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Togo

An assessment of decentralized hydropower potential

NRECA Small Decentralized Hydropower (SDH) Program

Togo: An assessment of decentralized hydropower potential*

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PREFACE

This report was prepared by Paul J. Clark, SDH Program staff member, based on a study of Togo's decentralized hydropower potential performed by NRECA consultants Walter Lawrence, Tobie Lanou, and Paul Kirshen in April 1981. The team's report, "Togo Small Decentralized Hydropower Study" (July 1981) was subsequently found to contain errors in the economic analysis of two potential hydro projects studied by the team. In general, this report follows the findings and text of the original report, but with modifications in the economic aspects of the study. Except where noted, the data contained in this report were drawn from information collected during the team's visit to Togo in 1981. The reader should be particularly mindful of this in the section **Economics**, where economic data and energy-supply and demand estimates are found. It is NRECA's view, however, that more recent data would not alter the general conclusions of this report.

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ABBREVIATIONS AND TERMS

NRECA - National Rural Electric Cooperative Association

GOT - Government of Togo

CEET - Compagnie Energie Electrique du Togo

AID - U.S. Agency for International Development (USAID)

CEB - Communante Electrique du Benin

mm - milimeters

m^3 - cubic meters

cms - cubic meters per second

km - kilometers

kW - kilowatts (power, capacity)

kWh - kilowatt hours (energy)

kV - kilovolts

kVA - kilovolt amperes

NPW - net present worth

ERR - economic rate of return

O&M - operation and maintenance

OCB - oil circuit breaker

Exchange Rate — 350 CFA Francs = $US 1

SUMMARY

INTRODUCTION

Early in 1981, the Government of Togo (GOT) requested AID's assistance in preparing a country-wide survey of small decentralized hydropower potential. The primary focus of this study was to identify sites where small hydro installations could serve the energy needs of remote off-grid communities. In Apil 1981, the National Rural Electric Cooperative Association (NRECA), through its Small Decentralized Hydropower Program, provided a team consisting of an economist, a hydrologist, and an engineer for three weeks in Togo to undertake the study. This report presents the findings and recommendations of that team.

TERMS OF REFERENCE

Due to the shortness of the team visit, the country survey had to be of a preliminary nature and limited to known sites with reasonable ease of access. The GOT and international agencies in Togo provided available information on 17 potential hydro sites ranging from waterfalls to an existing dam and reservoir. Following field reconnaissance of 10 sites, listed in Table 1 and shown geographically in Fig. 1 the sites were rated according to initial information on monthly waterflow characteristics, power and energy potentials, proximity of potential users of electricity, and their energy demand characteristics, ease of access for construction, a judgment on construction costs, and, in two cases, more detailed construction cost estimates.

Table 1. List of Sites, Togo Hydropower Site Survey

Site	Site Name (Village)	Location
Sites Inspected in the Field		
1.	Borgou	East of Dapaong on the Sasargou River
2.	Kankanpieni	East of Dapaong on the Bamoana River
3.	Londa Pozenda-Kara	East of Lama-Kara on the Kara River
4.	Londa Pozenda-Sara	East of Lama-Kara on the Sara River
5.	Bougoulou	South of Bassar on the Mo River
6.	Legouanselande	NW of Sokode on the Mo River
7.	Ezime	West of Atakpame on Koulasson River
8.	Tomegbe	South of Badou on the Domi River
9.	Alokoegbe	West of Tsevie on the Sio River
10.	Wonougba	SE on Palime on the Sio River
Other Potential Sites		
A.	Missahohe	North of Palime
B.	Yipka	North of Palime on the Agoumassa River
C.	Djedrame	North of Palime on the Danyi River
D.	Bogon	South of Bassar on the Mo River
E.	Souroukou	South of Bassar
F.	Mandoundja	West of Kante on the Kara River (site of UNDP and FED projects)
G.	Nangbeto [1]	East of Atakpame on the Mono River

[1] Project under construction with World Bank funding.

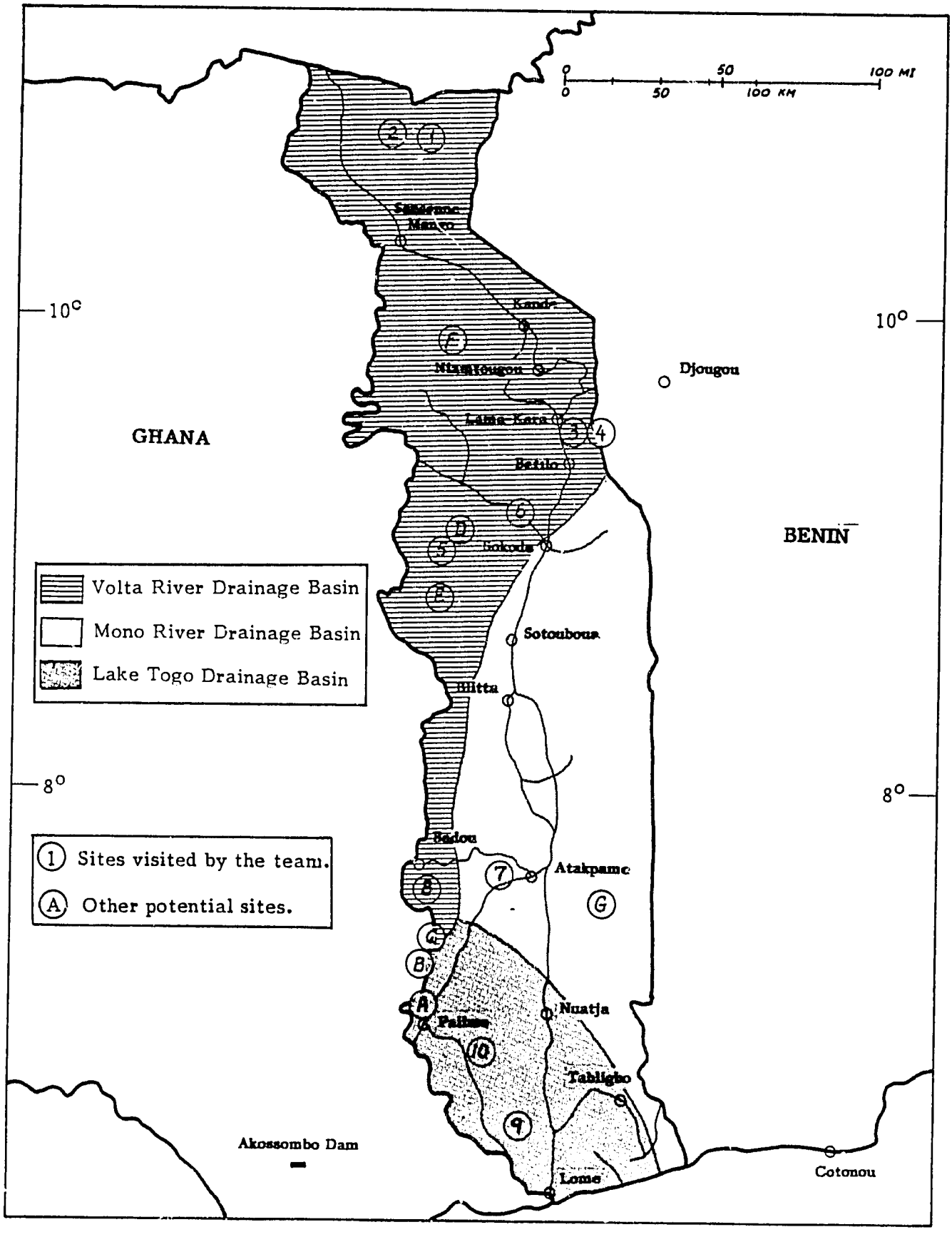

Fig. 1. Map of Togo showing potential small hydro sites and major drainage basins.

GENERAL FEATURES OF TOGO

The shaded areas in Fig. 1 delineate the three main geographic, demographic, and climatic zone features of Togo, which spans a latitude range of about 6°-11° N. Climate is mixed—the south is humid much of the year with temperatures ranging from 76-90 $^{\circ}$F (23-32 $^{\circ}$C). In the north, temperatures range from 65-100 $^{\circ}$F (18-38 $^{\circ}$C) while the rainfall pattern and hot winds combine to make the north area comparatively arid with many streams going dry from November to early spring. The majority of Togo's population and economic activity are concentrated in the southern half of the country.

Physical features

The climate, topography, and geology of Togo combine to make economically attractive small hydropower sites difficult to find.

Climate

Even though the average annual rainfall is greater than or equal to 1000 mm throughout the country, it is concentrated in one or two wet seasons. This results in highly seasonal rainfall, with months of zero or extremely low precipitation and then periods of extremely heavy rainfall. Moreover, the climate is generally quite arid, resulting in high evaporation rates.

Topography

Togo is a very flat country, except in several areas in the southern half. Consequently, reservoir sites over most of the country are hard to find and the large exposed area of those that can be developed experience exceptionally high evaporation rates, limiting the value of storage dams.

Geology

Rock outcroppings are evident over much of Togo. Although making the terrain favorable for construction, the apparent rock layer prevents percolation of water deep into the soil, resulting in relatively little return flow into the river systems. Consequently, the streamflow pattern follows the highly seasonal rainfall pattern.

Economic features

About 78% of the labor force is engaged in agricultural production, principally yams, manioc, millet, sorghum, cocoa, coffee, and rice. A major industrial export activity is production of phosphates (over 2 million tons/year). A phosphoric acid plant is under construction. Export of cement clinker from extensive in-country limestone deposits is planned in the near future.

Power consumption in Togo, which was 151 x 10^6 kWh in 1980, is expanding rapidly. Between 1978 and 1980, the overall growth in electricity consumption was 37%. Most of this power is supplied by the Communaute Electrique du Benin (CEB) which purchases power from the huge Akossombo Dam in nearby Ghana. All but 7% of power consumption occurs along the coastal transmission grid in the southern part of the country. The remaining power consumption, in the provincial areas north of the grid, is supplied from diesel generators. Power consumption in these areas between 1978 and 1980 grew by 75%. Until plans to extend the grid northward to serve these areas are implemented, the

rapidly growing power demand in the rural sector will have to be supplied by decentralized sources, which for the present are diesel generators.

METHODOLOGY USED IN THIS STUDY

The utilization of water flowing downhill involves impounding or rerouting the water so that the drop in elevation occurs at one place--the basic criterion for site selection. The sites selected for study by the team are at known falls or at places where the river channel gradient is steep enough to direct water from the river on a flatter gradient to a point where it can be dropped over a short distance to generate power and be returned to the river or another water course. Another type of site would form a reservoir behind a main dam (saddle dams frequently are needed in addition to the main dam). One of the sites studied is an existing dam built for agricultural water supply.

Isolated sites

Ideally, an isolated site would provide water with the same flow day after day throughout the year plus have the ability to vary that same total daily flow according to the changing hourly electrical-energy requirements. In general there is a wide range of hourly variation patterns from constant process loads to the more typical village rural loads which, during initial development stages, would be small during daylight hours and many times as much during nighttime lighting hours. As load magnitudes and diversity increase with time, that ratio would decrease and accordingly would become more favorable.

After examination of river stage and flow data, it was evident that the flows were very seasonal. In many instances, particularly in the north, flows drop to zero flow several months each year. Efforts were made to find reservoir storage sites with sufficient volume to regulate flows evenly by months, but this proved impossible for the sites studied. Accordingly, the use of seasonal hydro energy for feeding into the national grid to displace thermally generated electricity was considered. Although the existing national system is and will continue to be dependent largely on imported hydro generation, diesel installations will be the prime generation sources for the presently isolated systems in the central and north sections, away from the so-called Maritime coastal system connected to the large Akossombo hydro plant in Ghana. It would be profitable to run the hydro stations and shut down the diesels during periods of hydro availability since the cost of hydro generation is much less than the cost of diesel fuel. Economic analyses in this report will illustrate this principle.

Grid-tie sites

The function of small hydro plants in an interconnected system is determined by the principle of economic dispatch, whereby generation sources having the lowest marginal cost are used first, supplemented by progressively higher-cost sources as loads increases. Where the hydro construction is limited by hydrologic conditions, two patterns generally occur. If the small hydro plant can be operated for short periods of time (because water storage capacity is small), but at any point during the year, the hydro energy is used to provide peaking power (kW) and energy (kWh), with base loads served by large hydro and thermal plants. The small hydro plant therefore replaces high-cost sources, such as gas turbines, which are otherwise operated for short periods of time when electricity demand in the system is highest. A necessary condition is that the small hydropower capacity is available at all times, otherwise its usefulness as a peaking power source is limited.

A second application of small hydro in an integrated mode is when the plants have considerable generating capability part of the year, but little or no generating capability at other times. This is the situation in Togo, in most cases, due to the generally uneven streamflow pattern. The role of such plants is limited to energy (kWh) substitution, with little or no capacity (kW) benefit. In such cases, the small hydro plant is most profitably used as a substitute for thermal plants or other more costly sources at all times when hydro generation is possible, enabling the latter (which have high specific fuel-consumption rates at low loads) to be shut off.

CONCLUSIONS AND RECOMMENDATIONS

Physical and economic conditions in Togo tend to conspire against using small hydro as a means to serve isolated loads, for the most part. In general, hydrologic conditions are the greatest impediment to this type of development—radically uneven rainfall and resulting streamflow patterns and rapid evaporation of water which otherwise could be stored behind dams. Where projects might be technically feasible in remote areas, moreover, demand for electricity is quite low, limiting the potential return on investment.

Table 2 summarizes the team's site-survey findings, and ranks projects as "poor," fair," or "good." The most promising hydropower area is the hilly region running north and slightly east from north of Palime, roughly at a point where the three geographic zones converge (see Fig. 1). Higher-head and deeper valley sites, plus a better hydrologic pattern make this area attractive. Moreover, this area is the most prosperous area in the country outside Lome, providing a relatively sound economic basis for hydropower investments. Electricity demand in this area is presently served by small diesel stations.

Sites in this "good" hydropower zone are generally larger than the capacity range the team was directed to study, averaging 2-5 MW. These are high-head sites, meaning relatively low per-kilowatt construction cost, and are capable of generating electrical energy at favorable costs. Even in these cases (e.g. Tomeghe and Ezime), however, the output is seasonal, making them most suitable for feeding energy into a larger power system on a fuel-substitution basis. Seen in this context, such sites appear to be excellent energy investment opportunities.

The Compagnie Energie Electrique du Togo (CEET) estimates that the average full cost of generating power from diesels in 1981 was $0.21/kWh,* with two-thirds of that cost going to purchase fuel from foreign exchange reserves annually. These costs are expected to increase. Electricity tariffs in Togo in April 1981 reflected an average sales rate of $0.055/kWh, meaning that the average CEET subsidy to users of diesel-generated power was $0.159/kWh, roughly equal to the entire fuel cost. Recently announced tariff increases would reduce the cost of this subsidy somewhat, but even at the new average tariff of $0.097/kWh, the financial consequences of meeting growing power demand by means of diesel generation remain considerable.

In light of these consequences, it is recommended that decentralized hydropower sources be considered as a cost-saving strategy for Togo's national power program. Such hydropower plants in Togo, however, would not add generating capacity, due to the

*All figures given in this report are based on a currency exchange rate of 350 CFA/$U.S.

Table 2. Site Evaluation Summary

Site No.	Site	Location	Estimated Average Annual Energy Production (kWh)	Power (kW)	Overall Feasibility Evaluation	Comments
1	Borgou	E. of Dapaong	Not calculated	-	Poor	No flow 4 months of year
2	Kankanpieni	E. of Dapaong	Not calculated	-	Poor	No flow 4 months of year
3	Londa Pozenda-Kara	E. of Lama-Kara	790,000	200	Fair	Fairly steady flow for 6 months with low month flow of 0.06 cms. Power benefit is fuel replacement value.
4	Londa Pozenda-Sara	E. of Lama-Kara	200,000	55	Poor	Unit energy cost appears prohibitive.
5	Bougoulou	S. of Bassar	4,900,000	1,250	Fair	Fairly steady flow for 6 months and potential head of 15 meters combine to a significant generation potential, but only for fuel replacement.
6	Legouanselande	NW of Sokode	390,000	100	Poor	Reasonably close (15 km) to Sokode load area, but seasonal flow and generation indicate value for fuel replacement only.
7	Ezime	W. of Atakpame	10,500,000	2,500	Good	Hydrological calculations are conjectural, but site has high head and good minimum flow.
8	Tomegbe	S. of Badou	30,000,000	8,000	Good	Hydrological calculations are conjectural, but site has high head and good minimum flow. Project shows a very favorable return on capital.
9	Alokoegbe	W. of Tsevie	Not calculated	-	Poor	Head would be only the drop from the head gate to the canal and accordingly very small much of the time.
10	Wonougba	SE of Palime	690,000	160	Fair	Project has reasonably good production characteristics, but only for fuel replacement

Feasibility evaluation factors are defined as follows:

Good - Favorable stream flow pattern (observable minimum flow); site development problems and costs reasonable; favorable generation potential per unit of water flow--meaning generally, higher heads. Production costs clearly below thermal fuel costs. Reasonably close to load or future grid system.

Fair - Stream flow pattern - lower or zero minimum compared to above, but averaging enough for 6-8 months of the year to produce a reasonable output; however, production quantity marginal with respect to thermal generation within economic transmission distance.

Poor - Zero stream flow for 4-5 months per year; little chance of storage; remote from load centers or connection to the future grid system.

absence of any significant year-round firm power at the sites studied. The economic criterion on which to base the net benefits arising from these projects is the marginal cost of the next-best-alternative means of providing energy during the periods where the hydro stations can be operated. For purposes of this study, the next-best alternative was considered to be diesel generation. However, further study is necessary before a more exacting estimate of net benefits can be made. Issues requiring further study include:

- more detailed analysis of site-specific hydrologic conditions, to refine estimates of firm capacity and energy potential;
- more detailed design and cost studies of selected sites to provide better estimates of capital costs and to identify the lowest-cost design approach possible;
- more detailed analysis of power and energy demand in areas which could be served on a decentralized basis by specific plants, and for the country as a whole in order to identify load parameters for grid-tied projects;
- more detailed analysis of alternative generating sources, either existing or planned, and their costs, in order to determine actual cost savings which could be realized; and
- a general survey of site inventories which have been made, including field visits to more promising areas where potential small-to-medium grid-tie sites may be found (including existing irrigation or water supply dams) to ascertain the potential magnitude of a national decentralized hydro program.

The objective of further study would be to determine what role a decentralized hydropower program could serve in Togo's long-term electrical energy supply plan. An important aspect of the recommended follow-up study would be to understand the socio-economic consequences of such a program, including its impact on foreign exchange requirements for Togo's power supply and national security implications. Furthermore, additional study of the financial, institutional, and training requirements to implement such a program may also be warranted at some point.

HYDROLOGY

This section presents a description of the hydrologic features of Togo, including topographical features, precipitation patterns, evaporation amounts, and, finally, characteristics of the three major drainage basins of Togo.

Topography

Togo is traversed from northeast to southwest by a large plateau covered by several mountains and hills, with a maximum elevation of 1000 m. In the southwest section of the country is the large plain of the Mono River. The northwest section of the country is also flat. Foothills separate the plateau from the surrounding plain areas.

Precipitation

In the plain areas of the southeast and the northwest, the average annual precipitation is approximately 1000 mm. In the plateau areas, the precipitation is approximately 1400 mm. There are two major precipitation (and streamflow) regimes in Togo—Sudan and Guinean.

The Sudan-type occurs generally north of 8° N and is characterized by a rainy season from March through October and dry season (often with no rain) from November through February. The heaviest rainfall occurs in the months of August and September.

The Guinean climate, generally south of 8°N, is characterized by two rainy seasons with a drier period in between. The two rainy periods are usually March through July (with a peak in June) and September through November (with a peak in October). The second rainy season is less distinct than the first and has less rainfall, sometimes with no rainfall at all during drought years.

In the Sudan region, the rainfall is in short, high intensity showers. In the Guinean region, the first wet season starts with short-duration, high-intensity storms and ends with longer-duration, less intense storms (i.e. monsoon pattern). The second wet season starts with monsoon type rains and ends with short-duration, high-intensity storms. In both regions, the amount of the annual rainfall can vary considerably from one year to the next. This is particularly true in the Sudan region. Periods of extreme drought also appear to occur every 30-40 years; the last major drought was in the mid-1970s.

Evaporation

Compared to the rainfall, evaporation is relatively constant throughout the year, ranging from approximately 150 mm per month in Lome to 300 mm per month in Mango. The monthly evaporation generally exceeds the monthly precipitation, except during the rainy season.

MAJOR DRAINAGE BASINS AND STREAMFLOW

Shown in Fig. 1 are the three major drainage basins of Togo. The Oti and its major tributaries (the Koumongou, the Mo, and the Kara) drain northern Togo into the Volta River basin in Ghana. The Mono and its major tributaries (the Anie, the M'Amou, and the Kra) drain central and southern Togo into the Atlantic Ocean. The Sio, the Haho, and other smaller rivers drain southwestern Togo into Lake Togo on the southern coast.

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Because of the relatively low amounts of infiltration and groundwater storage, the streamflow regimes in each drainage basin generally follow its precipitation patterns, and exhibit the same extreme peak flow in September and extreme low flows in the spring and winter. At Sansanne-Mango, the range in flows may vary from an average of 1 cms in March to 1000 cms in September. The tributaries in the Sudan also exhibit this extreme variability; oftentimes, there is little or zero flow during the dry season. This can be seen in the hydrograph for the Sara River (see Fig. 2).

Because so much of the Mono basin is in the Sudan climate zone, the river and its tributaries usually have their peak flows occuring in September. The variations in flows are slightly less than in the Oti basin because of the transition from Sudan to Guinean climate occuring in this basin (e.g. for the Mono at Athieme, the discharge might range from 1 cms in March to 700 cms in September).

The Lake Togo basin exhibits the general characteristics of the Guinean climate; oftentimes, high flows occur in both summer and fall. This can be seen in Fig. 3, the hydrograph of the Sio River at Wonougba. Generally, the flow variation is less in the Guinean region than in the Sudan region.

METHODOLOGY FOR DETERMINING HYDROLOGIC CHARACTERISTICS

For the broad purposes of this hydropower study, there exists an adequate number of streamflow stations. However, the data for the years 1971-1980 are not available and most records start only in 1960. Since the period 1960-1970 is generally considered a wetter than normal period in West Africa, the streamflow values for the study were reduced.

To determine specific site hydrologic conditions, a site was located on a map and correlated to a guaged site based upon climate, drainage, size, and topographical similarities. The discharges at the site were then determined by adjusting the guage flow by ratios of drainage areas and precipitation quantities. This was done for all sites, except Site 7 (Ezime) and Site 8 (Tomegbe). The periods of record used at the guaged sites were 1960-1970, even though hydrologic records for a few of the sites were longer. This was done to make valid comparisons between discharges. Since the period 1960-1970 is generally considered to have had more rainfall than normal, all flow values were reduced 30% to obtain longer-term mean values. (see Fig. 2.) *

For each site, the following hydrologic characteristics were found:

- o mean annual discharge,
- o mean monthly flow of the low-flow month,
- o peak daily flow (based upon 1960-1970 period of record),
- o head (from site visits), and
- o estimates of active storage at the site.

The estimates of active storage of site were developed by determining the average channel slope at a site, determining the length of the backwater, if it only occurred in

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*The 30% reduction is a judgment factor based on experience with longer-term hydraulic records available elsewhere in West Africa.

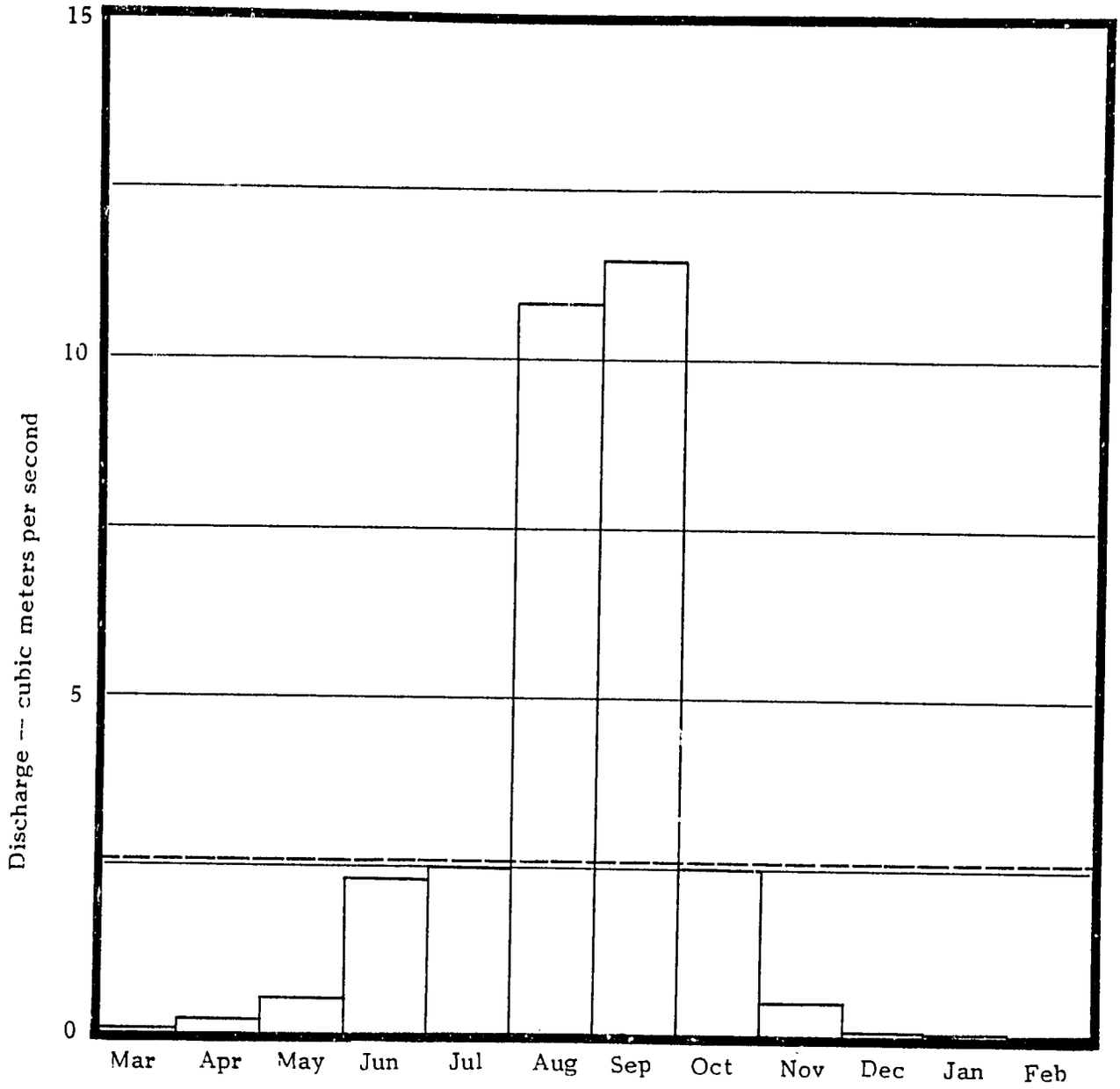

Fig. 2. Average-year hydrograph for Londa Pozenda—Sara site (typical Sudan-type average monthly discharge pattern)

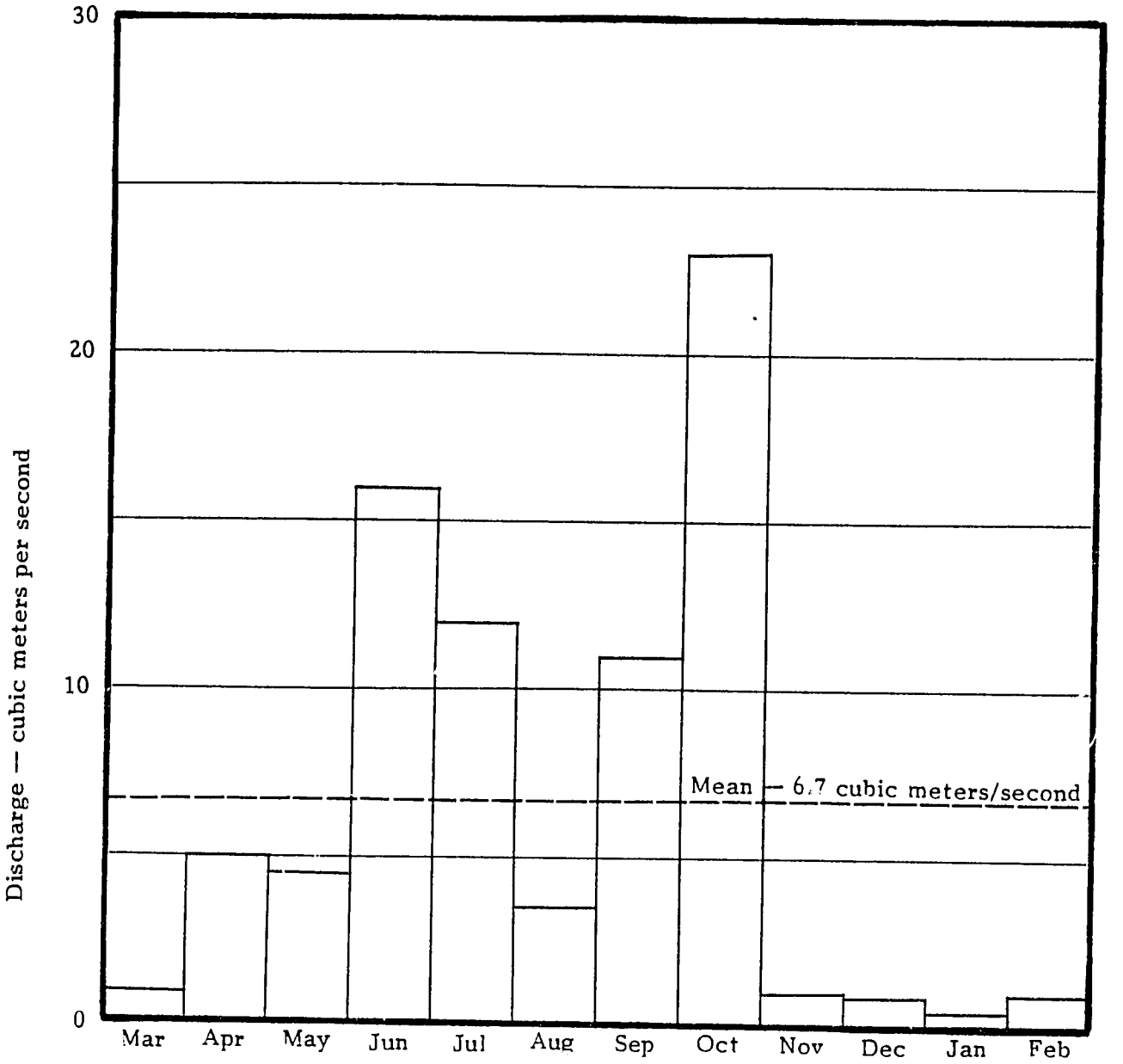

Fig. 3. Average-year hydrograph for Wonougba site (typical Guinean-type monthly discharge pattern)

one channel (by multiplying the proposed dam height by the inverse of the slope), doubling this length to account for storage in several channels upstream, and then assuming the active storage is 1 m and stored in a prism of 1 m depth and triangular area.

Because of the unique characteristics of the Ezime and Tomegbe sites, it was not possible to find guaging stations that correlated with them. Therefore, based upon the discharge that was estimated to be actually flowing when the Tomegbe site was visited and general knowledge of the hydrology of the region, design values were estimated for both sites.

Because of time and data limitations, all the design values should be considered approximate and may vary in reality by plus or minus 25%-35 %. Therefore, any site selected for development will need more discharge and storage surveys. The hydrologic data for each site are summarized in Table 3.

Table 3. Site Hydrologic Characteristics

Site No.	Name	Mean annual flow (cms)	Mean monthly low flow (cms)	Peak daily flow (cms)	Head (m)	Flow type S=Sudan G=Guinean	Design capacity (kW)	Average annual energy (kWh 10^3)
3.	Londa Pozenda on Kara River	17.6	.06	500-800	3	S	200	790
4.	Londa Pozenda on Sara River	2.6	.02	60	3	S	55	200
5.	Bougoulou	21.6	.65	430	15	S	1,250	4,900
6.	Legouanselande	4.31	.13	86	6	S	100	390
7.	Ezime	0.8	.04	16	300	G	2,500	10,500
8.	Tomegbe	4.0	.20	80	250	G	8,000	30,000
10.	Wonougba	6.7	.36	119	3	G	160	690

METHODOLOGY FOR POWER AND ENERGY ESTIMATES

Since the discharge at all the sites fluctuate considerably, rendering meaningless the concept of firm power, it was decided that the value of the hydropower sites would be limited to energy, calculated in kilowatt hours. Based on the observation that there is reasonable flow for at least five months of the year in most streams (see Figs. 2 and 3), the design flow selected was that available at least five months of the year during most years. For Sudan type streams, this was found to be approximately 50% of the total mean annual discharge. For Guinean type streams, the design flow would be approximately the mean annual discharge.It was further assumed that each site would be operated at the heads given in Table 3 and that 1 m of active storage would be available, with the exception of the Tomegbe site. Generally, the storage volumes are only sufficient to control fluctuations in daily or weekly flows. Therefore, it was assumed that flows above the design flows could not be captured. On the other hand, it was

assumed that flows occurring below the design flows could be captured. This provides 10% more energy for Sudan-type streams and 15% more energy for Guinean-type streams.

IMPLICATIONS FOR SMALL HYDRO DEVELOPMENT

The hydrologic characteristics of Togo appear to present many problems for the development of small hydropower, due to the following reasons:

- Intermittent streamflows. As was noted, the streams in Togo, particularly in the Sudanese region, exhibit extreme variation in monthly flows. Therefore, unless large storage reservoirs are built (which is unlikely, see below), very little firm power can be developed at a site compared to mean-flow conditions. The only method to capture a significant portion of the power at a site is to use a series of turbines, all of which do not operate year-round. The extreme flow variations also means that large spillways are needed, extra measures must be taken to protect against the flooding of powerhouses, and there will exist very high tailwater depths during the wet season.

- Flat terrain. Because of the flatness of the terrain, there are few large reservoir sites to compensate for the extreme flow variations. The high evaporation rate during the long dry season also decreases storage potentials.

- Heavy sedimentation. The rivers, particularly in the northern part of the country, carry large sediment loads. This can fill reservoirs and cause turbine and equipment damage.

One favorable aspect of the hydrology of Togo for hydropower development is that since the ground is generally of low infiltration capacity, seepage losses from reservoirs would be small.

ENVIRONMENTAL AND PUBLIC HEALTH CONSIDERATIONS

Unlike large hydropower plants requiring dams and reservoirs, small hydro plants entail few environmental or public health hazards. Impounding water behind large dams can result in damage to natural ecosystems which depend on the free flow of water in rivers and streams and has been responsible for health hazards such as increases in the incidence of schistosomiasis (bilharzia) and malaria. The creation of large reservoirs also removes land from alternative productive uses and may necessitate the relocation of human settlements. The danger of dam failures to settlements downstream, moreover, is always present. All of these consequences add to the economic and social costs of large hydropower projects.

NEGATIVE ENVIRONMENTAL AND HEALTH IMPACTS

Because the proposed projects are of smaller scale and are generally run-of-river, few if any of the negative environmental impacts that accompany the construction and operation of large dams and reservoirs are as likely to occur. Those negative direct environmental and health effects which are possible, however, include:

- o local stream-bank erosion due to fluctuations in the level of the pond behind the dam and releases through the turbine;
- o minor eutrophication (depletion of dissolved oxygen) in the pond due to accumulation of nutrients;
- o turbine damage to fish and the creation of barriers to fish migration; and
- o increased risk of schistosomiasis and mosquito-borne diseases.

Because of the small scale of these projects, it should not be difficult to minimize these impacts.

The provision of electricity to an area may also carry certain negative environmental impacts. For example, the population might expand and strain local public service capacities, or the electricity might be used in an industrial process having a hazardous effluent. However, with careful planning it will be possible to mitigate these impacts.

The major negative possible public health impacts arise because construction of a dam will create a pool of relatively still water which is conducive to the propagation and spreading of snails that carry schistosomiasis and the breeding of mosquitoes.

Schistosomiasis is a disease of the urinary and/or gastrointestinal tracts. Severe infections can lead to death. Parasites living in snails are a major part of the schistosomiasis cycle. The snails live in still or slow moving water (so as not to be washed away) and feed on vegetation on the banks and bottom. The parasites invade the bodies of persons wading in pools of water through the skin. Schistosomiasis is widespread throughout Togo, except the coastal areas, and is very difficult to control. One method is to line the banks and bottom of a pond with concrete or construct a pond in a rocky area (in both cases, the goal is to have no vegetation for the snails to feed upon). The disease can also be controlled if people (who might be infected, thereby contributing to the cycle) can be taught to not urinate or defecate into a pond.

Mosquitos need still water for the larvae to mature to adults. Mosquito control is desirable because they transmit many diseases, notably malaria. There are several proven measures available to reduce these risks to public health.

POSITIVE ENVIRONMENTAL AND HEALTH IMPACTS

Balancing out the possible negative environmental and health impacts are several positive impacts. If the pond could also be used as part of a filtered and chlorinated local water-supply project, many possible positive public health impacts could occur. These include control of guinea worm, typhoid, hepatitis, polio, and other similar diseases. A project would also induce positive public health impacts, for example, by providing electricity to a local hospital and by increasing local cash income, resulting in greater public awareness for preventive health practices and the means to adopt these practices.

ECONOMICS

This section addresses the overall economic and energy context in which the study was conducted at the time of the team's visit. It is important to keep in mind that this report is based on information collected almost three years prior to this writing and that certain references to data and estimates (e.g. tariff rates) may no longer be valid.

This section also provides a summary of the economic methodology which was used in the specific site studies. In the case of two projects, the methodology was expanded to assess the general economic merit of interconnecting these projects with the grid.

TOGO'S ECONOMIC OUTLOOK

GNP growth in Togo was negative at the time of the team's visit, despite a mid-term GNP growth rate estimate by the World Bank of 5% per year. Inflation is expected to fall between 10%-20% for the forseeable future.

Possibilities for economic growth include: expansion of import and export volumes at the Port of Lome; creation of a port gateway to the Sahel through Togo to the north; increased cement production; recovery of world phosphate prices and increased phosphate production; a new oil refinery; a kaolin factory; and a glass factory. The latter three possibilities depend on the offshore oil outlook in the Seme Sea.

STRUCTURE OF THE ELECTRIC POWER SECTOR IN TOGO

The CEET is a parastatal corporation which functions both as a power company and as a regulatory body. It sells and sets rates for electrical energy and has monopolistic control of public electrical energy sales.

The CEET is self-sustaining. Its rates, in effect since 1967—but soon to be boosted by about 77 percent--are designed to cover capital costs of production and distribution plant, fuel costs, replacement and operation and maintenance costs.

At the present time, CEET power needs are supplied to the extent of about 93% by the Communante Electrique du Benin (CEB), the Togo-Benin corporation set up to purchase power from the Akossombo Dam in nearby Ghana. Remaining power needs, some 7%, are supplied by diesel generators directly owned and operated by CEET in the larger city areas north of the so-called maritime system along the coast since that system does not extend very far north at present.* CEB transmission facilities extend eastward into Benin and Nigeria, serving a major portion of requirements of those countries as well as Togo's requirements. Akossombo, one of the largest hydropower sources in Africa (6 x 160 MW), is largely committed to an alumina to metallic aluminum reduction plant in Ghana.

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* A small hydro plant (2 x 1 MW), built in 1963, north of Palime, along with diesel generation serves Palime and nearby areas.

TOGO'S ELECTRICAL ENERGY OUTLOOK

In spite of a slowing of economic growth, Togo's electrical energy demand is up sharply in the country as a whole, in provincial centers as well as in Lome, the capital. In Ghana, by way of comparison, overall energy consumption appears to be down currently, possibly influenced by the fact that the bulk of the Akossombo hydro project in Ghana goes to an aluminum plant, the output of which may be reduced due to the leveling off world demands for metals.

Rural electrification is taking place to a moderate extent, within the framework of integrated rural development projects. Outside of such projects, rural electrification is minimal.

Togo's total electric consumption grew from 110 x 10^6 kWh in 1978 to 151 x 10^6 kWh in 1980 (representing a derived demand figure of roughly 40 MW), a growth of 37% in two years. Consumption in Lome, representing the bulk of Togo's consumption, went from 102 x 10^6 kWh to 137 x 10^6 kWh, a growth of 34% over the period of two years. The provincial centers grew from 8 x 10^6 kWh to 14 x 10^6 kWh, a growth of 75% in two years. Energy consumption is expected to increase even more sharply in the future, both because of a growing number of customers and a growing average usage.

Types of customers are classed as: low-tension users (domestic, small business, public lighting) and high-tension or industrial users. The low-tension sector grew from 53 x 10^6 kWh in 1978 to 75 x 10^6 kWh in 1980, a growth of 41%, the equivalent of about 19% per year.

In the domestic, small commercial, and other low-tension user categories, growth was twice as fast in the provincial centers as in Lome, a fact which would be expected, given the smaller number of users and lower use per connection in the provincial areas. Provincial growth is strong and accelerating rapidly.

To feed this provincial market growth, it has been necessary to increase the amount of electrical energy produced by fuel-burning sources. Since the provincial loads even collectively are too small to justify a large central steam plant and since the only transmission network is along the coast, isolated diesel generation will be the source for these provincial loads for perhaps 10 years or so. The CEET's diesel-fuel consumption grew from 2.5 million litres in 1978 to 4.7 million litres in 1980, up 88%. The CEET expenditure increase for diesel fuel was up 180% in the same period, reflecting sharply increasing fuel prices. The fuel costs for electricity represented a $2 million drain on the country's foreign reserves in 1980, a situation which will intensify in the future as the prices for oil are expected to rise indefinitely.

The outlook for low-cost power supplied to the CEET in the short-term looks good. However, the present contract with the CEB is due to expire before the end of the decade, at which time power-supply levels and prices will be renegotiated. Price increases could be significant. The supply outlook is also uncertain, due to growing demand for Ghana's excess power from other neighboring countries. However, Ghana will soon have additional capacity available from the completion of a second stage of the Akossombo project (Pongue Dam), and there is also talk of power importation from Nigeria by 1989.

The proposed Mono River Project (Nangbeto) in southern Togo would also add significantly to low-cost power availability, once it is constructed.

However, such a low-cost and relatively abundant power supply will need to be supplemented by other costlier sources to meet growing demand in the hinterland beyond the initial reach of the grid. Whole regions of Togo will be unaffected by announced plans for a national power grid, starting in Lome and eventually reaching Lama-Kara and other centers. These more remote centers will need energy supplied by diesel or other means.

The rapidly growing diesel-supplied power sector in Togo will add significantly to CEET's base cost of producing power, unless other cheaper means of producing electricity are developed.

CEET PRICING AND PRODUCTION COSTS

In 1980, CEET charged an average of 19.22 CFA francs per kilowatt hour of consumption. Domestic, small businesses and public lighting consumers paid an average of 22.23 CFA francs per kilowatt hour. Industrial users paid 16.23 CFA francs per kilowatt hour. Table 4 provides a summary of electricity consumption and average tariff rates.

Table 4. 1980 Electricity Consumption and Average Rates

	kWh	CFA FY 79-80	Avg. CFA/kWh
Domestic	57,041,987	1,314,564,968	23.05
Small business	14,891,268	286,498,471	19.24
Public lighting	3,392,233	73,110,196	21.55
B.T. (low-tension)	75,325,488	1,674,173,635	22.23
M.T. (medium-tension)	75,898,587	1,231,747,014	16.23
Total	151,224,075	2,905,920,649	19.22

Based on a revised rate structure (as yet unofficial), CEET rates will rise about 45% for low-tension users and 105% for industrial users. Using the past energy-consumption profile as guide, overall rates would rise on the order of 77%. Thus, rates would move from 19.22 CFA francs to about 34 CFA francs per kilowatt hour. The rates would be in effect for a period of three years. The announced unofficial rate structure is shown in Table 5. Since it is unofficial, it is illustrative only.

Table 5. Existing and Proposed Electricity Rates

	1980 Rate (CFA F)	1981 Rate (Proposed) (CFA F)
Rate A - Domestic		
0-100 kWh/month	28.00	34.00
100-200 kWh/month	22.00	33.00
above 200 kWh/month	18.50	30.00
air conditioner	18.50	–
Rate B small business	18.50	30.00
Rate C public lighting	22.00	28.00
Rate D high tension		
D1 - Industrial use	14.00	25.00
D1 - Non Industrial use	14.00	9.00
D2 - 20 kV high-tension	11.25	23.00
off peak rates	7.40	19.00
Monthly Meter Charge		
meter from 0 - 5 kVa	98.00	120.00
meter from 5 - 10 kVa	140.00	200.00
meter over 10 kVa	224.00	400.00
Monthly Connection Charge		
2 wire connection (single phase)	56.00	80.00
4 wire connection (three phase)	84.00	200.00
high-tension connection	168.00	400.00

The overall cost of energy supplied by Ghana to the CEB/CEET will increase as shown in Table 6.

Table 6. Costs of Energy to CEET

	1981 (Existing) (CFA Francs)	1981 (Announced) (CFA Francs)
CEET power purchased from CEB	6/kWh	11/kWh
CEET power produced by diesels:		
fuel cost only	52/kWh	52/kWh
total production cost	75/kWh	75/kWh

The overall production cost of electrical energy shown in Table 6 will continue to rise. As shown by the comparison between CEB-purchased energy and diesel-generated energy, the CEET has an incentive to identify additional low-cost sources of electrical energy to enable it to carry out its national program of electrification without being forced to raise its rates to levels beyond the reach of consumers.

ECONOMIC METHODOLOGY

For each of the sites studied by the team, a general assessment of the energy-generating potential and energy demand in the immediate vicinity was made to ascertain whether

the site was economically feasible. Two of the projects, Tomegbe and Wonougba, received more detailed attention to determine specific costs and benefits. These sites, one representing a "good" investment opportunity and one rated as "fair," were selected to ascertain, in general terms, the net economic benefits of interconnecting small and medium run-of-river hydropower plants to the grid. The methodology used in making this analysis consisted of two levels:

- o Cost-effectiveness analysis to compare the production cost of small hydropower projects with two alternative energy-supply strategies, diesel generation and the purchase of power from CEB;

- o Net incremental benefit analysis to determine the economic effect of additional power-sector investments in small hydropower projects whose role is to replace diesel-generated energy.

Sensitivity analyses were also done to determine the effect of changing different assumptions, such as higher capital costs and higer diesel fuel costs. The study period for these analyses is 30 years, a useful-life period usually attributed to small hydro plants for purposes of economic analysis.

Cost-effectiveness analysis

This methodology is frequently utilized by public works and public service entities to conduct initial screening of projects. The assumption is already given that a service, such as transmitting electrical power, must be provided. The purpose is to determine the cheapest way to provide the service. Cost-effectiveness analysis is also often used to rank several projects of a similar nature. In this case, the methodology is used to perform both functions.

Discounting techniques are generally used in this type of analysis. In comparing projects with different investment regimes and annual cost profiles, discounting is usually favored over the undiscounted method in order to reflect the time-value of money over many years. Equal sums of money spent today and 10 years from today have different real values. In comparing hydro investments with diesel investments, discounting is especially appropriate since hydro investments require the majority of life-cycle expenditures to be incurred initially, whereas expenditures for diesel projects are spread more evenly throughout the life of the project.

In this analysis, discounting will be used in order to reflect these differences. Diesel costs are shown in terms of unit (fuel cost/kWh) costs multiplied by the number of kilowatt hours that could be provided by the hydro plant.

Net incremental benefit analysis

In the second level of analysis, costs and benefits are calculated for each project to find the net economic consequences of investing in small hydropower projects where the role of the hydro project is explicitly to reduce expenditures for diesel fuel. Costs and benefits are derived directly from the calculations made in the previous level of analysis. Benefits are equal to total cash savings achieved from replacing diesel-generated energy with energy generated by the hydropower plant.

SITE ANALYSES

Each site is discussed in terms of its geographic characteristics, the hydrology influencing the streamflow, the physical features and related construction characteristics, the power (kW) and energy (kWh) potentials (only for Sites 3 through 8 where streamflows can be estimated), and the general economic situation around the site area and its effect on the marketability of electrical energy. Some repetition of certain hydrologic and other general data is intentional to clarify the specific site situations.

SITE 1. BORGOU

This site is near the road to Borgou and about 3 km south of the town. A bridge on a loop at the river at that point is frequently topped by flood flows. The Sansargou flows generally south at that point, then turns east, joining the Oti River 15-20 km downstream. As a result of the high flood flows, the river moves a lot of rocks and shows a considerable sand load at the site. A reservoir at that point would soon fill with sand.

Although there were a few pools of water in the riverbed, the flow was nil at the time of the team's visit. A well in the nearby village showed a watertable level of about 8-10 m below ground level.

Hydrology

This site is on a Sudan-type stream that only flows during the wet season and is usually dry during January through March or April. A peak discharge is obtained during August and September.

Construction

Construction features for this site would include a rock rubble gravity dam about 6 m high with a crest length of about 30 m. An inlet channel to a turbine would be cut into the right abutment rock with a stilling pool to allow sand to settle. A sluiceway would be necessary to move sand out of the reservoir and a connection made to the turbine intake stilling pool through a stoplog structure. A 150 m long tailrace would be excavated from the turbine discharge back to the river which would be effective only during low to moderate flow. At flood flows, the dam would be an uncontrolled spillway over its entire crest with the tailrace water level rising several meters during floods, making it necessary to place the generator above flood level and connect it by an extra-long shaft to the turbine.

Economics

This dam site, like its companion site at Kankanpieni nearby (Site 2), is located in the poorest region of Togo. The subsistence farming activity is millet grain and cotton, producing gross family farm incomes of a few hundred dollars a year. The nearby farm village of Borgou counts 600 people, according to the 1970 census, and the population in the region is thinly distributed.

Electricity demand in the larger region around Borgou is almost non-existent. The town of Dapaong (population 12,000), to the west about 50 km, has only recently been electrified, with a present annual consumption of 840,600 kWh. An integrated rural development project near Mandori, about 25 km away from the Borgou dam site, is too far to be served economically from this site. The site also falls outside the grid.

All in all, it is difficult to imagine concentrated demand levels generated in this region in the future.

Due largely to the required quantities of rock excavation necessary for the power canal and tailrace improvements, plus zero streamflow for three to four months during the dry season, and other uncertainties concerning water flows, no estimates were made of power or energy production. From a financial and economic standpoint, this site would not be feasible to develop and the rating accordingly is "poor."

SITE 2. KANKANPIENI

This site is on the Bamoena River near the village of Kankanpieni, about 15 km east and a little south of Dapaong. At the site, the flow is zero during the dry season; upstream reaches of the river are indicated as intermittent on maps. The surrounding area was extremely dry with relatively little plant cover at the time of the site visit. A dike about 500 m long ending in a partially destroyed bridge formed a roadway until floods broke through the dike in several places.

Hydrology

This site is on a stream similar to that of Site 1, a Sudan-type stream which is dry a significant part of the year.

Construction

The dike probably could be rebuilt with available earth and should hold if it could be raised about 2 m with a roadway on top. A dam with a roadway could then be built in place at the bridge with an uncontrolled spillway under it. Two other spillways with crests somewhat higher than the main spillway, but lower than the dikes, would provide additional safety for the bridge and dike structures.

The rather flat topography of this site and the limitations of the existing topographic maps with 20 m contour intervals make it impossible to determine whether an enclosed reservoir could be formed behind the proposed dam and dike structures. Even then, it appears unlikely that sufficient reservoir content would be available for regulation of the high wet-season inflows through the dry season for steady monthly electricity generation. If the dikes and the bridge ever justify rebuilding, the possibility of the dam and dike improvements could be reconsidered and the total cost allocated between roads and power.

Economics

This site presents an economic picture very similar to that of Site 1, Borgou. It is found in a poor thinly populated-farm region in northern Togo. Gross family farm incomes run a few hundred dollars a year. The village of Kankanpieni counts 150 people according to the 1970 census, and the dispersed population in the area reflects sparse settlement patterns, making electrical service costly, even where demand does exist.

Electricity demand in the area is minimal. Dapaong, the town of 10,000 population about 40 km to the west, has only recently begun electrical service, but consumption at 840,600 kWh (a peak demand of roughly 200 kW) in 1980 is still very small.

From a financial and economic standpoint, this site does not offer adequate feasibility characteristics and it is classified as "poor."

SITE 3. LONDA POZENDA—KARA

This site, about 10 km east of Lama Kara, is on the Kara River which rises in Benin, runs westerly and slightly northerly through Togo, and joins the Oti River, which eventually flows into Lake Volta in Ghana.

At the site, the river channel is rock, laced with eroded passages and carries a significant sand and boulder load during floods. Flow was about 1 cms at the time of the site inspection, which was somewhat above minimum. The flow builds up during the summer, peaking in September/October, according to a UNDP resident representative.

Hydrology

Site 3 is on a stream that follows a Sudan pattern—extremely low flows during the dry season (aproximately late fall, winter, and early spring) and then large flows during the wet season. The average flow of the low-flow month is estimated to be 0.06 cms and mean annual flow is 17.6 cms with a reasonably steady flow of about 8 cms for five or six months each year. The peak flow, occurring in September or October, can be as great as 500-800 cms. This stream, and the streams for the remaining sites, usually have some flow year-round.

Construction

An overflow dam of rock rubble about 3 m high, keyed into the rock base and rock abutments, would be suitable for developing hydraulic head. Sluice gates should be provided to move accumulated sand well downstream. More extensive surveys or examination of stereo-aerial photographs, if available, would show if any significant seasonal reservoir storage could be found. To develop power at the dam site would require rock excavation for a power canal and turbine setting and tailrace rock excavation. Channel deepening below the dam would be necessary to reduce tailwater elevation during flood flows. The possibility of dropping water from the reservoir pool into another water course should be investigated.

Economics

The demand for power at this site may be said to be similar to that described for Site 4, Londa Pozenda—Sara. A UNDP-sponsored experimental farm would be the principal consumer, with an excellent ability to pay. The small village of Londa-Pozenda is not expected to contribute to demand. The village is at the pre-electricity stage of income affordability.

A detailed economic analysis was not conducted for this site. Preliminary hydrologic and engineering cost data indicate this site shows a benefit/cost ratio well under unity, the principal cause being excessive cost factors for the given output.

The average minimum monthly flow of 0.06 cms and a six-month flow average of 8 cms plus reasonably favorable dam site combine to give the site a "fair" rating. Installed capacity would be 200 kW and annual generation would be 790,000 kWh.

SITE 4. LONDA POZENDA—SARA

The Sara and Kaliola streams each drain a small catchment area northeast of Bafilo before joining each other to become the Sala River. Site 4 is about 75 m below a split in the Sala and above its confluence with the Kara River where rock on each bank forms a narrow channel. Above the site, the UNDP operates a seed production experimental farm, water for which is lifted to the area by a small diesel engine pump of about 5 hp.

Hydrology

Site 4 is on a Sudan-type stream. The mean flow of the low-flow month is approximately 0.02 cms. The mean annual flow is approximately 2.6 cms and the peak flow is estimated to be 60 cms.

The hydrograph for an average-flow year is shown in Fig. 2 in the general section on hydrology. As can be seen, the flow has a single peak in late summer/early fall which greatly exceeds the flow during other months. The persistence of the low flow during the dry season can also be seen.

Construction

At the chosen dam site, a rock masonry overflow dam, 40-50 m long and 4 m high with abutments 2 m higher tapering down to training walls along the downstream sides appear to be a logical development plan.

Although some of the site features indicated an initial promise of providing a useful amount of electrical power, the foregoing hydrologic analysis shows the minimum monthly flow to be well under 1 cms. Furthermore, the best possible estimate of hold-over storage potential of the site puts that figure at 1.5 million cm^3 while an active storage volume of 2-2.5 million cm^3 is necessary to maintain a steady flow at 1 cms for one month.

Since the dry season lasts for four months or more, it is impossible to develop enough hold over storage for uniform monthly water releases without a dam of immense proportions, considering the flat site topography. The 2.6 cms available for five months indicates a power generation capacity of 55 kW, with an annual equivalent generation of 200,000 kWh. Furthermore, in terms of unit costs, this site would be very expensive to develop.

Economics

The principal existing and future power demand here is generated by a UNDP experimental integrated farm which at present has its own diesel-generating capacity. Hydroelectric power could provide potentially cheaper service. UNDP project users include: a small tool factory, a training school, a diversion pump operation, a project office, cadre housing and, potentially, project lighting and air conditioning.

As a potential user, the UNDP project has excellent customer characteristics. The project is funded, and can pay. Informal discussions with German volunteer service

personnel reveal strong potential interest in assisting with the construction of any hydro project here.

The village of Londa Pozenda is a small farm community nearby of 1,200 persons, according the 1970 census. Farm families gross an estimated $600/year from agricultural sales. Discretionary income amounts do not allow for any electricity purchasing power, even if demand, not now evident, were to materialize.

Beacuse on-site demand appears to be substantial, a detailed economic analysis should be conducted for this site. However, a rough feasibility judgment—accounting supply potentials and the demand outlook, together with probable cost levels—indicates this to be a project with inadequate feasibility. Based on preliminary hydrologic and engineering cost judgments, it was decided this site did not merit specific study and is rated "poor."

SITE 5. BOUGOULOU

About 30 km south of Bassar and near the village of Bougoulou, the road ends at a rocky gorge on the Mo River where a low bridge in the bottom had been started, but was washed away. A bridge still is needed at that point and a Bailey Bridge—the type which can be cantilevered out from each bank—has been proposed. However, if a dam were to be built here, a roadway could be built above a full-length spillway. Elevation at the site is about 920 m above sea level.

Hydrology

Site 5 exhibits the characteristics of a Sudan stream. The mean monthly low flow is 0.65 cms, the mean annual flow is 21.6 cms, and the peak flow is 430 cms.

Construction

The main gorge is about 30 m wide and 10 m deep with a higher river channel 25 m wide forming the left bank, so that a total length of about 55 m would be necessary to span the river with a dam/bridge structure.

Construction would have to be done in stages, the deeper section first up to the level at the left abutment. Then during low flow, rock masonry could be built out from each side, leaving a notch for flood flows until, during the third year, the notch could be filled in, with piers for the bridge formed at that time. Bridge beams and the road surface could then be added.

Favorable features of this site are the deep gorge and resultant substantial head of 15 m, good dam abutments, material for a rock masonry dam available from tailrace excavation, and a possible cost allocation of the total structure cost to its function as a bridge. However, the substantial flow of 10 cms occurs for only about six months of the year which means that this potential plant would be suitable only for working into an existing power system. The indicated flow and head could produce 1250 kW with an annual generation of about 4,900,000 kWh.

Economics

This site is very isolated, about 30 km south of Bassar at the head of the Fazao game preserve. The whole region is served only nominally by roads. Given its isolated character, it is not considered to possess any significant power demand characteristics immediately nearby.

The site has, conjecturally, an estimated average annual energy production of 4,900,000 kWh, based on preliminary hydrological studies. But particularly in this case, hydrologic estimates are considered extremely conjectural and require more study.

The site appears expensive to develop according to the site evaluation. But a detailed economic analysis here was not considered possible given the quality and reliability of the available data. Accordingly, this site is rated "fair."

SITE 6. LEGOUANSELANDE

This site on the Mo River features steep vertical rock sides about 500 m downstream from a bridge over the river, at about 15 km from Sokode on the Sokode-Bassar Road. The river flows westerly at that point. The rock is highly fractured and there were pools in the channel, but no flow was visible.

Hydrology

Site 6 is a Sudan stream with a mean monthly low flow estimated to be 0.13 cms, a mean annual discharge of 4.3 cms, and a peak flow of 86 cms.

Construction

A crest length of 50-60 m and a height of about 6 m are indicated for a rock masonry dam at this site. Channel deepening below the dam would need only be moderate and should provide material for a rock masonry uncontrolled spillway dam structure. The river does not seem to carry much sand in the site area. For five to six months of the year, the monthly flow would be about 2 cms, a power potential of about 100 kW is indicated with a related energy potential for five months of about 390,000 kWh.

Economics

This site is situated at the north end of the unpopulated Malfakassa Game Reserve. The village of Legouanselande near the site is evidently too minor to be reported in the 19780 census. Electrical demand does not exist in the area now.

The site appears expensive to develop, with substantial rock displacement necessary. A dam and a power plant of about 100 kW would be of potential interest as a supply source for the large town of Sokode, about 15 km away. Sokode has a population base of 29,100, according to the 1970 census, and is a thriving commercial center with a growing demand for electricity and a spreading urban base. It would, for instance, be possible to serve the northern areas of Sokode from the Legouanselande site with lines running a good deal less than 15 km, the nominal village-to-city distance. However, the dry season power potential would be virtually zero, meaning that thermal (diesel) generation would be needed for a continuous supply. Consequently, the energy potential is useful only as fuel replacement.

A detailed economic analysis of this site seemed impossible, given the conjectual quality of the hydrologic data and related power and energy outpout estimates. It is a site with only a "poor" promise of feasibility.

SITE 7. EZIME

This site features a cascade about 1 km north of Ezime village, which is about 5 km from Amlame on the road to Atakpame. The water comes over a rock ledge and falls down an

almost vertical rock face. From topographic sheets, the drop was estimated at 300 m and by observation the flow was estimated at about 1/4 cms at the time of the site visit.

Hydrology

Site 7 is on a Guinean-type stream. Therefore, it may exhibit flow peaks twice a year in early summer and in fall, or only in the summer. Because of its relatively northern location, however, peak flow generally occurs only during the summer. Conversations with local residents indicate that the stream generally has flow even during the dry months. The mean flow of the low-flow month is .04 cms. the mean annual flow is 0.8 cms, and the peak flow is 16 cms.

Construction

Available topography with 20 m contour intervals made difficult a worthwhile determination of reservoir site possibilities and, for purposes of this study, only daily regulation of flows was considered feasible. Most likely the water would be diverted at the top of the cascade to a less steeply sloping area where the water from the plant would run into another water course.

Based on a six-month average flow of 1 cms and a head of 300 m, a power potential of 2500 kW and an annual energy production of 10,500,000 kWh are indicated.

The 300 m high head of this site increases its value compared to others, but the seasonal flows, and related seasonal energy output, relegate it to a fuel replacement role.

Although this cascade does not seem to attract as many visitors as at Tomegbe (Site 8), consideration should be given to providing some watear flow over the falls at all times to preserve the beauty of the falls.

Economics

The Ezime site is situated near the prosperous village of Ezime, which has a population of 2,050, according to the 1970 census. The village is at the center of coffee and cocoa plantations and the waterfall is a significant tourist attraction.

There is no evidence of electrical usage in the town of Ezime now, but one can visualize a future containing more modern and varied agro-industrial production facilities, development of a tourist hotel, and other economic activities demanding power. Judging from the appearance of the housing stock in this area, as well as conversations with CEET officials there is domestic electric purchasing power as well, not only in Ezime, but in the towns to the east toward rapidly urbanizing Atakpame, an urban center of 16,000, 20 km away. CEET plans to provide grid power to this area soon.

If appropriate technical solutions could be found, the site at Ezime could provide sufficient energy to service a large town of about 10,000-20,000 at current rates of per capita consumption in conjunction with a diesel generation source of comparable capacity. Thus, the site has significant interest. Alternatively, the output potential of 10,500,000 kWh per year could be readily introduced into the national grid proposed to serve this area.

A detailed economic study of this site is warranted. For the moment, its feasibility characteristics appear to be similar to those of the site at Tomegbe, the waterfall site in the same region, which has been studied more closely and is reported on in this report.

SITE 8. TOMEGBE

This site is on the west side of north-south subrange of mountains and 1 km east of Tomegbe village, which is about 7 km south of Badou. At that point, the Domi River drops over a vertical cliff at about 40 m height into a small pool and continues down a series of small falls to Tomegbe.

Hydrology

The hydrologic characteristics of this site are similar to site 7 except the mean flow of the low-flow month is 0.20 cms, the mean flow is 4 cms, and the peak flow is 80 cms.

Construction

Some re-regulation storage appears possible at this site and the available flow was modified accordingly to enhance the generation pattern given below. Using available topographic maps, a reservoir site was plotted and a water conduit 2500 m long laid out along a contour line, which in turn would connect to the top of a penstock about 750 m long, to develop a head of about 200 m. The water would be fed to four turbines of 2000 kW each at the bottom. The turbine discharge would go into an intermittent water course.

With a better monthly flow pattern (5 cms continuously for six months) afforded by the potential reservoir storage, the annual generation, mostly over a period of eight months, would be 34.5 million kWh. This figure was reduced to 30 million to acknowledge the benefit of not using all available water for power and leaving at least the historic minimum for the falls. Actually, the project could be operated to enhance the falls during the dry season.

Since this site seemed to have more promise than the others, a rough cost-estimate was made, including a small rock masonry dam, low-pressure steel pipe to a high strength steel penstock, splitting to the four Pelton turbines (see **Economic Feasibility Tests—Two Selected Sites**). The seasonal generation pattern of this site makes it suitable only for integration with a larger power system with a diversity of generation sources such as thermal, as well as hydro. Accordingly, a 33 kV, double-circuit line to Atakpame is included to connect with diesel generation scheduled there soon.

Economics

From a purely demand standpoint, this site has excellent characteristics. It is situated in a thriving coffee/cocoa production area, with several agroindustries in place. The town of Tomegbe near the site has a population of 5,700 and now has electrical service available. Public lighting, domestic, and industrial users have established a consumption pattern and it is growing.

Adding to demand, the town of Badou, with a population of 10,000 in 1970, is about 12 km from the site. It, too, is well urbanized and has a growing consumption pattern of electricity now in evidence.

The most logical way to use the power generated at Tomegbe, estimated at 30,000,000 kWh/year, would be to introduce it into the proposed grid lines serving the region.

SITE 9. ALOKEGBE

This site is an existing dam and irrigation diversion works structure about 17 km due west of Tsevie and about 35 km northwest of Lome. Built by the Chinese, this dam was thought to have some small hydro potential in the form of irrigation water discharge. However, instead of dropping into an open canal, the water goes into a free-flow cut and cover tunnel which has to be as high at the dam end as possible in order to get the water to the irrigated area. Consequently, the potential head at the dam varies from virtually zero at minimum storage to only a few meters. An output varying from zero to perhaps 50 kW might be developed.

Hydrology

The streamflow pattern was not researched due to the characteristics of the site described above.

Construction

Similarly, no construction criteria were derived.

Economics

This site was considered to have no significant power potential. Accordingly, no demand analysis was conducted for this site.

SITE 10. WONOUGBA

This site is southeast of Palime on the Sio River and is where the river falls over a rock ledge into a pool about 2 m below. Above the ledge is a more gradual fall of about 1 m, for a total drop in that section of 3 m. After visiting the 10 sites, it was decided that this site would serve as a model to determine the order of costs for such hydro sites. In view of poor local load prospects, the power would be fed into the future system on a fuel replacement basis.

Hydrology

This site is on a Guinean stream and, because of its relatively southern location, may be expected to have two peak flows per year—one in summer and one in fall. Because of its southerly location, it also exhibits less flow variability than northern streams. The flow of the low-flow month is 0.36 cms, the mean annual flow is 6.7 cms, and the peak flow is 119 cms. The hydrograph for an average flow year at this site is shown in Fig. 3. As can be seen, it has two periods of peak flow, persistant low flow, and less variation in flows than a Sudan stream.

The mean annual flow of 6.7 cms, as indicated, was used to compute a power potential of 160 kW. Using 5 cms as available flow for six months and 4 cms for one month (August) and neglecting the low flows, the potential energy production would be 690,000 kWh per year.

Construction

The dam would have a crest length of 20 m, a crest width of 4 m, a 1 m^3 keyway, and a horizontal face of 5 m on both the upstream and downstream sides. This would require approximately 640 m^3 of rock masonry. Downstream training walls and riprap would

require another 150 m^3. Tailrace excavation of about 800 m^3 would allow for a proper turbine setting and would increase the available head, totaling 3 m. Additional excavation of 50 m^3 needed for the turbine chamber and 20 m^3 for the keyway would account for a total excavation volume of 870 m^3.

Economics

This site is near Wonougba, an isolated small village in what appears to be a sparsely populated area. Farming activities support local families at subsistence levels. There is no electrical demand evident in this immediate area.

However, the site has reasonably good potential for serving the national grid line from Lome to Palime. Connection to the grid for this site, with a potential output of 690,000 kWh, would require only a 10 km connection. Accordingly, this site was rated "fair."

ECONOMIC FEASIBILITY TESTS--TWO SELECTED SITES

It is the general conclusion of the study that few opportunities exist in Togo for the implementation of small hydro projects to serve isolated loads. In most cases, this was due to a relatively high cost of construction compared to local electrical energy demand, poor hydrologic conditions, or both factors. Consequently, decentrlized hydro projects may serve to the greatest advantage as import-substitution projects whereby the full energy generating capability of such plants is fed into regional and national grid transmission lines.

In order to establish an order of magnitude of the economic feasibility of such projects, two of the most promising sites out of 10 surveyed were chosen for prefeasibility analysis.

TOMEGBE

Site 8, Tomegbe, located near the Badou on the Domi River, has a substantial potential of 30,000,000 kWh created by a high-head waterfall and is also well located with respect to the proposed national grid. The Tomegbe region is prosperous and growing. The Tomegbe waterfall is thought to be fairly typical of similar waterfall sites in this region. Ezime also falls in this category, for instance, and there are other potential sites in this region which could be surveyed as well.

Construction costs for the Tomegbe project are given in Table 7. Annual O&M costs are considered to be 1.5% of capital costs, or $150,000. This will cover the salaries

Table 7. Capital Costs for Tomegbe Project

Civil structures and penstock		
rock masonry dam	140,000	
low pressure pipe	265,000	
penstock	1,800,000	
penstock anchors and piers	525,000	
valves	100,000	
surge tank	50,000	
powerhouse	720,000	
Total		3,600,000
Turbine-generator equipment		
turbine-generator equipment	2,000,000	
auxilliary electrical equipment	700,000	
transformers and controls	300,000	
Total		3,000,000
Transmission and terminal equipment at Atakpame		
60 km of 33 kv transmission line to Atekpame	800,000	
terminal equipment-Atekpame	200,000	
Total		1,000,000
Enigneering		
design	500,000	
supervision	500,000	
Total		1,000,000
Contingencies		900,000
Total Project Cost		9,500,000

of operations staff and supplies needed for regular maintenance of the plant, including minor replacements. There, of course, is no fuel cost (other than lubricants, etc. for plant operation) associated with hydropower plant operations.

Cost-effectiveness

Unit capital costs for Tomegbe are quite low, about $1,200/kW installed, largely due to the high-head characteristics of this site and the effect of economies of scale. These facts, combined with the water storage capability at Tomegbe, make the Tomegbe project very cost-competitive with diesel. Annual energy production is estimated to be 30,000,000 kWh. Discounted unit energy cost in the baseline calculation for the hydro option is $0.012/kWh, compared to $0.06/kWh for the diesel and $0.01/kWh for the CEB power. Average undiscounted costs per kilowatt hour for the hydro (assuming financing terms of 10% for 30 years) is $0.039/kWh, compared to $0.21/kWh for diesel and $0.03/kWh for the CEB option. The hydro plant could result in considerable savings to the GOT if the alternative energy source is assumed to be diesel. It is also noteworthy that the hydro unit cost in the case of Tomegbe approaches the cost of purchasing power from CEB.

Net incremental benefit

The Tomegbe project offers an extremely attractive investment opportunity. The net present worth in the baseline calculation is $24,878,000, which indicates that a decision to build this plant would be imperative, given the assumptions of this analysis. It should be remembered that the benefits for this analysis are equal to only the fuel costs of producing comparable energy by diesel generation.

Sensitivity Analysis

The purpose of sensitivity analysis is to determine what effect the altering of certain assumptions has on the economic return of projects. As such, sensitivity analysis should probe those project ingredients about which the greatest uncertainty exists. This is helpful at the prefeasibility stage since it points to those issues which should receive greater care during subsequent, more detailed, project anlaysis. The sensitivity analyses on the Tomegbe project indicate, predictably, that increased costs for diesel fuel (calculations 6 and 7) and for CEB-purchased electricity (calculation 8) improve its attractiveness. A lower discount rate has a similarly postive effect since it raises the relative value of costs in later years, which are greater for thermal than hydro projects. On the other hand, higher construction costs for the hydro project (calculations 4 and 5), a higher discount rate (calculation 3), and a lower fuel-substitution rate (calculation 9) reduce the economic attractiveness of the project. The most critical assumption is that regarding the hydro output which can be used to substitute diesel energy (calculation 9). The baseline case assumes that all of the energy available from the plant is used to substitute diesel generation. If this estimate is reduced by 50%, the net incremental benefit is reduced drastically, although still remaining very good. Tables showing the conclusions of the sensitivity analyses are provided in the **Appendix**.

WONOUGBA

Site 10, Wonougba, is located about 18 km southeast of Palime. It is situated in an area where agro-industial demand is too sparse to be readily serviced from this site. However, Wonougba is near the proposed grid extension line from Lome to Palime scheduled in the near future. The Wonougba site, with an annual production estimated at 690,000 kWh, would represent a meaningful increment of low-cost energy to feed the

national grid. The CEET is naturally interested in any hydro project which promises to generate power at a cost lower than diesel.

Construction costs are $380,000 (see Table 8). Operation and maintenance costs are estimated to be 4.5% of capital costs, or $15,000 annually. Normally, the percentage of capital costs which is assigned to small hydro plants for O&M costs is lower than 4.5%, but for smaller plants such as Wonougba the standard percentage of 1.5% of capital costs is unrealistic. Of course, there are no annual fuel costs.

Table 8. Capital Costs for Wonougba Project

Excavation		
compressors, drills set up	3,500	
loaders to move rock	3,000	
870 m^3 of excavation @ $15.50	13,500	
keyway excavation	1,500	
turbine excavation	1,000	
Total		22,500
Rock Masonry and Riprap		
dam 640 m^3 @ $140	90,000	
training walls 150 m^3 @ $22.50	3,500	
sluice gate structure	1,500	
sluice gate	3,500	
powerhouse	2,000	
Total		100,500
Mechanical/electrical equipment		
160 kw 230/380 volt turbine-generator	120,000	
auxiliaries, controls, etc. for step-up	4,000	
175 kVA .230/21 kv transformer	4,000	
21 kV structure	2,000	
21 kV OCB	3,000	
controls	2,000	
radio supervisory control	3,000	
Total		138,000
Tramnsmission lines and terminal equipment near Glekope		
21 kV structure	2,000	
21 kV OCB	3,000	
controls	2,000	
10 km of 21 kv line (@ $4,000/km)	40,000	
Total		47,000
Engineering		
design	17,000	
supervision	17,000	
Total		34,000
Contingencies		38,000
Total project costs		380,000

Cost-effectiveness

The baseline calculation for Wonougba's cost-effectiveness finds that the proposed small hydropower project would provide power at considerably less cost than diesel-generated power, but could not compete with power bought at wholesale rates from the CEB. It is estimated that total annual energy production would be 690,000 kWh. Average unit cost in present worth terms would be roughly $0.06/kWh for the diesel, $0.024/kWh for the hydro, and $0.01/kWh for the grid-purchase option. In terms of the undiscounted average unit cost (with financing terms the same as those for the Tomegbe project), the hydro would cost $0.08/kWh, as compared to $0.21/kWh for the diesel and #0.03/kWh for the power purchased from the CEB.

Net incremental benefit

The preceeding analysis of cost-effectiveness demonstrates that the Wonougba project would produce energy at roughly one-third the annual cost of a diesel generator, which, it is assumed, is the next cheapest means of generating the electricity. In this level of analysis, the discounted costs of constructing and operating the hydro project are subtracted from the discounted costs of producing the same amount of electrical energy from diesels, giving the net benefit in net present worth terms. The baseline calculation for Wonougba shows a net present worth of $391,000, which, from an economist's point of view, means that it is worth undertaking, given these assumptions.

Sensitivity Analysis

In a more inflationary setting, the hydro option appears less attractive, as reflected in calculations 2 and 3. A higher discount rate makes the relative value of expenditures early in the study period greater than those made later. Conversely, should interest rates continue to fall, the hydropower project would become more attractive. If higher inflation is driven by increasing energy costs, on the other hand, the hydropower project's value increases. This effect is reflected in calculations 6 and 7, which assume real annual increases (above the general inflation rate) in the cost of diesel fuel. It should be noted here that the less favorable terms of trade may have already had an effect on the real cost of imported fuel. Calculations 4 and 5 reflect the consequences of underestimated capital costs. It is not known what rate of increase can be expected for CEB-purchased power. However, even with the 3% annual escalation factor assumed in calculation 8, the hydro option remains uncompetitive with this option. Again, as in the case of the Tomegbe project, the most important assumption is the rate of diesel fuel substitution which is possible. If only 50% of the energy output of the Wonougba plant could be used to substitute diesel fuel, the NPW would be negative (see **Appendix**).

CONCLUSIONS

The basis for assessing the return on investment from the projects described here should be, what positive economic results are possible with the installation of hydropower facilities that would otherwise not be gained? In this case, the benefits to the project derive from "avoided costs" in supplying the power to consumers. Revenues from the sale of power should not be counted as a benefit since this value is already attributable to the diesels or grid-supplied power. Other economic benefits normally attributable to electrification are likewise already attributable to previous investments. Utilities should count revenues and other indirect benefits as benefits to a small hydropower project only to the extent that the project supplies additional capacity. This need not be year-round capacity, provided that the demand can be satisfied on a part-year or part-day basis. It is assumed that this is not the case here, and that supplementary power sources will be

needed. An exception to this general rule would occur under conditions where the power supplied by the back-up capacity is not subsidized by the government. Under such conditions, the cheaper hydropower may result in additional benefits to the area's consumers, including presumably, more rapid growth in demand for electricity, and economic growth generally. Again, this is not the case in Togo, since electricity rates are subsidized by the GOT, regardless of the means of generation.

In general, the purpose of this analysis is to examine the economic advantages of developing hydropower projects to replace diesel-generated power. It is, therefore, assumed, for purposes of these analyses, that the proposed hydropower projects would be tied to transmission lines which are served by diesel-generated energy at least equivalent to the output potentials of these plants, and that the full power generation potential of the hydro projects will be utilized. These assumptions, however, may not be realistic, as will be discussed in the following section. In short, more study is clearly required to ascertain the full economic potential of grid-tied projects having the characteristics of the sites discussed in this report.

CONCLUSION

Presented in this report is a preliminary assessment of the potential for small decentralized hydropower development in Togo. Two types of projects were considered: (1) isolated hydro plants to serve remote population centers; and (2) decentralized hydro plants which could be interconnected with regional or national transmission lines serving larger loads. While the primary focus of this study was on the former project type, it is its general conclusion that interconnected projects offer the better investment opportunities.

Consequently, the analyses bearing the most importance in this report are those in **Economic Feasibility Tests—Two Selected Sites** on the Tomegbe and Wonougba sites. The total cost savings could potentially exceed $1 million annually from the construction of the Tomegbe and Wonougba plants alone. This economic gain could possibly be doubled if other sites, particularly Londa Pozenda-Kara, Bougoulou, and Ezime were also found to be feasible for grid-interconnection. Moreover, the real value of these benefits are possibly greater than their face value in the sense that the net savings would be realized in foreign currency. However, since the vast majority of the time spent during this survey was devoted to assessing smaller, isolated projects—under the terms of reference—the analyses of these two grid-tie projects are very preliminary and are based on assumptions which, upon more detailed study, may be found to be invalid:

- that electricity demand will be sufficient to absorb the full 24-hour output potential of the plants; and

- that this demand would otherwise be served by diesel generators.

It is unlikely that the first assumption would bear out if the hydropower plants are to serve loads isolated from the main transmission grid, at least in the short- to middle-term. The total annual electricty consumption outside the city of Lome in 1980 was 80 million kWh, representing a little more than double the estimated output of the Tomegbe site alone. Only a portion of this provincial demand is found in the Tomegbe-Badou region. Moreover, even assuming a high plant factor for an isolated plant of say, 50%, the demand profile for the Tomegbe project would result in a substitution rate far below the assumed 30 million kWh.*

Thus, it is recommended that both the Wonougba and Tomegbe plants be connected to transmission lines connecting Lome with Atakpame and Palime, making the issue of local demand moot for these two projects. This raises certain problems with the second assumption. By virtue of connecting the hydropower project to the grid, the real economic determinant may change from a comparison of generating costs with diesels to the costs of generating energy from other sources as well. Put differently, the economic benefits would be based on the avoided costs of energy supply means which are not based on diesel generators alone (or possibly at all), but on imports of electricty from Ghana, or on other non-diesel thermal generating means.

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*If is assumed that 15 million kWh, only half of the estimated energy output at Tomegbe would be used to displace diesel fuel costs, the NPW drops from $24,878,000 to $17,145,000, but this is still a good net incremental benefit.

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In short, further study on the role of grid-tied decentralized hydro sites of the type studied herein is needed before an accurate statement on the economic merit can be made. This should include not only more detailed review of alternative supply means, bu on the specific time-patterns of demand served by the grid, and the cost of alternative energy sources during those times when the hydro plants could be operated. Thus, the hydrologic estimates for the potential hydro sites are quite important. The reconnaissance methodology used in this report permitted only very general assessments of the hydraulic power potentials of the sites studied. Additional study is needed to refine these estimates, and possibly to consider design options to increase power and energy potentials, reduce project construction costs, or both.

Finally, since the thrust of the recommended additional study would be to identify the magnitude of decentralized hydropower potential to serve Togo's national power network, a more complete inventory of such sites would be desirable. These would generally be small-to-medium sites of higher heads, to keep costs down, based on run-of-river designs. While such plants would not contribute significantly to capacity, the low-cost energy potential of such sites—as illustrated in this report—could offer a meaningful economic contribution to Togo's national energy program.

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COST-EFFECTIVENESS ANALYSIS (Tomegbe)

1. Baseline

	Hydro Option			Diesel Option			CEB		Cost Comparison		
Year	Capital	O&M	Total	Capital O&M	Energy Cost	Total	Total	PW Factor	Hydro	Diesel	CEB
1	3,167,000	0	3,167,000	0	0	0	0	1.000	3,167,000	0	0
2	3,167,000	0	3,167,000	0	0	0	0	.909	2,878,803	0	0
3	3,167,000	0	3,167,000	0	0	0	0	.827	2,619,109	0	0
4	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.751	112,650	4,827,428	708,193
5	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.683	102,450	4,390,324	644,069
6	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.621	93,150	3,991,788	585,603
7	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.564	84,600	3,625,392	531,852
8	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.513	76,950	3,297,564	483,759
9	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.466	69,900	2,995,448	439,438
10	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.424	63,600	2,725,472	399,832
11	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.385	57,750	2,474,780	363,055
12	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.351	52,650	2,256,228	330,993
13	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.319	47,850	2,050,532	300,817
14	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.290	43,500	1,864,120	273,470
15	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.263	39,450	1,690,564	248,009
16	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.239	35,850	1,536,292	225,377
17	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.218	32,700	1,401,304	205,574
18	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.198	29,700	1,272,744	186,714
19	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.180	27,000	1,157,040	169,740
20	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.163	24,450	1,047,764	153,709
21	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.149	22,350	957,772	140,507
22	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.135	20,250	867,780	127,305
23	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.123	18,450	790,644	115,989
24	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.112	16,800	719,936	105,616
25	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.101	15,150	649,228	95,243
26	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.092	13,800	591,376	86,756
27	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.084	12,600	539,952	79,212
28	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.076	11,400	488,528	71,668
29	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.069	10,350	443,532	65,067
30	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.063	9,450	404,964	59,409
31	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.057	8,550	366,396	53,751
32	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.052	7,800	334,256	49,036
33	0	150,000	150,000	1,971,000	4,457,000	6,428,000	943,000	.047	7,050	302,116	44,321
Total	19,501,000	4,500,000	14,001,000	59,130,000	133,710,000	192,840,000	28,290,000		9,833,112	50,061,264	7,344,084

NET INCREMENTAL BENEFIT ANALYSIS (Tomegbe)

Discount rate: 10%

1. Baseline

Yr.	PW Factor	Project Costs Nominal	Project Costs Discounted	Benefits (fuel savings) Nominal	Benefits (fuel savings) Discounted	Net Economic Return Nominal	Net Economic Return Discounted
1	1.000	3,167,000	3,167,000	0	0	-3,167,000	-3,167,000
2	.909	3,167,000	2,878,803	0	0	-3,167,000	-2,878,803
3	.827	3,167,000	2,619,109	0	0	-3,167,000	-2,619,109
4	.751	150,000	112,650	4,457,000	3,347,207	4,307,000	3,234,557
5	.683	150,000	102,450	4,457,000	3,044,131	4,307,000	2,941,681
6	.621	150,000	93,150	4,457,000	2,767,797	4,307,000	2,674,647
7	.564	150,000	84,600	4,457,000	2,513,748	4,307,000	2,429,148
8	.513	150,000	76,950	4,457,000	2,286,441	4,307,000	2,209,491
9	.466	150,000	69,900	4,457,000	2,076,962	4,307,000	2,007,062
10	.424	150,000	63,600	4,457,000	1,889,768	4,307,000	1,826,168
11	.385	150,000	57,750	4,457,000	1,715,945	4,307,000	1,658,195
12	.351	150,000	52,650	4,457,000	1,564,407	4,307,000	1,511,757
13	.319	150,000	47,850	4,457,000	1,421,783	4,307,000	1,373,933
14	.290	150,000	43,500	4,457,000	1,292,530	4,307,000	1,249,030
15	.263	150,000	39,450	4,457,000	1,172,191	4,307,000	1,132,741
16	.239	150,000	35,850	4,457,000	1,065,223	4,307,000	1,029,373
17	.218	150,000	32,700	4,457,000	971,626	4,307,000	938,926
18	.198	150,000	29,700	4,457,000	882,486	4,307,000	852,786
19	.180	150,000	27,000	4,457,000	802,260	4,307,000	775,260
20	.163	150,000	24,450	4,457,000	726,491	4,307,000	702,041
21	.149	150,000	22,350	4,457,000	664,093	4,307,000	641,743
22	.135	150,000	20,250	4,457,000	601,695	4,307,000	581,445
23	.123	150,000	18,450	4,457,000	548,211	4,307,000	529,761
24	.112	150,000	16,800	4,457,000	499,184	4,307,000	482,384
25	.101	150,000	15,150	4,457,000	450,157	4,307,000	435,007
26	.092	150,000	13,800	4,457,000	410,044	4,307,000	396,244
27	.084	150,000	12,600	4,457,000	374,388	4,307,000	361,788
28	.076	150,000	11,400	4,457,000	338,732	4,307,000	327,332
29	.069	150,000	10,350	4,457,000	307,533	4,307,000	297,183
30	.063	150,000	9,450	4,457,000	280,791	4,307,000	271,341
31	.057	150,000	8,550	4,457,000	254,049	4,307,000	245,499
32	.052	150,000	7,800	4,457,000	231,764	4,307,000	223,964
33	.047	150,000	7,050	4,457,000	209,479	4,307,000	202,429
Totals		14,001,000	9,833,112	133,710,000	33,711,000	119,709,000	24,878,000

Net present worth:	$24,878,000
Benefit/cost ratio:	3.5
ERR:	33.1%

SUMMARY TABLE — SENSITIVITY ANALYSES (Tomegbe)

Changed assumption	Cost-effectiveness			NPW
	Hydro	Diesel	CEB	
1. Baseline	9,833,000	50,061,000	7,344,000	24,878,000
2. Discount rate 8%	10,262,000	62,043,000	9,102,000	32,757,000
3. Discount rate 12%	9,483,000	41,306,000	6,060,000	19,158,000
4. Hydro capital cost +25%	11,997,000	50,061,000	7,344,000	22,714,000
5. Hydro capital cost +50%	14,164,000	50,061,000	7,344,000	20,547,000
6. Diesel fuel cost +2%	9,833,000	56,596,000	7,344,000	31,413,000
7. Diesel fuel cost +4%	9,833,000	65,305,000	7,344,000	40,121,000
8. CEB electricity +3%	9,833,000	50,061,000	9,579,000	24,878,000
9. Diesel substitution -50%	9,833,000	25,032,000	7,344,000	17,145,000

COST-EFFECTIVENESS ANALYSIS (Wonougba)

1. Baseline

	Hydro Option			Diesel Option			CFB		Cost Comparison		
Year	Capital	O&M	Total	Capital O&M	Energy Cost	Total	Total	PW Factor	Hydro	Diesel	CFB
1	190,000	0	190,000	0	0	0	0	1.000	190,000	0	0
2	190,000	0	190,000	0	0	0	0	.909	172,710	0	0
3	0	15,000	15,000	45,000	103,000	148,000	22,000	.827	12,405	122,396	18,194
4	0	15,000	15,000	45,000	103,000	148,000	22,000	.751	11,265	111,148	16,522
5	0	15,000	15,000	45,000	103,000	148,000	22,000	.683	10,245	101,084	15,026
6	0	15,000	15,000	45,000	103,000	148,000	22,000	.621	9,315	91,908	13,662
7	0	15,000	15,000	45,000	103,000	148,000	22,000	.564	8,460	83,472	12,408
8	0	15,000	15,000	45,000	103,000	148,000	22,000	.513	7,695	75,924	11,286
9	0	15,000	15,000	45,000	103,000	148,000	22,000	.466	6,990	68,968	10,252
10	0	15,000	15,000	45,000	103,000	148,000	22,000	.424	6,360	62,752	9,328
11	0	15,000	15,000	45,000	103,000	148,000	22,000	.385	5,775	56,980	8,470
12	0	15,000	15,000	45,000	103,000	148,000	22,000	.351	5,265	51,948	7,722
13	0	15,000	15,000	45,000	103,000	148,000	22,000	.319	4,785	47,212	7,018
14	0	15,000	15,000	45,000	103,000	148,000	22,000	.290	4,350	42,920	6,380
15	0	15,000	15,000	45,000	103,000	148,000	22,000	.263	3,945	38,924	5,786
16	0	15,000	15,000	45,000	103,000	148,000	22,000	.239	3,585	35,372	5,258
17	0	15,000	15,000	45,000	103,000	148,000	22,000	.218	3,270	32,264	4,796
18	0	15,000	15,000	45,000	103,000	148,000	22,000	.198	2,970	29,304	4,356
19	0	15,000	15,000	45,000	103,000	148,000	22,000	.180	2,700	26,640	3,960
20	0	15,000	15,000	45,000	103,000	148,000	22,000	.163	2,445	24,124	3,586
21	0	15,000	15,000	45,000	103,000	148,000	22,000	.149	2,235	22,052	3,278
22	0	15,000	15,000	45,000	103,000	148,000	22,000	.135	2,025	19,980	2,970
23	0	15,000	15,000	45,000	103,000	148,000	22,000	.123	1,845	18,204	2,706
24	0	15,000	15,000	45,000	103,000	148,000	22,000	.112	1,680	16,576	2,464
25	0	15,000	15,000	45,000	103,000	148,000	22,000	.101	1,515	14,948	2,222
26	0	15,000	15,000	45,000	103,000	148,000	22,000	.092	1,380	13,616	2,024
27	0	15,000	15,000	45,000	103,000	148,000	22,000	.084	1,260	12,432	1,848
28	0	15,000	15,000	45,000	103,000	148,000	22,000	.076	1,140	11,248	1,672
29	0	15,000	15,000	45,000	103,000	148,000	22,000	.069	1,035	10,212	1,518
30	0	15,000	15,000	45,000	103,000	148,000	22,000	.063	945	9,324	1,386
31	0	15,000	15,000	45,000	103,000	148,000	22,000	.057	855	8,436	1,254
32	0	15,000	15,000	45,000	103,000	148,000	22,000	.052	780	7,696	1,144
Total	380,000	450,000	830,000	1,350,000	3,090,000	4,440,000	660,000		491,230	1,268,064	188,496

NET INCREMENTAL BENEFIT ANALYSIS (Wonougba)

Discount rate: 10%

1. Baseline

Yr.	PW Factor	Project Costs Nominal	Project Costs Discounted	Benefits (fuel savings) Nominal	Benefits (fuel savings) Discounted	Net Economic Return Nominal	Net Economic Return Discounted
1	1.000	190,000	190,000	0	0	-190,000	-190,000
2	.909	190,000	172,710	0	0	-190,000	-172,710
3	.827	15,000	12,405	103,000	85,181	88,000	72,776
4	.751	15,000	11,265	103,000	77,353	88,000	66,088
5	.683	15,000	10,245	103,000	70,349	83,000	60,104
6	.621	15,000	9,315	103,000	63,963	88,000	54,648
7	.564	15,000	8,460	103,000	58,092	88,000	49,632
8	.513	15,000	7,695	103,000	52,839	88,000	45,144
9	.466	15,000	6,990	103,000	47,998	88,000	41,008
10	.424	15,000	6,360	103,000	43,672	88,000	37,312
11	.385	15,000	5,775	103,000	39,655	88,000	33,880
12	.351	15,000	5,265	103,000	36,153	88,000	30,888
13	.319	15,000	4,785	103,000	32,857	88,000	28,072
14	.290	15,000	4,350	103,000	29,870	88,000	25,520
15	.263	15,000	3,945	103,000	27,089	88,000	23,144
16	.239	15,000	3,585	103,000	24,617	88,000	21,032
17	.218	15,000	3,270	103,000	22,454	88,000	19,184
18	.198	15,000	2,970	103,000	20,394	88,000	17,424
19	.180	15,000	2,700	103,000	18,540	88,000	15,840
20	.163	15,000	2,445	103,000	16,789	88,000	14,344
21	.149	15,000	2,235	103,000	15,347	88,000	13,112
22	.135	15,000	2,025	103,000	13,905	88,000	11,880
23	.123	15,000	1,845	103,000	12,669	88,000	10,824
24	.112	15,000	1,680	103,000	11,536	88,000	9,856
25	.101	15,000	1,515	103,000	10,403	88,000	8,888
26	.092	15,000	1,380	103,000	9,476	88,000	8,096
27	.084	15,000	1,260	103,000	8,652	88,000	7,392
28	.076	15,000	1,140	103,000	7,828	88,000	6,688
29	.069	15,000	1,035	103,000	7,107	88,000	6,072
30	.063	15,000	945	103,000	6,489	88,000	5,544
31	.057	15,000	855	103,000	5,871	88,000	5,016
32	.052	15,000	780	103,000	5,356	88,000	4,576
Totals		830,000	491,000	3,090,000	882,000	2,260,000	391,000

Net present worth: $391,000
Benefit/cost ratio: 1.8
ERR: 20.1%

SUMMARY TABLE — SENSITIVITY ANALYSES (Wonougba)

Changed assumption	Cost-effectiveness			NPW
	Hydro	Diesel	CEB	
1. Baseline	491,000	1,268,000	188,000	391,000
2. Discount rate 8%	522,000	1,542,000	229,000	552,000
3. Discount rate 12%	468,000	1,065,000	158,000	273,000
4. Hydro capital cost +25%	583,000	1,268,000	188,000	300,000
5. Hydro capital cost +50%	673,000	1,268,000	188,000	210,000
6. Diesel fuel cost +2%	491,000	1,434,000	188,000	557,000
7. Diesel fuel cost +4%	491,000	1,655,000	188,000	779,000
8. CEB electricity +3%	491,000	1,268,000	246,000	391,000
9. Diesel substitution -50%	491,000	629,000	188,000	-54,000