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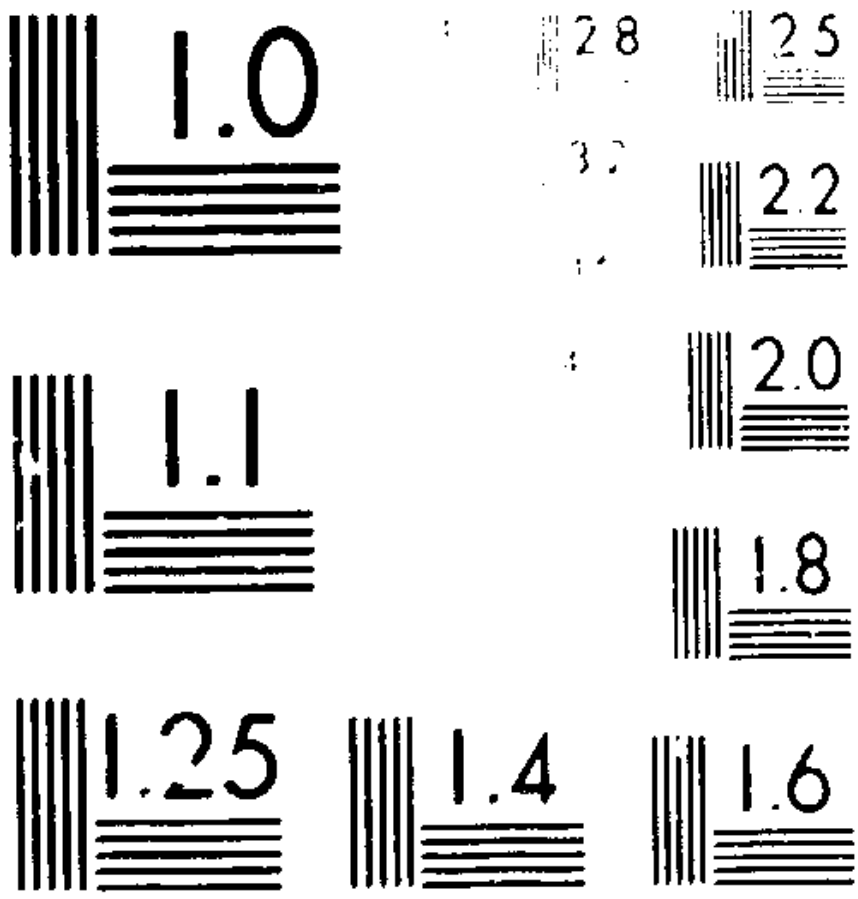
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Distr.
LIMITED

ID/WG.329/17
23 June 1981

ENGLISH

United Nations Industrial Development Organization

Second Seminar-Workshop/Study Tour in the Development and Application of Technology for Mini-Hydro Power Generation (MHG)

Hangzhou, China, 17 October - 2 November 1980

Manila, Philippines, 3 - 8 November 1980

SMALL-HYDRO POWER GENERATION IN PERU*

by

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V.81-27031

A. PRESENT STATUS, POTENTIAL PROSPECTS AND PLANS OF SMALL SCALE HYDROPOWER PLANTS.

Electricity supply for inhabited and economic centres located in remote rural areas with very low energy demand, such as most of the small towns, small mining districts, etc., in the Andes of Perú, represents a technical and socio-economic problem of a non-conventional solution, because the alternative of connecting them to the large transmission lines is too expensive. The possibility of using generating sets drived by internal combustion engines is not always advisable due to the necessity of relying on qualified personnel for the service, repairing and maintenance of the plants and due to the high costs of the fuel and its transportation to the station sites.

The peruvian Andes are very rich in hydraulic resources of small power which has still not been completely exploited. Considering that the economic and social integration of a great part of the peruvian population can not been postponed, it is necessary to support the use and development of small hydropower plants. It is also advisable, if possible, to standardize the plants equipment and components for the ease adaptation to the many possibilities of head and water flow rates combinations without suffering basic modifications of its components.

The use of small hydropower plants will also accelerate the social and economic development of the remote regions if the manufacturing of the most parts and components of the stations in regional workshops is encouraged. Appropiate design of the components will permit the standarlized production with the result of a lower plant costs.

Figure 1, shows the distribution of the population of the small towns of Peru according to the National Census of Population of 1972. It can be made known that only 536 towns of the total have electric energy and that 410 of them are supplied by small power plants. From the 410 towns, 146 of them are supplied by small hydropower plants and 264 by thermal power plants. In general terms, it can be said that about 50 % of the total number of towns with a population between and 10000 inhabitants do not have electrical energy, but on the other side they have many possibilities of hydropower. Figure 2, shows the geographycal situation of small towns in Perú.

To face up this situation, the goverment has recently announced the National Plan of Small Hydoelectric Plants, which has been outlined by the Ministry of Energy and Mining. The plan covers majors goals related to the energy supplying for remote centres using the great amount of small power sites of the peruvian Andes, the gradually replacing of the small thermoelectric plants by hydropower and the development of a local technology apt to design, manufacture, install, operate and maintain the equipment of the plants.

The plan anticipates the implementation of 50 projects of small plants for the period 1980-1985 with an investment of US $ 12.5 millions.

Figure 3, shows briefly the distribution and technical data of 39 of the 50 projected stations. It can be noted, that 30 stations cover the lower range between 50 kW and 300 kW, 6 stations the range between 300 kW and 600 kW and only 3 the upper range between 800 kW and 1000 kW. The mini hydropower plants between 50 kW and 500 kW are therefore predominant.

Figure 4, gives information of the installed capacity of the electric power plants in 1975.

b. ORGANIZATIONAL SET UP INCLUDING DIVISION OF RESPONSIBILITIES AND TASKS FOR PLANNING, CONSTRUCTION, MANAGEMENT AND OPERATION OF SMALL HYDROPOWER PLANTS.

The activity of the electric energy in Perú depends of the Ministry of Energy and Mining, which by means of the General Board of Electricity, performs the functions of dictating norms and to manage, coordinate, promote and control the electricity activity.

The necessity of developing the small hydropower generation has become apparent. In november 1978, the Ministry declared of first priority the Programme of Small Hydroelectric Plants to be managed by a special Council. Later on, in december 1978, the Council recommende to the electricity state company ELECTRO PERU the creation of a special fund for financing the programme. The fund was approved and ELECTRO PERU will allocate the 15 % of its yearly income for financing the plan.

In december 1978, ELECTRO PERU has also created the Office of the Programma for Applied Technology (OPTA) which has the responsibility of supervising and coordinating the Programme of Small Hydroelectric Plants. For the implementation of the plan, ELECTRO PERU has also created 5 Regional Units of Exploitation. Figure 5, shows the division of responsibilities described before.

In a similar way, the Ministry of Industry and Tourism, by means of the Institute of Industrial Technology Investigation and of Technical Normalization (ITINTEC) is carrying out, from october 1978, an investigation programme on mini-hydropower plants in the range between 5 kW and 50 kW. The programme has as main goals to propose a method for the design, manufacturing, etc. of the plants as well as writing a practical handbook for designers and users.

It is also known that similar efforts in this field are being carrying out by private companies like ELECTRO LIMA and HIDRANDINA and by universities like the National University of Engineering of Lima (UNI).

C. TECHNICAL, ECONOMIC AND ENGINEERING DATA OF RECENT SMALL HYDROPOWER PLANTS CONSTRUCTION INCLUDING INFORMATION ON WHO BUILT, WHO OWNS, WHO MANAGES, WHO FINANCES, ETC.

The information requested in this item will provide data about some small hydropower plants and about a new group recently put into service.

- Plant of Milloc (Lima): 1967, 12 kW, head of 40 m, flow rate of 40 lt/seg, 1170 rpm, altitud 4350 m, Michell-Banki turbine, ELECTROLIMA Co.
- Plant of Marcapomacocha (Lima): 1967, 120 kW, head of 12 m, flow rate of 250 lt/seg, 1200 rpm, Michell-Banki turbine, ELECTROLIMA Co.
- Plant of Churin (Lima): 46 kW, head of 28 m, 1200 rpm, altitud 2000 m, Francis turbine, ELECTRO PERU Co.
- Pilot Plant of Obrajillo (Lima-Canta): 1978-1980, 16 kW, head of 56.5 m, flow rate of 48 lt/seg, 1800 rpm, Michell-Banki turbine, PVC-penstok, ITINTEC.

The following small hydropower plants has been put into service in 1979 by ELECTRO PERU Co.:

Plant of Acos (Lima) of 150 kW.
Plant of Tacabamba (Cajamarca) of 105 kW.
Plant of Vischingo (Ayacucho) of 100 kW.
Plant of Carhuanca (Ayacucho) of 24 kW.
Plant of Huambalpa (Ayacucho) of 35 kW.

Figure 6, shows the geographical situation of existing small hydropower plants in Perú.

D. SALIENT TECHNO-ECONOMIC FEATURES IN SMALL HYDROPOWER PLANTS SYSTEMS APPLIED IN THE COUNTRY.

Perú has a surface of 1'285,000 Km^2 and is geographycally divided into 3 natural regions (Figure 2), namely:

- the coastal region with a surface of 136000 Km^2 (11 %) which extends between the 0 m and 2000 m of altitud and has a variable wide between 50 Km and 100 Km.
- the mountains region (Andes region) with a surface of 385000 Km^2 (30 %) and extends from 2000 m altitud over the high Andes mountains towards the jungle.
- the jungle region with a surface of 764000 Km^2 (59 %).

From the hydrographic point of view Perú can be divided into 3 great basins, namely: the Pacific basin, the Amazon basin and the Titicaca Lake basin.

From the point of view of electric planning Perú can be divided in 4 zones, namely: the northern, central, southern and the eastern.

The Ministry of Energy and Mining with the cooperation of the West Germany government has recently finished the evaluation of the theoretical available hydroelectric potential of the country. This reaches the figure of 206108 MW, distributed in 29257 MW (14.2 %) for the Pacific basin, 176287 MW (85.5 %) for the Amazon basin and 564 MW (0.3 %) for the Titicaca Lake basin. Furthermore, the hydroelectric potential that can be technically developed is about 58346 MW with a production capacity of about 390775 million of kWh/year. This potential corresponds only to the developments greater than 30 MW. At present, scarcely between 3 % and 4 % of this potential has been exploited.

However, the previous estimation has not included the small scale hydropower developments which are mostly located in the sub-basins which have great heads (up to 300 m) and small flow rates (up to 500 l/seg). Between

those limits it is expected to have about 1000 sub-basins apt to be transformed in about 1 million kW by employing small-scale hydropower plants. Most of the plants would operate with Pelton, Francis and Michell-Banki turbines.

The small hydropower plants in Perú may be classified according to the following ranges:

- Small hydropower plants: up to 500 kW
  - Mini-micro H.P. : up to 5 kW.
  - Micro H.P. : 5.5 kW to 50 kW.
  - Mini H.P. : 51 kW to 500 kW.
- Medium hydropower plants: 501 kW to 5000 (10000) kW.

With respect to the economic aspect, the cost of small scale and medium scale hydropower stations is relatively high. Withe reference to 1979, the costs are of the order of 2500 US $/kW for the micro hydropower plants and range from 2.00 US $/kW for the mini H.P. to about 1800 US $ for the medium H.P.

E. CAPACITIES AND CAPABILITIES FOR LOCAL MANUFACTURING OF EQUIPMENT IN THE FIELD OF SMALL HYDROPOWER GENERATION.

According to the degree of the technologic development of Perú, it can be stated that the country is capable to implement a plan for the manufacturing of small water turbines and related equipment. There are many private and some state factories and workshops with the experience for that purpose.

With respect to the penstock, local manufacturers produce piping of diameters up to 100 mm; greater sizes can be specially made by rolling and welding. ITINTEC is also investigating lower cost piping alternatives by using materials other than steel like asbesto-cement,

polyethylene, polyvinil-chloride (PVC), fiber glass, etc. These pipings are offered in the market in diameters up to 500 mm and can tolerate pressures between 10 kgf/cm^2 and 15 kgf/cm^2. They are less expensive than steel, easier to transport and to install because of its easy adaptation to the ground profile, etc.

With reference to the manufacturing of water turbines, there are some workshops and factories with experience of more than 20 years in the construction af small Pelton turbines and in maintenance and repairing of large Pelton and Francis turbines, like HIDRANDINA Co. The Michell-Banki turbine is also an interesting alternative because of its lower cost and relatively easy manufacture. This turbine is, at present, being investigated mainly by ITINTEC (Refs. 4-6) and also by the National University of Engineering (UNI) of Lima (Refs. 1-2-3) and HIDRANDINA Co. With respect to the Francis, this can be made by using the experience of the centrifugal pump manufacturers.

With respect to the manufacturing of electric generators, these are offered in units ranging between 3 KVA and 200 KVA but only for use in thermoelectric plants. ITINTEC is also supporting an investigation programme for the adaptation of generators with 2 and 4 poles, for use in small hydropower plants by reinforcing the generator coils in such a manner that may stand runaway speeds of the order of twice the nominal speed of the turbine.

In a similar way exists great experience in the construction of dams, canals, buildings, etc. and the same with respect to the construction of transmission lines. Transmission towers of steel can be replaced by towers of wood by using the eucalyptus which grow abundantly in the peruvian Andes.

Figure 7, shows schematically a small hydropower plant.

F. EXISTING PROGRAMMES FOR DEVELOPMENT AND TRAINING IN FIELD OF SMALL HYDROPOWER.

The implementation of a massive programme of small hydropower development demands the participation of qualified personnel for the design, manufacturing, operation, managing and maintenance of power plants.

It is therefore necessary the planning of short. medium and long term courses in the universities, technical schools, etc., to train the engineers, technicians and skilled workers with hydropower knowledge.

Peruvian universities, by means of its Faculties of Mechanical, Electric, Civil Engineering should play an important role in this field by including in the curricula the necessary courses related to hydropower plants. In this respect U.N.I. has played and is playing this role by means of its Academic Departments of Energy and Mechanics, Electricity and Electronics, Hydraulic, etc. through investigation thesis, laboratory work, seminars, plant visits and academic courses. Most of the engineers who are at present engaged in the development of the hydropower generation are graduates from UNI.

With respect to the training of technicians, it is very important to emphasize the recently establishment of the Technical School of Hydraulic Technology (ETEHI) of HIDRANDINA Co. The school has the specific purpose of providing courses for the training of qualified personnel for the operation and maintenance of small and large hydropower plants.

REFERENCES

1. Coz P., A.F., "Diseño de una turbina Michell-Banki". Thesis, Fac. of Mech. and Elec. Eng., UNI, Lima, 1961.

2. Coz P., A.F., "Turbinas hidráulicas de flujo transversal". Paper, IV CONIMERA (IV National Conference on Mechanical and Electrical Engineering), Lima, july 4-9, 1977.

3. Hernandez B., C., "Diseño, construcción y ensayo de turbinas hidráulicas de flujo transversal para microcentrales hidroeléctricas". Thesis, Fac. of Mech. and Elec. Eng., UNI, Lima, 1979.

4. Hernandez B., C., "Desarrollo tecnológico para el equipamiento de pequeñas centrales hidroeléctricas". Report, ITINTEC, Lima, april 1980.

5. Indacochea, E., "La electrificación rural y el proyecto de microcentrales hidroeléctricas", Report, ITINTEC, Lima, 1978.

6. Indacochea, E., "Problemática del desarrollo de la tecnología de microcentrales hidroeléctricas y su constribución a la electrificación rural". Report, ITINTEC, Lima, june 1979.

7. Ministerio de Energía y Minas, "Anuario de estadística eléctrica 1975". Report, Lima, 1975.

8. Bustamante, H., "Pequeñas centrales hidroeléctricas". Paper, I National Simposium on Energy, Vol. II, Lima, july 25-28, 1979.

9. Ministerio de Energía y Minas, "Plan nacional de pequeñas centrales hidroeléctricas". Report, Lima, july 1980.

Size	No. of towns	Population
0 - 499 inhab.	607	200750 inhab.
500 - 999	348	261000
1000 - 1999	311	466500
2000 - 3999	175	519000
4000 - 5999	63	315000
6000 - 7999	30	210000
8000 - 10000	17	153000
Total	1545	2'125250 inhab.

Figure 1 Data of the population of small towns (Ref. 9)

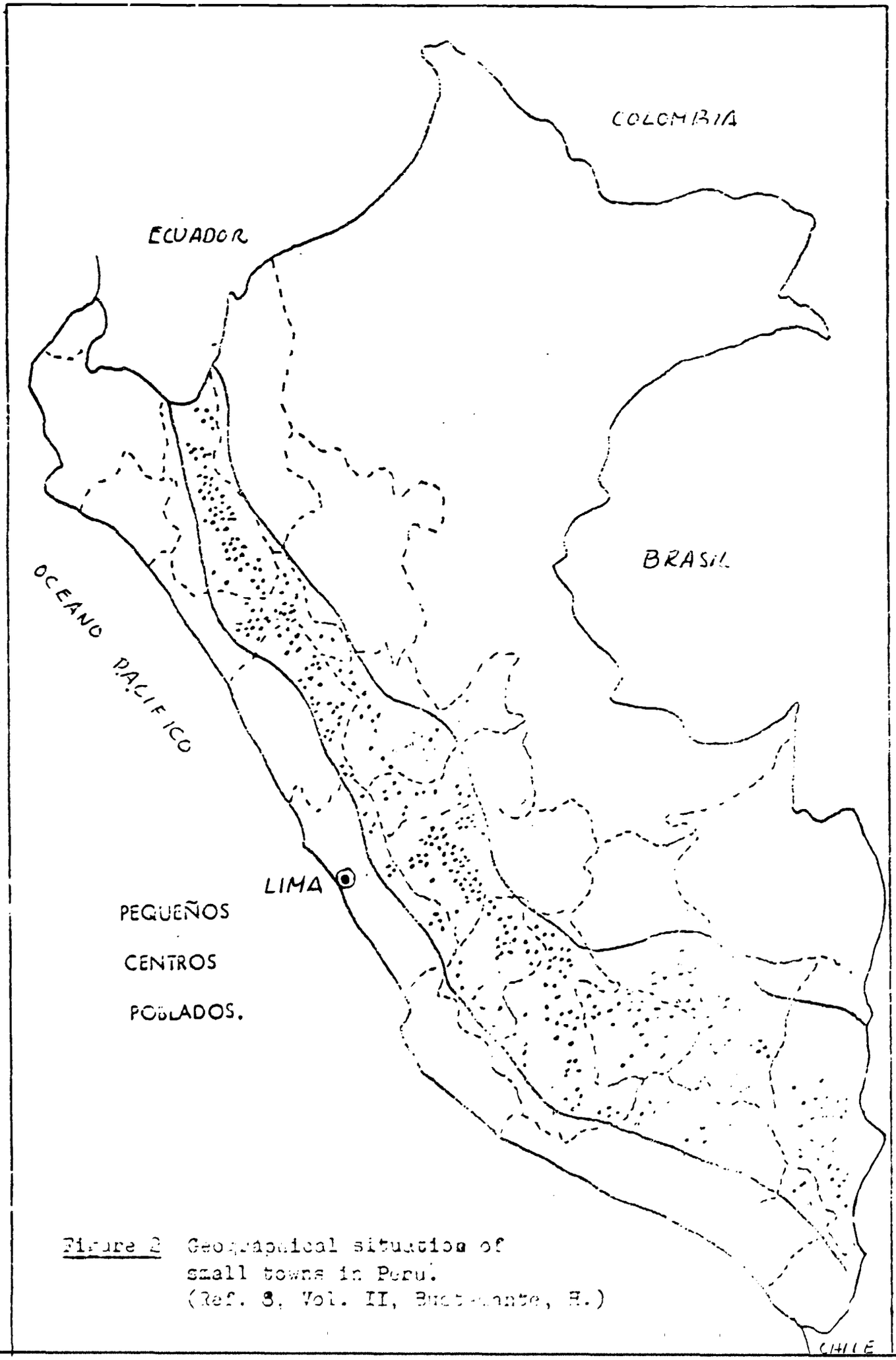

Figure 2 Geographical situation of small towns in Peru. (Ref. 8, Vol. II, Bustamante, R.)

Hydraulic Plants	Place	Installed Capaci (KW)
1. Encañada	Cajamarca	150
2. Namora	Cajamarca	99
3. San Miguel	Cajamarca	120
4. Lonya Grande	Amazonas	730
5. Semanga	Amazonas	104
6. Pulac	La Libertad	50
7. Huari	Ancash	1,350
8. Paucas	Ancash	45
9. Cuncos	Ancash	50
10. Pallasca.	Ancash	30
11. San Marcos	Ancash	109
12. Santa Leonor	Lima	110
13. Canta	Lima	264
14. Horcas	Lima	150
15. Rovira - Pacaraos	Lima	60
16. Sayán	Lima	1,000
17. Pozuzo	Pasco	500
18. Tantamayo	Huánuco	120
19. Quilcata	Ayacucho	70
20. Incaya	Ayacucho	173
21. Aucaré Cabana	Ayacucho	140
22. Huancasancos	Ayacucho	72
23. Pichanaqui	Junín	600
24. Surcubamba	Huancavelica	65
25. Huanca	Arequipa	85
26. Camaná	Arequipa	630
27. Cotahuasi	Arequipa	200
28. Chivay	Arequipa	185
29. Caraveli	Arequipa	750
30. Chuquibambilla	Apurímac	310
31. Villa Chiara	Apurímac	100
32. Ocobamba	Apurímac	50
33. Pomacocha	Apurímac	200
34. Quincamil	Cuzco	73
35. Tintamarca	Cuzco	350
36. Ocongate	Cuzco	125
37. Ocuto	Cuzco	50
38. Roque	San Martín	50
39. Tres Unidos	San Martín	200
TOTAL		9.561 KW

Data of 39 projected small hydro-power plants (Ref.9)

INSTALLED CAPACITY BY RANGES AND TYPE OF SERVICE AND GENERATION, 1975

Type of Service and Range	Hydraulic Plants		Thermo Plants								Total		Grand Total	
			Steam		Gas		Diesel							
	Number	KW	Núm.	KW	Núm.	KW	Núm.	KW	Núm.	KW	Núm.	KW	Núm.	KW
A. Public Service	180	1 156 373	2	14 497	4	143 940	280	153 063	286	311 500	466	1 468 [illegible]
from 100KW	125	4 170					180	7 292	180	7 292	305	11 [illegible]
de 101 a 500KW	29	6 541					59	12 565	59	12 565	88	19 [illegible]
de 501 a 1 000KW	6	4 080					15	11 298	15	11 298	21	15 [illegible]
de 1001 a 5 000KW	6	12 362	1	2 500	1	1 500	20	51 458	22	55 458	28	67 820
de 5001 a 10 000KW	2	12 610					2	11 273	2	11 273	4	23 883
Mayores de 10 000KW	12	1 116 610	1	11 997	3	142 440	4	59 177	8	213 614	20	1 330 224
B. Selfproducers	74	240 934	26	327 935	2	58 931	450	263 180	478	650 046	552	890 980
from 100KW	22	617	1	37			166	6 [illegible]	167	6 [illegible]	232	7 [illegible]
de 101 a 500KW	14	3 934	3	903			125	33 907	128	34 810	142	38 [illegible]
de 501 a 1 000KW	18	12 967	6	5 436	1	880	60	44 [illegible]	67	51 [illegible]	85	64 [illegible]
de 1001 a 5 000KW	13	22 176	5	17 592			76	159 332	81	176 [illegible]	94	199 [illegible]
de 5001 a 10 000KW	4	26 640	4	30 318			3	18 168	7	48 [illegible]	11	75 [illegible]
Mayores de 10 000KW	3	174 400	7	273 654	1	58 051			8	331 705	11	506 [illegible]
C. Total :	254	1 397 307	28	342 432	6	202 871	730	416 243	764	961 546	1 018	2 [illegible]
from 10KW	147	4 907	1	37			346	14 154	367	14 191	514	19 [illegible]
de 101 a 500KW	43	10 475	3	903			184	46 472	187	47 [illegible]	230	57 [illegible]
de 501 a 1 000KW	24	17 047	6	5 436	1	880	75	56 209	82	62 [illegible]	106	79 [illegible]
de 1001 a 5 000KW	19	34 538	6	20 092	1	1 500	96	210 790	103	232 382	122	266 920
de 5001 a 10 000KW	6	39 250	4	30 318			5	29 441	9	59 759	15	99 [illegible]
More than 10 000KW	15	1 291 010	8	285 651	4	200 491	4	59 177	16	545 319	31	1 836 329

Figure 4 Installed capacity of electric power plants in 1975. (Ref. 7)

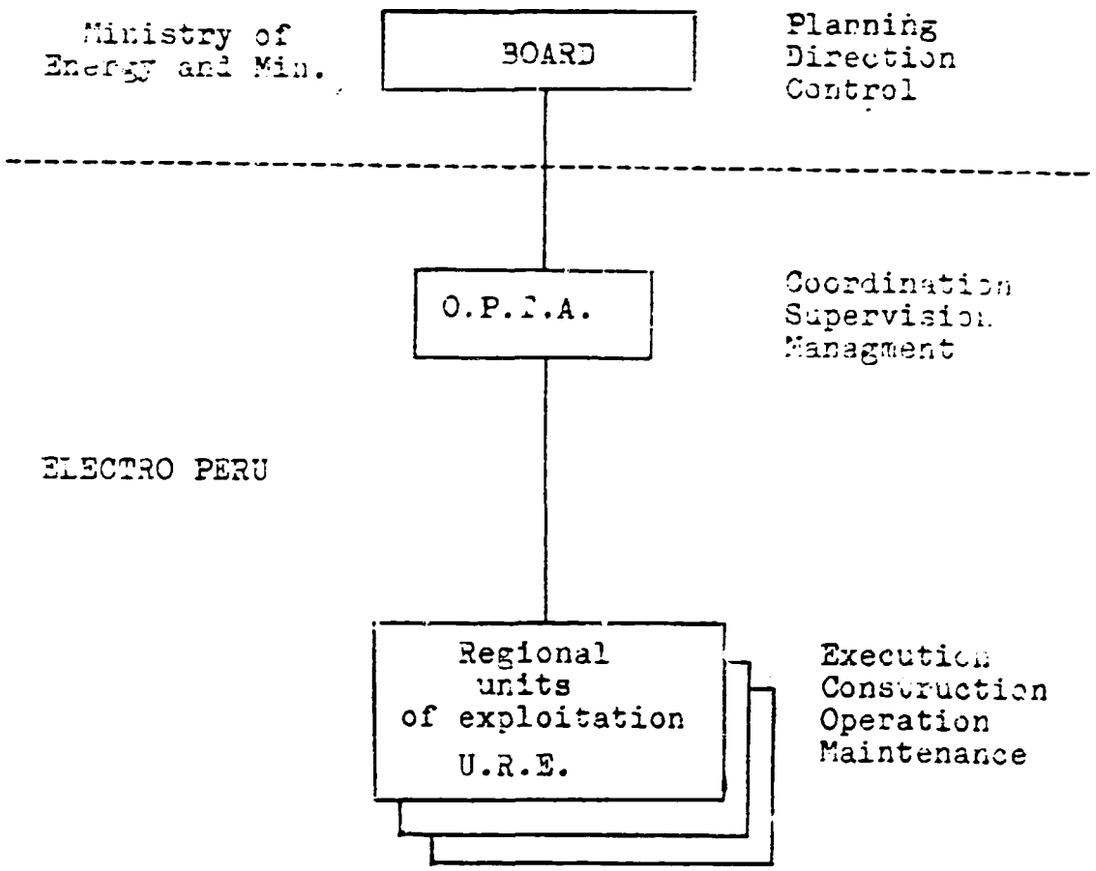

Figure 5 Organization of the Programme of Small Hydroelectric Plants .
(Ref. 8, Vol. II, Bustamante,H.)

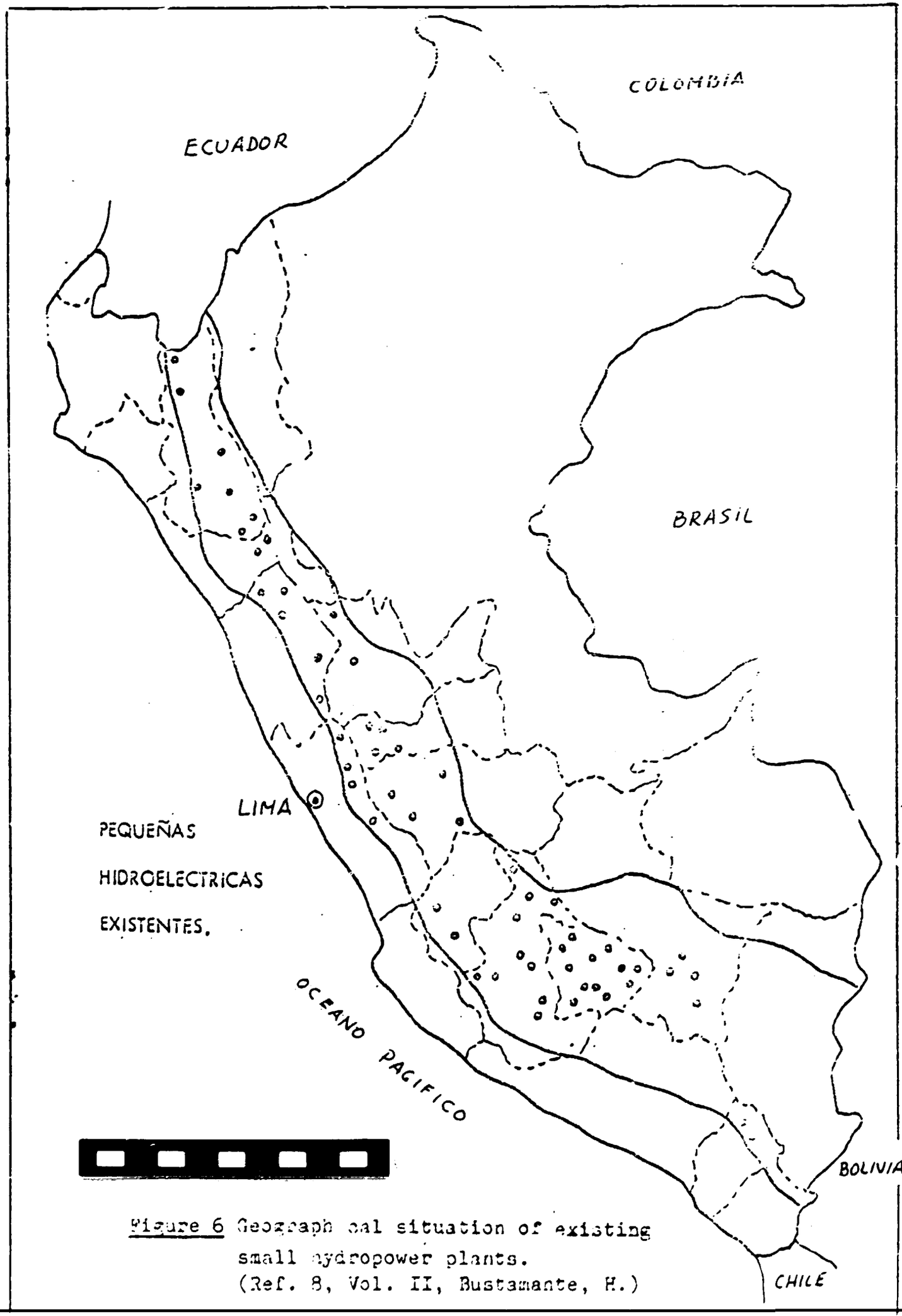

Figure 6 Geograph cal situation of existing small hydropower plants.
(Ref. 8, Vol. II, Bustamante, H.)

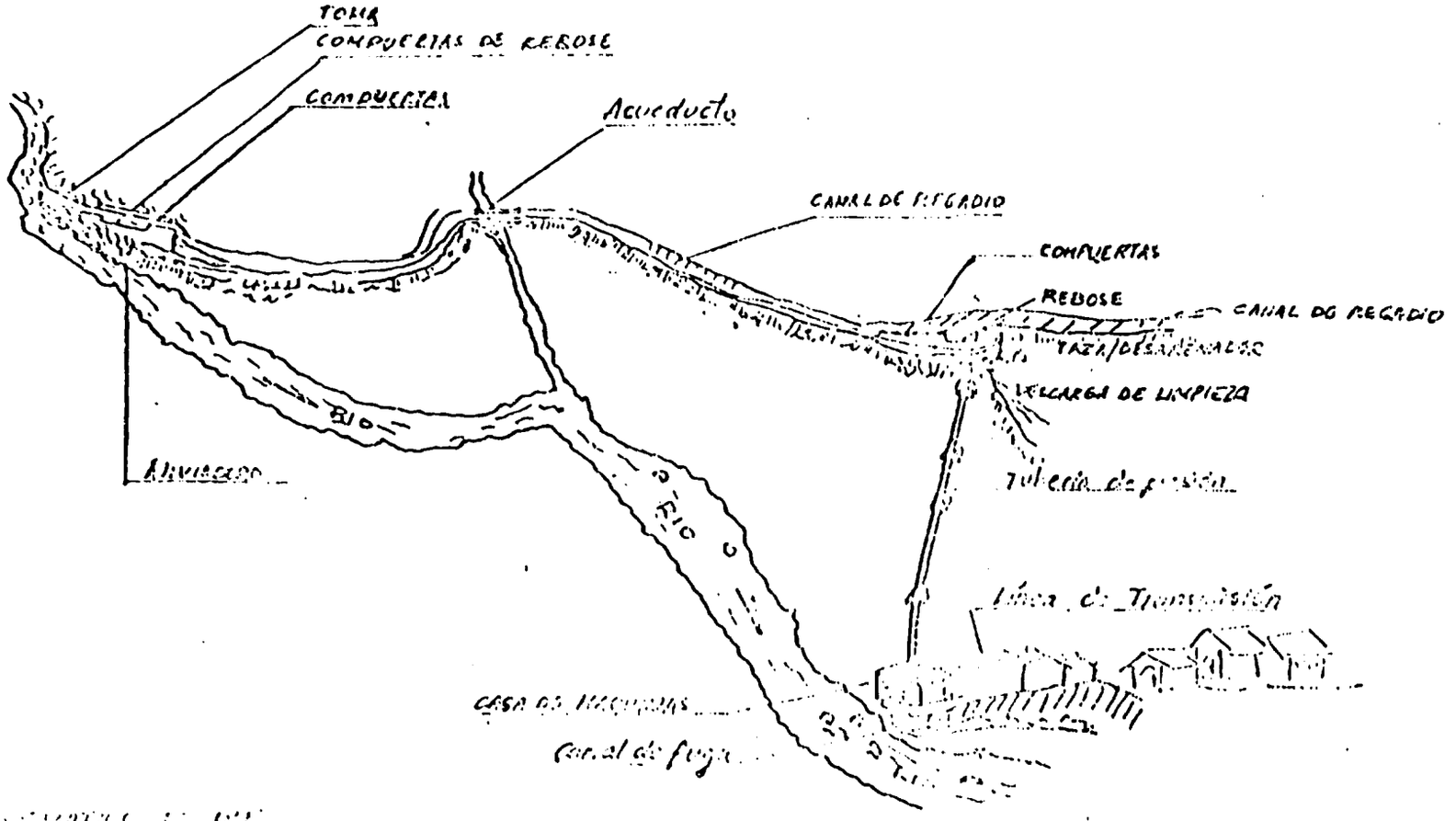

Figure 7 Mini hydropower plant (Ref. 5).