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ENVIRONMENTAL DESIGN CONSIDERATIONS FOR RURAL DEVELOPMENT PROJECTS

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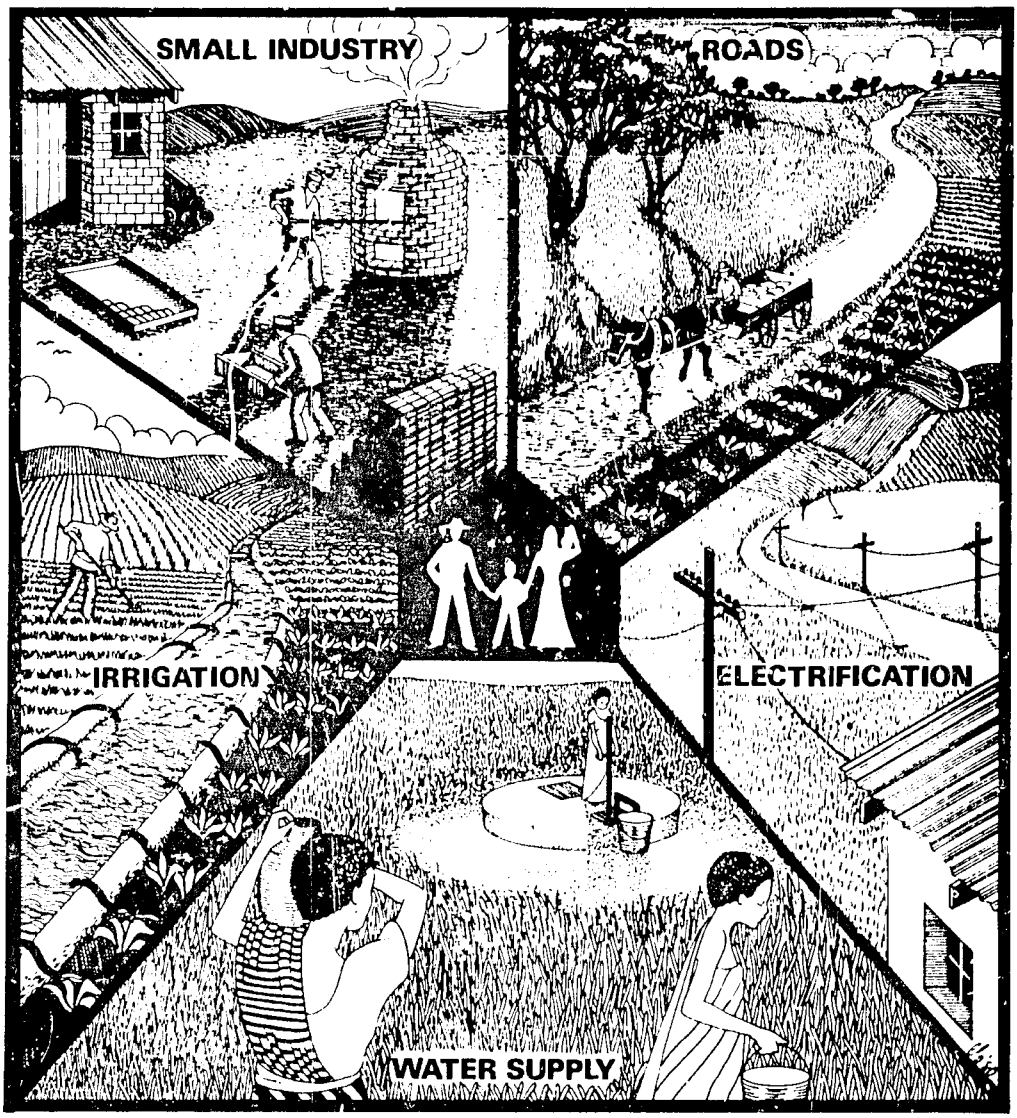
ENVIRONMENTAL DESIGN CONSIDERATIONS FOR RURAL DEVELOPMENT PROJECTS



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UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

ENVIRONMENTAL DESIGN CONSIDERATIONS FOR RURAL DEVELOPMENT PROJECTS

OCTOBER 1980

PREPARED BY
HARZA ENGINEERING COMPANY

PREFACE

The 1980's will be a critical period for the developing countries of the world. Although progress has been made in many of these countries to overcome poverty, hunger, malnutrition and disease among the rural poor, much more assistance will be required in the future. This manual was prepared in order to help rural development project planners integrate environmental design considerations into the early stages of project plans involving roads, electrification, water supply and sanitation, irrigation, and industries. In so doing, these important projects can hopefully be made environmentally sound and avoid many of the pitfalls that occurred during the last two decades. The environmental design considerations were developed specifically for rural projects using appropriate technology guidelines. Special emphasis has been placed on social and public health considerations, which are so important in rural villages and small communities undergoing development.

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At Harza Engineering Company, significant contributions to this manual were made by Dr. Peter L. Ames, Project Scientist; Dr. Gerald I. Bresnick, Water Quality Biologist; Dr. G. Roy Elmore, Water Supply Engineer; Mr. Evan M. Krith, Road Engineer; Dr. Deane M. Manbeck, Irrigation Engineer; Mr. T. Henry McGreer, Electrical Engineer; Mr. James D. McWain, Environmental Engineer (Industry); Mr. William Parker, Water Quality Engineer; Dr. William L. Partridge, Social Anthropoligst; Dr. Curt R. Schneider, Environmental Health Scientist; and Dr. James H. Thrall, Ecologist. Dr. Brain J. Gallagher, Environmental Scientist, was the Harza Project Manager. The cover was drawn by Kathy Clo.

The American Public Health Association also made important contributions to the manual by editing material on water supply and sanitation (Chapter 4) and on environmental health (Appendix B).

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I. INTRODUCTION

This manual is intended to assist A.I.D. field officers, development consultants and host country planners in identifying potential societal benefits and undesirable environmental effects that may accompany small rural projects[1/]. Such effects are termed environmental because they arise from interactions of the project with the totality of its surroundings. For the purposes of resource development planning, the term environment has come to include all of the natural and social systems that come in contact, directly or indirectly, with the structures or programs under consideration.

Valuable insights can be gained through the study of similar past developments. The more conspicuous and usually detrimental side effects of certain projects are described in numerous published accounts, many of which reflect hard lessons learned by developers about what to do and what not to do in project planning. This manual brings many of these lessons to bear on small rural projects and offers guidelines for those who wish to enhance the acceptability of future projects.

General Considerations

Environmental design considerations require a basic understanding of the science of ecology, which is concerned with the interrelationship of organisms and their environments. Ecology means "study of the home." In this case, "home" refers to the unique place or community where the organism (plant, animal, human being) lives and where food, energy, shelter and waste assimilation are provided. A central theme of ecology is the concept of a community where different species of organisms live and are dependent on each other and their environments in many complex ways. The concept of community and its ecological relationships will be stressed throughout this manual.

Ecologists use the term ecosystem to describe a geographical area of a particular type which contains certain communities of organisms that are bound together in a special way. For example, a lake is an aquatic ecosystem that is defined spatially by the limits of the water in the lake and in the surrounding soils. Within this aquatic ecosystem live many different aquatic organisms such as fish, water plants, insects and microorganisms, as well as some higher animals. These organisms are dependent on each other and on their environment, which is basically the water and sediments. Although no two lakes are identical, all aquatic ecosystems have the same general environmental processes and biological relationships. Many of these processes and relationships are strongly influenced by the water quality variables, such as dissolved oxygen, acidity, temperature and chemical composition.

1/ Covered here are: roads; electrification; water supply and sanitation; irrigation and on-farm water management; and small industries.

Similarly, all ecosystems of a particular type share common characteristics which have led to a classification of similar ecosystems called "biomes." The classification system is complex but is primarily based on annual average temperature and moisture, which in turn are obviously related to climate. Certain climatic zones have been identified which tend to support similar biomes such as the tropical rain forest or the arid desert biome. Table I-1 lists the most general biomes and their major characteristics.

Since rural development projects are currently being planned with A.I.D. assistance in more than 70 countries throughout the world, it is not possible to provide specific environmental and ecological guidelines on project design for each particular region or biome. The project planner should be knowledgeable of the geographical and ecological uniqueness of his area and should use this knowledge to adapt appropriately the general guidelines presented in this manual. In order to gain a better understanding of the particular biomes that might be influenced by the proposed project, the planner should refer to the material on biome classification (Odum, 1959) in the bibliography.

This manual is concerned with rural development projects and therefore with rural communities. A few general characteristics of rural communities can be described in ecological terms which will be helpful in assessing potential environmental impacts. First, rural communities are small and internally not too diverse. Community in an ecological sense includes all organisms living together, such as man, domestic animals, wild animals, wild and cultivated plants, and even insects, parasites, bacteria and other small and sometimes harmful organisms. Diversity of species within a community is extremely important; in general, high diversity supports greater functional stability and vice-versa. This concept can be extended into human ecology by considering different groups of community residents based upon their age, education, sex, skills, income, etc., as diverse components. A community depends on all its residents, regardless of their roles, and this should be a major consideration for all projects. Due to a relatively low social diversity in rural communities, development projects cannot be totally successful if they benefit almost everyone but eliminate certain critical roles. Similarly, if the project tends to alter the composition of the community by attracting certain workers and displacing others, it must be carefully planned or it could again adversely affect the community's stability and growth potential.

The same general principle of diversity applies to production systems of the community, including agricultural and manufacturing activities. Maximizing one component while diminishing others could lead to disaster in the long run. It is not necessary (or even possible) to always improve everyone's welfare as a goal of the project, but it is essential to understand the negative impacts and to minimize these impacts to an acceptable level.

Table I-1

TERRESTRIAL BIOMES

Biome	Dominant Plant Life	Geographic Distribution
Tundra	Low shrubby broad-leafed plants; cold adapted	Subpolar (arctic tundra) and high mountains (alpine tundra) above tree line
Coniferous Forest	Coniferous trees (spruce, larch, fir, etc.)	North and south subpolar zones; mountains just below alpine tundra
Deciduous Forest	Broad-leafed trees	North and south temperate zones
Tropical Forest	Broad-leafed trees and palms	Equatorial and subtropical regions, worldwide
Grassland	Grasses and broad-leafed annuals	Temperate and tropical, worldwide
Desert	Shrubs and grasses adapted to extreme aridity	Temperate and tropical, worldwide
Marshes and Swamps	All groups; adapted to permanent or frequent flooding by fresh or salt water	Worldwide, except in permanently frozen areas

A second general principle of rural communities is that they tend to be isolated and therefore largely self-sufficient. This is a very positive attribute that can be used to stimulate controlled growth within the limits of naturally available resources. Obviously, trade and greater social contacts with other rural communities and cities are worthwhile. But rural development should concentrate on raising the quality of life through improved production, nutrition and health care of the local residents by removing the debilitating constraints of infertile soils, poor transportation, lack of energy resources, unreliable water supplies and sanitation facilities, and low economic base. Once these obstacles are removed, the local residents can be motivated to upgrade themselves without undue dependence on others. The central point of this discussion is that rural development should concentrate on available resources within naturally occurring limits that must be recognized.

Demographic Types of Regions Covered

Although the principal stress throughout the manual is on rural areas, the discussion perforce also includes situations that apply to larger villages and periurban regions. What is rural in some countries (e.g., India) would be considered urban in parts of African and Latin America. Thus, the impacts of projects developed would vary in significance according to the local circumstances.

Specific Project Considerations

Every project interacts with its human and natural environments in ways that are determined not only by the type of project but also by the specific characteristics of its surroundings. This localized specificity places on the planner the burden of understanding both the ecosystems and the social systems of the region. This manual provides examples of certain ways in which each of the five project types will interact with its environment, but the extent and manner of each kind of interaction will be governed by the details of project and environment. Each chapter indicates in general which interactions should be expected. To help in evaluating the environmental side of each interaction the appendices provide relevant specialized information.

Each country, whether highly industrial or "less developed," has some level of environmental concern, which may be oriented largely toward the human or social environment or toward natural resources. It is the planner's responsibility to ensure that the project at hand does not violate either the local or national environmental values and that the long-term needs of the country are not sacrificed for short-term returns.

In this manual we pinpoint areas in which environmental effects may be expected to result from five categories of rural development. We emphasize these areas because legislation, regulation and public pressure in developed and developing countries have demonstrated a general interest:

- Human Ecology. Human communities are complex organizational systems that relate to their surroundings and to each other in ways that parallel the ecology of plant and animal communities. Understanding the fundamental aspects of these relationships is essential to identifying and controlling project impacts, particularly long-term, term, indirect effects, which are extremely important. For this reason, a discussion of basic social considerations relevant to long-term project impacts is presented in Appendix A.

- Environmental Health. For many rural projects, improved public health is considered among the major benefits. Adverse health effects also may occur, however, unless appropriate measures are taken. Major diseases that often are affected by development projects are discussed in Appendix B.

- Water Quality. Improvement of domestic or irrigation water and proper management of wastewater discharges is the primary objective of many rural projects. This achieved, other benefits, in health, agriculture and industry, may be expected to ensue. Proper attention to water quality should be a part of every development project, even if, as in roads and electrification, the water resource is not a direct part of the project. A discussion of water quality impacts and mitigation measures is presented in Appendix C.

- Pesticide Contamination. Efforts toward greater agricultural productivity usually involve increased use of chemical fertilizers and pesticides. Even proper use may produce adverse environmental effects, such as food chain contamination (sometimes with severe effects on species important to man) and the poisoning of nontarget species. Such effects are difficult to prevent but may be minimized through careful chemical selection and application. Other problems, more easily avoided, arise through improper handling and storage of toxic chemicals, equipment and containers or through inadequate training of spray technicians. Planners whose projects will involve chemical pesticides should consult Regulation 216.3b of A.I.D. Environmental Procedures (Pesticide Procedures) and the "Food Crop Protection" Section of DS/AGR, which manages the Pest Management and Related Environmental Concerns Project. This project can provide consultants to perform pesticide analyses at no cost to the mission.

- Air Quality. Some air pollution is accepted in many developing countries as an unavoidable side effect of development. Dusts, fumes, mists, gases, odors, smoke and vapor may be tolerated in many situations, but the planner should be alert to situations in which contamination presents a hazard to human health, agriculture or livestock. In few a cases, air pollution may also cause visual or physical degradation of cultural monuments, such as temples and statues. However, for most rural projects in developing

countries, air pollution would normally not be a severe problem. The important considerations for these types of projects would be careful siting and adequate stack design for point source emissions such as may be encountered in some rural industries. For any severe problem, the planner should request special assistance from A.I.D.

- Endangered Species. Interest in the conservation of rare or endangered animals and plants is based on the scientific, medical, cultural or economic (usually tourism) values. Ecological changes resulting from development projects may affect certain endangered species. The 1973 "Convention on International Trade in Endangered Species of Wild Fauna and Flora" (CITES) has been ratified by more than 50 nations, including the United States. Lists of animals and plants covered by CITES may be obtained from the U.S. Fish and Wildlife Service, Washington, D.C. 20240, and special assistance should be requested from A.I.D. if an endangered species appears threatened by any development project.

A similar situation exists with certain wild plants and animals that have special agricultural or nutritional value but are not considered in danger of extinction. Such species, many of which are wild relatives of domesticated forms, may be threatened by projects that introduce more advanced strains into their areas. When agricultural development is contemplated in an area believed to contain wild species of actual or potential use, the advice of the U.S. Department of Agriculture should be sought on preserving wild stocks.

Consideration of Indirect Effects

Environmental effects often are divided into direct (primary) effects and indirect (secondary, tertiary, etc.) effects. Indirect effects, which result from other effects rather than from the project itself, sometimes can be foreseen at the third, fourth or even more distant steps from the actual project, but these more remote effects are more often difficult to recognize, except by hindsight. Nevertheless, a good planner always follows the chain of project effects as far as experience permits and this may be several steps removed from the project. For instance, agricultural runoff frequently consists of moderately enriched water, due to the use of fertilizer by farmers, resulting in the enrichment (the primary effect) of receiving streams; such enrichment promotes the growth of aquatic weeds, such as water milfoil (secondary effect); the vegetation tends to support denser populations of aquatic snails (tertiary effect), some of which are vectors of schistosomiasis (bilharzia); the fourth effect in this chain is an increase in the prevalence and intensity of schistosomiasis in the rural population. The chain is not quite this simple; there are other factors affecting the components of the sequence and other side effects arising from it.

Secondary impacts often are difficult to predict to any degree of reliability, because for many types of development

and many ethnic situations there is not a sufficient base of information. Nevertheless, a careful reading of Appendix A (Human Ecology) will reveal many situations where secondary impacts might be expected.

Secondary effects frequently are experienced by social groups not expected to benefit directly from the project. Within the area of project influence one may identify several groups of people who will be affected directly or indirectly by the project:

- The Target Population is the group expected to receive most of the direct benefits of the project. They are the recipients of domestic or irrigation water and of electricity, the users of roads, the employees of small industries and the consumers of new products.

- The At-Risk Population consists of people not expected to benefit directly from the project but likely to be disadvantaged by it. The reasons may be economic, geographic, cultural or medical.

- The Migrant Population includes people moving into or out of the area because of the project.

The separation of these groups may be indistinct. The man who provides truck-transported water in an arid region may lose much of his business when piped water is introduced, although he and his family may be among project beneficiaries. Similarly, when a region receives electricity the manufacturer or seller of nonelectric equipment may be "at risk" through a loss of demand for such products. Such secondary impacts may be mitigated or turned into benefits with proper planning. For example, the manufacturer may be assisted, technologically and financially, in converting his plant to produce electric items.

Integrated Project Considerations

Each development project should be viewed in a regional and national context. Projects compete for money and resources (manpower, land, materials and energy) and for the attention of politicians and the public. Projects also may support each other by providing materials, energy or water, improving worker health and living standards, and focusing national attention on one section of the country. These interactions should be examined for collective effects, regional needs and agency requirements.

Cumulative Effects

The use of communal resources frequently is allocated on a "first come, first served" basis, with the earliest user given priority rights over later users, regardless of whether or not the general public benefits. Often the initial demand on the resource is a light one and other demands are added gradually until the resource is overtaxed or exhausted.

A single project may not exert a significant environmental impact but if several projects have been or will be developed the cumulative effects should be considered. For example, an isolated water well may have an insignificant effect on the ground water resource, or aquifer, but many wells, taken together, could lower the water table to the point of making the more shallow wells unusable. The central point is that the planner should identify all of the projects that will rely on the same resource and consider them collectively.

The problem of cumulative waste is frequently encountered where several agro-industries discharge organic wastes into a single river or lake. Such byproducts might be beneficial in small amounts, providing needed nutrients and increasing fish production. Often the same water body receives large amounts of human and animal wastes from population centers. The body of water may support a rich and productive aquatic ecosystem while near the limit of its capacity to absorb additional organic matter. Many natural systems do not respond in a linear manner to increases in a particular type of disturbance. In some cases the response is not noticeable or is considered beneficial (such as increased fish production) until certain limits, "threshold values," have been exceeded. Then the ecosystem responds drastically and uncontrollably, as one biological reaction triggers another. In the case of the water body receiving a variety of wastes, the decline may be triggered by exceeding threshold concentrations of "limiting" nutrients (e.g., phosphorus and nitrogen), beyond which the lake becomes overfertilized and may deteriorate rapidly.

Estimation of cumulative effects should consider predictable population growth and migration into the developing area. In the example cited above, not only will the pollution load on the body of water be greater as population density increases but additional demand for water (for irrigation, industry and domestic use) may reduce the water replacement rate, making it less able to assimilate wastes.

Regional Considerations

The benefits and potential impacts of a project may be felt at the local level (within the geographic boundaries of the project) and also at the regional and/or national level. The planner should become aware of other plans and projects that could affect his project and be affected by it. Usually this can be accomplished by maintaining close contact with the appropriate agencies and major private developers in the region. Occasionally modifications will be called for in one or more projects in order to take advantage of opportunities offered by others or to avoid adverse interactions. For example, a shift in the routing of a road might be desirable in order to provide better access to a planned industrial development, avoid dividing a future agricultural development, combine rights-of-way with a transmission line or canal, or avoid introducing settlers into a forested area needing protection.

Interagency Coordination

Government agencies in developing countries, like their counterparts in the industrialized nations, often disagree over responsibilities and jurisdictions, with the result that some areas receive duplicate services and others none at all, or certain tasks that are politically unpopular, such as removing squatters from protected lands, are not performed. It is difficult for the project planner to avoid such situations or to break such deadlocks directly when they occur, but the A.I.D. project may become the catalyst for dialogue between agencies or for the formation of coordinating committees which may help resolve them.

How to Use the Manual

Environmental planning proceeds through a series of logical steps that parallel the engineering planning process. Ideally, environmental planning and management should be initiated when the project is in the conceptual stage and should continue through all stages of the development. This manual is designed to enable the planner to bring environmental considerations into the project during the earliest planning stages, but it can also be used as a checklist during later stages. It should be remembered that the methods suggested here will be most effective if employed from the start of the planning process. In fact, if the environmental procedures presented in the manual are utilized by the planning and design teams from the beginning, the resulting project should be environmentaly sound, as well as more cost-effective over the long term.

The five types of rural development projects covered by the manual are discussed separately in the next five chapters. The material is kept as brief and clear as possible, to provide the maximum amount of guidance for the specific project type. Complex technical matter has been avoided in these chapters, so as not to burden the reader who is looking for project environmental planning guidelines or decision-making assistance. However, the chapters make considerable reference to the more technical appendices, which have been arranged by environmental subject matter common to all rural development projects (i.e., human ecology, environmental health, water quality). Throughout the manual, where material in the text may be further clarified by reference to one of the appendices, the letter of that appendix is presented in brackets, i.e., [A], [B], etc. The planner can decide which issues are of most concern for his project and use the appendices and referenced material to obtain a more detailed understanding of the probable environmental impacts and benefits. The material in each project chapter, especially the planning information list and impact matrix, has been developed to assist the planner in accomplishing the above.

The text of this manual is aimed at the general reader, but the use of technical terms is unavoidable. Words marked with an asterisk (*) in the text are defined in a glossary at the end of the manual.

Project Definition

The first step is to identify clearly all components of project construction and operation that are likely to affect the human environment, beneficially or adversely. This is not a simple task, for it is easy to overlook aspects of the project that may seem "non-environmental" (e.g., exploratory programs). The matrix provided with each of this manual's major sections will aid in identifying significant project components. The planner should:

- Describe the project in terms of size and design.
- Consider land requirements, not only for the project itself but for worker housing, vehicle yards, access roads and other support facilities.
- Identify the resources (water, fuels, minerals, etc.) to be used or consumed during project construction and operation, and any effluents or byproducts to be produced.
- Estimate the size of the work force required for construction and determine what section of the population (or what extranationals) will provide this force.
- Determine what products will be required for project operation and maintenance (e.g., pesticides or fertilizers, vehicles) and how these products will be obtained.
- Identify the government agencies whose jurisdictions include all or part of the project.

Project Area Characteristics (Baseline Conditions)

Concurrently with the defining of project characteristics an understanding should be gained of the region's human and natural resources that may be affected, directly or indirectly, by the project. These should include land use and settlement patterns, natural resource distribution, condition and use, the physical environment (topography, climate, geology), social conditions (e.g., employment, education, housing, health, nutrition, religion), transportation and communication networks, and administrative and governmental structures. Data on baseline conditions should be assembled centrally and maintained in a current state so that the project's impacts may be monitored during its execution. In addition to understanding existing conditions, the planner should forecast conditions as they will be at the time of project initiation and during project life, for most (but not all) effects occur during the periods of construction and operation.

Potential Impacts

Once the characteristics (baseline conditions) of the affected region and of the proposed project are well understood, the next step is to analyze the ways in which the two may be

expected to interact. Potential impacts are identified and generally evaluated, whether advantageous or detrimental, so that appropriate modifications can be made in the project. The success of this analysis depends on a combination of common sense, knowledge of a variety of development projects, and the ability to foresee causative sequences. This manual assists the planner by focusing attention on certain well-recognized relationships between human activities and the environment and by applying these relationships to each of the five types of development considered.

The prediction of potential environmental problems is one of the most difficult tasks facing the planner, since the interactions involved are varied and often subtle. To aid in this analysis, each chapter of the manual contains a matrix in which components of the project are arrayed against various aspects of the natural and social environment. The annotations at the intersects of the matrix provide the planner with a checklist of the most likely impacts to be looked for and allowed for in project planning. Other impacts, not shown on the matrix, also are possible, depending on the specific project being considered.

Mitigation Planning

Once the types and magnitudes of interactions between the development project and its environment are identified, the next step is to devise and implement actions that will minimize adverse impacts and enhance benefits. Such actions may involve actual changes in the project itself, but frequently they consist of "companion activities."

A project is considered "environmentally sound" when there are no unacceptable adverse impacts and all reasonable steps have been taken to reduce even minor impacts and maximize benefits. Just what constitutes an "acceptable" impact varies from country to country and among social, ethnic and economic groups within each country. Much is left to the judgment of the planner, who must apply the values of the host country and his own wisdom in deciding when and how to adapt the project to its environment.

It is a mistake to believe that mitigating actions must adversely alter the project's cost-benefit ratio. In the long run, most actions to mitigate environmental impacts will make the project more effective, by promoting the achievement of short-range goals (e.g., improved food production) without compromising the long-range objectives (improved quality of life).

Project Modifications. Most changes in a project cost money and there is a temptation to avoid changes that will elevate the identifiable cost of the project to achieve benefits or avoid penalties that may be difficult to measure in economic terms. Project modifications need not be costly, however; sometimes a major environmental problem can be solved by a very small change in a project component or in the loca-

tion of some project related action. A minor route change in a road or pipeline may reduce forest clearing or protect an archeological site. Often a potential impact on a water body can be reduced by moving a discharge outlet. Temporary structures such as worker camps, motor pools, and aggregate plants often are placed where most convenient (hence economical) for the contractor. Other things being equal, this probably is the best policy, but other things seldom are truly equal if examined closely. Even a relatively small unit, such as an area used for formulating pesticides or for treating wood power poles with creosote, can exert intense local effects and should be examined closely for location and method of operation.

Companion Activities. Many environmental effects require mitigating actions by agencies other than the one directly responsible for the project. Examples of this type of impact are those affecting public health and education. The appropriate agency may require substantial lead time to allocate personnel and funds to the area of the project and to develop the required programs. Not infrequently, planners experience difficulty in eliciting interest on the part of administrators, whose agencies may be understaffed and inadequately funded. The planner must decide whether the needed companion activity is small enough to be accepted by agency personnel at the local level without additional input of funds from the central administration. Where educational programs in schools or additional vigilance by health personnel are required, these may be accomplished through direct contact with the local leader, who is usually more sensitive than those in the central administration to the problems of local development. If structures or additional personnel are required, more persuasion and a longer lead time usually are necessary. In such cases, an interagency committee may be needed, in order to establish responsibility and ensure action.

Use of the Project Planning Checklist and Impact Matrix

To assist A.I.D. project planners in the systematic identification and characterization of environmental benefits and/or impacts which might be associated with their specific rural development projects, a blank impact matrix, suitable for copying, and a planning checklist, for use in filling out the matrix, are included in this section of the manual. General instructions for the use of this material are given below.

Relationship to Completed Matrices

A matrix of potential project impacts is included at the end of each of the five chapters dealing with specific types of rural development projects. These matrices have already been filled out by the authors of this manual. The example matrices are generic in nature, however, and are not intended for direct application to a specific project. Rather, they provide a quick reference to the types of impacts or benefits which may be associated with development projects and are intended to alert project planners to areas of potential con-

cern. For example, quick reference to the matrix at the end of the chapter on rural roads will show that siting decisions for penetration roads may have major environmental consequences, while the matrix on small-scale irrigation projects shows that aquatic and wetland ecosystems are often sensitive to this type of development.

Prepration of a Project Specific Matrix

For actual project planning purposes, copies of the blank matrix included at the end of this section should be made, and, using the planning checklist, several versions of the matrix should be prepared, refining the level of detail at each successive step.

The following, specific steps describe the recommended procedures for completing th impact matrix:

1. After thorough review of the appropriate chapters and appendices of this manual, along with other literature from the recommended readings and review of the preliminary project plans, several members of the planning team should be assembled to complete the project impact matrix.

2. The planners should first determine the major project component decisions that will have to be made, such as routing, site locations, and water resources to be used, and list them in proper order on the left column of the impact matrix. Note that the project components should be divided into the three separate stages of 1) planning and design, 2) construction, and 3) operation.

3. Using appropriate portions of the "Planning Checklist" (Exhibit 2) as a guide, determine, to the extent possible, the potential impact of each project component decision on the applicable environmental components listed across the top of the matrix (changes or additions to the suggested environmental components should be made as necessary). The planning checklist provides a convenient scale for designating the estimated impact. The abbreviated scale is interpreted from left to right as follows:

   ND - Not Determinable[1/]

   HA - High Adverse

   MA - Medium Adverse

   LA - Low Adverse

1/ Not Determinable should be considered the same as High Adverse until an improved evaluation is possible.

O - None or Insignificant

LB - Low Beneficial

MB - Medium Beneficial

HB - High Beneficial

4. Repeat this process until all potential impacts have been preliminarily assessed. The process is meant to be repeated several times as more information becomes available, and the planners should not let any item of uncertainty hold up the process. Other specialists should be consulted, as necessary, to assist in removing "unknown" answers, develop project modifications if required, and determine a final impact estimate.

5. When the best estimate of all impacts has been made on the Planning Checklist, enter an appropriate symbol on the Impact Matrix.

6. When the Impact Matrix is complete, review the entire project plans by focusing in on those impacts considered most adverse. Relevant project decisions should be reviewed to see if either they can be modified or if additional mitigation actions can be planned to reduce the degree of the estimated impact to an acceptable level.

In accomplishing this process, the following points should be kept in mind:

- No one matrix or checklist can be designed to fit all projects. Revisions and modifications will be required to fit each specific project.

- Use of the planning checklist and impact matrix is intended to be an aid to the planning process rather than an end in itself. The entire process should be repeated several times, adding new information as possible. Changing the components entered in the matrix columns and rows and modifying basic project concepts, as high impact areas are identified, will result in the most environmentally acceptable plans.

- Use of the system of dots and circles shown in the matrices at the end of each chapter is not mandatory. A system of plus and minus signs, various degrees of shading, colors or other methods may prove to be more useful for your specific purposes.

- The completed planning checklists and impact matrices are not expected to be submitted to A.I.D. They are only intended as personal planning guides and records for the project planners' own use.

PROJECT IMPACT MATRIX

PROJECT COMPONENTS	ENVIRONMENTAL COMPONENTS →	PHYSICAL ENVIRONMENT													BIOLOGICAL ENVIRONMENT											SOCIAL ENVIRONMENT							
		AGRICULTURAL LANDS	SOIL EROSION	SLOPE STABILITY	ENERGY / MINERAL RESOURCES	SURFACE WATER QUANTITY	SURFACE WATER QUALITY	GROUND WATER QUANTITY	GROUND WATER QUALITY	AIR QUALITY	NOISE	AQUATIC ECOSYSTEMS	WETLAND ECOSYSTEMS	TERRESTRIAL ECOSYSTEMS	ENDANGERED SPECIES	MIGRATORY SPECIES	BENEFICIAL PLANTS	BENEFICIAL ANIMALS	PEST PLANTS	PEST ANIMALS	DISEASE VECTORS	PUBLIC HEALTH	RESOURCES / LAND USE	DISTRIBUTION SYSTEMS	EMPLOYMENT	AT-RISK POPULATIONS	MIGRANT POPULATIONS	COMMUNITY STABILITY	CULTURAL/RELIGIOUS VALUES	TOURISM / RECREATION	NUTRITION
PLANNING																																	
CONSTRUCTION																																	
OPERATION																																	

EXHIBIT 2

PROJECT PLANNING CHECKLIST

To be used as a guide in assessing each major project decision as to its environmental impact

A. PROJECT TYPE (Road, Industry, etc.): _____

B. PROJECT PHASE (Planning/Design, etc.): _____

C. PROJECT COMPONENT (Routing, Site location, etc.): _____

D. PROJECT DECISION POTENTIAL IMPACTS:

1. Agricultural Lands

a) Are there cultivable lands in the project area?	Yes___	No___	Unk___
b) Will project decision result in more or improved cultivable land?	Yes___	No___	Unk___
c) Will project decision result in less or damaged cultivable land?	Yes___	No___	Unk___

ESTIMATED IMPACT ON AGRICULTURAL LAND.....ND..HA..MA..LA..O..LB..MB..HB

2. Soil Erosion

a) Will project decision help to prevent soil loss or erosion?	Yes___	No___	Unk___
b) Will project decision directly cause or worsen soil loss or erosion?	Yes___	No___	Unk___
c) Could project decision indirectly lead to practices that could cause soil loss or erosion?	Yes___	No___	Unk___
d) Is it necessary to consult a soils scientist?	Yes___	No___	Unk___

ESTIMATED IMPACT ON SOIL EROSION.....ND..HA..MA..LA..O..LB..MB..HB

3. Slope Stability

a) Does project decision involve actual modification of slopes?	Yes___	No___	Unk___
b) Will project decision affect stability of slopes indirectly?	Yes___	No___	Unk___
c) Will project decision result in other conditions that could affect slope stability?	Yes___	No___	Unk___
d) Could project decision cause people, livestock or property to be located where existing unstable slopes could be a hazard?	Yes___	No___	Unk___
e) Is it necessary to consult a geotechnical engineer?	Yes___	No___	Unk___

ESTIMATED IMPACT ON SLOPE STABILITY.....ND..HA..MA..LA..O..LB..MB..HB

4. Energy-Mineral Resources

a) Do energy-mineral resources exist in project area? Yes___ No___ Unk___
b) Will project decision help to develop, now or in the future, important energy-mineral resources? Yes___ No___ Unk___
c) Will project decision cause significant consumption of additional energy-mineral resorces such as engine fuels? Yes___ No___ Unk___
d) Could project decision prevent or impede future development of essential energy-mineral resources? Yes___ No___ Unk___
e) Is it necessary to consult with a minerals agency or mining engineer? Yes___ No___ Unk___

ESTIMATED IMPACT ON ENERGY/MINERAL RESOURCES.....ND..HA..MA..LA..O..LB..MB..HB

5. Surface Water Quantity

a) Do surface water resources exist in project area? Yes___ No___ Unk___
b) Is information available on present and future demands on water resources as result of the project? Yes___ No___ Unk___
c) Will project decision help to increase or preserve available surface water supplies by such things as improved drainage/run-off conditions? Yes___ No___ Unk___
d) Will project decision increase demand or cause loss of available surface water either directly or indirectly? Yes___ No___ Unk___
e) Is it necessary to consult a hydrologist? Yes___ No___ Unk___

ESTIMATED IMPACT ON SURFACE WATER QUANTITY.....ND..HA..MA..LA..O..LB..MB..HB

6. Surface Water Quality

a) Is information available on present water quality? Yes___ No___ Unk___
b) Will project decision lead to additional natural or man made discharges into surface waters? Yes___ No___ Unk___
c) Will project decision help to improve or protect surface water quality? Yes___ No___ Unk___
d) Could project decision cause deterioration of surface water quality either directly or indirect? Yes___ No___ Unk___
e) Is it necessary to consult a water quality engineer or agency? Yes___ No___ Unk___

ESTIMATED IMPACT ON SURFACE WATER QUALITY.....ND..HA..MA..LA..O..LB..MB..HB

7. Ground Water Quantity

a) Do ground water resources exist in project area? Yes___ No___ Unk___
b) Is information available on present and future demands on water resources as result of the project? Yes___ No___ Unk___
c) Will project decision help to increase or preserve available ground water supplies by such things as improving recharge conditions? Yes___ No___ Unk___
d) Will project decision increase demand or cause loss of available ground water either directly or indirectly? Yes___ No___ Unk___
e) Is it necessary to consult a geohydrologist? Yes___ No___ Unk___

ESTIMATED IMPACT ON GROUND WATER QUANTITY.....ND..HA..MA..LA..O..LB..MB..HB

8. Ground Water Quality

a) Is information available on present water quality? Yes___ No___ Unk___
b) Will project decision cause any natural or man made discharges into ground aquifers? Yes___ No___ Unk___
c) Will project decision help to improve or protect ground water quality? Yes___ No___ Unk___
d) Could project decision cause deterioration of ground water quality either directly or indirectly? Yes___ No___ Unk___
e) Is it necessary to consult with a ground water quality specialist? Yes___ No___ Unk___

ESTIMATED IMPACT ON GROUND WATER QUALITY.....ND..HA..MA..LA..O..LB..MB..HB

9. Air Quality

a) Is information available on existing air quality? Yes___ No___ Unk___
b) Will project decision produce any air emissions directly? Yes___ No___ Unk___
c) Will project decision help to reduce existing air pollution sources such as open burning operations? Yes___ No___ Unk___
d) Could project decision lead to practices that worsen air quality such as causing increased road traffic or industrialization? Yes___ No___ Unk___

9. (Cont.)

e) Could project decision lead to a change in engine use or fuel combination that could cause serious air problems? Yes___ No___ Unk___

f) Is it necessary to consult an air quality specialist? Yes___ No___ Unk___

ESTIMATED IMPACT ON AIR QUALITY.....ND..HA..MA..LA..O..LB..MB..HB

10. Noise

a) Is noise now a problem in project area? Yes___ No___ Unk___

b) Will project help in reducing undesirable noise conditions? Yes___ No___ Unk___

c) Will project cause temporary or sustained increases in noise generating conditions such as heavy machinery or road travel? Yes___ No___ Unk___

d) Could project cause movements of people to high noise level locations? Yes___ No___ Unk___

e) Is it necessary to consult a noise specialist? Yes___ No___ Unk___

ESTIMATED IMPACT ON NOISE.....ND..HA..MA..LA..O..LB..MB..HB

11. Aquatic Ecosystems

a) Are there any aquatic ecosystems of the types listed below which, by nature of their size, abundance or type, can be considered significant or unique?

rivers?	Yes___	No___	Unk___
streams?	Yes___	No___	Unk___
lakes?	Yes___	No___	Unk___
ponds?	Yes___	No___	Unk___

b) Are these systems essentially:

pristine?	Yes___	No___	Unk___
moderately degraded?	Yes___	No___	Unk___
severely degraded?	Yes___	No___	Unk___

c) Are these systems used by the local people:

i) Consumptively

For drinking water?	Yes___	No___	Unk___
For irrigation?	Yes___	No___	Unk___
For livestock?	Yes___	No___	Unk___

ii) Non-consumptively

For Washing and Bathing?	Yes___	No___	Unk___
For Waste Disposal?	Yes___	No___	Unk___

11. (Cont.)

	Yes___	No___	Unk___
For Harvest of non-domesticated plants or animals as food, fiber fur or other useful product?	Yes___	No___	Unk___
d) Will the project directly affect consumptive use of water?	Yes___	No___	Unk___
e) Will the project directly or indirectly affect either non-consumptive or consumptive uses of these ecosystems by:			
Use or production of toxic materials (both during construction and/or operation) which might enter these systems?	Yes___	No___	Unk___
Alteration of drainage patterns?	Yes___	No___	Unk___
Increasing erosion?	Yes___	No___	Unk___
Causing increase in populations so as to place added stress on their systems?	Yes___	No___	Unk___

ESTIMATED IMPACT ON AQUATIC ECOSYSTEMS.....ND..HA..MA..LA..O..LB..MB..HB

12. Wetland Ecosystems

a) Are there any wetland ecosystems of the types listed below which, by nature of their size, abundance or type, can be considered to be significant or unique?			
Marsh?	Yes___	No___	Unk___
Swamp?	Yes___	No___	Unk___
Bog?	Yes___	No___	Unk___
Flood Plain?	Yes___	No___	Unk___
Estuary?	Yes___	No___	Unk___
b) Are these systems:			
pristine?	Yes___	No___	Unk___
Moderately degraded?	Yes___	No___	Unk___
severely degraded?	Yes___	No___	Unk___
c) Are these systems used by local people for:			
Drinking Water?	Yes___	No___	Unk___
Livestock Water?	Yes___	No___	Unk___
Washing and Bathing?	Yes___	No___	Unk___
Waste Disposal?	Yes___	No___	Unk___
Agriculture?	Yes___	No___	Unk___
Harvest of non-domesticated plants or animals as food, fur, or fiber.	Yes___	No___	Unk___

12. (Cont.)

d) Is there currently a trend towards draining wetlands in the project area for conversion to some other use? Yes___ No___ Unk___

e) Will the project either directly or indirectly affect wetlands by:

Changing population or land use practices so as to increase drainage of wetlands for use as agricultural, industrial or urban land?	Yes___	No___	Unk___
Use or production (either during construction and/or operation) of toxic materials which might enter wetlands?	Yes___	No___	Unk___
Use the water directly?	Yes___	No___	Unk___
Alter drainage patterns so as to affect wetlands?	Yes___	No___	Unk___
Increase erosion so as to affect wetlands?	Yes___	No___	Unk___

ESTIMATED IMPACT ON WETLAND ECOSYSTEMS.....ND..HA..MA..LA..O..LB..MB..HB

13. Terrestrial Ecosystems

a) Are there any terrestrial ecosystems of the types listed below which, by nature of their size, abundance or type, could be classified as significant or unique?

Forest?	Yes___	No___	Unk___
Savanna?	Yes___	No___	Unk___
Grassland?	Yes___	No___	Unk___
Desert?	Yes___	No___	Unk___

b) Are these ecosystems:

Pristine?	Yes___	No___	Unk___
Moderately Degraded?	Yes___	No___	Unk___
Severely Degraded?	Yes___	No___	Unk___

c) Are there present trends towards alteration of these ecosystems through cutting, burning, etc. to produce agricultural, industrial, or urban land? Yes___ No___ Unk___

d) Does the local population use these ecosystems to obtain non-domesticated:

Food plants?	Yes___	No___	Unk___
Medicinal plants?	Yes___	No___	Unk___
Wood products?	Yes___	No___	Unk___
Fiber?	Yes___	No___	Unk___
Fur?	Yes___	No___	Unk___
Food Animals?	Yes___	No___	Unk___

Harza Engineering Co. Environmental Design Considerations for Rural Development Projects. Washington, D.C.: Agency for International Development, 1980. 189 p. (PN-AAJ-322).

Environmental design considerations require a basic understanding of ecology. AID rural development projects are being planned for over 70 countries, and project planners should be aware of unique geographic or ecological characteristics of their areas. This manual is intended to assist AID officials, consultants, and host-country planners in identifying potentially beneficial and undesirable environmental effects that may accompany small rural projects; general guidelines are presented for possible application to specific projects. The report discusses the characteristics of local rural communities and the demographic types of regions covered, including some situations that apply to larger villages and periurban regions. Specific project considerations, including human ecology, environmental health, air and water quality, pesticide contamination, and endangered species are discussed. Projects should be treated in an integrated regional or national context, because individual projects may compete for resources that supplement each other and often require interagency coordination. Guidelines are provided. The manual addresses project planning, area characteristics, potential impacts, and mitigation planning and includes a checklist and matrix of impacts defined. Five specific types of rural projects are addressed in detail: roads, electrification, water supply and sanitation, irrigation and on-farm water management, and small-scale industries. Approximately 100 references are cited.

13. (Cont.)

e) Will the project require clearing or alteration of:

Small areas of land in these ecosystems?	Yes___	No___	Unk___
Moderate areas of land in these ecosystems?	Yes___	No___	Unk___
Large areas of land in these ecosystems?	Yes___	No___	Unk___

f) Does the project rely on any raw materials (wood, fiber) from these ecosystems?	Yes___	No___	Unk___
g) Will the project decrease use of products from these ecosystems by producing or providing substitute materials?	Yes___	No___	Unk___
h) Will the project cause increased population growth in the area, bringing about increased stress on these ecosystems?	Yes___	No___	Unk___

ESTIMATED IMPACT ON TERRESTRIAL ECOSYSTEMS.....ND..HA..MA..LA..O..LB..MB..HB

14. Endangered Species

a) Is the existence of endangered species in the project area:

Very unlikely	Yes___	No___	Unk___
Probable	Yes___	No___	Unk___
Highly probable	Yes___	No___	Unk___
Documented fact	Yes___	No___	Unk___

b) Are these species: Of scientific interest only	Yes___	No___	Unk___
Of scientific interest and highly sought after by local people for food, hides, sale to animal dealers.	Yes___	No___	Unk___
c) Will the project affect the habitat of these animals: Directly by destruction of habitat?	Yes___	No___	Unk___
Indirectly by altering habitat through changing drainage, land use.	Yes___	No___	Unk___
d) Will the project increase ease of access to these habitats?	Yes___	No___	Unk___
e) Will the project increase population in the project area, thus placing increased pressure on these species and/or on their habitat?	Yes___	No___	Unk___

ESTIMATED IMPACT ON ENDANGERED SPECIES.....ND..HA..MA..LA..O..LB..MB..HB

15. Migratory Species

a) In the project area are there any:

Migratory fish?	Yes___	No___	Unk___
Migratory birds?	Yes___	No___	Unk___
Migratory Mammals?	Yes___	No___	Unk___

b) Are these species used by local people for food, fur, or other products? Yes___ No___ Unk___

c) Will the project require any dams, roads, pipelines or other alignments which could interfere with these migratory animals? Yes___ No___ Unk___

d) Will the project destroy any habitats (resting, feeding, reproductive) which are critical to these species? Yes___ No___ Unk___

e) Will increased population place additional stress on these species? Yes___ No___ Unk___

ESTIMATED IMPACTS ON MIGRATORY SPECIES.....ND..HA..MA..LA..O..LB..MB..HB

16. Beneficial Plants

a) Do non-domesticated plants occur in the project area which are used or sold by local people as:

Food?	Yes___	No___	Unk___
Fiber?	Yes___	No___	Unk___
Fuel?	Yes___	No___	Unk___
Ornament?	Yes___	No___	Unk___
Medicine?	Yes___	No___	Unk___
Forage?	Yes___	No___	Unk___
Building Material?	Yes___	No___	Unk___

b) Do these plants occur in:

Undisturbed habitats?	Yes___	No___	Unk___
Moderately disturbed habitat?	Yes___	No___	Unk___
Severely disturbed habitat?	Yes___	No___	Unk___

c) Are these plants:

Utilized heavily?	Yes___	No___	Unk___
Utilized moderately?	Yes___	No___	Unk___
Utilized only occasionally?	Yes___	No___	Unk___

d) Is this use:

Peculiar to the local population?	Yes___	No___	Unk___
Universal in the region or country?	Yes___	No___	Unk___

16. (Cont.)

e) Will the project:

Decrease habitat for these plants?	Yes___	No___	Unk___
Increase habitat for these plants?	Yes___	No___	Unk___
Increase access to these plants?	Yes___	No___	Unk___
Provide substitute products or the necessary money to replace the use of these plants?	Yes___	No___	Unk___
Increase use of these plants through increased population?	Yes___	No___	Unk___

ESTIMATED IMPACT ON BENEFICIAL PLANTS.....ND..HA..MA..LA..O..LB..MB..HB

17. Beneficial Animals

a) Do non-domesticated animals occur in the project area which are used or sold by the local people as:

Souvenir products?	Yes___	No___	Unk___
Food?	Yes___	No___	Unk___
Fur?	Yes___	No___	Unk___
Pets?	Yes___	No___	Unk___

b) Do these animals occur in:

Undisturbed habitats?	Yes___	No___	Unk___
Moderately disturbed habitats?	Yes___	No___	Unk___
Severely disturbed habitats?	Yes___	No___	Unk___

c) Are these animals:

Utilized heavily?	Yes___	No___	Unk___
Utilized moderately?	Yes___	No___	Unk___
Utilized only occasionally?	Yes___	No___	Unk___

d) Is this use:

Peculiar to the local population?	Yes___	No___	Unk___
Universal to the region or country?	Yes___	No___	Unk___

e) Will the project:

Decrease habitat for these animals?	Yes___	No___	Unk___
Increase habitat for these animals?	Yes___	No___	Unk___
Increase access to these animals?	Yes___	No___	Unk___
Provide substitute products or necessary money to replace the use of these animals?	Yes___	No___	Unk___
Increase the use of these animals by increased population?	Yes___	No___	Unk___

ESIMATED IMPACTS ON BENEFICIAL ANIMALS.....ND..HA..MA..LA..O..LB..MB..HB

18. Pest Plants

a) Are there currently any pest plant problems in the project area?	Yes___	No___	Unk___
b) Are there any potential pest plant species known to exist in the project area?	Yes___	No___	Unk___
c) Are these pest plants associated with:			
Severely disturbed land?	Yes___	No___	Unk___
Agricultural land?	Yes___	No___	Unk___
Stagnant or polluted water?	Yes___	No___	Unk___
d) Will the project?	Yes___	No___	Unk___
Increase habitat for pest plants?	Yes___	No___	Unk___
Decrease habitat for pest plants?	Yes___	No___	Unk___
Provide opportunity for control of pest plants?	Yes___	No___	Unk___
Increase the possibility of introduction of pest plants through increased commerce?	Yes___	No___	Unk___

ESTIMATED IMPACTS ON PEST PLANTS.....ND..HA..MA..LA..O..LB..MB..HB

19. Pest Animals

a) Are there currently any problems with pest animals in the project area?	Yes___	No___	Unk___
b) Are there any animals in the project area which, under altered ecological conditions, have the potential for becoming pest species?	Yes___	No___	Unk___
c) Are these species associated with:			
Severely degraded land?	Yes___	No___	Unk___
Agricultural land?	Yes___	No___	Unk___
Aquatic Habitats?	Yes___	No___	Unk___
d) Will the project:			
Increase habitat for pest animals?	Yes___	No___	Unk___
Decrease habitat for pest animals?	Yes___	No___	Unk___
Increase the possibility of introduction of pest animals through increased commerce?	Yes___	No___	Unk___
Provide the opportunity for control of pest animals?	Yes___	No___	Unk___

ESTIMATED IMPACT ON PEST ANIMALS.....ND..HA..MA..LA..O..LB..MB..HB

20. Disease Vectors

a) Are there known disease problems in the project area transmitted through vector species such as mosquitos, flies, snails, etc.? Yes___ No___ Unk___

b) Are these vector species associated with:

Aquatic habitats?	Yes___	No___	Unk___
Forest habitats?	Yes___	No___	Unk___
Agricultural Lands?	Yes___	No___	Unk___
Degraded habitats?	Yes___	No___	Unk___
Human settlements?	Yes___	No___	Unk___

c) Will the project:

Increase vector habitat?	Yes___	No___	Unk___
Decrease vector habitat?	Yes___	No___	Unk___
Provide opportunity for vector control?	Yes___	No___	Unk___

d) Will the project work force be a possible source of introduction of disease vectors not currently found in the project area? Yes___ No___ Unk___

e) Will increased access to and commerce with the project area be a possible source of disease vectors not presently occurring in the project area? Yes___ No___ Unk___

f) Will the project provide opportunities for vector control through improved standards of living? Yes___ No___ Unk___

ESTIMATED IMPACT ON DISEASE VECTORS.....ND..HA..MA..LA..O..LB..MB..HB

21. Public Health

a) Are vector-borne diseases an important part of the local public health situation? Yes___ No___ Unk___

b) Are there clinics or other disease control programs in operation or planned for the area? Yes___ No___ Unk___

c) Will the project decision result in an increase in disease vector density or distribution? Yes___ No___ Unk___

d) Will the project decision result in workers or other persons entering the area with contagious or vector-borne diseases? Yes___ No___ Unk___

e) Will the project decision result in clearing operations that could expose workers to disease vectors? Yes___ No___ Unk___

21. (Cont.)

f) Will the project decision increase the hazard of accident to the local population? Yes___ No___ Unk___

g) Will the project decision improve opportunities for the local population to receive health care? Yes___ No___ Unk___

h) Is it necessary to consult with a public health specialist? Yes___ No___ Unk___

ESTIMATED IMPACT ON PUBLIC HEALTH.....ND..HA..MA..LA..O..LB..MB..HB

22. Resource/Land Use

a) Are the natural resources of the area under intensive use pressure? Yes___ No___ Unk___

b) Are lands in the project area intensively developed? Yes___ No___ Unk___

c) Will the project decision increase pressure on land resources? Yes___ No___ Unk___

d) Will the project decision result in decreased holdings by small land owners? Yes___ No___ Unk___

e) Will the project decision increase depletion rates of natural resources? Yes___ No___ Unk___

f) Should a land use planner be consulted? Yes___ No___ Unk___

ESTIMATED IMPACT ON RESOURCES AND LAND USE.....ND..HA..MA..LA..O..LB..MB..HB

23. Conventional/Nonconventional Energy Sources

a) Will the project increase the demand for conventional energy sources (petroleum, hydropower)? Yes___ No___ Unk___

b) Will the project increase the demand for nonconventional energy sources (fuelwood, dung, agricultural wastes)? Yes___ No___ Unk___

c) Should an energy planner be consulted? Yes___ No___ Unk___

ESTIMATED IMPACT ON ENERGY SOURCES.....ND..HA..MA..LA..O..LB..MB..HB

24. Distribution Systems

a) Are the production/distribution networks for agricultural and manufactured commodities fully understood? Yes___ No___ Unk___

b) Will the project decision enhance the equitable distribution of these products? Yes___ No___ Unk___

c) Will the project decision increase the demand for certain commodities within or outside the area? Yes___ No___ Unk___

24. (Cont.)

d) Will the project decision decrease the demand for certain locally produced goods? Yes___ No___ Unk___
e) Will the project decision improve the ease with which consumers in the area obtain commodities? Yes___ No___ Unk___
f) Will the project decision decrease the production of certain vital commodities? Yes___ No___ Unk___
g) Is it necessary to consult a social anthropologist? Yes___ No___ Unk___

ESTIMATED IMPACT ON DISTRIBUTION SYSTEMS.....ND..HA..MA..LA..O..LB..MB..HB

25. Employment

a) Is the potential work force in the area fully employed? Yes___ No___ Unk___
b) Will the project decision substantially increase the rate of employment? Yes___ No___ Unk___
c) Will the project decision remove job opportunities in the area? Yes___ No___ Unk___
d) Will the project decision result in drawing workers from other local employers? Yes___ No___ Unk___
e) Is it necessary to consult with a socioeconomist? Yes___ No___ Unk___

ESTIMATED IMPACT ON EMPLOYMENT.....ND..HA..MA..LA..O..LB..MB..HB

26. At-Risk Population

a) Are the adverse impacts of the project unequally distributed in the target population? Yes___ No___ Unk___
b) Have the at-risk groups been identified? Yes___ No___ Unk___
c) Have all possible actions been identified that would lessen the impact on at-risk groups? Yes___ No___ Unk___
d) Is the assistance of a social anthropologist required to adequately answer these questions? Yes___ No___ Unk___

ESTIMATED IMPACT ON AT-RISK POPULATION....ND..HA..MA..LA..O..LB..MB..HB

27. Migrant Populations

a) Are there presently certain mobile groups in the target population? Yes___ No___ Unk___
b) Will the project decision result in immigration of people to the area? Yes___ No___ Unk___

27. (Cont.)

c) Are local institutions and agencies adequately geared to handle this influx? Yes___ No___ Unk___

d) Will the project decision result in the movement of people out of the area? Yes___ No___ Unk___

e) Can their probable destinations be predicted? Yes___ No___ Unk___

f) Are local institutions and agencies or receiving agencies able to handle these migrant groups? Yes___ No___ Unk___

g) Is it necessary to consult a social anthropologist? Yes___ No___ Unk___

ESTIMATED IMPACT ON MIGRANT POPULATIONS.....ND..HA..MA..LA..O..LB..MB..HB

28. Community Stability

a) Are the interrelationships of various social groups in the project area understood? Yes___ No___ Unk___

b) Will the project decision establish institutions that will improve these interrelationships? Yes___ No___ Unk___

c) Will the project decision create competition among social groups that would reduce community cohesion? Yes___ No___ Unk___

d) Is it necessary to consult a social anthropologist? Yes___ No___ Unk___

ESTIMATED IMPACT ON COMMUNITY STABILITY.....ND..HA..MA..LA..O..LB..MB..HB

29. Cultural and Religious Values

a) Have studies been conducted of the cultural values of the project area? Yes___ No___ Unk___

b) Are the cultural characteristics unique to the project area adequately known? Yes___ No___ Unk___

c) Will the project decision adversely affect the religious attitudes of area residents? Yes___ No___ Unk___

d) Are there special superstitions or religious taboos that will affect the acceptance of the project by the target population? Yes___ No___ Unk___

e) Is it necessary to consult a social anthropologist? Yes___ No___ Unk___

ESTIMATED IMPACT ON CULTURAL AND RELIGIOUS VALUES.....ND..HA..MA..LA..O..LB..MB..HB

30. Tourism and Recreation

a) Is there at present a significant degree of tourism in the area? Yes___ No___ Unk___
b) Is there unexploited tourism or recreation potential in the area? Yes___ No___ Unk___
c) Will the project decision result in more effective utilization of present or future tourism opportunities? Yes___ No___ Unk___
d) If so, will this adversely affect the lifestyles of local people? Yes___ No___ Unk___
e) Will the project decision adversely affect an existing or potential tourist or recreation attraction? Yes___ No___ Unk___

ESTIMATED IMPACT ON TOURISM AND RECREATION.....ND..HA..MA..LA..O..LB..MB..HB

31. Nutrition

a) Have adequate data been gathered on the nutritional levels in the project area? Yes___ No___ Unk___
b) Do these data differentiate among various population subgroups, by age, sex or social level? Yes___ No___ Unk___
c) Will the project decision result in changed food habits in the target population? Yes___ No___ Unk___
d) Will these changes result in higher caloric levels and improved nutritional characteristics? Yes___ No___ Unk___
e) Are the services of a nutrition specialist required? Yes___ No___ Unk___

ESTIMATED IMPACT ON NUTRITION.....ND..HA..MA..LA..O..LB..MB..HB

II. RURAL ROADS

Project Description

General Characteristics

A.I.D.'s rural road projects are usually aimed at bringing accessibility to villages or remote project sites that currently are inadequately connected with the national transportation system of the country. A road system is a fundamental necessity for rural development, providing for the flow of people, goods and services in and out of the region. The project goals thus fall in two general categories.

1. Egress is provided for the transportation of products to markets, access for village people to employment, health facilities, markets and government service.

2. Access to villages is provided for government services (health, extension services, administration and legal services) and the flow of goods.

Rural roads are selected for construction and upgrading on the basis of whether improvement can be expected to accomplish the above goals. Criteria for selection require that:

1. Most of the farms in the benefit area are small. The size limits and required percentage of small farms vary from country to country, but they are set so as to benefit the rural poor (including those in villages).

2. Each road section being upgraded should connect with a road of equal or greater quality to that proposed for the project.

3. The completed road system should connect the benefit area with a market center.

4. The local government agency responsible for the upgraded section should have the resources (personnel, equipment and funds) for maintaining the project roads.

Rural road projects generally follow already established tracks. When and if the road project will open up new areas for development, a comprehensive study is needed to determine whether the areas provided access are appropriate for the other types of development that the road will indirectly encourage and whether such areas can support additional people. Not infrequently a road must be partially rerouted in order to avoid a section that is badly eroded by surface water runoff, obtain a flatter grade (vertical alignment) or relocate a river crossing. Such realignments usually do not result in opening up undeveloped areas.

For high volume roads, many English speaking countries have adopted, often with considerable modifications, the design standards of the European countries or United States Federal Highway Administration. Most A.I.D. funded projects provide for two-lane roads, approximately 6 meters (20 feet) wide, with shoulders of 1 to 1.5 meters. Where single-lane roads are constructed, turnouts for passing should be provided at line-of-sight intervals.

Protection should be provided against soil erosion from slopes, water runoff from the road surface, and from the natural runoff of the surrounding drainage area. Culverts are provided where this water must be passed under the road. Streams and rivers may be forded or bridged, depending on the characteristics of the watercourse.

In all road projects preference should be given to the use of local materials for the road embankment and surface, culverts, and bridges; provided the materials are environmentally and structurally stable. If the project construction is to be labor-intensive, special consideration to accommodate labor should be effected in the design stage. In areas where a high percentage of the work force is actively employed or unskilled, more equipment intensive-methods may be called for.

Location Sensitive Factors

The routing of rural roads is governed initially by topography and settlement patterns. Most of the routes have developed over a period of many years (sometimes centuries) and have strongly influenced, and have been influenced by, regional development patterns. At a more local level, alignments take into account both natural and human ecology.

Natural Ecology. Most established roads in developing countries have created, during their first few years of life, land development extending several kilometers from the road on each side. Occasional exceptions are found in roads passing through protected natural areas (wildlife preserves), national parks or tribal lands. Thus, natural ecological impacts rarely present serious problems in the selection of roads for upgrading or in the siting of accessory areas, such as borrow pits (areas supplying fill), spoil areas (for disposal of unwanted rock or soil), construction camps, and vehicle parking areas.

Where a penetration road is required in an area that is sparsely inhabited, comprehensive planning is required to protect the natural ecosystems. Initial consideration should be given to routing the road to minimize direct destruction of ecologically important areas, such as water holes and breeding areas for wildlife. The assistance of a biologist probably will be required to identify significant aspects. Routing decisions may also influence indirect effects on ecosystems by maintaining barriers, e.g., mountains, rivers and steep gorges, between the road and ecologically sensitive areas. If mapping

is inadequate, a ground survey should be conducted in order to locate environmentally sensitive areas such as wetlands, ground water recharge zones, endangered species habitats, or migratory paths for important animals.

Human Ecology. The distribution of population and of agricultural production is a central consideration in the selection of roads for improvement. A social scientist should be used for population projections and community planning studies. In addition to population centers, other human activities may strongly influence a road routing, such as building reservoirs (which may be barriers) and military reservations, which may present major barriers to civilian roads.

Environmental Considerations

Natural Environment

The most serious and far-reaching consequences of rural road development occur when a new road penetrates an area of natural forest not previously accessible to development. Impacts on social systems [A], public health [B] and terrestrial ecosystems are the most critical; impacts on aquatic ecosystems and water quality [C] also should be evaluated. In most developing nations it has proven extremely difficult, if not impossible, to prevent the exploitation of a newly available forest resource by timber cutters, hunters and shifting cultivators, resulting in loss of valuable plants, habitats, and soils (through increased erosion). This exploitation may occur in an uncontrolled manner in the absence of penetration roads, but is greatly accelerated by the presence of new roads.

Where roads cross rivers and streams there is a potential for siltation and disturbances of the stream bed due to the construction of bridges and fords. Further disturbance of the water may arise from the tendency of local people to gather near the bridge or ford to wash clothes, bathe and water livestock, resulting in contamination by organic materials, such as soaps and detergents, and resuspension of silt.

A major cause of siltation and erosion during road construction is the frequent practice of contractors of building the major features of the road, such as the embankment (the built-up sections), cuts and bridge abutments, without adequate erosion control. All denuded slopes should be reseeded and stabilized as soon as possible, to minimize soil loss from runoff By the time the ditches and culverts have been installed, heavy rains may have caused severe erosion, siltation of watercourses, and flooding of areas where natural drainage is blocked. Proper alignment and design, as well as precautions during construction (e.g. earth or straw berms for control of runoff) can prevent most if not all erosion.

Human Environment

Public Health. Properly designed, constructed and maintained,

the upgraded rural road should bring no severe additional public health problems to areas through which it passes. On the contrary, the additional access to urban medical facilities and improved transportation for rural medical teams should result in broad improvements in the rural health situation.

One potential problem occasionally overlooked is the risk of injury to humans (especially the elderly and children) and livestock through the increase in traffic and in vehicle size and speed through areas unaccustomed to such traffic.

When all or part of a road penetrates a relatively untouched natural area, the clearing of the right-of-way may result in increased disease risk to road workers, due to the descent to the ground level of treetop insect vectors (disease carriers). In areas where malaria, encephalitis, leishmaniasis and yellow fever [B] are continually present in arboreal wildlife, such as birds, sloths and monkeys, the tree-living insects rarely have access to man except when the trees are felled. The crews performing the clearing operation should be adequately protected.

Social Effects. The major social consequences of improving rural roads are the secondary effects of more effective and less costly transport of goods and people, providing better access to markets, health facilities, education, extension services and other amenities. In addition, problems can occur that may be prevented by adequate advance planning.

The combination of increased information flow within the rural sector and between the rural and urban communities and the improved transportation network is likely to accelerate changes in the employment patterns in the region. There may be more urban migration of wage-earning males, but, depending on the distance, these workers may seek day-labor that allows them to return to their rural homes at night. Rural laborers will look further afield, providing more even distribution of jobs. Work opportunities for unskilled or semiskilled laborers in road construction and repair and vehicle maintenance will draw some workers from agriculture. The increased opportunities for off-farm jobs in rural areas may slow the urban migration that currently exists in many developing countries.

The improved access to markets will bring about changes in cropping patterns, as the more enterprising farmers concentrate on cash crops. This, in turn, will increase the cash flow in the rural area and create a demand for manufactured goods and processed foods. This change is generally considered a project benefit, but the planner must be aware that such benefits are not uniformly distributed among the affected population [A]. Locally produced commodities, such as food, cooking utensils and clothing, may be replaced with externally manufactured commodities, with a consequent loss of income to local producers. Also, better roads will stimulate development, which could lead to excessive use of local resources unless secondary (indirect) impacts are fully recognized and properly controlled [A].

Many A.I.D. road projects are designed for labor-intensive methods, except in areas where the pool of available labor is so small that the use of the local work force on the road would result in removing laborers from other employment. The road planner must be alert to the reverse phenomenon, in which local industry or critically important agricultural employment draws workers away from the road project.

Mitigation and Enhancement Measures

Companion Activities

Companion activities include programs and projects that are not directly required for achieving the project's primary objectives, but which serve to decrease its environmental costs and increase or speed up its benefits. Many of these activities are the responsibilities of agencies not directly involved with road planning, construction or maintenance. Some of the activities suggested here are designed to ensure that project benefits are fully achieved, since the failure of any project to live up to the expectations of its beneficiaries results in a variety of negative impacts. For example, if the road is expected to lead to cash cropping but no agricultural extension assistance is provided to farmers, some farmers may switch to cash crops without sufficient know-how and suffer crop failure.

Assistance should be provided to farmers in the transport of harvested crops to market, whether through loans for vehicles, an extension service or a cooperative. Few small farmers in the benefit area will be able to capitalize on the new access to markets without some forms of financial and technical assistance. If this is not provided, the road could have effects opposite to those intended, i.e., increased urban migration, increased holdings by larger farmers, and squatter settlements. The extent to which a road project can produce its intended benefits in the absence of companion activities will be determined primarily by the type of socioeconomic system being served and the degree of stability that it has attained.

For co venience, companion activities may be separated into those required during construction and those needed when the road is in service, although some will continue through both periods.

Health officials should be aware of the possible transmission of communicable diseases from workers to residents, and vice versa, during construction and should take necessary preventive measures.

Local governments and their various agencies should be alert to the attraction of the road for squatter settlements and uncontrolled line communities, especially in urban and peri-urbian areas, but also in connection with construction camps. Such settlements, especially at road junctions, represent incipient urban centers and may eventually develop their own governmental structures. During their development period they should

be monitored by the central agencies responsible for health, law enforcement and other services.

During the period when the new road is in service, all government agencies whose jurisdiction extends into the area served should be alert to changing conditions. These could normally include the national and local agriculture, forestry, recreation, health, education and transportation agencies.

The ministry of agriculture should be made aware of the possibility that the increased movement of plants and animals along the new road may accelerate the spread of plant and animal diseases and pests. In the event of a localized outbreak of such conditions, an inspection station should be established along the road to prevent the movements of infected crops or livestock into other areas.

In addition to the general monitoring of health conditions in the new settlements that will probably develop at key points along the improved road, health officials for the benefit area should collect morbidity statistics, not only to provide information on programmatic needs but also to shed light on benefits or adverse impacts of the road, if any. The health teams also should be alert to standing water in roadside ditches, which often become clogged, impeding drainage. Such blockage by weeds may cause only minor problems with the road itself, depending on the extent of vegetation on the shoulders, but the water in the ditches may support vectors of malaria, encephalitis, schistosomiasis and contain water-borne disease organisms [3]. Roadside ditches frequently become receptors of human wastes; where pedestrian traffic is heavy this waste creates a major health problem.

Restoration and Reutilization

Certain areas required for project construction become available for other uses during project operations. Such areas include borrow pits, spoil areas, construction campsites, and other temporarily used areas. In addition, rights-of-way and other areas required during project operation may be planted or otherwise treated to serve multiple uses.

The revegetation of the road shoulders usually is an integral part of the project, necessary to protect the shoulders from erosion. If the right-of-way is wide enough, careful selection of plants can render these areas useful for grazing, fuelwood, shade or shelter from the wind. The mix of plants selected should be such, however, that overgrazing or overcutting will not denude the area and permit severe erosion. Care should be taken that such plantings do not result in an increased livestock hazard on the road itself. In Pakistan, a massive program of shelterbelt planting is providing shade, fuelwood and timber along many of the larger roads. The acute shortage of forage has led to excessive (illegal) cutting of leafy branches in some areas, a practice almost impossible to control when the resource is so widely dispersed. Such cutting of branches has severely affected the shelterbelt properties

of the tree strip, but has not greatly affected road use. The presence of this forage undoubtedly has been an aid to local farmers who lack adequate forage for their livestock.

Borrow pits are often large and shallow, and sometimes receive natural runoff, creating ponds. Where an adequate supply of good water is assured and adequate drainage can be provided, such ponds can produce large yields of fish, with adequate management. Where possibilities are seen to exist, a fisheries biologist should be consulted early in the project. Management should include initial stocking with the appropriate fish species and periodic monitoring to ensure that the pond is not being overexploited. Water quality monitoring may be required, where surface water tends to be saline, but a substantial salt load may not preclude the use of a pond for aquaculture if salt tolerant species, such as Tilapia, are used. Attention must be given to the danger of creating mosquito problems and the transmission of schistosomiasis and other water related diseases.

Environmental Controls

Proper road designs will protect the road from damage by the elements and minimize adverse effects of the road upon the environment. Measures taken to ensure proper drainage of the road also function to prevent degradation of local water quality. In most cases no further water quality controls are necessary, but where chemicals are used to remove or prevent plant growth they must be selected with regard to subsequent use of the water that drains from the road.

Air quality controls normally are not built into the road design and concern for air quality has lagged behind that for water quality in most countries. The primary adverse impacts of rural roads upon air quality are fugitive dust and to a lesser extent exhaust emissions, and these are felt primarily in villages, although crops near the road may also be affected.

Road dust is primarily a nuisance rather than a serious health hazard, for those dwelling along the road. Where water is plentiful, villagers frequently wet the road in front of homes and shops, in order to keep down dust. Where the dust becomes particularly severe, the stretch of road passing through a village may require stabilization of the surface or paving.

Operational Evaluation and Monitoring

Skills and Training

The planner should examine the ways in which the benefited (target) population is suited to respond to the demands and opportunities created by the upgraded road. Are all of the required skills available in the populace? Or are courses in vehicle maintenance and repair, or even finance, needed to enable the local people to respond to opportunities? Is a traffic safety program needed in local schools? Such programs, if

needed, may fall within the jurisdiction of the ministry of education, but the need may go unrecognized by the ministry for months or even years after the project is implemented.

Testing and Review

In addition to routine road maintenance, periodic examinations should be performed to ensure that culverts are not causing erosion at their discharge points and siltation of streams. The water in roadside ditches should be monitored for the presence of disease organisms and vectors.

The transportation agency should periodically examine the effect of the road on livestock, and vice versa if large herds of animals are driven on or across the road. Occasionally wildlife may be endangered by the road traffic. It may be necessary to fence the right-of-way at certain points and/or provide wider culverts and bridges to facilitate the passage of animals. The same agency should monitor the road for accidents to remedy accident-causing conditions.

Special Assistance

Some of the measures recommended above may require laboratory facilities or technical expertise not available near the road project. The planner should attempt to identify any special test facilities required for non-project monitoring and determine whether they exist in the country.

Planning Information Required

I. Planning/Design Stage

a. Selection of Alternatives. For each road section under consideration for improvement or extension.

1. Benefit Area Characteristics:

Topography

Farm size range and distribution; ownership/tenancy; other land use

Population density and demography

Socio-cultural conditions - local social structure; community cohesion; employment; migrations; ethnic background

Production/consumption patterns - locally produced and externally produced goods

Natural systems/ecological conditions - aquatic and terrestrial; extent of use

Natural Resources - water, minerals, availability; current use; ownership;

Mapping and aerial photography

Climatic conditions

2. Existing Transportation System(s): structure;

   Distribution; maintenance; seasonality; existing use; safety; connections
   Vehicular - powered or animal drawn
   Foot - human and animal
   Other forms - air, boat

3. Government Agencies: jurisdiction; programs; budget; staff; history of service; local image, Ministries responsible for:

   Transportation
   Health
   Natural Resources (forestry, wildlife, fisheries)
   Agriculture
   Recreation
   Education
   Family Assistance and Social Services

4. Other Agencies Active in the Region

   International - e.g., UNDP, UNEP
   Church
   Philanthropic

5. Expected Future Without - Project Conditions
   Socioeconomic (all topics in "1" above)
   Government and other programs

b. For Selected Alternative(s)

1. Upgrading Existing Roads

   Existing road network - layout, connections
   Culverts and ditches
   Crossing - rivers, ravines, canals
   Vertical alignments
   Surface

2. Realignments and Penetration Roads

   Topographic considerations - slopes
   Crossing of rivers, ravines, canals, wetlands
   Natural Areas - evaluation, future protection
   Socioeconomically Important Areas - settlements, religions and/or archeological site, special resources.

3. Design

Roadway Embankment
Shoulders or Berm
Surface
Drainage Features
Crossings

4. Environmental Mitigation

Companion Activities - Contacts with ministries of health, education, agriculture

Restoration and Reutilization - slope stabilization, spoil area reclamation; borrow area restoration, shelterbelt planting

Environmental Control - programs for monitoring and controlling strip development; effluents from worker camps; public health and safety

II. Construction Stage

a. Right-of-way Preparation

1. Contract conditions

Clearing methods
Control of hunting/poaching and woodcutting
Control of off-road vehicle movements
Placement of burn sites
Placement of camps

2. Supervision by AID or agency personnel

3. Restoration of disturbed areas

b. Construction Camps

1. Placement

2. Health and Sanitation Programs

3. Programs for Prevention of Hunting/Poaching and Woodcutting: education, supervision

4. Control of Squatter Settlements

5. Restoration or Reuse of Camp Areas

c. Access Roads and Exploratory Programs

1. Routing - conditions as for project road

2. Control of Use - by poachers, shifting cultivators, woodcutters

3. Subsequent blockage or restoration

4. Helicopter Use: prevention of frightening of wildlife and aborigines; placement and restoration of landing areas

d. Involvement of Agencies - Programs proposed and/or initiated during Planning stage:

1. Health and Social Welfare - monitoring of local health conditions vis-a-vis workers

2. Education - preparation for measured road use and development opportunities

3. Agriculture - monitoring of plant and animal disease movements; loans to farmers for crop shifts, chemicals; extension service changes

4. Transportation - arrangements to upgrade vehicle fleet; provide maintenance services; improve fuel availability

III. Operation Stage

a. Inspection and Maintenance

1. Road Surface

2. Embankment and Drainage System - vegetation control or enhancement; maintenance of visibility; aesthetics; clearing of ditches to prevent standing water; monitoring for erosion, especially at culverts and ditch discharges

b. Land Use Management

1. Prevention of strip development where undesirable

2. Protection of ecosystems along penetration roads

3. Control of placement of roadside development vis-a-vis blind corners, bottlenecks, bridges, etc.

c. Health and Safety

1. Monitoring of roadside ditch conditions; other water collections

2. Health and sanitation in roadside development

3. Monitoring of transportation-related disease distribution

RURAL ROADS POTENTIAL IMPACTS

PROJECT COMPONENTS	ENVIRONMENTAL COMPONENTS →	PHYSICAL ENVIRONMENT										BIOLOGICAL ENVIRONMENT												SOCIAL ENVIRONMENT						
		AGRICULTURAL LANDS	SOIL EROSION	SLOPE STABILITY	ENERGY / MINERAL RESOURCES	SURFACE WATER QUANTITY	SURFACE WATER QUALITY	GROUND WATER QUANTITY	GROUND WATER QUALITY	AIR QUALITY	NOISE	AQUATIC ECOSYSTEMS	WETLAND ECOSYSTEMS	TERRESTRIAL ECOSYSTEMS	ENDANGERED SPECIES	MIGRATORY SPECIES	BENEFICIAL PLANTS	BENEFICIAL ANIMALS	PEST PLANTS	PEST ANIMALS	DISEASE VECTORS	PUBLIC HEALTH	RESOURCES / LAND USE	DISTRIBUTION SYSTEMS	EMPLOYMENT	AT-RISK POPULATIONS	MIGRANT POPULATIONS	COMMUNITY STABILITY	CULTURAL/RELIGIOUS VALUES	TOURISM / RECREATION	NUTRITION
PLANNING & DESIGN	ROUTING – PENETRATION ROADS		●	●	◑	●	●	●	●	●	◐	●	●	●	●	●	◑	◑	●	●	●	◑	◑	◑	○	●	◑	◑	◑	○	◑
	ROUTING – UPGRADED ROADS	●	◑	◑	●	◑	◑			◑	●	◑	◑	●	●	◑		●	●	●	◑	◑	◑	◑	○	●	◑	◑	◑	○	◑
	ROUTING – SLOPES, CUTS & FILLS		●	●		●	●	●	●		●	●	●	●	●	●	◑	●			●										
	ROUTING – BRIDGES											◑	◑								◑				○						
	SURFACE – TYPE		◑	◑	●	◑	◑			◑	◑	◑	◑		◑	◑						●	◑		○				◑	◑	
	DRAINAGE – SHOULDERS		◑	◑		◑	◑					◑	◑						●	●											
	DRAINAGE – CULVERTS	◑	◑			◑	◑					◑	◑			◑					◑				○						
	WORK FORCE – SOURCES														●		●	●			●	●	◑	◑	◑	◑	◑	●	◑	◑	◑
	WORK FORCE – HOUSING	●	●	●		●	●	●	●		●	◑	◑	◑						●	◑	●	●		◑	●		●	●		◑
	WORK FORCE – SERVICES																				○	◑	●	●	○	●	●		◑	○	●
CONSTRUCTION	R.O.W. CLEARING		●	●		●	●			●		●	●	●	●		●	●	●	●	●	◑	◑								
	BORROW PITS					◑	●	●	●			◑	◑	●		○			●		●	●	●								
	SPOIL AREAS	●	●			●	●	●	●	●		●	●	●							●	●	●								
	CONSTRUCTION CAMPS	●	●			●	●	●	●	●	●	●	●	●							●		●		◑	●		●	●		◑
	CONSTRUCTION WASTES	●	●				●		●	●		●	●	●	●						◑	●	●								
OPERATION	TRAFFIC									●	●				●	●						◑									
	MAINTENANCE		◑	◑	●		●		●	●		●	●	●							◑	◑			○						
	DRAINAGE	●	◑	●		●	●					●	●	●							◑	◑									

KEY

BENEFICIAL
- HIGH ○
- MEDIUM ○
- LOW ○

ADVERSE
- HIGH ●
- MEDIUM ●
- LOW ●

III. RURAL ELECTRIFICATION

Project Description

Rural electrification projects provide a wider distribution of electrical energy in rural areas and smaller villages and help to increase productivity and improve the quality of life for the rural poor. The project may improve the efficiency and expand an existing system or bring electricity to an area that has had no electrical facilities. The facilities provided may involve all phases of the electrical system, from generation to consumer, and may include transformers, transmission lines, substations, distribution lines (5-25 kilovolts), distribution transformers, secondary distribution lines (120-480 volts), services to consumers, and meters.

Project Planning

The project scope should be defined both for the immediate needs and for future development, including all existing electrical facilities and proposed interconnections. The scope should also define the overall geographical boundaries and the electrical limits of the project. In addition to the physical components to be provided, considerable training of local personnel probably will be required. Examples of questions to be addressed early in planning are as follows:

- What source of electric power is contemplated?
- Would alternative energy sources (other than electricity) be more appropriate?
- What is the end use of the power generated?
- What is the status of the country's existing generating and transmission system? Can it meet future demand?
- Will a high-voltage transmission line be included in the planned project?
- Are new substations included?
- How many kilometers of new distribution lines are to be built and at what voltage?
- What are the approximate sizes and quantity of distribution transformers proposed?
- Is low voltage secondary distribution included, i.e., connections to customers' premises?
- If so, are customers' meters included?

In planning a rural electrification program, one should analyze the entire spectrum of energy resource utilization, at the local and national levels, for the present and projected future situations. This analysis should include the nonrenewable

of energy consumption (including a breakdown by end-use) present and projected generation requirements; present and projected transmission and substation requirements; present and projected mileage (kilometers) of distribution lines; and proposed voltages, together with future voltage increases that appear expedient.

Location Sensitive Factors

An explanation of the considerations that led to the specific proposal should be included, showing the factors that entered into the final facility locations and route selections. The following listing may be used as a guide:

- Were substations located near load centers?
- Are substations located on arable land or land that may be needed for future commercial or residential purposes?
- Is there adequate space for future expansion?
- Will noise be a factor at substation locations?
- Was the routing of transmission and distribution lines selected to minimize interference with farming, commercial and industrial activities.
- If new transmission is included, is there a route available that has minimal adverse environmental impact?

Environmental Considerations

An electrification project has both positive and negative effects upon the total environment. It is expected to improve the living standard of the human population, but may harm some natural ecosystems, introduce new hazards to human life, increase disease vectors, increase or decrease pollution problems, cause population shifts, and introduce unforeseen effects.

Natural Environment

The total effect upon the natural environment should be investigated before the project is started. The most obvious negative impacts are erosion from construction roads and movement of erection equipment; removal or trimming of trees and brush; side effects of the use of herbicides and insecticides; people using rights-of-ways for access to new lands; obstruction of animal movements by fencing; death of large birds that roost on structures, causing short-circuits; weeds along roadways or fences spreading to agricultural areas. There is always the possibility of unforeseen events such as the spread of plant or animal diseases and zoonoses* down a transmission corridor [B].

Human Environment

Both positive and negative effects of electrification must be considered [A] and the negative effects minimized. On the positive side, the quality of life may be improved directly through the provision of energy for lighting, cooking, household

appliances, radio and even television. Among other benefits, the provision of a reliable supply of electricity makes possible greater efficiency in health center operations, allowing storage of vaccines and biologicals and efficient sterilization of syringes, needles, instruments and other equipment. Agricultural and industrial processes may be changed or made possible, resulting in shift in productivity and income. In some countries, Pakistan, for instance, a major benefit of rural electrification is the replacement of diesel driven irrigation and well pumps with electrical ones. The facilitating effect of the availability of electricity has been a substantial boost to agricultural development.

During construction, especially, project workers and job seekers may move into the area, temporarily or permanently, bringing with them diseases to which the resident population has not developed immunity [B]. Construction camps may have insufficient or poorly maintained sanitary facilities or sanitary waste may be discharged untreated into the region's water bodies [C].

Death or injury from electrocution may result in a population unfamiliar with the household use of electricity or with the danger from harmless looking distribution or transmission wires.

A hazard encountered in high-voltage transmission is the induction of electric current in wires, such as fences and telephone lines, running parallel to and some distance from the high-voltage line. In systems operating at 230 kv or below, this form of electromagnetic induction seldom occurs under normal operation, except in telephone and telegraph lines using a one-wire system with a ground return. Should one part of the transmission line become short-circuited to the ground, however, the sudden surge of current may induce a dangerously high voltage in parallel fence wires and conductors. A person or farm animal in contact with such wires could be severely injured or electrocuted.

Demand for television, radio, heat and appliances may alter the local economy once electricity is introduced, with resulting changes in employment or redistribution of income, benefiting certain groups of the population and penalizing others [A].

Unless careful planning is conducted, the new system may be electrically incompatible with small existing generating plants, thus precluding easy transfer of power during normal or emergency conditions and leading to disappointment in the service provided by the new system.

Regional Planning

The environmental impact of electrical development should be considered in relation to the overall regional or national development plan. The electrification project should be coordinated with regional planning, particularly with electrical

development over the larger region, but also with other local facility developments such as communications, roads, water and sewage systems, irrigation systems and industrial, mining or processing plants. If such planning has not been conducted, conflicts over resource and energy allocations are sure to occur.

Mitigation and Enhancement Measures

The project plan should show that possible means for mitigating negative environmental effects and enhancing the environment have been considered.

Companion Activities

Before Construction. During the preliminary stage of detailed planning, and prior to letting of contracts, programs should be initiated to inform the public regarding potential health and other problems and obtain reactions from those most concerned. At this time final locations and routes can be selected to minimize interference with other community needs. The contracts should be written to include the contractor's obligations toward protection of the environment and his responsibility for sanitary measures at his work places and encampments.

During Construction. During construction the activities arranged for with public health services and wildlife management are to be put into action. This will require regular inspection of construction areas and construction encampments to be sure that the contractor is meeting his obligations under the contract and to alert public officials of actual or impending problems that are beyond the contractor's responsibility.

During the construction phase planning activities should be continued and changes made if required. Assistance should be given to local communities in their preparations for the advent of the new electrical system. This may involve assistance in arranging financing for new schools, hospitals, recreational facilities, new housing and business ventures. Educational activities in the safe installation and the use and conservation of electricity should be intensified. Operational personnel should be recruited and specially trained for their future responsibilities. They should be involved in planning and construction to the greatest extent possible.

During Operation. Safety education of the public and training of planning and operational personnel should continue indefinitely. Maintenance crews should be made aware of their responsibilities toward the environment and follow-up procedures initiated.

Restoration and Reutilization

Landscaping of generating facilities and substations should be undertaken and plantings made in rights-of-way where

possible to improve esthetics, control weed growth and provide for wildlife habitat.

Environmental Controls

In all phases of the project strict controls are necessary to prevent unnecessary damage to the environment. In particular, practices that will lead to wind or water erosion must be avoided as far as possible. If erosion is found to be occurring possible remedies such as plantings, riprap, or fencing should be sought and utilized. If it is necessary to control weeds and brush by the use of herbicides great care should be used to prevent spraying useful plants or allowing run-off water to contaminate surface water bodies [C].

Chemical preservatives used to treat wooden poles should be handled carefully, with due attention to their health hazard and potential for environmental contamination. Spillage and waste products should be contained and disposed of properly.

Operational Evaluation and Monitoring

Skills and Training Requirements

The project proposal should include an assessment of the skills that are available and the training that will be required for the project, from planning through construction and for operation and maintenance. If educational and experience requirements cannot be met locally, shortcomings should be overcome by importing personnel from other areas or by training local people. Depending upon the scope of the project and the amount of assistance available from the regional or national offices, several additional departments and personnel may be required.

System planning departments will require supervisors familiar with load measurement and load forecasting. This is an ongoing requirement, starting very early in the project and continuing indefinitely.

Design departments should be staffed well before construction begins. At least one experienced distribution engineer will be required. A transmission line engineer will be required if transmission lines are under the jurisdiction of the local authority.

If the project is extensive, a substation department will be required.

A construction and maintenance department also will be required. Personnel for the post-construction period should be drawn as far as possible from those who worked in some capacity during the initial construction period. Additions and changes will be required for many years after project construction is complete.

An operations department will be required on large projects. This department will keep usage records, supply operators if required, and schedule outages for maintenance.

A business department will be needed, to maintain records, read meters, keep accounts, bill users and process payments.

In addition to training personnel directly concerned with the project, it is desirable to provide general training in the safe use of electricity prior to its availability. Prospective electricians are especially important targets, but general education should start in grade schools. Instruction in safe installation of wiring should be provided, in order to avoid electrical shocks and fires. Local merchants of electrical items should be made knowledgeable of the hazardous aspects of the electrical equipment and appliances that they sell, so that they can give proper advice to their customers. Community planning agencies should consider programs to monitor health, employment and social changes resulting from electrification [A].

Standards and Procedures

Standard house wiring methods should be prepared that will be effective, affordable and enforceable. Standards employed in the industrialized countries may require considerable modifications to take into account local building conditions, pests, and materials availability in the developing country. Inspection of the wiring by a proper authority should be made before electrical service connections are made.

Electricity Board employees should make periodic inspections to detect any illegal taps, which may be dangerous. Buildings that require especially safe conditions, such as hospitals and schools, should be periodically inspected for safe wiring or usage practices.

Physical tests of equipment should be made from time to time in order to make repairs before accidents occur. For example, a wood pole may be attacked by termites without much external evidence until final failure. An alert inspector can detect the termites and order replacement, preventing an outage or a hazardous live wire at ground level.

Special Assistance.

The expertise available in the local area and elsewhere in the country should be analyzed to determine whether outside assistance will be required and if so, in which disciplines.

A social anthropologist and a terrestrial ecologist may be required in the identification and evaluation of environmental impacts. The scope of the problem and the time required before an experienced and trained staff can be assembled from local personnel should be estimated. The prime objective should be to accomplish sufficient training to enable local personnel to take over all phases of the project as rapidly as possible.

Planning Information Required

General

Existing electrical use estimates, if any, should be shown geographically in matrix or equivalent form, including a breakdown into various types of end-use. Demand proposed for the project should be forecast for 5, 10, 15, and 20 years. This will determine approximate locations and routes for the system, but local land use, streets and roads should also be considered. The 20-year plan will guide the project.

An analysis of renewable and nonrenewable energy resources should be conducted, including both those now in use and those with future utilization potential.

I. Design Stage

In the design stage the following points should be considered as a minimum, as far as applicable.

a. For all existing generating equipment:

1. Age
2. Condition
3. Reliability
4. Energy source (fuel, water, etc)
5. Kilowatt capacity - rated and actual
6. Voltage and frequency
7. Efficiency

b. Cost data for existing systems.

1. Generation
2. Administration
3. Maintenance

c. Relationship of existing generating capacity to proposed system

d. Retirement schedule for existing equipment

e. Environmental impacts of new generating facilities

f. For existing distribution system

1. Age
2. Condition
3. Reliability
4. Type of component
5. Voltages and frequencies

g. Relationship of existing distribution system to new project (including differences of voltage and frequency)

h. Alternative energy sources considered: cost, availability, current use

1. Renewable - hydroelectric, solar, wind
2. Natural fuels - wood, charcoal, dung

i. New generating facilities

1. Energy source type, availability.
2. Relation to other facilities

j. Economic effects

1. On local industry
2. On agriculture

k. Social Effects

1. Housing quantity and quality
2. Settlement density
3. Employment/unemployment rates
4. Income distribution
5. Immigration/emigration

l. Substations

1. Locations - basis for selection, alternative land use
2. Relation to transmission and distribution lines
3. Aesthetics

m. Transmission lines

1. Routes - preferred vs. alternatives
2. Rights-of-way - existing ecological and sociological conditions; land use
3. Towers - design materials (including sources); protection of humans and wildlife; river and highway crossings
4. Future management of right-of-way - land use, vegetation control
5. Esthetics - in relation to historical/religious sites; tourism

n. Safety Aspects

1. At generating facilities
2. Along transmission lines
3. At substations
4. Along distribution lines
5. At house connections

II. <u>Construction Stage</u>

a. Right-of-way preparation

1. Conditions to be imposed on contractor to prevent erosion, protect wildlife and vegetation
2. Means of ensuring that conditions are met
3. Restoration

b. Construction camp(s)

1. Location
2. Health measures
3. Environmental sanitation
4. Prevention of environmental degradation by workers (poaching, wood cutting, etc)
5. Control of squatter settlements
6. Use after completion of the project

c. Access roads

1. Siting
2. Control of use

III. Operation Stage

a. Access roads:

1. Control of use by poachers, shifting cultivators, etc.
2. Maintenance

b. Right-of-way: maintenance

c. Public education and assistance

1. Programs of economic technical assistance
2. Training of electricians, repairmen, etc.
3. Safety education in schools

RURAL ELECTRIFICATION POTENTIAL IMPACTS

PROJECT COMPONENTS	ENVIRONMENTAL COMPONENTS →	PHYSICAL ENVIRONMENT													BIOLOGICAL ENVIRONMENT									SOCIAL ENVIRONMENT						
		AGRICULTURAL LANDS	SOIL EROSION	SLOPE STABILITY	ENERGY / MINERAL RESOURCES	SURFACE WATER QUANTITY	SURFACE WATER QUALITY	GROUND WATER QUANTITY	GROUND WATER QUALITY	AIR QUALITY	NOISE	AQUATIC ECOSYSTEMS	WETLAND ECOSYSTEMS	TERRESTRIAL ECOSYSTEMS	ENDANGERED SPECIES	MIGRATORY SPECIES	BENEFICIAL PLANTS	BENEFICIAL ANIMALS	PEST PLANTS	PEST ANIMALS	DISEASE VECTORS	PUBLIC HEALTH	RESOURCES / LAND USE	DISTRIBUTION SYSTEMS	EMPLOYMENT	AT-RISK POPULATIONS	MIGRANT POPULATIONS	COMMUNITY STABILITY	CULTURAL/RELIGIOUS VALUES	TOURISM / RECREATION	NUTRITION
PLANNING & DESIGN	GENERATION – SMALL HYDRO	●	●	●	○	◑	◑	◑				◑	◑	◑	◑	◑	◑	◑	●		●	◑	◑	◑	◑	●	◑	◑	●	○	◑
	GENERATION – FOSSIL FUEL	●	●	●	●	●	●		●	●	●	●	●	●	●				●	●	●	●	●	◑	◑	●	◑	◑	●	●	
	ROUTING – TRANSMISSION LINES	●	●	●	●	●	●					●	●	●	●	●	◑	◑	●		●	◑	○		○	●	●	◑	●	●	
	ROUTING – DISTRIBUTION LINES				●								●				●						●								
	ROUTING – ACCESS ROADS	●	●	●	◑	●	●			●	●	●	●	●	●	●	◑	●	●		●	●	◑	○	○	●	◑	◑	◑	○	◑
	SYSTEM – MATERIALS				◑		●		●			●	●			●	○						◑		◑						
	SYSTEM –VOLTAGE/FREQUENCY																●				●		◑	◑			◑		◑		
	SYSTEM – TERMINAL CONNECTIONS				◑													●			●		◑	◑	●	◑	◑	◑	○	◑	
	WORK FORCE – SOURCE														●	●		●			●	◑	◑	◑	◑	◑	●	◑	◑	◑	
	WORK FORCE – HOUSING	●	●	●		●	●	●	●		●	◑	◑	◑					●	●	●	●		◑	●		●	●		◑	
	WORK FORCE – SUPPORT SERVICES																			○	◑	●	●	○	●	●		◑	○	●	
CONSTRUCTION	R.O.W. CLEARING		●	●		●	●			●		●	●	●	●		●	●	●	●	●	◑	◑								
	ACCESS ROADS	●	●	●		●	●			●	●	●	●	●	●						●	●	●	●				●	●	●	
	CONSTRUCTION MATERIALS/METHODS	●	●	●	◑	●	●		●	●	●	●	●	●	●	●					●	●	●	●	◑	◑	◑	◑	◑	◑	◑
	SPOIL DISPOSAL	●	●	●			●		●			●	●	●									●								
	CONSTRUCTION CAMPS	●	●			●	●	●	●	●	●	●	●	●						●	◑	●		○	●		●	●		◑	
OPERATION	LINE MAINTENANCE										●	●	◑	◑	◑	◑	◑	◑	◑	◑	◑	◑	◑	○			◑		◑		
	ACCESS CONTROL															●				●					●		●				
	OUTAGE CONTINGENCIES																			●		●	○				◑		◑		
	USER EDUCATION																			◑	◑	◑	◑	◑			○		○	○	

KEY

BENEFICIAL
- HIGH ○
- MEDIUM ○
- LOW ○

ADVERSE
- HIGH ●
- MEDIUM ●
- LOW ●

IV. RURAL WATER SUPPLY AND SANITATION

Project Description

General Characteristics

A.I.D.'s rural water supply and sanitation projects are planned to provide safe, reliable, and convenient water supply and sanitation in villages and periurban zones where these facilities may be inadequate. The quality and especially the quantity of water supply and the adequacy of sanitation determine in large measure the level of public health which can be achieved in a community. The improvement of these services may stimulate periurban growth. Therefore, careful consideration of secondary effects of these improvements is required to plan facilities that would be able to meet any increases in levels of service which might result from increases in the population. A complete description of all aspects of the proposed project will be required in order to evaluate the wide range of potential environmental effects.

Water Users. In order to evaluate the suitability of a system, the users must be identified. In small rural villages, handpumps or water supply systems with few public standposts may be provided. In more economically advanced areas, water service may also be provided to schools, hospitals or other institutions and to individual dwellings. Decisions on what types of users are to be served will affect the choice of alternative facilities.

Sanitary facilities to protect the water supply and to improve public health are companion concerns to water supply systems. A.I.D should not fund one without being assured that the other is taken care of adequately. Smaller communities may depend on household pit latrines. Larger communities may integrate water-borne waste systems with latrine systems. The water-borne systems could be collection tanks to be pumped periodically, septic tanks, or sewer systems with appropriate final disposal of wastes. These systems could be used individually or in combination. Complete descriptions of waste disposal facilities are required for meaningful assessment of environmental impacts.

Water Sources. Potential water supply sources should be identified by observing supplies currently in use, by examining any available interpretive reports on water resources, and by review of streamflow and ground water data files. Additional inventory activities such as aerial photography, exploratory drilling, electrical resistivity surveys, seismic surveys, and gaging of streamflow and precipitation may be considered. Consultation with hydrologists, hydrogeologists, and other professionals familiar with the study area should be sought.

Rural water supplies generally should be developed from wells (drilled or dug), infiltration galleries or protected springs, all of these being ground water sources, since they

usually provide a reliable and safe source of water and can be protected much more readily than surface water. Surface water sources may be subject to competing demands. According to circumstances, streams, lakes or manmade reservoirs may be chosen for development of water supplies. Surface sources are more likely to be selected for multi-village systems or to provide the required quantity of water for large populations.

As a companion requirement, the methods and locations for disposal of human excreta must be identified. Protection of water supplies from contamination by human excreta must be given high priority.

Project components. A.I.D sponsored water supply systems normally include all of the facilities required to bring safe water to the consumer and to dispose of waste water without contamination. Excreta disposal systems normally are also included. These facilities may include all, some or part of the following:

- Collection system: A dam and reservoir, with intake, a catch basin for a spring, or a well field.
- Conveyance system: Usually a pipeline, but occasionally an open channel.
- A water treatment system: simple systems, slow sand filters.
- Storage cisterns at the village level.
- Distribution system to public standposts or fountains, or to residential outlets.
- A metering system to determine total consumption and monitor demand variations. If this is not cost-effective, another method should be found for cost recovery.
- A waste water collection system.
- An excreta disposal system; this may consist of individual latrines or toilets; by community, household or other user group.
- A waste water treatment system when sewage is water-borne; septic tanks, stabilization ponds, etc.
- A method of disposing of treated water and of solids removed from waste water.

For surface supplies, the location of the stream, lake, or artificial impoundment should be identified and the tributary watershed described by the consultant. Estimates of the watershed yield and its variability should be made from available meteorologic and hydrologic records. If no records exist, the

yield can be estimated on the basis of rainfall and vegetative cover. Competing demands for the water supply should be described, and any resulting limitations on the proposed project should be determined. Chemical and bacteriological quality of the source water should be determined and needs for treatment identified by a water supply engineer. Reference should be made to the water supply standards for quality [C] to identify required treatment and suitability of the quality of potential sources. Taste and odor should be considered because these factors affect the acceptance of the supply by the users.

For ground water sources (springs, infiltration galleries or wells) the aquifer or aquifers to be developed should be identified and described as completely as feasible. Important aquifer properties are depth beneath the land surface, transmissibility and permeability, piezometric head and its seasonal variability, recharge areas and rates, material in the aquifer, and the position of the aquifer relative to other aquifers, aquicludes*, and water bodies. Knowledge of these factors can be used to estimate aquifer yield, pumping and well construction requirements, interference between wells, and potential routes of contamination. As with surface water, chemical and bacteriological quality must be acceptable. Taste and odor also limit the acceptance of ground water supplies.

On islands or in coastal areas, salt water may contaminate an aquifer if ground water withdrawals are not carefully controlled. Ground water withdrawals must not exceed the ground water aquifer recharge rate. For example, in the situation typical of many low islands, a lens of fresh water floats on the more dense sea water in the aquifer. The depth of the fresh water lens below sea level will be about 40 times the depth above sea level (Ghyben-Herzberg relation). Conversely, pumping from the lens could cause sea water to rise 40 meters into the lens for each meter of fresh water drawdown. Therefore, avoidance of salt water contamination may require shallow well construction, reduced pumping rates, or other methods for "skimming" of the fresh water to limit intrusion of salt water from saline zones. In other situations, deep well construction could perforate formations that afford natural protection and thereby allow leakage of saline water.

The location and types of waste disposal facilities must be considered in relation to the water supply system. Special precautions should be taken to avoid seepage of human wastes into ground water aquifers or their discharge to surface streams. Discharge of untreated human wastes to surface streams will very likely enhance the transmission of pathogenic* organisms to users of these waters [B].

Treatment proposed for water or wastes should be described. The World Health Organization recommends disinfection of public water supplies, but it recognizes that this is not feasible for many rural systems. The alternative favored is the use of carefully constructed and protected wells, infiltration galleries or springs.

Where the water system has been designed for water to flow by gravity or to be pumped manually environmental effects may be small. In other situations where electric motors and diesel engines are used, the attendant environmental effects may be significant.

Water distribution systems must be designed for continuous operation. Intermittent operation creates conditions for negative pressure and increases the possibilities for contamination through crossconnections. Adequate pressure must be maintained throughout the system and positive measures for control of water wastage must be instituted.

For the description of a water supply or sanitation project to be complete it is necessary that it includes the means of financing the project construction and its operation and maintenance, the steps by which the required support and operating skills are to be maintained, and the special requirements to avoid negative health effects. If user charges are to be made, they will undoubtedly influence project acceptance and the extent of use. Trained manpower for operation, maintenance and management must be available for any new utility. Manpower training should begin at the very inception of the project. Where the management will be located and under what type of organization must be delineated in a manner consistent with national policy. Furthermore, for the success of projects the availability of necessary supplies and replacement parts must be reliably ascertained.

Size and Scale Factors

Water supply demand characteristics necessary for design also are required for assessment of environmental effects. Demand is calculated by consideration of the following factors:

1. Household water use

   a. Population or number of households
   b. Per capita or per household demand

2. Other demands (authorized and unauthorized)

   a. Institutional uses (schools, hospitals, etc.)
   b. Industrial and commercial uses
   c. Watering livestock
   d. Irrigation of gardens or ornamental plants
   e. Fire fighting
   f. Public uses (dust control, aesthetics)

Daily per capita water consumption in rural areas of LDCs varies over a wide range. Different situations will have different demands, including some listed above. The planner must, therefore, conduct a study for each project to determine the projected water requirements with realistic estimates of

seasonal, daily and hourly flow variations so as to ensure sound engineering design.

The variability of demand should be described. If the season of high demand coincides with the season of low supply, environmental effects will be more pronounced than at other seasons. Likewise, the growth in demand should be estimated. An improved and more accessible water supply may be expected to stimulate growth in demand through increased per capita use and through attraction of new users, whether commercial, industrial, or other.

A project to be viable must be within the range of charges affordable by its users. The rate of charges may include the recovery of capital costs and costs of operation, maintenance and management measured against some unit of service or volume of water supplied. Participation by the community and its leaders at the planning stage is important to ensure that the service will be used and maintained as planned. In Haiti, for example, where local water supply projects are given high priority, the government has found that installing a potable water system without firm local support is not workable. Learning from experience, the government has provided water to a number of villages under a system wherein a committee of local leaders arranges for labor inputs, engenders local support, selects the method of charging, and administers the operation of the system. The level of local involvement attained in Haiti is exceptional, but its success underscores the advantage of involving the beneficiaries at every level of project planning and operation. Malawi is another country where success has been achieved through community involvement in water supply projects.

Location Sensitive Factors

The vulnerability of facilities to natural events such as earthquake, fire and flood should be assessed. Flooding is the most frequently significant of these events, potentially causing structural damage and contamination of water supplies. Failure of a dam or embankment forming a reservoir could cause catastrophic damage in the downstream valley. Wells located within flood plains or natural drainage ways could become the route for flood waters to enter and contaminate the ground water. Flooding of waste disposal facilities greatly increases the potential for spread of disease and should be prevented.

Water distribution may stimulate changes in land use. Settlements may cluster near the supply points. Transmission pipelines may stimulate settlement at points along the line if access to the water is allowed. The abandonment of an existing source may likewise lead to shifts in settlement patterns. Water distribution points should be located and constructed carefully to avoid developing health hazards and nuisance from poor drainage of spilled or wasted water. When water collects in low depressions, mosquito breeding may occur and domestic animals will be attracted to it. The surroundings will very likely become an odoriferous quagmire.

In the cases where a water-borne sewerage system is constructed, the discharge of untreated waste water can pose a public health threat, cause nuisance odors, and degrade the quality of the receiving water body. Because most A.I.D. rural water supply projects will not include sewers, this will not be a frequent concern.

Opportunities for public uses should be evaluated. Irrigation of public gardens and landscape vegetation, or wetting of busy roads for dust control may improve the quality of village life. Other significant opportunities for public uses unique to a project area may be identified.

Alternative Solutions. Before implementing rural water supply and sanitation projects, alternatives that will accomplish the same goals should be investigated. For water supply, surface and ground water sources should be compared with respect to costs, benefits, quantity, quality, and operation and maintenance required.

Environmental Considerations

Natural Environment

The majority of potential environmental effects of water supply and sanitation benefits lie in the areas of human health (great potential for benefits but possibilities of adverse effects), and aquatic ecology (potential for adverse impacts). Secondary effects may be observed, either beneficial or adverse, in the areas of land use, population movements, community stability and employment.

Surface Water Development. The impacts of a reservoir on the natural environment include siltation of the reservoir, erosion of shorelines, reduction of downstream flow, reduction of sediment discharge downstream, and alteration of natural ecosystems in the reservoir area. On the other hand, reservoirs may also serve for flood control by leveling out floods.

During construction of a reservoir and associated embankments, the land clearing and earth moving activities will disturb land area and its plant and animal life, especially in relatively large-scale projects. Soil will be exposed to increased rates of erosion. Access roads may be required and these will exert their own impacts (see "Rural Roads," above). Dust and noise from the construction activities will affect the surrounding area. Many of these adverse effects can be wholly or partially mitigated with proper planning and at most are only minimally disturbing, due to the small scale of most rural projects.

To maintain the storage capacity of a reservoir, sediment input should be controlled by watershed management and by building sediment control structures. Constant high water in a reservoir may increase erosion of the shoreline. Downstream channel erosion also may increase if there is a constant reservoir release. More uniform downstream flow may cause the

ground water table to stay consistently high, causing salt build-up on farmland or creating marshes. Reduction of flows downstream of the reservoir may affect other water users (see below, "Human Environment").

Discharges from reservoirs may create an environment more ideal for the black fly, the vector of onchocerciasis. This disease occurs in Central America, northern South America, and tropical Africa south of the Sahara. The black fly breeds in well aerated and rapidly running waterways. Reservoirs, when used as the place for drawing water, may enhance the transmission of dracontiasis, or Guinea worm disease. Leptospirosis may be transmitted by water contaminated by urine of infected animals. Domestic and wild animals have been found to be infected.

Reduction of sediment discharged downstream may be beneficial or harmful to downstream users. Clear water is generally considered better for municipal, industrial, and agricultural uses, but in larger river basins sediment in water may be valuable as a source of nutrients to flood plains and wetlands. The loss of these nutrients can reduce the agricultural productivity of affected croplands and the biological productivity of wetlands and estuaries.

The installation of a dam or canal will affect fish and wildlife of the project area but most rural water supply projects do not involve large reservoirs. If the reservoir level is fairly stable, benefits may include providing a year-round supply of drinking water for wildlife, breeding grounds for waterfowl, and spawning areas for fish. If the reservoir is severely drawn down during the dry season, most of these benefits will not be realized. Waterfowl will require a permanent marsh for breeding and, unless part of the reservoir is diked off, drawdown will destroy marsh vegetation. Similarly, drawdown may destroy vegetation vital for fish spawning and growth of young and may dry out the eggs of bottom nesting species. Management of the reservoir to enhance fish and wildlife benefits in the reservoir may compromise its ability to provide water when needed, but planners should study carefully the tradeoffs, with regional needs in mind.

The important factors for the survival of fish populations are water quality, water temperature, and mobility. Pollutants such as toxic materials, pesticides, and sediment entering the reservoir during and after construction should be controlled. Water temperature influences the migration, breeding, and hatching of fish. Each species of fish has an optimal temperature range for survival and spawning. Consideration should be given to the temperature range which will exist in the reservoir and the stream below the dam due to the reservoir release. If the reservoir is deep, the temperature of downstream releases may be controlled by a selective multilevel outlet structure.

The likelihood that a rural water supply reservoir will severely affect migratory fish populations is small, but the

planner should attempt to obtain information on seasonal fish movements in the stream being dammed. If a significant fishery resource appears to exist which would be blocked by the proposed dam, devices to pass fish into and out of the reservoir should be considered.

The possible effects of reservoirs on wildlife include removal of feeding areas, loss of habitat, and limitation of mobility. Canals and pipelines may limit wildlife mobility or restrict access to feeding areas. Canals also can be hazardous to wildlife. Where justified, fences can be built to prevent animals from falling into canals or escape structures can be built on canal side slopes to help them to get out. Control of insects and other vectors also must be considered when constructing reservoirs.

- Ground Water Development. Most environmental effects of ground water development of primary concern to man (see below, "Human Environment"), involve changes in the quantity (location) and/or quality of the ground water itself. Where the water table is close to the surface, these changes may affect deep-rooted vegetation. Occasionally, a spring on which wildlife depends may suffer loss of flow or lowered water quality. In rural water supply projects, however, these effects usually would be minimal.

Human Environment

The primary effect of water supply projects on people is improved public health due to a greater quantity of domestic water and, to a lesser degree, higher quality of the water, as well as to the sanitation that is introduced as part of the project package. Time saved in transporting water may be utilized in more productive activities, although this benefit frequently is not realized, due to social conditions and local customs [A]. If meaningful and economically attractive jobs are not provided to fill the time void created by the new water system, very little incentive will exist for the maintenance of the systems.

The public health benefit may not be attained during the initial stages of project life if the initial increment, perhaps 10 lcd, is too meager for greatly improved personal hygiene. The potential public health benefits will require attention to water handling within the household so that contamination is not introduced by storage or carrying containers. Additional increments of supply, as the system develops, will permit higher levels of hygiene.

Where individual houses are connected to the water supply system, the World Bank (1976) suggests 100 lcd as a realistic level of supply. Differences in climatic and cultural conditions may greatly influence per capita demand.

Planners should be alert to the possibility of creating conditions that increase the likelihood of diseases such as onchocerciasis, Guinea worm and leptospirosis. Where water

supply dams are to be constructed the potential for enhancing the transmission of onchocerciasis should be carefully evaluated. Guinea worm disease develops when man ingests water containing crustacea of the genus Cyclops in water harboring the organism. Since an infected man himself is the reservoir, one positive control measure is to preclude contact of man with the water in the reservoir. Where leptospirosis is a concern, preventing the contact of animals with water in the reservoir should be planned. Rodent control by burning fields in the area has been found useful.

Ground Water Development. The problems resulting from the improper development of ground water supply include (1) lowering of ground water table or piezometric surface*, (2) interference with the operation of nearby wells, and (3) contamination of the aquifer through abandoned wells. Most of these problems primarily affect human water use.

Ground water wells must be spaced an appropriate distance apart to avoid excessive drawdown that may affect the yield of other wells or cause them to go dry. Some wells may have to be deepened to maintain yield or be abandoned due to inadequate yield.

Abandoned wells can provide direct channels for contaminants to move from the surface into an aquifer. Therefore, such wells should be properly plugged.

Waste Disposal. Appropriate facilities for disposal of human excreta in rural areas may include pit privies, water-seal latrines, wet and dry vaults, composting privies and pour-flush latrines with soakaways. These facilities may cause water and land pollution. Odor and insect nuisances can result from improper construction and maintenance of these systems.

Land and water pollution can result from seepage and overflow of wastewater. Ground water contamination caused by seepage depends on the watertightness of the waste disposal facility, the depth to the ground water table, and the permeability of the ground below the facility. If seepage must be reduced to avoid ground water contamination, the facility should be located at a site underlain by impermeable material such as clay or by using impermeable material to construct the facility. Seepage also can cause pollution of lakes or streams if they are connected with the polluted ground water aquifer.

Overflow of waste facilities can contribute polluted runoff to surface water. Overflow may be caused by improper sizing of the facility, inadequate waste removal frequency, seepage of ground water into the facility, or collection of rainwater and surface runoff. Frequent overflow also can reach the aquifer.

In a typical septic tank installation, the effluent from the tank is discharged into a soil absorption field or seepage pit. The wastewater is then absorbed into the soil. The

ability of the soil to accept the wastewater must be checked by a percolation test, and other necessary soil characteristics must be ascertained. The use of septic tanks would be very limited in most rural areas and ground water monitoring would probably never be done.

Waste from Water Treatment. If the water is treated, there will be residual material from the process of sedimentation and filtration to be disposed of. If a sedimentation tank is used to settle suspended solids in the water, the sludge will collect in the bottom of the tank and must be removed periodically. Engineers familiar with LDC water supplies suggest the use of slow sand filters to treat relatively clear water directly or after sedimentation for somewhat turbid water. The conventional slow sand filter is renewed by scraping off a few inches of a clogged sand bed. The design of the slow sand filter and its operation are relatively uncomplicated. However, an engineer must be consulted. Sludge and filter scrapings should be disposed of safely so as not to contaminate water supply sources.

Where sedimentation basin and slow sand filter are used and sludge and filter scrapings are disposed of on land, an environmental problem may be the contamination of runoff and ground water by leachate* of the residual material. Ground water contamination caused by leaching depends on the depth to the water table and the permeability of the ground below the storage site. The leaching can be reduced by locating the storage area at a site underlain by impermeable material such as clay or by providing proper lining of the storage area. The runoff problem depends on the frequency and intensity of rainfall. Runoff can be contained by dike or excavated pond. This type of treatment system and its accompanying problems are usually not found in most rural areas of developing countries. Energy and other operational costs are far too great to allow their application in these situations.

An additional, although minor, benefit of the project is the creation of new employment opportunities in the construction and operation of the system. If possible, project employees should be selected from the local population. They will be more prone to take pride in the system, and more likely to remain with it, and will tend to spend their income locally.

Community Effects. The addition of a water supply system often brings profound changes in a community [A]. Water demanding industries and other services, such as clinics and schools, will be encouraged to locate there, stimulating immigration and community growth. With appropriate planning, such growth can produce broad benefits; without adequate planning, numerous problems of health, unemployment, overcrowding and social conflict may be expected.

Accident Hazards. At locations where accidents can occur, protective devices and warning systems should be installed. At certain components of a dam/reservoir system, such as the spillway, water supply intake, outlet works intake, and stilling basin, there is a possibility of injury

or drowning. Rural water supply projects often are too small to warrant the security forces provided to large dams. Canals often have steep side slopes which prevent climbing out and inverted siphons (where the canal passes under another canal), which are extremely dangerous. Steps or cleats along the side slope of a canal should be installed at appropriate intervals so that humans and animals who fall into the canal can get out.

Recreation. The possibility of accommodating recreational activities in a water supply project such as a reservoir should be considered. For example, a viewing area or foot path can be provided at minimal cost. Signs showing the history and function of the project can be both educational and recreational.

Environmental Standards

The recommended quality standards for water supply are the World Health Organization's "International Standards for Drinking Water", Third Edition (1971) [C]. Since these standards are quite rigorous and unlikely to be met in most rural water projects, "safe" water in adequate amounts should be the primary goal.

Mitigation and Enhancement Measures

Companion Activities

Companion activities that should be considered in implementing a water supply and sanitation project include (1) sanitation or hygiene education, and (2) project education.

Good sanitation habits are a more important factor for good health. Proper design of waste disposal pits and/or proper collection and handling of waste can make low-technology alternatives effective in promoting good health. Therefore, an important companion activity for a rural water supply and sanitation project is educating the users about sanitary habits.

Appropriate locales for such education would be in the health posts/centers and in the schools where the respected health-related personnel and teachers can get the message across. In addition, midwives, shamans and others involved in health delivery, as well as agricultural extension workers, should be valuable persons to involve in the educational process. Medical clinics and schools are the most opportune places, since a receptive audience and an informed teacher usually are present. When a water system is introduced in an area public meetings should be held, presided over by respected local leaders, in which both water conservation and public health messages are put across. Further education may be obtained through simple pictorial signs displayed where water use or sanitation problems may occur.

Sanitation, especially, may require considerable public education if facilities are to be effectively used and maintained. In some developing countries there are long-established cultural practices that must be overcome. In Guyana, for example, Amerindians, although in many ways acculturated into Guyanese society, believe that it is unclean to defecate or urinate where anyone has done so before. This belief effectively precludes the use of pit latrines and possibly toilets, unless the Amerindians can be persuaded that the flushing action removes all traces of prior use. The cultural basis of this problem is under study by Guyanese sociologists.

Water Conservation

Water conservation measures should be considered in the design and operation of a water supply system, in order to avoid depletion of the source and to reduce the costs of construction and operation. Every means to reduce wasted water should be considered, especially through education concerning good water use practices. Among steps to be considered are self-closing hydrants and taps, low pressure distribution systems, small diameter pipes, flow restriction fittings, operation of pressure systems for only part of the day, and careful installation and maintenance of all components of the system. Certain of these measures have disadvantages, depending on local conditions. Reducing the pressure of the distribution system for part of the day may allow impure water to contaminate the system through infiltration (the flow of water into a buried pipe from the surrounding soil) or backsiphonage (movement of water back along the line from an elevated end point). Flow restriction devices conserve water at the expense of energy. Some self-closing hydrants and taps often have a higher initial cost and may require more maintenance and repair than conventional fittings. Moreover, careful selection of self-closing fittings is required where women and small children fetch much of the water.

Restoration and Reutilization

Recovery of resources in the waste material should be considered in implementing a water supply and sanitation project. After treatment, human excreta and other household waste could be used as fertilizer. Compost from double-vault composting latrines can be used to improve land productivity. A double-vault composting latrine consists of two compartments, each large enough to hold six months of waste. When one is full, the other is used, thereby proving a six-month composting period. Grass clippings, food scraps, leaves, and animal wastes are added to the human excreta to maintain a carbon to nitrogen ratio suitable for composting (McGarry, 1978). Care must be taken to provide a suitable moisture level. The Vietnamese style composting latrine adds nitrogen-rich urine to improve the moisture balance and increase the nitrogen level.

The bioconversion plant can be used to produce biogas (carbon dioxide and methane) from farm and household wastes, and even human excreta (McGarry, 1978). The biogas can be used for cooking and lighting. The waste ferments without air in a covered digestion tank. The biogas bubbles out of the digesting material and is drawn off through a tube and stored for use. Thoroughly digested material is a relatively odorless and innocuous slurry, which can be used as fertilizer either directly or after drying.

Environmental Controls.

In a reservoir project, important environmental controls to be considered are protection of the reservoir from siltation and water quality degradation. Sediment inflow to the reservoir can be excessively high due to the existing watershed condition or due to accelerated erosion resulting from more intensive land use stimulated by the reservoir project. Sediment by itself can be a pollutant which causes siltation and degrades the environment for some fish species. Sediment also acts as a carrier of other pollutants, such as pesticides and other organic toxicants.

Quality criteria for effluent from waste disposal and water treatment facilities should be established to protect water, land, and air resources. Effluent criteria also should be set for all industrial and commercial wastes [C].

Operation Evaluation and Monitoring

Even simple water supply projects are dependent for continued success on maintaining the quantity and quality of the water supply source, the equipment necessary for operation, the personnel required for operation and repair, and the financial support program. Changing conditions, unanticipated environmental effects, and new policies may also call for continued attention to the project. In order to ensure a reasonable level of project success over time, information about current conditions should be reviewed periodically and the capability of making corrections and improvements should be maintained.

Skills and Training

Basic to the continued operation of any water supply system is access to manpower with the understanding and skills necessary to operate, maintain, and repair all the components of the system. Local operators require the skill and knowledge to maintain and repair pumps, motors, pipes, and other components of the system. Local users should have enough understanding of how the system works and how it is designed to protect public health so that they will cooperate in avoiding unauthorized use of the system which could damage or contaminate it and be alert for potential problems which may develop. Continued training of village residents is required to maintain an understanding of public

health hazards and how water supply and sanitation facilities operate to protect their health.

At a regional level, more specialized skills should be maintained. These would include:

- Health education specialists to instruct local operators, teachers, and residents about the connections between water and sanitation and improved health.
- Sanitarians capable of performing bacteriological sampling and testing.
- Engineers capable of diagnosing system operation problems and prescribing feasible solutions.
- Geologists capable of evaluating aquifer behavior.
- Environmental scientists capable of evaluating environmental effects which may be developing very slowly.
- Administrators to facilitate and direct the variety of activities necessary for a successful program, able to recognize the occasional need for outside assistance and to obtain it.

Standard Testing and Review

A key to effective maintenance and operation is the maintenance of adequate and accurate records. Periodic observations or tests should be made by personnel from the regional level to monitor trends and performance related to:

- Water levels in wells
- Pump discharges
- Bacteriological and chemical quality of water
- Volume of water delivered or used
- Pressure in piping systems
- Dates and details of routine maintenance and repairs
- Morbidity* in the affected population

Records of such observations can be used to detect emerging problems with equipment, declining aquifers, deterioration of piping, or unexpected increases in demand. They may also indicate the need for more or less maintenance or inspection than originally planned.

Special inspections should be planned on a less frequent basis than the above observations. Dams and embankments at reservoirs should be inspected for excessive seepage or other signs of structural weakness. These inspections should be performed at regular intervals and immediately following major storms or floods. Periodic surveys of water supply systems should be scheduled to detect unauthorized uses, such as animals being watered at wells designed for human use only. Inspections of transmission and distribution systems should detect illegal water connections and cross-connections between safe and contaminated water. Where latrines have been constructed, periodic inspection to determine cleanliness and evidence of acceptance and use can be helpful in planning public health education programs and in other efforts to improve the utility of such facilities.

Special Assistance

In addition to the special skills described above, special facilities may be required to serve regional needs. Chemical and bacteriological laboratory facilities to monitor and evaluate water quality at the regional level are particularly important. Rigs for well drilling and specialized supplies, such as well screens and pipe for casing wells, are not generally available in local areas. Pumps and other equipment suited to the local conditions may be manufactured at a central location. Warehousing of spare parts may also be centralized. Such decisions will be influenced by the ease of communications and transportation in the region.

Planning Information Required

I. Planning and Design Stage

a. Selection of Benefit (Target) Population. For each population group considered:

1. Existing Water Supply
   - Source - distance; characteristics
   - Quality - at origin; at point of use; sources of degradation; future
   - Quantity - flow; seasonality; reliability
   - Demands - existing; projected
   - Transportation by users

2. Social Conditions
   - Culture - especially pertaining to water
   - Health - conditions; attitudes and myths; services
   - Education - schools; adult
   - Local Government - leadership; structure; attitudes; stability

3. Potential Water Sources
   - Surface Water - quantity (total, seasonality, reliability); quality (at origin,

pollution sources, future); distance future).
Ground Water - quantity (capacity, recharge); quality; depth (average, variation); other demand (present, future)

4. Existing Sanitation System
   Disposal of Excreta - domestic; other places; livestock and other wastes
   Cultural Factors
   Health Related Problems

b. Project Design

1. Surface Water Source - river, lake,
   Diversion Structure - dam/reservoir, tank
   Conveyance system - canal, pipes
   Pumps Tanks for local storage
   Hydrants or house connections

2. Ground Water Source
   Wells
   Pumps
   Conveyance System - pipes
   Cisterns for local storage
   Hydrants or house connections

3. Waste Treatment
   Drainage for users
   Conveyance System - to treatment
   Waste Treatment - collective facility, septic tanks, leaching fields
   Nonwater disposal/treatment of human wastes - pit latrines; composting privies; dry vaults

4. Environmental Considerations
   Protection of Water Source - watershed management; pollution control; allocations to other users.
   Management of System - quality monitoring; system integrity; training
   Water Conservation - devices; education
   Health Protection - drainage; vector monitoring
   Reservoir Planning - releases downstream; fish protection; plant control.

II. Construction Stage

a. Training and Use of Local Employees

1. Exploration
2. Construction

b. Continuing Community Education Programs

c. Local Participation in System Management

III. Operation Stage

a. Flow Monitoring and Cost Recovery

b. Maintenance of System Integrity

1. Structures
2. Water Quantity
3. Water Quality

c. User Education - health, sanitation, conservation

1. School
2. Clinics
3. Other gatherings
4. Indigenous health workers (e.g., midwives, home visitors, extension workers)
5. Literature and signs

RURAL WATER SUPPLY AND SANITATION POTENTIAL IMPACTS

PROJECT COMPONENTS	ENVIRONMENTAL COMPONENTS →	PHYSICAL ENVIRONMENT										BIOLOGICAL ENVIRONMENT												SOCIAL ENVIRONMENT										
		AGRICULTURAL LANDS	SOIL EROSION	SLOPE STABILITY	ENERGY/MINERAL RESOURCES	SURFACE WATER QUANTITY	SURFACE WATER QUALITY	GROUND WATER QUANTITY	GROUND WATER QUALITY	AIR QUALITY	NOISE	AQUATIC ECOSYSTEMS	WETLAND ECOSYSTEMS	TERRESTRIAL ECOSYSTEMS	ENDANGERED SPECIES	MIGRATORY SPECIES	BENEFICIAL PLANTS	BENEFICIAL ANIMALS	PEST PLANTS	PEST ANIMALS	DISEASE VECTORS	PUBLIC HEALTH	RESOURCES / LAND USE	DISTRIBUTION SYSTEMS	EMPLOYMENT	AT RISK POPULATIONS	MIGRANT POPULATIONS	COMMUNITY STABILITY	CULTURAL/RELIGIOUS VALUES	TOURISM / RECREATION	NUTRITION
PLANNING & DESIGN	SOURCE – SURFACE WATER	●	●	●		◑	◑					◑	●	◑	◑	◑	◑	◑	●		●	◑	◑	◑	◑	◑	◑	◑	◑	○	○
	SOURCE – SPRINGS	●				●	●					●	◑	◑	●	●	●	●			◑	◑	◑	◑	◑	◑	◑	◑	◑	○	○
	SOURCE – GROUNDWATER	●			●			●	●				●										◑	◑	◑	◑	◑	◑	◑	○	○
	COLLECTION/TRANSMISSION	●	●	●	●	◑	◑					◑	◑	●	●	●	●	◑	●		●	●	◑	◑	◑	◑	◑	◑	◑	◑	◑
	RAW WATER TREATMENT				●		●		●			●	●									○	○	◑	○			◑		○	
	STORAGE/DISTRIBUTION				●															◑	◑	◑	◑	◑	◑	◑	◑	◑	◑	◑	◑
	USE CONTROLS					◑		◑					◑								◑	◑	◑	◑	◑	◑	◑	◑	◑	◑	◑
	DRAINAGE/COLLECTION SYSTEMS	◑	◑			◑	◑		◑			◑	◑	◑					●	●	◑	◑	◑	○	◑	◑	◑	◑	◑	◑	
	SANITATION FACILITIES				○		◑		◑	◑		◑	◑							◑	◑	◑	◑	○	◑		◑		◑		
	WASTEWATER TREATMENT	○			◑		○		◑	◑		◑	◑	◑							◑	◑	◑	○	○			◑	◑	○	
	WORK FORCE															●	●	●				●			○			◑			
CONSTRUCTION	CLEARING		●			●	●			●		●	●	●					●	●	●	●	◑								
	ACCESS ROADS	●	●	●		●	●			●	●	●	●	●					●		●	◑	◑	◑	○			◑			
	CONSTRUCTION ACTIVITIES	●	●	●	●		●		●	●	●	●	●	●							●	●					◑	◑			
	WORK FORCE – SUPPORT																				●	●						◑			
	CONSTRUCTION WASTES						●		●	●		●	●	●							●	●			○			◑			
OPERATION	SOURCE PROTECTION		◑			○	◑	○	◑			●	●												○	◑	◑				
	FACILITY MAINTENANCE	◑	○	○		○	○	○	○			○	○	○	○		○	○	○			○	◑	◑	◑	◑	◑	◑		○	
	WATER MONITORING						○		○			○										○			○						
	WATER CONSERVATION	○	○		○	○	○	○	○			○	○	○									○	○		○	○	○		○	
	USER EDUCATION	○	○		○																○	○		○				○			

KEY

BENEFICIAL
- HIGH ○
- MEDIUM ○
- LOW ○

ADVERSE
- HIGH ●
- MEDIUM ●
- LOW ●

V. SMALL SCALE IRRIGATION AND ON-FARM WATER MANAGEMENT

Project Description

General Characteristics

Small-scale irrigation projects serve to supply water to agricultural crops, supplementing natural rainfall. The crops are grown by farmers on small operating units. The increased crop production resulting from irrigation and other inputs provides additional food and income to the farm families and others. The on-farm water management aspect of irrigation projects aids in irrigating as efficiently as feasible, to reduce the waste of water and to increase production.

A.I.D. sponsored irrigation projects may develop previously unirrigated land or improve and expand existing irrigation systems. Water is supplied from surface or underground sources. Project components include any or all of the following: distribution canals, surface drainage systems, land grading, surface water diversions, irrigation wells, subsurface drainage systems, pipelines, pumping stations, control structures, water recovery systems, agricultural extension services, monitoring programs and erosion control.

Size and Scale Factors

The intention of A.I.D. sponsored small-scale irrigation projects is to help farmers with relatively small arable areas to increase their agricultural production. The smaller the individual farmer's area, however, the more intensive must be the systems of water distribution, farm-to-market roads, and extension services. Most individual operational units in small-scale irrigation projects are from 0.5 to 5 hectares, but a few units may be larger. The total irrigated area served by a project may be up to 500 hectares and could involve 100 to 300 families. Several small-scale projects may use a common water supply, such as a large canal, river or ground water source. Usually, however, a large conveyance system with a flow capacity greater than 0.5 cubic meters per second will not be funded as part of a small-scale irrigation project.

Location Sensitive Factors

Soil, topography, water quantity and quality, access to markets, sources of agricultural inputs, other land and water uses, native flora and fauna, available rural population, and potential long term agricultural improvement are important factors in siting successful irrigation projects. Existing irrigation systems are normally located in the most favorable sites of a given region, but these systems often can benefit from project improvements.

Soil characteristics and land topography affect erosion, crop production potential, percolation below the crop root zone, and water runoff. Projects are more successful if they are close to markets for the agricultural products and to sources of agricultural inputs. The intended cropping pattern and irrigated area must be matched with an adequate water supply of acceptable quality [C]. Preproject allocations of available water and land to other uses may limit project size.

Environmental Considerations

Serious disruptions of the social structure and infrastructure can result if an irrigation project functions for a generation or more and then becomes inoperative because of waterlogging, shortage of water, siltation, or saline/alkaline conditions.

Virtually every aspect of an irrigation project may have environmental implications. Many aspects enhance the project environment, improving the economic well-being and quality of life of the target population through the development of permanent agriculture, but some can negatively affect the natural and human environments. Drainage systems have a great potential for environmental influence, but an effective drainage system reduces waterlogging, water contamination and, generally, soil erosion, without undue flooding, silting or introducing increased salt problems on downstream water users. No irrigation project can be successful and environmentally sound without effective drainage.

Natural Environment

Serious soil erosion may occur when water is applied to steep slopes by surface irrigation methods, unless the topography is modified by land grading and land shaping. Sprinkler and drip irrigation systems may be safely used on steep slopes as well as level areas. Soils which have relatively little pore space (even though individual pores are large as with coarse textured soils) or which are shallow have limited capacity to store water for plant use. More frequent application of smaller amounts of water should be made. Irrigation water should be applied over short distances on soils with high infiltration rates, if surface irrigation methods are used. Otherwise, in both low water holding capacity and high infiltration rate situations, excessive water percolation below the crop root zone will occur. This percolation wastes water and may cause future ground water contamination and subsurface drainage problems. Using surface methods to irrigate soils with low infiltration rates, such as many fine textured soils, can result in wasteful and perhaps contaminated surface runoff of water from the end of a field. Fine textured soils usually hold large amounts of water for crop use, but may have serious waterlogging problems unless the natural or artificial subsurface drainage is adequate. Thus, a soil with medium infiltrability and water holding capacity, at least 1.2 meters deep and with a maximum surface slope of two percent, is the most suitable for surface application of irrigation water.

Land clearing may be required before an irrigation project can be implemented on new lands. Destruction and disruption of the native flora and fauna are inevitable consequences. Removal of the natural vegetation will lay the soil open to erosion by wind and water, unless immediate protective measures (cover crop, terracing, windbreaks) are taken.

The quantity and quality of the water in both the source and the outlet of an irrigation system must be considered. Insufficiency of water for the amount of arable land or failure to have an assured supply during the intended life of the project can cause disruptions of the planned crop production and all associated human activities - less food, less income, temporary or permanent migration from the project area, and other negative impacts [A]. Too much water applied results in wasteful runoff and percolation, carrying with it some of the fertilizer needed for crop growth. Drainage channels can erode with the excess runoff.

The quality of the irrigation water may be detrimental or beneficial to crops: detrimental if undesirable chemical products from industrial plants, other irrigated areas, or saline/alkaline ground water are present; beneficial if residuals useful to crops are present from animals, food processing plants, and waste treatment facilities. Pesticides, herbicides, and fertilizers in runoff water, and saline/alkaline subsurface drainage water are most often harmful to downstream users, although some can be beneficial if similar crops are grown. Plant diseases spread easily when water from an infected field is applied to another field with a susceptible crop. A large amount of irrigation or storm water runoff, though wasteful in some respects, may dilute these chemicals to tolerable levels. Low quality water can be made usable by diluting it with high quality water.

Cropping patterns change with implementation of irrigation projects. Previously uncultivated lands experience the most pronounced changes. Native trees and plants may be completely eliminated and entirely new plant life introduced; native animals and birds may be forced to move to new areas where competition with resident animal populations causes ecological disruption. Water intensive crops may be introduced and crop production increased when water is added to previously rainfed or poorly irrigated areas. Whenever the irrigation project is adjacent to natural habitat the projects will attract wildlife, by providing food and water. Water-inhabiting snakes, turtles, rodents, and other animals and aquatic plants will invade the irrigation canals and drainage channels. Some may become crop pests or weeds that block the waterways while others can be important links in natural food chains. Some plants will help to retard erosion. New plants and animals should not be introduced to an area without careful appraisal of their negative and positive aspects. In the absence of their natural controls, they may reproduce to nuisance levels or compete with populations of desirable local species.

The availability of water with some assurance of reliability throughout an area will reduce the concentration of humans and animals at the few water sources previously used, abating the erosion and loss of vegetation that may have taken place over a long period. The new widespread water availability, however, offers the potential for the same problems at many new sites as the local people gather to bathe, wash clothes, obtain water for household use, water and bathe livestock, and simply cross the irrigation and drainage channels. These disturbances can result in contamination of the water by laundry products, animal wastes, soil and bank erosion, and resuspension of channel materials unless properly controlled.

Human Environment

Every project should be part of a regional or national master plan, if one exists. Land and water proposed for an irrigation project may have potentially greater beneficial use for human domestic use, industry, or recreation. Water allocated to one project area is not available for other upstream and downstream areas. The schedule of power generation may determine the availability of water from a hydroelectric facility for irrigation during the crop growing season. Local water laws and customs also may affect the success of irrigation projects. All of the influences and conflicting uses of land and water should be evaluated before the appropriate decisions are made.

Small-scale irrigation leads to intensification of agriculture and tends to increase population density. Provisions must be made to accommodate these people in terms of housing, schools, shops, roadways, cemeteries, and cultural and religious centers [A]. Good irrigable land often is inadvertently used for these other purposes but this misuse of land capability can be minimized with comprehensive planning.

A common environmental concern associated with irrigation projects is water-related human health problems, some of which are mosquito-borne (malaria, yellow fever, encephalitis), snail-transmitted (schistosomiasis, in which the snail is an intermediate host), or water-borne (dysentery, leptospirosis, typhoid fever) [B]. In tropical Africa, where irrigation ditches support brush along their courses, a habitat may be developed that is favorable to tsetse fly, the vector of African sleeping sickness. Aquatic plants in the channels will make the control of vectors and intermediate hosts more difficult. Some control of mosquito and snail populations can be attained by maintaining water velocities of at least 0.5 meters per second. Open channels should be designed for at least this minimum velocity, but velocities higher than one meter per second will cause channel erosion in many soils. Some soils will erode at velocities less than one meter per second. Land grading and other surface drainage systems should be provided to avoid stagnant water.

Chemicals and bacteria in the water, especially from animal and human wastes, may actually benefit crop growth but may also cause a variety of human health problems, especially

if irrigation water is also used domestically. Provision should be made for a safe domestic water supply, drawn from a protected source, or from a surface source and made safe by treatment. The convenience of the irrigation water supply may still result in hazardous domestic use if the good quality water sources are too distant. The attractiveness of open water may also result in drowning accidents, particularly of children who have not learned how to swim. These problems can be minimized by information and education programs on the proper health and safety precautions for using the irrigation water supplies.

To be successful, small-scale irrigation projects often require that the farmers change agricultural and social practices which have been in effect for centuries. This can be a traumatic experience if the changes are not introduced with full awareness of all of the social, religious, cultural, and physical factors which influence the farmers' actions [A]. For example, different crops or varieties which respond better to the additional water of the project may have strange new tastes or cooking requirements. Modern irrigated agriculture requires many inputs and timely farming operations which can be frustrating to a farmer who is accustomed to a more relaxed and simple farming approach. This is especially true of the change from a primarily pastoral to a primarily agricultural mode of life. Logical and efficient overall layouts of irrigation/ drainage systems may cut across existing operating units and other land uses, such as housing, wood lots, grazing land, and cemeteries, which may be difficult for the local populace to accept. Unless each operating unit has its own water supply (well or surface diversion) and outlet to a public drainageway or the project is publicly run, the farmers must cooperate to varying degrees in order to successfully operate and maintain irrigation and drainage systems. If the farmers do not have a history of cooperation, careful motivation and training will be needed to attain the necessary cooperative action to schedule the water from one unit to another, to allow water to pass over other units, and to maintain the systems. In the Philippines, past cooperation within social groups did not result in cooperation between groups when the irrigation system served several groups (A.I.D., 1974).

Small-scale irrigation may stimulate some farmers to adopt mechanized equipment, thus reducing labor needs. Agricultural laborers may be forced to migrate elsewhere, intensify collecting activities, and/or colonize marginal lands. Farmers who are successful in adopting mechanized equipment may drive out less successful farmers and consolidate the production units, with similar consequences for labor. Local construction industries, shops and services may suffer as a result of emigration of consumers. The exact nature of human ecological effects must be studied carefully [A].

Mitigation and Enhancement Measures

Other actions may be required in addition to physically establishing a system for delivering irrigation water to fields

and drainage systems for removing excess water from the area. The irrigation/drainage scheme usually is a part of a more general agricultural development program, which includes many of the companion activities cited below either as a part of the small-scale irrigation project or as separate projects. They all serve to improve the environmental acceptability of the irrigation project by either reducing negative impacts or increasing positive aspects.

Companion Activities

A key ingredient in the success of all irrigation projects is a dynamic and effective agricultural extension service. Information on crops, cultivation techniques, animal husbandry, irrigation methods, fertilizers, pesticides, herbicides, drainage, marketing, harvesting, crop storage, in short all aspects of the agricultural economy, should be conveyed to the farmers. A parallel extension service for home improvement is helpful to present assistance on meal preparation, sanitation, housing, health requirements, and clothing. Health services are of critical importance to provide preventive medicine and treatment, especially for water related diseases.

Most irrigation projects are not self-sufficient. A network of roads and paths is needed to transport crops produced in excess of local requirements to markets and to bring commodities and services, such as chemical products, improved seed, agricultural machinery, extension services, health services, and education to the farming community. The spoil banks and berms of open channels often serve as good locations for penetration access to irrigated areas. Such roads should of course conform to guidelines presented in Chapter II of this manual.

Modified or new agricultural equipment often is needed to handle the increase in production and to ensure timely operations of irrigated farming. This equipment, such as hand tools, small cultivators, chemical spreaders, and threshers, offers the opportunity for the development of small-scale industry (see Chapter VI). Local industry (area, regional, or country, depending on manufacturing conditions, equipment uniqueness, and market size) should be encouraged to manufacture this equipment in order to provide local employment, develop the local economy, and perhaps respond more knowledgeably to specialized local equipment needs. Local industry, however, should not enjoy a monopoly because if the available equipment does not serve the farming needs, the farmer must have recourse to other equipment solutions rather than suffer difficulties in his farming operations. Proper operation and maintenance of all farming equipment are key factors in successful mechanization and should be carefully taught to the farmers.

Sanitary domestic water supply must be available to avoid the temptation to use the convenient irrigation system as the source for human consumption. It is normally prohibitively expensive to prevent the contamination of an irrigation system

sufficiently so that the water is suitable for human consumption. If the source of the irrigation water, such as a well or spring, is acceptable for humans, a separate, small pipe system can be considered for the domestic supply. This alternative usually is more cost effective than protecting the entire irrigation supply. A system of excreta disposal is required, in order to prevent the contamination of irrigation systems and water supplies.

The spread of schistosomiasis has accompanied irrigation projects in lands where the disease is endemic. In the planning stages of a project, consideration should be given to a multi-pronged approach to this problem: mollusciciding for snail control, health education to bring about behavioral changes, and latrine construction to limit transmission. Protection of workers and the avoidance of swimming or wading in infected waters also are recommended.

Where leptospirosis is endemic, rodent control in and around human dwellings and the burning of fields have had some measure of success.

A program and organization for operating and maintaining the irrigation and drainage systems should be established and implemented. These functions may be performed by the farmers themselves, by someone paid by them, by the irrigation agency, or through a combination of these groups.

Provisions for monitoring the project should be designed and installed. These include observation wells to measure the ground water levels and quality, and water measuring devices (weirs, flumes, flow meters) in the irrigation system to aid in properly managing the project. A monitoring program for the postimplementation stage (after A.I.D. funding) should be established.

Restoration and Reutilization

If the quality is acceptable, water in excess of crop needs which runs off an operating unit through surface and subsurface drainage can be used for irrigating other units, for industries, animals, fish production, and recreation. Borrow pits and constructed ponds may be stocked with fish; special tanks adjacent to pipelines and access ramps in the irrigation and drainage channels can be constructed for watering animals.

Trees, shrubs, and brush should never be permitted in and along open irrigation and drainage channels. In tropical Africa such vegetation creates favorable habitat for tsetse flies. Canal linings are easily damaged by the roots of large plants growing too close to the canals. Earthen channels need grass and other low vegetation above the normal water line on the banks and berms to prevent soil erosion. Larger vegetation in the canal may increase erosion by reducing grass cover through shading and competition. Larger plants may also cause extensive overbank flooding by reducing the flow area of the

canal. Large vegetation along earthen irrigation canals tends to be species which transpire large amounts of water needed elsewhere. If trees are needed for fuel, wood products and fruit, areas away from the channels should be designated. These woodlots and orchards can be irrigated with available excess water. The sites should be chosen carefully so as not to interfere with any probable subsurface tile drainage systems.

Aquatic plants in the channels also reduce the flow area and their proliferation may be more difficult to control than trees and shrubs. Chemical, mechanical, and manual methods may be used to eliminate undesirable aquatic plants. They may be harvested, however, for animal feed, and to make compost for fields and gardens, or to generate biogas.

Environmental Controls

Irrigation canals should be lined with compacted earth or with concrete, asphalt, rubber, or plastic products when the soil is so porous that seepage would exceed acceptable amounts. Less effective solutions are a drainage system and a high water use crop to intercept some of the seepage flow.

Channels constructed across a slope must not interfere with the natural drainage. Culverts, inverted siphons, and cross drainage structures should be provided. Sediment from above the channel must not be allowed to enter the channel. Drop structures are needed in channels on steep slopes to prevent erosive velocities.

Valves and gates in pipelines and gates and turnouts in open channels help in controlling the flow of water. Weirs, flumes and water meters measure the flow, so that the correct amount of water is applied to the crop at the proper time to reduce the waste of water or to avoid under-irrigation, i.e. applying less water than the crop needs.

When the source of water is used for more than one operating unit, a system of water allocation should be developed and used. The system may depend on time, flow rate, irrigated area, water volume, or demand. A demand system requires that the irrigation canals have adequate capacity to serve all of the operating units at the same time and that the drainage system also be large enough to safely and concurrently remove all unwanted water.

Mere installation of physical features will not ensure all necessary environmental controls. Training, supervision and enforcement must be provided for all water allocation procedures, chemical applications, and soil and water management, in order to minimize the negative environmental aspects of the project.

Operational Evaluation and Monitoring

Skills and Training

Small-scale irrigation projects will undoubtedly introduce new water use and associated agronomic features which will be unfamiliar to the farmers. Farmers should be instructed on how to irrigate within the water allocation system, to apply the water to the crops, to manage new cultural practices and increased production, operate and maintain agricultural equipment, handle and apply fertilizers and other chemical products, and maintain the irrigation and drainage systems.

Water user associations can be helpful in encouraging the farmers to correctly operate and maintain their irrigation and drainage systems. If the farmers are not able to perform these tasks without undue group pressure or legal sanctions, personnel should be assigned to operate and maintain the major portions of the irrigation system. It may be advantageous to have specially trained operators to apply toxic chemicals rather than attempt to train all of the farmers who need to use them. Generally, specially trained operators are not needed for the control structures in a small-scale irrigation project because usually these structures are small and simple.

Farm education should begin in the elementary schools with principles of soil and water conservation, irrigation management, and agronomy. The children are future farmers and are often in and around the water and participate in farming activities. Moreover, if they understand the principles of modern farming and the rationale for the changing methods, they may be capable of seeing the advantages of being farmers, instead of migrating to the cities. Traditional skills, training, and information dissemination methods should be used whenever they can be effective.

Standard Testing and Review Procedures

Before a small-scale irrigation project is implemented, baseline surveys should be completed, whenever possible, as references for all future monitoring. The differences between the base surveys and future data will indicate the effects of the project.

Water quality, especially total salts and sediment levels, and quantity of the project inflows, outflows, and ground water, ground water levels, soil salinity/alkalinity and fertility levels, disease vectors in water bodies, the presence of waterborne diseases in the community [B], physical condition of existing irrigation channels and drainageways, and crop production levels should be surveyed for base data. Periodically during project life similar surveys should be conducted at sufficient frequencies to detect any significant changes. Additional appropriate items should be surveyed when it is suspected that some significant new contamination is occurring.

Flumes and weirs are normally installed permanently to measure the flow of water in open channels. Water meters may be portable or permanently installed, depending on cost effectiveness and frequency of measurement. Ground water levels may be determined with simple rods, tapes, or electric sounding lines. Electrical conductivity and pH meters are probably the only types of field chemical determination equipment which are warranted for a small-scale irrigation project. Several irrigation projects and other users are required to generate enough volume of work to justify specialized laboratory equipment, such as a spectrophotometer, atomic absorption unit, and Kjeldahl unit.

Special Assistance

A small-scale irrigation project will need considerable outside assistance, unless the irrigation agency also serves enough other projects to have appropriate diversity of trained personnel and facilities. The planner should identify the availability of suitable extension, operation and maintenance, and chemical testing capabilities. Government agencies, private firms, research centers, and educational institutions are potential sources of special assistance.

Many chemical and biological tests for environmental aspects not only require elaborate and carefully controlled equipment but must also be conducted in a timely and correct manner. To avoid incorrect conclusions, the results of one test should be interpreted in relation to the results of other tests, to sampling procedures, and to field conditions and their history [C].

Planning Information Required

General

The planning checklist is a useful tool for summarizing environmental considerations of irrigation/drainage systems. It also serves as a reminder of the environmental aspects that should be analyzed in developing a project. Various environmental considerations are listed below and their relative importance is shown in the impact matrix.

Design Stage

Many negative environmental implications of an irrigation/drainage project can be mitigated and even avoided through good planning and design. The following items should be considered in the planning and design stages:

Soil Type and Depth
Quantity and Quality of Available Water
Crop Water Requirements
Land Cover and Classification
Soil Erosion Potential
Flooding Potential

Allowable Quantity and Quality of Runoff Water
Native Flora and Fauna
Surface and Subsurface Drainage Requirements
Irrigation Method
Health Requirements
Energy Source (if pumps are used)
Monitoring Program
Accessways for farm inputs and outputs and for system operation and maintenance

Construction Stage

Soil is disturbed during construction of an irrigation/drainage project; there is potential for soil erosion by water and wind. Undesirable soil movement can occur as result of:

Land Clearing
Land Grading
Worker Camps
Channel Construction

Operation Stage

Negative environmental impacts can occur during the operation of a project due to lack of proper:

Maintenance of Canals, Drains and Equipment
Water Management
Monitoring of Flows and Ground Water

SMALL-SCALE IRRIGATION AND ON-FARM WATER MANAGEMENT POTENTIAL IMPACTS

PROJECT COMPONENTS	ENVIRONMENTAL COMPONENTS →	PHYSICAL ENVIRONMENT										BIOLOGICAL ENVIRONMENT										SOCIAL ENVIRONMENT									
		AGRICULTURAL LANDS	SOIL EROSION	SLOPE STABILITY	ENERGY / MINERAL RESOURCES	SURFACE WATER QUANTITY	SURFACE WATER QUALITY	GROUND WATER QUANTITY	GROUND WATER QUALITY	AIR QUALITY	NOISE	AQUATIC ECOSYSTEMS	WETLAND ECOSYSTEMS	TERRESTRIAL ECOSYSTEMS	ENDANGERED SPECIES	MIGRATORY SPECIES	BENEFICIAL PLANTS	BENEFICIAL ANIMALS	PEST PLANTS	PEST ANIMALS	DISEASE VECTORS	PUBLIC HEALTH	RESOURCES / LAND USE	DISTRIBUTION SYSTEMS	EMPLOYMENT	AT-RISK POPULATIONS	MIGRANT POPULATIONS	COMMUNITY STABILITY	CULTURAL/RELIGIOUS VALUES	TOURISM / RECREATION	NUTRITION
PLANNING & DESIGN	LAND – LOCATION		◑	◑	●	◑	◑	◑	◑			◑	●	●	●	●	●	●	◑	◑	◑	◑	◑	◑	◑	◑	●	◑	◑	◑		◑
	LAND – GRADING	◑	◑	◑	●	◑	◑	◑	◑	●		●	●	●				◑		◑	◑	◑	◑	◑	◑	◑	●					
	SOURCE – SURFACE WATER	●	●	●		◑	◑					●	●	●	●	●	●	●		●	●	◑	◑	◑	◑	●	◑	◑				
	SOURCE – GROUND WATER	●			●			●	●			◑	◑									◑	◑	◑	○	●	◑	◑				
	TRANSMISSION SYSTEM	◑	●	●	●	●	●					◑	●	●		●			●	●	●	◑	◑	◑	○	●	●	◑				
	DISTRIBUTION SYSTEM		●	●		◑	◑	◑	◑			◑	●	●				◑	●	●	●	◑	◑	◑	○	●	◑	◑				
	PUMPING AND CONTROL SYSTEMS		◑	●	●	◑	◑	◑	◑	●	●	●	●									●	◑	◑	◑	●	◑	◑				
	DRAINS – SURFACE		◑	◑		◑	◑					◑	●	●							●	◑	◑		○			◑				
	DRAINS – SUBSURFACE		◑	◑				◑	◑			●	●	●							◑	◑	◑		○			◑				
	WATER RECOVERY/DISCHARGE		◑			◑	◑	◑	◑			◑	◑			●					●	◑	◑			◑		◑				
	WORK FORCE											●	●	●	●	●	●	●	●	●	●	●	◑	◑	◑	●	◑	◑	◑			◑
CONSTRUCTION	LAND PREPARATION/GRADING	◑	◑	◑	●	◑	◑	◑	◑	●	●	●	●	●	●	●	●	●	●	●	●	●			○							
	TRANSMISSION/DRAINAGE SYSTEM		◑	◑		◑	◑	◑	◑			●	●	●	●	●	●	●	●	●	●	●	◑	◑	○							
	ACCESS ROADS	●	●	●		●	●			●	●	●	●	●	●	●	●	●	●	●	●	●	◑	◑	○			◑				
	WORK FORCE SUPPORT											●	●	●							◑	◑	◑	◑	◑			◑				◑
	CONSTRUCTION METHODS/MATERIALS	●	●	●	●		●		●	●	●	◑	◑	◑											◑	●	◑	◑				
OPERATION	EQUIPMENT MAINTENANCE		◑			○	◑	○	◑			●	●											○	○							
	SOURCE PROTECTION	◑	○	○		○	○	○	○			○	○	○	◑	◑	◑	◑	◑	◑		○	◑	◑	◑	◑	◑	◑		○		◑
	WATER MONITORING						○		○			○	○								○	○		◑	◑			◑				○
	SOIL MONITORING	○	○	○	○									○			○		○				○	○		◑	◑	◑				○
	EXTENSION SERVICES	○	○	○	○	○	○		○	○	○	◑	◑	◑					○	○	○	○	○	◑	○	◑	◑	◑				○

KEY

BENEFICIAL
- HIGH ○
- MEDIUM ○
- LOW ○

ADVERSE
- HIGH ●
- MEDIUM ●
- LOW ●

VI. SMALL-SCALE INDUSTRIES

Project Description

General Characteristics

The rural industrial projects in which A.I.D. may participate are diverse in both size and type of industry. The industries listed in Table VI-1 are a brief representation of the types of small-scale industries that may be appropriate for rural development.

Small, rural industry in developing countries will usually consist of transforming agricultural, livestock, forestry and earth resources into internally consumable products. There may be a few exceptions, such as service industries and export of manufactured goods when production capabilities exceed local demand.

In general, small-scale industry in a rural community will not have a severe environmental impact, simply due to its size. However, an exception would be any operation handling or releasing a toxic, obnoxious or contaminating compound that could either pose a health threat or degrade the environment. Good environmental practices in larger industries, such as reuse of waste materials, are applicable to small-scale industries also, when appropriate. The planner must keep in mind the size and scale factors of the particular industry to be developed and adapt these guidelines accordingly.

Size and Scale Factors

The smallest industry is the seasonal or part-time cottage industry where the home is the "shop" or "factory". These industries frequently develop to supplement family incomes during periods when demands for agricultural labor are low, but under the right conditions can grow to full-time industries. Weaving, woodcraft, and leathercraft are examples of this type of industry.

Defining the upper size of small-scale industry is arbitrary. The following factors are among those which might be considered in establishing this limit.

- Labor Force - Source of skilled and unskilled labor; Number of employees, specialization and division of labor
- Raw Materials - local, domestic, imported
- Markets - local, domestic, export
- Technical - availability of businessmen, managers and technical skills

Table VI-1

REPRESENTATIVE SMALL-SCALE INDUSTRIES

Agricultural Processing	Animal & Human Food Production	Animal Based	Forest Product	Earth Based	Metal	Service & Misc.
Textiles	Bakery	Textiles	Furniture	Cement	Farm implements	Art works
Rug Making	Fermentation Products	Rug Making	Pulp	Brick	Vehicle Assembly	Soap
Rubber	Canning	Tannery	Paper	Block	Machine Parts	Engine Repair
Copra Processing	Coffee	Meat Processing	Charcoal	Sand	Appliance -assembly -manufacture	Motor Repair
Sugar	Dairy	Packing plant	Lumber	Gravel	Plating	Printing
Sorghum		Fish processing	Dimensional Stock	Salt	Stamping	Blacksmith
					Wire nails	
Milling			Parquet	Potter	Foundry	Construction
				Plaster		Tourist
						Garments
						Drying

- Economic - source of capital and financing - local, domestic, foreign, value of product

- Policy - governmental, financing institution

Larger industries, having up to 30 employees, could include sugar refining, canning, meat packing, furniture manufacturing, brick making and leather tanning.

Of course, between the cottage and the larger industries are a wide variety of sizes and types of industries ranging from one-man shops, such as a blacksmith shop, to almost any type of industry with many employees.

Location Sensitive Factors

Factors which affect the selection or avoidance of an individual location include the following:

Natural Ecological Factors

- Susceptibility to natural disasters such as high intensity storms, flooding and earthquakes

- Geologic and topographic factors affecting foundations, drainage, spoil areas, fill material and waste disposal areas

- Proximity and availability of raw materials, including natural resources, process water and fuel

- Climatological factors such as temperature, prevailing winds and precipitation

Human Ecological Factors

- Present and future land use patterns

- Capacity of existing community to absorb immigrants attracted to the area

- Access to skilled and unskilled labor force

- Access to educational, training and health facilities

- Esthetic considerations

Economic Factors

- Proximity and size of product markets

- Availability of transportation for raw materials, products and work force

- Energy sources and capacity of existing supply

- Availability of potable water and sanitary waste disposal

It is quite evident that each of the above environmental, economic or social factors affecting the selection of a site has a significant potential impact.

Environmental Considerations

The environmental factors to be considered for a project are unique to each industry type, size and specific location; that is, they are project specific.

A generalized approach can be followed to identify the significant environmental factors for any industrial project, but the actual specifics of the project (costs, quantities, etc.) are required to determine the degree of significance.

Evaluation Techniques

Preliminary Screening. A preliminary screening of a project for the environmental factors to be considered can quickly identify those factors which have an insignificant impact or none at all and can be eliminated from further evaluation. For instance, a dry industry will not have any liquid waste discharges; one which uses only imported raw materials cannot have an impact on domestic raw materials; and one whose labor force walks to work will not stress local transportation facilities.

The preliminary screening can also identify those factors which have a beneficial impact, such as the consumption of an agricultural waste product which would otherwise be discharged and create a pollution problem. These beneficial factors should certainly be identified but whether or not they need to be evaluated or quantified will depend upon their significance to the project.

Preliminary Evaluation. When those factors which have beneficial or insignificant impacts have been isolated, the remaining factors are those which have a potential negative impact or which cannot readily be categorized by a preliminary screening technique.

A preliminary evaluation of these remaining factors can further reduce the number that should be evaluated in detail. This can be done by determining which negative impacts can be tolerated without mitigation. An example might be the negative impacts of additional road traffic hauling raw materials and finished products and transporting people for the industry. If the anticipated wheel loads and vehicular density are below those for which the roads were designed, the negative impacts associated with the roads, such as noise, dust and dangers to pedestrians, should be within acceptable limits.

At this level, if there is a question as to whether or not a factor has a significant negative impact, it is convenient to assume that it does. If the anticipated negative impact can be tolerated and is not amenable to reduction, that factor can be eliminated from further evaluation. If not, a more detailed estimate of the impact will be developed during a detailed evaluation.

Detailed Evaluation. A detailed evaluation will be required for those factors which have not been eliminated by the preliminary screening or evaluation procedures. This evaluation should be carried to the point of determining that a factor can be tolerated or that mitigation or enhancement measures are required.

Factors Affecting the Environment

The aspects of the particular industry that exert environmental effects should be identified and evaluated, and mitigating and enhancement measures defined during the planning and design phases of the project. Continued monitoring during the construction and operating phases should be relied upon to refine the degree of anticipated impacts rather than identifying unanticipated ones.

Site Considerations. Although the general area of a rural industry project site probably will be selected for economic reasons, opportunities may exist to refine the site selection to reduce environmental impact (reducing erosion, improving disposal of wastes, enhancing land use practices).

Project site selection should be consistent with the regional land use plan, if one exists. In the absence of a regional plan, the rural industry site should be selected with future land use needs in mind. Planners should bear in mind that the industrial plant itself, even if small, will influence local land use through demands for resources, employees, transportation and services.

Most small rural industries are not highly demanding of these services, but some (e.g., sugar refining) routinely require high inputs of one or more services or discharge an effluent (in the case of sugar, a process water carrying an extremely high organic load) that may easily exceed the capacity of local facilities.

The availability of public services (water supply, waste treatment, power, transportation) and certain private services (e.g. machine shops) is an important consideration in site selection. If these services are available, have the design capacity for the extra load and are being operated efficiently, the addition of a small industrial plant probably will not unduly stress the system.

The other sections of this manual concerning electrification, roads, water supply, sanitation and water management are generally applicable to providing power, potable and process water, sanitation and industrial waste disposal and roads for small scale industries.

Cottage industries and the smaller industries will probably have little impact on the labor force. The larger industries can have considerable impact, particularly where unemployment is low or where the community cannot provide the skilled labor required [A].

Competition may develop between industry and demands for labor needed for agriculture and other purposes, especially if wage scales are different. A need may develop for the increased use of transient labor or the relocation of labor from areas of lower employment [A]. Alternatively, host government policy may demand the placement of industries in rural areas, in order to provide employment and to stem the flow of workers to overcrowded cities.

Seasonal, agriculture-based industries (such as canning) may present a unique situation with the peak industrial labor demands coinciding with peak agricultural demands. This situation can promote the growth of transient labor camps for either industrial or agricultural labor or both.

More stable labor demands will result in migration of labor from areas of lower employment or in the labor force traveling greater distances daily [A]. Any situation which either temporarily or permanently reults in increasing the population of the community will increase the load on all aspects of the local environment (food supply, shelter, transportation, water, sanitation, education, health facilities, recreation, etc). To the extent that these facilities are capable of assimilating the additional load, no immediate negative impact exists. Should planned or future overloads be identified, mitigation or enhancement measures will be required.

The lack of local labor with specific skills will require either training of local labor or relocation to the community of labor having the required skills. Local labor may be trained on the job by industry personnel or through local educational facilities.

The project may have an indirect impact on the local labor force by stimulating or replacing existing industries and commerce [A]. The use of local raw materials will stimulate the industry producing them, with a likely increase in the labor demand of those industries. Similarly, an increase in population (labor force) will stimulate all facets of commerce (retail, financial).

Transportation (primarily roads) is essential to industry and will play a major role in the selection of the location for a project. The project industry will depend upon the transportation system to deliver raw materials (including fuel), transport the labor force between their homes and the industry, deliver finished product to markets, and carry waste materials to disposal sites. Only those industries using readily available local raw materials and local labor, and producing a product for local consumption, will have only minor impacts on the transportation system. Any increased demand upon the transportation system should be defined and compared with the capacity of the system in order to determine the actual impact. The increased demand can be defined in terms of number and types of vehicles, wheel loads, road speeds and service facilities. The environmental impacts are

discussed in the section on Rural Roads (Chapter 2). Additionally, there will be greater need for food and housing for vehicle operators, service and maintenance facilities, and fuel.

Depending upon the actual impact on the transportation system, a proposed rural industry may a) overstress the system to the extent that a different location should be selected b) provide the justification for expanding the existing system or developing a new one, or c) be assimilated without undue stress on the system.

Raw Materials. Small scale industry in a rural setting usually will be dependent for raw materials upon local natural resources (clay, stone, or wood), agricultural products (hides, sugar cane, soybeans, palm oil, sorghum) and fuel (wood, coal, oil). Some materials from outside the local area or imported raw materials may also be used.

In recent years, productive uses have been found for many materials that are usually considered wastes. Examples of such uses (summarized by Loehr, 1979) include animal feed from fruit and vegetable wastes, fish processing wastes, whey (from cheese making) and even animal manures; alcohol from a variety of food processing residues; biogas (methane) from animal manures, food processing solid and liquid wastes, and crop residues; and glues and gelatins from tannery and meat processing residues. Loehr notes that in addition to identifying the appropriate technology to convert agricultural residues into useful products, the planner must be sure of:

- Availability of residues: amounts available, constancy of supply, logistics of location, storage ability.
- Convertibility: handling, separation, transportation and physical processing of residues and end products.
- Demand for end product: markets (size and location), seasonality, rate of growth of demand.

To these might be added the consideration of competing demand or uses for the residues and competing suppliers of the end product, both of which may affect and be affected by the proposed industry. Guidelines for the utilization of agricultural residues have been prepared by FAO (1978).

Raw materials and fuels to be used by the proposed rural industry should be inventoried and each evaluated for direct and indirect environmental impacts at the source, during transportation to the industry, and in storage at the site before use.

The project's demand for raw materials may lead to increased production by suppliers, possibly placing a strain on the resource. A slowly renewable resource, such as timber, which is subject to demands for fuel as well as lumber, may be unable to sustain further exploitation.

Special consideration should be given to the transportation and storage of toxic, explosive and flammable materials to ensure that they are handled and stored safely and that adequate provisions are made to deal with accidental spills or discharges. Toxic materials in particular, sometimes in small amounts, can be devastating to the natural and human environment. These materials should be specifically identified and control measures defined during the planning phases of the project.

Food products which are not indigenous to the local area present opportunities for the introduction of plant pests or disease vectors. Similarly, workers entering the area to take advantage of employment opportunities may bring with them diseases not present in the area [B].

Storage of materials at the site should be reviewed for esthetic impact, air pollution such as dust and odors, and water pollution from seepage or leachate such as coal pile runoff.

An adequate supply of acceptable quality water is essential to many industries. This water may become part of the product, as in canning, or be used only for wash down or cooling. Industrial water demand may compete with other demands (potable water or irrigation) to the extent that the supply is inadequate and an alternative source must be developed. The water may have to be treated to achieve acceptable quality or prevent contamination of the product [C].

Industrial Processes. In many instances the industry's impact upon the environment can be reduced by proper consideration during the design phase. The optimization of process efficiency will usually reduce discharges to the environment For instance, the use of heat recovery systems, such as closed loop steam or cooling water, is considerably more efficient than single pass systems. They result in lower fuel consumption and reduced thermal discharges. Such systems require higher initial costs, however, and can usually be justified economically only on life cycle costs.

Where heat is required, local fuel sources should be studied in terms of cost and regional benefits. Care should be taken to ensure that the plant does not place undue pressure on a limited fuel resource, such as wood. Locally available fuels, such as bagasse (sugar cane residue), may be inexpensive and their use will aid in protecting the local environment.

Designing for recycling is usually economical and will tend to reduce discharges, or at least concentrate them. The emphasis should be on the reuse of waste materials, where possible, rather than on treatment and discharge for asssimilation by the ecosystem.

Human impacts should be considered in the process design: worker safety, noise, lighting and even color schemes. Interior and exterior esthetics should be considered, including

architecture, landscaping, and color. Consideration should be given to making plant design compatible with local architectural styles.

Employee training in industrial safety can be profitable by increasing productivity.

Industrial Discharges

Discharges to the air, land and water probably have the greatest potential for adverse impacts upon the rural environment. Each discharge should be identified as to source, point of discharge, quantity of discharge and pollutant characteristics. Although probably minor for most small-scale industries, the pollutant characteristics to be identified will depend upon the specific industry and discharge and may include the following:

- Gaseous and Airborne Discharges - particulate matter, noxious chemicals, toxic chemicals.
- Solid Discharges - soluble toxic chemicals and heavy metals, biodegradable materials
- Liquid Discharges - Oxygen demand, suspended solids, heavy metals, acids, toxic chemicals, heat.

Limiting values for quantities of each pollutant at its point of discharge or in the receiving environment should be selected so as not to exceed the assimilating capacity of the environment or value established arbitrarily [C]. If the discharge does not exceed the limiting value, it may be tolerated but it must be evaluated in terms of the total pollution load on the receiving body. If the load is excessive mitigating or enhancement measures will be required.

In those instances where background quantities of the pollutant already exist in the receiving environment, the quantity permitted in the discharge will be the difference between the quantity which can be assimilated by the environment and the background quantity.

Construction Activities

The environmental impacts of construction activities for small-scale industrial projects are similar to those for most other rural project types.

Care must be taken that scarce local commodities, such as cement or timber, are not preempted by the plant construction. The resulting scarcity and local inflation would have a depressing effect on other developments. The same may be said of labor, but the situation is more complex and the effects often longer lasting. Both the construction force and the plant operating force may exert effects out of proportion to the sheer numbers, by requiring more skilled labor (e.g., drivers) who may be important in agriculture [A].

Runoff from the construction site may be high in suspended solids and cause disruption of local drainage patterns and water quality.

Environmental Standards

Discharges may constitute the most significant environmental impacts of small-scale industries. Maintenance of environmental standards is usually achieved by placing quantitative limits on these discharges, consistent with the assimilative capacity of the environment, or by limiting the quantity or concentration of specific substances in the environment. Governmental regulation may establish these quantitative limits. When regulations do not exist, the limits should be established by determining the assimilative capacity or the quantitative limit of the critical elements of the environment.

The most universally accepted standards are the International Standards for Drinking Water published by the World Health Organization (see Table C-1). These standards establish maximum concentrations of a number of parameters for drinking water. Supplies exceeding these limits in either ground or surface waters used for human consumption should not be accepted.

Maximum concentrations of many parameters have been established for various plant and animal life. For specific waters, these may be translated into limits on discharges.

Mitigation and Enhancement Measures

Mitigation or enhancement measures will be required whenever an intolerable environmental impact has been identified. The majority of these measures should be identified and incorporated into the project during the planning and design stages.

Companion Activities

If public services, such as power, water supply, sanitation and access roads are not available or are inadequate to serve the project industry they should be developed locally.

If the industry is to rely on local labor some training will often be required. Most small-scale, rural industries do not seriously strain the local labor supply but, instead, provide employment on a seasonal or part-time basis, or employ individuals who, through inclination or ability, are not regularly employed. If a larger work force is required than can be obtained locally, some immigration may be expected, with stress on local housing, health and educational facilities. Local agencies should be alerted to the possibility that more people may move into the area than can be employed by the proposed industry [A].

Transportation facilities may require improvement to handle the need of the additional labor force or the transportation of raw materials and finished product.

Construction Activities

Construction procedures should be monitored to ensure that erosion and siltation are maintained within acceptable limits.

Additional housing and transportation facilities may be required to accommodate the construction work force.

Industrial Processes and Discharges

Primary mitigation and enhancement measures are the careful selection of points of discharge, the use and reuse of materials to eliminate or reduce discharges, and the treatment of discharges to acceptable levels. During plant operation each discharge having an unacceptable environmental impact should be traced to its source and evaluated to determine if 1) the process can be modified to eliminate, reduce or concentrate the problem (treatment is usually easier with higher concentrations), 2) the discharge can be isolated from other discharges, 3) it can be recycled through the process or 4) it can be reused or converted to a usable product.

The primary emphasis should be on using waste materials rather than treating discharges. Recycling can reduce the quantity of a discharge, concentrate undesirable constituents or, in some instances eliminate the discharge. An example is a closed loop cooling system rather than a once-through system. The total heat discharged to the environment is the same in either case (although the point of initial discharge may be changed from water to the air) but the liquid discharge is limited to the system blow-down.

The reuse of a waste material as a useful or possibly marketable product effectively eliminates the problem or at least transfers it to a more acceptable circumstance. The use of bagasse as a fuel in a controlled atmosphere, as a base for wallboard, as an animal feed ingredient or as a soil conditioner, rather than uncontrolled burning with resulting air pollution, is an excellent example. Another example is the use of whey (possibly stabilized with formaldehyde) as an animal food.

Again, if economic evaluation of these options is to be made, it is important to use life cycle costs (including operation, maintenance, financing, etc.) rather than capital costs.

The selection of the point at which a waste is discharged can affect its acceptability. Chlorine gas discharged to the atmosphere is toxic, corrosive and usually unacceptable while, within limits, if dissolved in water it can be made acceptable and, in some instances, beneficial. The discharge of chemicals to a small watercourse or irrigation ditch may result in concentrations which are toxic to plants, animals or humans, while discharge of the same quantities to a large stream may result in acceptable concentrations. Discharge of contami-

nants where they can leach into the ground water (leach pits, dumps, land fills) may be unacceptable but isolation from the ground water and/or discharges to a large stream may be made acceptable [C].

The final alternative is to treat the discharge to acceptable levels by removing undesirable contaminants.

Operational Evaluation and Monitoring

Skills and Training

Labor and/or management skills training programs are often required. These may be accomplished by industrial training programs or through local educational facilities. Where appropriate, industrial safety training programs should be instituted.

Standard Testing and Review

All identified adverse environmental impacts should be monitored to ensure compliance with established criteria. This may be done by a combination of inspection and testing. The frequency of monitoring each factor should be related to the significance of its impact and its susceptibility to change. A critical discharge may require sampling and testing daily while a physical feature may need only a single inspection at the completion of construction.

Special Assistance

Special assistance may be needed during the planning and design phases to evaluate the industrial processes, reuse and recycle options and the treatment of discharges.

During the construction and operation phases technicians and laboratory facilities may be required to monitor discharges.

Should the local government not provide the usually expected inspections and monitoring for such functions as public health [B], education and industrial safety, it may be necessary to provide them as part of the project.

Population immigration and/or displacement will require planning by specialists in community development, colonization and resettlement [A]. These usually are not available locally but must be sought at the national university or outside the country.

Planning Information Required

I. Planning and Design Phase

a. Markets

1. Domestic (import replacement)
2. Export
3. Marketing Channels

b. Site Selection

1. Land Use: On plant site and locally.
   Influence on local land use and cropping

2. Transportation (refer to Chapter II)

3. Materials and Supplies: Sources, Access, Reliability

   Raw Materials
   Packaging
   Plant supplies

4. Waste Storage/Disposal

   Solids
   Liquids

5. Energy

   Fuel
   Electricity

6. Labor

   Unskilled
   Skilled and management

c. Plant Design

1. Technical Processes

2. Materials Storage and Handling

3. Residues and Effluents

   Recovery and Reuse
   Treatment and/or Disposal
   Air Quality

4. Energy

   Fuel Storage
   Capability for use of alternate fuels

5. Training

   Unskilled to skilled labor
   Management

6. Health and Safety

   In-plant safety - devices and education
   In-plant health - air quality, sanitation
   Off-plant protection - public safety, vector-borne diseases

II. Construction

a. Materials

1. Local-competition with other needs

2. Borrow/fill areas - protection of water quality, suppression of disease vectors

b. Transportation: safety, disturbance

1. For workers

2. For materials

c. Environmental Protection

1. Air Quality - dust, noise

2. Water Quality - site runoff

III. Operation Phase

a. Continued Training Programs

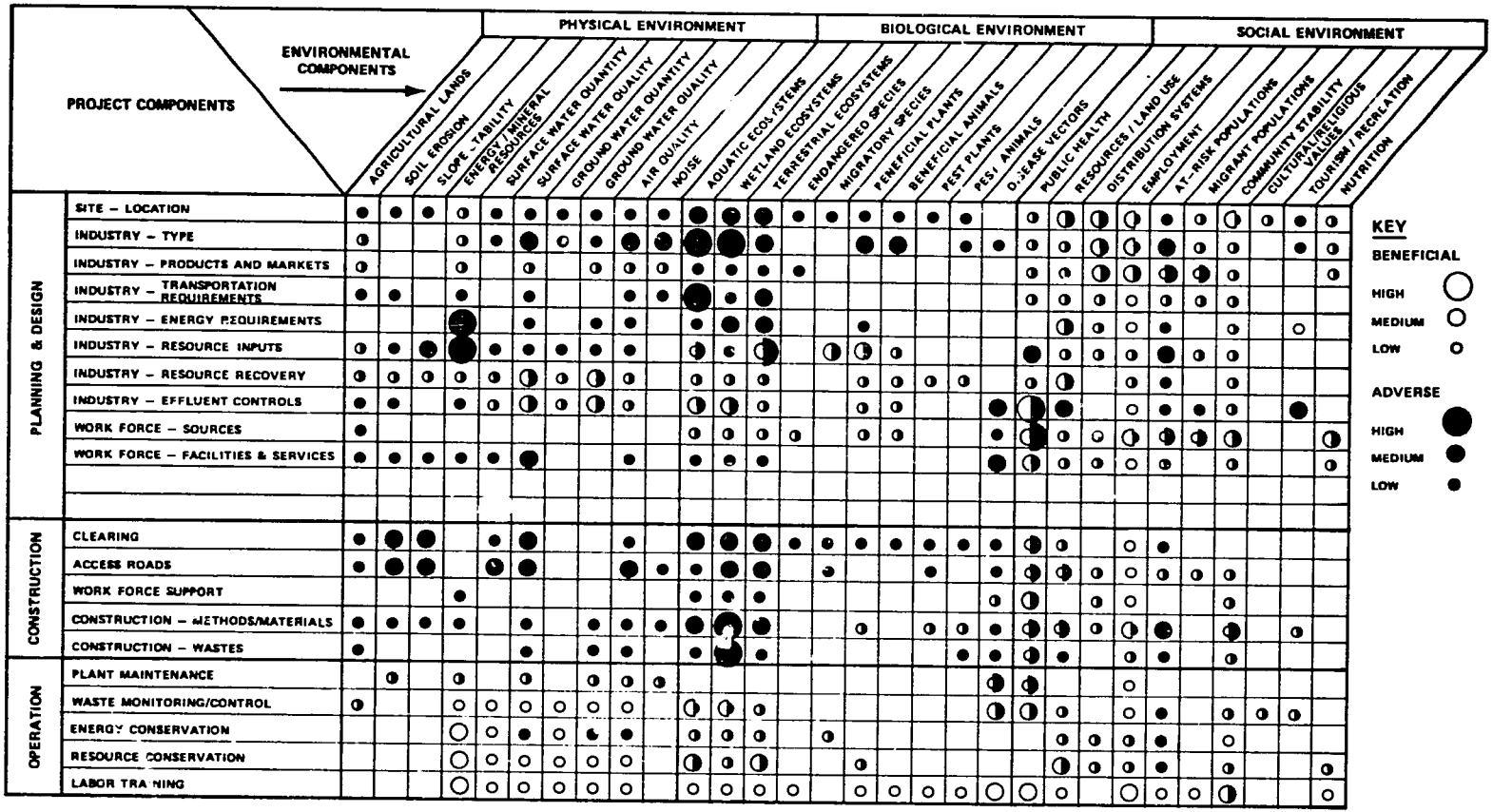
b. Continued alertness to opportunities for residue sale or reuse, or use of materials from other local industries

c. Health/Safety

1. In-plant Monitoring - safety conditions, health checks (especially for new workers); storage of toxic and volatile chemicals

2. Outside Conditions - monitoring of standing water for disease vectors; road safety

SMALL-SCALE INDUSTRY POTENTIAL IMPACTS



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Appendix A

HUMAN ECOLOGY

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APPENDIX A

HUMAN ECOLOGY

General Considerations

Development projects change the natural environment or the man-made environment or both. They alter an environment directly as when a mule path is transformed into an all-weather road, stimulating commodity traders to use trucks for purchasing agricultural products and farmers to commercialize production. And they may also alter an environment indirectly as when the new road and resultant commercialization of agriculture increase land values and costs of production, which in turn may drive some farmers out of the area to clear forest and plant crops elsewhere. Whatever the project, human communities in the area of project influence will respond to environmental changes and their responses will set in motion still further consequences for the environment.

The people in an affected community do not benefit equally from a given development project. Human communities are not homogeneous; they are organizational systems that unite diverse population segments. Communities survive to reproduce themselves because their systems require individuals and groups to cooperate in processes of production and in the distribution of environmental resources. Such social obligations, often called cultural tradition, are enforced by a customary set of penalties and rewards, constraints and incentives. Environmental change modifies these customary constraints and incentives, forcing changes in traditional obligations and organizational systems.

Some segments of a community have the capacity and the willingness to respond to new opportunities which occur in new conditions. Other segments may respond only slowly and only with some assistance to the new set of constraints and incentives. Still others will be unwilling or unable to respond, even with assistance. Each of these different responses has different consequences for the environment. This appendix presents some methods for predicting the responses of human communities to development projects, which may, in turn, produce new human pressures on environmental resources.

Key Operational Concepts

When it is recognized that a project affects segments of a community differently, it then becomes important to predict the magnitude of positive or negative impacts for each segment. The following concepts are useful because they facilitate the quantitative expression of benefits and costs, which permits a rational evaluation of economic, social and environmental soundness. The concepts are operational in the sense that the groups to which they refer are project-specific or defined in a different way by different kinds of projects.

- Host Population: This term refers to all persons or groups living within the area of project influence. For example, in a small-scale irrigation project the host population could be farmers who will have access to additional water, farmers who will continue with fallow systems, commodity traders who buy from both, transporters who haul commodities, laborers who work the fields, and [possibly] urban consumers.

- Target Population: This segment is defined as those persons or groups expected to directly participate in and benefit from the project. Continuing with the irrigation example, the target population might be all farmers with five or more hectares currently in fallow farming in a specified region, the laborers who work their fields, the traders who buy their products, the transport specialists who haul the products, and the urban consumers.

- At-Risk Populations: This segment will be composed of persons or groups who are likely to be disadvantaged by the emergence of a competing system. They are those unable to risk experimentation by participating in the project either because they lack adequate resources or because they are unwilling. In the irrigation example they might be farmers with less than five hectares, their laborers, their buyers, their transport specialists, and their consumers. The farmers can be expected to lose their land due to changing factor markets* and prices stemming from competitive advantages won by target farmers. While some may withstand such impacts, typical at-risk segments include low-income workers, the landless or small holders, possibly minorities, etc. In communities where women play important roles in production, a project directed at males only may place women in an at-risk status, as well as their infants and children. Where malnutrition is endemic to certain households, such as the elderly, low-income, or minority, these may form an at-risk segment which cannot afford to divert capital or labor resources from traditional activities into experimentation, and their status may worsen as the community develops. Quantitative estimates of the magnitude of the at-risk segment are particularly important, since the human costs of a project will be borne mostly by this segment.

- Migrant Populations: This segment includes both immigrants to the project area attracted by the benefits and spin-offs, and emigrants who will be displaced or officially resettled either because project design calls for their relocation or because immigrants will gradually push them out. In the example of small-scale irrigation, the project may be based on the assumption of displacement of farmers and their replacement by immigrants with greater skills or capital resources. Similarly, immigrant merchants, transport specialists, and laborers may be attracted to the area. It is incumbent upon developers to predict such immigration

and displacement, and to provide measures to ensure the viability of the new communities in the project area as well as the resettlement or colonization zones to which migrants must move.

Human Adaptation to Specific Environments

A community adapts to and transforms its environment primarily through its system of production, which entails the collection, cultivation, or management of resources. Renewal of those resources, the technology applied, the labor expenditures required, the commodities produced, and the carrying capacity or numbers of people supported, all are important features of production systems. Each is likely to be affected by development, creating changes with lasting environmental consequences.

A particular production system will require that human energies be organized in a compatible fashion. While there is no precise correlation between types of social institutions (values and beliefs, family forms, etc.) and kinds of production systems, the broad human organizational parameters by which a technology is applied and labor energy is mobilized do correspond to types of production systems. These include the community authority structure which provides leadership and coordination of individual energies, and the set of constraints and incentives which motivate individuals and groups to comply.

Farming Systems

Fallow Farming. These systems involve alternating plots of land between cultivation and noncultivation (Boserup, 1973). Forest-Fallow farming* entails clearing by burning secondary forest, which releases plant nutrients for soil fertilization. A variety of crops are planted and harvested for two or three years, after which the plot lies fallow* for 20 to 25 years, allowing the forest to regenerate before the farmer returns to cultivate it again. Output per hour of labor is high, since little labor is needed for clearing or weeding, but extensive land areas are required to support a small human population. Fallow lands are abundant sources of wild plants, animals, and insects, which are important dietary elements.

Fallow periods may be shortened as population pressure reduces availability of forest land. Long-fallow* farming cycles involve cutting brush and small trees to open up plots and release plant nutrients by burning. Crops are planted and harvested until invading grasses and insect pests can no longer be contained without large labor investments. The plot is not cultivated again for 6 to 10 years, during which brush and small trees displace grasses. Wild plants, animals, and insects are still harvested from the fallow plot. Unlike forest-fallow, long-fallow systems require greater labor inputs for cutting brush and weeding. Productivity per man-hour of labor is lower, but since land is used more

frequently (intensively) the carrying capacity is about the same as forest-fallow.

Continued shortening of the fallow cycle generally requires the use of plows and draft animals to open grasslands to planting. Cropland is cultivated for one or two years or until grasses invade, after which it lies fallow for one to two years. Fertilization of the soil depends mainly on the manure deposited by draft animals which feed on the natural grasses of the fallow plots and the stubble of harvested fields. If draft animals or plows are unavailable, farmers cannot easily reduce the fallow period without much larger labor investments to combat grasses. The carrying capacity of short-fallow farming systems is great because more land is simultaneously cultivated, but productivity per hour of labor is lower than with longer fallow cycles, due to greater labor investments in animal husbandry, farm implement manufacture and maintenance, fencing, fertilizing, plowing, and other tasks.

Fallow farming requires the dispersal of human populations over an extensive territory. Any one settlement will consist of family groups under the leadership of a skilled individual called a headman. Since there is little need for cooperative labor, families can easily split off to clear plots elsewhere. The incentives and constraints by which a headman leads are largely the product of his power to redistribute surplus produced by the group.

Shortening of the fallow cycle requires increasingly larger and more coordinated labor inputs and more administration (leadership). Households of the community must pool labor resources on a reciprocal basis, resulting in greater interdependency among families. Leaders arise from among the elders who coordinate and keep track of land use rights and the labor and product exchanges. The use of the plow and draft animals requires still greater interdependency. Draft animals are expensive to acquire and maintain, and cooperative arrangements among households, entailing communal grazing areas, animal cooperatives, credit and rental or sharecropping systems, center on their use.

Continual farming systems involve continuous cultivation of a plot and are associated generally with plow technology (Grigg, 1974). Draft animals either graze on cultivated fodder or fodder is cut for the animals. A variant of this system, the in-field/out-field system, alternates leguminous fodder crops with grain crops in a multiplot rotation, which keeps land in continual production, providing fodder for animals and renewing soil with manure and nitrogen fixation. The human carrying capacity is much higher than for fallow systems, but the total labor input rises while output per hour of labor falls due to year-round agricultural labor expenditure. The step to continual farming is taken when growth of population compels, and technology permits, more frequent use of the farm plot.

Multicropping, the cultivation of more than one crop annually on the same plot, may involve irrigation. The change from rain-fed to irrigated farming results in much higher productivity, due to increased labor inputs, perhaps 20 times that required for fallow farming systems. Intensive weeding and transplanting seedlings raise yields still further. Construction and maintenance of waterways, planting or transplanting, weeding, and harvesting all result in seasonal peak labor demands, since the timing of activities is critical. The carrying capacity of multicropping systems is high, but their labor-intensive character results in low productivity per hour of labor compared to other systems.

The human organization of continuous farming communities is most often characterized by greater centralization of authority than fallow farming communities. Access to land resources is carefully regulated by leaders because of the permanent nature of investments. Even in communal land tenure systems, authority is vested in a body of elders or a council which regulates use-rights, protects investments and resolves disputes. The central authorities coordinate labor inputs and direct them to urgent tasks. The system of constraints and incentives is continually negotiated and adjusted by the interplay of rival factions competing for power to control communal labor and land resources. Where irrigation exists, the power of authorities may be intensified due to the magnitude of labor needed to maintain the system.

Pastoral Systems

Transhumant Systems. Pastoral systems are called transhumant* when they involve the seasonal movement of animal herds and human groups between water and natural pastures (Horowitz, 1979). The pasture may be burned in dry seasons to decrease pests such as the tsetse fly and to increase the nutritive value of pasture. The climatic conditions and pasture utilized by transhumants are generally ill-suited to agriculture, or pastoral communities would have been displaced by agriculture millennia ago, but it is suited to grazing, provided optimal size and dispersal of human communities and animal herds are maintained. Limited water and grass dictate small herds grazing extensive areas and a limited human carrying capacity. Productivity per hour of labor is low, due to the large labor input required for watering in dry season and managing the continual movement of herds and human camps.

Where pastoralists live near farmers, a mutual dependence may exist which entails grazing animals on the farmers' fallow fields to manure the soil, a service for which farmers usually pay. Farmers in turn may own herd animals which are consigned to pastoralists under contract and pastoralists may own farm land rented to tenant farmers.

The human organization required for transhumant pastoral production is local autonomy and decentralized authority, for competition results in optimal spacing of herds and humans.

Water sources are controlled by headmen of kin groups, and incentives and constraints center on the redistribution of water and products of the herd to dependent families.

Ranching. This production system involves raising livestock behind fences. Ranching systems are less extensive than transhumant systems, requiring greater abundance of water and food for animals in a smaller territory, and are therefore located on better soils or in more suitable climate. Human energies must be expended to remove weeds, brush and small trees in order to maintain grasslands. Ranching pasture is usually created and maintained by cutting and burning, either through a symbiotic* relationship with fallow farming systems or through laborers permanently attached to the ranch. Productivity per hour of labor is greater than in transhumant pastoralism because individualized care of animals is much less important and because the labor used in maintaining pasture is relatively small. Ranching systems are associated with socioeconomic stratification and centralized administration.

Impacts of Development Projects

Changes in production systems and the human organizations which command them mean changes in demographic pressures, income distribution, dietary patterns, and human pressures on natural resources. These in turn will mean that the altered human communities will have an altered capacity for further adaptation to new environmental circumstances. For example, as livestock ranches displaced long-fallow farming on the valley floors in a river basin in southern Mexico, due to the stimulus of improved roads, the farmers were forced to concentrate production on the slopes and to shorten fallow cycles in an effort to feed the same numbers of dependents. This resulted in erosion of the slopes and escalating sediment loads in the river (Nugent et al., 1978). Similarly, deep wells dug by developers in an arid region of the Sahel utilized by transhumant pastoralists created public access to grazing areas traditionally managed exclusively by one group, resulting in overgrazing, as well as conflict among pastoral communities. Environmental degradation stimulated herdsmen to petition the government to have the deep wells shut off in order to save their herds (Horowitz, 1979).

Prior to 1950, indigenous communities in a river valley in northern Mexico irrigated plots and manufactured and sold mats from wild cane that grew along the river. As water was diverted for a new irrigation scheme the cane disappeared, and the people were forced to cut forest from a nearby reserve and sell firewood to replace the lost income source (Erasmus, 1961). In Nicaragua better access to markets resulted in turtle meat being sold for cash by hunters rather than being eaten, and hunters who previously distributed meat to non-hunters of the community stopped such gifts. The result was that cash income was too low to purchase processed foods to replace lost nutrients in the diets of hunters, and meat

disappeared from the diets of nonhunters. Consequently hunting pressures on turtles have increased to the point of near extinction of the resource (Nietschmann, 1973).

Development projects can also diminish a community's capacity for further adaptation to changing environmental conditions, as when developers attracted colonists to a small-scale irrigation scheme on tropical soils in a grassy savanna region of southern Mexico. Families which participated lost their capital and ruined their credit when the costs were found to be higher than original estimates. Some were unable to retain their original plots. Others did pay off loans but adopted the continual farming system advocated by developers on soils poorly suited for it. Fallow farming was precluded by the small size of plots and loss of capital prevented investment in livestock. The result was declining soil fertility (Poleman, 1965).

Differential impacts of development upon nutritional status can increase the incidence and severity of malnutrition for certain population segments, while elevating the nutritional status of others. In the situation of flux created by a development project a few producers can dominate access to new technology made available by developers, acquire the best access to transport and markets, and monopolize the best soils. Other producers suffer declines in income and dietary intake as factor markets and commodity prices change. Their only recourse is to increase pressure on natural resources (Partridge et al., 1980).

These and other unforeseen and unintended impacts of development projects can only be mitigated if they can be predicted in the planning and design stages of a project. Such predictions are made by tracing the human ecology consequences of altering traditional production systems and forms of human organization.

Planning Stage Considerations

The objective of human ecology studies at the planning stage is to estimate how segments of communities will respond to a project and what significance such responses have for the environment. These must be preliminary forecasts based on preliminary data. Reliable and comprehensive information is not likely to be found in urban areas or government offices of developing areas, but this does not mean there is no information available. It means that planners must consult local community merchants, professionals, and other educated or informed leaders in order to carry out planning stage analyses. School teachers and health workers (particularly WHO malaria campaign workers or their equivalents) are excellent sources of preliminary information.

The belief that traditional ways of life can and will be swept aside is frequently encountered among urban elite groups in developing countries. This belief is often the single most

important obstacle to empirical study of existing communities, and often subverts the planning process because no one knows the real situation in the area. Where such beliefs exist it is even more imperative to consult local people regarding human ecology factors. The following factors should be included in preliminary estimates of project impacts:

- Groups present in the community, as these are defined traditionally by ethnicity, language, religion, and other cultural characteristics.

- Principles of recruitment and bases of work group organization in production systems, such as age, sex, kinship, residence, socioeconomic status, membership in a ritual group, or other social attributes.

- Demographic patterns, including settlement size, population density, sex ratio, age structure, fertility, mortality and morbidity* rates, and migration rates.

- Community structure of communities or ways groups are integrated by leaders, perhaps on the basis of seniority in a kin group, accumulated wealth, achievement of prestige, etc.

- Distribution of resources, goods, and services within and between communities, such as reciprocal exchanges among households, redistribution through a leader, or markets.

- Aspirations, expectations, and values of the groups.

The next planning step is the preliminary estimation of project impacts on the community. Having identified the major human ecology characteristics, the planners should then project the desired outcomes for the host population. When these projections are completed they should identify the target segment, any potentially at-risk segments, and migrant segments. The following elements should be included:

- Changes in access to resources (e.g., land, water, credit).

- Changes in commodities produced (e.g., type, amount, quality).

- Changes in demand for commodities (acceptability, values, aspirations, expectations).

- Changes in population distribution (labor demand, growth of market towns, transshipment points, housing demand).

- Changes in income distribution (costs of production, wages, factor markets, costs of commodities).

- Changes in caloric requirements (hours worked, morbidity rates, stress, pregnancy, etc.).

- Changes in dietary characteristics (foods purchased, foods produced, foods gathered, preparation, quantity, quality).

Initial identification of changes in resources utilization patterns, population characteristics, income distribution, and consumption patterns will identify approximate sizes of the target, at-risk, and migrant groups. These estimates are then employed to calculate likely changes in human pressures on natural resources including resource substitution:

- Forest resource use patterns such as fuel, housing materials, fences, food for animals consumed, plants gathered.

- Water resources use patterns such as livestock and crop watering, domestic consumption and other domestic uses, transport and communications.

- Wildlife resources use patterns, including dietary items, sources of income such as pelts and hides, and raw materials for manufacturing useful items.

- Aquatic resources (flora and fauna) use patterns, including significant elements of diet and raw materials for manufactured items.

- Land resources use patterns, including soils types and fallow requirements, for cropping, pasture settlements, migration routes.

- Historical and archeological resources, including burial areas, rock carvings, cave paintings, and other sacred areas.

Planning stage human ecology considerations are completed when preliminary estimates of benefits and costs for each segment of the community can be stated, the response of each segment to these benefits and costs is projected, the potential impacts upon the natural and manmade environments stemming from these responses are estimated, and culturally appropriate mitigation and companion measures have been identified. These conditions then become the basis for design of the project, and they point up any gaps in information needed for design.

Design Stage Considerations

The objectives of design stage human ecology studies are to predict precisely the magnitude of responses to the project, and to design project features to enhance desirable responses and mitigate undesirable ones. Predictions must be based on quantitative information, so the less quantitative sources of information used for preliminary estimates may be no longer

useful. Design studies almost always involve research by social anthropologists who speak the language of the affected communities and can, therefore, collect primary information. Ideally, the specialists are from the host country. If international specialists should be brought in, they should be recruited on the basis of special expertise or knowledge of local community conditions, languages, and culture.

Changes in allocations of time, resources and energy will be required by a development project. Some things that have never been accomplished before must begin, and, therefore, other things that are now being accomplished will end. The central task in design is to anticipate these changes, consider the consequences for the people, and predict the human response. This can be done in two phases:

Phase One

The full range of production systems in the area of project influence should be identified. This is done in several steps. First, food networks are traced in order to identify kinds and amounts of existing resources utilized, the number of individuals who transform the resources into commodities, the numbers of individuals to whom the commodities are distributed, and the importance of the commodities in the diets of producers, distributors, and other consumers. Second, socioeconomic exchange relationships which govern the processes of production and distribution and consumption are traced. This is done by outlining the sequence of activities necessary to produce each commodity and distribute it, and then identifying the social units which carry out these activities. They might be family units, all males between the ages of 7 and 18, all married females, or males belonging to a ritual brotherhood. When such units are known, income levels, expenditure obligations, and consumption patterns must be calculated. In addition, designers should consider the multiple social functions these social units perform. For example, will changes divert time, energy and resources from child care and education, political integration and social control, religion and ritual, dispute regulation, regulation of access to resources, manufacturing of useful items, and other elements of community life?

Phase Two

The potential project impacts for target, at-risk, and migrant population segments are then expressed quantitatively. What food distribution networks will be broken which are now operating, and how many people are affected? Will substitutions occur? Will new producers intervene to fill the gap? Will earnings be sufficient to replace items lost from the diet? Which socioeconomic exchange relationships will change, and how many people will be affected? How many will gain and how many lose credit? Which groups will receive more or less income? How will expenditure obligations change? Will the authority structure be challenged? Will labor recruitment patterns change? How will production systems be organized?

When the numbers of people affected in the target, at-risk, and migrant populations are known, the designer can then quantify the magnitude of impacts on forest, water, land, wildlife, aquatic, and historical resources. Of particular importance will be the responses of the at-risk segment and the migrant segment. People who are placed at-risk by the project will seek means of replacing lost incomes, calories, security, and other losses by initiating novel production activities. These might be harvesting trees to produce charcoal for sale, hunting animals for meat and pelts for the market, clearing more pasture land, opening to cultivation marginal soils subject to erosion and degradation, intensifying farming by shortening fallow periods, or catching smaller fin fish and shellfish. Immigrants will also exert new pressures on these local resources, particularly if their numbers exceed the capacity of the new or traditional production systems to absorb them. Displaced populations will exert increased pressures on the environment of the location to which they move.

Following quantification of potential impacts, mitigation measures can be designed to reduce the potential for negative impacts and companion measures can be designed to enhance positive impacts. For at-risk segments, examples of mitigation measures include food supplement programs, long- and short-term credit plans, preventive medical services, infrastructure construction, soils studies, crop experimentation, agricultural extension services, housing, and public services for health, protection, and education. For purposes of designing mitigation measures, the immigrant populations can be considered in the same terms as the at-risk populations. Segments to be resettled present special problems (Scudder, 1973):

- There should be a complete census.
- Values of lands, buildings, trees, and other income producing property should be assessed.
- Indemnification payments should be made.
- The people should be prepared and organized for mobilization and movement to the new site.
- Food allowances for at least two production seasons should be allocated.
- New housing and infrastructure should be constructed.
- Soils studies, crop experimentation, credit, agricultural extension services, and other services should be extended.

In the case of target populations, companion measures may enhance positive impacts. Depending on the type of project, these may include health services for humans, livestock and plants, agricultural extension, soils studies, crop experimen-

tation, credit and other services, child-care centers for working mothers, public health and nutrition education programs, technical training programs, modifications of social control and public protection agencies, and implanting community development planning agencies (Arensberg and Niehoff, 1964).

The final step in design stage human ecology studies is the selection of indicators for monitoring project impacts, in order to detect serious problems and modify project features accordingly. The nutritional status of children is the most sensitive indicator of sociological problems in a project. A short-hand monitoring technique is to compare weights and heights for age of a one-percent random sample of children with published standards for the country (available from cognizant host country agencies; see Jelliffe, 1966). Dietary intake is also a useful indicator, and can be monitored by 24-hour dietary recall interviews of a one-percent random sample of households (Jelliffe, 1966). Calculations of consumed nutrients from dietary recalls can be compared with published nutrient intake recommendations for the country. Residential crowding is a useful indicator, for in many societies an excessive number of persons per household is correlated with marginal socioeconomic status and poor health conditions (Arensberg and Niehoff, 1964). Mortality and morbidity rates can be monitored through interviews with local health workers (Robson, 1972). Differential access to commodities and resources can be indicators of project success or failure, and can be measured by monitoring changing food prices, land sales and values, and costs of labor and services (Partridge et al., 1980). One or more of these indicators may be appropriate, but if monitoring is to be useful in the implementation and operation of the project it should be based on indicators selected during the design stage.

Construction Stage Considerations

The major human ecology concerns the developer should consider at the construction stage are:

1. Implementation of the project features in such a way as to be compatible with community organization.

2. Implementation of mitigation and companion measures in such a way as to assure their accuracy and utility.

Information from the planning and design stages can now be used to implement the project features so they are compatible with community traditions. For example, if centrally directed construction, administration and maintenance is a feature of a water supply system to be implemented in a community of transhumant pastoralists or fallow system farmers, it is likely to conflict with the decentralized authority structure of the communities. Village autonomy, multiple and overlapping domains of leadership, and distrust of central government are likely to mean that the project directed from above will be neglected or opposed at the community level

(Arensberg and Niehoff, 1964). In contrast, centrally directed projects in communities of continual farmers and ranchers might be quite compatible with existing traditions. Similarly, if female work groups have traditionally played significant roles in farming and a proposed irrigation project is implemented entirely through males of the household, conflict and opposition will inevitably result (Boserep, 1970). If the system of incentives and constraints dictate that a specialist repair traditional farming implements, he will have neither time nor inclination to repair novel implements introduced by developers to the extent traditional farming continues and with it his traditional obligations (Epstein, 1967). In summary, there is no "cook book" formula for assuring compatibility of a project and a community. For this reason human ecology factors must be well understood.

Implementation of mitigation and companion measures begins with the recruitment of local community members to the existing or planned agency which will carry out the project. To the extent that there is no local commitment, there will be no continuity (Arensberg and Niehoff, 1964). The developer should also be concerned that adequate budgetary commitments have been made, not only for hardware but for personnel from the community and elsewhere. Programs which call for novel activities without new fiscal resources are likely to be doomed. Similarly, it cannot be assumed that personnel skill levels are sufficient to carry out tasks, and provision for training community members and outsiders should be made. The interface between agencies charged with delivery of critical services should be specified and agreed upon, and budgetary commitment for personnel is again the bottom line. Designation of such responsibilities should be considered in terms of past performance, knowledge of local conditions, and propensity to utilize information made available by monitoring activities in order to modify programs.

Implementation of monitoring of indicators designed into the project should be considered in the same terms as above. Attention should be paid to recruitment of local community members, budgetary commitments, skill levels and training, and interface with collateral agencies. In addition, accurate monitoring that is to be useful must be based on appropriate samples and analytical procedures, a specified frequency and duration of data gathering, and dissemination of results to the community, development agency, and others.

Operational Stage Considerations

During operation the objective should be the refinement of the project based on results observed and the evidence provided by monitoring of indicators (Opler, 1954). Project goals may be modified if results indicate that predictions were inaccurate. Program elements should be dropped and new elements designed if monitoring indicates problems.

Techniques of implementation should be refined and made more compatible with the real situation. The key operations

for this stage are monitoring and consulting with local communities in order to discover why goals, elements, or strategies are having the impacts they are. It can safely be predicted that continuing adjustment to unanticipated results will be the single most enduring and universal human impact of a development project.

Evaluation of a project over the long range, generally taken to mean after the passage of a generation, can assist future planners, designers, and administrators in understanding the responses of human communities to development projects and lead to the creation of more successful projects. Such evaluation can be facilitated by initiation of baseline data collection at the moment a project becomes operational. Without such baseline data on the situation as it existed at the outset, long-range evaluation is rarely comprehensive, systematic, or useful to future developers and the communities in which they work.

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APPENDIX B

ENVIRONMENTAL HEALTH IMPLICATIONS

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APPENDIX B

ENVIRONMENTAL HEALTH IMPLICATIONS

General Considerations

Program officers must anticipate any adverse health impacts that may be associated with development planning. In the underdeveloped areas of the world many of these impacts result from the so-called tropical diseases, some of which are household words and others are relatively unnoticed except by specialists. It is not possible to address all the tropical diseases in this manual; twenty of the more important diseases that have relevance to rural development programs are listed and discussed briefly. For additional information the reader is directed to the list of basic bibliographic references at the end of this appendix.

Diseases to be considered. The 20 diseases included in the manual were selected because, for one reason or another, some aspect of the transmission pattern permits intervention and the disease is of interest in some area of the world because its transmission may be affected by development programs (Table B-1).

Some diseases do not fit the categories listed in Table B-1 but are highly visible in underdeveloped countries. They include leprosy, treponematoses, trachoma, meningitis, poliomyelitis, and measles. These have in common that today all can be dealt with on a mass basis by chemotherapy or vaccination. It would probably be a waste of time to try to deal with them on an environmental basis, since transmission is person-to-person and governed by personal habits.

Vectors and Intermediate Hosts. The role of arthropods or mollusks is extremely important in tropical disease transmission. All are included under the rubric of vectors, although the mollusks are not proper vectors, but rather intermediate hosts. With regard to vector control, planners will want to know what they are dealing with. This involves a knowledge of the biology and life cycle of the insect, mite, or snail in question. Little good has ever come of plunging into "snail control" or "mosquito control" without properly understanding the bionomics*, of the target. It is intelligent to recognize that all are "different" animals, with different ecological niches in nature and usually with widely differing biological requirements. For example, an action to kill brackish-water mosquitoes did not end malaria transmission in one Mediterranean area, although the target species, the main vector, was effectively controlled, because the area also supported a tiny population of a different mosquito species that was able to invade and populate some of the sites left open by the control operation; the new mosquito also proved to be an efficient vector.

In general it is wise to concentrate on vector control, rather than eradication. Attempts to eradicate disease vectors have given satisfaction in only a few instances, usually where a vector is new to an area (as in the case of

Table B-1

TROPICAL DISEASES LIKELY TO BE AFFECTED BY RURAL DEVELOPMENT PROJECTS

		Rural Roads	Electrification	Water Supply/Sanitation	Small-Scale Irrigation	Small-Scale Industry
1.	African Sleeping Sickness	●	●		●	
2.	Dysentery (Bacillary & Amoebic)			●	●	
3.	Chagas' Disease	●	●			●
4.	Cholera			●		●
5.	Dengue	●	●		●	
6.	Filariasis[a/]	●	●	●	●	●
7.	Guinea Worm Disease			●	●	
8.	Hemorrhagic Fever					●
9.	Hookworm Disease	●	●		●	●
10.	Malaria[a/]	●	●	●	●	●
11.	Leishmaniasis[a/]	●	●			
12.	Leptospirosis			●	●	●
13.	Onchocerciasis	●	●		●	
14.	Plague	●	●			
15.	Rabies	●	●			●
16.	Relapsing Fever	●	●		●	
17.	Schistosomiasis[a/]			●	●	●
18.	Typhoid & Paratyphoid Fevers	●	●			●
19.	Scrub Typhus	●	●		●	
20.	Yellow Fever	●	●			

a/ One of six major diseases in the World Health Organization Special Program for Research and Training in Tropical Diseases.

Anopheles gambiae in Brazil) or where the land area is limited, as on islands.

Reservoirs

A reservoir is an animal host in which a parasite or disease agent occurs naturally and which is a potential source of infection for humans (or other animals, as the case may be). Wild monkeys are reservoirs of yellow fever when the virus can circulate in their blood without incapacitating them. Inherent in the concept is the idea that a reservoir host is little damaged by the parasite: even rabies virus, ultimately fatal to almost all warm-blooded animals, may persist quietly in the fat bodies of certain bats for long periods.

Humans may be reservoirs for their own parasites if these are highly specific. In the case of cholera vibrios it is speculated that the parasites must persist in the intestines of a small number of rapidly occurring cases between outbreaks. When the phenomenon of protective immunity forms part of the picture, parasites are in danger of extinction if they cannot be transmitted and there are no reservoirs. The attempt to extinguish human malaria during the WHO global effort of a decade ago was based in part on the knowledge that malaria parasites cannot persist without transmission in human populations.

Endemic Geographic Areas

It is convenient in geographic medicine to group endemic areas and the political entities comprising them. The latter are independent countries, most of them categorized economically as "developing". Most are tropical. Some countries must, of necessity, be listed in two different areas.

Classification of Diseases by Endemicity

A health impact is adverse if conditions imposed by development permit the new establishment of a disease, an upward shift in number of cases, or an increase in the intensity of infection of an established disease. Infections maintained at a stable prevalence in a population are called endemic. When for any reason the number of cases increases rapidly, through heightened transmission, to a high prevalence, the disease becomes epidemic. Planners should avoid changing the environment in such a way as to promote disease transmission. On the other hand, they will want to know about health conditions which are not apt to be worsened by development activities.

1. Diseases of High Global Endemicity. Some of the most important diseases in tropical areas are of global distribution and cannot be ignored in planning programs anywhere: bacillary dysentery, typhoid and paratyphoid fevers, hookworm disease, malaria, schistosomiasis, and filariasis.

2. Diseases of Low But Potentially Great Endemicity. Certain tropical diseases have relatively low but potentially great endemicity and may give rise to epidemics under conditions imposed by development programs: cholera, plague, relapsing fevers, leptospiroses, typhus fevers, dengue, yellow fever, leishmaniases.

3. Diseases Associated With Serious Complications. Some diseases have significant local importance because of their association with high mortality and/or other serious complications: Guinea worm infection, rabies, onchocerciasis, Chagas' disease, African sleeping sickness, viral encephalitides, and hemorrhagic fevers.

4. Diseases Directly Transmitted. Of interest to public health practitioners but of less concern to development planners is a short list of infectious tropical diseases transmitted from person to person under conditions dictated more by sociology than by environment: leprosy, treponematoses (syphilis and yaws), trachoma, meningococcal infections, poliomyelitis, and measles.

5. Nutritional Deficiency Diseases. This manual will not deal with nutritional deficiency diseases or with conditions imposed by tropical physiology or climatology.

Control Methods

Under this heading are considered (a) methods for controlling existing endemic or epidemic diseases and (b) methods for preventing disease. Both approaches should be implicit in environmental management.

Infectious tropical diseases may be controlled either through the human host (by using drug prophylaxis or immunizatior or through the environment (by attacking reservoirs or vectors or by environmental sanitation). The number of infectious tropical diseases that cannot be controlled by known measures is today very small.

Interrupting Fecal Transmission. Control of some diseases is generally approached by sanitary and hygienic measures. When sewage disposal and piped water supply are adequate, these diseases tend to disappear. The unsanitary habits of people are responsible for the spread of these diseases, so public health education (seldom the province of development planners) may loom large in their control. They include: bacillary dysentery, cholera, hookworm disease (in part), and typhoid and paratyphoid fevers, schistosomiasis (*S. mansoni* and *S. japonicum*) and ascariasis.

Immunization. A few conditions, notably caused by viruses, rickettsiae, or bacteria, are routinely attacked by

immunization, in addition to vector control: cholera, plague, rabies, typhus fevers, and yellow fever.

Control of Animal Reservoirs. Diseases with important animal reservoirs are important in the tropics and reservoir control may constitute a major segment of a control program: Chagas' disease (in part), hemorrhagic fevers (in part), leishmaniases (in part), leptospiroses (in part), relapsing fevers, and schistosomiasis (in part).

Vector Control. This remains one of the most powerful weapons against tropical diseases which utilize mollusk or arthropod* transmitters: African sleeping sickness, Chagas' disease (in part), dengue, filariasis (in part), hemorrhagic fevers (in part), leishmaniases (in part), malaria (in part), onchocerciasis, relapsing fevers, schistosomiasis (in part), and the viral encephalitides.

Chemotherapy. In the form of drug prophylaxis* chemotherapy has a definite place in control of certain infections. Although it is not the responsibility of the development planner, he should be aware of the position of chemotherapy within the control equation in his area. Mass prophylaxis is useful in the control of: African sleeping sickness (in part), filariasis (in part), leishmaniases (in part), and malaria (in part).

Tropical Diseases and Rural Development

The following list includes diseases of significant endemicity in the underdeveloped areas of the world, chiefly the tropics. All are of interest in rural development projects because transmission patterns can be altered by developmental interventions. Each disease is briefly discussed in terms of its public health significance and relevance to rural development projects. Where vectors or intermediate hosts are involved, they are noted. For more complete discussion the reader is referred to the publication, Control of Communicable Diseases in Man, 12th edition, edited by Benenson and published by the American Public Health Association. Also refer to the distribution maps of selected diseases in this appendix.

African Sleeping Sickness or African Trypanosomiasis

This is an acute* or chronic* protozoan infection found in Africa south of the Sahara. The disease has been under attack for several decades in Africa and has shown signs of receding in the face of the organized forces of preventive medicine and tsetse fly control. Yet localized foci of high endemicity persist in many areas. More than half the population of Africa inhabits areas which still report disease.

There are two forms of the disease: the riverine, found in western, central and eastern Africa, and the savannah, found in central, eastern and southern Africa. The vector is the tsetse fly and man in the principal reservoir of the riverine form. Wild game and domestic cattle are the chief animal

reservoirs of the savannah form. Tsetse flies that transmit the riverine form are always found in the vicinity of water; the species that transmit the savannah form breed in loamy, loose soil and feed indifferently on man and animals.

Road-building and rural electrification (Chapters II and III) may create new resting sites for adult flies and irrigation (Chapter VI) may encourage breeding of the riverine tsetse. An awareness of the possibility that a project will increase tsetse fly populations should accompany any development activities in the endemic areas. A very real risk in development activities in Africa is the introduction of the parasite by migrants into previously parasite-free communities

Dysenteries, Bacillary (Shigellosis) and Amoebiasis

Bacillary dysentery is a common acute or chronic incapacitating disease of man in warm climates, resulting in inflammation or ulceration of the intestine with resulting diarrhea, abdominal pain and blood in the stools. Shigellosis is one of the most widely distributed of all infectious diseases. Although transmission is usually direct, filth flies have been incriminated as mechanical vectors. Man is the reservoir and there are carriers who go unnoticed.

Amoebiasis, or amoebic dysentery, is sometimes termed in developing countries as the "walking diarrhea" since many are infected with the protozoa that cause the diarrhea, but they are not so sick as to require to be in bed. The disease, however, can be severe and even fatal. Amoebiasis is also widely distributed in the tropical world. The disease has the fecal-oral transmission route, and food and water contaminated with cysts of the organism are often involved. Environmental conditions that favor the bacteria also favor the protozoa, such that infection of one person by both organisms is not uncommon.

Construction activities in rural areas may create environmental conditions that promote the spread of these diseases. Improper fecal disposal, contamination of food and water, and breeding of filth flies are important in the transmission chain and must be controlled.

Chagas' Disease or American Trypanosomiasis

Chagas' disease is an acute or chronic, febrile disease of rural areas, principally among children under the age of two years. In the acute state it may resemble typhoid fever. In the chronic form, the destruction of heart muscle tissue or neuropathologic changes may occur. The disease has been reported from Mexico, Guatemala, El Salvador, Costa Rica, Panama, and every South American country. In many endemic areas a large proportion of the rural population remains at risk.

The vector is a cone-nosed bug (also called "kissing bug" or "assassin bug"). The insects dwell in holes, cracks, or thatch of rustic rural homes of the "wattle-and-daub" type. The bugs are nocturnal, feeding only when inhabitants of the

hut are asleep. By day they retreat to their dark corners and cracks.

The principal reservoir is the armadillo, which often lives in association with humans, usually in a hole beneath the house. Opossums have also been implicated as reservoirs. Other wild mammals and some domestic ones are implicated occasionally but the significance of these with regard to maintaining endemic levels of infection in humans is not known.

Construction activities in rural areas of South America may require low-cost temporary housing for employees. The risk that such housing may come to harbor the vector of Chagas' disease should be considered and proper efforts should be made to deny premises to the vectors and to armadillos.

Cholera

Cholera is an acute, toxemic* infection of the intestine marked by vomiting, profuse diarrhea, and loss of body fluid, and often followed by prostration and circulatory collapse. The death rate is high. The home of cholera is the Ganges Delta of India and Bangladesh. From this focus cholera has spread to other parts of the world. It continues to be a major cause of illness and death in the underdeveloped world.

Man is the reservoir, and transmission occurs through ingestion of water contaminated with feces or vomitus of patients and to a lesser extent feces of carriers, food contaminated by water, soiled hands, or flies.

The danger of introducing a cholera epidemic into a rural development project is probably remote in most parts of the developing world. It should be anticipated, however, as a possible problem when itinerant labor is employed, particularly if the workers come from areas where cholera has occurred in the recent past.

Dengue or Breakbone Fever (Dandy Fever)

This is an eruptive fever marked by intense headache, rash, and severe rheumatic pains in the joints and limbs. Dengue hemorrhagic fever is marked with headache, abdominal pain and vomiting followed by rash and hemorrhagic manifestations (nose bleeds, vomiting of blood, black stools). The disease is caused by Group B viruses and is endemic in south-central, southeast, and east Asia, Oceania and in some areas of the Caribbean.

The vector is the *Aedes* mosquito and man is the only known reservoir of the virus.

Dengue is an occupational hazard of rural field personnel in coastal areas of Asia and the Pacific. If areas where this disease occurs, civil engineering activities that may affect mosquito breeding, such as dams or road building, may facilitate local dengue outbreaks.

Filariasis

Filariasis is an acute and chronic inflammatory nematode worm infection of the lymphatic system, often with accompanying acute fever, toxemia and chronic disfigurement and disability. Bancroftian filariasis is found widely distributed in the world, in North Africa south of the Sahara, Indian Ocean, southwest Asia, south-central Asia, southeast and east Asia, Oceania, islands of the Caribbean and along the Amazon River. The Malayan filariasis is limited to Asia and Oceania. Four genera of mosquitoes transmit Bancroftian filariasis; Malayan filariasis is transmitted by Mansonia and Anopheles mosquitoes.

Man is the only known definitive host of the causative agent of the Bancroftian filariasis. Cats and monkeys are reservoirs in addition to man of the Malayan filariasis.

Mosquito control should become an essential aspect of all temporary construction operations in endemic areas. Water management schemes involving establishment of standing water near houses should include mosquito control as a matter of routine.

Loiasis is another chronic filarial disease manifested by local edema and itching in response to the presence of nematode worms in the subcutaneous tissues. The vector of the clear disease is the day-biting mango fly. The flies breed in clear, flowing streams in rain forests and the adults come to clearings to feed. Man is the only known reservoir of the disease.

This disease is apt to be a problem in West Africa where rural roads or rights-of-way for rural electrification projects penetrate rain forests. Newly created clearings may attract the jungle mango flies to come and feed.

Guinea Worm Disease (Dracontiasis or Dracunculosis)

Guinea worm is a nematode also called "Medina worm" or "fiery serpent". It causes a rural disease associated with painful ulcers and swellings of the feet and legs. The disease occurs where there are step-wells and other water sources which can be entered. It is common throughout Africa, western Asia, in parts of India and in parts of Indonesia. Man is the only significant reservoir of infections.

Control of transmission of the Guinea worm disease can be achieved by improving rural water supplies. Where open water supplies are created that can be entered the disease will increase.

Hemorrhagic Fever

Hemorrhagic fever is an acute, febrile disease accompanied by headache, chills and vomiting, skin rash and bleeding gums;

severe cases show nosebleed, vomiting of blood, and blood in urine and stools. The disease is caused by viruses and the reservoirs are wild rodents. The disease has been recognized in Argentina northwest of Buenos Aires, and in the northeast lowlands of Bolivia.

Although extremely sporadic, epidemics of this disease have occurred in the wake of environmental changes by man.

Hookworm Infection and Disease

Differentiation is made here between infection and disease, since it is possible in some areas of the world that some will be infected but show little evidence of disease. The disease occurs throughout the warm regions of the world where the level of sanitation is primitive. Man is the only reservoir of the parasite.

Temporary housing with poor sanitation may create conditions ideal for the transmission of the hookworm disease.

Malaria

Malaria is a mosquito transmitted disease with a worldwide distribution. Some areas of the world where the disease had been controlled are today seeing the return of the disease because of the resistance developed by the vectors to insecticides. Man is the only vertebrate reservoir of the species that infect man.

Rural development projects may increase the risk of infection. Civil engineering projects such as road and water supply construction may affect mosquito breeding. Laborers from areas free of infection entering endemic areas will be affected.

Leishmaniasis

Leishmaniasis is sometimes classified as three distinct diseases involving separate species of flagellate protozoa but all transmitted by sandflies. (a) Kala-azar or visceral leishmaniasis is a disease characterized by chronic, irregular fever, enlargement of spleen and liver, anemia, and ulceration of the colon. It is widely distributed in Asia, Middle East, Africa, and South and Central Americas. (b) Oriental sore or cutaneous leishmaniasis is a disease of the skin caused by the bite of the sandfly. It is prevalent in rural areas of Africa and Asia. (c) The American leishmaniasis, also a cutaneous leishmaniasis, called "espundia," "uta" and other local names, is a skin infection which may subsequently involve the naso-pharyngeal membranes. The nasal form may be fatal. It is endemic in countries from Mexico to northern Argentina, except Chile. Besides man, dogs and, to a lesser extent, cats and wild rodents are reservoirs in kala-azar and American leishmaniasis. Man is the principal reservoir of oriental sore.

Road construction through jungle areas of Central and South America may give rise to good transmission conditions for

jungle leishmaniasis. When totally susceptible workmen, reservoir and sand flies have come together in the past, epidemics have occurred.

Leptospirosis

Leptospirosis is also known by many names including infectious jaundice, Weil's disease, swineherd's disease, swamp fever, and canefield fever. These names have come about because of occupational exposures involved in the transmission. The disease organism gets into the environment in the urine of infected animals. There are many domestic and wild animal reservoirs, and they include rats, dogs, cattle, horses, swine, squirrels, voles, goats and racoons. There are many serotypes of leptospira, some in limited geographical areas and others distributed worldwide.

Construction projects for rural water supplies and irrigation in areas with infected wild rodents will have health hazards. The nonimmune worker newly introduced into an infected-water work situation is at prime risk.

Onchocerciasis (River Blindness)

This disease is a chronic, filarial disease which frequently leads to blindness. The causative organism is a nematode worm. The vector is the black fly which breeds in well-aerated streams. The only natural definitive host of the organism is man. The disease is found in tropical Africa, southern Mexico, Guatemala and in the northern countries of South America. In the Western Hemisphere the disease may develop with fibrous nodules in the skin and tissues of the head and shoulders. In Africa the nodules occur in the pelvic girdle and lower extremities. The larvae of the worm migrate to the skin causing rash, altered pigmentation, edema, and atrophy.

Water supply and irrigation projects in endemic areas may create good breeding conditions for black flies. Fast moving, well-aerated streams and spillways of dams are extremely attractive breeding sites for the vector.

Plague

Plague, the black death of history, although declining in recent years, is still wide-spread in the underdeveloped world. It is reported in North Africa, Africa south of the Sahara, in the Indian Ocean, in Asia and in South America.

Plague is a zoonosis of rodents, transmitted by fleas, and man is attacked by accident. Today it is largely sylvatic and man is in danger when he enters the environment where infected wild rodents exist. When contact between domestic rodents and wild rodents takes place, e.g. at harvest times in rural areas, the threat of plague moves into the human community. Bubonic plague has a rat-flea-man transmission cycle. Pneumonic plague is an epidemic, person-to-person transmitted dis-

ease. It is spread by the airborne route by droplets from those who have developed plague pneumonia.

Rural development projects that will bring people into contact with infected rodent populations will cause outbreaks of plague. Rodent and insect controls are measures to be considered. Immunization for field workers may also be a prudent step.

Rabies

Rabies is a virus disease transmitted through the bite of an infected animal. It is a disease of world-wide distribution, except for the islands of the Pacific, from which no human cases have been reported. The rabies organism is a neurotropic virus, attacking the nervous tissue and brain. A variety of wild and domestic carnivores (dogs, foxes, mongooses, skunks, etc.) are reservoirs. In the tropics of the New World vampire bats and a number of insectivorous bats are found to be infected.

As a disease, rabies is not so common today. It remains a significant problem, however, since the need for the emergency Pasteur treatment following animal bites is numerous in almost all areas of the world. Where industrial development includes livestock, special control measures should be considered.

Relapsing Fever

This is a worldwide disease in which recurrent fever lasts two to nine days, followed by two to four days without fever. It is caused by spirochetes and is transmitted by lice and ticks. Louse-borne epidemics have been common under conditions of human stress and poor sanitation, such as in times of war and famine. Tick-borne relapsing fever is primarily an endemic (localized) disease.

Man is the reservoir of the louse-borne relapsing fever. In the tick-borne disease wild rodents, in addition to man, are thought to be reservoirs.

Provisions for the maintenance of personal hygiene are important in the louse-borne disease. The types of temporary housing available for construction projects and the lack of rodent control may create situations in which the disease can be transmitted.

Schistosomiasis (Bilharziasis)

This is a blood fluke infection, sometimes referred to as snail fever. There is a urinary form and there are intestinal forms of the disease. Among a population with a long history of exposure to schistosomiasis, the disease is not often fatal but is debilitating. Persons from areas lacking the disease are likely to be more severely stricken. There are several species of schistosomes and several genera of snail intermediate hosts involved.

The disease occurs in Africa, the Middle East, the Caribbean and the Orient. Man is the principal reservoir. In the Orient there are numerous mammals that serve as important animal hosts for the schistosome species that exist there. In development projects in areas where schistosomiasis is endemic, planners must be alert to the increased possibility of workers and area residents in contact with water contaminated with feces and urine of infected persons. Such increased contact is possible in irrigation projects, rural roads and industrial development, depending on social conditions and health programs. New irrigation schemes have been responsible for the spread of schistosomiasis into previously uninfected areas. An important measure in the breaking of the man-snailman cycle is the proper disposal of feces and urine.

Typhoid and Paratyphoid Fevers

These are systemic fevers and toxemias caused by the invasion of the intestinal walls by bacteria of the genus *Salmonella*. They are world-wide in distribution, but occur in epidemic form in many developing nations. They are among the most widespread of all infectious diseases.

Man is the reservoir. He may also become a carrier. Fecal carriers are more common than urinary carriers, though the latter are seen frequently where the urinary schistosomiasis occurs. The transmission of the disease occurs through ingestion of food and water contaminated with the organisms.

Where development programs create unsanitary conditions during their execution, the possible spread of these diseases becomes enhanced. When food vendors set up their operations near construction sites without sufficient controls, carriers among them are likely to contribute to outbreaks. The aim of the rural water supply and sanitation programs are, of course, to control enteric diseases.

Scrub Typhus or Tsutsugamushi Disease

Scrub typhus is an acute, febrile rickettsial disease transmitted by mites. It is marked by an ulcer where the arthropod bite has occurred, macular skin eruption and continuous fever for about two weeks. It occurs in Asia and the islands of the southwest Pacific.

The organism persists in nature as infection of wild rodents and mites. Known non-human hosts include field mice, wild rats, and three species of shrews. As the name of the disease indicates, the vector, in the larval stage, is countered in low, damp areas where scrub and underbrush are found.

While rural development projects would seem more likely to reduce transmission of scrub typhus, rather than exacerbate it, the disease remains a definite occupational hazard to field personnel working in endemic areas in Asia. Projects that open forested areas and offer conditions favorable for lush secondary growth may increase areas which harbor mites.

Yellow Fever

Yellow fever is an acute, biphasic viral disease with fever, headache, nausea, and vomiting occurring in the first phase, followed by a second phase of jaundice, prostration and either death or uneventful recovery. It occurs in Africa south of the Sahara, Central America and South America where vector mosquitoes can be found.

Urban yellow fever is transmitted in a man-mosquito-man cycle. The mosquito that transmits urban yellow fever is extremely domesticated. It breeds in water collections in tin cans, flower vases, discarded tires, and rain barrels. The jungle, or sylvan, yellow fever is transmitted by the tree-hole breeding mosquitoes among canopy-living monkeys in a monkey-mosquito-monkey cycle. Man becomes an accidental host when he ventures into the environment. Past reports have shown that tree fellings have brought infected canopy mosquitoes to the ground. When workmen were bitten and infected, it became the beginning of urban epidemics.

Activities that bring construction teams into established jungle foci of infection will bring together the jungle vector and man. Whether the disease becomes established in the urban phase will depend on the watchfulness of public health authorities, the state of urban mosquito control, and the immunization status of the working personnel.

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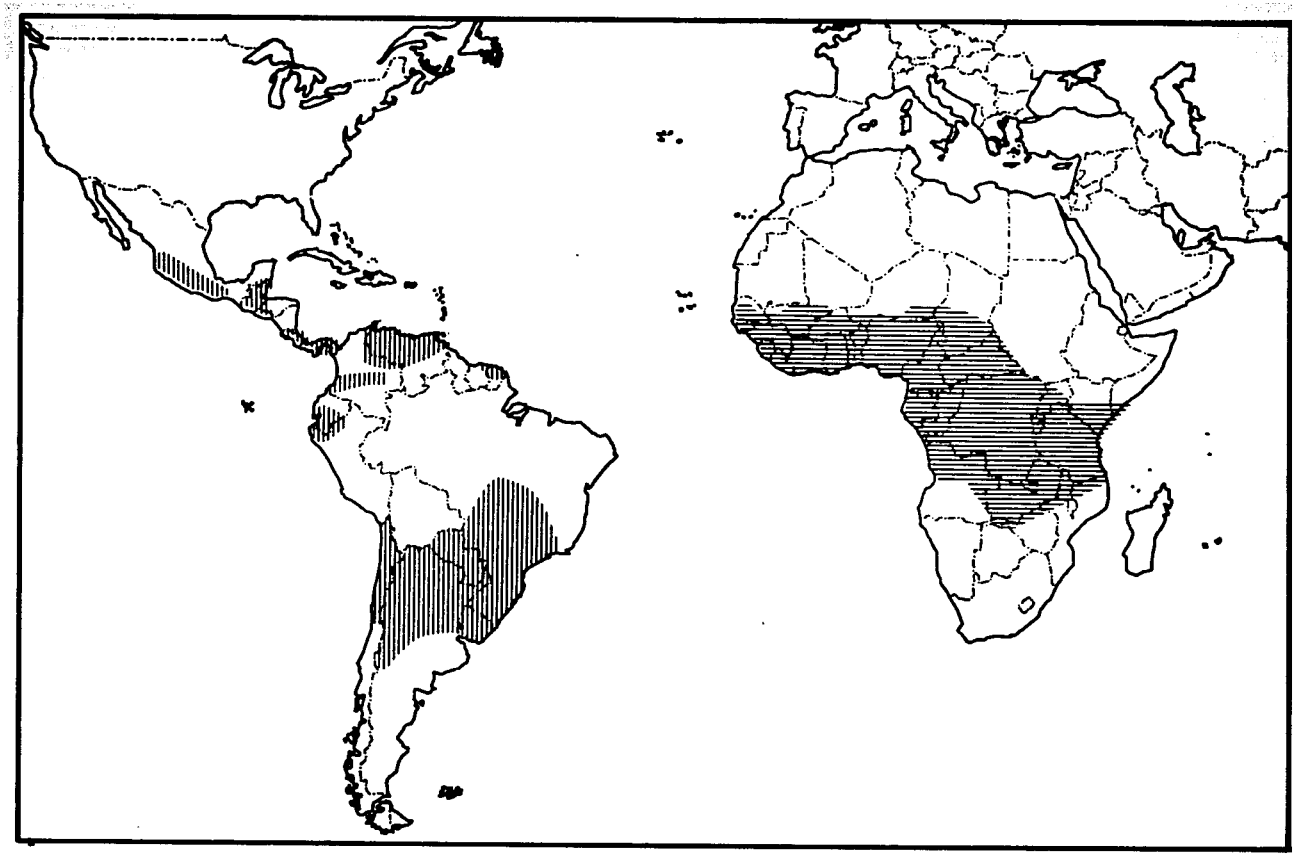

FIGURE B–1

Figure B–1 Distribution of African Sleeping sickness and of Chagas' disease

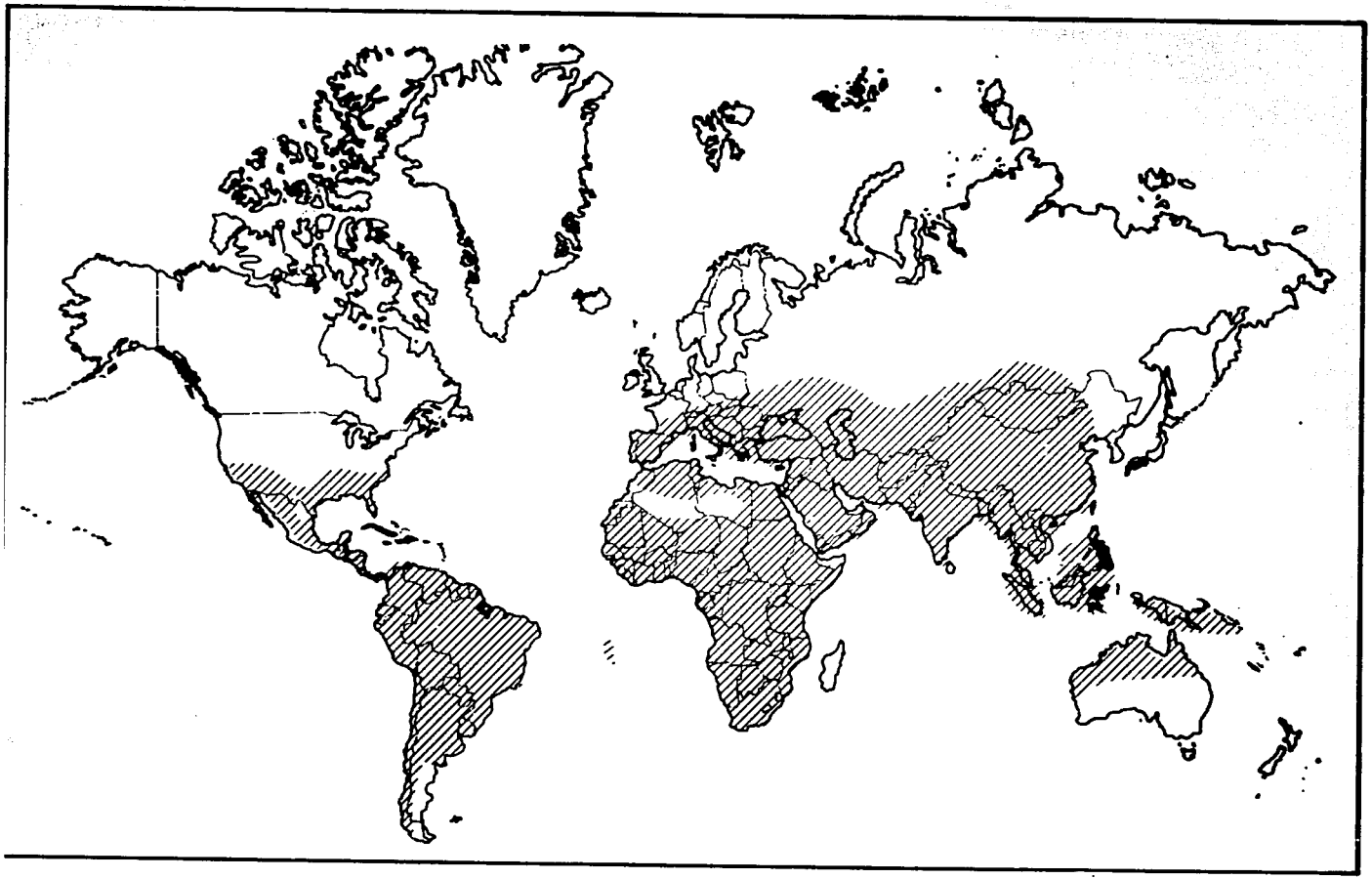

FIGURE B–2

Figure B–2 Distribution of Dengue and its Mosquito Vectors

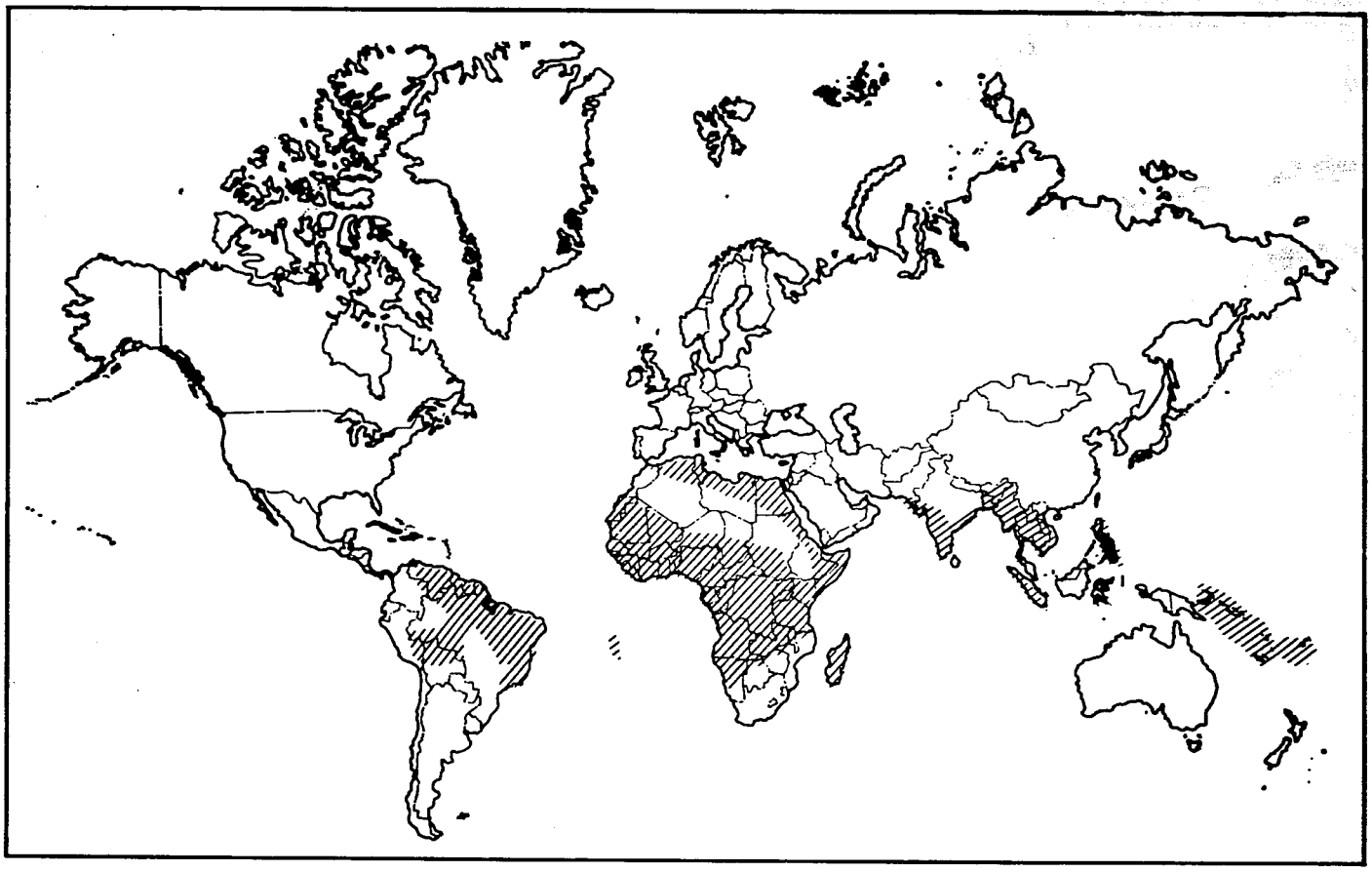

FIGURE B–3

Figure B–3 Distribution of Bancroftian Filariasis

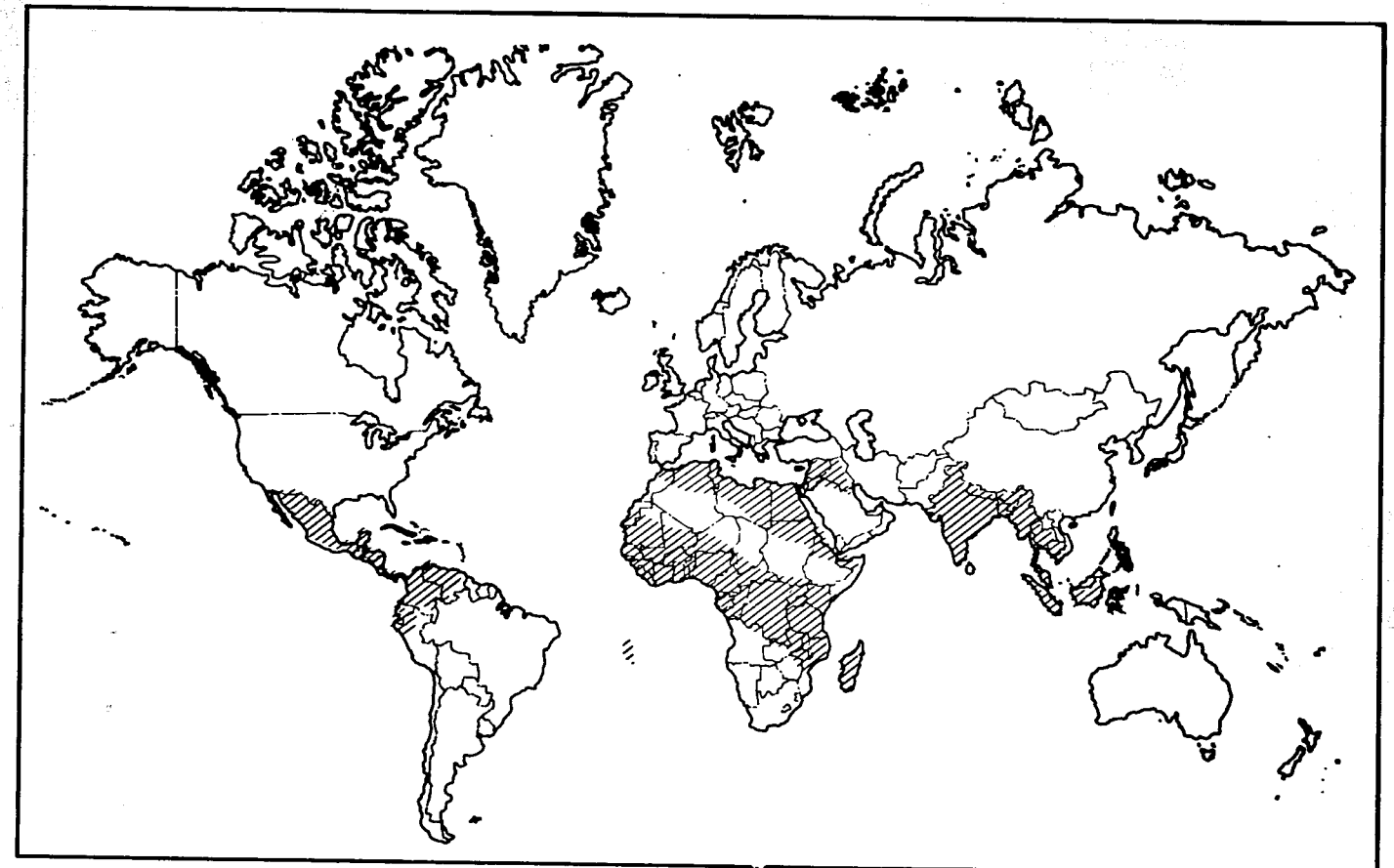

FIGURE B–4

Figure B–4 Distribution of Hookworm

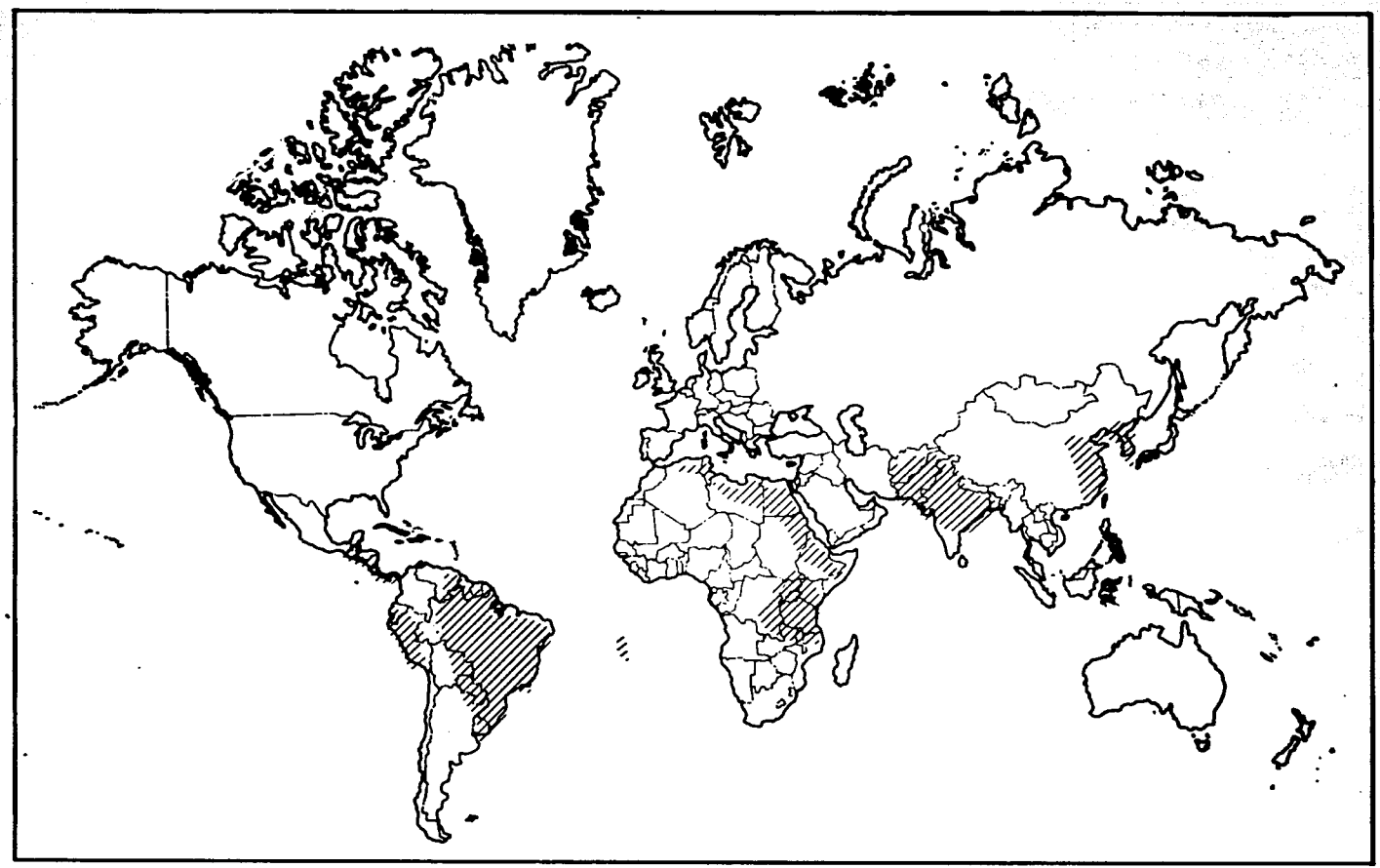

FIGURE B–5

Figure B–5 Distribution of Leishmaniases

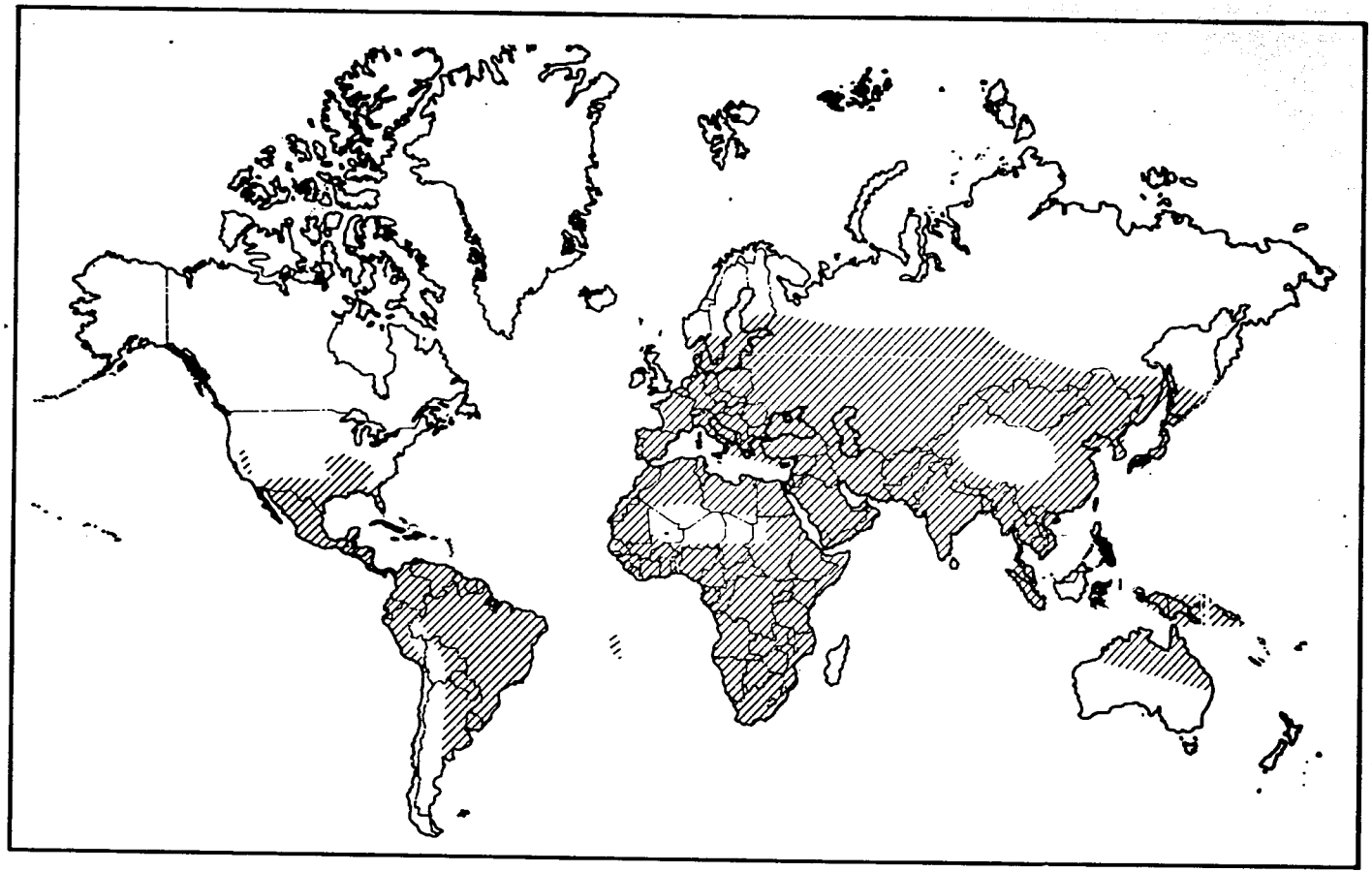

FIGURE B–6

Figure B–6 Distribution of Malaria (All human forms)

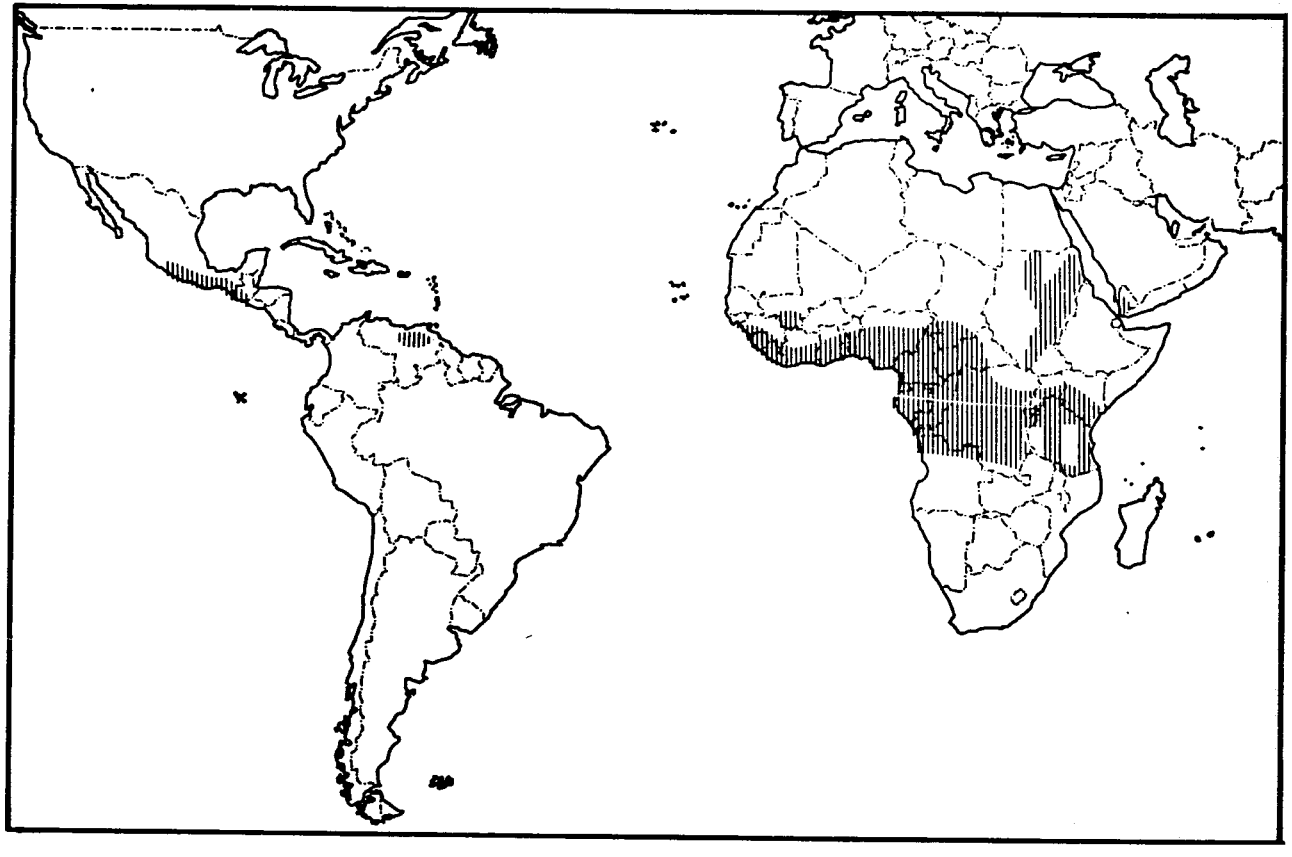

FIGURE B–7

Figure B–7 Distribution of Onchocerciasis

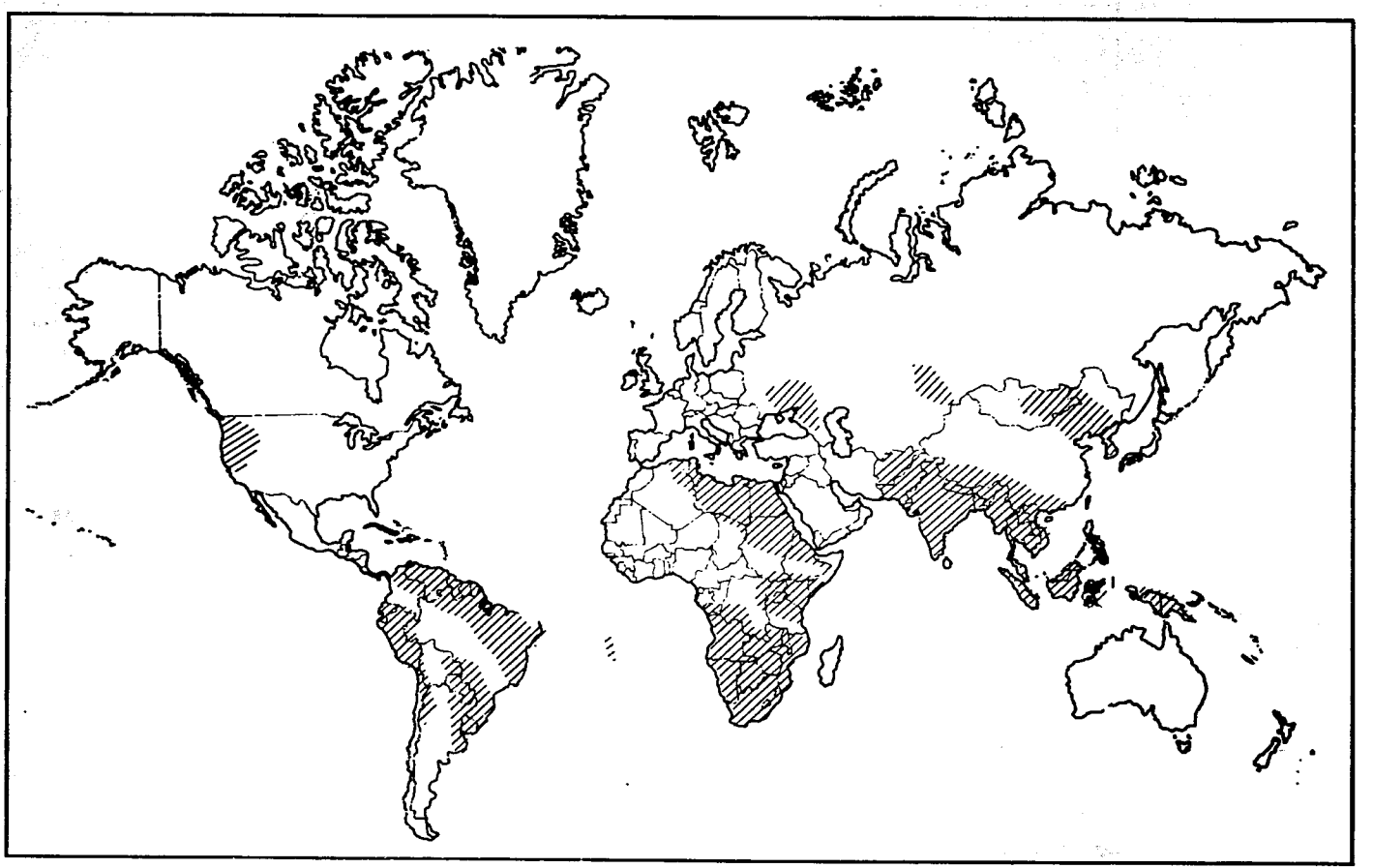

FIGURE B–8

Figure B–8 Distribution of plague

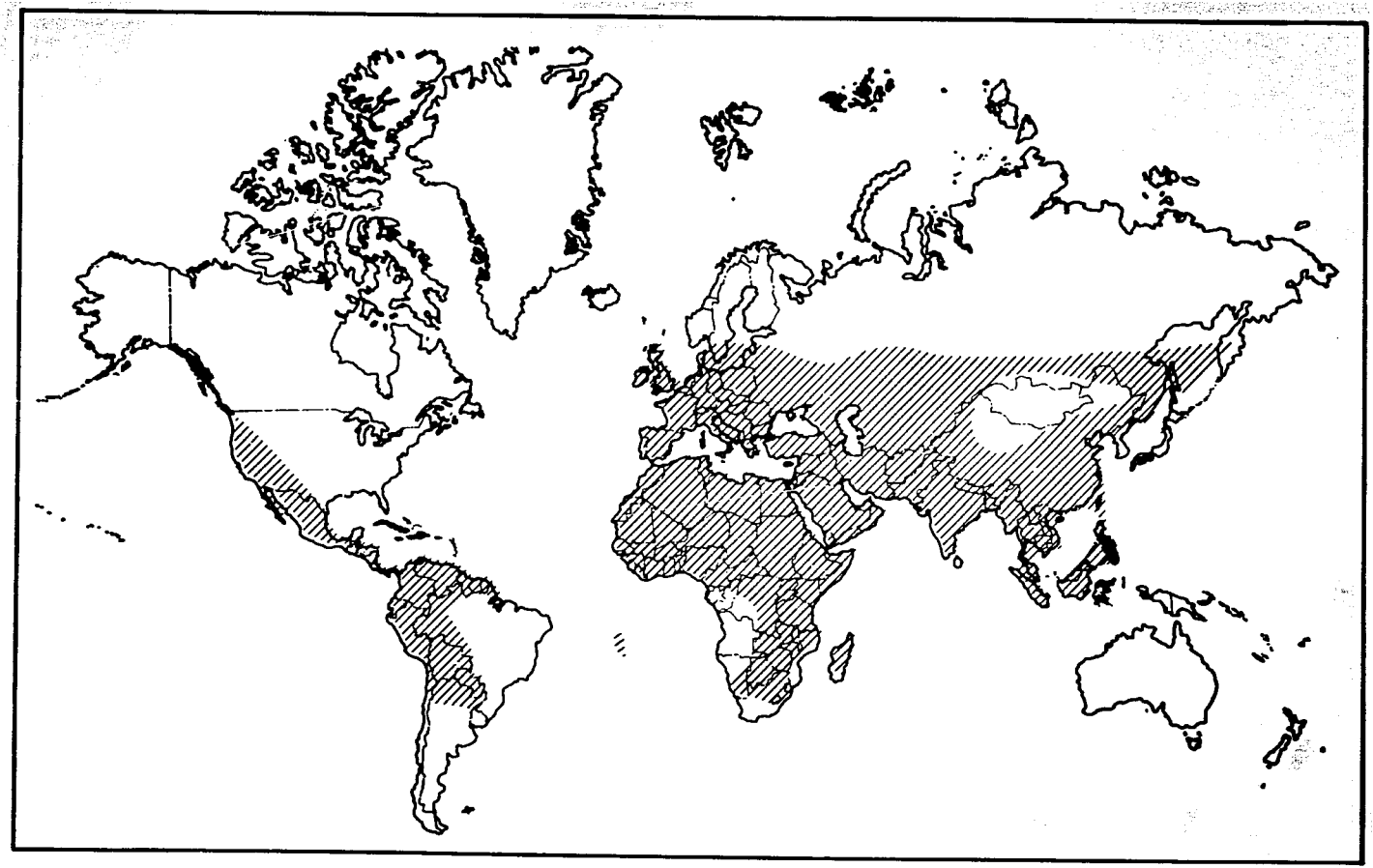

FIGURE B–9

Figure B–9 Distribution of Relapsing Fever

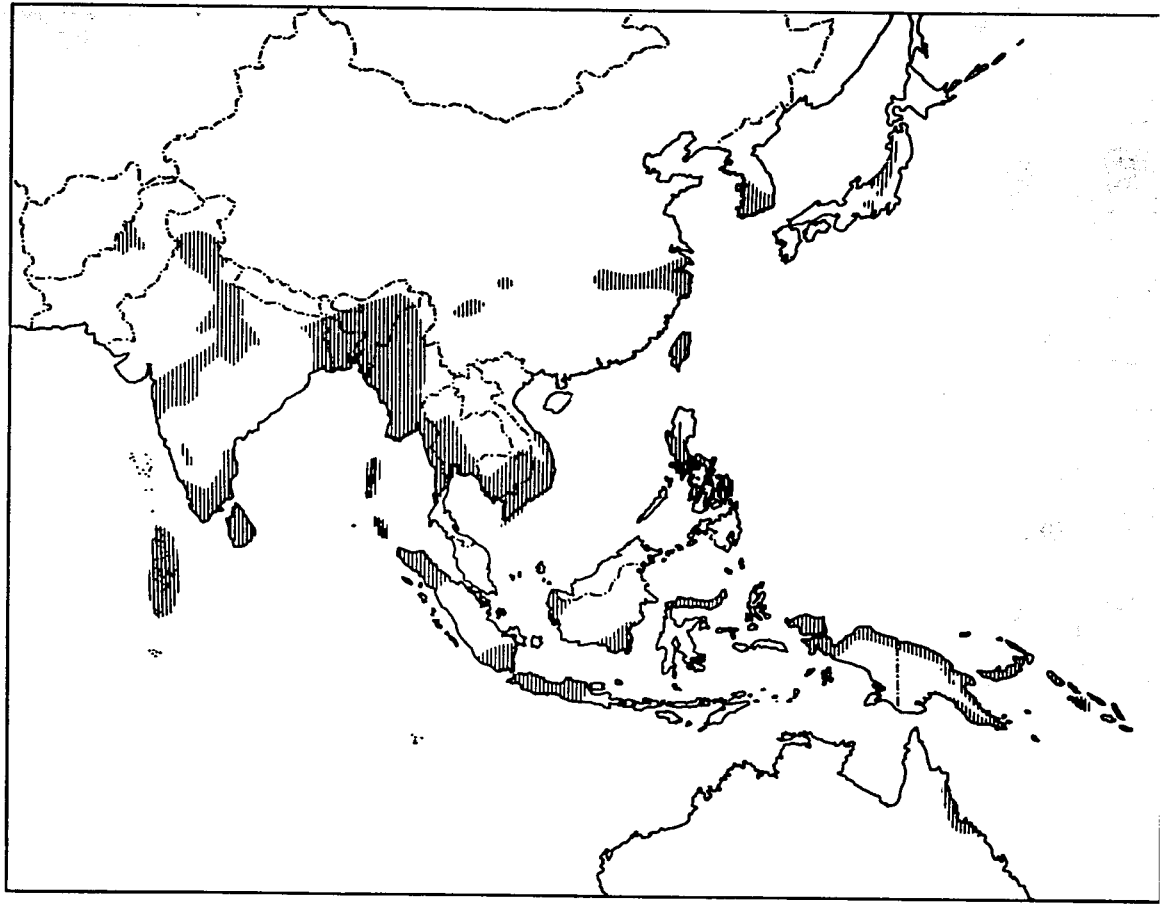

Figure B–10 Distribution of Scrub Typhus

FIGURE B–10

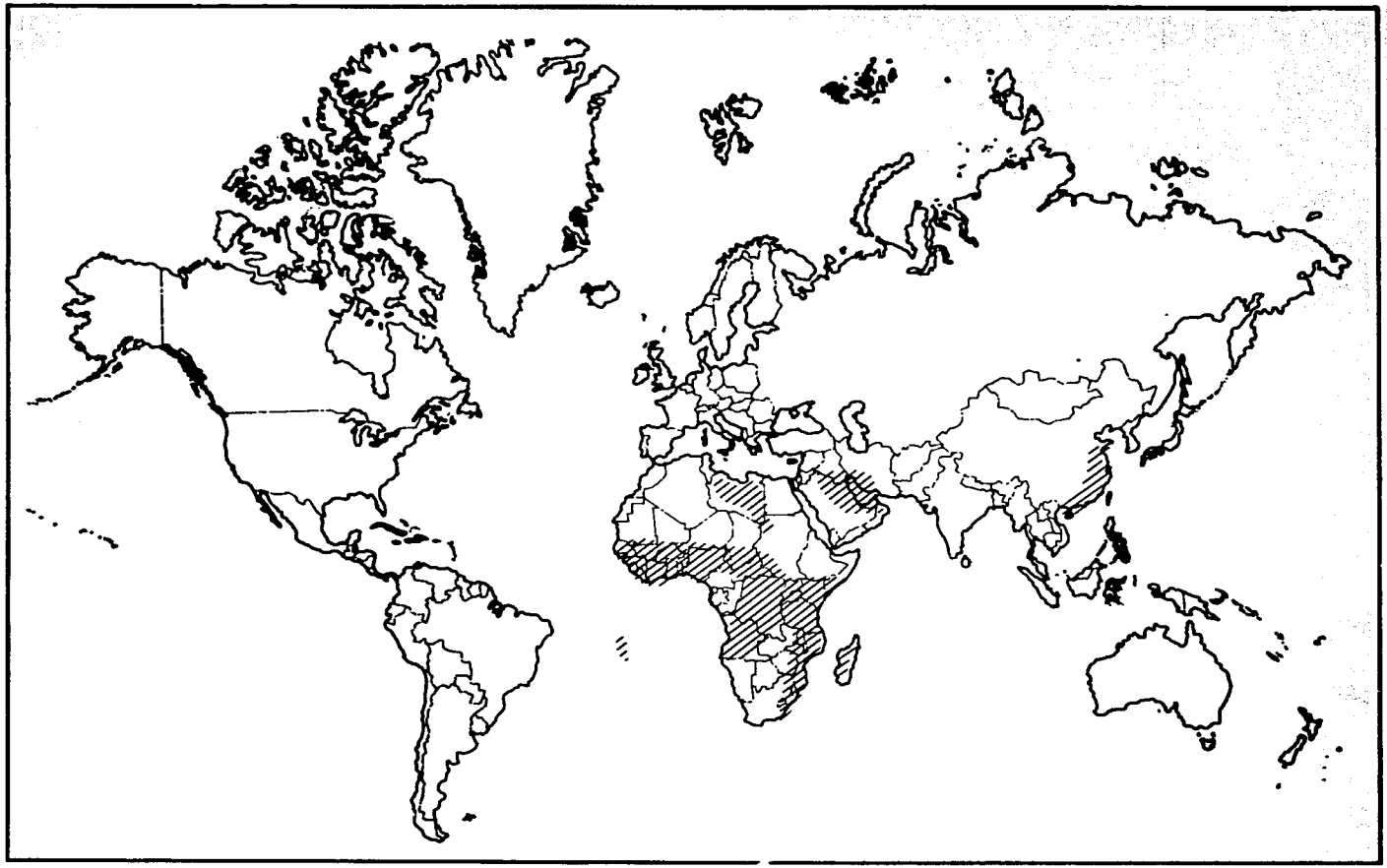

FIGURE B–11

Figure B–11 Distribution of Vesical Schistosomiasis and Asian Schistosomiasis

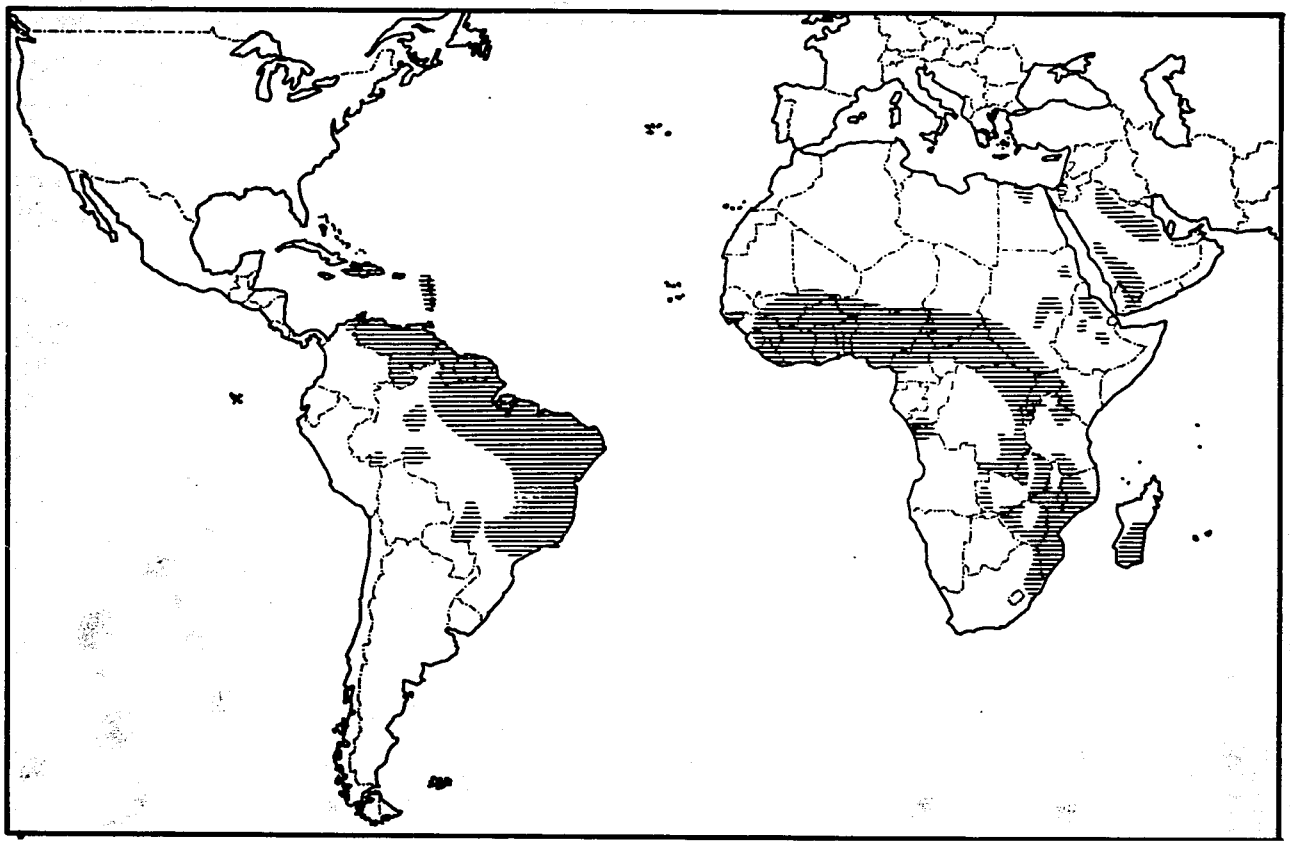

FIGURE B–12

Figure B–12 Distribution of Intestinal Schistosomiasis

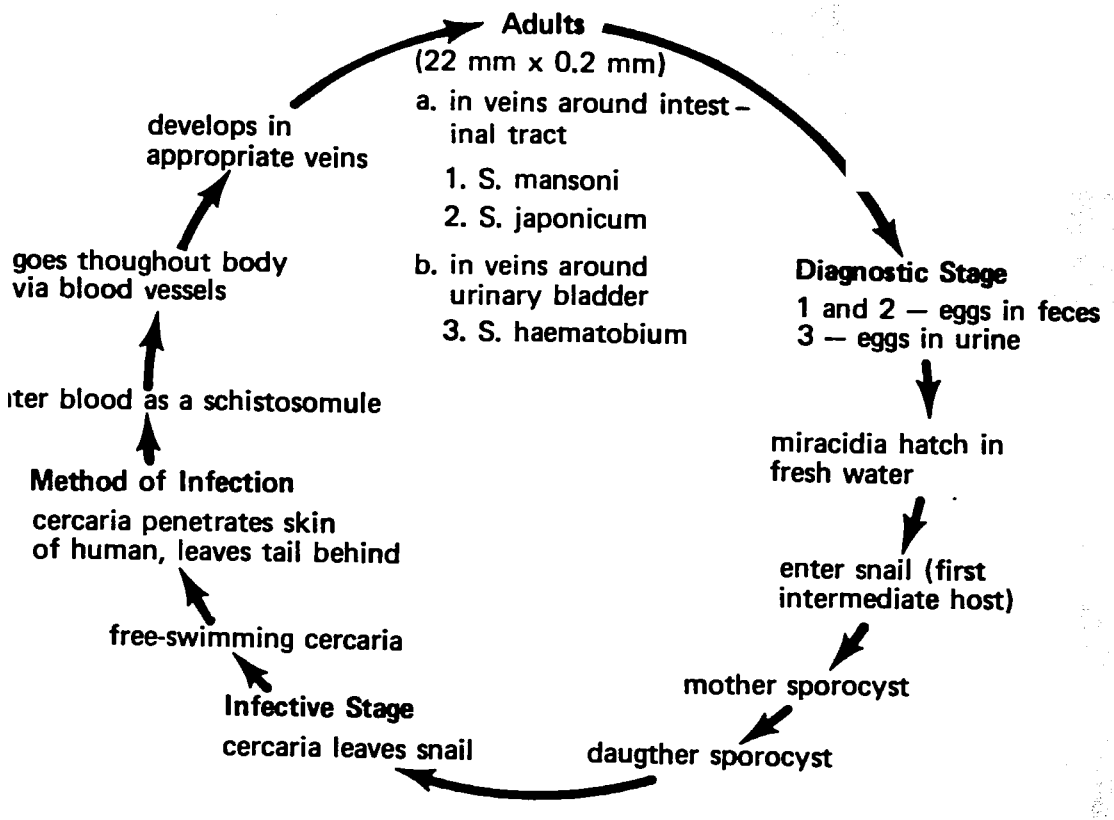

FIGURE B–13

Figure B–13 Life cycle of Schistosomiasis (All forms)

APPENDIX C

WATER QUALITY

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APPENDIX C
WATER QUALITY

Introduction

In addition to the essential role water plays in all life systems and the absolute necessity of drinking water to support human populations, water is used by man for irrigation, livestock watering, power generation, industrial processing, transportation, assimilation and dispersion of waste, swimming and bathing and esthetic enjoyment. Water supports populations of fish, crustaceans, mollusks, other animals and plants which are harvested by man and used for food or provide some useful product (fur, fiber, etc.). On the negative side but equally important, water supports and/or transports populations of disease organisms and vectors and is a primary route for transmission of many types of illnesses to humans. Thus, almost any resource development project undertaken either involves the use of water or has some effect on water. It is obvious that intelligent use, management and protection of this essential resource deserves the highest priority.

The diverse and important roles played by water in any biological or socioeconomic system make water quality management an interdisciplinary activity. Sanitary engineers, aquatic biologists, fisheries scientists, chemists, civil engineers, hydrologists, economists, epidemiologists and social scientists all may play a role in developing and implementing intelligent water quality management programs.

Given the importance and broad nature of the subject of water quality it is impossible to cover all aspects in detail in this appendix. References are provided in the bibliography to several sources which provide additional detail for the interested reader. Also, the reader is referred to the appendix on public health [B] for related subject matter.

In this appendix, emphasis is placed on identifying and defining the various parameters affecting water quality, describing the means utilized for measuring these parameters and discussing their importance in terms of rural development projects.

Natural Water

Natural water is a complex solution which varies considerably, depending on factors such as climate, geology, and, often most importantly, human activities. The exact composition of this solution determines how a specific source of water may be used. Thus, in planning any water related development project the water quality characteristics of the water source should be considered.

The water of the oceans, for example, contains concentrations of dissolved salts which render it generally unfit for drinking or agricultural purposes. Other surface waters such as lakes and rivers often, but not always, have low concentrations of dissolved salts and thus may be suitable for irriga-

tion and drinking. However, levels of sediment, organic material and bacterial contamination may be higher in these waters as compared to deep ground water sources. These in turn, are often highly mineralized and can contain specific materials such as boron and arsenic which make them unsuitable for irrigation or drinking.

Additional water quality considerations of importance regarding the water source to be utilized include size of the system and its "openness" and recharge capacity. Lakes, usually closed or partially closed systems, do not lend themselves to waste disposal, while rivers, which are open systems, are well known for their waste assimilation capacity.

Special Considerations

Although the diversity of the physical, ecological and social systems encountered in A.I.D. assisted countries precludes any comprehensive listing of water quality problems to be expected, a few generalizations may be helpful in alerting planners to the types of problems already existing in their areas.

Many developing countries, especially in the tropics, are characterized by dense human populations, inadequate sanitary waste disposal systems, and intensive land use with little or no soil conservation being practiced. In these types of areas little question exists as to the major water quality problems to be expected. Water-borne disease organisms, heavy organic loading and erosion induced sediment are the major problems.

In areas where intensive agriculture is practiced, especially in the tropics, crop pest and disease problems have become serious and have resulted in an ever increased use of pesticides and toxic materials. Often these materials are present in dangerous levels both in water supplies and in fish or other aquatic animals used for food by the local people. Where irrigation is practiced on a large scale, irrigation return flows can be expected to have both high pesticide levels and high concentrations of dissolved solids.

Finally, in areas where mining and industrial development are important, improper treatment and disposal of surface water runoff and process water have led to high levels of many heavy metals and other toxic chemicals in the water supply.

Defining Water Quality

Analysis and characterization of water quality should always be done with regard to the anticipated use of that water. Thus, water to be used for human consumption is analyzed by a different set of standards than is irrigation or industrial process water.

Basically, quality is measured in terms of the types and amount of dissolved and suspended chemicals and biological organisms present in the water. These water quality characteristics are measured using a set of standardized tests such as

those given in Standard Methods for the Examination of Water and Wastewater.[1/]

In current practice, where multiple uses are required, guidelines should present more stringent criteria. Criteria represent attempts to quantify water quality in terms of its physical, chemical, biological and esthetic characteristics. Those who establish or evaluate criteria must do so within that overall use framework. The fundamental evaluation criteria for water quality, therefore, are based upon the level of use man makes of that resource. To evaluate the quality of water required for various uses, it is essential to know the limits of quality that have a detrimental effect on a designated use.

Criteria and Standards

The distinction between water quality criteria and water quality standards must be understood as a prerequisite for rational development of a particular resource. Criteria are generally defined as "the scientific data evaluated to derive recommendations for characteristics of water of specific uses" (NAS-NRC, 1966).

Establishment of recommendations implies access to practical methods for detecting and measuring the specified physical, chemical, biological and aesthetic characteristics. In some cases, however, less than satisfactory methods are available and in other cases less than adequate methods or procedures are used. If, however, adequate criteria for recommendations are available, and the identification and monitoring procedures are sound, the fundamentals are available for effective standards, which generally are established by law and require political, social and economic input.

Pollution and Contamination

When water is not in conformance with water quality standards, either existing or intended, the water is said to be polluted. Water can be said to be contaminated, however, only when there exists a real health hazard or damage risk from using that water for some specific purpose.

Characteristics of Water Quality

General water quality characteristics fall into four major groupings; chemical, physical, physiological and biological. It should be noted that the analytical expression of many water quality measurements is in units of milligrams per liter (mg/l).

1/ Many countries have adopted other methods, often based on practices followed in Europe. Some references to European methodologies and standards are included in the bibliography. Standards from International Standards for Drinking Water published by the World Health Organization are presented in Table C-1 of this appendix.

This unit is, with few exceptions, interchangeable with parts per million (ppm). There are some measurements of water quality, most notably physiological and biological, which are not expressed as mg/l. These measurements are discussed with their respective grouping.

Chemical Characteristics

The chemical characteristics of water are divided into three major sub-groups: organic, inorganic and gaseous chemicals.

Organic: Organic compounds are composed primarily of a combination of carbon, hydrogen and oxygen and may sometimes contain nitrogen. Organic compounds may be found either free (dissolved or suspended in water) or bound into living material, such as plankton* or algae.

The total organic content of water is commonly measured by one of several laboratory tests designed to reflect the amount of organic matter that is oxidizable. The most common measure of organic strength is the 5-day biochemical oxygen demand test (BOD_5). This determination involves the measurement of the dissolved oxygen concentration before and after storage at 20°C for five days, and represents the amount of oxygen necessary to stabilize organic matter.

Specialized tests, usually involving well-equipped laboratories, are used to determine the specific quantities of defined organic material which in total is represented by the BOD_5 test. The more important constituents are described below with reference to the type of water use requirements.

Inorganic: Chemical constituents of concern in water quality management include pH, halogens, alkalinity, nitrogen, phosphorus, sulfur, heavy metals and toxic compounds. All of these tests, with the exception of some heavy metals and toxic compounds, can usually be performed with simple metering or packaged titration* kits (most of which can be readily ordered and come complete with necessary chemicals, glassware and instructions).

The elements nitrogen, phosphorus, and sulfur are all essential to life. Nitrogen and phosphorus, and to a limited degree sulfur, when present in undesirably high concentrations, may cause excessive growth of algae. Algae, in turn, may limit many beneficial uses of the water by exerting a significant oxygen demand when dead and decaying, imparting an undesirable taste to the water, and creating a generally unpleasant appearance. High concentrations of the nitrate form of nitrogen in drinking waters may cause a disease known as methemoglobinemia* in infants fed the water.

Small concentrations of many trace metals are important to the support of various living organisms present in the water. Quantities of some of these metals in excess of these essential concentrations may, however, exert adverse effects on living

organisms (toxicity, carcinogenicity*, or other debilitating measures).

Certain toxic compounds may also adversely affect the beneficial use of water. In addition to the heavy metals, these include other anions* such as chromate and cyanide.

Gases. Dissolved gases are important to the maintenance of aquatic life. The most important of these is dissolved oxygen (DO), necessary to all aquatic aerobic* organisms. Oxygen is only slightly soluble in water. Therefore, the balance of oxygen entering the water at its surface and oxygen being used up by aquatic organisms is exceedingly important. Dissolved oxygen may be simply measured by commercial potentiometric* metering or by use of a standard titration test (Winkler Test).

Physical Characteristics

The physical characteristics of water may be divided into three major subgroups: temperature, turbidity/solids, and color.

Temperature. Temperature is a significant characteristic of water for a variety of reasons. Perhaps of prime importance is susceptibility of aquatic organisms to variation in water temperature. Other concerns for temperature relate to beneficial uses of water such as drinking water supply and industrial cooling water application. Temperature is perhaps the simplest parameter to measure, and one of the most variable.

Turbidity/Solids. The solids content of water is classified in three groupings: dissolved, collodial, and suspended. Total solids of the water is a measure of the sum of these groupings. Suspended solids are generally defined as particles greater than one micrometer (10^{-6} m) in diameter. Turbidity is a measure of the light transmitting properties of water and indicates the quality of water with respect to colloidal matter. Colloidal material is defined as those solids between 10^{-9} and 10^{-6}m. Material in solution of particle size smaller than that of colloidal material is classified as dissolved.

The solids content of water in any of the above described classifications may interfere with the beneficial uses of water. Each beneficial use has certain standards with respect to solids content. Measurements of suspended and dissolved solids can be carried out in almost any laboratory equipped with filtration apparatus, drying ovens and analytical balances.

Color. Color is generally a rather qualitative measure of water quality and may stem from both manmade and natural causes. Color may additionally be indicative of low oxygen conditions in the water. The problem of color is primarily an esthetic one, but often may indicate the presence of undesirable constituents. True color can only be accurately measured by spectrophotometric* means employing standard platinum cobalt reference blanks.

Physiological Characteristics

The physiological characteristics of water may be broken down into two major subgroups: taste and odor.

Taste. Certain constituents in water will produce an undesirable taste and therefore principally affect the beneficial use of water as a drinking source. Constituents that produce an unwanted taste include ABS* (surfactants), chlorides, copper, zinc, iron, manganese, phenols (when in the presence of chlorine), and dissolved solids. Excessive growth of certain species of algae may also produce undesirable taste in water.

Odors. Odors are due to dissolved gases present in the water and may have an undesirable effect on the use of water for drinking. Hydrogen sulfide (the odor of rotten eggs) is a common dissolved gas of this nature. Other gases may be those emanating from anoxic* decomposition of organic material in or underlying the water.

Biological Characteristics

Biological characteristics of water are generally grouped into three major subgroups: protista, viruses, and plants and animals.

Protista. The protista include bacteria, fungi, protozoa, and algae. The presence of protista and viruses in water is usually of interest in regard to potential disease problems. Plants and animals present in water supplies may be of interest both from the point of view of disease transmission and for establishing the "health" of an aquatic ecosystem.

The disease-producing potential of water is most often tested by the presence of coliform organisms. The presence of coliform bacteria (not strictly pathogenic* themselves) indicates the potential for the presence of other disease causing organisms, both bacterial and viral.

The most common method for determining the number of coliform organisms present is with the use of the multi-dilution lactose fermentation test. Test results are interpreted as the most probable number of coliforms per 100 ml. The test set-up lends itself to statistical expression. The number obtained is, therefore, a statistical estimate.

Viruses. Virus organisms are the smallest known biological units containing the information necessary for reproduction. Because of their size, viruses may be viewed only with the aid of an electron microscope. Disease causing viruses are known to be contained in the excreta of many animals, so that the control of these wastes becomes of critical importance for a variety of beneficial uses of water (see Public Water Supply section).

Plants and animals. Plant and animal indicators of water quality range from microscopic rotifers and worms to larger crustaceans and fish. The presence and diversity of these organisms in water bodies and bottom deposits often indicate the general health or suitability of the water for various beneficial uses (see Taras et al., 1971).

Water Quality Criteria for Beneficial Use Considerations

This section will discuss the major beneficial uses of water and some of the more generally accepted water quality criteria or standards for each.

Public Water Supply

Modern water management techniques and a wide variety of available water treatment processes make possible the use of raw water of almost any quality to produce an acceptable public water supply. However, management and treatment techniques must be consistent with the amount of capital and degree of technology available to meet appropriate standards.

Some raw (untreated) surface waters may meet all drinking water standards with no treatment other than disinfection. Usually, however, drinking water derived from surface sources should be subject to treatment. The treatment processes should employ appropriate technology.

Unlike surface waters, ground waters characteristically contain little or no suspended sediment and are largely free of, and easily protected from, bacterial and viral contamination Therefore, no defined treatment is assumed for ground water, although this does not preclude the need for treatment as determined by careful testing.

Sampling and Monitoring. The importance of an effective sampling and monitoring program cannot be overemphasized. Multiple sampling of the raw water source, from different locations and over different times, must be obtained, and a monitoring station at the point of entry to the supply system should be established. Care should be taken to recognize two possible hazards:

(1) the chronic hazard where constituent concentrations are near the limit of acceptability much of the time; and,

(2) the periodic hazard caused by upstream releases of wastes or accidental spills.

Especially for drinking water, initial sampling and subsequent monitoring programs should be designed and supervised by a qualified technical specialist (sanitary engineer, public health specialist, water quality chemist).

Quality Criteria. From the standpoint of safeguarding public health, the use of water as a domestic supply mandates relatively strict water quality standards. These standards cover potential constituents in all four major groupings of water quality characteristics: chemical, physical, physiological and biological. Many organizations have developed water quality standards for domestic supply. Table C-1 presents drinking water standards promulgated by five organizations and agencies. It is to be noted that standards often permit variances and exceptions. In some, standards vary with differing situations. For example, in the International Standards for Drinking Water there are bacteriological quality standards for disinfected and non-disinfected, treated water and for untreated water. They are: virtually no coliform in 100 ml, not more than 3 per 100 ml, and not more than 10 per 100 ml, respectively. For detailed discussions of water quality criteria, the reader is referred to the publications, Drinking Water and Health by the Safe Drinking Water Committee of the National Academy of Science and Quality Criteria for Water by the U.S. Environmental Protection Agency.

Alkalinity. The predominant chemical system present in natural waters is the carbonate equilibria in which carbonate and bicarbonate ions and carbonic acid are in equilibrium. Alkalinity is a measure of this system or the capacity of the water to neutralize acids. Alkalinity is reported in mg/l of $CaCO_3$.

The alkalinity of natural waters has a wide range (usually 50 to 100 mg/l). Below 25 mg/l with only chlorination practiced, an inadequate buffer system may be present to prevent the pH from dropping to corrosive levels. Conversely, extremely high alkalinities may lead to unpleasant taste.

No recommendations are made regarding alkalinity levels because the desired level is associated with other constituents such as pH and hardness. Alkalinity can be measured relatively simply using standard titration techniques with color indicators (see Taras et al., 1971, or equivalent texts).

Arsenic. Arsenic is a common metalloid* which can be both acutely and chronically toxic to man. It exists in both trivalent* and pentavalent* forms with the trivalent being the more toxic.

In most water supplies arsenic ranges from trace amounts to 0.1 mg/l, although higher levels do occur naturally. Several epidemiological studies have linked hyperkeratis* and skin cancer to drinking water containing more than 0.3 mg/l arsenic (Borgono and Greiber, 1972).

In man, subacute and chronic arsenic poisoning may be gradually and exceedingly harmful. In mild cases symptoms may consist solely of fatigue or loss of energy requiring specialized medical diagnsois to confirm the causative agent.

Table C-1

DRINKING WATER STANDARDS

	USPHS 1962	WHO EURO-PEAN 1970	WHO INTER-NATIONAL 1971	AWWA GOALS*[a]	U.S. EPA 1974
Bacteriological Quality:					
Coliforms-no./100 ml[b]	1.	0.50	0.05	0.00	1.
Physical Quality:					
Turbidity-units	5.			0.1	1.
Color-units	15.		50.	3.0	
Odor-Number	3.			0.0	
Chemical Characteristics mg/l:					
Affecting aesthetics and tastes:					
ABS	0.5	0.2	1.0	0.2	
Cl	250.	200.	600.		
Cu	1.0	3.0	1.5	0.2	
CCE	0.2	0.5	0.04		
CN	0.01				
F	0.6-1.7[c]	0.7-1.7[c]	0.6-1.7[c]		1.4-2.4[c]
Fe	0.3		1.0		0.05
Mn	0.05		0.5		0.01
NO_3^-	45.	50.			10.

Table C-1 (Cont'd)

DRINKING WATER STANDARDS

	USPHS 1962	WHO EURO-PEAN 1970	WHO INTER-NATIONAL 1971	AWWA GOALS*a/	U.S. EPA 1974
Phenols	0.001	0.0001	0.002		
=		250.	400.		
SO_4	250.				
TDS	500.		1500.		
Zn	5.0	5.0	15.	1.0	
H_2S		0.05			
Hardness ($CaCo_3$)		500.			
DO		5.	500.	80	
NH_3		0.05			
Affecting health:					0.05
As	0.05	0.05	0.05		1.0
Ba	1.0				0.01
Cd	0.01	0.01	0.01		
Cr	0.05	0.05			
CN	0.02	0.05	0.05		
F	0.8-1.7c/	0.8-1.7c/	0.8-1.7c/		0.05
Pb	0.05	0.1	0.1		0.01
Se	0.01	0.01	0.01		0.05
Ag	0.05			0.001	0.002
Hg					

a/ Jour. American Works Assoc., 13117 (Dec. 1968).

b/ At consumer tap - some statistical variation allowed.

c/ Temperature Dependent.

Arsenic quantity determinations in drinking water should be performed by a laboratory equipped either with a variable band spectophotometer or specific chemical analysis and appropriate glassware.

Bacteria. Procedures for the detection of disease causing bacteria, viruses, protozoa, fungi, etc. are complex, time consuming and generally require specialized equipment and personnel. Therefore an indirect approach to potential hazard determination is normally relied upon.

Coliform bacteria, which are normal inhabitants of fecal discharge, are used to indicate the relative amount of sewage waste present in water supplies. The rationale behind the use of this indicator is simply that coliform bacteria, although usually relatively harmless, are found along with pathogenic microorganisms (e.g. Salmonella) and serve as an indicator of contamination.

The standard test for coliforms may be carried out using a multiple-tube fermentation technique or a membrane filter technique with results expressed as the Most Probable Number (MPN). The MPN is actually an estimate based on certain probability formulas. For most applications, coliform determinations can be made using standard packaged membrane methods and reagents available from many commercial suppliers. Recent advances in packaging allow for adequate determinations to be performed in remote field stations, providing supplies can be replenished at regular intervals.

For the routine examination of drinking water, particularly that which has been subject to the defined treatment process the object of the test is to determine the presence or absence of coliform organisms as an indication of treatment plant efficiency. A properly running treatment will be expected to meet a value of about 1 count per 100 ml of water, with most tests being entirely negative. Usually, an occasional positive test can be discounted unless positive results are repetitive and increase over time. Such results indicate the need for corrective action to the treatment process.

Due to the usual efficiency of the defined treatment procedure, raw surface water will generally be rendered potable if the geometric means* of fecal and total coliform densities before treatment do not exceed 2,000/100 ml and 20,000/100 ml respectively.

Barium. Although relatively abundant in nature, barium occurs in potable waters generally in trace amounts only. Due to its extreme toxicity as a muscle stimulant, barium levels in excess of 1.0 mg/l should be avoided in public water supply sources. Levels in excess of this value generally indicate an industrial pollutant.

Barium can be reliably measured only by a well equipped laboratory with personnel skilled in atomic absorption spectroscopy.

Cadmium. Due to the extremely toxic nature of cadmium (renal* artery damage, nausea, and association with Itai-itai* disease in Japan) cadmium concentrations should not exceed 0.01 mg/l in potable water. Cadmium generally enters water supplies from industrial pollution or deterioration of galvanized iron supply pipes.

Cadmium determinations may be made either by atomic absorption spectrophotometry (preferred) or photometrically employing color indicators and a filter photometer.

Chloride. On the basis of taste, chloride concentrations should generally not exceed 250 mg/l. In undefined high levels, chloride may enhance corrosion of water facilities and household utensils.

Chloride may be measured with standard titration methods employing color indicators.

Chromium. The carcinogenic potential of hexavalent* chromium is well established. However, chromium is rare in natural waters and generally found only in the presence of industrial processes.

Chromium can be measured with spectrophotometric or color photometric techniques (both requiring a moderately equipped laboratory). Due to insufficent evidence regarding long term toxicity, chromium values should not exceed 0.05 mg/l in public water supplies.

Color. For public water supplies, color removal to an end point of 50 platinum-cobalt units is recommended. Fortunately, the defined treatment process, coupled with pH adjustment can remove the majority of true color in most raw water sources.

Color is determined by visual comparison of the sample with known concentrations of colored solutions. Numerous field and laboratory methods for color determination are available with field methods (available in kit form from commercial suppliers) recognized as being in substantial agreement with more sophisticated laboratory analyses.

Copper. Although an essential element to human health, copper doses above 1 mg/l can cause taste problems. Therefore public water supplies should not exceed this figure if practicable.

Copper may be measured by atomic absorption spectroscopy or by color photometric methods. Generally, for unknown raw water supplies, atomic absorption is preferred, as photometric methods can give misleading results when other substances interfere with the test.

Cyanide. Proper chlorination will generally reduce the cyanide level in raw water to levels below the recommended limits. Due to its extreme toxicity, however, cyanide should be routinely sampled in raw water supplies receiving industrial wastes.

Several methods are available to measure cyanide concentrations. A moderately equipped laboratory, with either spectrophotometer, filter photometer or cyanide distillation apparatus is recommended for such determination.

Dissolved Oxygen. Although not of direct health concern in public water systems, low dissolved oxygen levels in raw water sources serves as an indicator that excessive quantities of undesirable oxygen demanding wastes are probably present. Therefore, it is generally desirable that raw water sources contain dissolved oxygen at or near saturation (solubility dependent upon temperature and chloride concentration).

Dissolved oxygen may be accurately determined by a variety of methods. The simplest is by means of commercially manufactured dissolved oxygen meters. Such meters are generally portable and battery operated, allowing accurate field determination.

Fluoride. The fluoride ion* has potential beneficial effects in drinking water in the prevention of dental decay. However, as fluorosis* may occur when the fluoride level exceeds recommended limits, defluoridation should be practiced in natural waters which exceed approximately 3.0 mg/l.

Optimum fluoride concentrations are difficult to define and depend upon local drinking water usage. Such dosage limits and fluoride measurements should be made by specialized personnel.

Foaming Agents. Many naturally occurring or industrially produced substances will cause water to foam when agitated or when air is entrained.* The most common foaming agent is linear alkyl benzene sulfonate* (LAS), used as a base for common detergents.

Anionic surfactants*, such as LAS, are generally measured by indirect means of a methylene blue reaction, which requires a spectrophotometer or color photometer for determination. For public water supplies these methylene blue active substances should not exceed 0.5 mg/l.

Iron. This common metal is objectionable in public waters principally because of taste problems. Concentrations less than 0.3 mg/l are generally undetected and that limit is therefore recommended. Total iron may be readily measured by several field methods.

Lead. Because of its toxicity to humans, lead concentrations in water supply sources should not exceed 0.05 mg/l. Lead determinations should be made by atomic absorption spectroscopy.

Manganese. This metal, like iron, is objectionable principally because of taste problems. Concentrations of less

than 0.5 mg/l are generally acceptable and that figure should be regarded as a limit in public water supply sources. Atomic absorption spectroscopy is the preferred technique for determining manganese concentrations.

Mercury. Although distributed throughout the environment, mercury is highly toxic. Elevated mercury levels, sufficient to contaminate public waters, are generally associated with industrial wastes or agricultural practices. Mercury should not exceed 0.0002 mg/l in supply sources. Determinations of mercury concentrations should be made by atomic absorption spectroscopy.

Nitrate-Nitrite. Serious and sometimes fatal poisonings in infants have occurred from ingestion of well water containing nitrate concentrations of more than 10 mg/l. These concentrations are generally associated with shallow wells on farms and in rural communities with inadequate separation of water table and domestic or animal waste material.

Nitrite toxicity in man is also well known. However, nitrite concentrations in raw water rarely exceed 1 mg/l and are readily converted, through chlorination, to the nitrate form.

For routine public health protection, nitrate should be frequently sampled, especially in well water supply systems. Ultraviolet spectrophotometry is the preferred method of analysis.

Pesticides. Determining the presence of pesticides in water requires expensive and specialized equipment, as well as specially trained personnel. In addition, pesticides include numerous types of materials with varying toxicities and cannot be routinely classified. Recommendations for pesticide limits in public water for some of the more common compounds are presented in Table C-2.

Phenols. Phenolic compounds are waste products of oil refineries, chemical facilities and degradation products of certain pesticides. Phenols impart significant odor to water, a problem which may be worsened through normal chlorination processes. To restrict this ojectionable odor, supply sources should contain no more than 1 mg/l of phenolic compounds.

The presence of phenol should be determined only by a qualified laboratory as numerous natural substances can interfere with proper readings.

Selenium. The toxicity of selenium resembles that of arsenic and is not reduced by the defined treatment process. Although not generally common in natural waters, selenium can be a problem in well water from seleniferous areas. Measurement of selenium requires spectrophotometric or color photometric techniques. Due to its toxic nature, public water sources should not contain more than 0.01 mg/l selenium.

Table C-2

RECOMMENDED PESTICIDE LIMITS

Compound	Long-term levels with minimal or no effects			Calculated maximum safe levels from all sources of exposure			Intake from diet		Water	
	Species	ppm in diet	mg/kg body weight/day [a]	Safety factor	mg/kg/day	mg/man/day [b]	mg/man/day %	% of Safe level	% of Safe level	Recommended limit (mg/l) [e]
Aldrin	Rat	0.5	0.083	1/100	0.00083	0.0581				
	Dog	1.0	0.02	1/100	0.0002	0.014 [d]	0.0007	5.0	20	0.001
	Man		0.003	1/10	0.0003	0.021				
Chlordane	Rat	2.5	0.42	1/500	0.00084	0.588 [d]				
	Dog	N.A.	N.A.				T	T	5	0.003 [c]
	Man	N.A.	N.A.							
DDT	Rat	5.0	0.83	1/100	0.008	0.56 [d]				
	Dog	400.0	8.0	1/100	0.08	5.6	0.0021	3.4	20	0.05
	Man		0.5	1/10	0.05	3.5				
Dieldrin	Rat	0.5	0.083	1/100	0.00083	0.581				
	Dog	1.0	0.02	1/100	0.0002	0.014 [d]	0.0049	35.0	20	0.001
	Man		0.003	1/10	0.0003	0.021				
Endrin	Rat	5.0	0.83	1/500	0.00166	0.1162				
	Dog	3.0	0.06	1/500	0.00012	0.0084 [d]	0.00035	4.1	20	0.0005
	Man	N.A.	N.A.							
Heptachlor	Rat	0.5	0.083	1/500	0.000166	0.1162				
	Dog	4.0	0.08	1/500	0.00002	0.0112 [d]	0.0021		2	0.0001 [f]
	Man	N.A.	N.A.							

Table C-2 (cont'd)

RECOMMENDED PESTICIDE LIMITS

Compound	Long-term levels with minimal or no effects			Calculated maximum safe levels from all sources of exposure			Intake from diet		Water	
	Species	ppm in diet	mg/kg body weight/ day a/	Safety factor	mg/kg/ day	mg/man/ day b/	mg/man/ day %	% of Safe level	% of Safe level	Recom-mended limit (mg/l) e/
Heptachlor	Rat	0.5	0.083	1/500	0.000166	0.01162				
Epoxide	Dog	0.5	0.01	1/500	0.00002	0.0014 d/	0.0021	150.0	5	0.0001
	Man	N.A.	N.A.							
Lindane	Rat	50.0	8.3	1/500	0.0166	1.162				
	Dog	15.0	0.3	1/500	0.0006	0.042 d/			20	0.005
	Man	N.A.	N.A.							
Methoxychlor	Rat	100.0	17.0	1/100	0.17	11.9 d/				
	Dog	4000.0	80.0	1/100	0.8	56.0	T	T	20	1.0
	Man		2.0	1/10	0.2	14.0				
Toxaphene	Rat	10.0	1.7	1/500	0.0034	0.238 d/				
	Dog	400.0	8.0	1/500	0.016	1.12	T	T	2	0.005 c/
	Man	N.A.	N.A.							

LEGEND:
a/ Assume weight of rat=0.3 kg and of dog=10 kg; assume daily food consumption of rat= 0.05 kg and of dog=0.2 kg.
b/ Assume average weight of human adult=70 kg.
c/ Chosen as basis on which to derive recommended limit.
d/ Assume average daily intake of water for man = 2 liters.
e/ Adjusted for organoleptic effects.
f/ Adjusted for interconversion to H, epoxide.
N.A. No data available.
T Infrequent occurrence in trace quanities.

Sulfate. Concentrations of sulfate in public water, especially in the presence of magnesium, can cause both taste problems and a laxative effect. Sulfate concentrations are generally highest in ground water supply systems. Due to its above mentioned effects, sulfate should not exceed 250 mg/l in public water.

Viruses. Many types of viruses are excreted in the wastes of humans and animals. Due to the uncertain correlation between quantificable virus species and populations and human health, and because of a lack of adequate monitoring techniques, viral control is presently assumed to be related to coliform control as described previously.

Zinc. Although an essential and beneficial element, Zinc may impart objectionable taste in water. A limit of 5 mg/l is recommended in public water sources.

Industrial Water Use

The requirements for industrial water use are as diverse as the many users themselves. The quality requirements for use may be very low in some instances, while quality well in excess of drinking water standards may be necessary in other cases. The major industrial uses of water include: 1) use in the actual product; 2) use as a buoyant transport medium; 3) use as a cleansing agent; 4) use as a coolant; and, 5) use as a source of steam for heat and the generation of power.

Modern water treatment technology is capable of treating almost any raw water to render it suitable for any industrial use. The treatment, however, may be so expensive, both in initial capital cost and in maintenance costs, that the entire project is rendered economically unfeasible. It is evident, therefore, that the more nearly the composition of the raw water source approaches the particular composition required, the more desirable that source (or location) becomes.

Generally, the most stringent industrial requirements for water quality in developing nations will be associated with products for human consumption (food preparation and processing, bottling, canning, etc.). The water used in these products must not only be potable, but free of substances which would alter the taste or appearance of the product. Usually, such plants receive water directly from public supply systems and augment this municipal treatment with specific techniques applicable to the product.

Because of the wide range of industrial water uses and requirements, water quality required for specific uses will not be presented here. In part due to the need of industry to often treat water for its own use, the constancy of raw water yield and quality is probably more important than the actual raw water quality itself. The reader is referred to any of a number of texts (e.g., Nordell, 1961) on industrial water use for specific use requirements.

Agricultural Water

Water used for irrigation purposes may follow a number of different paths through the hydrologic cycle. Irrigation water is lost by surface runoff, evaporation, or percolation through soil strata. The water that percolates through the soil is either: 1) used consumptively by the plants; 2) held in the soil to be later used by the plants; or 3) lost by further lateral or downward percolation.

The water that is held in the soil is known as the soil solution, and is of critical importance to the success of the crop. Further consumptive use of the soil solution, by the plant, or loss of solution by capillary action and surface evaporation tends to concentrate the constituents originally contained in the irrigation water. Through this process the soil solution will contain increasingly higher concentrations of constituents, some known to be generally harmful to crops: total salts, compounds of boron, silicon, fluorine, sulfur, phosphorus, and iron, and cations and anions such as calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride and nitrate.

As is the case with industrial water use, irrigation water requirements are fairly diverse and based on the tolerance of the crop to be irrigated. Irrigation waters can, however, be itemized into three summary classifications. A description of each classification and its water quality standards are presented in Table C-3.

Livestock and Domestic Animals

It may generally be said that water suitable for human consumption is also satisfactory for stock and wildlife watering. Conversely, evidence has been found indicating that animals are more tolerant of salinity than humans. Salinity levels are, nonetheless, a main concern in stock and wildlife watering, along with toxic materials and bacteriological water quality.

Salinity. The threshold salinity concentration that is tolerable to stock and wildlife is largely dependent upon 1) the type of animal, 2) climatic conditions (i.e., temperature, humidity, etc.), and 3) the chemical nature of the salts represented by the total salinity. Because many of the feed water sources in Western Australia are highly saline, much of the work done on salinity tolerances of stock and wildlife has been carried out there. From this work (McKee and Wolf, 1963), it can be generally stated that livestock can tolerate salt concentrations up to 5000 mg/l (containing chloride, sulfate, and bicarbonate salts of sodium, magnesium, and calcium, with up to 75 percent sodium chloride). Stock specific standards used in this region, however, are illustrated in Table C-4.

Table C-3

SUMMARY OF CLASSIFICATIONS OF IRRIGATION WATERS[a]

Class	% Na $\frac{Na \times 100}{Na+CaMg+K}$ as meq per liter	Boron, in mg/l	Chlorides in meq/l	Sulfates in meq/l	$EC \times 10^6$ at 25°C Specific conductivity concentration of ions)	Total salts mg/l
I	Less than 30-60% (Most recent work favors a 60% limit)	Boron recommendation for water of this class is generally accepted as less than 0.5 mg/l; however tolerant plants will not be injured by 1-1.5 mg/l.	Less than 2-5.5	Less than 4-10	Earlier papers suggested limit of about 500, but more recently 1000 has been accepted.	Up to about 700
II	30-75%	0.5-2.0 mg/l, although for tolerant plants water with boron up to 3.35 mg/l may be satisfactory	2-16	4-20	500-3000	350-2100
III	More than 70-75%	More than 2 mg/l although water with more than 10 may be highly unsuitable for sensative plants	More than 6-16	More than 12-20	More than 2500-3000	More than 1750-2100

Class I-Excellent to good, or suitable for most plants under most conditions.
Class II-Good to injurious, harmful to some under certain conditions of soil, climate, practice.
Class III-Injurious to unsatisfactory, unsuitable under most conditions.

a/ Adapted from McKee and Wolf, 1963.

Table C-4

SUGGESTED SALINITY LIMITS
FOR STOCK WATERING PURPOSES

Animal	Threshold Salinity Concentrations in mg/l
Poultry	2,860
Pigs	4,290
Horses	6,435
Cattle, Dairy	7,150
Cattle, Beef	10,150
Adult Sheep on Dry Feed	12,900

Toxic Substances

Many substances dissolved or suspended in water may be toxic to livestock. The concentrations at which these substances render the water unfit are subject to a number of variables. These include age, sex, species, water intake, diet, temperature and the physiological state of the animal. Due to these variables, it is extremely difficult to develop specific recommendations for safe concentrations of toxic substances. The problem is further compounded when such toxic substances are accumulated in animal products for human consumption. Table C-5 presents some recommended limits for toxic ions and elements in livestock water. For a discussion of these elements, the reader is referred to the section on domestic water supply (above).

Table C-5

SOME RECOMMENDED LIMITS FOR TOXIC
ELEMENTS IN LIVESTOCK WATER

Element	Concentration (mg/l)
Aluminum	5.0
Arsenic	0.2
Boron	5.0
Cadmium	50 mg/l
Chromium	1.0
Cobalt	1.0
Copper	0.5
Lead	0.1
Mercury	10 mg/l
Nitrates and Nitrites	100 ppm (NO_3N + NO_2N)
Selenium	0.05
Vanadium	0.1
Zinc	25

In addition to the above-mentioned toxic elements and ions several other constituents of water can be considered hazardous to livestock. Generally, for example, waters bearing heavy growths of blue green algae should be avoided due to known toxicity of several species. Additionally, the presence of fish in the supply source may be an excellent monitor for toxic levels of pesticides. In general, fish have lower tolerances for persistent pesticides, such as chlorinated hydrocarbons, than do livestock and poultry but there is a great deal of variation among species in all animal groups.

Pathogens and Parasites. One of the most significant factors in the spread of infectious diseases of domesticated animals is the water they consume. Protection and treatment for livestock should be provided for through routine veterinary care.

Protection of Aquatic Life

More work has been conducted on the effects of pollutants to aquatic life than has been done with regard to any of the other beneficial uses of water. Because of the proliferation of this work and the wide variation in conditions under which it was performed, presentation of a single set of standards from these efforts is not appropriate. Moreover, other variables enter when considering water quality standards for the protection of aquatic life. These variables include, but are not limited to:

- The species, size, age, and physiological condition of the organism.
- Background conditions such as temperature, dissolved oxygen, and hardness as well as synergistic* effects of different materials present together.
- The hydrographic features of the stream, lake, or estuary and the associated hydrologic regimen under which the water body operates.

For a detailed presentation of water quality criteria relative to the protection of aquatic life the reader should consult one or more of the numerous texts available on this subject (for example, U.S. EPA, 1977).

Swimming and Bathing

Waters for swimming and recreation purposes should be expected to conform to three general conditions. These conditions are 1) freedom from objectionable odors, colors and floating and suspended materials, 2) freedom from toxic materials and skin irritants, and 3) freedom from "excessive" amounts of pathogenic organisms.

While the first two criteria listed above are rather straightforward, some discussion concerning the last crite-

rion is necessary. Standards for coliform bacteria in bathing and swimming water vary widely from country to country. Standards have been reported between 50 and 3000 coliforms per 100 ml. Variations exist in the standards for reporting monitoring results; monthly arithmetic mean, monthly geometric mean, and maximum values have been used. The numbers by themselves have little meaning. Field studies have shown that increase in coliform concentrations does not necessarily lead to increase in disease frequency. Water quality standards for swimming and bathing are best established based on epidemiology. Further, the importance of sanitary surveys must not be forgotten. An increase in coliform concentrations at a beach near a sewer outfall has significance different from a similar occurrence along a beach where there are no outfalls.

Esthetics and Boating

The standards traditionally established for esthetics and boating are less stringent variations of those set forth for swimming and bathing. The principal concern for the establishment of standards for esthetics and boating is the prevention of objectionable odors, colors, floating or suspended materials, slimes or algae blooms, and foams. Control of industrial and municipal wastes can often eliminate many of the above problems. Effective control of algae blooms and/or slimes requires limiting the discharge of inorganic nutrients to the water. Nutrients of concern include nitrates, phosphates, carbonates, and silicates. Limitation of surfactants discharged to the water will effectively control foaming. Bacteriological water quality, although not mentioned above, is sometimes an attendant concern in water designated for esthetics and boating.

Water Power and Navigation

Pollutants that interfere with the beneficial use of water for power and navigation purposes are: 1) acids or alkalis that encourage corrosion of equipment; 2) debris and silt that may block channels or clog water intakes; 3) excess organic matter that promotes anoxic conditions, and produces corrosive gases such as hydrogen sulfide; and, 4) deleterious marine organisms that contribute to the destruction of equipment.

Standards are rarely established for this water use. To minimize some of the effects listed above, however, constituents such as hydrogen ions, sulfides, chlorides, free carbon dioxide, temperature, and certain types of bacteria, algae, fungi, worms, and mollusks should be controlled.

Transport, Assimilation, and Dispersion of Wastes

The beneficial use of water for the transport, assimilation, and dispersion of wastes is the lowest classification of the major uses. This is due to the fact that use of water for this purpose usually degrades water quality in respect to all the other uses.

Watercourses can be classified as either water quality limited or effluent limited. Small, slow moving streams and rivers generally have limited assimilative capacity, while the opposite may be true for larger, fast flowing streams. The degree of treatment of wastewater required for local discharges to avoid pollution problems or to exceed in-stream water quality standards is dependent on that capacity.

Simple Tests to Indicate Changing Conditions

There are numerous tests which can be performed quickly and reliably in order to indicate changes in water quality. It should be noted that the tests for many of the constituents mentioned above require complex laboratory equipment, highly trained personnel and significant amounts of time. There are, however, less complex field test kits available which, in the hands of a knowledgeable person, can be used to make preliminary evaluations of water quality for specific projects. With additional back-up, more complete information and interpretations can be made for project evaluation, design and operation.

Physical. Simple physical tests which can be performed to indicate water quality include temperature, dissolved oxygen, suspended solids, conductivity, and color. Conductivity, color, temperature, and dissolved oxygen may be determined almost instantaneously (with appropriate field meters), while measurement of suspended solids would require the capability to filter a sample, evaporate the water to produce a residue, and finally weigh the products.

Chemical. Primary chemical constituents which can be fairly easily measured include pH, alkalinity, and BCD_5. All these tests would require either specific metering instrumentation or a moderately equipped field laboratory. Other tests of interest, requiring more equipment, include those for chlorides, nitrogen forms and phosphates.

Biological. The single most important test to indicate biological water quality is the test for coliform bacteria. This test is an indicator of potentially harmful biological pollution. This test also requires a moderately equipped laboratory.

Additional important information concerning water quality may be gained through analysis of biological samples and the presence of certain indicator organisms. These organisms are those which have been shown through historical and documented collection to become overabundant or absent in response to certain water quality criteria. Tubifex worms*, for example, are known to occur in great numbers under conditions of high organic pollution. In employing indicator species, great care must be taken in the correct identification and preservation of the organisms through knowledge of their distribution and tolerances. For more information on this subject, the reader should consult Hynes (1960) or Ingram et al., (1966).

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GLOSSARY

ABS (alkyl benzene sulfonate). A synthetic base for detergents used extensively prior to development of LAS (which causes less foaming in waste water). See: LAS.

acute. In public health, having a rapid onset, short duration, and pronounced symptoms. See: chronic.

aerobic. Living, active, or occurring only in the presence of oxygen.

ambient. Surrounding on all sides; encompassing.

anemia. Deficiency of blood as a whole, in hemoglobin content or in the number and quality of the red corpuscles.

anion. The ion in an electrolyzed solution that migrates to the anode (the positive electrode); broadly, a negatively charged ion. See: ion.

anionic surfactants. Surface-acting substances, e.g. detergents

anoxic. Relating to a deficiency of oxygen reaching the tissues of the body (the condition is so severe as to result in permanent damage).

arenaviruses. Rodent-associated zoonotic viruses characterized by sand-like particles in the nucleocapsid.

aquiclude. Soil formation that prevents the flow of ground water, for example, a clay layer.

arthropod. Any member of the phylum Arthropoda, invertebrate animals characterized by a jointed body and limbs, usually a chitinous shell molted at intervals, and the brain dorsal to the alimentary canal and connected with a ventral chain of ganglia.

asexual. Without sexual differentiation; without union of germ cells.

asymptomatic. Without symptoms. See: symptom, sign.

biological vector. A vector in which a parasite develops or multiplies. See: vector.

bionomics. Ecology.

cachexia. Weakness and emaciation due to poor nutrition.

carapace. A bony or chitinous case or shield covering the back of a shelled animal, such as a crab.

carcinogenicity. The relative extent to which a substance or agent produces or incites cancer.

chemotherapy. Treatment of disease by means of chemicals or drugs. See: prophylactic chemotherapy, therapeutic.

cholera vibrio. A short, curved, motile, gram-negative rod bacterium possessing a single polar flagellum.

chronic. Of long duration. See: acute.

coliform. Resembling certain bacteria, as Escherichia coli, which are usually inhabitants of the intestine.

commensal. Describing to the relationship between two kinds of organisms in which one obtains food or other benefits from the other without penalizing or benefiting its partner.

copperas. A green hydrated ferrous sulfate $FeSO_4 \cdot 7H_2O$ used in water treatment.

definitive host. An organism which harbors the adult stage of a parasite. See: host, intermediate host.

detoxify. To remove a poison or toxin.

dispersion climatology. The local weather conditions affecting the mixing of air pollution and atmosphere.

ecological niche. The home or part of the physical environment inhabited by an organism.

ecology. Science concerned with the interrelationships of organisms and their environments.

Entamoeba histolytica. A pathogenic amoeba parasitic in the intestine.

enteric. Relating to the intestines.

etiologic. Relating to all of the causes of a disease or abnormal condition.

factor markets. The values of land, labor and capital, the classic factors of production, which are set by supply and demand forces or traditional customs.

fallow. Left untilled or unsown after plowing.

fallow farming. A farming system involving periods of cultivation alternating with periods during which the plot is abandoned and allowed to regenerate native vegetation, the fallow period.

febrile. Feverish; of or relating to fever.

flagellate. A type of protozoan or one-celled animal that moves by means of a whip-like organelle or flagellum.

fluorosis. An abnormal condition (as of the teeth) caused by an excess of fluoride.

forest-fallow farming system. Shifting cultivation involving clearing by cutting and burning secondary forest, a fallow period of 20-25 years, and a simple technology such as axe and digging stick. Primary forest is avoided where possible because of huge labor investment required for clearing and lower fields.

geometric mean. The nth root of the product of n numbers.

hexavalent. Having a valence of six.

host. An organism which harbors a parasite. See: definitive host, intermediate host.

hyperendemic. In epidemiology, a disease or condition usually present at a high frequency in a given area. See: discussion of endemic, epidemic in Appendix B.

hyperkeratosis. Hypertrophy or excessive development of the corneous layer of the skin.

intermediate host. A host which harbors the larval or asexual stages of a parasite. See: definitive host, host.

ion. An atom or group of atoms that carries a positive or negative charge as a result of having lost or gained one or more electrons.

Itai-itai. Severe endemic disease associated with ingestion of cadmium.

leach. To pass out or through by percolation; to dissolve out by the action of a perolating liquid.

leachate. A solution or product obtained by leaching. See: leach.

lepromatous. Referring to lesion of leprosy.

linear alkylate sulfonate (LAS). A synthetic anionic surfactant used as a base for synthetic detergents. See: anionic surfactant.

long-fallow farming system. Shifting cultivation involving clearing by cutting and burning brush and small trees, a fallow period of 6-10 years, and a machete-and-hoe technology. The fallow period can be reduced and productivity raised with increasing labor inputs to combat grasses and insect pests.

malodorous. Ill-smelling.

mechanical vector. A vector which transmits parasites without development or multiplication of the parasite within it. See: vector.

mesenteric. Referring to a supportive membrane.

metalloid. A nonmetal that can combine with a metal to form an alloy.

methemoglobinemia. Disease in which a soluble blood pigment, methemoglobin, replaces hemoglobin in the blood cells and is unable to combine reversibly with molecular oxygen.

morbidity. The relative incidence of disease in a population.

nasal mucosa. The mucous membrane lining the passage of the nose in man and other mammals.

nematode. Any of a class (Nematoda) of elongated cylindrical worms parasitic in animals or plants or free-living in soil or water.

nest detritus. In bird and mammal nests, the debris, consisting of food remains, hair and feathers, and plant material that accumulates during nest use.

neurotrophic virus. Those viruses involved in the causation of hemorrhagic fevers.

oocyst. A hard-walled sporocyst; in malaria parasites, an encysted zygote located on the stomach wall of the transmitting mosquito, which gives rise to sporozoites. See: sporozoite, zygote.

papules. Small, solid usually conical elevations of the skin.

paroxysmal chills. Convulsive shivering.

pathogenic. Causing or capable of causing disease.

pentavalent. Having a valence of five.

peripheral blood. The blood in the small blood vessels lying in and immediately under the skin.

piezometric surface. The elevation to which the water level rises in a well that taps an artesian aquifer.

plankton. The passively floating or weakly swimming, usually minute, animal and plant life of a body of water.

plant axil. The angle between a branch or leaf and the axis from which it arises.

potentiometric. Referring to measurements of electromotive forces using a potentiometer.

prophylactic chemotherapy. Prevention of disease by means of chemicals or drugs. See: chemotherapy.

prophylaxis. Measures designed to preserve health and prevent the spread of disease.

pustules. Small circumscribed elevations of the skin containing pus and having inflamed bases.

renal. Relating to, involving, or located near the kidneys.

reservoir. In public health, a host which maintains a parasite in nature and which serves as a source of infection for others.

reticulo-endothelial cells. A diffuse system of cells arising from mesenchyme and comprising all the phagocytic cells of the body except the circulating leukocytes.

serological. Dealing with serums and especially their reactions and properties.

short-fallow farming system. Shifting cultivation involving clearing by burning grasses and bush, a fallow period of 1-2 years, and a plow and draft animal technology.

sign. In public health, a physical change or indication of disease not necessarily felt or noticed by the patient. See: symptom.

soil adhesion. The ability of soil to stick to substances other than soil.

spectrophotometric. Referring to the relative intensities of light in different parts of the spectrum as measured by a photometer.

spirochetes. Any of an order of slender, spirally undulating bacteria, including those causing relapsing fever.

sporozoite. An infective nucleated organism resulting from multiple fission within a sporocyst or oocyst. See: oocyst.

stasis (lymph). A slowing or stoppage of the normal flow of body fluids.

sylvatic (plague). Refers to nondomestic character of reservoir host, namely, wild rodents. See: reservoir, host.

symbiotic. The association of two dissimilar systems in a mutually beneficial relationship.

symptom. A change, due to disease, which is felt by the patient. See: sign.

synergistic. Having the capacity to act in synergism or cooperative action of discrete agencies such that the total effect is greater than the sum of the effects taken independently.

therapeutic. Curative.

titration. A method or the process of determining the strength of a solution or the concentration of a substance in solution in terms of the smallest amount of a reagent of known concentration required to bring about a given effect in reaction with a known volume of the test solution.

toxemia. Presence of toxins, but not necessarily the organisms producing them, in the blood.

toxin. A protein-like poisonous substance produced by animal or plant cells.

transhumant. Characterized by seasonal movement of livestock, especially sheep, between two areas, such as mountain and lowland pastures.

transhumant pastoralism. In contrast to true nomads who move continuously; transhumant pastoralists move seasonally between two or more defined regions each of which is considered a homeland.

trivalent. Having a valence of three.

tubifex worm. Any of a genus of slender reddish oligochaete worms that live in tubes in fresh or brackish water.

vector. An arthropod, or other animal, which transmit a parasite from one vertebrate host to another. See: biological vector, mechanical vector.

volatile compounds. Readily vaporizable at a relatively low temperature.

zoonosis. Disease or infection naturally transmitted between vertebrate animals and humans. Plural: zoonoses.

zygote. An organism produced by the union of two germ cells; a fertilized egg cell.