SOLAR PUMPING
FOR
VILLAGE WATER SUPPLY SYSTEMS
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Partial Project Completion Report
for
Truk State Government
Federated States of Micronesia

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INTRODUCTION

Truk State is one of the four states in the Federated States of Micronesia. It consists of all the islands in Truk lagoon (hereafter referred to as Truk), the Mortlock Islands south of Truk, and a number of atoll islands to the west and north of Truk. All of these islands are located in the Eastern Caroline Islands roughly between 148° and 154° east longitude and 5° and 9° north latitude. The only high volcanic islands in Truk state are located within the Truk lagoon. All the other islands in the State are low and coralline and are generally situated on the reefs defining the various atolls.

Truk enjoys a tropical island climate with an average daily temperature of approximately 81°F. The average annual rainfall in Truk is approximately 145 inches; however, the rainfall is not uniform and distinct wet and dry seasons occur. The rainfall may vary significantly from year to year and droughts are common. The climate on the other islands in Truk State is similar, although accurate weather data are not available.

Most of Truk State is not served by central water supply and sewer systems. In these areas, traditional methods of obtaining potable water and disposing of wastewater must be used. Sources of potable water on high islands include streams, springs, shallow wells, and rainwater catchment systems. On low islands streams and springs are not available. Wastewater from washing clothing and kitchenware and from bathing is simply allowed to fall to the ground in the washing area. Toilet facilities consist of over-land or over-water benjos (outhouses) or water-sealed toilets.

Unfortunately, traditional methods of water supply in Truk State often do not provide water of adequate quality and in sufficient quantity. Surface and groundwater are often contaminated because of animal and human wastes. Rooftop catchment systems, which produce the highest quality water, generally are not functional during the dry season (January through March) because of insufficient catchment area and/or storage capacity. Perennial streams do not exist in all villages and, in the dry season, the yield of shallow wells may be seriously reduced or eliminated completely. The result is great inconvenience for the local people (i.e., carrying water for a long distance), compounded by increased consumption of water of marginal quality (i.e., no rooftop water available).

During the past year (1982) a cholera epidemic took place in Truk State. This emphasized the need for safe potable water supplies and, as a result, funds from the U.S.A. became available for assistance with a number of projects:

1. construction of water-sealed toilets
2. construction of ferro cement rainwater storage tanks
3. construction of shallow solar-powered (photovoltaic cell) wells

This report describes portions of the third project.

OBJECTIVES AND SCOPE

The Water and Energy Research Institute (WERI) was contracted by the Truk State government to perform a number of tasks:

1. Design a simple "standard" solar pumping system suitable for extracting ground water from low atoll islands or flat sandy coastal areas of high islands.
2. Provide an illustrated instruction manual for the installation of such systems.
3. Procure hardware required for the installation of a minimum of 150 such systems.
4. Install approximately 25 such systems.
5. Train Rural Sanitation Program personnel in the installation of such systems.
6. Design, procure hardware for, and install "special" solar pumping systems as required. Such systems might involve pumping larger quantities of water, pumping to higher elevations, pumping over longer distances, etc.

The design and installation of the "standard" solar pumping system or "WERI Well" (items 1 and 4) are described in a previous report (Winter, McCleary, and Watters, 1983). This present report covers the design and installation of "special" solar pumping systems (item 6).

DESCRIPTIONS OF SYSTEMS

Four "special" systems were designed, tested, and, in three cases, installed. The systems on Dublon, Moen, and Tol were installed in December 1983 and January 1984. The system in Satawan was installed in July 1983. Following is a description of the background, purpose, design, and present status of each system.

Dublon

Background

A number of large (approximately 27 feet diameter by 6 feet deep) poured concrete tanks of Japanese vintage exist in Kuchua Village on Dublon. A few are still in use. The others are not used because they are damaged or are too distant from existing water sources. Two of these tanks are situated behind the residence of Sokichy Fritz. The closest one is used to store water collected from the roof of the residence. The other tank, which is slightly higher than the first (approximately 6 feet) and slightly farther from the residence, is presently unused both because of severe cracks and because it is too high for water to flow from the roof to the tank by gravity. During extended rainy periods, the tank that is in use overflows. During extended dry periods, there is a need for additional water storage.

Purpose

The purpose of the system is to pump water from the lower tank to the upper one. A prerequisite for operation of the system is repair of the upper tank.

Design

Three 28 watt Solar Power Corporation solar modules were connected in parallel to drive a Rule 800 submersible bilge bump. The modules are located on the top of the residence (Figure 1) and a switch is provided for actuating the system. One half inch PVC pipe connects the pump, situated approximately 6 inches from the bottom of the lower tank, to the upper tank (Figure 2). The total length of pipe is approximately 15 feet.

The head on the pump can vary from 12 feet (bottom tank empty) to 6 feet (bottom tank full). Nine feet was used as the design head. Two hundred gallons per hour (3.5 gpm) was used for the design flow as, over a 5 hour pumping period, this would provide approximately 1000 gal/day. Thus, the tank could be filled in approximately one month (calculated capacity of around 26,000 gal).

The selection of the pump and module configuration was based on pump curves provided in the Appendix. With a head of approximately 9 feet on the pump, it was tested at approximately 5 gpm, somewhat higher than predicted by the pump curves. A possible explanation for the difference between predicted and observed performance is that each pump curve is based on only a single test.

The tank is being repaired with "Thorite" patching compound (Figure 3). This is a Thorosystem product and is mixed with water to produce a very fast-curing patch. At ambient temperatures in Truk, it sets in less than 5 minutes; so, only a small quantity can be mixed at a time. Care must be taken to prepare a relatively dry mix as a wet mix produces a patch that can easily be penetrated with a knife when dry (and is probably not watertight). It is also important to keep the patch moist during the first half hour of curing (after initial setting has taken place).

Status as of January 1984

All plumbing is permanently installed and the floor of the tank has been patched. Remaining is the patching of the sides of the tank.

Moen

Background

A number of wells are located at considerable distance (around 1,000 feet) from Epinup Village on Moen. These wells are situated adjacent to a large taro patch and are the only perennial source of water for the village. One of the wells has a protective enclosure over it. During extended dry periods, water is transported manually from these wells to the village or a gasoline driven pump is used to pump water from the protected well through a series of pipes and hoses to the village. This pumping system has a number of defects: pumping rate too great, piping system not permanent and subject to contamination, and high potential for failure of the engine.

Purpose

The purpose of this system is to pump water from the distant protected well to the center of the village.

Design

Three 28 watt Solar Power Corporation solar modules were connected in parallel to drive a Shurflo Series 200 diaphragm pump. Four hundred fifty feet of 3/4 inch and 20 feet of 1/2 inch PVC pipe were added to the existing 300 to 400 feet of 3/4 inch and 1-1/2 inch galvanized and plastic pipe. The pipe is routed through a taro and mangrove area to the center of the village, temporarily discharging into a 55 gallon drum (Figures 4, 5, and 6). The pump is installed within the enclosure over the well (Figure 7). Because of fear of vandalism, the solar modules are not permanently mounted in the open. Rather, they are stored in the well enclosure (Figure 7) and placed on the roof of the enclosure when pumping is desired (Figure 8).

The water level in the well is a foot or so above sea level. The discharge point is presently approximately 6 feet above sea level although the design discharge location is at a point approximately 20 feet above sea level. Using a design flow of 2 gpm, the total head on the pump, including a loss of 8 feet in the pipe (based on 600 feet of 3/4 inch plastic pipe), is approximately 27 feet. The pump and solar module configuration was selected using the pump curves in the Appendix.

The system was tested using the temporary location of the discharge point, a total head of approximately 13 feet. The pump delivered 2 gpm, slighty lower than the 2.3 gpm predicted by the pump curve for this reduced head. A possible explanation for this reduced performance is dirt and/or rust in the existing lengths of pipe that are used in the system.

Status as of January 1984

The pump is installed in a temporary configuration pending completion of improvements to the well and construction of a new enclosure. A ferro cement storage tank will be built in the village and the pipe discharge point rerouted to it.

Tol

Background

The Liebensel School in Chukianeu Village, Tol, utilizes rainwater and water piped from two distant springs for its water supply. In drought periods, water is drawn from a well situated on the school grounds. The well is approximately 4 feet in diameter, lined with concrete block, and covered with a concrete slab. A wooden door (with lock) provides access. The total depth of the well is 10 feet, the water depth varying from approximately 1 (during extended droughts) to 7 (during normal rainy season) feet.

Purpose

The purpose of the system is to pump water from the well to an existing tank.

Design

Four 28 watt Solar Power Corporation solar modules were connected in parallel to drive both a Rule 400 submersible bilge pump and a Shurflo Series 200 diaphragm pump, also connected in parallel. The bilge pump is located within the well and the diaphragm pump is located on top of the well. Approximately 120 feet of 1/2 inch PVC pipe connect the well to the tank and the difference in elevation is approximately 30 feet. The modules will be mounted on a pole approximately 100 feet from the well next to a house (in order to reduce chances of vandalism).

None of the existing pumps in stock were suitable to provide for the needs of this system alone. Consequently, although reliability would be reduced, two pumps were used. The intent of the bilge pump is to lift the water to the ground level and the intent of the diaphragm pump is to lift the water from the ground to the tank. Assuming an average water depth of 5 feet, the lift required from the bilge pump is approximately 5 feet. Using one module (referring to the pump curves in the Appendix), this will result in a flow of 1.75 gpm. For a 30 foot lift and using three modules, the diaphragm pump will also provide a flow of 1.75 gpm. By wiring all modules and pumps in parallel, it was hoped that the system would function better at differing water levels in the well.

The system was tested (Figure 9) with a water depth of 6 feet in the well. The measured flow rate was 2.4 gpm, significantly higher than the 1.75 gpm anticipated. In order to simulate a low water level situation, the diaphragm pump was elevated approximately 6 feet above the ground surface (however, this does not increase the total lift from water level to discharge point). No change in pumping rate was observed.

Status as of January 1984

No portions of this system were permanently installed. The installation will be carried out by staff at the Liebensel School. The well will also be improved by adding a concrete lip around the opening and by providing a locking enclosure to protect the diaphragm pump.

Satawan

Background

Water Supply for the Satawan dispensary (Figure 10) is provided by rainwater runoff from the dispensary roof. This runoff is collected in two large fiberglass tanks. A "southern cross" windmill has been installed to pump the stored water to a smaller tank mounted at an elevation of 40 feet on a tower platform (Figure 11). This tank would provide the feed water for the dispensary at a pressure suitable for operation of most fixtures and toilets.

There are two major problems with the water system:

1. The breadfruit trees are higher than the windmill. Consequently, little wind reaches it and no water is pumped.
2. During the dry season the supply of rainwater is inadaquate for the needs of the dispensary.

Purpose

The purpose of the system is to supplement rainwater catchment with groundwater and to improve pumping to the elevated tank.

Design

The system consists of two separate installations. The first installation is a well next to one of the large storage tanks. The well is shallow (6 feet) and is a standard "WERI Well" system (Figure 12) which pumps about 180 gallons per hour to the tank during periods of peak sunlight.

The second installation utilizes four 28 watt Solar Power Corporation solar modules connected in parallel to drive a Shurflo Series 200 diaphragm pump. The pump is located on top of the large storage tank next to the tower and lifts water from it to the elevated tank on the tower. The suction lift on the pump depends on water level in the large tank and does not exceed 5 feet. The pump discharge provides a lift of 45 feet to the top of the elevated tank through approximately 60 feet of 1/2 inch PVC pipe. The flow rate into the upper tank was measured at approximately 120 gallons per hour during periods of peak sunlight.

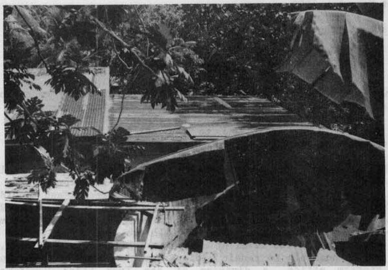

Figure 1. Solar modules mounted on roof of residence in Kuchua Village.

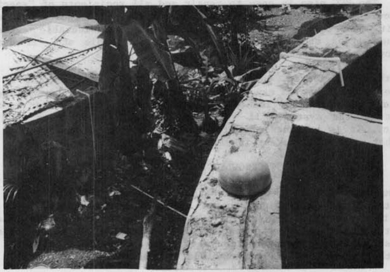

Figure 2. Pumping system connecting tanks in Kuchua Village.

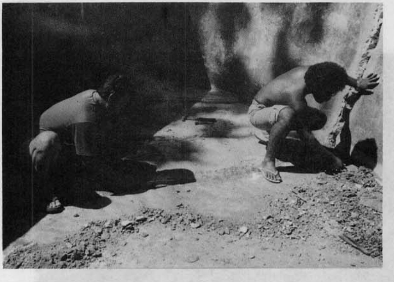

Figure 3. Repairing cracked tank in Kuchua Village with Thorite patching compound.

Figure 4. Pipe leaving pump enclosure and entering taro patch near Epinup Village.

Figure 5. Piping from pump to Epinup Village.

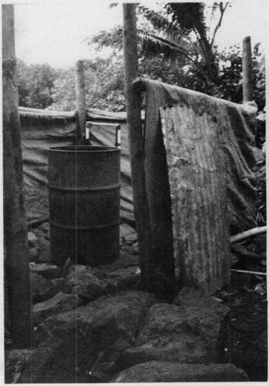

Figure 6. Temporary discharge point of pipe in Epinup Village. (photo on left)

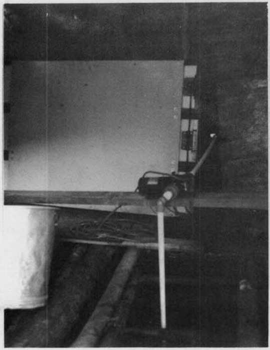

Figure 7. Pump within enclosure near Epinup Village. Note solar modules stored in background. (photo on left)

Figure 8. Solar modules temporarily mounted on pump enclosure near Epinup Village.

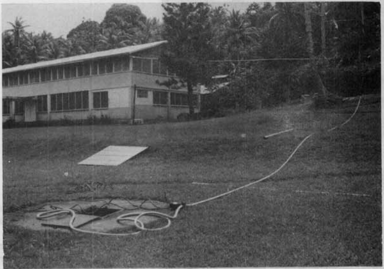

Figure 9. Setup for test of solar pumping system at Liebensel School in Chukianeu Village.

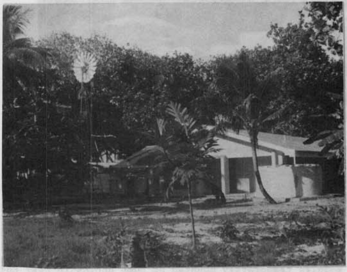

Figure 10. Satawan dispensary.

Figure 11. Elevated water tank and windmill at Satawan dispensary.

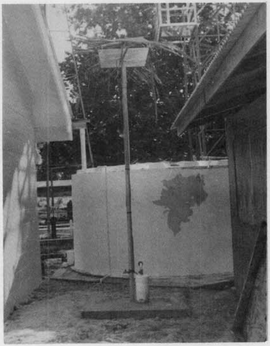

Figure 12. "WERI Well" installation at Satawan dispensary. (photo on left)

Status as of November 1983

The system is functioning as installed.

DISCUSSION

When any technological improvement is introduced to an undeveloped area, one logically wonders what the longevity of the improvement will be. The answer to this question is related to the reliability and ease of maintenance of the improvement and to the ability and desire of the recipient community to maintain it.

It is believed that the only components of the water systems installed that will show wear and require maintenance and/or replacement are the pumps. The bilge pumps are difficult or impossible to repair and should be replaced if a malfunction occurs. They are fairly inexpensive (the Rule 400 costs less than ten dollars) and can be replaced in minutes. The most likely components of the diaphragm pump to fail are the rubber valves and diaphragms. Depending on the level of expertise available in a village, it may or may not be possible to repair a diaphragm pump locally. The Rural Sanitation Program office, a division of the Truk State Government, maintains a stock of spare pumps and parts and has the required expertise so that repairs/replacements can be made in a timely manner after notification of that office.

Damage to the pipes or solar modules can occur by accident or vandalism. The PVC pipe is easy to repair and all recipients of "special" systems should be able to make repairs on their own. If a solar module is damaged, it must be replaced, unfortunately, at considerable expense. Finally the wiring of the systems is extremely simple and, if damage occurs, should be repairable locally.

Everything considered, the most important factor contributing to the longevity of a solar system may be the need and interest of the village in it. If there is no need or interest, the simplest malfunction can lead to abandonment of the system. If there is, a major malfunction will be attended to. It is believed that the chances of a major malfunction are slim and that need and interest in all systems installed are high.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Nachsa Siren and the members of his staff in the Rural Sanitation Program office for their support in all phases of this project. This includes guidance during the initial phases of contract preparation, arrangement for transportation and other logistic support, assistance with construction activities, secretarial support, and numerous other items that are too numerous to mention.

LITERATURE CITED

Winter, S. J., L. D. McCleary, and R. D. Watters. 1983. The WERI Well on Truk: A solar photovoltaic pumping project. University of Guam, Water and Energy Research Institute, Technical Report No. 39.

APPENDIX

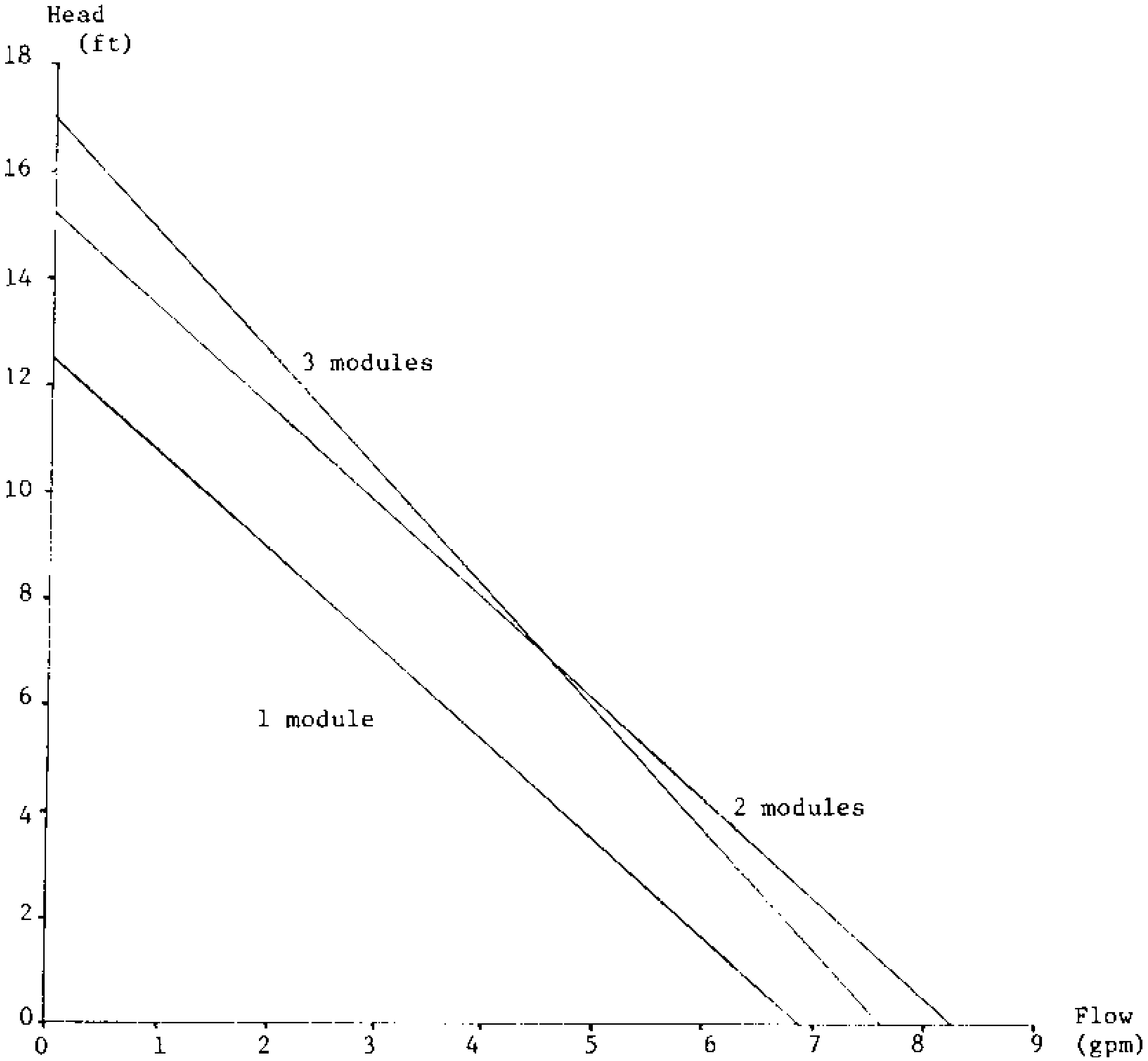

Figure A1. Pump curves for Rule 800 bilge pump.

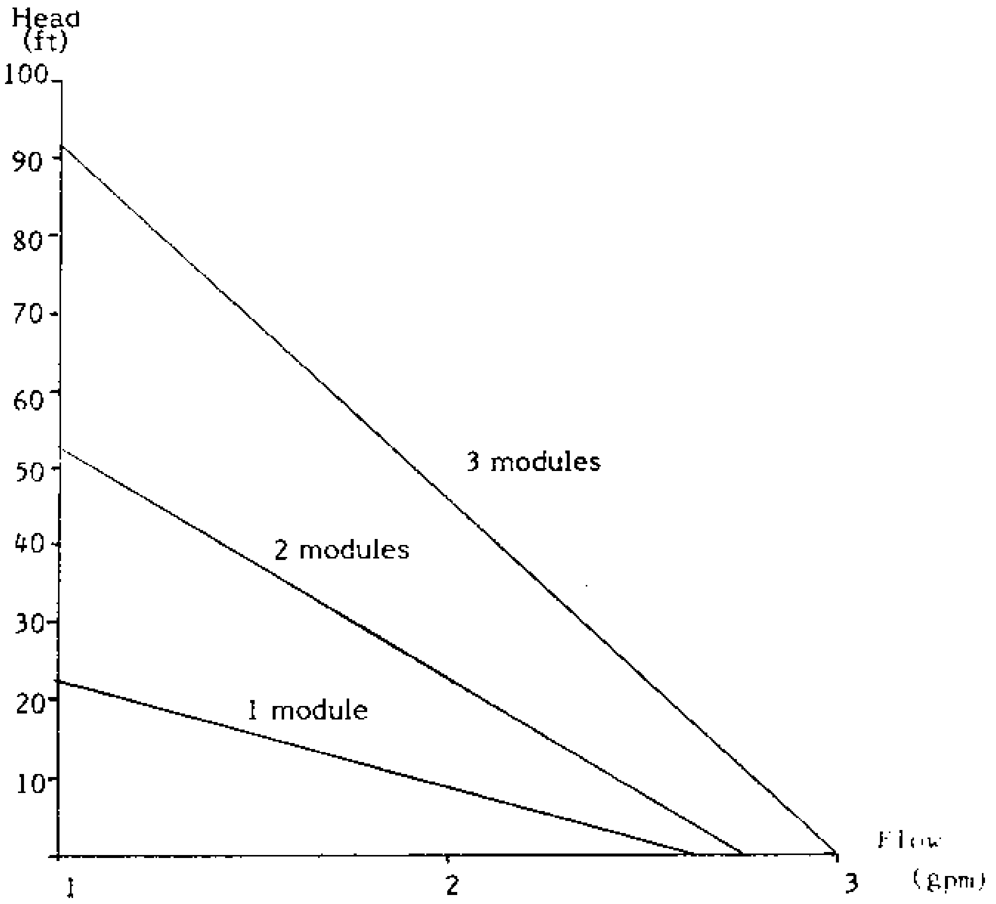

Figure A2. Pump curves for Shurflo Series 200 diaphragm pump.