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JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

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

THE STUDY ON THE DEVELOPMENT OF WATER RESOURCES IN NORTHERN CHILE

SUPPORTING REPORT D : WATER SUPPLY DEVELOPMENT

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SUPPORTING REPORT - D
MUNICIPAL WATER SUPPLY DEVELOPMENT

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SUPPORTING REPORT D.

MUNICIPAL WATER SUPPLY DEVELOPMENT

D-I. ARICA CITY

Chapter I. EXISTING WATER SUPPLY SYSTEM

1.1 Water Supply System

1.1.1 Outline of the System

The existing public water supply system for Arica City, operated and maintained by a semi-governmental organization, ESSAT (Tarapaca Sanitary Services Enterprise), is outlined below:

[Groundwater] --> [Deep Well Pump] --> [Intake Pipeline] --> [Collection Tank]

--> [Transmission Pipeline] --> [Distribution Tank] --> [Consumers]

The water source is groundwater, submerged along the San Jose River, which flows east to west towards the Pacific Ocean, penetrating the city area. The groundwater is extracted from deep wells, located in the Azapa Valley along the river and in the city area, by submersible pumps installed in each well.

The water extracted from the wells is first transmitted through an intake pipeline to a collection tank located at approximately the center of the well-field. At the collection tank, the water is sterilized by using hypo-chlorite, which is either injected to the inlet pipeline or to the outlet pipeline of the tank. The chlorinated water is then delivered to the distribution tanks located on hilly areas in the east of the city. From the distribution tanks, water flows by gravity through the distribution networks to the consumers in the city.

1.1.2 Area and Population Served

The existing water supply system covers about 1,680 ha, which isdivided into 4 service sectors of the urbanized area of the city, serving almost the entire population of the city. The total population was 169,200 in 1992, as per the preliminary census results.

The number of service connections registered was 39,040 as of Feb. 1994. The number of connections added during a period of one year from Feb. 1993 to Feb. 1994 was 1,210.

A sketch of the existing water supply system including the areas of service sectors, is shown in Figs. D-I,1.0, 1.1 and 1.2.

1.1.3 Water Production and Consumption

The rate of water production, consumption by category and losses in 1992 are summarized as follows:

	1992 Quantity (x1,000 m^3)	%
Production	16,940.7	=(46,410 m^3/day = 537 l/sec)
Consumption	10,635.2	100
- Residential	8,170.8	76.8
- Commercial	1,087.3	10.2
- Industrial	919.3	8.6
- Other	457.8	4.3
Losses	6,305.5	(= 37.2% of production)

Note: The water losses indicated above consist of physical leakage and commercial losses, including the unbilled water consumption occurring in the residential category as a result of meters in poor operating conditions and illegal connections.

The above production was obtained from 28 deep wells (16 in the Azapa Valley and 12 in the city area), with an authorized capacity of 503 l/sec. During the year 1993, additional deep wells, producing 227 l/sec, were developed and commissioned by ESSAT as an Emergency Project.

Thus, the per capita water production and consumption on capacity basis in 1992 and 1994 are estimated as follows:

	Year	1992	1994
(A)	Production capacity of deep wells	503 l/sec = 43,500 m^3day	730 l/sec = 63,070 m^3/day
(B)	Population served	169,212 (Census)	175,100 (linear growth rate of 1982-1992)
(C)	Per capita water use available		
	(1) Production basis	257 l/day	360 l/day
	(2) Total consumption basis	161 l/day	226 l/day
	(3) Residential consumption basis	124 l/day	174 l/day

Note: (1)=A/B
(2)=(1)x62.8%
(3)=(2)x76.8%

1.1.4 Present Problems

Technical problems in the present water supply for Arica are summarized below:

1) Supply Capacity

Due to the shortage of water, water supply in Arica City was limited to 10.5-15 hours per day in all the service sectors until the year 1992. Additional deep wells were developed in 1993, both in the upper Azapa Valley and in the city, in order to supplement the supply capacity. Due to above supplement, the water restriction has been remarkably decreased. However, even now (early 1994) water restrictions are imposed in two service sectors (II & III) and the supply is limited to 14-15 hours per day.

2) Water Source

The present water source is solely concentrated in the San Jose River Basin (the Azapa Valley and in the city) from which the water is mainly extracted for agricultural purposes by the commercial sector and for municipal water supply by ESSAT. Thus, the river has been already developed beyond its' full capacity. It has been verified that further development of water source could not be possible.

The future water demand will inevitably increase according to the growth of the population and the development of the city. In order to meet the future demand, new water sources need to be developed in places other than the Azapa Valley.

3) Water Quality

The groundwater extracted from the existing deep wells located along the San Jose River contains considerably high concentration of TDS which causes salty taste. This occurs particularly at deep wells located in the city area, being near to the sea. This might be due to the excessive extraction of groundwater. Such an excessive intake of the groundwater from the San Jose River Basin will undoubtedly deteriorate the water quality in future.

Therefore, from the points of view of quality and quantity, new water sources other than the Azapa Valley need to be developed without any further delay.

4) Water Loss

The water loss, ie. the unpaid water in the system, is comparatively higher which was found to be 37.2% of the total production in 1992.

The loss consists of (i) physical loss (leakage from pipelines, distribution networks in particular) and (ii) commercial loss (unbilled water consumption occurring mainly in the residential areas as a result of meters in poor operating conditions and illegal connections).

An unaccounted amount of water loss take place between the service meters and the consumers due to domestic leakage and wastage.

The above losses are apparently recognized as the physical waste of the water resource and a financial loss to ESSAT.

A well-maintained public water supply system would be able to keep the water loss in a range of 20% of the production.

There is no specific methodology to reduce the water loss. The problem of the loss could be solved only by the steady and continuous effort by the maintenance body, ESSAT.

In order to minimize the water loss through the system, the following tasks are to be considered in general and performed.

- Immediate repair work for visual leakage on main pipelines.
- Replacement and repair of old/deteriorated pipes.
- Detection and repair of invisible leakage on distribution networks, particularly on service connections.

- Technical check on existing service water meters in doubt, and repair or replacement of deteriorated meters.
- Detection of illegal connections.
- Reduction of high pressure in the pipelines to a reasonable lower pressure.
- Public education program in order to increase the awareness of water saving among the public.
- Encourage the consumers to use water saving devices, plumbing fixtures, etc.

1.2 Water Supply Facilities - Arica

1.2.1 Deep Wells and Intake Pumps

There were 45 deep wells for the public water supply system for Arica, as of February 1994. Their locations are distributed (i) in the Azapa Valley and (ii) in the city area. The details of wells are; depth approximately 50-110 m, casing pipe diameters 250-340 mm, and yields approximately 15-25 l/sec (18 l/sec on average). All wells are equipped with submersible pumps, capacity of which is 20-35 l/sec in majority, 50-130 m in total head. The electric power for all the pumps is supplied by a public electric enterprise (EMELARI). The groundwater extracted from the deep wells is raised by the submersible pumps to a collection tank through intake pipelines.

All the existing deep wells are listed in Table D-I, 1.1 and the details of the submersible pumps are given in Table D-I,1.2.

A typical well structure is sketched in Fig. D-I,1.13 and a typical layout of a pump house is shown in Fig. D-I,1.14.

1.2.2 Collection Tanks

The groundwater extracted from the wells first flows into a collection tank. At the site of the collection tank, the water is chlorinated by adding hypo-chlorite. There are three (3) collection tank stations: (i) Pago de Gomez Station and (ii) Azapa Station, both located in the Azapa Valley; and (iii) Estadio Station in the city area. The tanks which were made of steel or reinforced concrete, are located slightly below the ground level.

From the tanks, the potable water is transmitted to the distribution tanks, through the transmission pipelines. The collection tanks located at higher places in the Azapa Valley supply water by gravity to the Chuno distribution tank, the Saucache distribution tank and the Pampa Nueva distribution tank. In the case of the Estadio station, being situated at a lower altitude within the city area, water is lifted by pumps at the station to the La Cruz distribution tank.

All the collection tanks are listed in Table D-I,1.3 and layout of the three tank stations is shown in Figs. D-I, 1.3, 1.4, 1.5 and 1.12.

1.2.3 Distribution Tanks

There are six (6) distribution tanks in Arica City, as of February 1994. All the tanks are made of steel or reinforced concrete and are constructed slightly below the ground level, on the eastern side or southern side hills of the city.

They are:

(i) Chuno Tank (V=5,000 m^3, HWL=+84.5 m; to Service Sector II)
(ii) Saucache Tank (V=2,500 m^3, HWL=+104.6 m; to Sector III)
(iii Pampa Nueva Tank (V=1,000 m^3, HWL=+129.1 m; to higher land of Sector III)
(iv) La Cruz Tank (V=2,500x2=5,000 m^3, HWL=+81.5 m; to Sector I)
(v) Rosado Tank (V=800 m^3, HWL=+109.5 m; to Sector IV)
(vi) La Lisera Tank (V=200 m^3, HWL=+30 m; to south-coastal area of Sector I)

The Pago de Gomez and Azapa Collection Tanks supply water by gravity to the Chuno, Saucache and Pampa Nueva Tanks. To the La Cruz Tank, water is pumped from the Estadio Station. Some of the water in the La Cruz Tank is transferred to the Rosado Tank by booster pumps installed at the site of the La Cruz Tank. The La Cruz Tank also supplies water to the La Lisera tank. The water flows by gravity up to the foot of the La Lisera hill and then is lifted up to the tank using the booster pumps installed at the foot of the hill.

The potable water stored in the distribution tanks is supplied, by gravity through distribution networks to service sectors in Arica City.

The distribution tanks are listed in Table D-I,1.4 and layout of the tank station is shown in Figs. D-I, 1.6 to 1.11; and structural drawings of typical distribution tanks in Figs. D-1, 1.15 and 1.16.

1.2.4 Transmission Pipeline

The groundwater extracted from the wells in the Azapa Valley is transmitted to distribution tanks located in the city area by gravity transmission pipelines.

The water from the well fields in Cabuza and San Miguel is transmitted to Pago De Gomez via an AC pipeline, 400 mm in dia. at the maximum. Wells located between San Miguel and Pago de Gomez, are also connected to this transmission line. There are collection tanks at Pago de Gomez, which collect the water within the Pago De Gomez well field (4 wells); and at Azapa collecting the water in the Azapa well field (9 wells). Between Pago de Gomez and Azapa, there are two parallel transmission pipelines, each approx. 3.2 km long and 450 mm diameter. One transmission line carries water to the Chuno distribution tank and the other to the Saucache distribution tank.

Details of the transmission pipelines are shown in Table D-I, 1.5.

1.2.5 Transmission/Booster Pumps

Transmission Pumps

The Estadio collection tank is situated at a low altitude place. Therefore, water in the tank is transmitted to the La Cruz distribution tank (HWL=+81.5 m) by the transmission pumps which are installed in the Estadio Station.

Specification of the transmission pumps is given in Table D-I, 1.6.

Booster Pumps

In addition to the above, there are three small booster pump stations located in some fringe areas of the city, in order to boost water pressure for the supply to high altitude areas or remote areas. They are at places of (i) La Cruz tank (for Rosado tank) (ii) Rosado tank (for higher altitude hinterlands) and (iii) at the foot of the La Lisera hill (for La Lisera tank).

Specifications of the booster pumps are given in Table D-I, 1.7.

1.3 Organization and Operation

(Note): The following information and data cover both Arica and Iquique Cities at an aggregated level.

1.3.1 Organization

Water supply management is being carried out by Empresa de Servicios Sanitarios de Tarapaca (Tarapaca Sanitary Services Enterprise, ESSAT). It is a stock company established on April 9, 1990 and replaced the Servicio Nacional de Obras Sanitarias, SENDOS Region I (National Service for Sanitary Works, SENDOS Region I).

ESSAT has only two shareholders, Corporacion de Fomento para la Produccion (Production Promotion Corporation, CORFO) and the Public Treasury. The former owns 99% of the shares and the latter, 1%.

The objective of ESSAT is to produce and distribute drinking water, recollect, treat and dispose sewage, and carry out other services related to such activities in the way and manner established in the Decree-Laws No. 382 and No. 70, both issued in 1988 by the Ministry of Public Works.

ESSAT serves the Tarapaca Region (Region I) that includes Arica, Iquique, Pozo Almonte, Pica, Matilla, Huayca, La Tirana, La Huara, and Pisagua.

ESSAT is managed by a Board of Directors composed by seven members who are appointed for a two-year period. The directors are designated by the Ordinary Meeting of Shareholders.

In turn, the Board of Directors elects its own President and Vice-President and designates the General Manager.

There are the following Managerial Departments:

- General Management
- Engineering
- Administration and Finance
- Planning

Arica and Iquique have Provincial Branches and their managers also belong to the top management of ESSAT.

Besides the above mentioned Managerial Departments, ESSAT has the following Counseling Units.

- Legal
- Internal Control
- Rural Drinking Water
- Public Relations

The Engineering, Administration and Finance, and Planning Departments, and the Iquique and Arica Provincial Branches all depend on the General Management Department.

The Engineering Management Department carries out studies concerning drinking water and sewerage, and set the technical norms for operation of the firm; it also coordinates and controls the operation and maintenance programs, water quality, and sewage collection.

The Administration and Finance Management Department is in charge of administration of human, financial and information resources related to administrative and commercial aspects of the firm. This department sets norms and policies seeking to maximize revenues, minimize costs and optimize utilization of human and material resources, and required services for operation of the firm. It also sets the norms regulating the relationship on commercial matters between the firm and its clients.

The Arica and Iquique Provincial Branches are responsible for the operation and maintenance of the installations, works and equipment of the drinking water and sewerage systems. They are also in charge of the invoicing and collection of tariff for water and sewerage services.

Personnel is made up of 289 people at the end of 1993 and is classified as shown below:

Top management	10
Technical staff	53
Other staff	226
Total	289

Source: ESSAT 1993 Annual Memory

Second-level chiefs, professionals and qualified personnel are considered as technical staff. Administrative staff, drivers, watchmen, etc. are within the "Other Staff" category.

Remuneration are decided based on collective agreements reached between the management and workers. These agreements contemplate the semi-annual readjustment of remuneration up to a 100% of the variation of the consumer's price index.

1.3.2 Operation and Maintenance

1) Budget and Revenues

The budget for the year 1993 was 17% higher than that for 1992. See below for details.

Budget for the Period 1990-1993
(Unit: Million Pesos)

Item	1993	%	1992	%	1991	%	1990	%
Remuneration	839	25	733	26	571	24	364	19
Services	303	9	225	35	167	20	139	7
Materials	167	5	176	6	125	5	46	2
Energy	1,579	48	1,395	50	1,328	55	1,258	66
Fuel	52	2	42	1	35	2	22	2
Overhead cost	356	11	249	9	171	7	84	4
Total	3,296	100	2,820	100	2,397	100	1,913	100

Source: ESSAT 1993, 1992 Annual Memories

Total revenue collected during 1993 was $7,627 million. Breakdown of the revenue is shown below:

Revenues for the 1990-1993 Period
(Unit: Million Pesos)

Item	1993	%	1992	%	1991	%	1990	%
Water sale	5,349	70	4,244	79	3,372	83	2,237	98
Investment profit	126	2	47	1	17	-	17	1
Transfers	1,913	25	1,077	20	680	17	-	-
Other revenues	240	3	2	-	1	-	18	1
Total	7,627	100	5,370	100	4,070	100	2,272	100

Source: ESSAT 1993, 1992 Annual Memories

Invoicing is done on a monthly basis for all clients and during 1993, 97% of total invoiced tariff was actually collected.

Tariff Collection Efficiency
(Unit: Million Pesos)

Year	Invoiced $	Collected $	Collection efficiency %
1990	2,371	2,237	94
1991	3,549	3,372	95
1992	4,430	4,244	96
1993	5,529	5,349	97

Source: ESSAT 1993, 1992 Annual Memories

2) Production and Invoicing

Water production and invoicing for the period 1990-1993 are shown below:

Production and Invoicing for Period 1990-1993
(Unit: Million Pesos)

Year	Production	Invoiced	%
1990	35,891	21,327	59
1991	34,787	22,031	63
1992	35,692	22,494	63
1993	38,189	21,466	56

Source: ESSAT 1993 Annual Memories

3) Tariff Structure

Tariffs are set by the Government through the Ministry of Economy, Foment and Reconstruction. The tariffs are denominated "self-financing tariffs" because they are set aiming to recover the costs of the water supply companies; they are based on an economic efficiency point of view and taken into consideration the long-term development and growth costs of the companies. The government sets the "self-financing tariffs" or "target tariffs" which must be reached within a period of 5 years; it means that ESSAT has 5 years to reach those tariffs. Tariffs are adjusted based on two concepts:

- Through adjustment of the tariffs themselves: They correspond to an annual percentage increase determined by the Government in order to reach the "self-financing tariffs" within the established period of 5 years (1990 to 1994).

- Through readjustment of the price indexes considered in the formulas applied for setting up the tariffs: Re-adjustments will be applied each time any of the indexes shown below raises above 3%.

The indexes are:

PIC	:	Price Index of Cement
PII	:	Price index of Iron
PIR	:	Price Index of Remunerations
PIIE	:	Price Index of Industrial Electricity
PIPD	:	Price Index of Petrol, Diesel
WPI	:	Wholesale Price Index
WPIIP	:	Wholesale Price Index of Imported Products

Tariffs applied at present by ESSAT correspond to 75% of the "self-financing tariffs" set up by the government.

The present "self-financing tariffs" were established through Legislative Decree No. 376 issued on November 15, 1990, by the Ministry of Economy, Foment and Reconstruction.

The tariff structure contemplates imposing following charges to the clients:

- Fixed Charges for Water and Sewerage: These charges are independent from water and sewerage services consumption.
- Fixed "Client Charges": These charges aim to cover the expenses incurred by ESSAT when attending the clients like water meter reading, inspections, etc.

- Variable Charges: These charges depend on the water consumption measured in cubic meters.
- Over-consumption Variable Charges: They are applied during the summer season, denominated "peak season", from December to March, to the consumption over the average consumption obtained during the "off-peak season" from April to December. These charges apply to consumption over 30 m^3.

The tariffs applied at present by ESSAT for Arica and Iquique are as follows:

Water and Sewerage Tariffs (February 1994)

(a) Group No.1: Arica-Pica-Matilla-La Huayca

Monthly Fixed Charge

Service Diameter (mm)	Water Tariff $	Sewerage $	Client $
13 Rebated	231	104	206
15 Normal	334	151	297
19 Normal	667	302	297
25 Normal	1,335	605	297
32 Normal	2,002	907	297
38 Normal	3,003	1,361	297
50 Normal	5,005	2,268	297
75 Normal	11,678	5,293	297
100 Normal	20,019	9,074	297
125 Normal	30,028	13,611	297
150 Normal	45,042	20,416	297
200 Normal	80,075	36,295	297

Monthly Variable Charge

	$ Normal	$ Rebated
- Water consumption	140.02	108.68
- Water consumption during peak season	140.02	108.68
- Water over consumption	363.74	363.74
- Sewerage without treatment	43.45	25.01
- Sewerage with treatment	51.68	29.75

(b) Group No.2: Iquique-Pozo Almonte-La Tirana-Huara-Pisagua

Monthly Fixed Charge

Service Diameter (mm)	Water Tariff $	Sewerage $	Client $
15 Rebated	209	93	194
15 Normal	337	149	298
19 Normal	675	298	298
25 Normal	1,350	597	298
32 Normal	2,025	895	298
38 Normal	3,037	1,343	298
50 Normal	5,062	2,239	298
75 Normal	11,812	5,223	298
100 Normal	20,249	8,954	298
125 Normal	30,373	13,432	298
150 Normal	45,560	20,147	298
200 Normal	80,995	35,817	298

Monthly Variable Charge

	$ Normal	$ Rebated
- Water consumption	233.44	130.90
- Water consumption during peak season	230.82	130.20
- Water over consumption	564.20	564.20
- Sewerage without treatment	41.90	19.65

4) Clients and Coverage

By the end of 1993, ESSAT was supplying water services to 77,264 clients and sewerage services to 73,845 clients. It means that almost 98% of the population of the region in 1993 received drinking water services while 96% was covered by sewerage services. See below for details.

Clients and Water Service Coverage

Service	1993 Clients (number)	1993 Coverage (%)	1992 Clients (number)	1992 Coverage (%)	1991 Clients (number)	1991 Coverage (%)
Arica	38,821	99	37,423	99	34,770	99
Iquique	35,126	98	33,332	98	30,175	98
P. Almonte	1,061	95	920	95	786	94
Pica	967	100	943	100	865	100
Matilla	270	100	261	100	248	100
La Tirana	1,042	85	1,000	85	928	78
La Huayca	132	100	122	100	110	100
Huara	172	100	159	100	148	100
Pisagua	73	100	57	100	53	100
Total	77,664	98	74,217	98	68,083	98

Source: ESSAT 1993 Annual Memories

Clients and Sewerage Service Coverage

Service	1993 Clients (number)	1993 Coverage (%)	1992 Clients (number)	1992 Coverage (%)	1991 Clients (number)	1991 Coverage (%)
Arica	38,238	98	36,924	98	34,222	97
Iquique	34,502	96	32,815	96	28,961	94
P. Almonte	709	95	587	61	484	58
Pica	396	41	388	41	244	28
Total	73,845	96	70,714	96	63,911	95

Source: ESSAT 1993 Annual Memories

Clients can be classified as follows:

Classification by Type of Client

Year	1993				1992			
Type of Client	Water	%	Sewerage	%	Water	%	Sewerage	%
Residential	71,462	92	68,516	93	68,123	92	65,426	93
Commercial	3,262	4	2,725	4	3,442	5	2,879	4
Industrial	2,098	3	1,916	2	1,849	2	1,730	2
Other	842	1	688	1	803	1	676	1
Total	77,664	100	73,845	100	74,217	100	70,714	100

Source: ESSAT 1993, 1992 Annual Memories

In order to offer better services to its clients, ESSAT has 24 offices where they can make payments and 5 centers for general consultation.

5) Main Installations for Water and Sewerage Services

Main installations of ESSAT correspond to the infrastructure for production and distribution of drinking water and collection system and final disposal of sewage.

Main Installations of ESSAT

Water intake	Arica:	29 deep wells
Water intake	Iquique:	26 deep wells
Water transmission pipeline	Arica:	19,175 m
Water transmission pipeline	Iquique:	177,348 m
Water pumping station in Arica:	4 with a capacity of 277 l/s	
Water pumping station in Iquique:	5 with a capacity of 706 l/s	
Water reservoirs in Arica:	8 with a storing capacity of 14,500 m^3	
Water reservoirs in Iquique:	38 with a storing capacity of 78,700m^3	
Water distribution network in Arica:		372,637 m
Water distribution networks in Iquique:		246,942 m
Sewerage collection networks in Arica:		350,629 m
Sewerage collection networks in Iquique:		227,678 m
Sewerage pumping stations in Arica:	2 with capacity of 600 l/s	
Sewerage pumping stations in Iquique:	3 with capacity of 1,300 l/s	

Source: ESSAT 1993 Annual Memories

Table D-I, 1.1 List of Deep Wells - Arica/ESSAT (No. 1)

Well No.	Location	Altitude above sea level (+ m)	Year of Constuction	Casing Diameter (mm)	Well Depth (m)	Total Screen Length (m)	Actual Yield (l / sec)	Static Water Level (m)	Dynamic Water Level (m)	Water Level Drawdown (m)	Depth of Pump Installed (m)	Remarks
1471 Sn. Miguel	San Miguel Plant	248	1993	305	96	# 16 * 29	18.5	32.7	50.25	17.55	72	
1472 Sn. Miguel	San Miguel Plant	249	1992	305	100	# 15 * 35	22.7	26.7	49.93	23.23	66	
92 Agricultores	San Miguel Plant	248	1947	254	50		38	S/I	40			
93 Agricultores	San Miguel Plant	248	1951	254	48		39	S/I	46			Rented
1113 (No. 1)	Pago de Gomez Plant	149.8	1992	254-305	100	# 15 * 30	12.9	31.93	64.3	32.31	66	
1114 (No. 2)	Pago de Gomez Plant	150.85	1992	254-305	100	# 15 * 10	6.9	31	49.5	18.5	72	
1142 (No. 3)	Pago de Gomez Plant	153.05	1975/84	305	100	# 15 * 30	10	30.26	43.15	12.89	66	
Centella	4.5km Azapa Road		1993				12.9		55.25			Rented
Ordonez	4.5km Azapa Road		1993				8.5					Rented
Fernandez	4.5km Azapa Road		1993				12	22.94				Stopped
47	Azapa Plant	107	1987	350-400	90	*50.5	10	39.43	65.5	28.07	78	
48	Azapa Plant	108	1987	350	90	* 34	8.5	33.05	57.75	24.7	60	
184	Azapa Plant	111	1987	350-400	90	* 38	12.5	34.25	54.05	19.8	54	

screen

* slotted pipe

Table D-I, 1.1 List of Deep Wells - Arica/ESSAT (No. 2)

Well No.	Location	Altitude above sea level (+ m)	Year of Constuction	Casing Diameter (mm)	Well Depth (m)	Total Screen Length (m)	Actual Yield (l / sec)	Static Water Level (m)	Dynamic Water Level (m)	Water Level Drawdown (m)	Depth of Pump Installed (m)	Remarks
434	Azapa Plant	102	1987	350/400	90	* 41	13.5	33.56	57.71	24.15	60	
491	Outside near Azapa Plant	106.5	1962	254/340	90		11.8	35.3	63.6	28.3	72	
491 A	Azapa Plant	S/I		350/400	90	* 46	11.3	36.77	57.03	20.26	66	
492	Azapa Plant	110.5	1987	254/400	90	* 40	11.6	36.21	57.8	21.59	72	
568 Los Pinos	City	58	1989	355	98.4	* 36	14.92	33.03	52.2	19.17	72	
569 Pilon 18	City	53	1962	355	96.15		21.6	40.1	60.45	20.35	66	
650 Saucache R.	City	57	1989	355	85.15	* 40	17.5	28.1	65.1	37	60	
714 Estadio	City	39	1963	350	90	*65,12	23.8	31.75	44.9	13.15	66	
715 Copaja	City	46	1965	340	91		18.8	34.41	50.81	16.4	78	
San Jose	City	16.5	1963	300	100		14.3	24.25	43.5	19.25	60	
Liga Empleados	City	31	1967	400	100		21.8	25.88	50.12	24.24	66	
4897 Tucapel	City	39	1965	350	100		30.3	24.33	54.7	30.37	78	
Planta Estadio	City	S/I	1989	350	90	40.69	15	36.4	47.75	11.35	60	

Table D-I, 1.1 List of Deep Wells - Arica/ESSAT (No. 3)

Well No.	Location	Altitude above sea level (+ m)	Year of Constuction	Casing Diameter (mm)	Well Depth (m)	Total Screen Length (m)	Actual Yield (l / sec)	Static Water Level (m)	Dynamic Water Level (m)	Water Level Drawdown (m)	Depth of Pump Installed (m)	Remarks
Rodoviario	City	S/I	1987	350	80		8	17				
108	Cabuza Setor 1		1993				23.8		39.35			Rented
115	Cabuza Setor 2		1993				47		37.95			Rented
Lido Carbone	Km 15 Azapa Road		1993		90	36	40		29.12			Rented
Las Riveras			1993				22		22.8			Rented
Ordonez 2			1993				6.1		44.17			Rented
Ortuno			1993				24					Rented
Devoto 2			1993				22.2		49.25			Rented
Devoto 1			1993				14.2		57.2			Rented
Tambo Quemado			1991		97	30	26					
Nueva Esperanza			1991	400			12	41.34	49.7	8.36		
J. Aracena			1993		95	95	6		52.6			
Loa			1993		115	115	7		62.5			

Table D-I, 1.1 List of Deep Wells - Arica/ESSAT (No. 4)

Well No.	Location	Altitude above sea level (+ m)	Year of Constuction	Casing Diameter (mm)	Well Depth (m)	Total Screen Length (m)	Actual Yield (l / sec)	Static Water Level (m)	Dynamic Water Level (m)	Water Level Drawdown (m)	Depth of Pump Installed (m)	Remarks
O' Higgins			1993		109	30	15		75.85			
Angelmo			1993		143	48	24		70.3			
Sobraya 1			1993				10.1		52.25			Rented
Sobraya 2			1993				7.6		63.75			Rented
Las Torres			1993		120	36						

Table D-I, 1.2 List of Intake Pump Arica/ESSAT (No. 1)

Well No.	Flow direction	Type of Pump	Year of Instal-lation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l/sec)	Total Head (m)	Ele. Power (KWh)		
1471 Sn. Miguel	Sn. Miguel-Pago de Gomez Conveyance	Submersible motor pump	1993		17.8		38		
1472 Sn. Miguel	Sn. Miguel-Pago de Gomez Conveyance	〃	1993		30	76	40		
92 Agricultores	Sn. Miguel-Pago de Gomez Conveyance	〃							
93 Agricultores	Sn. Miguel-Pago de Gomez Conveyance	Submersible motor pump					55		
1113 (No. 1)	Pago de Gomez Tank	〃	1993		22	70	40		Rented
1114 (No. 2)	Pago de Gomez Tank	〃	1993				22		Rented
1142 (No. 3)	Pago de Gomez Tank	〃	1993				40		Rented
Centella	Pago de Gomez Tank	〃	199?						
Ordonez 1	Pago de Gomez-Azapa Conveyance	〃	1992		25	52	18		
Fernandez	Pago de Gomez-Azapa Conveyance		199?						
47	Azapa Tank	〃	1993		22	90	30		
48	Azapa Tank	〃	1993		22	70	22		
184	Azapa Tank	〃	1992		25	52	22		

Table D-I, 1.2 List of Intake Pump Arica/ESSAT (No. 2)

Well No.	Flow direction	Type of Pump	Year of Instal-lation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l/sec)	Total Head (m)	Ele. Power (KWh)		
434	Azapa Tank		1988		30	70	30		
491	Azapa Tank	Submersible motor pump	1993		20	70	22		
491 A	Azapa Tank	〃	1992		40	70	37		
492	Azapa Tank	〃	1990		25	89	33		
568 Los Pinos	Estadio Station	〃	1993		20	70	22		
569 Pilon 18	〃	〃	1990		35	60	30		
650 Saucache	〃	〃	1990		35	80	45.5		
714 R, Estadio	〃	〃	1990		35	80	30		
715 Copaja	〃		1993		22	90	30		
San Jose	〃								
Liga Empleados	〃	Submersible motor pump	1993		25	80	30		
4897 Tucapel	〃		1992		35	80	45.5		
Planta Estadio	〃		1993		22	70	22		

Table D-I, 1.2 List of Intake Pump Arica/ESSAT (No. 3)

Well No.	Flow direction	Type of Pump	Year of Instal-iation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l/sec)	Total Head (m)	Ele. Power (KWh)		
Rodoviario	La Red								
108 Cabuza 1	Pago de Gomez				30	70	30		
115 Cabuza 2	Pago de Gomez	Submersible motor pump			45	80			Rented
Lido Carbone	〃	〃			40	60	37		Rented
Las Riveras	〃	〃			24	35	13		Rented
Ordonez 2	〃	〃							Rented
Ortuno	〃	〃							Rented
Devoto 2		〃			20	80	24		Rented
Devoto 1		〃			220	105	30		Rented
Tambo Quemado	Saucache Tank	〃			25	116	52		
Nueva Esperanza	〃	〃			30	76	37		
J. Aracene	Chuno Tank	〃			6.5	120	52		
Loa	〃	〃			6.5	130	18		

Table D-I, 1.2 List of Intake Pump Arica/ESSAT (No. 4)

Well No.	Flow direction	Type of Pump	Year of Instal-lation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l/sec)	Total Head (m)	Ele. Power (KWh)		
O'Higgins	Estadio Station				25	130	33		
Angelmo					24	80	33		
Sobraya 1	La Red				20	70	18		Rented
Sobraya 2	La Red	Submersible motor pump	1993		20	70	18		

Table D-I, 1.3 List of Collection Tanks - Arica/ESSAT

Name of Tank	Location	Direction of Flow	Ground Altitude above sea level (+ m)	Number of Tanks	Year of Construction	Construction Material	Water Level (+ m)	Dimension & Water Depth	Capacity (m3)	Total Capacity (m3)
Pago de Gomez	Azapa Valley	From deep wells in Azapa Valley to Chuno Tank, Saucache Tank and Pampa Nueva Tank	+ 150	1		Reinforced Concrete	HWL= + 154.63 LWL= + BL= + 150.23	Diam. 17.03m H 5.7m	m3 1,000	m3 1,000
Azapa	Azapa Valley	Same as the above	+ 100	1		Reinforced Concrete	HWL= LWL= BL= + 106.66	Diam. 11.98m H 4.25m	500	500
Estadio	City area	From deep wells in city area to La Cruz Tank	+ 43.1	1	1984	Rein forced Concrete		L= 11.10m W= 4.35m H= 2.65m	100	

Table D-I, 1.4 List of Distribution Tanks - Arica/ESSAT

Name of Tank	Location	Flow Direction	Ground Altitude above sea level (+ m)	Number of Tanks	Year of Construction	Construction Material	Water Level (+ m)	Dimension & Water Depth (m)	Capacity (m3)	Total Capacity (m3)	Remarks
(1) Chuno	Eastern hill of the city	From Pago de Gomez and Azapa to service Sector II	+ 81	1	1985	Reinforced Concrete	HWL=84.50 LWL=+ BL=79.00	D: 32.57 H: 6.4	5,000	5,000	
(2) Saucache	Southwester hill	From Pago de Gomez and Azapa to Sector III	+ 99.1	1		Reinforced Concrete	HWL:104.6 LWL: BL:99.10	D: 22.03 H: 6.4	2,500	2,500	
(3) Pampa Nueva	Vicinity of Saucache Tank	From Pago de Gomez and Azapa to highland of Sector III	+ 124.5	1	1994	Reinforced Concrete	HWL=+129.1 BL=+124.5	D: H:	1,000	1,000	Commissioned in Feb. 1994
(4) La Cruz	Southern hill	From Estadio to Sector I	+ 76	2		Steel	HWL:81.5 LWL: BL:76.00	D: 23.3 H: 6.0	2,500 × 2	5,000	
(5) Rosado	South of La Cruz Tank	From La Cruz to Sector IV	+ 105	1		Steel	HWL:109.50 LWL: BL:105.00	D: 15.1 H: 4.9	800	800	
(6) La Lisera	South hill near coast	From La Cruz to coastal area of I	+ 25	1		Reinforced Concrete	HWL: LWL: BL:25	D: 7.85 H: 4.15	200	200	
								Total Capacity		14,500	

Table D-I, 1.5 List of Transmission Pipelines - Arica/ESSAT (No. 1)

Site Name of Pipeline	Gravity Flow or Pumped	Design Flow (l/sec)	Year of Construction	Diameter (mm)	Distance (m)	Pipe Material	Other Fittings	Remarks
From Cabuza To San Miguel	Gravity	200	1993	300	7,258	Asbest of Cement	10 Air-release valve 2 Drain	
From San Miguel +246.60 To +154.23 Pago de Gomez	Gravity	392		400	6,025	Asbest of Cement	6 Air-release valve 1 Valve in front of Pago de Gomez	Valve Normal Position: Close
From Pago de Gomez To Chuno Tank	Gravity	226		450	3,214	Asbest of Cement	4 Air-release valve 1 Fire hydrant 2 valves 1 Flow meter out of order	Pago de Gomez - Azapa Plant section
	Gravity	226		350	2,350	Asbest of Cement	1 Air-release valve out of order	Azapa Plant - Callejon Motel Section
	Gravity	226		250 350	430 430	Asbest of Cement Asbest of Cement	2 Valves for connection pipes	Callejon Motel - Diego Portales Section Parallel pipes

Table D-I, 1.5 List of Transmission Pipelines - Arica/ESSAT (No. 2)

Site Name of Pipeline	Gravity Flow or Pumped	Design Flow (l/sec)	Year of Construction	Diameter (mm)	Distance (m)	Pipe Material	Other Fittings	Remarks
From Pago de Gomez To Chuno Tank	Gravity	226		400 400 400	1,310 760 574	PVC Steel Asbest Cement		Rotonda Diego Portales-Estanque Chuno Section
From Pago de Gomez To Chuno Tank	Gravity	226			9,064			Total
From Pago de Gomez To Saucache Tank	Gravity	178.5		400	3,207	Asbest Cement	3 Air-release valve	+150.43 +103.08 Pago de Gomez - Azapa Plant section
	〃	178.5		250 250	2,002 2,002	Asbest Cement Asbest Cement		Azapa Plant - Callejon Motel Section Parallel pipes
	〃	178.5		350	1,050	Asbest Cement	2 Scour valves	Callejon Motel - Saucache Tank Section
From Pago de Gomez To Saucache Tank		178.5			8,261			Total

Table D-I, 1.5 List of Transmission Pipelines - Arica/ESSAT (No. 3)

Site Name of Pipeline	Gravity Flow or Pumped	Design Flow (l/sec)	Year of Construction	Diameter (mm)	Distance (m)	Pipe Material	Other Fittings	Remarks
From Azapa Plant To La Cruz Tank		390		450		Steel	3 Air-release valve 1 Scour valve	Connection with Pago de Gomez - Chuno Tank Pipeline in Diego Portales Sector
From Azapa Plant To Chuno Tank				400		PVC (?)	1 Drain	From Azapa Plant - La Cruz Tank, Pipeline in Diego Portales Sector

Table D-I, 1.6 List of Transmission Pumps - Arica/ESSAT

Name of Pumping Station	Pump No.	Type of Pump	Year of Installation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l / sec)	Total Head (m)	(KWh)		
Estadio (From city wells to La Cruz Tanks)	No. 1	Double Suction Volute Pump	1984		303	50.3	110	Pump : KSB / RETA 200-400 Motor : IP-54 315M	Equipments in Parallel one Stand-by
	No. 2	Double Suction Volute Pump	1984		303	50.3	110	Pump : KSB / RETA 200-400 Motor : IP-54 315M	
	No. 3	Double Suction Volute Pump	1984		303	50.3	110	Pump : KSB / RETA 200-400 Motor : IP-54 315M	

Table D-I, 1.7 List of Booster Pumps - Arica/ESSAT

Name of Pumping Station	Pump No.	Type of Pump	Year of Installation	Technical Specification of Pump				Name of Manufacturer and Model Number	Remarks
				Diameter (mm)	Discharge (l / sec)	Total Head (m)	(KWh)		
Rosado Booster Pumps (To make sure minimas Pressures in the Sector)	No. 1	Single Suction Volute Pump	1984		60	25	15	Pump : ROTOS POMP NE6X16-M Motor : ERCOLLI MARTELLI	The Station has 3 Hydropak Tanks with 200 l capacity each Equipment in parallel
	No. 2	Single Suction Volute Pump	1984		60	25	15	Pump : ROTOS POMPE NE6X16-M Motor : ERCOLLI MARTELLI	
	No. 3	Single Suction Volute Pump	1984		60	25	15	Pump : ROTOS POMPE NE6X16-M Motor : ERCOLLI MARTELLI	
	No. 4	Single Suction Volute Pump	1984		60	25	15	Pump : ROTOS POMPE NE6X16-M Motor : ERCOLLI MARTELLI	
La Lisera (From Distribution system to La Lisera Tank)	No. 1	Submersible			12			Pump : PLEUGER	
	No. 2								Out of Service
Cerro La Cruz (From La Cruz Tank to Rosado Tank)	No. 1	Single Suction Volute Pump	1984 (Remodeled)		100-150-200	63-58-45	37	Pump : Rotos Pompe NE8X25M Motor : ERCOLLI MARTELLI	Equipments in parallel - one Stand-by
	No. 2	Single Suction Volute Pump	1984 (Remodeled)		100-150-200	63-58-45	37	Pump : ROTOS POMP NE8X25M Motor : ERCOLLI MARTELLI	

Table D-I, 1.8 Hydraulic Calculations for Existing Transmission Pipelines, Arica

Point to Point	Dia. (mm)	Distance (m)	Material	C	Flow (l/sec)	I	H=IL	V (m/sec)
(+??)								
Cabuza	300	7,258	ACP	130	200	0.0235	170.36	2.83
- San Miguel?? () Sondaje Riego??								
(+246.6m)								
San Miguel	400	6,025	ACP	130	392	0.0201	120.98	3.11
- Pago de Gomez (+154.2m)								
(+246.6m)-(+154.2m) = 92.4m								
	400	6,025	ACP	130	350	0.0163	98.10	
	400	6,025	ACP	130	335	0.0150	90.46	---> OK
	400	6,025	ACP	130	320	0.0138	83.11	
(+150.4m)								
Pago de Gomez	450	3,214	ACP	130	226	0.00409	13.14	1.42
-Azapa Plant (+102.9m)								
(+102.9m)								
Azapa Plant	350	2,350	ACP	130	226	0.0139	32.64	2.35
- Callejon Motel (+65.3m)								
(+65.3m)								
Callejon Motel	250	430	ACP	130	66	0.00733	3.15	1.34
	350	430	ACP	130	160	0.00733	3.15	1.66
	399	430	ACP	130	226	0.00733	3.15	
- Diego Portales (+58.1m)								
(+58.1m)								
Diego Portales	400	1,310	PVC	130	226	0.00725	9.50	1.79
	400	760	Steel	90	226	0.0143	10.88	1.79
	400	574	ACP	130	226	0.00725	4.16	1.79
		2,644					24.54	
- Chuno Tank (+85.1m)								
Total Head Loss = 13.14 + 32.64 + 3.15 + 24.54 = 73.47m								
{Pago de Gomez (+150.4m) - Chuno Tank (85.1m)} = 65.3m								
(+150.4m)								
Pago de Gomez	400	3,207	ACP	130	178.5	0.00469	15.02	
- Azapa Plant (+103.1m)								
(+103.1m)								
Azapa Plant	250	2,002	ACP	130	89.25	0.0128	25.63	1.82
	250	2,002	ACP	130	89.25	0.0128	25.63	1.82
	325	2,002		130	178.5	0.0128	25.63	
- Callejon Motel								
Callejon Motel - Saucache Tank (+105.5m)	350	1,050	ACP	130	178.5	0.00898	9.43	1.86
Total Head Loss = 15.02+ 25.63 + 9.43 = 50.08m								
{Pago de Gomez (+150.4m) - Saucache (+105.5m)} = 44.9m								

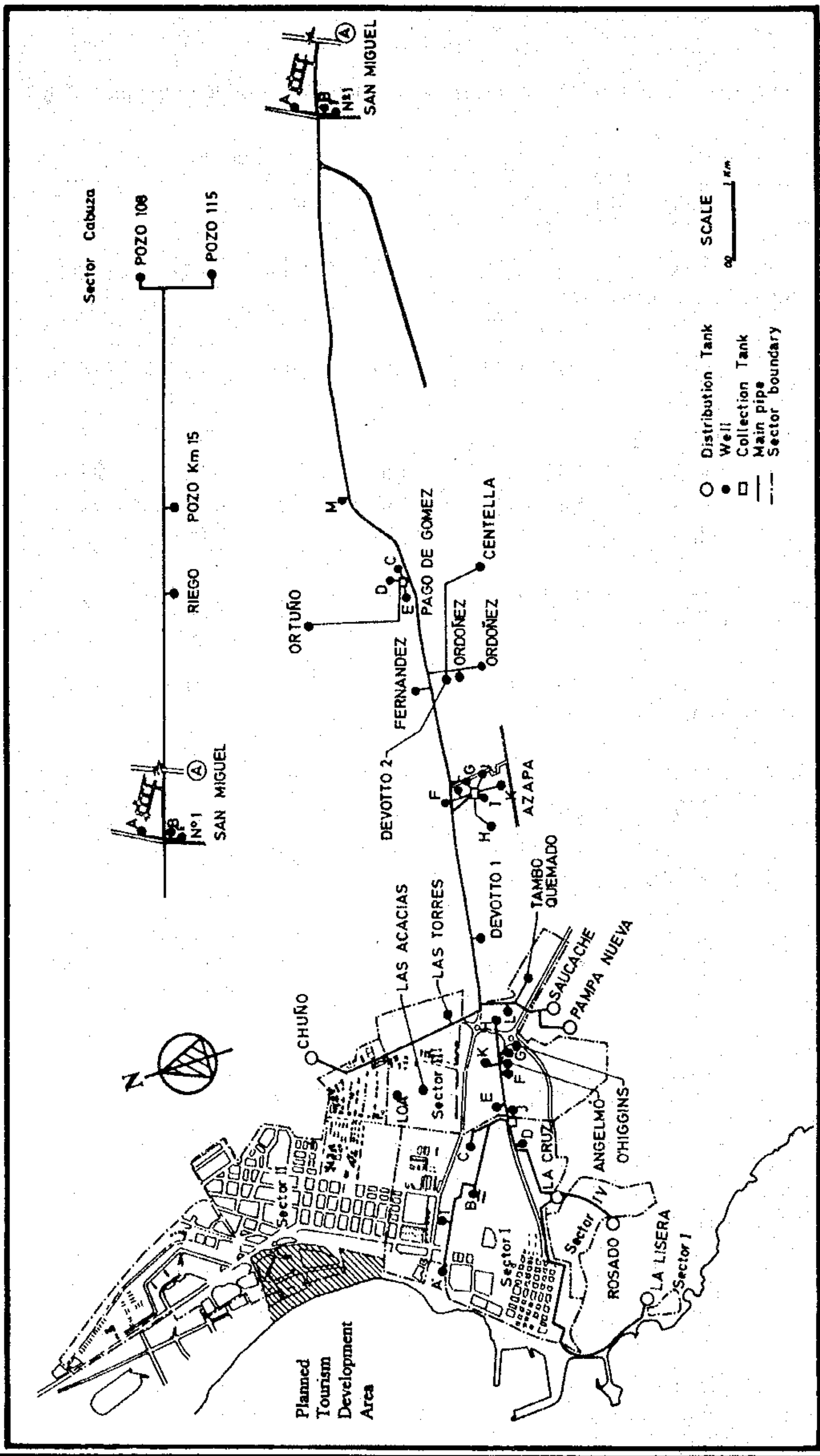

Fig. D-I, 1.0 General Plan of Existing Water Supply System - Arica

< Planta General del Sistema de Abastecimiento de Agua Existente - Arica >

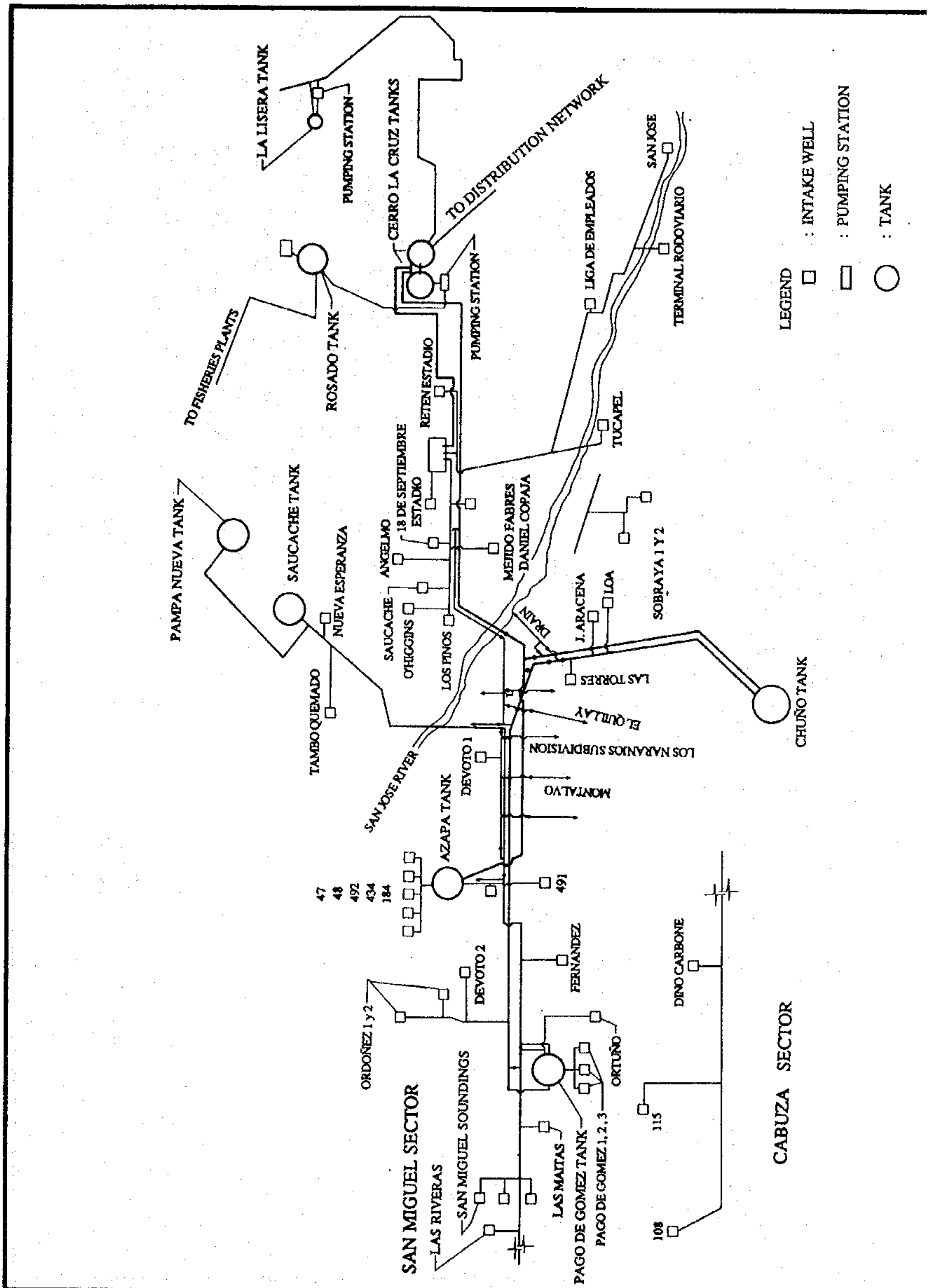

Fig. D-I, 1.1 Outline of the Existing Water Supply System for Arica

< Bosquejo del Sistema Existente del Abastecimiento de Agua para Arica >

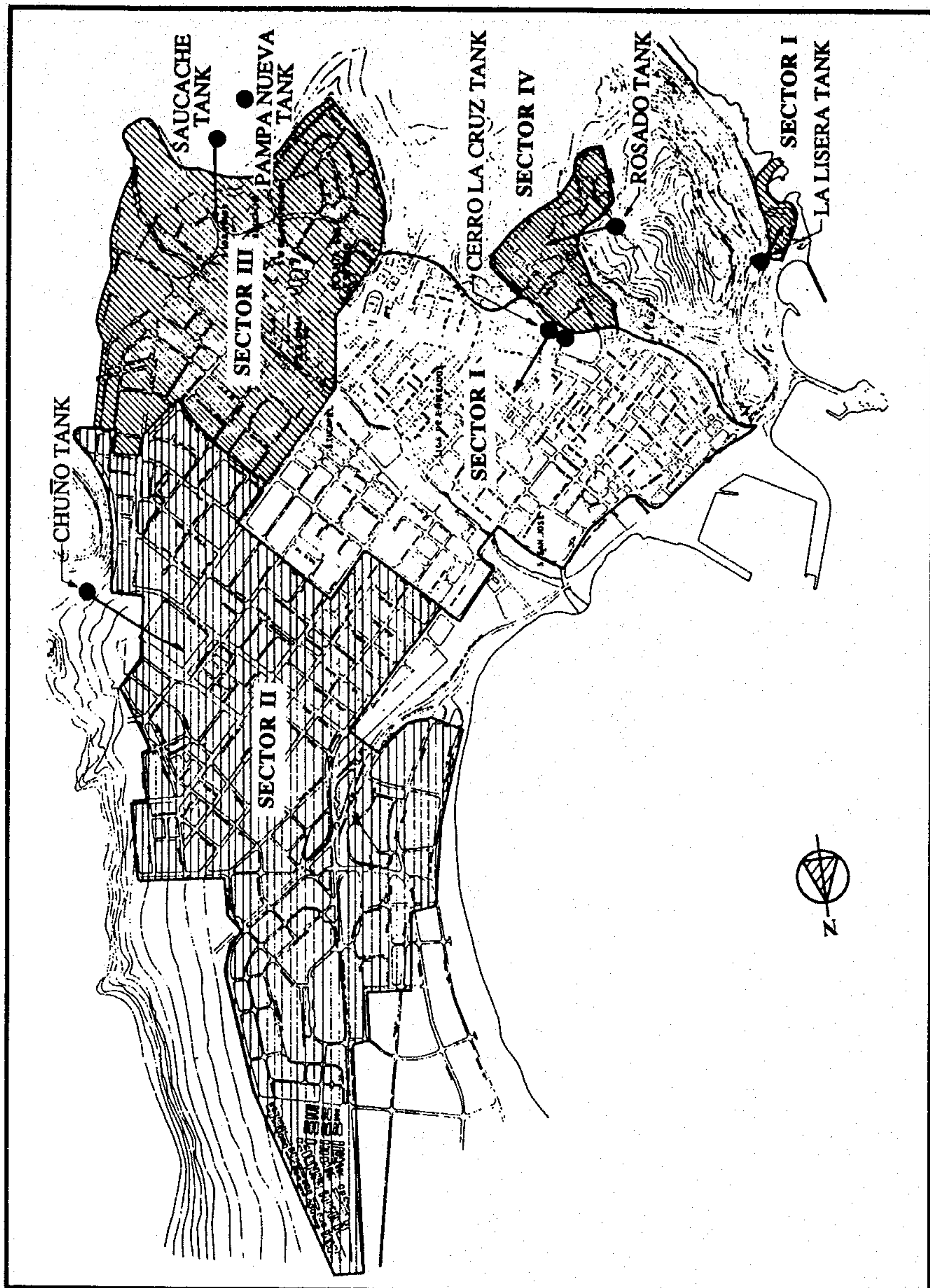

Fig. D-I, 1.2 Water Supply Service Area - Arica

< Area del Servicio de Abastecimiento de Agua - Arica >

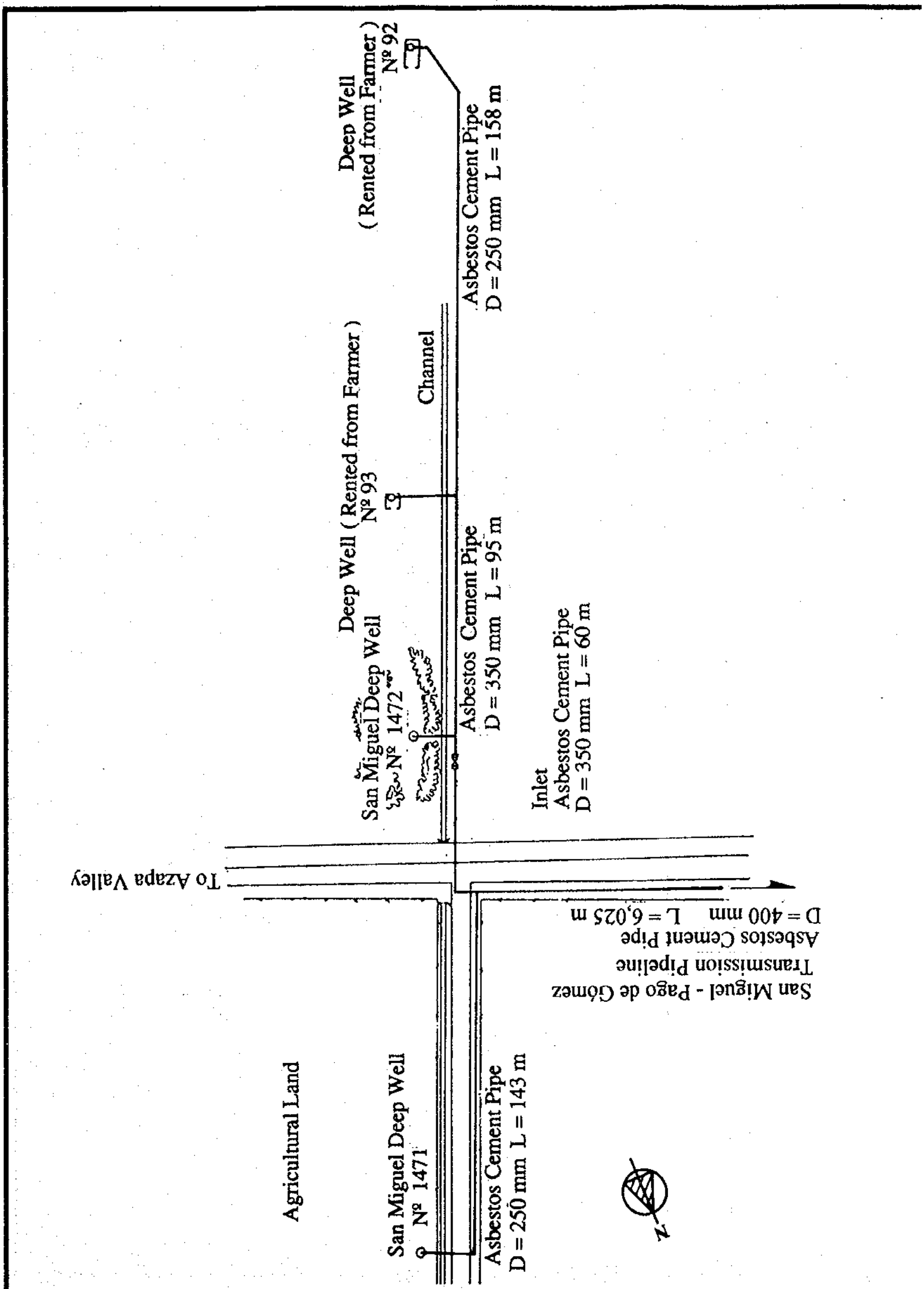

Fig. D-I, 1.3 San Miguel Well Field - Arica

< Area de Pozos San Miguel - Arica >

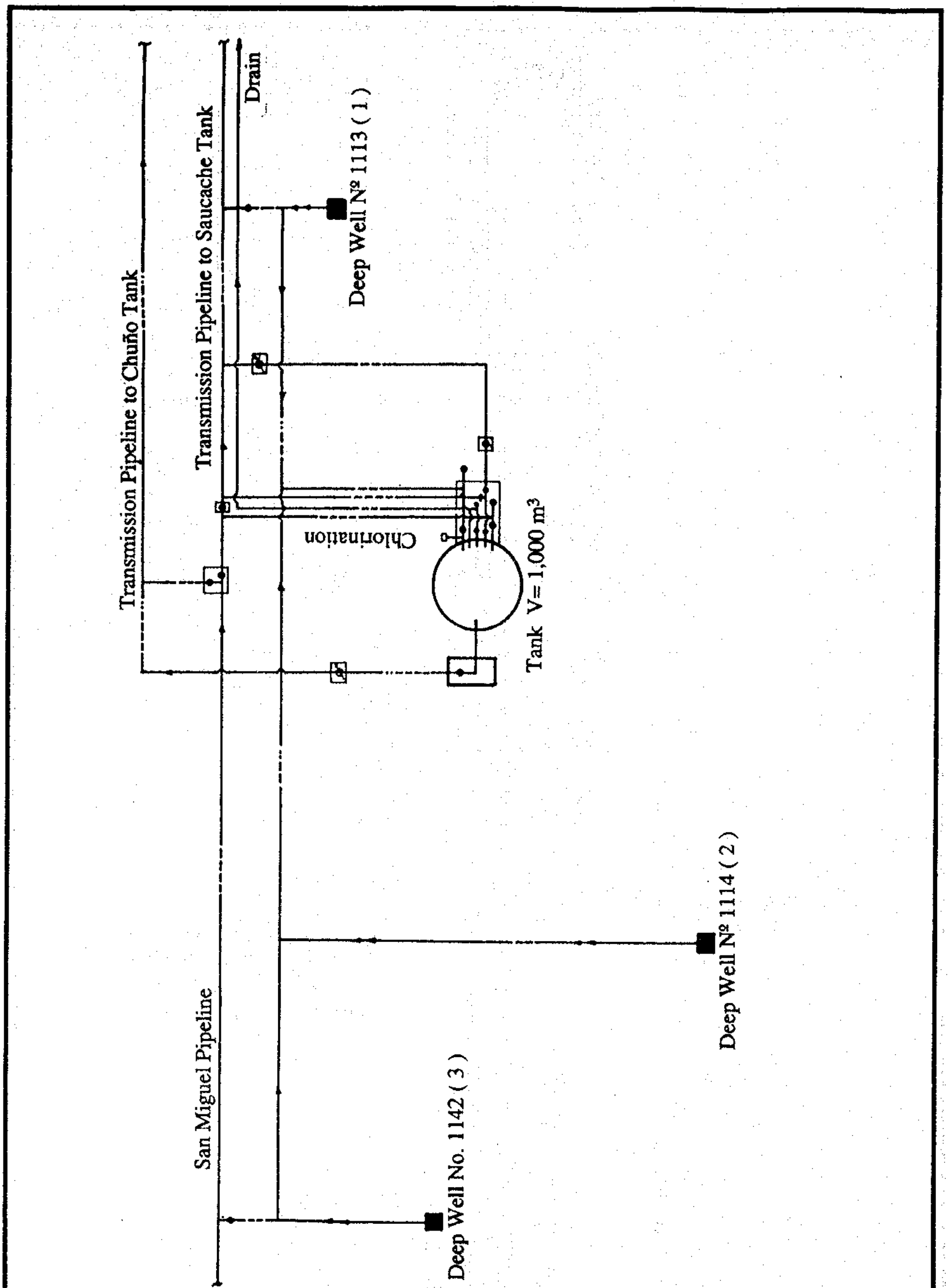

Fig. D-I, 1.4 Pago de Gomez Plant Layout - Arica

< Distribución Planta Pago de Gómez - Arica >

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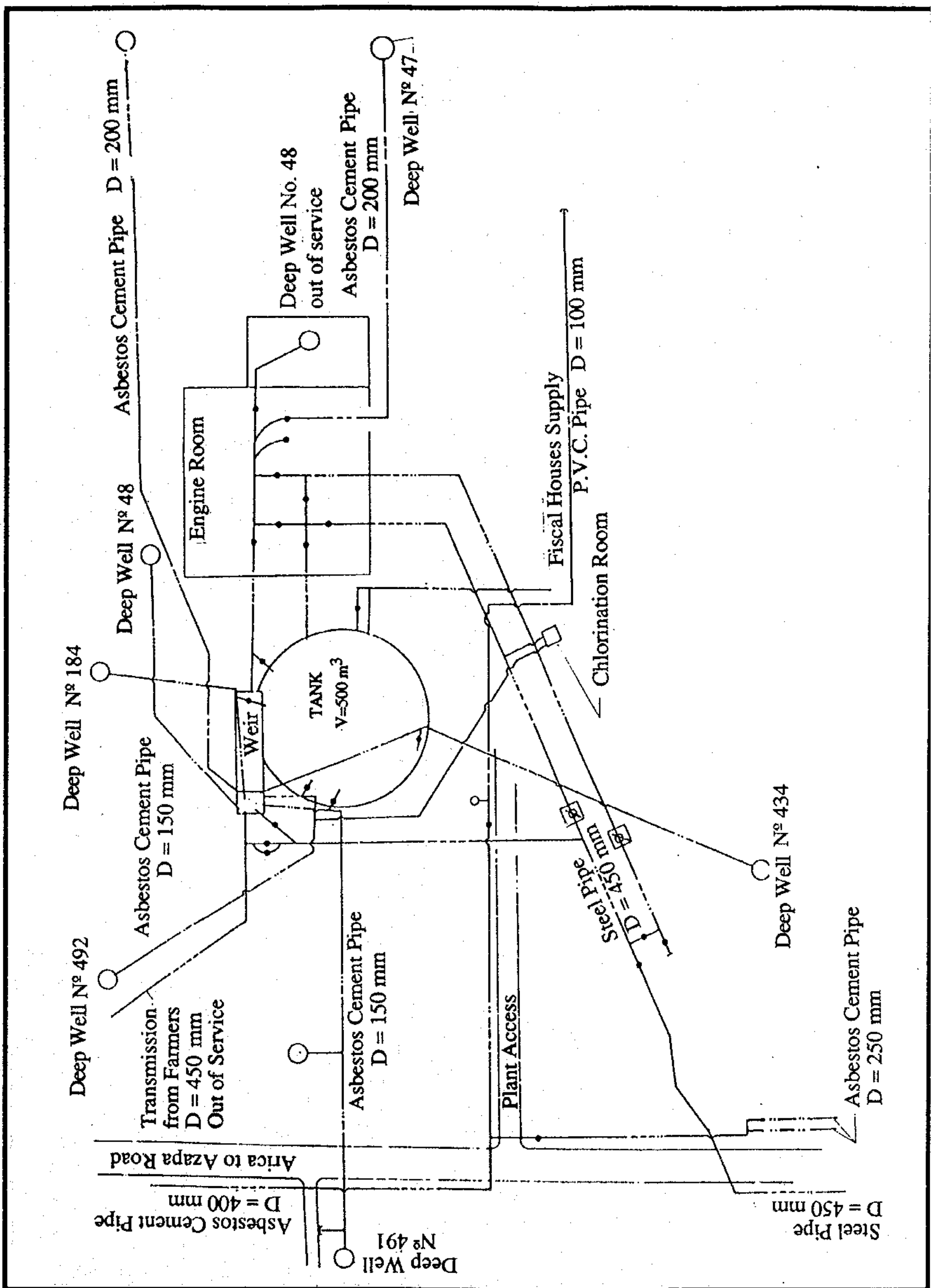

Fig. D-I, 1.5 Azapa Plant Layout - Arica

< Distribución Planta Azapa- Arica >

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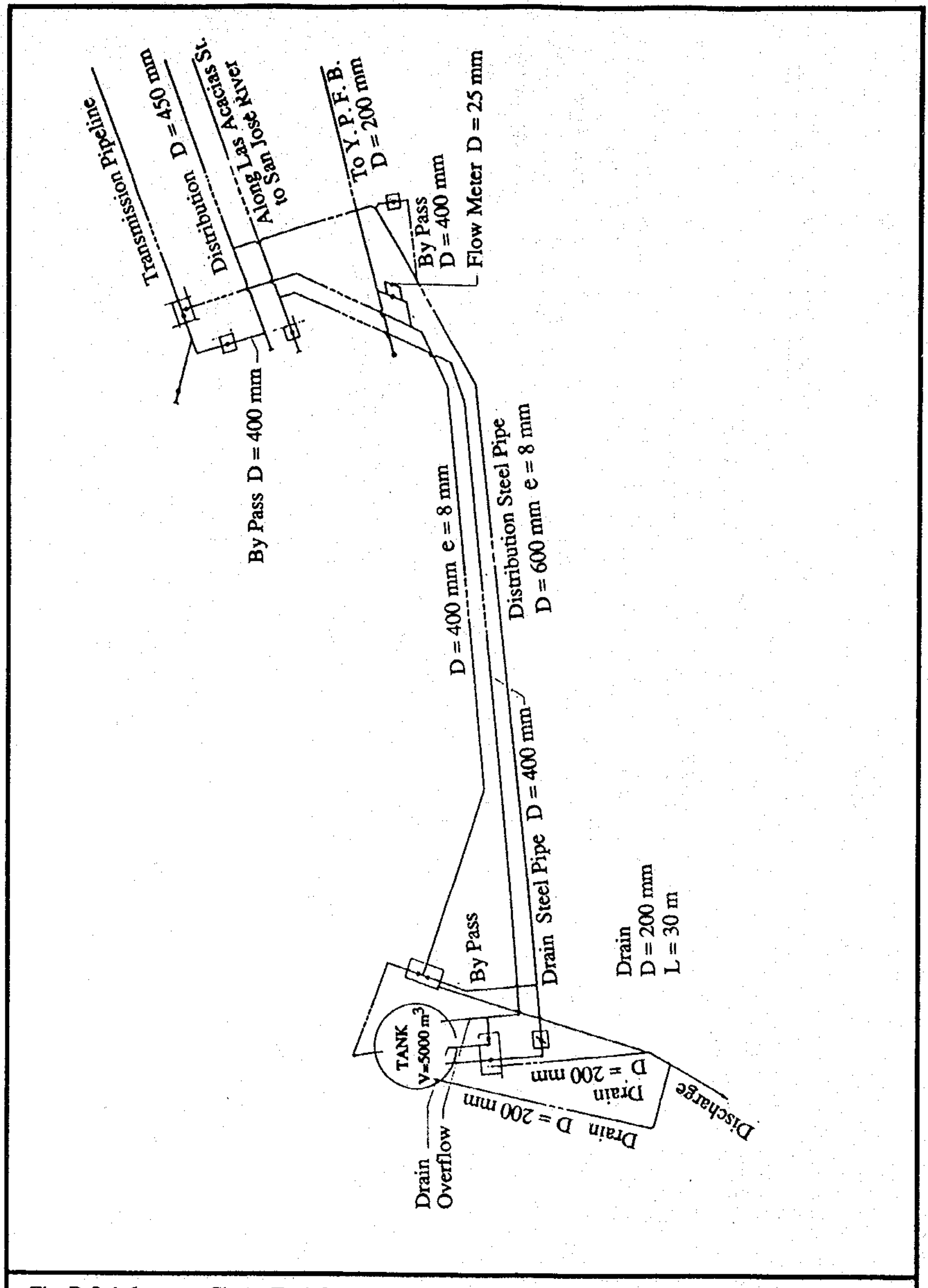

Fig. D-I, 1.6 Chuño Tank Layout - Arica

< Distribución Estanque Chuño -Arica >

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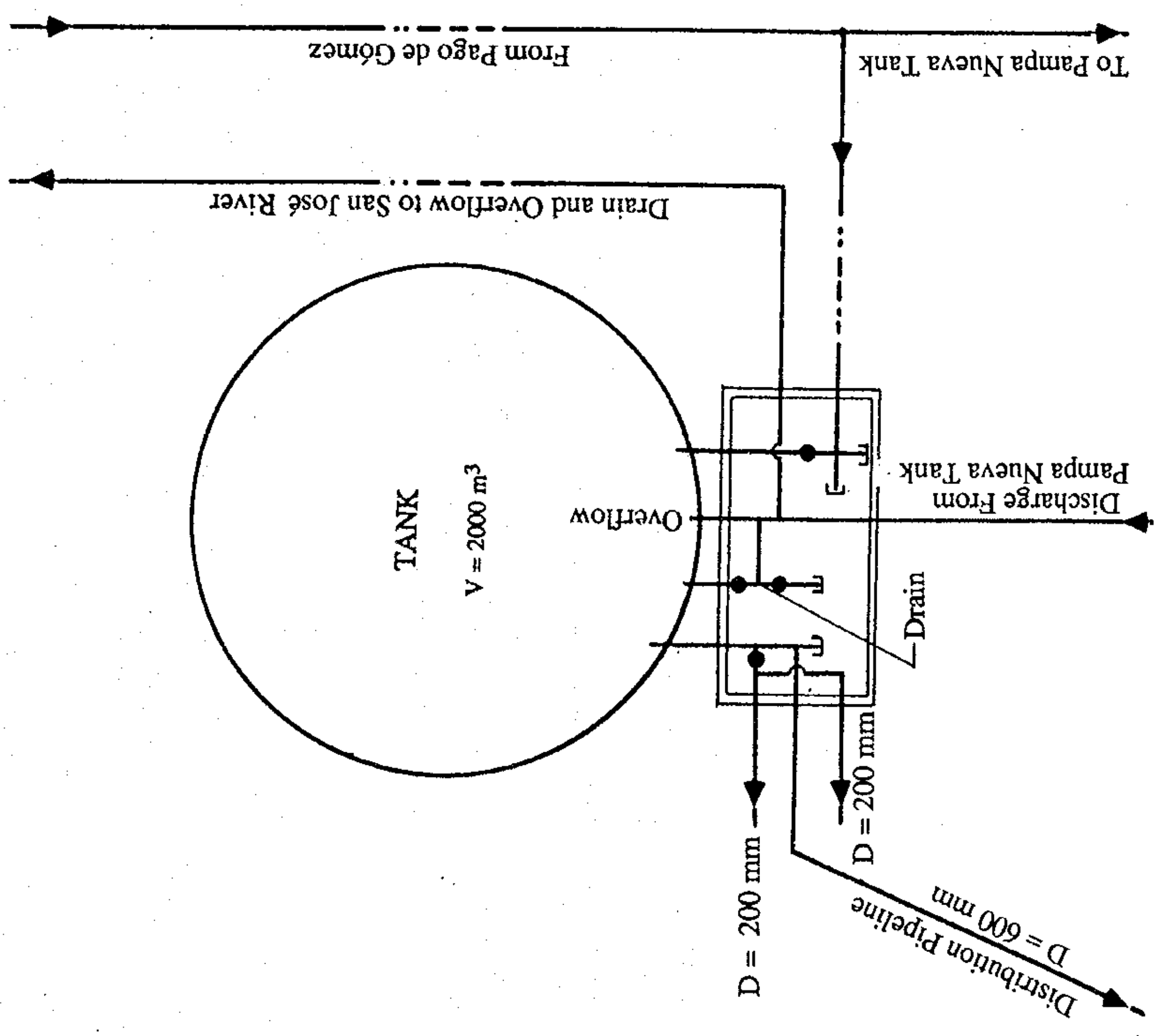

Fig. D-I, 1.7 Saucache Tank Layout - Arica

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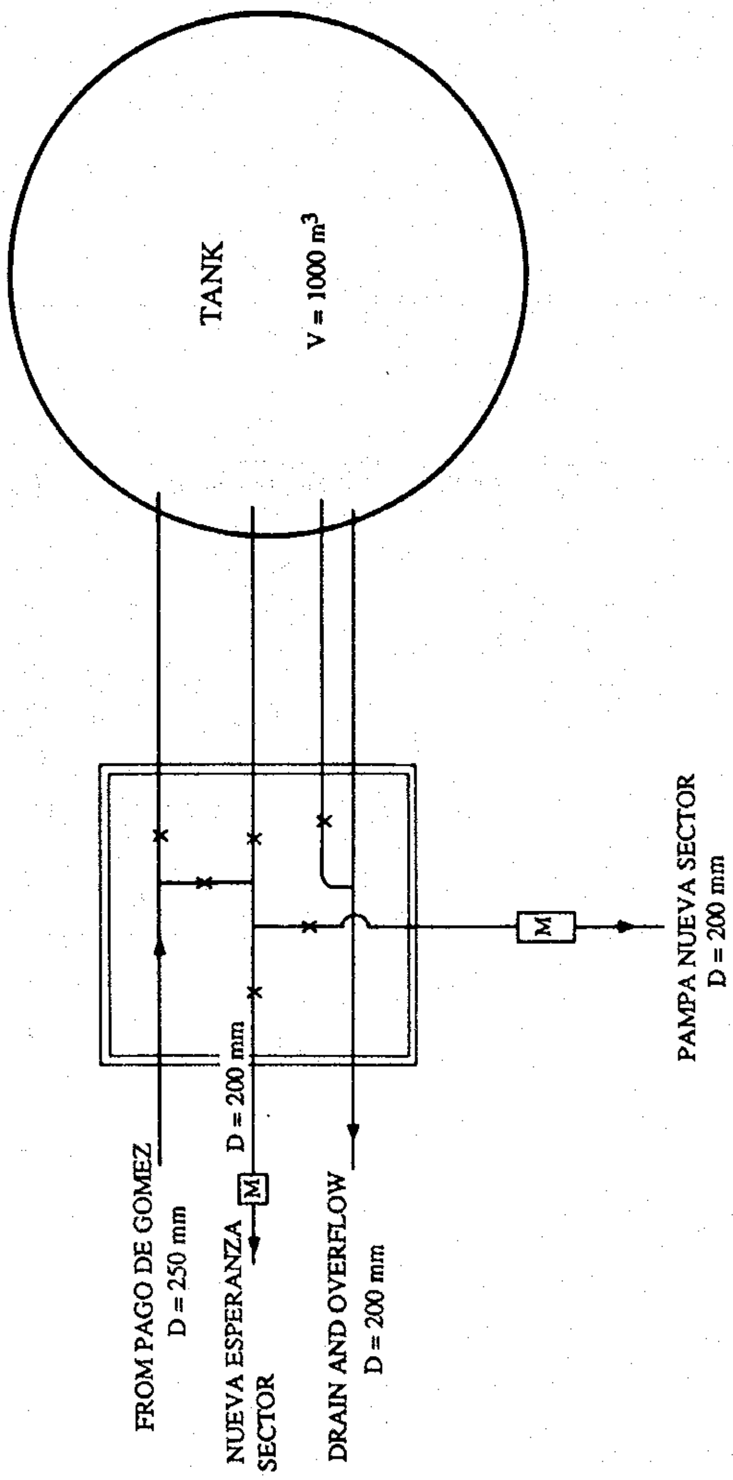

Fig. D-I, 1.8 Pampa Nueva Tank Layout - Arica

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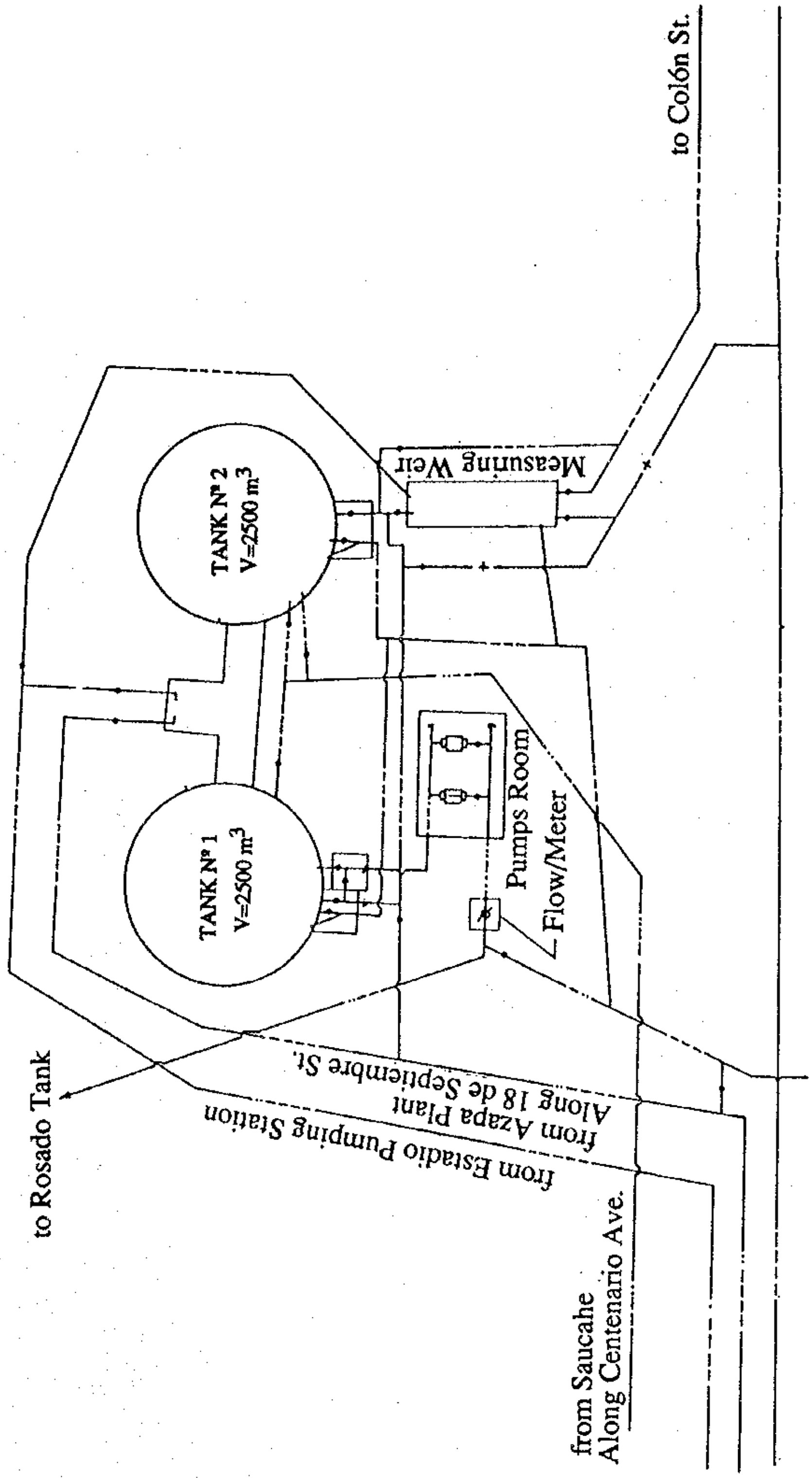

Fig. D-I, 1.9 La Cruz Tank Layout - Arica

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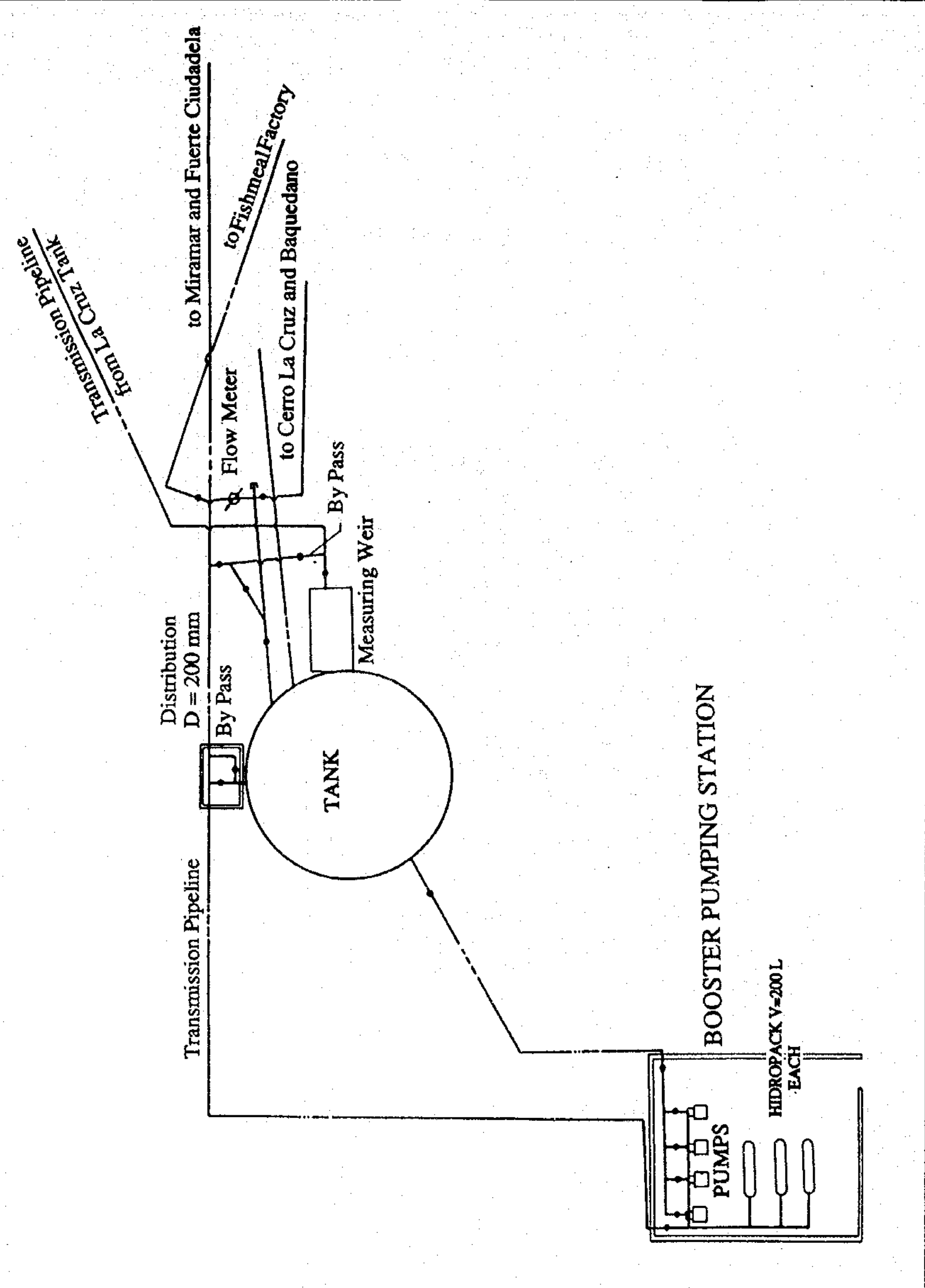

Fig. D-I, 1.10 Rosado Tank Layout - Arica

< Distribución Estanque Rosado - Arica >

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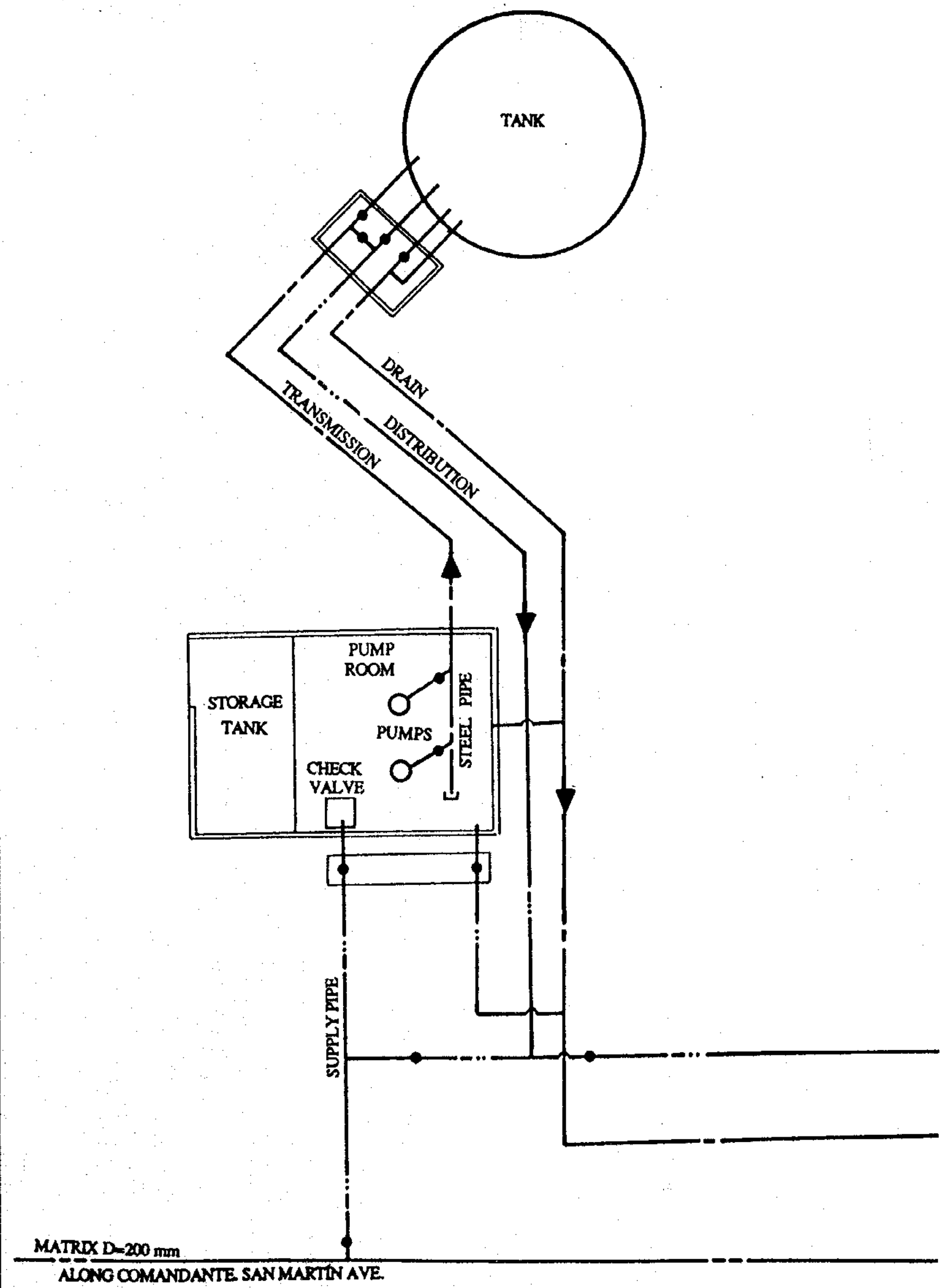


Fig. D-I, 1.11 La Lisera Tank Layout - Arica

< Distribución Estanque La Lisera- Arica >

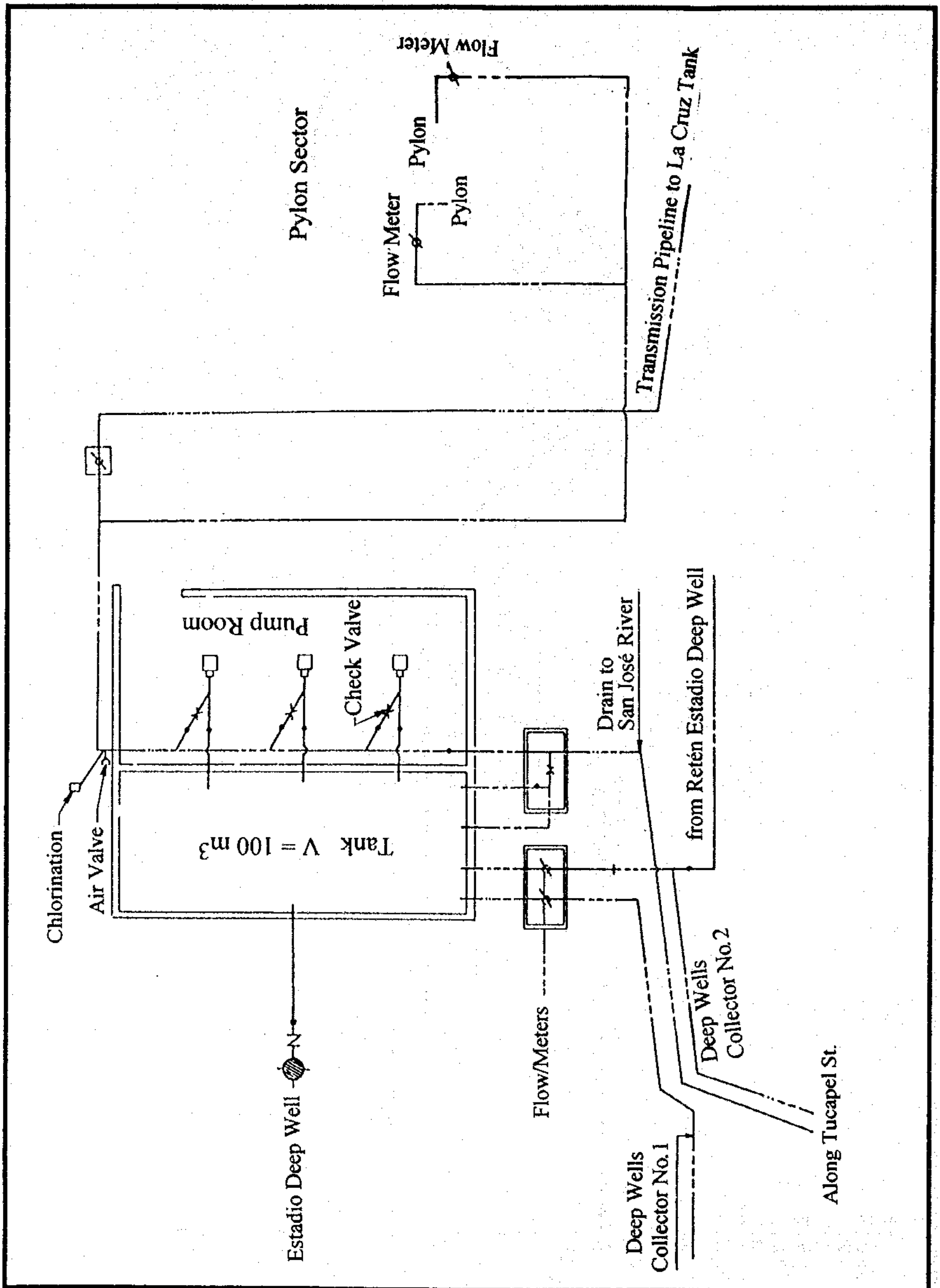


Fig. D-I, 1.12 Estadio Station Layout - Arica

< Distribución Estación Estadio- Arica >

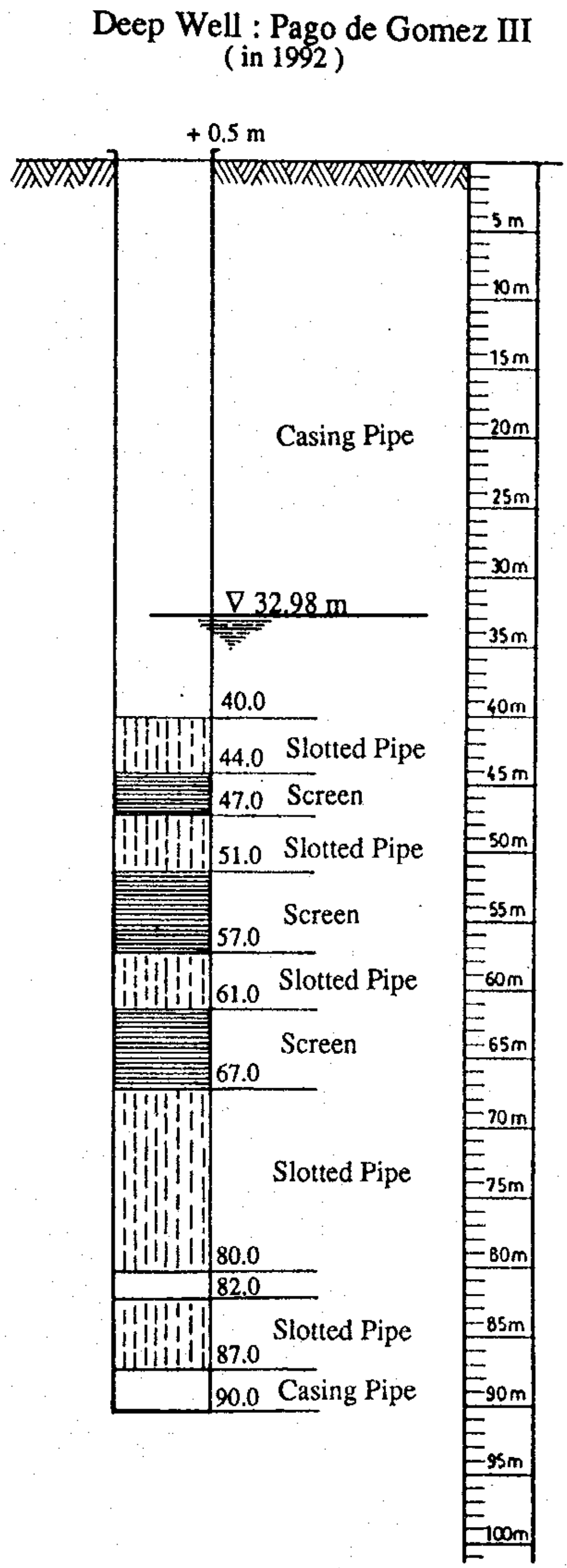
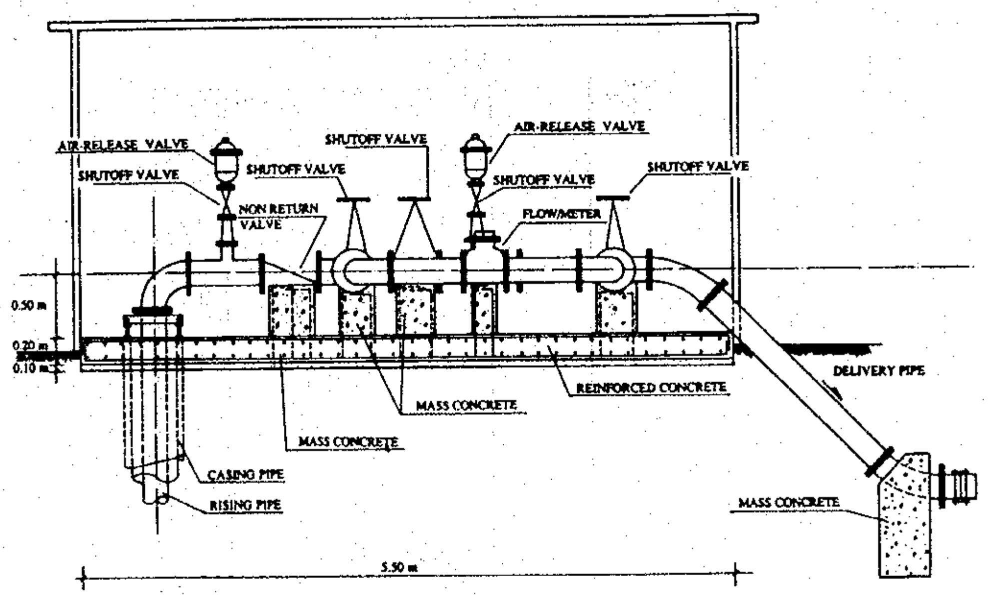
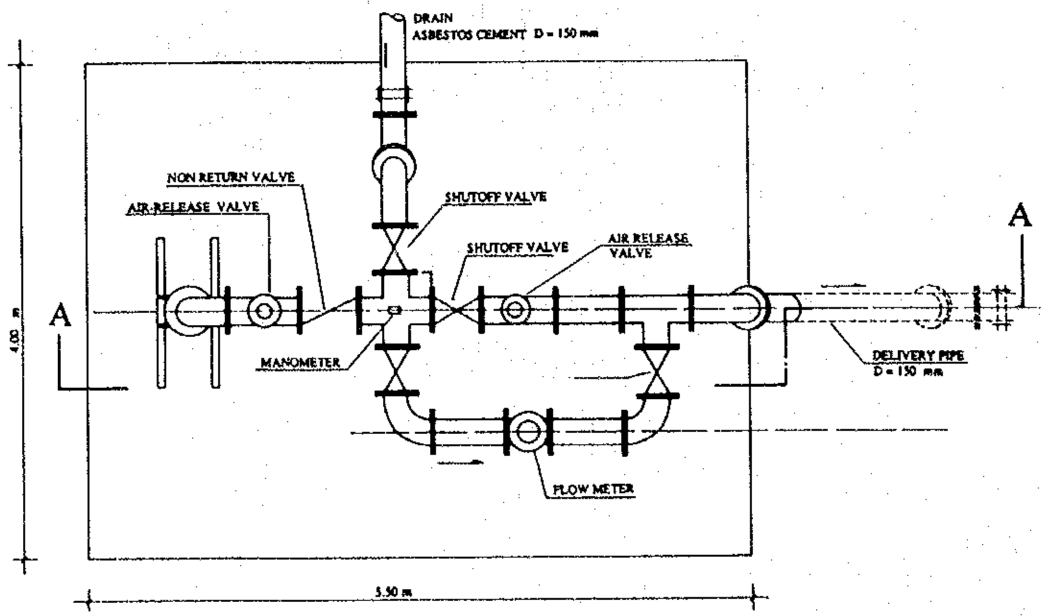


Fig. D-I, 1.13 Typical Existing Well Structure - Arica

< Estructura Típica de Pozo Existente - Arica >



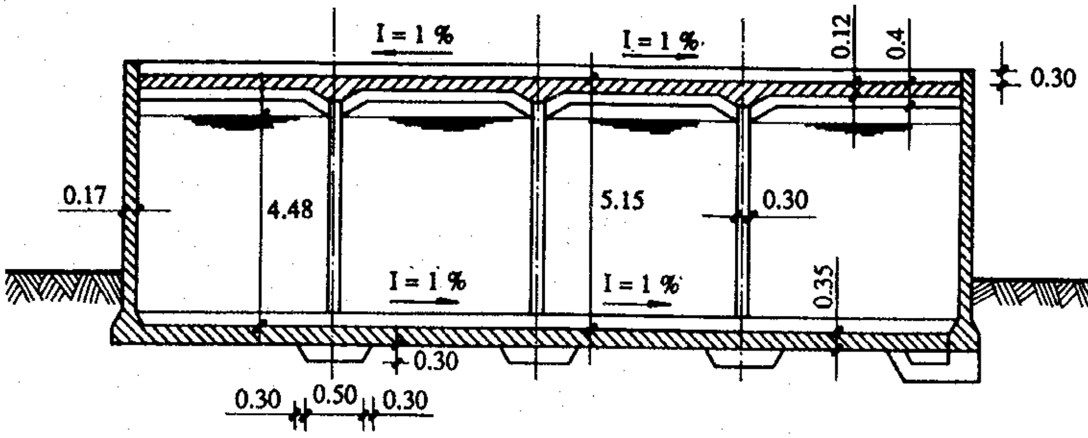
SECTIONAL ELEVATION A - A



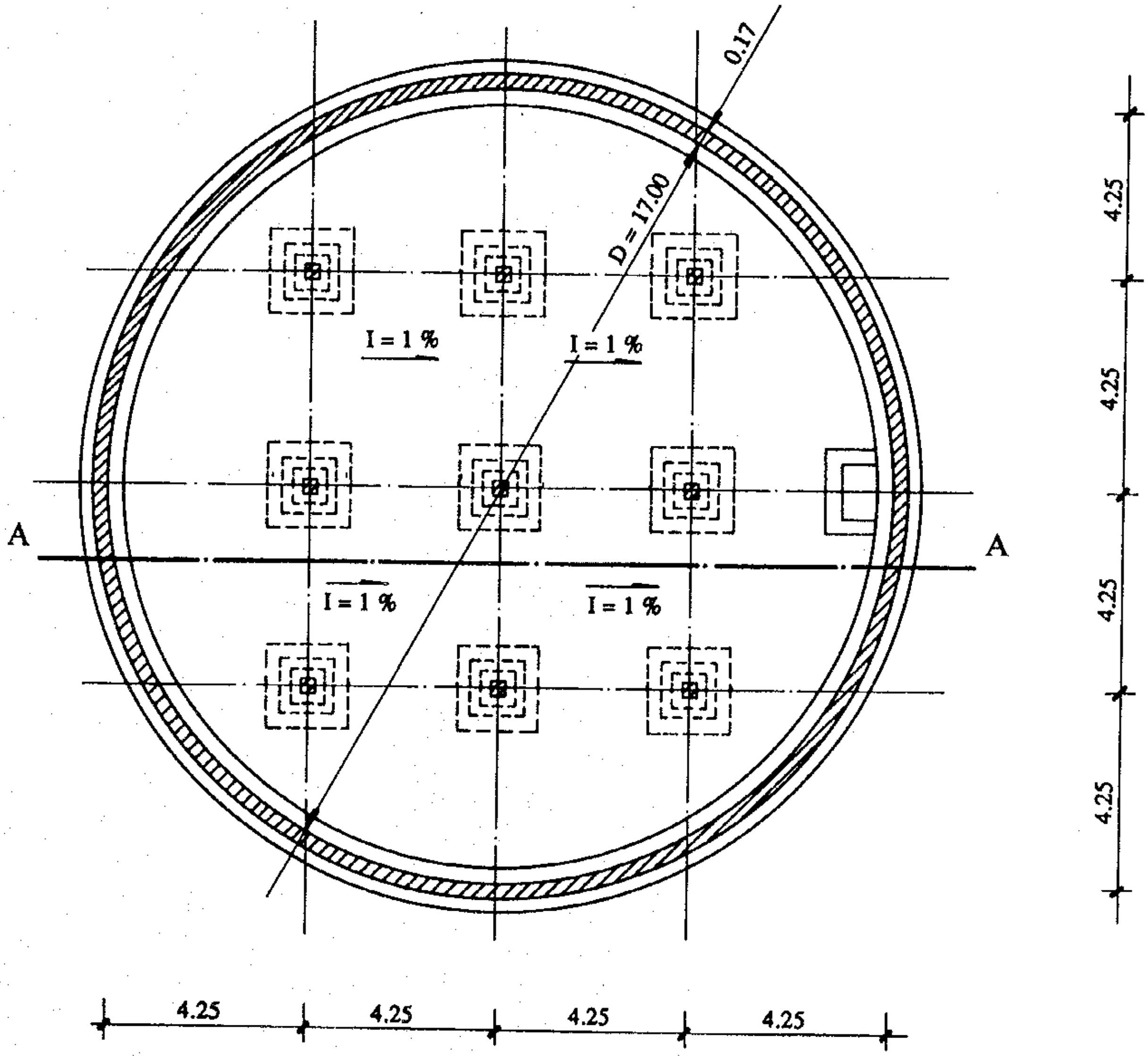
PLAN

Fig. D-I, 1.14 Typical Intake Pump House - Arica

< Caseta Típica de Bomba de Captación - Arica >



SECTIONAL ELEVATION A - A



FLOOR PLAN

Fig. D-I, 1.15 Concrete Tank Structure Standard (V= 1,000 m³)

< Estructura Estándar de Estanque Concreto (V= 1,000 m³) >

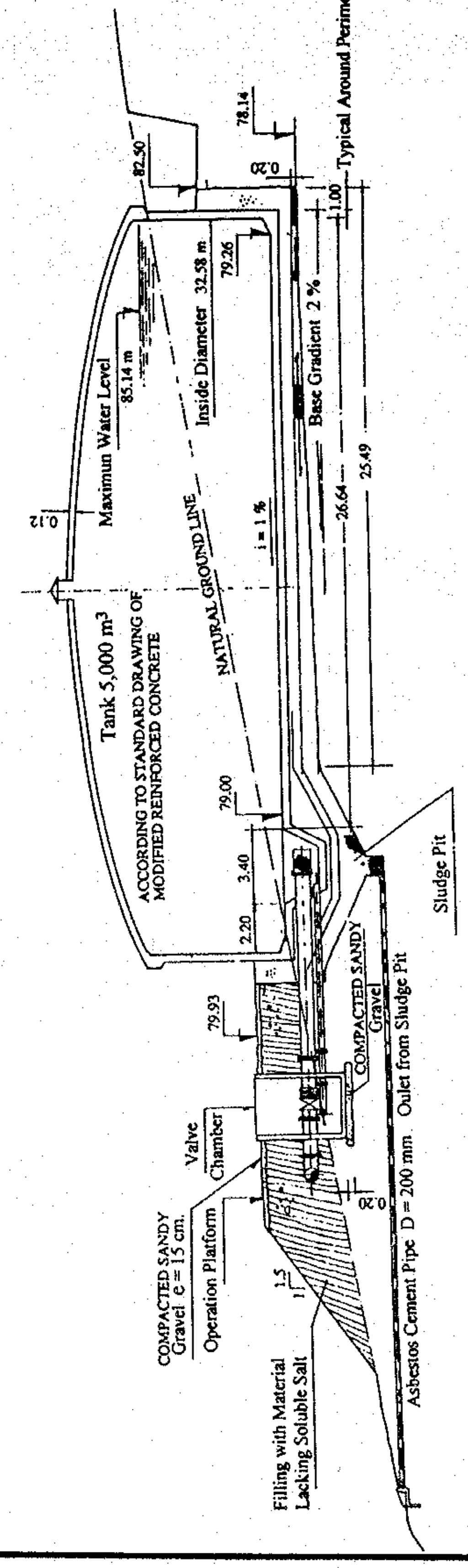


Fig. D-I, 1.16 Chuño Tank Structure (V = 5,000 m³) - Arica

< Estructura del Estanque Chuño (V = 5.000 m³) - Arica >

References

<1: "Analisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca S.A": Prefactibilidad. Book I: Informacion Basica - Ciudad de Arica. By Bustamante y Schudeck, Ingenieros Consultores Ltda., March 1992.

<2: "Analisis Programa de Desarrollo de Empresa de Servicios Sanitarios de Tarapaca S.A": Prefactibilidad. Book II: Definicion Proyecto Inversion - Ciudad de Arica. By Bustamante y Schudeck, Ingenieros Consultores Ltda., March 1992.

Chapter II. SUPPLY AND DEMAND BALANCE

2.1 Future Water Demand

According to the forecast of future population and the projection of future water demand, the following figures of water production demand are estimated for the Arica City. (See the Supporting Report C "Water Use" for detail.)

- For the year 2005, a production capacity of 840 l/sec on the daily average basis (= 1,092 l/sec on the daily maximum)

and,

- For the year 2015, a production capacity of 1,091 l/sec on the daily average basis (= 1,419 l/sec on the daily maximum).

(Note): Daily Maximum Demand = 130% of Daily Average Demand

2.2 Supply Capacity and the Balance

The authorized capacity was 503 l/sec in the year 1992, hence the deficit, the capacity to be added to the existing capacity will be as follows:

- For the year 2005:

  The deficit = 1,092 - 503 = 589 l/sec (Daily maximum),

and,

- For the year 2015:

  The deficit = 1,419 - 503 = 916 l/sec (Daily maximum)

(Refer to Table D-I, 2.1 and Fig. D-I, 2.1.)

Table D-I, 2.1 Water Demand Projection for Arica

(Unit: l/sec)

	Year	1995	2000	2005	2010	2015
	Target			Short-Term		Long-Term
(A)	Daily Average Production Demand	779	797	840	959	1,091
(B)	Daily Maximum Production Demand	1,013	1,036	1,092	1,247	1,419
(C)	Existing Production Capacity as of 1992	503	503	503	503	503
(D)	Deficit (Capacity to be Added to 1992 Capacity)	510	533	589	744	916

(Note): (A) From the report of "Water Use" (Supporting Report "C" / JICA)

(B) Criteria:
(Daily Average) : (Daily Maximum) = 1.00 : 1.30
(B) = (A) x 130%

(C) Existing capacity: 503 l/s
Additional capacity by Emergency Project is considered as a temporary one.

(D) = (B)-(C)

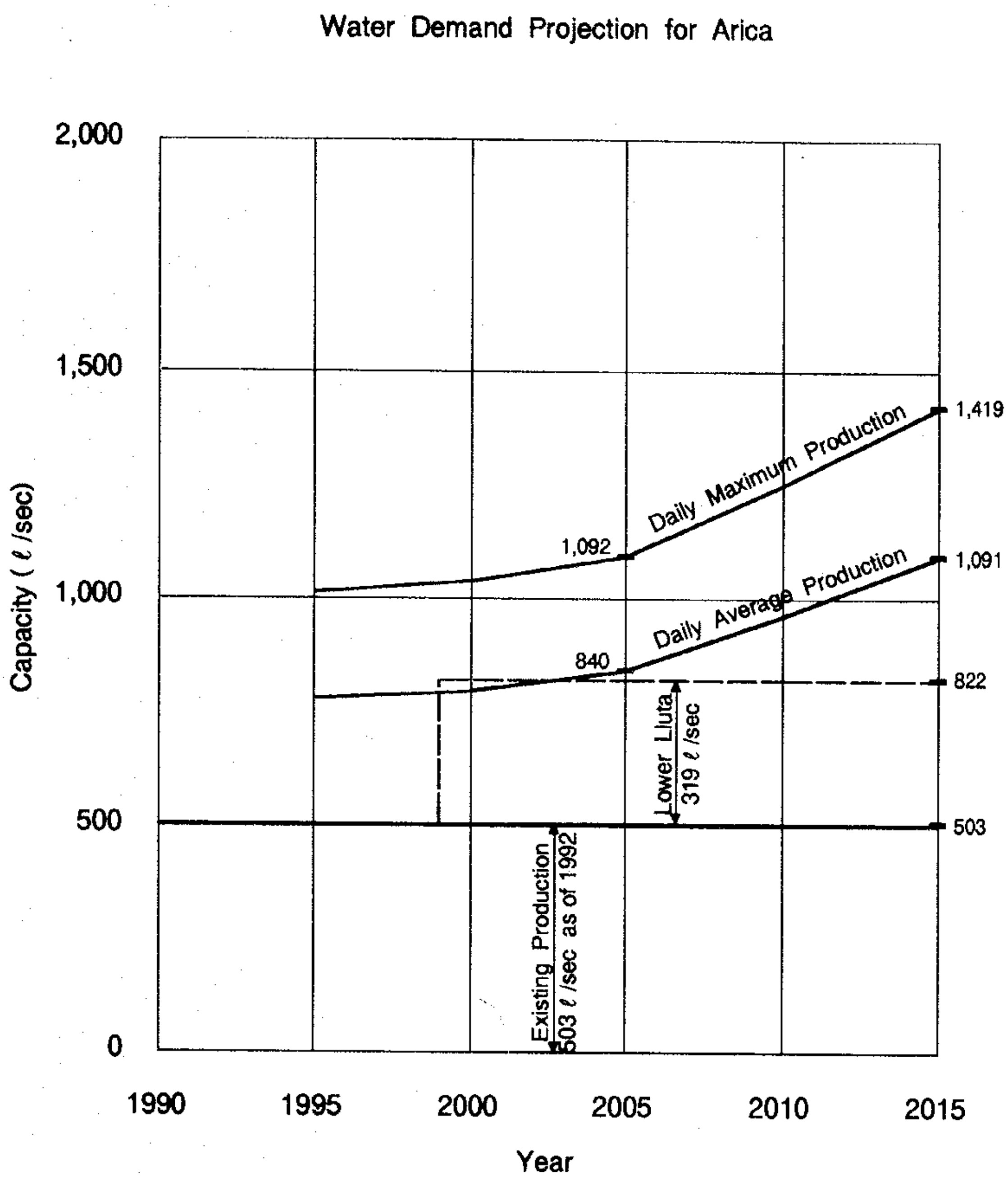


Fig. D-I, 2.1 Water Demand Projection for Arica

< Proyeccio'n de Demanda de Agua para Arica >

Chapter III. DEVELOPMENT PLAN

3.1 Water Source and Development Capacity

The short-term goal is to develop the water resources to meet the water demand until the year 2005. The water production requirement in the year 2005 is estimated to be 1,092 l/sec on the daily maximum basis (840 l/sec on the daily average basis), and the long-term target is to produce water at a rate of 1,419 l/sec on the daily maximum basis (1,091 l/sec on the daily average basis) by the year 2015. The required additional production capacity in future is shown in Table D-I, 3.1.

According to the field investigations, the number of potential water sources in the surrounding area are very limited. The groundwater submerged in the downstream areas of the Lluta river (Lower Lluta Valley) has been identified as a potential water source. However, this source is not sufficient to meet even the short-term (Year 2005) water intake requirement. Although the water intake capacity is large enough to meet the year 2005 water demand, the rate of water production is reduced due to dissolved salts present in the water. The proposed treatment process produces wastewater quantity equivalent to 25% of the intake capacity. Therefore, the supply is adequate to meet the water intake requirement until the year 2003. Due to the scarcity of water, it is decided to develop this water source to meet the immediate water demand of the Arica city. However, as the demand increases with time, more field investigations shall be carried out, in order to find suitable sources to meet the future demand.

The field investigations revealed that the maximum water extraction capacity from the above source is 552.5 l/sec on the daily maximum basis, or 425 l/sec on the daily average basis. It is proposed to construct 26 deep wells (including 3 wells on standby) with a depth of 150 m or 120 m, at 500 m apart, along the Highway No.11, to extract groundwater. The first well (No.1) is located approx. 3,600 m away from the intersection of Highways No.5 (Pan-American Highway) and No.11. The wells are equipped with submersible pumps with an average discharge capacity of 25 l/sec and the pump head of 54-88 m. The Fig. D-I, 3.1 shows the location of the proposed well field. The typical deep well structure is shown in Fig. D-I, 3.4.

3.2 Transmission Facilities

3.2.1 Pipelines

The wells are located on a gradually sloping terrain, along the road, and the elevation difference between the furthest well (No.26: GL=+347 m) and the Lluta Treatment Plant

(GL+131 m) is not so extremely high, 216 m. Therefore, asbestos cement pipes (ACP) can be used for the raw water transmission pipeline, if break-pressure tanks are provided. The water flow in the transmission pipelines is by gravity. The diameters vary from 150 to 500 mm.

The hydraulic calculations for the transmission pipeline are given in the Table D-I, 3.2 and Fig. D-I,3.2. The longitudinal profile of the transmission pipeline is shown in Fig. D-I, 3.3.

The specification for the submersible pumps are given in Table D-I, 3.3.

The pipes will be laid in trenches with a 1.2 m distance from the ground level to the top of the pipe surface. The pipes will rest on a 200 mm thick sand bed and will be covered with sand 300 mm above top of the pipe. Fig. D-I, 3.5 show cross-sections of typical pipe trenches. The pipe bridge of the transmission pipeline is shown in Fig. D-I, 3.8.

3.2.2 Break-Pressure Tanks

There are four (4) break-pressure tanks located along the pipeline, between the wells, at strategically important locations. The tanks are located at chainages L= 0 m (near the Well No.26), L= 3,000 m (near the well No.20), L= 5,500 m (near the Well No.15) and at L= 8,500 m (near the Well No.9). The tanks are made of concrete and are designed to have 10 minutes' detention time. The tanks are designed to serve as water collection tanks as well as break pressure tanks. The specifications and standard design of the tanks are shown in Fig. 3.6 and Fig. 3.7 respectively.

3.3 Water Quality and Treatment

The Lower Lluta groundwater contains substantially high concentrations of TDS (total dissolved solids). The level of Boron (B) is also high, although the Chilean Drinking Water Standards NCH 409 does not specify the allowable limits of Boron (B) in drinking water.

As the raw water contains high concentrations of TDS, a desalination plant is required to be constructed to reduce the TDS contents to an acceptable level. The desalination process shall also be capable of removing about 75-80% of Boron present in water. Location of the new treatment plant is recommended to be at Well No.1 site, along the Highway No. 11, at the ground elevation of +131 m above MSL (See, Fig. D-I, 3.9).

Following desalination techniques are considered for treating the raw water:

- Reverse Osmosis (RO)

or,

- Electrodialysis Reversal (EDR)

The final selection of the desalination technique, will depend on the cost for installation and operation and maintenance, of the treatment plant. (See Appendix-2)

However, there is no experience of the treatment of such brackish water with a high content of Boron as the groundwater of Lower Lluta Valley in actual potable water supply. Therefore, the groundwater of Lower Lluta Valley was experimentally treated in this Study. The experiment was conducted by using a small-scale RO treatment with a cooperation of ESSAT in Arica during August to September 1994. The results are summarized below.

	TDS	Na	SO4	Cl	Fe	B
Raw Water (mg/l)	3,438	565	1,018	929	0.12	22
Treated Water (mg/l)	43	8.7	2.5	14	0.02	4.5
Treatment Efficiency (%)	99	98	99	98	82	79
Permissible Limit (mg/l)	1,000	200	250	250	0.3	5.0

In the above test, the recovery efficiency was 76.2% under the pump pressure of 20 kg/cm^2.

As evident from the above table, RO method is effective for the treatment of the groundwater of Lower Lluta Valley. Boron is considered the most critical water quality element for the treatment. Therefore, RO method is adopted in this Study.

For details of the experiment, see Appendix 5.

The calculation of the equipment capacity of the treatment plant is shown in Table D-I, 3.4. The flow diagram and layout of the proposed treatment plant are shown in Fig. D-I, 3.10 to Fig. D-I, 3.13.

A high quantity of wastewater, about 25% of the intake capacity (552.5 l/sec x 25% = 11,900 m^3/day), will be produced during the desalination process.

It is proposed to discharge wastewater directly into the sea, through an exclusive drain pipeline by gravity, from the Lluta Treatment Plant.