water-fitted holes.

Loading: Crude ore and muck blasted out will be loaded onto dump trucks by means of a 10 m^3 class motor-driven shovel.

Hauling: Crude ore and muck are to be hauled by 100-ton class rear dump trucks to the first stage crushing plant and muck bank respectively.

It is of critical importance to maintain the haul roads in good condition in order to reduce tire costs and truck maintenance costs. For this purpose, it is necessary to arrange for road sprinkers, bulldozers, graders, dump trucks and so forth exclusively for road maintenance purposes.

2-4. Model Plan for Ore Dressing

Outline: The ore dressing plant produces Cu concentrates and Mo concentrates by a bulk flotation system.

Since flotation tests have not been performed at all on the ores produced here, it will be necessary to carry out at least batch testing at the earliest possible time so that the information gained may be used in mapping out future plans.

Production volume: Because of the total lack of experimental data necessary for estimating the recovery rate from ore dressing and the grades of concentrates, we assume herein that the recovery rate will be 70% both for copper and molybdenum and that the concentrate grade will be 20% for copper and 85% in terms of MoS_2 for molybdenum in calculating the production volume.

Table 2-6. The Anticipated Ore Dressing Performance

Factor / Volume Treated (T/D)	Grade of Crude Ore (%)		Recovery Rate of Ore Dressing (%)		Grade of Concentrate (%)		Concentrates Produced (T/D) (%)	
	Cu	Mo	Cu	Mo	Cu	MoS_2	Cu	MoS_2
30,000	0.17	0.0604	70	70	20	85 (Mo 51%)	178.5	24.9
20,000	0.17	0.0604	70	70	20	85 (Mo 51%)	119.0	16.6

The total annual production of concentrates is calculated as follows.

Crude ore treated 30,000 tons/day

Cu concentrate:

30,000 tons x	0.17%	÷ 70%	x 20%	x 300
	Grade of Crude Ore	Recovery Rate of Ore Dressing	Grade of Concent-rate	Working Days

≑ 55,000 tons

Mo concentrate (MoS_2):
30,000 tons x 0.064% x 70% ÷ 51% x 300 ÷ 7,500 tons

Crude ore treated 20,000 tons/day

Cu concentrate:
20,000 x 0.17% x 70% ÷ 20% x 300 ÷ 36,000

Mo concentrate (MoS_2):
20,000 x 0.0604 x 70% ÷ 51% x 300 ÷ 5,000

Ore dressing plant: The ore dressing plant will be constructed in the Cueva de Perez area, and consist of a first stage crushing plant, second and third stage crushing plants, an ore polishing plant, a flotation plant, and a concentration and dehydration plant.

The overflow from concentrate thickner and tailing thickners will be recycled for reuse.

Ores (with moisture contents of 8%) accumulated in the ore storage after dehydration will be taken out by truck, but the more precious Mo concentrate will be packed in cans before being hauled out.

Adjacent to the ore dressing plant, a machine repair shop, a welding shop, an electrical repair shop and a light vehicle repair shop will be installed. These shops serve not only for the ore dressing plant alone but also for other mining operations.

The site of the ore dressing plant is selected relatively far from the pit in order to avoid the area where the potential for disco vering enlarged ore deposits in the future seem to exist.

Tailing bank: (Dumping site for tailings) The tailing bank, for the following reasons, should preferably be in the valley of the Cunchi area located about 3.5 km down from Cueva de Perez.

(1) The topography of the area is such that it comprises a perfect basin with a capacity large enough to adequately accommodate the potential volume to be treated (about 130 million cubic meters against minable ore reserves of 200 million tons).

(2) Rocks, earth and sand usable as construction materials can readily be obtained in the neighboring area.

(3) No cultivated land or private dwellings exist in the area so there will be no complications with respect to site aquisition and mining pollution.

However, since not even a single topographic map has been made of this area as yet, it will be necessary to prepare one inclusive of the adjacent peripheral areas on a scale of 1 : 10,000 and re-examine the above points in more detail (Refer to Fig. 2-6).

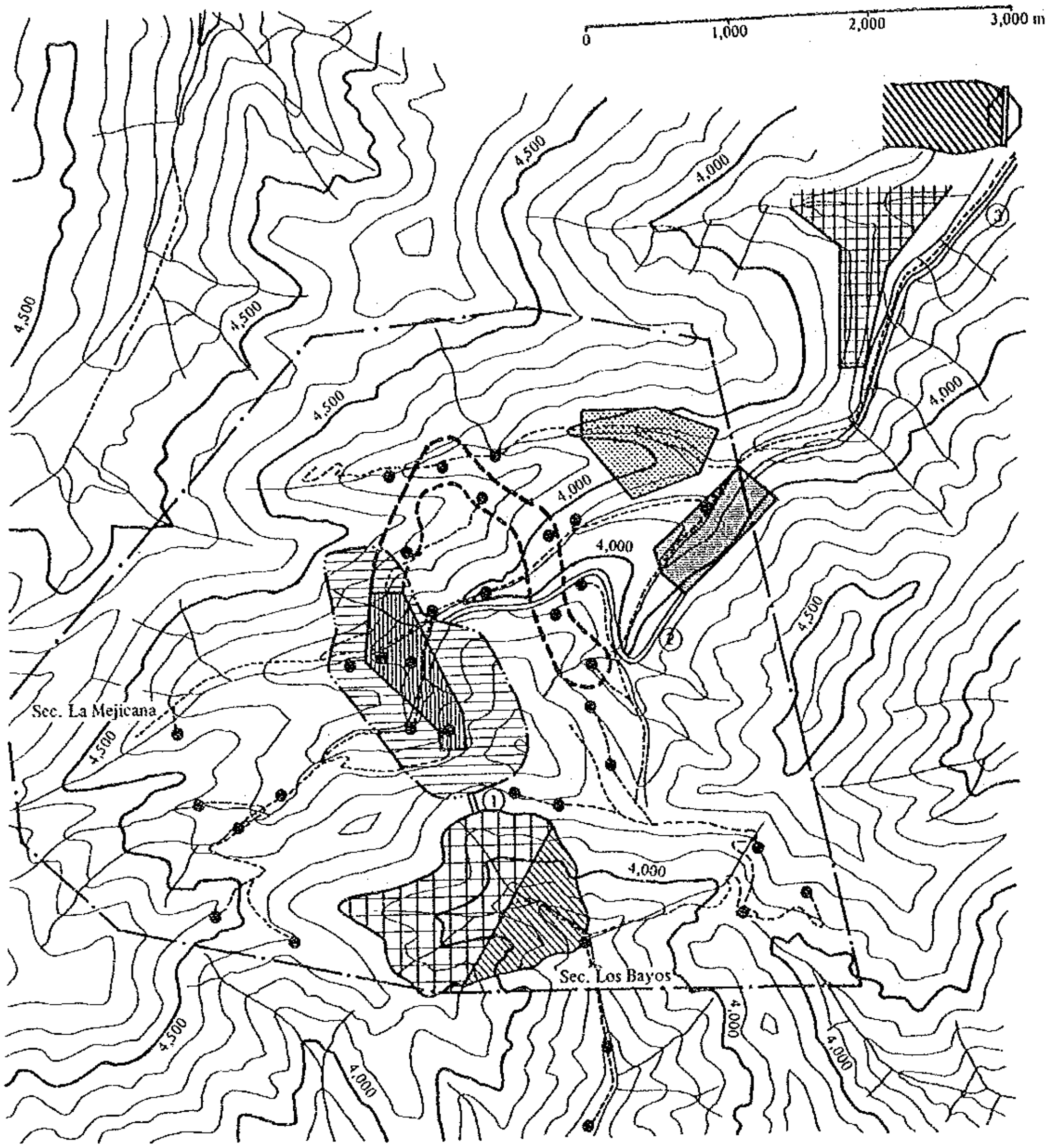
2-5. Costs for Developing the Mine

Initial Expenses for Prompting Development:

Table 2-7. Initial Expenses for Prompting Development (in millions pesos)

Function \ Volume Treated (tons/day)	30,000	20,000
Mining Function	156,000	117,000
Ore Dressing Function	234,000	175,500
Total	390,000	292,500

Fig. 2-6. Explanatory Map of Mining Facilities Plan (Proposed)



Legend:

Area of Minable deposits	Site for Ancillary Facilities of Mine (25 ha)
Area of Open Cut Mining, Stripping and Waste Mining	Additional Spare Site for Above
Area of Potential Deposit Enlargement	Dumping Site for Tailing (Cunchi Area, 135 million m^3)
① Route for Hauling Stripping & Waste	③ Pipe for Slurry Transport of Tailing (3.5 km) and Road.
Dumping Site for Stripping & Waste (177 million m^3)	
② Road for Transport of Crude Ore (2.5 km)	Already Drilled Holes and Road
Site for Ore Dressing Plant (35 ha)	Area Frozen as the Famatina Reserve Area (Zona de Reserva No. 1)

Table 2-8. Breakdown of Mining Function Expenses

(Unit: Million pesos)

Discription \ Volume Treated (tons/day)	30,000	20,000
Machinery	109,200	81,900
Civil Engineering Works	7,800	5,900
Initial Stripping	27,300	19,500
Other Miscellaneous	11,700	9,700
Total	156,000	117,000

Table 2-9. Breakdown of Ore Dressing Function Expenses

(Unit: Million pesos)

Discription \ Volume Treated (tons/day)	30,000	20,000
Machinery	152,100	113,100
Civil Engineering Works	58,500	44,800
Electrical Works	23,400	17,600
Total	234,000	175,500

The construction period shall be three years. Disbursements of initial expenses by fiscal year will be as tabulated below.

Table 2-10. Initial Expenses for Prompting the Development Required for Each Year

(Unit: Million pesos)

Fiscal year	Volume Treated (tons/day)	30,000	20,000
Mining Function	1st F.Y.	35,100	23,400
	2nd F.Y.	46,800	31,200
	3rd F.Y.	35,100	23,400
	11th year after start-up	39,000	19,500
	21st year after start-up	-	19,500
	Total	156,000	117,000
Ore Dressing Function	1st F.Y.	58,500	46,800
	2nd F.Y.	78,000	62,400
	3rd F.Y.	58,500	46,800
	11th year after start-up	39,000	9,750
	21st year after start-up	-	9,750
	Total	234,000	175,500

Of the initial expenses for promoting development, the ratios between domestic currency and foreign currency are assumed to be 40 : 60 for the portion of initial investment outlay and 50 : 50 for the portion of additional investment outlay.

Operating Expenses: The ratio between domestic currency and foreign currency for operating expenses are assumed to be 98 : 2 for labor costs and 60 : 40 for others.

Besides the above, electric power cost, water costs and administrative overhead for each function shall be added to the operating expenses.

Table 2-11. Operating Expenses

(Unit: US$/tons of crude ore)

Function \ Volume Treated (tons/day)	30,000	20,000
Mining Function	1.6	2.0
Ore Dressing Function	2.4	2.8
Total	4.0	4.8

2-6. Molybdenum

Molybdenum originally derives from the Greek word "Molybdos" (meaning "lead-like"), but the German word "Molybdan" is commonly used.

The most common mineral containing molybdenum (atomic symbol of Mo) is molybdenite. Molybdenite's chemical components are MoS_2 which stoichiometrically contains 60% Mo. Most of the currently mined crude ore contains 1 – 1.5% of MoS_2, which is dressed for shipment into molybdenum sulfide concentrate of 85 to 90%. The 85% MoS_2 concentrate contains 51% molybdenum (Mo). It is also shipped as molybdenum trioxide after being roasted.

The United States accounts for most of the world's molybdenum ore production, followed by Canada and Chile. The Climax Mine in the State of Colorado, U.S.A. (owned by American Metal Climax Inc., or AMAX) is the most famous. Although the Climax Mine et al. produce only molybdenum, large copper mines in North and South America are producing molybdenum ores (normally of a crude ore grade of about 0.03 to 0.04%) as a by-product, and the production share of these mines is rising.

Molybdenum is a metal of silver-grey color with a high melting point of 2,610°C. It demonstrates high malleability and ductility at high temperature for casting and rolling. Also, it not only has the characteristics of increasing hardness when added to other metals but also of improving heat resisting and corrosion resisting properties. Accordingly, most of demand for molybdenum is for steel making. For example, 18-8 stainless steel contains 2% molybdenum besides 18% chromium and 8% nickel. In addition, it is used in such special steels as tool steel, structural alloy steel, spring steel and bearing steel which are extensively used for various parts in the automotive and aircraft industries, etc.

Besides the above, it is also used as a raw material in pigments, reagents, surface coatings, printing ink and so on.

Chapter 3.

POWER DEVELOPMENT PLAN

CHAPTER 3. POWER DEVELOPMENT PLAN

1. Estimation of Power Demand

The quantity of power required to process one unit ton of crude ore is approximately 25 kWh. The annual power demand is, therefore, as follows, since the quantity of crude ore treated per year is nine million tons.

25 kWh x 9 million tons = 255 million kWh

Assuming 300 days or 300 x 24 hours operation per year, the average power generating capacity required is:

225 million kWh ÷ 300 days ÷ 24 hours = 31,250 kW

Assuming a loading rate of 75%, the maximum power generating capacity to be installed is 42,000 kW. These figures provide the basis for establishing the power supply plan.

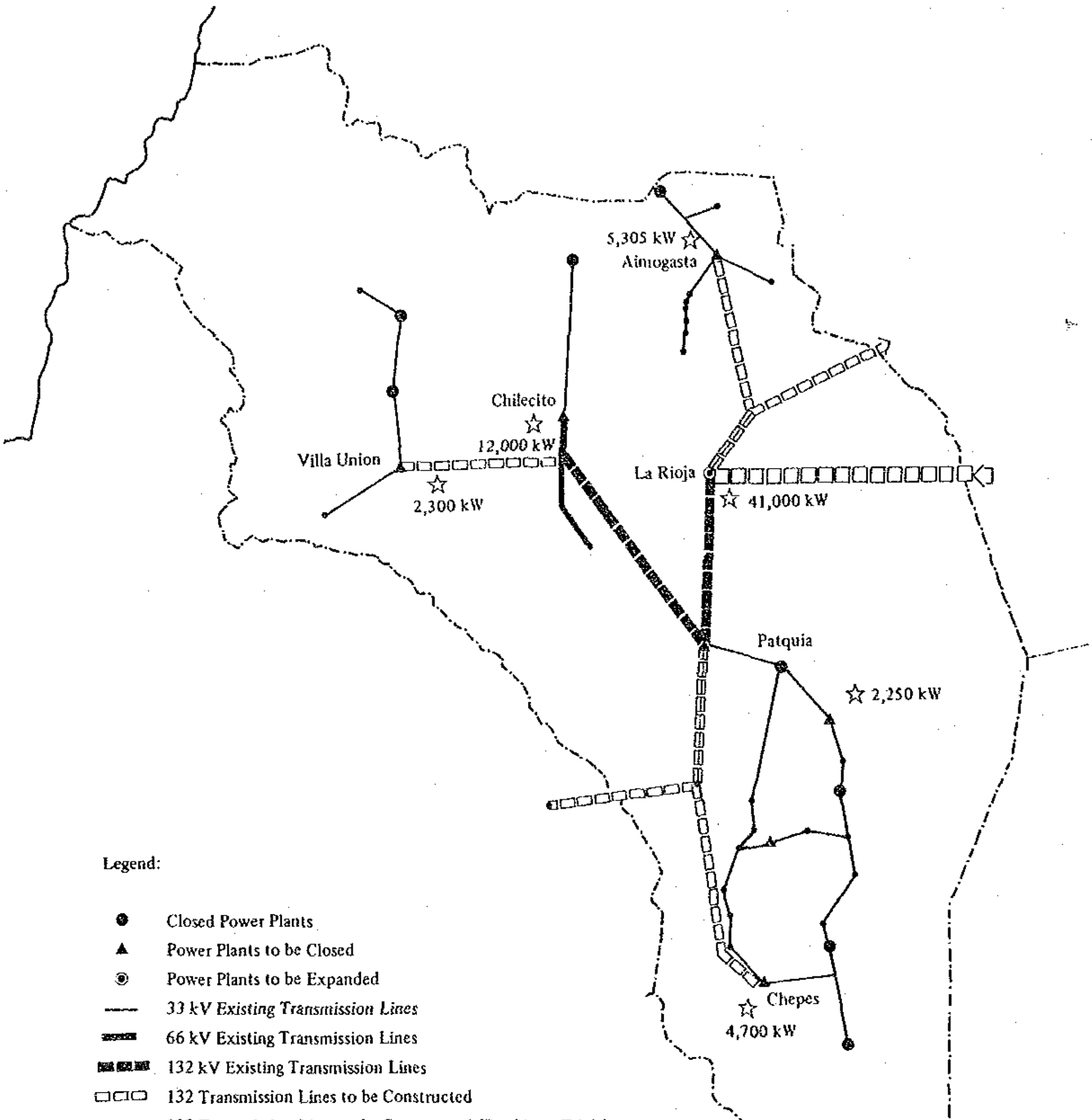
This power demand represents the total required at the mining site for mining and dressing operations including illumination, conveyor operations, slag disposal, operations of various pumps, ventilation fans, crushers, mills, etc.). The power demand for pumping-up water is separately dealt with in Chapter 4, but about 10% of 42,000 kW capacity will be used for this purpose. The power demands in the mining town mentioned in Chapter 5, may be satisfied by existing power facilities.

2. Power Demand in Surrounding Areas

The first question is whether it is possible to meet the demand of 225 million kWh/year or the maximum capacity of 42,000 kW required for the Famatina Mine with existing facilities. At present, the power transmission network in La Rioja State is isolated from the Central System. Many isolated power systems exist throughout Argentina. Although the entire power network is gradually expanding, interconnected systems accounted for 69.2% in terms of kWh, and 67.5% in terms of kW as of 1977. By the year 2000, however, the entire system is expected to be unified.

In La Rioja Province, there are two major power systems. One is the La Rioja System, having a generating capacity of 41,000 kW, including old and new power plants. The other is the Chilecito System with a generating capacity of 12,000 kW. In addition to the above, there are the Gordillo System and others but they are minor in scale. The cities of Chilecito and La Rioja are connected by a 132 kV transmission line. The locations of power plants and the present status of power transmission lines in the province are as shown in Fig. 3-1.

Fig. 3-1. Power Transmission Network in the Province of La Rioja



Legend:

- Closed Power Plants
- Power Plants to be Closed
- Power Plants to be Expanded
- 33 kV *Existing Transmission Lines*
- 66 kV Existing Transmission Lines
- 132 kV Existing Transmission Lines
- 132 Transmission Lines to be Constructed
- 132 Transmission Lines to be Constructed (Double or Triple)
- 220 kV Transmission Lines to be Constructed
- Output

According to demand estimates for the north-western regions of Argentina made by Agua Energia Electrica, Empresa de Estado (AEE), total electric power requirements for the La Rioja System and the Chilecito System are as given in Table 3-1. The table shows that the power demand was 11,070 kW for the La Rioja System as of 1978, 8,900 kW for the Chilecito System or about 20,000 kW in total. The power supply capacity, on the other hand, was 53,000 kW, as mentioned in the previous paragraph. For a supply capacity of 5,300 kW, however, it should be noted that some generators cannot be fully operated. Thus, the actual capacity should be lower than this figure. In any case, however, it may be judged that these systems still have sufficient reserve capacity. By the year 1985, when the Famatina Mine is put into operation, the demand will have increased to 19,090 kW for the La Rioja System, and 15,490 kW for the Chilecito Ssytem, or 34,580 kW in total. If the demand of 42,000 kW for the Famatina Mine is added to this the supply capacity will be insufficient (Refer to Table 3-1 on p. 84).

3. Establishment of Alternate Plans

Since the power requirements for the Famatina Mine cannot be satisfied by existing power generation facilities in La Rioja Province, it will be necessary to develop new power sources. Two distinct plans may be conceived:

(1) a plan for construction of an independent power plant, and
(2) a plan for connecting with the Central Power System.

Construction of an Independent Power Plant: It is basically possible to construct a power plant anywhere, and the construction costs of the power plant itself will not vary significantly regardless of location. Thus the construction site for the plant may be selected anywhere between the base of the mine and Chilecito, where the mining town is to be constructed. The construction costs for the transmission line will be smaller if it is constructed near the mine, while the transportation costs for fuel, etc. will be smaller if it is constructed near the city of Chilecito on the outskirts of the mine. With this project, however, it should be noted that the mine is located at an altitude of about 4,000 m and the efficiency of power generation diesel engines will be reduced if the power plant is located near the mine. This will result in additional investments in facilities and a higher fuel cost (including transportation cost). Fig. 3-2 illustrates this point schematically. Candidate sites for the power plant are (1) the mining area, (2) the city of Chilecito and (3) the village of Los Corrales. The last alternative was included, because it is located at a moderate altitude, relatively close to the mine, and it is easy to secure a site for the plant as the on-site surveys reveal (Refer to Fig. 3-2 on p. 85).

If the power plant is constructed near the mine or in Los Corrales, all related facilities, have to be newly constructed. On the other hand, if it is constructed in the city of Chilecito, facilities may be constructed either newly or as an expansion to the existing steam power plant at Chilecito.

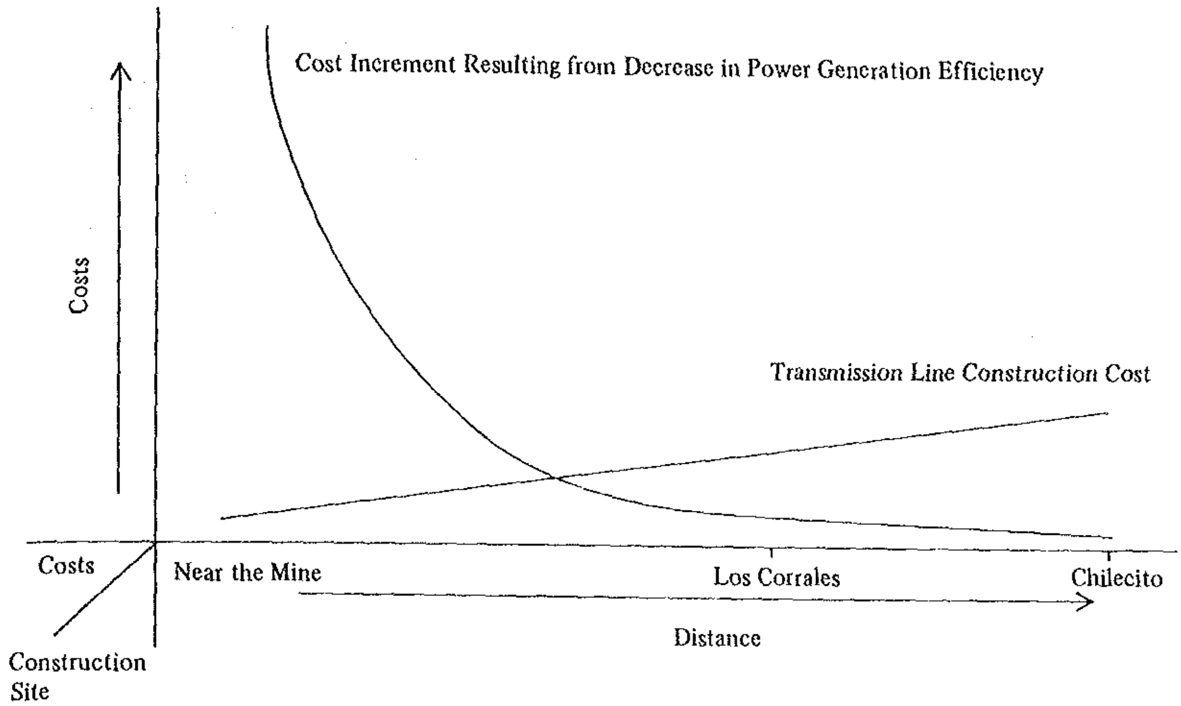
Advantages of expanding the existing power plant over constructing an entirely new plant are as follows:

Table 3-1. Estimated Power Demand in the La Rioja Region

		Year	Power Consumption (GWH)	Power Generation Capacity (GWH)	Peak Power (MW)
Actual	La Rioja System	1978	30.58	34.83	11.07
	Chilecito System	1978	30.72	31.83	8.90
Estimated	La Rioja System	1980	34.94	39.69	12.36
		1985	57.06	64.38	19.09
		1990	87.54	98.16	27.69
		1995	128.62	143.37	38.47
		2000	185.61	206.23	52.66
	Chilecito System	1980	34.21	38.01	10.42
		1985	53.46	59.40	15.49
		1990	78.64	87.38	21.68
		1995	111.37	123.74	29.22
		2000	155.71	173.01	38.86
Increase Rates	La Rioja System	1990/1978	2.86	2.82	2.50
		2000/1978	6.07	5.92	4.76
	Chilecito System	1990/1978	2.56	2.51	2.44
		2000/1978	5.07	5.44	4.36

Source: Agua Energia Electrica, Empresa de Estado.

Fig. 3-2. **Relationship between Costs and Distance of Private (Independent) Power Generation Site**



(1) The installation costs will be significantly reduced, since it is unnecessary to consider reserve generating capacity, and

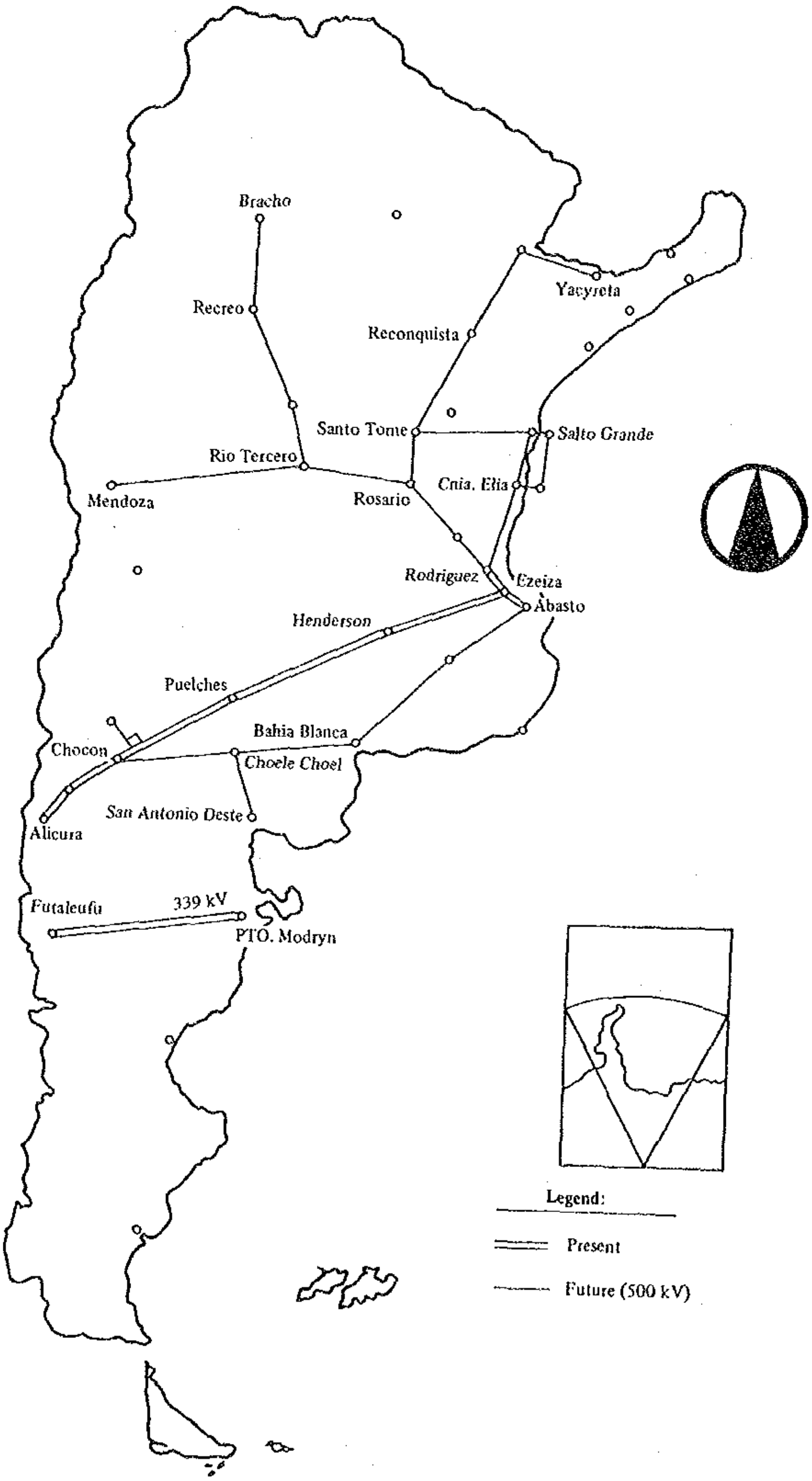
(2) Operation costs such as management cost, personnel cost, etc. can be saved.

As expansion was already planned in the past, and because of the fact that the Chilecito Power Plant has a large site construction of additional facilities is quite feasible. It will, therefore, be most appropriate to take this option if the city of Chilecito should be selected.

To sum up, alternative sites for the power plant are (1) the mining area, (2) Los Corrales, and (3) the city of Chilecito. The existing facilities are to be expanded if the city of Chilecito should be selected, while the entirely new facilities should be constructed for the other two alternatives.

Plan for Interconnection with the Central Power System: Argentina established a project in September, 1979, concerning power generation and transmission facilities up to the

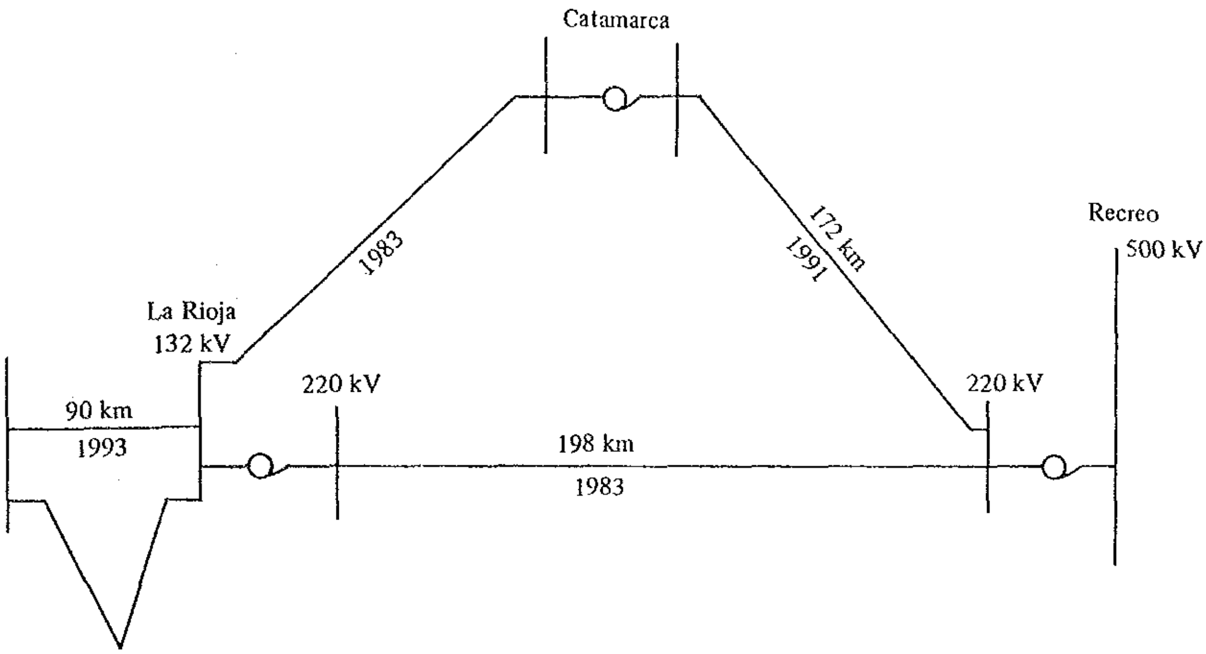
Fig. 3-3. Arterial Transmission Systems – Argentina



year 2000. Fig. 3-3 shows a schematic of 500 kV arterial transmission line routes based on this project, including conditions which existed as of 1978 and predictions for 1985. According to project plans, a 500 kV arterial transmission lines connecting Recreo in the province of Catamarca is scheduled to be completed by 1985 (Refer to Fig. 3-3 on p. 86).

Various plans have been considered for the transmission line covering the Recreo – La Rioja – Chilecito route. One of the plans is shown in Fig. 3-4. By 1983, a 220 kV transmission line up to La Rioja will be completed. The initiative for construction of arterial transmission lines will be taken by the Hydroelectric Power Public Corporation, while the initiative for construction of the transmission line interconnecting Recreo – La Rioja – Chilecito will be taken by the State Electricity Bureau (or the Hydro electric Power Public Corporation). In this project, the completion of a 132 kV transmission line between La Rioja and Chilecito is scheduled for 1993.

Fig. 3-4. Example of Recreo-Chilecito Transmission Line Construction Plan



It is highly likely that the transmission line between La Rioja and Chilecito cannot be completed before initiation of mine operations. Therefore, two alternatives are currently under consideration for this plan to interconnect with the Central Power System. Namely, (1) the construction costs of the transmission line from the mine to Chilecito are to be borne by the mine, and the rest is to be borne by the Government, or (2) all costs are to be borne by the mine. According to these plans, the mine has to construct at least some portion of the transmission lines and at the same time purchase electric power from the Hydro electric Power Public Corporation. In any case, the necessary prerequisite is the completion of arterial transmission lines and a transmission line between Recreo and La Rioja as scheduled.

4. Scale of Alternate Plans

Plan to Establish New Power Plant near the Mine: The mine is located 82 km by road from the city of Chilecito and 3,800 m above sea level. Considering this altitude, electric power diesel output is reduced drastically by 30% or so from normal output. Moreover, the costs for transporting fuel over the long distance will be significant. On the other hand, construction costs for a transmission line become zero. The viability of this alternative, therefore, depends on the difference between the cost increases resulting from the reduced output and additional transportation cost and the cost decreases associated with not having to construct a transmission line.

In order to obtain 225 million kWh to meet mine power demand by means of diesel electric power generation, it will be necessary to transport about 48,620 tons/year of diesel oil. Assuming that the cost per ton is 13,300 pesos, the annual cost will be 48,620 tons x 13,300 pesos = 646.65 million pesos.

Plan for Construction of New Power Plant in Los Corrales: Los Corrales is relatively close to the mine, 2,200 m above sea level, and 52 km from the city of Chilecito. Thus as compared with the plan to construct a new power plant near the dressing site, generation efficiency loss can be avoided, but construction cost of the transmission line, 30 km in length to the mine would increase. As described below, the total costs, including 83,350,000,000 pesos for the power generation facilities and 2,650,000,000 pesos for the transmission line, total an estimated 86,000,000,000 pesos. In addition, the annual fuel cost is estimated to be 17,260,000,000 pesos, and operation and maintenance costs 4,170,000,000 pesos, for a total of 21,430,000,000 pesos per year.

1) Necessary Facilities

Power Plant:

Service Output:	40,000 kW (diesel 8,000 kW x 5)
For Stand-by Service & Construction:	8,000 kW (diesel 4,000 kW x 2)
Transmission Line:	132 kV, single line, 300/50 mm^2 30 km

2) Construction Costs

Power Generation Facilities:

Direct Construction Costs:	70,640,000,000 pesos (including 132 kV/11 kV transformation facilities)
Engineering Costs:	3,530,000,000 pesos

Management Costs:	2,120,000,000 pesos
Others:	7,060,000,000 pesos
Sub total	83,350,000,000 pesos
Power Transmission Costs:	2,650,000,000 pesos (88,300,000 pesos/km)
Total Construction Costs	86,000,000,000 pesos

3) Annual Costs

Operation & Maintenance Costs:	4,670,000,000 pesos
Fuel Cost:	18,960,000,000 pesos
Total	23,530,000,000 pesos

The substation at the mine receiving 132 kV for conversion to 13.2 kV is regarded as an independent station for the mine and one of the mine facilities, as in the case of various electric works (e.g., 13.2 kV and 0.4/0.220 kV). Hence costs for the substation are not included in the costs mentioned above. The same applies in following alternatives.

Plan for Construction of Additional Power Plant in Chilecito: Of the three alternate plans, this plan employs a location farthest from the mine. Nevertheless, construction costs and operation costs can be substantially saved if the existing facilities of the thermal power plant in Chilecito are utilized. This plan was previously considered independently of the current mine development project. As compared with the Los Corrales plan, two diesel power generators of 4,000 kW are not required in this case. Therefore, the construction costs for power generation facilities can be reduced by the amount calculated as follows:

83,350,000,000 pesos − 68,080,000,000 pesos = 15,270,000,000 pesos

1) Necessary Facilities

Power Plant:

Service Output:	40,000 kW (diesel 8,000 kW x 5)
For Stand-by Service & Construction:	Unnecessary (existing facilities can be utilized)
Transmission Line:	132 kV, single line, 300/50 mm² 34 km

2) Construction Costs

Power Generation Facilities:

Direct Construction Costs:	57,690,000,000 pesos (including substations and switching stations)

Engineering Costs:	2,890,000,000 pesos
Management Costs:	1,730,000,000 pesos
Others:	5,770,000,000 pesos
Sub total	68,080,000,000 pesos
Power Transmission Facilities:	3,000,000,000 pesos (88,300,000 pesos/km)
Total Construction Costs	71,080,000,000 pesos

3) Annual Costs

Operation & Maintenance Costs:	3,500,000,000 pesos
Fuel Cost:	18,700,000,000 pesos
Total	22,260,000,000 pesos

Since five new power generators have a total output capacity of 40,000 kW, power demand for the mine can be met. However, there are thirteen existing spare power generators, ten of which are currently in operation. Classification of these thirteen generators is as follows:

No.	Name of Generator	KV	KVA	KW (NOM)	KW (EP)	OBS.
1	M.A.N.	0.400	640	300	300	
2	M.A.N.	0.400	640	300	300	
x 3	NOATIONAL					STa. GORD
x 4	VOITH	2.300	430	180	100	RAD. DE SERV.
x 5	S. GIORGIO	0.380	300	250	100	RAD. DE SERV.
6	FIAT	13.200	1,340	1,070	900	
7	FIAT	13.200	1,340	1,070	900	
8	FIAT	13.200	1,340	1,070	900	
9	FIAT	13.200	1,340	1,070	900	
10	FIAT	13.200	3,750	3,000	2,500	
11	FIAT	13.200	4,250	3,200	2,700	
12	FIAT	13.200	4,250	3,200	2,700	

Source: Agua Energia Electrica, Empresa de Estado.

In Case of Construction of New Transmission Lines and Purchase of Power: The capacity of the existing transmission line going through La Rioja – Patquia – Chilecito is inadequate to provide 40,000 kW power for the mine. The plan to construct a new 132 kV – 70 km transmission line between La Rioja and Chilecito via the Velasco Mountains will, therefore, necessitate completion of a new 500 kV – 70 km Argentina arterial transmission line going up to Recreo in the state of Catamarca, and the completion of a 22 kV transmission line between Recreo and La Rioja. The construction costs for this are estimated as follows:

1) Necessary Facilities

Transmission Line:	(the mine – Chilecito) 132 kV, one line 300/50 mm^3, 34 km
Transmission Line:	(Chilecito – La Rioja) 132 kV, one line 300/50 mm^3, 90 km
Transmission Line:	(La Rioja – Recreo) 220 kV, one line 435/55 mm^3, 198 km

2) Construction Costs

Transmission Line:	(the mine – Chilecito) 2,960,000,000 pesos (87 million pesos/km)
Transmission Line:	(Chilecito – La Rioja) 7,830,000,000 pesos (87 million pesos/km)
Transmission Line:	(La Rioja – Recreo) US$16,592,400 (US$83,800/km)

Construction costs for the transmission line between the mine and Chilecito are to be borne basically by the mine. The rate upon purchase of power will also be payable by the mine. According to the power supply provisions and tariff schedule the Hydroelectric Power Public Corporation in 1980, electricity rates were as follows:

Demand Rate (kW/month):	22,440 pesos/month
Energy Rate (kWh):	51 pesos

The power requirements for the mine are, as mentioned earlier, 42,000 kW in terms of max. power demand, and 225 million kWh in terms of total annual demand. Hence, annual payable electricity rates will be:

22,400 pesos x 12 months x 42,000 kW = 11,310,000,000 pesos
51 pesos x 225 million kWh = 11,480,000,000 pesos,

which will total 22,790,000,000 pesos.

5. Comparison and Review of Alternate Plans

The alternative plans described so far may be summarized as follows:

		The Mine	Los Corrales	Chilecito	Power Purchase
(1)	Generators	7	7	5	0
(2)	Transmission Line	0	30 km	34 km	322 km
(3)	Fuel/Year	63,210 tons	48,620 tons	48,620 tons	0
(4)	Fuel Transport Distance	82 km	50 km	0	0
(5)	Electricity Rate/Year	0	0	0	22,800,000,000 pesos

For power generation facilities of (1) above, two reserve generators can be excluded by utilizing the existing facilities in Chilecito. For the purchase of power, the electricity rate of (5), corresponding to the power generation facilities, will be required. For the fuel of (3), the fuel consumption will be increased by 30% due to a 30% reduction in generating efficiency at the mine, in order to maintain the same power generation capacity. For the fuel transport distance of (4), the transport cost becomes higher for the first and the second alternatives according to the distance between Chilecito and the mine (82 km) and between the mine and Los Corrales (50 km), respectively. Advantages and disadvantages of the alternate plans cannot be easily compared, because some cost elements are fixed factors, such as the construction costs of power facilities, and other costs such as electricity rates are incurred over many years. The alternate plans will, therefore, be compared and examined in the following to determine the optimum plan.

Comparative Review of mine Alternative: Of the three alternate plans described so far concerning the construction of an independent power plant, it is evident that the plan to construct it at the mine is inferior to others because of the higher total costs. To be specific, the fuel transport cost is higher than the construction cost of a transmission line itself in this case, even if the power generation facilities are the same as those of the others. Construction costs for the 30 km transmission line will be approximately 3,000,000,000 pesos, but the fuel transport cost will be 870 million pesos per year, which will evidently result in higher overall costs if this annual cost should continue for 22 years. The transport of fuel by means of pipeline is not considered feesible.

Comparative Review of the Los Corrales Alternative: Secondly, a comparison between the plan to construct the power plant at Los Corrales and the plan to construct it at Chilecito reveals definite disadvantages for the former. That is if the power plant is to be constructed in Los Corrales, two additional power generators will be necessary, and the fuel transport distance will have to be extended by 50 km. Moreover, the length of the transmission line in this case is only 4 km shorter than the Chilecito plan. Therefore, the Chilecito plan is more advantageous than the Los Corrales plan.

Comparative Review of the Chilecito Alternative: From the foregoing comparisons, this alternative is the most advantageous for construction of an independent power plant. Finally, the comparison between the Chilecito plan and the power purchase alternatives will be made in the following to select the optimum plan. A comparison of these two plans can be made in terms of economic costs. Firstly, the economic costs of the Chilecito plan can be obtained through following calculations.

This plan makes use of two existing generators as reserve generating facilities. It may be assumed, in terms of the entire nation's costs, that these two generators will be shared equally by the public and the mine. In this respect, the cost of 7,630,000,000 pesos for one more generator has to be added to the Chilecito plan. Table 3-2 shows an investment schedule based on the premises that investment in the construction of transmission line will be made in 1983 and 1984 at a ratio of 4 : 1, investment in the construction of power generation facilities will be made in 1984 and 1985 at a ratio of 7 : 3, and that the ratio of foreign currency and domestic currency will be 6.5 : 3.5 for the transmission line, 7 : 3 for the power generation facilities and 3 : 7 for operating costs (Refer to Table 3-2 on p. 94).

In order to calculate direct costs (economic costs) for independent power generation, taxes should be deducted first from the financial cost, then the remaining figure should be adjusted with the potential foreign currency exchange rate. Assuming a potential exchange rate of 33% (refer to Chapter 7), the economic costs are calculated as shown in Table 3-2.

Table 3-3 gives the calculation of economic costs of independent power generation per kWh. Namely, since capital investment is made over three years and the operating cost is incurred over 22 years to generate power of 225 million kWh annually, each cost element should be discounted to allow a comparison of the present value. Discounted by 10%, an amount which corresponds to the opportunity cost of capital, the present value of total costs becomes 246,897,000,000 pesos (Refer to Table 3-3 on p. 95).

On the other hand, the total energy generated over 22 years is equivalent to the present value of 1,610 million kWh discounted by 10%, and the unit economic cost is thus calculated as 153 pesos/kWh in the case of independent power generation.

Comparison with Power Purchase Economic Costs: To estimate the economic costs of power purchase by means of the transmission line connected with the Central System. The unit economic cost per kWh has to be known. It is difficult, however, to make an accurate calculation of the prime cost. Power generation facilities vary depending on the power generation methods used such as hydroelectric, thermal and nuclear power generation, and also on when the investments were made. In this study, the unit economic cost per kWh is estimated based on future development projects of AEE as delineated in 1979 (Refer to Table 3-4 on P. 96).

Table 3-2. Investment Schedule and Economic Costs

(Unit: Million pesos)

	1983		1984		1985		1986–2008	
	F[1]	D[2]	F	D	F	D	F	D
Power Transmission Line (F 65%)	1,560	840	390	210	–	–	–	–
Power Generation Facilities (F 30%)	–	–	37,098	15,899	15,899	6,814	–	–
Operating Cost (F 30%)	–	–	–	–	–	–	6,666	15,555
Financial Cost Total	1,560	840	37,488	18,109	15,877	6,814	6,666	15,555
Taxes (-10%)	–	84	–	1,811	–	681	–	1,555
Potential Exchange Rate (33%)	2,075	–	49,859	–	21,116	–	8,866	–
Economic Costs Total	2,831		66,157		27,249		22,826	

Notes: 1) F is foreign currency.
2) D is domestic currency.

Table 3-3. Calculation of Economic Cost per kWh of Private Power Generation

(Unit: Million pesos)

	10% Reduction Factor	Cost (Million pesos)	Generated Energy (Million kWh)	Cost after Reduction	Generated Energy after Reduction
1983	1,000	2,831		2,831	
1984	909	66,157		60,137	
1985	826	27,249		22,520	
1986	751	23,643	225	17,756	169
1987	683	"	"	16,148	154
1988	621	"	"	14,682	140
1989	564	"	"	13,335	127
1990	513	"	"	12,129	115
1991	467	"	"	11,041	105
1992	424	"	"	10,025	95
1993	386	"	"	9,126	87
1994	350	"	"	8,275	79
1995	319	"	"	7,542	72
1996	290	"	"	6,856	65
1997	263	"	"	6,218	59
1998	239	"	"	5,651	54
1999	218	"	"	5,154	49
2000	198	"	"	4,681	45
2001	180	"	"	4,256	41
2002	164	"	"	3,877	37
2003	149	"	"	3,523	34
2004	135	"	"	3,192	30
2005	123	"	"	2,908	28
2006	112	"	"	2,648	25
2007	102	"	"	2,412	23
Total				249,309	1,633

Note: 249,309 ÷ 1,633 = 153 pesos

Table 3-4. Predicted Electricity Rates
(Overall Prime Costs & Sales Unit Price)

(*Unit:* US$ Million)

	1979	1982	1985	1990
Generated Energy for Sales (GWh)	27,740	35,890	46,010	69,170
Overall Prime Costs				
Fuel Cost	430	510	546	458
Personal (Labor) Cost	476	547	651	900
Capital Cost	694	1,282	1,805	2,942
Others	203	302	385	763
Total	1,803	2,641	3,387	5,063
Average Sales Unit Price	65.0	73.6	73.6	73.2

Source: Plan Nacional de Equipamiento para los Sistemas de Generación y Transmisión de Energía Eléctrica, 1979–2000.

Application of an exchange rate 1 US$ = 1,288.50 pesos as of June 1979 gives the following:

1,288.50 pesos x US$0.065 = 83.75 pesos

The average unit sales price per kWh as of 1979 was 83.75 pesos. Considering an inflation rate of 80% for the period between January, 1980, and October, 1980, the unit price per kWh as of October, 1980, should be:

83.75 pesos x 180% ≒ 151 pesos

The economic cost, therefore, is about 151 pesos.

Optimum Alternate Plan: From the foregoing analysis, it may be said that power of 1 kW can be obtained at a smaller cost in the order of the power purchase plan, the Chilecito plan, the Los Corrales plan, and the Mine plan. There is, however, no significant difference in economic cost between the Chilecito plan and the power purchase plan. Moreover, it should be kept in mind that the accuracy of the calculation of economic cost for power purchase cannot be unconditionally ensured. On the other hand, the power generation cost per kWh may be estimated as approximately 150 pesos. This figure of 150 pesos/kWh represents the appropriate value for the economic cost of power in either case of power purchase plan or of independent power generation plan.

6. Power Supply Plan

Power Cost for Economic Analysis: From the foregoing analysis, it was found that power purchase from the Central System is optimal. For economic analysis, therefore, the cost of generating power by means of the Central System is used as the power cost. This is based on the figure of 151 pesos per kWh determined in the preceding section. The annual power cost will thus be as follows:

225 million kWh x 151 = 33,980,000,000 pesos

The economic costs can be calculated by breaking down the total costs calculated above into foreign currency and domestic currency referring to Table 3-4 and multiplying the foreign currency by the shadow exchange rate. Although the precise ratio of foreign currency and domestic currency is not known, it may be estimated that foreign currency accounts for approximately 30% of the total cost, assuming that foreign currency accounts for 30% of fuel cost, 0% of personnel cost, 70% of capital costs and 0% of other costs. For domestic currency, a 10% reduction is made for taxes.

The following calculations are carried out to estimate the economic costs of power (34,960,000,000 pesos) required annually for mine operation.

Foreign Currency:

33,980,000,000 pesos x 30% = 10,190,000,000 pesos

Domestic Currency:

33,980,000,000 pesos x 70% = 23,790,000,000 pesos

23,790,000,000 pesos x 90% = 21,410,000,000 pesos

10,190,000,000 pesos x 133% = 13,550,000,000 pesos

13,550,000,000 pesos + 21,410,000,000 pesos = 34,960,000,000 pesos

Power Cost for Financial Analysis: This is the actual cost required by the mine, including construction costs for the transmission line and electricity purchasing costs. It is assumed here that 80% (2,370,000,000 pesos) of the total investment (2,960,000,000 pesos) for the transmission line between Chilecito and the mine will be made in 1983, and the remaining 20% (590,000,000 pesos) in 1984.

The mine may also have to bear construction costs of 7,830,000,000 pesos for the construction of the transmission line between Chilecito and La Rioja. Effects of cost increases that may result from the above will be dealt with by sensitivity analyses. The electricity rate for the power purchased from the Central system should be lower than the power generation cost of 151 pesos/kWh since the former is a public utility charge. Concerning future electricity rates in Argentina, it is expected that the average unit sales price of 65.0 US$ mills/kWh in 1979 will be increased to 73.0 US$ mills/kWh in 1982, this level will then be maintained up to 1985 and will finally drop to 73.2 US$ mills/kWh (146.4 pesos/kWh = 15.7 Yen/kWh) in 1990. The electricity rate at the time of the survey was calculated to be 101 pesos/kWh. According to the power supply provisions & tariff schedule of AEE, the rates were as follows.

kW rate → Demand Charge: kW/month .... 22,440 pesos/month/kW
kWh rate → Energy Charge: kW/hour .... 51 pesos/kWh

The power requirements for this mine, as mentioned earlier, are maximum power of 42,000 kW and total annual demand of 225 million kWh. Thus the annual electricity rates are:

22,440 pesos x 42,000 kWh x 12 months = 11,310,000,000 pesos
51 pesos x 225 million kWh = 11,480,000,000 pesos

for a total of 22,790,000,000 pesos.

The electricity rate per kWh is therefore:

22,790,000,000 pesos x 225 million kWh ≒ 101 pesos,

hence total electricity cost is 22,790,000,000 pesos. In calculating operating costs, power cost of 1,740,000,000 pesos was added to the cost of 22,790,000,000 pesos calculated above for a total of 24,530,000,000 pesos.

<u>In Case the Mine Operates at a Scale of 20,000 tons of crude ore per day:</u> Since the maximum power demand is 28,000 kW and the total annual demand is 150 million kWh, the annual electricity rates can be calculated in the same way as the case of a daily processing volume of 30,000 tons of crude ore:

22,440 pesos x 28,000 kW x 12 months ≒ 7,540,000,000 pesos
51 pesos x 150 million kWh = 7,650,000,000 pesos

for a total of 15,190,000,000 pesos.

Therefore, the electricity rate per 1 kWh is:

15,190,000,000 pesos ÷ 150 million kWh = 101 pesos,

which results in a total electricity rate of 15,190,000,000 pesos. In calculating the operating costs, a power cost of 1,610,000,000 pesos was added to 15,190,000,000 pesos, for a total of 16,800,000,000 pesos.

Chapter 4.

WATER RESOURCES DEVELOPMENT

CHAPTER 4. WATER RESOURCES DEVELOPMENT

1. Background

1-1. Geographic, Geologic and Meteorological Conditions of the Region

The Famatine region is situated in the northern central part of the Province of La Rioja. The eastern part of the region is a narrow semi-Pampean plain lying between the Sierra de Velasco on the east and the Sierra de Famatina on the west; the latter constitutes a part of the Andean preranges. The altitude ranges from about 1,100 m on the east to over 4,000 m in the mine area on the west.

The mine area is underlain widely by sedimentary rock of the Ordovician age, which underwent active orogenic movements in the tertiary age resulting in extensive formation of folds and faults. This formation is intruded by granite rocks of the Devonian age, which turned the surroundings into hornfels. Also distributed in the area are numerous intrusive bodies together with dikes of dacitic-porphyry or rhyodacitic-parphyry, which are considered to be associated with mineralization in the western part of the region.

The climate of the region is semi-arid to arid; annual precipitation ranges from 200 mm on the eastern plain to over 400 mm in the mountain areas on the west (see Fig. 4-1). Seasonal variations in temperature and precipitation are high, as indicated by the data given in Table 4-1. Both temperature and precipitation are high in summer (December through May) and low in winter (June through September). In high altitude areas, however, the precipitation patterns are somewhat different, since the precipitation during winter is much higher, taking the form of snow-falls. Also the precipitation in summer often takes the form of storms with sharp hydrographs (Refer to Fig. 4-1 on p. 100 and Table 4-1 on p. 101).

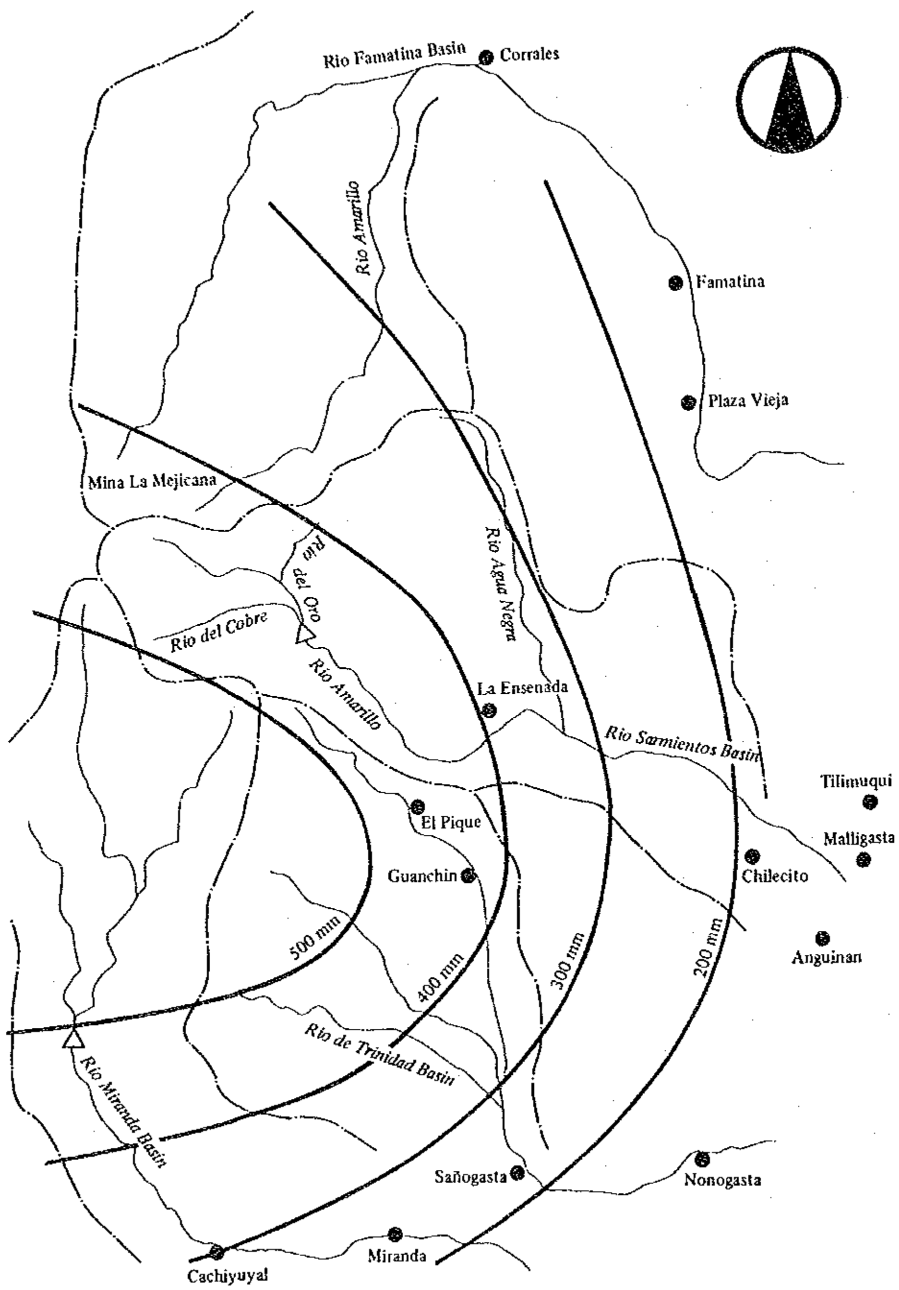
The high seasonal and daily precipitation variations make the availability of surface water quite unreliable, while the groundwater supply may be comparatively more stable, since melting snow contributes to the groundwater reserves. In fact, low streamflow during dry seasons is considered to be largely attributable to base discharge from groundwater.

1-2. Overview of Water Endowment of the Region

The project region consists of four major drainage basins -- Rio Famatina, Rio Sarmientos, Rio de Trinidad and Rio Miranda (see Fig. 4-1). Unfortunately time-series of flow in these rivers that are sufficiently long and complete are largely unobtainable.

Catchment areas above respective downstream points as shown in Fig. 4-1 are 283 km^2 for Rio Miranda, 260 km^2 for Rio Sarmientos, 405 km^2 for Rio Famatina and 265 km^2 for Rio de Trinidad. These areas, however, do not by themselves give a good indication of surface water availability at the different points in these basins for a few reasons. First, precipi-

Fig. 4-1. Project Area with Annual Projection Contours



Legend:

River	Potential reservoir site
River basin boundary	Precipitation measuring station
Annual precipitation contour	

Table 4-1. Average Monthly Precipitation at 8 Stations and Average Temperature at Chilecito

Average monthly precipitation (mm)

Station	Month 1	2	3	4	5	6	7	8	9	10	11	12	Annual Total
Famatina	53	28	36	5	1	0	1	0	5	9	2	13	164
Corrales	76	30	43	11	1	2	2	4	9	11	1	38	223
La Ensenada	181	100	103	81	11	11	0	8	18	49	30	49	634
Sañogasta	42	44	35	1	1	1	1	3	7	8	8	36	153
Miranda	94	64	31	20	4	2	2	0	7	14	5	36	279
Cachiyuyal	113	49	25	9	5	0	5	3	12	19	7	34	281
Guanchin	118	55	83	15	3	2	7	5	7	15	13	70	393
Chilecito	46	41	37	9	5	4	4	4	4	8	22	28	212

Note: The average is taken over 4 to 7 years depending on the particular station, except for Chilecito, where the average is based on 17 years record.

Source: Centro Regional de Agua Subterranea (C.R.A.S), San Juan.

Average temperature of Chilecito 1951–67 (°C)

Month 1	2	3	4	5	6	7	8	9	10	11	12	Annual Average
24	23	20	17	13	9	9	12	15	18	21	24	17.4

Source: Secretaría de Estado de Recursos Hidricos (Direccion General de Obra Hidraulicas, Dpto Estudios y Projectos), La Rioja.

tation patterns differ depending on the particular basin or sub-basin; secondly, the extent surface water flow goes underground and the extent surface water flow is fed by secondary discharge from groundwater vary depending on the geological and topographical conditions of particular sites; thirdly, surface water withdrawal for irrigation and other purposes varies for different areas. It is not unusual that much higher flow is observed in the upper reaches of a river than in its lower reaches.

Relatively rich groundwater resources are found in the region, and have been used to varying extents in downstream areas. Exploration of the groundwater reserves near the city of Chilecito has been undertaken by Direccion General de Agua Subterranea (DGAS), La Rioja. Several layers of aguifer have been confirmed in this area within 600 m depth, but in Chilecito and the surrounding areas water is usually taken from 120 m to 200 m depth. No exploration of groundwater has been undertaken in high altitude areas of the region. It is reported, however, that water gush was observed at 4 out of 36 wells during prospect drilling in the mine area.

1-3. Outline of Current Water Uses in the Region

Water supply systems of some of the smaller communities in the region are summarized in Table 4-2. A comparison is made in Table 4-3 of flow in some tributaries in the region and flow diverted from them. For the Rio Samientos basin it is reported that about 83ℓ/sec of water is taken from the Rio Agua Negra tributary to serve the city of Chilecito and an additional 200 to 300ℓ/sec for downstream irrigation.

Table 4-2. Water Supply Systems at Some Communities in the Region

Community	Source	Treatment	Population served	Water use 1)	Remarks
Famatina	Surface water	Sedimentation, filtration, chlorination	2,200	7.6 ℓ/sec.	
Sanogasta	– ditto –	– ditto –	2,400	8.3	
Anguinan	Groundwater	Chlorination	1,900	6.6	Total pumping capacity 110 HP
Malligasta	– ditto –	– ditto –	1,200	4.2	150 HP
Tilimuqui	– ditto –	– ditto –	800	2.8	100 HP

Source: Secretaria de Estado de Recursos Hidricos (Direccion de Agua Potable Rural,) La Rioja.

Note: 1) The water-use figures represent rough estimates calculated on the basis of per capita water use of 300 ℓ/day.

Table 4-3. Distribution of Surface Water Flow in the Region

Flow	Month/Year			
	11/'79	3/'80	6/'80	8/'80
Rio Amarillo:				
Total	–	0.84 m^3/sec.	–	–
Canal Peñas Negras	0.51 m^3/sec.	0.78	0.64 m^3/sec.	0.49 m^3/sec.
Rio Sarmientos:				
Total	0.75	0.78	1.20	0.90
Rio Pismanta (Guanchin)	0.20	0.65	0.28	0.17
flow 1	0.07	0.10	0.09	0.06
2	0.06	0.03	0.05	0.08
3 (filtration gallery)	0.03	0.02	0.03	0.02
Rio Miranda	0.25	1.20	0.47	0.39
(Cañadán canal)	–	0.30	–	0.29

Source: Centro Regional de Agua Subterranea, San Juan.

These figures for diverted flow do not necessarily give the amount of water actually used, but indicate roughly what fraction of the stream flow has been diverted into artificial systems for irrigation and other purposes. In the Rio Famatina basin, a comparatively higher fraction is diverted as more communities exist in the downstream areas. The downstream area of Rio Sarmientos has also been developed, but most agricultural communities rely on groundwater, as seen from Table 4-2.

1-4. Water Resource Development Policies and Projects

The Argentine Government is promoting development of hydro-power in order to decrease in the long run the nation's dependence on petroleum as an energy source. Although the Province of La Rioja, being climatically semi-arid to arid, offers only modest opportunities for hydro-power generation, every effort is being made to develop its potential.

Another major concern of the Province and in particular of the District of Chilecito is a stable supply of water for irrigation and other activities. Irrigated land in the Province amounts to 20,000 ha., about one-third of the total cultivated area, of which about 5,500 ha. lies in the northern central region. Development of groundwater and better utilization of surface water will be necessary to expand agricultural production.

In accordance with the above, a project is being carried out to construct a dam on Rio Miranda for the purpose of developing downstream areas through provision of irrigation water and hydro-power. Also, exploration of groundwater is being continued, with 74 new wells being drilled in the Province during fiscal 1980. Other development plans include miner-scale hydro-power generation in the Rio Sarmientos basin and restoration of a small irrigation dike on a tributary of Rio de Trinidad, although these are no more than just ideas at the present stage.

2. Formulation of Water Resource Development Alternatives

2-1. Development Objectives

The objective of the present analysis is to identify water resource development plans for the Famatina region which will best serve not only the mine itself but the region as a whole. More specifically, the plans should serve the following purposes:

i) to develop a sufficient quantity of water having suitable qualities for mineral concentration;

ii) to procure water for the mining camp and the mining town;

iii) to secure water for agricultural and domestic users downstream, with some additional development of supply sources, if necessary;

iv) to minimize water quality problems that may result from mining and concentration operations and their adverse effects on the region.

2-2. Estimation of Water Requirements for Mine Development

A prerequisite for formulating alternative development plans is to estimate the amount of water necessary for different purposes. The water requirements for the concentration plant are estimated based on 3 m^3 of water per unit ton of crude ore and a water recycle rate of 50%. Assuming 300 days annual operation of the mine, the total water requirements are 9 Mm^3 and 13.5 Mm^3 per year respectively for operating scales of 20,000 tons-crude ore or 30,000 tons-crude ore per day. These figures correspond to 428 ℓ/sec and 285 ℓ/sec, respectively, as shown in Table 4-4 (See next page).

Estimation of the water requirements for the mining camp and the mining town is based on the expected population, and a per capita water use of 300 ℓ/day. The results are also given in Table 4-4.

As is obvious from Table 4-4, the dominant factor in formulating water resource development plans is how to procure water for the concentration plant, which amounts to 90% of the total water requirements of mine development.

Table 4-4. Water Requirements for Mine Development[1)]

	Development Scale	
	20,000 tons/day	30,000 tons/day
Concentration Plant	9 Mm^3/year = 285 ℓ/sec	13.5 Mm^3/year = 428 ℓ/sec
Mining Town	28 ℓ/sec	38 ℓ/sec
Mining Camp	5 ℓ/sec	7 ℓ/sec

Note: 1) Estimates are based on the specifications given in Chapter 2.

2-3. Alternative Water Resource Development Plans

Alternative water resource development plans should be formulated to meet the water requirements specified above and to satisfy as far as possible the objectives described earlier. As the bases of analysis, Section 4-1 provides background information on water available from different sources, current water usage, existing or proposed water resource projects and other relevant aspects regarding the region.

In view of the fact that the Rio Miranda is the most abundant in surface water readily available and that there exists a dam project on this river, alternatives to utilize surface water flow in Rio Miranda basin are first analyzed in Section 4-3. Next, in Section 4-4, the availability of groundwater near the mine described in Section 4-1 is assessed to determine the feasibility of alternatives to rely on this resource. Finally, alternatives of combining both surface water and groundwater are investigated in Section 4-5.

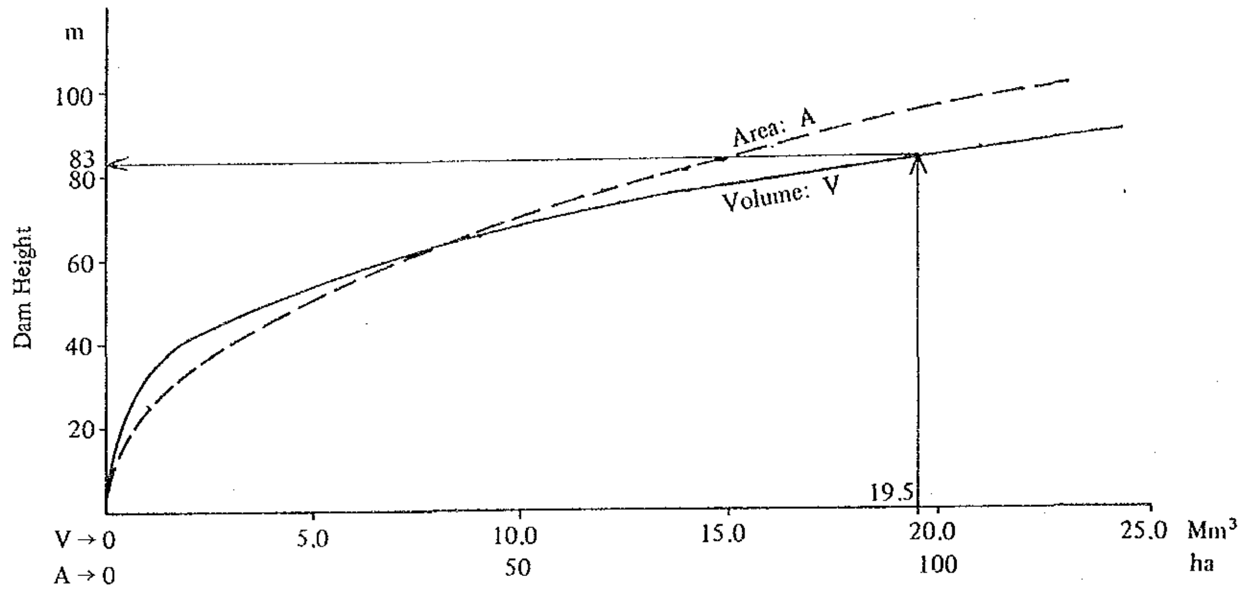
3. Rio Miranda Alternatives

3-1. Rio Miranda Dam Project

The original objective of the Rio Miranda dam project is to construct a dam on the middle reaches of the Rio Miranda for the purpose of providing a stable supply of water for irrigation and domestic use and also for generating hydro-power. Several sites were analyzed by the Secretaría de Estado de Recursos Hídricas (SERH), La Riaja, from geological, topographical and other points of view as to suitability for locating the dam.

The site finally settled on is located about 20 km upstream from the village of Miranda at an elevation of 2,200 m (see Fig. 4-2). Inflow time-series of the river at this site are given in Table 4-5 (see on p. 107). Data were constructed by SERH for the period between 1968 and 1977 based on much longer historical records with adjustments made for flood flow and low flow which often elude precise measurements.

Fig. 4-2. Storage Curve for Rio Miranda Reservoir



It is estimated that approximately 870ℓ/sec water can be made available by constructing a dam of 90 m height. This water would make it possible to develop 2,500 ha. of land for irrigated agriculture. Also hydro-power generating capacity of 1,670 kW is expected to be installed.

3-2. Sizing of the Dam

To investigate the possibility of utilizing the Rio Miranda reservoir as a water source for the concentration plant and its effects on downstream usage, the reservoir site is first analyzed using the same data prepared by SERH. The storage curve for the reservoir site and irrigation demand as estimated by SERH are given in Fig. 4-3 and Table 4-6, respectively.

Table 4-5. Monthly Flow of Rio Miranda at Reservoir Site

(Unit: Mm^3/month)

Month	Year									
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1		8.3	15.1	5.2	9.6	8.2	5.7	8.5	8.8	5.3
2		3.8	10.6	2.5	3.7	3.4	2.7	3.1	7.5	5.5
3		1.0	3.7	0.7	1.0	0.8	1.1	1.1	2.9	2.3
4		0.9	2.9	0.6	0.9	0.7	1.0	0.9	0.9	0.8
5		1.0	2.2	0.5	0.9	0.7	0.7	0.8	0.9	0.7
6		0.8	1.5	0.6	0.8	0.6	0.8	0.7	0.7	0.6
7		0.7	1.3	0.5	0.9	0.6	0.8	0.8	0.6	0.5
8	0.8	2.8	1.9	0.5	0.8	0.6	0.8	0.8	0.6	0.5
9	0.8	2.9	1.1	2.3	0.7	0.5	0.8	0.8	0.6	
10	2.4	2.3	1.4	1.8	1.9	0.9	1.3	0.7	0.6	
11	2.1	4.6	1.3	2.2	3.7	1.3	1.8	1.3	1.0	
12	6.8	12.0	4.0	9.8	7.1	4.6	6.5	1.3	1.3	
Annual Total		41.1	47.0	27.2	32.0	22.9	24.0	21.2	26.4	

Source: Secretaría de Estado de Recursos Hidricos, La Rioja

Fig. 4-3. **Determination of Over-Year Storage Requirement for the Rio Miranda Reservoir**

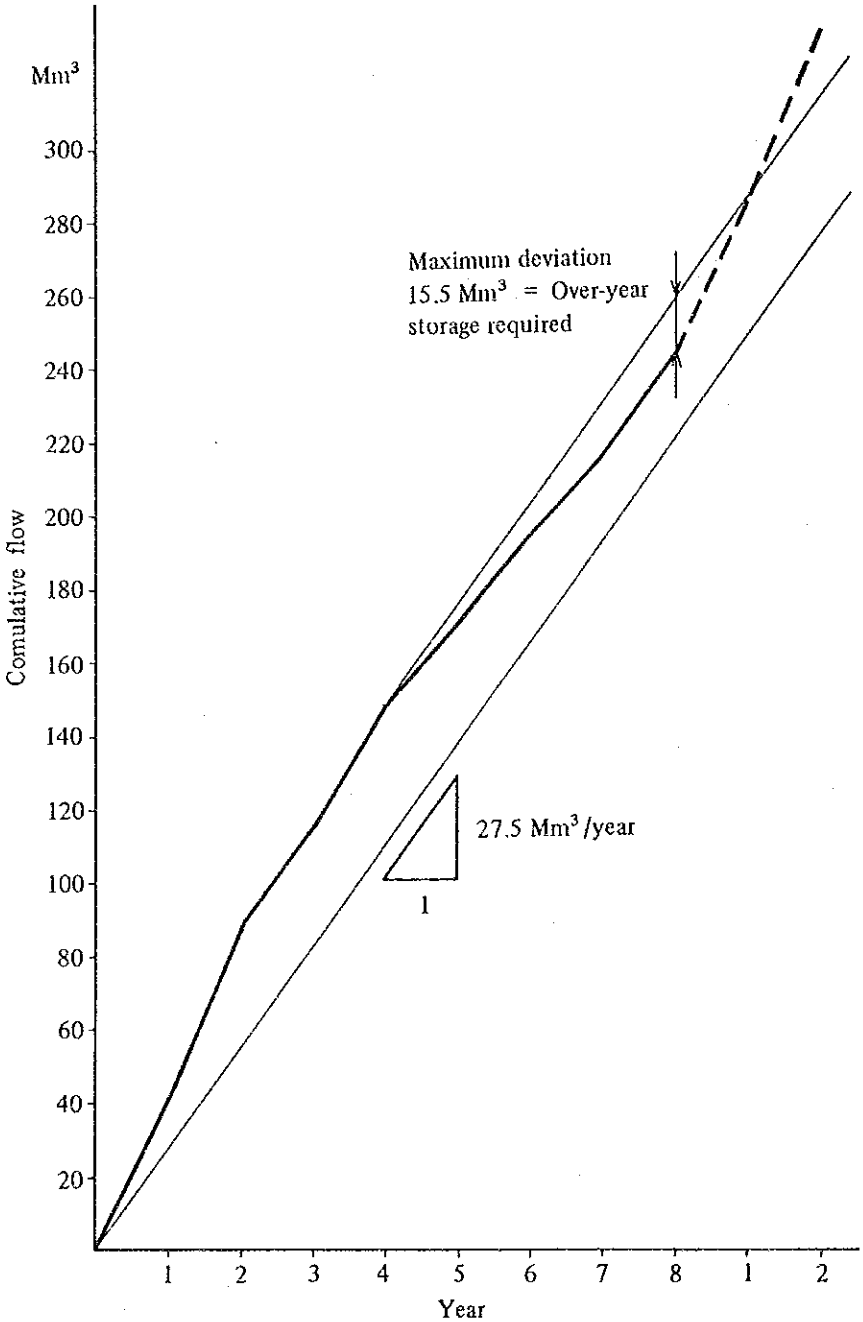


Table 4-6. Monthly Irrigation Demand Expected in Downstream Rio Miranda Areas

(Unit: Mm^3/month)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Demand	4.9	3.2	1.5	1.6	0	0	0	0.8	1.6	3.3	4.8	5.8

Source: Secretaría de Estado de Recursos Hidricos, La Rioja.

Using the annual flow for the period between 1969 and 1976, the over-year storage requirement can be estimated graphically as explained below. First the cumulative flow is plotted as in Fig. 4-4; secondly the straight line corresponding to an annual irrigation demand of 27.5 Mm^3 is drawn from the origin; thirdly the line is shifted to determine the required over-year storage as 15.5 Mm^3 (Refer to Fig. 4-4 on p. 110).

To estimate the seasonal storage requirement, take the year 1972 as an average year and use the monthly flow of this year with minor adjustments. The graphical method cannot be easily used because irrigation demand varies by month. By using a modified version of the sequent peak algorithm, the seasonal storage is estimated to be 4 Mm^3 (see Table 4-7 on p. 111).

With a total storage of 19.5 Mm^3, water can be withdrawn from the reservoir according to the irrigation schedule specified in Table 4-6. The dam height required to obtain this storage is found from the storage curve in Fig. 4-3. to be 83 m. This value corresponds well with the height of 90 m that was eventually adopted by SERH. The reservoir, as planned, has some allowance for sedimentation and loss of water due to evaporation and seepage, and probably some reserve storage capacity as well.

3-3. Diversion to the Concentration Plant

Suppose now that a quantity of water made available by the Rio Miranda reservoir is diverted to the concentration plant. This will completely change the operating schedule of the reservoir. The amount of water that will remain for use by downstream communities is evaluated following the same procedure used to determine the storage of the reservoir.

If the mine is to be operated at 20,000 tons crude ore capacity per day, a monthly withdrawal of 0.75 Mm^3 will be necessary. Irrigation water use would be reduced accordingly and the total monthly withdrawal would be as given in Table 4-8. To make possible withdrawal according to the schedule, a seasonal storage of 4.9 Mm^3 rather than 4 Mm^3, as previously determined, would be required (see Table 4-8). This difference, however, is considered small enough to leave sufficient over-year storage for full control of the variations in surface water

Fig. 4-4. Determination of Storage for Rio del Oro Reservoir

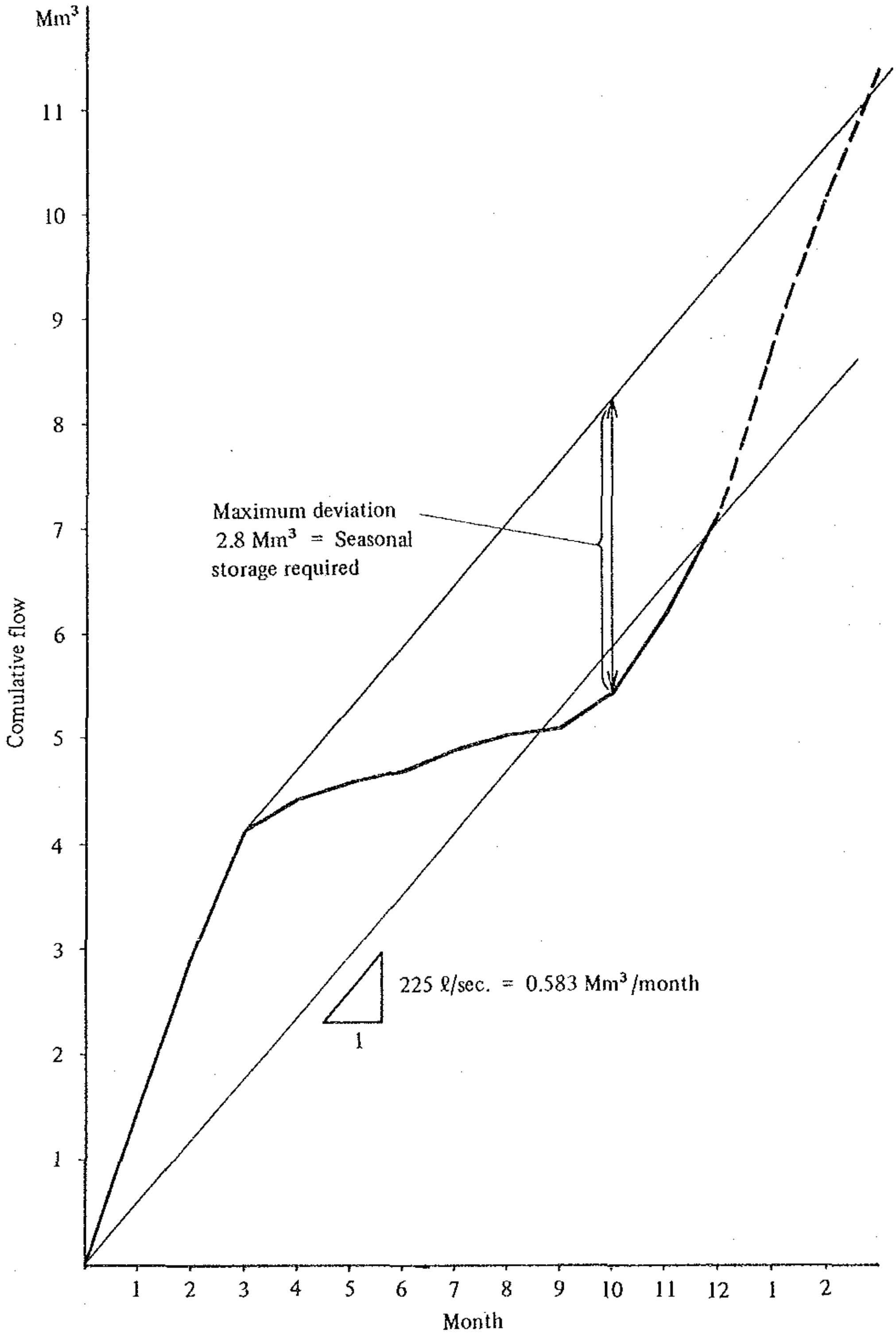


Table 4-7. Determination of Seasonal Storage Requirements by Modified Segment Peak Algorithm

(Unit: Mm^3)

Month t	Yield Yt	Inflow It	Previous Storage S_{t-1}	Current Storage[1] $St = (Yt - S_{t-1} + It)$
1	4.9	9.3	0	0
2	3.2	3.4	0	0
3	1.5	0.9	0	0.6
4	1.6	0.9	0.6	1.3
5	0	0.8	1.3	0.5
6	0	0.8	0.5	0
7	0	0.9	0	0
8	0.8	0.8	0	0
9	1.6	0.7	0	0.9
10	3.3	1.6	0.9	2.6
11	4.8	3.4	2.6	4.0 = maximum
12	5.8	6.8	4.0	3.0 storage required
1	4.9	9.3	3.0	0

Remainder is the same as first round.

Note: 1) Current storage required is calculated as

$$St = \begin{cases} Yt - S_{t-1} + It & \text{if } Yt - S_{t-1} + It > 0 \\ 0 & \text{otherwise} \end{cases}$$

availability to obtain a total annual yield of 27.5 Mm^3, especially when the reservoir has some reserve capacity as mentioned above. Thus, if 9 Mm^3 is diverted annually to the concentration plant, 18.5 Mm^3 will remain for use by downstream users.

Similarly when the mine operates at 30,000 tons-crude ore capacity per day, 13.5 Mm^3 water must be diverted annually to the concentration plant, leaving 14 Mm^3 for downstream use.

Table 4-8. Determination of Seasonal Storage Required for the Diversion

(Unit: Mm^3)

Month t	Yield Yt	Inflow It	Previous Storage St-1	Current Storage[1] St = (Yt - It + St-1)
1	4.1	9.3	0	0
2	2.9	3.4	0	0
3	1.7	0.9	0	0.8
4	1.8	0.9	0.8	1.7
5	0.7	0.8	1.7	1.6
6	0.7	0.8	1.6	1.5
7	0.7	0.9	1.5	1.3
8	1.3	0.8	1.3	1.8
9	1.8	0.7	1.8	2.9
10	3.0	1.6	2.9	4.3
11	4.0	3.4	4.3	4.9 = maximum storage required
12	4.6	6.8	4.9	2.7
1	4.1	9.3	2.7	0

Remainder is the same as first round.

Note: 1) See Note 1 for Table 4-7.

3-4. Variant Alternative

The total cost of alternatives utilizing the Rio Miranda dam will vary depending on how construction ocsts of the dam are shared by different users. Another major cost element, however, is the cost of transporting water over a 30 km distance and an 1,800 m difference in altitude.

It is possible to locate a smaller reservoir for use exclusively by the concentration plant further upstream on the Rio Miranda in order to reduce the transmission distance as well as dam construction costs. This would simply reduce the availability of flow at the downstream reservoir site, since use of water for concentration is totally consumptive. Thus, it would call for modification not only of downstream agricultural development but also of the design of the dam itself. This alternative, therefore, does not seem practical when we consider that implementation of the Rio Miranda dam project is expected to begin in 1981.

4. Groundwater Alternatives

4-1. Groundwater Reserve in the Mining Area

The existence of a groundwater reserve to the east of the mine has been reported, as mentioned in Section 4-1, but no extensive or systematic exploration of groundwater resources has been conducted in the ara up to this time. Assessment of this reserve, therefore, is based only on some scattered observations, and only a rough estimate can be made of water that can be safely extracted for use at the concentration plant.

During the field survey in October, 1980, observations were made of surface water flow in different parts of the project area. Generally, in arid to semi-arid regions, the streamflow toward the end of a dry season is primarily supported by base discharge from the groundwater. Thus, the flow observed at this time can be regarded as the minimum amount of water available from the corresponding groundwater reserve. Near the potential site for the concentration plant at Cueva de Perez, which is located at an altitude of 3,830 m, the discharge was observed to be approximately 100 ℓ/sec.

It is reported, based on observations of water gush during prospect boring, that the groundwater table on the east side of the mine is approximately 150 m from the ground surface. No data, however, are available on the exact value for each well, and the altitude of the boring sites in the area of groundwater reserve ranges from about 3,900 m to 4,080 m. It is assumed in this study that the groundwater head is located at approximately 3,850 m.

4-2. Estimation of Groundwater Yield

Given a groundwater head at 3,850 m and an average distance between the reserve and Cueva de Perez of 1,200 m, the average hydraulic gradient can be calculated as

$$\frac{2h}{2\ell} = \frac{3{,}850 - 3{,}830}{1{,}200} = 0.016$$

The groundwater flow Q is in proportion to the corresponding hydraulic gradient and given by

$$Q = KA \frac{2h}{2\ell}$$

where K is the hydraulic conductivity and A is the cross-sectional area of the aquifer.

If the total discharge observed at Cueva de Perez can be regarded as the groundwater flow from the reserve near the mine,

$$Q = 0.1 \text{ m}^3/\text{sec}$$

so that $KA = \frac{0.1}{0.016} = 6.25 \ m^3/sec$

The location of the wells from which water gush was observed indicates that the aquifer is at least 800 m wide. Assuming the effective depth of this aquifer to be 20 m, the hydraulic conductivity is calculated as

$$K = \frac{6.25}{20 \times 800} = 0.000391 \ m/sec$$

The transmissivity T is the conductivity multiplied by the thickness of the aquifer:

$$T = 0.000391 \times 20 = 0.00782 \ m^2/sec = 676 \ m^2/day$$

Using the value of transmissivity T estimated above, the possible rate of extraction from the aquifer can be estimated as follows. First the following relationship holds between the extraction Q_W and the transmissivity T:

$$Qw = \frac{2\pi(S_1 - S_2)}{\ell n(r_2/r_1)}$$

where, S_1 and S_2 represent the drawdown of groundwater head at distance r_1 and r_2 from the extraction point. Taking r_2 sufficiently large ($r_2 = r\ell$) to make S_2 negligible, and letting the drawndown at the radius of the well $r_1 = r_W$ be $S_1 = S_W$' the above formula becomes

$$Qw = \frac{2\pi S_W T}{\ell n(r\ell/r_W)}$$

Usually the distance $r\ell$ is taken to be 300 m and the radius of the well is $r_W = 0.15$ m. Assuming the maximum allowable drawdown at the well be $S_W = 10$ m, the possible extraction Q_W is calculated as

$$Qw = \frac{6.28 \times 10 \times 0.00782}{7.601} = 0.0646 \ m^3/sec$$

Wells with this capacity should be located at least 500 m apart from each other to minimize interference between them. The aquifer is considered large enough to locate four wells so that water can be extracted at a rate of 258 ℓ/sec (= $4Q_W$) in total.

The groundwater table fluctuates seasonally and annually, and the estimation of the level given above is admittedly rough. Consequently the error associated with the groundwater yield can be significant, especially when the hydraulic gradient and the discharge are relatively small. Still, alternatives to relying exclusively on the groundwater are not considered feasible at this time, since the estimated yield does not cover the full requirements of the concentration plant. Extensive study, including physical exploration, will be necessary to assess more precisely the potential of the groundwater resources.

5. Hybrid Alternatives

5-1. *Selection of Potential Reservoir Sites*

The amount of water that can be safely extracted from the aquifer near the mine is not by itself sufficient to provide the necessary water for the concentration plant. In this section, therefore, alternatives combining both groundwater and surface water are investigated.

A major problem in formulating hybrid alternatives is where to locate a surface water reservoir. Each drainage basin is examined for its suitability from the viewpoints not only of geology, topography and hydrology but also of the effects on downstream areas.

The Rio Miranda basin was examined in detail in Section 4-3, and thus is precluded from analysis in this sub-section. The Rio de Trinidad basin is considered unfavorable for several reasons. First its location is remote from the concentration plant, separated by ranges of high mountains. Flow upstream of the Rio de Trinidad is small; near the village of El Pique, only about 60 ℓ/sec flow was observed during the field survey in October, 1980, a substantial fraction of which is taken for irrigation. Also there is a small irrigation dike on the Rio Pigmanta, a tributary of the Rio de Trinidad, although it is apparently not functioning.

Rio Amarillo in the Rio Famatina basin has several disadvantages as a source of water for the concentration plant. First, water quality characterized by pH 2 to 3 is not suitable for concentration, and considerable cost would be required to raise the pH to a satisfactory level. Secondly the amount of water drawn by downstream communities is large compared with the total flow available in the basin, as indicated by Table 4-3. Thirdly and probably most importantly, the flow in the Rio Amarillo itself would be reduced if a large amount of water were extracted from the aquifer near the concentration plant located in the same basin.

The Rio Sarmientos has also been used extensively by downstream communities including Chilecito, the second largest city in the Province of La Rioja. The city of Chilecito is taking about 83 ℓ/sec of water from the Rio Agua Negra, a tributary of the Rio Sarmientos. This corresponds to approximately 25% of the total average flow of this tributary. There exist four simple dikes to withdraw water for irrigation – two on the Rio Agua Negra, one on the Rio Amarillo and another on the main stream of the Rio Sarmientos. The water is transported partly by a concrete tunnel but mostly by open channels. Flow in different parts of this irirgation system amounts to as high as a few cubic meters per second in total, but it is not clear how much of this is actually used for irrigation. It is observed, however, that the flow in the Rio Amarillo part of the basin is largely untapped. Also, the upstream area of this tributary has geological conditions similar to those of the Rio Miranda basin, characterized by granitic rocks, and is thus more suitable as a reservoir site than the two other basins.

5-2. Precipitation-Runoff Analysis of the Upstream Rio Sarmientos

Unfortunately no data are available on flow in the Rio Sarmientos – in particular, its tributary the Rio del Oro. Precipitation records are available for two locations in the basin – La Ensenada and Chilecito. The average monthly precipitation data for these two locations are given in Table 4-1. Based on this information and the total annual precipitation contours given in Fig. 4-1, the average annual precipitation in the Rio del Oro area is estimated to be about 450 mm.

To calculate surface runoff from the precipitation data, the runoff coefficient must be estimated. Usually in steep mountain areas, the runoff coefficient is in the range of 0.70 to 0.90. Particularly in the case of a large storm, the ratio of direct discharge to total precipitation can be quite high. On the other hand, in a dry area, direct discharge from small precipitation would be virtually nil, especially when such precipitation follows a spell of dry days.

The monthly time-series of the flow in the Rio Miranda as given in Table 4-5 are used to calculate the runoff coefficient for this basin. The drainage area above the potential reservoir site is about 175 km^2 and the annual precipitation in this area is 500 mm on the average. Using the average annual flow in the river, the average value of runoff coefficient is calculated as

$$\frac{30.3 \text{ Mm}^3}{500 \times 10^{-3} \times 175 \times 10^6 \text{ m}^3} = \frac{30.3}{87.5} = 0.346$$

Since no better or more consistent data are available on precipitation and runoffs in the region, and since the Rio del Oro catchment area has similar geologic, topographic and vegetational characteristics as the upstream Rio Miranda basin, the average value of runoff coefficient is taken to be 0.35 for the Rio del Oro area.

To pinpoint a reservoir site on Rio del Oro, close investigation of geological, topographic and other conditions of the area are necessary. It is assumed in this study that a reservoir be located near the confluence where Rio del Cobre, another tributary of the Rio Sarmientos, meets Rio del Oro (see Fig. 4-1). The catchment area is approximately 45 km^2 so that the total annual flow at this point can be calculated as

$$450 \text{ mm} \times 45 \text{ km}^2 \times 0.35 = 7.09 \text{ Mm}^3/\text{year} = 225 \text{ ℓ/sec}$$

5-3. Sizing of Rio del Oro Reservoir

In general, the availability of surface water in a particular year is more susceptible to precipitation in that year, while groundwater sources can provide more stable supply. Thus a promising water supply scheme is to use a surface water storage reservoir to cope with seasonal variations in surface water availability and to use groundwater to even out the over-year variations.

Since no monthly streamflow data are available for the Rio Sarmientos basin, seasonal variations of the streamflow are to be derived from monthly precipitation data. Usually, the streamflow variations are less than the variations in precipitation, since secondary discharge from the groundwater tends to even out the flow. This is especially true for the upstream areas of the region, since a considerable fraction of the precipitation there takes the form of snowfalls, which cultivate groundwater reserves.

The average monthly precipitation values at La Ensenada and Chilecito, as given in Table 4-1, are highly correlated with each other -- the correlation coefficient is 0.90. The data for Chilecito therefore can be regarded as representing the seasonal variation of precipitation in the Rio Sarmientos basin.

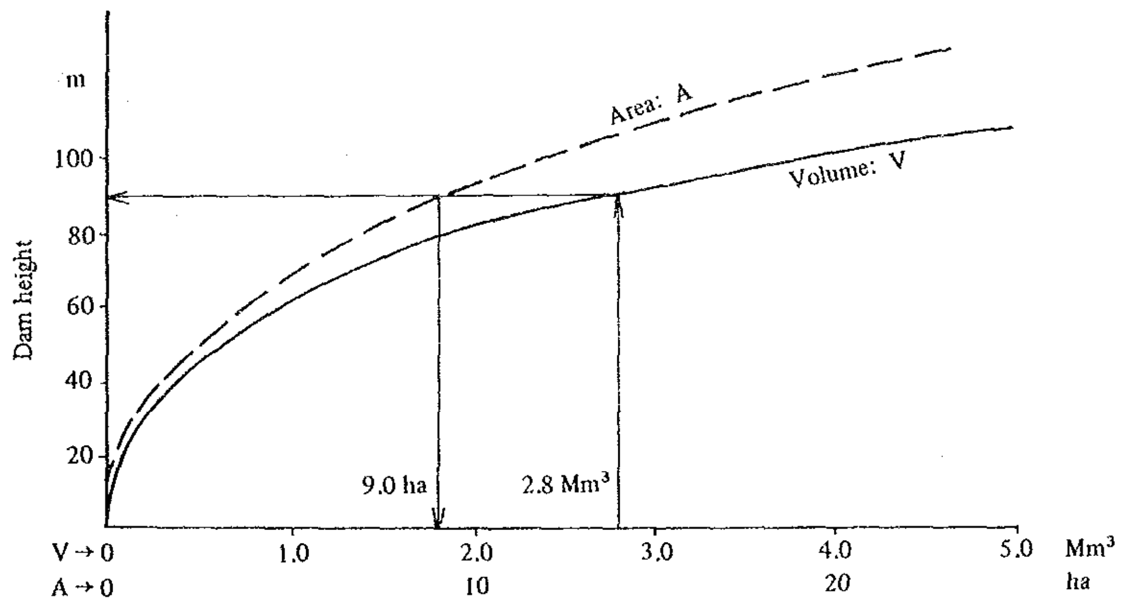
The total annual flow of 7.09 Mm^3 calculated above is distributed monthly in proportion to the average monthly precipitation at Chilecito, with the results given in Table 4-9. Using this information, the storage required to even out the seasonal variation of streamflow is determined graphically, as done in Section 4-3 for the Rio Miranda reservoir. Fig. 4-5 shows that storage of 2.8 Mm^3 would be required to extract water at the rate of 225 ℓ/sec in an average year.

Table 4-9. Calculated Monthly Flow in the Rio del Oro

(Unit: Mm^3)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual Total
Flow	1.52	1.38	1.28	0.28	0.17	0.14	0.14	0.14	0.12	0.27	0.75	0.93	7.09

Fig. 4-5. Storage Curve for the Rio del Oro Reservoir



Given that a dam is constructed near the confluence of the Rio del Oro and the Rio del Cobre, the storage curve can be drawn as in Fig. 4-5. (Also shown is the surface area of the reservoir as a function of storage volume.) It is seen from this figure that a dam of height 95 m is necessary to impound 2.8 Mm^3 water at this site. The dam would be approximately 180 m long.

5-4. *Scale of Groundwater Development*

If the mine should operate at 20,000 tons-crude ore capacity per day, an additional 60 ℓ/sec water would have to be taken from the groundwater during an average year. Taking account of the allowance for dry years when more water has to be withdrawn from the aquifer to compensate for reduction in available surface water, two wells, each having an extraction capacity of 65 ℓ/sec, would be required.

To make possible daily handling of 30,000 tons of crude ore, some 200 ℓ/sec water must be supplied by the groundwater in an average year. Considering again the allowance for dry years, four wells should be sunk into the aquifer near the mine, and each should be installed with an extraction capacity of about 65 ℓ/sec.

5-5. *Variant Alternatives*

Some variants of the alternative examined above are considered. First a reservoir can be located further downstream on the Rio del Oro to collect more water. However, costs of transporting water up to the concentration plant would become excessively high. Also the reduction in water available for downstream uses would exceed tolerable limits.

On the other hand, if a reservoir is located upstream from the confluence of the two tributaries, the transmission costs would be reduced but at the cost of reduction in the amount of water made available by the reservoir. This would call for more extensive utilization of groundwater resources, which can not be recommended at this time when sufficient data to support such a scheme are not available. Also, the storage to embankment ratio, which indicates the effectiveness of a dam, becomes smaller as a reservoir is located at a higher altitude where the slope is steeper. Alternatives to construct two (or more) dams of smaller size are clearly uneconomical due to the high capital costs associated with dam construction.

6. Water Supply Schemes for Mining Camp and Mining Town

6-1. Configurations of Water Supply Systems

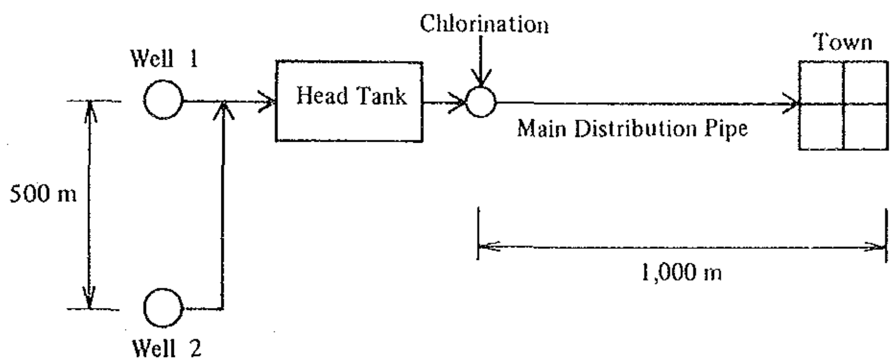
The quantity of water to be used at the mining town and the mining camp for domestic purposes is very small in comparison with the quantity required by the concentration plant (see Table 4-4). Only the most likely schemes to provide water for the camp and the town are described in this section.

As the mining camp is to be located in the Rio Famatina basin near the confluence of the Rio Amarillo and its small tributary at 3,000 m altitude, surface water can easily be tapped using a simple dike. The tributary of the Rio Amarillo has much better water quality and only simple filtration and chlorination would be required to treat the water. Rio Amarillo itself on the other hand, is not recommended as a water supply source since water quality is questionable and additional facilities would be required to treat the water to a satisfactory level.

The mining town should rely for its water supply source on groundwater, which has been extensively used in the area around Chilecito. Use of surface water is less favorable since availability will be reduced if the Rio del Oro is used as a water source for the concentration plant. Even if this is not the case, use of surface water in the Rio Sarmientos basin would involve more complicated physical and institutional arrangements as this source has been used by the city of Chilecito.

A water supply scheme for the mining town is illustrated in Fig. 4-6. Two wells should be located about 500 m apart from each other with a 500 m^3 capacity storage tank, and the water is transmitted to the town after chlorination.

Fig. 4-6. Water Supply Scheme for the Mining Town



6-2. Cost Estimation

Construction costs of the water supply facilities for the mining town include costs associated with well boring and casing, pumps, a head tank, chlorination equipment and main distribution pipes. The total cost is estimated to be about 360 million pesos. Costs necessary to operate and maintain the system are about 130 million pesos and 150 million pesos annually for the respective mining scales of 20,000 tons/day and 30,000 tons/day.

Cost of the water supply scheme for the mining camp would be approximately 30 million pesos. Operation and maintenance costs are considered to be within the allowance of mine operation costs.

7. Evaluation and Comparison of Atlernatives

7-1. Factors Affecting Viability of Alternatives

Several distinct water resource development alternatives and some variants were examined in previous sections. Of these, the alternative of relying exclusively on groundwater cannot be recommended at this time, since the confirmed groundwater reserve does not guarantee sufficient yield. Other alternatives, in particular the Rio Miranda alternative and the Rio del Oro alternative, are evaluated and compared in this section.

The viability of alternative water resource development plans depends on numerous factors that work directly or indirectly for or against the alternatives. These factors include the following:

- Location of mining camp and town
- Water supply schemes for the camp and the town
- Location of the concentration plant and the wastewater disposal reservoir
- Availability of electricity for pumping up water and for other purposes
- Conflict with existing water rights
- Effects on existing water supply systems serving small communities downstream with respect to both water quality and quantity
- Effects on groundwater regime
- Interface with other on-going or proposed projects

Some of these factors are reflected in the total cost of the alternatives, while others cannot easily be evaluated in monetary terms or in any commensurable terms at all. For instance, the location of the concentration plant largely determines the cost of transporting water from a downstream reservoir. On the other hand, the effects of water resources development on the groundwater regime and in turn on water supply systems based on groundwater cannot easily be assessed. In subsequent sub-sections, the development alternatives are first compared with respect to the project costs, and then other aspects of the alternatives are examined, including their effects on the region.

7-2. Estimation of Project Costs

Construction Costs: Construction costs are estimated by each cost element for the Rio Miranda and the Rio del Oro dams, and results are summarized in Table 4-10. Although a preliminary estimate of total costs for the Rio Miranda dam has been given by SERH, estimates in Table 4-10-(2) represent consistent and comparable results for both dams. Costs of groundwater development necessary under the Rio del Oro alternative are estimated to be 484 M pesos and 872 M pesos respectively for 20,000 tons/day and 30,000 tons/day operating scales (Refer to Table 4-10- (1) & (2) on pp. 121 & 122).

A scheme for transporting water from the Rio del Oro reservoir to the concentration plant is illustrated in Fig. 4-7, where the elevation of each node and the distance on each arc are also given. Pumping capacity required to transport water at the rate 225 ℓ/sec on each arc is

Table 4-10. Estimates of Construction Costs for the Rio Miranda and Rio del Oro Reservoirs

(1) Rio del Oro reservoir

Item	Specifications	Total costs x 10^6 pesos	Foreign elements %
Auxiliary works			
Access roads	8 km	320	30
Power transmission line	7.2 km	626	35
Other facilities	Transformation, Substation, etc.	100	40
Sub-total		1,046	33.95
Diversion	600 m tunnel	996	35
Main construction works			
Excavation	Total volume: 12,000 m^3	1,016	35
Foundation treatment	Grouting: 2,700 m perforation, 30 tons cement	2,515	35
Embankment	Center-core, rock-fill type, Total volume: 912,000 m^3	17,982	40
Others	Spillway, intake facilities, etc.	2,836	30
Sub-total		24,349	38.11
Total		26,391	37.82

Table 4-10. (continued)

(2) Rio Miranda reservoir

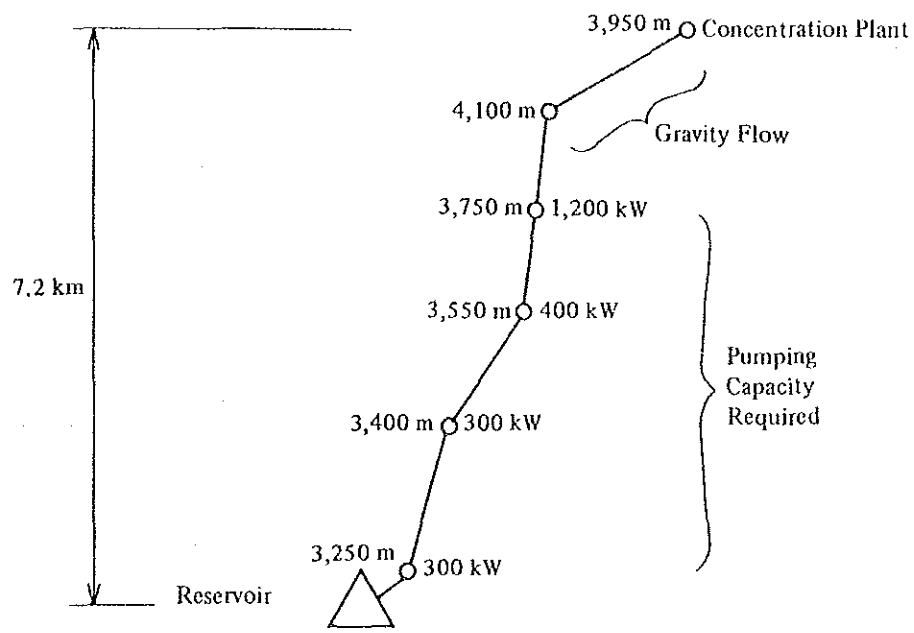
Item	Specifications	Total costs x Million pesos	Foreign elements %
Auxiliary works			
Access roads	15 km	600	30
Power transmission line	30 km	2,610	35
Other facilities	Transformation, substation, etc.	150	40
Sub-total		3,360	34.33
Diversion	480 m tunnel	1,387	35
Main construction works			
Excavation	Total volume: 20,000 m^3	1,694	35
Foundation treatment	Grouting: 3,750 m perforation 40 ton cement	3,538	35
Embankment	Center-core, rock-fill type, Total volume: 1,440,000 m^3	27,727	40
Others	Spillway, intake facilities, etc.	5,586	30
Sub-total		38,545	37.87
Total		43,292	37.50

estimated based on a pipe diameter of 500 mm and a pumping efficiency of 0.7. The results are also given in Fig. 4-7. Costs of pumps with a total pumping capacity of 2,200 kW and of a pipeline with a total length 7.2 km are estimated as follows:

Pumps:	2,950 million pesos
Pipeline:	576 million pesos
Total direct costs:	3,526 million pesos

Taking, as an allowance for contingencies, 15% of the total direct costs, the total cost of water transmission is estimated to be 4,055 million pesos.

Fig. 4-7. Water Transmission Scheme for the Rio del Oro Alternative



Costs of water transmission facilities for the Rio Miranda alternative can be estimated in a similar way. However, since no map is available with detailed contours for the entire length of the pipeline, the cost estimate is based only on the distance between the reservoir site and the concentration plant and the total pumping head required.

The total pumping capacity required is calculated for two operating scales of the mine, assuming 70% efficiency for the pumps and 500 mm and 700 mm pipe diameter for the respective scales of water transmission.

20,000 tons/day:

$$9.8 \times 0.285 \ m^3/sec \ (1,800 + 240) \ m / 0.7 = 8,140 \ kW$$

30,000 tons/day:

$$9.8 \times 0.428 \ m^3/sec \ (1,800 + 75) \ m / 0.7 = 11,235 \ kW$$

Since actual pumping capacity required may be higher depending on local topography, the transmission costs are calculated based on 9,000 kW and 12,000 kW capacity.

20,000 tons/day:

Pumps:	12,100 million pesos
Pipeline:	2,400 million pesos
Total direct costs:	14,500 million pesos

30,000 tons/day:

Pumps:	16,100 million pesos
Pipeline:	3,300 million pesos
Total direct costs:	19,400 million pesos

Taking a 15% allowance for contingencies, the total cost of water transmission is estimated as follows:

20,000 tons/day:	16,675 million pesos
30,000 tons/day:	22,310 million pesos

If the total construction costs are compared for the Rio Miranda and the Rio del Oro alternatives, the former is clearly inferior since both the dam construction costs and the water transmission costs are higher for this alternative (see Table 4-11). The Rio Miranda reservoir, however, would be shared agricultural users, and the construction costs of the dam could be shared between the mine and the province interested in agricultural development. There exist a variety of methods proposed for or applied to cost allocation problems. A simple method is to allocate total costs in proportion to water usage. Following this scheme, the costs to be allocated to the mine are calculated for the respective operating scales as follows:

20,000 tons/day:

$$43,292 \times 285 / 870 = 14,182 \text{ million pesos}$$

30,000 tons/day:

$$43,292 \times 428 / 870 = 21,298 \text{ million pesos}$$

The total construction costs of the Rio Miranda alternative with cost allocation are given also in Table 4-11. This alternative requires larger capital investment if the mine is to be operated at 30,000 tons/day, but for the 20,000 tons/day operating scale construction costs become slightly smaller than for the Rio del Oro alternative.

Table 4-11. Comparison of Total Construction Costs for the Rio Miranda and the Rio del Oro Alternatives

(Unit: Million pesos)

	Scale of Development	
	20,000 tons/day	30,000 tons/day
Rio del Oro Alternative	30,930	31,318
Rio Miranda Alternative	59,967	65,602
Rio Miranda Alternative with Cost Allocation	30,857	43,608

Operation and maintenance costs: Major elements in the cost of operating and maintaining the water supply facilities are wages and electricity costs. It is assumed that the Rio Miranda alternative requires one superintendent and one skilled worker for regular operation of the system and two additional workers for maintenance. For the Rio del Oro alternative, it is assumed that maintenance of the system would be covered by the mine operation itself and thus only a superintendent and a skilled worker would be necessary. Electricity costs are estimated on the basis of a rate of based 101 pesos/kWh and total electricity requirements for water transmission.

The total operation and maintenance costs are estimated for the Rio Miranda and the Rio del Oro alternatives with the results summarized in Table 4-12. The Rio Miranda alternative is cleary less favorable for either operating scale due to the excessively high costs required to transport water by pumps and pipelines.

Table 4-12. Total Operation and Maintenance Costs for the Rio Miranda and the Rio del Oro Alternatives

	Scale of Development	
	20,000 tons/day	30,000 tons/day
	million pesos	million pesos
Rio del Oro alternative		
Personnel	60	60
Electricity	1,610	1,740
Total	1,670	1,800
Rio Miranda alternative		
Personnel	100	100
Electricity	6,180	8,240
Total	6,280	8,340

Salvage value: The salvage value of a dam can be computed based on benefits that will accrue from the best alternative use of the dam after the termination of the mine operation. The procedure is given in the Appendix for the Rio del Oro dam.

The salvage value of the Rio del Oro dam is estimated to be 6.97×10^9 pesos. The salvage value of the Rio Miranda dam can also be computed in the same way based on the amount of additional water available after the mine operation terminates, and equals to 12.2×10^9 pesos and 18.7×10^9 pesos respectively for the operating scale of 20,000 tons/day and 30,000 tons/day.

7-3. Effects on the Region

Some of the factors affecting viability of the water resource development alternatives are not directly reflected in the project costs. These factors are analyzed in this sub-section from regional viewpoints.

A major disadvantage of the Rio del Oro alternative is that availability of surface water will be reduced in the Rio Sarmientos basin by the dam constructed upstream. This may constrain the development of Chilecito and other communities in the surrounding area. In particular, agricultural development on the east side of Chilecito may be suppressed since the new mining town to be located in the same area will depend on groundwater for water supply.

On the other hand, the water made available by the Rio Miranda reservoir can be fully allocated to agricultural uses. In fact, according to the original plan, the reservoir is expected to serve not only the immediate downstream area of the river, but water is to be transported further to the Sañogasta and Nonoagasta areas by means of canal systems. Therefore, rather than further developing irrigated agriculture in the area east of Chilecito, expansion could be directed toward these southern areas of the region, if the Rio del Oro alternative should be adopted.

Flow in Rio Amarillo will be reduced if water is extensively extracted from the aquifer on the east side of the mine according to the Rio del Oro alternative. This, however, may be partly offset by a waste disposal reservoir which is to be located in the same basin. That is, water in the waste disposal reservoir is partly disposed of by evaporation but mainly by infiltration into the ground, thus improving the local groundwater regime at least in terms of quantity.

A positive aspect of the Rio del Oro reservoir plan is that it will work as a buffer against possible adverse effects of the waste dump planned to be located in the catchment area of Rio del Oro. The waste dump might otherwise cause water quality problems for downstream communities, although such effects are difficult to evaluate in monetary terms.

The Rio Miranda alternative has an advantage in that it makes use of the on-going dam project, for which a subsidy has been granted by the Argentine Government for 1981, the first year of construction. Also this alternative will not involve serious conflict with existing water rights, since the area immediately downstream is relatively undeveloped. However, allocation of water in the reservoir to the concentration plant and new development of agricultural land further downstream would involve another conflict. It is not clear at this point how financial aspects of the project, including cost allocation and reimbursement requirements of the Government subsidy, would be affected by water diversion to the concentration plant. Although it is possible to compute opportunity costs (or benefits foregone) of the diversion and compare them with benefits accruing from the mine, this sharing problem may demand more than just such an economic solution.

8. Conclusions and Recommendations

Several water resource development alternatives for the Famatina mine area have been formulated and analyzed in this chapter. The alternatives to depend exclusively on groundwater cannot be recommended, in part due to the lack of data available. A crude estimate of yield from the confirmed groundwater reserve on the east side of the mine indicates that this source can satisfy only a part of the water requirements for the concentration plant.

Two distinct alternatives appear to be more feasible. One is diversion of water in the Rio Miranda reservoir which is currently planned by SERH (the Rio Miranda alternative); the other is a combination of a new reservoir to be located on Rio del Oro and use of groundwater near the mine (the Rio del Oro alternative). These alternatives were evaluated and compared in terms not only of costs but also of effects on the region.

The Rio Miranda alternative is inferior primarily because of the excessive costs incurred by pumping water up by 1,800 m over a 30 km distance. The Rio del Oro alternative is the most cost-effective of all the alternatives examined herein, and may be more favorable also with respect to effects on the region, as discussed in Section 4-7.

Still, the construction costs of the Rio del Oro dam are high because it is located at a high altitude and because additional costs would be incurred to pump water up by 850 m to the concentration plant. The size of the dam, and thus its costs, will be reduced, it more water can be extracted from groundwater reserves in or around the mining site. It is highly recommended therefore that systematic exploration of groundwater resources initiated by DGAS in the area near Chilecito be extended to the mining areas. In fact, the exploration of groundwater should proceed in parallel with further prospect boring at the mine site.

Better meteorologic and hydrologic data for the region, especially its high altitude areas, will allow for more precise evaluation of the availability of water from alternate sources. Continuous streamflow records at several points along each river will also help in analysis of the groundwater regime, since interactions between surface water and groundwater are comparatively more significant in local hydrologic cycles in arid to semi-arid regions.

Annex: **Computation of Salvage Value for Rio del Oro Dam**

The operation of the mine will terminate after same 20 to 30 years from its initiation, unless new reserves are discovered in the meantime. Physical life of a dam, on the other hand, is usually much longer. If the dam can not be diverted to same other productive uses that will yield sufficient benefits, it has no economic value after the termination of the mine operation; its salvage value would be zero. In other words, the dam has salvage value only to the extent that it is diverted to any other project that would yield just sufficient benefits.

It is difficult to determine at this stage how the dam will be utilized after the termination of the mine operation in same 30 years time. However we can be reasonably sure that it will be used for same purposes as the dam enables to provide more stable supply of water. Possibilities are diversion of water in the reservoir to agricultural or domestic uses or hydro-power generation.

Suppose the water in the Rio del Oro reservoir be used to irrigate newly developed agricultural land near Chilecito. The irrigation water made available by the dam can be used to develop much larger agricultural area than otherwise possible when only natural flow of the stream is to be used. To Determine how much larger area can be irrigated, first estimate the area that could be developed for irrigated agriculture by using only the natural streamflow. The streamflow available at the reservoir site is estimated and given in Table 4-13.

Table 4-13. Satisfaction of Irrigation Demand by Natural Streamflow

Month	Natural Streamflow Mm^3/month	Irrigation Demand Mm^3/month	Satisfaction %
1	1.52	1.25	100
2	1.38	0.83	100
3	1.23	0.39	100
4	0.28	0.40	70
5	0.17	0	100
6	0.14	0	100
7	0.14	0	100
8	0.14	0.21	67
9	0.12	0.40	30
10	0.27	0.84	32
11	0.75	1.22	61
12	0.93	1.56	60
Total	7.09	7.09	--

Also given in this table is monthly irrigation demand computed according to the estimates made by SERH for the Rio Miranda project.

As is clear from Table 4-13, September is the most critical month as long as irrigated agriculture is concerned, and only 30% of requirements is satisfied by natural flow of the stream. That is, the area that can actually be irrigated is only 30% of the potential area which appears to be irrigable from the annual total availability of water.

According to the original plan of the Rio Miranda project, approximately 2,500 ha land would be irrigated by using the total amount of water 27.5 million m^3/year made available by the dam. Therefore by using the 7.09 million m^3/year water from the Rio del Oro reservoir, approximately

$$2{,}500 \times 7.09 / 27.5 = 645 \text{ ha}$$

land can be potentially irrigated.

Use of natural flow of the stream, however, would make it possible to develop only 30% of the potential area as described above. This corresponds to 194 ha. If the Rio del Oro reservoir is used to adjust the seasonal variations in streamflow, the additional 451 ha (= 645 – 194) would be irrigated in an average year. Since the storage volume of the reservoir may not allow full adjustment of annual variations in streamflow, the following analysis will be made based on 400 ha land to be developed for irrigated agriculture by using water in the reservoir.

A detailed study has been done by Secretaría de Estado de Asuntos Agrarios (SEAA), La Rioja, on the costs of developing 30 ha agricultural land for grape production in the western part of the Province of La Rioja. The following calculation is mostly based on this study, since the grape is the most promising cash crop in this area.

The total costs incurred in each year including rents for machinery and equipments are computed by using the data provided by SEAA and given in the second column of Table 4-14. Annual benefits given in the third column of the table are calculated based on the price of grapes 400 pesos/kg and estimated yield for each year. In the fifth year the production reaches the maximum of 30 tons/ha which will be maintained in subsequent years. Additional investment would be required to build a canal system to transport water to irrigation sites. The costs for this are estimated to be 360 million pesos. Including this cost element, the net benefits of the 400 ha agricultural development for each year are as given in the last column of Table 4-14 (see next page).

From the data given in Table 4-14, the salvage value of the dam can be computed as follows. For the agricultural development project to be economically justified, its internal rate of return (IRR) should be at least 10%, considering conditions prevailing in capital markets in Argentina and the Province. If it is less than 10%, this project should not be implemented, but the actual rate depends on how much costs are assessed for the dam. In other words, the dam should be assessed only that value which makes the IRR of the agricultural development project equal to 10%, should this project be implemented. Thus the salvage value SV of the dam is

Table 4-14. Costs and Benefits of Agricultural Development Project

Year	Costs (million pesos)	Benefits (million pesos)	Net Benefits (million pesos)
1	5,605 + 360[1)]	0	-5,966
2	1,183	0	-1,183
3	2,241	800	-1,441
4	1,737	2,400	663
5	2,925	4,800	1,875

Note: 1) This additional element corresponds to the costs of building a canal system as described in the text.

Source: Secretaría de Estado de Asuntos Agrarios, La Rioja (SEAA)

calculated from

$$\frac{1,875}{r(1+r)^3} + \frac{663}{(1+r)^3} = SV + 5,996 + \frac{1,183}{1+r} + \frac{1,441}{(1+r)^2}$$

where r = 0.1 (10%) and all the value for benefits and costs are expressed in million pesos.

Thus, $SV = 6.36 \times 10^9$ pesos

Since there is no apriori reason to believe that the agricultural development is the most beneficial way to make use of the Rio del Oro dam after the termination of the mine, two other possibilities were considered. Ore is diversion of water in the reservoir to municipal uses in Chilecito, and the other is hydro-power generation.

The benefits of water diversion to Chilecito are calculated based on the costs associated with the second best alternative to procure the same amount of water — i.e. the alternative to develop more groundwater. The benefits of hydro-power generation were calculated based on the 225 ℓ/sec. flow, the available head of 180 m and the prevailing electricity rate of 100 pesos/kWh, assuming 80% efficiency and 7,000 hours annual operation of the facilities. The calculated salvage value is 2.7×10^9 pesos for municipal water supply and 2.1×10^9 pesos for hydro-power generation, each if additional investments to make such uses possible are ignored.

Chapter 5.

MINING TOWN DEVELOPMENT PLAN

CHAPTER 5. MINING TOWN DEVELOPMENT PLAN

1. Mining Town Development Plan

With the development of mines, it becomes necessary to have towns for employees of the mines, their families and also people engaged in various service activities. In this section, let us firstly enumerate the necessary conditions for locating mining towns in general. Next, refering to these conditions and also considering other development conditions of this particular project, a desirable form of mining town development will be determined.

1-1 Necessary Conditions for Locating Mining Towns

The factors considered in general as requisite conditions for locating mining towns are summarized into five items as described below.

Commuting problems: Generally in local areas where mines exist, the socially acceptable time for commuting is limited to only about half an hour. Therefore, it is an important condition that mining towns be located near the mine within easy commuting distance.

Elevation limit: Contrary to the commuting problem, if mining towns are located too close to the mine, it may happen that high elevations cause unpleasant and be inconvenient for human life. We can find many temporary lodging facilities existing in locations approx. 4,000 m above sea level and we can also find examples of towns located approx. 3,400 m above sea level and it is possible to live at these altitudes (for example, Cuzco City in southern Peru). However, since such a high elevation makes people coming from lower areas feel unpleasant, we judge it beyond generally acceptable conditions for location of a town. It is desirable that the town be located below 3,000 m so that many people are able to live without excessively uncomfortable feelings.

Topography and geography: Besides the limits on commutation and high elevation, another prerequisite is that ample space which can be readily developed topographically be selected. What is meant by "ample space" here is an area equivalent to the pown scale estimated in detail in the following section, namely 100 ha to accommodate the minimum population, or 200 ha considering future population increases of population or even 300 ha if possible. On the other hand, for such large scale town development one of the representative elements of the "can be readily developed topographically" condition is the land slope. A steep slope does not preclude development, but it implies inefficiency of land utilization and requires a relatively more spacious area to provide facilities. It will also increase construction costs because much more earthwork and stone piling would be required, and the residence after completion of development would be inconvenient. There will be no problems if the average slope is below 5%, above which inconvenience increases sharply. If it becomes 15%, it becomes impossible to utilize the land as a large scale residential area. Other conditions include the location of water supply sources for the town (planned level of water supply: 300 ℓ per person per day).

Relations with existing villages: Relations with existing villages are important socio-economic conditions. Regarding various connections with existing villages, the following should be noted:

(1) To what extent existing town facilities and services can be shared.

(2) What kind of positive (scale merit, etc.) or negative (competition, etc.) effects the town will have on existing economic activities.

(3) Whether hinder once is caused to existing land use patterns (agricultural uses, etc.)

Relations with existing villages may sometimes have considerable influence on the salvage value - what utilization value would remain after the projected life of the mine. Further, location conditions of a mining town include the condition that there are no problems in relation to existing development plans, land ownership and land value.

Other conditions: Other than the above-mentioned, the location of mining towns should be examined for flood hazard and contamination problems from exhausted smoke and water from the mine.

1-2 Selection of Mining Town Location

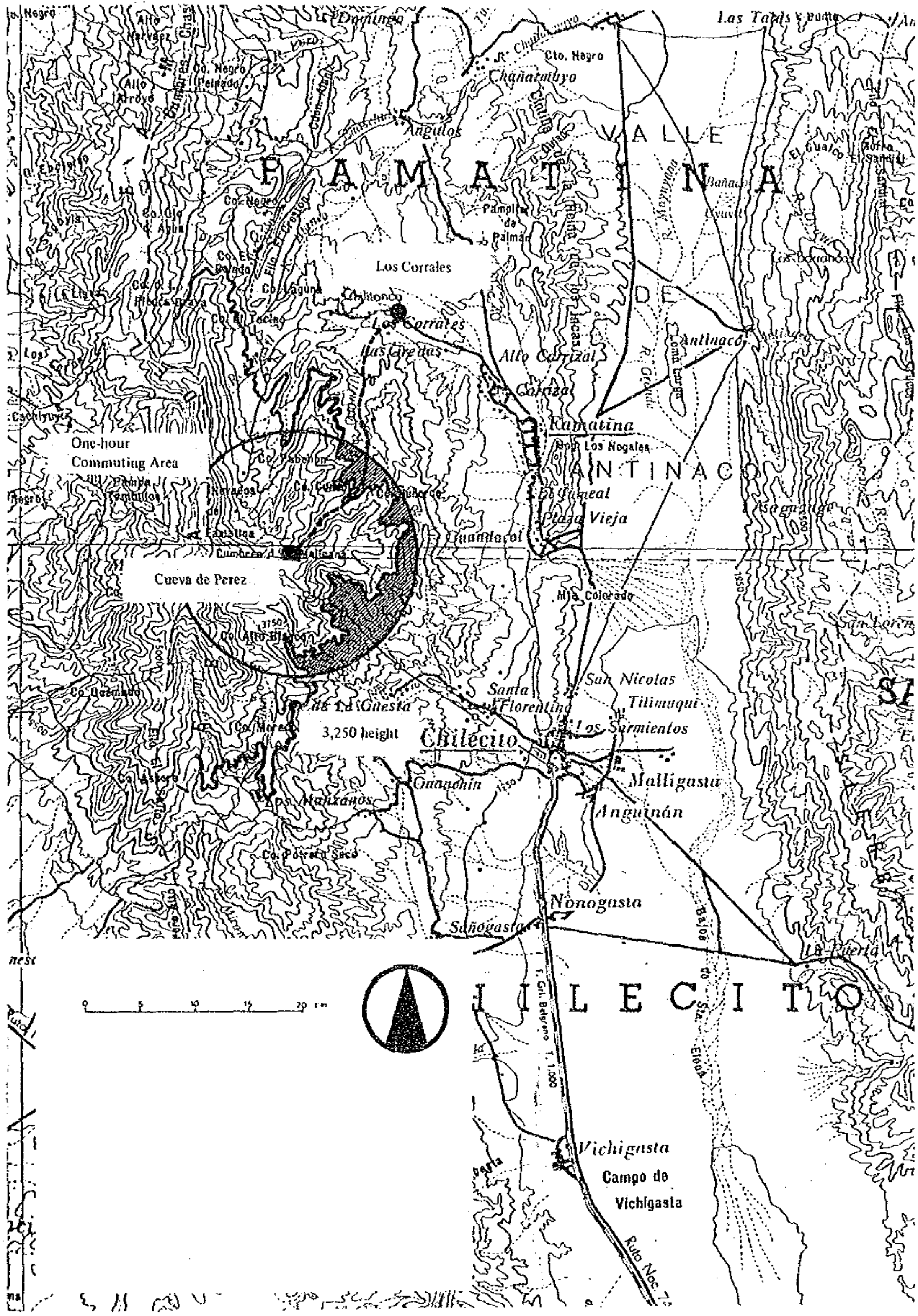
With regard to the commuting problem, in La Rioja Province, the socially acceptable commuting time is 10 to 20 minutes in the cities of La Rioja and Chilecito. In the village of Famatina, most people live in close proximity to their working places, i.e. farms. In the case of mine workers, though a large concession is obliged to be made to the allowance of commuting time, the limitation is still half an hour, or one hour at most.

Figure 5-1 shows data for study in selection of a mining town location. Taking the commutation and elevation conditions mentioned as flexibly as possible, one hour commuting time and 3,250 m above sea level are considered the max. acceptable limits, respectively. The possible locations which satisfy these two conditions are limited to the shaded area in Figure 5-1.[Note] Further, in addition to the upward slope of the mountainside, owing to the complicated ridge and valley topography, it is clear that there is no gentle slope extending over a wide area suitable for town development.

In Cueva de Noroña, approx. 13 km form the mine at on approx. Altitude of 3,000 m, the land has a 10% slope on the average. The space available there is only 10-20 ha however and a river runs through the area which poses potential flood danger during the rainy season (November – March).

Note: As explained in detail in Chapter 6, the gravel road to be developed from the mine follows a route to Los Corrales via Cueva de Noroña to cnnect with existing roads. The transportation time required from the mine to Los Corrales (30 km) after completion of road development is expected to be 3 hours by 20 ton semitrailer for crude ore transport, 2 hours by bus for employee commuting and approximately one hour and a half by ordinary passenger car.

Fig. 5-1. Plan of Mining Town Location



There is also some gently sloping land in Las Pacetas, approx. 30 km South-east of the mine at an approx. altitude of 2,000 m, but hte space is limited to only 10 ha and far beyond the commuting range limit. As explained in the next section, there is also a problem with road construction along this route.

Descending far outside the commuting range limit to the skirts of mountains, we can find a belt-shaped site available for residential development of about 100 ha near Los Corrales and Famatina. There still remains, however, a 6 – 8% slope and as the site is along the river, flooding could pose a problem. Further, in the city of Chilecito, a suitable site for development with an average slope of 5% or less can be obtained for several hundreds several thousands hectares near the the city area.

1-3 Combination of Camp and Mining Town

As is clear from the above study, the mountain foothills, where sites for development of mining towns exists, are located beyond the commuting range, being from 2-3 hours from to the mine site. Plans which disregard the social conditions in the region and force employees to travel 4-6 hours should be avoided. In fact, unreasonable plans ignoring these socio-economic problems have caused some troubles in other parts of the world, e.g., Bethlehem copper mine in South-western Canada.

Consequently, in this project, it was decided to plan to mining town development at the mountain skirts. Families of the employees can reside here and the mine workers can return home on weekends. Dormitories in which the workers stay on weekdays would be provided at the mine. There are some examples of this combination of camp and mining town even overseas. In Argentina, there are also cases where the workers live away from home on weekdays. Taking account of these examples, the employment plan for this project and the social situaiton of the region, the conclusion has been reached that there are no basic problems with this combination of mining camp and mining town.

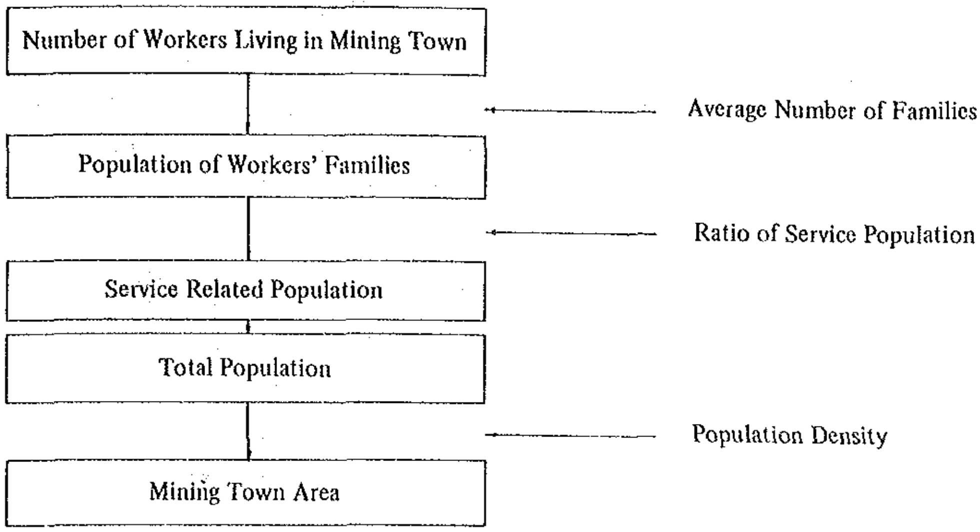
When a site for development of a mining town is located far beyond commuting range, the weight of the commuting consideration as one of the above-mentioned general conditions for locating the mining town decreases significantly. Instead, another condition, that of relations with existing villages, becomes of major importance. It is beneficial to locate the mining town near an existing town, considering the possibility of joint utilization of town facilities and services already established. The positive efforts of interaction in economic activities and the salvage value of the mining town are also considered as profits. Consequently, for the location of the mining town, focus is drown on (a) the vicinity of Famatina Village and (b) the vicinity of Chilecito city and these sites compared.

After estimating the scale of the mining town in Section 2, Section 3 studies the potential of the two sites proposed.

2. Mining Town Scale Estimation

A simplified process for estimating the scale of the mining town is shown in Figure 5-2. In this section, we will estimate the scale of the mining town following this process.

Fig. 5-2 Mining Town Scale Estimation Process



2-1 Population of Mining Town

The number of mining company workers will be 2,000 in the case of 30,000 ton operation per day and 1,500 in case of 20,000 ton operation per day, respectively. These workers are working classified according to working place, as shown in Table 5-1. Among them there is a possibility for men on duty at the Chilecito office and at the mine to live in the mining town. In accordance with the worker recruiting plan, all staff will be from areas outside the Chilecito vicinity. On the other hand, it is expected that 300 of the workers will be from around Chilecito and we therefore assume that they will be living in their own existing houses. Accordingly, we may suppose that the number of workers living in the mining town will be 515 staff and 1,100 of workers or 1,625 in all in the case of 30,000 ton operation per day, and similarly 390 of the staff and 758 workers or 1,148 in the case of 20,000 ton operation.

Table 5-1 Mining Company Employees

Employees	30,000 tons/day			20,000 tons/day		
	Staff	Laborers	Total	Staff	Laborers	Total
Workers in Buenos Aires Office	30	20	50	20	15	35
Workers in La Rioja Office	15	10	25	10	7	17
Workers in Chilecito Office	15	10	25	10	8	18
Mine Workers	500	1,400	1,900	380	1,050	1,430
Total	560	1,440	2,000	420	1,080	1,500

Since the workers' average age at marriage is generally 22, we must regard all of them as non-bacheler households when making plans for the mining town. Also, as to the average number of family members, we regard 5.0 persons per family as acceptable in consideration of the 4.5 – 4.7 persons per family average for La Rioja Province and the 5.0 per family planning standard of the Secretaria de Estado de Desarrollo y Urbano y Vivienda, La Rioja. Let us suppose that the ratio of the population engaged in service industries is 20% in consideration of the present situation in Chilecito City when compared with the standard mining town population plan obtained in this way. Should the planned population of the mining town be estimated on the basis of the above study, it would be 11,000 persons in case of 30,000 ton operation per day and similarly, 8,000 persons for 20,000 ton operation, as shown in Table 5-2.

Table 5-2 Estimation Results of Planned Mining Town Population

Residents		30,000 tons/day	20,000 tons/day
Employees	Staff	515	390
	Laborers	1,110	758
	Total	1,625	1,148
Total Population of Workers and their Families		8,125	5,740
Service Related Population		2,031	1,435
Other		844	825
Planned Town Population		11,000	8,000

Since the number of workers will not change hereafter regarding this project, and based on the assumption that the natural increase of population would flow out and that there would not be any social increase in population, this would be the planned subject population of the mining town and no change would occur in town scale. Realistically, however, in the case of this scale, the portion of natural population increase will find employment opportunities and an inflow of population can also be expected. In case of this project, since the mining town will located adjacent to an established town, as mentioned in the former section, there is a strong possibility of urban growth due to natural and social factors after completion of town development.

It is not necessary to include the increasing population after completion of town development in the analysis, but it becomes a factor when studying the location conditions of mining town. A site which can accommodate a population increase is more desirable than one having no room for urban expansion topographically. In this way the development of the mining town may enhance socio-economic contributions to the area in a greater way. Let us study the population situation assuming a certain increase ratio in order to obtain useful data for studying the location conditions of the mining town. Assuming a natural population increase of 1.3% per year following the Argentine total and social increase model of 1.0% based on data for Chilecito, we may predict that a population of 11,000 persons will grow to approx. 18,000 persons during the 22 year project life and, similarly, that a population of 8,000 will grow to approx. 16,000 in 33 years. Also, as covered in the next section, because major expansion of established urban areas in both Chilecito City and Famatina Village is difficult for topographical reasons, etc., the forecast population will be even larger if the expected population increases in these villages should also be included in the mining town figures.

2-2 Total Area of Mining Town

Let us now estimate the total area necessary for the mining town, considering the urban population estimated above. At present, dwellings in La Rioja Province are mostly single-family houses or two-family houses due to geographical reasons and the life style. There are same terrace-house-style dwellings, but no condominiums. When making plans for the mining town, considering the project life and the salvage value of the urban facilities, we have to think much of the conditions prevailing in the area. At the same time, it is desirable to improve construction efficiency by building many terrace-house-style dwellings in consideration of the financial situation of the mining company. Accordingly, for the entire mining town we have decided to build one- and two-family houses and terrace-house-style housing on a 50/50 basis.

Based on the population density shown in Table 5-3, the urban area necessary for accommodating 11,000 persons is estimated to be 100 ha, as shown in Table 5-4. Of course this is the minimum area necessary to accommodate the expected population. It will be useful to secure a site of 200 ha, considering future population increases. Even 300 ha would be desirable, taking account the potential development of the town. Of the total area estimated above, the site which the mining company itself must acquire is 41.6 ha of the residential site for 1,625 mine workers families (net population density 200 persons per ha) in case of 30,000 ton operation per day. A similar estimation has been made in the case of 20,000 ton operation per day.

Table 5-3 Standard of Population Density

Style of Dwellings	Gross Population Density (person/ha) 1)	Net Population Density (person/ha) 2)
Single-Family House and Two-Family Houses	100	150
Terrace House	200	300
Condominium upto 3 Stories	360	500
Condominium Higher than 4 Stories	600	800

Source: Ministerio de Bienestar Social Secretaria de Estado de Desarrollo Urbano y Vivirnda

Notes: 1) Gross population density is the population density per total area including the roads sites, public facilities sites, sites for commercial facilities, etc.

2) Net population density is the population density per the area of housing sites (including access roads and playgrounds only) only.

Table 5-4 Estimate of Required Town Area

Operation Scale	30,000 tons/day	20,000 tons/day
Total Town Population	11,000	8,000
Population Accommodated in Single-Family House and Two-Family Houses	5,500	4,000
Population Accommodated in Terrace House	5,500	4,000
Gross Area of Housing Site of Single-Family House and Two-Family Houses (Gross Population Density, 200 persons/ha)	55 ha	40 ha
Gross Area of Housing Site of Terrace Houses (Gross Population Density, 200 persons/ha)	27.5 ha	20 ha
Total Area of Housing Sites	82.5 ha	60 ha
Mining Company Site 1)	12.5 ha	10 ha
Town Reserve Site 2)	5 ha	5 ha
Requisite Town Area	100 ha	75 ha

Notes: 1) The Mining Company Site is the land which the mining company acquire for offices, accommodations, materials yards, etc.

2) Town Reserve Site is the land which is secured as a reserve for roads, public facilities, commercial facilities, etc. (Chilecito City, for example, owns a sewerage site of 15 ha for 30,000 person use. If the mining town is located in this vicinity, the above site is available for use. Yet it is insufficient when the pervation rate of sewerage of Chilecito City and the mining town reaches 100%.)

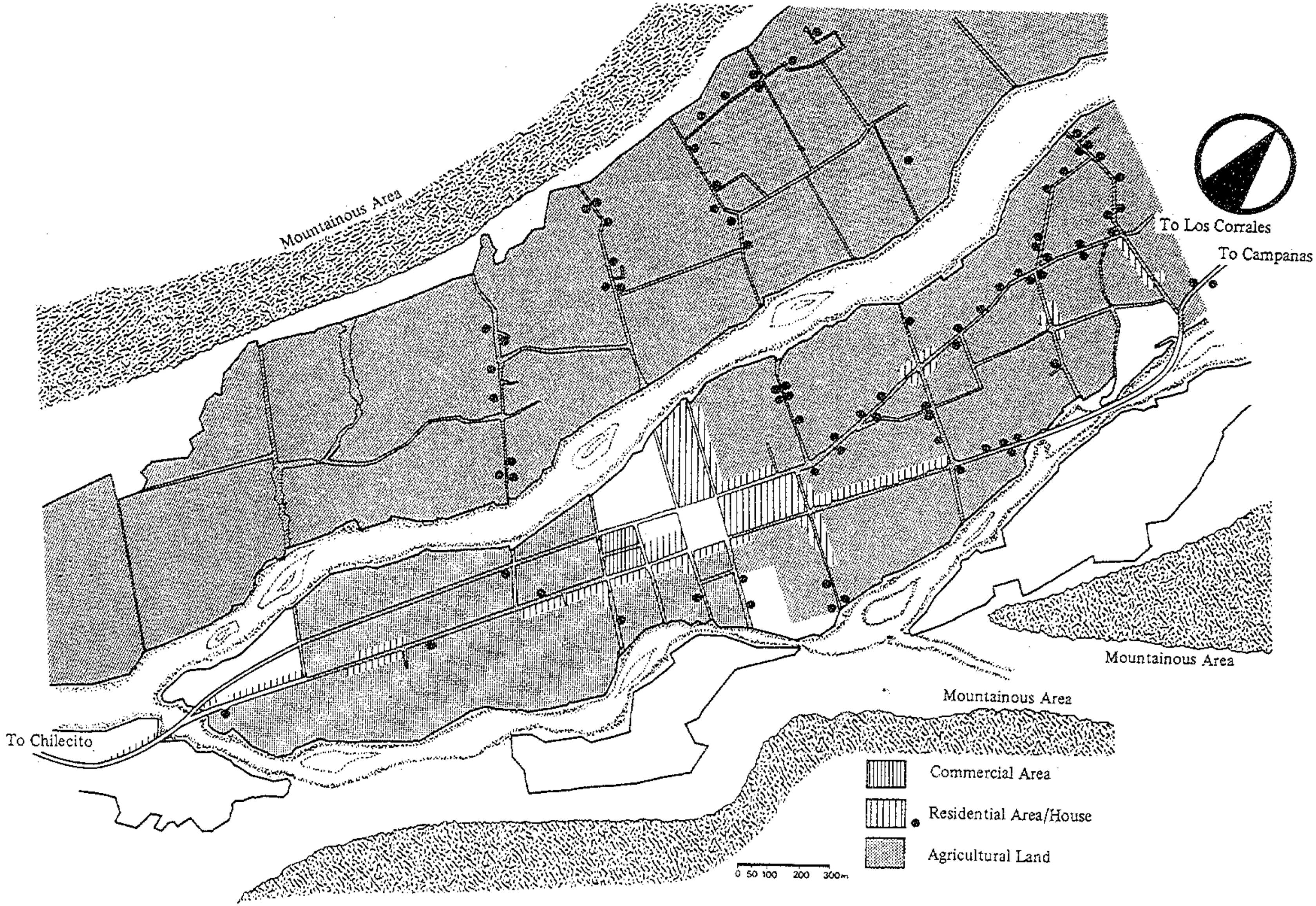
3. Selection of Mining Town Location

In Section 1, we focused attention for prospective mining town site location basically on (1) the vicinity of Famatina Village and (2) the vicinity of Chilecito City. In this section, we will estimate the aptitude of these two prospective sites and select the most suitable one for location of the mining town.

3-1 Prespective Site for Mining Town

Vicinity of Famatina Village: At present, the population of Famatina Village is about 4,000 persons; most of whom live primarily on agricultural production. The village, however, is surrounded by mountain foothills, as shown in Figure 5-3, and, moreover, land utilization of the village is such that the houses are scattered, being close to the owners' fields. It is, therefore, impossible to find suitable land for development in this village. In the outskirts

Fig. 5-3. Present Status of Land Utilization in the Vicinity of Famatina Village



of Famatina Village, the situation is such that a belt-shaped site of about 100 ha can be secured along the river. In addition, the ownership of this private land is not certified and so is administered by the provincial government. There is no problem, therefore, with regard to land ownership. However, flood control works such as embankmenting would be necessary because the mountain skirts have a slope of 6 – 8% and the land is along a river. Also, as the land belt is narrow and thus less attractive for town facilities as it makes efficient land utilization planning difficult. As for transportation, the distance to Chilecito city is 35 km and, considering the planned road construction route of road, Famatina Village is nearer to the mine. However, as the mining town of this project is being planned in the combination with a camp at the mine, the impotance of the commuting problem is considered to be fairly megligible.

As for public facilities in Famatina Village, there exist only neighborhood facilities such as a church and a school. When the mining town of a scale of about 10,000 persons is completed, all town facilities must be newly constructed. Although the poor town facilities and services in Famatina Village are expected to improve under the influence of the construction of the mining town, negative socio-economic effects may also be created due to differences in life styles between the mining town residents and the existing village populations. For example, existing small-scale stores would face stiff competition and the present land use patterns characterized by agricultural communities with scattered dwellings might collapse.

Assuming that no other new mine development starts, after the project life of this mining town has ended, the possibility of any industry other than mine created employment opportunities, the possibility of using the town facilities can be considered as follows.

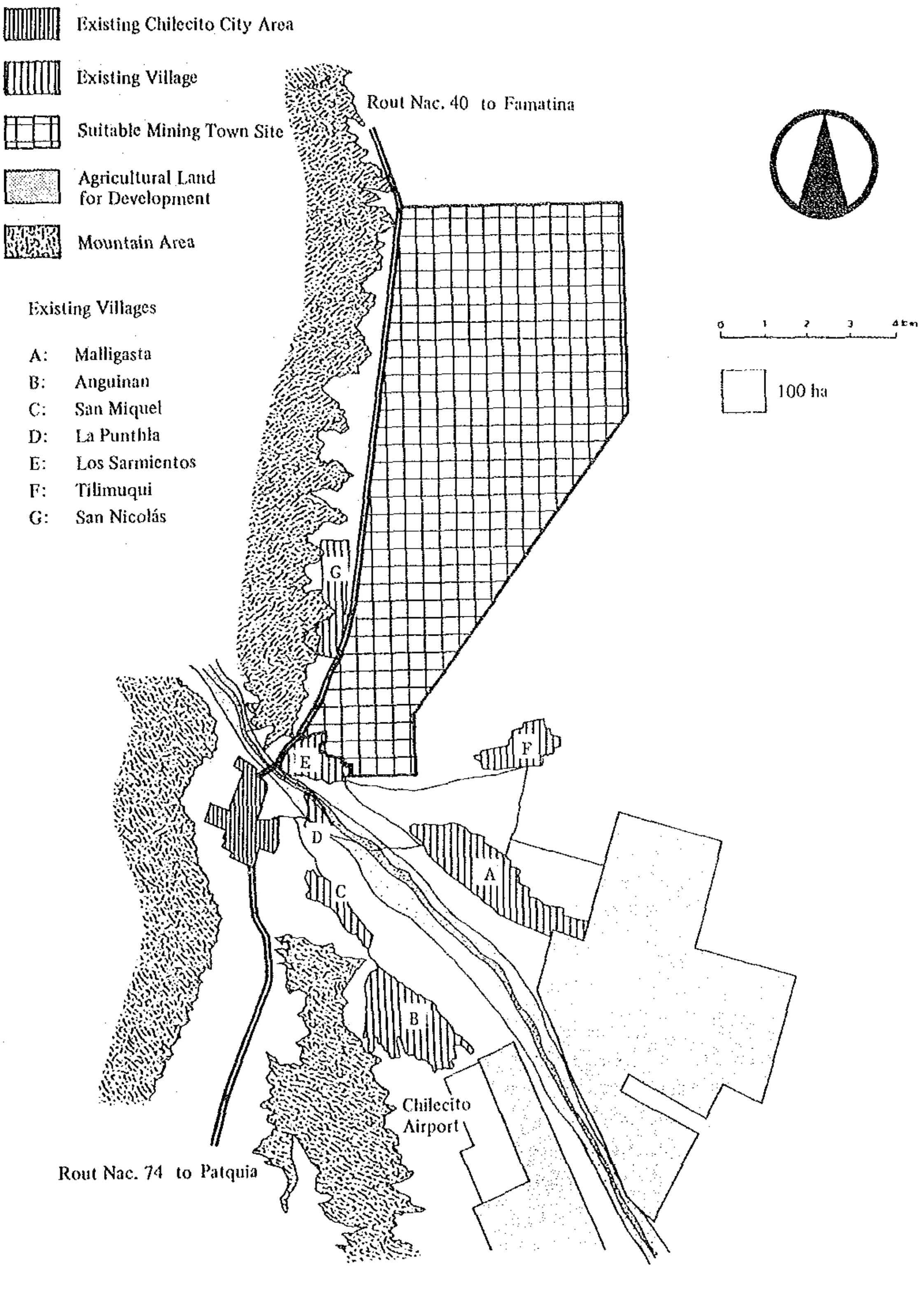
Firstly, as for agriculture, which already exists in the area, there is a limit to the increase in agricultural workers due to the limited land available for development. Also, as for the possibility of manufacture and commerce, considering the aspects of location, technique, market and transport, development can not be expected to surpass Chilecito or La Rioja cities. In conclusion, after the closing of the mine there is a strong possibility of population movement into Chilecito City, La Rioja City and other towns and cities and, accordingly, it is thought that commercial functions will gradually decline as well. Considering these together, if the mining town is located in the neighborhood of Famatina Village, there would not be much to expect with respect to the salvage value of the town.

Vicinity of Chilecito City: The existing urban area of Chilecito itself is surrounded by rivers and mountains in all directions and it is impossible to carry out further large scale. However, to the east and beyond the mountains and rivers, almost flat land of large area is available, and in fact there exist seven villages existing as satellite communities of Chilecito City. Among them, the most suitable site for development of a mining town is the northern neighborhood of Los Sarmientos, shown in Figure 5-4. Regarding this district, the following characteristics can be enumerated:

(1) No threat of flooding

(2) Buffered from noise and danger posed by airport

Fig. 5-4. Land Utilization in Outskirts of Chilecito City



(3) Private land ownership of which ownership is unknown and land now under provincial government administration, except around Chilecito City.

(4) Price of land is same as in the neighborhood of Famatina Village.

A suitable site for development at Los Sarmientos amounts to several thousand ha. There would be no problem with town expansion from the topographical point of view. Also the site is superior from the viewpoint of socio-economic salvage value. As for agriculture, an agricultural promotion and development plan subsidized by the province has been carried out in recent years around Chilecito City and will be continued. There is also a high possibility that a new settlement plan around the mining town would be made. For manufacturing, development is not necessarily guaranteed. However, based on the actual performance of existing wineries a canning factory and a ceramics factory etc., a scale of manufacturing development capable of maintaining the present manufacturing employment ratio of 15 – 20% could be expected. Also, as for commerce, existing urban commercial activities would exhibit complementary development though expansion of the town scale.

Regarding town facilities, in the case of Chilecito City, unlike the case of Famatina Village, apart from neighborhood facilities, there is a district center provided with facilities for cultural activities, security and medical treatment, etc. Some of these have reserve capacity. Also, Los Sarmientos is located over one bridge form the existing urban area of Chilecito and is within the commuting distnace. Joint utilization of city facilities would be helpful in increasing the efficiency of the plan.

3-2 Estimate of Location Aptitude

From the above explanation for the prospective locations of the mining town, it is understood that Los Sarmientos near Chilecito Village is more advantageous than the vicinity of Famatina in regard to location at aptitude. Here let us try two approaches to confirm this suitability.

(1) First, Table 5-5 summarizes the qualitative suitability of the locations discussed above. According to this, the vicinity of Famatina has advantages over Los Sarmientos concerning transport conditions but the airport problem, land ownership and the price of land are the same. As for all other standards, Los Sarmientos is superior.

(2) Next, to analyze the aptitude of the two locations quantitatively the following model can be considered under a set of assumptions. This is an attempt to measure the difference in the aptitude of location between the two prospective locations as economic costs with respect to four indices which serve as for quantitative estimation among all indices for estimation of the location aptitude. Here, the figures are shown, for the example, as they apply to mine operation of 30,000 tons per day.

Table 5-5 Qualitative Estimation of Mining Town Locational Aptitude

Estimation Standard	Vicinity of Famatina Village	Vicinity of Chilecito City, Los Sarmientos
1) Area of Site (Possibility of Expanding Town in Future)	Only small area meeting the minimum requirement is available.	Expandable upto several thousand ha.
2 Shape of Land (Efficiency of Land Utilization)	Delt-shaped, (Problem of town facilities distance).	Efficient planning available in every way.
3. Land Slope	Slope of 6 -- 8%, higher cost of development.	Almost flat, no problem.
4) Flood Hazard	Necessity for flood control.	No problem.
5) Possibility of Noise from Danger Posed by Airport	No problem.	No problem.
6) Land Ownership	Under government administration, no problem.	Under government administration, no problem.
7) Price of Land	Same. (300,000 pesos/ha)	Same. (300,000 pesos/ha)
8) Transportation to Mine	35 km nearer.	35 km further.
9) Possibility of Common Use of Existing Town Facilities	Almost all facilities must be newly constructed.	Common use of town center facilities possible.
10) Influence on Existing Land Utilization and Economic Activities	Possibility of collapse of village agricultural land utilization.	Promotion of urban economic activities.
11) Salvage Value of Town	Population flow out, little remaining expected.	Considarable employment in agriculture, manufacturing and commerce expected. Town function can be quite well maintained.

Slope of Site: As mentioned above, Los Sarmientos is located on almost flat ground, while the Famatina site is on a 6 – 8% slope. For inclined ground, earth moving and stone work increase considerably. Although it cannot be estimated precisely at this stage, however, the cost of construction work for the Famatina site is regarded as being one and a half time higher than that of the Los Sarmientos site. The difference is equal to half time estimated roughly as 100 (ha) x 144,070,000 (pesos/ha) x ½ = 7,203,500 pesos.[1]

Transport to the Mine: As for the time necessary for transport to the mine, Famatina is more advantageous than Los Sarmientos; the difference is about half an hour. If we could assume the transport time for 1,900 mine workers coming and going to the mining town prior to and after the weekend were shortened, and could convert this to wages for all the workers, the portion saved would reach 0.5 (time) x 2 (one way) x 52.14 (weeks) x 17,600,000 (pesos) = 917,660,000.

Possibility of Sharing Existing Town Facilities: If the town were located at Los Sarmientos, the existing town facilities could be utilized to a considerable extent, while if the towns were located in the vicinity of Famatina, such would not be the case. In the latter case, many more facilities would be needed as outlined in Table 5-6. To build these in Famatina would cost 0.7175 (ha) x 144.07 (pesos/ha) x 10^6 x 1.5 (times) = 155,050,000 (pesos), and the construction cost would become 2,975 (m^2) x 720,000 (pesos) = 2,142,000,000 (pesos) for a total of 2,297,050,000 pesos.

Table 5-6 Demand Increase for Town Facilities in Case of Famatina Outskirts Site

Facility	Hospital	Municipal Office	Police Station	Fire Department	Library	Theater	Church	Bus Terminal	Total
Floor Space (m^2)	1,100	330	250	150	330	440	275	100	2,975
Building Lot (m^2)	2,750	660	375	300	660	880	550	1,000	7,175

Salvage Value of the Town: In the case of the Los Sarmientos site, the economic salvage value is calculated as follows (cf. Table 5-14):

163,764,430,000	x 0.6	x 0.8	= 78,606,092,000
Total Economic Costs in Case of Los Sarmientos (peso)	Physical Salvage Value	Social Salvage Value	

Regarding the salvage value in case of the Famatina site, the physical salvage value of the town facilities is calculated at 60%, as in the case of the Los Sarmientos site.[2]

Notes: 1) Regarding cost details, refer to Section 4.

2) We estimate the durability of ferroconcrete built town facilities to be 50 years and use depreciation to be in fixed-amount.

However, the social value, in the sense that other industries would spring up and tthese facilities would be used continuously, is expected to be about 80% in the case of the Los Sarmientos site. In case of the Famatina site, it is reasonable to consider about 50% because an outflow of the population is anticipated owing to the above-mentioned circumstances. Accordingly, the salvage value of the mining town located in the neighborhood of Famatina is calculated as follows:

163,764,430,000	+	72,035,000,000	+	2,297,150,000
Total Economic Cost of Town Construction in Case of Los Sarmientos Site (peso)		Extra Building Costs in Case of Famatina Vicinity Site (peso)		Extra Construction Costs of Town Facilities in Case of Famatina Vicinity Site (peso)

Total Economic Costs of Town Construction in Case of Famatina Vicinity Site (peso)

x 0.6	x 0.5	= 51,979,520,000 peso
Physical Salvage Value	Social Salvage Value	

From the above results, the salvage value of the Los Sarmientos townsite is higher by 26,627.4 million pesos than the Famatina townsite.

When the above four quantitative indices are discounted to the present value, as shown in Table 5-7, it becomes clear that the aptitude of location of Los Sarmientos is higher by 5,014,340,000 pesos than the vicinity of Famatina. Of course, this model is based on some assumed figures, but the conceptional basis is clear and it is considered that errors in assumped figures will not alter the conclusion. Rather, this conclusion can be proved more definitely if one considers that: (1) in the case of the Famatina site additional costs would be incurred for flood control works in the model, (2) the advantage of the Famatina alternative is overstimated by converting the saved transportation time to the mine directly into workers wages, (3) all estimation standards are affirmative in favor of Los Sarmientos. Also, when the model is used for an operating scale of 20,000 tons per day or for a case where the town is separated into two parts, the same conclusion is obtained almost proportionally, considering the contents of the indices.

As a result of the above considerations, we have selected the Los Sarmientos site, the aptitude as a suitable location for the mining town is clear, and will carry forward the following plans.

Table 5-7 Quantative Estimation of Mining Town Locational Aptitude

Year / Estimation	Construction Period			Operation Period					Salvage Value
	0	1	2	3	---	n + 2	---	24	25
Slope of Site	7,204	–	–	–	–	–	–	–	–
Transportation to Mine	–	–	–	△918	---	△918	---	△918	–
Possibility of Common Use of Existing Town Facilities	155	1,071	1,071	–	–	–	–	–	–
Salvage Value of Town	–	–	–	–	–	–	–	–	26,627
Discount Rate of Existing Value	1.0	0.909	0.826	= 7,249					0.092
Present Value	7,359	974	885	△6,652.12					2,450

Conclusion: Regarding the existing value of location aptitude, Los Sarmientos is higher by 5,014.34 x 10^6 pesos.

Note: + shows advantage in favor of Los Sarmientos site.
△ shows advantage in favor of outskirts of Famatina site.
○ Discounted in the 1st year of construction period.
○ Capital opportunity cost is 10%.

4. Facility Planning for Mining Town

In this section, firstly we will plan the contents, scale, and construction of town facilities as well as the housing in the mining town which may be shared by both the mining company and public organizations and estimate financial costs accordingly. Next, we will estimate the scale and financial cost for the camp dormitory facilities near the mine. In this section, the figures and costs are for an operating scale of 30,000 tons per day with figures in parenthesis representing a scale of 20,000 tons per day.

4-1 Plan of Mining Town Facilities to be Developed by Mining Company

Land Acquisition and Development Plan: Of the requisite town area of 100 ha (75 ha) calculated in Section 2, the mining company must acquire 55 ha (40 ha) at a cost of 300,000 pesos per ha. Land development costs, including costs for land preparation, construction of breast walls, access roads in the site, plantation, etc., are estimated to be about 144,070,000 pesos. From the viewpoint of finanical analysis, for the site acquired by the mining company, costs for land development will be borne by the mining company.

Water Supply and Electricity Facilities Plan: Plans for primary water supply facilities and electrical facilities were studied in the chapters on a water resources development plan and an electric power plan, but the plan for terminal facilities will be studied here as a part of the plan for town facilities. The total costs for these faciliteis are assumed to be a uniform 5,445 pesos per ha, although they depend on population density distribution in connection with the land utilization plan.

Sewage Facilities Plan: In Chilecito City, sewage facilities at present serve about one third of the population. This rate is expected to improve in future. To accord with this tendency, it is essential for the mining town also to establish sewage facilities. In case of a town with a population density of 10,000 persons, the cost of sewage facilities is estimated at one billion pesos for terminal treatment facilities two billion 500 million pesos for main sewage lines and one billion 562 million 500 thousand pesos for branch sewage lines per 10,000 persons. From the viewpoint of finanical analysis, the costs of water supply, electricity facilities and sewage facilities are to be borne by the mining company.

Housing Construction Plan: For the 1,625 (1,148) mine employees living in the mining town, we will make housing plans for a floorspace of 80 m² each for 515 families (390 families) of the staff and a floorspace of 60 m² each for 1,110 families (758 families) of the workers. For reference, an example of a two LDK house design with a floorspace of 60 m² is shown in Figure 5-5. The total floorspace of housing which the mining company must first build is 107,800 m² (76,680 m²), while the cost of the housing construction is estimated at 900,000 pesos per square meter.[1] The housing lot development cost is included in the development cost mentioned previously. The total area of a housing lot for a 60 – 80 m² house is about 250 m².

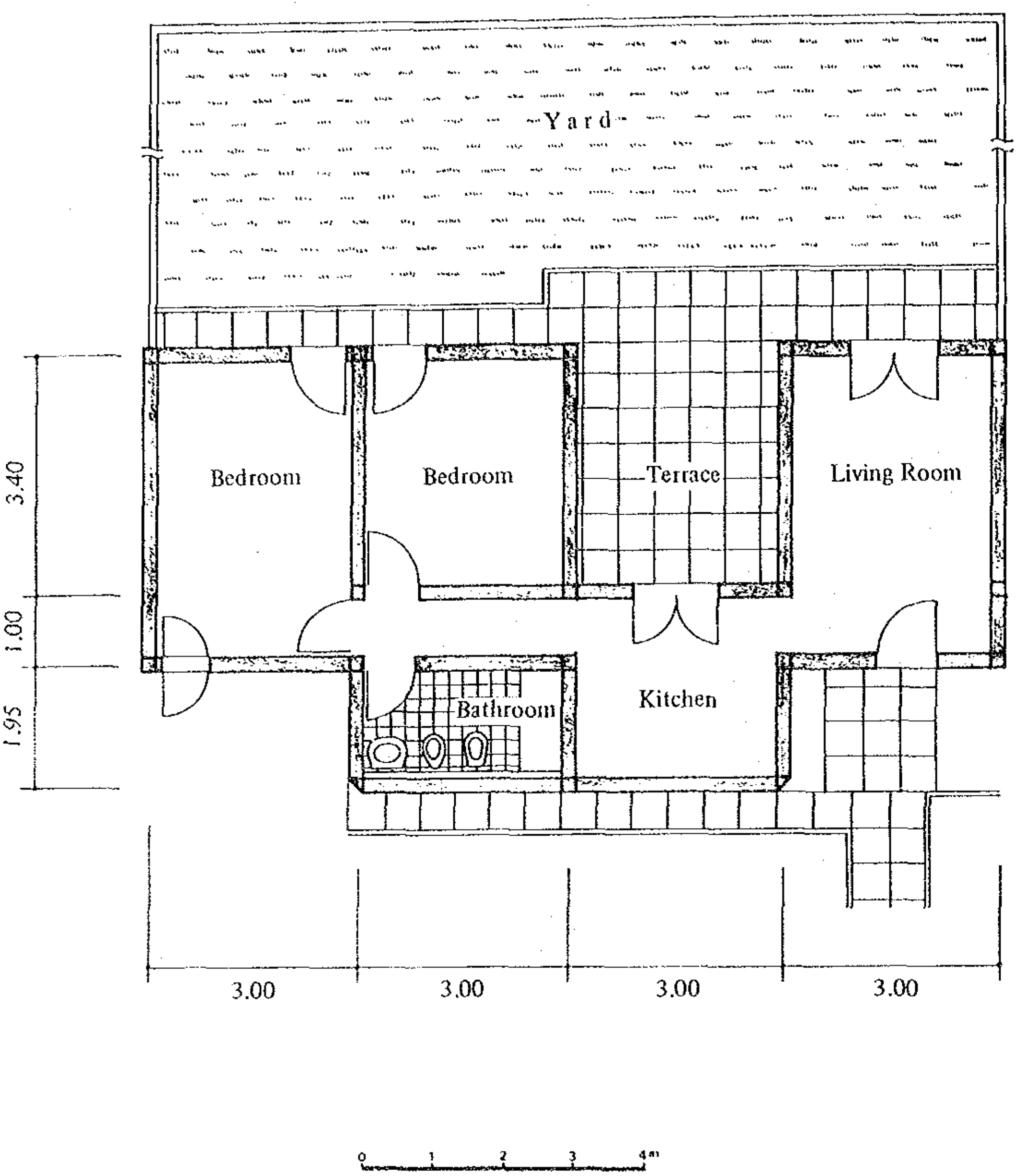
Mining Company Facilities: The employees at the mining town include 15 staff (10 staff) and 10 workers (8 workers), for a total of 25 (18). The floorspace of the offices of the mining company and in the mining town total 250 m² (180 m²) when the net office floorspace is taken as 5 m² per person and the common space rate is 100% of the net office floor space.[2]

In addition, it is necessary to secure space similar to office space for accommodation facilities, warehousing, etc., and accordingly, total floorspace of the facilities of the mining company will become 500 m² (360 m²).

Notes: 1) In La Rioja Province, almost all buildings are of ferroconcrete with partitions and outer walls of block piling. In this project, we will use the same structure because: (1) prefabricated steel frame buildings are not yet common in the area, (2) earthquakeproof design is necessary, and (3) the currently used structural form is the easiest for local contractors to build.

2) The common use portion mentioned here includes meeting rooms, corridors, halls, toilets, water boiling rooms and so on.

Fig. 5-5. House Plan (2 LDK)



The construction costs for these facilities are estimated at 720,000 pesos per square meter of floorspace.

Of the total financial costs for mining town development, the share borne by the mining company is explained above and calculation results are sumarized in Table 5-8.

Table 5-8 Financial Cost of Mining Town Development Borne by Mining Company

Cost Item	Unit Price	Operation Rate 30,000 tons/day		Operation Rate 20,000 tons/day	
		Quantity	Cost	Quantity	Cost
Cost of Land Acquisition	0.3×10^6	55 ha	16.50	40 ha	12.00
Cost of Land Development	144.07×10^6	55 ha	7,923.85	40 ha	5,762.90
Cost of Water & Electricity Facilities	54.45×10^6	55 ha	2,994.75	40 ha	2,178.00
Cost of Sewage Facilities	$5{,}062.5 \times 10^6$	8,125 persons	4,113.28	5,740 persons	2,905.88
Cost of Housing Construction	0.9×10^6	107,800 m^2	97,020.00	76,680 m^2	69,012.00
Cost of Construction of Mining Company Facilities	0.72×10^6	500 m^2	360.00	360 m^2	259.20
Total	–	–	112,428.38	–	80,129.98

4-2 Plan for Other Facilities of Mining Town

Among essential facilities for the mining town other than those borne by the mining company, there are commercial other facilities which must be developed by private sectors and public facilities which must be paid for by the nation or by local public organizations. The costs of the commercial facilities are naturally borne by each private service industry. However, as for public facilities such as principal roads and education facilities, if we let the mining company bear the construction costs and then transfer the facilities to be operated by public organizations, the financial burden of the mining company will become too heavy.

Considering the strong support given to the project by concerned public organizations, we will carry out analysis on the assumption that for public facilities the costs of site acquisition and construction will be borne by the concerned public organizations. As the construction costs of commercial and public faciliteis are not borne by the mining company, they are not included in the financial analysis, but are counted as economic costs in the economic analysis.

The essential town facilities for a population of 11,000 persons (8,000 persons) are given in the following. This facilities plan is based on standards established by the Ministeria de Bienestar Social, Secretaria de Estado de Desarrollo Urbano y Vivienda and Subsecretaria de Desarrolo Urbano as to all aspects, including facility contents, composition, scale, catchment area and so on. Naturally, it complies with various laws, financing conditions and social circumstances. Also, among the established town facilities in Chilecito City, we assume that facilities such as the hospital, sports park, municipal offices, police stations, fire department, library, theater, church, cemetry, bus terminal and commercial services are shared with existing communities either partially or entirely. For reference, we assume that the average construction cost of these town facilities is 720,000 pesos per square meter of floorspace.

Educational Facilities: Planned as shown in Table 5-9.

Table 5-9 Educational Facilities Plan

Facility	Operation Rate 30,000 tons/day			Operation Rate 20,000 tons/day[Note]			Remarks
	Number of Facilities	Area of Building Lot per School	Total Floor Space per School	Number of Facilities	Area of Building Lot per School	Total Floor Space per School	
Kinder-garten	2	500 m^2	200 m^2	2	500 m^2	200 m^2	For Children Aged 2-5 Years
Primary School	2	5,040 m^2	2,520 m^2	2	5,040 m^2	2,520 m^2	For Children Aged 6-12 Years, Building Area: 1,260 m^2, Two-story-building
Secondary School	1	4,440 m^2	2,800 m^2	1	4,440 m^2	2,800 m^2	For Students Aged 13-17 Years, Building Area: 940 m^2, Three-story-building
Total	5	15,520 m^2	8,240 m^2	5	15,520 m^2	8,240 m^2	

Note: The doubleshift school system is adopted for kindergarten, primary school and secondary school. As in the case of a mine operating scale of 20,000 tons/day, the difference in number of students does not change much from the number in the case of 30,000 tons/day because of simultaneous utilization. Therefore, the scale of facilities is the same.

Medical Treatment Facilities: The existing facilities of the hospital in Chilecito are to be utilized. However, one medical facility with an 830 m^2 (600 m^2) building lot and floorspace of 330 m^2 (240 m^2) is needed.

Park Facilities: Planned as shown in Table 5-10. For reference, the average construction cost of park facilities is estimated at 70,000 pesos per square meter.

Table 5-10 Park Facilities Plan

Facility	Operation Rate 30,000 tons/day		Operation Rate 20,000 tons/day	
	Number of Facilities	Area per Facility	Number of Facilities	Area per Facility
Playground	4	1,380 m^2	3	1,340 m^2
Neighborhood Park	2	5,500 m^2	2	4,000 m^2
Sports Park	1	27,500 m^2	1	20,000 m^2
Total Area	44,020 m^2		28,020 m^2	

Government and Public Offices: Regarding municipal offices, police stations and fire department, it is possible to utilize existing facilities of the head offices. Although there is possibility of construct of branch stations, we will ignore this because the scale is very small. As for the post office, one facility with a building lot of 350 m^2 (350 m^2) and floorspace of 300 m^2 (300 m^2) will be necessary, because the catchment area is as small as 100 ha.

Social-Cultural Facilities: For the library, theater, church, etc., existing facilities in Chilecito City can be utilized, and therefore, only those facilities shown in Table 5-11 will be necessary.

Table 5-11 Social and Cultural Facilities Plan

Facility	Operation Rate 30,000 tons/day			Operation Rate 20,000 tons/day		
	Number of Facilities	Area of Building Lot	Floor Space per Facility	Number of Facilities	Area of Building Lot	Floor Space per Facility
Public Nursery	5	360 m^2	180 m^2	4	320 m^2	160 m^2
Church	1	560 m^2	280 m^2	1	400 m^2	200 m^2
Total	–	2,360 m^2	1,180 m^2	–	1,680 m^2	840 m^2

Commercial Facilities: With regard to commercial facilties such as banks, hotels and so on, the existing facilities in Chilecito City can be utilized, and in the mining town the commercial facilities shown in Table 5-12 become necessary.

Table 5-12 Commercial Facilities Plan

Facility	Operating Scale 30,000 tons/day		Operating Scale 20,000 tons/day	
	Total Area of Building Lot	Total Floor Space	Total Area of Building Lot	Total Floor Space
Sales Industry	4,840 m^2	2,420 m^2	3,520 m^2	1,760 m^2
Service Industry	2,200 m^2	1,100 m^2	1,600 m^2	800 m^2
Total	7,040 m^2	3,520 m^2	5,120 m^2	2,560 m^2

The total floorspace of the educational facilities, medical treatment facilities, Government and public offices, socio-cultural facilities and commercial facilities will be 13,570 m^2 (12,180 m^2), and the park area 44,020 m^2 (28,020 m^2). The financial costs of mining town construction to be borne by public organizations or private sectors other than the mining company are as shown in Table 5-13, including the costs of readjustment of infrastructure.

Table 5-13 Financial Cost of Mining Town Development Borne by Public Organizations and General Private Sectors

(Cost Unit: Million pesos)

Cost Item	Unit Price	Operating Scale 30,000 tons/day		Operating Scale 20,000 tons/day	
		Quantity	Cost	Quantity	Cost
Cost of Land Acquisition	0.3 x 10^6	45 ha	14	35 ha	11
Construction Cost of Transportation Facilities	300 x 10^6	18 ha	5,400	13.5 ha	4,050
Cost of Land Development	144.07 x 10^6	27 ha	3,890	21.5 ha	3,097
Cost of Water Supply and Electricity Facilities	15.45 x 10^6	27 ha	1,470	21.5 ha	1,171
Cost of Sewerage	5,062.5 x 10^6	2,875	1,455	2,260	1,144
Cost of Housing construction for Population of Service Industry	0.9 x 10^6	40,250 m^2	36,225	31,640 m^2	28,476
Construction Cost of Public Facilities	0.72 x 10^6	13,570 m^2	9,770	12,180 m^2	8,769
Readjustment Cost of Park Facilities	0.04 x 10^6	44,020 m^2	1,761	28,020 m^2	1,121
Total	–	–	59,985	–	47,839

Note: As these financial costs are not borne by the mining company, they are not included in the financial analysis. However, the costs converted into economic cost are included economic analysis as the cost of this project.

4-3 Camp Dormitory Facilities Plan

In the neighborhood of the mine, minimum public welfare facilities such as the following will be necessary. (1) Offices for 500 (380) staff and other related facilities such as meeting rooms, (2) Dormitory facilities for 1,900 (1,430) employees in total including 1,400 (1,050) workers, (3) 4 dining rooms and a sports ground.

Firstly, regarding the office room, assuming that net office floorspace is 5 m^2 per person and the common use area [1] is 80% of the net office space 4,500 m^2 (3,420 m^2) of floorspace will be required for 500 (380) staffs. As for the dormitory facilities, assuming the net bedroom floorspace area is 10 m^2 per staff and 5 m^2 per laborer, and also that the common use area [2] is 100% of the net space, 24,000 m^2 (18,100 m^2) floorspace will be necessary for 500 (380) staff and 1,400 (1,050) laborers.

To accommodate a total floorspace 28,500 m^2 (21,520 m^2) of office rooms and dormitories at the measurement rate of 100%, a site area equal to the total floorspace becomes necessary. Other than these, when a site of 21,500 m^2 (18,480 m^2) is prepared for a sports ground, a facility for outdoor parties and storage of construction and other materials is necssary and the area required becomes 5 ha (4 ha) in total.

The most promising way for securing this 5 ha (4 ha) site, from the topographical viewpoint, is to develop the south-western part of the existing camp facilities in Cueva de Perez by cutting into the hills at the back. However, since this area has been chosen for the mining site, the area north-eastward from this site will be used for this purpose. The location of this area does not pose any serious problem because of its extremely small site in comparison with the area of the mining town. The land development cost, however, is considered as about 288 million 140 thousand pesos per ha, since land with a sloped of 10% degree or more must be high altitude leveled.

Also, the construction cost is higher in this area than the area at the foot of the mountain and is estimated to be approximately 864,000 pesos per square meter.

Naturally the total amount of 26 billion 64 million 700 thousand pesos (19 billion 728 million 560 thousand), including one billion 440 million 700 thousand pesos (one billion 152 million 560 thousand pesos) for 5 ha (4 ha) land development cost and 24 billion 624 million pesos (18 billion 576 million pesos) for total floorspace of 28,500 m^2 (21,500 m^2) of facilities construction cost should be borne by the mining company.

Notes: 1) The common use portion mentioned here includes meeting rooms, corridors, halls, toilets, water boiling rooms, storerooms and so on.

2) The common use portion mentioned here includes dining rooms, bars, recreation rooms, corridors, halls, toilets, bathrooms, health centers, custodial rooms and others.

5. Estimation of Development Cost of Mining Town

5-1 Financial Costs of Mining Town Development

In developing the town facilities, the costs to be borne by the mining company are (1) the construction costs of mining town facilities enumerated in Table 5-6 and (2) the construction costs of camp dormitories etc. described at the end of the last section. Regarding the investment period of these financial costs, the existing facilities in Chilecito can be used temporarily during the construction period as the mining town is adjacent to the city and will not be necessary to construct any particular facilities beforehand.

Accordingly, the timing of investment is as follows: (1) the costs of acquisition and development of the site of the mining town are to be invested in the first year of the three-year-construction period, (2) all of the costs of water supply and sewerage facilities and one half of the construction costs of housing and the facility costs of the mining company are to be invested in the second year, (3) the remaining construction costs of the mining town are to be invested in the thrid year. As for the dormitory facilities, etc., we presume that investment will be made: (1) in the first year for land preparation, (2) for half of the construction costs of the facilities in the second year, and (3) for another half in the thrid year.

With regard to housing for the mine workers in the mining town, there remains the problem of whether to sell the houses to the workers after construction or to make them available rent free or at low rent. At the present stage, we will carry forward analysis on the assumption that the mining company will provide the workers with housing almost free. However, as for the houses themselves, we consider the financial salvage value, assuming that 80% of the houses can be sold at the end of the project life at 60% of the housing construction costs in case of an operation rate of 30,000 tons/day and at 40% in case of 20,000 tons/day. Also, we presume the salvage value of the camp dormitory facilities to be zero.

In sum, the financial costs of mining town development will be as shown in Table 5-14. However, maintenance costs for the mining town and the dormitory facilities are included in the general management cost calculated separately.

5-2 Economic Costs of Mining Town Development

For development of town facilities, the costs associated with this project in economic analysis can be divided into following items: (1) construction costs of mining town facilities enumerated in Table 5-8, (2) construction costs of facilities such as dormitories, etc. near the mine as stated at the end of the preceding section, and (3) construction costs for town facilities borne by public organizations and general private sectors as enumerated in Table 5-13. However, what we have investigated in the preceding section is the financial costs and, therefore, we must convert these to economic costs in this section.

To convert these financial costs to economic costs, we will use the following two procedures. Firstly, (1) we will exchange the costs of land acquisition because they are considered as interval transfers between sectors in the case of economic analyses from a national

Table 5-14 Flow of Financial Costs Related to Town Facilities

Cost Item		Operation Rate (tons/day)	Construction Period 1st year	2nd year	3rd year	Salvage Value
Construction Costs of Mining Town	Cost of Land Acquisition	30,000	17	–	–	–
		20,000	12	–	–	–
	Cost of Land Development	30,000	7,924	–	–	–
		20,000	5,763	–	–	–
	Cost of Water Supply Electricity Facilities	30,000	–	2,995	–	–
		20,000	–	2,178	–	–
	Cost of Sewerage	30,000	–	4,113	–	–
		20,000	–	2,906	–	–
	Cost of Housing Construction	30,000	–	48,510	48,510	△46,570
		20,000	–	34,506	34,506	△22,084
	Cost of Construction of Mining Company	30,000	–	180	180	–
		20,000	–	130	130	–
Construction Costs of Dormitory Facility	Facilities Cost of Land Development	30,000	1,441	–	–	–
		20,000	1,153	–	–	–
	Cost of Construction of Facilities	30,000	–	12,312	12,312	–
		20,000	–	9,288	9,288	–
Total		30,000	9,382	68,110	61,002	△46,570
		20,000	6,928	49,008	43,924	△22,084

part of view. (2) Regarding all other construction costs, we will deduct 25% to cover internal transfers such as taxes.

For the investment period of economic costs, firstly it is natural that the items financially borne by the mining company follow the case of financial analysis. However, in regard to the costs borne by public organizations and general private sectors, we will make the same presumption as in the case of financial costs. Namely, investment is to be made during the three-year-construction period as follows: (1) construction costs of transport facilities and land development costs are invested during the first year, (2) the costs of water supply and electricity facilities, the costs of other facilities are invested in the second year, and (3) the remaining costs are invested in the third year.

Regarding the economic salvage value of the mining town, as studied in detail in Section 3, 60% of the economic costs related to construction of the mining town in the case of an operation scale of 30,000 tons/day and similarly 40% in the case of 20,000 tons/day are taken as the physical value. Also, we will consider the social value to be 80% of the physical value. However, for facilities such as dormitories and so on, we consider the remaining value to be zero, as in the financial analysis, since they are not expected to be utilized after the project life ends.

Of these economic costs, the composition of domestic currency and foreign currency is assumed to be 9:1 noting the high utilization of construction machinery. For maintenance and repairing costs of town facilities during the project life, we have decided not to consider these because (1) the maintenance cost are small in comparison with construction costs and (2) repair costs become very small when discounted to the present value as they are incurred at a fairly late stage of the project.

Table 5-15 summarises the economic costs and their flow described above.

Table 5-15 Flow of Economic Costs Related to Town Facilities

(Unit: million pesos)

Cost Item		Operation Rate (tons/day)	Construction Period			Salvage Value
			1st year	2nd year	3rd year	
Construction Costs of Mining Town Borne by Mining Company	Cost of Land Development	30,000	7,528	–	–	△ 3,613
		20,000	5,475	–	–	△ 1,752
	Cost of Water Supply Electricity Facilities	30,000	–	2,845	–	△ 1,366
		20,000	–	2,069	–	△ 662
	Cost of Sewerage	30,000	–	3,908	–	△ 1,876
		20,000	–	2,761	–	△ 883
	Cost of Housing Construction	30,000	–	46,085	46,085	△ 44,241
		20,000	–	32,781	32,781	△ 20,980
	Cost of Construction of Mining Company	30,000	–	171	171	△ 164
		20,000	–	123	123	△ 79
Construction Costs of Dormitory Facilities	Facilities Cost of Land Development	30,000	1,369	–	–	–
		20,000	1,095	–	–	–
	Cost of Construction of Facilities	30,000	–	11,696	11,696	–
		20,000	–	8,824	8,824	–
Construction Costs of Mining Town Borne by Public Organizations and General Public Sectors	Cost of Construction of Transportation Facilities	30,000	5,130	–	–	△ 2,462
		20,000	3,848	–	–	△ 1,231
	Cost of Land Development	30,000	3,695	–	–	△ 1,774
		20,000	2,943	–	–	△ 942
	Cost of Water Supply Electricity Facilities	30,000	–	1,397	–	△ 670
		20,000	–	1,112	–	△ 356
	Cost of Sewerage	30,000	–	1,383	–	△ 664
		20,000	–	1,087	–	△ 348
	Cost of Housing Construction (Service Related Population etc.)	30,000	–	17,207	17,207	△ 16,519
		20,000	–	13,526	13,526	△ 8,657
	Cost of Construction of Public & Commercial Facilities	30,000	–	4,641	4,641	△ 4,455
		20,000	–	4,166	4,166	△ 2,666
	Cost of Arrangement of Park Facilities	30,000	–	836	836	△ 803
		20,000	–	532	532	△ 341
Total	30,000 tons/day	Domestic Currency	15,950	81,152	72,572	△ 70,746
		Foreign Currency	1,772	9,017	8,064	△ 7,861
	20,000 tons/day	Domestic Currency	12,024	60,283	53,956	△ 35,007
		Foreign Currency	1,337	6,698	5,995	△ 3,890
	Total	30,000	17,722	90,169	80,636	△ 78,607
		20,000	13,361	66,981	59,952	△ 38,897

Chapter 6.

TRANSPORTATION PLAN

CHAPTER 6. TRANSPORTATION PLAN

1. Tasks of Transportation Plan

1-1. Major Study Items

Demands for transportation generated by the development of the mine consist of the following items:

a) Transport of copper and molybdenite ore from the dressing plant (mining site) to Buenos Aires,

b) Transport of materials (spare parts, machinery and equipment, chemical reagents, etc.) necessary for mining and dressing from the procurement point (Buenos Aires) to the mining site, and

c) Transport of people and goods between the mining site and the mining town (Los Sarmientos).

As to the transportation of refined ore,

a) Transport costs will be calculated by formulating a transportation plan in which it is assumed that the refined copper and molybdenum are transported from the mining site to Buenos Aires, where international prices of refined ore are set.

With regard to copper ore, the following two alternatives will be formulated:

a) Utilization of a copper smelting plant at Andalgalá, construction of which is planned by the La Alumbrera mine, and

b) Utilization of a copper smelting plant at Barreal, construction of which is planned by the El Pachón mine.

Transportation costs for each alternative will be calculated and used as the input for overall assessment of the transportation plan.

Formulating an optimal transportation plan involves several major decisions. First, it is necessary to determine the optimal route for road construction between the mining site and Chilecito City, assuming that 20 ton semi-trailers are used for transportation. Second, with regard to transport from Chilecito City onward, there remains the major choice of optimal transportation mode, i.e., either extending road transportation or connecting to railway transportation. In this sector, financial and economic costs of both road and railway transportation are calculated. The optimal transportation plan is determined by comparison of the results of these two alternatives in Section 5. Note) Costs for the use of a shipping port, assuming export of the refined copper or electrically cathode copper are also estimated in the transportation plan.

1-2. Background and Tasks of Road Transportation

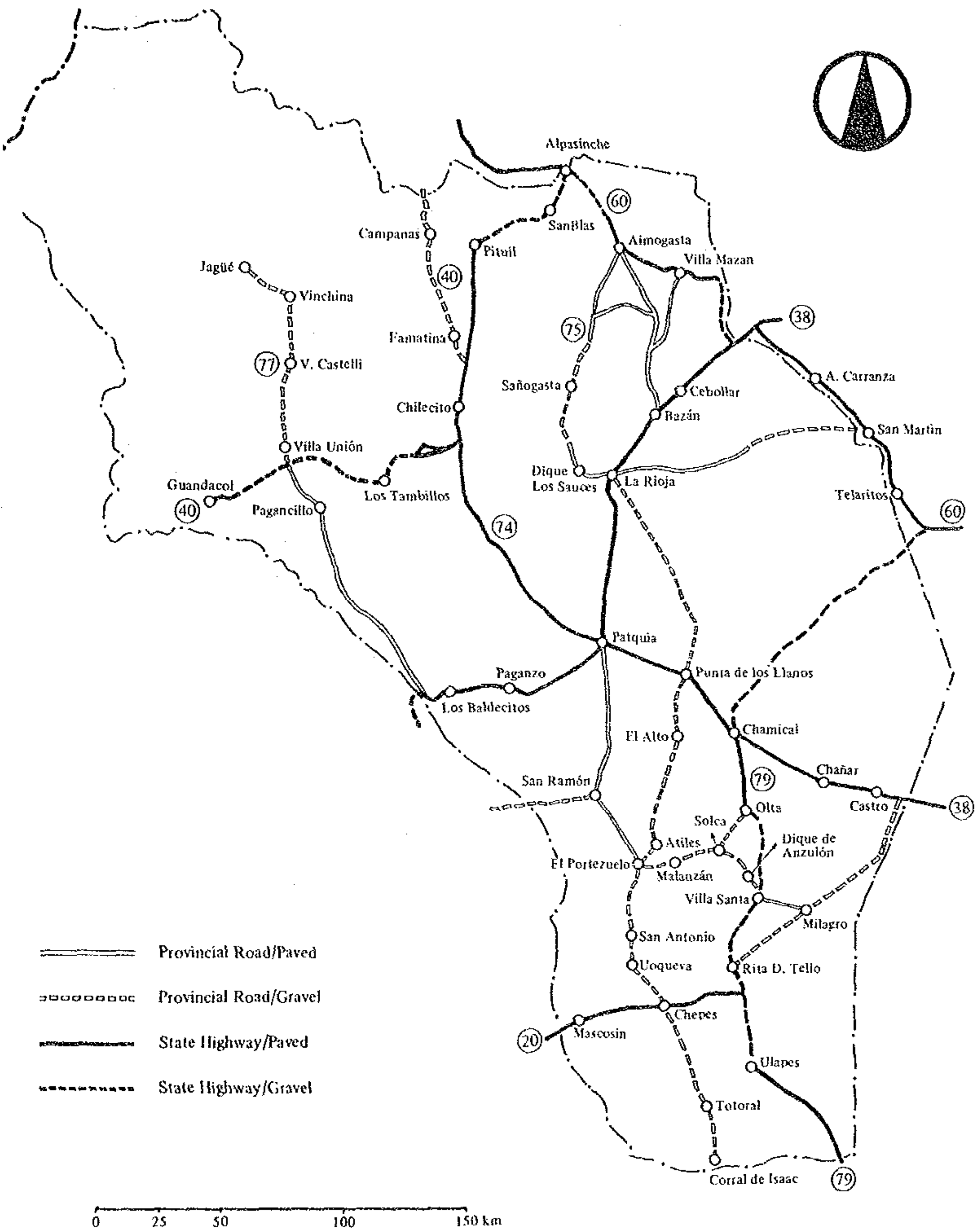
The total length of national highways of Argentina was approximately 47,500 km in 1977. About 50%of the total length was paved. On the other hand, about 68,800 km of provincial roads are used as major arterial routes. Some 22%of the provincial roads are paved. In addition, there exist 94,000 km of minor trunk roads, but the pavement ratio of these is less than 2%. Provincial roads include gravel and dirt roads and the total length is estimated to be 955,300 km.

The responsibility for road administration is held by the Directorate of National Highways (Dirección Nacional de Vialidad), which is in charge of planning, construction and maintenance of National Highway. Although it is under the supervision of the Ministry of Public Works (Ministerio Transporte y Obras Publicas), it functions independently. The headquarters of the Directorate of National Highways, which is located in Buenos Aires, coordinates highway budgets and development plans and undertakes economic as well as technical research, while branch offices at more than 24 locations in the country are responsible for construction supervision and maintenance of roads under the supervision of the headquarters. With regard to Provincial Roads, Directorates of Provincial Roads (Dirección Provincial de Vialidad) are basically in charge of planning, construction and maintenance.

Figure 6-1 shows the present network of national highways and provincial roads in La Rioja Province. It is clearly indicated in this figure that a transportation route from the mining site would connect with the existing road network at Famatina Village (Los Corrales) or Chilecito City (6 km north-west of Guanchin). However, at present there is only a temporary road from the mining site to these points which was constructed up to Los Corrales for prospecting. Therefore, the first task in formulating a road transportation plan is to determine a road construction route between these points, and consequently, the selected optimal route of road construction will be dealt with as "Road Construction Plan between the Mining Site and Los Corrales" in the following Section 3. The road between the mining site and Los Corrales will be used exclusively for the project and construction as well as maintenance costs will be borne by the mining company.

Note: Financial costs are costs which the mining company spends directly, in this case transportation expenses, and they are used as input itemes for financial analysis of the project as well as for formulation of the optimal transportation plan. On the other hand, economic costs are the costs which are substantially spend for transporting goods and services by constituents of a country regardless of the sector. Internal transfers between sectors such as net profits, making-up of deficits, taxes, etc., are not taken into account in cost calculations. Computed economic costs will be used as inputs for economic analysis of the project as well as for formulation of the optimal transportation plan.

Fig. 6-1. Existing Road Network in La Rioja Province



Although there is a cable-way between the mining site and Chilecito which was constructed for the Mejicana mine in 1913, utilization of this cable-way is not considered feasible since (a) the life of the equipment is over and (b) the structure and function are old-fashioned and so it cannot bear the generated transportation volume of this project. It may be theoretically possible to make use of alternative transportation means other than the road, e.g., pipelines and a new cable-way. The survey team has come to the conclusion that road transportation is the most efficient means between the mining site and Chilecito for the following reasons:

a) It is necessary not only to bring out refined ore, but also to bring in materials, and equipment, including large scale machinery which roughly equivalent in weight to the refined ore; and
b) Road transportation is considered most efficient from the experience with modern technologies used in mine developments.

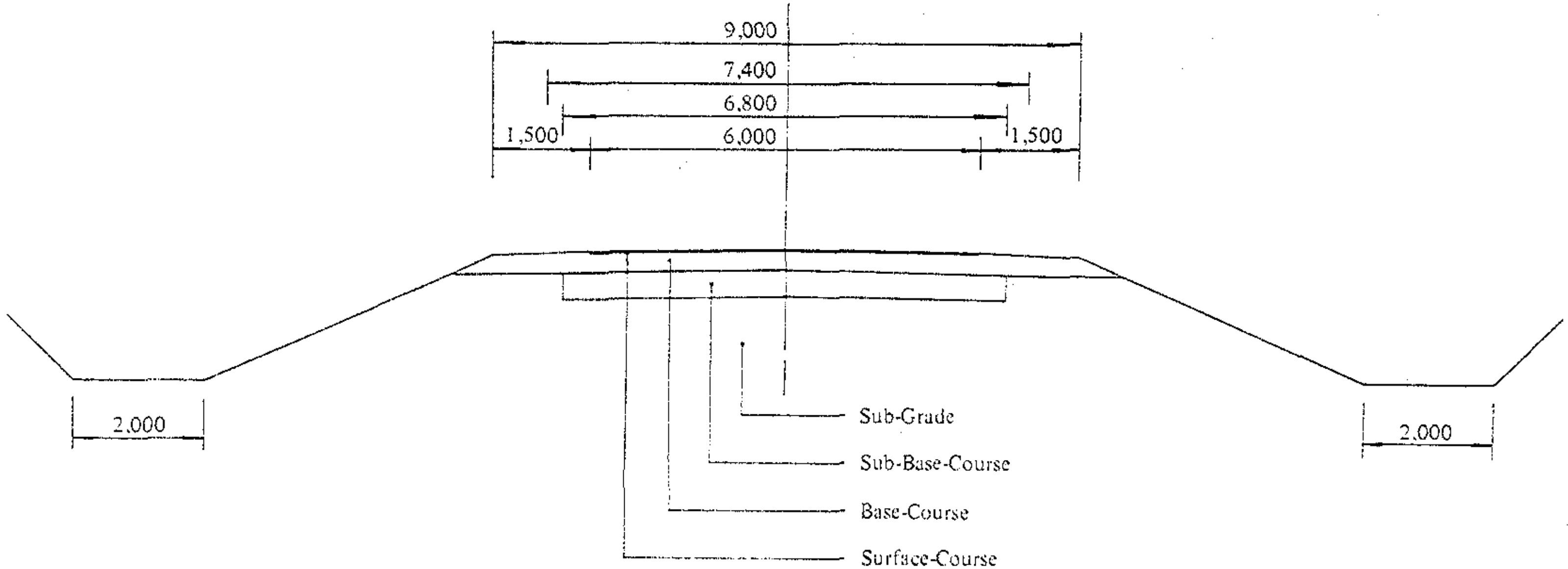
The present road network of the Province can be used from out of Los Corrales, as mentioned previously. As for the question of whether it is necessary to improve or repair sections of the present road network, the following considerations are made:

(1) Figure 6-2 indicates a typical Cross-section of the national highway. It is felt that improvement of the road section for an additional traffic volume of 20 semi-trailers per day of 20 ton capacity generated by the project is not necessary if routine maintenance work is carried out. However, there are several sections between Chilecito and Patquia an Route 74 of the national highway where (a) major repair work is necessary at presnet due to cracks in the road surface, (b) dip crossings of dry-river beds pose a major obstruction to traffic, and (c) the grade of pavement is rather poor. The Directrate of National Highways has plans for improvement work (for certain sections the present road will be demolished and new parallel roads will be constructed), however, this improvement plan is being implemented without taking account the progress of this project and benefits which this project might receive from the road improvement plan are minor considering the present average daily traffic of 412 vehicles over this section. Therefore, road improvement costs for these sections will be excluded from financial as well as economic analysis of this project.

(2) Construction of a bypass road to detour traffic around the center of Chilecito City will be required since the trailers used in this project will otherwise pass through the urban center of Chilecito from Famatina on Route 40 to Route 74. However, the city of Chilecito and the Ministry of Social Welfare (Ministería de Bienestar Social de la Nación) have formulated a construction plan for this bypass road. Therefore, construction costs for the bypass road will be excluded from the project cost estimation for the same reasons stated in the previous paragraph.

(3) The 15 km section from Famatina to the crossroads with Route 40 is currently a paved provincial road, and its design standards are similar to those of the national highway indicated in Figure 6-2. Consequently, there will be no problem in dealing

Fig. 6-2. Typical Cross-Section of Existing National Highway



with estimated traffic over this section. As to road maintenance costs for this section, there is no doubt that the Provincial Government should bear the costs from the financial point of view. However, since a considerable portion of the traffic over this section will be generated by the project, it might be necessary to assess some maintenance costs to the project from the point of view of economic analysis. However, since this section of the road has already been constructed, and since the present average daily traffic of 215 vehicles exceeds the estimated traffic volume generated by the project, maintenance costs are excluded from economic analysis of this project.

(4) Presently, a section of 128 km of national highway between Chilecito and Andalgalá and a section of 106 km of national highway between Andelgalá and Córdoba are gravel surfaced roads. The roadway of these sections is maintained in good condition. It would be interesting to determine whether the traffic volume generated by this project will be large enough to justify investment for pavement works on these sections. However, the daily traffic volume which is generated by this project and which uses the route via. Andalgalá is estimated to be less than 10 vehicles per day, while the average daily traffic which justifies paving of these road sections is estimated to be at least 500 vehicles per day (refer to Appendix (1) of this Chapter). For this reason, the project will not become a major factor in paving works of these road sections. Therefore, it is felt that it is not necessary to add a portion of any pavement costs to the costs for economic analysis of the project even when implementation of paving work is undertaken.

(5) Presently, the 17 km section of provincial road between Los Corrales and Famatina is gravel surfaced road. Although 30%of this section has a good road condition with two-lane width, the remaining 70%of this section needs improvement works inclusive of lane widening. Since this road belongs to the Province, improvement and maintenance costs for this section should be borne by the Province from the point of view of fianancial analysis. However, because most of the traffic over the section is related to the mine project, as stated above, 80% of improvement and maintenance costs are included in the economic analysis of the project.

1-3. Background and Tasks of Railway Transportation

Since the railway system in Argentina was constructed long before the era of road transportation development, various rationalization plans should be undertaken before new investment for monderization is made. That is, the National Railway has formulated a plan in which Phase I has three basic policies [(a) large investment, (b) small investment, and (c) no investment], since it is faced with a significant deficit.

In freight transportation, the following six goods have high priorities: grains, sugar, cement, petroleum, wire and iron ore. For passenger transport, however, the National Railway plans to abolish all railway lines except for the major inter-city lines such as Buenos Aires to Cordoba, Mendoza, Bariroche, etc., and commuter railway lines. With these basic policies in mind, the National Railway plans to reduce its operating length from 42,000 km in 1976 to 28,000 km in 1981 as one of its rationalization policies. Up to the present, the National Railway has abolished 6,000 km of lines and 450 stations, closed down three railway maintenance factories, and reduced the number of staff by about 50,000 from 158,000 to 105,000.

Under the circumstances, a section of the G. Belgrano Line Note) between Chilecito and Serrezuela which is being considered as a transportation route for copper ore produced by the project, has been given one year grace of abolishment, and trains are currently operating according to transport demands. Also, since a section of the G. Belgrano Line between Chumbicha and Recreo has already been abolished, it is necessary to go back on the same line to Patquia in order to transport copper ore from the Andalgalá dressing plant (an assumed name) to Buenos Aires. With regard to the section between Chilecito and Serrezuela, it is assumed that the present rolling stock can be used for the next three or four years since it will not be removed after the abolishment.

1-4. Background and Tasks of Export Port Utilization

In formulating a transportation plan, the question arises as to which port can be used in order to make a comparison of prices with international prices of molybdenum, refined copper ore and electro-copper. There are three ports which offer some possibility; (a) the Port of Buenos Aires, (b) the Port of Rosario, and (c) the Port of Somisa, which is owned by the national iron foundry, Sociedad Mixta Siderurgia Argentina and is located in San Nicolás facing the Parana River.

Note: Outline of G. Belgrano Line

Guage: 1,000 mm
Length of line: 10,688 km
Condition of line: 94% good for better
Power: 91.3% of gross annual mileage 23,055,000 km is operated by diesel locomotives
Volume of transported passengers: 1,251,500,000 person.km/1978
Volume of transported freight: 3,379,200,000 ton.km/1978
Operating costs: 136,200 million pesos
Operating revenues: 61,000 million pesos

Outline of San Martín Line

Gauge: 1,676 mm
Length of line: 4,523 km
Condition of line: 95% good or better
Power: Diesel locomotives are used for 100% of gross annual mileage 10,256,000 km
Volume of transported passengers: 1,623,400,000 person.km/1978
Volume of transported freight: 3,285,400,000 ton.km/1978
Operating costs: 66,200 million pesos
Operating revenues: 61,000 million pesos