DEVELOPING SUSTAINABLE COMMUNITY WATER SUPPLY SYSTEMS

KEY QUESTIONS FOR AFRICAN DEVELOPMENT FOUNDATION APPLICANTS

WATER AND SANITATION
FOR HEALTH PROJECT

DEVELOPING SUSTAINABLE COMMUNITY WATER SUPPLY SYSTEMS

KEY QUESTIONS FOR AFRICAN DEVELOPMENT FOUNDATION APPLICANTS

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November 1989

WASH Field Report No. 270

ADF Working Paper Series No. 4

African non-governmental organizations working with community water programs who wish to translate these guidelines into a specific local language may receive permission to do so by writing either the African Development Foundation or the Water and Sanitation for Health Project.

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Water and Sanitation for Health Project
Contract No. 5942-C-00-4085-00, Project No 936-5942
is sponsored by the Office of Health, Bureau for Science and Technology
U.S Agency for International Development
Washington, DC 20523

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INTRODUCTION

1.1 Objectives

The purpose of this paper is to provide information to groups applying to the African Development Foundation (ADF) about the factors to consider as they design a new community water supply system that will be both sustainable and successful in meeting the established needs of their community. This information can be transmitted and discussed within community meetings by community leaders accustomed to dealing with written materials, or by the ADF Country Liaison Officer (CLO) as he/she begins initial discussions with a community that has initiated a water supply proposal. The guidelines contained herein have been written for communities, because it is they who will be using the information, although it is recognized that a facilitator will often be used for those communities not strong in literary skills.

Communities which have initiated a proposal process with ADF know what they want to achieve in terms of improving their water supply, but they don't always have enough information to make the best technology selection and identify the areas where problems are most likely to arise as the new water supply is constructed and maintained. Therefore, the specific objective of this report is to provide basic information to the applicant organization so that informed decisions can be made on the technical, cost, management, service, health, and environmental issues that impact on initial success and long-term sustainability for community water supply. This process at the community level will, in turn, allow ADF to receive a community proposal for improved water supply wherein all of the relevant technical and sustainability questions have been addressed by the community itself. This process of informed local control is seen by ADF as a major contributor to long-term sustainability.

1.2 How to Use the Guidelines

This report is designed to assist the community in three specific activities described below:

1. **To decide which water technologies can be considered and what information must be gathered to undertake comparative discussions**

Chapter Two, "Water Technologies," provides a short description of typical technologies appropriate for rural water supply along with their advantages and disadvantages. This chapter should be consulted when deciding which technologies to consider. Chapter Three, "Key Questions Related To Technologies," should be used to identify technical and financial questions on which the community needs to collect information before key community discussions are held.

2. **To orient community discussions on the pros and cons of each possible water technology in terms of the technology's ability to meet the water needs of the community, and the ability of the community to maintain the water system over the long-term**

Chapter Three, "Key Questions Related to Technologies," and Chapter Four, "Key Questions Related to Management and Health," provide guidelines and general information upon which community discussions can take place. Generally, the information provided in these chapters can be transmitted directly to the villages with the expectation that the communities will orient their proposal to answer the questions raised. Chapter Five, "Critical Factors for Sustainability," is intended to assist the community to sharpen its analysis for a final decision. It defines five critical or vulnerable points where new water systems easily fail unless communities take specific decisions or actions. It is suggested that a facilitator (CLO) be used to convey the ideas outlines in Chapter 5 as explanations with relevant examples will probably be needed due to the complexity of the issue.

3. **To make an informed technology selection that has the strong backing of the participating community members, and to formulate a community water point maintenance plan**

When community discussions have covered all points necessary and consensus has been reached on all outstanding questions, the community can go forward with implementing its decisions. A "Work Plan" for construction is an obvious need. However communities should also prepare a "Water Point Maintenance Plan" to document all of the decisions that have been made to date, and to note outstanding questions that will need to be addressed in the future when more and different types of information become available. These guidelines can also be used as a checklist as decisions are finalized and work plans prepared.

2

WATER TECHNOLOGIES

Water technologies may be conveniently divided into two categories–water provision methods and water lifting or conveyance systems. This division is necessary to distinguish between the process of tapping into or reaching water sources and lifting or conveying the water to a distribution point where it can be collected and used.

Water provision methods include

- **spring**
- **dug well**
- **drilled well**
- **dam**
- **catchment**

Water lifting or conveyance methods include

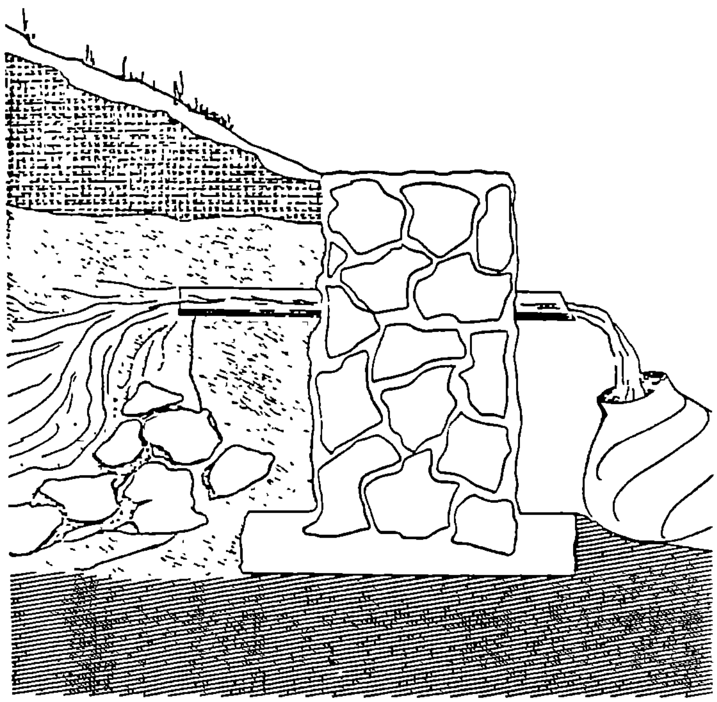
- **gravity fed pipeline**
- **handpump**
- **diesel engine**
- **solar pump**
- **windmill**

2.1 Spring

Spring development consists of capturing an underground flow in a protective structure as it emerges at the surface. The process requires the construction of a cutoff wall to channel the flow into a collection gallery and then allowing the water to flow into a pipe for collection. The structure is usually built of concrete or masonry. Water may be collected at the spring or, if the topography is favorable, water may be piped long distances via gravity.

The advantages of spring capping are

- process is well understood and commonly practiced
- good reliability of water flow
- water quality is generally good
- cost of construction is usually low
- maintenance costs are very low



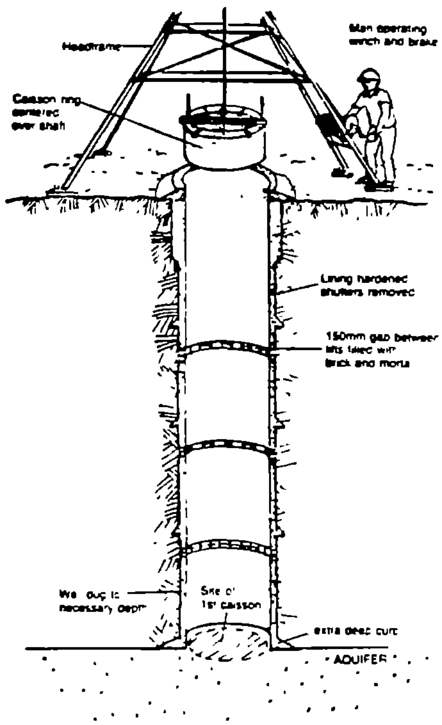
(A Workshop Design for Spring Capping, WASH Technical Report No. 20)

The disadvantages are

- location of the spring may not be convenient or easily accessible
- opportunities for spring capping are limited to few regions
- flow of the spring cannot be increased

2.2 Dug Well

Modern dug wells are usually dug by hand to a depth up to 30 meters, although deeper wells exist. The average depth is about 12 meters. Modern wells are lined with concrete or masonry, usually with an inside diameter of 90 centimeters. Dug wells usually penetrate only about one meter into the dry season water table. These wells may be capped and equipped with a pump or left open to have water drawn with a rope and bucket.



Hand dug concrete lined well (USAID, 1982)

The advantages are

- **simple to use and maintain**
- **availability and quantity of water easily determined**
- **flexibility to use a pump or, in case of pump breakdown, to use alternative means of lifting water**

The disadvantages are

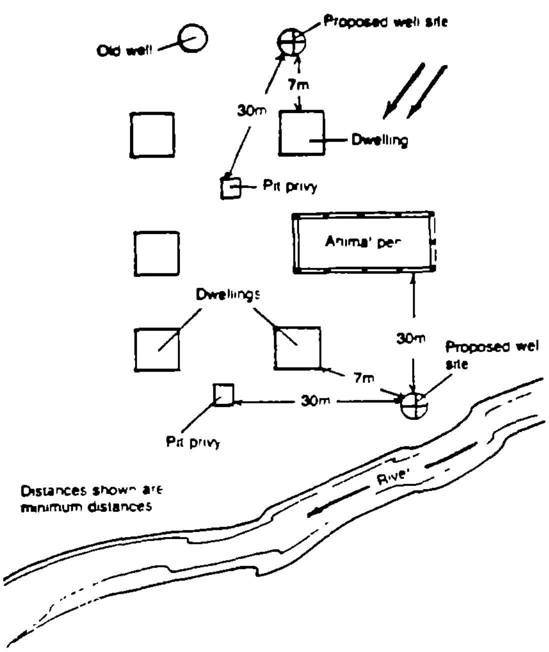
- **subject to pollution when left open**
- **subject to seasonal variation and droughts**

2.3 Drilled Well

Drilled wells may be constructed through a variety of methods, but the most common rely on drilling rigs which use either rotary or percussion tools. For rural villages, wells average about 40 meters and seldom exceed 100 meters. Drilled wells are usually equipped with casing and screen made of steel or plastic with diameters of either six or eight inches. A pump is required.

The advantages are

- **not generally affected by drought**
- **usually good quality water**
- **often may be constructed in locations convenient to consumers**

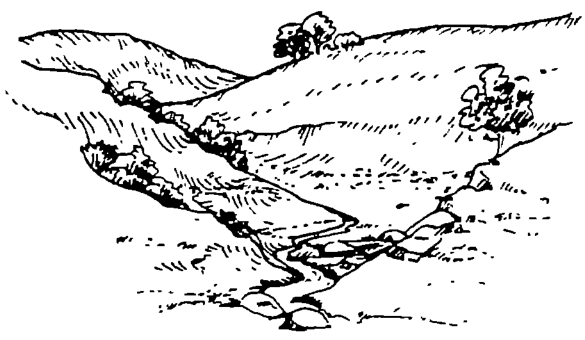


Location map for proposed well site (USAID 1982)

The disadvantages are

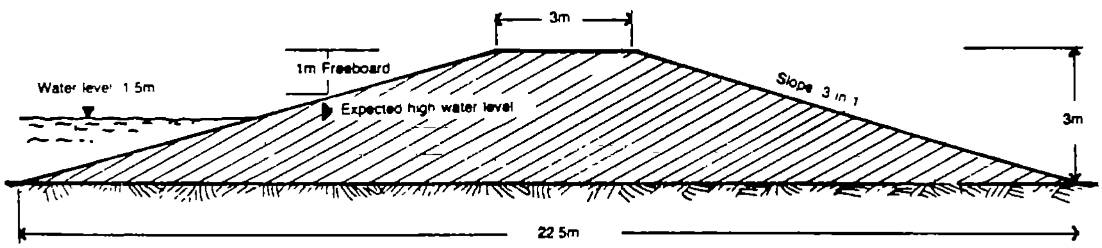
- **requires high technology approach with little opportunity for community participation in construction**
- **pump breakdowns affect reliability**

2.4 Dam



Appropriate dam site

Small dams may be constructed to effectively impound water for stock watering, irrigation, and human consumption. Each site must be evaluated separately to determine the proper location, size, and material of construction. For rural communities, dams are typically constructed as earth fills (with heights ranging from less than 1 meter to as much as six meters) across small gullies to impound water from annual runoff. Dams are designed to store water sufficient for only about a year's needs as larger dams require the use of elaborate design and construction principles and offer higher risks.



Cross-section of clay dam embankment (USAID, 1982)

The advantages are

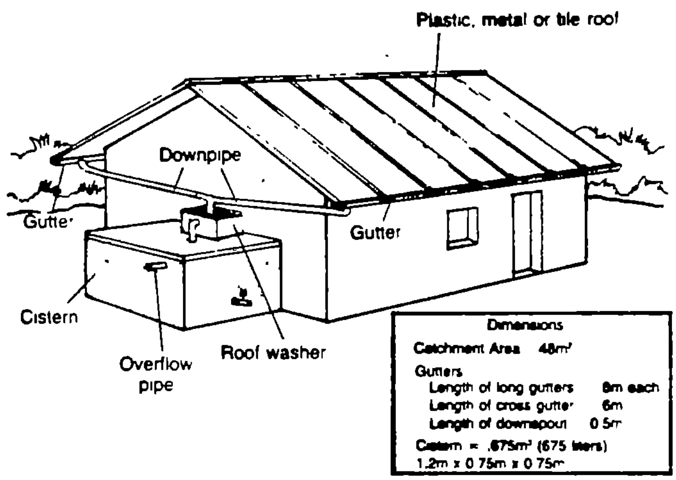
- **for irrigation–dams allow potentially large volumes of water to be stored and delivered to fields by gravity**
- **for stock watering–large numbers of animals have access to water without need for pumping or human attendants**

The disadvantages are

- **water quality from surface runoff is poor and not recommended for human consumption without treatment**
- **surface runoff fluctuates greatly from year to year, particularly from small watersheds, and causes uncertainties in planning**

2.5 Catchments

Catchments are similar to dams as both rely on annual surface runoff to replenish water supplies. Catchments, however, use an impermeable surface to channel water into a storage container. A large catchment would typically rely on runoff from a rock outcrop which would be collected in an underground concrete or rock and mortar lined gallery. A small version of the catchment approach relies on runoff from roofs to store water in cisterns. Catchments are feasible where rainfall is abundant and well distributed throughout the year. In lower rainfall areas catchments may be considered an alternative only if groundwater is not available.



Roof Catchment system (USAID 1982)

The advantages are

- **storage containers allow water to be protected from pollution better than an open reservoir behind a dam**
- **losses from evaporation and infiltration are less than those of an open lake**
- **the only alternative in areas where groundwater is not available**

The disadvantages are

- **water quality is poor and not recommended for human consumption unless treated**
- **water volume is limited and uncertain due to rainfall variability**

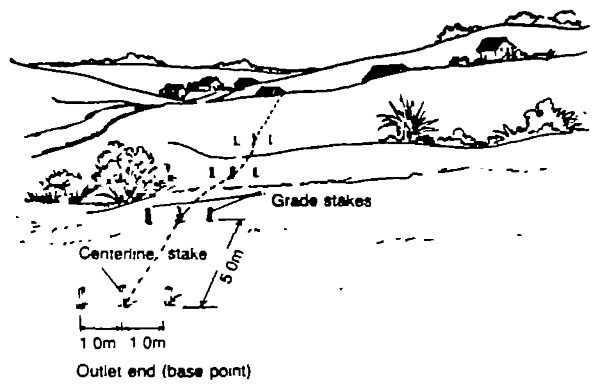
2.6 Gravity Fed Pipeline

Pipelines are commonly used to transport water from storage tanks or spring gallery boxes at higher elevations to points of convenient access. If elevation differences are large, as in the case of springs located in hills above a village, then pipelines can be many kilometers in length. Water can, of course, be pumped to a storage tank mounted on a tower or hill and then distributed by gravity.

The construction of storage tanks using concrete or brick and mortar and the laying of pipeline is a labor-intensive process requiring community participation. Pipe may be either steel or plastic and is usually buried in trenches. Long pipelines and large storage tanks require professional expertise in the design.

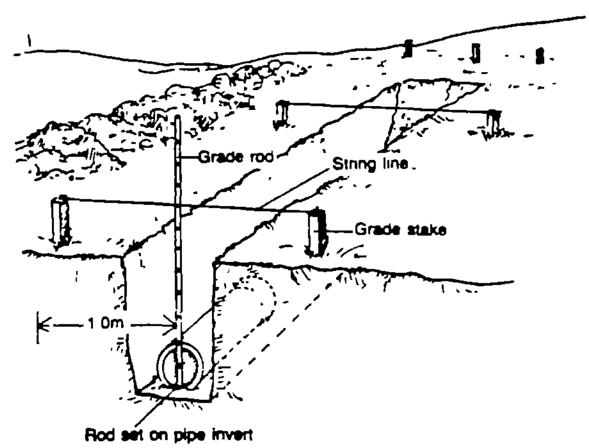
The advantages are

- **potentially large volume of water may be transported**
- **for volume of water transported, the construction cost is moderate, assuming free community labor**
- **maintenance and operation costs are low**
- **simple and reliable technology**



The disadvantages are

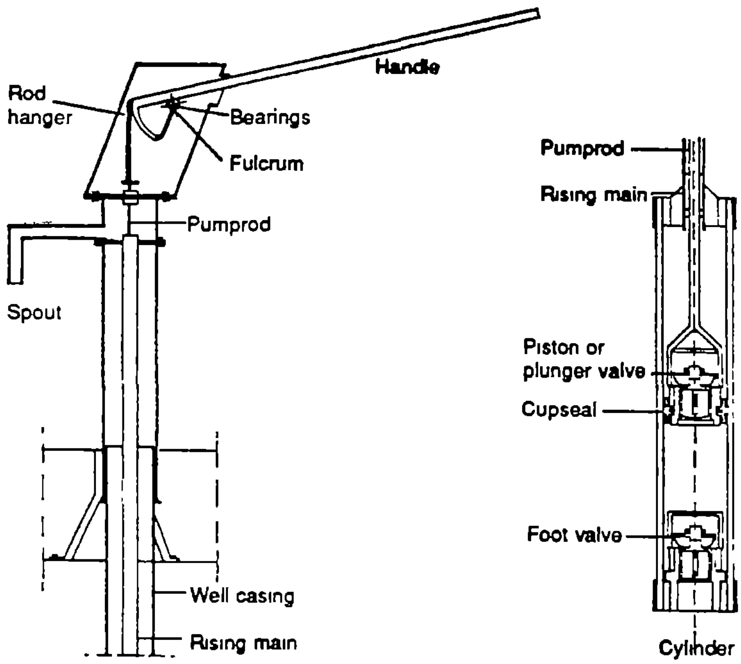
- **opportunities for complete gravity fed systems are few and limited to mountainous areas**



Gravity fed piped water system (USAID 1982)

2.7 Handpump

Handpumps may be installed on either large diameter hand dug wells or small diameter drilled wells. There are a large variety of handpumps on the market, but in an individual country only a few may be commonly available. Some pump models are manufactured especially for village level maintenance and repair while others are designed for robust use or deep pump settings. The practical limit of most handpumps is about 30 meters, although some models can be used up to 100 meters. The volume of water that can be pumped varies with the model, depth, and strength of user.



Handpump (terminology may vary depending on type of pump) (IRC 1988)

The advantages are

- easy to operate
- low cost to purchase and to maintain
- often maintainable at village level

The disadvantages are

- maintenance and procurement of spare parts may be a problem
- reserve funds are needed for repairs
- limited volume of water can be pumped

2.8 Diesel Engine

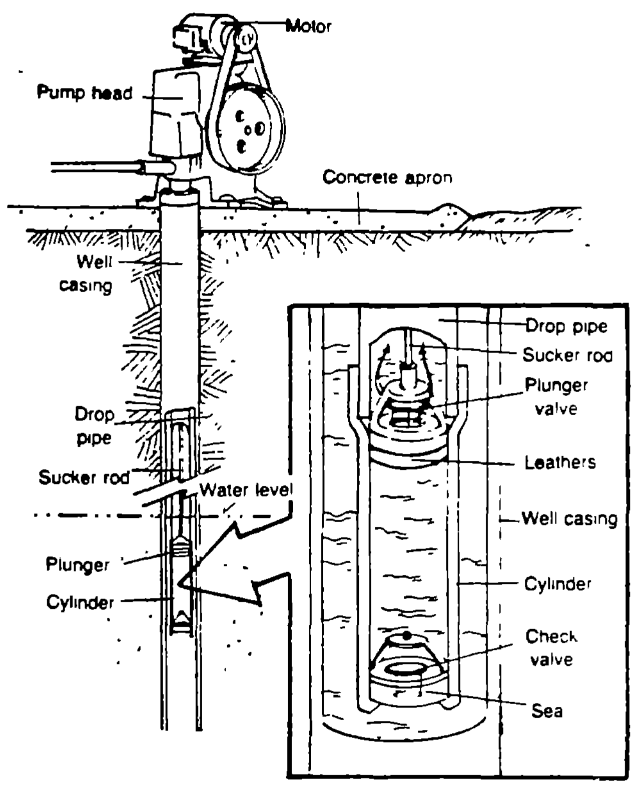
Pumps driven by diesel or gasoline engines are utilized when larger volumes of water are needed and/or significant depths or lifts are involved. Engines may be connected directly to pumps or generators may be used to power electrical pumps. Engines and pumps are available in sizes according to the volume of water to be moved.

The advantages are

- **large quantities of water may be pumped**

The disadvantages are

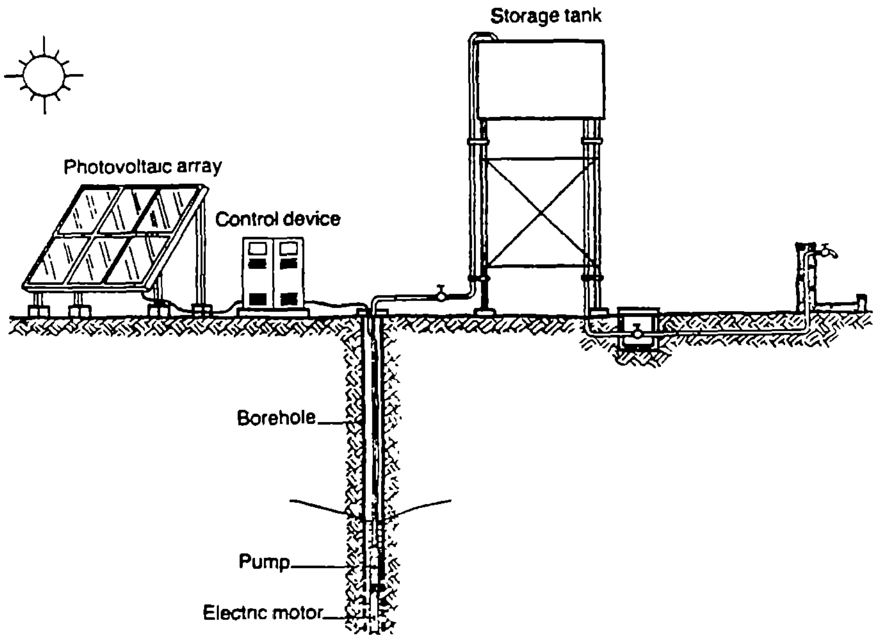
- **engines and pumps are relatively expensive to purchase**
- **repairs of engines usually require specialized technicians**
- **a maintenance and operation fund must be maintained**
- **fuel must be continually procured**
- **procurement of spare parts is often a problem**
- **a pump operator is required**



Motor driven pump (Positive displacement submerged piston) (USAID, 1982)

2.9 Solar Pumps

Solar pumping systems typically consist of a photovoltaic array, power conditioning equipment, electric motor, and pump. Generally, solar conditions in Africa are most favorable for solar pumping systems, however there are some exceptions. Professional expertise is needed for design and installation of equipment.



Solar photovoltaic water pumping system (Hofkes, 1986)

The advantages are

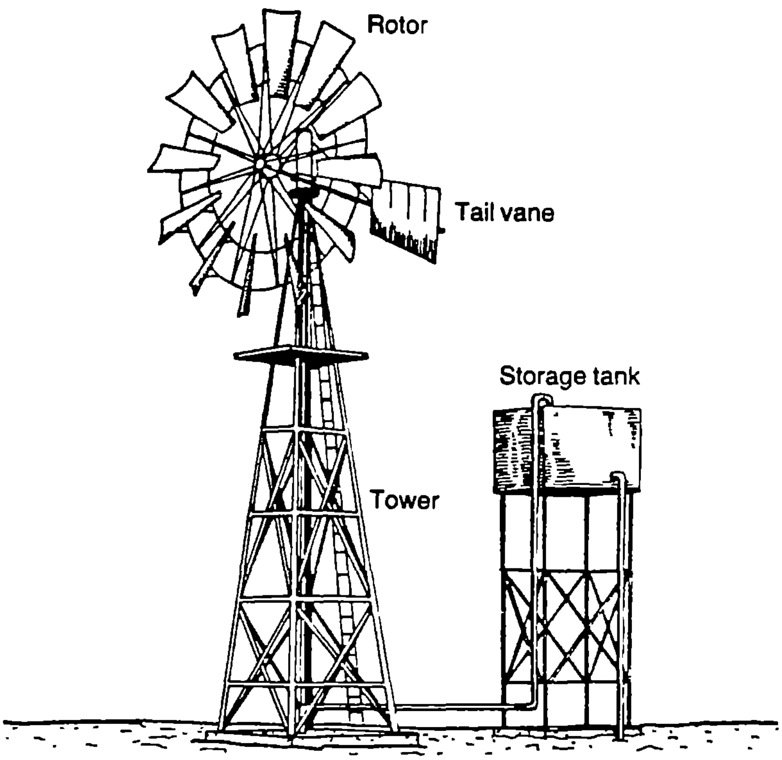
- low costs for operation (no fuel needed), maintenance, and repairs
- unattended operation
- high reliability for power supply (solar array) although energy (sun) can vary over the short term

The disadvantages are

- relatively high capital costs
- water only available during daytime unless storage tank is provided
- very limited availability of equipment and spare parts

2.10 Windmill

Wind pumps normally consist of a windmill and transmission mounted on a tower with rods connected to a piston pump. Wind pumps require careful consideration of sites to assure that wind conditions are favorable. There are a great variety of windmill models and combinations to chose from to meet specific needs. Windmills can potentially be used to pump from great depths and produce significant volumes.



Windmill pumping system (Hofkes, 1986)

The advantages are

- **low operational costs, moderate maintenance and repair costs**
- **unattended operation**

The disadvantages are

- **high capital costs**
- **limited opportunities of finding favorable wind conditions**
- **storage tanks are needed to assure steady supply**
- **element of uncertainty as wind energy may be highly variable**

2.11 Summary: Comparative Criteria

Each of the water provision methods and water lifting technologies can be compared, on a relative basis, by an analysis of specific criteria. The criteria are

- **water quantity**
- **water quality**
- **reliability**
- **construction techniques**
- **construction costs**
- **maintenance techniques**
- **maintenance costs**
- **operations management**

The comparative analysis of the **water quantity** criterion has two aspects. For water provision methods, it refers to the system capacity to minimize influence of rainfall variability. For example, a drilled well is more likely to penetrate deep into the aquifer than a hand dug well and therefore is less likely to be affected by drought. For water lifting systems, quantity refers to the capacity of the pump to deliver water. A diesel pump is more suitable for delivering large volumes than a handpump.

Water quality refers to the typical conditions of the water source proposed for development. Surface water sources will always be more likely to be polluted than groundwater. Pumping technologies have no effect on water quality.

Reliability is the frequency of breakdown or damages which require repairs to become operational. High reliability means that breakdowns are typically infrequent for that technology.

Construction techniques refers to the degree of complexity in constructing the system which is likely to require expertise from outside the community.

Construction cost is the relative cost of purchasing, constructing, and installing a typical system.

Maintenance techniques refers to the expertise and spare parts required outside of the community to maintain the system.

Maintenance cost is the relative cost of operating and maintaining a system.

Operations management refers to the management and organization, including financial management, required within the community to operate a water system.

Table 1, "Comparison of Water Provision, Water Lifting and Conveyance Systems," provides a summary of the relative advantages of each of the technologies according to the criteria discussed above. Each technology was given a score within a range of "high", "medium", or "low" as a relative indication of favorability. High means that the technology is a good or favorable choice, while low means that the technology has low value according to the criteria in question.

TABLE I
COMPARISON* OF WATER PROVISION,
WATER LIFTING AND CONVEYANCE SYSTEMS

Comparative Criteria

	Water Quantity	Water Quality	Reliability	Construction Techniques	Construction Cost	Maintenance Techniques	Maintenance Cost	Operations Management
Water Provision Methods								
Spring	V	H	H	H	H	H	H	H
Dug Well	L	M	H	M	M	H	H	H
Drilled Well	H	H	M	L	M	L	M	M
Small Dam	V	L	L	V	V	H	M	H
Catchment w/Storage	V	M	M	M	M	H	H	M
Water Lifting/ Conveyance Systems								
Gravity fed Pipeline	V	-	H	H	V	H	H	H
Handpump	L	-	L	M	H	M	M	M
Diesel Engine	H	-	L	M	M	L	L	L
Solar Pump	L	-	M	L	L	L	M	M
Windmill	V	-	L	L	L	M	M	M

*Technologies are rated among the selected criteria according to their comparative advantages as choices for rural village water supply system

H = Highly favorable choice
M = Moderate
L = Low or poor choice
V = Variable

To exemplify the use of the table, suppose a community indicates a need for a large volume of water to be supplied. It can be seen from the table that under water quantity the technologies of drilled well with diesel pump are rated high. Technologies which are rated variable (spring, catchment, pipeline, and windmill) may provide large volumes of water if individual site conditions and system design are suitable.

If the community wants high reliability without worrying about breakdowns, then the less sophisticated technologies including springs, dug wells without pumps, and pipelines are rated highly favorable. If the community wishes to keep construction costs low, then the best choices are springs and handpumps. Dams and pipelines have variable costs depending on their size.

In some cases the technology may be applicable to a range of conditions, depending on the size of the technology, and is therefore rated variable. It is assumed that each technology is a typical application applied to an average African rural community. Obviously exceptions will sometimes occur.

3

KEY QUESTIONS RELATED TO TECHNOLOGIES

3.1 Water Demand

An initial step in choosing appropriate technologies for rural water users is to determine water demand. A census of the number of people and animals that will be using the water system is needed. The table below provides typical design figures.

DEMAND IN LITERS PER DAY	
People	20-40
Cattle	20-40
Goats or sheep	5-15
Poultry	.2
Hogs	10-15
Camels	20-30

Consideration should also be given to population growth. The population of African countries is growing at an average rate of 3.1 percent per year. This means that a population of 1,000 will be more than 1,350 in ten years. It should be noted that the provision of water to a village often attracts new settlers and an additional estimate should be made for this factor.

3.2 Spring

1. What is the yield of the spring?

Springs vary considerably in yield. Many springs have large annual variation with diminished flows during the dry season. Yields should be determined during the dry season to obtain the lowest flow. Normally the yield is expressed in liters per minute.

2. What is the quality of the spring water?

Groundwater is usually of good quality from both a bacteriological and mineral perspective. Exceptions occur for two reasons. First, bacteriological pollution may occur when the area around the source has concentrations of people or animals. Normally, if the source is surrounded by at least 15 meters of fine grained soil, then contaminants are filtered out, although local geological conditions may cause exceptions. Second, mineral concentrations of certain harmful elements may be present because of the local geology. Information from other wells and springs in the vicinity will be helpful to judge water quality at the proposed site. If there is any evidence of contamination, it is advisable to request an analysis by government technicians.

3. What is the access to the spring?

Springs occur in areas with significant differences in relief. The occurrence of springs is fairly limited on a worldwide basis; although in favored mountainous regions they may be numerous. It is often most desirable to develop a spring since it offers the advantage of not requiring a pump. However this must be balanced with considerations of access to the spring. Excessive distances, more that about one-half kilometer, to a spring may suggest consideration of other technologies. In mountainous terrain not only distance but also time required to fetch water under difficult walking conditions must be considered to determine access. If the spring is at a higher elevation than the village, a piped distribution system should be considered.

4. Are experienced artisans available to cap the spring?

Although spring capping is basically a simple process, there are frequently subtle differences between springs. Improper approaches can lead to blocking the spring or reducing its flow. Reliance on experienced artisans is advisable.

5. How much will it cost?

Spring capping is usually a low cost technology although springs with high yields may require extensive concrete works. Many springs are developed for the cost of cement alone if labor is unpaid, and costs may be as little as a few hundred dollars.

6. What are the recurrent costs?

Recurrent costs are minor. Most springs require only annual cleaning and some patchwork to the concrete to repair cracks and erosion damage.

3.3 Dug Well

1. How deep is the well expected to be?

The average depth of wells is about 12 meters. Depths beyond 30 meters are most ambitious although some successful wells have been dug even as much as 100 meters. Information on the depths of other wells in the vicinity should provide an indication of expected depths.

2. What is the expected yield of the well?

Information from other wells in the area will answer this question. Shallow wells are usually subject to large seasonal variations and the dry season yields are the most significant. The yield of dug wells is dependent not only on rate of water recharge into the well but also the depth below the water table that the well is dug. Normally a dug well can be constructed only about one meter below the water table. If a high yielding pump is used during the digging then deeper depths may be reached which will improve yields and provide a water reserve.

3. What is the expected water quality?

See answer 2 under springs.

4. What construction techniques are proposed?

There are several methods of constructing modern hand dug wells. The most typical method of construction uses workers to dig the well with hand tools and a tripod with pulley to raise and lower materials, equipment, and workers into the shaft. Metal forms are used to position the well lining which is made of concrete and steel reinforcing bar. In rocky terrain dynamite or air hammers are sometimes used. Rock and mortar are acceptable for shallow wells. In most cases it is desirable to contract with experienced well diggers to supervise the construction and furnish the needed equipment.

5. How much will it cost?

Since most of the cost is connected with the concrete and reinforcing bar, cost is proportional to depth. The cost of transporting the materials to the site may also be significant. In Burkina Faso, the average cost of a well 25 meters deep is about $4,100 or $163 per meter.[1]

6. Will the well be capped and equipped with a handpump?

If the well is not capped then ropes and buckets will be used to obtain water. Water quality will always be suspect but maintenance problems will be minor.

If the well is capped and equipped with a handpump maintenance of the pump becomes an issue.

3.4 Drilled Well

1. How is the drilling site to be chosen?

There are two considerations. First, an understanding of the local geology is needed in order to maximize the chances of drilling a productive well. If the geology is generally uniform, without lateral variations and other wells have been successfully drilled nearby, the site should be selected as close to the village as possible. If, however, the terrain is broken and the geology complex, groundwater conditions can change radically within a short distance and experienced technicians are recommended.

In many cases several possible sites, from a geological perspective, may be available. The second consideration is then to site the well where a maximum number of people will have convenient access. This should be a community decision with wide participation.

2. How deep is the well expected to be?

As depth increases so do potential problems including the need for more sophisticated pumps, more energy required for pumps, and greater cost of construction and maintenance. A depth of about 30 meters is average, over 60 meters raises questions about pumping issues, and over 100 meters should only be considered in special cases. Data from nearby wells if available should be used; otherwise an experienced technician should be consulted.

[1] Costs provided are based in US $ equivalents at 1988 prices.

3. What is the expected yield?

The major advantage of a drilled well is that it is sunk deep into an aquifer and therefore is less prone to drought effects. The hydrogeological character of the aquifer, of course, determines the potential yield. Again local data from nearby wells may be adequate to indicate the probable yield otherwise technicians should be consulted from either local drilling forms or government agencies.

4. Who is doing the drilling and what guarantees are involved?

There may be several choices of drillers in a specific country. Often the government provides this service as well as several private entrepreneurs. Costs of drilling may vary considerably and so it may pay to ask for bids. If a driller is experienced in an area he may guarantee that a productive well will be provided. Similarly his experience may indicate that the risks are too great to provide a guarantee and he will quote a price on the basis of drilling a hole to a specified depth. The question of whether to try a new site if the first site fails to yield water should be considered in advance and again after the results of the first attempt are completed. It is advisable to have a written statement of any guarantees and a plan of work.

5. How is the well to be constructed?

The following are important factors in constructing a drilled well:

- depth
- diameter of borehole
- diameter of casing
- method of completing the well
- method of determining yield
- type of casing
- design of apron
- type of pump

A written design and description of each of the above factors should be attached to the price quote from the drilling firm.

6. How much will it cost?

The average cost in Togo of a well drilled to a depth of 45 meters, equipped with 6 inch casing, and a concrete apron is about $8,700, not including a pump. This is about $193/meter.

7. What is the maintenance plan?

Since a drilled well is necessarily equipped with a pump, a plan to operate and maintain the pump needs to be formulated. The plan should consider the cost of maintenance, how the money will be raised, who will do the repairs, and where the spare parts will be found.

8. What are the maintenance costs?

There are generally no maintenance costs associated with the well, only the pump. The well casing can be expected to last 20 years and longer. Occasionally, encrustation will build up on the well screen which reduces yield, and this will require cleaning by a driller.

3.5 Dam

1. How much water will the dam provide?

The storage volume of the reservoir behind the dam is primarily a function of topography but also the height and width of the dam. In broad flat areas a dam of modest height may provide a shallow lake but one of large extent and volume. A stage-volume graph which shows the volume of water stored for each water level is desirable. In the absence of such a graph, which would require a survey by an experienced technician, some estimate of the volume based on the average depth and area dimensions is needed.

2. What assurances are there that annual runoff will be sufficient to fill the dam?

For small watersheds this is often a difficult task. If the site is fed by a small stream with relatively steady flow, the flow can be estimated. If the site is fed by relatively short lived flows which occur only after rains, the estimate is more difficult and an experienced technician is needed. If there is any indication that a dam will store significant amounts of water (more than 10,000 cubic meters), an engineer should be consulted to provide an appropriate design and assure that there is no danger from flooding.

3. Does the community have experience in dam building?

Each site will vary enormously as to its suitability. If the community has had previous experience in building dams of similar size, then a dam may be appropriate. If not, an engineer should be consulted to design and supervise the construction of the dam, especially if the dam is to exceed three meters in height.

4. Is the dam to be used for several purposes including water supply?

Dams are best used for irrigation and stock watering. Because of pollution, surface water should be considered for human consumption only if other sources are not available. If surface water must be used, there should be a plan for treating the water to avoid waterborne diseases.

3.6 Catchment with Storage

1. How much water will be stored?

Water availability is dependent on the size of the storage container, the frequency and magnitude of rainfall, and the area of the catchment. Ideally, the rainy season should be spread out over the year with dry seasons of short duration. Rainfall records showing frequency and distribution over the year are needed. The zone between latitudes 10 degrees north and south of the equator is generally suitable. If the dry season is relatively long, the volume of the storage container must be increased proportionately.

2. What are the costs involved?

Costs made be divided into two components, the catchment surface and the storage container. When a natural catchment is available such as a rock outcrop or an existing rooftop, a significant part of the cost is reduced. Most of the cost is usually in the cistern or gallery where the water is stored. A variety of storage containers, both in material and volume, are possible, so costs will vary considerably.

3.7 Gravity Fed Pipeline

1. What is the reliability of water?

Since the construction of the delivery system can be a major investment, it is important to have confidence in the water source. Some measure of the yield and annual variation is needed whether this be a spring, lake, or well.

2. What is the design of the system?

A complete design and layout of the reservoir and pipeline system should be completed. Unless the community has had experience in a similar system, an engineer should be consulted.

3. What is the construction plan?

The construction of pipelines is particularly conducive to community efforts. Organization and supervision require planning to assure that materials, equipment, and people are mobilized at the proper time. A detailed plan which depicts the timing and responsibility for each phase of work is essential.

4. What are the costs of construction?

Pipelines vary enormously according to their design capacity, storage capacity, and length.

5. What is the maintenance plan?

Gravity fed systems are inexpensive to maintain but basic skill is needed in plumbing to undertake maintenance. Regular preventive maintenance will reduce the problem of major breakdowns. It is desirable to have at least one person in the community who is trained in plumbing and responsible for the pipeline system.

3.8 Handpump

1. How many people are to be served?

In general handpumps have an upper limit of about 10 cubic meters per day at average depths but only about half that volume at depths of 50 meters. Handpumps can usually serve about 250 people. When communities are larger than about 300 people then a second well should be considered. Small gardens and village animals can be served by the well but these activities are generally modest.

2. What brand of pump is to be purchased?

There are many manufactures and types of handpumps. For communities which will be responsible for their own pump maintenance it is important to purchase a pump which is designed for village level maintenance. Two pumps are particularly recommended, the Afridev and the India Mark II. Other pumps may also be appropriate in local situations. Some African countries manufacture their own pumps.

3. How are spare parts to be obtained?

The most critical aspect of maintaining pumps is the procurement of spare parts. This is a recurring problem of grand proportions in rural Africa. The availability at a convenient location of spare parts for the particular pump chosen must be assured. If the pump is purchased from a local dealer then the dealer will usually stock spare parts but this should be verified.

4. Who is responsible for maintaining the pump?

At least one person in the community should be trained in maintaining the pump and should have the necessary tools at his disposal.

5. What are the purchase costs?

Costs, of course, vary with the make and model. In Kenya, an India Mark II costs about $800, including pipe for a 25 meter well.

6. What are the maintenance costs?

In Benin, the annual costs of maintenance for an India Mark II are $300, which includes paying local mechanics, transportation of mechanic to the site, and spare parts.

7. How are funds for maintenance to be collected and held?

In order to assure the repair of the pump a fund is needed which is set aside for this purpose. The community should provide a plan to collect and account for such funds.

3.9 Diesel Engine

1. What are the volume and lift requirements for the pump?

If more than 10 cubic meters per day are needed or if the lift is more than 50 meters, a diesel engine may be needed. Villages with populations of more than 300 people or projects which propose irrigation often rely on diesel pumps.

2. What size pump is needed?

Each pump model has a unique pump curve (i.e., this describes the pump's operating range in terms of lift, flow rate, and efficiency) and must be evaluated to serve the purposes required. Experience is needed to make this determination. A reputable dealer is appropriate to make the decision.

3. What model should be chosen?

Many suitable models may be available. The most important characteristics are the availability of spare parts and qualified mechanics. Since recurring costs of diesel pumps are high it is important that the right size pump be chosen to assure efficient operation.

4. What are the purchase costs?

Costs will depend on the size of pump which is proportional to the scale of pumping required. It would be helpful to obtain bids from available dealers.

5. What are the recurring costs?

Fuel costs are significant as are repair costs. The community should have an estimate of the fuel needed for their particular pump. The costs for mechanics and spare parts should also be estimated.

6. What is the management plan?

Since both fuel and a pump operator are needed on a daily basis, a revolving fund is needed. The community should describe a detailed management plan.

3.10 Solar Pump

1. Who has designed the pumping system?

Solar pumping systems are useful within rather rigid limits. The range of technical information required in designing the system requires an engineer of appropriate qualifications.

2. What are the costs involved?

In Botswana a system designed to pump 30 cubic meters per day from 20 meters depth costs about $9,000 for the modules and $2,000 for a pump and motor. This does not include installation (mounting and wiring) or a concrete pad or storage tank.

3. What are the recurring costs?

Although the major advantage of a solar system is low recurring cost, this cost is not negligible and must be considered.

3.11 Windmill

1. What information is available on wind at the proposed site?

Wind is, of course, critical in determining the usefulness of a windmill. Wind conditions can be most variable within a short distance and each site needs to be individually evaluated. Unless wind speeds of at least 3.5 meters per second are available over sustained periods, windmills are not usually appropriate. It would be helpful to know if other windmills are operating in the area.

2. Who is designing the system?

As with solar systems the technical considerations of windmills are sufficiently complex to require an experienced technician.

3. What are the costs?

In Kenya a windmill of 24 foot diameter on a 40 foot tower costs about $11,000 while a 12 foot diameter model is about $5,000. This does not include installation, concrete pad, or storage tank.

4

KEY QUESTIONS RELATED TO MANAGEMENT AND HEALTH

Equally important to the questions of technology are questions relating to management and health. Successful water projects should assure a complete consideration of all three components to achieve the needed balance for sustained benefits.

4.1 Management

Communities need to review the management and health resources that already exist in the community that will be used to achieve and maintain the objectives for the new water supply. Where existing resources are not sufficient, the community should consider and define the need for training and technical assistance. Possible training and TA resources available to the community can then be identified. The following questions can assist in the community resource review.

1. Is there a community group with responsibility for monitoring use of existing sources?

People in the community are already managing many resources under their control. One of these resources is, no doubt, an already existing water source. The community may choose an existing organization to continue to manage the new proposed source. Such people are usually the best ones to continue their management functions.

2. Are craftsmen and local bicycle repairmen available to maintain the improved system? Are such skilled people generally rewarded for their services?

Community people who will best be able to work as operators of the systems could be skilled in community crafts. Identifying who these individuals are and how they can be included in the management of the system is very important.

3. If they have long-term daily responsibility for performing functions in the improved systems, how will they be compensated?

Some communities may expect the work to be done on a volunteer basis but if the chosen technology requires a lot of work, then compensation should be considered.

4. Does the community have access to a private repairman able to complement community skills. Is the community able to contact him when needed? Who will be responsible for doing so?

For certain technologies such as a diesel pump, a mechanic will be needed from time to time. A plan is needed on how to procure his services.

5. Have agreements been worked out with the person/tribe/family on whose land the improved system will be?

The community should assure that there are no disputes surrounding a particular site. Sometimes hydrogeologic considerations dictate sites that may be restricted for some other use. Communities have traditional rules about ownership of water sources, which should be discussed or explained if pertinent.

6. How much are people contributing for various development/social activities in the community? What will be done with the maintenance money that is accruing? Should it be lent out at interest, or should it be reinvested in community assets? Such options need to be clearly formulated.

7. How much will community members be willing to contribute to meet operations and maintenance costs?

If there is limit of available resources, this may affect the choice of technology.

8. Are there community organizations already in place with responsibility for finance?

Information on the maintenance of public facilities such as mosques or churches would be helpful.

4.2 Health

1. Is improved health considered a priority of the community?

(IRC, undated)

In some communities, health improvements may be presented as a priority. If this is the case, then community members may need information on how to bring about health improvements through their improved use of water.

To achieve health, there are several very basic ideas that need to be understood: a) good quality water in sufficient quantity should be used all year round; b) poor quality water should be avoided (although some uses such as washing may rely on less than potable water); c) the source must be conveniently placed. However, given these minimal requirements, one cannot expect positive health outcomes to happen right away. Hygiene education. intended to change behavior, and sanitation are also needed to maximize health benefits.

2. Are there standards of water quality established?

The World Health Organization (WHO) has established a recommended water quality standard. Such a standard is not always appropriate for developing countries. A suggested rule of thumb regarding water quality will be that the improvement of the existing water source or development of a new source will reduce present contamination levels. If, however, water testing is possible, the figures may be compared with acceptable standards. For example, the National Water Resource Master Plan of Malawi suggests that for bacteriological testing up to 50 FC/100 ml is an acceptable level for developing countries although the WHO states 0 FC/100 ml as the norm.

3. If no formal standards exist, what is used to determine acceptability of water?

When people assess the quality of drinking water, it is the appearance, smell or taste that determine the quality and acceptability. However, these sensory qualities do not mean that water is safe for drinking. Contamination by sewage or by human or animal excreta is the greatest danger associated with water. If a water source is contaminated by excreta, it may cause infections. These infections can also occur through food contamination from dirty hands and/or flies.

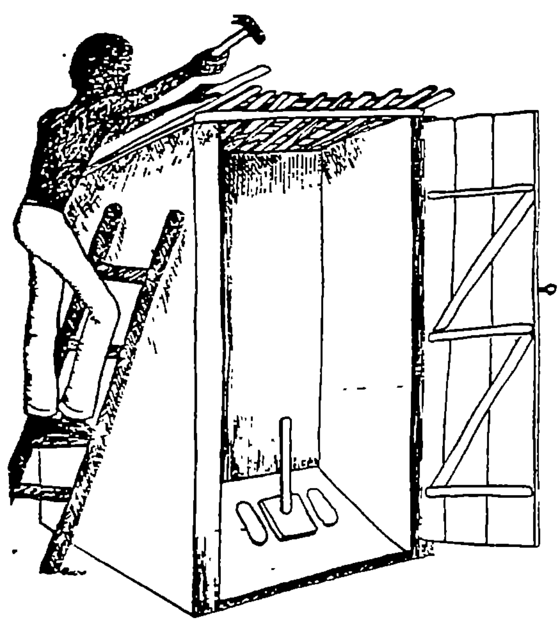
People, however, are usually less concerned with the quality of water. In general, people are more concerned with whether there is sufficient water available all year round or whether the source is nearby and convenient to walk to.

In many communities where improved sources have been installed, it is placed in a hydrogeologically appropriate part of the village. However, the distance is further than the old sources, and, because of this, people have not used it. In other cases, one may find that when people do not understand the importance of safe water to their health, they will keep using the polluted sources that are close to their homes.

4. Is hygiene education needed to enhance water benefits?

This is a most important aspect of water projects aiming at improving health. It deals with the behavioral change of water use and sanitation practices. It concerns a range of actions to improve the surroundings in which people live.

Hand washing and excreta disposal are basic actions in a hygiene education program. Field experience shows that such programs cannot be imposed. They can be introduced as solutions to problems that community people identify. For example, if a community identifies dysentery or diarrhea as one of its priorities, then latrines and hand washing can be introduced. If skin diseases are identified, then increased quantity of water used for bathing can be introduced.



(IRC, undated)

5. Are there other outcomes, other than health, that are sought?

Evaluation of success or failure of water projects should not necessarily be judged on health outcomes. Health outcomes can be influenced by many factors, such as economic conditions, nutritional intake, or educational level. For this reason, it is more realistic and convenient to measure the actual behavior that has changed. If the improved behaviors are sustained over time, one can eventually expect to see actual changes in mortality and morbidity statistics.

6. What should be the content of hygiene education programs?

Hygiene education in water supply may include the following:

- Use of latrines for excreta disposal
- Hand washing after defecation and before food preparation
- Frequent bathing
- Proper handling of children's fecal matter
- Cleaning dishes
- Keeping animals out of living quarters

The community will need to set up training sessions in these subjects. It may be necessary to request assistance from government or PVO health groups.

4.3 Gender Issues

Women are the primary carriers, users, and local managers of water in most rural and urban areas around the world. They are usually responsible for the fetching, deciding upon the different uses of the water and arranging for ongoing maintenance of traditional water sources. For this reason, they are a very important segment of any community requesting an improved water source. Their role in planning, designing and managing needs to be stressed as they have great interest vested in the sustainability of improved sources. Access to water and the amount of time required to haul water are very significant to the daily lives of women.

As mothers, they are also the ones who teach sanitation and hygiene practices in the family. Therefore, whether the approach of the project is one that focuses on health or one that focuses on the sustainability of the water technology, women's active participation and direct involvement must be stressed and ensured by community leaders.

(IRC, undated)

1. Are women involved in preparing the project?

The purpose of ensuring women a voice in preparing a water project design is to ensure project success, measured in terms of steady community functioning, utilization of the water point, maintenance of the water point, and eventual achievement of the health and economic benefits expect by the community. Since women stand to gain the most from water projects, they therefore ought to be involved as much as possible in the decision process.

2. Are women involved in operating the water system?

In many water projects, systems break down because of poor operations and maintenance. While there are many reasons for this, operations and maintenance can be improved through the following remedial actions which will involve women:

- Choosing water systems that can be repaired easily at the local level by women as well as men without depending on external government agencies.
- Ensuring that facilities are managed by community groups or committees that include women.
- Consideration can be given to employing women on a paid basis as caretakers of water points as they are more likely to welcome part-time employment and less likely to migrate out of the community.
- Conversely, women should not be solely responsible for all the labor intensive chores of collecting fees, cleaning the water points, and other time consuming tasks. This should be a shared responsibility.

3. Is there any provision for training women?

Training courses at the community level may need to include women. Such courses should be held in places and at times that women can attend. Such training courses can include the following skills:

- Explanation (using visual materials) on how facilities are constructed.
- How to detect a problem.
- How to repair equipment.
- Where to buy spare parts.
- When to seek outside help.
- How to protect water sources.
- Why and how to build latrines and keep them clean.

5

CRITICAL FACTORS FOR SUSTAINABILITY

5.1 Community Analysis of Critical Factors

There are five critical factors that must be considered when planning a new water supply system if long-term sustainability is to be a reasonable expectation. These factors need to be analyzed in terms of each water technology that is under consideration. The five factors are 1) community water service requirements, 2) water system costs, 3) maintenance and management arrangements, 4) probable environmental impact and, 5) expected health changes. Once probable expectations for all factors has been established for each technology under consideration, then the community can discuss what options they have and what trade-offs they are willing to make. This community analysis and decision making as to what trade-offs are most acceptable strongly increases the probability of successful long-term maintenance.

5.2 Factors to be Considered

Critical factors and their impact on sustainability are briefly discussed below. Each of these critical factors needs to be discussed in terms of establishing the actual advantages and disadvantages that each technology will offer.

1. Water Service Expectations

Quantity, access, reliability, and quality of water (QARQ) are the water service factors around which people judge whether a specific water system is satisfactory and meets their needs. Reliability of water supply is often the first priority, but the mix and value given to each factor are usually very specific to a community. Discussing the mix of water service factors to be expected and ranking them in order of priority are essential. If this is not done, one or more incorrect assumptions are often made.

One incorrect assumption is that a specific technology will maintain a certain level of service on one factor while increasing it on another. This is rarely the case. For instance, a drilled well with handpump will increase quality and quantity of water, and maybe even access. However, reliability will decrease when compared to the open well that has poor quality water all year round. "Downtime" (time in which the pump is inoperable) on mechanical water pumps may average 20 percent per year. Therefore, "quantity" and "quality" of water will be increased with a drilled well, but "reliability" may be decreased.

Emphasis on quantity and quality at the expense of reliability and access can lead to negative situations. Increased quantity and quality of water may initially appeal to a community but may not be sustainable because the fees necessary for that type of technology might be too high over the long term. Another negative situation arises when certain water service factors such as reliability and access–important to the women who are the local managers and responsible for day-to-day maintenance–are not taken into consideration when technology choices are made.

In all of these cases, if the advantages and disadvantages of each water technology are not thoroughly discussed and understood by all community members, there is a risk that certain portions of the community will, after using the new water point for a short time, become dissatisfied and refuse to pay maintenance fees or use the new water point.

2. Water System Costs

Construction, installation, operational, and replacement costs for each technology considered need careful review. Fees collected must cover on-going and future costs, and individual users must be satisfied with the water services they receive in return for fees paid. If this is not the case, usership, and therefore benefits, may decline, and the water point will ultimately fall into disrepair and be abandoned.

It is therefore necessary to make a careful estimate of both maintenance and reoccurring costs, define a fee level to cover these costs, and establish who in the community will pay them and how and when fees will be collected. Costs and fees will obviously be different for each technology, and community members will most likely be interested in establishing the most effective ratio of cost vs. water service as a guide for technology selection.

3. Maintenance and Management Arrangements

Underestimating the amount, and type, of maintenance and management needed for sophisticated technologies easily happens if the present water system requires low maintenance and needs few spare parts. A fairly simply mechanical breakdown can become serious and extended if unforeseen and unprovided for in the planning stages. Several unexpected mechanical problems of this nature can contribute to the permanent breakdown of a new system, where the users quickly return to the old water system which offers less in terms of service but continues to be reliable. Careful arrangements for both spare parts and maintenance repair resources need to be discussed and decided upon.

4. Environmental Impact

When a community decides to increase significantly the quantity and quality of water available to the community, the probable environmental impact of increased numbers of animal users and human population growth must be considered. The negative effects on the environment and how to mitigate these possible outcomes needs to be considered and planned for.

5. Expected Health Changes

Improved community health is a possible but not automatic outcome of improving water supply. For instance, there are specific health benefits that can be obtained by using greater quantities of water irrespective of its quality, but how best to obtain these benefits needs to be identified. On the other hand, health benefits from increased quality of water is often expected to appear automatically, but in reality such benefits occur only if the community seeks out and utilizes specific "how-to" knowledge that changes certain behaviors.

What health benefits are easiest to attain, and which are more difficult because of needed interventions, need to be identified by the community. This is most often possible if the community invites local NGO or government health agents to discuss community plans for improving water supply and health.

5.3 Summary

Information provided in this and preceding chapters can assist the ADF applicant in creating the basis for an informed community decision on technology selection, developing a description of a "Work Plan for Implementation," and developing a definition of a "Community Water-Point Maintenance Plan."

We hope these guidelines are of use to you as you undertake the very important work of improving community water supply. We would greatly appreciate hearing how these guidelines worked for you and what additions or deletions you would suggest for the future. Best wishes to you and your community.

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