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ENVIRONMENTALLY SOUND SMALL-SCALE WATER PROJECTS

GUIDELINES FOR PLANNING

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ENVIRONMENTALLY SOUND SMALL-SCALE WATER PROJECTS

GUIDELINES FOR PLANNING

BY

GUS TILLMAN

COORDINATION IN DEVELOPMENT

VOLUNTEERS IN TECHNICAL ASSISTANCE

Cover design and illustrations by Susann Foster Brown

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PREFACE

This is the second volume of the Guidelines for Planning series. The first volume, Environmentally Sound Small Scale Agricultural Projects, was jointly published in 1979 by VITA and The Mohonk Trust. The remainder of the series is being produced by CODEL and published jointly by VITA and CODEL. The booklets can be ordered from VITA.

This booklet has been written for community development workers in developing countries who are not technicians in the area of water resources. It is meant to serve as a general guide when planning environmentally sound small-scale water projects, that is, projects which protect and conserve natural resources in a manner which allows sustainable development to take place. Sources of more detailed and specific information are listed in the text.

CODEL is grateful to members of the CODEL Environment and Development Committee who have supported this effort and commented on the material:

Father John Joe Braun, Missionaries of Africa, Committee Chairperson
Ms. Elizabeth Enloe, Church World Service
Mr. George Gerardi, Attorney at Law
Mr. George Mahaffey, The Peace Corps
Dr. Ragnar Overby, The World Bank
Ms. Agnes Pall, International Division, YMCA
Mr. C. Anthony Pryor, Center for Integrative Development
Mr. A. Keith Smiley, Mohonk Consultations on the Earth's Ecosystem

Pastor Charles Fluegel, a former Committee member, deserves special thanks for his thoughtful, practical contributions. In addition, two other former members of the Committee should be recognized for their involvement in the project: Miss Marion Morey and Mr. Michael Hayes.

CODEL is pleased to publish a booklet written by Dr. Gus Tillman whose environmental training, expertise and overseas experience make him a unique resource to the development community. Dr. Tillman also serves on the CODEL Committee.

Special appreciation is reserved for Mr. Philip W. Quigg for his invaluable editorial and technical expertise.

Several persons reviewed the draft manuscript: Dr. John M. Kalbermatten, Mr. James H. Patric, Dr. Daniel A. Okun, Mr. R. Paul Chakroff, Ms. Marilyn S. Chakroff and Dr. Patricia Rosenfield. In addition, the book was reviewed by VITA volunteers and AID personnel, among them Ms. Molly Kux, AID Office of Forestry, Environment and Natural Resources.

Ms. Kux and Mr. Albert Printz, AID Environmental Coordinator, have been a constant source of support for the Environment and Development Program and especially the publication series. We are also appreciative of the continuing support of the AID Office of Private and Voluntary Cooperation.

We welcome comments from readers of the book; a questionnaire is enclosed for your convenience. Please share your reactions with us.

Rev. Boyd Lowry, CODEL
Ms. Carol Roever, CODEL
Ms. Helen L. Vukasin, CODEL

ABOUT CODEL

Coordination in Development (CODEL) is a private, not-for-profit consortium of 38 development agencies working in developing countries. CODEL funds community development activities which are locally initiated and ecumenically implemented. These activities include health, agricultural and career training projects, among others.

The Environment and Development Program of CODEL serves the private and voluntary development community by providing workshops, information and materials designed to document the urgency, feasibility and potential of an approach to small-scale development which stresses the interdependence of human and natural resources. This booklet is one of several materials developed under the Program to assist development workers in taking the physical environment into account during project planning, implementation and evaluation. For more information, contact CODEL at 79 Madison Avenue, New York, New York 10157 USA.

ABOUT VITA

Volunteers in Technical Assistance (VITA) is a private nonprofit international development organization. It makes available to individuals and groups in developing countries a variety of information and technical resources aimed at fostering self-sufficiency--needs assessment and program development support; by-mail and on-site consulting services; information systems training. VITA promotes the use of appropriate small-scale technologies, especially in the area of renewable energy. VITA's extensive documentation center and worldwide roster of volunteer technical experts enable it to respond to thousands of technical inquiries each year. It also publishes a quarterly newslettter and a variety of technical manuals and bulletins. For more information, contact VITA at 3706 Rhode Island Avenue, Mt. Rainier, Maryland 20822 USA.

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AUTHOR'S NOTE

Users, Uses and Mea Culpa

This manual is written for all those who are planning, implementing, or responsible for a water project to benefit small segments of the world's urban or rural poor. Depending on the reader's level of expertise, the manual may be criticized for over-simplification of complex topics or for being too technical. It is meant to provide a beginning for ecological analysis and a reference to the necessary technical materials. The manual is best suited as an initial guide for planning and discussion with community leaders.

In using this manual, it is hoped that the development worker will read the section which applies to the proposed project and then select one or more technical references from the bibliography. The worker may then write to the distributors (Appendix II) to obtain a copy of the relevant references.

The author acknowledges with thanks the fine editorial work of Philip Quigg as well as assistance from Julie Morgan and typist Phyllis Haight of the Cary Arboretum. References listed in Appendix I were invaluable. The author accepts all responsibility for technical sins of commission and omission.

G.T., Millbrook, New York
1981

1. WATER - USERS AND USES

"The greatest problem in communication is the illusion that it has been achieved."

Anonymous

Our planet contains an estimated 336 million cubic miles of water. However, nearly 95% of this prodigious supply is saltwater contained in the oceans and seas which cover two-thirds of the earth's surface. Of the 5% that is freshwater, all but 1% is frozen in polar ice caps or vast northern glaciers. The remaining 3.36 million cubic miles, which is at least theoretically available for human use, is distributed approximately as follows:

Ground water	98.55%
Lakes	1.0
Soil (between particles)	0.2
Rivers and streams	0.1
Atmospheric vapor	0.1
Biolcgical (in plant and animal tissue)	0.05

If freshwater supplies were uncontaminated and equally distributed around the globe, there would be little need for water development projects and even less need for this development manual. However, common sense and numerous global studies tell us that water supplies are neither uncontaminated, nor equally distributed; therein lies the need for water development projects. According to a recent global survey of 91 countries conducted by the World Health Organization (WHO), 86% of the rural populations (1.11 thousand million people) are without "reasonable access to safe water." By region, the numbers and percentages of rural people without reasonable access to safe water are as follows:

Africa	136.0 million	89%
Americas	92.1 million	76%
Eastern Mediterranean	139.5 million	82%
Europe	23.3 million	56%
Southeast Asia	661.7 million	91%
Western Pacific	59.0 million	79%
All regions	1,111.6 million	86%

(after Feachem, 1977)

In view of these staggering statistics, the World Health Assembly set a seemingly modest target at the start of the last decade: to give 25% of the rural populations of developing nations reasonable access to safe water by 1980. However, just to maintain 1971 levels, world population growth would require new water supplies for 297 million additional people since the start of the decade. In spite of the intensive and costly efforts to increase safe water supplies, it is likely that a larger percentage of rural people lack access to safe water in 1980 than in 1971. To gain ground, water development efforts will have to increase in quantity and improve in quality. Therein lies the principal need and purpose of this manual.

It is not always possible to obtain the professional studies and analyses that might be desired. New water-related projects are increasingly being developed to meet pressing local needs in agriculture and health without benefit of professional scientific or engineering advice. Small-scale projects are initiated, planned and often implemented by highly motivated, experienced development workers, who have insufficient technical skills and experience in water resource development. Given ideal conditions, field workers can develop the necessary expertise to plan and implement small-scale water projects. But realistically, assignments are short-term, needs are at crisis point, available experts are overworked on large-scale projects and literature is so difficult to obtain it might as well be on the moon.

To address this reality, this manual was prepared as a guide or aid in planning and executing environmentally sound small-scale water resource projects. It is not intended to replace technical literature or professional advice when available, but to serve as a helpful substitute when those sources of information are unobtainable or as a guide to topics on which further information may be needed. Through a discussion of the environmental factors which relate to water development and use, the manual encourages the incorporation of environmental considerations into water development planning to increase the probability of long-term project sustainability.

WHO SHOULD USE THIS MANUAL?

Anyone who must plan, review, supervise or implement small-scale water resource projects and:

- has limited experience in water resource technology or minimal access to technical experts

- wishes to learn more about the environmental relationships that affect water resource projects

- must prepare or review a report on the environmental aspects of water development projects

- must prepare a training program on small-scale water development projects.

WHAT DOES THE MANUAL PROVIDE?

- Basic ecological principles which relate to water resource development

- A guide for planning small-scale water projects

- Suggestions for low-cost techniques to avoid adverse impacts of water development

- Basic information and resources for planning and implementing projects in water supply, water conservation, water distribution systems, waste-water treatment, agriculture, energy and public health.

ECOLOGY AND THE ENVIRONMENT

Today the terms ecology and environment often are used interchangeably, but they are not the same. Quite simply, ecology is the study of the relationships and interactions of the living and non-living parts of our surroundings. The living parts include plants, animals and one-celled organisms (e.g., bacteria and algae), while weather, soil, rocks, energy, topography and water are some of the non-living elements in our surroundings. All these factors are interrelated, mostly in ways which we do not fully understand, although many of the major relationships have been defined by ecologists. We have learned that it is impossible to alter one part of our surroundings without producing changes in some other components. Since a water development project will alter major parts of a particular ecologic system, we know that other parts will change. Through sound planning and implementation, we can try to ensure that changes will not produce severe negative effects.

Environment is an even simpler term to define because it can be used interchangeably with surroundings, if one keeps in mind that surroundings are all-inclusive, involving _all_ living and non-living parts. Within this definition, it is proper to include man and the social and cultural activities associated with humans. It is clear from the definitions that ecology is the study of environment; therefore these are not interchangeable terms and will not be used in this manual as though they were.

The natural environment is a term used to describe systems which have evolved over millions of years, approaching a harmonious, or perhaps, dynamic balance. In natural systems, water cycles, soil fertility and plant-animal relationships tend to be stable and predictable, although often upset by natural catastrophes such as earthquakes, floods, volcanic eruptions or lightning-induced fires. Man, who has the ability to alter significant parts of a system, produces artificial environments such as cities, farms and lakes. The new environments contain many benefits to be sure, but also may create many unfavorable conditions: increased disease, contaminated water supplies, deforestation, desertification and eroded soils. Recently, through ecology, we have learned that if artificial environments can be made to function more like natural environments, they tend to be more stable and predictable. Therefore, it is in our best interest to understand the functioning of a natural system so that the conditions ensuring stability and long-lasting benefits can be preserved, at least in part, in man-devised projects. Scientists often identify smaller units within the natural system called ecosystems. See section on "Ecosystems" in Chapter 2.

2. WATER AND ENVIRONMENT

"...For in the wilderness shall waters break out and streams in the desert."

The Bible

The primary goal of water resource development is to provide safe and reliable water supplies for human use. This may involve the development of a new water source, expansion of an existing source, improvements in collection and delivery, or methods of water conservation. In some cases, water quantity may be adequate, but inferior quality requires a plan for purification or improved sanitation. In addition to developing potable water supplies for human consumption and hygiene, communities often want more water for agriculture or manufacturing to increase employment opportunities and improve the standard of living.

Even where water development projects are implemented with the best intentions, unforeseen environmental factors can produce negative effects, often outweighing the benefits of the project. Dramatic increases in water-related disease, loss of soil fertility, increased erosion and changes in the hydrologic balance are some of the adverse side effects of poorly planned water projects. Determining the possible positive and negative effects may be the most important task faced by planners of small-scale water projects. Through the selection of an alternate technique or a minor modification of a proposed project, many of the unwanted consequences can be either reduced or avoided altogether. An understanding of basic ecological concepts and an awareness of environmental relationships can help planners to judge the direction and magnitude of environmental changes that various alternatives might cause and to assess the positive and negative effects of the possible options.

It is in tropical regions, where most of the developing countries are located, that we find the greatest inequities in water distribution. The extensive arid and semi-arid regions of the tropics are plagued not only by inadequate rainfall for crops, but also are subject to extreme variations of rainfall from season to season and from year to year. When rainfall is normal, it is often restricted to brief intervals during the year--not long enough for plant growing seasons. In the past, such lands were sparsely occupied, usually by nomadic tribesmen who moved their families and livestock from place to place to find seasonal water and vegetation. Rising populations of people and domestic animals have put intense pressure on these small, seasonal sources, often resulting in their destruction through overuse.

On the other hand, moist tropical areas receive amounts of rainfall far in excess of that required for plant growth.

The excess water moves over or through the soil to form immense tropical rivers such as the Amazon, Niger, Congo, Mekong and Nile. The enormity of these river systems illustrates the unequal distribution of freshwater: one river, the Amazon, discharges approximately 20% of the world's runoff of freshwater. This overabundance of water can create serious problems, as we will see, if the natural vegetation is altered for development purposes.

In both arid and moist regions, increased human activities have produced changes in natural water cycles, some yielding obvious agricultural or industrial benefits while others have caused serious unforeseen consequences and increased human suffering.

MAJOR SOURCES OF WATER FOR DEVELOPMENT PROJECTS

- Precipitation, in the form of rain or snow, cannot yet be effectively controlled by man. Water resource projects must be designed to accommodate the wide range of annual as well as seasonal precipitation.

- Surface waters are the most obvious source of freshwater that can be tapped. Lakes, ponds, rivers, streams, reservoirs and catchments are examples of surface water sources.

- Ground water refers to the subsurface supplies fed by precipitation and surface water. It is a major reservoir for freshwater. Ground water supplies contained in aquifers are relatively stable unless influenced by man's activities. When ground water is within 3 meters of the land surface, it may move upwards, against gravity, through small soil pores by a process known as capillary action. It thus becomes available to shallow rooted plants, such as most agricultural crops. In some areas, or during periods of excessive rainfall, ground water may be at or near the surface, flooding the root zone and killing most plants. Ground water may also be held in pockets far down in the earth's crust and can be reached only by drilling deep wells through rock. A shallow pocket is also an aquifer. Some aquifers, such as those found in northern Africa, often contain huge volumes of water but were covered in an earlier geological time with impervious rock layers which do not permit recharge from surface sources. These "fossil water" aquifers have remained in place for thousands of years and since they cannot be replenished by natural means, they must be considered non-renewable resources.

The upper level of the ground water is called the water table and how far it is beneath the surface of the land is as important to consider in water development projects as the volume of ground water itself. The height of the water table will change with the seasons and the amount of rainfall. The relationships of water table, ground water, surface water, geologic features and precipitation are shown in Figure 1.

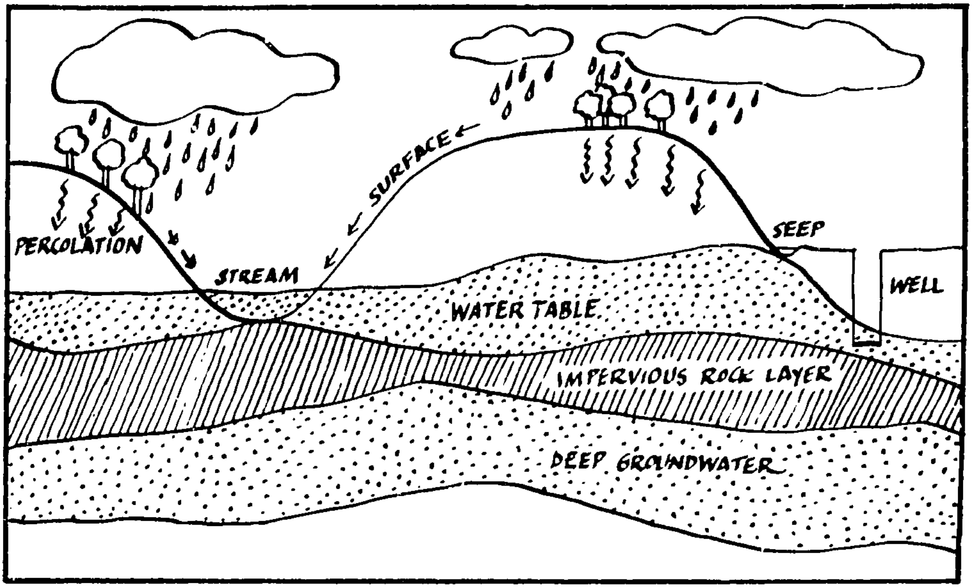


Figure 1. Ground Water and Water Table

- Distillation and condensation are minor and expensive sources of freshwater. Distillation and condensation of a saline water supply will produce freshwater, but require a large amount of energy. Some small, solar-powered stills can provide supplemental water for domestic use with inexpensive materials. Natural condensation of water vapor (dew) is a minor source of water for plants, but has little or no potential for human use.

THE HYDROLOGIC CYCLE

The movement of water from earth surfaces to the atmosphere and back to the earth is called the hydrologic cycle. It is the basis for all water development projects, large and small, and a firm understanding of the basic process and its vagaries are important to water resource planning.

The hydrologic cycle involves evaporation, transpiration (emission of water vapor from the leaves of plants), condensation, cloud formation, precipitation, surface runoff, water storage and percolation (Figure 2). These processes in turn affect the patterns, practices, quantity and quality of human life. Most water development projects seek to make minor local changes in the natural cycle so as to provide additional human benefits in the form of additional water supplies or water movement. Alteration of the hydrologic cycle does not involve changes in the basic processes, but rather in their rates or volumes.

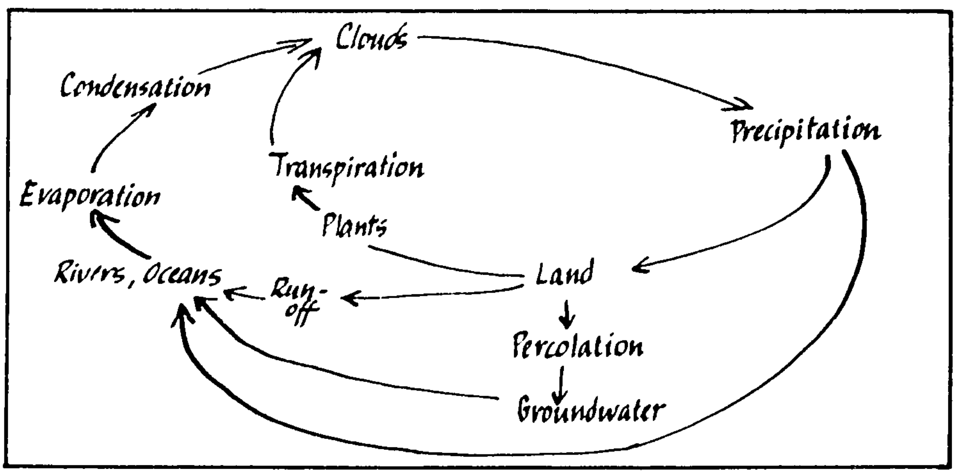


Figure 2. The Hydrologic Cycle

When sunlight strikes a water surface, whether it be an ocean, a river or saturated land, the water molecules get warmer and begin to move faster. As the movement increases, some molecules break away from the liquid surface and move into the atmosphere as a gas, in this case, water vapor. This process is known as evaporation and is responsible for most of the water vapor in the atmosphere. Most of the global water evaporation takes place over the oceans which comprise nearly 70% of the surface area of the earth. When water and other liquids are evaporated from land or water surfaces, the larger and slower molecules, such as salts and metals, are left behind.

Transpiration is the second major contributor of atmospheric water vapor and it too is powered by energy from sunlight. Water absorbed by plant root systems is passed internally to the upper portions of the plant. In the green portions of the plant, principally the leaves, some water is used for photosynthesis, but most of the water is passed through small pores or openings in the leaves. At the leaf surface, the sunlight causes the water to change to a vapor which then rises into the atmosphere as it is heated. The amount of water moved by transpiration is amazing; for instance, one hectare of corn can transpire 37,850 liters (10,000 gal.) per day or 1,900,000 liters (500,000 gal.) per growing season. A single mature tree may transpire up to 378 liters (100 gal.) per day. In areas where soil moisture is excessive, plants are often used, along with artificial drains, to remove the excess moisture in the soil.

In analyzing moisture loss or water requirements for agriculture, evaporation and transpiration figures are combined as evapotranspiration losses. Since both processes are directly affected by temperature, relative humidity, wind and available water, the rate of evapotranspiration loss is an important indicator of the climate of the area. More commonly, the climatic factors can be used to estimate the evapotranspiration loss for proposed agricultural projects.

Condensation of water vapor in the atmosphere produces the various cloud formations that will eventually lead to precipitation. The vapor gradually cools as it rises, and eventually its molecules strike small particles, such as dust, in the atmosphere and condense to form clouds. The moisture laden clouds may cool further by passing over a mountain range or by meeting a cold air mass. The sudden cooling further compacts the water molecules into droplets of water that fall as rain or in frozen form such as snow or sleet. Topography, cloud altitude and prevailing wind direction all contribute to the uneven distribution of precipitation. Some areas, such as the windward slopes of coastal mountains, may receive over 3000 mm per year while the other side of the same mountains may not record any precipitation for an entire year.

Most soils, especially if covered with vegetation, absorb water and only the excess becomes part of the surface runoff. But if all or parts of the soil are even slightly impervious to water due to rock cover, soil compaction or baking, runoff will be heavy.

Surface water will either flow to the oceans, seep into the ground water, or evaporate. Because surface water is so precious in most countries, it may be used for several human activities before it reaches the ocean. For instance, surface water could pass through a hydroelectric generator, flow on to an irrigated field, pass through an industrial cooling system or be used for sewage removal for a riverside city. Each use would have effects on water quality and minor effects on parts of the hydrologic cycle by increasing or decreasing the rate of evaporation or percolation.

Rapid or uncontrolled surface runoff can produce flooding, land slides and serious erosion. Even on a lesser scale, runoff can have deleterious environmental effects. As it moves across the land, the water picks up soil particles and organic materials important to soil fertility. Their removal from agricultural land decreases productivity. Of course, if the particles of topsoil are deposited on downstream agricultural areas, those lands are improved. However, the soil particles are usually transported to water courses and are carried as suspended solids until deposited as sediments in slow-moving bodies of water, such as reservoirs, lakes or oceans. Although this may enrich aquatic systems, it represents a serious loss to agriculture.

Water falling on vegetation is more likely to remain in place than water which strikes bare soil. The plant material not only dissipates the force of the rainwater but also impedes surface flow. Vegetation allows more time for the soil to absorb the rainwater and also improves the soil structure so that it can absorb more water at a faster rate.

Once absorbed into the soil, the water can percolate down to aquifers in rock or gravel, or strike an impervious rock layer and move horizontally as a subsurface or ground water flow. Some of the subsurface water will be taken up by plants. The rest, if untapped by wells, will either remain as ground water or eventually feed into streams or rivers, becoming a part of the surface water system. Since subsurface flows are more leisurely than surface flows, the water remains available for human use for longer periods.

In spite of the seemingly incredible amount of plants and animals in the world, only a miniscule fraction of the total freshwater supply is held in plant and animal tissue and can be disregarded in planning for water resource development.

This oversimplified explanation of the hydrologic cycle indicates major areas for analysis before implementing a water development project. It suggests where water is likely to be found and is the basis for determining the best methods to develop and protect the source.

ECOLOGICAL CONCEPTS IMPORTANT FOR WATER RESOURCE DEVELOPMENT

Development implies change for the better--a change from existing conditions or resource use to a system that is safer or more productive; in other words, producing more benefits for a larger number of people. Development involves the alteration of resources or imposes a different strategy for using the resources available. By understanding ecological principles, developers can increase the probability of success, i.e., there will be more positive than negative effects.

Ecosystems

Since a study of ecological systems can be so all encompassing, the shorthand term "ecosystem" was coined to define the smaller units which ecologists choose to study. Thus, a scientist may study a forest of several thousand hectares or a decaying log and yet investigate principles and concepts common to both systems. The term allows the scientist to place recognizable boundaries on the area of investigation to fit the needs of research objectives.

As with many scientific terms, "ecosystem" has been widely and often used erroneously and now has a much broader meaning. Generally, the term applies to an area of homogeneity of one particular part of the natural system, such as type of vegetation, amount of rainfall, topography or physical feature. Further, ecosystems can be classified as natural or artificial. In natural ecosystems, man is not the dominant factor and changes tend to be minor unless some catastrophic event occurs. In studies of natural ecosystems, scientists have found dynamic balances achieved through constant minor adjustments within the system. These balances ensure relative stability in plant and animal populations, minor fluctuations in water movement, and nutrient inputs nearly equal to nutrient losses. If more had been known about the reasons for stability and productivity of the natural ecosystems, the artificial ecosystems created by man might have been a lot more productive.

The biological bases of any ecosystem consist of three major groups: producers, consumers and decomposers. The ecosystem producers are the green plants, whether algae, grasses, trees or weeds. By the process of photosynthesis, plants combine carbon dioxide and water in the presence of sunlight (for energy) to produce carbohydrates (sugars and starches) and release oxygen as a by-product. Using the carbohydrates for energy, the plants can take other nutrients from the environment to produce fatty acids, protein and vitamins, forming the energy and nutritional base for the other biological parts of the ecosystem. The goal of many water development projects is to supply water essential to these producers.

The consumers in the ecosystem are animals, including man, which eat plants or other animals. In order to produce energy, consumers must combine food with oxygen, releasing small amounts of carbon dioxide and water in the process. Animals use the energy for heat, growth, movement, and the production of more complex chemical compounds, such as fats and proteins, which are important in storing energy, building new tissue or transmitting genetic materials to offspring. Consumers require additional supplies of water to construct new tissue to transport various chemical compounds within the body, and to regulate internal temperature.

Plants cannot absorb nutrients unless they are in very simple chemical forms. For instance, the roots of a forest tree cannot use the nutrients in a dead animal's tissue unless the complex carbohydrates, fats and proteins are broken down into simpler molecules which contain carbon, nitrogen, potassium, calcium and phosphate. Decomposers, mainly bacteria and fungi, break down the large molecules in dead plant and animal tissues or wastes into the simpler forms that can be used by plants. These microscopic organisms play a vital role in the ecosystem, for without their presence, the producers would not be able to construct new tissues. Water development projects, whether for agriculture or sanitation, must rely on viable populations of decomposers to continue the recycling of nutrients through the ecosystem.

The role of plants and animals in an ecosystem is not limited to production, consumption and decomposition. There are many other functions such as soil protection, water retention, microclimate modification, pollination and seed dispersal, just to name a few. So when someone wishes to alter a part of an ecosystem to make it more productive (or less hostile) for man, it is necessary to examine aspects other than productivity.

WHAT HAPPENS WHEN NATURAL SYSTEMS ARE ALTERED?

The dominant natural feature of most land ecosystems is the plant cover or vegetation. The type and density of the vegetation influences soil structure and content, water movement, nutrient balance, type and abundance of animal populations and microclimate. When the native plant cover is removed or changed for development, each of these areas can be affected. For instance:

- If vegetation is removed, wind can blow away soil particles and organic matter in the topsoil, thereby removing the most fertile part of the soil.

- The combined action of wind and sun on exposed soil increases evaporation, often causing the soil to become dry and brittle, less likely to be suitable for agriculture.

- Soil particles with attached nutrients, as we have noted, may be dislodged by hard rainfall striking the ground rather than plant leaves. Runoff carries the soil particles and nutrients from the land, where they are needed to maintain soil fertility, to waterways where they are not needed. As silt and sediments, they may clog water courses, kill fish, increase flooding and fill reservoirs.

- Nutrients carried into the waterways may increase the growth of algae or waterweeds, rendering the water unfit for desirable animals, but more suitable for animals that transmit diseases (vectors). The nutrients may also make the surface water less desirable for human consumption.

- Protection from flooding is reduced when covering vegetation is removed. Plants maintain soil porosity which helps the soil absorb water. In addition, the roots and stems retard the flow of surface water. With the vegetation removed, water does not percolate easily into the soil if the terrain is not level, but tends to run over the surface in sheets or rivulets, increasing soil erosion and the danger of flooding in downstream areas.

- Traditional sources of wood, fruits, medicines and cooking herbs may be lost if the native vegetation is removed or replaced by agricultural crops.

- Diversity of animal life is decreased. Animals which depend upon natural plants for food or shelter will be forced to move if the vegetation is removed by man. These animals are often replaced by animals that live all too comfortably with domestic crops or livestock--basically agricultural pests. The animal population may decrease the number of different species, but increase the number of individuals, which may be the unwanted types.

There are, of course, many other effects on the environment when natural ecosystems are altered; it would be impossible to make a complete list. Some changes are complex and difficult to predict; others are rather straightforward. In water resource planning, we obviously want to capitalize on the changes which are beneficial and minimize those changes which are detrimental. Each water development project will cause changes (environmental impacts) and proper planning involves an analysis of these impacts before the project is implemented. The following chapters should help development workers plan and implement water resource projects within an environmental framework that identifies impacts of alternative schemes and helps to ensure the selection of the most appropriate option.

3. WATER AND HEALTH

"Where water goes, disease follows in its wake."

Anonymous

Small-scale water development projects are intended to improve the quality of the human environment. Most health-related projects are designed to provide potable water, safe excreta disposal, or water for agriculture to improve nutrition. If well-planned and well-designed, the projects are successful and the people benefit. However, if planning is haphazard and designs are incomplete, there is a strong possibility that disease may increase. In many cases, a water project may bring about a decrease in one type of disease but cause an increase in a more severe type. This unfortunate outcome is most common in projects designed to improve local agriculture or to provide additional energy through the use of water.

POSSIBLE EFFECTS OF WATER DEVELOPMENT PROJECTS ON HUMAN HEALTH

- Water carries microscopic organisms that can cause disease in humans and livestock. The microscopic organisms include bacteria, viruses, fungi and single-celled protozoans.

- Water provides an environment necessary for the development of many animals (e.g., snails and insects) that transmit diseases. These animals, called vectors, rarely cause sickness directly but instead carry the microscopic organisms that cause serious illness. Flies and mosquitoes, especially, help to pass germs from sick people to healthy people, thereby spreading the disease. In many cases, the insect spends only a part of its life or life cycle in water, but can transmit disease to humans without their direct contact with infected water supplies.

- Water sources can provide suitable environments for animals that are extremely common parasites of humans. These parasites, which can be single-celled organisms, flat worms or round worms, are responsible for the world's most common diseases, causing massive expenditures for medical care and treatment as well as terrible suffering. Schistosomiasis, filariasis and amoebic dysentery are common examples of parasitic diseases. Table 1 lists some of the major water-related diseases.

- Water from polluting industries or agriculture can carry toxic chemicals that cause grave illnesses or death if the water is used for human consumption.

- Health is affected by the amount of water available for personal hygiene: washing clothes, bathing and washing of utensils and household items. If supplies are limited, personal hygiene is often neglected. A safe supply of water for personal use is essential to good health.

- Water is directly and indirectly related to proper nutrition. Each adult must have a water intake of at least 6 liters per day to maintain adequate body fluids. In addition, agricultural produce requires water for survival and growth. If water supplies are not sufficient, agricultural production will decline and adversely affect nutrition.

TABLE 1

WATER AND HEALTH

Disease	Infectious Agent	Role of Water
Schistosomiasis (Bilharziasis)	Helminth worm	Direct Transmission/ skin penetration
Diarrhea/enteritis	Symptom of many agents	Direct Transmission/ ingestion
Hepatitis (Infectious)	Virus	Direct Transmission/ ingestion
Cholera	Bacteria	Direct Transmission/ ingestion
Typhoid Fever	Bacteria	Direct Transmission/ ingestion
Ascariasis	Helminth worm	Direct Transmission/ ingestion
Dracontiasis	Helminth worm	Direct Transmission/ ingestion
Amoebic Dysentery	Protozoa	Occasional Transmission
Bacillary Dysentery	Bacteria	Occasional ingestion
Malaria	Mosquito	Vector habitat
Filariasis	Mosquito	Vector habitat
Onchocerciasis	Black Fly	Vector habitat
Yellow Fever	Mosquito	Vector habitat
Flukes	Helminth worm	Habitat of intermediate host

COMMON WATER-RELATED DISEASE AND CONTROL

Of the diseases listed in Table 1, four specific diseases and one general category of disease are especially significant in terms of their total incidence, their widespread distribution and their long-term impacts on human populations as shown below.

TABLE 2

ESTIMATED WORLD-WIDE PREVALENCE OF CERTAIN DISEASES RELATED TO WATER RESOURCE DEVELOPMENT

Disease	Prevalence
Schistosomiasis (Bilharziasis)	200,000,000
Filariasis	200,000,000
Onchocerciasis	40,000,000
Malaria	25,000,000
Enteric Disease	Unknown

(after McJunkin, 1975)

Schistosomiasis

This disease, also known as Bilharziasis, is caused by worms which spend a part of their lives in snails before infecting humans. There are three species of the schistosomes which cause disease throughout the tropical and subtropical parts of the globe. *Schistosoma mansoni* is found in central and southwest Africa and is increasing in eastern and northern South America. *S. haematobium* is found throughout Africa, in many areas overlapping with *S. mansoni*. *S. japonicum* is restricted to parts of Asia.

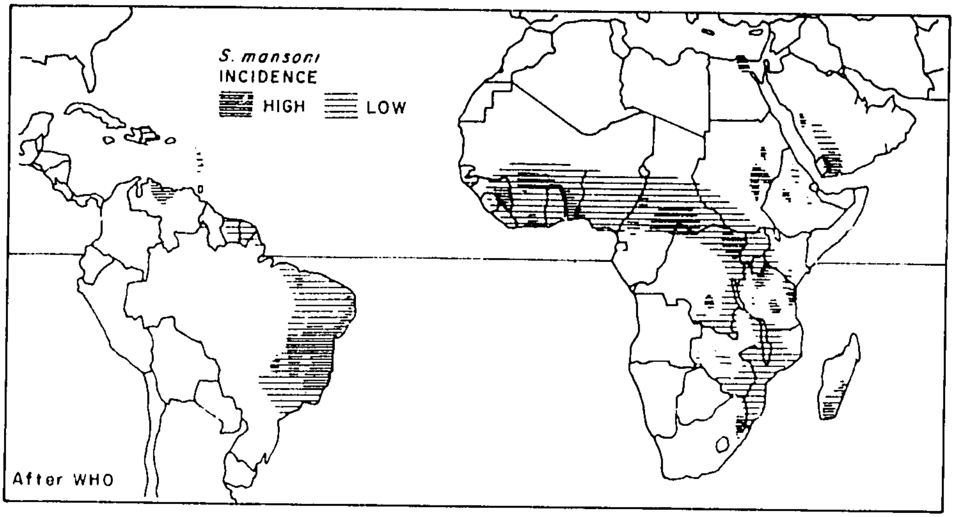


Figure 3. World Distribution of S. mansoni
(after, McJunkin, 1975)

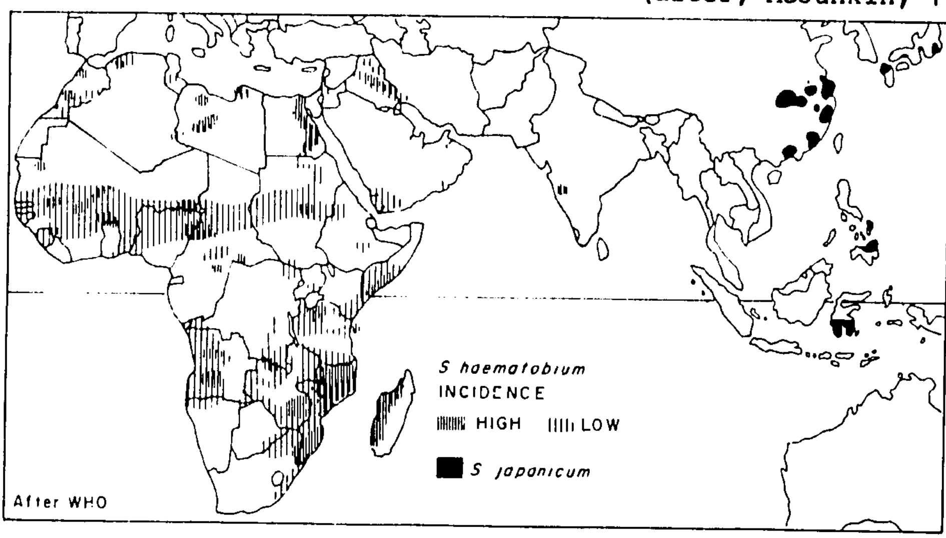


Figure 4. World Distribution of S. haematobium and S. japonicum (after McJunkin, 1975)

Like most intestinal worms (helminths) schistosomes require two different hosts during their lifetime. The adult worms, 7 to 26 mm long, live either in the intestines (S. mansoni and S. japonicum) or in the bladder (S. haematobium) of man or other animals. After mating, the female lays eggs that are passed out of the human body in feces or urine. To survive, the eggs must reach water within a month and, if successful, the eggs hatch into small swimming larvae called miracidia. These larvae must penetrate the skin of certain species of freshwater snails within 24 hours or die. Once inside the snail, each miracidium reproduces asexually, producing thousands of larvae called cercariae. These forked tailed larvae leave the snail and swim about vigorously, searching for a suitable host. Man is the principal host for S. mansoni and S. haematobium, although infections of S. mansoni have been reported in baboons, dogs, cattle, rodents and other small mammals. In S. japonicum, the non-human hosts play a more important role. If the cercariae do not find a host within 72 hours, they perish; but if they make contact with human skin, they quickly penetrate and enter the blood stream of their new host. After reaching the liver via the blood vessels, the larvae mature into adult worms; they mate and migrate to veins in the intestinal or urinary tract where they may live for years, constantly producing new eggs. (Figure 5.)

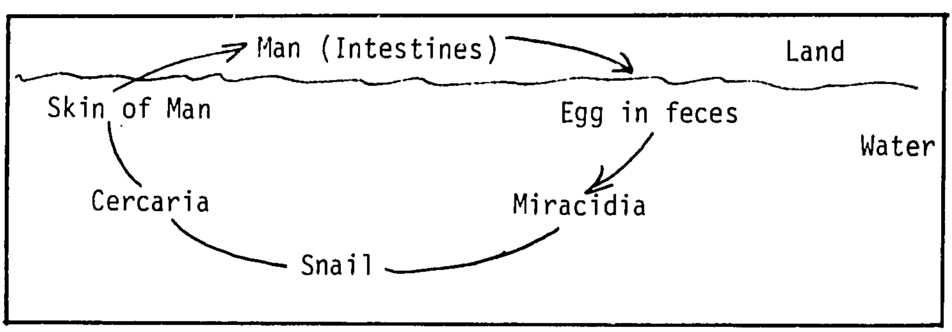


Figure 5. Life Cycle of Schistosoma mansoni

The symptoms of schistosomiasis caused by S. mansoni and S. japonicum are very similar. After infection, a skin rash may appear, diarrhea is common and the liver may enlarge. The diarrhea continues and the abdomen enlarges and is painful when the adult worms begin to lay eggs.

In S. haematobium, the bladder becomes infected, producing internal lesions which usually result in bloody urine. Diarrhea or dysentery is not common with S. haematobium.

Medicines for treating schistosomiasis are expensive and often cause undesirable side effects. The disease is more debilitating than deadly, although severe infection can cause death. The weakened physical condition of the victim also increases the susceptibility to other diseases.

Filariasis

The parasitic roundworms (nematodes) which cause filariasis also require two hosts. The adult worms live and reproduce within human lymphatic tissue, a part of the circulatory system. The female worm produces smaller worms called microfilariae which may be ingested by blood-sucking mosquitoes. In the mosquito the larvae undergo changes until they reach an infective stage. As the mosquitoes feed on another human, the larvae pass into the host's circulatory system where they move to lymphatic tissue and there develop to maturity.

The symptoms of filariasis consist of painful swellings of the lymphatic glands under the arm and especially of the groin, genitals and thighs. If the infection is extreme, grotesque enlargements of the breasts, genitals or lower extremities may occur. This condition, called elephantiasis, is severely debilitating, as well as disfiguring.

The role of water in the spread of filariasis is to provide breeding habitat for the many types of mosquitoes which are capable of transmitting the disease. Unlike the conditions for schistosomiasis, direct human contact with water is not necessary. Because so many kinds of mosquitoes carry the disease, it is widespread in all tropical regions (Figure 6). As with schistosomiasis, the disease does not respond well to medical treatment except in minor infections.

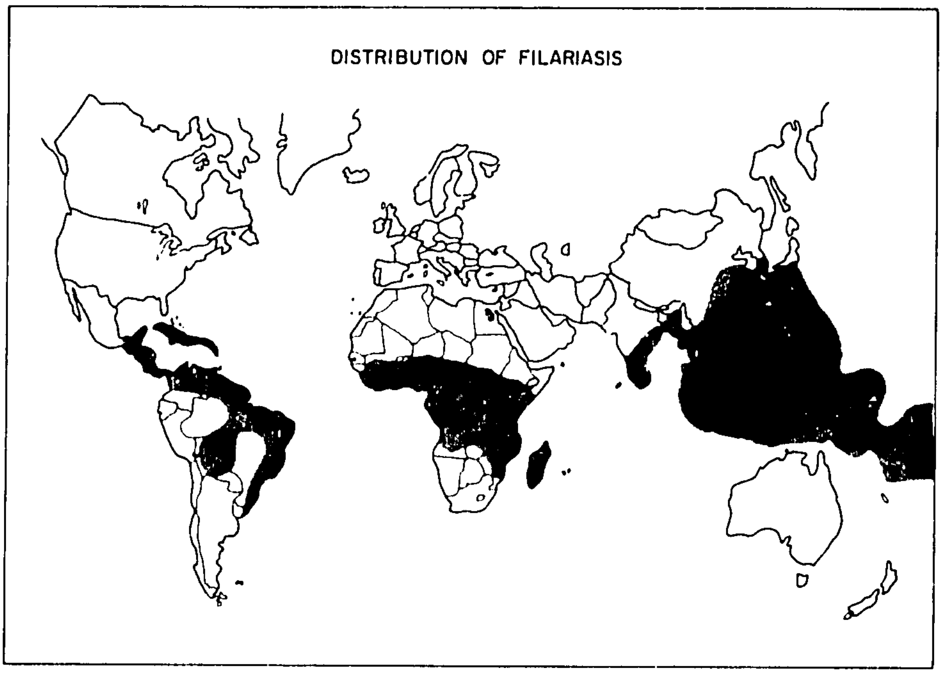


Figure 6. World Distribution of Filariasis (after McJunkin, 1975)

Onchocerciasis

This disease, commonly called River Blindness, is caused by another nematode, transmitted by the bite of a black fly. It is most common in Africa (Figure 7), although it is found in parts of Central and South America. The adult worms live just beneath the skin of humans, where the female produces microfilariae. When a certain species of black fly (Simulium sp.) bites an infected human, some of the microfilariae go into the fly where they develop into infective larvae. As the fly bites another human, the larvae enter the blood vessels in the skin to complete the life cycle.

At first the worms produce a severe itching of the skin; later, thickening and loss of pigmentation in the infected areas are common symptoms. The severity of the disease increases when the worms reach the eye, where they can and often do cause blindness. In some areas, more than 10% of the population may be infected by this terrible disease which does not respond well to present-day medicines.

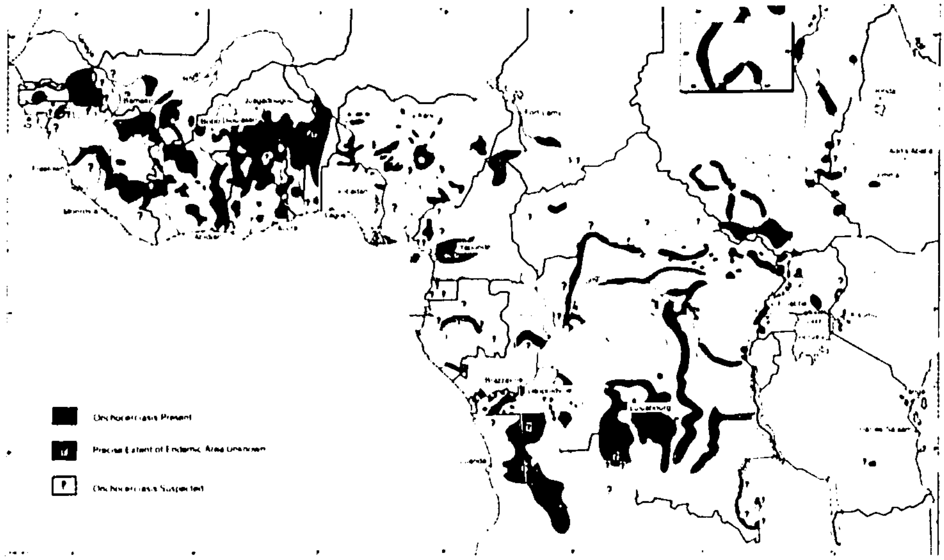


Figure 7. Distribution of Onchocerciasis in Africa (after McJunkin, 1975)

Malaria

The parasite responsible for this widespread tropical disease is a one-celled organism (protozoan) from the genus Plasmodium (Figure 8). Four different species of this parasite (Plasmodium falciparum, P. vivax, P. ovale and P. malariae) cause different types of malaria, differing in severity and timing of the malarial fevers they produce.

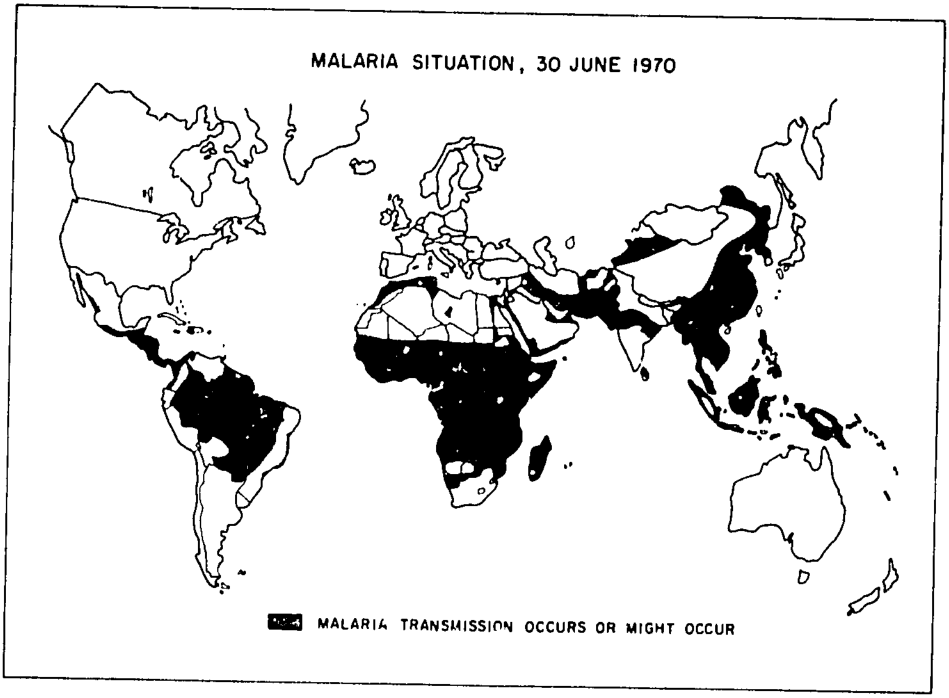


Figure 8. World Malaria Situation
(after McJunkin, 1975)

The parasite is introduced into a human bloodstream through the bite of an infected mosquito, commonly one of the many species of Anopheles. The parasite multiplies in the liver and the blood stream of the human host, eventually invading the red blood cells. After being taken into a mosquito during a blood-meal, some of the parasites reproduce and become infective. Lodged in the mosquito's salivary glands, they can be injected into a human on the next blood-meal.

The symptoms of the disease are recurrent fevers and chills plus abdominal enlargement. The disease does respond well to several modern and classic medicines such as quinine and atabrine. Other medicines have been discovered that can prevent the development of the parasite, but weekly treatment is required. However, recently, there have been reports of more virulent forms of malaria that do not respond to normal treatment or to prophylactic measures.

Enteric Disease

More for the sake of simplicity than precision in medical terminology, several actual diseases are lumped together here under the general term "enteric disease." Caused by a variety of pathogenic microorganisms (viruses, bacteria, protozoans), the diseases share common characteristics in that they all involve intestinal disorders resulting from ingestion of water contaminated by human excreta. The severity of the disease depends on the type of infection, ranging from the high mortality rates of cholera and typhoid to the less serious but debilitating diarrheal diseases. Bacillary and amoebic dysentery, gastroenteritis, enteroviral and rotaviral are also included.

Symptoms vary with the specific diseases, but all involve degrees of diarrhea, abdominal pain and fever. As we would expect for such a broad category, the duration of the symptoms is variable, as is the method of treatment. What is uniform and important to the community worker is the high rate of infection. Some experts estimate that as much as 90% of all people living in tropical rural areas suffer from some type of enteric disease.

DISEASE PREVENTION IN WATER PROJECTS

Since most water-related diseases do not respond well even to expensive modern medicines and since treatment in any case can produce side effects, the best way to control the diseases is to prevent their spread through water improvement projects. Table 3 shows the potential for disease control through various types of common improvement projects. To control disease one needs to know a good deal about it and how it is transmitted. For instance, if the disease is caused by a parasite transmitted by a non-human vector, it is helpful to know the complete life cycle of the parasite, the biology of the vector, and the most likely points of contact between humans and the vector. Within this complex arrangement, weak points in the transmission cycle can be identified and the environment altered to make disease transmission less likely.

TABLE 3

PERCENTAGE REDUCTION OF DISEASE BY WATER IMPROVEMENT

Disease	Estimated reduction by water improvement (%)
Cholera	90
Typhoid	80
Hepatitis (Infectious)	10?
Bacillary Dysentery	50
Amoebic Dysentery	50
Gastroenteritis	50
Scabies	80
Yaws	70
Leprosy	50
Diarrheal Diseases	50
Ascariasis	40
Schistosomiasis	60
Guinea worm	100
Sleeping sickness	80
Onchocerciasis	20?
Yellow Fever	20?
	(after Bradley in Feachem, 1977)

Schistosomiasis Prevention

- Dual water systems are an excellent, although expensive means to limit snail-human contacts. Except in the case of fishermen and irrigators, the most frequent human contact with water in rural villages involves fetching domestic supplies for drinking and cooking, bathing, washing clothes and recreational bathing, all of which may risk exposure to schistosomiasis. If one water supply is developed solely for drinking, cooking and washing while the other system is kept for agriculture or waste disposal, infection is less likely to occur. This may be quite simple in the moist tropics where new water supplies can be easily found. In fact, in moist tropics, catchments and cisterns can be developed so that potable water can be collected with each rainfall and protected until used. In more arid regions, new tubewell techniques and inexpensive polyvinyl chloride (PVC) pipes are providing uncontaminated water for village use.

- Eliminate snail habitat. Although the different snail vectors prefer slightly different habitats, they all like stagnant or sluggish water. Therefore, removing sediment and waterweeds and increasing the rate of flow in waterways will help control snail populations.

  Unlined canals or channels are more likely to harbor snails than those lined with concrete, plastic or any other material. The lining prevents burrowing, eliminates plant growth and improves flow velocities. Pipes or covered conduits are the best but most expensive means of eliminating snail habitats.

- Efficient drainage. Snails can breed in small areas of standing water, such as seeps from unlined canals, clogged ditches or borrow pits (places where earth has been excavated for use elsewhere). Improving the drainage of these areas will reduce the habitat available to the snail.

- Physical barriers between likely snail environments and human activity reduce the chance for infection. If fences or distance separates necessary but slow-moving ditches or drains from village compounds, humans--especially children--are not as likely to use the water for recreation or bathing or to defecate or urinate into the water channels.

- Improve sanitation. If the eggs of the schistosomes do not reach water, the cycle can be interrupted. Improved sanitation can reduce the number of eggs in snail-infested water. Simple latrines and waste treatment eliminate a large percentage of the helminth ovi reaching water bodies--though not all.

- Several molluscicides have been developed for snail control and, if properly used, can be effective. If the chemicals are applied to water with high snail populations just before the main breeding period, they are quite efficient. Since molluscicides are expensive and their effects on other organisms are not fully known, their use should be restricted to those times and sites of high snail densities and at concentration specified on the container label.

  Chemical control with natural products is another possibility. For instance, in Ethiopia, an astute observer noted that downstream from a riverbank, much used for laundering, there were relatively few snails. Investigation revealed that a local berry used for soap, and appropriately named soapberry (Phytolaca deocodandra), contained a chemical lethal to snails. This area of research has been sadly neglected, but it holds some promise if only development workers and scientists could spare the time to pursue field studies.

- Biological control is a preferred alternative. In some places it is possible to introduce snails that eat the schistosome snails, but do not carry schistosomiasis. However, this type of program involves trained people who are familiar with the biology of the different snail species. Also, there has been encouraging research showing that some species of marsh flies have larvae that eat snails. The marsh fly does not bite humans and, so far as is known, does not carry any human diseases. Other research has found certain species of fish which eat snails and could be introduced into snail habitats. Development of a biological control program would require support from a technical assistance organization or a local university.

Control of schistosomiasis depends on the use of all the available techniques. Successful control based on a single method is very unlikely or, at best, temporary. Nor is it likely that a complete, comprehensive control program can be instituted at once. The development worker must select options that are possible and implement them as best he can--more than likely, one step at a time. Above all, care should be taken to see that a new project does not increase the disease through poor planning.

Onchocerciasis Prevention

Control of onchocerciasis or River Blindness is a frustrating problem. The disease does not respond well to medical or chemical treatment, nor is it easily controlled by environmental changes. The black fly vector breeds in swift, turbulent water, such as waterfalls or rapids. Moreover, the insect is a strong flyer, capable of traveling more than 50 km from its breeding site. The disease is not affected by improved sanitation or health education programs. The only control programs involve resettlement or application of chemicals. Where the disease is prevalent:

- Avoid project designs that will create breeding sites for black flies, such as fast, open spillways or turbulent sluiceways.

- Remove fast, turbulent waters where possible, through the construction of small impoundments or barriers.

- Use insecticides on critical areas during periods of black fly breeding or seasonal human use.

- Insofar as possible, provide protection from black fly bites. Mosquito netting or settlement at breezy sites may reduce incidence of the disease.

Malaria and Filariasis Prevention

Measures for effectively controlling malaria and filariasis in water development projects depend on elimination of mosquito breeding sites. Mosquito larvae require stagnant water in which to mature. Extremely small areas will suffice as breeding habitats--a discarded food can or an abandoned tire.

- Uncovered standing water should be eliminated around living and work areas. This is especially true in the moist tropics where frequent rains can produce small but persistent pools that provide ideal conditions for mosquito breeding. Artificial containers, such as abandoned pails, barrels or pots should not be left to accumulate water.

- Ditches and drains should be maintained to permit constant water flow. Waterweeds provide excellent mosquito habitat. Community efforts are required to remove waterweeds from small water bodies, ditches and drains.

- In arid regions, all water storage devices should be kept covered to restrict egg-laying by adult mosquitoes. An inventory of potential mosquito breeding sites will almost always reveal exposed standing water which could be easily covered, drained or deepened to deny additional breeding grounds.

- Chemical control measures work best when the chemicals can be directed at the larvae. Larvicides are less toxic to other animals and, when mixed with oil, can be applied as a thin film over breeding surfaces. Pesticides for adult mosquito control are relatively toxic, more persistent and more costly. These chemicals should only be applied to homes and public buildings at rates and concentrations listed on container labels. These insecticides are too costly and polluting to use outdoors. Coordinated programs of larvicide sprays on breeding sites and periodic spraying in dwellings have been effective in controlling malaria in many communities.

Enteric Disease Prevention

The key to control of enteric disease is the disruption of the fecal-oral route of contamination. This requires improvements in domestic water supply and human excreta disposal.

- Implementing dual water systems, one for safe domestic water and the other for non-potable uses, is a preferred method. Ground water from deep wells or boreholes is usually safer to drink than surface water. If surface water or shallow dug wells are used for domestic water, disinfection or filtration systems should be instituted (as described below).

- Excreta disposal methods should be developed to reduce or eliminate fecal contamination of domestic water. This does not necessarily mean the use of an expensive sewerage system--merely the control of human waste disposal at sites where potable water must be protected.

- Education programs are essential in the control of enteric diseases. If people can be convinced that these diseases have causes that can be corrected and need not be a natural condition of life, they will avail themselves of water supplies and sanitary measures to reduce enteric infections. Without an education program and community support, projects are not likely to be effective.

Whether the project involves domestic or agricultural water supplies or the development of community sanitary stations, the project should be planned so as to avoid increasing the level of disease in the community, and preferably to reduce it. Wherever possible, the project should have as an objective the reduction of a prevalent water-related disease by a certain percentage or within a certain age group. Given the constraints of time and budget, this may not be realistic where irrigation is the primary objective. Often the development worker can only hope to maintain existing disease levels while anticipating longer-term community health benefits from better nutrition, higher standards of living or reduced work-loads.

WATER PURIFICATION

Water for drinking and cooking can be improved at relatively little cost and with great benefit to health. An accurate but inexpensive chlorinator is the most effective method for killing water-borne pathogens, but may not be available or cost-realistic in remote, sparsely populated areas. In these situations, no other single process can equal the improvements in the physical, chemical and biological quality of surface water produced by a slow sand or biological filter. These simple and inexpensive systems do not require chemicals, energy or excessive maintenance. Ideally, surface water supplies should receive both filtration and accurately measured chlorination while sub-surface waters require only chlorination. The slow sand filter is encouraged since it can be constructed from locally available material by local labor and the quality of the water supply is significantly improved.

The essential parts of a slow sand filter are: 1) a water-tight container (a 55 gallon barrel--200 liters--is a good size); 2) a small amount of gravel; and 3) washed sand (Figure 9).

After making sure that the container or drum did not carry highly toxic chemicals, it should be thoroughly scrubbed and disinfected with bleaching powder. A 5 cm layer of clean gravel should be placed on the bottom of the drum, covering the perforated outlet pipe. A 70-75 cm layer of clean sand is placed over the gravel, leaving 10-15 cm to the top of the drum. The raw water inlet pipe enters the filter near the top. A flat rock or small dish placed under the inlet will prevent disturbance to the sand layer. Simple valves for the inlet and outlet pipes plus a top cover complete the filter and it is ready to deliver filtered water at rates of up to 1 liter per minute. The filter will not be completely effective until the biological layer becomes fully active, which takes a few days.

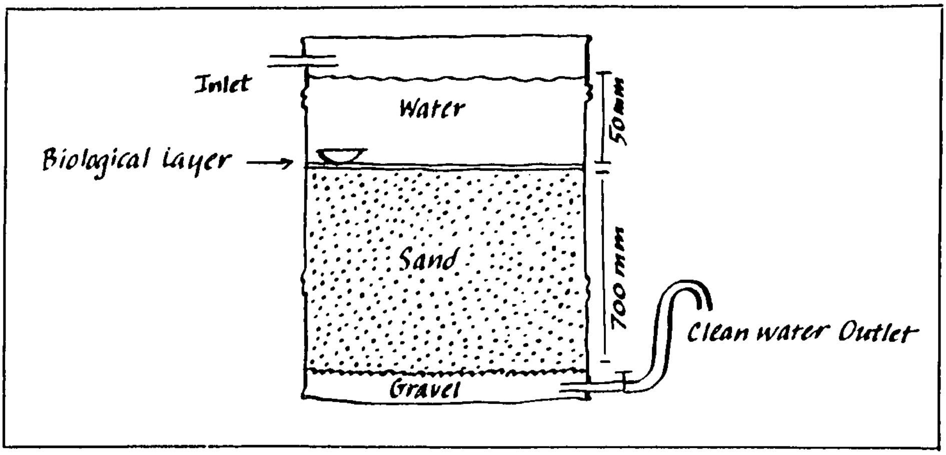


Figure 9. Slow Sand Filter
(after Cairncross & Feachem)

The biological layer is a thin film of algae, bacteria and other microorganisms that develops on top of the sand and is very important in the purification process. The microorganisms break down organic matter in the water and strain out much of the inorganic particles. As the water moves through the sand, other microorganisms continue to remove impurities. By the time water reaches the gravel and the perforated outlet, over 99% of the bacteria and schistosome larvae will have been removed if the filter has been properly maintained.

Fortunately, maintenance is a simple task. When water flow at the outlet is noticeably reduced, it is time to clean the biological layer. After allowing the water to drop below the level of the sand, the biological layer, plus a few millimeters of sand, are removed. That is the extent of the frequent maintenance (every 2-4 weeks). When more than half of the sand has been removed, it is necessary to replace the sand and gravel with freshly washed materials. This may be necessary once or twice a year.

The slow sand filter can be further improved by two other inexpensive additions: a settling container and an aerator. The settling container can be another drum, placed so that water must enter it before passing to the filter. The suspended solids in the water held in the first drum settle out before reaching the filter. The absence of suspended materials prolongs the useful life of the biological layer in the filter, thereby cutting down on maintenance.

During filtration, oxygen is removed from the water by the microoganisms in the filter. Water tastes better when it has oxygen, so an aerator can be added to the filtration system. Water coming out the drain can be aerated by passing it over an inclined plane or series of cascades (steps) into a storage container. Or the water can be passed over built-in weirs as in Figure 10.

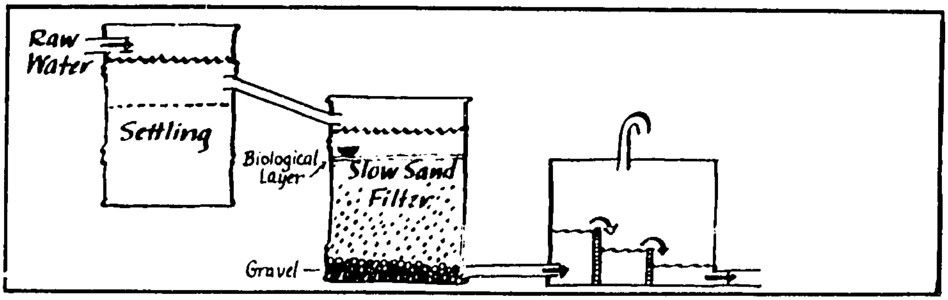


Figure 10. Settlement, Filtration, Aeration System

Another method of purifying domestic water supplies is disinfection. The two most common methods are boiling and chlorination. Boiling for 20 minutes does destroy most pathogens but alters the taste of water and uses large amounts of fuel, which is often in very short supply.

Chlorination is effective and relatively inexpensive. Chlorine solutions can be prepared from bleaching powder or high-test hypochlorite. To maintain the chemicals' effectiveness, both forms should be stored in a cool, dark place in non-corrosive containers. Stock solutions can be made by adding 40 grams of bleaching powder or 15 grams of high-test hypochlorite or 150 ml of liquid bleach to one liter of water. These stock solutions can then be used to disinfect drinking water by adding three drops of any one of the solutions for each liter of water to be disinfected. If the organic material in the water is high enough to color the water, the dosage should be doubled. The water should be mixed and allowed to stand for 30 minutes before use.

Simple chlorinators can be devised from local materials to purify well water.

a. Single pot chlorinator (Figure 11). A 12-15 liter earthen pot with two 6 mm holes is filled with a mixture of 1.5 kg bleaching powder and 3 kg coarse sand. After the top has been fitted with a water-tight cover (rubber or polyethelene), it is suspended 1 meter below the low water level of the well. The chlorinator will disinfect a well which yields up to 1200 liters per day for seven days.

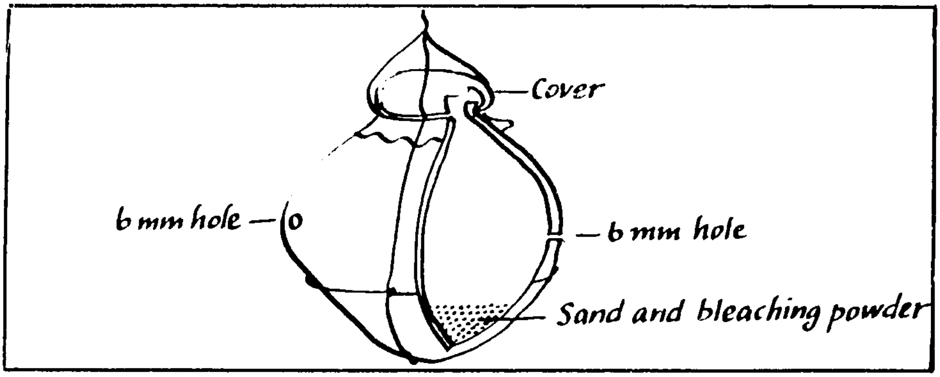


Figure 11. Single Pot Chlorinator
(after Rajagopalan and Schiffman)

Another version of this can be made with a large coconut, split horizontally and hollowed out. Three .5 cm holes are burned or bored midway down the lower portion of the shell. A plastic bag with 1 kg each of sand and bleaching powder is sealed and two .8 cm holes are made near the top. The bag is placed in the coconut and the halves are closed with twine. The shell is hung 30 cm below water level and can disinfect yields up to 90 liters per day for about 3 weeks.

b. Double pot chlorinator (Figure 12). This type, which is more effective for a longer period, consists of a container filled with a 1 kg of bleaching powder and 2 kg of sand placed inside a second container. The inner container should have a 1 cm diameter hole approximately 3 cm above the sand-bleaching powder mixture. The larger container should have a water-tight cover and a 1 cm diameter hole about 4 cm above the bottom. The chlorinator is placed 1 meter beneath the water surface. Most family wells (under 5000 liters) can be disinfected for 2-3 weeks with this chlorinator.

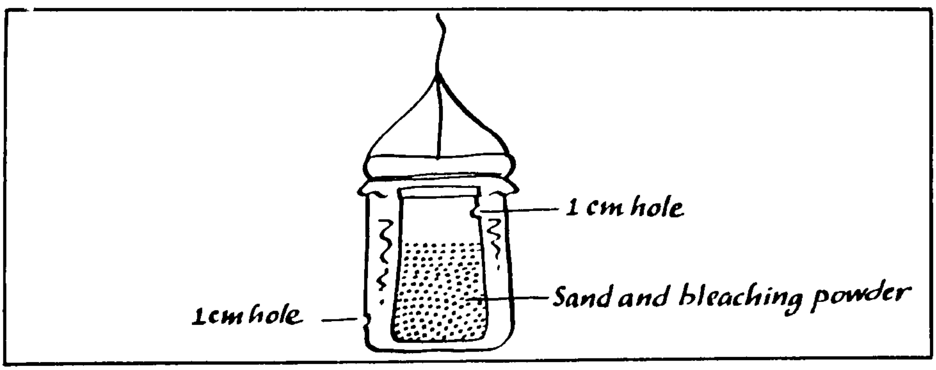


Figure 12. Double Pot Chlorinator

Table 4 provides guidelines for the amounts of chlorine in alternate substances which could be used to disinfect large amounts of water for domestic use. Remember, these are guidelines for water with "average" amounts of organic material and tests would have to be done to determine if the amount is correct for a specific water supply.

TABLE 4.

AMOUNTS OF CHLORINE NEEDED TO DISINFECT DRINKING WATER

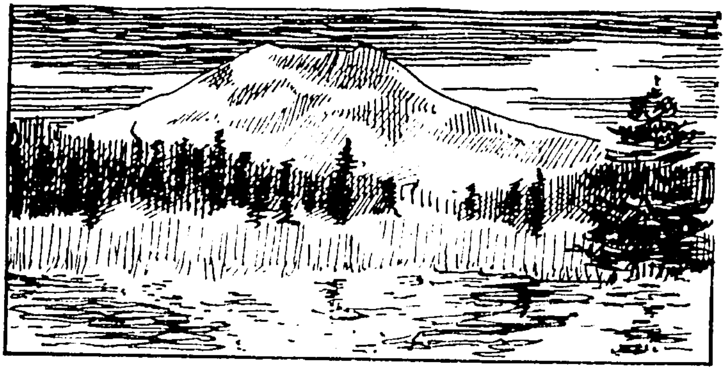
Water PLUS	Bleaching Powder	OR	High Strength Calcium Hypochlorite	OR	Liquid Bleach (5% Sodium Hypochloride)
1 cubic meters	2.3 grams		1 grams		14 milliliters
1.2 PLUS	3	OR	1.2	OR	17
1.5	3.5		1.5		21
2	5		2		28
2.5	6		2.5		35
3	7		3		42
4	9		4		56
5	12		5		70
6	14		6		84
7	16		7		98
8	19		8		110
10	23		10		140
12	28		12		170
15	35		15		210
20	50		20		280
30	70		30		420
40	90		40		560
50	120		50		700
60	140		60		840
70	160		70		980
80	190		80		1100
100	230		100		1400
120	280		120		1700
150	350		150		2100
200	470		200		2800
250	580		250		3500
300	700		300		4200
400	940		400		5600
500	1170		500		7000

(after Ram 1979)

Neither the simple filter nor the primitive chlorinators will make the drinking water absolutely safe for drinking, since even the most modern systems cannot totally eliminate the transmission of water-borne disease. However, these simple devices will make the water safer at low cost and, to the world's rural poor, these are the most important considerations.

For projects in larger villages with more resources, planners may select low-cost chlorinators which are available and are much safer. These new chlorinators are reliable, durable and require minimum attention for operation and maintenance.

The decision as to which water treatment system is most appropriate will depend on the number of people to be served by each unit and the amount of funds available.



4. ENHANCEMENT, DEVELOPMENT AND PROTECTION

"Water is the driver of life."

Leonardo da Vinci

The goal of water projects is most often to increase the amount of water available to a community. The supply can be increased in several ways:

1. Make more efficient use of existing water supplies. In most existing systems, a large amount of water is wasted through unwise use or poor methods of collection.

2. Improve water delivery systems to reduce water losses through evaporation or seepage.

3. Enlarge existing sources.

4. Develop new sources of water.

5. Protect watersheds and other sources of water in order to maximize water output and avoid wide fluctuations.

The list given here is arranged in order of priority for the community worker but not strictly by environmental preference. The fifth alternative is the most ecologically sound approach to water management. Water projects have a better chance of gaining community support if the benefits are immediate and apparent. Watershed protection or improvement projects are long term; benefits are indistinct or accrue to future generations. Therefore, these projects are less likely to receive enthusiastic support unless an education program can persuade the community of their present importance and future value.

The first three alternatives receive high priority because: 1) community benefits are immediate and apparent; 2) investment is relatively low; 3) environmental impacts are not significant; and 4) cultural adjustments are minimized.

When there are deficiencies in community water supplies, marked either by insufficiency or high rates of water-borne disease, the first reaction is generally to locate and exploit a new source of water without first considering improvement of the existing system. For economic, social and environmental reasons, community workers should reject proposals for new sources until the first three alternatives (above), either singly or in combination, are judged to be insufficient or unsound. Indeed, all alternatives should be examined before selecting the best method for increasing the water supply to meet the desired objectives.

CALCULATING AND USING WATER CAPACITY AND CONSUMPTION INFORMATION

The first step in the process is to calculate the water requirements of the community and measure the capacity of the existing system.

In small villages with a limited number of water sources, such as community wells or standpipes, actual water consumption can be measured by recording the amount of water taken from each source over a period of two or three days. From these data, annual water use can be estimated. It is important to remember that if water is made more readily available, annual consumption is likely to increase. Another method is to employ minimum standards for domestic water use proposed by various international organizations. For instance, UNICEF recommends a daily per capita minimum of 38 liters for drinking, cooking and bathing. This figure multiplied by the community population would provide an estimate for domestic water requirements. For agricultural or commercial water supplies, estimates can be gained from the technical literature or from technical advisors, if available.

Evaluating the capacity of the existing system requires a little field work and investigation. Each community water source should be mapped and notes taken on capacity and quality, as well as the type of use for each source, e.g., drinking, washing or agriculture. The yield of the spring can be determined by measuring the time required to fill a container of a given volume. Yields from wells can be measured by bailing or pumping a given volume after marking the initial water level. The time required for the well to return to the original level is then used to calculate the yield per unit of time. The volume of water in a stream or channel can be estimated by measuring the cross-section area of the water flow and calculating the water velocity by timing a float along a measured distance. VITA's Village Technology Handbook and Peter Stern's excellent reference, Small-Scale Irrigation, (see Appendix I) provide assessment methods for each water source.

Planners should not overlook the educational opportunities in the mapping and measuring exercises. Local teachers could use the occasion for teaching math, public health or mapping. Student involvement will also increase the level of community participation, since the students can be expected to relate their experiences and lessons to their parents.

Of course, account must be taken of seasonal variation in the water sources. Village elders can provide the necessary information for this adjustment to the estimate. The elders will know which wells run dry and for how long and can describe the low water flows of streams and channels during the dry seasons. Unless storage facilities are available, the dry season capacity should be used in evaluating the project alternatives.

If community water supplies are greater than water requirements, as is often the case in tropical moist areas, then the real question may be how to protect the water from pollution or how to use it wisely. If the wet season capacity exceeds community requirements and there is a shortage in the dry season, then the best water development project may be some type of storage system so as to use the yearly water supply more efficiently.

In arid regions, the maximum seasonal water supply may be adequate or barely adequate; for the rest of the year outputs may fall well below minimum requirements. If minimum consumption requires more than a 100% increase in water supplies, it is likely that new sources will be needed. Otherwise, the objective may be achieved through a water conservation program, improving delivery or storage systems, or enlarging existing sources. In fact, these three alternatives are productive even if the development of new sources is ultimately necessary.

COMMUNITY WATER CONSERVATION PROGRAM

The most obvious waste of water is from a source that runs constantly whether in use or not. Water is also wasted when the flow cannot be constrained to conform to the rate at which containers or conduits can be filled. Water sources should be equipped with devices, such as valves or reduction pipes, that can vary the flow and force of water being delivered.

Excessive use of water is most common in agriculture, where farmers tend to put out more water than livestock require or to irrigate with larger quantities than are needed by the plants for optimal production.

Evaporation and seepage losses can be reduced to provide more available water. Exposed water surfaces, whether in reservoirs or ditches, lose huge quantities of water. Covers for water storage units or ditches can reduce evaporation up to 50%. By digging reservoirs and ditches deeper, more water can be moved or stored with less surface area exposed to evaporation. Seepage can also account for immense losses. Dug wells, springs or unlined irrigation canals allow water to seep into the soil. Lining with impervious materials like concrete or rocks can reduce the loss substantially. If pipes rather than open unlined canals are used, the water that can be delivered is effectively doubled simply by reducing losses. In addition, lined canals or closed pipes do not provide good habitat for snails and mosquitoes.

Conversion to closed water systems can be programmed over several years as labor, materials and funds are available. Each section of open canal or storage system that can be covered or lined will reduce water losses, until the system has been completely converted.

IMPROVED DELIVERY OR STORAGE SYSTEMS

Often, the water supply for a community would be adequate if it were evenly distributed over the year. Where it is not, improved storage systems can capture more water when it is available, for times when it is scarce.

The construction of enclosed water storage containers or cisterns can be quite effective. The Village Technology Handbook provides construction details for several types. Cisterns require a collection area or catchment to gather water during the wet season. A common method, used in the Caribbean, is to collect rain from the roof, allowing it to drain into a covered tank (Figure 13). Later the water can be purified with small amounts of chlorine.

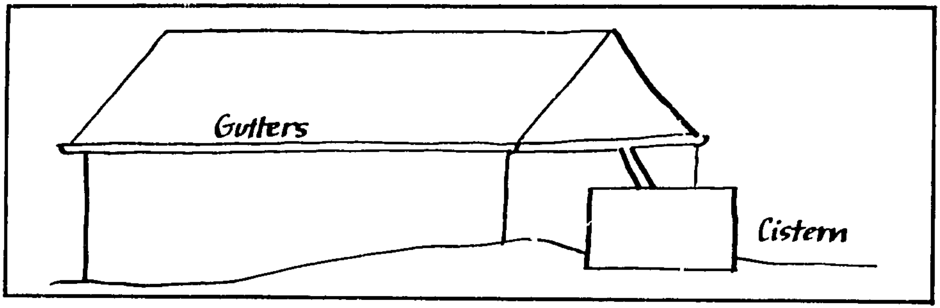


Figure 13. Cistern with Roof Catchment

Catchments for agricultural cisterns were a common practice in the arid Middle East. Channels or furrows were placed along barren hills leading to large cisterns or open reservoirs at the base of the hill. Surface water running off the hill was diverted by the water channels into the reservoir or cistern (Figure 14). This practice, over 2,000 years old, is being reintroduced in Israel with excellent results. During the dry season, the catchment can be improved by compacting the furrows or lining the catchment channels with rocks, concrete or plastic membranes. Asphaltic concrete has been applied to entire catchment areas, so as to capture even more of the precious water. The National Academy of Sciences devotes an entire chapter in its book More Water for Arid Lands to domestic and agricultural catchments. (See Appendix I.)

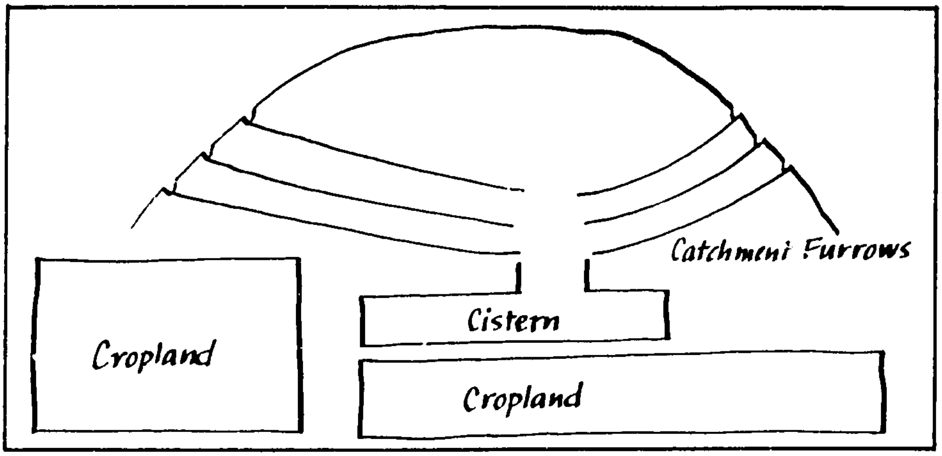


Figure 14. Catchment on Barren Hill

In all types of storage systems, closed cisterns are preferred to open reservoirs. By enclosing the storage tank, evaporation and seepage losses are kept at a minimum and the tanks do not provide breeding habitat for snails or mosquitoes. The cisterns should be placed as close as possible to the point of use to minimize the expense and complexity of delivery systems. In community systems, the roof area of several houses can feed into one cistern, thereby reducing the costs of construction.

Often, safe water is available to a community only at considerable distances, requiring the women and children to walk many kilometers several times per day to secure household supplies. If the burden becomes too great, they may turn to a source that is unsafe, but nearer by. Improving the delivery system is always an expensive task unless local labor and materials can be used. The advantages of lining or piping are apparent, but heretofore the high cost of concrete, fiberglass or polyvinyl chloride (PVC) has been prohibitive. Recent improvement and transfer of PVC technology provides exciting new possibilities. In countries where the technology is available, the light and flexible PVC pipe is relatively inexpensive and adaptable to rural conditions. Many community systems have been built with PVC pipe using local labor to dig trenches and to transport the durable piping.

Obviously, there are prerequisites to piped water systems. Unless the water source is at a higher elevation than the village, expensive pumps are necessary. The pipe must be buried, since sunlight makes the material very brittle. Unfortunately, rodents seem to be attracted to PVC, often gnawing small holes in the pipe. Frequent inspection and repair of the system is therefore necessary. The use of PVC is expected to increase as more developing countries acquire the pipe-making facilities.

Concrete is more commonly used for linings or conduits in developing countries. The advantages of concrete are that it can be cast on-site and local labor can easily develop the necessary construction skills. The Village Technology Handbook provides technical information plus designs for forms and molds that can be used for casting linings or conduits for water supply systems.

Concrete lining permits construction of narrow and deep canals with higher water velocity to reduce mosquito and snail breeding and less surface area to minimize evaporation. Water flow is more easily regulated in pipes or lined canals so less water is wasted through uncontrolled flows. Seepage losses in both situations are virtually eliminated.

In tropical moist areas, wood conduits may be used to carry water. Bamboo makes excellent piping, where small water volumes are handled. The villagers will know how to remove the internal barriers in the bamboo. The ends can be shaved or widened to form water-tight connections, once wrapped with tarred rope. The bamboo is light, sturdy and somewhat flexible--a good piping material for bringing water from spring or cistern to a dwelling or central square.

ENLARGING EXISTING SOURCES

Any water source unattended for a number of years has been reduced in efficiency and capacity by the addition of debris and sediments. Dug wells and tube wells slowly fill in as walls erode. As these wells are cleaned, they can also be enlarged either in depth or diameter. With lined wells, or tube wells with casings, increasing the diameter is not recommended, since the lining would have to be removed. However, the well can be enlarged below the lining or casing and, unless there is impervious rock layer, can be dug deeper.

Open reservoirs and surface-water cisterns accumulate sediments and require periodic cleaning. The reservoirs can be enlarged during cleaning by removing more material both in and around the reservoir. Care should be taken not to disrupt any impervious layer or to exceed the water volume that can safely be held back by the dam or barrier.

DEVELOPING NEW WATER SOURCES

If all the alternatives for improving existing sources have been explored and a community is still short of water, the search for new sources should be undertaken with recognition that the easy or obvious may have already been done; new sources may be harder to find or more expensive to develop. Some possibilities--such as cisterns--have been discussed under the heading of improvements. The most likely new source will be various kinds of wells.

- In rural areas, dug wells are a very common method of providing new water. If lining materials such as concrete or masonry are available, dug wells are inexpensive and durable. Wells 1.5 meters in diameter can be dug by two men, and sections of the concrete casing can be cast in place. After the first section is cast, the well-diggers merely remove soil beneath the casing and, as it is lowered, new sections are cast on top until the well goes below the dry season water table.

  Linings are recommended for dug wells to prolong well life and to reduce contamination. The casing or lining should rise at least one meter above ground level. This prevents small children and animals from falling into the well and also reduces the amount of contaminated water spilling back from the ground surface.

  Ideally, the well should be covered and water removed by some type of hand pump, rather than expensive and hard-to-repair motorized pumps. Realistically, however, in many remote areas even hand pumps create insurmountable repair problems and the most feasible well design incorporates simple bucket mechanisms. The bucket should be a part of the well so that people do not use their own containers, which may be contaminated, to dip water. Several bucket designs, including self-tipping varieties, are available in appropriate technology literature.

- In areas of soft soils, sand or limestone, bored wells can be made with hand-powered borers or augers. If and when water-bearing layers are penetrated, small diameter pipes with strainers are sunk into the bore hole and a pump is attached. The well should be capped to prevent contamination. The Village Technology Handbook offers directions on how to construct simple boring equipment and advice on techniques. The book also has technical designs for concrete tile machines to make well casings. Bore or tube wells are commonly used for domestic and agricultural water supplies. If soils are favorable and the boring equipment is available, the bored wells are an environmentally sound source of water, providing non-motorized and easily maintained pumps can be used.

- Driven wells are made by driving a well-point (a pointed strainer) into soft or sandy soils. The well is driven by pounding pipes (with a special cap) connected to the perforated well-point until water-bearing layers are reached. The pipes provide a well casing as they are driven into the ground. The driven wells require a special pump and this may produce maintenance problems.

A problem common to all types of wells is seepage of contaminated water back into the source. Even the best casings cannot prevent all seepage, so methods to reduce spillage or seepage must be devised. Wells should be surrounded by sloping concrete aprons with drainage furrows. Water spilled at the well will then be directed away rather than back toward the casing. Trenches of loose gravel around the edge of the apron will eliminate puddles which encourage snail or insect breeding. Layers of clay mixed with water puddled around the casing will also reduce seepage into the well (Figures 15 and 16).

To keep livestock away from wells, water should be carried by conduits to troughs or holding tanks some distance away. Gravel beneath and around the trough and tanks eliminates standing water.

People can also be encouraged to do laundry or bathe away from the well by the addition of a cement laundry or bathing pads 20-25 meters from the well. Gravel drains should also be included in these areas.

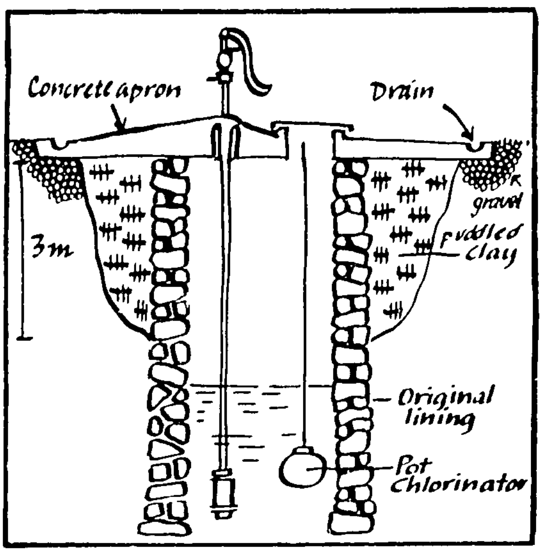


Figure 15. Well with Pump (after Wagner & Lanoix)

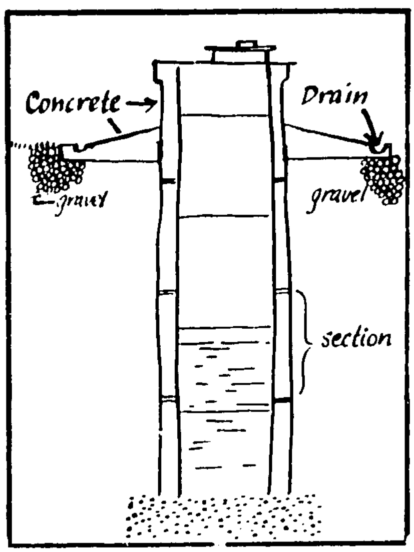


Figure 16. Well with Wall (after Rajagopalan & Shiffman)

- Sand reservoirs can be constructed in arid regions to provide new sources of water. A low barrier (approximately 1 meter) can be built across seasonal streams. If the sediment load of the stream is sand, it will settle behind the barrier. The dam can be raised in one meter increments for the next 3-4 years, if topography permits. Water will remain in the spaces between the sand grains and can be tapped with driven wells (Figure 17). Sand reservoirs can hold a great deal of water without excessive loss from evaporation and they do not provide habitats for disease vectors.

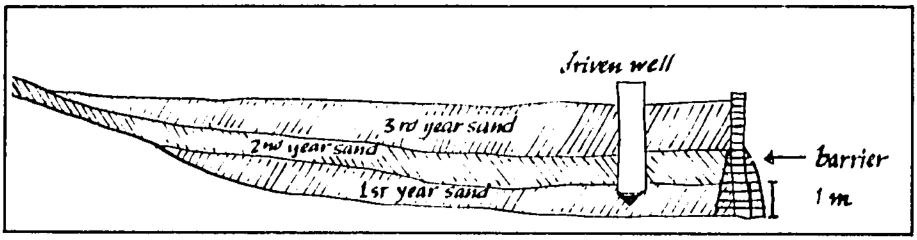


Figure 17. Cross Section of Sand Reservoir

- Open reservoirs are not a preferred alternative in arid zones because evaporation is excessive and health risks are serious. However, open catchments can serve as temporary livestock watering areas. Also, open reservoirs can be useful in recharging aquifers in order to raise the water table and thereby refill dug wells.

PROTECTING WATER SUPPLIES

Once water sources are developed, they should be protected from damage by humans and animals. Burying pipes or building fences around wells can be helpful. The value of these protective measures can easily be demonstrated. However, protection of the watershed is often neglected because the value is not readily apparent. Watershed protection is a long-term investment that only gradually improves the water supply. It is difficult to see that many current water problems are the result of poor watershed management in the not-so-distant past.

If, in arid regions, surface water is allowed to escape as surface runoff before it can be utilized, a major loss has occurred. Natural ecosystems prevent excessive runoff and erosion by providing a vegetation buffer between rain and soil. In order to maintain this natural protection, plant cover must be retained in water collection areas or areas adjacent to water supplies. The vegetation can consist of a mixture of grasses, shrubs and trees. The first step in developing this protection is through reforestation projects. Young trees can be planted and tended until roots reach deeper water layers. As the trees begin to bind the soil and provide shade, other types of plants may be introduced artificially or naturally, until a complete mixture of grasses, shrubs and trees is established, providing three plant layers of soil protection.

Water development projects should include strategies for protection by some form of plant cover in the watershed. The first step is education designed to convince the community of the necessity of protecting water sources with plants. If the community does not understand or appreciate the need, the project will fail.

In order to protect watersheds it is not necessary to create inviolate preserves, but rather a management area. Plants or wood products can be harvested as long as the natural rate of replacement is equal to or greater than the amount harvested. However, the management area should be well-defined and should receive higher levels of protection than areas that do not contribute to the water supply.

On watersheds unprotected by vegetation, development of water resources must begin with afforestation, whether with quick-growing trees or other kinds of plants. The species of trees to be planted can be selected with the advice of government forestry experts. However, trees should be selected on the basis of utility to the community as well as characteristics of quick growth for watershed protection. For instance, fruit or nut trees can perhaps be planted to supplement food supply or develop a cash crop. If fuel is scarce, trees can be selected for their value as firewood. The key to the success of tree planting is maintenance of their future growth. It will not suffice to plant hundreds of trees and fail to monitor their progress or provide them with some degree of protection. Even if properly planted, most trees wil not survive unless they receive added care for a few years. Seedling trees are vulnerable to damage by animals and are susceptible to drought until the root systems become established. A tree planting program must include provisions for temporary protection from animals with barriers or fencing and may need supplemental water for at least two years. If the community supports the project, "tree guardians" can be appointed to care for the trees and to supply small amounts of water when the symptoms of drying become apparent.

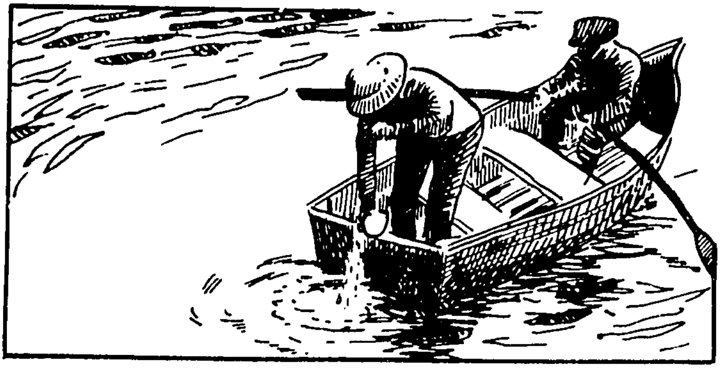
The rewards of a well-executed watershed management program are not dramatic. Unless records are kept, the improvements are so subtle that villagers will not see the results nor remember the conditions before the project began. Like most environmental change, increments are small and spread over long periods but they can produce significant results. Efforts to protect watersheds are one of the best investments for the future.

OPERATION AND MAINTENANCE

Improving or creating water supplies is gratifying, but is only one-half of the project. Unless provisions are made to ensure effective maintenance, the water supply may quickly return to pre-project levels yet be expected to fulfill an increased demand. Plans and organization for operation and maintenance should be established before the project begins. Community support and acceptance of responsibility for the project are as crucial to maintenance as to development. Water development projects in which villagers were assigned or elected as titled caretakers or watchmen trained in operation and maintenance have had great success. A community organization to "care for the water" can benefit water projects. Effective water projects will involve development of new skills and experience in working with metals, masonry, pumps and in preventative maintenance where appropriate. This will contribute to sustaining the project after the departure of the development team.

Local technology should be the basis of the project. If the project depends on outside skills or foreign parts, it will be only as good as the availability of those goods or services. Before accepting a pump or other mechanical device, make sure the replacement parts are available and repairs can be made by members of the community.

Increasing or improving water supplies is a difficult and expensive task. The United Nations' goal of providing safe water for everyone by 1990 seems out of reach. But to relieve the daily lives of those people to whom 38 liters per day would be a luxury is an achievement not to be measured in numbers alone. Small steps in water development taken in thousands of villages are far more effective than gigantic projects at a few sites.



5. SANITATION AND WASTE TREATMENT

"In many instances, it is a question of life or death, not speak of human dignity and self-respect. One cannot teach a child to read if he is debilitated by diarrhea, or expect a man to take a great interest in improving his shelter if he has to wade through his own, his neighbors' and his animals' filth."

Grava

In all of the nations of the world, one common problem is adequate sanitary waste collection and excreta disposal. However, excreta should be regarded as a resource rather than a waste. In many parts of the world, human excreta is regarded as a valuable commodity, carefully collected and sold for fish farming or agriculture. However, many health hazards are associated with these practices. In other areas, human excreta and other organic wastes are used to provide domestic energy supplies while satisfying the seven performance criteria of Wagner and Lanoix.

The problems of collection and disposal are particularly far from being solved in developing nations. Improvements in excreta disposal are essential in order to raise levels of public health. Small-scale waste disposal technology has lagged behind the recent advances in water supply. Yet, both technologies are equally important, for if water supply is increased and sanitation is not improved, the new water supply provides a vehicle for the further spread of disease. Often the typical response to waste disposal problems is to apply industrialized technology which is expensive and wasteful of natural resources. Water-borne sewer or septic systems, which work well in temperate zone industrial nations, are often inappropriate in tropical areas. Fortunately some efforts have been made recently to determine which small-scale disposal technologies are cost-effective for the rural tropics.

OBJECTIVES FOR EXCRETA DISPOSAL SYSTEMS

The 1958 World Health Organization publication by Wagner and Lanoix (Appendix I) is still the best source of information on the disposal of human wastes in developing countries, although the Village Technology Handbook offers many of the same designs and recommendations. Wagner and Lanoix offer seven rather stringent criteria for any excreta disposal system:

- The system should be simple and inexpensive in construction and operation

- Handling of fresh excreta should be kept to a strict minimum

- Excreta should not be accessible to flies or animals

- Contamination of wells and springs should be prevented
- Pollution of surface water should be safeguarded against
- The surface soil should not be contaminated
- There should be freedom from odors or unsightly conditions.

These criteria have been listed in order of priority, although some may disagree with the arrangement. Surprisingly, if some of the conditions can be met, the others fall into place or are met at least in part. In addition to these criteria, the system must be culturally acceptable and supported by the community. The collection, storage and treatment of the water must not be incompatible with local customs or religious practices.

BASIC WASTE DISPOSAL METHODS

The many methods of waste disposal are all variants of three basic types:

- Removal, where excreta is collected and transported, either manually or automatically to a discharge site or a central facility for further processing. A common method in urban areas.
- Infiltration, or the absorption and dispersion of waste materials into soil or ground water. Common in rural areas and a source of serious contamination.

- Destruction, where excreta and other wastes are converted into useful and harmless substances.

The relationship of the three methods is diagramed in Figure 18.

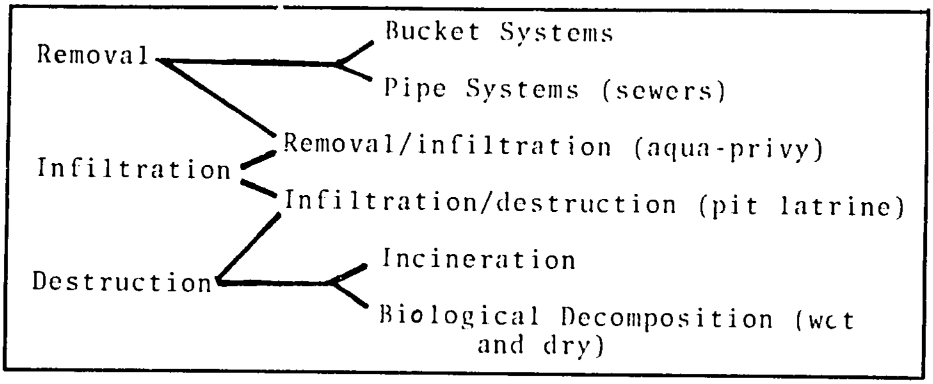


Figure 18. Classification of Disposal System (after Winblad)

Other than bucket latrines, the most common excreta disposal systems are combinations of the three basic methods. Using combinations of new and old techniques may be the best approach in designing small-scale village sanitary systems, because one method is not likely to meet economic, social and environmental criteria for an entire village. A slight difference in soil texture, ground water or proximity to surface water or cropland in one location can make a method less suitable than it might be at another location.

Removal systems with pipes or conduits for human wastes are generally too costly for rural projects. In urban areas, where large sewer mains are available for connection, piped systems may be very appropriate. Sewer systems are capital intensive and require large volumes of water for operation, rendering them less suitable for arid regions.

Removal by bucket is a common and viable option for excreta disposal. This is especially true in villages and cities near agricultural areas where human excreta, or night soil, has been traditionally used to fertilize croplands. In many Asian communities, collectors pay householders for the wastes which are then transported in tank trucks or push-cart vaults to farm areas and sold to farmers. The system is inexpensive and does not require water; but it may create health hazards from handling or exposure to flies and also is odorous. In the best of the bucket systems, the bucket is routinely cleaned and tarred or disinfected and equipped with a tight-fitting vermin-proof cover.

In more urbanized areas, a ventilated vault may replace the bucket. The vault is pumped out by a vacuum truck and the excreta taken to a central site for treatment or directly into the country to be sold to farmers. The system is an improvement over buckets in that handling and odors are reduced.

The chemical toilet is also a modification of the bucket latrine. Bacteria-killing chemicals, such as formaldehyde, are added to the bucket to reduce odors and handling hazards. The initial cost of the chemical toilet is low but depends on a constant supply of expensive chemicals. Furthermore, the chemicals may cause environmental harm at disposal sites by killing fish and vegetation. The chemicals also destroy natural bacteria in the excreta and delay the decomposition process. The chemical toilet is not recommended as a means for excreta disposal in rural areas.

The aqua-privy (Figure 19), a removal/infiltration technique, eliminates some of the problems of bucket latrines but at increasing cost. The unit consists of a watertight vault or tank in which water is kept at a constant level by an overflow drain. Waste material, dropped beneath the surface of the water, is decomposed by anaerobic bacteria (bacteria that do not require oxygen), which are normally present in fecal material. The resulting sludge must periodically be removed (by pumping or vacuum truck). If the sludge is not exposed to fresh pathogens for three weeks, it can be spread on croplands with little health risk. The overflow liquids, mostly urine and contaminated water, infiltrate the soil and may introduce pathogens, so aqua-privies should not be located within 15-20 meters of a well or other domestic water source. The soil surrounding the aqua-privy should be permeable to allow rapid percolation of the effluent. To prevent too heavy concentration of the effluent, units should be at least 15 meters apart.

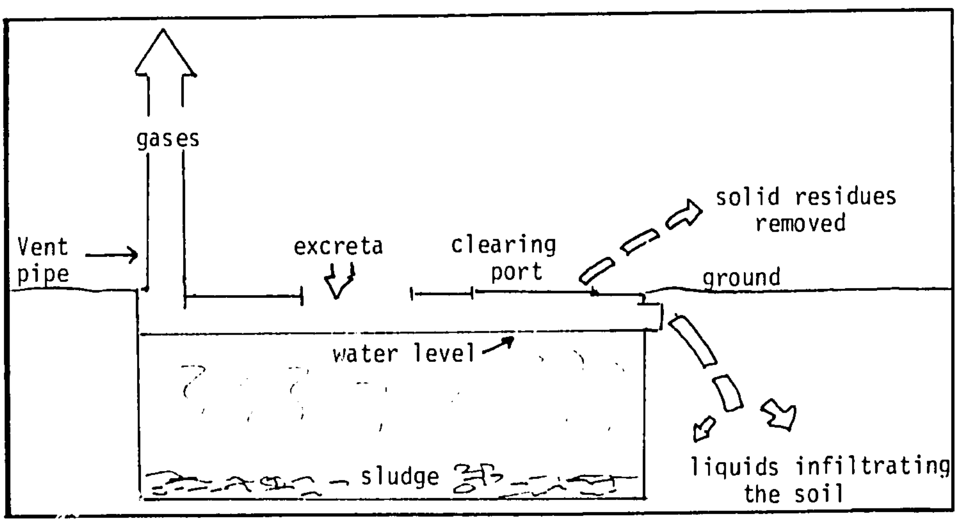


Figure 19. The Aqua-Privy

The reduction of health hazards and odor may be worth the increased cost of the aqua-privy, if construction material is locally available. Unless vents and other openings are screened or covered, insects can use the water for breeding. The vents are necessary because anaerobic decomposition does produce a combustible gas. The vents should not be placed near open flames and should extend at least two meters high. In some systems, the gas can be captured for domestic cooking and heating.

The septic tank is another removal/infiltration approach, direct from the temperate industrialized areas (Figure 20). In this system, water is added to the excreta before entering the infiltration tank. Effluent infiltrates the soil by way of an overflow drain which can go directly into the soil or be directed to a soakage pit or filter drains. Solids are retained in the tank and slowly decompose anaerobically. The residue, or sludge, must be removed when the tank becomes filled with solid material. It is much the same as an aqua-privy, except for much higher water consumption, a serious disadvantage in arid regions. The septic tank requires permeable soil or an extensive drain field of gravel and pipes. In areas of high water tables or impermeable soils, the effluent may rise to the surface, providing breeding habitat for disease vectors.

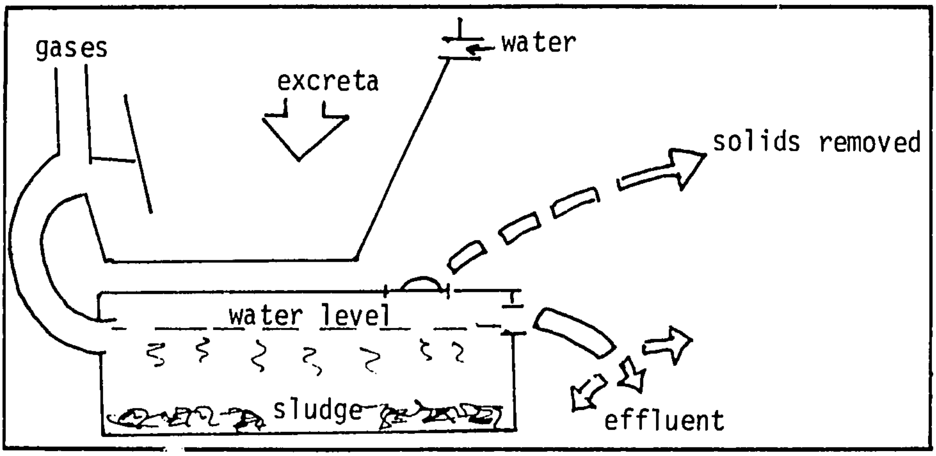


Figure 20. Septic System

The pit latrine, which may be nothing more than a hole in the ground, is commonly used as a temporary waste disposal method or as the first step in the development of village sanitary systems. With improvements, the pit latrine can be less temporary and more sanitary.

This cheap and simple latrine consists of a hole or trench, often covered by a plate or slab. Liquid wastes seep off into the soil and the solids accumulate, slowly decomposing, until the pit is filled. Thereafter, a new pit is dug and the old one is covered with earth.

Designs for the latrine slab can be found in Village Technology Handbook and the publication by Wagner and Lanoix. The pit latrine does have drawbacks, to be sure. Some soil is contaminated by the wastes and nearby water supplies may be polluted. Latrines should not be located near a water source. The problems of odor and flies are not solved by pit latrines. Squatting plates can be provided with covers, but they may be left open. Selfclosing covers have not been successful, although several designs are available. Squatting plates can be made of wood, bamboo or concrete. Designs for squatting plates with construction directions are provided in Village Technology Handbook.

The newest innovations in small-scale waste disposal use destruction methods. Destruction is a poor term because the aim is to produce something useful. Incineration is an exception since burning of wastes requires expensive equipment without provisions for capturing the released energy. For small-scale projects, incineration is not recommended. Any of the following is a better alternative.

The "dry composting" techniques not only destroy wastes but provide an inoffensive, stable soil conditioner. The dry composter, or Multrum, consists of a water-tight container equipped with air intake and ventilation ducts and two access chutes, one for excreta and the other for organic kitchen wastes (Figure 21). Before operation, a layer of partially decomposed organic material (leaves, grass or sediments) mixed with soil is placed on the bottom of the container. Aerobic bacteria (bacteria that require oxygen) in the partially decayed material, along with those in the excreta, decompose the contents into an enriched humus which can be added to garden soils. Water and carbon dioxide, by-products of the decomposition, escape through the vent. As the waste settles down into layers, it is reduced to less than 10% of the original volume. The bottom layer, or compost, is fully decomposed and can be removed through a small door. Heat generated from the decomposition destroys most pathogenic organisms including roundworm eggs and bacteria. Covers and vent traps should be used to keep insects away from the top layers of the tank.

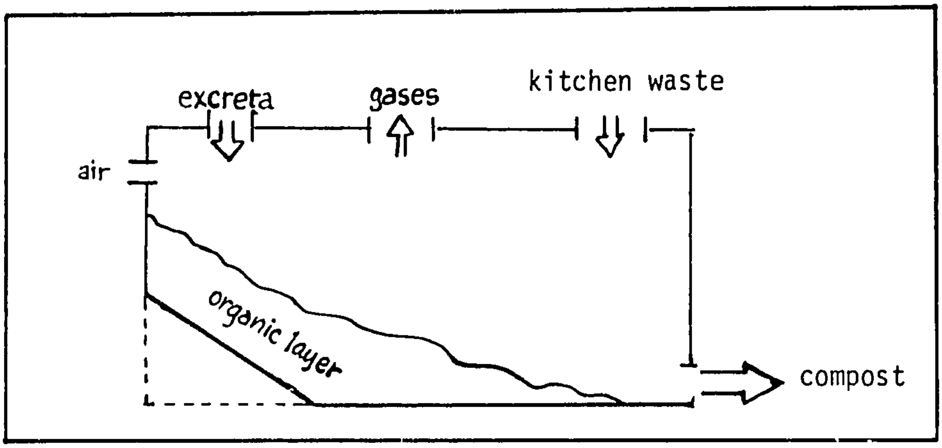


Figure 21. The Multrum, Dry Composting Disposal

The Multrum dry composter meets the performance criteria for waste disposal systems. Initial costs are high but, if the value of the recycled nutrients is subtracted from the original costs, the cost/benefit ratios become very favorable. Dry composting is simple and economical and is one of the most ecologically sound techniques for human waste disposal.

In Viet Nam, a double vault composting latrine (Figure 22) was developed for dry composting of human excreta. Two cement-lined vaults are constructed above ground level with access doors for each vault. The vaults are covered with "squatting plates", one opening into each vault. One vault is used until filled, then sealed off while the other vault is in use. After 45 days, the filled vault is opened and a rich, harmless, odorless fertilizer is removed through the access door. Urine is separated from fecal matter by a groove in the squatting slab. The latrine design is being promoted by UNICEF in other Asian countries.

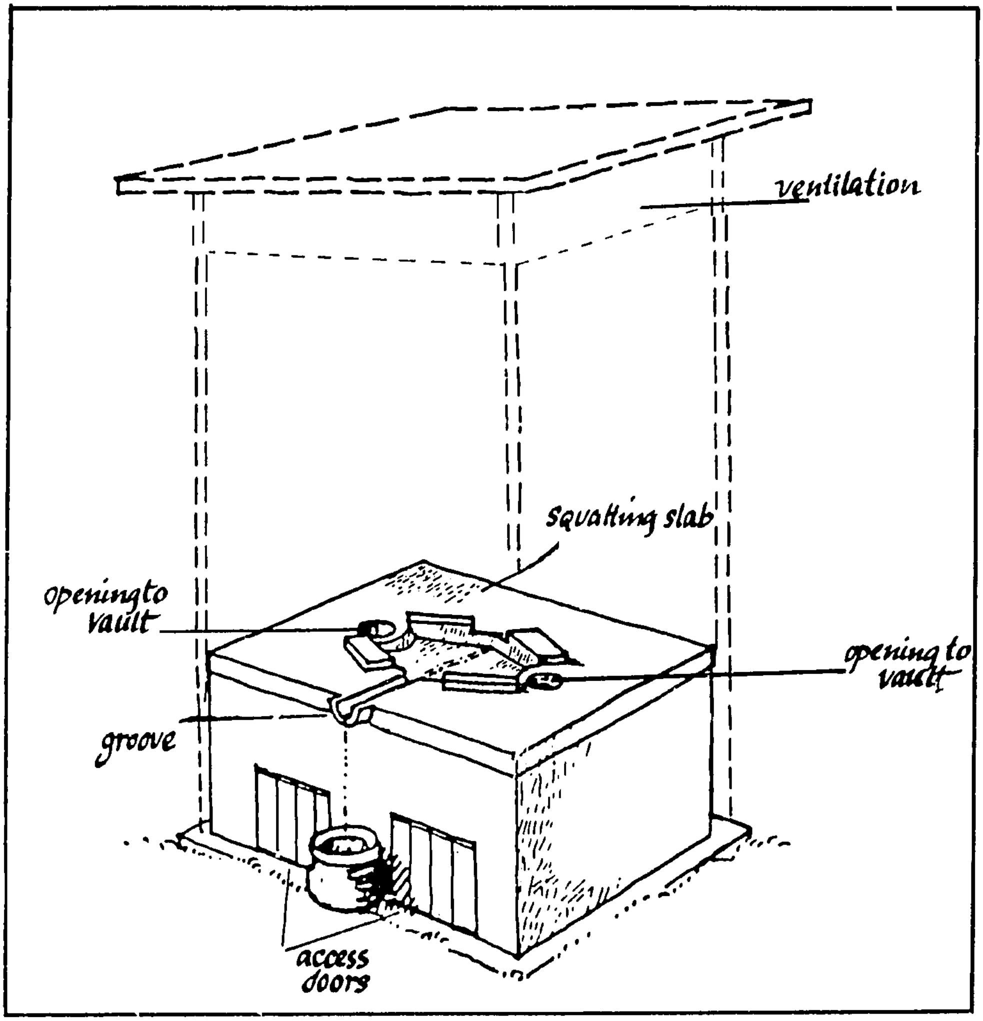


Figure 22. Double Vault Composting Latrine (after UNICEF News)

Wet composting methods offer equally sound alternatives for waste disposal and are becoming increasingly common in developed and developing countries. The People's Republic of China has reported success with a three-stage method of waste disposal that is particularly effective in reducing the incidence of schistosomiasis. In this design, a container with three internal compartments is used to render the wastes less hazardous to human health and produce a valuable by-product (Figure 23). Wastes are introduced into the first compartment through a water trap. The wastes begin to undergo anaerobic decomposition and the schistosome eggs, being heavier than water, begin to sink. The diluted excreta moves into the second compartment while decomposition continues. When the material reaches the third compartment, decomposition may be nearly complete and all of the schistosome eggs have been removed or rendered inactive by chemical changes in the effluent. The residues removed from the third compartment are a valued resource to be spread on cropland or added to fish culture ponds.

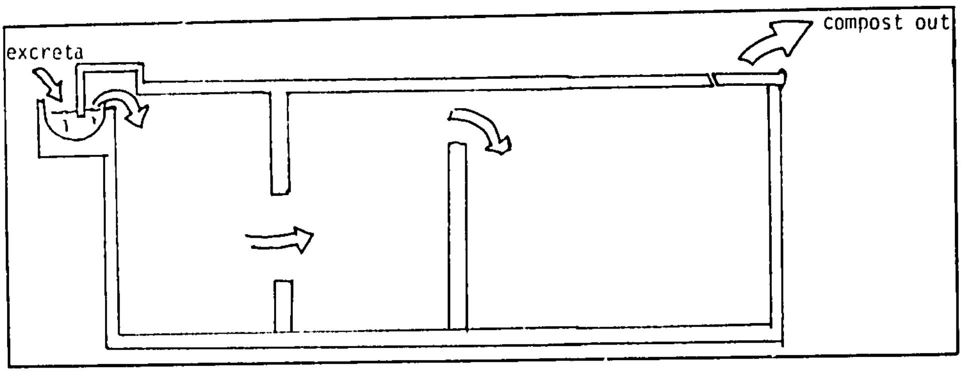


Figure 23. Cross Section, Chinese Three-Stage Cesspool

Initial cost is high, as in dry composting, and the residue is likely to contain pathogens other than schistosomes. Anaerobic decomposition proceeds at a much slower rate than aerobic decomposition and does not generate as much heat; therefore pathogenic bacteria will survive the process. Anaerobic decomposition is also likely to create a thick scum on the surface which hardens enough to require a complete clean-out on a regular basis.

Another method of waste disposal exploits another feature of anaerobic decomposition. When the bacteria break down wastes without oxygen, a gas containing methane is produced. This biogas is combustible and produces between 30-60% of the energy contained in natural gas. Large and small biogas plants have been built around the world to supplement dwindling supplies of firewood or petroleum products. It is estimated that there are over 10,000 plants in operation in India, 29,000 in Korea, 7,000 in Taiwan and 80,000 in the People's Republic of China.

The amount of gas produced from wastes depends upon several conditions, the most important ones being temperature and the type of waste used. For example, the dung from one medium-sized animal (cow, bullock or buffalo) can produce 500 to 600 liters of gas per day while the daily production of gas from a human's waste is only 30 liters. The optimum temperature is either between a low range of 30-40° Celsius (C) or between a high range of 48-60° C. The farther away from either temperature range, the greater the reduction in gas production. The higher range (48-60° C) is usually not considered practical for small-scale projects as it requires supplemental heat. Peter-John Meynell's book, Methane: Planning a Digestor, has all of the elements for planning and designing a biogas plant.

While it is beyond the scope of this book to describe the various types of biogas producers or anaerobic digestors, a simple design can be offered for small-scale use (Figure

24). This digestor uses three barrels (200 liters, 160 liters and 120 liters) without tops commonly used for chemical or petroleum products, some metal tubing or rods, a simple valve and some flexible tubing (rubber or polyethelene). The smallest barrel is placed inside the largest barrel and filled with wastes (dung, sawdust, leaves, kitchen wastes, urine) and partially filled with water and the middle barrel is inverted over the smallest barrel. Water is added to the larger barrel to make an airtight seal. The rods keep the barrel from tipping as it rises from the pressure of the biogas bubbling out of the wastes.

The digestors are odorless as is the gas, which can be burned without further processing. The holes on the burners may have to be enlarged if the burner was designed for bottled or natural gas. It would be wise to spill a small amount of oil on the water in the larger barrel to eliminate mosquito larva.

After the gas begins to give out, usually between 20-28 days, the waste materials must be replaced. With each filling, there is a delay in gas production for 2-3 days until the bacteria become well-established. What happens to the residue after digestion? It is an excellent soil conditioner and can be added to the garden, fish culture pond, or dried and fed to livestock.

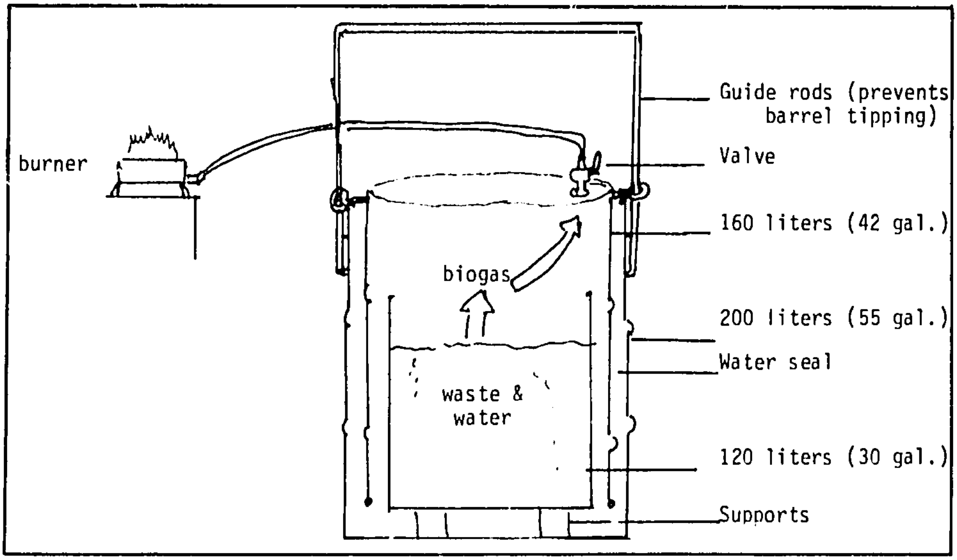


Figure 24. Barrel Biogas Generator (Tillman, Livellara & Vose. Unpublished.)

While not completely pathogen free, all the schistosome ova will have become inactive. Biogas digestors need more refinement but, even in a primitive state, they take community wastes and return two very useful products.

Microbial decomposition systems, or digestors, do offer great potential for the developing countries. Experimentation with these units on a village or multi-family level will improve the technology and reduce the costs of construction. Wider practice of controlled decomposition can relieve energy shortages, return valuable nutrients to the soil, improve water retention capacities of porous soils, reduce ground and surface water pollution, and lower the incidence of water-related disease. The higher initial costs are well worth the long range multiple benefits, environmentally and economically.

6. WATER AND AGRICULTURE

"And we created from water every living thing."

The Koran

The role of water in agriculture is well-known, especially by farmers in arid and semi-arid regions of the world. Good crop growth depends upon the availability of plant nutrients in the soil, sunlight and adequate water for seed germination, growth, flowering and maturation. For the most part, developing countries have plenty of sunlight and have undeveloped areas of potentially arable land. In the wetter parts of the tropics, rain-fed cultivation is the common practice. In these areas, the limiting factor in crop productivity is soil fertility. The farmer must control the movement of water so as to minimize the loss of soil nutrients and changes in soil structure.

In arid or semi-arid regions, there is little doubt that water is the limiting factor and farmers must select crops with low water requirements, develop techniques to conserve water, and devise methods to provide water other than rainfall to the crops. As a broad generalization, soils in arid and semi-arid regions tend to be more fertile than soils in the moist tropics. The exceptions would be the rich alluvial soils in the flood plains of large tropical river systems. These soils are fertile whether in moist or dry tropics.

Historically, the type of agriculture practiced in the tropics reflected the nature of the environment. In the moist tropics, farmers developed the "cut and burn" or "swidden" cultivation, where patches of forest were cut, burned and sown to crops. The new plants profited from the release of nutrients from the ashes for 2-3 years. When the nutrients were depleted, the farmer moved to a new site and repeated the cut-burn-sow process, allowing the abandoned plot to capture nutrients and slowly return to forest. The system, still widely employed in the moist tropics, does provide ample crops if human population densities are low and the abandoned plots have sufficient time to return to forest before being cropped again. Increasing agricultural pressures and changing patterns of land ownership have shortened the fallow period (time of natural regrowth) so that there is not enough time to replenish the nutrients necessary for a healthy crop. In addition, as more and more new forest is cut for agriculture, the hidden environmental services performed by natural forests are lost. Natural forests, besides accumulating and storing nutrients, protect soil, retain water (in plants and soil), provide habitat for wild animals and native plants, give haven to aboriginal populations, purify air, moderate micro-climate and maintain a repository for the genetic information and characteristics contained within the thousands of plant and animal species, some found only in moist forest and some yet to be discovered by science. The rate of moist forest removal is cause for world-wide alarm and agricultural practices must therefore be modified so as to get maximum production from each hectare cut, if forests are to survive.

In the dry tropics, the agricultural patterns were different, but with the same basic concept of fallow agriculture. The lands were often occupied by nomadic tribesmen who would move livestock from area to area to capitalize on small seasonal water supplies and forage. In the less arid regions, some farming would develop with a pattern of crop and fallow, but in this case it was in order to benefit from the moisture which would accumulate in the soil beneath the native, fallow vegetation. If the fallow period was long enough, soil moisture would increase to a point where one crop could be sustained over a growing season. As in the moist tropics, conditions have changed due to population increases and land tenure pressures, resulting in shorter, inadequate fallow periods. To meet agricultural needs in the dry regions, irrigation has been widely introduced. It provides obvious benefits, but also can create many perplexing environmental and social problems.

Many of the problems of tropical agriculture stem from the misapplication of agricultural technology. Agriculturalists from developed nations assumed that the technologies which produced the massive crop surpluses in temperate zones could be transferred to tropical soils and climates. To a distressing extent, the results of this transfer have been disastrous, economically, socially and environmentally. Although some are still attempting the transfer, we have generally come to realize that temperate agricultural methods are not likely to be successful in tropical developing countries. Despite its recent origins, research in tropical agriculture has produced exciting results. Among other things it has given direction to environmentally sound water development for agriculture.

WATER AS TRANSPORT

A quick review of the water-agriculture relationships will provide a common base for discussing environmentally sound projects. For good or ill and often both, water moves things on agricultural lands and within plants. Regardless of the sources, water moves matter to and from agricultural sites, chemically and physically.

Chemical Transport

Many minerals, nutrients, pesticides and other chemicals are dissolved and carried in water through surface runoff, subsurface flow or percolation.

As overland flow, water moves by gravity toward streams, picking up chemicals, nutrients and soil particles on the way. Depending upon the amount of runoff, the kinds of materials carried and the amount of materials dissolved in the water, a number of negative effects can result from chemical transport. Increased nutrients can promote uncontrolled growth of algae and waterweeds in water bodies. These plants are capable of cutting off sunlight to the bottom plants, reducing their capacity for photosynthesis. As the algae and waterweeds die, decay depletes the oxygen in the water which, when coupled with the lower rate of photosynthesis, kills fish and other aquatic animals. Pesticides in runoff are also lethal to aquatic organisms at very low concentrations. Excessive nitrates and phosphates from agricultural fertilizers are health hazards when they are allowed to run off and contaminate domestic water supplies.

Percolation may move nutrients down below the root zone of plants where they are useless to agriculture. This is the major reason for the infertility of tropical soils in areas that receive over 2000 mm of rainfall annually. The amount and frequency of deep percolation depend upon the soil structure, amount of organic materials in the soil, the vegetative cover (amount and type), amount of rainfall and the underlying geologic formation.

Percolation has beneficial effects as well. Percolation is necessary for the recharging of ground water. Another benefit is the moving of dissolved salts deeper into the soil where they are not injurious to plants. A large percentage of the arid soils contain high levels of salt and percolation is necessary to remove those salts before crops are planted.

Physical Transport

Raindrops falling on unprotected soil strike with amazing force, adequate to dislodge particles and carry them from the site. Within limits, this movement--or erosion--is a natural and necessary process within the ecosystem. A flow of nutrients to aquatic environments is needed to maintain biological systems. The rich valley and plains soils are derived from erosion of an earlier geologic era and the fertility of flood plains is enhanced by the annual increments from upstream highlands. Erosion, then, is an important part of natural ecosystems, but can have unpleasant results when it is allowed, or encouraged, by man to become excessive.

Water carrying the suspended soil particles eventually slows when the topography becomes less steep. As velocity decreases, the heavier particles settle as stream or lake sediments, which can choke or divert streams, increase flood potential, foul turbines or cooling devices, and kill aquatic life. The suspended lighter material not only decreases passage of sunlight, but also presents a filtering problem for domestic or commercial water supplies.

Unfortunately, some development programs have failed to institute necessary erosion control measures and have actually increased the rate of erosion, thereby further impoverishing the people who were to benefit. In nearly every case, closer examination has shown that increased erosion was an unneccessary cost which could have been avoided through careful planning and little additional expense.

SOURCES OF WATER

Those seeking to develop agricultural water sources can generally be guided by the discussion of water sources in Chapter 4. There are some differences worth noting, however, since they do influence project planning. For instance, although it should not be assumed any water source can safely be used for cultivation, agricultural water supplies do not have to meet as high standards as those for drinking water. The presence of pesticides, nutrients and high bacterial or algal populations does not necessarily compromise use of water for agriculture. In fact, the additives may be beneficial to crop production.

Unlike domestic water requirements, agricultural needs are seasonal, limited to all or parts of a growing season. Normally, small-scale projects need not provide water for year-round irrigation. Crops can be selected to take full advantage of a wet season and supplemental sources may be needed only for short periods at the beginning or end of the growing season.

Water resources for agriculture can be intermittent. Unlike humans, or industry, most crop plants do not require a constant flow or constant volume of water. Plant water requirements vary with time in the life cycle (i.e., germination, growth, flowering, maturation) and during some stages plants are capable of surviving with little or no rainfall. Using the soil as a water reservoir, plants can endure long periods between rainfalls or irrigations.

Because of these differences between agricultural and other uses, the planner has a wider range of sources to tap for development. For instance, a surface source unacceptable for human consumption because of algal blooms or fecal contamination can still be used for irrigation. On the other hand, water may contain levels of boron, for example, which are not injurious to humans but are toxic to plants. Or, more common in arid lands, water may contain salts which affect taste but are not necessarily harmful to humans, yet can accumulate in the soil and kill plants. So, while issues of water supply and quality are less demanding for agriculture, there are still important limitations.

UTILIZING WATER RESOURCES

Since rainfall cannot be increased except by unreliable and expensive technology, ways must be found to increase the agricultural utility of the amount that does fall. There are several possibilities that may produce excellent results.

Increased Water Retention

Maintaining a vegetative cover is the best method to retain soil moisture. Surface runoff is greatest when land is stripped of vegetation. In order to minimize this loss, "no-tillage" agriculture is increasingly used with good results. In this method, the vegetation is not burned nor plowed under in preparation for seeding. Small areas are slightly opened to receive the new seeds and as the crop begins to grow, competing weeds are removed by hand. A plant canopy shields the soil from direct sun and prevents high evaporation rates all year, first by weeds and grasses, and later, by the growing crops. Water loss and erosion are controlled by this technique.

When plowing is necessary, water can be held longer if furrows follow the contour, cutting across slopes instead of up and down the slope. In this way, furrows act as barriers to the flow of surface water. Unplowed strips also accumulate soil moisture for the next season's crop. If the unplowed strips consist of legumes (a large plant family which includes alfalfa, clover, beans and groundnuts), the soil will be enriched with nitrogen and a crop can be harvested. World Neighbors publishes inexpensive and easily understood directions for making contours (see Appendix I). Terraces are another means of halting surface runoff, but involve more careful design and construction skills than do the other options.

Increasing the organic content of soil aids in water retention. By adding humus or the residues of composting to the soil, more water is held between the soil particles. For best results, the humus or compost should be worked lightly into the soil.

Organic mulching, or covering soil with agricultural wastes, is a proven method for retaining water and reducing erosion. Stalks, leaves and inedible parts of crops and other decaying material spread over the surface of the soil reduce evaporation and provide a physical barrier against wind and water erosion, while releasing nutrients to the soil.

Crop Selection

In most areas, crops are selected for reasons other than their water efficiency. As a result, they use far more water than other crops which could produce the same amount of nutrients. Some cash crops transpire large amounts of water during the growing season. By selecting crops with lower transpiration rates such as barley, sorghum, millet or beans, less water is lost from the small rain water supply. Table 5 summarizes water requirements of some plants.

Table 5. Plant Water Requirements

Low	Barley
	Beans
	Millet
	Oilseeds
	Onions
	Potatoes
	Sorghum
	Tobacco
	Tomatoes
Moderate	Corn
	Flax
	Soybeans
	Sugar beets
	Sweet potatoes
Higher	Alfalfa
	Citrus fruits
	Cotton
	Grapes
	Rice
	Sisal
Highest	Bananas
	Cocoa
	Coffee
	Dates
	Sugar cane

Since the amount of water used is governed in part by the length of the growing season, planners can conserve water by selecting crops that mature more rapidly and require less water. Under optimal rainfall conditions, these crops would have small yields than traditional or high-yield varieties. But during years of limited rainfall, they will produce relatively higher yields.

Many crop varieties have been developed especially for their water-saving characteristics. For instance, a short-strawed wheat is used in arid lands because it transpires less water than the varieties with taller stalks. In many cases, researchers have developed strains or varieties that do better in drier climates without reductions in crop yield.

Crops can also be selected for their ability to thrive on water of lower quality. The saline waters of some arid regions cannot be used on crop varieties which are successful in temperate regions, but salt-tolerant strains are available. Certain types of cotton, barley, wheat-grass, sugar beets, olives, date palms and pistachios have been cultivated successfully under conditions too saline for other crops.

Another exciting and potentially rewarding possibility is to cultivate plants which have not been traditionally exploited for agriculture, but which thrive in a variety of climates and soils. The National Academy of Sciences publication, Underexploited Tropical Plants with Promising Economic Value, describes 36 possible crops covering cereals, roots and tubers, vegetables, fruits, oilseeds, forage and other non-food crops. Some of the plants are adapted for moist tropics, others for dry tropics and still others for saline environments.

Timing of Planting

Much of the world still determines the time of planting by other than scientific methods. Planting by "signs" and "spiritual messages" or predetermined planting dates is still very much with us. Fortunately, some of the planting practices which appear to be based on traditional or supernatural events are actually based on knowledge gained through centuries of trial and error and cannot be improved upon. In other cases, these non-scientific methods miss the most opportune planting times. By selecting the earliest planting date when temperatures are cooler and soil moisture highest, the crops get maximum benefits from reduced evaporation and residual soil moisture. The wise planner will take a careful deliberate look at traditional practices to see if they maximize moisture retention of the soil.

IRRIGATED AGRICULTURE

Irrigated agriculture involves very complex soil-water interrelationships and should not be entered into lightly or in ignorance. Agricultural benefits can be high but environmental repercussions may well reduce the benefits--often to the point where costs exceed benefits and endure long after the project has ceased yielding any positive returns.

Irrigation has been practiced for over 5000 years. Some irrigation systems in Mesopotamia, Egypt, India, China and Peru, dating back thousands of years, are still in operation. Today irrigation technology is rapidly expanding through experimentation, and new knowledge permits the introduction of irrigation on sub-marginal lands and on smaller scales. However, the environmental consequences of a poorly planned and managed system remain perilous.

Peter Stern's recent book, Small Scale Irrigation (see Appendix I), is the most useful reference for anyone planning or implementing a small-scale irrigation project.

There is no single "best" method of irrigation. An appropriate method, always a compromise, will depend on several factors, including:

- supply and quality of water
- distance between water source and land to be irrigated
- topography of site
- infiltration and percolation rates of the soil
- water-holding capacity of the soil
- chemical characteristics of the soil
- moisture requirements of the crop
- climate
- amount of funds available
- amount of skilled and unskilled labor
- prevalence of water-related disease
- experience with irrigated agriculture
- cost of energy.

In spite of its length, this list is not exhaustive nor is it arranged in order of priority, but it helps to illustrate the complexity of irrigation decisions.

Irrigation projects can have far-reaching effects on the environment over an area larger than the project site. Irrigation has triggered dramatic increases in water-related diseases, especially schistosomiasis and malaria. Infection rates for schistosomiasis have jumped from 10% to 80% of the local population in some new irrigation areas. Insect pest populations, normally reduced to low levels during dry seasons, prosper from the year-round water, thereby increasing the reliance on expensive pesticides for control. Irrigation can also have an impact on water table depth, water quality, soil productivity, as well as consequences for society in terms of family structure, human mobility patterns, economic status of farmers and land ownership patterns. Hostilities between neighbors, adjoining communities and even countries have resulted from disputes over irrigation water and practices.

Just as irrigation projects affect the environment, some environmental factors can have a devastating impact on irrigation. Deforestation or mismanagement of the watershed can cripple an otherwise well-designed irrigation system. Industrial wastes from upstream sources may kill crops and render soils unsuitable for agriculture. Increased soil salinity or water-logging may put croplands out of production and be terribly costly to correct. Each year, thousands of hectares of agricultural lands are lost due to poor water control, often in small-scale projects. Planners must take precautions to ensure that environmental changes outside the project area will not have uncontrollable negative effects.

EFFECTS OF USING SURFACE WATER FOR IRRIGATION

Irrigation water from surface sources, usually diverted via canals, ditches or closed conduits, is commonly used for small-scale projects. The diversion of the water can affect aquatic and terrestrial environments.

Aquatic Environments

- Removal of water from rivers and streams reduces downstream flows, decreasing habitat for aquatic plants and animals.
- After irrigation, water returned to surface sources is of poorer quality than original water, often containing substances lethal to aquatic organisms.
- Lowered streams or rivers entering the sea will suffer increased encroachment of saltwater.
- Reduced water flows may cause increased siltation and sedimentation of rivers downstream .

Terrestrial Environments

- Irrigation may increase the amount of subsurface water until the water table rises into the plant root zone. The raised water table inhibits the growth of most agricultural crops by water-logging the soil, so that the exchange of oxygen between roots and soil pores cannot take place.
- The elevated water table may leave standing water at the surface providing ideal breeding sites for crop pests as well as snail and mosquito vectors of disease.

- As evaporation from high water tables increases, salt residues form unless the water is exceptionally free of salts. The salts may remain at toxic levels for a long period unless remedial steps are taken. Salinization caused by improper irrigation is the most common cause of abandoned cropland in arid or semi-arid regions.

EFFECTS OF USING GROUND WATER FOR IRRIGATION

The effects of using ground water for irrigation are similar in many respects to the effects of using surface water, especially in the terrestrial environment. If the ground water is applied in excess and runs off to surface waters, then the effects will be similar to those caused by return flows from surface sources, although the volume of the stream may be increased.

One significant difference does exist. Drawing irrigation water from ground water supplies does lower the water table, although not necessarily at the irrigated fields. The lowered water table causes secondary effects which must be considered by the planner:

- Marshes, springs and seeps may dry up. These areas provide habitat for wildlife.

- Stream and river flows may be reduced.

- Dug wells, used for domestic supplies, may run dry.

- Local vegetation, no longer able to reach the water table, may die. Animals dependent on native plants will disappear or become crop pests. Plants which are rare or unique to the area may disappear.

MAJOR PROBLEMS IN IRRIGATION

The most frequent and major negative effects of irrigation are water-logging, soil salinization, soil alkalinization and increased disease.

Water-logging is caused by seepage from irrigation canals or over-application of water, accompanied by insufficient drainage. To correct this may require artificial drainage systems--either open interceptor ditches placed at intervals on the fields to collect and drain excess water from the fields, or subsurface drains consisting of a series of perforated tile, concrete or plastic pipes in the soil. Subsurface drains, although more expensive, are the preferred option because they do not take up crop space, require less maintenance and do not provide habitat for disease vectors.

Farmers often operate on the philosophy that if a little water is good, more is better; therefore, they over-irrigate crops. One way to increase irrigation efficiency is to levy water use fees. Even if charges are minimal, farmers will be less likely to waste water. The fees can be used to pay for the routine maintenance of the system.

Salinization is the accumulation of mineral salts--sodium, calcium, magnesium or potassium--in the upper soil layers, including the plant root zone. A white crust or powder on the surface is characteristic of severe salinization, although crop yields decline before crusting appears. So-called secondary salinization occurs when ground water rises, carrying the salts upward to the root zone, and evaporation at the surface leaves the salts behind. If fields are well-drained and sufficient water is applied, the salts will generally leach down out of the plant root zone and will not affect plant growth. It is unfortunate that irrigation drainage does not receive the same degree of attention as the development of the water supply.

Alkalinization is a less common but more serious problem than salinization. Alkaline ground waters or sodium-rich irrigation waters can increase sodium ions in the upper layers of the soil by the same processes which cause salinization. The sodium ions change the soil structure, making it difficult to till and nearly impermeable to water. Alkalinization can be ameliorated by deep horizontal drains, application of large doses of organic manures, and permanent use of acids, but a cure requires expert analysis and treatment.

Increased disease associated with irrigation and other water projects has been treated earlier in Chapter 3.

IRRIGATION METHODS

The type of irrigation selected for a small-scale project depends upon many variables; each method has its advantages. Some have specific site, water or material requirements. A brief summary of the different methods will highlight some of the benefits or limitations of each type.

Watering Can

The simplest form of irrigation is with a watering can. With this technique, one man can manage a garden of about 500 sq. meters if the water source is adjacent to the plot. If the water source is 500 meters distant, he can manage only 250 sq. meters, illustrating the obvious disadvantage of this method.

Subsurface Clay Pots

Like the watering can, this method is labor intensive but requires little capital investment. Crude, unglazed clay pots are buried in the soil next to the crop seeds. The pots are filled with water and covered with a lid. Moisture slowly seeps through the sides of the pot in amounts sufficient to sustain many crop plants. The pots are refilled when necessary.

Pots can be made by unskilled labor, and children can help manage the system. Since pots are covered, they will not provide breeding sites for snails or mosquitoes. Water is conserved because seepage will not exceed the plants' requirements, and evaporation is minimal. There is no threat of water-logging or salinization, and the technique is well-adapted to no-tillage farming. It is possible to substitute other materials for the clay pots (e.g., bamboo tubes, gourds or cans with fibrous mesh covers) as long as small openings can be made in the container.

Both of these methods are economical of water but are labor intensive. They are best used with fruit or vegetable crops where individual plants have high value and are spaced so that moisture from the pots can reach each root system.

Basin Irrigation

This method is widely used and easy to operate. The basins, ranging in size from 1 sq. meter to several hectares, are surrounded by low banks (30-50 cm) called levees, bunds or dykes. The size of the basin depends on land ownership, topography and soil characteristics. Since the basins must be level, the amount of earth-moving can be reduced if smaller basins are used rather than large ones. Water is flooded into each basin from pipes or ditches and is allowed to soak into the soil. Rice, cotton, grain, maize, groundnuts, vegetables and orchard trees can be irrigated by the basin method. In fact, if each orchard tree has a basin, it doubles as a micro-catchment, collecting rainwater from a larger area.

Water input must be carefully regulated so as not to saturate the plants' root zones for extended periods. For crops other than rice, water should not be allowed to stand for longer than 24 hours.

Basins are arranged adjacent to supply channels and water is passed through gates (turn-outs) or siphons to each basin, as required. Ideally, basins should be constructed as narrow rectangles with the long axis perpendicular to the supply channel, so that the largest number of farmers can be served by a water supply channel of given length (Figure 25).

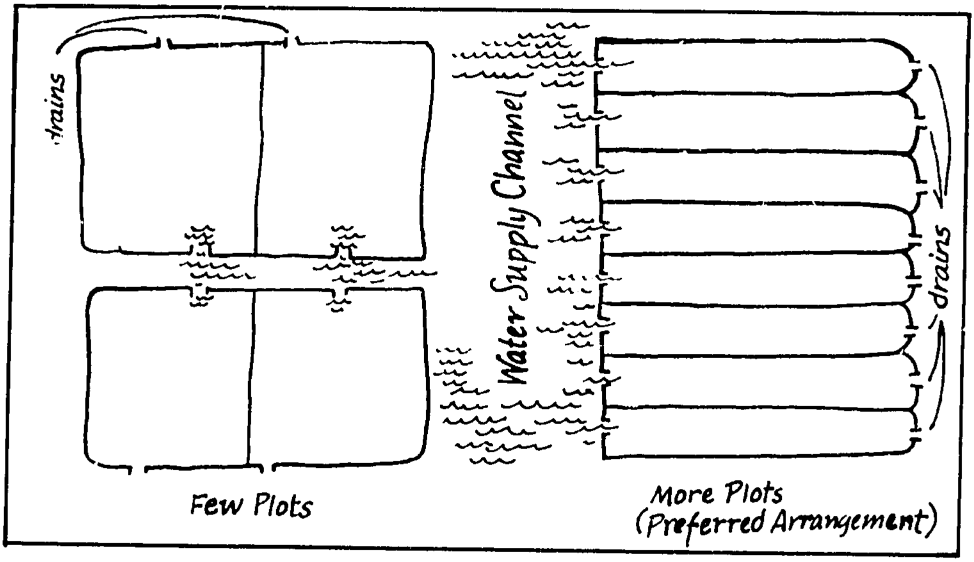


Figure 25. Basin Arrangement

Basin irrigation is not capital intensive and requires very little equipment. Land leveling can be done by hand or by draft animals pulling simple scrapers. Levees can also be constructed and maintained by hand tools or with simply fabricated ridgers.

Basin irrigation does pose health hazards, providing breeding sites for snails and mosquitoes. Water-logging and salinization are also threats unless drainage is provided. The levees can be destroyed by draft animals or wild animals. Erosion is not a serious problem.

Border Irrigation

This method makes use of parallel earth levees (20-25 cm high) to guide water down a long gentle slope, thereby irrigating the land between the levees (Figure 26). The width of the border (3-30 meters) and length (100-800 meters) depend on water supply, soil permeability and degree of slope. Periodically, a large volume of water is gated in and a sheet of water proceeds down the slope, percolating into the ground. If the proper amount of water is applied, all the water will have infiltrated into the soil as the leading edge of the water reaches the end of the border, and the risk of water-logging, salinization and disease will be small. Drains at the lower end will draw off excess water. Success with the system depends on an understanding of the relationship between slope and rate of infiltration, so it is not well-suited for small-scale projects.

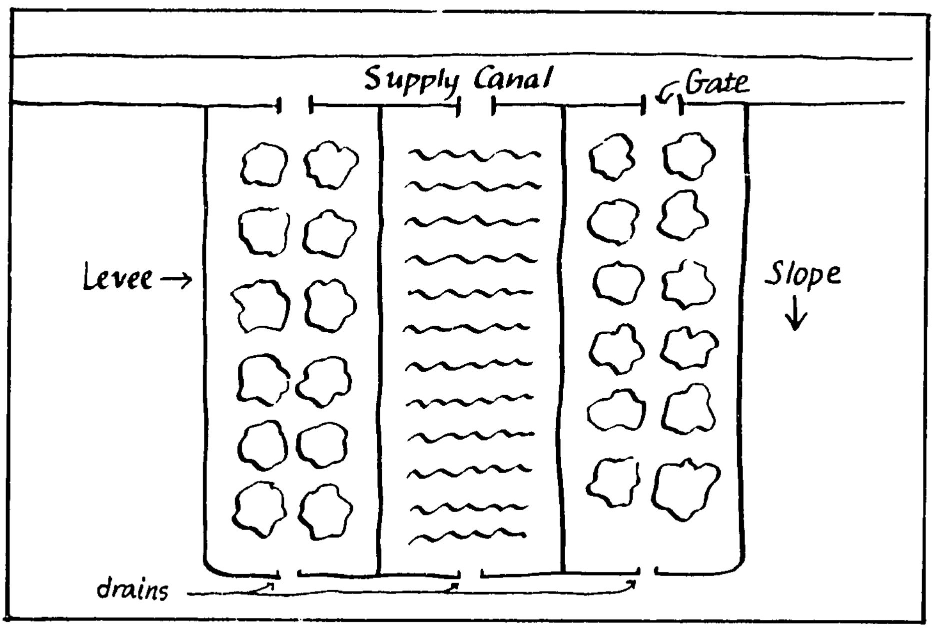


Figure 26. Border Irrigation

Wild Flooding

This method consists of spilling water through gates or siphons from a canal along the upper border of a sloping field. Water is allowed to flow freely down the field unless diverted by interception ditches or bunds. The method is best adapted for pasture or forage crops, where exposed soil is minimal. Efficiency is low, as the water released is not precisely controlled.

Furrow Irrigation

This method involves moving water in small channels (furrows) between rows of crops, down a gentle slope to a drainage ditch. Frequently used for high-value vegetable or fruit crops, it is the most complex of open-channel irrigation methods. Precise land grading is necessary and the furrows require continued attention. Furrow irrigation can produce excellent results and can be adapted to small-scale ventures. In large systems, the canals are often deep and water is controlled by gates. In small systems, supply canals can be dug by hand and water diverted by shoveled openings for each furrow. The length of the furrow can be determined by experience, since it will depend on water flow and soil porosity. For small-scale projects, the method is best used for higher value crops which cannot tolerate variable rainfall conditions.

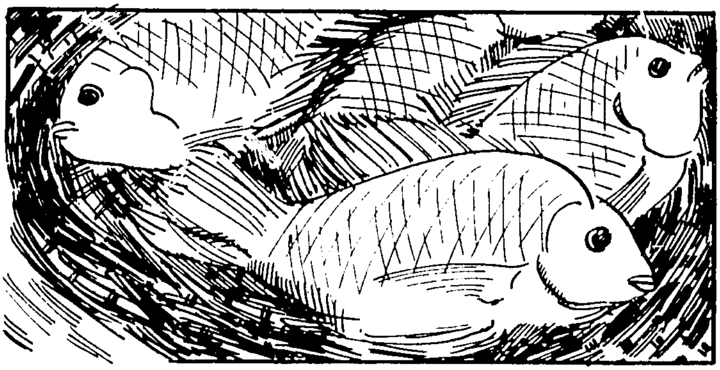
Sprinkler Irrigation

This method of irrigation is widely used in the developed nations but is normally inappropriate for small-scale projects. Water is sprayed on or beneath crops from high pressure sprinklers. The materials, usually imported, are expensive and require frequent replacement. The system is highly efficient and eliminates most health hazards. Since water volumes can be precisely regulated, waterlogging and salinization are unlikely. Unfortunately, this capital intensive method is not likely to be employed for rural small-scale projects.

Trickle Irrigation

Also known as drip irrigation, this is a high-technology version of the clay pots and is costly to install and maintain. In this method, hoses or pipelines deliver small amounts of water to the bases of high-value plants as needed. The tiny openings in the pipe clog easily so irrigation water must be filtered in advance. It is possible that local materials such as bamboo can be used; otherwise the cost will be prohibitive, which is unfortunate, because trickle irrigation can be very efficient and avoids the environmental problems of other irrigation systems.

Author's note: Before embarking on an irrigation project, the reader is urged to secure a copy of Peter Stern's Small Scale Irrigation. It is a most useful source of information.



7. AQUATIC PRODUCTS

"And he has set up the balance in order that ye may not transgress balance."

The Koran

Harvest of aquatic products can provide important supplements to the nutrition or the economy of local areas. Culture projects with fast-growing fish species have often been highly successful and have great potential for protein-deficient countries. Annual fish harvests exceeding 1000 kg per hectare have been demonstrated in several countries and the technology is suited for other areas. However, the success of artificial culture techniques such as fish ponds should not obscure other alternatives, such as the harvest of natural plant or animal products and for uses other than nutrition. Many plants or animals can be exploited on a sustained-yield basis to provide raw materials for craftwork, such as jewelry, clothing or furniture. If the plant or animal can provide food as well, so much the better. Obviously if an aqua-culture project depends on fresh water, it will be more appropriate to the moist tropics than to arid areas.

ENVIRONMENTAL GUIDELINES FOR NATURAL PRODUCT PROJECTS

- Regardless of economic value, recognized rare or endangered species should not be harvested. In spite of increasing international limitations, trade in endangered species, for pets or hides, is still common. Unfortunately, as species become rare, the economic value of the species increases, encouraging illegal trade. Development workers must discourage this type of activity.

- Projects should be developed for sustained yield. The removal rate of the plant or animal must not exceed the natural reproductive rate of the resource.

- The project must not jeopardize the existence of animals higher in the food chain. If a plant or animal is a major food source for larger animals, it should not be removed to such an extent that other animals in the ecosystem will suffer.

TYPES OF NATURAL PRODUCTS FOR SMALL PROJECTS

The harvest of native fish is generally well-established, although in many areas certain species are not taken because there is no market for them. A development worker may usefully examine the operation of native fishermen to determine if some types of fish are routinely cast away and whether it is possible that new methods of processing or preparation, such as fish meal, can win acceptance and add to the community's protein supply.

Shellfish are often ignored as a food source, merely because the community has little or no experience with preparation or utilization. Clams, mussels or even snails are excellent food sources and shells can be used to fashion jewelry or souvenir items for sale in urban areas. A warning here, however: shellfish are notorious accumulators of toxic substances, including bacterial and viral sources of disease. The water supply must not be contaminated if the shellfish are to be used as food.

Native plants can also be used for foods or craft materials. Plants normally thought of as weeds often produce leaves, tubers or seeds than can be very nutritious. Care must be taken to determine if any poisonous compounds are present, although most toxic plants are rendered harmless through cooking.

Seeds from native plants have been widely used for decorative items or jewelry. Fibers in the leaves or stalks can be used for furniture, household goods or cords, as with hemp. Other plant products may include resins for fuel, dyes or adhesives. Native plants, including some serious nuisances such as waterweeds choking waterways, can be used for agricultural mulching, bedding for livestock or as fodder. Insecticidal characteristics of some plants can reduce insect infestations of the animals, if the plants are used for livestock bedding.

AQUATIC CULTURE PROJECTS

Well-planned aqua-culture projects to produce fish, seaweeds, turtles or shellfish can yield many community benefits without adversely affecting environmental quality.

The ancient practice of fish culture is more common than turtle or shellfish culture and can be used as a model for discussion.

The most popular fish varieties under culture are carp and Tilapia, an African fish. The popularity of carp is due to its rapid growth rate and high productivity in managed ponds fertilized with night soil (human excreta). The most commonly stocked carp include silver carp (Hypophthalamichthys molitrix) and big-head carp (Amstichthys nobilis) which feed on plankton, common carp (Cyprinus carpio) and mud carp (Corrhina molitcrella) which feed on bottom detritus, and the grass carp (Ctenopharyngodon idella) which feeds on pond weeds. The Chinese often mix these species to maximize the production from the different nutrient sources in the pond.

The Tilapias are prolific producers with possible yields over 2000 kg/ha in fertilized ponds. The most common Tilapias (renamed Sarotheroden sp.) for fish culture are S. mossambicus and S. niloticus which feed on algae.

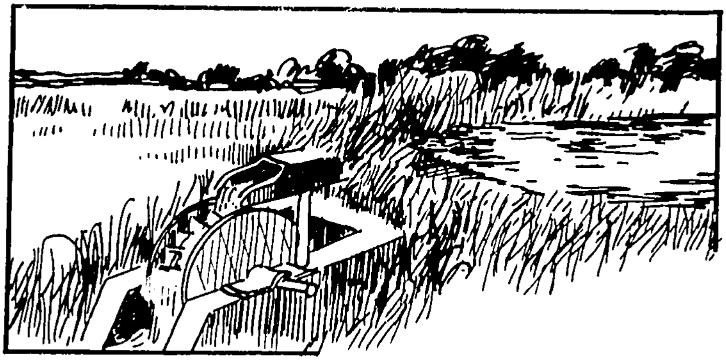
In preparing for a fish culture project, several environmental factors must be considered, first being the amount of water available for the ponds. Water supplies must be adequate to fill the ponds and replenish water lost by evaporation or seepage. Water must be free of toxic chemicals and, if unlined ponds are planned, the soil must be relatively impermeable to water.

To avoid extensive leveling or earth-moving, the topography of the pond site must be considered. To avoid pumping it is important that the water source be higher than the proposed pond or ponds. Accumulated bottom sediments and organic debris should not be released into water courses, where they will be polluting; instead they should be removed and deposited on agricultural lands (if they are nearby), where they will add valuable nutrients.

Fish culture can also be practiced in natural water courses. In Indonesia, cages (karambas) are constructed with 1-4 cm spacing between bars. The cages are stocked with small carp and anchored in rivers. After 2-3 months, the fish double in weight and 5075 kg of fish can be taken from a karamba with a volume of only one cubic meter. This type of culture is appropriate for nutrient-rich rivers and estuaries.

The danger of human disease is high in most fish culture projects, especially where ponds are fertilized with night soil. The threat is increased if raw or partially cooked fish are traditionally consumed by the villagers. The incidence of liver fluke (Clonorchis sinensis) and lung fluke (Paragonimus) and fish tapeworm (Diphyllobothrium sp.) is increased, as each of these parasites requires fish for the infective larvae. Cooking or drying will destroy most of the parasites in the fish, but does not reduce the levels of schistosomiasis or malaria associated with aqua-culture.

A more complete and technical discussion of fish culture can be found in Freshwater Fish Pond Culture and Management by Marilyn Chakroff (see Appendix I).



8. WATER AND ENERGY

"Fools rush in where angels fear to tread."

Anonymous

The development of inexpensive, decentralized energy from renewable resources is beginning to attract considerable attention for small-scale projects, and rightfully so. Recent advances in simple solar-powered devices, windmills and biogas generators are encouraging for small-scale use. It is only natural that water flow also be considered an inexpensive power source. Unfortunately, water-powered devices are not as sound as the other alternatives.

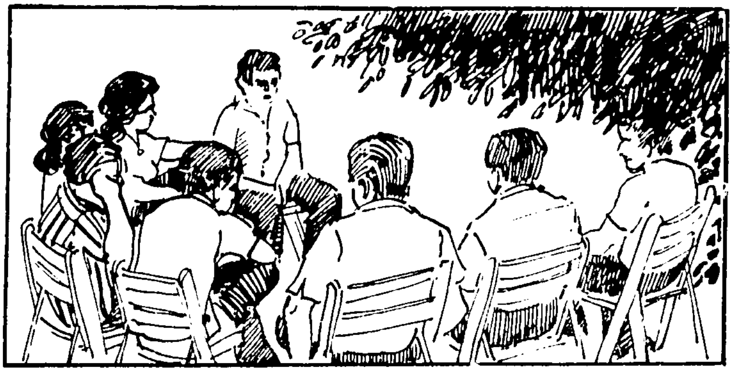
Water can be used to power a pump, as with the hydraulic ram. The water ram is a simple and inexpensive device for pumping water higher than the original source, if topography allows for a free-fall between the original source and the pump. The water ram cannot pump all the water that falls since more than 80% of the falling water is used for pumping energy and less than 20% is actually pumped to a higher elevation. For this reason, the water ram is only useful in areas of abundant water or in situations where the water is falling for other purposes.

For centuries water has been used to turn water wheels. The designs have not changed appreciably over time and furthermore have not been adapted to the wide fluctuations in flow found in tropical water courses. The wheels are usually not sturdy enough to withstand the turbulent floods during the wet season and they may not have enough water to operate during the dry season. Flumes or canals which could direct part of the river flows to a water wheel carry all the negative impacts of stream diversion and are very expensive.

Low head hydroelectric power is often mentioned as potentially small-scale, but it is small only in relation to the giant projects which cost millions of dollars. The cost of low head hydroelectric turbines, transformers and distribution facilities is still beyond the scope of projects discussed in this manual.

Any water power project in the tropics will experience development problems. In arid regions water is usually too limited for small-scale power projects. In the moist tropics, the violent flows are difficult to harness at low cost. With the rapid expansion of rural electrification programs in developing countries, villages may do better to press for expansion of electrical distribution from the central government and concentrate their water development efforts in other sectors, such as water treatment and sanitization. Further, unless the community has had experience with water-powered machinery, it is difficult to gain community support for these types of projects.

Water-powered machinery also requires constant and skilled maintenance. In most cases, the small amount of energy derived from primitive water power devices is not worth the effort, funds or materials expended, nor is the energy in a form that is most useful, such as heat or electricity. For small-scale energy projects, the development worker is best advised to look toward more promising sources of energy, such as solar and wind power or biogas production.



9. PLANNING [1]

"Why care for people? Because people are the primary and ultimate source of any wealth whatsoever. If they are left out, if they are pushed around by self-styled experts and high-handed planners, then nothing can ever yield real fruit."

E. F. Schumacher

Planning as it is used in this manual refers to the process of thinking through a water development project in terms of all its components and how they interrelate. It includes determining objectives, selecting strategies to fulfill them on a sustained basis, evaluating costs and benefits (including environmental costs), and developing means to protect the project well into the future.

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1 Adapted from "The Planning Framework" by Laurel Druben, Environmentally Sound Small Scale Agricultural Projects, 1979.

It is not the purpose of this chapter to replace the many available methodologies for planning projects, but rather to offer a planning process which emphasizes environmentally sound approaches to water projects. Experienced development planners will not have to be convinced of the need for some of the steps outlined here, although some of the material relating specifically to water projects may be of interest and incorporated into other methodologies. The planning process is described for the benefit of those planners who want a review of the total process.

Sound planning of small-scale water development projects does not necessarily take a long time. It is recognized that in many cases the projects are needed to meet a serious crisis requiring immediate solutions and that some environmental risks may be inescapable. However, even short-term objectives can be more successfully met if the planner is aware of some very basic planning methods and knows the right questions to ask.

A PLANNING PROCESS

A sound and flexible planning procedure is shown in Figure 27. Using the diagram as an overview of the planning process, we can examine the components in more detail as they apply to water development projects.

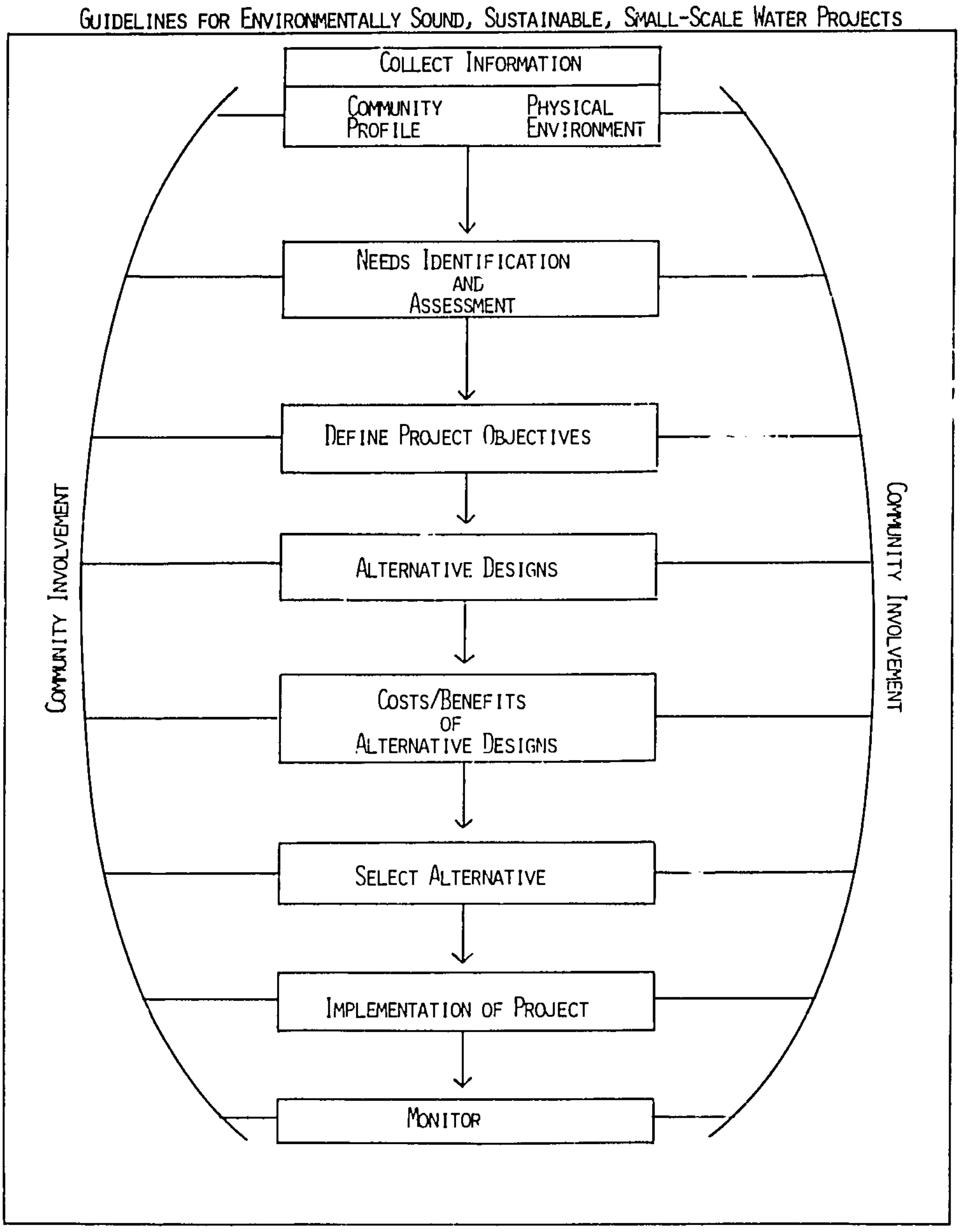

Figure 27. A Planning Process

GUIDELINES FOR ENVIRONMENTALLY SOUND, SUSTAINABLE, SMALL-SCALE WATER PROJECTS

Setting guidelines is the first planning step. These guidelines provide standards for design and evaluation of alternative project options. Guidelines can be developed for environmental, social, economic and cultural considerations. Since this manual is primarily concerned with environmental issues, the guidelines for ecologically sustainable projects will receive more attention. Sample environmental guidelines require that projects:

- maintain or enhance water quality
- use water efficiently
- protect native plant and animal populations
- maintain or improve soil productivity
- protect water rights of existing users
- use existing social organizations and cultural values for environmental rehabilitation and conservation
- include plans for protection of native species and undisturbed wild areas
- maintain or decrease existing levels of water-borne disease
- insure long-term sustainability of water resources.

More specific ecological guidelines, such as maintenance of an endangered species or unique habitat, may be added if necessary.

In addition to the environmental criteria, the development worker may wish to use criteria or guidelines which reflect the principles of appropriate technology/appropriate development. The project should:

- make optimal use of locally available material and human resources
- have community support and involvement
- be based on community-identified and/or community-realized needs
- increase potential for community self-reliance in both short and long-term
- be compatible with available funding
- make use of and adapt traditional technologies
- have reasonable time frame for the community to take responsibility for the project
- have potential for being maintained and monitored by the community.

These guidelines are not definitive. They should be adapted and expanded to specific projects by the development planner.

Other guidelines may also reflect goals of a sponsoring agency or financial constraints. Obviously, the project will be governed by cultural guidelines developed from a community profile and discussions with community leaders.

After the guidelines have been agreed upon, they should not be changed during the planning process except for very good reasons. The planners must adapt project options to meet the criteria rather than altering the criteria to satisfy project designs.

COMMUNITY INVOLVEMENT

Small-scale development projects should originate from a community problem or perceived community need. It is unpardonable to plan for a community instead of with the community. Countless examples from all development sectors can be cited to emphasize the importance of community involvement in project planning and implementation. Planners must realize that people, not water, are the most important factors in water development planning.

A prerequisite for effective planning is continual interaction with the community. Without community involvement a project will not necessarily be supported by the people. Such a project may yield short-term benefits but will ultimately fail. Community involvement is the only base from which sound project planning can proceed.

COLLECT INFORMATION

Community participation should begin at the earliest stages in project planning when the development worker begins to collect information. The information collected should yield: a community profile and an inventory of the physical environment.

Community leaders can help the development worker with the preparation of the community profile. This profile is an extremely important planning tool if it is structured to provide easy-to-use data on economic, social and cultural characteristics of the community. Data can be added or refined throughout the project development process. The profile can include many topics, but the minimum profile for water development projects should identify the following:

- social structure and family relationships of the community
- cultural traditions and characteristic behavioral patterns of the community
- official community leaders and other people of influence
- social or special interest groups and their role in community decision-making
- relative economic level of the community, not necessarily in per capita monetary units, but in relation to other communities in the area
- land tenure policies and practices
- educational organizations including informal methods and extension services
- judicial procedures used to settle community disputes
- available health data including disease surveys, health facilities and medical personnel
- water management or water rights policies, which may appear to be indistinct or informal
- human resources which could be available for a water development project, such as the type and

amount of skilled and unskilled labor which could be spared from normal community activities.

In addition to the community profile, an inventory of the physical environment is required. For a small-scale project, the inventory need not turn into an extensive environmental impact study. It should be a quick assessment of the natural resources within the project area. As the project alternatives become more clearly defined, detailed environmental data may have to be collected. However, the preliminary information should include the following topics:

<u>Water</u>

- Location and size of local water sources
- Users and uses of local water resources
- Quality of water
- Water delivery systems
- Dependability of the water supply, annually and seasonally
- Type of vegetation around water sources
- Type of protection of water resources
- Water resource extremes (flooding and drought)
- Type of watershed management or protection

<u>Climate</u>

- Annual rainfall patterns (when and how much)

- Annual temperatures
- Amount of annual evapotranspiration
- Pattern of winds (direction and velocities)
- Intensity of solar radiation
- Basic relative humidity information

Soil

- Basic soil composition data (gravel, sand, clay)
- Amount of organic material in soil
- Type of vegetation cover on soil
- Depth of soil to bedrock
- Soil permeability (relative rates of percolation)
- Amount of local erosion
- Amounts of local fertilizers used

Agricultural Practices

- Types of crops grown
- Amount of crops grown for local use
- Food shortages or surpluses
- Common pests (bir , rodents and insects)
- Common pest control practices

- Comparative crop yields (compared to national averages)

- Comparative crop yields (different farmers in community)

- Type of agriculture (rainfed, irrigation, flood recession)

- Factors limiting increased production

- Amount and type of livestock grazing and migration

<u>Natural Communities</u>

- Amount of natural forest

- Amount of natural vegetation other than forest

- Direct threats to natural communities

- Common wild animal populations

- Potential rare or endangered species

- Degree of protection for natural areas

Many other areas could be considered to evaluate specific project proposals. Use the information in this manual to select other inventory items.

As with many stages of planning, the development worker may want some additional assistance in compiling the physical environment inventory. In this case, the development worker could:

- Seek advice from local residents. Their knowledge and understanding of changes in environmental conditions are not usually available elsewhere. They are a resource too important to be overlooked.

- Contact local universities, government agencies and local representatives of international organizations. Often they have a great deal of pertinent information on local soils, climate, terrain and plants and animals native to the region. They may have insights and suggestions for other resources.

NEEDS IDENTIFICATION AND ASSESSMENT PROCESS

In the needs identification phase, background data are reviewed for the perspective they yield on the local community's view of needs and priorities. Records kept of interviews with local residents can provide particularly good insights, but all of the material collected should be reviewed.

A careful reading and weighing of background data during the identification phase may indicate need for several small-scale project activities. For example, community members may voice strong concern over both the need for erosion control and for improved sanitation; the inventory of the natural environment may have indicated a need for crop irrigation. If the need is "discovered" by the development worker but not voiced by community residents (as in the case of crop irrigation), the development worker must decide where that need fits into community priorities, if at all. After the needs have been identified, the assessment process follows.

A needs assessment can be undertaken in two steps. The first is to look more closely at each identified need in terms of the size of the effort required and the kinds of resources which would be necessary to meet it. This can be done by preparing a Needs Assessment Sheet, as shown on the next page, and by filling it out as indicated. Each identified need should be placed on a separate sheet. For each need it is necessary to define question areas which have to be considered when preparing to work to meet that need. The categories given on the sample sheet can be refined or modified, based on the specific project.

SAMPLE NEEDS ASSESSMENT SHEET

DATE__________ IDENTIFIED NEED__________

QUESTION CATEGORIES	ANSWERS	RATING*
The following question categories are likely to remain standard for any effort, but the specific questions to be rated will change depending upon the need being considered.	Filled in in terms of the specific situation.	*Practicability* SCALE 1: Low 1 2 3 4 5 6 7 8 9 10 High *Relevance* SCALE 2: Low 1 2 3 4 5 6 7 8 9 10 High

Resource Requirements and Availability. List the resources which would be required to meet the need. Resources can be defined as information, money, technology, people--anything that will or might be needed. Then look at whether the material and human resources are available. Locally? Regionally? If available, what are the costs of using such resources--in terms of money, length of time, etc.?

Scope of Project Required. Look at the project in terms of the network or system of activities of which it is a part. Does meeting this need create others? If so, can they be addressed? Is meeting this need technically, culturally, socially possible within the context of a small community project? Would a larger effort help to insure success? In other words, is there a possibility that a larger-scale activity would be of longer-term value?

Project Design Possibilities. Can meeting this need be accomplished with several, different project designs? Does one project enable use of local resources and expertise, while the other one does not? What would be the differences between these project designs--in social, cultural and economic terms? Does well-tested technology already exist for adaptation or is extensive research required? Will the community participate in project design activities?

Time Frame. Is meeting this need a short or long-term effort? Or can it be met now on a provisional basis and later, in a phased approach, tackled on a longer-term basis? Would a project undertaken quickly now make it more difficult to undertake another effort later? Is there a local timing factor to be considered; for example, do residents have more time available to support a project at one time rather than another, or do local climatic conditions suggest timing constraints?

Community Support. Who expressed this need? Will powerful community members and groups support efforts to meet this need? If the need has not been identified vocally by the community, is there a forum where it can be discussed?

Cultural, Social Considerations. Does meeting the need being considered require dealing with current widely held, social practices? For example, Would a project mounted to meet the need described involve women and therefore have to deal with constraints on their participation, e.g., traditional home duties, lack of access to credit and so on.

* Each significant component of the question area and the answers pertinent to it should be measured for relevance to project guidelines and for practicability in terms of these scales.

Step two involves measuring the answers in terms of 1) overall relevance to stated guidelines (page 118) and 2) their practicability, given the type of effort required and significant constraints which may exist, such as money, expertise or cultural bias. Two scales, numbered from one to ten, should be set up. One scale is to measure relevance; the other is to measure practicability.

Practicability in terms of constraints present and resources needed

SCALE 1: Low — High

1 2 3 4 5 6 7 8 9 10

Each component of an effort to meet the need should be viewed in very practical terms. In other words, if providing improved harvesting methods is being considered in terms of the availability of resources required and investigation shows that all resources are available locally, this component would be ranked high. Depending upon other considerations, the planner might move lower on the scale as resources are harder to find, more expensive, etc.

Relevance to preset guidelines

SCALE 2: Low — High

1 2 3 4 5 6 7 8 9 10

Each component should be viewed in terms of whether it fits within the guidelines, or project boundaries, discussed earlier. As answers indicate that a project goes outside of more and more of the guidelines. the rating moves lower--toward the left. A "high" rating indicates the project is well within the set guidelines.

Once each Needs Assessment Sheet has been completed and the answers rated, average the two figures from the two scales to determine an overall rating. A comparison of the averages will give a fairly good indication of which need is the one to tackle first.

PROJECT OBJECTIVES

The next step is to formulate project objectives which reflect the priority need. These objectives must be clearly defined: for instance, increase the water supply so that each person will be able to have a daily allotment of 38 liters of potable water. The project planners can then accurately determine the dimensions of the task. A goal of "improving the water supply" is basically meaningless because it does not define what is to be achieved. A clearly defined objective not only sets the task precisely but also provides a standard for measuring project success.

ALTERNATIVE DESIGNS

Once objectives are defined, alternative designs can be considered. This is another time when the development worker may want to seek some additional planning assistance. For example, the problems of a particular area may indicate the need for specialized expertise. In a case where one of the alternative designs includes an irrigation system, consultation with ecologists, irrigation engineers, water resource managers or agricultural economists would be recommended before going very far with the planning process.

Such consultations may involve local, national or international contacts. If local resource people are available, an interdisciplinary team can be organized to visit the possible project sites. The team can discuss the project from their respective viewpoints. Depending on the type of project, the team might include representatives from several of these fields: ecology, hydrology, soil science, geology and so on.

As planning continues locally, the development worker may also want to get in touch with other organizations and individuals around the world. See the list in Appendix II.

Even when and if the project seems to be relatively simple and easily tackled, it is a good idea to pass the proposed alternatives through a review process and outside apprai-sal. The information and data collected in the planning process thus far will provide reviewers with excellent background information to which they can respond.

COSTS/BENEFITS

In this manual, an analysis of the costs/benefits of a project is based on a comparison of the alternative designs to four categories of criteria based on 1) guide-lines set at the beginning of the planning process and 2) the stated project objectives.

The guidelines, as discussed earlier, and the project objectives cover many subjects. For purposes of analyzing water projects, the following criteria are suggested:

- economic returns
- technical resources
- social and cultural environment
- physical environment.

For each of the criteria, some explanation is offered here. However, the development worker will want to expand this to be more specific.

The alternative designs are evaluated and measured for each of the four criteria by using a simple scale numbered from 1 to 10. The lower end (left) of the scale represents costs or negative effects; the upper end (right) represents benefits or positive effects. The five point mark in the middle of the scale represents a situation where benefits and costs are evenly balanced. The four ratings are then averaged to give the development worker a total average for the design. Alternative designs can then be compared and the development worker can select the design which appears most beneficial.

There is no magic about this measuring system; it seems convenient and relatively easy to use. Development workers are encouraged to adapt the system to fit a particular situation.

Date ____________________

SAMPLE COSTS/BENEFITS
ANALYSIS CRITERIA

Description of alternative design: ____________

ECONOMIC RETURNS

Self-Sufficiency. Rank high a project which can be shown to lead to jobs, skills, training, improved markets or other economic gains which are returned directly to the community and can be shown to increase local self-sufficiency. Move toward the lower end of the scale if a project must rely on continued subsidy and/or it becomes less clear that the economic gains will be returned to the community.

Funding Availability. Rank high a project where funds are available quickly and easily (perhaps from local sources). Move toward the middle for projects where some funding is available but additional funds must be sought. Use the lower end of the scale in cases where funding is not readily available and a long time lag seems likely.

Net Profit. Rank high a project where careful calculation of economic factors indicates that the product or project will bring in more than it cost. Move lower on the scale as the project's economic profitability appear less clear.

TECHNICAL RESOURCES

Local Technical Support. If the project requires involvement of change agents, technical support groups, extension services, and these are available, rank high. Move toward the opposite end of the scale as availability and access to such support becomes less clear and/or difficult.

Technology Availability. Rank as high a situation where the technology exists and seems adaptable to the situation. Move toward the lower (costs) end as the technology requires more extensive commitments to research and development. Rank high situations where technology makes maximum use of local human and material resources. Move lower toward the opposite end as resources must be obtained from outside sources and this could cause delays and/or failure to use local resources adequately.

Technical Impact. Rank high a project in which the technology or project once launched can be maintained by local residents--this implies training in upkeep and repair and arrangements for replication. Move lower on the scale in situations where provision for these activities has not been made. Rank high a project which introduces a technology which seems to require little change in everyday life. Move toward the lower end as the technology seems to require alterations in life-styles, culture, traditional patterns, etc.

SOCIAL AND CULTURAL ENVIRONMENT

Community-expressed Need. Rank high a project based on community-expressed need. Move toward the opposite end as community involvement in need identification becomes less clear.

Social Returns. Rank high projects which can be shown to bring cultural and social gains to the community. Move toward lower end as social and cultural gains become less clear and/or the effects of the effort seem likely to be socially or culturally descriptive. Rank high a project which enables residents to participate with least risk. Move toward the lower end of the scale as it becomes clear that participants run more risk, i.e., as their investment demands a level of commitment which would have serious consequences were the project to fail. Assume for project feasibility that the smaller the degree of change required in local custom, the easier it will be to get the project underway. Rank as high projects which require little change; move lower as more change is required.

NATURAL ENVIRONMENT

Relevance to Guidelines. Rank as high a project which meets all or most of the guidelines for an ecologically sustainable activity. Move lower as the project fails to meet these guidelines.

Alternative Design #1	(Costs) 1 2 3 4 5 6 7 8 9 10 (Benefits)
	− +
economic returns	
technical resources	
social/cultural	
physical environment	

Alternative Design #2	
economic returns	
technical resources	
social/cultural	
physical environment	

IMPLEMENTATION OF PROJECT

Community participation should be factored into project implementation as much as possible. For instance, if villagers are willing to manually dig trenches for buried pipe, this is preferable to the speedier method of using heavy machinery. Projects should encourage the use of local materials and local craftsmen wherever possible instead of relying on imported materials or machinery. In this way, future maintenance is not likely to be beyond the local resources. Community pride developed through community participation is the best guarantee for continued maintenance and long-term benefits.

MONITORING

Small projects may not have small effects on the environment; the impacts of any project may be smaller or larger than the scope of the project itself. Also, changes caused by a water project may not be readily apparent, perhaps being masked by the successful achievement of project objectives. No one can hope to predict all impacts because the environmental interactions are very likely more complex than we are able to comprehend. Therefore it is important to continue to monitor the project after it has been implemented.

A simple program of measuring change should be developed before the project begins. This may consist of inspections of water courses for the amount of sedimentation or growth of waterweeds. Or it may require weekly or monthly measurements of water levels in wells, ponds or other water bodies. Even these simple measurements can identify trends which may be harmful if allowed to persist. The post-project monitoring can also help to identify maintenance procedures necessary for continued operation. Unforeseen benefits may be encouraged, while negative trends may be corrected before the problems become too severe. In water resource development, post-project monitoring and maintenance are as important as pre-project planning.

APPENDIX I

BIBLIOGRAPHY OF CITED REFERENCES

Following is a selected list of publications for use in small-scale planning. No doubt others of equal value are available, but the information contained in these references should provide enough information for any small-scale water development task. Addresses of publishers or distributors of the references can be found in Appendix II.

Cairncross, S. and R. Feachem. 1978. Small Water Supplies. Bulletin No. 10, Ross Institute and Advisory Service, London.

Small, compact reference with technical information, diagrams and designs for small-scale water supply projects.

Chakroff, M. 1976. Freshwater Fish Pond Culture and Management. VITA, Mt. Rainier, Maryland.

Lengthy paperback on planning, construction and operation of fish culture ponds. Inexpensive.

Feachem, R., M. McGarry and D. Mara (eds.). 1977. Water, Wastes and Health in Hot Climates. John Wiley & Sons, New York.

An expensive, scholarly collection of papers on all aspects of water and health in tropical climates. Much of the information is very useful in the planning and design of water projects. It is difficult to obtain, but it is a highly recommended reference.

International Development Research Centre. 1978. Appropriate Sanitation Alternatives: A Field Manual. Energy, Water, and Telecommunication Department, Washington, D.C.

A clearly illustrated manual of intermediate technology.

Litzenberger, S.C. (ed.). 1974. Guide for Field Crops in the Tropics and Subtropics. Agency for International Development, Washington, D.C.
Exceptional reference on the standard field crops normally cultivated in the tropics. Data on cultivation, requirements and productivity for most tropical crops.

Mann, H. T. and D. Williamson. 1976. Water Treatment and Sanitation: Simple Methods for Rural Areas. Intermediate Technology Publications, Ltd., London.
How-to reference with readable text and excellent diagrams.

McJunkin, F. E. 1975. Water, Engineers, Development and Disease in the Tropics. Agency for International Development, Washington, D.C.
A classic in disease prevention design for engineers and project planners. While all water-related disease is covered, the focus is on schistosomiasis.

Meynell, P. J. 1976. Methane: Planning a Digester. Prism Press, Dorset, U.K.
A small, easily readable book on biogas production. Information is given on planning design, construction and operation, plus data on productivity and raw materials.

National Academy of Sciences. 1974. More Water for Arid Lands: Promising Technologies and Research Opportunities. National Academy of Sciences, Washington, D.C.

Great discussion on methods for conserving and exploiting water sources in arid regions. Many of the suggested methods can be applied to small-scale projects.

National Academy of Sciences. 1979. Tropical Legumes: Resources for the Future. National Academy of Sciences, Washington, D.C.

Good discussion of many species of tropical legumes not traditionally cultivated throughout the tropics but which possess potential for development.

National Academy of Sciences. 1975. Underexploited Plants with Promising Economic Value. National Academy of Sciences, Washington, D.C.

An exciting book for small-scale planners. Thirty-six species of plants are described in terms of potential economic development.

Quigg, P. W. 1976. Water, the Essential Resource. National Audubon Society, International Series No. 2., New York.

A brief paper that describes the global water crisis. It provides a proper perspective for the small-scale planner.

Rajagopalan, S. and M. Shiffman. 1974. Guide to Simple Sanitary Measures for the Control of Enteric Diseases. World Health Organization, Geneva.

An excellent manual for the planning, design and operation of water supply and sanitary systems.

Ram, E. R. 1979. "Safe Water - Essential to Health." Contact 52, August, 1979. World Council of Churches, Geneva.

A very handy small publication covering the most essential aspects of safe water supplies.

Stern, P. H. 1979. Small Scale Irrigation. Intermediate Technology Ltd., London and the International Irrigation Information Center, Bet Dagan, Israel.

The best reference for small-scale irrigation, includes technical aspects, design and sound advice.

United Nations. 1980. "UNICEF News" 103/1980/1. Available from UNICEF office or UNICEF National Committee in many countries.

A small, regularly published pamphlet with consistently helpful information.

VITA. 1979. Environmentally Sound Small Scale Agricultural Projects. VITA-Mohonk Trust, Mt. Rainier, Maryland.

Similar to this manual in format, providing information on planning and design of small-scale agricultural projects.

VITA. 1977. Village Technology Handbook. Mt. Rainier, Maryland.

A one-of-a-kind reference. Contains a treasury of information on a wide range of village level projects. Has been modified and reprinted several times, with input from field workers.

Wagner, E. G. and J. N. Lanoix. 1958. Excreta Disposal for Rural Areas and Small Comunities. World Health Organization, Geneva.

The best there is.

Wagner, E. G. and J. N. Lanoix. 1959. Water Supply for Rural Areas and Small Communities. World Health Organization, Geneva.

A still-valuable classic on water supply. Much of the material in this book still serves as the basis for newer works.

Winblad, U. 1972. Evaluation of Waste Disposal Systems for Urban, Low Income Communities in Africa. Scandinavian Consulting Group for Planning, Architecture and Building, Copenhagen.

A small reference which discusses the various alternatives of waste disposal. The discussion and recommendations are valid for rural areas.

The World Bank. 1976. Village Water Supply, A World Bank Paper. The World Bank, Washington, D.C.

World Neighbors. Contour Ditches Help Conserve Our Soil. Volume 6, Number 2E. World Neighbors, Oklahoma City, Oklahoma.

One of the "World Neighbors in Action" newsletters which are characterized by their simplicity and usefulness.

APPENDIX II

Where to Order References

(Complimentary copies of references are often sent to people working in developing countries.)

Christian Medical Commission
World Council of Churches
150, Route de Ferney
1211 Geneva 20, Switzerland

Intermediate Development Technology Research Center
P.O. Box 8500
Ottawa, KIG 3H9, Canada

International Irrigation Information Center
Volcani Center
P.O. Box 49
Bet Dagan, Israel
or
International Irrigation Information Center
P.O. Box 8500
Ottawa, KIG 3H9, Canada

John Wiley and Sons, Inc.
605 Third Avenue
New York, New York 10016 USA

National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418 USA

National Audubon Society
950 Third Avenue
New York, New York 10022 USA

Prism Press
Stable Court, Chalmington
Dorchester, Dorset, UK

Ross Institute of Tropical Medicine
London, UK

U.S. Agency for International Development
Washington, D.C. 20523 USA

VITA
3706 Rhode Island Avenue
Mt. Rainier, Maryland 20822 USA

United Nations
New York, N.Y. 10017 USA

The World Bank
1818 H Street, N.W.
Washington, D.C. 20433 USA

World Health Organization
1211 Geneva 27
Switzerland

World Neighbors International Headquarters
5116 North Portland Avenue
Oklahoma City, Oklahoma 73112 USA