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WATER PUMPING ISSUES AND OPTIONS IN SOMALIA:

A PRELIMINARY REPORT

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PREFACE

This consultancy report is the result of an initial reconnaissance trip to Somalia made in November 1985 by Mr. Richard McGowan. Mr. McGowan is senior engineer for Associates in Rural Development, Inc. (ARD), of Burlington, Vermont. This work was performed for the U.S. Agency for International Development (AID) under AID contract PDC-000-I-05-4104-00.

The purpose of Mr. McGowan's trip was to develop a background paper to be used by USAID/Somalia to examine the constraints of and potential opportunities for conducting a technical training effort and parallel comparative evaluation and testing program for water pumps in rural Somalia.

The report discusses the potential for displacement of some fossil fuel-driven pumps for village water supply, stock watering and irrigation. It also makes suggestions for increasing the efficiency and lowering the unit water delivery cost of these pumps, which are now, and will likely remain, the de facto standard in Somalia (particularly for high head and high water demand situations).

This preliminary report, which presents the areas that must be examined, is the basis for a more comprehensive document that will examine these areas in greater detail, and will contain the results of a more inclusive series of interviews and site visits with water resources development groups within the Government of the Somali Democratic Republic (GSDR), relevant donor agencies and private voluntary organizations (PVOs), and individuals in the private sector of Somalia. The more comprehensive document will be a part of the follow-on work to be undertaken in the spring of 1986.

The author would like to thank Mr. C. Anthony Pryor, energy officer for AID/REDSO, for his helpful input to this report, and Ms. Laurie Gee for her assistance in its preparation.

I. SUMMARY OF FINDINGS AND RECOMMENDATIONS

This summary is based on preliminary observations and interviews during the initial consultancy, and will be refined during the second phase, in March 1986. Some of the difficulties facing any group interested in water resources development in Somalia are pointed out. The conclusions are divided into technical findings, institutional constraints, and recommendations.

Technical Findings

1. Water quality in Somalia generally ranges from acceptable to very poor. This not only causes severe problems in terms of availability for water consumers, but can significantly reduce the useful lifetime of pumping equipment, thereby increasing unit water delivery costs.

2. Water tables can vary considerably in different areas of the country. However, a large portion of the boreholes for which hydro-geological data, i.e., rest water level, yield and salinity, were examined--largely through data collected by the U.S. Agency for International Development's (AID) Comprehensive Groundwater Development project (CGDP)--suggests significant potential for the use of pumping systems other than diesel-driven ones. This is particularly true for the low-yielding boreholes, and for low- to moderate-head and water-volume requirements.

3. There is considerable potential for the use of hand-operated pumps in Somalia. In the northwest region, shallow, hand-dug wells alongside river beds are the main source of potable water during much of the year. Several donor agencies and private voluntary organizations (PVOs, such as CARITAS, OXFAM, and ERDGS through UNHCR) have successfully used conventional hand pumps (India Mark II and Monolift) there and in the south. The Shabelle River Valley also has potential for using the locally manufacturable "Rower" pump (from Bangladesh) for very low-head suction lift conditions to satisfy low water-volume demands for small irrigation plots and sand-filterable drinking water. The AID-funded CGDP has also used hand pumps, but with mixed results thus far.

4. Wind is a significant, yet widely underutilized energy resource for water delivery in many areas of Somalia. Wind regimes commonly encountered are both high and, relatively speaking, uniform throughout the year, reducing the need for back-up systems and unduly large water storage tanks when using windmill water pumps.

5. While there is significant potential for use of wind energy in water pumping applications, potential limitations include difficulty of local manufacture, which might lower capital costs of imported equipment; corrosion problems, particularly for coastal installations; and long-term maintenance and repair difficulties due to the lack of adequately trained personnel and readily available spare parts inventories.

6. Diesel-driven pumps (or grid electric pumps where reliable grid power is available) will continue to be relied upon for all large water demands or high head (>50 to 70 meters total head) conditions. Nonetheless, widespread use of diesel engines for pumping (either for driving electrical generators and electric submersible pumps, or for direct-drive operation of downhole pump elements) is problematic. Operational limitations, such as lack of reliable fuel supply and spare parts, inadequately trained mechanics, and the subsequent high recurrent costs of operation, maintenance and repair, are exacerbated by conditions commonly encountered in rural areas of Somalia.

7. Solar photovoltaic (PV) pumps have been used extensively in Somalia (with about 60 units installed), particularly in refugee camps for potable water supply. While experience with these first-generation units has been mixed (at best), using currently available second-generation PV pumps (which are less expensive, more efficient and more reliable) would preclude recurrence of the early failures. PV modules have the distinct advantages of low maintenance and long-term reliability. Questions on the probable extent of vandalism damage to the PV modules and the limits of economic application in Somalia have yet to be adequately examined.

8. The renewable energy resource data base is scanty, and should be expanded. Although several groups (particularly the Italians) have conducted extensive data collection efforts to characterize wind regimes, the data reviewed thus far, while very encouraging, have many gaps and do not provide sufficient information for precise system design.

9. Although some preliminary studies have been made, there is no solid data base on the technical performance and life-cycle costs of any type of pumping systems currently in use in Somalia. Some information on diesel pumps is currently being gathered and analyzed by the CGDP. Performance data on wind, solar and hand-operated pumps are scanty. The Somali Unit for Research on Emergencies and Rural Development (SURERD), OXFAM and the World Bank have gathered some preliminary information on some of these systems.

10. Despite the potential for animal traction pumps, social considerations mitigate against their widespread use, since drawing water is not considered an appropriate use of camels in many parts of the country.

Institutional Constraints

1. A serious lack of coordination exists among both donor agencies and the Government of the Somali Democratic Republic (GSDR) for activities in the water resources development sector. Not only does this adversely affect project planning and cause duplication of effort, but it strongly inhibits standardization of equipment.

2. Equipment standardization, a cornerstone of successful water resources development schemes in many countries, is not currently practiced. There are three main advantages of standardization: reduction of spare parts inventory requirements; reduction of the training requirements that would otherwise result from an unnecessarily wide range of equipment options; and reduced unit costs due to bulk purchase of equipment. For all these reasons, standardization should be encouraged by donor agencies, even if their country's equipment is not chosen as the standard.

4. While the Water Development Agency (WDA) is ostensibly responsible for maintenance and repair of diesel pumps, several circumstances mitigate against its successful handling of this responsibility. These include: severe limitations on availability of technically trained manpower (partially due to the earlier exodus of trained manpower to the Gulf States where higher wages prevailed); logistical difficulties of fuel and spare parts shortages; transportation problems; lack of adequate funding; and inadequate incentives on all levels to encourage personnel to pursue further training and properly perform current tasks. None of these seems likely to change dramatically in the near term, and this situation will continue to inhibit WDA from adequately carrying out its responsibilities.

5. Lack of sufficient incentives in the public sector, both in terms of salaries and career prospects, is a major factor in the lack of adequately trained technicians in GSDR water resources development agencies. Low salaries often make it necessary to hold more than one job in order to provide adequate family subsistence.

6. Formal technical training programs by both donor agencies and PVOs have met with little success. In addition to the language difficulties and generally low education levels, technicians are reluctant to attend training outside of the

regular working day due to the demands of other jobs. Trainees should receive supplemental compensation in addition to their normal salaries to encourage training attendance. Otherwise, programs will continue to fall short of their goals.

7. Given the constraints on the public-sector role in water resources development, it would be useful to develop recommendations that the GSDR could use to alter its current policies, which greatly limit private-sector involvement (see Appendix B, #1f). Reducing government overregulation of the private sector would allow the private sector to provide additional project implementation, administration and planning capability to complement that of the overburdened WDA (and other government agencies concerned with water resources development).

Recommendations

1. Given the lack of an adequate institutional support infrastructure (lack of trained technicians, spare parts, and reliable fuel supplies) and the typically harsh operating conditions encountered by diesel pumps in Somalia, a concerted effort should be made to examine the technical, economic and social/institutional feasibility of the alternatives to diesel. The preliminary analysis given in this report shows that there appears to be some potential for a number of other equipment options.

2. This effort should include:
   - --an assessment of the indigenous energy resources (wind regime, solar radiation levels, human and animal power) that might be used for water pumping;
   - --a survey of the available equipment that best meets the typical site constraints encountered in rural Somalia; and
   - --the ranking of these options by general robustness, and simplicity of installation, operation and maintenance.

3. Based on this assessment, field tests (not lab tests--this should be off-the-shelf production equipment tested under actual field operating conditions) of the best pumping-system options should be undertaken in rural Somalia. These tests would be primarily directed at determining long-term recurrent costs and the level of skills required for installation, operation, maintenance and repair. All of these criteria should then be used as a basis for recommending standardized equipment for future water development efforts in Somalia.

4. Since technical skill levels in Somalia are such a crucial issue in water resources development, a major component of the tests should be training of technicians in all of the skills required to support the systems on a long-term basis.

5. As much as possible, the effort should seek to include private-sector participation (for equipment installation, maintenance and repair, testing, and perhaps procurement), since this would encourage later private-sector involvement in dissemination of the equipment that proves most appropriate to the operating conditions encountered in rural Somalia.

6. The assessment, field tests, training, and any follow-on dissemination efforts should solicit input from other donor agencies, PVOs, and interested individuals within the GSDR in an effort to establish a precedent for cooperative efforts in future project design and implementation in the water resources development sector.

II. INTRODUCTION

A. Purpose of the Consultancy

As part of a joint effort between USAID/Mogadishu and AID's Regional Economic Development Support Office (REDSO), Mr. Richard McGowan, senior engineer from Associates in Rural Development, Inc. (ARD), spent several weeks in Somalia on an initial reconnaissance trip to advise the mission on water pumping issues and options for both village water supply and irrigation. During his final week in Mogadishu, Mr. McGowan was joined by REDSO's energy advisor, Mr. Tony Pryor.

Based on ARD's related, ongoing work in Botswana and Malaysia, this report makes certain preliminary recommendations for measuring and comparing, within the specific social/institutional context of Somalia, the technical and economic performance of various pumping options to:

- determine which is most appropriate for a given set of site conditions, and

- point out potential obstacles to cost-effective water pumping for both drinking water supply and irrigation.

The primary purpose for Mr. McGowan's consultancy was to develop this background report for use in preparing a later, more detailed internal options paper. The options paper is to be essentially a pre-investment study that attempts to quantify technical, social/institutional and financial/economic issues pertaining to water pumping in rural Somalia. The study is to provide AID and other donor agencies with a methodological approach to the comparative evaluation of various water pumping options, whether for refugee support programs, village potable water supplies, or irrigation systems.

The tasks in the scope of work for this consultancy included:

- reviewing literature from related comparative water pumping studies;

- initial discussions with CGDP personnel from Louis Berger International, Inc. (LBII), in both Washington, D.C., and Somalia;

- visiting the CGDP wind pump test site;

- making recommendations for monitoring instrumentation; and

- writing a draft scope of work for the follow-on study, which would serve to more carefully quantify inputs to the pump comparative testing and evaluation methodology.

The preliminary reconnaissance was to be followed by a full-scale reconnaissance, if warranted, to more fully develop the initial findings as well as determine how much of the data required as inputs to the methodology were already available. To this end, some time was spent examining any renewable and conventional energy resource assessments related to water delivery that had already been performed in Somalia.

Water resources and energy specialists both in the GSDR and from AID, other international donor agencies and PVOs, particularly from AID-funded groundwater-related projects, e.g., LBII, Bureau of Reclamation (BuRec), and the PVO projects, were interviewed. These interviews were an effort to determine exactly which organizations and individuals were involved in what water-related projects, whether and how duplication of effort had occurred, and what effort at coordination of water resources development planning and implementation would likely be required to increase both the efficiency and consequent cost-effectiveness of these development efforts. Much of the hydrological information used to arrive at the tentative conclusions given in this report were taken from a series of reports issued by LBII/CGDP, particularly the Interim Report (see Appendix B, #1b).

B. <u>Previous Water Pumping Cost Studies in Somalia</u>

Several groups have made preliminary analyses of the little data currently available on the technical and economic performance of water pumps in Somalia. As an adjunct to its well-drilling and pump-installation program, the LBII/CGDP project is currently developing a computer-based model for the life-cycle cost analysis of the direct-drive diesel and hand pumps it has been installing. This model includes the costs of developing the wells and all support costs (well drilling rigs, exploratory wells, administrative costs, etc.) amortized over the number of boreholes equipped. In that sense, it is a much more ambitious study than that suggested in this preliminary report. While the actual costs incurred for the installations are known, the long-term recurrent costs (which normally represent the majority of the life-cycle cost of diesel pumping) must be estimated. It is by far the most detailed study done to date on the costs of pumping in Somalia.

SURERD issued an interim report (see Appendix B, #4) on a study of the costs of water lifting, storage and distribution for several pumping options, including diesel, hand, animal, solar and wind pumps. The report, released in July 1985, is currently undergoing revision and is not yet available. Among the data contained in the report are the following:

- there are far more hand-dug wells than boreholes in the country, indicating that the groundwater development potential in Somalia has yet to be taxed;

- while there appears to be considerable potential for wind pumping because of the relatively high wind regime measurements obtained thus far, much of the data appear to be less than reliable, the data were measured using different instruments at different heights, and much of the analyzed data were extrapolated beyond reasonable limits;

- the majority of the windmills installed in Somalia thus far are no longer functioning due to lack of proper operation, maintenance and repair procedures;

- of the approximately 66 solar PV pumps installed in Somalia (mostly in refugee camps in the northwest region), many have failed due to design flaws and a lack of understanding of proper operational limitations;

- while at least one of the PV pumps had a water flow meter on it, little actual monitoring of any of the installations was done; and

- while some tentative economic analysis was performed, it was limited by lack of comprehensive data (e.g., the cost of the diesel pump analyzed was not known) on costs, renewable energy resource availability and water output.

The SURERD study was a preliminary attempt at quantifying the large number of unknowns which have thus far inhibited an adequate comparison of water pumping options. Presumably, the final report will contain considerably more data, which will be useful inputs into a more comprehensive analytical approach, such as that suggested in this report.

Another brief study (see Appendix B, #17) was done on the comparative costs of solar, wind and diesel pumping in Nigeria, Somalia and Zimbabwe by the Energy Resources Branch of the Natural Resources and Energy Division of the United Nations. The study seems to have been based largely on capital equipment costs and assumptions about the long-term costs of operation, maintenance and repair (of all the types of pumps mentioned) from sites other than Somalia. Wind regime assumptions were based on the Italian work mentioned below. They do not seem to include adequate consideration of the fuel and spare parts supply or technical skill constraints encountered in Somalia. While the study provides adequate general coverage of the topic, it does not account for site-specific conditions in rural areas of Somalia.

The Italian Ministry of Foreign Affairs funded a faculty member at the University of Somalia to do some long-term studies on wind water pumping (Refs. 11, 18). The studies included extensive wind data collection and analysis from a number of meteorological sites around the country. In addition to the sites already established by GSDR meteorological agencies, 11 anemometry (wind measurement) stations were set up around the country, using three different types of instruments. Two Tozzi and Bardi wind pumps were also installed for performance monitoring purposes. While some performance data were collected at each of the two sites, the report indicates that the two machines were not suitable for long-term operation in Somalia. They were not well designed for high wind speed areas, and Somalia's salt-laden air severely corroded the inadequately protected metal. For these reasons, the wind pumps suffered several breakdowns during the testing period. Economic analysis generated from the test results was not included in the reports.

A wind specialist from VITA visited Somalia in 1983 and made a preliminary study (see Appendix B, #6) of wind resources and various groups' experiences with wind pumping. The recommendations in that report included the following:

- while there was substantial interest among many different groups in the potential of wind pumping, there was then, as now, little coordination among them;

- there is considerable potential for rehabilitation of many of the windmills which are currently in a state of disrepair due to a lack of proper maintenance and repair (inadequate technician training exacerbated this situation);

- corrosion is a serious problem in Somalia, particularly along the coast, thus all machines considered for installation in coastal areas should be adequately protected against corrosion (e.g., hot-dip galvanized); and

- installation of standardized wind pumping equipment, a carefully conceived, comprehensive training program for mechanics, a wind pump rehabilitation program, and collection of reliable long-term wind data, would likely provide a cost-effective alternative to diesel pumping in many areas of Somalia.

Unfortunately, few if any of the suggestions made in the VITA specialist's report have been implemented.

The final study mentioned during a series of interviews with water resources specialists was a study underway for the Ministry of Livestock and Forestry to determine the water delivery costs for livestock (conversation with D. Hattem, Save the Children Federation, or SCF). No additional information about this study was ascertained.

C. Groups Involved in Water Resources Development

There are several international donor agencies and PVOs working in water resources development in Somalia, including the United States (AID), West Germany (GTZ), the EEC, Italy (the Italian government project under the Ministry of Foreign Affairs, or IGP), Denmark (DANILO), Japan, the Peoples' Republic of China, UNDP, UNHCR, OXFAM/America, OXFAM/UK, Austrian Caritas, VITA, SCF, InterChurch Response in the Horn of Africa (ICR), German Freedom from Hunger, UNICEF, WHO, International Development Enterprises (IDE), and the Ecumenical Relief and Development Group for Somalia (ERDGS).

LBII/CGDP has been primarily involved with a well-drilling and borehole-equipping program over the last four years. While most of their boreholes were equipped with Mono/Lister diesel combinations, two U.S.-made Wind Baron wind pumps were purchased, and one has been installed thus far. Five hand pumps, U.S.-made Moyno rotary-drive progressive-cavity pumps, have also been installed. Preliminary monitoring of the wind pump was initiated (see Appendix C), although meaningful performance data are not yet available. The project is also working on a computer data base of all known drilled wells in Somalia on the IBM system at WDA, from which the data categories can be accessed from any parameter description (e.g., static water level, borehole yield, etc.). They are also involved in a private-sector study to try to determine the potential and appropriate extent of private-sector involvement in the development of water resources. The results of these studies will be included in the final report for the project. New Transcentury Corporation is also involved in a well-drilling program in the northwest, and will drill up to 12 boreholes for test pumping.

GTZ's efforts are coordinated by the economic advisor to the Ministry of Planning. GTZ has been involved in water-related projects since the late 1970s. Its first water project, "Water One," developed urban water systems for four towns around Mogadishu. GTZ provided initial capital equipment funding and technical assistance, but no funding of recurrent costs. "Water Two" is a similar project for five towns in northern Somalia. Initially planned to focus on institutional development, it has evolved into direct support programs.

SCF, under AID funding, is nearing completion of a 320-hectare irrigation project near the refugee camp at Qorioley. SCF is also in the process of procuring a small wind pump (a U.S.-made Dempster with an eight-foot diameter) for installation near a secondary school in Qorioley to replace an inoperational diesel-driven electric generator (or genset) driving an electric submersible pump. ERDGS is primarily involved in village water supply, and has worked with wind, solar and water-driven pumps (German made "stream pumps"). It has installed several solar PV pumps for the Refugee Water Supply Unit (RWS) and ICR, and is currently working with UNHCR. German Freedom from Hunger also sponsored the installation of several PV pumps in refugee camps, as did OXFAM/America, OXFAM/UK, UNICEF and UNDP. PVOs and donor agencies are now beginning to focus their efforts outside of the refugee camps, as the awareness spreads that, in many circumstances, the people outside of the camps are in greater need than the refugees.

Austrian Caritas is managing a small project through the Ministry of the Interior (MOI), installing Gelib wind pumps for potable water supply in the Lower Shabelle region. The village water end-users are required to provide a certain minimum input into each installation (labor or contributed funds) before the installation is begun. This is a critical first step in trying to get the end-users more involved in the project, with the intent of getting them to accept more responsibility for the recurrent costs of maintenance and repair.

VITA, while primarily involved in a fuel-efficient stove project, has been involved with water pumping issues in the past. A VITA windmill consultant undertook a study on wind pump use in Somalia, but did not include economic analysis. VITA also installed two windmills, one at a camp and the other at a hospital, both of which have had mixed operational records. The Settlement Development Agency (SDA) imported two wind pumps. The agency apparently is no longer a functioning entity, and the wind pumps were apparently never installed.

DANIDO has proposed a project for the installation of five 50-kW wind turbines for electrical generation near Mogadishu. ICR is apparently not involved in water projects currently. Personnel in the Japanese and Chinese water projects have not yet been interviewed to determine the nature of their projects.

III. CONSTRAINTS ON DEVELOPMENT OF WATER PUMPING IN SOMALIA

The discussion in this section is based on a series of interviews which are not yet completed, and thus should be considered preliminary. The constraints are discussed in three separate groups--technical, institutional/infrastructural, and financial/economic.

A. Technical Constraints

The technical constraints on water pumping in Somalia fall into several categories: water quality; hydrological variables such as borehole static water level and yield; available equipment; and technical problems encountered thus far.

Water quality varies considerably throughout the country, and even within relatively small areas. The specific conductance (in micromhos) of a water sample is a measure of the concentration of dissolved minerals in ion form. The generally accepted limit of specific conductance in acceptable drinking water is <3,500 micromhos for human consumption, <7,000 for sheep, goats and cattle, and <10,000 for camels. Many of the test wells drilled by CGDP had specific conductance levels in excess of 10,000 micromhos. Not only would the water be unacceptable for either consumption or agricultural purposes, but it would rapidly corrode many of the common types of pumps that might be used to lift it. Submersible electric pumps, unless properly protected, can have severely limited useful lifetimes when used in such corrosive water. Downhole pumps such as Monos can also be affected, since the minerals can begin to coat the stator material, increasing friction between the rotor and the stator, increasing energy consumption, and even completely locking up the pump element. Pumping equipment should therefore be chosen primarily on the basis of robustness and simplicity of operation and maintenance, rather than strictly on the basis of efficiency and cost.

Static water levels and borehole yields affect pumping in several ways. Pumps are designed to operate at a particular head and flow for a given power input. Every pump has design heads at which it operates most efficiently. Increasing head or flow increases power consumption. Beyond a certain head limit, a pump cannot operate. Therefore, knowledge of total pumping head is essential for proper pump selection. This is truer for certain types of pumps than others. For instance, a Mono can successfully operate well off its design head by simply absorbing more power. A centrifugal pump (such as an electric submersible), if placed in a situation where the actual head is considerably greater than the design head, may pump little or nothing at all. It therefore takes more engineering skill to properly size a centrifugal than a Mono pump.

Low-yielding boreholes present a special problem in pump sizing. For pumps that usually have high flow rates, such as diesels, pumping a low-yield borehole beyond its yield will cause drawdown in the borehole, thereby increasing the pumping head and hence energy consumption. If the pump pumps faster than the borehole recharge rate, the water level can be pulled down to the point where very little water at all is pumped. This is the sort of application where low-yield, low-head pumps can be most cost effective. Diesel pumps delivering very low flows at low heads normally operate well off their design point, where system efficiency is low, and are often not as cost effective as smaller pumps (such as wind or solar) which are designed to operate with high efficiency under these conditions. On the other hand, if a borehole has a moderate to high yield, it would be unwise to install a small pump (assuming sufficient demand exists). Thus the amortization period of the high cost of drilling the borehole would be extended in inverse proportion to the reduction in daily output, due to the smaller pump.

According to the LBII Interim Report (see Appendix B, #1b), average static water level for boreholes drilled in the Central Rangelands was 53 meters, and 35 meters for boreholes drilled in the Bay Region. Thus, there are many boreholes that would be suitable for low- head (<60 meters) pumps such as solar or PV. Hand pumps are normally used for pumping heads of less than 35 meters or so. In the Central Rangelands coastal areas, there are many hand-dug wells where the depth to groundwater does not exceed six meters, and they are usually dug to less than two meters below water table. Typical yields are generally more than adequate (11 m^3/hr in most cases, and some as low as 3.5 m^3/hr). Wells with 10 m^3/hr or more were equipped with diesel engine-driven Mono pumps.

Because of the relatively high wind speeds in much of the country, there is considerable potential for using wind pumps to deliver low to moderate quantities of water through low to moderate heads (<60 meters). Currently, there are approximately 340 to 370 windmills (primarily American and Italian) installed around the country, many of which are in a state of disrepair due to a lack of preventative maintenance and adequately trained mechanics to perform the minimal periodic maintenance procedures required to keep the machines operational. The Tozzi windmills imported by the Italians seldom operate unless they are installed in or near refugee camps, since there are trained windmill mechanics in some camps. To date, no African-made wind pumps (such as the Kijito from Kenya) have yet been used in Somalia, although this may soon change. Wind pumps are also subject to strong corrosion by the salt air near the coast (where wind speeds are normally the highest), particularly when the equipment is not properly hot-dip galvanized for protection.

Windmills (and solar pumps) invariably encounter periods of low energy resource availability (low wind speeds or cloudy days) where either large storage or back-up systems are required. The relatively high and uniform wind and solar radiation regimes in Somalia reduce the requirements for back-up systems, which add expense and complexity to the basic system. Nonetheless, hybrid wind/diesel and solar/diesel systems should be investigated further, so that unnecessarily large storage is not required during the occasional periods of low wind speed. Since most diesel life-cycle costs are operating and maintenance costs, the trade-off between excessively large storage for stand-alone renewable energy technology (RET) systems such as wind or solar and the costs of on-demand diesel pumping capability must be carefully weighed against each other.

The capital costs of windmills in Somalia are relatively high due to the fact that virtually all of the machines installed thus far have been imported. There has been considerable discussion on the part of GSDR agencies and international donor agency representatives and consultants over the possibility of the local manufacture of wind (and hand) pumps. Two potential sources for local manufacture are private-sector foundries and the National Foundry and Mechanical Workshop (NFMW). Although there is not an obvious choice for the private-sector group, several consultants have looked at the capabilities of the NFMW, and have generally felt that the manufacture of long-lasting, reliable wind pumps is not yet within NFMW's capability. While NFMW has assembled several wind pumps and manufactured a first run of 10 conventional hand pumps (including the cast cylinders), none has received sufficient testing yet to adequately judge its quality. NFMW has also worked on the rehabilitation of several Italian machines.

It has been suggested that the extensive equipment inventory and personnel of NFMW be leased to a private firm for development. Should this occur, and loans can be provided to modernize their operations, there may well be more adequate funding to allow additional training of current employees and the hiring of additional technically trained personnel to begin a more broadly based program of wind and hand pump manufacture.

Although an earlier GTZ proposal suggested that wind pump manufacture and rehabilitation might be possible at the NFMW, this was later rejected for several reasons, including the significant deterioration observed in some of the machines, as well as uncertainties about the number of wind pumps for which rehabilitation was a feasible option. The proposal was then refocused to include wind, solar PV and hand pumps, and is currently under discussion. GTZ has suggested that the proposed program be implemented either through the Ministry of Mineral and Water Resources (MMWR) or MOI, instead of directly through WDA.

Wind speeds have been estimated by several sources to range between five and seven meters per second (m/sec) along much of the eastern coast, and nearly that at many inland sites. Usually, however, the inland sites have neither quite so high nor as uniform (on an annual basis) winds as does the coast. The northwest has slightly lower average wind speeds (on the order of four m/sec), but still quite adequate for pumping in many areas. Given these wind speeds, the World Bank energy-sector study states that for demands of up to 200 m^3/day and up to 15 meters' head, wind pumping would be the most cost-effective water pumping option available.

To date, experience with PV pumps in Somalia has not been particularly promising. However, this was largely due to the fact that the equipment was first-generation design, which was sold as production equipment, but was in fact prototype. Field use under the harsh operating conditions encountered in Somalia exacerbated design faults in one model (SEI/KSB solar pump) and caused eventual failure of many of the pumps. More recent installations of second-generation equipment have had considerably better track records. The currently available generation of PV pumps has had the benefit of considerable field operating experience, so that current designs are more robust, more efficient and less costly than earlier models. These conditions combine to give PV pumps (in low to moderate head and flow conditions) considerable promise in an area such as Somalia where there are high and uniform solar radiation levels.

Care must be taken, however, in the choice of system for a specific application, since the quality of solar pump subsystem components varies considerably. While many pumps and controllers are now available, only a few have had sufficient field exposure to recommend their use. While very recently developed equipment shows considerable potential under laboratory testing conditions, the importance of field testing to turn prototypes into production units cannot be overemphasized. The power modules themselves are generally of very high quality, and have been developed to a point where manufacturers are now routinely offering 10-year warranties specifying a minimum degradation of power over that period. Extensive accelerated use testing has shown that the modules can be expected to generate power at design levels for periods of 20 years.

One potential problem which may lead to higher than expected operation and maintenance costs in Somalia is vandalism. Rocks can crack the PV module surface, possibly allowing penetration of moisture or particulates which could short out the electrical connections over time. While preliminary tests of these conditions (in Botswana) have shown that as long as the module does not get very wet, little degradation of output occurs in cracked modules, one must assume a certain minimum level of replacement due to vandalism over the lifetime of the system.

Many hand pumps have been installed in refugee camps, and several groups (LBII, ERDGS, OXFAM, CARITAS, etc.) have installed hand pumps throughout the country. While there has been some resistance to this technology, given its limited head and water delivery capability, there are nonetheless many applications in which hand pumps are the best choice from technical, social and economic points of view. Hand pumps are sometimes regarded as second-rate technology by government-level decision makers, and so their use is often officially discouraged. However, given the alternatives in the field, many users would rather have the hand pump, which has low recurrent costs and requires no fuel and little maintenance other than periodic replacement of cylinder leathers.

Several groups (such as VITA, IDE and the AID refugee section) have expressed interest in the "Rower" pump developed in Bangladesh. It is specifically designed for very low suction head (less than five meters) and low flows, and has been used for village water supply and small-plot gardening irrigation. Its major advantage in Somalia is that it is locally manufacturable, hence locally repairable. Researchers in numerous countries have conducted comparative studies of many of the wide variety of hand pumps currently available. Technical and economic characteristics are beginning to be quantified for comparative evaluation with alternative pumping systems.

Storage technology options should also be investigated for application to rural Somalia. The use of locally available materials (such as many of the components of ferrocement) should be investigated, rather than focusing on imported steel tanks. WDA has expressed interest in using fiberglass storage tanks at its installations. If these can be locally manufactured and supported after installation, they might be a reasonable choice. However, if the intent is to import the tanks, more attention should be focused on indigenous material and technology instead.

The problems with hand, solar, and wind pumps have been mentioned above. The de facto standard pump in Somalia is the diesel, either driving a generator and an electric submersible pump, or direct-driving a downhole pump element such as a Mono or vertical turbine pump. While diesel pumps are without doubt a very mature technology, several institutional and logistical shortcomings reduce their cost effectiveness in rural Somalia. The problems of inadequate fuel and spare parts supply have been mentioned. The lack of trained technicians inhibits proper periodic maintenance procedures, so that diesel pumps, like virtually all other pumps in rural areas, receive principally corrective rather than preventative maintenance. As can be imagined, this shortens equipment lifetimes, reduces operational efficiency, and thereby increases water delivery costs. There is an exceedingly wide variety of diesel pumps commonly used in Somalia, including U.S., British, Italian, French and Japanese makes. This lack of standardization further inhibits successful long-term operation of many of these units because of the high spare parts inventory demands, which are simply unmet in many cases (see below).

B. Institutional/Infrastructural Constraints

Issues of inter-agency coordination, training, incentives and the extent of private-sector involvement are integrally related to water resources development efforts in Somalia. The sections that follow discuss each of these problems briefly, and in some cases make suggestions about what might be done to alleviate them.

Coordination of Efforts

There is no single institution in Somalia's public sector that is directly responsible for coordination of either water- or energy-related activities. Water projects can fall under MMWR's WDA, MOI, the Ministry of Agriculture (MOA), the Juba Valley Authority (JVA), or the National Rangelands Agency (NRA).

WDA has responsibility for most boreholes drilled in the country, but this responsibility is shared by NRA when the boreholes are in the national rangelands areas. All donor projects involving borehole installations have to be cleared by MMWR through WDA. Since there is often no WDA representative in a rural village, the clearance goes through the village head via MOI. If the borehole is agricultural, then MOA must be consulted. If it is in the Juba Valley, then JVA must be contacted. MOI is apparently deepening its involvement in village water supply schemes. The list of donor agencies and PVOs working in the water resources development sector has already been mentioned. There seems to be little or no formal interaction or cooperation among these agencies either.

Formerly, the Technical Committee for Alternative Energy coordinated efforts into RET-based water pumps. This no longer seems to be the case, since the group has been renamed the Technical Committee for Energy, and seldom meets on any regular basis.

This general lack of coordination has several effects. In a country where development is severely constrained by a lack of financial, material, and skilled human resources, lack of coordination inhibits standardization of equipment, which has been an important component of successful water resources development schemes in many countries. This causes increased spare parts inventory requirements, increased unit costs of equipment since bulk purchases are not possible, and increased training requirements (in an area where trained technicians are very scarce to begin with) by forcing technicians to be knowledgeable about an unnecessarily large variety of equipment. Accumulated experience with fewer types of pumps gives a broader understanding of the limitations and applications of that particular equipment. In spite of all this, virtually every donor project apparently uses different types of equipment.

At the NFMW, the chief engineer pointed out a bench full of submersible pumps needing repairs. Not only were they all made by different manufacturers, but also in different countries. Each required different types of replacement parts, few of which were easily available locally. Private-sector suppliers have little incentive to address relatively small markets, thus many pump models are not well supported.

GTZ has used primarily diesel gensets with electric submersible pumps thus far. Although GTZ is not specifically constrained to buy German equipment, its funding organization prefers to do so. GTZ is, however, considering importing Kenyan Kijito wind pumps as part of a currently proposed small-scale water supply project (see below). SCF, at its Qorioley irrigation site, uses Italian Lambordini diesels for pumping from a reservoir up to the secondary canals. IGP projects use exclusively Italian pumps. OXFAM used German KSB pumps for its solar PV systems. CGDP has installed Lister diesel and Mono pump combinations on all of its boreholes where handpumps were not used. Monos are very reliable, inexpensive and robust pumps, but require somewhat more skill and equipment for installation than do electric submersible pumps. Lister diesels have acquired an enviable reputation for longevity and reliability when properly maintained.

WDA uses German, Russian and Italian generators on its electric submersible pump installations, but all new pumps are becoming standardized to diesel/Mono combinations, which are simpler to service than the electric systems. ERDGS uses Lister diesels and Goodwin pumps from Great Britain, and occasionally Italian generators driving Danish Grundfos pumps.

While it is unlikely that any of the donor agencies would want to subscribe to a policy of using another country's equipment exclusively in its development programs, this would certainly be a great benefit to Somalia. Rather than choosing, for example, any particular European or American unit, perhaps African-made equipment (such as Mono pumps made in Zimbabwe) could be chosen as the pump toward which standardization efforts are directed. This might well decrease costs as well as encourage inter-African trade efforts. Equipment should be chosen, however, principally on the basis of robustness and simplicity of installation, operation and maintenance.

Discussions on equipment standardization should be a part of any water resources donor-community coordination effort. On a larger scale, it is important to encourage interested donor agencies to mutually participate in project design and implementation discussions. Too often, donors inadvertently encourage a lack of concern for long-term ramifications of using a particular type of equipment simply because of a general feeling that if something doesn't work properly, or if a lack of proper operation and maintenance procedures leads to the early demise of one donor's equipment, another donor will be more than willing to step in and provide its brand. This does nothing to encourage the development of infrastructural support in terms of spare parts inventories, well-trained technicians to handle particular types of equipment, or willingness to invest time in trying to get the best equipment available. There were many anecdotes about equipment that was abandoned because only minor repairs were required. While GTZ claims to be changing its policy of supplying capital goods as opposed to encouraging proper operation and maintenance procedures, it is uncertain whether other donors will follow. Obviously, a mutual, concerted effort would be necessary for this policy to have any long-term effect.

Several people have mentioned the possibility and desirability of rehabilitation and maintenance training programs to try to address the problem of abandoned pumps or those which have simply fallen into disrepair due to a lack of proper maintenance or spare parts. Both VITA and GTZ have proposed similar programs. Any such program should also focus on the standardization issue as much as possible, if replacement rather than rehabilitation is required. It is anticipated that follow-on activities to the current reconnaissance will generate specific recommendations to address the standardization issue.

Training

A lack of adequately trained technicians was mentioned by virtually every person interviewed during the consultancy as a major obstacle to the success of any water development projects. This situation has several causes, including a generally low education level, lack of both proper facilities and qualified instructors for technical training, insufficient funds allotted for technical training, and little formal experience within the government or private sector for organizing training programs (either as formal or on-the-job training). On-the-job training is not normally seen as a standard component of any technical job, so supervisors do not necessarily feel any responsibility to include training as part of the daily schedule. Consequently, any training that is done (and it is usually included as a part of virtually all donor agency projects) is separate from normal job responsibilities. Participants are not adequately encouraged (i.e., not paid for their attendance), so attendance and interest are frequently sparse.

CGDP found that there were few incentives to encourage the well drillers they trained to stay in the well-drilling field after a project is over. For instance, unskilled house guards at some expatriate homes receive up to three times the wages of a government-employed, experienced well driller. Although they have been giving technical training to well drillers and pump installation crews, technicians feel that government wage levels (which they will be paid once the project is over and they no longer receive additional compensation from the project) are inadequate. Since the GSDR has specifically circumscribed the extent of private-sector involvement in water resources development, there is not currently a large demand for skilled technicians in the private sector. CGDP expatriate technicians feel that in addition to specific technical training, further English language training is particularly important since all equipment manuals (such as for well-drilling rig operation) are in English.

GTZ has had similar difficulty in formal training programs. Since the trainees were not specifically paid to attend, few did. In addition, since WDA felt that the employees being trained were not putting in a full-time day, WDA refused to pay their full salaries. No more formal training programs are planned by GTZ; on-the-job training will be attempted instead. Several donors have financed Somali students pursuing degrees in Europe or the United States. GTZ found that after completing their studies in Germany, students would sometimes disembark early on their way back to Somalia to seek work in the Gulf states. They have since instituted the practice of sending all diplomas directly to Somalia to encourage students to use their newly developed skills at home.

Pumping systems which have relatively high maintenance and repair requirements are particularly affected by this lack of trained technical personnel. Diesel pump use is severely constrained by the lack of skilled and semi-skilled manpower for the proper operation, maintenance and repair procedures, which are absolutely necessary to deliver water at reasonable cost.

Incentives and the Private Sector

A lack of adequate incentives is pervasive in the public sector. In any coordination efforts among water development groups, it would be necessary to pay Somali members of any joint oversight committees to ensure their interested involvement. There are good reasons for this. GSDR salaries are generally so low that employees must seek additional sources of funds through outside work. In effect, being paid as part-time employees, it is unrealistic for the training program to expect them to behave as full-time employees, unless they either get full-time pay or are learning skills that will help them make money in the private sector. Expecting them to attend or devote much energy to voluntary groups without providing sufficient incentives to do so is completely unrealistic. Project funds to account for this situation should be specified as a line item in the budget. This is also an argument for as much private-sector involvement as possible in the oversight committees, since there would presumably be a vested interest in participating.

As a rough estimate, a technician in the public sector earns So.Sh.900 to 1,500 per month, but it has been suggested that between So.Sh.10,000 and 15,000 per month is required for an average family living in Mogadishu. This lack of adequate incentives must be dealt with in order for technical training programs to have any success. Trainees must receive compensation (either in monetary terms or skills which they readily perceive to be marketable) for attending training programs in addition to their normal salaries; otherwise, their attendance is unlikely.

There is also an apparent trend within the donor community to encourage private-sector support of virtually all water-related activities (site selection, well drilling, civil works construction, equipment supply, installation, maintenance, etc.). While it makes sense that the private sector should be involved in the procurement of water pumping equipment, current practice impedes this function. While no duties are charged on imported agricultural goods, import licenses have sometimes been required for importers, and these are not always easy to obtain. GSDR reaction to these privatization efforts is not yet clear.

CGDP is working on a Water Industry Systems Model that makes suggestions on private-sector involvement in the water resources development sector. It is currently undergoing review by GSDR officials. Included is some information on possible local contractors and equipment suppliers outside of Mogadishu that who be interested and able to provide equipment, services and material support to various water projects. Other donors are looking increasingly to the private sector for support.

Logistics

A review of project reports and evaluations shows that logistical difficulties can be overwhelming in Somalia. Obtaining required equipment and materials, particularly when they are imported, can be a major procurement effort.

Transportation limitations increase delivered costs in rural areas and introduce additional uncertainty in supply networks. For example, the major problem that slowed completion of drilling for CGDP apparently was the frequent unavailability of diesel and petrol. There were also many problems with getting enough materials (e.g., cement) and equipment (e.g., diesel pumps). The U.S.-made Robbins-Meyers hand pumps that CGDP used initially had inadequate shafts that broke in several instances. It was very difficult to clear this matter up with the manufacturer simply due to communications and shipping difficulties. Such problems should be anticipated by future projects.

C. Financial/Economic Constraints

Since at this point only preliminary work has been done to adequately characterize the life-cycle costs of the pumping systems currently in use in Somalia, the comments provided here are principally institutionally related cost constraints. The illustrative analysis in the following section gives a tentative technical and economic comparison of various pumping alternatives.

The primary limitations to diesel pump use are the long-term recurrent costs of operation, maintenance and repair. Other pumping options offer a trade-off between relatively higher capital costs and lower recurrent costs. Several of the groups mentioned in Section II.C above have done preliminary analyses, but detailed cost and performance data remain to be collected. Two cost analysis models are being developed by CGDP using present worth and internal rate of return analysis, one for well drilling and pump installation, and the other for well maintenance and amortization (see Appendix B, #1b).

Several factors must be incorporated into this type of analysis. One is the frequent lack of availability of sufficient diesel fuel through prescribed government channels, particularly in rural areas, which forces users to resort to the considerably higher-priced fuel (normally about So.Sh.30/liter as opposed to the GSDR rate of So.Sh.17/liter) that is usually available on the parallel market. Further, it is difficult to assign a value to lost crops or to having to walk another five kilometers to obtain drinking water when the only pump in the area is diesel-driven and no diesel fuel is available.

While economists strive for objectivity in their analyses, subjectivity in evaluating unquantifiables is unavoidable. In a situation such as Somalia's, investments should be weighted in favor of systems that require little maintenance, even if capital equipment cost is high (to a point). Costing should somehow reflect the difficulties in obtaining proper maintenance skills and spare parts replacement over the system lifetime.

Comparative analysis must reflect a measure of the relative reliability characteristic of each of the various pumping options. For example, solar PV pumps are generally considered to have a greater mechanical reliability than diesel pumps. However, variable solar radiation levels can reduce the actual availability of water delivery from the solar pump (as a lack of diesel fuel could reduce availability of the diesel's output). Availability of output should therefore consider both the energy resource and the mechanical reliability of the equipment itself.

A second factor is the issue of user fees, which seems to be a critical one in the water supply sector. The fees currently charged hardly even cover operation costs, let alone capital equipment or maintenance and repair costs. WDA is obligated to provide maintenance and repair services as part of the user fees, but in reality seldom does. The user fee per cubic meter of water was So.Sh.10, but apparently this has recently been raised to So.Sh.18/m3. According to some studies (see Appendix B, #4), even this fee does not begin to cover costs adequately.

For donor-provided water supply systems, donors normally provide the capital investment and, in theory, villagers are supposed to meet the recurrent costs. This often requires the use of shillings to buy foreign exchange to get parts (and sometimes even fuel, which is supposed to be supplied by WDA, but in fact is often simply unavailable). In the Bay region, for instance, a villager might have to walk several days to get to the regional capital city, spend a week talking with local WDA officials to obtain the fuel allotment, then walk back to the village. It would be (and frequently is) much easier, and about the same total cost, to obtain the fuel on the local parallel market rather than trying to go through official channels. All of this increases actual unit water cost to the user.

The actual extent of government subsidy of diesel and grid electric costs is not yet certain. The tariffs charged for electricity from the national grid are artificially low, completely apart from the reliability and availability issue. Other studies (Refs. 2, 3) indicate that the tariffs do not even cover operating costs for the electric utility, let alone equipment capital investment or the cost of system expansion. Besides the problem of rural distribution networks (even the distribution networks in Mogadishu are overloaded and experiencing difficulty in meeting demand), expanding the use of grid electric pumps would further overload an already-overloaded generation and distribution capacity. Given these considerations, extensive use of grid-connected electric pumps is not considered a viable option for rural water supplies.

Since one of the biggest constraints to the widespread adoption of RETs for water pumping is their relatively high capital equipment cost, private parties interested in purchasing pumping equipment would likely require some financing mechanism. Several SCF advisors interviewed expressed the opinion that people in rural areas are more interested in loans than grants. SCF has a small loan program for water projects, and thus far has been paid back completely in every instance. Since self-help cooperative arrangements are not uncommon in Somalia, it might be possible to have pump-purchasing cooperatives to cover initial capital costs of equipment, as well as to coordinate the meeting of long-term recurrent costs associated with equipment use.

IV. ILLUSTRATIVE TECHNICAL AND ECONOMIC ANALYSIS FOR PUMPS

This section gives a tentative example of the type of technical and economic analysis which is necessary to adequately characterize and comparatively evaluate alternative pumping system options.

A. Technical Performance

Pump and engine manufacturers' performance specifications are normally derived from laboratory tests under nearly ideal operating conditions, and therefore are often overly optimistic. It is unrealistic to use those figures to estimate pump performance under actual field operating conditions, where well-used equipment, often not properly maintained, is the rule rather than the exception. Therefore, the technical output in terms of water flow at the chosen head for the respective pumps was estimated in the following ways.

For solar pumps, the performance results have been extrapolated from experience with similar pumps in other field tests (Botswana). Based on estimated (not measured, see #4 in Section V) local solar radiaton levels in Somalia, the water output was generated using a simple computer algorithm with pumping head and monthly radiation levels as input variables. The equipment was assumed to be largely U.S.-manufactured (except in the case of Mono pumps) and the costs were based on FOB U.S. costs with estimates of shipping charges, as well as on similar pumps already installed in Somalia Costs of European PV equipment would be similar.

For wind pumps, water output is considerably more difficult to estimate. To some extent, the estimates given below are extrapolations from actual measured performance for similar machines in other field tests (Botswana, Canada, Kenya). However, wind speed distributions vary much more by site than solar radiation intensities, so the results must be viewed with more caution. While tests of certain of the machines (i.e., Wind Baron) analyzed have been conducted in Somalia, the paucity of data gathered thus far does not allow for accurate output calculations.

For diesels (diesels directly driving Mono pumps as well as diesel generators driving electric submersibles), the water output results were based on field tests performed in other countries (Botswana, Kenya). The financial and economic inputs rely, however, on work currently underway as part of CGDP. This is particularly true of the recurrent costs of operation and maintenance, which cannot (and should not) be based on data from other areas, given the particular constraints on the successful long-term operation of diesel pumps in Somalia.

Although hand pumps have not specifically been included in this example, there are many sites in rural Somalia where hand pumps would be the most appropriate choice of equipment for low-head, low-demand situations. While the output of hand pumps is known, based on field tests of similar pumps in other areas (Botswana, and many other countries as part of the World Bank hand pump research and development program), local labor rates and use patterns have yet to be ascertained for Somalia, so the analysis will be left to the follow-on study. The cost data will be based on prices quoted FOB Nairobi, and should include estimated shipping costs to Somalia.

While import duties in Somalia on most equipment are 100 percent, equipment brought in for use by refugees is duty-free. Local transportation can add considerably to the delivered price of commodities in rural areas. Import duties have not been considered in this preliminary analysis, but could add considerably to systems with a high capital cost if favorable import duty status for water pumps is not forthcoming.

B. Financial/Economic Analysis

Life-cycle cost (LCC) analysis, which calculates the present worth of all costs, capital, operation and maintenance, and replacement parts over the lifetime of the system, is the standard method used for the financial and economic comparison of water pumping alternatives and will be used here. The costs considered in this example do not include well drilling or development, the water distribution system, or storage tanks. Any system components which are common to all systems (e.g., borehole, civil works, etc.) are not included in the costing.

Economic analyses attempt to place a "true" value (cost to the national economy) on various cost components, which is not necessarily what these costs would be in the marketplace. They attempt to quantify such real costs to the overall economy as the cost of government subsidies (hidden or otherwise), anomalies in the marketplace, imbalances in exchange rates, or scarcity in the availability of foreign exchange. Diesel and grid electricity costs are often subsidized in many African countries. While the real economic cost of subsidies would not be taken into consideration by the average consumer, it should be taken into account by government planners who are concerned about the scarcity of foreign exchange, much of which is caused by importing fossil fuels.

A number of assumptions were made when performing the LCC analysis. Input variables such as the discount and real inflation rates, assumed (or measured) system lifetimes, shadow pricing of labor and foreign exchange, and expectations about the availability of capital all can dramatically affect the outcome of the analysis, either individually or synergistically. That level of detail is not included here, since all of these inputs, which will require careful and detailed specification, will be included in the actual analysis done in the follow-on report. Sensitivity analyses will be performed to see what effects variations in the base-level assumptions can have on the overall analysis.

The primary figure of merit calculated in the analysis was to the annualized life cycle cost (ALCC) per cubic meter of water delivered per unit head. This is also referred to as the unit cost ($/m^3*m). The energy required for pumping water is directly proportional to both the volume of water pumped and the head (or lift) through which it is pumped. This tends to normalize the performance of pumps at different sites and reflects the additional energy input required to pump water from a deeper borehole.

Although a benefit/cost ratio, net present value, or internal rate of return could also be used to evaluate the pumping options, the value of a delivered unit of water would have to be assumed, introducing yet another assumption into the analysis. Assumptions in the analysis include the following:

- Since the government was assumed to be the primary purchaser of PV pumps, no import duties were assessed against the equipment.

- Shadow costs of labor and foreign exchange were taken to be 1.0 and 1.0 respectively. It is likely that these will be revised to be 0.5 and 1.1 to reflect a scarcity of foreign exchange and abundant local labor, respectively, depending on GSDR accepted policy. Sensitivity analysis will be performed on this assumption in the follow-on report.

- Incremental training costs for PV and wind pump technicians should be factored into the recurrent operation and maintenance costs of the systems. The magnitude of this incremental cost is difficult to evaluate and, hence, is not included here. While the training expenses associated with the diesel pump maintenance infrastructure are indeed sunk costs, they should similarly be included in any comparative evaluation of pumping technologies. Some estimate of the likely extent of long-term demand for systems must be made so that the training and infrastructural support development costs can be amortized over that number of probable systems.

- The price of diesel fuel used here is the standard government tariff of So.Sh.17/liter. However, villagers in rural areas often pay the parallel market rate of So.Sh.30/liter, and even considerably more (charges of up to So.Sh.100/liter were mentioned) depending upon local scarcity of supply. This will dramatically increase the cost of diesel pumping beyond what is shown here.

- Salvage values for all equipment were assumed to be zero.

- Calculations were made in dollars rather than Somali shillings to avoid the difficulties associated with several different rates of exchange.

- In order to give a feel for the division of upfront capital expenditure and long-term recurrent operation and maintenance costs, the ratio of installed capital equipment costs to LCC was calculated for each pumping system. This reflects the need for the availability of capital in each case.

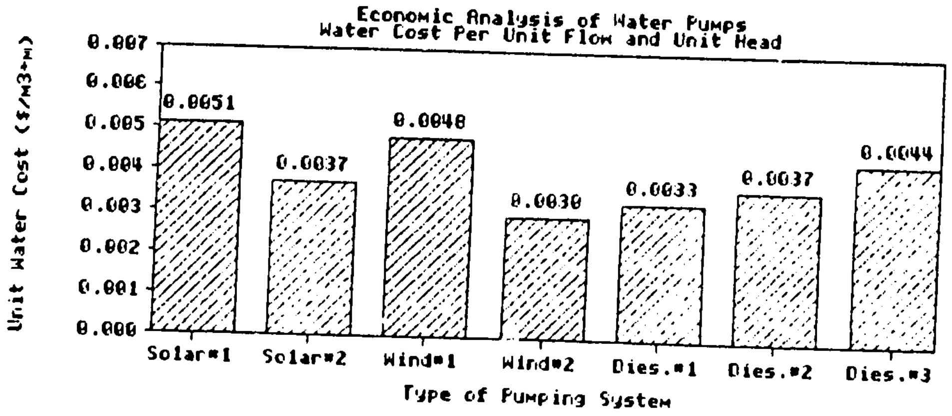
- Discount rates and the real cost increases of equipment/labor above the general rate of inflation were taken to be six percent and zero percent respectively, reflecting fairly standard assumptions for public-sector financing. GSDR figures for these assumptions will be used in the later analysis. Private-sector discount rates will be somewhat higher (16 percent interest rates for private-sector financing are common). Assumptions of lower discount rates tend to bias the analysis in favor of technologies with higher initial capital costs and lower long-term recurrent costs (i.e., PV and wind will seem relatively more favorable than diesel because of such an assumption).

The spread-sheet shown on the following page gives the results of the tentative analysis. A graphic interpretation is given as well. Again, <u>these results are based on estimated data only</u>, and should be viewed only as illustrative of the analytical process. The categories in the spread-sheet are as follows:

Example of Financial/Economic Analysis for Water Pumps in Somalia

Value of Water ($/m3) = $0.30

System/Site :	Solar#1	Solar#2	Wind#1	Wind#2	Dies.#1	Dies.#2	Dies.#3
Water (m3/day):	17	27	22	60	67	67	67
Total Head (m):	37	24	37	37	80	80	80
Vol*Head Prod.:	629	648	814	2220	5360	5360	5360
Amortiz.Period:	20	20	20	20	20	20	20
Discount Rate :	5%	5%	5%	5%	5%	5%	5
COSTS							
Capital Cost :	$9,891	$6,556	$12,638	$23,016	$12,000	$12,000	$12,000
Installation M:	$80	$80	$262	$411	$1,000	$1,000	$1,000
Installation L:	$200	$211	$319	$913	$1,000	$1,000	$1,000
PW Recurr.Cost:	$4,728	$4,285	$4,945	$6,757	$68,062	$76,333	$93,861
Total LCC :	$14,699	$10,921	$17,845	$30,184	$81,062	$89,333	$106,861
BENEFITS							
Annual Volume :	6205	9855	8030	21900	24455	24455	24455
Value of Water:	$1,862	$2,957	$2,409	$6,570	$7,337	$7,337	$7,337
PW of Benefits:	$23,198	$36,845	$30,021	$81,877	$91,429	$91,429	$91,429
Ben/Cost Ratio:	1.58	3.37	1.68	2.71	1.13	1.02	0.86
Inst.Cost/LCC :	0.69	0.63	0.74	0.81	0.17	0.16	0.13
Ann.LCC ($/m3):	0.1901	0.0889	0.1783	0.1106	0.2660	0.2931	0.3506
Ann.LCC ($/m4):	0.0051	0.0037	0.0048	0.0030	0.0033	0.0037	0.0044



- capital cost--including such items as the major system components (for PV: modules, support structures, batteries, controller, lights; for diesel: pump, engine, fuel storage, pump house, etc.) as well as wiring, crimp connectors, cable ties, etc.;

- installation cost--"M" for materials and "L" for all labor and transportation costs incurred during the installation;

- present worth (PW) of recurrent costs--present value of all expected operating and maintenance costs over the lifetime of the system, including any spare or replacement parts or labor and transportation charges that will be incurred;

- total LCC--present value of all costs incurred in the purchase, installation, operation, maintenance and repair over the system lifetime;

- the benefit/cost ratio is calculated based on an assumed value per unit volume (m^3) of water delivered--this could be set to be the GSDR tariff rate, or for irrigation, based on the market value of the incremental crops produced due to irrigation (since the benefit calculations involve a number of assumptions, the benefits section is given mainly for the reader's convenience rather than as a primary evaluation criterion);

- ratio of system installed cost to total LCC, a measure of upfront capital requirements; and

- ALCC, the LCC divided by the present worth factor for the discount rate and system lifetime assumptions, and divided by the estimated annual volume of water pumped--the ALCC was calculated both per unit volume ($\$/m^3$) of water delivered and again in terms of cost per unit of hydraulic energy required (volume times head product, or $\$/m^4$).

The different systems are as follows:

- Solar #1--DC electric submersible pump driven direct by a 32-module array, module costs at $8/Wp (peak watt, the method of specifying module output). This was the cost as of January 1985.

- Solar #2--As above, but costed at the currently available module cost of $6/Wp (FOB U.S.) December 1985.

- Wind #1--a 20-foot rotor diameter windmill operating at an efficiency of 0.16 at an average wind speed of four m/sec (i.e., in the better wind areas of Somalia).

- Wind #2--a 20-foot rotor diameter windmill operating at an efficiency of 0.16 at an average wind speed of 6.5 m/sec (i.e., in the best wind areas of Somalia).

- Diesel #1-#2-#3--standard diesels driving progressive-cavity downhole pumps using assumptions which bracket the range of standard operation and maintenance costs. Note the considerably larger output and relatively high installed capital cost of the diesels, bearing in mind that unit water costs normally increase considerably for smaller demands and heads. All of these calculations assume the official GSDR tariff on diesel fuel. This is often considerably less than consumers actually pay. Also, this analysis does not account for the frequently encountered pump outages due to simple unavailability of fuel or spare parts. Thus, this example is somewhat biased in favor of diesel pumps.

The illustrative conclusions taken from this analysis, as mentioned above, are based on tentative data. In general, the following conclusions can be drawn:

- wind pumps show potential for being cost-competitive with diesels at the better wind sites in Somalia under the assumptions made here at low flows and low to moderate heads, and could be very competitive at the best wind sites, particularly when these are distant from diesel maintenance and fuel supplies;

- solar pumps using current costs at low to moderate flows, and at low to moderate heads show potential for being cost-competitive with diesel when diesel maintenance and repair costs are estimated on the high side, or when fuel costs are greater than official rates;

- diesels (or electric submersible pumps driven from reliable grid power) are the technology of choice for moderate to high heads and moderate to high flow when properly maintained, which is not always to be assumed in Somalia; and

- the overall conclusion is that there is considerable potential for displacement of diesel pumps at many of the lower demand sites--further data collection and analysis will define the scope of this potential.

V. CONCLUSIONS AND RECOMMENDATIONS

Based on the preliminary data collection and analyis efforts of the initial reconnaissance mission, the following tentative conclusions and recommendations are made.

1. Because of the extensive problems associated with diesel pump use (particularly in remote areas) other types of pumps (wind, hand-operated, solar PV, and possibly animal traction) should be considered for application. Probable sites are those where diesel fuel availability and local repair and maintenance capability are limited, and where the often high capital costs of such systems (except hand pumps) are balanced by large savings in recurrent costs. This would most likely occur at sites with low to moderate head and low water volume requirements, particularly for higher-valued drinking water supply.

2. Water tariffs in Somalia seldom reflect the true cost of operation and maintenance of pumps, let alone capital equipment and long-term repair and replacement costs. Some revenue-generating mechanism must be arranged to cover long-term costs (which will not likely be borne by the donor community). Water tariffs should be raised (more than the So.Sh.10 to 18 increase approved recently) to cover all costs associated with water delivery (except perhaps the cost of well drilling, which could be subsidized by donor agencies through the GSDR). As long as water tariffs do not reflect actual costs, water conservation efforts will not be best served.

3. The recommendations of the LBII private-sector study, which suggest that as much as possible, infrastructural support activities should rely on the private sector, should be implemented as soon as possible. WDA should allow and encourage the private sector to become more involved in all aspects of water resources development, including well drilling and pump installation, maintenance and repair. WDA should confine its activities to administration, planning and coordination of water development activities, and let the private sector attend to the physical water supply structures.

4. Donor agencies and PVOs should more closely coordinate their efforts in the water resources development sector to reduce duplication of effort, encourage and support standardization of equipment, and mutually provide and accept peer review of project planning. The latter would help to discourage the feeling that if one donor group declines to fund a possibly less-than-cost-effective project, another donor can be found who will support it. These general coordination efforts

will be strengthened by the creation of the proposed National Water Data Center.

5. Due to the paucity of microclimatological data on wind and solar resources, data collection programs should be encouraged and carefully coordinated so that data collected by different groups are compatible. Meteorological data are being collected by the Meteorological Services of the Civil Aviation Department, Ministry of Transportation, as well as by the Agro-Meteorological Stations under the MOA. The data collection effort should seek to standardize both instrumentation, and collection and analysis techniques so that the results are mutually compatible and appropriate for use in RET system design. The collection of wind and solar data should be included in the climatological monitoring program of the proposed Shabelle River irrigation project.

6. There is a need to characterize water pumping equipment in terms of institutional and social acceptability as well as technical performance and costs, so that the best use of limited financial resources can be made when selecting equipment for a particular site and demand. Site-specific design criteria should include the consideration of RET-based pumping systems (such as hand-operated, wind, animal traction and solar pumps) where technical limits allow.

7. To facilitate the implementation of each of the preceding recommendations, an effort should be made to complete the collection of all water resources development-related studies done in Somalia into a central repository for reference (for instance, the proposed National Water Data Center).

8. Other water conservation and storage technologies, such as rainwater and surface water catchment schemes, and ferrocement (and other local materials), for less-expensive, long-lasting storage tanks should be examined as possible options for reducing the cost of water delivery.

9. Water supplies for humans and animals should be kept separate wherever possible. This is particularly true for shallow wells, which become so easily contaminated by animal feces when the wells are improperly designed or do not have stock watering physical structures (e.g., troughs, proper drainage facilities, etc.).

10. A carefully conceived and implemented public awareness program of water supply topics (well contamination, proper well design, using higher-efficiency furrow versus flood irrigation) would do much to alleviate many of Somalia's water-related problems.

11. Should further assessment studies warrant dissemination of some of the pumping technologies mentioned in this report, it would be best to initially confine the efforts to a small geographical area, and emphasize training and infrastructural support issues from the beginning. Pump selection should be needs driven rather than technology driven. Other donors should be involved as much as possible to reinforce, not duplicate, these efforts.

APPENDIX A

List of Individuals Contacted During Consultancy

USAID/Mogadishu:

1. Gary Nelson, Acting Director
2. Dan Vincent, Engineering
3. George McCloskey, Rural Development and Refugees
4. Bill Darkins, CGDP Officer
5. Sally Patton, Environmental Officer, Engineering
6. Frank Catania, Rural Development and Refugees
7. Ray Carpenter, Chief Agricultural Development Officer
8. Bill Keefe, PVO Project Officer
9. Peter Detwiller, Program Office
10. Debbie Prindle, Project Backstop Officer, AID/Washington

USAID/REDSO:

1. Analysis Section
   a. Stewart Callison, Economist
   b. Tony Pryor, Energy Officer
2. Engineering Section
   a. Jack Smith, Chief Engineer
   b. Fred Guymond, General Engineering Advisor
   c. Pushkar Brahmbhatt, Engineering Advisor
   d. Carlos Crowe, General Engineering Officer

GSDR:

1. Mohamed Abdi Deria, Chris Dufresne, MOI, SURERD
2. Andres Savva, Ministry of Planning, Water Resources Advisor
3. Abdi Haj, National Refugee Commission, Refugee Water Supply Unit
4. Eng. Abdulahi Ali and Eng. Abdulahi Hussein, Ministry of Industrial Development, NFMW
5. Mohammed Muse Issak, Ministry of Planning, Energy Section
6. Abakar Hussein Hassan, WDA Regional Director in Baidoa

AID Contractors:

1. LBII/CGDP (Mogadishu):
   a. Larry Cerrillo, Chief of Party
   b. Roy Lock, Economist/Planner
   c. David Douglas, Field Engineer
   d. Forrest Hall, Pump Specialist
   e. Wes Glessner, Driller
   f. Jack Gillespie, Hydrologist

g. Bill Williams, Driller
h. Phil Roarke, former Chief of Party (now w/ WASH project)
i. Mark Pape, Systems Analyst (LBII/Washington)
j. Thomas West, liaison project manager (LBII/Washington)

2. Everett Williams, Bureau of Reclamation, Juba Valley Analytical Studies project
3. Martin Wulfe, Energy Advisor, Ministry of Planning
4. Jack Boone and Myrna Seidman, Family Health Services project
5. W. Thomas Kelley, formerly Advisor to NRA, now with ARD Juba Environmental and Socioeconomic Studies project
6. Richard Ford, Resource Historian, Clark University
7. Patricia Polton, ISTI
8. Jon Hendrick van Leeuven, ISTI Business Development Specialist

Other Donors:

1. GTZ, Peter Conze, Ministry of National Planning Advisor
2. UNHCR, ERDGS, Arne Von Urk, Technical Advisor, and ERDGS Qorioley Camp Supervisor, Refugee Water Supply Division
3. Robert Wild Drilling Company, Hans Hugo Buck, Civil Engineer (GTZ Drilling Crew Coordinator)
4. UNDP, Laurie Schwede (Comprehensive Donor Project List)

PVOs:

1. SCF: Dennis Hattem, Civil Engineer, and Jeff Saussier, Program Manager of Qorioley Irrigation Project
2. VITA: Mohammed Hassan, Technical Director, Jim McCormick, Project Manager
3. OXFAM: Steve Cavell, Field Director

People to Be Seen During Follow-Up Consultancy:

1. Mootomi Tomaru, Assistant UNDP ResRep, coordinates donor water development activities
2. Dr. Amini, WHO representative in Mogadishu, interested in Water Decade activity
3. Khalif H. Farak, General Manager, WDA
4. Yasuf Elmi, LBII Counterpart in WDA
5. Ernst Mellbingar, CARITAS
6. Dick Williams, OXFAM Hydrologist for NW
7. Mohamad Hassan Farah and Husein Adam of SURERD (neither in town during first visit)
8. Constantino Faillace, GTZ Water Advisor in WDA
9. Mr. Karani, General Manager of NRA
10. Robin Bourthwicke, UNHCR
11. Mohammed Ali Dahir, National Foundry Manager
12. Lisa Anne Wiggins, New Transcentury Corp., Water Resources

Development project
13. INIDO/UNDP/UNSO representatives
14. ICR representatives
15. DANIDO (wind turbine installations)
16. Jur' 'n Fager, ERDGS
17. Uni   ty of Somalia, Mechanical Engineering Department
18. FAO representatives
19. Muhammed Ali Dahir, MMWR, Technical Committee for Energy
20. Dr. John D. Skoda, UNICEF Regional Advisor for Water and Environmental Sanitat_on, Nairobi
21. David Gray, Rural Water Supply Program, World Bank, Nairobi
22. Stuart McNab, CIDA/UNICEF, Water and Environmental Sanitation Project in Northwest
23. Dr. Bham Pathak, WDA Energy and Water Advisor

APPENDIX B

List of Documents Reviewed

1. Comprehensive Groundwater Development Project (LBII)
   a. Somalia Comprehensive Groundwater Project, Project Paper 9/79
   b. Interim Report
   c. Request for Extension
   d. Final Report
   e. Project Evaluation Summary, 5/83
   f. Water Resources Development Industries in Somalia

2. Issues and Options in the Energy Sector, draft, World Bank 5/85

3. Energy Strategies for Somalia: Summary Report of the National Energy Assessment (revised), E/DI, 10/83

4. Study of Water Lifting, Storage and Distribution Costs, Interim Report, Somali Unit for Research on Emergencies and Rural Development

5. EPD Report on Status of Electrical Generation and Distribution in Mogadishu, EPD, 7/85

6. Potential for Wind Energy for Water Pumping in Somalia, Technical Advisor's Report, Jon Hodgkin, VITA, 1983

7. Wind Energy Activities in Africa, Alan Wyatt and Jon Hodgkin, VITA

8. The Qorioley Refugee Irrigation Scheme, SCF Field Office, 11/85

9. Memorandum, Renewable Energy Project Identification in Somalia, Constantin Salame, 1982

10. A Status Report of Windmills in Somalia, Jon Hodgkin, VITA, 1/83

11. Water from Wind in Somalia, R. Pallabazzer, University of Somalia, 1984

12. Toward an SCF Water Resources Development Strategy, SCF, 7/85

13. Rural Development Project Proposals for the Alula District, Bari Region, Northeastern Somalia, Peter Detwiller, 8/85

14. Burao Seminar on Environmental Management and Energy Needs, H. Adam, T. Kelley, Mahamed Awaleh, 6/83

15. Preliminary Economic Analysis of the Comprehensive Groundwater Development Project, GSDR, Mark Pape, LBI, 5/82

16. Kienbaum Beratungen, Study for the Progressive Local Manufacture of Handpumps at the NFMW, 1983

17. Comparative Costs of Solar, Wind and Diesel Pumping in Nigeria, Somalia and Zimbabwe, Derek Lovejoy, World Bank, 10/84

18. Water from Wind in Somalia, Preliminary Investigation and Program, and Progress Report No.1, R. Pallabezzer, University of Somalia, 6/11/83

19. Energy Strategies for Somalia: Summary Report of the National Energy Assessment, revised, E/DI, 10/83

20. The National Foundry and Mechanical Workshop, Options for Survival, draft final report, ISTI, 10/85

APPENDIX C

Wind Baron Testing and Evaluation

Monitoring

One of the tasks in the Scope of Work for this consultancy was to visit the site of the Wind Baron wind pump, discuss with CGDP personnel their monitoring efforts thus far, and make recommendations for further performance monitoring.

Two Wind Barons were procured by the project. Thus far, one of these has been installed on a CGDP borehole in the Bay Region, and the other is awaiting selection of a suitable borehole in the National Rangelands areas. As has been the case with similar projects, the installation crews found it necessary, because of the size and weight of the machine, to use a crane for the installation, which significantly increased the cost and difficulty. (Since then, a similar machine was installed in Botswana without a crane.) The crew said that a similar installation in the Central Rangelands area would be considerably more difficult and costly due to the very long distances and poor roads that would have to be traveled.

During a visit to the Wind Baron site in Baidoa, ARD's senior engineer spoke with the installers and examined the machine for wear. The wind pump had been used to deliver a small amount of water to adjacent fields for irrigation purposes, but did not appear to have been used much. According to the flowmeter that had been installed in the water discharge line, the machine had only pumped about 755 m^3 of water in the eight months since it was installed. The storage tank was very small (about two m^3). When operating, the machine had quickly filled the small tank (probably in only a few minutes), and was then manually furled out of the wind. This did not constitute any real test of the machine's capacity for pumping water. The discharge line was in the process of being replumbed to deliver water to a nearby school. There was a much larger storage tank already installed at the school, and it appeared that there would be considerably greater demand, which would give a better test of the wind pump's capabilities.

When the wind machines were shipped out from the United States, the manufacturers included two Natural Power wind compilators with them. Compilators are electronic pulse-counting devices that count and accumulate the rotations of a three-cup anemometer mounted on a tower at the same height as the wind pump rotor centerline. The pulse counts are stored in wind speed "bins" of 0.5-1.5 m/sec (average 1.0 m/sec); 1.5-2.5 m/sec (average 2.0 m/sec); etc. The accumulated values in the 32 bins represent a histogram of the wind speeds at the site over the test period. From this histogram, and the simultaneous use of a water flow meter, the water output of the wind pump at any given wind speed can be measured. This process allows generation of output predictions over a longer period of operation, and these can be used in the type of economic analysis shown in Section IV of this report to allow comparison with other pumping options.

Apparently there were few instructions on the use of the compilators that came from Wind Baron. The compilators were intended to be driven by a battery which was to be powered by a single solar PV module. The instructions neglected to mention that a controller was also necessary to prevent the PV module from overcharging the battery and destroying it. At any rate, the compilator experienced problems that required its being sent back to the manufacturer in the United States. The repaired device had just been received back in Mogadishu when the site visit was made. ARD's senior engineer recommended a suitable controller that could be used in the instrumentation system.

Due to the more pressing issues of the drilling crew completing its borehole drilling by the end of the project, it seemed unlikely that much attention would be given to monitoring the Wind Baron. It is uncertain whether the second machine will be installed before the end of the project. If the recommendations given in the Scope of Work (Appendix D to this report) are accepted, performance monitoring of the machine will take place in the summer of 1986.

A comprehensive testing and evaluation methodology for most commonly used water pumps is being developed by ARD and IT Power of Great Britain. This methodology takes into account much of the testing done thus far by a wide variety of researchers, and integrates it into a standard format which can be applied by field researchers interested in the technical and economic comparison of a number of water pumping options. Since many of the studies done thus far have used different methodologies and testing procedures, much of the data collected are not easily compared. This comprehensive methodology will be submitted to many of the preeminent researchers in the field for critical comments before final publishing. It should be used in any follow-on studies in Somalia as well. It will be available in several months' time, in time to be incorporated in the various options listed in the recommendations of this report.

General Appraisal

There were several signs of wear on the Baidoa machine. The most ominous was the excessive wearing of the wire down-bridle connected to the upper walking beam. It appeared as though it would need replacement soon. This did not bode well for a machine that had been used so little. The second observation was that the tower was already beginning to show significant rust. Apparently th lower (and main) part of the tower had not been hot-dip galvanized before shipping, although the stub tower and the machine itself had been. In an area such as Somalia, where salty air can rapidly destroy unprotected metal, the manufacturers should have taken more precautions. Although the installation is well inland (several hundred kilometers) from the coast, there is often an early morning fog which coats the tower and apparently is quite saline. Installations along the coast would be expected to fare even less well. A third and relatively minor problem was that some teeth had been sheared on the manual furling winch.

The installer said that the depth to water was about 20 to 22 meters, and the cylinder was installed at the 90-meter level. Because of the relatively large pumping capacity of the 6.4-meter diameter wind pump, and the relatively low yield of the borehole, drawdowns to as much as 60 meters had been experienced. Since the wind compilator had never really been functioning properly since its installation, the installers did not have adequate data from which to make inferences on output as a function of wind speed. They said that they felt the machine was too complex to gain widespread acceptance in Somalia. Because of its counter-balancing mechanism (which allows start-up in lower wind speeds than would otherwise occur), the Wind Baron is considerably more complex to assemble than other wind pumps. However, its output is also considerably higher.

Other tests have shown the Wind Baron to hold considerable promise from a technical performance perspective. However, it seems that there are still several major bugs to be worked out before the machine can truly be regarded as appropriate for developing-country use. Apart from its technical characteristics, it is still very expensive (upwards of US$30,000 installed, including shipping from the United States). Unless successful efforts are made to manufacture the machine as part of a joint venture with local manufacturers in Africa, it is unlikely that it will ever find much of a market there. While negotiations with manufacturers in Zimbabwe have taken place, they have not yet yielded positive results.

CGDP personnel have also been looking into purchasing Kenyan Kijitos, and have received quotes from the manufacturer, Bobs Harries Engineering, Ltd. (BHEL), through the Export Trading Company (ETC) in Nairobi. BHEL is also interested in looking into possible joint ventures (perhaps with NFMW) for the local manufacture of Kijitos. ETC is also sending two India Mark II hand pumps gratis for installation by the project. These hand pumps have shown considerable promise in other testing, and were designed specifically to be locally manufacturable in most countries.