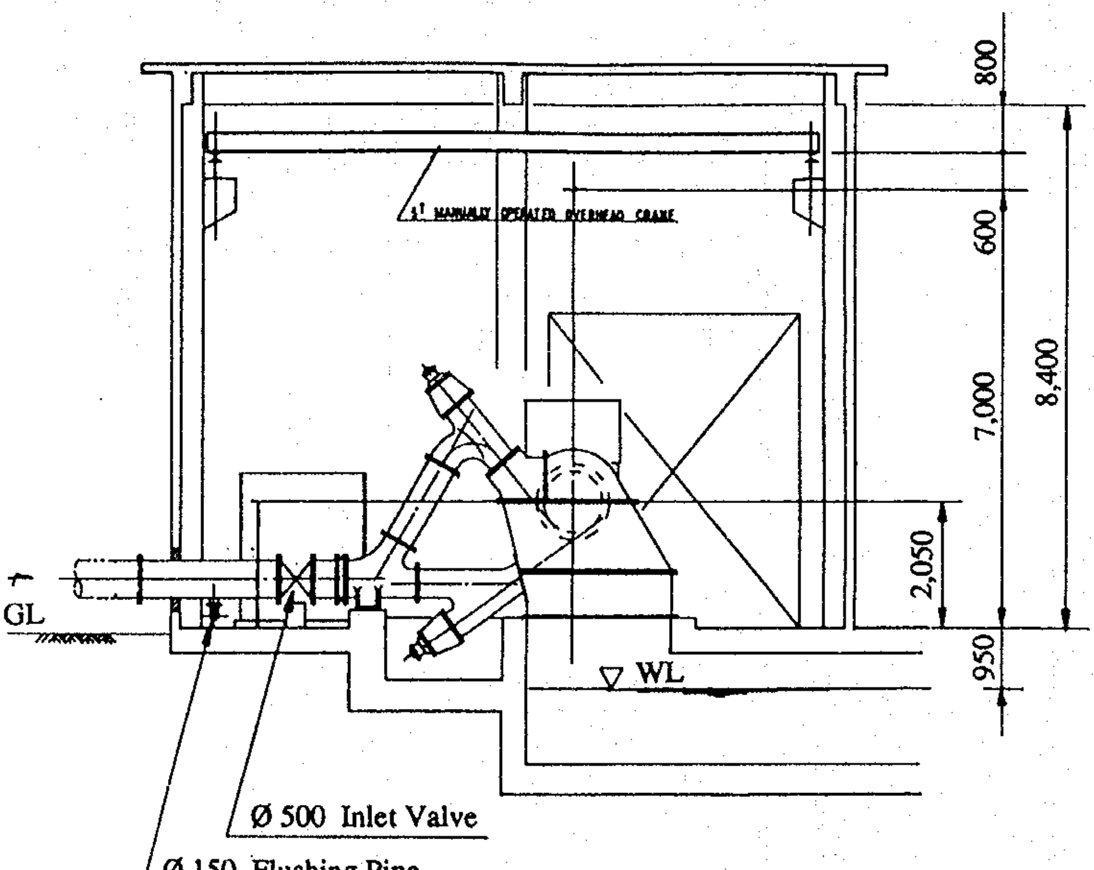


Fig.DA4-2 Layout of Alto Hospicio Hydropower Plant

< Esquema de Central Hidroeléctrica - Alto Hospicio >



Section A - A



Section B - B

Fig.DA4-3 Main Section of Alto Hospicio Hydropower Plant

< *Sección Principal de Central Hidroeléctrica - Alto Hospicio* >

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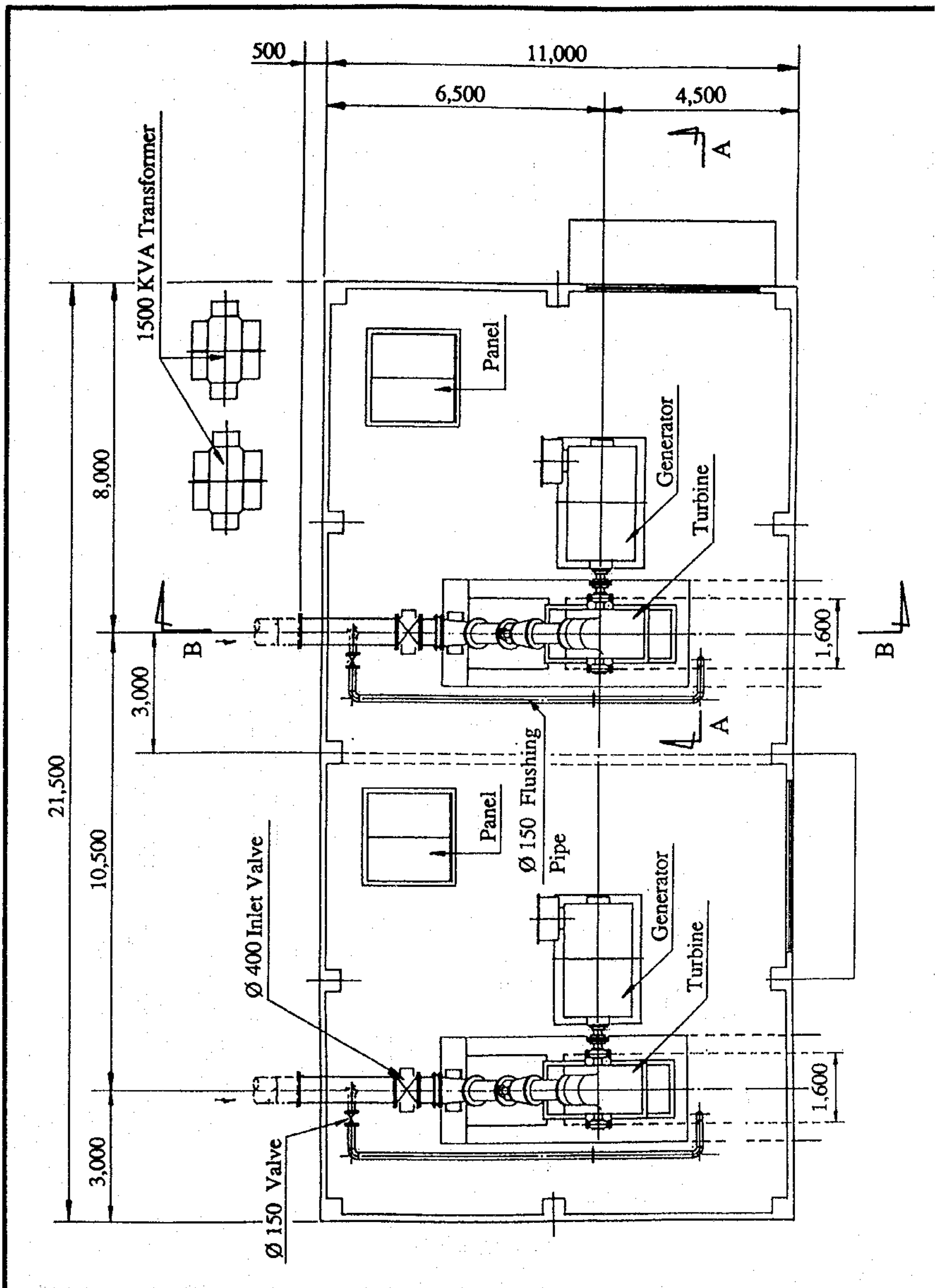

Fig. DA4-4 Layout of Cavancha Hydropower Plant

< Esquema de Central Hidroeléctrica - Cavancha >

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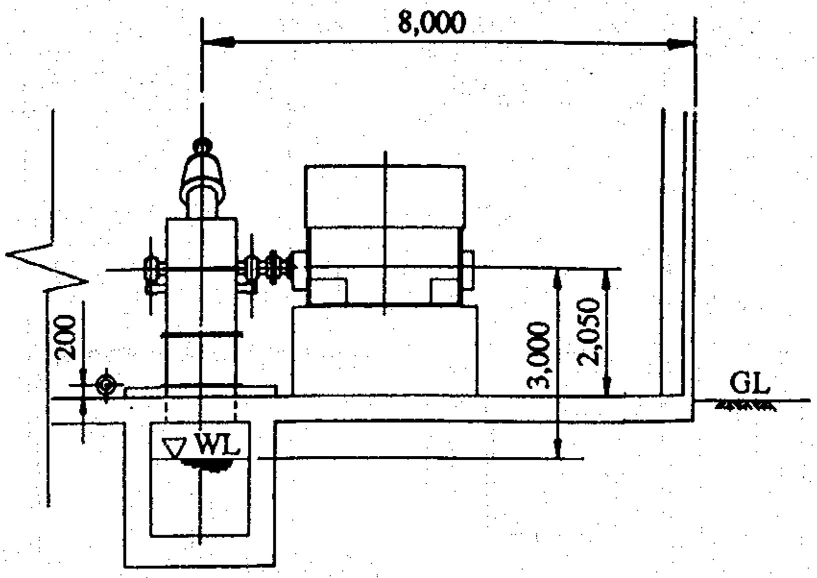
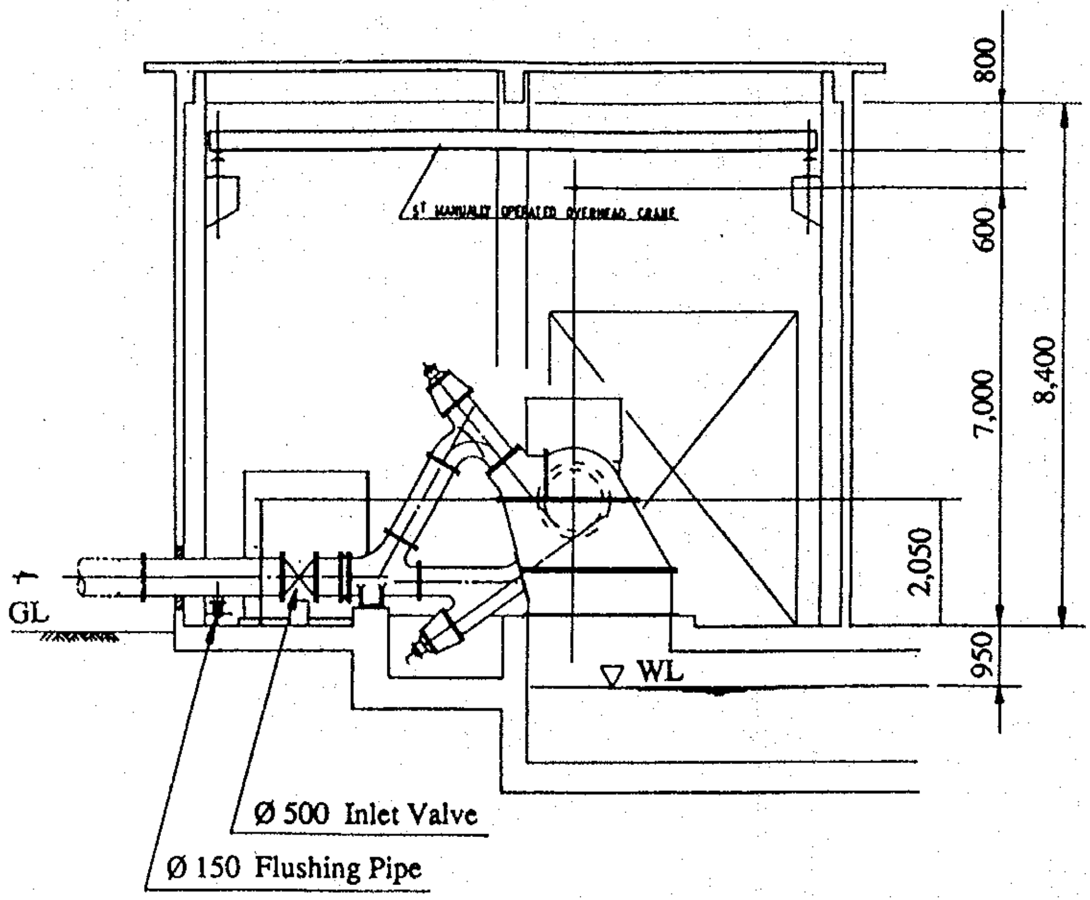


Section A - A



Section B - B

Fig. DA4-5 Main Section of Cavancha Hydropower Plant

< *Seccion Principal de Central Hidroeléctrica - Cavancha* >

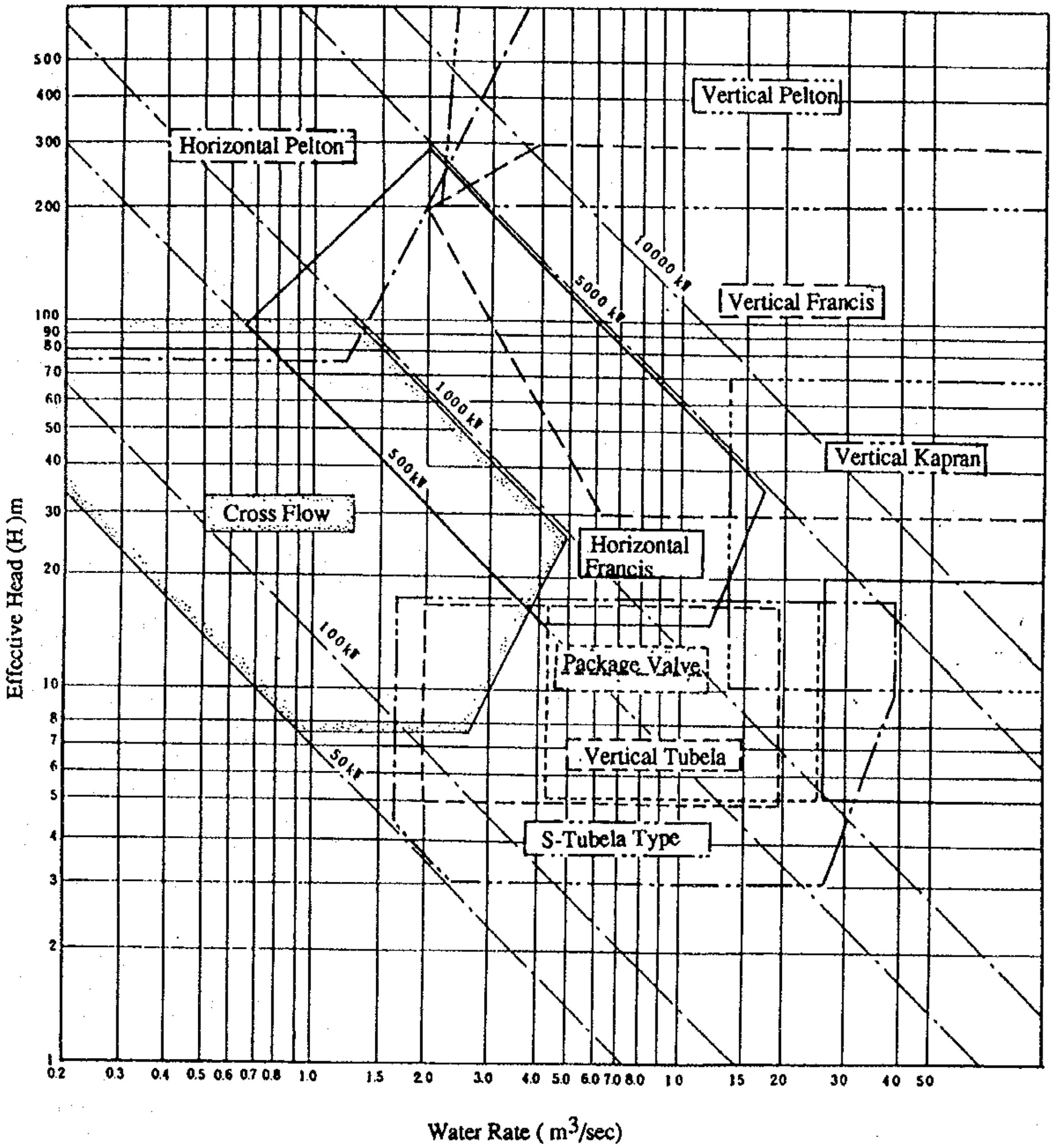


Fig. DA4-6 Selective Chart of the Type of Turbines

< Gráfico Selectivo del Tipo de Turbinas >

Appendix-5 Water Treatment Experiments for Lower Lluta Groundwater

1. Purpose of the Experiment

The new water source for future demand of Arica city is groundwater in Lower Lluta. However, this water source can not be used directly as the drinking water. Especially, Total Dissolved Solid (TDS) and Boron (B) exceeds the permissible limit of drinking water quality in Chile.

Therefore, JICA STUDY TEAM carried out this experiment to confirm the performance of Reverse Osmosis System in terms of TDS and Boron removed efficiency. And results of this experiments were reflected to design of this project.

2. Water Qualities of Raw Water and Target Treated Water

(unit : mg/l)

Item	Raw Water	Treated Water	Permissible Limit in Chile
TDS	3,300	1,000	1,000
Cl	1,030	250	250
B	20	5	----
Fe	0.5	0.3	0.3
As	0.03	< 0.03	0.05
Na	490	200	200
SO4	890	250	250
Cd	0.01	0.005	0.005
Ca	----	0.01	0.01
Mn	----	0.1	0.1

3. Period of the Field Experiments

Commencement : 22 Aug, 1994
Completion : 31 Aug, 1994

4. Place of the Experiments

Main Office of ESSAT in Arica
Juan Antonio Ríos 355 Arica, Chile

5. Sampling Point and Date of Raw Water Collection for the Experiments

1) Sampling Point

No. N - 6 Well
JICA STUDY TEAM selected the existing N-6 well water quality which was judged to represent the Lluta groundwater.

2) Sampling Date and Experiments Number

First Time	:	August 20.----- Experiment No. I-1/3
Second Time	:	August 23.---- Experiment No. I-2/3, I-3/3, II-1/3,
Third Time	:	August 30. --- Experiment No. II-2/3, II-3/3

6. Specifications of the Experimental Equipment

1) Capacity
Production Water Capacity : 3 m^3/day
(Treated Water)

2) Raw Water Pump

Type	:	Centrifugal Pump (Multistage)
Number	:	1 ps
Capacity	:	10 liter/minute x 24 mH
Motor	:	0.75 kW

3) Check Filter

Type	:	Cartridge
Numbers	:	2 pcs
Measurement	:	Diameter 65 mm, Length 508 mm

4) High Pressure Pump

Type	:	Piston
Number	:	1 ps
Capacity	:	10 liter/minute x 680 mH
Motor	:	1.5 kW

5) Reverse Osmosis

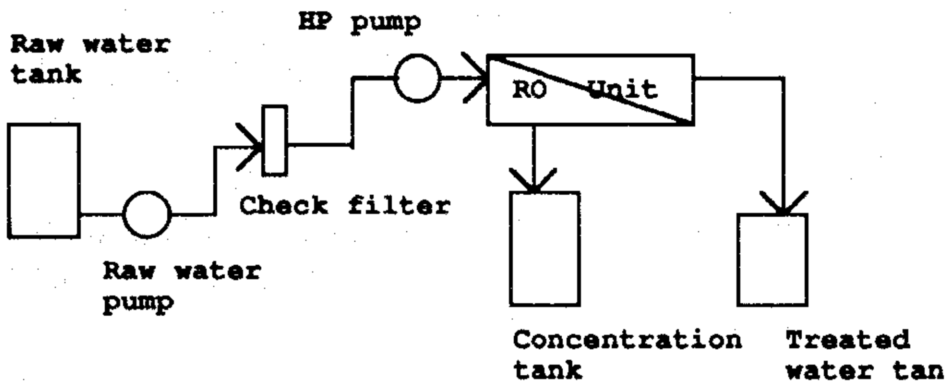
-1. Membrane

RO Membrane	Desalination Ratio	Recovery Ratio	Material	Number	Manufacturer
SW-HR2540	99.2~99.5 %	20 %/each	Hollow Fiber	2	Dow Chemical
BW-2540	98.60 %	30 %/each	Hollow Fiber	2	Dow Chemical

-2. Pressure Vessel

Numbers	:	2 pcs
Limit Pressure	:	105 kg/cm^2
Measurement	:	Diameter 72 mm, Length 1,130 mm
Material	:	FRP

7. Flow Diagram of Equipment



8. The Experiment Method

Raw water is supplied to the check filters by a raw water pump; then supplied to RO unit by a high pressure pump (HP pump). The treated water is received into the treated water tank and the concentrated water is received in the concentration tank.

Then the concentrated water received in the concentration tank is supplied again to the RO unit through the raw water pump, check filters and HP pump as the raw water. Furthermore, this operations is repeated in the same manner about 4 or 5 times. The actual equipment has similar condition as these.

These experiments were carried out three (3) times to confirm the reappearance of data.

The experimental equipment is shown in Fig. DA5-1 (photograph) which is used for this experiment.

9. Conclusions

1) Recovery Ratio of Treated Water

The recovery ratio of treated water were confirmed about 75 % in case of membrane for brackish water from this experiments. The results are shown below.

Experiment No.	Type of Membrane	Recovery Ratio (%)	Feed Pressure to RO (kg/cm^2)
I-1/3	for Sea Water	50.74	27.50
I-2/3	for Sea Water	47.96	27.50
I-3/3	for Sea Water	47.68	27.50
II-1/3	for Brackish Water	82.78	30.00
II-2/3	for Brackish Water	72.41	20.00
II-3/3	for Brackish Water	76.15	25.00

2) Treated Water Qualities

Both Total Dissolved Solid (TDS) and Boron (B) were confirmed to be less than the permissible limit of drinking water quality standard in Chile. Removal ratio of TDS and Boron are as follows.

Items	Membrane	
	For Sea Water	For Brackish Water
TDS	99.20 %	98.76 %
B	89.14 %	79.25 %

Therefore, water quality of treated water by RO system was confirmed to satisfy the target water quality of drinking water. However, it will need pH control.

The summary of water quality analysis and removal ratio for each parameter are shown below Table DA5-1.

Table DA5-1 The Summary of Water Qualities Analysis and Removal Ratio

Items	Membrane & Number of Experiment	Membrane : For Sea Water (SW-HR2540)				Membrane : For Brackish Water (BW-2540)			
		I-1/3	I-2/3	I-3/3	Average	II-1/3	II-2/3	II-3/3	Average
TDS	Raw Water (mg/l)	4040.00	4076.00	3924.00	4013.33	3544.00	3379.00	3392.00	3438.33
	Treated Water (mg/l)	31.68	28.29	36.35	32.11	42.89	45.79	39.41	42.70
	Removal Ratio (%)	99.22	99.31	99.07	99.20	98.79	98.64	98.84	98.76
Boron (B)	Raw Water (mg/l)	15.34	16.07	16.28	15.90	21.83	21.41	21.94	21.73
	Treated Water (mg/l)	1.86	1.62	1.69	1.72	4.25	5.00	4.26	4.50
	Removal Ratio (%)	87.87	89.92	89.62	89.14	80.53	76.65	80.58	79.25
SiO2	Raw Water (mg/l)	27.53	27.43	26.63	27.20	26.72	26.48	25.53	26.24
	Treated Water (mg/l)	0.45	0.34	0.43	0.41	0.25	0.28	0.39	0.31
	Removal Ratio (%)	98.37	98.76	98.39	98.50	99.06	98.94	98.47	98.83
Cl	Raw Water (mg/l)	970.27	992.60	947.59	970.15	931.60	928.10	927.70	929.13
	Treated Water (mg/l)	9.45	8.10	9.23	8.93	14.79	15.35	13.16	14.43
	Removal Ratio (%)	99.03	99.18	99.03	99.08	98.41	98.35	98.58	98.45
Fe	Raw Water (mg/l)	0.13	0.11	0.12	0.12	0.11	0.11	0.13	0.12
	Treated Water (mg/l)	0.07	0.03	0.05	0.05	0.04	0.01	0.01	0.02
	Removal Ratio (%)	46.15	72.73	58.33	59.07	63.64	90.91	92.31	82.28
As	Raw Water (mg/l)	0.007	< 0.005	0.007	0.006	0.005	0.006	0.006	0.006
	Treated Water (mg/l)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
	Removal Ratio (%)								
Ca	Raw Water (mg/l)	386.00	390.00	380.00	385.33	376.00	371.00	373.00	373.33
	Treated Water (mg/l)	2.22	1.48	1.82	1.84	2.39	1.93	1.80	2.04
	Removal Ratio (%)	99.42	99.62	99.52	99.52	99.36	99.48	99.52	99.45
Mn	Raw Water (mg/l)	0.425	0.446	0.207	0.359	0.197	0.203	0.200	0.200
	Treated Water (mg/l)	0.005	0.003	0.003	0.004	0.003	0.003	0.002	0.003
	Removal Ratio (%)	98.82	99.33	98.55	98.90	98.48	98.52	99.00	98.67
Na	Raw Water (mg/l)	515.20	515.20	515.20	515.20	562.10	570.40	562.10	564.87
	Treated Water (mg/l)	4.93	4.61	5.16	4.90	8.73	9.55	7.95	8.74
	Removal Ratio (%)	99.04	99.11	99.00	99.05	98.45	98.33	98.59	98.45
SO4	Raw Water (mg/l)	979.81	1075.87	1102.29	1052.66	1018.20	1018.20	1018.20	1018.20
	Treated Water (mg/l)	0.37	0.73	2.63	1.24	3.40	1.99	1.99	2.46
	Removal Ratio (%)	99.96	99.93	99.76	99.89	99.67	99.80	99.80	99.76
Cd	Raw Water (mg/l)	0.002	0.001	0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Treated Water (mg/l)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	Removal Ratio (%)								
E-Cond	Raw Water (mg/l)	5116.00	4969.00	4872.00	4985.67	5040.00	5110.00	5130.00	5093.33
	Treated Water (mg/l)	46.53	39.78	46.91	44.41	68.08	69.14	59.91	65.71
	Removal Ratio (%)	99.09	99.20	99.04	99.11	98.65	98.65	98.83	98.71
Turbi	Raw Water (NTU)	0.90	1.40	1.60	1.30	0.40	0.65	0.35	0.47
	Treated Water (NTU)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Removal Ratio (%)	88.89	92.86	93.75	91.83	75.00	84.62	71.43	77.01
pH	Raw Water (---)	7.02	6.95	6.94	6.97	7.35	6.90	6.90	7.05
	Treated Water (---)	6.29	6.09	6.11	6.16	6.16	5.73	5.55	5.81
Temp	Raw Water (deg)	24.00	20.00	20.00	21.33	18.00	24.00	19.50	20.50
	Treated Water (deg)	24.87	22.31	21.72	22.97	19.42	25.10	21.11	21.88
CO3	Raw Water (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Treated Water (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Removal Ratio (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	Raw Water (mg/l)	25.63	25.63	26.24	25.83	61.60	66.50	67.10	65.07
	Treated Water (mg/l)	6.31	4.28	4.42	5.00	5.58	6.60	6.33	6.17
	Removal Ratio (%)	75.38	83.30	83.16	80.61	90.94	90.08	90.57	90.53
Mg	Raw Water (mg/l)	112.00	114.00	112.00	112.67	115.00	113.00	114.00	114.00
	Treated Water (mg/l)	0.46	0.41	0.54	0.47	0.73	0.59	0.54	0.62
	Removal Ratio (%)	99.59	99.64	99.52	99.58	99.37	99.48	99.53	99.46
K	Raw Water (mg/l)	61.00	61.20	61.00	61.07	64.00	64.00	63.50	63.83
	Treated Water (mg/l)	6.07	0.70	0.80	2.52	1.09	1.36	1.06	1.17
	Removal Ratio (%)	90.05	98.86	98.69	95.86	98.30	97.88	98.33	98.17

DATA SHEET OF EXPERIMENT BY RO SYSTEM (1/6)

Experiment No.I-1/3 Kind of Membrane : For Sea Water (SW-HR2540)

Date of Experiment : Aug 22,1994

Experimenter : H.MIYAKOSHI

JICA STUDY TEAM (PCI TOKYO)

Items	Unit	Raw Water	Feed Number 1	2	3	4	5	Average or Total
Water Balance								(Total)
Supply Water	liter	---	164	123	92	68.5	40	
Concentrated W	liter	---	142	105	80	60	35	422
Treated Water	liter	---	22	18	12	8.5	5	65.5
Supply Time	min	---	15.77	11.87	8.82	6.27	4.00	46.73
Recovery Ratio	%	---	13.41	14.63	13.04	12.41	12.50	**50.74**
Water Rate								(Average)
Supply Water	l/min	---	10.40	10.36	10.43	10.93	10.00	10.42
Concentrated W	l/min	---	9.00	8.85	9.07	9.57	8.75	9.05
Treated Water	l/min	---	1.40	1.52	1.36	1.36	1.25	1.38
Supply Pressure								(Average)
Inlet of CF	kg/cm2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Outlet of CF	kg/cm2	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Inlet of RO	kg/cm2	2.4	27.5	27.5	27.5	27.5	27.5	27.5
Outlet of RO	kg/cm2	2.4	26	26	26	26	26	26
		Results of the Water Quality Analysis						
TDS	mg/l	4040.00	38.00	26.00	28.00	30.00	36.00	31.68
B	mg/l	15.34	1.61	1.73	1.96	2.26	2.46	1.86
Si02	mg/l	27.53	0.86	0.34	0.15	0.10	0.34	0.45
Cl	mg/l	970.27	11.34	8.15	8.15	8.50	10.60	9.45
Fe	mg/l	0.13	0.08	0.08	0.06	0.04	0.03	0.07
As	mg/l	0.007	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ca	mg/l	386.00	4.16	1.24	1.09	1.24	1.55	2.22
Mn	mg/l	0.425	0.005	0.005	0.005	0.004	0.003	0.005
Na	mg/l	515.20	4.60	4.60	4.60	5.52	7.36	4.93
SO4	mg/l	979.81	1.00	0.05	0.05	0.05	0.05	0.37
Cd	mg/l	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
E-Cond	mho/cm	5116.00	57.00	39.00	38.00	43.00	54.00	46.53
Turbi	NTU	0.90	0.10	0.10	0.10	0.10	0.10	0.10
pH	---	7.02	6.75	6.24	5.98	5.89	5.85	6.29
Temp	deg	24.00	24.00	25.00	25.00	26.00	26.00	24.87
CO3	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	mg/l	25.63	9.15	4.88	4.88	4.88	4.88	6.31
Mg	mg/l	112.00	0.60	0.37	0.35	0.40	0.48	0.46
K	mg/l	61.00	6.00	6.00	7.00	8.00	1.10	6.07

(Note)

1.Date of raw water collection : Aug 20, 1994

2. Place of raw water collection : N-6 Well (Villa Frontera)

3. Water quality analysis was carried out by DGA Santiago, Chile.

4. CF : Check Filter, RO : Reverse Osmosis

DATA SHEET OF EXPERIMENT BY RO SYSTEM (2/6)

Experiment No.I-2/3 Kind of Membrane : For Sea Water (SW-HR2540)

Date of Experiment : Aug 23,1994

Experimenter : H.MIYAKOSHI

JICA STUDY TEAM (PCI TOKYO)

Items	Unit	Raw Water	Feed Number 1	2	3	4	5	Average or Total
Water Balance								(Total)
Supply Water	liter	---	175	121.5	94	64	40	
Concentrated W	liter	---	155	105	82	57	35	434
Treated Water	liter	---	20	16.5	12	7	5	60.5
Supply Time	min	---	15.73	12.27	8.82	6.25	3.87	46.94
Recovery Ratio	%	---	11.43	13.58	12.77	10.94	12.50	**47.96**
Water Rate								(Average)
Supply Water	l/min	---	11.13	9.90	10.66	10.24	10.34	10.45
Concentrated W	l/min	---	9.85	8.56	9.30	9.12	9.04	9.17
Treated Water	l/min	---	1.27	1.34	1.36	1.12	1.29	1.28
Supply Pressure								(Average)
Inlet of CF	kg/cm2	---	3.1	3.1	3.1	2.8	2.9	3
Outlet of CF	kg/cm2	---	1.6	1.7	1.7	1.6	1.7	1.66
Inlet of RO	kg/cm2	---	27.5	27.5	27.5	27.5	27.5	27.5
Outlet of RO	kg/cm2	---	26	26	26	26	26	26
		Results of the Water Quality Analysis						(Average)
TDS	mg/l	4076.00	32.00	21.00	27.00	33.00	34.00	28.29
B	mg/l	16.07	1.37	1.48	1.69	1.93	2.49	1.62
Si02	mg/l	27.43	0.43	0.29	0.29	0.29	0.29	0.34
Cl	mg/l	992.60	9.57	6.38	7.44	7.80	9.93	8.10
Fe	mg/l	0.11	0.04	0.03	0.02	0.01	0.02	0.03
As	mg/l	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ca	mg/l	390.00	2.10	1.00	1.19	1.28	1.58	1.48
Mn	mg/l	0.446	0.004	0.004	0.002	0.003	0.004	0.003
Na	mg/l	515.20	4.60	3.68	4.60	5.52	6.44	4.61
SO4	mg/l	1075.87	1.00	1.00	0.01	1.00	0.05	0.73
Cd	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
E-Cond	mho/cm	4969.00	49.00	29.00	35.00	39.00	51.00	39.78
Turbi	NTU	1.40	0.10	0.10	0.10	0.10	0.10	0.10
pH	---	6.95	6.45	6.07	5.84	5.75	5.75	6.09
Temp	deg		20.00	22.00	23.50	25.00	26.00	22.31
CO3	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	mg/l	25.63	4.27	3.66	4.27	4.88	5.49	4.28
Mg	mg/l	114.00	0.58	0.29	0.33	0.35	0.44	0.41
K	mg/l	61.20	0.70	0.60	0.60	0.80	1.10	0.70

(Note)

1.Date of raw water collection : Aug 23, 1994

2. Place of raw water collection : N-6 Well (Villa Frontera)

3. Water quality analysis was carried out by DGA Santiago, Chile.

4. CF : Check Filter, RO : Reverse Osmosis

DATA SHEET OF EXPERIMENT BY RO SYSTEM (3/6)

Experiment No.I-3/3 Kind of Membrane : For Sea Water (SW-HR2540)

Date of Experiment : Aug 24,1994

Experimenter : H.MIYAKOSHI

JICA STUDY TEAM (PCI TOKYO)

Items	Unit	Raw Water	Feed Number 1	2	3	4	5	Average or Total
Water Balance								(Total)
Supply Water	liter	---	172	130	96.5	67	35	
Concentrated W	liter	---	153	115	85	59	30	442
Treated Water	liter	---	19	15	11.5	8	5	58.5
Supply Time	min	---	15.35	12.07	8.97	6.37	3.78	46.54
Recovery Ratio	%	---	11.05	11.54	11.92	11.94	14.29	**47.68**
Water Rate								(Average)
Supply Water	l/min	---	11.21	10.77	10.76	10.52	9.26	10.50
Concentrated W	l/min	---	9.97	9.53	9.48	9.26	7.94	9.23
Treated Water	l/min	---	1.24	1.24	1.28	1.26	1.32	1.27
Supply Pressure								(Average)
Inlet of CF	kg/cm2	---	3.1	3	3	3	3	3.02
Outlet of CF	kg/cm2	---	2.3	2.1	2.1	2	1.9	2.08
Inlet of RO	kg/cm2	---	27.5	27.5	27.5	27.5	27.5	27.5
Outlet of RO	kg/cm2	---	26	26	26	26	26	26
		Results of the Water Quality Analysis						(Average)
TDS	mg/l	3924.00	52.00	26.00	29.00	30.00	35.00	36.35
B	mg/l	16.28	1.45	1.60	1.79	1.96	2.24	1.69
Si02	mg/l	26.63	0.63	0.34	0.34	0.34	0.34	0.43
Cl	mg/l	947.59	12.76	7.44	6.74	7.80	9.22	9.23
Fe	mg/l	0.12	0.05	0.02	0.06	0.06	0.08	0.05
As	mg/l	0.007	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ca	mg/l	380.00	3.48	1.07	0.93	1.00	1.17	1.82
Mn	mg/l	0.207	0.005	0.002	0.002	0.002	0.002	0.003
Na	mg/l	515.20	7.36	3.68	3.68	4.60	5.52	5.16
SO4	mg/l	1102.29	8.00	0.05	0.05	0.05	0.05	2.63
Cd	mg/l	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
E-Cond	mho/cm	4872.00	76.00	32.00	29.00	34.00	43.00	46.91
Turbi	NTU	1.60	0.10	0.10	0.10	0.10	0.10	0.10
pH	---	6.94	6.60	6.11	5.75	5.66	5.77	6.11
Temp	deg		20.00	21.00	22.50	24.00	25.00	21.72
CO3	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	mg/l	26.24	4.88	3.66	4.27	4.27	5.49	4.42
Mg	mg/l	112.00	1.03	0.30	0.27	0.30	0.36	0.54
K	mg/l	61.00	1.10	0.60	0.60	0.70	0.90	0.80

(Note)

1.Date of raw water collection : Aug 23, 1994

2. Place of raw water collection : N-6 Well (Villa Frontera)

3. Water quality analysis was carried out by DGA Santiago, Chile.

DATA SHEET OF EXPERIMENT BY RO SYSTEM (4/6)

Experiment No.II-1/3 Kind of Membrane : For Brackish Water (BW-2540)

Date of Experiment : Aug 29,1994

Experimenter : H.MIYAKOSHI

JICA STUDY TEAM (PCI TOKYO)

Items	Unit	Raw Water	Feed Number 1	2	3	4	5	Average or Total
Water Balance								(Total)
Supply Water	liter	---	287	178	112.5	54	21.5	
Concentrated W	liter	---	200	123	73	40	16	452
Treated Water	liter	---	87	55	39.5	14	5.5	201
Supply Time	min	---	25.53	16.28	9.65	5.13	2.38	58.97
Recovery Ratio	%	---	30.31	30.90	35.11	25.93	25.58	**82.78**
Water Rate								(Average)
Supply Water	l/min	---	11.24	10.93	11.66	10.53	9.03	10.68
Concentrated W	l/min	---	7.83	7.56	7.56	7.80	6.72	7.49
Treated Water	l/min	---	3.41	3.38	4.09	2.73	2.31	3.18
Supply Pressure								(Average)
Inlet of CF	kg/cm2	---	3.05	3.05	3.05	2.9	2.9	2.99
Outlet of CF	kg/cm2	---	2.3	2.3	2.2	2.2	2.2	2.24
Inlet of RO	kg/cm2	---	30	30	30	30	30	30
Outlet of RO	kg/cm2	---	28	28	28	28	28	28
		Results of the Water Quality Analysis						(Average)
TDS	mg/l	3544.00	31.00	37.00	59.00	70.00	105.00	42.89
B	mg/l	21.83	3.16	4.60	5.13	6.18	6.70	4.25
Si02	mg/l	26.72	0.20	0.29	0.29	0.29	0.20	0.25
Cl	mg/l	931.60	10.60	13.80	18.40	25.50	37.60	14.79
Fe	mg/l	0.11	0.06	0.02	0.01	0.04	0.02	0.04
As	mg/l	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ca	mg/l	376.00	1.70	2.00	3.10	4.50	6.90	2.39
Mn	mg/l	0.197	0.002	0.003	0.003	0.003	0.004	0.003
Na	mg/l	562.10	6.00	7.40	11.50	16.60	25.30	8.73
SO4	mg/l	1018.20	0.50	1.00	9.10	11.00	13.00	3.40
Cd	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
E-Cond	mho/cm	5040.00	45.00	58.00	92.00	131.00	202.00	68.08
Turbi	NTU	0.40	0.10	0.10	0.10	0.10	0.10	0.10
pH	---	7.35	6.54	5.95	5.80	5.78	5.84	6.16
Temp	deg	18.00	18.00	19.50	21.00	22.00	23.00	19.42
CO3	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	mg/l	61.60	4.90	6.10	4.90	8.50	8.50	5.58
Mg	mg/l	115.00	0.50	0.60	1.00	1.40	2.20	0.73
K	mg/l	64.00	0.60	0.90	1.60	2.40	3.70	1.09

(Note)

1.Date of raw water collection : Aug 23, 1994

2. Place of raw water collection : N-6 Well (Villa Frontera)

3. Water quality analysis was carried out by DGA Santiago, Chile.

4. CF : Check Filter, RO : Reverse Osmosis

DATA SHEET OF EXPERIMENT BY RO SYSTEM (5/6)

Experiment No.II-2/3 Kind of Membrane : For Brackish Water (BW-2540)

Date of Experiment : Aug 30,1994

Experimenter : H.MIYAKOSHI

JICA STUDY TEAM (PCI TOKYO)

Items	Unit	Raw Water	Feed Number 1	2	3	4	5	Average or Total
Water Balance								(Total)
Supply Water	liter	---	267	183	116	70	41	
Concentrated W	liter	---	200	138	88	56	33	515
Treated Water	liter	---	67	45	28	14	8	162
Supply Time	min	---	23.43	16.17	10.53	6.53	4.02	60.68
Recovery Ratio	%	---	25.09	24.59	24.14	20.00	19.51	**72.41**
Water Rate								(Average)
Supply Water	l/min	---	11.40	11.32	11.02	10.72	10.20	10.93
Concentrated W	l/min	---	8.54	8.53	8.36	8.58	8.21	8.44
Treated Water	l/min	---	2.86	2.78	2.66	2.14	1.99	2.49
Supply Pressure								(Average)
Inlet of CF	kg/cm2	---	3	3	3	2.9	2.9	2.96
Outlet of CF	kg/cm2	---	2.3	2.3	2.2	2.2	2.2	2.24
Inlet of RO	kg/cm2	---	20	20	20	20	20	20
Outlet of RO	kg/cm2	---	19.5	19.5	19.5	19.5	19.5	19.5
		Results of the Water Quality Analysis						(Average)
TDS	mg/l	3379.00	33.00	39.00	55.00	76.00	106.00	45.79
B	mg/l	21.41	4.34	4.86	5.65	6.18	6.97	5.00
Si02	mg/l	26.48	0.24	0.29	0.34	0.34	0.34	0.28
Cl	mg/l	928.10	10.30	14.20	19.80	24.10	33.30	15.35
Fe	mg/l	0.11	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
As	mg/l	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ca	mg/l	371.00	1.20	1.60	2.60	3.40	4.90	1.93
Mn	mg/l	0.203	0.003	0.003	0.002	0.002	0.002	0.003
Na	mg/l	570.40	6.40	8.30	12.00	16.60	22.10	9.55
SO4	mg/l	1018.20	0.50	1.00	1.00	9.10	11.10	1.99
Cd	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
E-Cond	mho/cm	5110.00	47.00	60.00	85.00	118.00	165.00	69.14
Turbi	NTU	0.65	0.10	0.10	0.10	0.10	0.10	0.10
pH	---	6.90	5.90	5.72	5.49	5.51	5.57	5.73
Temp	deg		24.50	25.00	26.00	26.00	26.00	25.10
CO3	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	mg/l	66.50	5.50	6.10	7.30	11.00	8.50	6.60
Mg	mg/l	113.00	0.40	0.50	0.70	1.00	1.50	0.59
K	mg/l	64.00	1.00	1.10	1.60	2.30	3.30	1.36

(Note)

1.Date of raw water collection : Aug 30, 1994

2. Place of raw water collection : N-6 Well (Villa Frontera)

3. Water quality analysis was carried out by DGA Santiago, Chile.

4. CF : Check Filter, RO : Reverse Osmosis

DATA SHEET OF EXPERIMENT BY RO SYSTEM (6/6)

Experiment No.II-3/3 Kind of Membrane : For Brackish Water (BW-2540)

Date of Experiment : Aug 31,1994

Experimenter : H.MIYAKOSHI

JICA STUDY TEAM (PCI TOKYO)

Items	Unit	Raw Water	Feed Number 1	2	3	4	5	Average or Total
Water Balance								(Total)
Supply Water	liter	---	269	185	119.5	70	34.5	
Concentrated W	liter	---	200	136	88	53	27	504
Treated Water	liter	---	69	49	31.5	17	7.5	174
Supply Time	min	---	24.10	16.63	10.92	6.63	3.50	61.78
Recovery Ratio	%	---	25.65	26.49	26.36	24.29	21.74	**76.15**
Water Rate								(Average)
Supply Water	l/min	---	11.16	11.12	10.94	10.56	9.86	10.73
Concentrated W	l/min	---	8.30	8.18	8.06	7.99	7.71	8.05
Treated Water	l/min	---	2.86	2.95	2.88	2.56	2.14	2.68
Supply Pressure								(Average)
Inlet of CF	kg/cm2	---	3.05	2.95	3.05	2.95	2.95	2.99
Outlet of CF	kg/cm2	---	2.3	2.2	2.3	2.2	2.2	2.24
Inlet of RO	kg/cm2	---	25	25	25	25	25	25
Outlet of RO	kg/cm2	---	24	24.5	24.5	24.5	24.5	24.4
Results of the Water Quality Analysis								(Average)
TDS	mg/l	3392.00	25.00	34.00	50.00	64.00	107.00	39.41
B	mg/l	21.94	3.37	4.07	4.92	6.18	6.60	4.26
Si02	mg/l	25.53	0.53	0.24	0.34	0.39	0.39	0.39
Cl	mg/l	927.70	8.50	12.00	16.30	21.30	31.90	13.16
Fe	mg/l	0.13	0.01	0.01	0.03	0.01	0.02	0.01
As	mg/l	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ca	mg/l	373.00	1.10	1.50	2.40	3.10	4.80	1.80
Mn	mg/l	0.200	0.002	0.002	0.003	0.003	0.003	0.002
Na	mg/l	562.10	4.60	7.40	10.10	13.80	20.00	7.95
SO4	mg/l	1018.20	1.00	1.00	1.00	6.70	11.00	1.99
Cd	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
E-Cond	mho/cm	5130.00	38.00	52.00	76.00	99.00	157.00	59.91
Turbi	NTU	0.35	0.10	0.10	0.10	0.10	0.10	0.10
pH	---	6.90	5.72	5.44	5.38	5.45	5.57	5.55
Temp	deg		20.00	21.00	22.00	23.00	24.00	21.11
CO3	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	mg/l	67.10	4.30	6.10	9.20	7.90	11.00	6.33
Mg	mg/l	114.00	0.30	0.50	0.70	0.90	1.50	0.54
K	mg/l	63.50	0.60	0.90	1.40	1.90	3.10	1.06

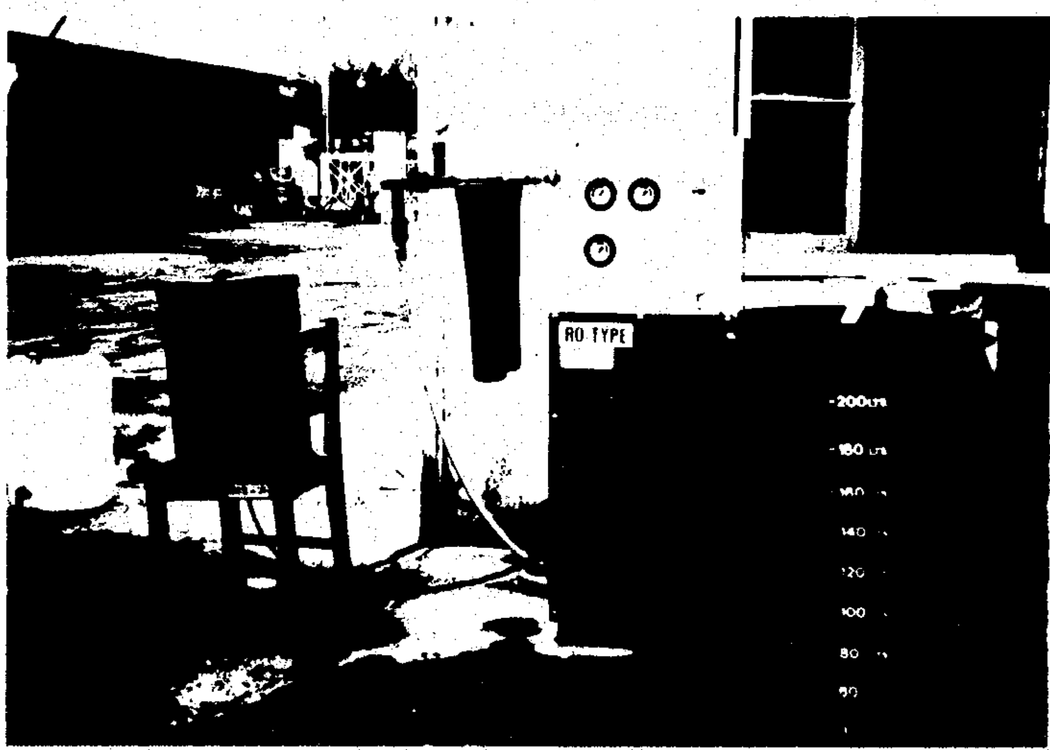
(Note)

1.Date of raw water collection : Aug 30, 1994

2. Place of raw water collection : N-6 Well (Villa Frontera)

3. Water quality analysis was carried out by DGA Santiago, Chile.

4. CF : Check Filter, RO : Reverse Osmosis



An overall View of RO Unit and Tanks

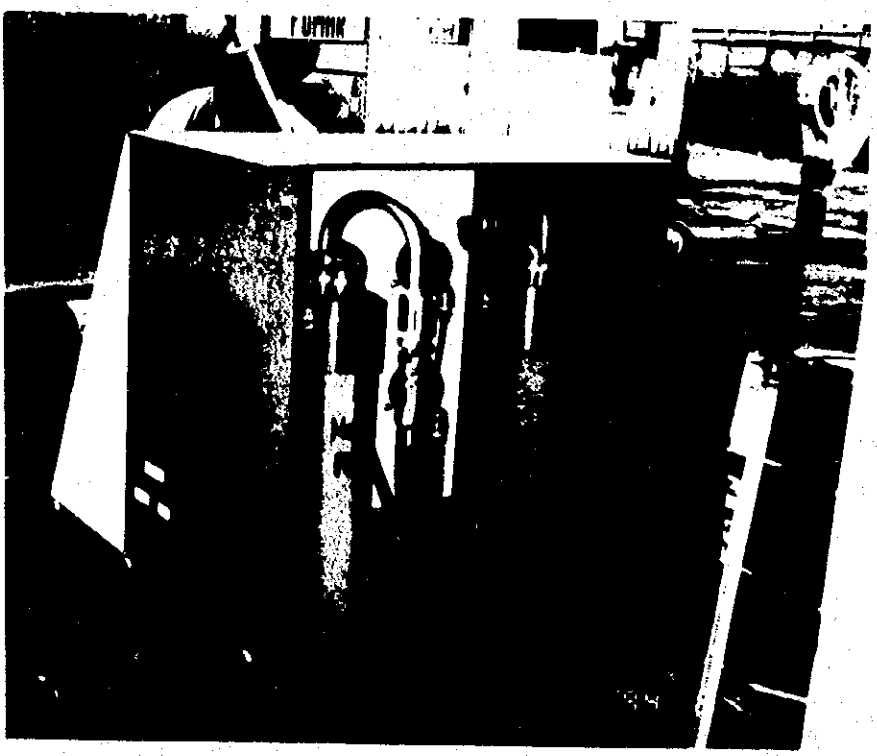
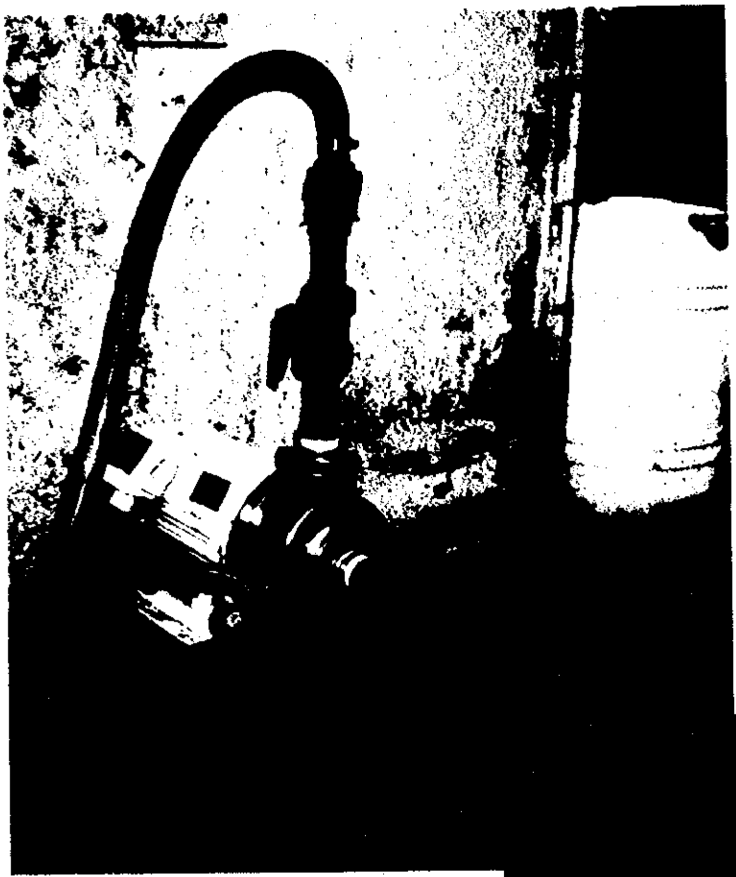
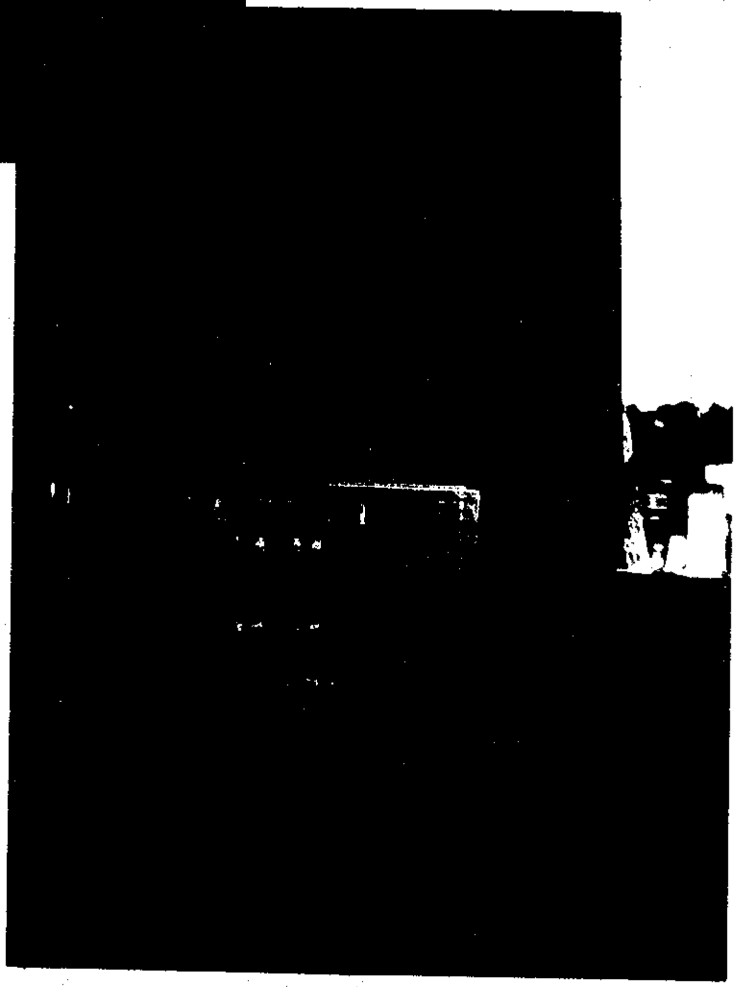

Rear of RO Unit RO Membranes

Fig.DA5-1 RO Experimental Equipment (1/2)

< *Equipo Experimental RO (1/2)* >



Raw Water Pump



Electric Panel

Fig. DA5-1 RO Experimental Equipment (2/2)

< Equipo Experimental RO (2/2) >

Appendix-6 Compensation Works in Lower Lluta Valley

The deep Aquifer of the Lluta Valley is recharged by the surface water mainly in the reaches between Poconchile and Chacabuco. The proposed groundwater development will lower the existing groundwater table, resulting in accerelation of river water infiltration into underground. It may infringe the existing river wter extraction for the irrigation use. Therefore, existing irrigation intakes located in the downstream of Poconchile (irrigation sector III, IV and V) shall be integrated to one (1) headworks proposed at Kesler. All the irrigation water for the sector III, IV and V will be extracted from this headworks. For recycling use of extracted water, collection channels are also constructed along the river banks. The design irrigation intake volume was determined to satisfy the existing water rights including legally authorized ones and customary ones (acción) throughout the year. The determined design intake volume is 819 l/s throughout the year (For calculation of the design intake volume, see Supporting Report B-II Chapter III). The new irrigation system and design of irrigation channels are shown in Fig. DA6-1 and Fig. DA6-2. The construction cost of the new irrigation system is estimated as shown in Table DA6-1.

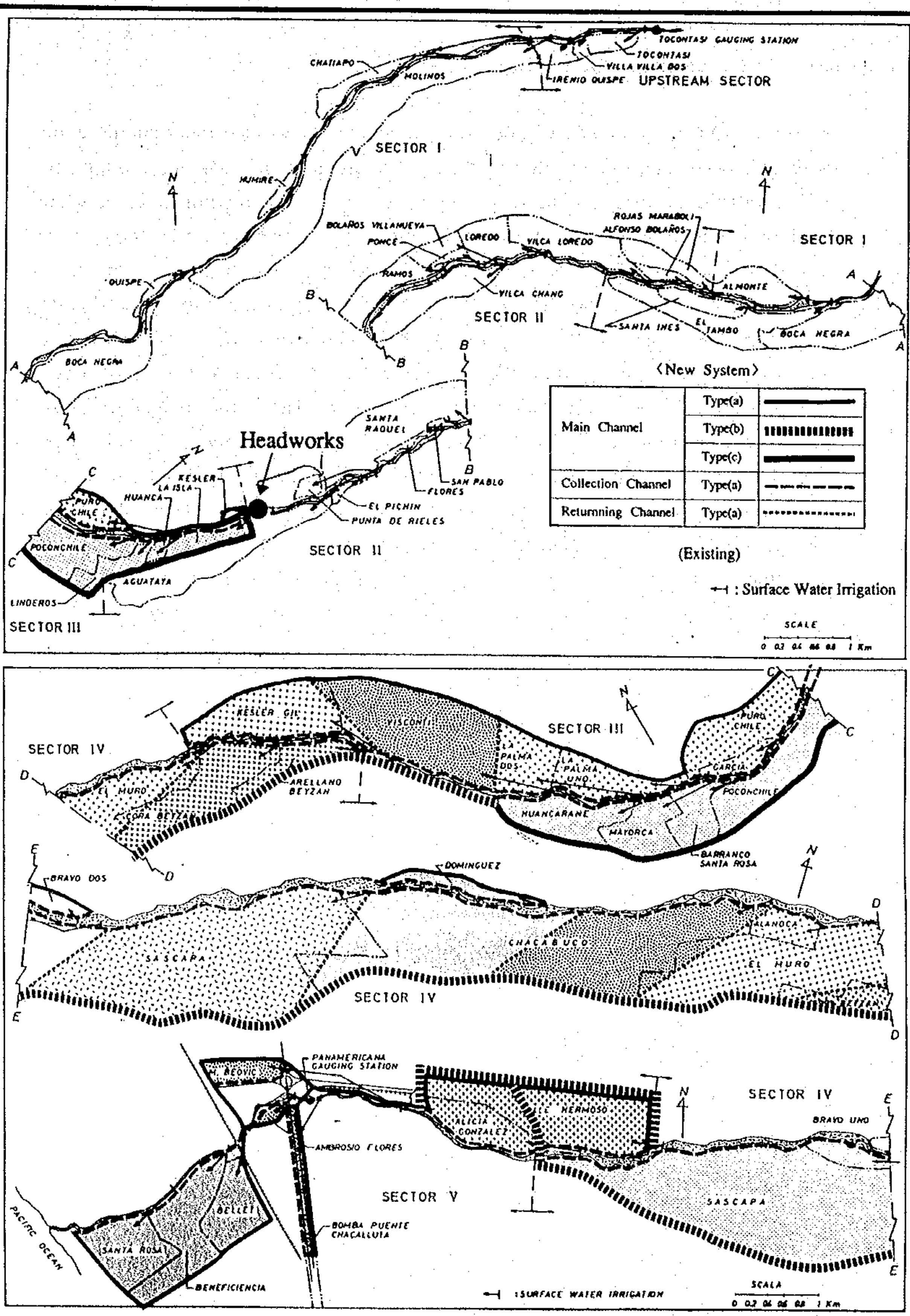


Fig. DA6-1 Proposed New Irrigation System

<Nuevo Sistema de Irrigación Prospuesto>

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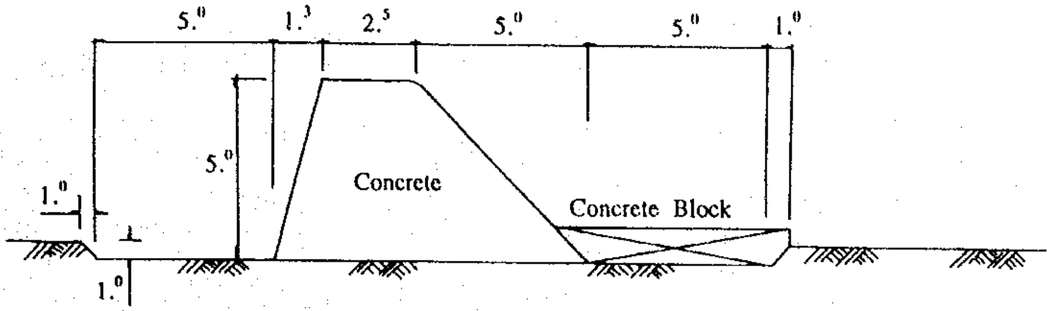
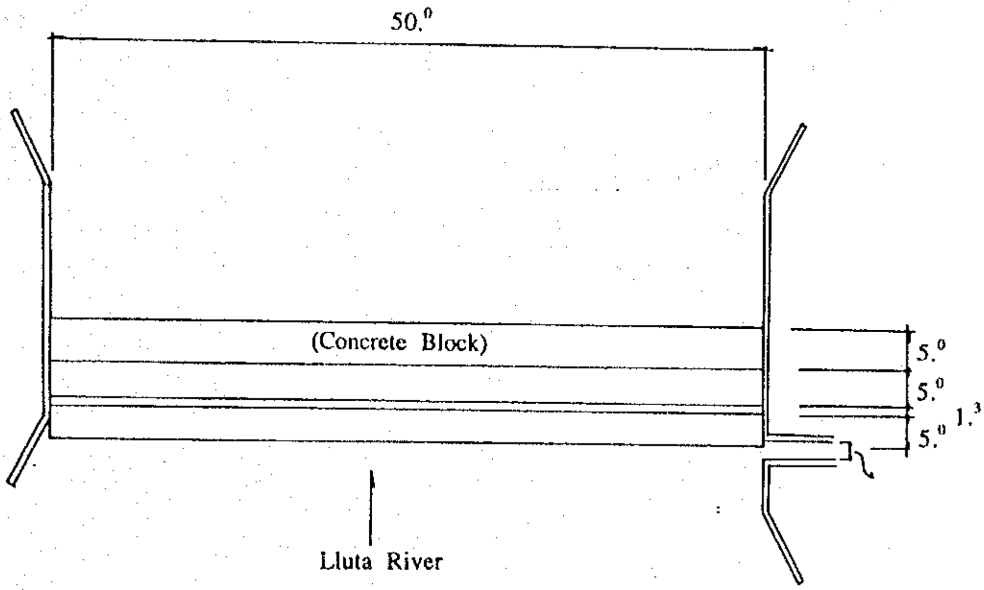
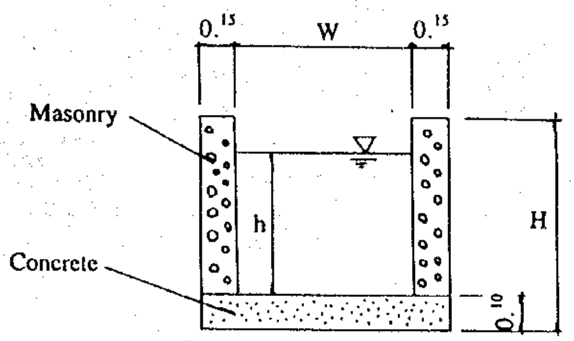


Section of Headworks



Plan of Headworks



Type	h(cm)	W(cm)	H(cm)	Q(l/s)	V(m/s)
(a)	30	40	50	190	1.6
(b)	35	65	55	460	2.0
(c)	50	70	70	810	2.3

Section of Irrigation Channel

Fig. DA6-2 Irrigation Facilities

<Facilidadses de Irrigación >

Table DA6-1 Construction Cost of New Irrigation System
<Cost de Construcción del Sistema Nuevo de Riego>

		Item	Section (m2)	Distance (m)	Volume	Unit Cost ($/m3)	Cost ($/m3)
Main Channel	Type (a)	Masonry W.	0.15	10,667	1,600	91,233	145,977,362
		Concrete W.	0.07	10,667	747	108,598	81,089,041
		Earth W.	0.42	10,667	4,480	3,600	16,128,504
	Type (b)	Masonry W.	0.165	24,444	4,033	91,233	367,966,410
		Concrete W.	0.095	24,444	2,322	108,598	252,184,104
		Earth W.	0.6175	24,444	15,094	3,600	54,339,012
	Type (c)	Masonry W.	0.15	8,222	1,233	91,233	112,517,659
		Concrete W.	0.1	8,222	822	108,598	89,289,276
		Earth W.	0.8	8,222	6,578	3,600	23,679,360
	Sub-Total						1,143,170,726
	Overhead						436,691,217
	Cost (1)						1,579,861,943
Collection Channel	Type (a)	Masonry W.	0.15	15,867	2,380	91,233	217,139,102
		Concrete W.	0.07	15,867	1,111	108,598	120,618,713
		Earth W.	0.42	15,867	6,664	3,600	23,990,904
	Type (b)	Masonry W.	0.165	0	0	91,233	0
		Concrete W.	0.095	0	0	108,598	0
		Earth W.	0.6175	0	0	3,600	0
	Type (c)	Masonry W.	0.15	0	0	91,233	0
		Concrete W.	0.1	0	0	108,598	0
		Earth W.	0.8	0	0	3,600	0
	Sub-Total						361,748,718
	Overhead						138,188,010
	Cost (1)						499,936,729
Return Channel	Type (a)	Masonry W.	0.15	18,356	2,753	91,233	251,200,942
		Concrete W.	0.07	18,356	1,285	108,598	139,539,742
		Earth W.	0.42	18,356	7,710	3,600	27,754,272
	Type (b)	Masonry W.	0.165	0	0	91,233	0
		Concrete W.	0.095	0	0	108,598	0
		Earth W.	0.6175	0	0	3,600	0
	Type (c)	Masonry W.	0.15	0	0	91,233	0
		Concrete W.	0.1	0	0	108,598	0
		Earth W.	0.8	0	0	3,600	0
	Sub-Total						418,494,956
	Overhead						160,759,266
	Cost (1)						579,254,223
Total Cost							2,659,052,895