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THE LIMARI-PALOMA WATER SYSTEM: CASE STUDY IN CHILE */

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Summary

The main objective of this study is to assess the efficiency with which water resources are used in the irrigation subsector in a given area.

In this analysis, the main emphasis has been on measuring or estimating certain quantitative elements which make it possible to interpret or forecast some of the implications or results of institutional efficiency —public, private and mixed— in the management of water resources.

Because of the need to scale down the ambitious objective mentioned above, the study has been limited to a single watershed.

The Limarí River basin was chosen for this study because its area has been clearly defined, for physical and administrative purposes, so as to coincide with the boundaries of Limarí province; also, quite fortunately, there are in this area three reservoirs, each with a different administration, which, taken together, represent the greatest capacity for storage of irrigation water in the country. In addition, there are other users of water resources in the basin, namely, the water supply system of the city of Ovalle, the Los Molles hydroelectric power plant, and the mining and industrial sectors.

I. INTRODUCTION

The case study begins with a description of the area under study, including its geographical, administrative, institutional, physical, demographic, urban, economic and social characteristics.

One of the most important elements of information has to do with the supply of water resources and their utilization, which is facilitated by the existence of large-scale irrigation infrastructures in the basin. Demand is represented by the traditional user sectors, such as agriculture, hydroelectric power generation, drinking water system, mining, industry and tourism.

Special attention has been given to the administration, organization, financing and co-ordination of the subsystems, partly because they influence results and partly because, in the case at hand, these parameters are easily observable. It should be mentioned that the Limarí basin is made up of three sub-basins, each one with a reservoir --Paloma, Recoleta and Cogotí-- the resource of which can be combined in order to irrigate some common areas of influence. In addition, there are many different owners, both public and private, who apply different management schemes.

All this makes the Limarí-Paloma water system an interesting subject of analysis. Hence, it is well worthwhile to devote some effort towards evaluating the efficiency and productivity of the work being done there.

II. DESCRIPTION OF THE AREA UNDER STUDY

1. Geographical location and administration

The Limarí River basin, which is the subject of this study, is located between latitudes 30°15' and 31°25'; it borders on the Elqui River watershed, to the north, and the Choapa River watershed, on the south.

The area covered by this basin generally falls within the boundaries of the province of Limarí; this greatly simplifies the analysis of the political and administrative aspects involved. It also means that statistical data are more readily available.

The provincial capital is Ovalle, the only major city in the area, and the center of administrative, sanitary and educational services, as well as of commercial, social and cultural activities in the area. Ovalle is located 385 km north of Santiago; of this distance, 352 km are covered by the Pan American Highway and the remaining 33 km by a well-kept-up secondary road. Another paved road, 86 km long, links Ovalle to La Serena, the capital of the Fourth Region, to which the province of Limarí belongs. Other fairly good roads connect Ovalle with towns in the interior of the province, such as Montepatria, Punitaqui and Combarbalá. In general, the road system is adequate and allows for communication among the towns and the farmlands within the basin. Thus, the area under study has connections to the national and regional capitals, the rest of the country, the Tongoy tourism center, and Coquimbo, a port from which fresh fruits produced in the province are exported to the United States.

The area under study is more or less rectangular in shape. It borders with the Andes mountain range on the east and with the Pacific Ocean on the west. It covers a total area of 13 461.4 km2.

Administratively, it is divided into the comunas (municipal districts) of Ovalle, Río Hurtado, Montepatria, Combarbalá and Punitaqui.

2. Physical features

For the purposes of this study, we shall consider the following parameters: annual rainfall, climate, soil, topography and vegetation. These are summarized below:

a) Annual rainfall

Rainfall varies according to season and specific location; it also varies over the years.

Precipitation occurs mainly from May to August; sometimes, and on a lesser scale, it rains in April and September. Table 1 shows the average rainfall in recent years. It will be noted that there is little precipitation in the intermediate zone and more in the foothills of the Andes.

Table 1

AVERAGE ANNUAL RAINFALL

Pluviometric station	Average annual precipitation (mm)	Altitude of station (meters above sea level)
Ovalle	114	220
Paloma	146	342
Caren	193	924
Tulahuen	204	1 239
Las Ramadas	232	2 056

Source: Irrigation Bureau.

The above data show, in the first place, that the area under study is quite arid, so that crops can only be grown under artificial irrigation, in riverbeds, on gentle slopes, and on terraces in the western section. In the second place, it may be seen that the existing reservoirs must also be used to regulate the availability of water from one year to another --by keeping surplus rain water in reserve for dry periods--, in addition to fulfilling the usual function of regulating the delivery of water within a given year.

b) Climate

Basically, the area has a desert climate, with the predominant feature being the aridity mentioned above. There are three main climatic zones: the coastal zone, about 15 km wide, which is very cloudy; the intermediate zone, starting from the edge of the coastal zone and extending to a few kilometers upstream from the reservoirs, which has a temperate climate; and the foothill zone, which is very cold.

Average temperatures in Ovalle are 20°C in summer and 11°C in winter. The extreme temperatures are: 30°C, the maximum mean; 9.8°C the minimum mean, in summer; and 24°C and 3.8°C, the maximum and minimum means in winter. In Montepatria, where extreme environmental temperatures are also measured, these have been found to be 34.3°C in February and 3.8°C in July.

The same stations have recorded average humidities of 54% in December, 77% in July and 46% in February.

Other important climatic parameters are the high levels of cloudiness and fogginess in the coastal zone, especially in the spring and autumn, and the severe freezing which occurs frequently in the foothill area. These circumstances affect soil use.

c) Soils

The soils are of alluvial origin, and have been classified as suitable for agriculture. They are thick in texture, and have a high content of salts, especially carbonates, sulphates and chlorides, and a low content of organic matter. The main limitations are the irregular terrain and its extreme rockiness.

d) Topography

The eastern edge of the area under study has altitudes of over 3 000 m above sea level, and has rocky, steep and narrow valleys which are cut through by torrential rivers.

Towards the west, altitudes are lower and the mountains separate, opening up into the small "interior" valleys which are characteristic of the foothills.

Further downstream, these valleys widen into small basins with gentler slopes, leading into the intermediate zone of plains and terraces, where the city of Ovalle is located. This zone consists of a plain which was originally a riverbed, measuring between 10 and 35 km in width; it is cut through by the Limarí River, which flows 90 m below the plain.

The coastal zone is similar to the intermediate zone, with terraces on both sides of the river, sloping down to the sea where the terrain is uneven.

The plains and terraces mentioned above are in use as farmland, and are watered by the rivers and canals mentioned later on in this report.

e) Vegetation

The vegetation in the coastal, or western, zone and in the intermediate zone is typical steppe or semidesert vegetation, consisting of brush, which grows higher and in greater density near the waterways. The foothill area and the interior valleys, on the other hand, have the unique characteristics of xeromorphic areas.

3. Urban and demographic aspects

The population of the area under study is concentrated mainly in Ovalle, the only densely populated community of the province, where 58% of the total population live. Of this population, 68.5% is urban, representing 74.6% of the urban population of the region. The rural population represents 46.8% of the total population (see table 2).

The average population growth rate of 1.16% per year is similar to the national average and reflects normal demographic development. The comunas of Combarbalá, Ovalle and Montepatria, located in the intermediate zone, have the highest population growth rates; this can easily be explained by the better terrain, climate and soils of these lands. There has also been a slight exodus

Table 2

LIMARI PROVINCE: DISTRIBUTION OF THE POPULATION

Comunas	Units	Total (1980)		Urban	Rural	Area	Density	Estimated total 1985		Annual
		Population	%	(1982)	(1982)	(km2)	(pop/km2)	Population	%	rate %
Total	Population	125 523	100.0	66 782	58 741	13 461	9.3	129 925	100.0	1.16
	Percentages	100.0	-	53.2	46.8					
Ovalle	Population	2 762	58.0	49 811	22 951	3 874	18.8	75 616	58.2	1.29
	Percentages	100.0	-	68.5	31.5					
Río Hurtado	Population	4 789	3.8	1 157	3 632	2 096	2.3	4 876	3.7	0.60
	Percentages	100.0	-	24.2	75.8					
Montepatria	Population	26 273	20.9	9 377	16 896	4 323	6.1	27 129	20.9	1.07
	Percentages	100.0	-	35.7	64.3					
Combarbalá	Population	12 083	9.6	4 853	7 230	1 858	6.5	12 707	9.8	1.69
	Percentages	100.0	-	40.2	59.8					
Punitaqui	Population	9 616	7.7	1 584	8 032	1 310	7.3	9 597	7.4	-0.07
	Percentages	100.0	-	16.5	83.5					

Source: Instituto Nacional de Estadísticas, Censo de 1982 and Síntesis estadísticas de la Cuarta Región, INEC/SERPLAC, 1985.

from rural areas to the cities. The comuna of Río Hurtado, with only 2.3 inhabitants per km2, is in the higher part of the basin, i.e., in the foothills, and has less potential for agricultural development. Finally, the population of the coastal comuna of Punitaqui, where mining and truck farming are the main activities, is declining because of the declining potential of the existing natural resources; this explains the migration to Ovalle.

4. Economic and social aspects

In the coastal zone, the high humidity and frequent fogs have made farming very difficult, and only a few vegetable crops, such as tomatoes and pimentos, have been successful. Small-scale copper and silver mining is also important, although not so much as in previous years, because of the increase in operating costs.

Conditions for agriculture are much better in the intermediate zone, which is drier and has higher temperatures and more sunlight. There are short spells of cold weather, and the combination of all these conditions has allowed for a remarkable --although incipient-- development of fruit and vegetable farming.

Traditionally, the farmlands in this zone had been used for crops which were not very profitable, such as alfalfa, olives, truck farms and pisco grapes. These crops are beginning to be replaced by export-quality eating grapes and by groves of fruit trees, such as avocado, apricot, plum and chirimoya. There has also been a gradual development of other crops, such as tomatoes grown under plastic cover, pimento, watermelon and melon.

Other important activities in this intermediate zone are the usual services --business, public administration, health and education-- to be found in a provincial capital.

The mining and industrial sectors are not very active. The only strong industry is the pisco industry, which has been developed and improved technically with the installation of four modern plants.

Ovalle also has a tradition of trading and slaughtering livestock, and is able to supply the demand of the areas located between the Second Region and the Metropolitan Region.

The more dynamic subsectors have to do with the exporting of fruits, especially table grapes, which are harvested, from December on, in the Huatulame River valley and the comunas of Combarbalá and Montepatria. These grapes are exported to the United States at very good prices. Activities pertaining to the exporting of fruits and vegetables, as well as the planting, irrigation and harvesting of such produce, have generated many new jobs, thus raising incomes and generally contributing to the economic and social advancement of the area.

Finally, in the foothill area, with its low temperatures, frequent frosts and high humidity, the main activity consists of small-scale farming of certain cereals and vegetables and, especially of alfalfa, as well as stockraising. Other minor activities are small-scale mining and hydroelectric power generation.

III. UTILIZATION OF WATER RESOURCES

Most of the water resources available in this basin are used for irrigation and, to a lesser extent, for water supply for the population and for hydroelectric power generation. Very little is used for industry and mining.

In this chapter, we shall discuss the demand generated by these sectors, as well as the supply available.

1. River structure of the basin

The hydrographic basin is made up of several major rivers which have their sources in the Andes and are filled by thawing snow from the mountains.

The Hurtado River drains the northeastern part of the basin. Along its lengthy course it is joined by many small tributaries formed by many pluvial streams.

In the lower section is the Recoleta reservoir, with a capacity of 100 million m3. This reservoir stores the fall and winter surplus water resources from the Hurtado River, so as to regulate them during spring and summer, when they are delivered through several canals and the former bed of the Hurtado River.

Several rivers with a relatively heavy streamflow run from the Andes into the central part of the basin, eventually flowing into the main water resource of the basin, the Grande River. Its main tributaries are the Turbio, Tascadero, Mostazal and Rapel rivers.

Most of the waters of the Grande River flow into the Paloma reservoir, which has a storage capacity of 750 million m3, and allows for interannual regulation of the surplus water produced in good years.

The Paloma reservoir delivers the water through three canals and the Grande River, which eventually joins the Hurtado to form the Limarí River. The Paloma reservoir is used to irrigate a large area of approximately 20 000 ha, which is the area of natural influence of the Grande and Limarí Rivers; it is also used to irrigate other areas which, theoretically, should be served with other resources.

The Pama, the Combarbalá and the Cogotí rivers originate in the southeastern area. Their waters flow into the third irrigation infrastructure of the basin, namely, the Cogotí reservoir, which has a storage capacity of 150 million m3 and is used to regulate winter surpluses from the Pama and Combarbalá rivers.

Table 3 shows the average flow of the rivers mentioned above and the area of farmlands usually irrigated. Figure 1 gives a map of the area under study, and figure 2 presents a schematic outline of the river structure of the area.

2. Infrastructure of the Limarí-Paloma water system

The water resources described above --reservoirs, riverbeds, canal systems and facilities-- taken together are known as the Limarí-Paloma water system, which includes the Recoleta, Paloma and Cogotí subsystems.

These infrastructures were built --in stages, over time-- mainly in order to provide irrigation for the farmlands in the Limarí River basin, which covers approximately 60 000 ha of arable land.

Following is a description of the main features of the subsystems.

a) The Recoleta subsystem

This includes the reservoir of the same name, six main canals and a secondary network of canals providing access to the farms themselves.

Table 3

MAIN RIVERS AND IRRIGATED FARMLAND

Source	Area of farmland (ha)	Most frequent average volume of flow (m3/sec)
	a) Interior rivers	
Hurtado River	3 325	2.5 - 1.1 a/
Grande River	4 990	10.0 - 8.0 a/
Rapel River	3 650	1.0
Palomo River	1 080	2.0
Ponio River	734	0.3
Mostazal River	2 887	1.1
Tulahuén River	1 504	0.2
Turbio River	400	2.0
Tascadero River	469	2.5
Others	1 611	0.5
Cogotí River	2 113	0.9 - 0.5 a/
Pama River	1 630	0.5 - 0.2 a/
Combarbalá River	2 985	0.8 - 0.4 a/
	b) Rivers flowing from reservoirs	
Hurtado River	100 to 250	0.1
Grande and Limarí Rivers	9 000	2.0
Huatulame River	953	0.6

Source: Dirección General de Aguas and Dirección de Riego.

a/ The first figure represents average volume measured at the bottom of the foothills; the second figure represents volume flowing into the reservoir.

Figure 1

LOCATION MAP

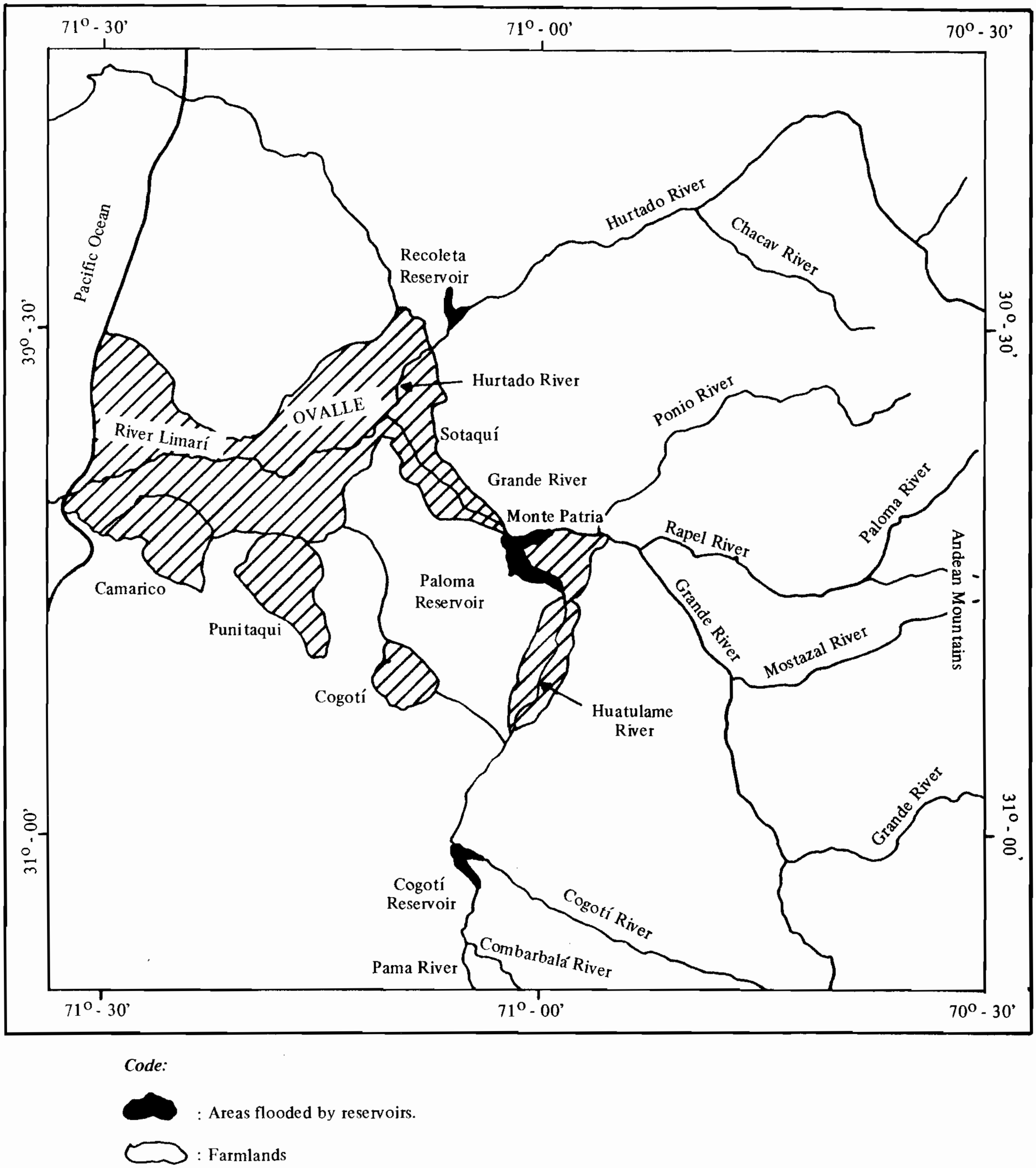
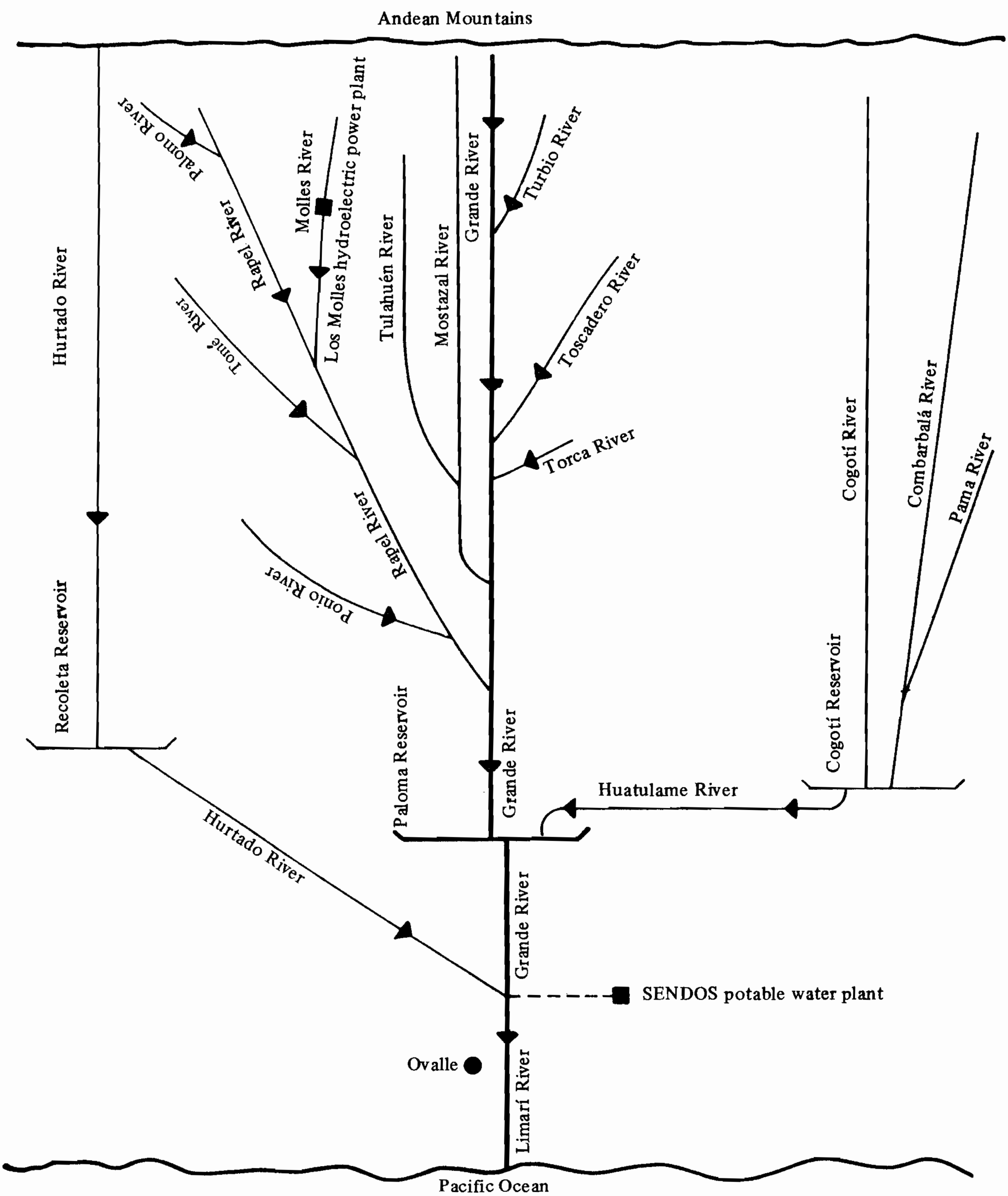


Figure 2
RIVERS IN THE LIMARI BASIN



The storage infrastructure consists of an earth-fill wall 70 m high and 1 000 m long, which makes it possible for the reservoir to store approximately 100 million m3 of water.

Construction of this infrastructure began during the second half of the 1920s; it was put into service in 1934. Thus, it is the first work of this type to be built in Chile.

At present, it is in fair condition; it has a high embankment and considerable seepage, both at the dam and in the hills surrounding it. In addition, the plant, the valves and the gates are in poor condition. This is due to the fact that there are no regular maintenance operations, and necessary repairs have not been made; the lake has never been emptied in order to observe and repair any deficiencies.

The water is delivered through the bed of the Hurtado River and six main canals, shown schematically in figure 3, and described below:

i) Villalón Canal. This canal is 48 km long and has an average capacity of 5.8 m3/sec, thus allowing for the irrigation of 8 998 ha in the Cerrillos de Tamaya microregion. This is facilitated by two regulating reservoirs having capacities of 5 million m3 each.

The canal is in poor condition, as it leaks over 30% of the resources flowing into it. It has no lining, and its 367-m siphon is damaged and will soon be out of service.

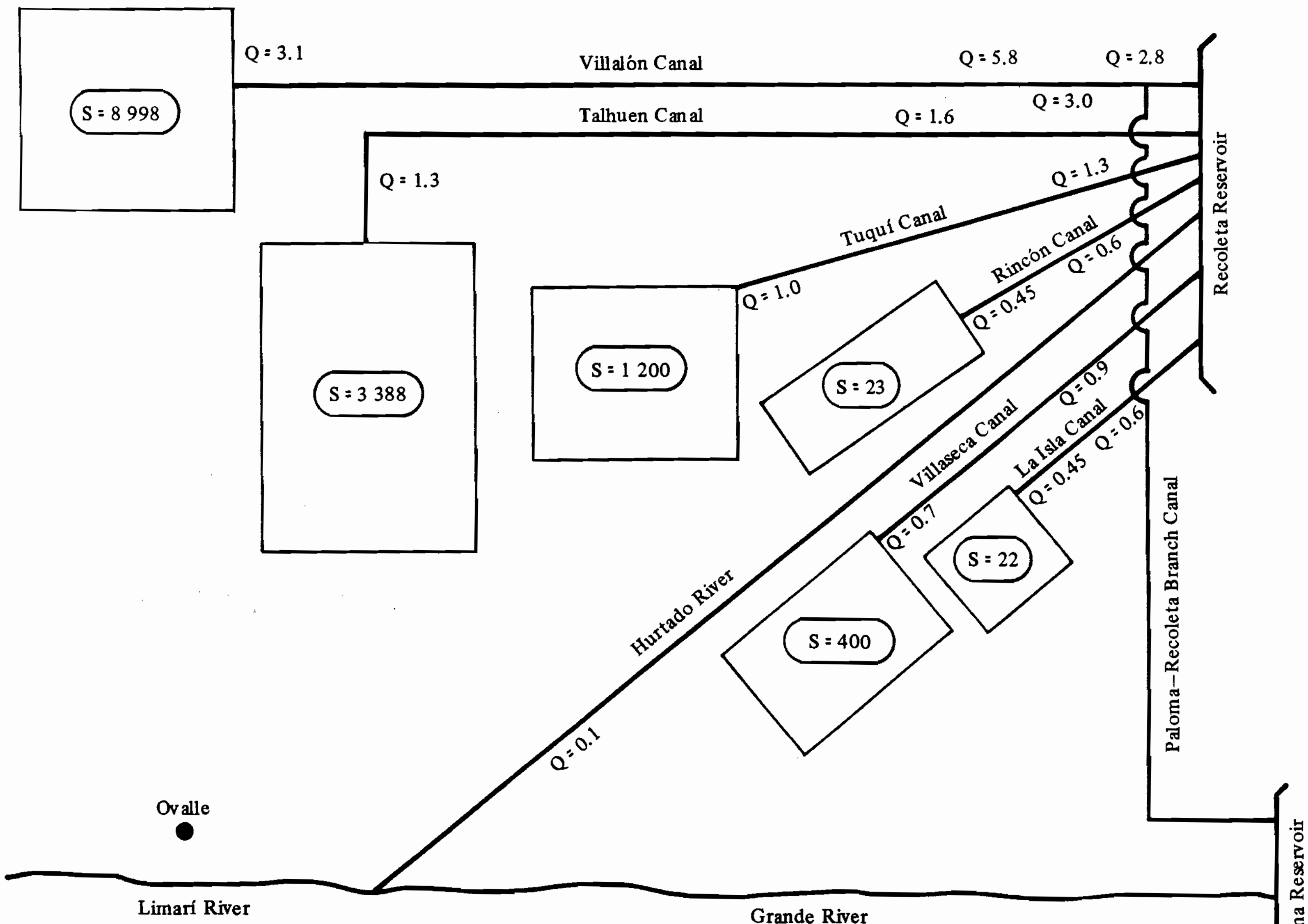
The Recoleta reservoir delivers 2.8 m3/sec into this canal, and the Paloma reservoir delivers 3.0 m3/sec, thus making the total of 5.8 m3/sec mentioned above. Of this amount, only 3.1 m3/sec are used, as the remaining 2.7 m3/sec leak out.

ii) Talhuén Canal. This canal receives from the Recoleta reservoir an average volume of 1.6 m3/sec, which is used to irrigate terraces located north of Ovalle. This area includes the land-reform settlements of Talhuén and Flor del Norte, which cover an area of 3 387 ha devoted to alfalfa and beef cattle.

Irrigation is supported by several regulating reservoirs which operate at night and have capacities ranging between 10 000 and 20 000 m3/sec. The canal is in poor condition, as it is not properly cleaned, has lost its shape, has no shoulders or banks, and is quite rocky; in addition, silt brought by rain waters causes many problems.

Figure 3

DIAGRAM OF CANALS IN THE RECOLETA SUBSYSTEM



Code:

Q = Volume of streamflow, in m^3/sec.

S = Area of farmland, in hectares.

iii) Other canals and the Hurtado River. The Recoleta reservoir also delivers water through other small canals, through the bed of the Hurtado River and through the 18-km Tuquí canal and the 17-km Villaseca canal; these, with volumes of 1.3 and 0.9 m3/sec, together with the river, irrigate the lands on the north and south of the river, covering areas of 1 200 and 400 ha, in that order.

In addition, the Rincón and La Isla canals serve areas near the ones mentioned above. The Rincón canal serves an area of 22 ha and the La Isla canal, 23 ha; each has a volume of flow of 0.6 m3/sec.

The main crop in the 1 645 ha of irrigated land is the pisco grape, which supplies the pisco plants mentioned previously.

The Rincón and La Isla canals are in fair condition. The Tuquí canal has concrete lining over 50% of its length, and is efficient. The Villaseca canal is in very poor condition, receives no maintenance, and has no shoulders. It serves many informal users --farmers and squatters-- both bringing water and discharging sewage.

iv) Operation and complementary facilities. The Recoleta reservoir was planned and designed to irrigate an area of 12 386 ha in the Hurtado River valley.

Nevertheless, it was not possible to meet this goal because of the inefficiency of a considerable percentage of the canal system and the wasteful methods used to irrigate the farms. These problems compound the inadequacy of the system.

In order to make up for these deficiencies, water is being supplied from the Paloma reservoir, which delivers 3 m3/sec to the Villalón canal, through the branch canal between Paloma and Recoleta. As a temporary measure, other areas in the Hurtado River basin are receiving supplementary water from the Paloma reservoir.

This has made it possible to free resources of the Recoleta reservoir, which is now delivering to the Tuquí, Villaseca, Rincón and La Isla canals. Any surpluses are returned to the Paloma subsystem through the former bed of the Hurtado River.

v) Results. Average consumption in the Hurtado River sub-basin is approximately 10.9 m3/sec; of this, 74.3% is supplied by the Recoleta reservoir, which produces approximately 125 million m3/year (see table 4).

Table 4

AVERAGE VOLUMES OF FLOW AND IRRIGATED AREAS IN THE RECOLETA SUBSYSTEM

Waterways		Volume of flow (m3/sec)	(%)	Irrigated area (ha)
Villalón Canal	A=B+C	5.8		
- supplied by the Recoleta subsystem	B	2.8		
- supplied by the Paloma subsystem	C	3.0		
a) Waste and seepage	D	2.7		
b) Volume actually used	E=A-D	3.1		8 998
Talhuén Canal	F	1.6		
a) Waste and seepage	G	0.3		
b) Volume actually used	H=F-G	1.3		3 388
Tuquí and Villaseca Canals	I	3.4		
Rincón and La Isla				
a) Waste and seepage	J	0.8		
b) Volume actually used	K	2.6		1 645 a/
Hurtado River (downstream from Recoleta reservoir)	L	0.1		b/
Total irrigated area	-	-		14 031
Subtotal supplied by Paloma subsystem	M=B	2.8	(25.7)	
Subtotal supplied by Recoleta subsystem	N=C+F+I+L	8.1	(74.3)	
Total supplied by both subsystems	P=M+N	10.9	(100.0)	
Subtotal waste and seepage	a=D+G+J	3.8	(34.9)	
Subtotal volume actually used	R=E+H+K+L	7.1	(65.1)	

Source: Irrigation Bureau and estimates.

a/ Estimate based on actual figures for 1985.
b/ Omitted because of lack of adequate information. Ranges between 100 and 250 ha per year.

Almost 35% of the water resources delivered are wasted because of physical deficiencies, seepage, the excessive length of the distribution system, the inadequate maintenance and monitoring of some canals, and the improper use of some streams.

Nonetheless, it has been possible to increase the irrigated area from the 12 386 ha envisaged to the 14 031 ha now served by the two reservoirs.

b) The Cogotí subsystem

The Cogotí reservoir was built between 1935 and 1940. It consists mainly of a dam made of selected large loose rocks which had been previously washed, in order to prevent settling.

The dam is 90 m high and 400 m long and has a storage capacity of 150 million m3. The infrastructure is located 75 km southeast of Ovalle and 18 km north of Combarbalá.

The reservoir receives average flows of 500 lt/sec from the Cogotí River, 350 lt/sec from the Combarbalá River, and 200 lt/sec from the Pama River.

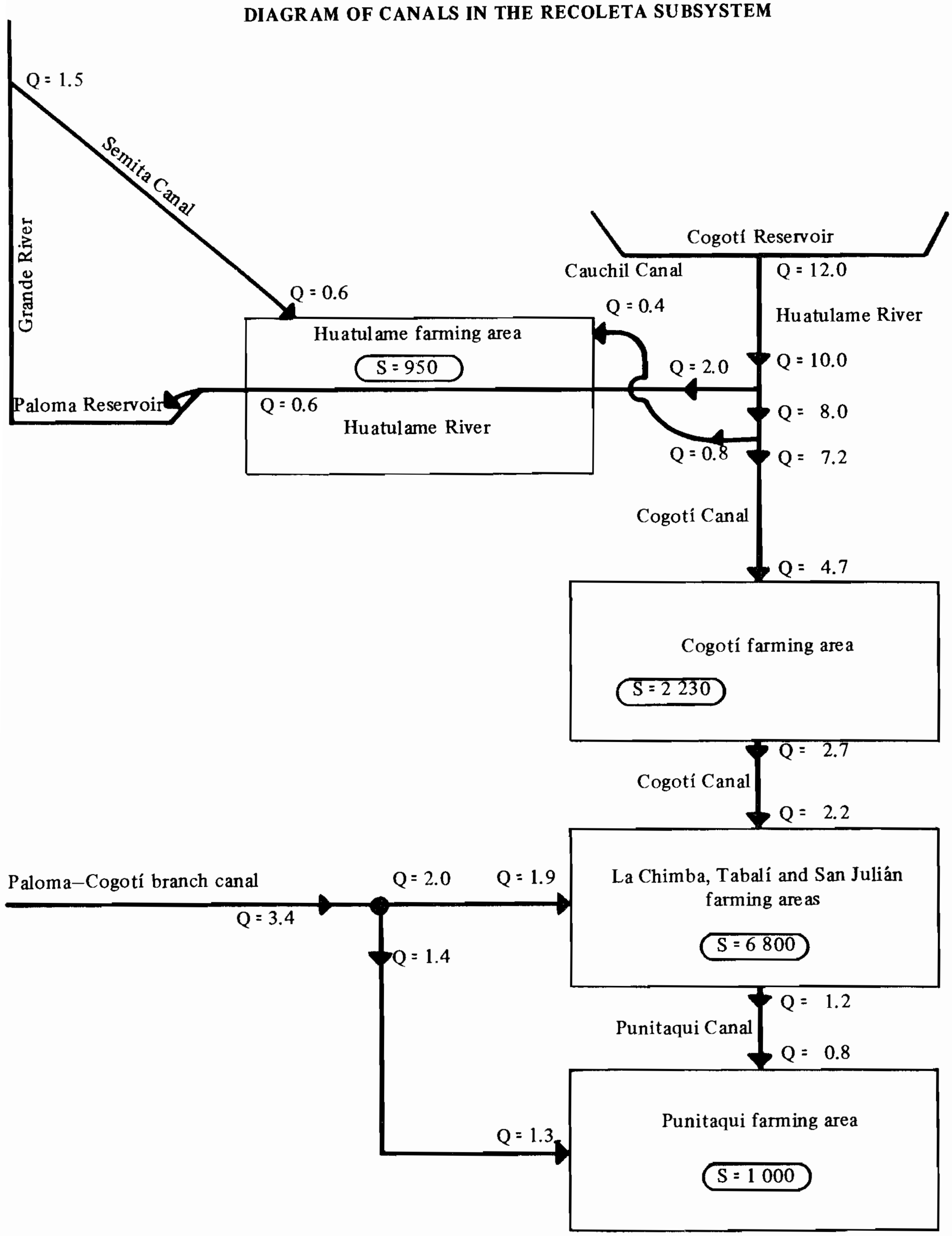
The reservoir is designed to store winter water surpluses and deliver them, in orderly fashion, in summer. The water is discharged directly into the natural bed of the former Huatulame River. Eighteen kilometres downstream is the intake of the Cogotí master canal, where 8 m3/sec are taken from the Huatulame River, which flows on into the Huatulame valley (see figure 4).

i) Cogotí master canal. This canal has a 10 m2 section, and is approximately 108 km long, from its intake in Chañaral Alto to Cruz Colorada, on the boundary between Ovalle and Punitaqui. It is in fair condition, receives regular maintenance and cleaning, and has a problem with seepage and waste.

This canal irrigates a large area of farmland west of the reservoir and south of Ovalle, consisting basically of three terraces, which descend in altitude towards the west; it is thus possible to supply them with water serially. The first terrace, located in the intermediate zone, has an irrigated area of approximately 2 230 ha, and is served exclusively with the water supplied by the Cogotí master canal, distributed among the individual farm canals in the secondary network.

Figure 4

DIAGRAM OF CANALS IN THE RECOLETA SUBSYSTEM



Code:

Q = Volume of flow, in m^3/sec.
S = Farmlands, in hectares.

The surplus flow is used to irrigate the areas of La Chimba, San Julián and Tabalí, which comprises an overall area of 6 800 ha. The 2.2 m3/sec supplied by the Cogotí canal are insufficient, and complementary irrigation is supplied by the 1.9 m3/sec provided by the branch canal between Paloma and Cogotí (see again figure 4).

In addition, some 800 lt/sec are brought from the Cogotí canal to irrigate the farmlands of Punitaqui, which make up another terrace. About 1 000 ha of land on this terrace are irrigated with the resources mentioned above, in addition to small volumes of water from streams and estuaries and the surplus flow from the branch canal connecting Paloma and Cogotí, estimated at 1.3 m3/sec (see again figure 4).

The Cogotí canal also supplies the Cauchil canal, which has its intake 21 km downstream from the Cogotí reservoir, and takes resources into the Huatulame valley over a zigzagging course which goes under the Huatulame River through a concrete siphon.

ii) Huatulame River. Beyond the intake of the Cogotí canal, the waters of this river are used to irrigate the farmlands of the longitudinal valley known as Huatulame. The average flow is estimated at 600 lt/sec, as seepage and waste deplete it of about 70% of the 2 m3/sec mentioned above.

This valley recovers water which has seeped down from the higher lands; in addition, water is obtained from the Cogotí canal, through the Cauchil canal, and from the Grande River, through the Semita canal. The Cauchil canal receives about 800 lt/sec and delivers only about 50% of that volume, as the remainder is lost through seepage. The Semita canal is even less efficient, as it delivers 600 lt/sec, which represents only 40% of the volume it receives.

The main characteristic of the Huatulame valley is its excellent climate and soils, which allow for the production of high-quality table grapes. These ripen in mid-December and are exported mainly to the United States, at high prices, which makes the activity very attractive.

This happy circumstance explains several unusual phenomena, such as the remarkable increase in farmed area, which --according to preliminary estimates-- will total almost 2 000 ha in 1986, i.e., double the area traditionally cultivated.

This also explains the existence and use of the Cauchil and Semita canals, which divert waters from other sources into this valley. This has been made legally possible under current legislation which allows for the transfer of water rights.

There also seem to be good reasons for introducing technology into irrigation at the farm level, which in this valley includes almost all the 950 ha in the lower section. Efforts and investments are also being made to pump up to the higher terraces the volume of water needed to irrigate approximately 1 000 ha of new farmlands. Most of the farms are using the drip irrigation system, because of its high efficiency even though this requires a high initial investment.

iii) Results and follow-up. The water resources of this sub-basin are delivered, basically, to two different valleys, one of them a small longitudinal valley, and the other a wide transversal one.

Table 5 shows the distribution of waters between these two valleys; as will be noted, the Huatulame valley is assigned a small proportion of the waters stored by the Cogotí reservoir. To these resources are added other elements which, together, have made it possible for fruit growing to develop at an amazing pace. This is also due to the excellent climate of the microregion and the boldness and creativity of a segment of the private sector.

Table 5

DISTRIBUTION OF WATER BETWEEN THE TRANSVERSAL AND LONGITUDINAL VALLEYS

Waterway	Volume of flow (m3/sec)
Huatulame River, first section:	
a) Initial flow	12.0
b) Final flow	10.0
Huatulame River, second section	2.0
Cogotí Canal	8.0

Source: Irrigation Bureau and estimates.

From another standpoint, it should be noted that efforts have been concentrated on introducing technology into irrigation at the farm level and on generating water resources, while less attention has been given to taking steps and making investments to improve the efficiency of distribution of the waterways coming into this valley. At present, the volume actually used is 1.6 m3/sec, which represents only 37% of the 4.3 m3/sec assigned to the area (see table 6).

Table 6

WATERWAYS SERVING THE HUATULAME VALLEY

Waterways	Volume of flow (m3/sec)	
	Initial	Actually used
Huatulame River	2.0	0.6
Cauchil Canal	0.8	0.4
Semita Canal	1.5	0.6
Total	4.3	1.6

Source: Irrigation Bureau and estimates.

Of the volume taken from the Cogotí reservoir, 45.5% is used for irrigation of terraces, 18.2% is diverted to the Huatulame area, and the remaining 36.3% is wasted (see table 7).

These losses and seepages occur mainly because of the excessive length of the Cogotí canal, the absence of lining and the poor condition of the canal. This situation has arisen as a result of legal provisions which stipulate that certain water resources must be carried to very distant places, a measure which makes for relatively low yield.

As a result of the above, the amount of water from the Cogotí reservoir which actually reaches the lower farmlands is insufficient for adequate irrigation; this problem is solved by bringing in resources from the Paloma reservoir, through the branch canal connecting it with Cogotí (see again figure 4).

Thus, the Paloma reservoir is supplying 22% of the water resources circulating in the Cogotí River sub-basin downstream from the reservoir bearing the same name.

Table 7

WATERWAYS AND IRRIGATED AREAS IN TRANSVERSAL TERRACES

Waterways	Symbols	Volume of flow (m3/sec)	Irrigated area Ha	%
Cogotí Canal, first section	A	8.0		-
Cauchil Canal	B	0.8		-
Available from Cogotí Canal, first section:	C=A-B	7.2		-
a) Seepage and waste	D	2.5	2 230	22.2
b) Volume actually used	E	2.0		
Remainder for second section of Cogotí Canal:	F=C-D-E	2.7		
a) Seepage and waste	G	0.5		
b) Delivered to areas of La Chimba, Tabalí and San Julián	H	1.0		
Branch canal between Paloma and Cogotí	I	1.9		
Subtotal delivered to La Chimba, Tabalí, etc.	J=H+I	2.9	6 800	67.8
Remainder for third section of Cogotí Canal:	K=F-G-H	1.2		
a) Seepage and waste	L	0.4		
b) Delivered to Punitaqui area	M=K-L	0.8		
Branch canal between Paloma and Punitaqui	N	1.3		
Subtotal designated for Punitaqui area	P=M+N	2.1	1 000	10.0
Total irrigated areas in Cogotí Valley	-	-	10 030	100.0
Subtotal supplied by Paloma subsystem	Q	3.4		
Subtotal supplied by Cogotí subsystem	R	12.0		
Total volume of water supplied	S=Q+R	15.4		
Subtotal volumes actually used	T=E+J+P	7.0		
Subtotal volumes diverted	V	2.8		
Subtotal waste and seepage	W=S-T-V	5.6		

Source: Irrigation Bureau and estimates.

c) Paloma subsystem

This system consists of a reservoir, plants and a network of branch canals, which were built in co-ordinated fashion. The wall is 85 m high and 900 m long; the flooded area covers 3 000 ha, and it has a storage capacity of 750 million m3. The network of canals covers a total of 100 km.

This work was executed during the 1960s, and is the largest, most recent and most modern irrigation infrastructure of the country. It serves two main purposes: on the one hand, it provides interannual regulation of surplus water resources produced during particularly rich years, which are then distributed in an orderly fashion during dry years, and, on the other hand, it backs up the seasonal regulation functions carried out by the Recoleta and Cogotí reservoirs, providing the complementary resources required.

The Paloma reservoir is in quite good condition. Seepage is at a minimum, and it is inspected and maintained frequently. It is operated by specialized staff of the Irrigation Bureau (Dirección de Riego).

The Paloma reservoir usually produces about 200 million m3 per year, distributed as follows: Paloma master canal, 115 million m3; Camarico canal, 35 million m3, and the remaining 50 million m3 are delivered downstream through the Grande and Limarí Rivers (see figure 5).

i) Paloma master canal. This canal is 25 km long, is fully lined, carries average volumes of 8 m3/sec and has seepage of only 7%, which reduces the volume of flow to 7.4 m3/sec. This canal eventually divides into the branch canal to Recoleta and the branch canal to Cogotí. The canal to Recoleta is 8 km long, is 50% lined, and receives 3.3 m3/sec, which is reduced to 3.0 m3/sec as a result of seepage which absorbs 10% of the volume of flow.

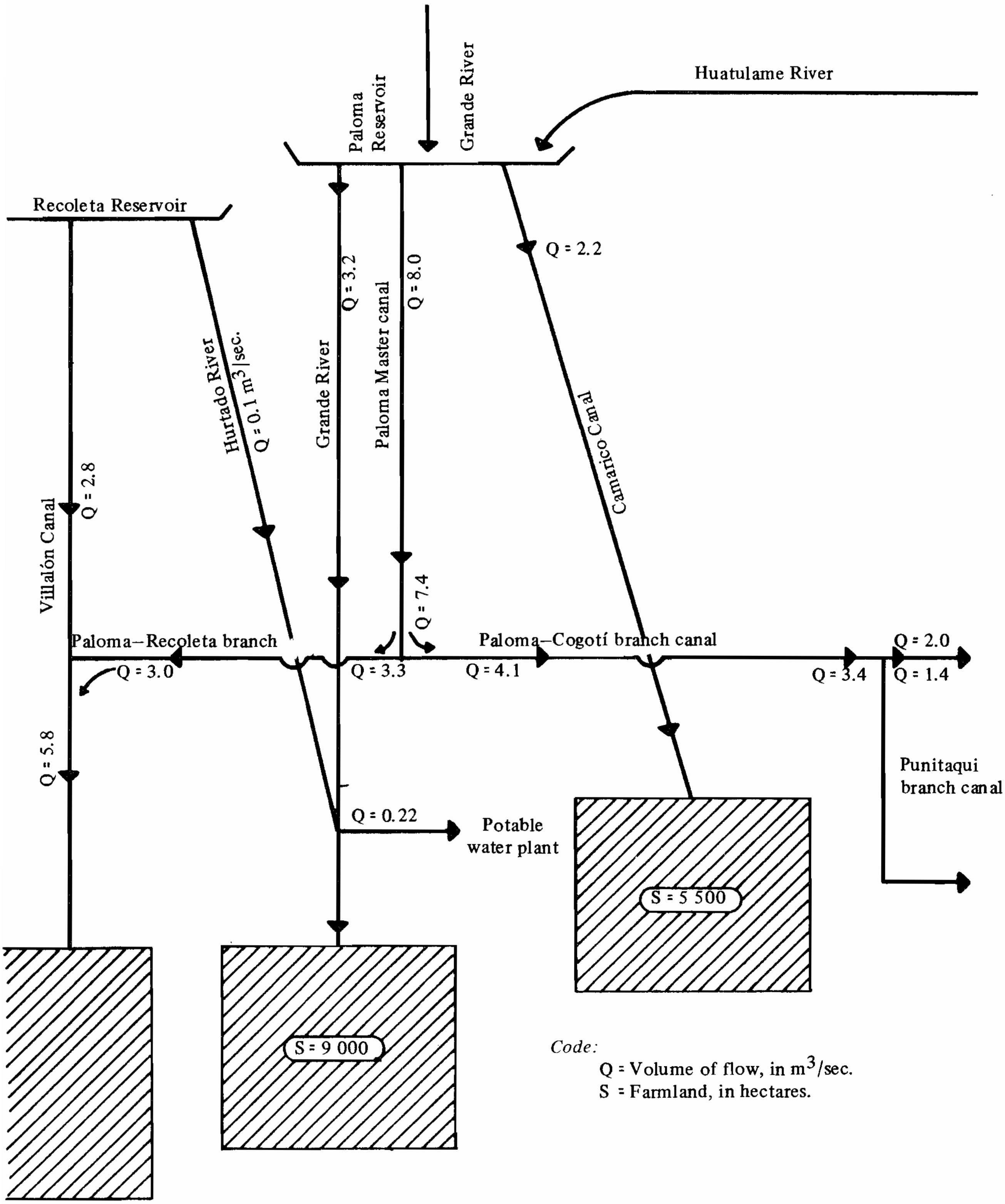
The branch canal between Paloma and Cogotí is 25 km long; of that distance, only 9 km have lining. The canal receives an average volume of 4.1 m3/sec, which is reduced to 3.4 m3/sec as a result of seepage, which absorbs 16% of the volume of flow (see again figure 5).

ii) Grande and Limarí Rivers. The average volume of flow delivered from the Paloma reservoir to the bed of the Grande River is 3.2 m3/sec. This water is used mainly to irrigate some 9 000 ha in the central part of the intermediate and coastal zones.

Two kilometres upstream from Ovalle is the confluence of the Grande and Hurtado Rivers, which gives rise to the Limarí River. The Limarí is about 40 km long and empties into the Pacific Ocean.

Figure 5

DIAGRAM OF CANALS IN THE PALOMA SUBSYSTEM



Code:

Q = Volume of flow, in m^3/sec.

S = Farmland, in hectares.

The river has the necessary intakes to serve a large network of secondary canals, which are generally in good condition.

Water resources in this valley are quite adequate, and often even surpass the needs of the area. A dramatic instance of this occurred in 1985, when 1.6 billion m3 went unused; on that occasion, the reservoir also made it possible to control the rising waters and prevent the flooding which would have followed.

The National Sanitary Works Service (Servicio Nacional de Obras Sanitarias) of Ovalle is a user of a small part of the streamflow from the Limarí River. It consumes an average of 200 lt/sec, which represents less than 10% of the waters flowing through the Limarí River, and 2.3% of the volume produced annually by the Paloma reservoir.

iii) Camarico canal. This is an old privately-owned canal, which was built before the reservoir. It receives an average volume of 2.2 m3/sec, and irrigates some 5 500 ha of land in the southeastern terrace of the basin. It is not lined, and loses 32% of its flow through seepage or waste. It is 80 km long.

iv) Summary of results. Table 8 shows the volumes actually used and those lost through seepage, along with the farmlands served by them.

This subsystem is quite efficient and allows for proper use to be made of available water and natural resources.

The Limarí River was chosen to carry part of the water because it runs through the agricultural area it serves; thus, seepage is at a minimum, as it occurs only along the short course of the river. This solution seems to be satisfactory.

It is thus possible to provide full and direct irrigation for some 14 500 ha of land. In addition, water resources are distributed from the Paloma reservoir to provide complementary irrigation to the areas served by the Recoleta and Cogotí reservoirs, as mentioned above. It is estimated --in terms proportional to the volumes of flow designated-- that this irrigation system covers 4 654 ha and 5 074 ha, or a subtotal of 9 728 ha. It may thus be inferred that the Paloma reservoir makes it possible to provide adequate irrigation for 24 228 ha in the Limarí basin.

Table 8

AVERAGE VOLUMES OF FLOW OF THE PALOMA SUBSYSTEM AND IRRIGATED AREAS

Waterway	Symbols	Volume of flow (m3/sec)	Farmlands (ha)
Paloma master canal	A	8.0	
a) Seepage and waste	B=A-C	0.6	
b) Volume available for distribution	C=D+E	7.4	
Branch canal to Recoleta area	D	3.3	4 654 a/
Branch canal to Cogotí area	E	4.1	5 074 b/
Grande and Limarí Rivers	F	3.2	
a) Seepage and waste	G	0.3	
b) Volume actually used	H=F-G	2.9	9 000
Camarico canal	I	2.2	
a) Seepage and waste	J	0.7	
b) Volume actually used	K=I-J	1.5	5 500
Total volume supplied by Paloma subsystem	L=A+F+I	13.4	
Farmlands served directly	M=H+K	-	14 500
Farmlands served indirectly	N=D+E		9 728
Total area of farmlands			24 228

Source: Irrigation Bureau, estimates, and tables 4 and 7.

a/ 51.7% of 8 998 ha.
b/ 65.5% of 6 800 ha, plus 62% of 1 000 ha (see table 7).

d) Waters upstream from the reservoirs

The foothill area benefits partially from the storage capacity established downstream, since this has freed users from the obligation of permanently contributing resources; irrigation users in the upper areas are now able to use freely such water resources as they need.

Three favorable conditions also contribute to this: there is an abundance of river water in the sub-basins of the foothill area; there are additional rain-water resources, and the demand for water is relatively low. Thus, relations between users in the higher and the lower sections are usually peaceful, contrary to what is often the case in other watersheds.

During periods of drought, the situation is somewhat different, but does not become critical thanks to the large volumes of water stored by the reservoirs mentioned above.

Table 9 shows the areas of farmland in use upstream from the reservoirs, broken down by watersheds. The watershed of the Los Molles River is not included, as its resources are used for hydroelectric power generation, in addition to irrigation.

e) Summary

Approximately 50 000 ha of farmland are irrigated by some 550 million m3 per year (see table 10).

From the totals in table 10, one may conclude that the overall average volume of water used per year per ha for irrigation is 11 378 m3; this figure is low compared with the values shown for this parameter in farmlands which do not have a storage infrastructure.

With respect to the operating capacity of the three infrastructures, it should be noted that in 1985, the Recoleta reservoir produced 125 million m3 and the Cogotí reservoir produced 190 million m3 per year. These are the maximum amounts that can reasonably be expected from them. The situation with the Paloma reservoir, on the other hand, is quite different, as it can produce enormous amounts, equivalent to several times the 207 million m3 mentioned above.

Table 9

AREAS OF FARMLANDS LOCATED UPSTREAM FROM RESERVOIRS

(Hectares)

Basins and rivers	Area
Total Limarí River basin upstream from reservoirs	10 041
Subtotal basins of Cogotí, Pama and Combarbalá rivers	2 083
Subtotal Hurtado River basin	3 723
Subtotal Grande River basin	4 235
- Turbio River valley	185
- Tascadero River valley	294
- Torca River valley	29
- Ponio River valley	15
- Mostazal River valley	1 364
- Tulahuén River valley	204
- San Miguel River valley	154
- Rapel River valley	1 795
- Tomé River valley	20
- Palomo River valley	175

Source: Irrigation Bureau.

Table 10

AREAS AND WATER RESOURCES APPLIED IN 1985

Sub-basins	Areas (ha)	Water applied (millions of m3)
Recoleta	14 031	125
Limarí	14 500	207 a/
Cogotí	10 030	190
Waters upstream from reservoirs	10 041	31
Totals	48 602	553

Source: Tables 3-9.

a/ Excluding 5 million m3 assigned for water supply to population.

3. The drinking water and sewerage subsectors

In some basins, drinking water and sewer systems account for a significant share of available water resources.

This is not the case here, as only the city of Ovalle requires a considerable amount of water, while consumption for the other localities is negligible.

The provincial division of the Sanitary Works Service (Servicio de Obras Sanitarias - SENDOS) takes care of demand for these services to homes and, in general, is responsible for operating the drinking water and sewer systems in Ovalle.

The water resources are taken from the Limarí River at a point 2 km east of Ovalle through a 100-m long concrete canal which has capacity for 450 lt/sec.

In practice, SENDOS operates the system 16 hours a day, during which time it only uses 220 lt/sec. This is equivalent to 4.6 million m3, or only 2.3% of the waters distributed from the Paloma reservoir and 0.8% of the overall resources of the Limarí River basin. This figure is insignificant by comparison with the demand of the irrigation subsector, which is the main subject of this study.

As regards results, the following should be noted: the potable water subsystem established in Ovalle suffers a loss of 36% in the distribution and channeling of water resources; the system covers 87% of the urban population, a satisfactory rate; only 9% of the rural population receives potable water, which is an extremely low coverage rate; sewerage services only serve 51% of the formally established urban population (including cesspools, an inadequate sanitary tool); the informal urban population has no sanitary service, and in the rural areas, only 2.4% of the population has septic tanks, 56% has cesspools, and the remainder have no sanitary service at all. The financial results are unsatisfactory as well, as SENDOS only recovers 75% of invoiced charges; the economic prospects are limited because of the methods used by SENDOS and EMEC to establish rates for services; and, finally, the management of water resources in these subsectors is further hindered by several adverse factors, such as the lack of sewerage in 6 localities; the small size of the subsystem in the city of Ovalle; the lack of treatment of the sewage produced by this service, which is discharged directly into the Limarí River along with the polluted waters of the Romeral canal. These waters are subsequently used to irrigate vegetable crops in some of the farmlands between Ovalle and the coast, thus generating unsatisfactory and risky health and environmental conditions.

4. The Los Molles hydroelectric power plant

This plant was put on stream in 1952. It is located 8 km from the Argentine border, at an altitude of approximately 1 200 m above sea level.

The intake, at an altitude of 2 600 m, constitutes a barrier which completely closes off the course of the Los Molles River, which has a volume of flow of between 2 and 3 m3/sec. The waters are taken in through two gates and diverted to a head canal --17 km long, with 5 tunnels-- to be stored in a reservoir having a capacity of 15 000 m3, from where they are then shot over a fall that is 1 153 m high.

ENDESA has water-use rights for 600 lt/sec, which may be used continuously and permanently, but not consumed. This means that it is required to restore the flow downstream, which, obviously, allows for re-utilization of these resources.

There are no conflicts of interest between the institution and the irrigation users, thanks to the above-mentioned circumstance; furthermore, the resources available are often well in excess of the demand within the area of influence. For the same reason, ENDESA is purchasing other water rights, with a view to expanding the power plant.

The plant currently generates 16 000 kW; this power is transmitted to the interconnected system.

5. The agricultural sector

The total area of farmland available in 1985 in the Limarí basin was estimated at 54 000 ha, including, of course, the 48 000 ha of irrigated land mentioned previously.

Table 11 shows the areas devoted to each crop, the yields attained and the average value --at the farm level-- of estimated production. These parameters are discussed below.

Table 11

SOIL USE, YIELD AND VALUE OF PRODUCTION, 1985

Species	Area (ha)	Yield (tons/ha)	Production (tons)	Unit price (thousands of pesos/ton) a/	Value (millions of pesos)
Limarí River basin	54 490	-	-	-	6 643,7
1. Annual crops	7 550	-	-	-	812,0
a) Wheat	6 070	3.5	21 245	34.0	722,3
b) Maize	1 060	2.8	2 968	10.0	29.7
c) Others (beans, potatoes, peas, lima beans, chili)	420				60
2. Fruits	6 180	-	-	-	2 344,3
a) Pisco grapes	3 150	10.0	31 500	15	472,5
b) Table grapes	2 070	16.0	33 120	50	1 656,0
c) Olives	383	3.0	1 149	50	57,5
d) Walnuts	138	-	-	-	10,0 b/
e) Avocadoes	122	6.0	732	70	51,2
f) Peaches	77	15.0	1 155	35	40,4
g) Lemons	50	18.0	900	13	11,7
h) Apricots	25	10.0	250	40	10,0
i) Others	165	-	-	-	35,0 b/
3. Vegetables	1 530	-	-	-	1 164,4
a) Tomatoes	830	21.0	17 430	45	784,4
b) Pimentos	600	16.0	9 600	37	355,0
c) Others	100	-	-	-	25,0 b/
4. Forage crops	2 040	-	-	-	115,0 b/
5. Alfalfa	22 080	12.5 c/	276 000	8	2 208,0
6. Forest species	8 745	-	-	-	-
7. Others, and fallow land	6 365	-	-	-	-

Source: National Statistical Institute, Agricultural and Livestock Service, El Campo magazine, El Mercurio newspaper, information provided by farmers in the area under study, and estimates.

a/ Prices in force at end 1985 and beginning 1986. See Jaime Baraqui, Selección de cultivos y optimización de soluciones para el Valle del Huasco.

b/ Overall estimate.

c/ Conservative estimate provided by Agrarian Planning Office.

a) Soil use

Pastures seem to be the preferred land use in the area under study, as they occupy 40% of the area currently in use. This is probably due more to tradition than to economic or hydrological considerations.

Wheat production is also explained, to a large extent, by tradition; also, producers know they can count on a stable price, which is set by the authorities in readjustable monetary units.

The dynamism of farming, on the other hand, is reflected in the production of table grapes, in the first place, and of tomatoes, pimentos and fruit and vegetable crops in general. In 1980, table grapes were grown on less than 1 000 ha; now they are grown on over 2 000 ha and, with more land being prepared and planted, it is estimated that in 1986, some 500 ha more will be in production. The areas devoted to growing tomatoes under plastic cover, pimentos, and avocados, apricots and chirimoya have also increased substantially. There has been a corresponding decrease in the area devoted to pisco grapes, which fell by 1 000 ha over the last 3 years; alfalfa; some annual crops, such as maize and potatoes, and olive and walnut plantations. This decline has been due to the low profitability of these crops, which in relative terms bring lower returns than exports of table grapes, tomatoes and other vegetable and fruit varieties.

The changes which are taking place in these activities reflect, to a large extent, the fact that the farmers have had the option of modernizing and updating their land-use techniques as a result of being assured (thanks to the existing storage capacity) that irrigation would be available.

This, obviously, has not been the case in other valleys, where traditional crops --unprofitable and requiring large amounts of water-- continue to prevail, along with outdated and inefficient methods of irrigation outside and within the farms.

Unfortunately, the area under study only covers 54 000 ha, or only 0.6% of the 9.5 million ha of arable land in the country.1/

b) Value of production

The actual values obtained in 1985-1986, in terms of yields and prices, show that the agricultural production of the area under study brought in approximately 6.6. billion pesos,2/ which is equivalent to about US$35.9 million.3/ Thus, the land produced approximately 122 000 pesos per ha, equivalent to about US$659; this figure is relatively good compared with the yields attained in most of the valleys in Chile.

These parameters are actually more interesting when referred only to the subgroup of annual crops and fruit and vegetable crops, where productivity is US$1 530 per ha. This yield is considerably higher than the overall value mentioned above, as it surpasses it by 132%; it is also, of course, well over the national average.

The productivity of the water resources used also represents a significant achievement: a gross income of US$0.65 per cubic metre of water applied to overall agricultural production in the basin.4/

Should an effort be made to draw further conclusions by establishing a correlation between the productivity of the use of water resources and the various species cultivated, consideration should be given to the influence of several other parameters, the analysis of which goes beyond the scope of this study. Nonetheless, the estimates given here allow us to infer that higher levels of productivity of water resources, as well as higher financial returns, can be obtained from certain vegetable crops and fruit plantations than from other, more traditional options.

6. Participation of other users

The mining, industrial and agroindustrial sectors use very small volumes of water; hence, their participation is not relevant to this study.

It should also be mentioned that they use negligible amounts of underground waters. The pisco industry, an important one in the area under study, sometimes uses underground water and sometimes uses potable water supplied by SENDOS. This consumption has already been taken into account in this study in conjunction with the supply of water to the towns.

IV. INSTITUTIONAL ASPECTS

The highest political authority and head of public administration is the Intendente, who represents the President of the Republic in the region. All the ministries of national government are represented in the region through their Regional Secretariats; these are located in La Serena.

Similarly, and on a lesser scale, the public administration is present in the province, with the main offices being located in Ovalle. Following is a description of some institutional aspects of these services, as they pertain to the purposes of this study.

1. Ministry of Public Works

This ministry has regional and provincial representatives, including offices responsible for irrigation, water and sanitary works.

a) Irrigation Bureau (Dirección de Riego)

One of the largest offices of this division, outside Santiago, is located in Montepatria. It is responsible for operating, supervising and maintaining the Paloma reservoir.

The State finances the operation and maintenance of these facilities through the regular budget; it does not charge users for the services provided.

The State also owns the rights for use of the stored waters: it assigns these resources to the traditional users of the waters of the Grande and Limarí Rivers.

b) Water Department (Dirección General de Aguas)

This division is represented by the Regional Water Office (Dirección Regional de Aguas), located in La Serena, which is responsible for studying water-use applications and recommending decisions on same, for planning and supervising hydrometric controls, for collaborating with other public agencies in planning the use of water resources, and for monitoring administrative and financial aspects within its sphere of competence.

The Provincial Water Office (Dirección Provincial de Aguas), located in Ovalle, is mainly responsible for helping users gather the information they need to prepare applications for water-use rights, and for receiving and processing these applications. It also supervises the operation of the system of hydrometric stations in the area, gathers and records hydrological statistics, and obtains and sends water samples for purposes of quality control.

Both of these offices are working satisfactorily, thanks to the fact that they are staffed by qualified personnel. In addition, it should be noted that ever since this agency was created, the water resources available in the area have easily exceeded the demand.

c) National Sanitary Works Service (SENDOS)

SENDOS also has regional and provincial offices. The provincial office in Ovalle is responsible for the production of drinking water, the operation of the water systems, the establishment of connections, the obtaining and recording of basic data for feasibility studies and engineering design, the supervision of projects and the subsequent execution of the works concerned, and, finally, the commercial management of activities pertaining to water services.

The regional office of SENDOS in La Serena, on the other hand, is responsible for administrative management, including cost and efficiency studies relating to the drinking water and sewage subsystems. It is also responsible for planning the development of the subsectors and, especially, for collecting the funds generated by the provincial offices and establishing incentives for this purpose.

2. Other ministries

The other ministries play a relatively minor role in comparison with the Ministry of Public Works, which participates significantly in the water sector.

The Ministry of Agriculture is represented in Ovalle by an office of the Agricultural and Livestock Service (SAG), which is mainly concerned with enforcing certain legal provisions pertaining to sanitary aspects of the agricultural sector, aimed at protecting crops and stock; thus, it is responsible for investigating and detecting plagues and diseases in general. The Agricultural Planning Office (ODEPA) of this Ministry is not represented in the province of Limarí.

The Ministry of Health also has offices responsible for taking samples of drinking water to be examined in the central laboratories.

There are some lands in the region which were expropriated by the Agrarian Reform Corporation (Corporación de Reforma Agraria) and were not subsequently assigned to the private sector. These lands now belong to the Ministry of National Properties (Ministerio de Bienes Nacionales) and are not being exploited; thus, the role of this ministry in matters pertaining to this study is a passive one.

3. National Planning Office

The Regional Planning Secretariat (Secretaría Regional de Planificación-SERPLAC), located in La Serena, has shown considerable interest in the water sector. Thus, it recently completed a Three-year Regional Development Plan in which important roles are assigned to the water sector, although the main emphasis is on the Elqui basin and, especially, the Choapa basin, the latter being a valley which has not been duly exploited, despite its great potential. This explains the priorities reflected in SERPLAC's plan.

This Secretariat is also responsible for obtaining technical assistance, and it has been quite active in this regard. It is now requesting UNDP to carry out a project in support of the agricultural communities in the Choapa basin.

Another important activity carried out by SERPLAC is the collection and edition of statistical data, in support of the work of the National Statistical Institute.

In general, it is satisfactorily carrying out its duties in the area of regional planning, project identification, co-ordination and support for other public agencies, and providing advisory services to the authorities, especially the office of the Intendente of the Region.

4. Local authorities

The Intendente of the Region is represented, in turn, by the Governor of the province of Limarí. The Governor, who is the highest political and administrative authority in the province, is concerned mainly with local government and the operation of public services.

As regards the utilization of water resources, the Governor of the province is participating actively in the search for harmonious solutions to the problem presented by some users who wish to transfer the exercise of their water rights under the terms of a provision of the Water Code, which is very clear on this matter. In an effort to make optimum use of certain water resources and to harmonize and reconcile certain positions and interests, the Governor is sponsoring meetings between public officials working in this area and representatives of the private sector. This matter will be dealt with later on in this report.

Another local authority is the mayor of each comuna, who is the head of the municipal government. His main duties are to facilitate social harmony and enforce legal provisions regarding construction, traffic, commercial permits, and the administration of fairs, markets, parks, gardens, libraries, public lighting and sports facilities.

The municipal government usually do not have much competence in the area of water resources, except as users of large amounts of water, in connection with the above-mentioned activities. In addition, the municipal government of Ovalle is helping its slum dwellers by providing them with free drinking water.

5. Public corporations

The public corporations which are active in the area under study are the National Electric Power Enterprise (Empresa Nacional de Electricidad - ENDESA) and the Electric Power Enterprise of Coquimbo S.A. (Empresa Eléctrica de Coquimbo S.A. - EMEC).5/

a) ENDESA

The provincial office is responsible for monitoring and maintaining the transmission of electric power both from the aforementioned interconnected system and from the Los Molles hydroelectric power plant, which, because of its importance, is discussed separately under section III-4.

At the regional level, it plays a similar role within the area under its jurisdiction, which, in this case, includes the Third and Fourth Regions of Chile, known as the Second Electric Power Zone.

b) EMEC

This corporation purchases electric power from ENDESA and distributes and sells it separately in the main urban centres of the Fourth Region. Both purchase prices and selling prices are governed by the provisions of the decrees on rates enacted by the public authorities.

V. ORGANIZATION AND ADMINISTRATION OF THE LIMARI-PALOMA WATER SYSTEM

The results achieved in connection with the utilization of water resources usually reflect, to a large extent, the efficiency with which they are managed. This in turn depends on the quality, size and co-ordination of the organizations concerned.

In this section, we shall assess the influence of those parameters in the management of the system under study. Our discussion will be limited to the irrigation subsector, as it is the main user of the water resources, as shown in previous sections of this report.

In this regard, it should be noted that not only are the issues involved complex ones, but the study of the Limarí-Paloma water system is further complicated by the fact that it includes seven formally established organizations which are responsible for the sub-basins or sub-sectors concerned.

Thus, the users of the various natural and artificial waterways are represented, in the management of the water resources, by the private organizations described below; in addition, the Irrigation Bureau has a part to play, as it administrates, operates and maintains the Paloma reservoir.

1. Recoleta Reservoir Canal Users Association (Asociación de Canalistas del Embalse Recoleta)

This legally established organization includes the owners of water-use rights pertaining to the Recoleta reservoir; they are also the owners of this infrastructure, its facilities and the network of distribution canals. Consequently, this Association has formally set up a private organization which is responsible for the operation, maintenance and repair of the reservoir; the distribution of waters among the Villalón, Talhuén, Tuquí, Rincón, Villaseca, and La Isla canals and the bed of the Hurtado River, mentioned previously; the distribution of the resources carried by these canals to the network of secondary canals and among the users; the maintenance, cleaning and repair of the entire distribution system, including canals, intakes, frames and facilities; the enforcement of turns and, in general, the equitable distribution of the waters; the collection of dues to be paid by users for the aforementioned services; the administration of funds thus collected and the financing of activities. It also represents the

Association at meetings relating to the assignment of the water resources of the basin, in which users and technical staff from other sub-basins and government officials and authorities also take part; it advises and assists irrigation users on technical matters and, in general, participates actively in all matters pertaining to the utilization of water resources downstream from the Recoleta reservoir.

It is interesting to note that the users located upstream from the reservoir have not formed any organization to represent them nor do they belong to this Association. Nevertheless, for the reasons mentioned previously in this report, no conflicts have arisen.

The greatest deficiency in the administration of the Recoleta subsystem arises from the lack of financial resources, as a result of which it is not possible to adequately maintain and rehabilitate the reservoir and the Talhuén and Villaseca canals.

The organization has a staff of eighteen, including a civil engineer, who is the administrator of the reservoir; an agricultural technician, who is the assistant administrator; an accountant and a secretary; four technicians in charge of maintenance; and ten watchmen.

Ownership of the subsystem and water rights is distributed among 22 589 shares, each of which entitles the bearer to about 5 500 m3 of water per year; in practice, however, the actual quantities differ, as, on the one hand, they are reduced by waste and seepage and, on the other, they are increased by the water received from the Paloma reservoir.

The Board of Directors of the Recoleta Reservoir Canal Users Association is made up of seven members, elected by the 618 individuals and legal entities who own the shares.

2. Paloma reservoir administration

As mentioned above, the main infrastructure, facilities and branch canals of this reservoir belong to the State which, on its own account and through the Irrigation Bureau, operates and maintains the system at no cost to users.

The plant has a staff of fifteen, several of whom are professionals specialized in the operation of large reservoirs. In addition, they are given the powers and the funds required to perform their duties efficiently and in a relatively independent manner.

It is important to point out that this office also provides co-ordination among the users of this reservoir, the persons responsible for the Recoleta and Cogotí reservoirs and for the branch canals, governmental authorities, irrigation subscribers and users in general; in brief, it provides leadership in connection with activities pertaining to the use of the water resources of the basin.

This leadership role was recently enhanced when the Irrigation Bureau took over certain duties of the National Irrigation Commission, an agency which, for the time being, has no offices in the region or the province. Thus, the aforementioned technical staff has first-hand responsibility for the application of the Promotion of Irrigation Act.

Relations between the users of the water resources of the Paloma reservoir and its administration have been smooth and direct, although the users do not have a legally established organization, a matter to be discussed in the following section of this report.

The Irrigation Bureau also supports the operation of the recently established Provisional Supervisory Board of the Limarí-Paloma Water System, which brings together the six user organizations set up in the basin, to be discussed below.

At the beginning of each farming year, water volumes are assigned in accordance with the stored and estimated supply; the Paloma Reservoir Administration then delivers the water, records the pertinent information and establishes the relevant balances.

3. Supervisory Board for the Grande and Limarí Rivers

This organization has existed for several decades. It is made up of the traditional users of the waters of the Grande and Limarí Rivers.

These irrigation users, however, do not own the Paloma reservoir, so that they have not been able to acquire legal rights for the use of the waters stored in this reservoir.

This means that the farmers cannot make investments having a medium-term maturity, inasmuch as they cannot be certain of how much water will be available to them over time: in case of drought, the Reservoir Administration may distribute the waters according to such proportions, quotas or shifts as it may deem advisable, and not necessarily according to the traditional custom, which favours the members of this Board. This risk has not occurred so far, however.

This situation is largely due to two circumstances: in the first place, more than enough water has been available for many years, and, in the second place, the State still does not charge these users for the cost of operating the subsystem --including the reservoir and the canals-- despite the regulations enacted in 1983.

4. Camarico Canal Association (Asociación del Canal Camarico)

This organization was legally established several decades before the Paloma reservoir was built. It includes users who own water rights over the Grande, Cogotí, Pama and Combarbalá Rivers, some of whom are also shareholders in the Cogotí reservoir.

Consequently, the Association operates in exercise of its legitimate rights, supplying these users with the necessary water resources. These are provided by the Paloma reservoir in compensation for the waters it receives from tributaries formerly assigned to the Camarico area (including the Huatulame River, to be discussed later).

This, this canal users association fulfills its main purpose; on the other hand, the water resources actually used are substantially reduced in relation to the volume of water taken in. This is due to the inadequate administration of the Camarico canal, which is not properly maintained and has high rates of seepage and waste.

These inefficiencies are caused by two factors: on the one hand, the canal administration is not sufficiently qualified and, on the other, the waters must be drawn from a point 80 km away from the Camarico microregion, and are carried through an antiquated canal which has no lining.

5. Cogotí Reservoir Canal Users Association (Asociación de Canalistas del Embalse Cogotí)

This is a legally established organization made up of shareholders who own the reservoir, as well as water-use rights over the Pama and Combarbalá Rivers and a small part of the Cogotí River. (Most of the owners of water rights on the Cogotí River are located in the Huatulame valley.)

As in the case of the Recoleta reservoir, this Association has also set up a technical organization charged with operating and maintaining the reservoir and its facilities, distributing the waters through the Cogotí master canal and maintaining and cleaning the distribution system, including the aforementioned canal, the secondary network, the intakes, frames and facilities, and so forth. This Association also has a qualified professional and technical staff to carry out these activities.

The main users are located on the terraces of Cogotí, La Chimba, San Julián, Tabalí and Punitaqui, which are irrigated serially. Thus, the waters assigned are sufficient to cover the needs of the first terrace, but insufficient for the following terraces, which receive complementary resources from the Paloma reservoir, as mentioned earlier in this report. This has helped alleviate the conflict created by competition --prior to the use of Paloma resources-- among users located in the different microregions. In this regard, it seems obvious that the same solution could be applied to further enhance efficiency by increasing the streamflow carried by the Paloma branch canal to Cogotí, whereby it would be possible to reduce the use of, or eliminate, the inefficient Punitaqui canals and the second section of the Cogotí master canal. It would, however, be necessary first to bring in line the water rights pertaining to the Paloma reservoir.

This organization is directly linked to the administration of the Paloma subsystem for purposes of assigning water resources in the Cogotí sub-basin. The relevant agreements are established by the Provisional Supervisory Board of the Limarí-Paloma Water System.

6. Punitaqui Canal Association (Asociación del Canal Punitaqui)

This longstanding organization, which is similar to the Camarico Canal Association, is legally established and exercises traditional rights on the resources which for many years were generated in the basins of the Grande, Combarbalá and Pama Rivers. These are provided through the inefficient Punitaqui canal; some users also have shares in the Cogotí reservoir.

This association is linked with the administrations of the Paloma and Cogotí reservoirs through the Provisional Board. In general, relations are good.

Some of the farmers who belong to this association have recently purchased land in the Huatulame valley, and are trying to transfer their water-use rights so as to be able to exercise them legally in that microregion.

7. Provisional Supervisory Board of the Huatulame River

This is not a legally established organization because its members do not have rights on the Cogotí reservoir, but only on the waters of the Huatulame River, of which the Cogotí River was formerly a tributary. The Cogotí reservoir now stores the waters of both rivers. Because of this complicated situation, there are conflicts between the Provisional Supervisory Board of the Huatulame River and the Cogotí Reservoir Administration, on which the Board, obviously, is not represented.

Since the Cogotí reservoir was built, there have been several developments related to this matter. One of them was the decision to build the Cauchil and Semita canals to divert water to the Huatulame microregion in order to alleviate this conflict. Another favourable development was the construction of the Paloma reservoir, which has provided water to areas irrigated from the Cogotí reservoir and freed resources from Cogotí for the Huatulame valley; this also helped attenuate the conflict that was building up. More recently, the situation was aggravated by the intensification of the use of resources in the fertile Huatulame microregion, thus increasing the demand for water. At present, the situation is both tense and complex because the new Water Code allows for the transfer of water rights from the same source, and some of the Cogotí reservoir shareholders who were formerly located in Punitaqui and Camarico and are now in Huatulame are claiming this legal option.

The situation has become more difficult because the Provisional Supervisory Board of the Huatulame River and the Camarico and Punitaqui Canal Associations do not have enough technical personnel or financial resources. As a result, the many options available have not been properly assessed, despite the fact that the water resources generated in these sub-basins are adequate.

The conflict has now gone beyond the parties concerned, and some local and provincial authorities are intervening, in an effort to find a harmonious solution.

8. Provisional Supervisory Board of the Limarí-Paloma Water System

This Board is made up of the six user organizations described in the preceding sections; it was created in order to organize equitably the water resources of the entire basin.

Thus, the Board is to provide the formal organizational link among the existing user organizations; at the same time, it is to provide an expeditious means for settling any conflicts of interests that might arise between its member organizations.

In practice, the Board fulfills this role to a considerable extent, especially as regards the overall distribution of the resources of the Limarí-Paloma water system. However, it can only act unofficially, as it is not a legally established organization, and this diminishes its competence.

This gives rise to another serious restriction, in that there are no legal rights to the use of the waters stored in the Paloma reservoir. This means that this broad-based and necessary organization, covering the users of the entire system, cannot be formally established.

VI. FINANCIAL ASPECTS

In order for the water resources to be managed effectively, it is essential that the necessary funds be available on a timely basis.

In this study, therefore, we have tried to analyse this matter, with a view to finding out what is the order of magnitude of some of the main parameters involved. Of particular interest are the regular operating costs of the system, including operation, upkeep and repairs; financial costs to be attributed; generation of funds assigned, and, in summary, the cost-benefit ratio arising from the establishment of the Limarí-Paloma water system.

1. Operating costs and collection of funds

The analysis of these matters must be broken down according to the three subsystems involved, as well as according to user organizations.

a) Paloma subsystem

The operating costs are those incurred by the Paloma Reservoir Administration, the Supervisory Board of the Grande and Limarí Rivers, and the Camarico Canal Association.

In the first case, it is quite easy to determine costs, inasmuch as the Irrigation Bureau keeps a record of such information. This shows that a total of 78.1 million pesos were spent during 1985; this amount is not recoverable.

In addition, data available in the other organizations show that the Camarico Canal Association spent 4.8 million pesos and the Supervisory Board of the Grande and Limarí Rivers spent 19.4 million pesos during 1985. These sums were spent mainly for salaries and wages, upkeep and cleaning of canals and transport. These amounts are recovered proportionately to the volumes of water assigned to the different users. Collection of these funds has varied over time, although the amounts collected have certainly allowed for the organization to operate regularly; however, they have not allowed for investments to be made in improvements, lining or major rehabilitation works.

b) Recoleta subsystem

The policy adopted by the administration of this subsystem consists of applying a fixed quota, which in 1985 amounted to 37 pesos per month per share, plus a variable charge based on the amount of water supplied to each user; in 1985, this charge was 20 centavos per cubic metre.

The amount actually collected was a little over 1 million pesos per month, which represented, basically, the fixed dues and only a small proportion of the monthly rate. This was due to two problems: firstly, the difficulty of measuring the streamflow delivered to each farm, as the users usually disagree with the official hydrometric reading, and, secondly, the reluctance of users to pay this component of the rate.

Consequently, because of the inadequate rate policy applied, the final collection amounted to a little over 15 million pesos in 1985.

This amount is way below actual expenditures, which amounted to 25.5 million pesos during the same period; this has led to indebtedness, a situation which has become worse over the past few years.

This financial deficit explains the failure to rehabilitate the reservoir and to conduct proper maintenance and cleaning operations in the Talhuén and Villaseca canals.

c) Cogotí subsystem

The Cogotí Reservoir Canal Users Association, contrary to the case mentioned above, applies a rate system based exclusively on each member's share of water-use rights, i.e., on the number of shares owned by each member. Each year, the reservoir administration prepares a detailed budget of expenditures which it then distributes among the 11 000 shares existing.

Table 12 shows the budget for 1985, broken down into eight items; as will be noted, it amounts to a total of a little over 20 million pesos. Thus, the monthly rate would amount to 130 pesos per share, although the actual amount charged was 172 pesos per share; this made it possible to generate cash resources, so necessary for properly administrating an activity such as this, which frequently entails unforeseen expenditures.

Table 12

ANNUAL BUDGET OF THE Cogotí RESERVOIR CANAL USERS ASSOCIATION
(Thousands of 1985 pesos)

Item	Amount	%
Salaries, fees, benefits	6 405,9	31.4
Repair and maintenance of reservoir	1 102,2	5.4
Upkeep and cleaning of canals (230 km)	7 125,0	34.9
Watchmen's camps	824,4	4.0
Transport	1 270,9	6.2
General expenditures	1 207,8	5.9
Contingencies	1 207,5	5.9
Service of bank debts	1 284,9	6.3
Total	20 428,6	100.0

Source: Table prepared with information provided by the Association.

The Punitaqui Canal Association and the Huatulame River Provisional Supervisory Board, for their part, spent, during 1985, 1.3 million and 1.1 million pesos, on the operation of their facilities. These amounts were totally recovered through the application of a rate system similar to that described in the preceding paragraph.

d) Summary

Table 13 shows a tabulation of the amounts mentioned above. As may be seen, the annual cost of operation, upkeep and minor repairs amounted to an overall total of a little over 150 million pesos, equivalent to approximately US$814 000.

Table 13

SUMMARY OF ANNUAL OPERATING EXPENDITURES OF THE SYSTEM

Organization	Expenditures (millions of pesos)	Equivalent to thousands of US$	%
Limarí-Paloma Water System	150,6	814,0	100.0
Paloma subsystem	102,3	553,0	68.0
- Reservoir Administration	78,1		51.9
- Supervisory Board of the Grande and Limarí Rivers	19,4		12.9
- Camarico Canal Users Association	4,8		3.2
Recoleta subsystem	25,5	137,8	16.9
- Recoleta Reservoir Canal Users Association	25,5		16.9
Cogotí subsystem	22,8	123,2	15.1
- Cogotí Reservoir Canal Users Association	20,4		13.5
- Punitaqui Canal Users Association	1,3		0.9
- Huatulame River Supervisory Board	1,1		0.7

Source: Developed on the basis of data supplied by the organizations concerned.

2. Financial and total costs

Table 14 shows the financial costs of the investments made to set up the irrigation infrastructures, at a discount rate of 8% per year and assuming a useful life of 100 years.

Table 14

FINANCIAL AND TOTAL COSTS OF THE SUBSYSTEMS

(Thousands of US$)

Subsystem	Estimated investment	Annual financial cost	Annual operating cost	Total annual cost
Paloma	300 000	24 010,9	553,0	24 563,9
Recoleta	45 000	3 601,6	137,8	3 739,4
Cogotí	72 000	5 762,6	123,2	5 885,8
Paloma system	417 000	33 375,1	814,0	34 189,1

Source: Table 13 and estimates based on information supplied by the Irrigation Bureau.

These figures lead to some interesting conclusions, especially as regards the composition of the overall cost and the distribution of costs and benefits. In the first place, it will be noted that the Paloma subsystem accounts for 72% of the total cost, which is not passed on to the beneficiaries. This means that there is a disproportionate and unfair transfer of state resources, whereby certain persons or enterprises are favoured, to the detriment of their competitors.

In addition, not enough data are available to allow for a comparison to be made between the cost of the system, i.e., US$34 189.1, with the gross income generated during 1985, which in table 11 was estimated at US$35 900. In this regard, it would not be appropriate to estimate indicators of profitability, such as the cost-benefit ratio, because of the following limitations: i) the value of production was only estimated for one year, which is not necessarily representative, and was based on conservative assumptions; ii) to the amount shown would have to be added the relevant figures for forest species and, especially, for stockraising, which is intensive in this basin; iii) other indirect economic and social results would also have to be taken into account, and the benefit of supplying drinking water to a large part of the population would have to be considered, as would the elimination or prevention of flooding, which in 1985, for example, could have caused considerable damage; and, iv) finally, once these benefits were estimated, it would be necessary to make allowance for other inputs involved in obtaining the values mentioned, especially fertilizers, pesticides, seeds and plants, and labour.

The preparation of estimates pertaining to these parameters obviously goes beyond the scope of this study, in which we do not intend to post-evaluate the investment decisions made in connection with irrigation in this basin. On the other hand, however, attention has recently been drawn again, at the international level --especially in agencies such as IBRD and IDB-- and in national institutions, to the controversy regarding the advisability of assigning large-scale investments to the irrigation subsector. In this regard, this study may provide some useful criteria concerning these issues. In the first place, we have already observed that the productivity of resources doubles when one compares the results achieved with crops having low irrigation requirements and bringing in high financial returns, such as certain export fruits and vegetables, and those attained with traditional commodities, such as alfalfa, which requires large amounts of water and is not very profitable. Thus, one may infer that crop selection is a decisive parameter when it comes to evaluating the advisability of investing in irrigation. Another important parameter is that of the efficiency of water management, especially as regards water distribution and channeling. Finally, the efficiency with which irrigation subscribers use the water resources is a third and equally decisive parameter.

VII. ANALYSIS OF RESULTS ACHIEVED

The best indicators of results achieved and of their projection over the medium term have been noted in the preceding sections. Basically, they have to do with efficiency in the use of water resources and the productivity achieved with them.

The first indicator may be evaluated at several stages of the overall process of water distribution, inasmuch as losses occur at each stage and hence, the efficiency is different each time. These stages may be tentatively identified as follows: impoundment of waters at the natural source, storage of these waters, distribution of streamflows in the main canal system, channeling of streamflows into the secondary canal system, intrafarm regulation, application to crops, and evacuation or drainage.

In this respect, it is important to point out that the existing water impoundment and storage works were located and executed in places where the geological and topographic features were appropriate and helped reduce the investment to be made, so that it does not seem pertinent to re-evaluate this parameter. Likewise, it would be superfluous to estimate evaporation of stored water, which is inevitable. Consequently, our analysis will concentrate on those stages in which improvements can be made.

It should be noted that the Recoleta reservoir loses approximately 30% of its water resources because of the serious seepage problem it has. This, in turn, is caused by lack of maintenance; here, then, we see the first serious shortcoming, which is a consequence of inadequate management on the part of the owners. This is also reflected in the underutilization of the reservoir's capacity, as well as in the lack of financial resources for operation, maintenance and repairs. Significant losses also occur in the Cogotí reservoir, although they are proportionally lower than those occurring in the Recoleta reservoir.

1. Distribution of streamflows in the canal system

This is one of the most important parameters, inasmuch as serious deficiencies are to be found at this stage.

Results in the Paloma subsystem are quite good, thanks to the quality of the master canal and of the two branch canals; this is not the case, however, with the long and inadequate Camarico canal.

In 1985, the overall efficiency of water distribution in the Paloma subsystem was 79.1% (see table 15). The results in the other subsystems, however, were quite different; the Recoleta subsystem had a rate of 65.8%, and the Cogotí system, of 40.0%.

The most interesting conclusions may be reached from partial analyses; for example, the Camarico canal detracts from the results of the rest of the

Table 15

EFFICIENCY IN THE DISTRIBUTION OF WATER RESOURCES

Subsystem	Volumes of flow (m3/sec) Delivered	Received	Efficiency (%)
1. Paloma	13,4	10,6	79,1
a) Grande and Limarí Rivers	3,2	2,9	90,6
b) Master canal	8,0	7,4 a/	77,5 b/
i) Branch canal to Recoleta	3,3 a/	3,0	-
ii) Branch canal to Cogotí	4,1 a/	3,4 a/	-
- Connection to La Chimba, etc.	2,0 a/	1,9	-
- Connection to Punitaqui	1,4 a/	1,3	-
c) Camarico canal	2,2	1,5	68,2
2. Recoleta	7,9	5,2	65,8
a) Villalón canal	2,8	1,5	53,6
b) Talhuén canal	1,6	1,0	62,5
c) Tuquí canal	1,3	1,0	76,9
d) Rincón canal	0,6	0,45	75,0
e) Hurtado River	0,1	0,1 a/	-
f) Villaseca canal	0,9	0,7	77,8
g) La Isla canal	0,6	0,45	75,0
3. Cogotí	12,0	4,8	40,0
a) Huatulame River	12,0	10,0 a/	83,3
i) Huatulame River	2,0 a/	0,6	30,0
b) Cogotí master canal	8,0 a/	7,2 a/	90,0
ii) Cauchil canal	0,8 a/	0,4	50,0
iii) Cogotí master canal	7,2 a/	2,0	-
c) Cogotí master canal	2,7 a/	1,0	-
d) Cogotí master canal	1,2 a/	0,8	-
4. Paloma system	33,3	20,6	61,9

Source: Prepared on the basis of data shown in tables 4, 7 and 8.

a/ Partial streamflow (not included in totals).
b/ Overall efficiency of the group made up of the Paloma master canal plus the two branch canals plus the two connecting canals.

Paloma subsystem, for the reasons mentioned several times before. In the case of Recoleta, inefficiency is general, although greater in the longer canals, such as the Villalón, and not so much in the shorter ones, such as the Villaseca and the Talhuén, although the former has less seepage per unit of length than the latter. In the case of Cogotí, the greatest inefficiency is found in the Huatulame valley, in which less than 30% of the river's streamflow and 50% of that of the Cauchil canal are utilized; thus, the weighted average is only 35.7%, which is much too low. In the rest of this subsystem, efficiency levels decrease considerably along the Cogotí master canal: efficiency is high in the first section, fair in the second, and very low in the third, for the reasons mentioned above.

The main conclusion to be reached from the above analysis is that, in general, the nearly 62% efficiency of water distribution in the overall Limarí-Paloma water system is relatively high, and much higher than the efficiency achieved in most watersheds in Chile. On the other hand, it could be improved through better management of the waters in the system and through improvements in the main canals.

2. Channeling and intrafarm regulation

These parameters were also found to have different values at the different locations. The Recoleta subsystem shows the lowest indicators because of the enormous network of secondary canals, where seepage and waste increase; paradoxically, the absence of secondary canals and of regulating lakes in the agrarian reform sectors, also affects efficiency.

The situation is different with regard to the Paloma subsystem because, thanks to the location of the secondary canals, a good portion of the former, antiquated network, was eliminated. Also, the farms are close to the waterways and there are regulating reservoirs on the farms.

The Cogotí subsystem may be described as being halfway between the two situations described above, for the same reasons mentioned before.

Table 16 shows the efficiencies relating to these parameters, as well as the overall results attained at the farm level.

These figures show that the good results obtained in distribution of water outside the farms are considerably reduced within the farms, where they fall to somewhat less than 50%.

Table 16

EFFICIENCY INDICATORS AT THE FARM LEVEL

(Percentages)

Subsystem	Distribution	Channeling	Farm
Paloma	79,1	85	67,2
Recoleta	65,8	70	46,1
Cogotí	40,0	78	31,2
Paloma system	61,9	79,6	49,3

Source: Table 15 and estimates based on data provided by the Irrigation Bureau.

3. Application to crops

The greatest discrepancies occur at this stage of the process; on the one hand, a small area has been provided with drip irrigation, which allows for high yields in the utilization of water resources, whereas on the other hand, large areas are still under flood irrigation.

Table 17 shows the results of a study of the yield of crops according to the irrigation method applied, carried out in several places in the Limarí basin. Since this is the only information available on this matter, we shall assume it is valid for the entire area under study. It covers four species (annual crops, fruits, vegetables and alfalfa) and five irrigation methods, i.e., flood, improved flood, furrow, basin and drip. Sprinkling was not included because this method is not used in the area under study.

In table 11, we indicated the average areas planted with the different agricultural species. These can be broken down according to irrigation method, on the basis of data and ad hoc samplings carried out in the area under study; the results of this analysis are shown in table 18.

By crossing the matrixes contained in tables 17 and 18, we find that actual utilization of the water applied to crops in the area under study is only 36.8% (see table 19).

Table 17

ACTUAL UTILIZATION OF WATER ACCORDING TO IRRIGATION METHOD USED

(Percentages)

Species	Utilization according to method				
	Flood	Improved flood	Furrow	Basin	Drip
Annual crops	25	35	50	-	-
Fruits	30	40	50	65	90
Vegetables	30	40	55	-	-
Alfalfa	25	35	-	-	-

Source: Preliminary study made by the Irrigation Bureau and the Ministry of Agriculture in the Limarí basin.

Table 18

CULTIVATED AREAS, BROKEN DOWN ACCORDING TO IRRIGATION METHOD

(Hectares)

Species	Total	Flood	Improved flood	Furrow	Basin	Drip
Annual crops	7.590	1.210	5.860	480	-	-
Fruits	6.180	-	-	830	3.250	2.100
Vegetables	1.530	-	230	1.300	-	-
Alfalfa	22.080	18.050	4.030	-	-	-

Source: Table 11 and ad hoc surveys.

Table 19

ACTUAL UTILIZATION OF WATER RESOURCES, ACCORDING TO MAJOR SPECIES

(Percentages)

Species	Efficiency	Area
Annual crops	34,3	20,2
Fruits	71,5	16,6
Vegetables	52,7	4,1
Alfalfa	26,8	59,1
Overall	36,8	100,0

Source: Tables 17 and 18.

Thus, the overall efficiency of the irrigation system in the basin, at the intrafarm level, drops from the 49.3% estimated for the stages outside the farms, to a disappointing level of 18.1%.

4. Conclusions and projections

Several different and interesting conclusions may be drawn from these estimates, although this is not so easy. A preliminary, though superficial and restrictive, approach would lead to the conclusion that despite the enormous investments represented in the case under study, only 18.1% of the water resources stored are actually utilized, which would mean that the remaining 81.9% were wasted. Likewise, under this simplistic criterion, one might conclude that the investments made in the irrigation infrastructures are not adequately compensated for by the low values generated.

On the other hand, a more careful look at the figures, developments, habits and institutions involved will lead to more positive conclusions, and may even give rise to encouraging expectations. In this regard, the partial figures on the different levels of efficiency that are being achieved with the different crops or species are quite useful. Table 19 summarizes the values found in respect of actual utilization of water resources with the four major species.

These figures make it clear that the low overall result --36.8%, indicating an overall efficiency of 18.1% for the entire process-- is seriously affected by the high share of alfalfa, a crop which takes up 59.1% of the farmed area and which has a farm-level irrigation efficiency of only 26.8%.

Fortunately, the participation of this crop seems to be declining over time, while at the same time there has been a dynamic increase in the land area planted in fruits and vegetables, where highly technical irrigation methods are beginning to be applied and where relatively high efficiency rates --71.5% and 52.7%, in that order-- are being achieved. Hence, the prospects are encouraging and the trend is towards an improvement in the efficiency of irrigation at the farm level. This trend is also highly positive from the financial, economic and social standpoints, inasmuch as the production and export of these commodities generate significant benefits.

Consequently, a more serious and positive conclusion to be drawn from this study is that it is wise to invest in major water infrastructure works provided improvements and changes are made in other parameters, especially as regards the distribution of waters, channeling and intrafarm storage of these waters, technification of farm-level irrigation and choice of crops.

VIII. EXPECTATIONS AND PROMOTION OF IRRIGATION AND DRAINAGE

Much of the inefficiency in the actual utilization of waters, particularly at the stages of distribution and intrafarm utilization, could be overcome through the State's efforts to promote irrigation within the private sector.

This interesting option has aroused considerable interest among users in the Limarí basin, and specific steps are being taken in this direction. Such action is being taken mainly by the administrations of the Recoleta and Cogotí reservoirs, but not yet by the farmers, partly because the proposal was made only recently and partly because the regulations governing this plan introduce certain restrictions, which are discussed below.

1. Projects under study, drawn up and presented

In mid-1986 the National Irrigation Commission published three public notices for competitive bidding for irrigation and drainage projects, which entailed a subsidy of 75% of the investment to be committed to these projects.

The Cogotí Reservoir Administration is preparing several projects for improving the master canal, for presentation in late 1986 or early 1987. The Recoleta Reservoir Administration has already submitted three interesting projects, which are currently being studied by the Commission.

One of these projects provides for the lining of the most deficient 100 m of the Villalón canal; the investment of slightly over 5 million pesos would make it possible to reduce the current high level of seepage. The other project involves replacing a siphon in the same canal with a new one; under the more ambitious alternative, this would cost 130 million pesos, while another option, which would partially solve the problem, would entail an investment of 80 million pesos.

The purpose of these projects is to ensure, to a large extent, the availability of the water resources needed to irrigate the area in question --the terraces on the northern side of the intermediate and coastal zones--, which produces mostly tomatoes, pimentos, maize and wheat, all of which are crops which in recent years have replaced unprofitable olive plantations.

The third project submitted to the National Irrigation Commission has to do with the Talhuén canal --the most deficient in the subsystem-- and consists of investing slightly over 6 million pesos for the construction of four overpasses --for stream waters-- and lining the most deficient sections of the canal.

At the same time, projects are being drawn up for the improvement of other sectors of the Talhuén canal, as well as of the Villaseca canal, which is also in poor condition.

Meanwhile, project ideas are being developed by the Huatulame River Provisional Supervisory Board, with a view to improving and lining the Cauchil and Semita canals, and by the Camarico and Punitaqui Canal Users Associations, for similar purposes.

In private circles, on the other hand, a more passive and cautious approach has been taken, in the hope that the National Irrigation Commission will introduce greater flexibility in some provisions which create difficulties for individual farmers.

2. Restrictions in existing regulations

Through the National Confederation of Canal Users Associations, irrigation users are making known their concerns with regard to certain parts of the regulations governing the competitive bidding process and the projects themselves, which, in their view, hinder the application of this interesting initiative.

Some of the main criticisms are the following: i) the excessive amount of technical and legal documentation which must accompany each application, which in practice has prevented many potential applicants from meeting the requirements, especially because the existing regulations require them to submit, among other things, contour maps, soil studies, engineering projects, specific choice of crops, and evaluation of the investment involved; ii) the need to "regionalize" criteria for evaluating applications, consistent with the characteristics and needs of each agricultural area; iii) the considerable increase of financial resources assigned by the State to deal with this matter, where potential demand would lead to a need for funds well in excess of those available; iv) the definitive granting of rights over waters stored in reservoirs which remain the property of the State; and v) State support to strengthen user organizations, especially as regards the improvement of technical, administrative and economic capabilities.

Notwithstanding the validity and consistency of these objections, which are currently being studied by the National Irrigation Commission and will probably lead to improvements being made in the regulations, it is important to stress that the plan to promote irrigation at the intrafarm distribution level is highly positive and timely, as it means that an effort is indeed being made to overcome the limitations which have caused the most serious deficiencies in the process of organizing and ensuring optimum utilization of water resources, especially in those areas which already have large reservoirs.

Notes

1/ National Statistical Institute. The figure includes 4.5 million ha of natural and improved ranges, 3 million ha of soils under preparation, 1 million ha devoted to grains and truck farms, with the remaining 1 million ha being distributed among vegetable crops, artificial pastures, forage, fruit crops and grapes.

2/ This figure, based on various estimates and representative of the year 1985, is close enough for the purposes of this study.

3/ Figured on the basis of a parity of US$1 = 185 Chilean pesos.

4/ During 1985, this amounted to 553 million cubic metres, as shown in table 10.

5/ Both corporations fall within the group of public enterprises which are subject to the privatization process. In the case of ENDESA, this takes place through the creation of new local companies for some projects and the sale of 30% of its shares. EMEC has been totally sold to private shareholders.