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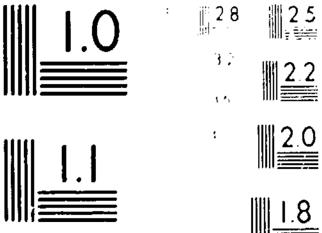
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MINI-HYDRO APPLICATION IN THE PHILIPPINES*

by

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PART I: THE PHILIPPINE SETTING

INTRODUCTION

For several decades, the urban population of the Philippines has received the benefits of electricity and the cities have had the glamor of neon glitter. The countryside remained dark and undeveloped. During the decade of the 1970's, the Republic of the Philippines initiated a massive program to uplift its rural people by bringing reliable and low cost electricity to even the remotest settlements. Although this program is by no means completed, major strides have been made; as of this writing, connections, providing twenty-four hours electric services, have been made for approximately 1,300,000 rural homes (thus providing electricity to about 8,000,000 persons).

The rural electrification program was originally based primarily on distributing electricity to be received from the national grid (the power was to be largely generated from oil fired, thermal plants); the grid source was to be replaced by diesel generation in the remoter locations. With the rapidly escalating oil prices now dominant in the world, this goal, of electricity for all, is being threatened. The Philippines produces only limited oil (perhaps 20% of its needs). Its rural population with its restricted purchasing power can ill afford electricity generated from the increasingly dear imported oil. Apart from the excessive price to the consumer, the nation is finding that its foreign exchange earnings are being gobbled up in buying less and less amounts of energy. In order to pursue the national objectives of rural electrification, it is thus necessary to develop alternative energy sources not based on expensive imported oil.

The Philippines is a tropical island country of sunshine, heat, and rain with a topography characterized by narrow coastal strips backed by steep, moderately high mountains. Under these conditions, two promising alternate energy sources for the rural areas are dendro-thermal and mini-hydro. The Republic has decided, as part of its energy diversification effort, to undertake intensive programs of power generation using these two sources. This paper provides a review of the mini-hydro half of this effort.

I. BACKGROUND

A. General Information

The Philippines is an archipelago with a basic North-South orientation. It is between 6 and 20 degrees North latitude and is thus tropical with steady warm, humid temperature. The islands are predominantly modest in size and with the primary exception of Mindanao are long in their North-South dimension and narrow East-West. There are over 7,000 islands with an aggregate land area of approximately 300,000 sq. km. The largest island, Luzon, accounts for 35% of the total land area.

The predominant topography is mountainous with the relatively flat, low-lands accounting for only about one third of total land area. There are a few low-land areas of significant extent, primarily on Luzon and Mindanao. but narrow coastal strips (often only 3 to 5 kilometers in width) backed by relatively steep and high mountains characterize the topography. The Philippines is a predominantly agricultural nation with its population concentrated in these rural low-land areas. Primary crops are rice, corn, sugar and coconuts. Much of the hilly area, now denuded of its original forests, is almost unused.

B. Population

The Philippines has a population of some 48 million persons growing at a rate of about 2.3% a year. A population of over 70 million is projected by the year 2000. Current population density is 258 persons per sq. km.; although if only arable land is considered the density is perhaps three times the above figure. This results from the country's mountainous nature.

C. Climate and Topography

There are two climatological seasons prevailing in the country, which are the dry and the wet depending on prevailing winds. From these two seasons, four generalized climatic types are usually described.

1st type - Two pronounced seasons: dry from November to April and wet during rest of the year. This climate type characterizes the Western coasts of the Northern Islands.

2nd type - No dry season: with a very pronounced maximum rainfall from November to January. The 2nd climate type is found on the Pacific coasts, especially in the North.

3rd type - Seasons not very pronounced: relatively dry from November to April and wet during the rest of the year. Characteristic of the central Visayas.

4th type - Rainfall more or less evenly distributed throughout the year. Characteristic of the South especially Mindanao.

Average rainfall is high (2,300 mm or more) over most of the country and is particularly heavy along the 300 to 1,500 meter elevations of the coastal mountain ranges. Wernstedt and Spencer[1] indicate, that although few reliable data are available for the upland Philippines extrapolating from lowland Philippine data and from data from Indonesia and other related areas". . . it can be assumed in the Philippines exposed slopes between 2,000 ft [600 m] and 5,000 ft [1,500 m] levels receive annual precipitations in excess of 100 inches [2,500 mm] and perhaps in excess of 150 inches [3,800 mm] in most places."

Such exposed slopes are the Western face of the Cordillera Central in Northern Luzon where peaks of up to 6,000 ft (1800 m) rise steeply from the South China Sea over a distance of 200 miles (north-south).[2] Again on Luzon, the Eastern Sierra Madre range flanks the Pacific coast for a similar distance although rising to only modest heights of 300 to 600 m except in the central section where elevations above 1,000 m are common.[3] Continuing south off of Luzon the other islands are largely similar in topography with, for example, Mindoro having peaks above 2,000 m and the central

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[1] The Philippine Island World, University of California Press Berkely, 1967, p. 52.

[2] Wernstedt and Spencer p. 18

[3] Wernstedt and Spencer p. 19

range of Negros reaching to 1,300 to 1,500 m. Because of the precipitate rise and proximity to the ocean these coastal ranges contain many relatively small, fast rushing streams.

At one time, these coastal mountains were heavily forested with tropical hardwoods. Today after years of commercial logging and the depredations of slash and burns cultivators of annual crops, these slopes are largely denuded of forests. These slopes are now used mainly for low intensity grazing or lie fallow, having been taken over by aggressive, non-usable grasses. Slash and burn cultivators still move through these areas wherever natural regeneration provides sufficient fertility to enable the periodic production of a food crop.

II. THE ELECTRICAL ENERGY SECTOR

A. General Information

Per capita consumption of energy is not high in the Philippines. Even so, about 90% of total energy requirements are generated from imported fuel sources. About one third of energy requirements are met from electricity. Oil fired thermal or diesel stations generate more than three forths of the electric power required. Hydro-electric and increasingly geothermal stations contribute almost all of the remainder. The electricity is consumed primarily in the urban and industrial sectors.

Manila and other urban center have large modern sectors with industry, entertainment, and light derived from the availability of electrical power. With jobs and glamor, the urban centers have drawn hordes of citizens who saw no future in the dull and backward countryside. Neither quality of life nor economic opportunity in the unlit barrio was such as to even match the squalor of squatter shanties with an electric bulb or two. At least in the squatter villages around the urban areas there was a neon glitter, a hope that a neighbor would have a TV, a hope for a job in the many factories. Any program for uplifting the countryside seemed infeasible without electricity. Thus a major objective of the Republic has been to bring reliable cheap electric power to its rural people both to upgrade the quality of their lives and to increase productivity.

In 1970, over 95% of the rural areas were without electricity. Since that date, electricity has been provided to close to 30% of rural households. As of 1980, electrical services are being provided to some 20,000 to 40,000 additional families each month. Per capita electrical consumption in the nation as a whole grew from 1970 to 1978 at an annual rate of 7% to a value of 255 KWH. Growth in consumption during the 1980's will be even higher with a projection of 521 KWH per capita by 1990. This growth reflects both an increase in power use and a sharply increased number of consumers.

This increase in electric services has meant a requirement for a significant increase in generating capacity. The generation of electricity (except for small plants under 5 MW) is the responsibility of the National Power Corporation (NPC). The NPC is a government held corporation which is also responsible for trunk line transmission of electricity. The rural electrification program, to bring the benefits of electricity to the people, was initiated in the era of relatively inexpensive oil and was based as noted in large measure on the NPC's oil fired thermal plants (in areas which could be connected to the national grid). Even in the areas beyond the reach of the grid, the generation of electricity was to be from oil . . . using small to medium sized diesel plants.

Although most generation of electricity is now done by the public sector, a few large private firms supply electric distribution services to the largest urban centers . . . Manila, Cebu, Davao. These private systems, covering the primary industrial centers, handle the distribution of the majority of generated power (about 80%). Demand in the cities is high because of industrial load and also for cooking and cooling and the private franchises have prospered while providing adequate services.

For many years, the Philippines also relied on private franchises to provide electricity to the hinterlands. However, the economics were such that the private franchise holder saw little future in extending the coverage of his small system beyond the centers of the market towns. A profit could be made by providing early evening lighting to the small number of better-off families residing within a few hundred meters of the market center. While it seemed possible that over time consumption would grow if 24-hour service were extended to a wider area, it was obvious that there would be a number of years during which new customer consumption, brought about by system expansion, would be very low if services were extended in space beyond the town centers or extended in time beyond the early evening hours. The private franchise holder faced a variant of the familiar chicken and egg dilemma. Growth in electric power use would not occur until reliable, 24-hour power was extended at reasonable rates. Profitable operation could not occur until power consumption was relatively high per connection. Thus, for many years the rural areas experienced very little increase in the availability of electrical services.

In planning its rural electrification drive during the 1960's, the Philippine Government reviewed this situation and concluded that the private franchise system could never be expected to bring electrical services to the rural people. As a consequence of this study, a totally new approach was outlined. The National Electrification Administration (NEA) was created from the former Electrification Administration and established as a government corporation. It was given the charter of electrifying the rural areas.

At the same time, it was realized that in a country as diverse and physically scattered as the Philippine Islands, it would not be practical to conduct an intensive, successful electrification program from a central national agency. True, it might be feasible to administer the construction of lines from a central agency; but no one believed that the system could be operated reliably and on a financially sound basis if authority and decision resided in Manila. In order to involve local expertise and motivation it was decided to establish electric cooperatives to administer the electric distribution systems. The NEA would establish policy and oversee cooperative operations. It is the NEA and the cooperatives which have administered the rural program.

In the decade since its inception this program has brought power to over 8 million rural dwellers and is currently adding new connections at the rate of about 30,000 (200,000 persons) per month. It is expected that by 1987, all but the remotest areas of the Philippines will have access to reliable 24-hour electric power. It is only because of the mobilization of local management skills and motiviation through the cooperatives that this massive program has been possible. And it is this, now well established, local organizational capacity which will make possible the implementation of the projected mini-hydro program with its many small and widely dispersed installations.

Currently, electric power consumption in the rural areas is very modest. Over 100 electric cooperatives are now operating with an average of 10,000 to 12,000 members each. The range of peak electric demand for the more typical cooperatives is from 3 to 8 MW. Total demand from all cooperatives is about 500 MW and is predicted to grow to 1200 MW by 1987. Sales in 1980 will be about 1,354 gwh growing to 4000 gwh by 1987. More than half of the consumers use less than a few KWH per month. Thus, although power use is growing, it is still true that relatively modest generating capacities can meet rural needs for a number of years to come.

B. Diversification of Energy Sources - Urban/Industrial

Currently, as noted earlier, about 75% of electricity is generated from oil, with about 80% of oil imported. Consequently, the Philippines is at the mercy of the oil producers both in terms of supply and price. To overcome this threatening situation, a program to diversify electric power sources has been adopted. The program is composed of two arms: 1) urban/industrial power generation and 2) rural power generation.

Over three quarters of electricity is consumed in the urban/industrial complexes of the country. Here the demand is for concentrated supply from large generating plants. Current total generating capacity is about 4,200 MW. It is planned to more than double this capacity by 1990 to about 10,000 MW. A further goal is to reduce the dependence on oil from the present about 75%, to no more than 25-35% by the 1990's. Electrical generation sources will be as follows:

Nuclear - A single large nuclear generating facility (620 MW) is under construction and is scheduled to become operational by the mid - 80's.

Geo-thermal - Because of its location on the Circum-Pacific Fire Belt the Philippines has a large number of exploitable geothermal sites. There are now in operation plants in Albay, Leyte and Laguna with a total generating capacity of 223 MW. Under construction are an additional 819 MW capacity and plans exist to bring the total geothermal capacity to 1,260 MW by the year 1990.

Coal - Existing plans are to substitute some coal fired thermal plants for oil fired plants. By the 1990's, it is expected that coal fired plants totalling over 1,000 MW will be in operation.

Large Hydro - Additional effort will be made to exploit the potential for large hydro sites. Apart from the huge capital investments required, an important constraint on development of large hydro facilities is the inundation of productive agricultural land and the attendent displacement of small farmers. Nonetheless, before the end of this century over 3,000 MW of large hydro generation capacity will be added to bring the hydro total to about 4,000 MW.

Intensive efforts will thus be made to diversify sources of fuel for major plant electrical generation. Although it will still be necessary to import much of the energy material by 1990, the Philippines reliance on oil as a source of energy for electrical generation should decline from 75% to about one third. In terms of generating capacity, the distribution is expected to be approximately as follows:

ENERGY SOURCE	PERCENT OF GENERATION CAPACITY	
Oil	1,900 MW	30 - 35%
Coal	1,100 MW	7 - 10%
Hydro	4,200 MW	30 - 35%
Geothermal	1,260 MW	10 - 15%
Nuclear	620 MW	- 6%
Non-Conventional	600 MW	4 - 6%

C. Diversification - Rural

For the rural sector a different program has been adopted. In the rural areas overall demand is still modest and small generating facilities can be quite useful. Currently, as noted, distribution is managed by locally owned and based cooperatives. As noted earlier, there is a large potential for generation of moderate amounts of electricity from indigenous energy sources (primarily dendro and mini-hydro). For a complex of reasons involving foreign exchange, energy security, pricing and local pride an objective of energy self-sufficiency, by individual cooperative has been adopted.

This objective (of energy self-sufficiency) will be achieved through the implementation of two programs both to be administered in part by the NEA and in part by the rural electric cooperatives themselves.

DENDRO-THERMAL: The first of these two programs will involve the development of wood fired generators (3MW class) and associated tree planting and cropping (the dendro-thermal program). This program has far reaching ecological and social objectives as well as those of local energy self-sufficiency.

Briefly, the program will involve extensive planting of fast growing trees on land which is currently underutilized (low hill lands). The tree planting, cultivation and harvesting will be the responsibility of local farmers associations under the technical guidance of the local electric cooperatives. The farmers making up the association will be selected from landless farmers particularly those practicing slash and burn cultivation. An area of about 1,000 hectares will be planted to provide a perpetual fuel source for a 3 MW generating plant. The generating plant will be owned jointly by the NEA, the electric cooperative and the farmers association. The objectives beside energy self-sufficiency are employment, income creation and reforestation.

It is planned to develop by 1987 some 50 power plants with a generating capacity of 150 MW. The tree plantations required to fuel these power plants will cover 50,000 to 60,000 hectares and create a source of livelihood for 6,000 to 8,000 families.

<u>MINI-HYDRO</u>: The second half of the energy self-sufficiency drive for rural cooperatives is based on the installation of mini-hydro generators to be owned and operated by the cooperatives. It is apparent from the rainfall and the topographic characteristics of the Philippines that an enormous potential exist for the installation of mini-hydro facilities (to date some 4000 sites have been tentatively identified). However, to date, there does not exist a comprehensive survey of this hydro potential. A preliminary overall survey exists and a few sites have been carefully examined, although even for this limited number of sites there is usually very limited hydrographic data.

Program targets have been established which are very conservative in terms of predicted hydro potential. In any case, the limitation on construction at least for the next few years will relate to A and E work and to installation capacity, not to the lack of feasible hydro sites. Thus, the following program will be revised and expanded as installation capacity grows and as more complete data are gathered on hydro power potential.

YEAR	CUMULATIVE ADDED CAPACITY	NUMBER OF HYDRO SITES
1987	305 MW	239

With the installed capacity planned under the dendro and mini-hydro programs the rural cooperatives should approach 50% of energy self-sufficiency by about 1987. In addition with the sharply lessened dependency on imported fuel and equipment the rural population of the Philippines will be isolated from any continued shortages and price increases taking place on the international scene. It is believed that rural development will thereby be secured and accelerated.

III. THE NATIONAL ELECTRIFICATION ADMINISTRATION (NEA)

The NEA will be responsible for developing policies and guiding implementation for the energy diversification/self-sufficiency program in the rural areas. This responsibility evolved from the NEA's decade of successful management of the Philippine program of rural electrification.

The National Electrification Administration, established in 1969 under the provisions of R.A. No. 6038 and re-organized and expanded in accordance with Presidential Decree No. 269 dated August 6, 1973, is a stock corporation fully owned by the Philippine Government.

As of October 1979, NEA's authorized capitalization is ₱5 000,000,000 with a foreign borrowing capability of $800,000,000. In addition, NEA was recently authorized to organize wholly and partly owned companies for the purpose of developing power, generation and distribution systems, including the manufacturing of power generating equipment and materials.

NEA is empowered to make loans to public service entities with preference to cooperatives, and is responsible for licensing electric power franchise. Since 1972, NEA has granted registration, mainly to rural electric cooperatives, which now number over 120 of which about 100 are now supplying electricity. The primary emphasis of NEA has been on the initial organization of cooperatives and on the implementation of the electrical distribution systems. However, NEA has advanced significantly in the areas of training, cooperative development, finance, construction supervision, and material procurement, handling, and warehousing.

NEA has a long range objective of total electrification of the rural areas by 1987. As of today it has accomplished over one third of that task. In 1981, new consumers will be added at the rate of 40,000 per month (250,000 persons at 6.2 persons connection). This involves massive financial and logistical requirements. To accomplish the program expenditures of about ₱ 62 million per month are necessary. And the program uses for example, materials such as 180,000 electric poles and 500,000 electric meters per year.

This massive program has been possible as the result of a major cooperative effort between the Philippine Government and International donors. Financing sources have been:

Philippine Government	₱ 5,000 Million
United States	$ 86 Million
World Bank	$ 60 Million
Federal Republic of Germany	$ 21 Million
Japan	$ 46 Million
France	$ 18 Million

Technical assistance largely from the United States was important in the initial years of the program. However, the NEA and the Philippine private sector now have more than adequate capability to perform almost all of the technical tasks required. Increasingly materials required for the program are being procured from local manufacturers. Thus, 1979 the NEA let contracts to local firms for ₱ 50 million for supply of materials such as meters, insulators, conductors, and transformers.

In one sense construction of the electrical distribution systems is the easiest aspect of the program. The government determined that the electric systems constructed would be operated reliably and on a fiscally sound basis Although, it might have been possible to construct the system from a single central agency no one believed that the goals of reliability and fiscal soundness could be achieved without decentralization and effective local involvement.

This recognition led to the decision to develop local cooperatives to own, develop and manage the local electric distribution system. Much of the energy of the NEA during the first years of the program was spent in fostering this establishment of responsible, locally controlled cooperatives with the technical and administrative capacity to have constructed and to manage electric distribution systems. Extensive training programs have been conducted and policy advice and general guidance provided.

Today, over 100 cooperatives have borrowed ₱ 2.8 billion from the NEA to establish the systems now serving 1,300,000 consumers. It is the evolution of this local managerial talent, this local initiative which has made it possible to expand the program at such a rapid pace while still maintaining low cost (₱1,500 per connection) and fiscal soundness (revenues adequate to cover capital and operating costs). Because of this unique experience and the importance of the cooperatives in the mini-hydro programs it is useful to devote some space to describing the cooperatives and their role in electrification.

IV. THE ELECTRIC COOPERATIVES

The rural electric cooperatives organized by NEA, are non-stock non-profit member owned public utility enterprises. An electric cooperative generally covers an average of 10 municipalities with a total population of from 100,000 to 500,000 people.

Each cooperative has full corporate powers to operate as an electric utility and to generate, transmit, and distribute electric power to its members. Electric service is extended by the cooperatives to all prospective consumers in the franchised area, not only in town centers, but also in outlying barrios, provided that extending such services does not impair the financial feasibility of the utility's operation. The electric cooperatives, which are service-oriented in nature, can extend service to outlying barrios on the principle that the high cost of bringing power to these places can be offset by margins derived in the profitable areas. In contrast to an ordinary private enterprise which is owned and run by a few individuals, the cooperative belongs to the members who exercise control over it through a board of directors that they themselves elect. Cooperative margins are returned to the memb 's and the general public as a whole in the form of improved service, expanded operation and reasonable rates.

The cooperatives borrow funds at low rates from the NEA for capital expenditures. The cooperatives must then charge rates such that the income generated will be sufficient to cover operating costs and to allow amortization of NEA loans. The cooperatives gradually evolve into nearly autonomous entities. In the early years of existence, the NEA provides considerable oversight and guidance. As the cooperative demonstrates its competence and responsibility the NEA reduces its involvement.

These rural electric cooperatives have become a unique institution in the Philippines. Tapping the enormous reservoir of educated people in the countryside the cooperatives have established a cadre of highly competent personnel. Tapping the Bayanihan spirit of the people,cooperation has blossomed. And as relatively large institutions (in terms of financial resources) in areas where there are few or no organizations with important resources these cooperatives have become a focus of development in the rural areas. For example, the cooperatives collectively employ 11,000 people perhaps 40% of whom have college or university training.

As the sources of electricity and as lending institutions they have stimulated other cooperative projects such as small industry coops, irrigation associations and other community self-help undertakings. The electric coops likewise promote active participation and involvement among the people toward improving the quality of their lives.

PART II

PLANNED MINI-HYDRO DEVELOPMENT 1980-1987

V. HISTORICAL BACKGROUND

The earliest known hydro project in the Philippines is a small unit installed in 1914 in Baguio, a city in the northern mountains. Several other small hydros were installed during the 1930's. After the Pacific War, a limited program to develop small hydro projects was initiated in 1947 and continued into the 50's and 60's under the direction of the National Power Corporation. Under these various efforts, there was installed a capacity of about 12.5 MW. However, in light of cheap and plentiful oil supplies NPC's major focus during this time was on oil fired thermal plants and on large hydro facilities with their significant economies of scale.

Nonetheless, a modest number of small hydro sites were placed into operation allowing the Philippines to develop experience and some expertise in this area. Twelve sites were developed, scattered through the country. The power plants installed under these programs have been operational for 20 to 30 years in most instances and in a few cases for 40 to 45 years.

The following table provides a summary of small hydro facilities in operation as of 1978.

SUMMARY OF NPC OPERATING MINI-HYDRO PROJECTS

LUZON PLANTS	PLANT CAPACITY (MW)
Amburayan	0.1
Baco	0.02
Balongbong Hydro	0.2
Cawayan Hydro	0.4
Lake Buhi-Barit	1.8
Asin	2.9

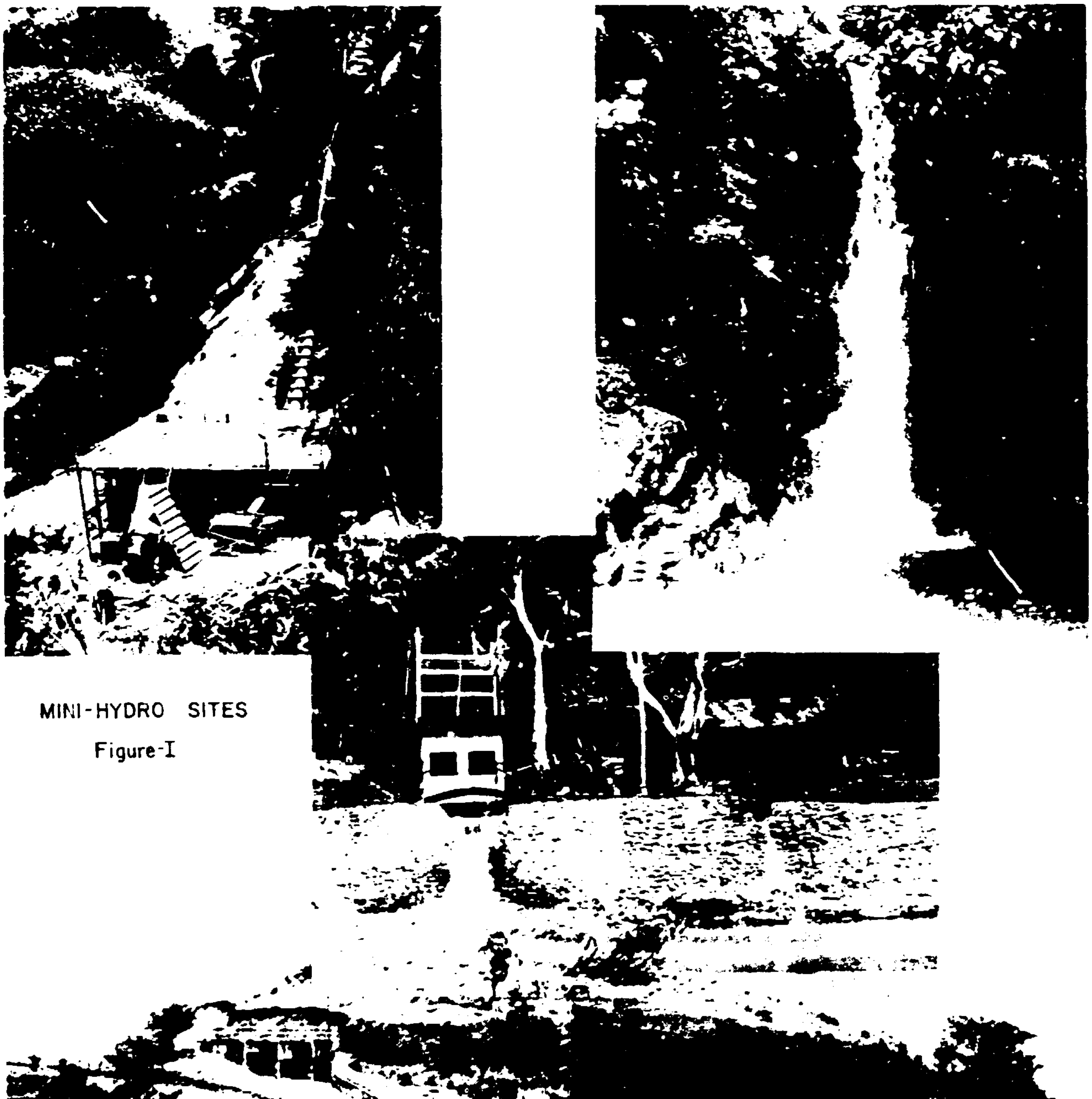
VISAYAS PLANTS:	PLANT CAPACITY (MW)
Amlan Hydro	0.8
Loboc Hydro	1.2
MINDANAO PLANTS:	
Agusan Hydro	1.6
Talomo River Hydro	3.1

During the 60's and 70's, the NPC with its responsibilities for providing electric power to meet the rapidly expanding urban/industrial demand devoted very little attention to smaller hydro generation and thus there was a plateau in construction. It is only with the advent of oil shortages and fossil fuel price escalation that an interest in small hydro systems has been revived.

VI. SMALL HYDRO POTENTIAL

The Philippines is a largely mountainous country with very high average rainfall. The mountains drop rather precipitately to the sea over most of the islands. Although there are relatively few large river basins, conversely the high volume of water received from the rainfall over these mountains rushes to the sea in a vast number of streams over short, steep watercourses. These streams with their steep watercourses offer many possible sites for small hydros. Another source of hydro sites are the irrigation systems. The photos in Figure 1 show typical sites -- two on a small waterfall and the other on an irrigation canal drop. The photo on the upper left shows construction at the site of the first locally fabricated system.

Even though it is known that a high potential exists, it will be some years before a thorough site-by-site estimate of the small hydro



MINI-HYDRO SITES

Figure-I

potential of the country will be available. A several year survey in the early 70's undertaken by a Philippine Government Interagency task force has on a preliminary basis, identified about 4,500 sites as possible locations for mini-hydro facilities. Even partial hydrological data was available for under 20% of these sites. Counting only the 770 sites for which some data existed at the time of the survey, a generating potential of 900 MW was estimated. Many of these sites by their very nature are in the remoter areas in which power from the national grid is not readily available and are thus particularly attractive.

Based on this early survey, more detailed studies are now underway. A team of consultants from the United Kingdom, in a survey of 21 sites in four provinces, has established a generating potential of at least 22 MW with estimated KWH cost ranging from ₱0.21 to ₱0.40 (current fuel oil costs for thermal plants are about ₱0.40/KWH). At these 21 sites, potential capacity ranges from 156 KW to 2,700 KW with most sites having a capacity between 400 KW and 1,000 KW.

A team of Japanese consultants has recommended a preliminary power development plan for the small province of Catanduanes in which 6 small hydro sites would be developed by 1986 with a total capacity of 7 MW.

Additional surveys by a Norwegian and a second Japanese team are also available providing more detailed data at least confirming the potential cited by the original inter-agency task force. The NEA has targeted the completion of a total of over two hundred feasibility studies by the end of 1981.

In summary, the mini-hydro potential is known to be very large.

Detailed surveys on over 40 sites have confirmed the early overall estimates as, if anything, conservative. Figure 2 shows, by region of the country, for sites with some data the preliminary estimate of the number of mini-hydro sites and the estimated generating capacity which could be installed at these sites. As these data illustrate, at least for the decade of the 80's the limitation on the development of mini-hydros (only 239 sites are proposed for development by 1987) will be in the construction and engineering areas not because of any lack of sites. Ultimate potential is probably in the several gigawatt range.

VII. ESTIMATE OF ECONOMIC FEASIBILITY

Given today's highly volatile international energy situation, the question of economic feasibility is one of considerable complexity. Nations all over the world depend on oil as a key source of energy. At the same time, a few producers have created an effective monopoly on internationally traded oil. This monopoly has been exploited for both political and economic gain. Prices have escalated beyond any comparable prior experience. Even worse in some respects supplies have become unreliable. It is fair to say that it is worth almost any price to be free of the economic dislocation, past and apparent future.

Yet, given time, there are a wide range of alternatives to oil, particularly for the generation of electricity. Several of these alternatives - - coal, nuclear, large-hydro, geothermal - - appear to offer the option for producing electricity at prices well below those from oil, even at today's oil prices. Nonetheless, such non-oil alternatives are not in place and future costs and quantities of supply must remain uncertain given the rapid changes occurring throughout the world in the use of

POTENTIAL MINI-HYDRO LOCATIONS

NUMBERS & CAPACITY OF SITES WITH DATA

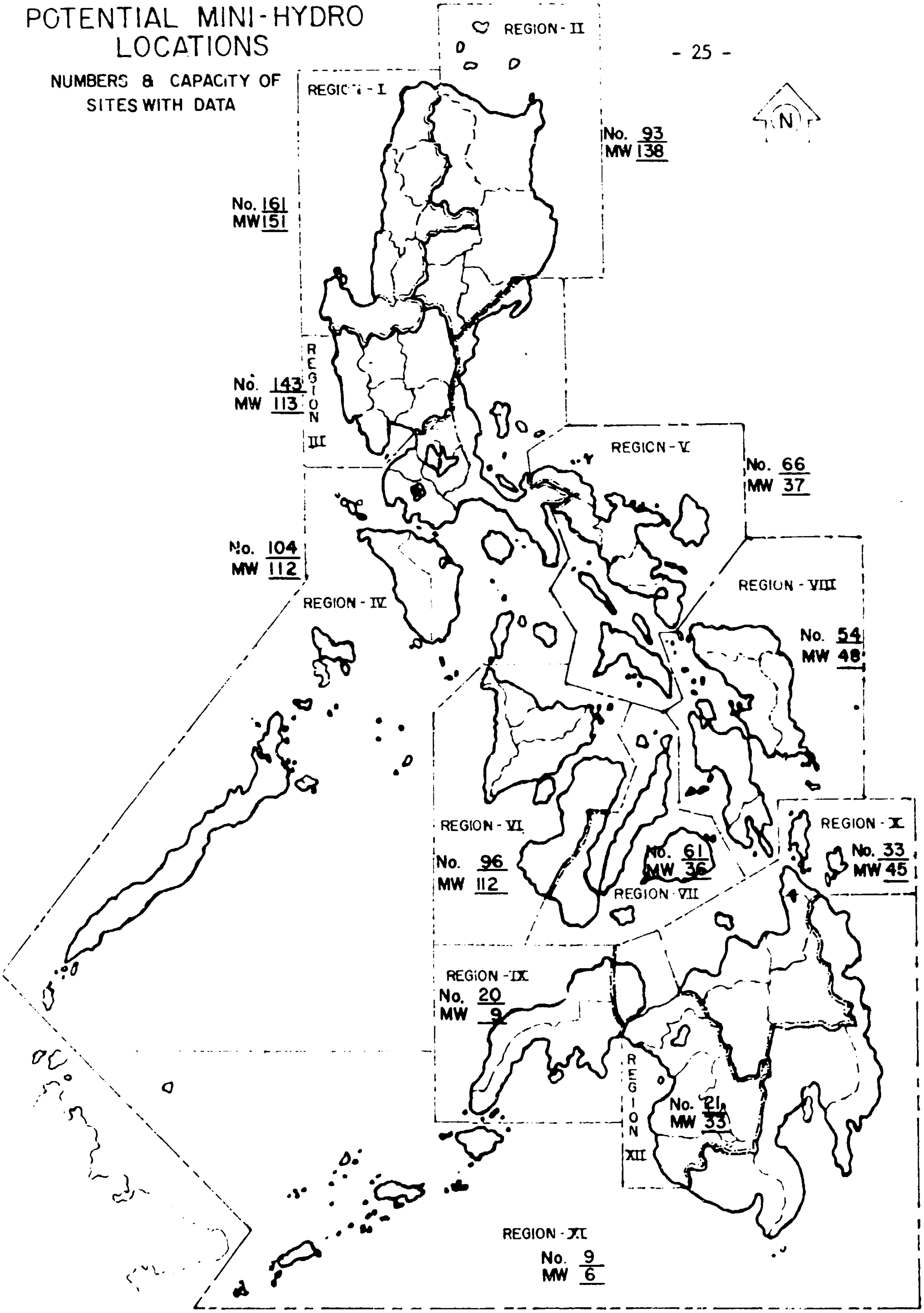


FIGURE 2

energy sources. It is possible that as the world searches for means to free itself from the stranglehold of the oil monopoly, the alternatives will be found to be limited in quantity or it will be found that demand will drive price up for these energy sources as well. It is only as a more stable situation evolves that price and supply estimates will become firmer.

The current oil prices, the general uncertainty as to what future supplies and prices of alternatives will truly be, suggest that a generous view should be taken as to what price will be used as the criterion of economic feasibility in the mini-hydro program. Yet, from another view, that of the quality of life of consumers with extremely limited purchasing power, it is highly undesirable to develop relatively high cost energy options if there is some chance that with a little more time, another alternative could give lower costs. Further, electric power is a key to economic development and high cost electricity will deter the growth of many types of productive enterprises. From these perspectives, quality of life and economic growth, the specification of production cost below which economic feasibility will be assured should be as low as future trends will possibly allow. Use of such a low cost criterion for feasibility decisions would help assure that the rural areas would not be burdened with high cost power generation sources.

In a time of rapid change, decisions made today, under conditions of considerable uncertainty, are going to impact in very important ways on a basic factor of production and of quality of life - - electric power. Under these conditions, it is imperative that options not be foreclosed insofar as possible. Given the lead time necessary for exploiting all potential sites, for a number of years to come it will be possible to develop only the more productive, lower cost mini-hydro sites. Thus, in this program's first years a conservative criterion of generating costs equal to be less than current oil based (thermal, or diesel depending on the area) generation costs will be adopted in deciding on economic feasibility. During this time, more experience and information will evolve thereby enabling better decisions and if later determined to be desirable the more difficult sites will be developed later. Costing for feasibility analysis will be done on cash flow requirements (interest, amortization and operations costs). This is a very conservative costing approach given the long life of small hydro units compared to the terms of the loans. Potential power plants which meet these criteria will be highly competitive.

There are now sharp cost differentials in electricity production costs in different parts of the country. On Luzon where oil thermal is the major generation source, grid costs now are approximately ₱0.40/KWH. Within a decade, most of the power going into the Luzon grid will come from non-oil sources and rates are not expected to escalate as sharply as in recent years. Calculations based on current costs suggest that generating costs from the 1987 mix may be 10-15% less than for the current oil heavy mix.

In outlying areas of Luzon, beyond the grid, and in most of the Visayas, electricity is generated from medium to small diesels. In these areas the fuel costs per KWH exceed ₱0.80. In most of these areas there are no plans by the NPC to diversify generation sources. In Mindanao, large hydros have the potential to meet near future demand at prices in the vicinity of ₱0.15/KWH. Thus for the near future little effort will be made to develop mini-hydros on Mindanao. However, mini-hydros will be particularly attractive in the Visayas.

Given these considerations, the following criteria have been adopted for determining the economic feasibility of a mini-hydro installation:

1. For areas now or soon to be served by the Luzon grid, the estimated average cost per KWH for a proposed power plant should be equal to or less than current grid costs of ₱0.40.
2. For areas in the Visayas or beyond the Luzon grid, and which areas are not to receive geothermal or a coal-thermal system, average cost should be equal to or less than 0.8 x current diesel fuel costs or (0.8 x ₱0.80 = ₱0.64). This lower cost criterion is used to try to reduce the cost differential in the already somewhat disadvantaged Visayas.
3. For areas outside the Luzon grid to receive geo or coal thermal power, mini-hydro costs must be equal to or less than the applicable alternative (geo or oil).

An added complexity is that in the early years, turbine, generator and associated electrical gear will be imported (at relatively high prices). However, in varying degrees this imported equipment will come in on concessional terms. With 5 or 6 donors involved, at least 5 or 6 sets of terms will be involved. The question of how the average piece of equipment is to be costed must be addressed. Currently, each donor's consultants are costing with their own techniques. In order to permit comparison, the NEA is using a standard technique for computing the estimated cost per KWH. Cost is the sum of annual loan amortization and interest charges plus estimated operational costs divided by the estimated annual energy produced in KWH. The amortization and interest charges are a composite of all money received. This is rather conservative approach.

Proposed mini-hydros vary widely in terms of flow, head, ease of access for construction, complexity of civil works and annual flow variation making it infeasible to define a typical case for cost illustration purposes. The following examples are selected as representing a range of situations and are selected as cases with sufficient reliable data to permit higher confidence cost estimates to be made.

1. Magat: A low head, impellor turbine type for installation on an existing irrigation canal. The equipment is to be funded under the French loan. Because of the location on an existing canal the civil works requirements are limited. Total installed capacity will be 2,800 KW.
2. Agua Grande: A high head, impulse turbine for installation in a easily accessible site below a series of waterfalls. The equipment is to be funded from the United Kingdom loan. The civil works requirements, mainly a low dam and 1.5 km. concrete pipeline is of moderate complexity. Total installed capacity will be 2,730 KW.
3. Cuyaoyao: A medium head (55m) Francis turbine installed at a single waterfall. The site involves a medium length steel pipeline and a very small diversion dam. Total installed capacity is 350 KW. The plant was locally designed and the turbine cast in Manila foundry - - the first such casting in the Philippines.

4. Hasaan: A low medium head (8.5M) Francis turbine installed on a very small irrigation ditch. A small dam was constructed to provide daily flow control and to increase the head some. The equipment was procured from the Chinese Government. Because of the small generating capacity, 30 KW, the civil works costs represent a large fraction of total costs.

5. Baliguian: A medium head, Francis turbine installed in a very remote portion of the Philippines. This power plant is of particular interest since it was designed by one of the local cooperative managers. The turbine was built-up in the province and welded rather than cast. The power plant has been operating at rated capacity of 100 KW for more than one year now. Costs are very low at ₱0.16/KWH.

The following table provides a comparison of these five systems.

(See attached table)

VIII. <u>PROGRAM TARGETS</u>

The National Electrification Administration was mandated by the President of the Philippines in PD 1645 to implement a program whereby the electric cooperatives are to develop and generate their own power resources by utilizing indigenous and renewable resources with the objectives of self-reliance and self-sufficiency in meeting power needs. To facilitate the implementation of this directive the NEA organized the

Comparison of Five Mini-Hydro Sites

	MAGAT A & B	AGUA GRANDE	CUYAOYAO	HASAAN	BALIGUIAN
1. Head	3.7 meters	180 meters	55 meters	8.5 meters	27 meters
2. Total Plant Capacity	2800 KW	2730 KW	350 KW	30 KW	100 KW
3. Annual Energy Generated	12,250,000 KWH	9,555,000 KWH	1,531,250 KWH	131,250 KWH	437,500 KWH
4. Equipment Cost	₱ 36 M	₱ 25 M	*	₱0.059 M	₱0.215 M
5. Cost of Civil Works	₱ 4 M	₱ 10 M		₱0.345 M	₱0.346 M
6. Total Project Cost	₱ 40 M	₱ 35 M		₱0.405 M	₱0.561 M
7. Equipment Cost Per KW	₱12,800; $1,710	₱9,261; $1,235		₱1,969; $263	₱2,155; $287
8. Investment Cost Per KW	₱14,259; $1,901	₱13,037; $1,738		₱13,491; $1,799	₱5,617; $749
9. Investment Cost Per KWH	₱3.26	₱3.72		₱3.08	₱1.28
10. Generating Cost Per KWH	₱0.35	₱0.39		₱0.40	₱0.16

*Still under construction! Data will be available later

	MAGAT A & B	AGUA GRANDE	CUYAOYAO	HASAAN	BALIGUIAN
11. Cost of Civil Works Per KWH	₱1,429; $191	₱3,776; $503		₱11,553; $1,540	₱3,462; $462
12. Equipment Cost (%)	90%	71%		15%	38%
13. Cost of Civil Works (%)	10%	29%		85%	62%
14. Equipment Manufacturer	FRANCE	UNITED KINGDOM	AG&P AND PHILEC	PROC	LOCAL

ECO-BLISS[1] Office to concentrate primarily on the Mini-Hydro and Dendro-Thermal programs.

The following overall power generation objectives have been established for the ECO-BLISS Office.

Short Range: To supply at least 20% of the energy requirements of the rural cooperatives by the year 1982.

Mid Range : To supply 50% of the energy requirements of the rural electric cooperatives by the year 1987.

Long Range : To supply the total energy requirements of the rural electric cooperatives by the year 2000.

Lately surveys have shown a potential for several thousand sites with a total capacity potential of 2,000 to 4,000 MW. Based on these preliminary data the NEA has established an ambitious set of program targets as follows:

Year	Sites Operating	Operating Capacity (MW)
1981	14	16.0
1982	27	29.0
1983	39	40.0
1984	51	45.0
1985	37	55.0
1986	42	59.0
1987	29	61.0
Cumulative	239	305.0

[1] Coined from the ecological objectives and the human settlements aims of the program. The BLISS program (an acronym from Tagalog) is designed to provide housing & livelihood for resettlements sites throughout the country.

This program (up to 1987) will cost on the order of ₱3,500 to ₱4,000 million. The total generating capacity to be installed is the equivalent of a medium sized thermal generating plant which would consume about 2 million barrels of oil per year.

IX. PROGRAM ADMINISTRATION

The NEA, as earlier noted, has established the ECO-BLISS Office to provide overall administration of the program. This Office will in the long run provide policy guidance and technical assistance to the cooperatives as well as act as a purchasing arm for equipment most efficiently purchased from a central office. In the short run the ECO-BLISS Office will be responsible for coordinating the inputs of the foreign consultants who will be heavily relied on for initial surveys to determine equipment design.

The foreign consultants will survey the sites in conjunction with local A & E firms. After sufficient data are collected to enable the foreign consultants to specify equipment design, the local engineering firm will be responsible for the design of the civil works and for construction supervision. The NEA will process the feasibility studies itself. However, in many ways, the key element in the long term administrative feasibility of the program is the electric cooperative. There will be dozens of sites under construction simultaneously in scattered and remote locations. It is the large reservoir of experienced, technical people, decentralized throughout the country which makes this program feasible - - feasible in cost, technical and administrative senses. The local cooperatives will collect the initial data on prospective sites. They will assist in the pre-feasibility work. A & E work will be done by private firms but the cooperatives will let the contracts, although NEA will assist in the contracting process. The construction work will either be by contract, let by the cooperatives, or by direct force account performed by the cooperatives. Thus, there are as many administrative centers in the program as there are cooperatives.

A particularly important aspect of relying on the local cooperatives is the economic and administrative efficiency attendent on using local personnel. In this way, lower local wage scales will apply. In addition, it is unnecessary to pay per diems and salary differentials as would be true if central personnel had to be sent to the remote areas to conduct the feasibility and construction elements of the program. The local people know the terrain and are known by the community. Perhaps, most important of all by vesting authority and responsibility with the users of electric power there is fostered a deep pride and desire to excel which are invaluable elements in a successful program. Ultimately, the electric cooperatives will manage and operate the mini-hydro power plants.

NEA will provide subsidized loans to the cooperatives for purchase of equipment and services to construct the power plants; but ownership of the generating facilities will reside with the cooperatives themselves. NEA will provide a reservoir of technical expertise which the cooperatives may call on as needed. In addition, NEA will provide extensive training programs for cooperative personnel in subjects such as site surveys, construction supervision, and power plant operation and maintenance.

As the system owners, the electric cooperatives will have to manage and maintain the mini-hydro power plants. The consumers as the owners of the cooperatives will receive the benefits of lower costs. It should be emphasized again that this decentralized system with its low costs and ability to mobilize highly motivated and trained local personnel is a key to the rapid and effective execution of the proposed program.

X. PROGRESS TO DATE

At this time, the operational aspects of the program are just getting underway. Three power plants are operating and financing is available for an intensive program, phase I of which will rely heavily on foreign inputs. The NEA has identified specific projects for most of the funds listed below.

FOREIGN FUNDS AVAILABLE
FOR IMPORTED EQUIPMENT

Source	Loan Amount ($ M)	Interest Rate (%)	Repayment Period (Years)
Peoples Republic of China	30	7.5	14
France	20	5.9	18
Federal Republic of Germany	2	2.0	30
Japan	20	3.0	25
Norway	2	GRANT	-
United Kingdom	30	5.7	18

Total foreign funds available as of this writing are $104 million with an average interst rate of 5.55 percent and an average term of

18.4 years. These loans will provide equipment with a total capacity of about 170 MW. Negotiations are underway with other possible donors and it is believed that further funds will be available as required at least through 1987.

U. K., Japanese and Norwegian Consultants have surveyed proposed sites (some 50 in number). Initial design work has been completed on 12 sites and construction can start on these within 1981.

To illustrate specific case studies, the appendix reproduces the descriptions of two representative projects from the study by the U. K. consultants.

XI. PHASE II LOCAL-PROCUREMENT

At the inception of the rural electrification program, the NEA relied heavily on foreign consultants for policy advice, A & E services and even for assistance with implementation. Much of the equipment for the rural electrification program has been imported, although, in recent years local manufacturers have started to supply some of the required items.

NEA envisages a somewhat similar approach for the Mini-Hydro program. However, the foreign input is planned to be narrower in scope and shorter in duration than the case for the rural electrification program. This more rapid transition is feasible because of the institutional capabilities developed during the implementation of rural electrification. The NEA, many of the cooperatives and a number of private sector firms are experienced and highly motivated organizations. It is expected that at least six local engineering firms will be capable of conducting the required number of feasibility studies and completing design work for all but the most complex sites. This would be consistent with the rural electrification experience, after allowances are made for the better base from which the mini-hydro program starts.

In terms of local fabrication of turbines, generators and electrical control equipment, some capability already exists. Two systems now operating were locally designed and fabricated. One of these, in operation for over 12 months, was actually designed by an officer of an electric ooperative and fabricated from equipment available in the province where the cooperative is located. This system has a rated capacity of 100 KW and uses a Francis type turbine to drive a standard, off-the-shelf generator. The power plant site is at a site with a 27 m head. Operating and maintenance costs now are averaging ₱0.02 KWH. During the past twelve months, the power plant has generated about 60% of theoretical potential.

A second system at Cuyaoyao in Camarines Sur is also locally designed and fabricated. The Cuyaoyao turbine, of the Francis type, was cast in a Manila foundry. This system has been in operation for only a few months so there is little operational experience yet. It is on a site with a 55 m head and a flow of 0.60 cumecs. The civil works involved considerable excavation and installation of a steel pipeline. This exercise was primarily an exercise in learning as a means to initiate development of local fabrication capacity. A retrospective view suggests several areas in which cost savings would have been possible.

Experience todate suggests that the turbine and associated electrical equipment can be fabricated locally for about one half the costs of importing these items. Assuming that local manufacturers will decide to develop the required capability the plan is to gradually shift procurement from imported to local equipment.

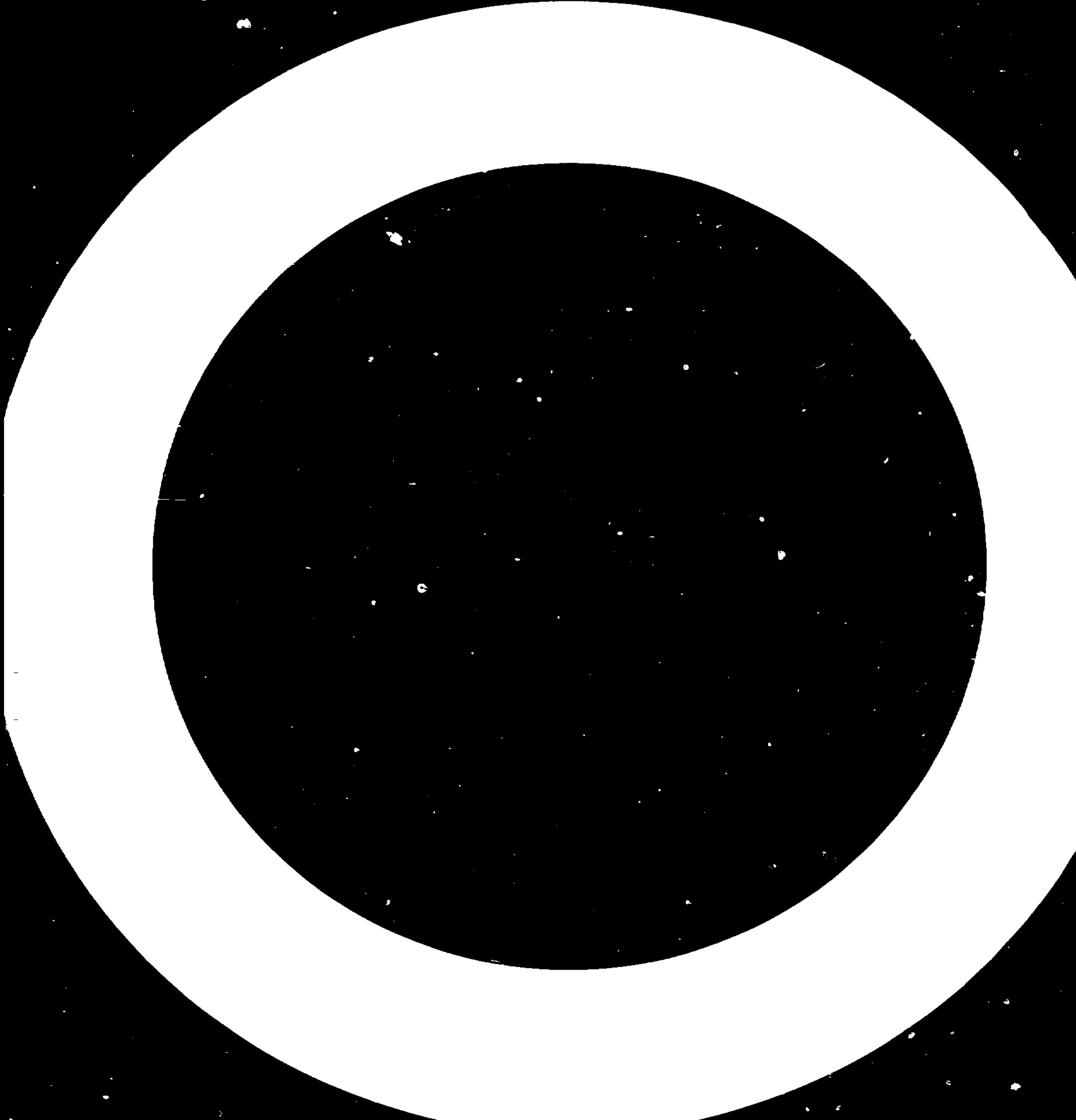
The following table gives the planned procurement of locally manufactured systems by years..

TARGETS FOR LOCAL PROCUREMENT

YEAR	# OF SITES	GENERATING CAPACITY
1983	3	3.0
1984	5	3.0
1985	8	5.0
1986	11	20.0
1987	14	30.0
Total	41	61.0

Because of the very low purchasing power in the rural areas and because of the desire to encourage small industries, it is imperative that electricity costs be kept to a minimum. Currently, much of the cost of the power plant derives from the tailoring of turbine and generator to fit the site in order to maximize the energy production. Standardized designs can considerably reduce prices at what appears at this time to be rather modest losses in expected total energy production.

For this reason, the move to local production will be based on standardized equipment packages which will them be adapted to the sites. In this way, the NEA hopes to provide the cheapest possible power to the rural people.



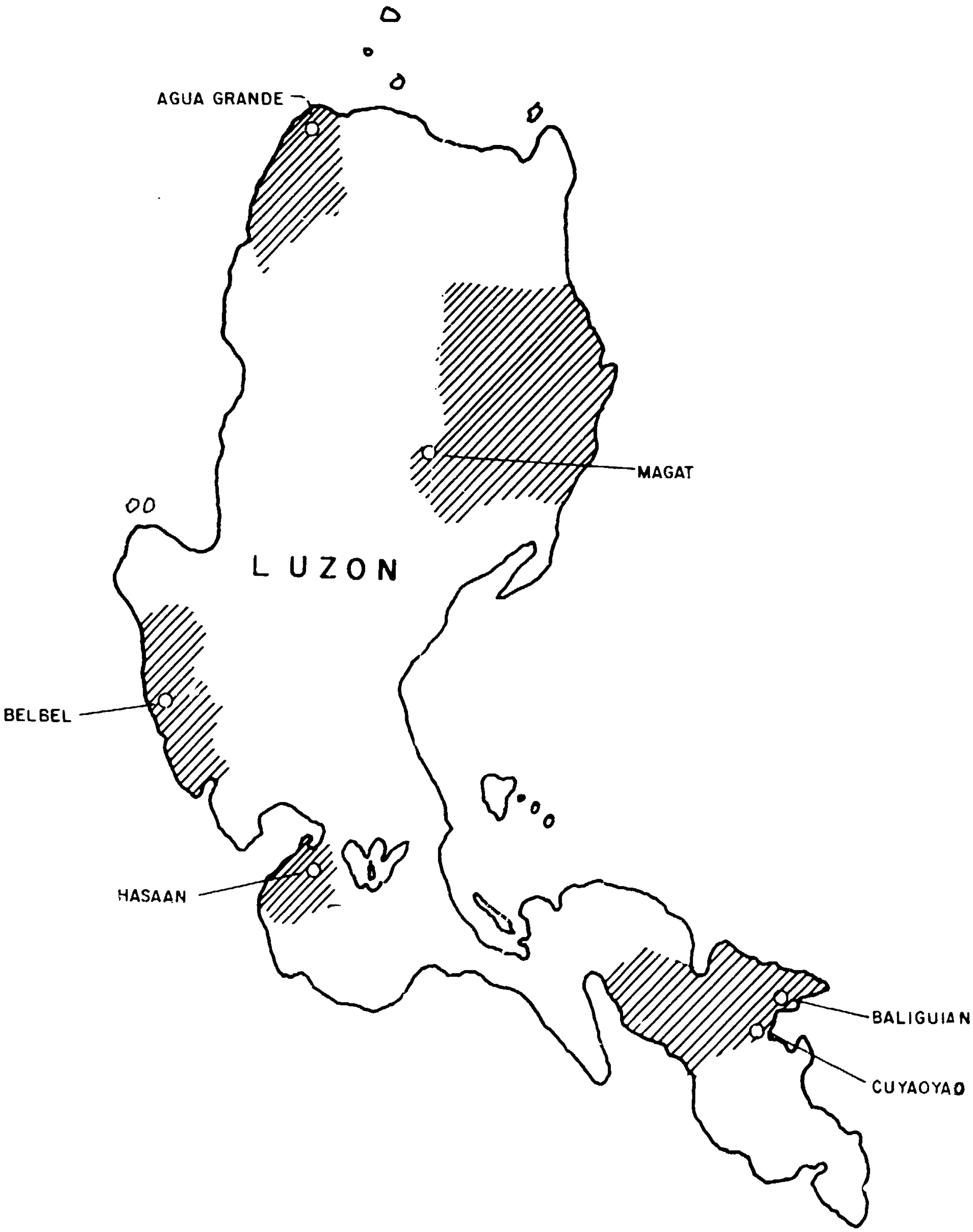
Appendix

Illustrative Case Studies of Mini-Hydro Sites

Taken from the Report of
Engineering & Power Development Consultants Limited
funded by Overseas Development Administration, London

MINI - HYDRO SITES WITH DETAILED COST DATA

Figure 1



REPORTS ON INDIVIDUAL SITES

Bel Bel (Zambales Province)

The Balin Baguero River, a tributary of the Bucao River, falls through a series of falls and rapids near the village of Bel Bel, near Moraza (see Fig. 2). This is some way inland from the existing grid which extends along the coastal plain. The initial hydro power development here would serve the local towns and villages. The power station layout would allow for addition of one or two generating units as required, to meet growth in use of electricity and extensions of the local grid, especially when it can be connected to the main grid as is planned.

There are a number of small villages and one small town in the area. The population of Zambales was about 0.4 million in 1975. A typical monthly peak demand was about 6 MW.

There are no regular measurements of river discharge on or near the Balin Baguero river but estimates of river flow at Bel Bel were 0.6 cumecs (in March 1978) and 1.8 cumecs (in November 1979). The stream flow is estimated to fall to about 0.35 cumecs in a dry period.

The proposed layout is shown on the Plan, Figure 3. A small concrete dam is located just downstream of a confluence of a tributary with the Balin Baguero. The dam is designed to pond up water and direct it into a pipeline. The pipeline runs along a contour until it reaches a point above the power station. From here a steel pipeline runs down to the power station.

The proposed initial installation comprises two 170 kW impulse turbines rated at 40 m net head. Each machine would take 0.6 cumecs for full load output.

Estimated capital costs and energy costs are given in Table I. Annual energy production from the scheme has been derived from Figure 4 the estimated flow duration curve.

After the station is linked to the Zambales electricity network then additional sets may be justified.

Agua Grande (Ilocos Norte Province)

The Agua Grande river is situated in the municipality of Bangui in the north of Ilocos Norte. (See Figure 7). The river falls directly to the sea in a series of falls and rapids within a narrow valley.

The population of Ilocos Norte was almost 0.4 million in 1975. In 1979 a typical monthly peak demand was about 7 MW.

A grid network is being extended close to the Bangui area and the power station can be connected to the grid as soon as it is constructed.

There are no regular measurements of river discharge on or near the Agua Grande river, but a flow of 1.5 cumecs was observed at the proposed dam site in December 1979 and 0.4 cumecs at the power station site in May 1980.

The scheme of development consists of a low dam across the river, just downstream of a major tributary. There is a small waterfall on the Agua Grande river but this would be upstream of the dam site. Consequently the additional head from the falls will be unavailable to the scheme. The additional flow from the major tributary, which would be unused if the dam were placed at the falls, is of greater value to the scheme than the additional head from the waterfall. The dam would include an intake to a 1.5 km nearly horizontal concrete pipeline which, in turn, connects to a steel penstock. The penstock connects to the power station located just upstream of the existing coastal road. The gross head is about 200 m. The scheme is illustrated on Figure 8.

Estimated costs are given in Table 3. Annual energy production from the scheme has been derived from Figure 9, the estimated flow-duration curve.

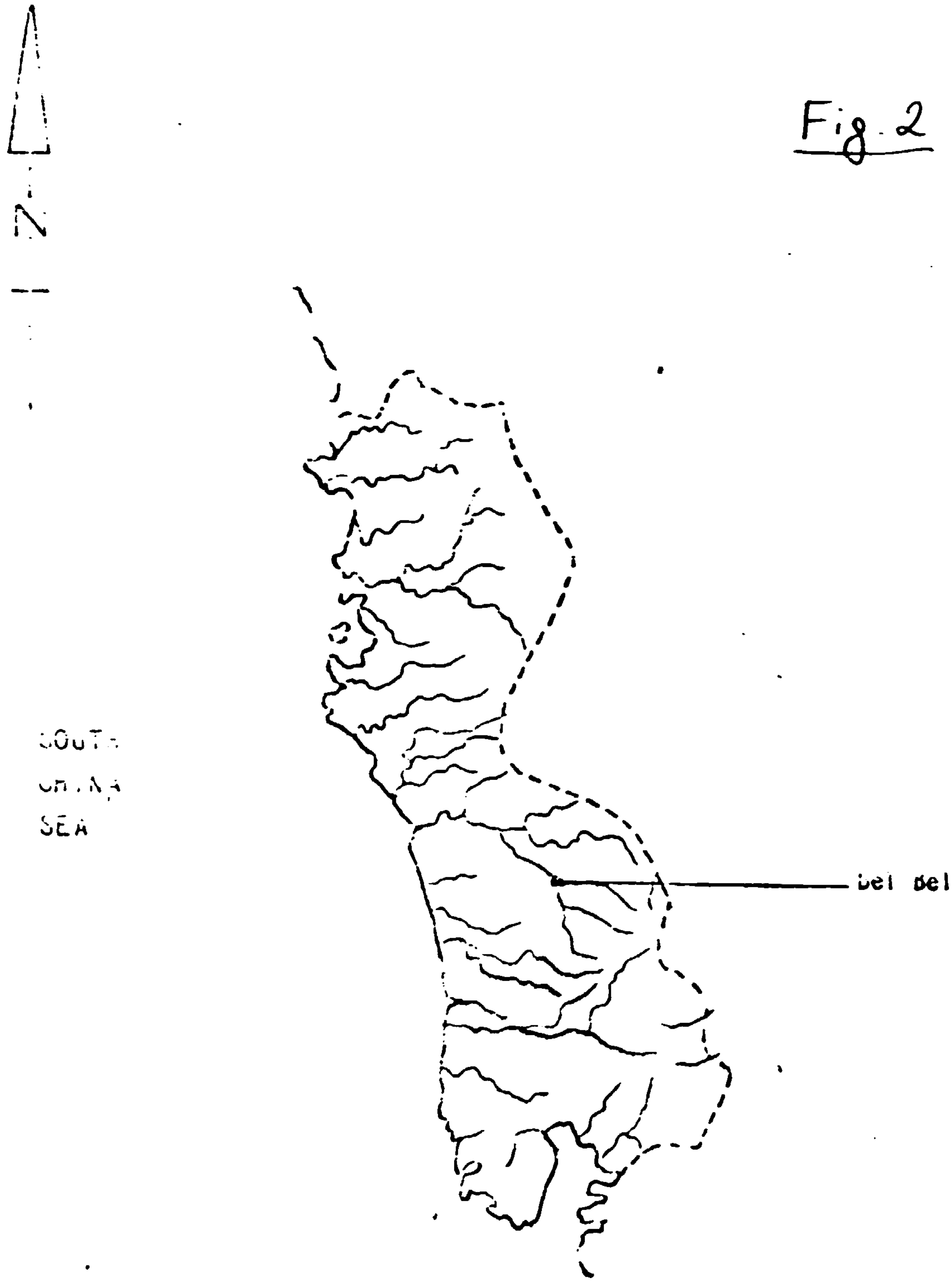
Based on the limited hydrological information available for this site, our preliminary economic analysis indicates an installation of approximately four units, each of 910 kW capacity under 185 m net head. It is possible that the estimated flow-duration curve somewhat under estimates or over estimates the true long-term averages for the site, e.g. by 20 or 30 percent. However, the site is clearly so attractive that commencement of development need not be delayed until a few years direct observations are available.

The recommended solution is that the project be planned to permit ultimate extension to 4 or 5 units, but that the initial installation should be of three 910 kW machines. A basis will exist for a decision on extension, after there has been two or more years experience with three units in service. There should then be reasonably reliable data on the availability of larger flows.

Agua Grande (Continued)

This recommendation takes account of the very similar opportunity nearby at Don Maxino Falls on Mabagabog Creek. This site will be dealt with in Part 2 of this EPDC Report. It appears that identical generating units can be employed at Mabagabog Creek, also at very attractive costs per kWh.

Fig. 2



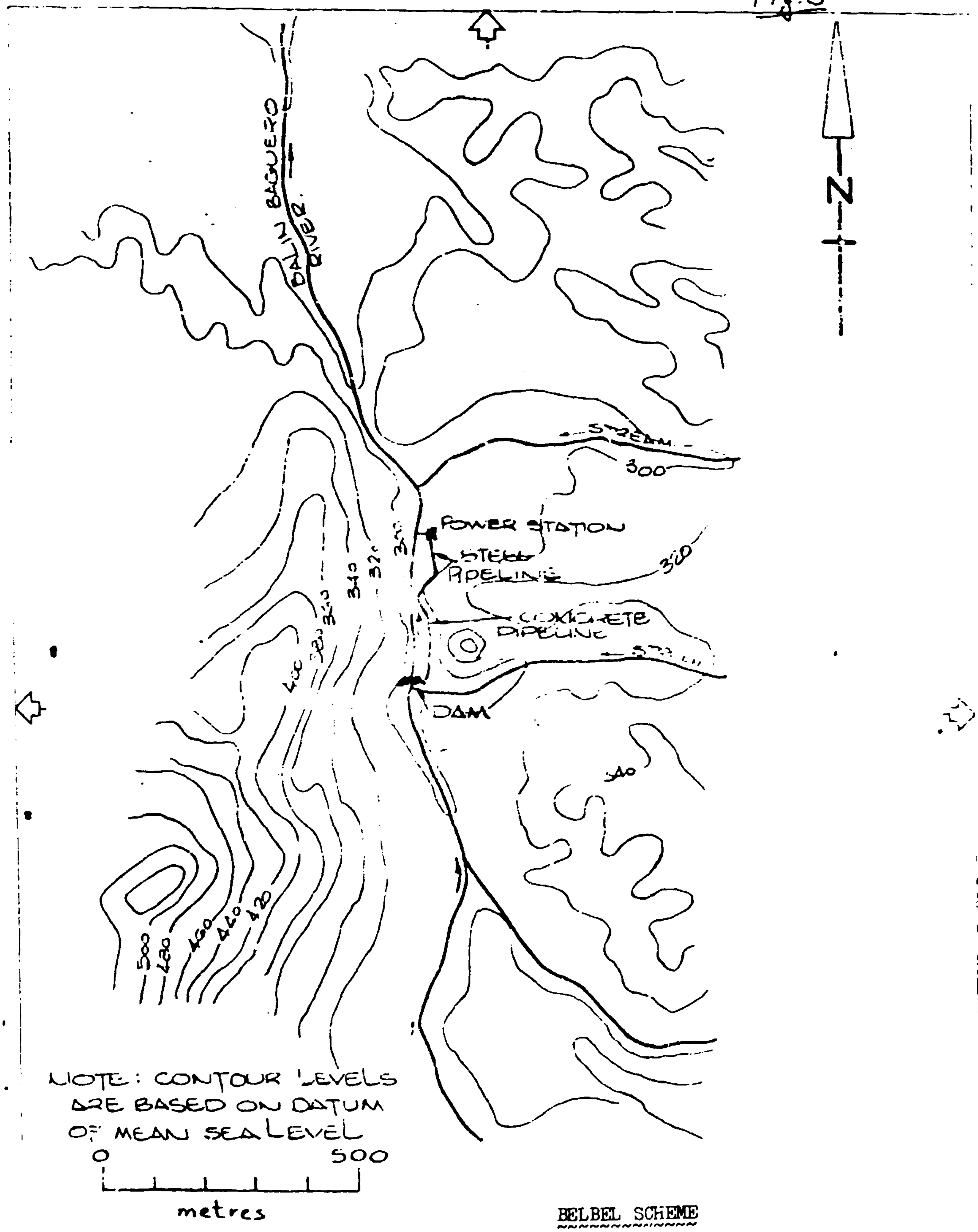
LEGEND

- RIVER
- PROVINCE BOUNDARY
- COASTLINE
- LOCATION OF MINI-HYDRO SITE

0 10 20 30 40 50 KM

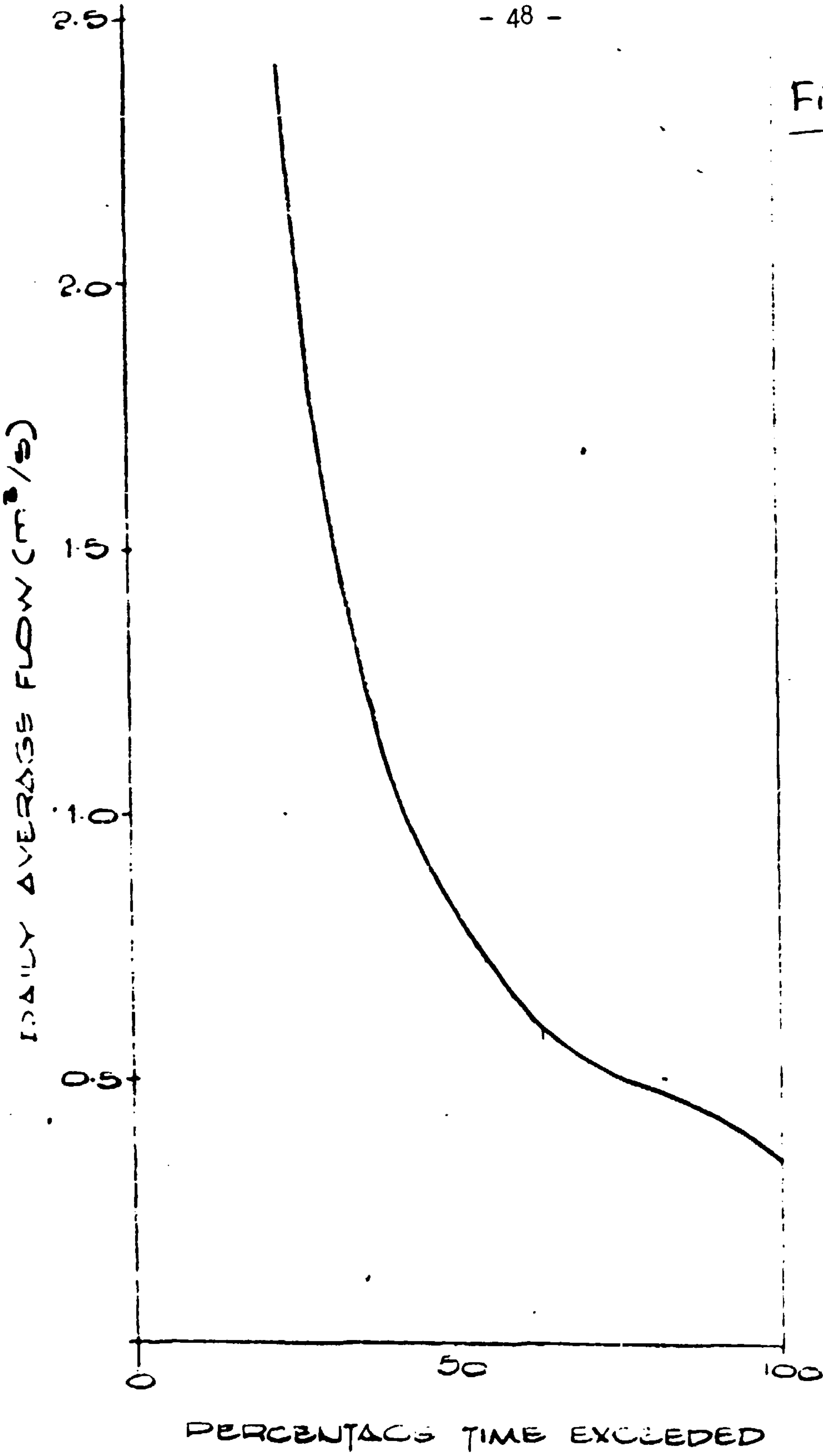
LOCATION MAP OF ZAMBALES

Fig.3



BELBEL SCHEME

Fig. 4



NOTE
CURVE BASED ON 11 YEAR RECORDS OF THE SAME RIVER AT A POINT FURTHER DOWNSTREAM

FLOW DURATION CURVE
BELBEL SCHEME

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Philippines Mini-Hydro Belbel Scheme, Zambales

Input Data

Mannings in Value: Concrete	0.0150	Steel	0.0120
Concrete (Per Cu. M.)	730.0	Conc Pipe (Per M.)	1050.0 * (Diam)**1.90
Excavation (Per Cu.M.)	30.0	Steel (Per Tonne)	43700.0
Canal Lining (Per M.)	50.0	Access Road (Per M.)	40.0

A and E Fees Assumed 15.0 percent of Civil Costs

Contingency (Percent) E and M 10.0 Civil 15.0

Flow Duration Curve (Percent - Cu.ME/SEC)

100 0.26 90 0.42 80 0.48 70 0.54 60 0.65 50 0.811 40 1.10 30 1.711 20 3.00 10 4.00

Max Number of Sets 6 at 170 KW using 0.60 CU.ME/SEC per Machine

Gross Head 42.0

Powerhouse: 74000 for One Unit, Plus 45000 for each additional Unit, (Pesos)

Estimated Quantities:

Volumes (Cu. M.) Dam		Intake	10.	Excavation 2000	
Concrete Pipeline (M)	250	Steel Penstock (11)	80		
Canal Length (M)	0	Access Road (M)	12000		

Optimisation

Number of Machines	1	2	3	4	5	6	
Cost of Concrete Pipe	188478	287998	368239	441661	511068	563569	Pesos
Cost of Steel Pipe	428731	548278	639658	709950	773213	822417	Pesos
Optimum Conc Dia	0.840	1.050	1.195	1.315	1.420	1.495	Metres
Optimum Steel Dia	0.610	0.780	0.910	1.010	1.100	1.170	Metres

TABLE IA

08-JUL-80 14:37:55

PHILIPPINES MINI-HYDRO BELBEL SCHEME, ZAMBALES

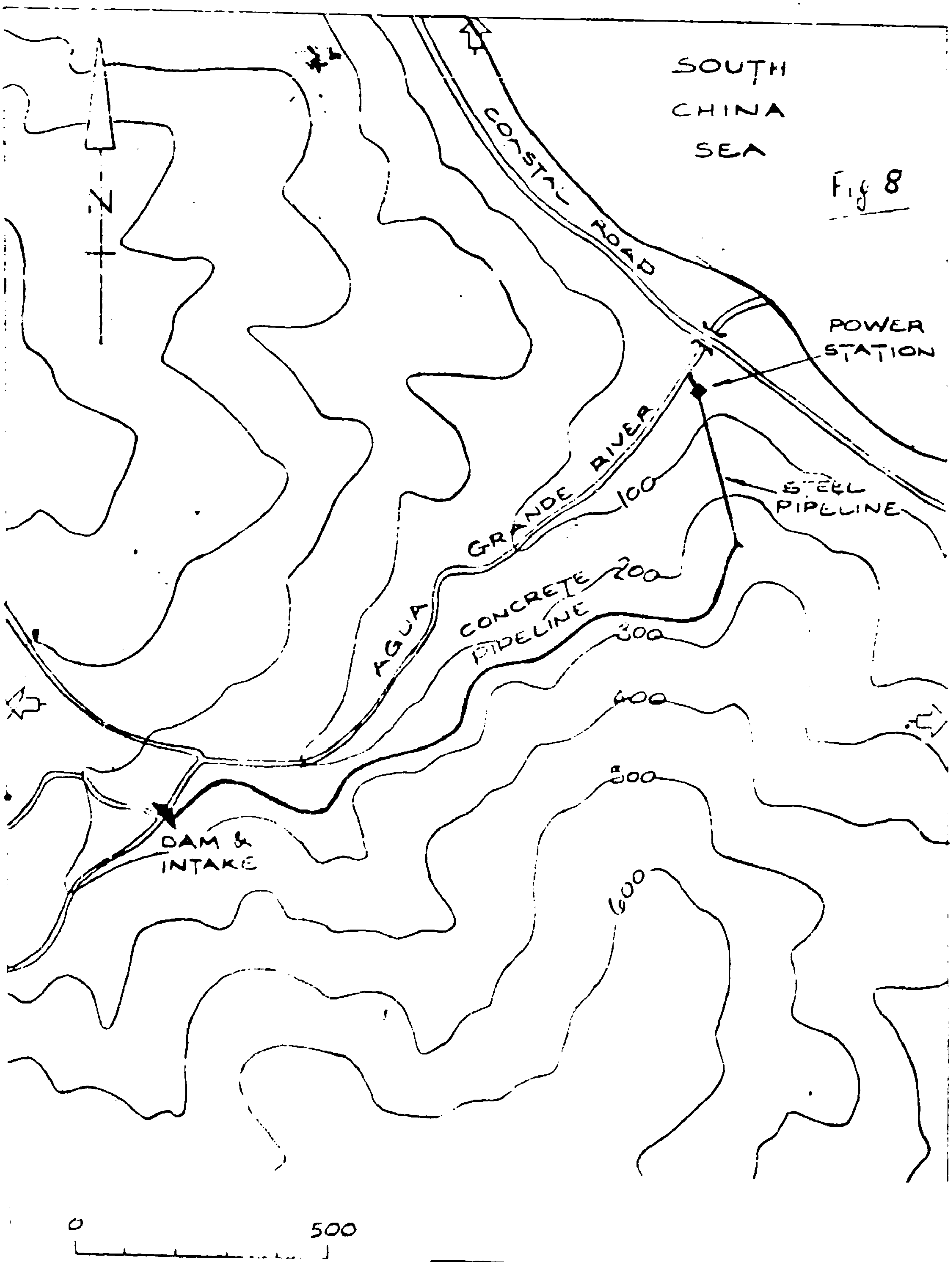
NUMBER OF MACHINES	1	2	3
MAXIMUM FLOW (CU.M/SEC)	0.585	1.175	1.765

CIVIL CONSTRUCTION COST BREAKDOWN

DAM	131.400	131.400	131.400
INTAKE	7.300	7.300	7.300
CONCRETE PIPE	188.478	287.008	368.239
STEEL PENSTOCK	428.781	548.278	630.658
ACCESS ROAD	480.000	480.000	480.000
EXCAVATION	60.000	60.000	60.000
CANAL	0	0	0
POWERHOUSE	74.000	119.000	164.000
CIVIL COST	1,369,959	1,633,077	1,850,507
A + E FEES	205,[illegible]	245,506	277,580
CIVIL CONTINGENCY	236,218	281,861	310,098
E + M PLANT COSTS	1,700,000	3,400,000	5,000,000
E + M CONTINGENCY	170,000	340,000	510,000
OVERALL COST ( )	3,681,771	5,000,034	8,057,413
ANNUAL REPAYMENT	368,177	500,093	805,741
NET ANNUAL ENERGY	1,374,419	2,115,343	2,628,606
UNIT COST PER KWH	0,268	0,279	0,307
INCREMENTAL COST	0,268	0,300	0,420
UNIT COST PER KW	21,657	17,356	15,709

TABLE 13

4	5	6	
2.356	2.050	3.546	
131.400	131.400	131.400	PESOS
7.300	7.300	7.300	PESOS
441.661	511.068	563.569	PESOS
700.950	773.213	822.417	PESOS
480.000	480.000	480.000	PESOS
60.000	60.000	60.000	PESOS
0	0	0	PESOS
200.000	254.000	299.000	PESOS
2,039,311	2,216,0[illegible]	2,[illegible],697	PESOS
305,[illegible]	332,517	[illegible],557	PESOS
351,7[illegible]1	3[illegible],[illegible]	437,736	PESOS
6,700,000	8,400,008	10,100,008	PESOS
680,000	850,000	1,020,000	PESOS
10,176,088	10,291,055	14,345,074	PESOS
1,017,600	1,228,106	1,434,597	PESOS
3,041,341	3,386,404	3,652,706	KWH
0,335	0,363	0,393	PESOS PER KWH
0,514	0,619	0,775	PESOS PER KWH
14,066	14,440	14,065	PESOS PER KWH



AGUA GRANDE SCHEME
ILOCOS NORTE

TABLE 3A

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PHILIPPINES MINI-HYDRO AGUA GRANDE RIVER, IDCOS NORTE

INPUT DATA

MANNINGS N VALUES: CONCRETE 0.0150 STEEL 0.0120

CONCRETE (PER CU M) 730.0 CONC. PIPE (PER M.) 1050.0 *(DIAM)**1.00

EXCAVATION (PER CU.M.) 60.0 STEEL (PER TONNE) 43700.0

CANAL LINING (PER M.) 50.0 ACCESS ROAD (PER M.) 40.0

A + E FEES ASSUMED 15.0 PERCENT OF CIVIL COSTS

CONTINGENCY (PERCENT): E+M 10.0 CIVIL 15.0

FLOW DURATION CURVE, (PERCENT, CUMEC)

100, 0.10, 90, 0.21, 80, 0.34, 70, 0.51, 60, 0.75, 50, 1.16, 40, 1.58, 30, 2.13, 20, 2.80, 10, 4.10

MAX. NUMBER OF SETS 6 AT 510 KW USING 0.68 CUMEC PER MACHINE

GROSS HEAD (M) 101.0

POWERHOUSE: 74,000 FOR ONE UNIT, PLUS 45,000 FOR EACH ADDITIONAL UNIT (PESOS)

ESTIMATED QUANTITIES

VOLUMES (CU.M.): DAM	400	INTAKE	0	EXCAVATION	20,000
CONCRETE PIPELINE (M):	1,450	STEEL PENSTOCK (M)	380		
CANAL LENGTH (M)	0	ACCESS ROAD (M)	100		

OPTIMISATION

NUMBER OF MACHINES

COST OF CONCRETE PIPE	1,168,543	1,888,307	2,433,647	2,865,324	3,227,285	3,543,965	PESOS
COST OF STEEL PIPE	2,141,014	2,998,513	3,700,130	4,212,162	4,619,437	4,974,055	PESOS
OPTIMUM COND DIA	0.870	1.120	1.280	1.395	1.485	1.560	METRES
OPTIMUM STEEL DIA	0.600	0.770	0.890	0.970	1.030	1.080	METRES

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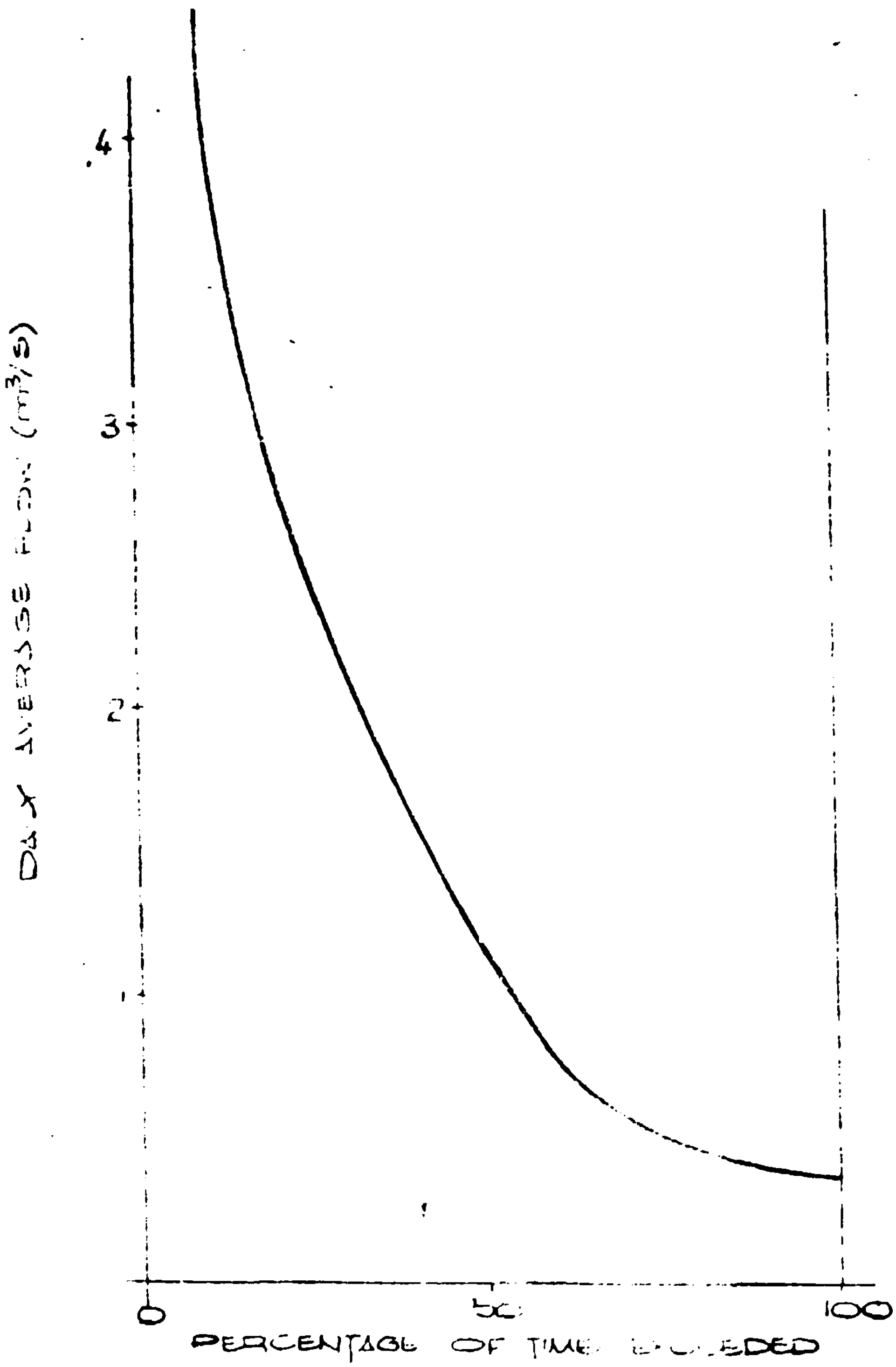
PHILIPPINES MINI-HYDRO AQUA GRANDE RIVER, ILOCOS NORTE

NUMBER OF MACHINES	1	2	3	4	5	6	
MAXIMUM FLOW	0,640	1,283	1,928	2,582	3,248	3,919	CUMECS
CIVIL CONSTRUCTION COST BREAKDOWN							
DAM	292,000	292,000	292,000	292,000	292,000	292,000	PESOS
INTAKE	0	0	0	0	0	0	PESOS
CONCRETE PIPE	1,168,543	1,888,307	2,433,647	2,865,824	3,227,285	3,543,965	PESOS
STEEL PENSTOCK	2,141,014	2,993,513	3,700,130	4,212,162	4,619,437	4,974,055	PESOS
ACCESS ROAD	4,000	4,000	4,000	4,000	4,000	4,000	PESOS
EXCAVATION	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	PESOS
CANAL	0	0	0	0	0	0	PESOS
POWERHOUSE	74,000	110,000	164,000	200,000	254,000	290,000	PESOS
CIVIL COST	4,879,558	6,501,820	7,793,776	8,732,086	9,596,723	10,313,020	PESOS
A + E FEES	731,934	975,273	1,169,066	1,317,448	1,439,509	1,546,953	PESOS
CIVIL CONTINGENCY	841,724	1,121,564	1,344,426	1,515,060	1,655,435	1,778,096	PESOS
E + M PLANT COSTS	6,289,999	12,579,998	18,869,998	25,159,996	31,449,998	37,739,996	PESOS
E + M CONTINGENCY	629,000	1,258,000	1,887,000	2,516,000	3,145,000	3,774,000	PESOS
OVERALL COST	13,372,214	22,436,656	31,064,268	39,291,406	47, 86,668	55,152,064	PESOS
ANNUAL REPAYMENT	1,337,221	2,243,666	3,106,427	3,929,150	4,728,667	5,515,297	PESOS
NET ANNUAL ENERGY	6,630,797	11,070,736	14,205,766	16,505,309	18,197,218	19,353,202	KWH
UNIT COST PER KWH	0,202	0,203	0,217	0,237	0,260	0,285	PESOS PER KWH
INCREMENTAL COST	0,202	0,204	0,268	0,358	0,400	0,678	PESOS PER KWH
UNIT COST PER KW	14,605	12,328	11,379	10,704	10,393	10,101	PESOS PER KW

TABLE 3B

Fig. 9



NOTE:
CURVE IS BASED ON 4 YEARS
RECORDS AT A GAUGING
STATION OF A DIFFERENT
RIVER WITH A LARGER
CATCHMENT AREA

FLOW DURATION CURVE
AGUA GRANDE