AN ASSESSMENT OF THE USE POTENTIAL OF THE FLOW OF WATER AT THE SPRING "OJO DE AGUA" IN AGUADILLA, PUERTO RICO

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I. INTRODUCTION

In the city of Aguadilla, in western Puerto Rico, the problem of water availability is a matter of serious consideration. There are neighborhoods of cluttered wooden houses that have no fire control system. These sectors are the mos populated parts of the city, and to make the situation worse, these areas are inaccessible by fire trucks.

There is also a small park in the center of Aguadilla, with a limited use during daytime hours because there is no illumination during the night. Vandalism takes advantage of this situation, making this area unsafe for residents during the night. The municipal government which operates on a deficit has not been able to sypply the needed lighting for this park. Besides, one-third of their inadequate budget goes to the expense of public lighting. A solution to these compounded problems may lie in a Karstic spring, "Ojo de Agua", that surges at this park and flows continuously all year long. It is tragic to see millions of gallons of water and the energy available in its flow totally wasted by discharging them to the nearby sea. These waters are not even for recreational purposes, other than their pleasant view on their way through the partk.

This study assess the potential utilization of the water supply and the energy which could be produced by the water flow from the Karstic spring "Ojo de Agua". It gathers the information that may lead to the utilization of the spring with regard to:

1. The creation of a water reserve to provide a fire security system.
2. The development of a mini-hydroelectric power plant to supply the energy for illuminating the park making it safe for night use.

3. Other uses for this water, such as active recreation.

The objective of this proposed project is to provide the municipal and state authorities at Aguadilla, Puerto Rico, with the framework for the utilization and conservation of the water flow generated at the Karstic spring "Ojo de Agua". This assessment will supply the information and technical assistance that will show the feasibility of the use of these waters to solve local problems of inadequate water supply and of energy shortages. It is also our goal to identify any other use that can be given to these waters.

II. TASKS REPORT

1. Flow Measurements

a) Construction of a weir

The concrete box containing the karstic spring was built last century. This water box constitute itself a wide weir (3.75 m) with a very low head (See Figure 1).

Typical heads are from 4 cm to 7 cm. The flow in a weir can be measured with the formula.

$$Q = C\ L\ H^{3/2}$$

where H is the head, L is the width and C is usually considered an experimentally determined coefficient.

In V.T. Chow Open-Channel Hydraulics, some theoretical aspects of the coefficient C are considered for the "flat broad crested weir (Example 3.2, p 53, V.T. Chow, Open-Channel Hydraulics, 1959 McGraw Hill). The flow equation is derived considering lesser experimental facts.

The coefficient C comes out to be

$$C = \frac{69}{16} \left(\frac{H}{H + Y}\right)^{1/2}$$

where H is the head and Y is the height of the crest. Considering the limits of Y to be from zero to infinite, the theoretical range for C comes out to be from 1.36 $m^{\frac{1}{2}}/S$. The practical range based in actual observations, is from 1.47 $m^{\frac{1}{2}}/S$ to 1.68 $m^{\frac{1}{2}}/s$. All these figures were transformed from the English system, as expressed in V.T. Chow, to the metric system.

There is data in the hydraulic literature (Brater and King, Handbook of Hydraulics, McGraw Hill 6th Ed.) to determine the appropiate coefficient C for different types of weirs, conditions and heads. In the particular situation of broad-crested weirs, considerable discrepancy exists in the different experiments to determine the coefficient C for low heads (below 15 cm).

The construction of a temporary smaller weir (inside the water box) was proposed. With the smaller weir, the head would be much bigger and a more appropiate coefficient would be got from the literature.

It would be very difficult to work at the site. The gate for draining the water box has been closed for years, and such a construction would be exposed to vandalism. The construction of the temporary small weir was cancelled.

It was decided to calculate the flow in the best possible way with the available data for coefficient C. The most appropiate description of the weir was a "Broad crested weir with the Crest Inclined Slightly Downward". Table 5.5 b (page 5-41) of Brater and King, Handbook of Hydraulics, McGraw Hill 6th Ed. gives the value of C for such a weir. For a 3 ft (0.91 m) weir, a slope of the creast of 18 to 1, and a head of 0.2 ft (6.1 cm) the table gives a value of C of 2.92 $ft^{\frac{1}{2}}/S$. The value of C in the metric system is 1.61 $M^{\frac{1}{2}}/S$. It is important to note that the first half of the crest has a slope of around 20 to 1 and that the second half has a slope of around 3 to 1. The discrepancies between the values for different conditions should be done in order to get the most appropiate value of C. Instead, it was assumed that the bigger slope in the second half of the crest does not affect the head. With this assumption, the conditions on the weir were such that it was possible to adopt a value directly from the table.

b) Flow measurements

Head measurements were suggested twice a day. A preliminary analysis (prior to the project time period) reflected that one head reading just before noon was a better indicator than the suggested two readings, the second one intended for the afternoon. The typical raining during the day is between 12 noon and 4 PM. Any afternoon reading would be directly affected by the rain in the two hours previous to the reading.

It was observed that not only the rain affected the reading almost instantly, but that after the rains stopped, the stabilization period was relatively short. These observations were confirmed with interviews to people who go frequently so to the park.

It is easy to do a qualitative analysis of this situation based on the physical characteristics of the water box where the head is measured (see Figure 2).

Most of the time the head is within the lower vertical (below 7.5 cm). Only on rainy season the head goes over to the diagonal section (between 7.5 cm and 19.5 cm), mainly on the raining hours. On exceptional flooding occasions the head goes to the upper vertical (above 19.6 cm). In some of those flooding occasions, the rain is so hevay, that a pluvial sewer, connected to the downstream canal of the water box, overruns the spring, and the head has nothing to do with the waters comming from the spring. This situation exists after two or three hours of very heavy rain, and typical measurement of the head might be around the 50 cm. This flooding occurs two or three times during the whole rainy season.

The consistency of the response to the interviews, based on three classes of head measurement (lower vertical, diagonal and upper vertical) and the relatively short period of stabilization of the head after raining, makes it reasonable to conclude that not only just one reading before noon is enough, but also that it is the best indicator of the off rainy season months behavior of the spring. The time for the daily reading was set to 11:00 AM. It is important to note that although the typical time for raining is in the afternoon, sometimes it rains during the morning hours in the rainy season.

It is also important to note that although the principal factor affecting the water level is the downtown rain, there was a certain correlation between the water level and the previous rains in areas in the order of 1 to 10 kms away from downtown. In Puerto Rico, rains are not uniformly distributed geographically. No quantitative analysis could be done of this correlation. The only practical information obtained is the possible confirmation that the underground river that emerges at the water box is a few kilometers long. There are some very interesting theories in the history of Aguadilla about this, and its relation with the controversy about where was Christopher Colombu's landing in Puerto Rico.

Appendix A includes all reading from April 1, 1981 to September 30, 1981. The smallest reading was 4.0 cm and it was measured early in April, and sometimes during subsequent months. Twice in May and once in June the head went over the diagonal to the upper vertical, produced by three of the floods experienced during the season.

In order to have a meaningful flow measurement, two figures are going to be used for the head, one representing the non rainy season, and the other the rainy season. No measurements were made of the non rainy season, but a value of 4 cm for the head is going to be adopted based on the observations expressed before. For the rainy season, the average of all readings during the period of the project will be adopted. The average, for these six months period is 5.76 cm. With these two quantities, a coefficient $C = 1.61\ m^{\frac{1}{2}}/S$ and a length of the weir $L = 3.75$, we can evaluate the flow during the non-rainy season Q_n and during the rainy season Q_r:

$$C = CLH^{3/2}$$

$$Q_n = 1.61\ m^{\frac{1}{2}}/S\ (3.75\ m)\ (0.04\ m)^{3/2} = 0.0483\ m^3/S$$

$$Q_n = 48.30\ Hlt/S = 766\ gpm$$

$$Q_r = 1.61\ m^{\frac{1}{2}}/S\ (3.75\ m)\ (0.0576\ m)^{3/2} = 0.0835\ m^3/S$$

c) The power potential

In order to get the maximum power from the spring without affecting the acsthetic and cultural values of the park, a construction of a small dam inside the water box is considered as the only possibility, see Figure 3. From the dimensions of the water box, it can be seen that the maximum head of the dam is around 1.25 m.

It is assumed that the flow will be the same with the rising of the water level due to the dam. This might be a very dangerous assumption, but the history of the use of the water box by the local kids make the assumption safe. Until a few years ago, when the strength of the front iron-grill allowed it, the local kids used to fill the water box completely in order to use it as a swimming pool. This was done by locating vertical against the from grill on the top of the weir. The water level would rise to overcomre the top of the panels and the flow woold start again downstream. Two facts are important in this assumption. The first one is that when this was done, no other flow would be initiated elsewhere in the neighborhood. The second is that this point (where the water box is located) is one of the lowest in town. This means that it is safe to assume that no water source was strangled by rising the water level.

At the present time, the illumination of the park is far from being adequate. The flow evaluated in the previous section is big enough to improve the illumination, but not big enough to do it adequatelly. The energy storaged in batteries during the day is going to be considered also, in order to make the most efficient use of this energy. In the following analysis all computations will be made both for the non-rainy season and for the rainy season. The following information will be used:

$$Q_n = 0.0483 \ m^3/S$$

$$Q_r = 0.0835 \ m^3/S$$

A head h = 1.25 m is going to be used based on the construction of the dam inside the water box. Two possibilities are going to be considered for both seasons. The evaluation of the power output without any energy storage and with energy storage using batteries.

The following typical efficiency factors are going to be applied in the analysis:

Overshot water wheel	$\omega w = 65\%$
Gear - box	$\omega g = 95\%$
Belt - drive	$\omega b = 97\%$
Alternator	$\omega a = 80\%$
Energy Storage in batteries	$\omega s = 78\%$

The theoretical power potential is given by the formula

$$P_o = hQ\gamma$$

where P_o = power

h = head (1.25 m)

γ = specific weight of water (9790 N/M^3)

The typical 70W, 120V sodium lamp is also going to be assumed in the analysis.

1- Non-rainy season, no storage

The theoretical power is

$$P_t = (1.25 \ m) \ (0.0483 \ m^3/S) \ (9700 \ N/M^3) = 591 \text{ watts.}$$

The combination of all the efficiency factors excepts for storage is wgba = 48%. This gives a real power of Pnn = (591 w) (0.48) = 284 W and a number of 70w sodium lamps of Nnn = (284 W) / (70 W/lamp) = 4 lamps.

Typically, around this same number of lamps are operating in the park at present, but the less efficient in can descent's and mercury vapor's.

2- Rainy season, no storage

The theoretical power is

$$P_t = (1.25)\ (0.0835)\ (9790) = 1{,}022\ W$$

The real power is

$$Prn = (1022)\ (0.48) = 491\ W$$

Number of lamps

$$Nrn = (491)\ /\ (70) = 7\ lamps$$

It is important to note that this is based on an average flow. This means that the actual number of lamps to be operated at a specific time will vary around those numbers. This suggests the use of more than one circuit, maybe two or three lamps per circuit. The operation of the second or third circuit would depend on the flow.

3- Non-rainy season, storage batteries

The use of batteries for energy storage allows for the use of the energy available during the whole day. The energy is stored directly from the generator, that is, prior to the alternator. Considering all the efficiency factors except those of the alternator and storage we get wgb = 60%.

This means that from the theoretical value P_t = 591 watts the amount to be stored is

$$Ps = (591w)\ (.6) = 354.6\ W$$

Assuming that day light is from 6:00 A.M. to 6:00 P.M., 12 hours of charging time would give the following amount of energy

$$Es = (354.6W)\ (12\ hr) = 4{,}255.2\ W\text{-}Hr$$

If this energy is used during the period from 6:00 P.M. to 11:00 P.M., when the greatest illumination is necessary, it would give a discharge time of 5 hours. The power available to the alternator, applying the efficiency factor of the battery system

$$Ps = 4255.2W\text{-}Hr\ (0.78)\ /\ (5\ Hr) = 663.8.W$$

The total power available to the alternator from the flow and from the battery is

$$P(alt) = 354.6 + 663.8 = 1{,}018.4W$$

Applying the efficiency factor of the alternator to this amount we get the real effective power available to the sodium lamps.

$$P_{cff} = (1018.4W\ (.8) = 815W$$

and the number of 70W sodium lamps is

$$Nns = (815W)\ /\ (70\ w/lamp) = 11\ lamps$$

4- Rainy season, storage batteries

From the theoretical value of 1022W, applying the combined efficiency factor of 60% (alternator and batteries not included) we get the amount of power available to storage.

$$Ps = (1022\ W)\ (.6) = 613.2W$$

Then, after 12 hours of changing time we get

$$Es = (613.22W)\ (12\ hre.) = 7{,}358.4\ W\text{-}Hr$$

In a discharge time of 5 hours, the power available to the alternator applying the efficiency factor of the batteries is:

$$P(alt) = 613.2 + 1{,}148 = 1{,}761\ W$$

The real effective power available to the sodium lamp (applying the alternator efficiency factor of 80%) is

$$P_{cff} = (1761\ W)\ (.80) = 1409\ W$$

From this effective power, we can get the maximum number of sodium lamp to be used to light the park.

$$N_{rs} = (1409\ W)\ /\ (70W/lamp) = 20\ lamps$$

2. Underground characteristics

After emptting the water box, we noted two orifices from which the water emerges.

A test was conducted to verify if the emanating water was from the same source, so a clay dam was built around one of the holes. The dam was built above water level. The flow of water of that orifice stopped when the dam went over its water level, and the inside level of the water in the hole remain constant. The quantity of total water was annoted before and after the dam in a down-stream spot. Both measurements were the same. A test was repeated with the other hole and the results were the same. This simple test revealed that the water emanating from both holes comes from the same source.

As to the underwater inspection, the two orifices in the bottom of the water box seemed to be too small for a scuba diver to go in with the tanks and equipment. Besides, the perimeter of the orifices is a limestone formation with serrated edges making it dangerous to go in without sophisticated equipment.

A diver gave us professional advice and penetrated part of his body into the holes as far as possible. Then with a high intensity lamp make a visual recognition of the underground passages.

With this visual inspection, we could establish that behind hole #1 there is a vault completely underwater that is at least 12 feet in diameter, and that behind hole #2 there is a tunnel leading towards hole #1.

We say the vault is at least 12 feet in diameter because that was the range of the light beam from the underwater lantern use. Also living fishes and shrimps were present in both orifices and behind them.

3. Water reserve alternative study

A. Physical characteristics:

The town of Aguadilla lies between the Jaicoa Mountains and the Atlantic Ocean. A cross cut of the topography shows and average 300 meters wide strip of land from the seashore, and then a sudden rise to the mountains. The stream "Ojo de Agua" emerges about halfway in the flat strip of land, and its flow is directed by a very curvilinear concrete open channel leading to the sea. Surrounding the emerging spot, and part of the concrete channel there is "El Parterre" which is a passive recreation park, covered mostly by concrete slabs and stairs. Around the park resides a multi use neighborhood composed, of government offices, commercial and housing units.

The clustered communities in need of a fire protection system are located on the side of the nearby mountains, which are approximately 150 meters away and at a higher altitude. This neighborhood consists predominanty of one or two stories one family wooden dwellings.

B. Size of the water reserve

"The acquired fire flow for residential districts consisting of samll area one-family dwellings one or two stories in height varies from 500 to 2,000 gpm for 2-4 hours, depending on the degree of exposure between buildings" (Urban Planning and Design Criteria Third Edition, Joseph De Chiara/Lee Koppelman Fire Protection-Water Supply pp. 399).

Being the conditions of the clustered neighborhoods to be served very hazardous and inaccesible by fire trucks, both extreme values cited before must be used in calculating the volume of the water reserve to be established. Thus, 2,000 gpm for a duration of four hours establishes a needed supply of 480,000 gallons of water.

The spring "Ojo de Agua" produces a minimum supply during off-rain season of 766 gpm, this accounts for 183,840 gallons over a period of four hours. Therefore, subtracting this quantity from the established 480,000 gal a reserve of 296,160 gallons of water is needed to provide adecuate protection for the communities involved. From this figure, we must subtract approximately 20,000 gal that are stored on the water box and the underground vault.

C. Possible places to establish the reserve

First we must note that the spring emerges and flows to the sea at a lower altitude than the neighborhoods to be served. Also there is no evidence, or definite information of its underground course, thus eliminating the possibility of intercepting the spring on a higher level in the mountains. Therefore, if water from the spring is to be used for a reserve, a mechanical or electrical pumping system must be foreseen. Either of two systems could be appropiate for this endeavor. They are similar to a "wet" or "dry" stand pipe system. One directly feeds water to a distribution line of fire hydrants and the other pumps into a tank higher in altitude than the clustered communities and then the water is released by gravity, to supply the hydrants.

Looking for places to establish the water reserve we found that adequate sites are abundant to built a dam or a tank in the mountains. The selection of the most appropiate one will depend on the construction cost and accessability of the possible sites. Defining the most adecuate one requires a comprehensive comparative study that is far ahead of the scope of our project.

On the other hand, there is adequate space inside the park which does not interfere with historical and cultural values, for the creation of a pond that may serve as the water reserve of an up-feed fire protection system. There is an open space totally covered by a concrete slab on the southwest corner of the park into which a 20 meter diameter pond or underground tank can be constructed.

At the same time, we must consider that the actual conrete box that surrounds the emerging openeings of the spring, and the underground vault that our study revealed, constitue a deposit of at least 20,000 gallons. This figure is a calculated minimum because as explain on part 2 of this report, the intensity of the lamp only allow us to see for 12 feet inside the valut, so it is expected to be larger than estimated.

4. Recopilation and analysis of related published material

Our investigation of related published material revealed that manuals, books and articles make references to micro hydroelectric plants that have larger values than the one available in our project. Our head values are only mentioned as extreme values and no details are given for its operations, such as its efficiency behavior.

The publications that proved to be most valuable for our project in the topic of micro hydro power are the following:

1. Harnessing Water Power Home Energy; Author Dermot McGuigan. Garden Way Publishing Co. Charlotte, Vermont 05445.
2. Micro Hydro Power Reviewing and Old Concept: by the National Center for Appropiate Technology. Authors, Ron Alward, Sherry Eisenbart, and John Walkman. U.S. Department of Energy, Idaho

Operations Office. DOE/ET/01752-1.

3. General View of a Milchell Turbine, Armando Cabrera and Javier Berrocal, Design #5 Project report for Mechanical Engineering Course MEEN 513 in charge of Professor Ray Jiménez. UPR., Mayaguez

4. Alternative Natural Energy Sources in Building Design. Authors, Davis & Schubert.

On the subject of water storage

Urban Planning and Design Criteria by Joseph DeChiara/ Lee Koppelman, Third Edition.

provided the information necessary to establish the capacity of the water reserve to be developed, based on data from the following source:

Standard Schedule for Grading Cities and Towns of the U.S., National Board of Fire Underwriters- 1956, New York Chicago, San Francisco.

5. <u>Pertinent legislation</u>

The parcel of land that contains the park in which the "Ojo de Agua" spring emerges belongs to the Commonwealth of Puerto Rico with the local Public Works Department assigned as the caretaker. This ownership is established on the records of the Treasury Department in their affairs at the Aguadilla Government Center. The assigned tax map number of this property is 01-19-045-016-054-08. Although this is so, the Municipal Administrator of Aguadilla is the one that gives maintenance and supervises the activities within the park based on traditional use and customs.

On the other hand, the park and the spring have a definite historical and cultural value. Notations of the springs refer as "Río Chico" date back to 1655 on a book titled "Derrotero". Also in 1776 Fray Iñigo Abad, a renowned historian mentions the existance of the spring on his history book. The water box was built 1850 and a group of citizens recollected monies in 1880 to buy the land in which the park is set.

After 132 years the water box is not only considered to have historic value, but also to have served as inspiration to famous poets José de Diego. One of his poems describes the place as rare and marvelous, and that the whole world has the bread of God, but that Aguadilla is the only place having the water of God.

Interviews with government officials, professionals and other community leaders confirm that the citizens are not only aware of the values expressed before, but are very much concerned and alerted to any project to be developed in the park.

The research went as far as to investigate the manner in which a project inside the park was to be developed. In order to make any kind of construction, a "Consulta de Ubicación" which is a coordinating document between state agencies must be filled to the Puerto Rico Planning Board. The Board will then request comments from all the state agencies, specially from The Institute of Culture, Environmental Quality Board, The Department of Natural Resources and the Governors Office of Cultural Affairs. Without the endorsement of these Agenices it is very unlikely that any project in the park will go throughout.

As far as the implication of producing electric power, an interview was held with the head of the Planning and Research Division of the Puerto Rico Electric Power Authority. He presented the regulating document "Tarifas y Condiciones de Servicio para Cogeneradores y Productores de Electricidad en Pequeña Escala". This establishes that it is possible in Puerto Rico to produce electric power and to sell such power to the PREPA.

6. Visit to similar facilities

The estimated power potential of the "Ojo de Agua" karstic spring is 1022 watts, as determined by the calculations applied to the daily flow measurements. Therefore, the hydropower equipment suitable for this low output, falls in the category of "micro" and it requires an energy storage system.

Existing public hydropower installations in the island are of a much larger scale, inapropiate to be compared with our project. We must also consider that historical and cultural values of the site, specially of the water box where the spring emerges, limits the possibility of using mass production equipment.

These considerations and the scarcity of private micro-hydro equipment in Puerto Rico led to a fruitless effort in finding comparable facilities to our project.

We must also note that the initial draft for the proposal of this project contemplated a voyage to Latin Americ or the United States in order to obtain first hand knowledge from the operators of micro-hydropower plants under present operation. Unfortunately, the program did not provide for such activity.

7. Determination of most appropiate equipment

There are two very important constrains to consider in the determination of the most appropiate equipment to be used in the micro-hydropower plant. The first one is the historic and aesthetic value of the park. This means that the visitor of the park should see the minimum and smoother changes as possible. Because of this constrain, the small dam (to rise the head to 1.25 m) inside the water box is the only alternative considered. The second important constrain is the low head available. The smallest head values in the category of micro-hydropower plants found in the literature are on the order of 3m to 5m (10 ft to 15 ft).

The power calculations were done assuming an overshot water wheel with a typical efficiency of 65% and a head of 1.25 m. Overshot water wheels required a big head to turn them which is not present here. Large diameter undershot water wheels can be turned with low head but they have a lower efficiency. The bigger diameter implies a very low velocity, and an inapropiate big speed ratio in the transmission drive. Beside, all these points against the water wheel, there was no indication in the literature that a samll head, like the one in consideration, would be sufficient to turn it.

The research done suggests that for the very-small-head projects the best choice is the cross flow turbine often called Mitcheel turbine. They have proven to produce output power in the range of the head size of the project (1 meter). Furthermore, the minimum head needed to the crossflow turbine, found in one of the publications was 0.254 m (10 inches). They have relatively high efficiency factor (around 80%). It is also very flexible in terms of efficiency vs flow rate. The efficiency does not vary considerably over the range of flows from 1/4 to full design flow. Its relatively high rotational velocity, compared with water wheels, alleviate the big speed ratio needed at the transmission drive. Besides, the turbine has a very important component, the nozzle. Figure 4 presents both components with typical dimensions. The characteristics of this project suggest the use of a small turbine runner of 0.3 m (12 inches) in order to have the bigger head of around 1m. The 1m head and the efficiency of 80% are equivalent in terms of the power calculation to the 1.25 m head and efficiency of 65% used on the previous calculations.

In the design of the turbine, the width of the nozzle is calculated from the formula:

$$W = \frac{14,350\ Q}{D\ H}$$

where:

Q is the flow in m^3/S

H is the head in m

D is the diameter of the turbine runner in cm.

The two possibilities considered in the study (non-rainy) and rainy season) produced two flow rates that differ by a factor of almost 2. This suggests the use of two turbines in series. The width W of each one will be evaluated for half the flow of the rainy season. The two combined turbines will work at design conditions. The flow in the non-rainy season Q_n is 0.0483 m^3/S. The diameter D is 30 cm and the head H is 1 m. The width of each of the two turbines to be connected in series is

$$W = \frac{14,350\ (0.0483)}{30\ \ \ \ (1)} = 23.1$$

The other important factor to consider in the design is the rpm of the turbine, given by the formula:

$$RPM = \frac{3903\ H}{D}$$

where:

H is the head in m

D is the diameter in cm

For this project it will be

$$RPM = \frac{3903\ \ 1m}{30\ cm} = 130\ rpm$$

If the turbine were to be connected to a typical 4 poles alternator the speed ratio on the transmission drive needed to connect them would be

$$\frac{1800 \text{ (for 4 poles)}}{130} = 13.8:1$$

where 1800 is the rpm of the alternator.

This is not an adequate ratio for a transmission drive. This suggests the use of an alternator with more poles like, for example, 6 or 8 that would require ratios of

$$\frac{1200 \text{ (for 6 poles}}{130} = 9.2:1$$

or

$$\frac{900 \text{ (for 8 poles)}}{130} = 6.9:1$$

where 1200 is the rpm for a 6 poles alternator, and 900 is the rpm for an 8 poles alternator. These slow-speed alternators generally last longer than the high - speed ones.

The need of the storage batteries eliminates the need of an alternator as the power converter. A DC generator is more adequate to convert the power if it is going to feed batteries. In the discharging time of the batteries, both the generator and the batteries are connected to a solid-state inverter, which will give AC current at the voltage and frequency required.

Beside all these equipment, also described in the power calculations section, an electronic load-diversion governor is needed. With it, the full output from the generator is continuosuly used. It operates by diverting the electric output from primary needs to secondary needs and vice versa as the input power is the flow varies. In this project all that is needed is lighting, so this implies turning on and off additional lamp circuits, varying two or three lamps each.

III. SOCIO-ECONOMIC ANALYSIS

The "parterre" project has three basic intervalated components:

A. The construction of a water reservoir against fire in the in-town populated hills.

B. The development of a recreative area that will include a small tank for children activities and a swimming pool. Besides, the beautiful surroundings will constitute an adecuate setting for passive recreation.

C. The development of a hydroelectric project to serve as power source for the illumination of the park.

This evaluation tries to measure the benefits and the costs associated with each of the above components. Due to the public nature of this project, the most significant benefits and costs are of social nature. The evaluation has to include the private, social benefits and costs. When a monetary value is assigned to the flow of benefits and cost it is necessary to establish some basic assumptions to simplify and approximate the actual values of this flows. In the situations where it is difficult to realize an appropiate estimate, cualitative values will be used. They will depend on a reasonable judgement.

A. It is possible to disclose three categories of social benefits in regard to the construction of a water reserve with waters from the spring "Ojo de Agua". These are:

   1. Protection of the private property in housing units and other structures. The community to be served is a high density housing community that runs from the "Cuesta Vieja" to "Barrio Visbal" sectors. According to data provided by Rat Control Program there are a

total of 2,711 housing units with about 12,740 persons. Recent appraisals of similar neighborhoods with the same socio-economical characteristics, set the average value of these structure at $9,000.

When providing a protection service against fires it will have an expected economic value equivalent to the product of the number of housing units, the probability of fire in that property, and the average loss in a typical damage caused on the housing units according to local experience. We have estimated each of this factors based on statistics of different sources.

The probability of fire was estimated on statistics provided by the Aguadilla Fire Department comming out to be 0.00286. The corresponding factor for the island of Puerto Rico is 0.00318. The same source provided the average estimated value of the damage in burnt houses which is $3,000.

According to this data, we can establish the annual expected benefit value for the protection against fire to be about $23,000 annually.

2,711 x 0.00286 x $3,000 = $23,260

2. Protection of the human life. Another benefit derived from the facilities to control fires is not permiting or reducing the probability of death of the residents. The economic value of this benefit can be approximated as the product of the probable number of casualtics and the economic value of a typical resident. The number of resident is 12,740 and the probability of death of a

person in a fire according to official statistics for Puerto Rico is 0.00000828. According to economical studies, the economic value to a typical person of 45 years (median age of people who die in fires in Puerto Rico) is reasonably $90,000 taking in consideration the condition of proverty of the neighborhood.

Based on the above factors the annual benefit of protecting the life of the residents is $9,494 annually.

12,740 x 0.00000828 x $90,000 = $9,494

3. Protection against the risk of economic incapacity.

As a result of fires, a number of persons become handicapped. No data exist to determine a precise estimate, but we would assign this contingency 20% of the preceeding value.

$9,494 x 0.20 = $1,898.82

Therefore, this benefit of avoiding economic incapacity can be said to be $2,000 annually.

4. The benefit of feeling secure.

Having facilities that minimize the risk of fire translate into a benefit where economic value is equivalent to the cost of an insurance premium against this disaster. For a wood house of $9,000, the insurance fee is $25 per unit per year. Therefore, this benefit will have a value of $67,775 annually. Adding up the previous factors, we get that the annual value fo the benefits of constructing a water reserve ascend to $102,499.

The cost of constructing the reserve is the investment in building a concrete holding tanks with a capacity of 280,000 gallons. Assuming a $200.00 per cubic yard of cost "in place" concrete and a circular or square tank configuration with 10ft depth we arrive at a cost of $40,000 to $50,000. Piping and fittings to use the fire truck pumps is estimated to be under $5,000. Therefore, the cost of building the facilities is set to be $55,000.

B. Recreational Services

The development of recreative uses of the spring waters will generate three flows of annual benefits associated with entertainment of children, swimming and passive recreation.

1. Benefit of a water pond. The monetary value derived from the benefit of having such facility will be based on the price that people will be willing to pay for the use of similar facilities and the annual expected number of users. Although, there are no similar facilities in the area to have a comparative price it had been observed that many children use toys in the pools where their parents pay an average of $2.00 for the access during standard business hours.

   The quantity of users depends more on the capacity of this facility than on any other factors. Assuming a reasonable cost of $2.00 and 5,000 annual users, we estimate a benefit of $10,000 for this first use.

2. Benefit of a swimming pool. The value of this benefit is the same to the one above. Estipulating and admission cost of $2.00 and 20,000 users, the economics value is $40,000.

3. Benefit of Passive Recreation. The economic value of enjoying the views inside the park is estimated to be

$2.00 times 4,000 users giving $8,000 annually.

The total benefits derived from this second component ascend to $58,000. Cost related to this benefits are minimal if the water reserve is used with dual purpose so the cost will be only in lining the tank with ceramic tiles and provide minimal facilities for human needs.

C. Economic Analysis of installing micro-hydroelectric equipment.

The economic value of this component will be estimated by the induced savings produced by using a direct source of energy instead of conventionally buying the energy from the Puerto Rico Electric Company. The cost for kilowatt hour generated by the selected equipment has been estimated at nine cents, meanwhile the Puerto Rico Electric Authority supplies energy at a rate of 12 cents per kilowatt hour.

Nevertheless, from this third component of the integral project other benefits are produced. The best of this benefits is the addition of a turistic attraction of an investment and non common facility in Puerto Rico. The place were this facilities will be set is considered an area of recreational, cultural and turistic planning and development within the Comprehensive Economic Development Plan for the Municipality of Aguadilla Public Works of this nature induce a crucial element in the provision of "things to see" within a gama of recreational and turistic services.

Socially speaking, the project exerts demonstration effect on the community that leads the people to seek new alternatives and sources of energy, and induce the better use of their natural resources. This benefit cannot be estimated in monetary terms, but they have an inmense economic value as catalytic elements on the economic development of the region.

IV. SOURCES OF FUNDS

Our research has proved that there is a great concern and interest of the Aguadilla citizens in the historical park where the spring Ojo de Agua emerges. This situation provides the adequate atmosphere for a public fund raising campaign combining the development of the hydroelectric facilities and the water reserve with a total rehabilitation of the park.

At the same time funds can be requested from the House of Representative of Puerto Rico and the Commission of Natural Resources of the Senate for the development of a demonstration project.

As to federal funding programs, the municipality participate as a Small City in the Community Development Block Grants program from Housing and Urban Development Administration with a great potential in becoming a Metropolitan Statistical Area. The funds available in this program can be used to develop all the recommendations of this report. The Federal Catalog no. for this program is 14.219.

Unfortunately, other federal program that provided funds for this activities have no appropiated funds due to the cutbacks of President Reagan Administration. Nevertheless, there are two programs that should be kept under permanent study because they may open up for funding, and are very suitable for energy projects:

1) Appropiate Technology Small Grants Federal Catalog No. 81.051. This program provided limited support for small scale energy conservation projects which are technically feasible, energy efficient and easy to install and operate.

2) Small Hydroelectric Power Project Feasibility Studies. Fed. Catalog No. 81.055. This program gives direct grants to conduct feasibility studies on future small hydroelectric power projects and to obtain licenses to initiate those approved projects.

V. RECOMMENDATIONS

Our study has proved that the development of the adequate hydro-electric facilities, and the creation of a water reserve and recreational uses with the waters of the spring Ojo de Agua are not only economically feasible for the Municipality of Aguadilla, but also that they would represent a great asset in the future development and social stability of the community.

We recommend that before a final design for this facilities is made, measurement of the flow of water during the non rainy season be registered, and its outcomes incorporated in the framework provided by this study.

Together with the creation of the proposed facilities we respectfully suggest:

1) The separation of the storm drainage channel from the water of the spring.
2) The total rehabilitation of the historic park.
3) Performing a study for the reactivation of the hydro-electric power plants revealed in the Río Llano study.
4) The integration of this water to the Recovery action Program of municipalities recreational facilities.

APPENDIX A

Daily head measurements April 1 - September 30, 1981

	April	May	June	July	August	September
1-	5.3	4.2	5.2	4.9	7.2	6.3
2-	5.1	4.2	4.3	4.8	7.1	6.3
3-	4.7	4.2	7.2	7.0	7.1	5.8
4-	4.0	4.0	6.2	4.7	6.8	7.0
5-	4.0	7.4	5.0	7.0	4.8	6.3
6-	4.0	5.4	4.6	6.5	4.9	6.1
7-	4.3	5.2	4.1	4.6	5.2	6.1
8-	5.2	5.5	4.0	9.1	4.9	5.8
9-	5.2	4.9	4.1	6.4	5.0	5.7
10-	4.9	4.5	7.6	5.1	5.1	5.2
11-	4.7	4.3	6.5	4.9	5.2	4.8
12-	4.6	4.2	5.8	4.8	5.1	4.4
13-	4.7	4.3	4.9	4.5	5.3	6.1
14-	4.8	7.9	4.3	4.4	5.7	5.2
15-	5.2	6.3	4.4	7.1	11.2	6.4
16-	7.5	5.8	4.6	6.5	7.6	5.7
17-	7.1	--	4.7	4.7	6.2	4.8
18-	6.9	7.6	4.6	5.9	5.4	4.2
19-	7.0	6.7	--	5.9	5.2	4.4
20-	6.5	8.7	7.6	5.7	4.8	4.2
21-	6.6	9.1	11.9	4.9	4.9	8.1
22-	6.5	7.4	5.5	4.3	5.3	7.3
23-	6.2	6.6	6.5	4.0	5.2	6.9
24-	6.0	5.8	5.0	4.0	5.0	6.2
25-	5.9	6.6	4.3	4.0	4.7	5.5
26-	6.6	6.1	15.3	4.5	10.9	4.8
27-	6.6	6.3	10.4	4.6	6.7	4.4
28-	6.5	--	7.0	4.9	5.7	4.4
29-	6.7	8.2	5.3	5.3	5.2	4.2
30-	7.0	7.4	5.0	5.2	5.1	4.2
31-	X	6.6	X	5.5	5.0	X