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Renewable Energy Load Assessment for Boquillas Del Carmen Coahuila, Mexico

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ABSTRACT

This report outlines the estimates that were made in 1992 of the potential load requirements for Boquillas del Carmen, a small Mexican village on the northern border of the state of Coahuila, Mexico near Big Bend National Park in southern Texas. The study was made to help determine the possibility that village might be electrified by solar or wind energy. Various estimates of are given of the potential load based on estimates ranging from basic use of lights, radio, television, and small household appliances to microwave ovens, refrigerators, and direct evaporative coolers. The low-energy consumption case was estimated to be at 23.0 kWh/month per residence per month, and the high-energy consumption case (with cooling) was 140.7 kWh/month per residence. On average, the typical residence is occupied by five individuals.

BOQUILLAS DEL CARMEN
COAHUILA, MEXICO

Southwest Technology Development Institute

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EXECUTIVE SUMMARY

A visit was made to the village of Boquillas del Carmen in 1992 in an effort to determine what the potential electrical load requirements would be for this village if it were to be electrified via solar or wind energy. Boquillas del Carmen is a small Mexican village located on the northern border of the State of Coahuila, Mexico, directly across from Big Bend National Park. The village is at 1,900 feet in elevation in the heart of the Chihuahuan desert. The current population is 209 persons occupying 44 residences. Additionally, there are seven (7) community buildings and five (5) businesses.

Boquillas' population currently owns 48 flashlights, 30 radios, 63 kerosene lamps, 6 propane lamps, 12 white gas lamps, 32 propane stoves, 1 white gas stove, 9 propane refrigerators, 3 televisions and 2 VCRs, 1 computer, and 1 satellite dish.

A number of homes and businesses are wired, complete with wall plugs, light sockets, and even bulbs, in anticipation of electrical service. An extensive power grid with 33 utility poles has been installed by the Mexican Government, originally to provide electricity via the U. S. power grid on the other side of the Rio Grande; however, this project was stopped for political and legal reasons.

Various estimates of the potential electrical load for the village are given in this report, based on estimates ranging from basic usage of lights, radio, television, and small household appliances to cases with lights and small appliances as well as microwave ovens, refrigerators, and direct evaporative coolers. The low-energy-consumption case was estimated to be at 23.0 kWh/month per residence, and the high-energy-consumption case (with cooling) was estimated to be at 140.7

kWh/month per residence. On average, the typical residence is occupied by five individuals.

It will be important to work closely with the village to help satisfy its basic needs in deciding what level of renewable energy electrical service is feasible and acceptable, and to develop a viable enforcement strategy for dealing with community restrictions on type of appliances allowed.

1.0 INTRODUCTION

A visit was made to the village of Boquillas del Carmen in the State of Coahuila, Mexico, at the end of April in 1992 by staff of the Southwest Technology Development Institute (SWTDI) in an effort to determine what the potential electrical load requirements would be for this village if it were to be electrified via solar or wind energy. Boquillas del Carmen is directly on the United States/Mexican border, across the Rio Grande river from Big Bend National Park near Boquillas Canyon.

SWTDI staff conducted a house-to-house visit of Boquillas in order to identify current energy usage patterns and assess the general demographics of the village to project future electrical load requirements after electrification.

1.1 Mexican Rural Renewable Energy Development Considerations

Nationally, total energy consumption in rural Mexico amounts to 100,000 billion kilocalories per year; of this, approximately 69% is supplied by fuelwood, 10% by gasoline, 10% by LPG, 6.5% by diesel fuel, 2.5% by electricity, and 2% by kerosene. The Northwest sections of Mexico have the highest rates of energy consumption nationally (Huacuz 1991). Boquillas is demonstrative of this trend of higher energy consumption in northern Mexico, with most residences owning propane stoves. The higher energy consumption found in northern Mexico is probably due to two reasons: proximity to the United States with access to relatively inexpensive appliances; and more severe winters than southern Mexico with significantly increased needs for heating and fuel consumption.

Over 85,000 communities in Mexico do not have electrical service. Boquillas is one of 44% of the 31,000 communities with a population range of 100 to 500 people that are not electrified in Mexico (Huacuz 1991).

Field studies in Mexico have shown that only the wealthiest 10% of the population in rural communities use electricity in amounts equivalent to, and with similar consumption patterns as, urban dwellers. The electricity consumed by the vast majority of rural residents is mostly used for lighting and some entertainment purposes (mostly radio) (Huacuz 1991). Boquillas electrical requirements can be expected to be similar to rural areas in other parts of northern Mexico.

Field surveys conducted in Mexico have shown that the best performing renewable energy electrification systems are those that have met the realistic expectations of the populations served. For instance, some users with renewable energy systems in Mexico have complained about poor reliability and requested grid extensions, because all the user received was lighting from the renewable energy system. The user also wanted to be able to watch television (Huacuz 1991). It is important to satisfy the basic needs of the user in order to ensure acceptance of renewable energy systems.

Boquillas is located only about a mile from Rio Grande Village in the United States where grid power is available. Villagers in Boquillas are well aware of what normal grid electrical service entails and have preconceived expectations as to what electrical service in Boquillas should be like. It is important to work closely with the village in deciding what level of renewable energy electrical service is feasible, and to develop a viable enforcement strategy for dealing with potential problems in

controlling user demand on a fixed-capacity power system (e.g., no electrical refrigerators are allowed, yet some residents install them anyway).

2.0 BOQUILLAS SITE DESCRIPTION

The village of Boquillas del Carmen is located on the northern border of the State of Coahuila, Mexico, directly across the Rio Grande river from Big Bend National Park near Rio Grande Village. Boquillas is situated a little over a mile from the west mouth of Boquillas Canyon, which is one of three principal canyons in Big Bend National Park. The village is approximately 1,900 feet in elevation in the heart of the Chihuahuan desert. SWTDI staff determined that Boquillas has a current population of 209 persons (57% of which are age 15 or older). Refer to maps in Appendix D for general location and layout of Boquillas.

Boquillas was originally founded as a mining community during the early part of the century and has evolved away from mining and now relies almost entirely upon tourism from Big Bend National Park for its survival. There are some agricultural and ranching activities in the area as well, but catering to Big Bend tourists is the dominant activity for the village. Villagers offer a variety of services to tourists, from selling leather, clothing, blankets, and rock carvings, to shuttling tourists across the river, and from the river crossing to town via burro or pickup truck. Tourism peaks with the Big Bend tourist season in spring. Some of the villagers also work for the Park Service sometimes residing away from Boquillas for days at the Chisos Basin Park. Finally, some Boquillas residents are U. S. citizens who work as river outfitters.

Boquillas is divided into two sections: upper and lower Boquillas, as shown in Figures 1 and 2. The upper section lies on top of a mesa north of the lower section, which is situated in an old flood plain of the Rio Grande. There are 44 occupied residences in Boquillas, with a combined total of 115 rooms; there is an additional one-room residence used by a Catholic priest occupied for a few days every three months or so. In addition, there are five (5) businesses in Boquillas (excluding business interests within private residences), with a combined total of 12 rooms.

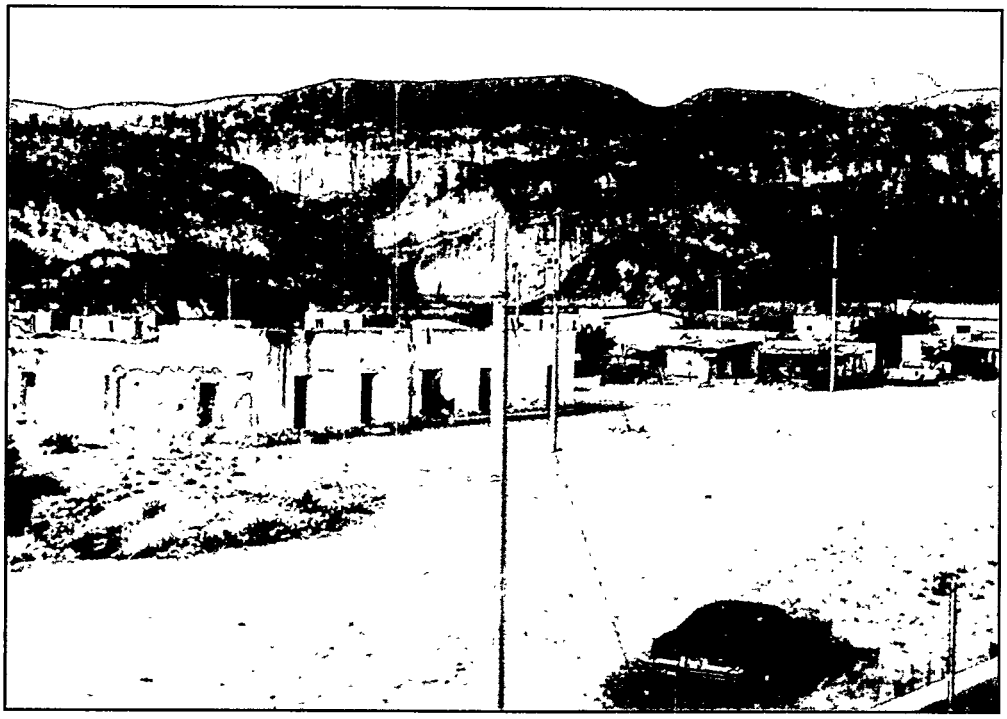

Figure 1. View looking northeast from upper Boquillas: Boquillas Canyon in background.

Figure 2. View looking south from upper Boquillas to lower Boquillas.

2.1 Residences

The vast majority of Boquillas residences are constructed of adobe, with only 11% of residences made of cinder block, owned by some of the wealthier residents. Construction of roofs in Boquillas is of the "carriso" style, which uses heavy timbers (as shown in Figure 20), with river reed canes laid perpendicular on top of the timbers. Cardboard, old cloth sacks, or other materials are laid over the canes, and a layer of dirt, several inches thick is placed on the roof. Figures 3 through 6 show some average dwellings and additional views of the community of upper and lower Boquillas.

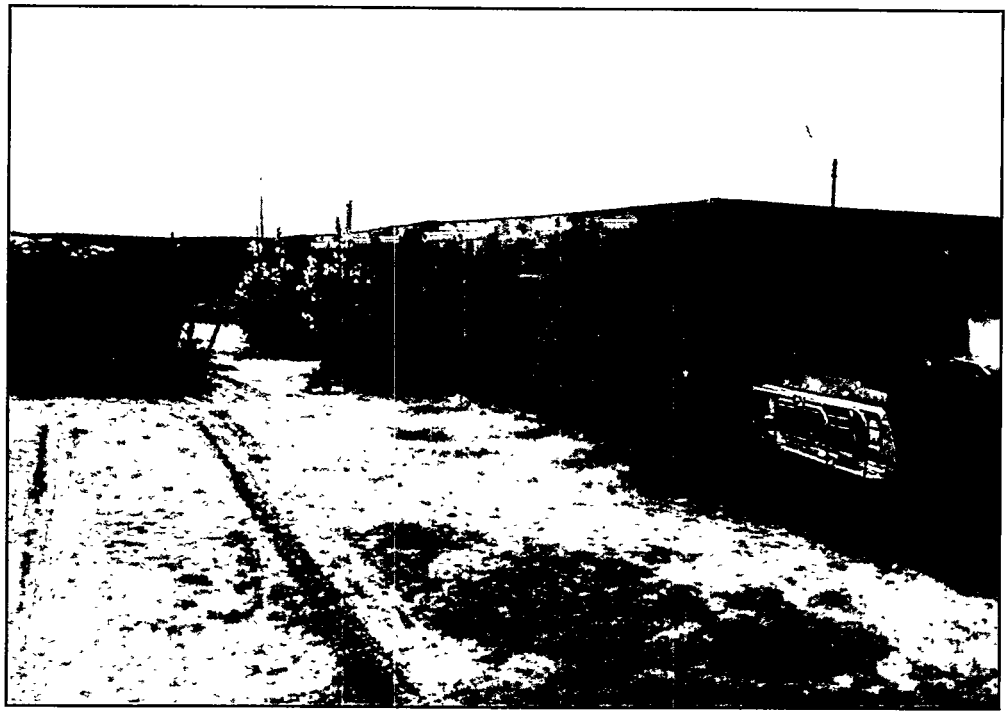

Figure 3. South side of residence in lower Boquillas.

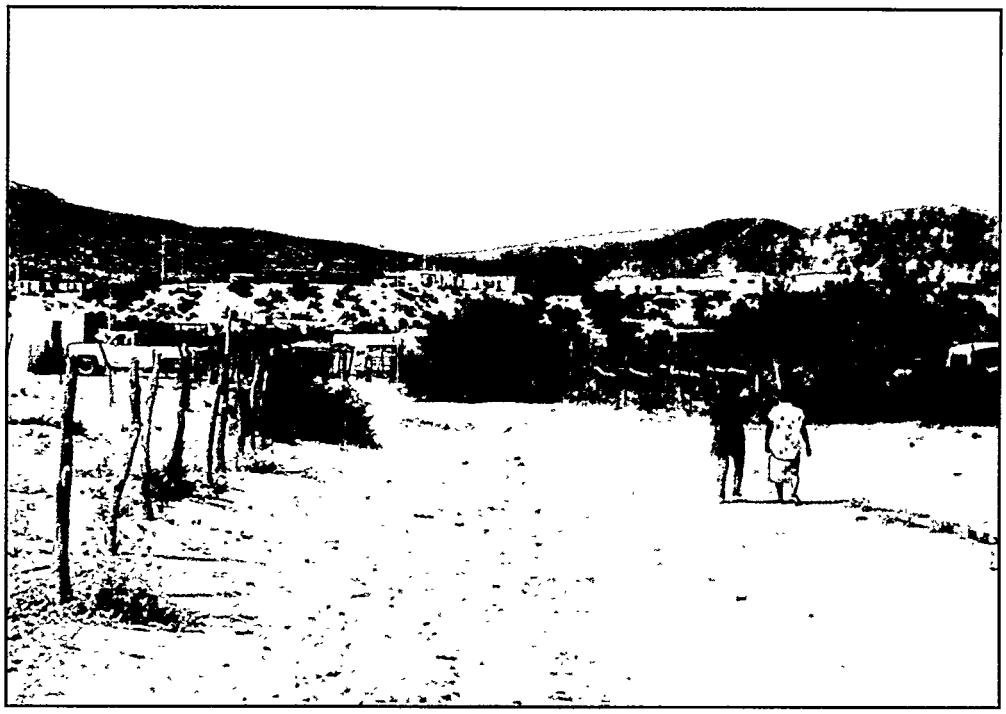

Figure 4. View looking north from lower Boquillas to upper Boquillas.

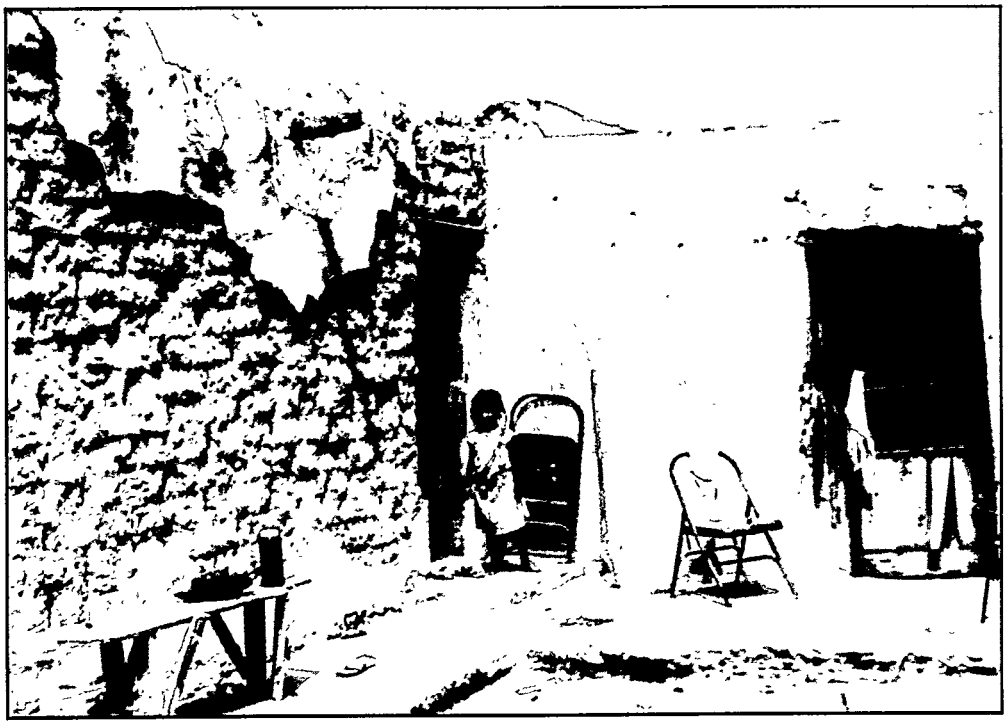

Figure 5. West side of residence in lower Boquillas.

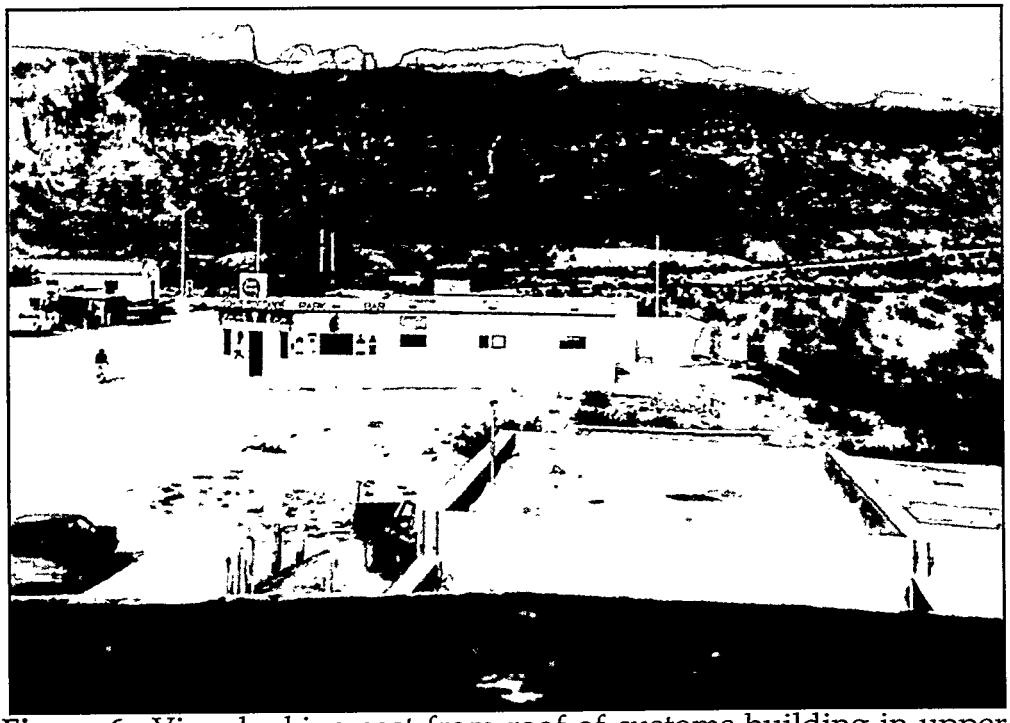

Figure 6. View looking east from roof of customs building in upper Boquillas; bar in middle of picture and solar/wind resource assessment tower in background behind the bar.

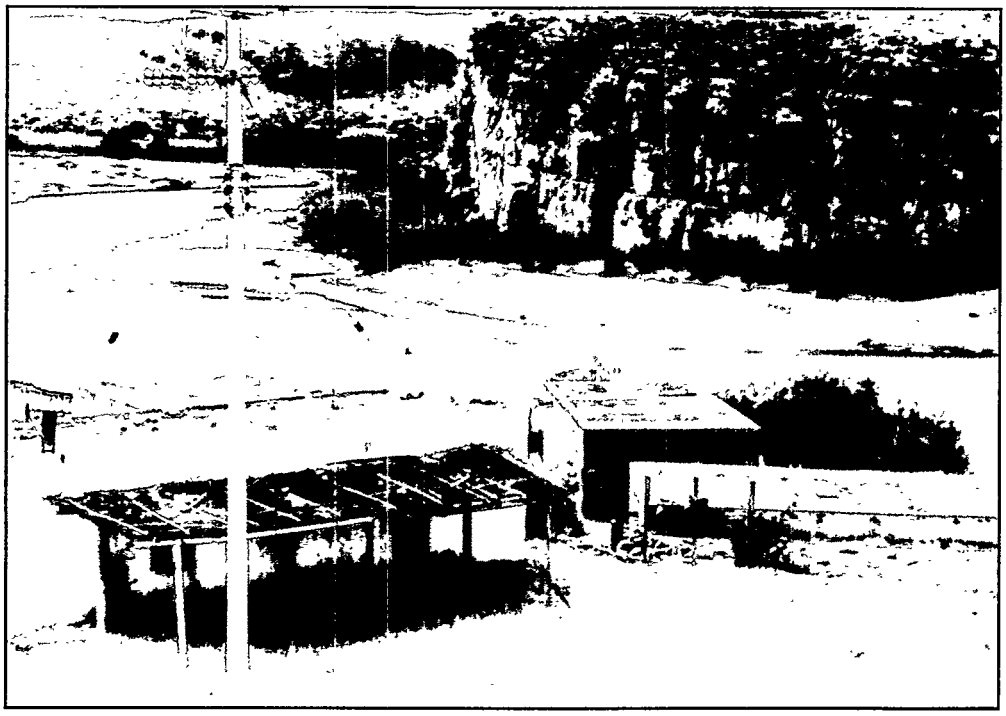

Figure 7. View of residences in upper Boquillas looking NW from customs building roof; the white house in background on the U. S. side (across the river) is the electrified Barker House of the U. S. National Park Service.

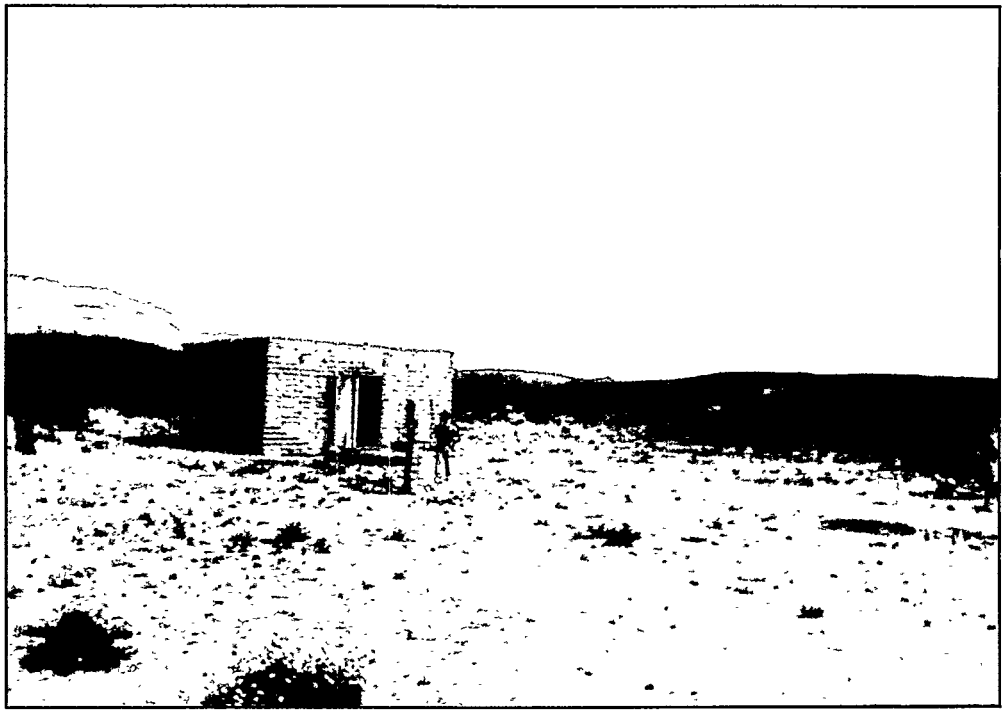

Figure 8. West side of residence in lower Boquillas.

2.2 Community Buildings

Boquillas has a number of community buildings currently being used only in the daytime. A description of these buildings follows.

Catholic Church:

An older adobe structure in upper Boquillas that currently seats about 50 persons, as shown in Figure 9. The church has a main chapel and a smaller sacristy in the back. It is used only once a month when the priest comes and conducts daytime services. Typically, only about 20 persons attend services.

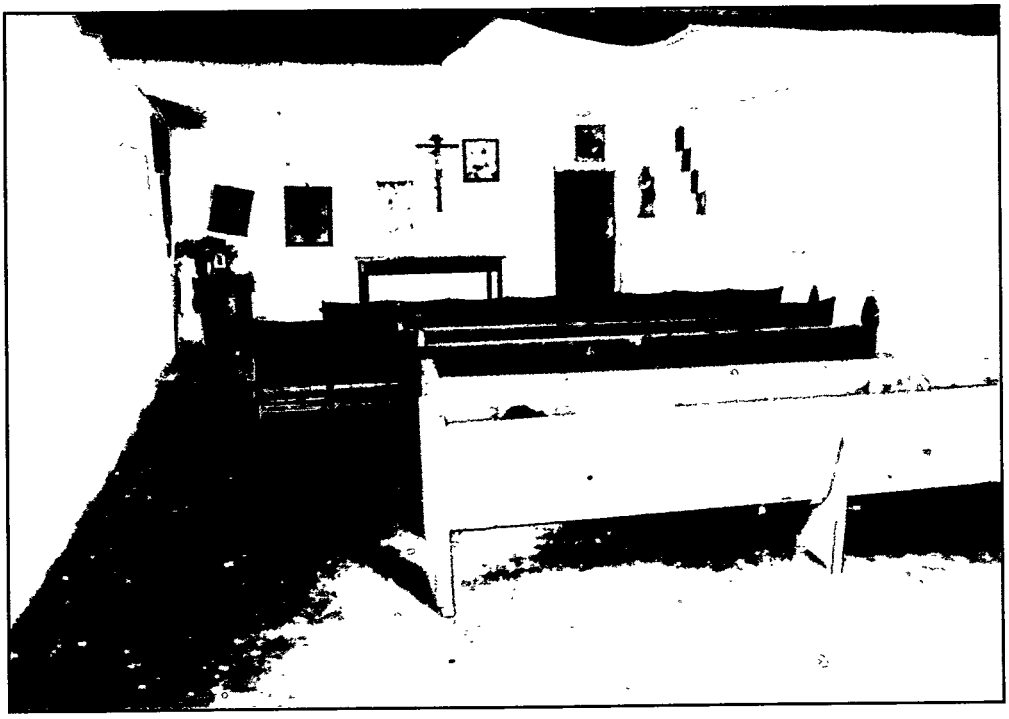

Figure 9. Interior view of Catholic church.

Baptist Church:

A new building in lower Boquillas that currently seats approximately 50 persons. Shown in Figure 10, it has a chapel area and a smaller room behind it. A Baptist preacher comes every Sunday from San Vicente (approximately 1/2 hour drive) to perform daytime services for about 20 persons on average.

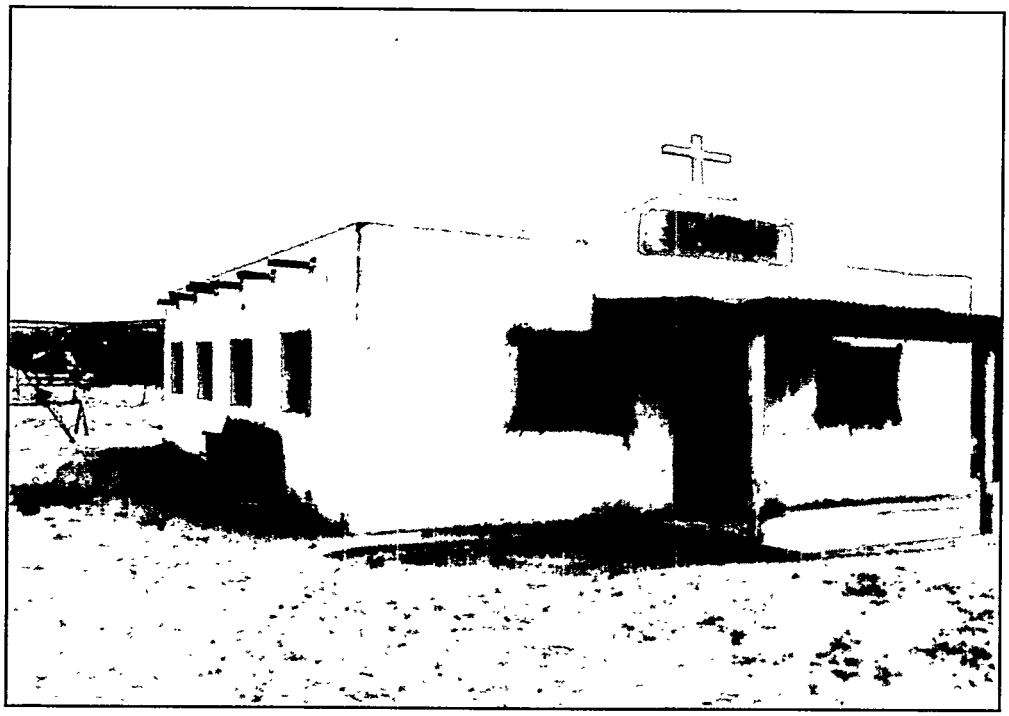

Figure 10. North side of Baptist Church

New School:

The school currently used is made of wood and has two rooms that can each seat about 30 students, as shown in Figure 11. The school is located in upper Boquillas.

School hours are from 8 a.m. to 1 p.m. when in session. Once a month, Big Bend National Park personnel use the school to show a movie in the evening (Park personnel bring a generator with them).

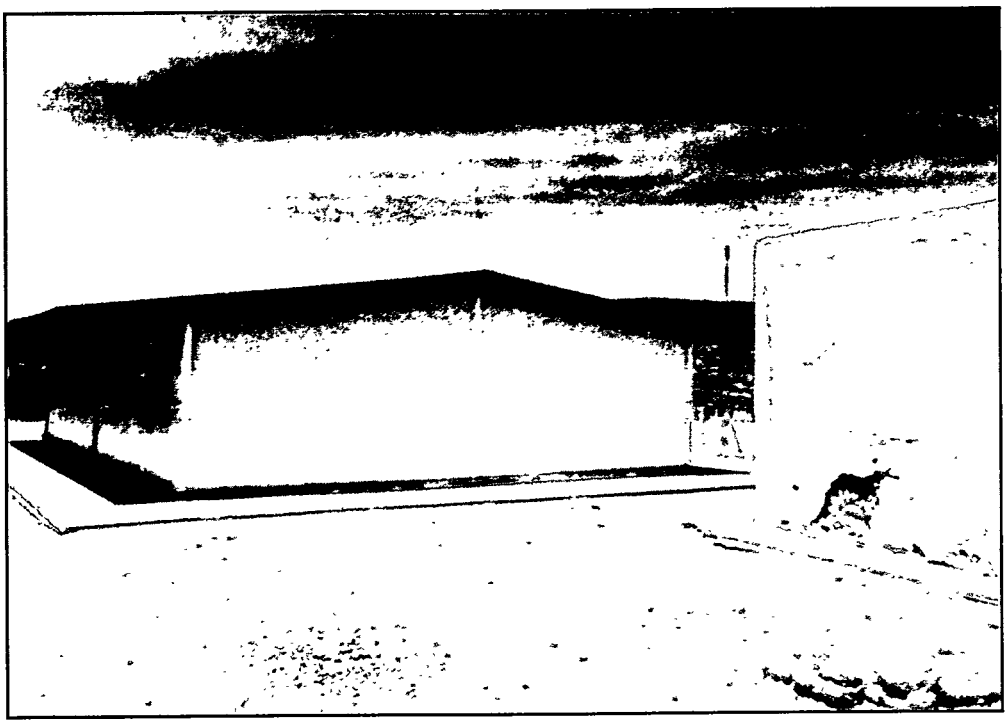

Figure 11. East side of new school next to old school in foreground at right.

Old School:

Unused adobe structure in upper Boquillas adjacent to the new school with 2 rooms, kitchen, and a storeroom in disrepair, shown in Figure 12.

Figure 12. West wall of old school.

Clinic:

Wood structure in lower Boquillas shown in Figures 13 and 14; 4 rooms are wired for electricity with 6 wall plugs and 8 light sockets. Once every three months a group of three doctors and medical technicians visits and spends the night; another similar medical group visits once every six months. The medical groups bring a generator to help perform dentistry and provide lighting for the building as well. No refrigeration exists for vaccines.

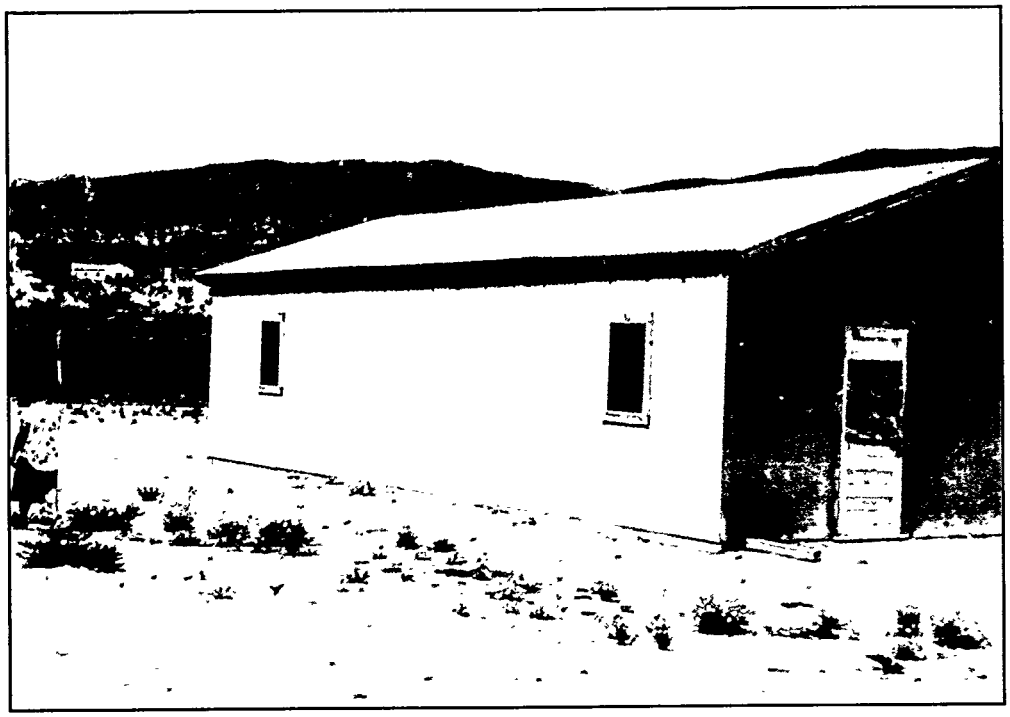

Figure 13. Looking north at the outside of the clinic toward upper Boquillas.

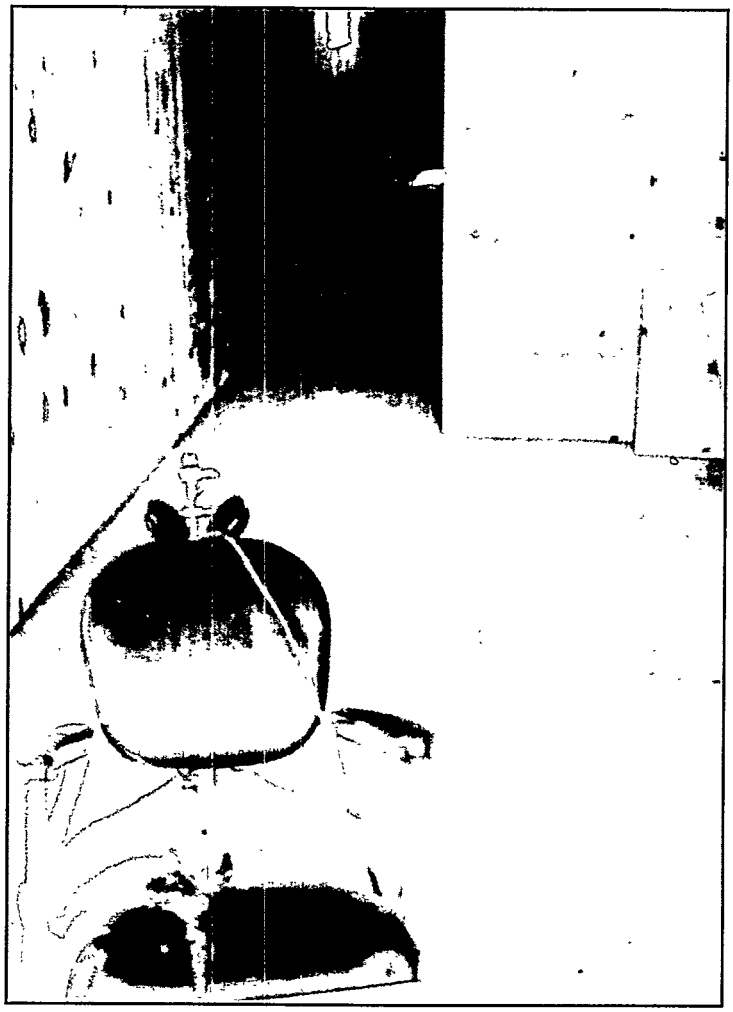

Figure 14. Interior view of the clinic dentistry area.

Customs Building:

The customs building (aduana) in upper Boquillas has been abandoned for about a decade and is in a bad state of repair, as shown in Figure 15. The building has 8 rooms and was wired for 15 fluorescent lights (5 fixtures of which are missing). Also, 3 old street lights are located around the perimeter of the customs building (see Figure 16), and another is directly across the street at the Falcon business.

Figure 15. South side of abandoned customs facilities.

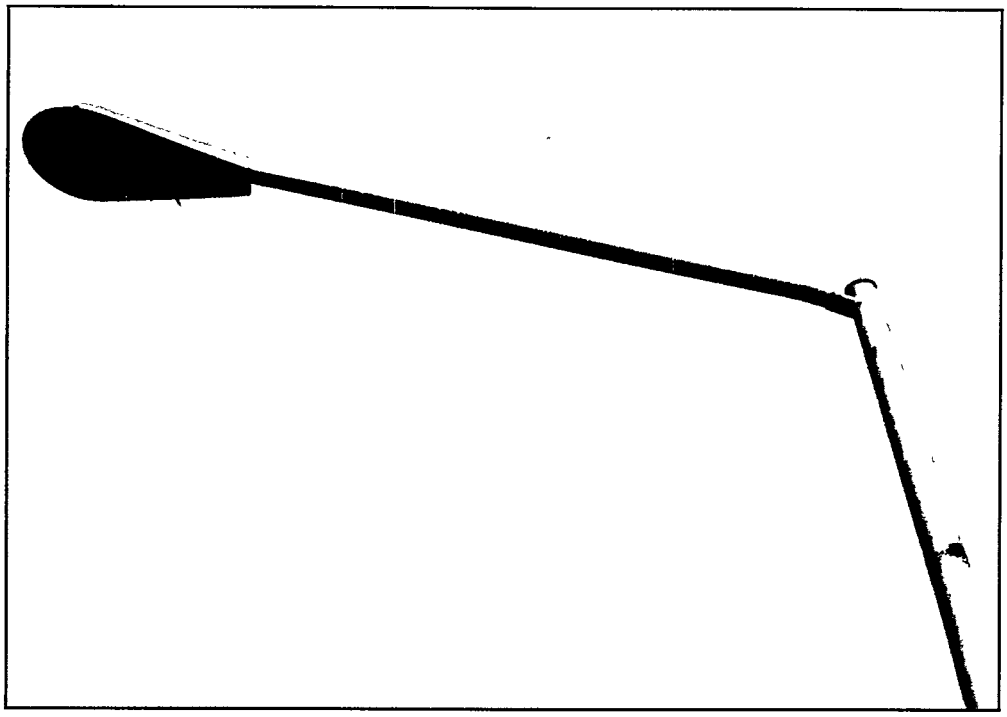

Figure 16. Old street light fixture by former customs facility.

Jail:

The jail is an old two room adobe structure in poor condition in upper Boquillas that is never used, shown in Figure 17.

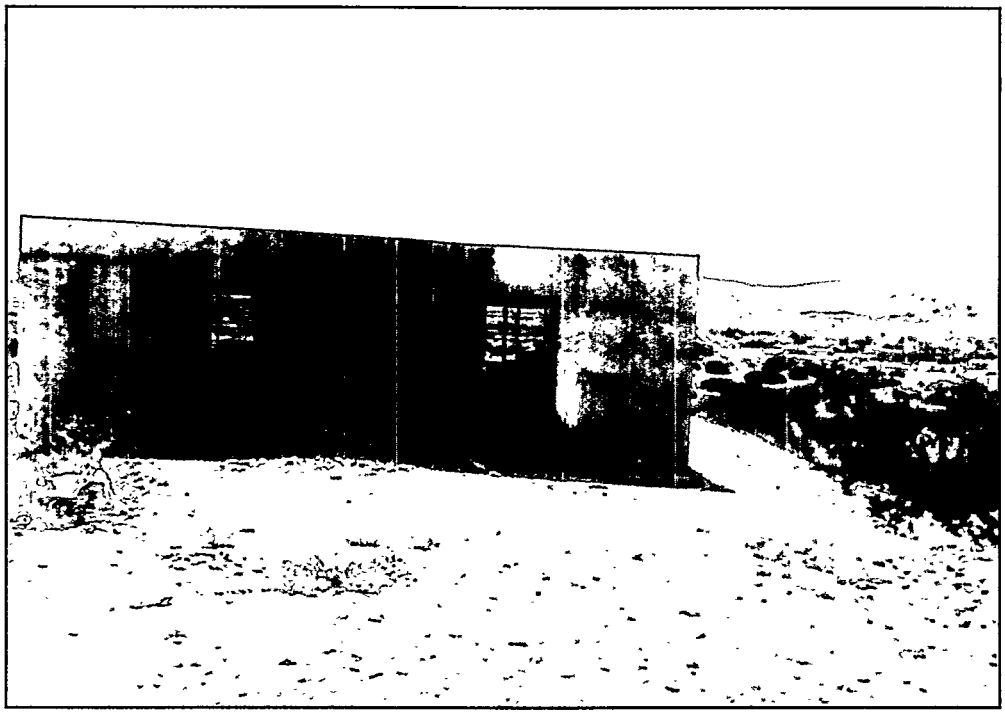

Figure 17. North side of local jail.

2.3 Boquillas Power Grid

Boquillas has anticipated electrification for several years. In fact, the Mexican Government has installed an extensive grid system in Boquillas in anticipation of electrification. Originally, it was thought that power lines would be strung across the Rio Grande to take advantage of the nearby U. S. electric grid fed by Rio Grande Electric Cooperative. However, for political reasons, this has not happened, thus forcing the Mexican Government to look at alternative solutions. There are 33 utility poles erected in Boquillas, with an additional 5 poles leading from Boquillas to Boquillas Crossing (Rio Grande local ferry river crossing) and the nearby U. S. electric grid. See Figure 18 for an example of the upper Boquillas power distribution system and Appendix D for a map showing utility pole locations for the area.

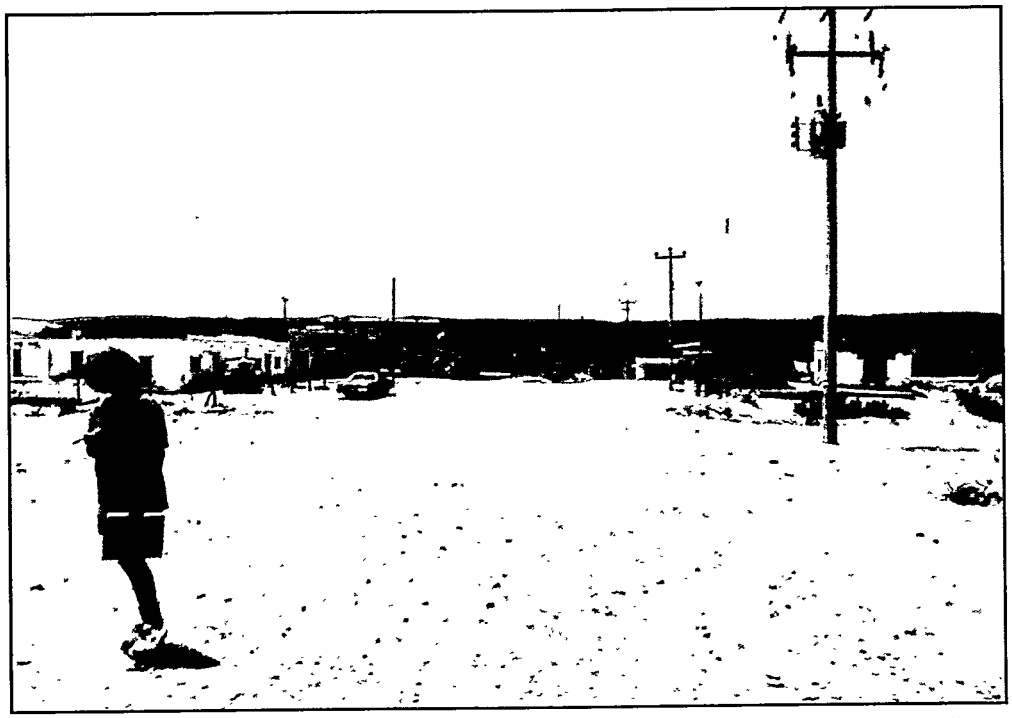

Figure 18. Upper Boquillas power distribution system (currently non-operative).

2.4 Residential Wiring

Several Boquillas residences and businesses anticipated the arrival of utility grid electricity by already having wiring installed by out-of-town Mexican electricians when their homes or businesses were built, or as an electrical retrofit on an existing building. The houses and businesses were wired by the electricians for grid power service similar to electrified cities further south of Boquillas. Despite houses being wired, only one residence in Boquillas (owned by American river outfitters) has an electric generator, used occasionally to run a drill. Figure 19 shows an exterior view of a wired residence in upper Boquillas with a conduit projecting out of the roof in anticipation of a future electrical hookup. An example of a wired light, complete with non-operational bulb, is shown in Figure 20. Figure 21 and 22 show exterior and interior views of a residential fuse box.

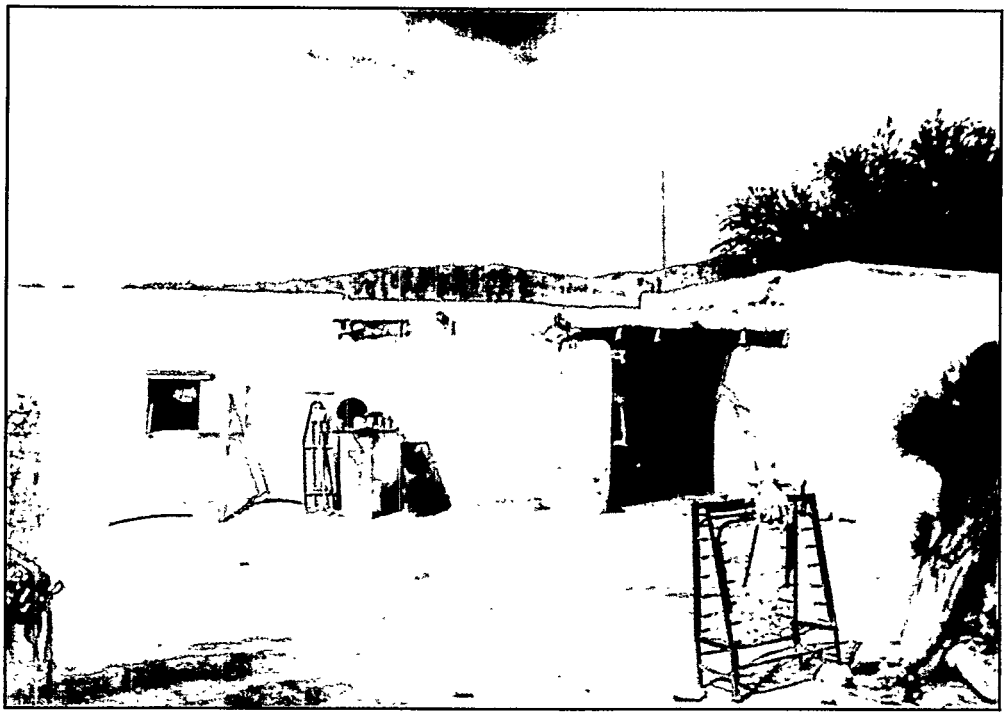

Figure 19. Upper Boquillas residence with electrical tie-in (electrical conduit with wires projecting from roof to left of tree) in anticipation of future power service.

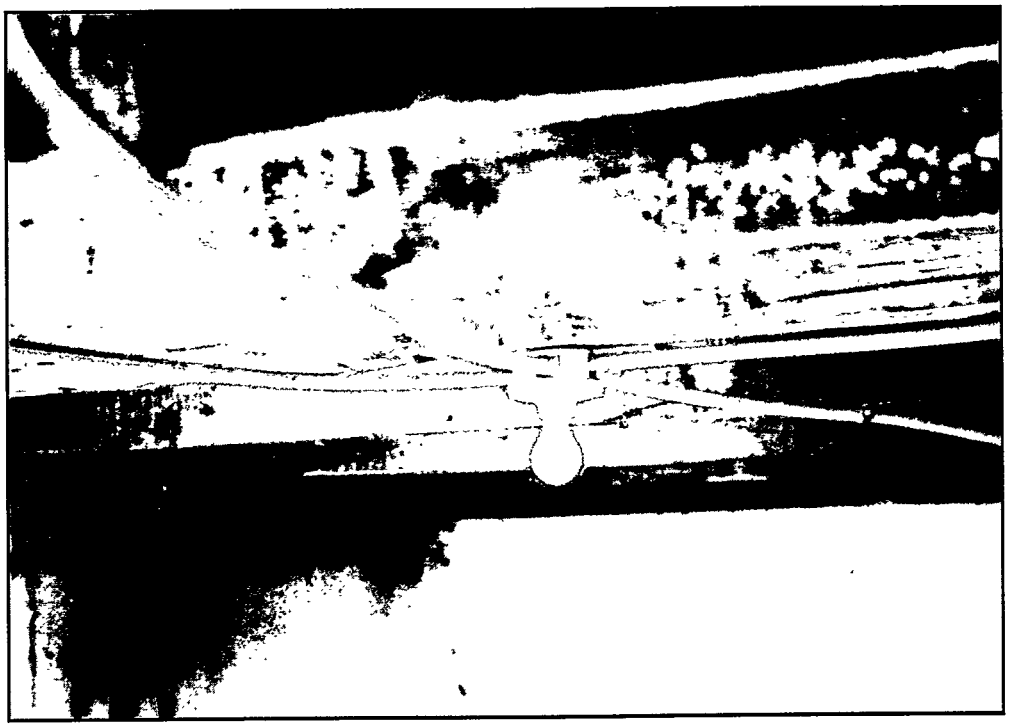

Figure 20. Non-operational residential light in lower Boquillas. Also shown are timbers of the "carriso" style roof construction typical of Boquillas residences.

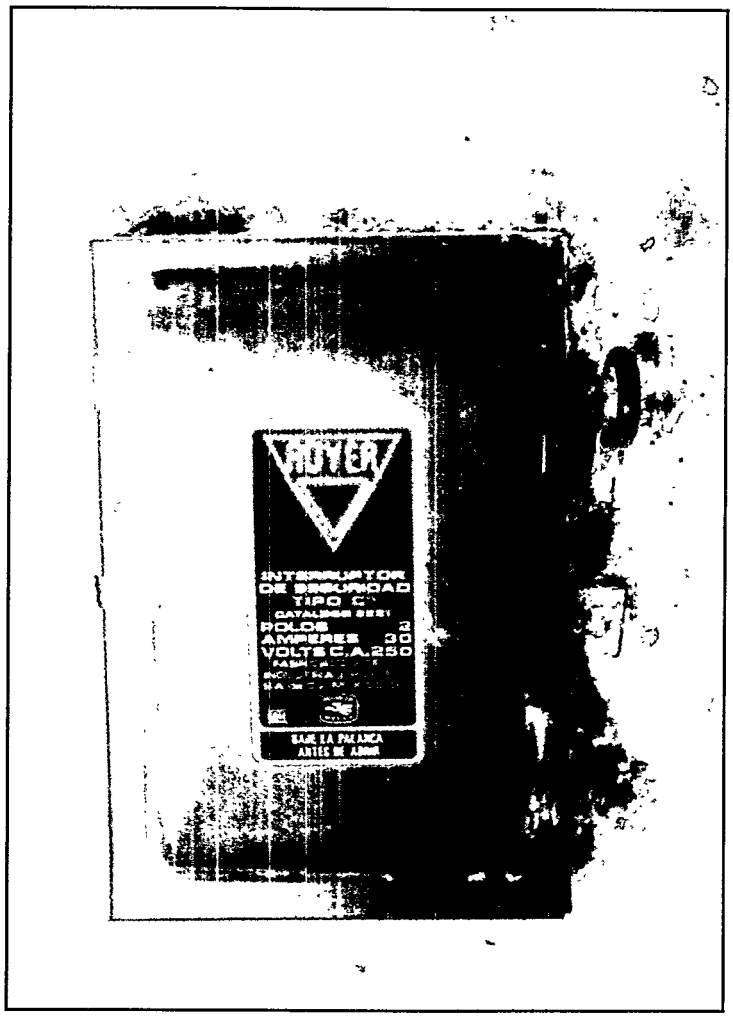

Figure 21. Exterior view of residential fuse box in lower Boquillas.

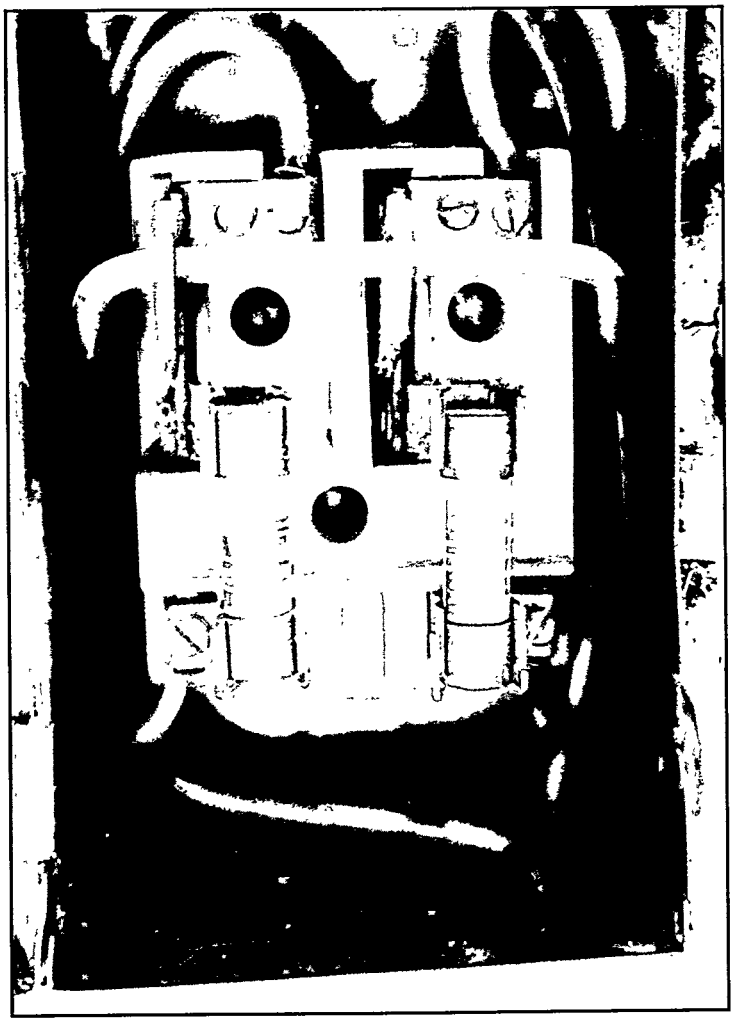

Figure 22. Interior view of same residential fuse box shown in Figure 21.

3.0 CURRENT ENERGY USAGE SURVEY

3.1 Survey Methodology

A questionnaire (in Spanish) was given to residents of Boquillas by SWTDI staff. Invaluable assistance was also provided by Lilia Falcon of Boquillas, who helped ensure that all residences and inhabitants of Boquillas were properly accounted for. A copy of the questionnaire is given in Appendix C; note that additional notes were taken at the time of questioning.

Results presented on current energy usage in the following sections should be regarded only as approximations of Boquillas' current energy demand profile. All results have been obtained by interviews with Boquillas residents; thus, this study reflects residents' perceptions about their energy use. Actual usage could vary. Residents were asked about the types of appliances they currently own and use, including radios, stoves, refrigerators, lights, and other electrical equipment. Wood energy contributions are not included in the cost analysis.

3.2 Boquillas Survey Results

Complete results of the current energy usage for Boquillas are summarized in Appendix A. Overall annual per capita energy expenditures in Boquillas, excluding wood contributions, were found to be US$48. Lights are used an average 4 hours a night per household; a few residences with small children leave a light on all night so that the children will not be afraid of the dark.

The village has 48 flashlights, 30 radios, 63 kerosene lamps, 6 propane lamps, 12 white gas lamps, 32 propane stoves, 1 white gas stove, 9 propane refrigerators, 3 televisions and 2 VCRs, 1 computer, and 1 satellite dish. The televisions, VCRs, computer, and satellite dish are not used because there are no available AC power

sources. Radios are the most common appliance found, with a community-wide average of about 19W: a typical radio is shown in Figure 23.

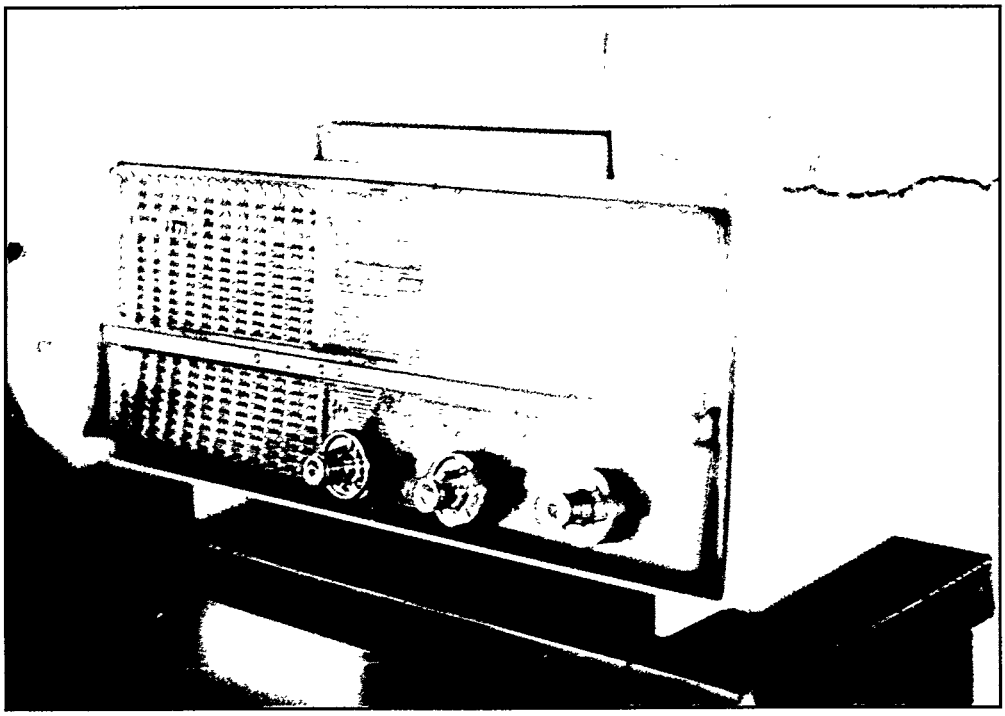

Figure 23. Typical Boquillas radio in lower Boquillas residence.

Overall, based on interviews with the residents of Boquillas, approximately 105 gallons of kerosene are consumed monthly, as well as 368 C or D cell batteries, 26 gallons of white gas, and about 23 large (45kg) and 3 small (5kg) size propane tanks. Note that these are average figures, and that they will vary depending on the time of year (e.g., more white gas is burned for lighting in the winter than the summer, less propane is used for refrigeration in the winter).

Water is generally hauled from nearby springs for most of Boquillas' residents. Either they haul it themselves or pay a small fee to a water hauler. Several residents in lower Boquillas have wells that they use for drinking water. There is no community water supply system for Boquillas, although an old water storage tank

used decades before is still there. Mexican officials have visited the community recently for planning purposes for a water supply system. Refrigerators are not common in rural Mexico (Huacuz 1991). In Boquillas, only 11.4% of the households have propane refrigerators and, in one case, these refrigerators double for commercial use to sell cold soft drinks to the public. Some of the residences do not run their refrigerators, but rather simply store fresh food in them to take advantage of the insulating capabilities of the refrigerator. During the winter, refrigerator owners report that they do not run the refrigerators at night since ambient temperatures are sufficiently cold to provide needed refrigeration.

It is reported that average fuelwood consumption in desert areas of Mexico is as low as 85 kg/month per household. Many families use fuelwood for cooking since it is cheaper and because of local beliefs that it imparts better flavor to cooked dishes (Huacuz 1991). However, a large majority of Boquillas residents do not regularly cook with wood, with 70.5% of the households owning gas stoves, of which 90% are used on a regular basis, as shown in Figures 24 and 25. Propane stoves, and many other appliances, are typically acquired in Fort Stockton, Texas or from other Texas sources.

Figure 24. Typical propane stove in lower Boquillas residence.

Figure 25. Lower Boquillas residence with propane tank by kitchen; note the electrical conduit projecting from left wall into the skyline with fuse box in wall.

Gas for propane stoves and refrigerators is trucked into the area from about 240 km south, according to residents. A large propane tank (45 kg) delivered is valued at about US$9.90, and lasts the average family (using only a stove), about a month. This gas consumption was found to be on a par with that reported by Huacuz of as high as 47 kg/month per household in rural Mexico (Huacuz 1991).

4.0 LOAD ESTIMATES

4.1 Assumptions

When predicting future electrical loads of a rural village such as Boquillas, there are no definitive rules for predicting that usage. Lighting is the largest source of electrical consumption in rural Mexico, followed by radio, television, and ironing in decreasing order of importance (Huacuz 1991). Boquillas is a unique village since it is right across the river from the United States, and there is no Mexican customs control; thus, residents have an easy time bringing over U. S. purchased appliances duty free. After electrification, the whole energy picture of the village can be expected to change dramatically. Radios will be cheaper to run for villagers and will be used more. After electrification, it will be possible to run televisions and other AC appliances (e.g., blenders, microwaves, irons, evaporative coolers, refrigerators) that were impossible to use before. Radio use may be replaced somewhat by television use. The best that the load assessment can do is to make reasonable predictions about the expected energy usage. In this regard, three cases were detailed: the first case involved relatively low electrical consumption, followed by cases of medium and high potential electrical consumption for Boquillas, with a high consumption subcase including use of direct evaporative coolers.

The low electrical consumption case assumed that residents would use radios, televisions, fans, irons, blenders, and efficient lights. The medium consumption case assumed all of the appliances previously stated, as well as microwave ovens, evaporative coolers, and less efficient lighting. Finally, the high consumption case assumed all of the above appliances, less efficient lighting, and the use of refrigerators. Following are the assumptions used for these various electrical consumption cases, using average appliance power demand estimates (Sandia National Laboratories 1991).

Future population growth rate for Boquillas was assumed to be the Mexican national average of 2.25% per year (Huacuz 1991). Actual growth rates could be even larger since Mexican residents in the nearby countryside might move to Boquillas in order to enjoy the benefits of electrification. One store owner interviewed who resides 14 km down the road said that he would immediately build a house in Boquillas if it were electrified. It was beyond the scope of this study to determine the potential migration to Boquillas from outlying areas.

Future population was calculated by using the relation (Spiller 1990):

$$F = (1+k)^n$$

where F = Future Population

k = Population Growth Rate

n = Number of Years in the Future

Lighting consumes the most electricity in rural Mexico, normally with 2 to 6 light bulbs used for 1 to 5 hours daily per residence (Huacuz 1991). Current lighting averages in Boquillas from the site visit were determined to be approximately 4 hours per night per residence. However, for the purposes of predicting future

consumption after electrification, it was assumed that light usage would increase. This prediction was based on observations of rural electrification programs in the Pacific Islands region, where villagers had expressed desires of wanting an average of four hours of light per night; however, experience showed that those same villagers were more likely to average six hours of light a night (Wade 1991). This observation also correlates well with experiences documented in the Dominican Republic where 3 to 4 bulbs are used 1 or 2 at a time for 3 hours (Hansen 1987). Thus, it can be expected that Boquillas' lighting use patterns will increase beyond the 4 hours average today as a result of electrification.

In Boquillas there is an average of 2.6 rooms per household; thus, it was assumed for load predictions that 1.5 rooms per household would be lit for 6 hours per night (i.e., equivalent to lighting one room for 6 hours and another room for 3 hours each night per residence). The low consumption case assumed 25W light bulbs, and the medium and high consumption cases assumed 60W light bulbs.

Based on interviews with residents, current radio usage in Boquillas in residences that use radios averages 2 hours a day. It would be reasonable to expect radio usage to increase in all residences after electrification. Radio ownership was assumed at 70% of households after electrification, which is about the current ownership ratio (68.2%). The radio size was assumed to be an average of a large radio (75W) and a small radio (15W), which is 30W and larger than the current average of 19W. Not all residences use radios regularly today because of the high cost of batteries; however, it was assumed that the residences that owned radios but did not currently use them would operate their radios after electrification. Current radio usage levels of 2 hours per day were assumed to double to 4 hours per day after electrification. Thus, the average radio use for future load estimates was assumed to be 30W,

operated 4 hours per day for 70% of the residences for the low, medium, and high consumption cases.

Two residences in Boquillas currently have televisions, one with a satellite dish. One of these residences operated a diesel generator in the past to run the television and other appliances; however, the generator later failed and the television is not currently used (it appears that the satellite dish probably would require a significant amount of maintenance to become functional). Thus, 4.5% of the residences in Boquillas currently have a television. This figure would undoubtedly increase after electrification. It was assumed that residences currently with radios would obtain television sets after electrification, so that 70% of all residences would eventually have a television. This figure correlates with a study of a rural site of 60 residences in Los Castillos of the Dominican Republic, where television ownership was found to be at 70%. This same study showed that televisions were used an average of 3.8 hours per day (Hansen 1987). For purposes of this study, television use was assumed to be equivalent to radio use at 4 hours per day for 70% of the residences for all three consumption cases.

Irons were assumed to be used by 65% of the population for two hours, four times a month based on observations in the Dominican Republic (Hansen 1987) for all three consumption cases.

Blenders were assumed to be owned by 20% of the population based on observations in the Dominican Republic (Hansen 1987). Blenders were assumed to consume 350W, with usage estimated at five minutes a day for a 30-day month for all three consumption cases.

Due to their proximity to the United States, it was assumed that some residences might obtain microwave ovens. Only 10% of the residences were assumed to have microwave ovens for the high-consumption case only. These microwave ovens were assumed to operate at 800W for 21 minutes a day.

Boquillas is situated in a hot, dry desert climate; thus, it can be expected that with electrification, some residences will purchase some sort of mechanical cooling equipment. Currently, only one residence has a fan (unused) in Boquillas. It was assumed that 40% of the residences would obtain fans. Fans were assumed to require 20W for all three consumption cases.

An estimate of a high-consumption case with direct evaporative cooling is also given. Evaporative coolers use 70% or less energy than vapor compression air conditioners in desert climates such as in Boquillas (Foster 1990). Thus, evaporative coolers would be the only acceptable energy-conserving air-conditioning method for a renewable energy system in Boquillas. Since there is no water supply to Boquillas, only a few residences would be capable of the luxury of bringing water for use in stand-alone evaporative coolers, to which water must periodically be added to the reservoir. However, if a public water supply were built, which is currently under consideration by the Mexican Government, then evaporative-cooler usage could be widespread, possibly proving even more popular than refrigerators. Evaporative coolers were assumed to have a 1/3 hp motor and 1/20 hp pump, with 50% motor/pump efficiencies, for a total electrical draw of about 430W. Evaporative coolers were only considered for the high-energy-consuming case with cooling. Forty per cent (40%) of the residences were assumed to have direct evaporative coolers, operating for 10 hours a day (summer only); this level of widespread

evaporative cooling use would prove unlikely without a public water distribution system in place to each residence.

No water pumping loads were assumed for this analysis. If a future water pumping system is installed for the village, it was assumed that either the renewable energy system would be expanded, or a separate power system for the water pump would be installed.

4.1.0 Predictions

Based on the assumptions made in the preceding section, general predictions of required energy use for Boquillas can be made. Note that all 1992 energy consumption predictions are hypothetical and not indicative of current energy consumption. They are listed for comparative purposes only as it would be unlikely that if Boquillas were electrified today that residents would immediately meet the appliance ownership schedules used in the model. The figures cited in the following tables are derived from estimates shown in Appendix B, and, where appropriate, have been translated to monthly energy consumption for residences based on a 30-day month and the number of residences.

4.1.1 Future Demographics

Future population predictions for Boquillas del Carmen are shown in Table 1 below. It was assumed that ratios of total-population-to-occupied-residences and population-to-total-village rooms would remain constant.

Table 1
Boquillas Future Population Estimates
Does not consider migration from outlying areas.
Based on 2.25% national average growth rate per year.

	1992	2002	2007	2012
Population	209	261	292	326
Occupied residences	44	55	61	69
Total village rooms	139	145	162	181

4.1.2 Low-Energy-Consumption Case

Based on assumed loads for efficient lighting, radio, television, fans, blenders, and irons, estimates for the monthly community energy consumption are shown in Table 2. The average residence for the low-energy-consumption case is predicted to use 23.0 kWh/month.

Table 2
Low-Energy-Consumption Case for Boquillas

	1992	2002	2007	2012
Entire Community (kWh/month)	1013.7	1266.6	1415.4	1582.2

4.1.3. Medium Energy Consumption Case

Based on assumed loads for average lighting, radio, television, fans, blenders, and irons, estimates for the monthly community energy consumption are shown in Table 3. The average residence for the medium-energy-consumption case is predicted to use 32.5 kWh/month.

Table 3
Medium Energy Consumption Case for Boquillas

	1992	2002	2007	2012
Entire Community (kWh/month)	1429.5	1785.9	1996.2	2231.1

4.1.4 High-Energy-Consumption Case

Based on assumed loads for average lighting, radio, television, fans, blenders, and irons, as well as loads for microwave ovens and refrigerators, estimates for the monthly community energy consumption are shown in Table 4. The average residence for the high-energy-consumption case is predicted to use 89.1 kWh/month.

Table 4
High-Energy-Consumption Case for Boquillas (without Evaporative Cooling)

	1992	2002	2007	2012
Entire Community (kWh/month)	3921.9	4899.0	5475.6	6120.0

4.1.5. Direct Evaporative Cooling with High-Energy-Consumption Case

Based on assumed loads for average lighting, radio, television, fans, blenders, and irons, as well as loads for microwave ovens, refrigerators and direct evaporative coolers, estimates for the monthly community energy consumption are shown in Table 5. The average residence for the high-energy-consumption case with evaporative cooling is predicted to use 140.7 kWh/month.

Table 5

High-Energy-Consumption-Case for Boquillas (with Evaporative Cooling)

	1992	2002	2007	2012
Entire Community (kWh/month)	6192.3	7735.2	8645.7	9663.0

4.2 Comparisons

In order to compare the predicted results of Boquillas electrical consumption, it is useful to first observe reported electrical consumption for rural communities in Mexico and other Latin American countries. Residential electrical consumption in Mexico is reported to vary for rural residences from 16 kWh/month in the smaller, undeveloped villages, to as much as 234 kWh/month in the larger towns (Huacuz 1991). In Guatemala, electrical consumption is reported to vary for rural residences with grid power between 7.9 and 45.2 kWh/month (Orosco 1991). In Los Castillos (a village of 60 residences with grid power) in the Dominican Republic, rural residential electrical consumption is reported to be approximately 75 kWh/month (Hansen 1987).

Thus, from the low-energy-consumption case of 23.0 kWh/month, to the high-energy-consumption case with cooling of 140.7 kWh/month, the Boquillas estimates appear to be reasonable and within the range of values cited in these earlier studies.

5.0 CONCLUSIONS

A range of factors will inevitably affect the final selection of the power plant for Boquillas. Financial constraints, solar and/or wind resource availability, legal requirements, and politics will all influence the final selection and size of the power generating facility for the village. Most Boquillas residents are familiar with normal grid power service, it would thus be prudent to meet their expectations by reasonably approximating grid service. Since extending the grid of the Rio Grande Electric Cooperative, the least expensive option identified in this work, might be impossible for planning purposes; the high-energy-consumption case is probably the most reasonable to pursue. If either the medium- or low-energy consumption cases are considered, then significant effort should be made to ensure that villagers will not purchase additional loads. It should be stressed that water pumping for a community water supply was not considered and results of this work should be adjusted accordingly should it be included.

Actively working with the community is also important to ensure acceptance and compliance with any restrictions that might be placed on the system. This activity should include providing adequate technical support training and employment to capable individuals in the Boquillas area to help with the operation and maintenance of the generating system. Certainly, these are not easy tasks to undertake, but are critical for the success of any power generating facility in Boquillas.

The author recommends that a follow-up visit be made to the village of Boquillas del Carmen in the State of Coahuila, Mexico to determine the impact of village electrification. The procedure for estimating the impact is based on engineering judgment and is not an exact science, although the need for this type of estimation is important. Successful system sizing depends on reasonable load-growth estimating and is critical for successful operation and long-term sustainability of any village power system.

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APPENDIX A

BOQUILLAS DEL CARMEN

CURRENT ENERGY USAGE SUMMARY

Business Owner	Business Type	Bldg Type	Number Rooms	Appliances	Total Batteries	Total Watts	Hours Used	Kero Lamp	Propane Lamp	Hours Used	Propane Stove	Propane Refrigerator	Light Socket	Wall Plug	Monthly Energy Purchases: No. of Batteries	Small Propane Tank	Large Propane Tank	Notes
Jose Falcon	Gift Shop/diner	B	4	None	0	0	0	2	1	1	2	3	14	4	0	0	2.6	Includes residential cooking
Hernan Hernandez	Leather Workshop	A	2	None	0	0	0	0	0	0	0	0	0	0	0	0	0	Day only
Casimiro Padilla	Grocery	A	2	None	0	0	0	0	0	0	0	0	0	0	0	0	0	Day only
Ricardo Moran	Bar/pool	B	2	Radio/Cass	8	60	5	0	2	3.5	0	2	10	4	24	2	2	3 - 4 hours at night
Ramiro Falcon	Grocery	B	2	None	0	0	0	0	0	0	0	0	0	0	0	0	0	day only
Totals			12					2	3	4.5	2	5	24	8	24	2	4.6	

Unit Cost	$0.65	$1.00	$9.90
Commercial Estimated Monthly Costs	$25	$2	$46
Commercial Estimated Yearly Costs	$295	$24	$546
Commercial Estimated Sum of Yearly Costs	$866		

Building Types:
A: Adobe
B: Block

Note:
Jose Falcon's business energy use includes his residential cooking usage, as well as most cooking for his daughter's family: Lilia Falcon

Average Commercial Lighting per Establishment 0.9 hours/night

Current Commercial Energy Usage for Boquillas del Carmen, Mexico: 1992

Business Owner	Number Adults	Number Kids	Bldg Type	Number Rooms	Appliances	Total Batteries	Total Watts	Hours Used	Flash lights	Kero Lamp	Propane Lamp	W. Gas Lamp	Hours Used	Propane Stove	Propane Refrigerator	Light Socket	Elec Plug	Kero Gallons	No. of Battery	W Gas Gallon	Small Prop Tnk	Large Prop Tnk	Notes
Falcon Rental	1	0	A	4	Radio/Cass	6	24	6	1	0	0	2	4	1	1	0	0	0	9	3	0	0	Gen 3.5 hp@ < 1 hour/week
					Mac Computer	0	100	0															Assume $.50/wk on average
					3/8" Drill	0	240	0.1															American Occupied
Zac Hubbard	3	0	A	3	Radio/Cass	6	24	6	6	1	0	0	4	0	0	0	0	1	9	0	0	0	U.S. Batteries @ $1 each
Totals	119	90		116					48	63	6	12		30	4	37	43	104.5	367.5	25.5	2.643	22.8	

Note:
Adults are defined as 15 years of age and older
Building Types:
A: Adobe
B: Block

Unit Cost	$1.40	$0.65	$3.00	$6.50	$9.90
Residential Estimated Monthly Costs	$146	$242	$77	$17	$226
Residential Estimated Yearly Costs	$1,756	$2,904	$918	$206	$2,709

Residential Estimated Sum of Yearly Costs	$9,210 including candles/gener
Commercial Estimated Sum of Yearly Costs	$866
Estimated Yearly Energy Costs per Capita (Business & residential use combined)	$48

Total Current Population of Boquillas:	209 persons
Average Lighting Used per Residence:	4.02 hrs/night
Avg. Wh for Elec Appliances per Residence:	27 Wh/day/residence

Current Residential Energy Usage for Boquillas del Carmen, Mexico: 1992

Residence	Number of Adults	Number of Kids	Bldg Type	No. Rms	Appliances	Total Battery	Total Watts	Hours Used	Fish Lights	Kero Lamp	Prop Lamp	W. Gas Lamp	Hrs. Used	Prop Stove	Prop Refg	Ligtht Sokt	Elec Plug	Kerosene Gallons	No. of Battery	W. Gas Gallons	Small Prop Tnk	Large Prop Tnk	Notes
Jose Sanchez	2	0	A	5	None				1	0	0	1	4	1	0	0	0	0	3	2	0	1	
Pedro Martinez	2	5	A	3	Radio/cas	6	15		2	2	0	0	2	0	0	0	0	3	22	0	0	0	Cook with wood
Pablo Robles	2	0	A	3	Radio	4	10		1	1	0	0	9	1	0	0	0	1	6	0	0	1	
Luna Rental 3	2	2	A	3	Radio/CD	8	32	1	1	0	0	0	01	1	0	4	2	0	2	0	0	1	American Occupied
					Elec Light	0	15	1															
					Solar Light	0	15	6.5															
Ramiro Luna	5	2	A	3	Radio/cas	6	15	3	1	3	0	1	1.8	1	1	0	0	4	12	2	0	1	Refig not working
Fransico Padilla	1	0	A	2	None				1	1	0	0	8	1	0	0	0	2	0	0	0	0	Stove not used
Juan Padilla	2	2	A	2	None				1	1	0	0	8	1	0	0	0	3	0	0	0	1	
Ricardo Moran	0	0			5 room home under construction (halted) for 3 adu																		
Geraldo Ureste	2	2	A	2	None				1	2	0	1	4	1	0	2	4	2	4	1	0	0.5	Coleman used in winter
Belia Romero	2	0	A	1	None				1	1	0	0	4	0	0	0	0	2	4	0	0	0	Wood Cooking only
Maria Gonzalez	4	6	A	2	Radio/cas	8	49	3	1	1	0	0	8	1	0	0	0	4	16	0	0	0	Stove not used
Guadalupe Davila	2	5	A	3	None				1	1	1	0	2	1	0	3	0	4	10	0		1	6m well
Catarino Ureste	2	4	A	3	Radio/cas	6	15	1	3	2	0	0	2	1	0	2	2	4	48	0	0	1	Owns 2 vacant houses
Catarino Romero	4	2	A	3	Radio/cas	6	15	0.2	0	2	0	0	2.5	1	0	0	0	2	3	0	0	1	
Oracio Falcon	4	2	A	3	Radio	6	15	0.5	1	2	0	0	8	1	0	3	7	4.5	12	0	0	0.5	
Ramiro Falcon	2	3	B	4	Radio/cas	4	10	2	1	2	1	0	8	1	1	4	8	4	8	0	0	2	
Juan Moran	3	0	A	3	Radio	4	15	1.5		3	0	0	2	1	0	5	4	2	4	0	0	1	8m well
Jose Moran	2	4	A	3	None				2	2	0	0	1	1	0	2	0	2	4	0	0	1	
Victor Valdez	4	3	A	6	Radio/cas (C)	4	5	1	1	5	0	1	3	1	0	6	6	3	8	1	0	1	Coleman in winter only
						2			0														8 m well
Fidencio Sandoval	4	4	A	2	Radio	6	6	2	2	1	0	1	3.5	0	0	0	0	3	6	0	0	0	No longer used coleman
Abundio Sandoval	2	1	A	1	None				2	1	0	0	2.5	0	0	0	0	4	0	0	0	0	
Isidro Sandoval	2	3	A	3	Radio	4	10	5	1	2	0	0	2.5	1	0	0	0	1	2	0	0	1	8m well
					Fan	0	30	0															fan not used
					Refrig/Range	0	150	0															5 ft3 refg w range
Demetrio Diaz	5	1	A	1	Radio/cas	4	10	1	1	1	0	0	3	0	0	0	0	2	4	0	0	0	
					Radio/cas	6	14	0									0						
Merihildo Diaz	2	3	A	1	Radio/cas	6	15	1.5	0	1	0	0	2.5	0	0	0	0	4	12	0	0	0	
Jose Martinez	2	4	A	2	None				0	1	0	0	4	1	0	0	0	4	0	0	0	0	

Residence	Number of Adults	Number of Kids	Bldg Type	No. Rms	Appliances	Total Battery	Total Watts	Hours Used	Fish Lights	Kero Lamp	Prop Lamp	W. Gas Lamp	Hrs. Used	Prop Stove	Prop Refg	Light Sokt	Elec Plug	Monthly Energy Purchases: Kerosene Gallons	No. of Battery	W. Gas Gallons	Small Prop Tnk	Large Prop Tnk	Notes
Jose Falcon	3	1	B	2	Radio/cas	6	15	0.2	1	2	0	0	1	0	0	2	4	1	1	0	0	0	
Lilia Falcon	2	0	B	3	Radio/cas/cd	10	40	2	1	2	0	1	2	0	0	0	0	3	40	2	0	0	Cook with wood
					Radio/cas	8	32	0															
					VCR	0	26	0															
					VCR	0	26	0															
					TV, Color 19"	0	180	0															
					TV, broken	0	100	0															
Roberto Falcon	2	4	B	3	Stereo/recvr		75	0	1	1	1	0	2	1	1	4	6	4	12	0	0	1	Stereo not used
					TV/color 19"		100	0															TV not used
					Radio/cas	6	9	1.5															Refrigerator not used
					Satellite dish			0															Sat dish not used
Hernan Hernandez	2	6	A	3	Radio	4	15	0	0	0	0	1	1	1	0	0	0	0	1	3	0	1	
Juan Hernandez	2	3	A	5	Radio/cas	8	32	1.5	0	2	1	0	2	1	0	0	0	2	16	0	0.2	1	2 electric ranges in yard
Casimiro Padilla	5	1	A	1	Radio/cas	6	14	1	0	2	1	0	3		0	0	0	4	28	0	2		
					Radio (size C)	4	5	1															
Estanilado Padilla	2	7	A	1	None		15		1	1	0	0	0.5	0	0	0	0	1	1	0	0	0	
Jose Luis	2	2	B	3	None				1	2	0	0	8	1	0	0	0	4	5	0	0	0.5	Lamp all night for kid
Luna rental	2	0	A	2	Radio (size C)	4	6	3.5	1	0	0	0	0.2	0	0	0	0	0	4	0	0	0	12 candle/wk @ $.65 ea
Luna rental	4	0	A	2	12V car radio	0	10	3	1	0	0	1	3	0	0	0	0	0	0	4	0	0	Am house, coleman stove
					12V elec light	0	15	3															12V coleman ref not used
Linda Valdez	2	1	A	2	None				2	1	0	1	2	1	0	0	0	2	1	0	0	1	
Candelario Valdez	6	1	A	5	Radio/cas	6	15	1	3	3	1	0	2	1	0	0	0	4	8	0	0.14	1	Building new house
					Radio/cas	6	15	0.5															
Guadalupe Ureste	2	0	A	1	None				0	1	0	0	2	0	0	0	0	2	0	0	0	0	
Juan Gonzalez	3	4	A	2	Radio	4	10	2	0	2	0	0	8	1	0	0	0	2	4	0	0	0.3	
Jose Padilla	7	1	A	3	Radio/cas	8	25	0.5	1	1	0	1	12	1	0	0	0	2	32	7.5	0	1	
Casmiro Padilla	2	0	A	2	Radio	6	15	0.2	1	2	0	0	8	1	0	0	0	3	3	0	0	1	
Manuel Padilla	1	0	A	1	None				1	1	0	0	8	1	0	0	0	3	0	0	0	0	Stove not used
Maria Padilla	2	1	A	3	Radio/cas	8	34	2	0	1	1	0	9	1	0	0	0	2	8	0	0.3		
Padre James	0	0		1																			House rarely used

Current Residential Energy Usage for Boquillas del Carmen, Mexico: 1992

APPENDIX B

BOQUILLAS DEL CARMEN

PREDICTED ENERGY USAGE SUMMARY

Boquillas del Carmen, Mexico in 1992 was found to have:

209 residences
44 occupied residences
4.8 residents per residence
116 residential rooms
12 commercial rooms
11 active community rooms
2.6 rooms per residence
0.67 village rooms per capita

Boquillas Future Population Estimates:

	1992	2002	2007	2012
Population	209	261	292	326
Occupied Residences	44	55	61	69
Total Village Rooms	139	145	162	181

Future Population Growth:
$F = (1+k)n$
F = Future Population
k = Population Growth Rate
n = Number of Years

Average Mexican Population Growth Rate: 2.25%

Estimates Appliance Ownership:

	Currently	Future	(After Electrification)
Lights	100%	100%	
Radio	68%	70%	
Television	5%	70%	
Fan	2%	40%	
Iron	0%	65%	
Blender	0%	20%	
Microwave	0%	10%	
Evaporative Cooler	0%	40%	
Refrigerator	11%	40%	Propane refrigerators today are assumed to be electric in future
Stove	71%	71%	Assumed propane for current & future

Assumed Future Applications Energy Consumption: Low, Medium, and High Consumption Cases:

	Low Cons W	Medium Cons W	High Cons W	Hours/Day	Low kWh/Day	Medium kWh/Day	High kWh/Day	
Lights	25	60	60	6	0.15	0.36	0.36	
Radio	30	30	30	4	0.12	0.12	0.12	Avg of 75 & 15 W radios
Television	150	150	150	4	0.6	0.6	0.6	
Fan	20	20	20	4	0.08	0.08	0.08	
Iron	1000	1000	1000	0.01	0.01	0.01	0.01	2 hrs, 4 times/month
Blender	350	350	350	0.008	0.003	0.003	0.003	6 hrs, month
Microwave	None	None	800	0.5	0	0	0.4	
Refrigerator	Propane	Propane	330	14	0	0	4.62	
Evaporative Cooler	None	None	430	10	0	0	4.3	Evap Cooler in Cooling Case Only
Stove	Propane	Propane	Propane	N/A	0	0	0	

Low Future Consumption Case (kWh/Day)

	1992	2002	2007	2012	
Lights	9.90	12.37	13.82	15.45	kWh/Day*% owning *1.5 Number of Residences
Radio	3.70	4.62	5.16	5.77	kWh/Day*% owning *Number of Residences
Television	18.48	23.09	25.80	28.84	kWh/Day*% owning *Number of Residences
Fan	1.41	1.76	1.97	2.20	kWh/Day*% owning *Number of Residences
Iron	0.29	0.36	0.40	0.45	kWh/Day*% owning *Number of Residences
Blender	0.02	0.03	0.03	0.04	kWh/Day*% owning *Number of Residences
Total (kWh/Day)	33.80	42.23	47.18	52.75	

Medium Future Consumption Case (kWh/Day)

	1992	2002	2007	2012	
Lights	23.76	29.68	33.17	37.08	kWh/Day*% owning *1.5 Number of Residences
Radio	3.70	4.62	5.16	5.77	kWh/Day*% owning *Number of Residences
Television	18.48	23.09	25.80	28.84	kWh/Day*% owning *Number of Residences
Fan	1.41	1.76	1.97	2.20	kWh/Day*% owning *Number of Residences
Iron	0.29	0.36	0.40	0.45	kWh/Day*% owning *Number of Residences
Blender	0.02	0.03	0.03	0.04	kWh/Day*% owning *Number of Residences
Total (kWh/Day)	47.66	59.54	66.53	74.38	

Large Future Consumption Case (kWh/Day)

	1992	2002	2007	2012	
Lights	23.76	29.68	33.17	37.08	kWh/Day*% owning *1.5 Number of Residences
Radio	3.70	4.62	5.16	5.77	kWh/Day*% owning *Number of Residences
Television	18.48	23.09	25.80	28.84	kWh/Day*% owning *Number of Residences
Fan	1.41	1.76	1.97	2.20	kWh/Day*% owning *Number of Residences
Iron	0.29	0.36	0.40	0.45	kWh/Day*% owning *Number of Residences
Blender	0.02	0.03	0.03	0.04	kWh/Day*% owning *Number of Residences
Microwave	1.76	2.20	2.46	2.75	kWh/Day*% owning *Number of Residences
Refrigerator	81.31	101.58	113.53	126.89	kWh/Day*% owning *Number of Residences
Total (kWh/Day)	130.73	163.32	182.52	204.02	

Cooling with High Future Consumption Case (kWh/Day)

	1992	2002	2007	2012	
Lights	23.76	29.68	33.17	37.08	kWh/Day*% owning *1.5 Number of Residences
Radio	3.70	4.62	5.16	5.77	kWh/Day*% owning *Number of Residences
Television	18.48	23.09	25.80	28.84	kWh/Day*% owning *Number of Residences
Fan	1.41	1.76	1.97	2.20	kWh/Day*% owning *Number of Residences
Iron	0.29	0.36	0.40	0.45	kWh/Day*% owning *Number of Residences
Blender	0.02	0.03	0.03	0.04	kWh/Day*% owning *Number of Residences
Microwave	1.76	2.20	2.46	2.75	kWh/Day*% owning *Number of Residences
Refrigerator	81.31	101.58	113.53	126.89	kWh/Day*% owning *Number of Residences
Evaporative Cooler	75.68	94.54	105.66	118.10	kWh/Day*% owning *Number of Residences
Total (kWh/Day)	206.41	257.86	288.18	322.12	

APPENDIX C

BOQUILLAS DEL CARMEN

EXAMPLE RESIDENTIAL FIELD QUESTIONNAIRE FORM

HOGAR

Dueño: Roberto Falcon

Cuantas personas viven en la casa? 2 adultos, 4 hijos

Que tipo de casa? (Block) Madera Adobe otro?

Que tipo de techo? Zinc Cana Concreto otro? carrizo

Cuantos habitaciones hay? 3 / under construction

Descripción de hogar: good quality

GASTAS ENERGETICAS AHORA

Que usa ahora para energía? Lampara de gas: propano (petroleo) queresene (butano)

✓ Pila (que clase)

~~Batería del carro~~

~~Planta electrica~~

Que son los gastos mensual?

	Precio por unidad?	
Petroleo	4 galones	$4,000 c/galon
Gas Butano	1 butano (45kg)	$30,000 (including transp
Pila	12	$2,000 each
~~Batería del carro~~		
~~Planta electrica~~		

Gastos Total Mensual

EQUIPO

	Especificaciones	Cuantas pilas?	Cuantos vatios?	Horas del uso diario?
Hay radio? ✓ Con toca cinta? ✓		6	9w	1½
Hay televisor? Cuantas pulgadas?	Color 19" RCA	old	~100w	0
Hay otro electrodomesticos?				

Donde lo consiguió? estufa de butano 3 Ft. from Stockton, TX satellite dish (old, not used)

(not functioning) refrigerador

1 stereo 110V plug-in

Hay bombillos/lamparas?

4 bulb sockets		
6 enchufles		

	Galones diario?	Altitude?	De que fuente de agua?
~~Hay bombeo de agua?~~			

Otras Aplicaciones? Explica

Que tiene?

Que quiere? refrigerador

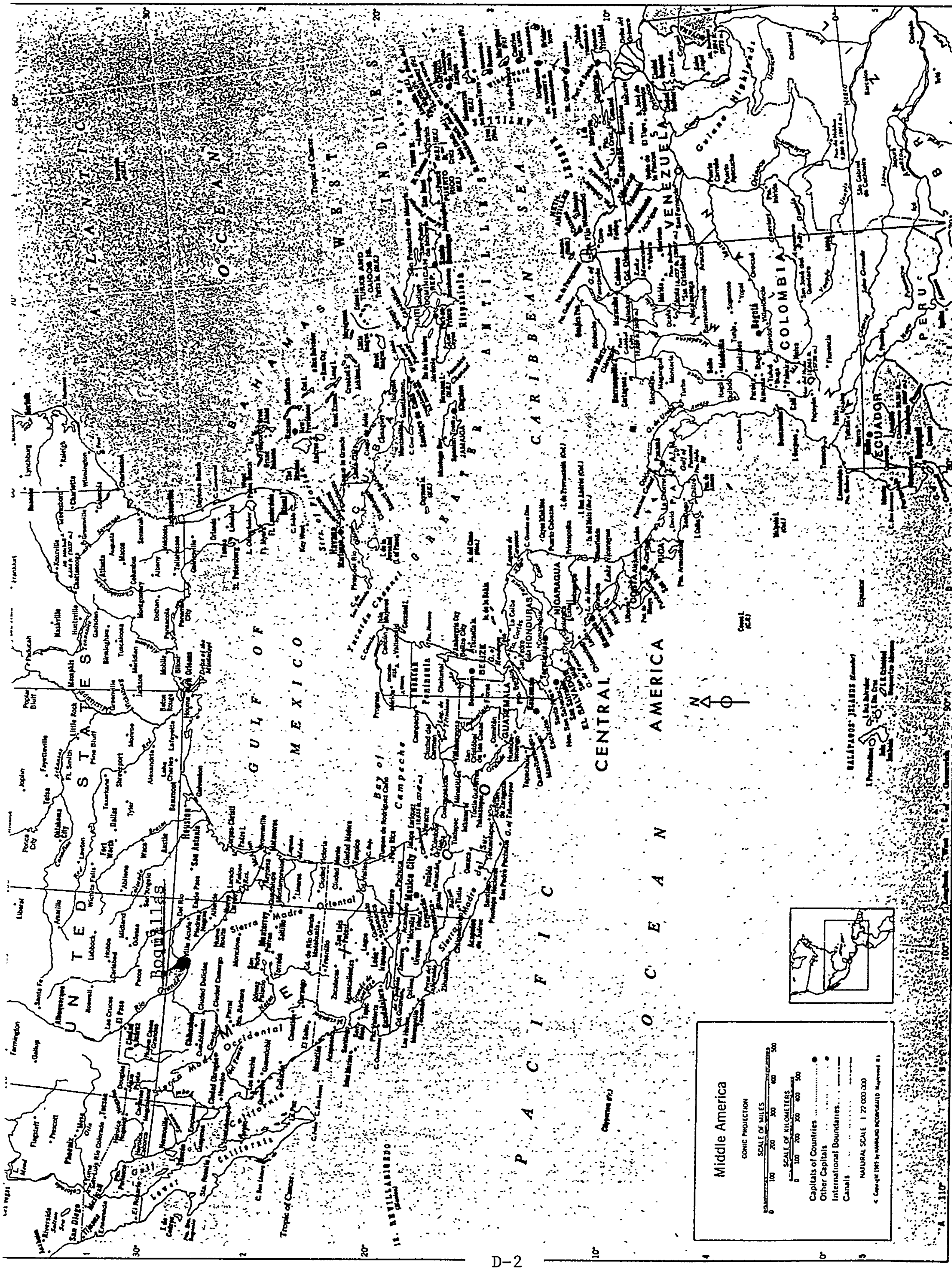
lavadora

plancha

APPENDIX D

BOQUILLAS DEL CARMEN

GENERAL MAPS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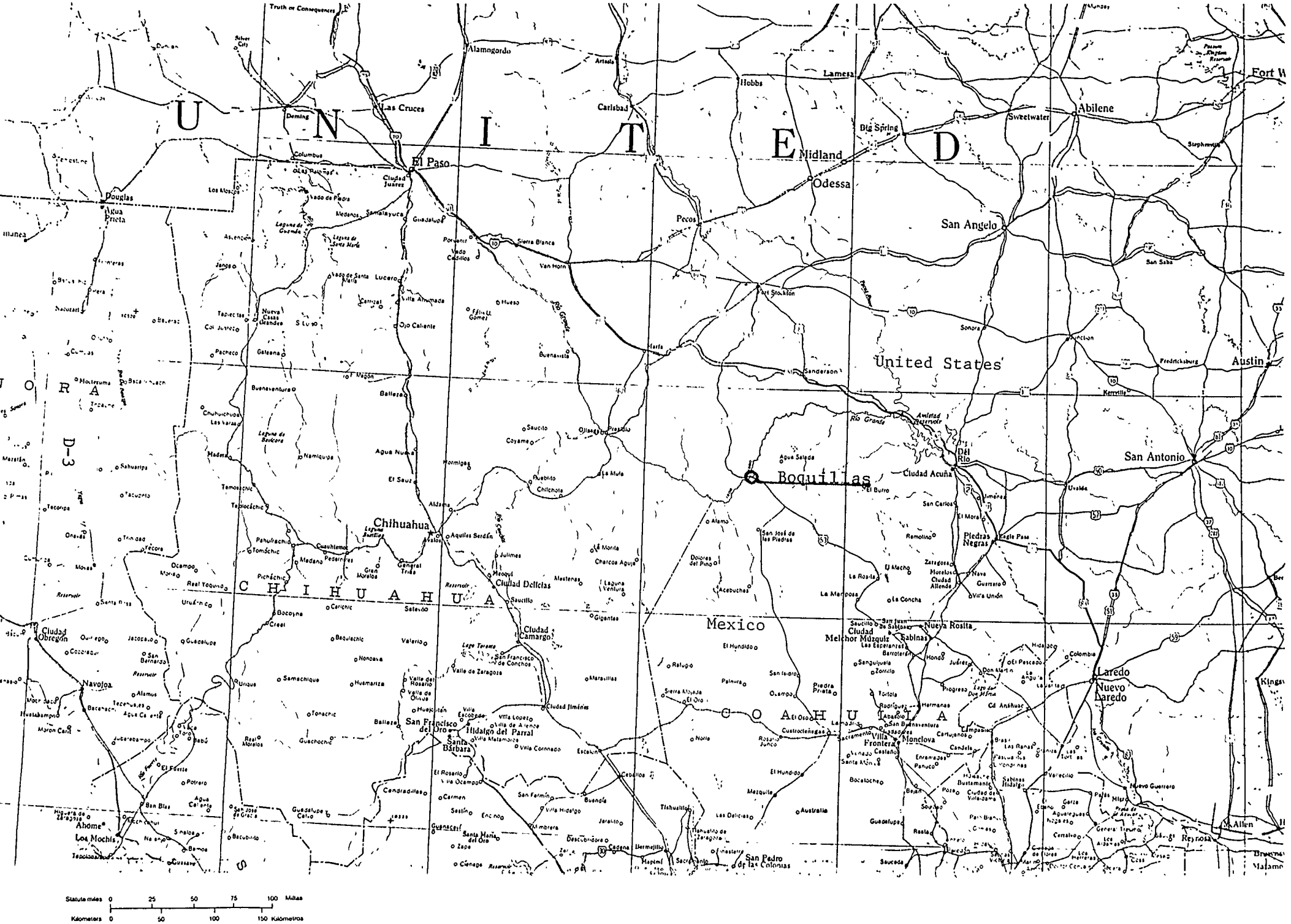
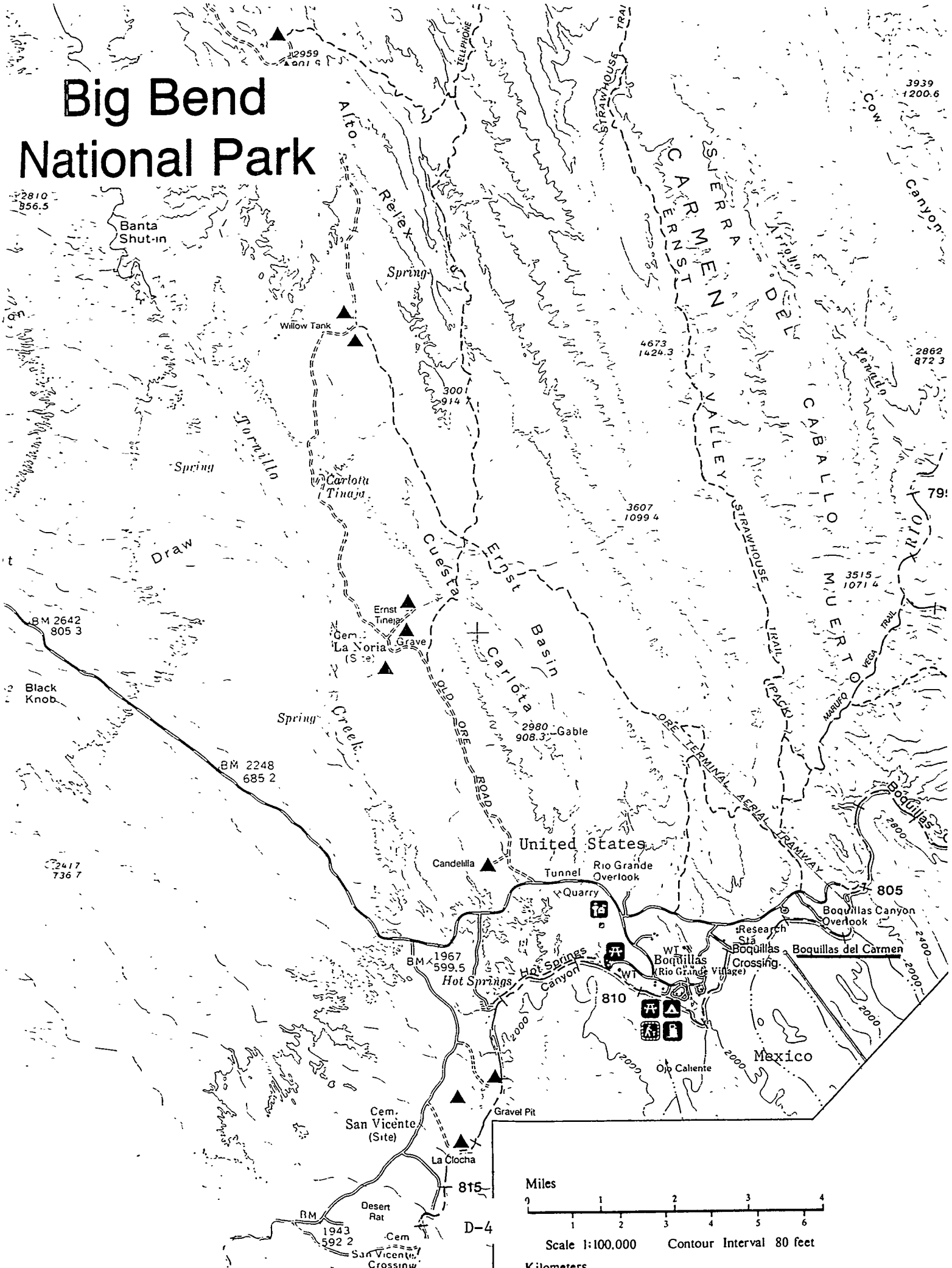
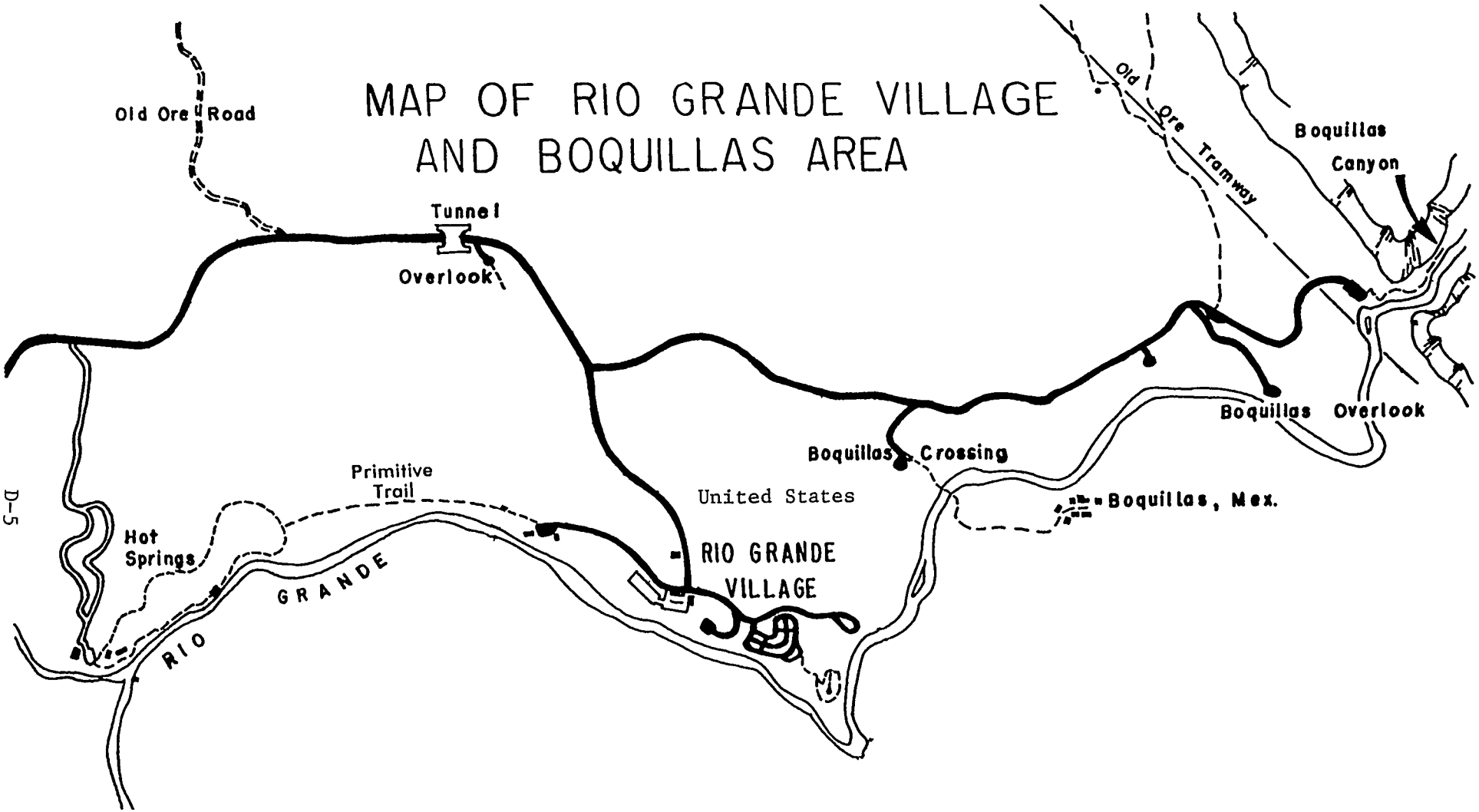
ECUADOR
PERU
Middle America
CONIC PROJECTION


U N I T E D
Truth or Consequences
Alamogordo
Las Cruces
Deming
Carlsbad
Hobbs
Lamesa
Abilene
Sweetwater
Big Spring
Midland
Odessa
El Paso
Ciudad Juárez
Columbus
Douglas
Agua Prieta
Pecos
San Angelo
Sierra Blanca
Van Horn
Fort Stockton
Sanderson
United States
Austin
San Antonio
Del Rio
Ciudad Acuña
Boquillas
Piedras Negras
Eagle Pass
Chihuahua
Ciudad Delicias
Ciudad Camargo
Ciudad Obregón
Navojoa
Ahome
Los Mochis
San Francisco del Oro
Hidalgo del Parral
Santa Bárbara
Ciudad Jiménez
Mexico
Ciudad Melchor Múzquiz
Nueva Rosita
Sabinas
Monclova
Villa Frontera
Laredo
Nuevo Laredo
McAllen
Reynosa
San Pedro de las Colonias
Torreón
Matamoros
Statute miles 0 25 50 75 100 Miles
Kilometers 0 50 100 150 Kilometros

Big Bend National Park




MAP OF RIO GRANDE VILLAGE
AND BOQUILLAS AREA
Old Ore Road
Tunnel
Overlook
Old Ore Tramway
Boquillas Canyon
Boquillas Overlook
Boquillas Crossing
Boquillas, Mex.
Primitive Trail
United States
Hot Springs
RIO GRANDE VILLAGE
RIO GRANDE
Mexico

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