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VILLAGE WATER SUPPLY AND SANITATION IN LESS DEVELOPED COUNTRIES

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Central Projects Staff
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VILLAGE WATER SUPPLY AND SANITATION
IN
LESS DEVELOPED COUNTRIES

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SUMMARY AND CONCLUSIONS

This report outlines the major factors which should be considered when planning investments in potable water supply systems in rural areas of less developed countries. Chapter I begins with a brief discussion of a few of the more frequently cited arguments for allocating resources to potable water supply systems in rural areas. The arguments center around the ultimate goals of redistributing real income and slowing population migration. There is little hard evidence, however, that water supply investment is a particularly effective or efficient means of achieving these objectives.

Chapter II discusses the definition of the term "rural" as applied to water supply and sanitation programs. Although frequently the subject of controversy, it is concluded that the distinction between urban and rural systems is essentially unimportant. What is important is that the water supply systems of a particular country should be categorized in a way that is problem-oriented, and in practice, such categorization should normally be influenced by the consideration that the less spatially concentrated the population, the more difficult it is to ensure that a piped water supply system is financially viable and properly operated and maintained.

Many rural communities do not have the ability to pay for the total cost of water supply systems, and in many cases even have difficulty in covering operation and maintenance expenses. In such cases, revenue from water sales clearly cannot be used as the sole indication of project justification, direct qualitative and quantitative analysis of project benefits therefore being desirable. However, this is a tremendously complex task, as subsequent chapters indicate.

Improvement in health is usually the rationale for large investments in village water supply and sanitation. However, the physical and economic impacts of such investments are extremely difficult to quantify. Chapter III discussed the many sources of water-associated diseases, and explains the difficulties involved in estimating the extent of the impact on health if drinking water is improved, or made more convenient to users.

A survey of the findings of twenty-six empirical studies carried out in various parts of the world and directed at the association between water supply and health certainly suggests that a significant relationship exists between an adequate, safe, and convenient source of water and the incidence of waterborne and water-related diseases. The studies provide evidence, particularly for diarrheal diseases, that a more convenient water supply outlet (closer to the user) is generally associated with lower infection rates and that villages with a piped water supply tend to have a lower incidence of a variety of water-associated diseases. However, the studies provide little information that intuition would not, for the magnitude of the relationship between improved water supply and sanitation
and health remains uncertain. It is normally so affected by other economic, environmental, social, and cultural factors that specific predictive statements cannot be used to forecast with acceptable accuracy the improvement to health from specific water supply improvements. At the same time, however, it can be concluded that all other measures, such as improved excreta disposal, food and market sanitation, personal hygiene, and village cleanliness, which can be taken to prevent and control the filth-borne diseases are so dependent on the availability of a good water supply that permanent improvements in health will be unlikely if not impossible unless a safe and convenient water supply either precedes or accompanies the other measures.

Accurate prediction of the physical impact of water supply and sanitation projects would in itself provide valuable information for investment planners. Ideally, such information would be supplemented by economic evaluation of the physical impact. This would allow the net economic benefits - or costs - of a program to be made explicit, even though the result of such a calculation would rarely be the sole criterion for decision. However, here too, the analyst runs into considerable problems of evaluation. While discounting changes in the future earnings stream of beneficiaries may be the best single way to value changes in health, such a calculation must be interpreted with great care: the question of whether earnings should be valued net of consumption; the problem of underemployment; and the weighting of benefits accruing to various income groups all require attention.

Economic growth and output is the focus of Chapter IV. The discussion covers general growth and redistributive effects on the national economy, possible short and long run direct effects (gardening, animal husbandry, property values, commerce and village industry, etc.), effects on labor inputs and earnings (death, morbidity, external health effects, additional time for productive work), problems of population growth and income, and the possibility of achieving savings in costs for society at large. It is concluded that, in general, the link between improved economic output and an improved village water supply is not very strong. This is particularly true where unskilled labor is abundant and greatly underemployed. In such cases, a rural water supply program which improves the health of the labor force may increase the extent to which there is an oversupply of labor while having very little impact on economic output and earnings.

Chapter V focuses on some other goals which are sometimes stated to be objectives of rural water supply programs. The most important of these is the general goal of influencing the location of population, by improving the "quality of life" in particular rural areas. The role of the water supply program as a catalyst to establish an organizational infrastructure at the community level is also discussed.

In Chapter VI the focus is on strategies for choosing which villages should be assigned a high priority for water service. It is concluded that if the water supply investment is intended to have a significant impact on
economic development, some form of rural growth point or complementary program strategy should be followed. A worst-first strategy, while achieving a relatively large short-run redistribution of income, could run into significant cost and maintenance problems in the longer run. In addition, a worst-first strategy would generally be the least efficient way to allocate resources if one of the goals of the program is economic development.

Chapter VII discusses miscellaneous problem areas of rural water supply programs. These include the role of pricing, quality of service, population acceptance, the role of "self-help" schemes, shadow pricing, level of technology, complementary programs, and the time frame for investment. Common practices in each area are discussed and, when possible, alternative methods and procedures are examined.

Chapter VIII deals with a number of problems of administration. It is particularly important that administration is geared to the crucial problem of operation and maintenance, the inadequacy of which characterizes most rural water supply programs. The advantages of centralized versus decentralized programs are discussed as well as the appropriate form of national agency involvement in the program. Different structures for financing rural water supply programs are also noted together with suggestions for income redistribution possibilities. Finally, the need for water supply-related training programs is discussed and several examples are cited. An existing program in which performance incentives are an important feature is also described.

The report does not offer any conclusion as to the single best means of designing and administering a rural water supply program in all countries. It also does not provide definitive methods for calculating the real and financial costs and benefits of rural water supply systems. Political, geographic, educational, income, and cultural differences among regions of the world, among countries, and even among regions within countries preclude generalization as to "correct" procedures.

What this report does attempt to do is to (1) identify the relevant factors which should be considered when allocating resources to rural water supply investment, (2) analyze these factors in view of the common goals of fostering better health, economic development, redistribution of income and slowing rural to urban population migration, and (3) suggest the effects of geography, political philosophies, income, education, and culture on different methods for achieving the above goals and on methods for measuring the extent of the goal achievement. It is hoped that with a selected set of program goals, together with a crude economic and demographic profile of a country, this report will provide sufficient information so that the problems associated with designing, constructing, and maintaining a rural water supply program can be foreseen and can be minimized.
Following is a summary of the major conclusions reached in the report:

Population to be Served and the Migration Problem

1. There are a number of factors which can be considered in choosing who should benefit from a rural water supply and sanitation program. The program can have many objectives such as improved health, economic development, real income redistribution, influencing migration patterns, and so on. Water supply and sanitation development policies should be determined by these objectives, subject to resource constraints, rather than by an arbitrary dichotomy between so-called urban and rural programs. There is no unique and universal definition of "rural" or "urban" which best fits all less developed countries and all of the possible objectives of water supply investment.

2. The more dispersed the population to be served, the less likely it is that a water supply system can be financially viable, and will be properly maintained, not only because of lower per capita village income but also because average system costs, for a given standard of service, will be higher.

3. It is possible that water supply systems together with improved sanitation and other complementary investment programs could slow rural to urban migration rates. There is little evidence, however, that in the short run a rural water supply program, by itself, will have any effect on migration. In fact, in the long run, if the water supply program results in a healthier, more potentially productive rural population, the lack of rural employment opportunities could result in an increase in the flow of population into urban areas.

4. While the short-run migration effects of a rural water supply and sanitation program are doubtful, it is more likely that potable water supply systems can be used to encourage, over a period of time, the grouping of dispersed populations into more economically viable village units.

Economic Development

5. A potable water supply for residents of an area may be a necessary condition for significant economic development. However, a potable water supply is clearly not sufficient - even as a catalyst - to achieve this objective.

6. Concentrating water supply and sanitation investment in rural growth points will tend to increase the long-run economic development impact of the investment.
7. A strategy of assigning the highest priority for water service to rural villages which are among the smaller, poorer, and least educated is a high cost and extremely risky venture. The smaller and poorer villages generally have higher per capita construction costs, and have difficulty contributing financial resources to construction or levying charges which are adequate to cover even operation and maintenance expenses.

8. Investing in complementary programs (sanitation, health education, feeder roads, marketing information, etc.) will increase the probability that the water supply program will have an economic development impact on an area.

9. If, in semi-arid regions or in areas with a dry season, a village water supply system is designed to include the provision that livestock can be watered and small gardens can be irrigated, the probability that the system will have a significant economic impact is increased substantially.

10. Underemployment is a common characteristic of rural areas in developing countries. Together with the frequently observed overvaluation of local currency this points to the need to shadow price inputs in order that in terms of real resources, the least cost means of construction and operation is selected. However, shadow pricing exercises themselves are costly, and an educational problem exists in persuading the relevant authorities, contractors and consultants to apply economic analysis to investment decisions. One reason for this is that the financial consequences of using shadow pricing may prove unpalatable to the water supply or relevant fiscal authority.

Health-Related Benefits

11. The review of the twenty-six empirical studies, which examine the relationship between the quantity and quality of water consumed and the level of various water-associated diseases, provides some evidence that more and better water and better sanitary facilities are associated with better health.

12. The empirical health studies also suggest that the degree of improvement in health which can be expected in any given population depends on the level of health in the first place, cultural habits, educational level, the general physical environment including adequate means of waste disposal, and income level. These factors are obviously interrelated, but the point is that identical water supply improvements in two different villages can have significantly different results.

13. In many rural areas of developing countries unskilled labor is abundant and is greatly underemployed. Therefore, a rural water supply program which is designed solely to improve the health of the labor force may increase the extent to which there is an over-supply of labor but have very little impact on economic output and earnings.
14. Most studies have shown that water-related health improvements are much greater among children, who are not members of the labor force. Consequently, with respect to those rural localities in which most of those who desire work can find income-generating work, estimates of increased income generation brought about by water supply-induced health improvements must take into account both the age distribution and the distribution of skills among the population.

15. There is some evidence, with regard to waterborne diseases such as typhoid and cholera, that improved sanitation is, in the long run, more effective and less expensive than vaccination. In a more general sense, preventive medicine is usually more cost-effective than curative medicine, and water supply and sanitation are key elements of preventive medicine.

16. There are several different methods by which changes in mortality and morbidity rates can be "valued." The most workable seems to be to discount any changes in expected life-time earnings which result from water supply-induced better health. This method, however, involves the dubious assumption that the economic output of humans reflects the value of life and health.

17. Factors which affect benefits also affect costs of a project. One approach to the cost-health improvement problem would be to formulate it in terms of the question: what amount of improvement in the major disease rates (valued either qualitatively or in income terms) would it take to make a given investment (and the level of service implied by that investment) worthwhile?

18. Studies of the association between health and quality of water supply and sanitation which allow an accurate prediction of health (and economic) improvements under a variety of circumstances have not been carried out. The primary reasons for this are (a) social, economic, and physical conditions vary greatly among target populations, precluding accurate generalizations, (b) sampling problems and problems of uncontrollable exogenous factors greatly increase the probability of significant errors in the results, and (c) the water supply-health relationship is highly collinear with a variety of environmental, social, and cultural factors, the effects of which are difficult, if not impossible, to isolate.

Redistribution of Income

19. Investments in rural water supply systems in developing countries are sometimes claimed to be a useful means of redistributing real income from higher income urban areas to lower income rural areas. This assumes, of course, that most of the real resources which are used in the rural water supply program would have been allocated to, and consumed in, urban areas; that the rural water supply program will not use resources which would otherwise have been consumed by low-income urban-slum dwellers; and that subsidization is a feature of the financing plan.
20. If redistribution of income is one of the goals of the water supply program, a national or regional water board with responsibility for urban and rural supplies may be in the best position to charge higher water rates to middle and upper income urban dwellers in order to subsidize lower income urban-slum and rural dwellers. Such a water board would in effect be using water charges as a tax.

21. Redistribution of real income in a developing country may be accomplished through the water supply sector by serving both rural villages and urban slums. Indeed, it is possible that meeting increasing urban area water supply needs should take precedence over rural programs if a failure to do so results in urban water supplies being furnished on an intermittent basis which, because of wastewater seepage, could turn a water distribution system into a vehicle for the transmission of disease. Eliminating intermittent water service frequently is of a primary benefit to the lower income groups; for only the relatively wealthy have private storage tanks or the money to install pumps to suck water from the main. Intermittent service in a rural village, it should be noted, might not be quite as undesirable from a health point of view since there will normally be no sewerage lines from which seepage can occur.

22. The income distribution case for financing rural water supply systems is not as straightforward as is generally thought. In many countries it is the wealthier villages which receive priority in obtaining water supply because of their political influence, their greater awareness of the benefits of clean water, and the greater chance that their systems will operate efficiently. Furthermore, from a health and income distribution point of view higher income rural villages are probably less in need of assistance than the urban slums, where alternative sources of supply are less available, where greater population density may encourage communicable disease, and where, moreover, subsidies can be generated from higher income users in the larger metropolitan system.

System Design

23. When designing and constructing a rural water supply project, the technology involved should be kept as simple as is possible so that local operators will be able to operate and maintain the system for long periods of time in the absence of a qualified engineer.

24. The design capacity of rural water supply systems should be at least partially dependent upon the presence of economies of scale and the relevant discount rate. In most instances, community needs for a period of not longer than 10 years provide a reasonable design capacity.

25. The quality of service or design criteria for a rural water system should depend primarily on the system's desired goals. Whether or
not residents in a village should have house connections or public standposts is part of the overall quality of service question and should be decided by considering (a) the quantity of water which the villagers should consume to meet minimum health standards, and (b) the expressed demands of water consumers to pay for more convenient house installations.

26. There are economies of scale associated with water supply construction and, for equivalent levels of service, per capita costs of urban systems will usually be lower than for rural. However, per capita costs of rural water supply installations can be less than urban installations, since per capita consumption may be less and the quality of water service lower. Investment programs should be specific in detailing the standards of service that are being aimed at in order that misunderstandings by budgetary and national planning authorities may be avoided.

Administration and Finance

27. The major administrative problems associated with providing water supplies in rural areas of developing countries relate to the operation and maintenance of the systems. In most developing countries it is difficult to find villages where the systems are working precisely as planned (both technically and financially), and it is common to find even relatively new systems which are not functioning at all.

28. Assigning a high priority for water service to villages which can pay a user-fee at least sufficient to cover operation and maintenance expenses, and which are enthusiastic about receiving improved water, increases the probability that the water supply systems will remain operational for a significant period of time.

29. There is some evidence that villages tend to value their water systems more highly, make better use of the systems, and operate and maintain them more efficiently when they have contributed resources (labor and/or money) to help cover construction costs, and are paying user-fees which at least cover operation and maintenance expenses.

30. Encouraging villages to contribute free labor to the construction of their piped water supply systems can lower both the economic and financial costs of the systems and can stimulate the rural population to take pride in their systems. However, numerous instances have been reported where difficulties with the reliability of the free labor force have more than negated any financial savings. In general, a community's contribution of free labor must be encouraged and closely supervised by a capable community water supply promoter, and any work which he does to encourage and supervise the free labor should be counted as one of the costs of the labor.
31. There is some evidence that a community water supply program which requires a contribution (labor or money) from village populations can be used as a catalyst to stimulate a community organizational infrastructure which will continue to function after the water supply project has been completed.

32. The level of education and skills which exist among the rural population is one of the major factors to consider in determining whether or not the operation and maintenance phase of the program should have a national, regional, or local administrative base. When village systems are turned over to low income, relatively uneducated local authorities to operate, the probability of system failure is high. However, many failures have been accompanied by a reluctance on the part of central water authorities to use their best men for the highly important function of training village operating personnel. In cases where it is decided that system operation and maintenance must be handled on a highly centralized basis, it is desirable to at least set up local village advisory committees so that local populations feel the water systems are their own and will take pride in seeing the systems operate properly.

33. To achieve efficient management and avoid duplication of effort, the national rural water supply program should be under the control of, and/or be coordinated by, one national or regional agency. The specific agency which should be in charge (an independent Water Board, Ministry of Public Works, National Planning or Rural Development Authority, Ministry of Agriculture, etc.) depends on the major goals of the program.

34. There are several advantages of combining urban and rural water supply systems under one semi-autonomous water board. In particular, such a board could (a) provide a stable source of revenue to subsidize rural operation and maintenance expenses, and (b) assure a greater availability of experienced engineers to supervise and provide technical assistance for operation and maintenance.

35. To increase the probability that permanent health and economic benefits will occur, the water supply program should provide for the training of pump or system operators, bill collectors and community promoters. An educational program for villagers which focuses on good sanitation and water-use habits and on any village gardening or livestock watering potential of the system should also be provided.

36. An output-oriented bonus incentive system for local and regional employees of the water supply program might be of value in increasing the probability that the continuing goals of the program are met at the local level.
I. INTRODUCTION

Objective of This Report

The objective of this report is to examine and summarize the important factors which must be considered by an agency or government which is considering becoming involved in rural or village water supply programs in less developed countries. This report reflects input from a literature survey (see bibliography) as well as field trips to South America, Asia, and Africa.

Essentially, the report attempts to (a) review the literature pertaining to rural water supply investments, (b) isolate and examine the relevant factors which must be considered before and during investment in rural water supply programs, and (c) pinpoint problem areas which need further examination. Attention is focused on alternative policy-related actions which affect costs and benefits of rural water supply systems.

Why the Emphasis on Rural Areas or Villages Rather Than on Big Cities?

When reviewing benefits and costs of investments in potable water supply systems in developing countries two basic questions keep reoccurring. First, to what extent does investment in water supply systems in rural areas represent an efficient allocation of the limited external and internal resources which are available to a developing country; and second, how far should economic growth considerations be subordinated to income distributional or other similar social goals. Whatever the decision about goals, however, it is clear that the achievement of non-quantifiable goals must in practice be weighed against the resulting economic efficiency implications.

An argument can be made that concentrating economic and social overhead investment in the more urban and densely populated "growth" areas would yield, in both the short and the long run, the greatest real return to the scarce resources of a less developed country. Whether or not this general argument applies to a specific investment decision in a particular country depends on the situation in the country or region at that time. However, if one of the objectives of the country is to attempt to maximize its rate of economic development it should examine its investment priorities and growth strategy very closely before committing resources to a less than "maximum probable return" program.

On the other hand, there are a number of reasons frequently cited (some reasonable and some not so reasonable) concerning why less developed countries and international agencies should become involved in water supply projects in "rural" areas. In many cases these contended reasons are not mutually exclusive and the position taken by this report is simply to present them and not necessarily to specifically endorse or refute them. Following is a list and brief description of the more common ones.

1. (Maximize the Population Served Per Unit of Investment)

   It is generally accepted that if we hold quality of service, geological factors, and climate constant it is cheaper per person to provide water in
highly concentrated urban areas than in rural areas with sparsely settled or spatially separated populations (Henderson 1964). Given that an adequate water source can be developed, there are economies of scale associated with the provision and distribution of water and with the administration of water supply systems (Lauria, 1972).

However, proponents of water supply investment in rural areas argue that in many cases it is not necessary to provide the same quality of water service to residents of rural areas as to residents of more densely populated and sometimes more affluent urban areas. Residents of large urban areas generally consider it desirable to have house connections, some houses with multiple connections, or, at the very minimum, convenient neighborhood standposts. On the other hand, the protection of an existing water source, the provision of several protected wells with hand pumps, or the provision of a larger well, an infiltration gallery, or an earth dam with a standpost distribution system may be a relatively major improvement in many rural areas of less developed countries. In many cases this lower quality of service—but quite safe—rural system can be constructed at a lower per person cost than a higher quality-of-service urban system.

In addition, it is generally assumed that lower income consumers using the lower quality-of-service rural systems will consume a smaller per person amount of water daily and therefore, in addition to smaller per capita investment in the distribution system, investment in the water source will not have to be as large on a per capita basis. This is primarily because lower income rural users do not generally have water using appliances, flush toilets, or kitchen sinks. Further, rural dwellers use smaller amounts when they have to carry water to their houses instead of having it piped to the house under pressure (White, et.al., 1972, Chapter 5; R. P. Marfitt & Associates, 1969; Frankel and Shouvanaberakul, undated).

While specific cost figures relating to differences in quality of service between urban and rural areas are difficult to find, some empirical evidence exists to support the contention that per capita costs (presumably for lower quality of service) in rural areas can be lower. For example see Pierce, 1966, Unakul, et. al., 1970; Warner, 1970; PAHO, Community Water Supply and Sewage Disposal Programs, 1969, p. 91; White, et. al., 1972, pages 88-89; WHO, Strategy of Cholera Control, 1971, p. 17; and Donaldson, 1973, p. 23. When interpreting financial cost figures, however, care must be taken to insure that the figures include all the costs i.e. planning, central administration, personnel training, and ongoing technical assistance. Finally, in some cases rural construction costs can be lowered because rural populations are supposedly more willing than urban populations to work and contribute free (financially) labor to the project.

In summary, if it is accepted that the quality of service in rural areas can or should be less than in urban areas, it is possible that an objective of maximizing population served per unit of investment can be accomplished by concentrating on a lower quality of service in rural water supply investment. Essentially this would involve a trade-off between economies of scale and density in urban areas and a lower quality of service in rural areas.
An additional case can exist where investment in rural areas is cheaper on a per consumer basis over the near term. This is where readily available sources of water have been used up around the developing country's big urban areas (long run marginal cost is rising very steeply) and a massive investment would be required to increase the available water supply to these areas (a major dam, reservoir, or lengthy aqueduct). In this case it might be cheaper on a per person basis to provide water in non-urban areas where low volume-relatively cheap sources of supply could be developed for the rural population. Arguing for water supply investment in rural areas on this bases, however, would not generally lead to an efficient resource allocation unless, possibly, the growth of the urban areas was completely stopped. This of course is very unlikely in most less developed countries.

2. (A Greater Proportion of the Poor Population in Most Developing Countries Live in Rural Areas and They Should Have Potable Water)

The implication of this "serve the people" argument is that the primary objective of investment in water supplies in a developing country should be a redistribution of real income. If it holds that income is higher in urban areas, then a program which uses scarce resources to provide water to rural areas is a program designed to redistribute the real income or resources of the country. If real returns on investment are higher in urban areas, a rural water supply program, although achieving some degree of real income redistribution within the country, would not necessarily be the way to achieve the country's maximum economic growth.

3. (Slow Rural to Urban Population Migration)

Most developing countries have been experiencing a migration of population from rural to urban areas. It is often true that this rapid flow of population puts a great strain on the social and economic overhead capital of the big urban areas and it is argued that if the population inflow were slowed the big cities would be better able to absorb and generate employment for new immigrants and to cope with internal development problems. Rural water supply programs have been suggested as a means of slowing the rural to urban migration because they can ease at least one of the basic causes. (Other causes include a lack of job opportunities, inferior social, economic, and health care amenities, and relatively poorer quality educational opportunities. See Levy and Wadycki, 1972, for a brief summary of some of the developing country migration literature.)

This argument contains some logic and a rural water supply program would certainly be one place to start in reducing the "push" factors of migration. However, it is also probable that isolated improvements in rural water supplies will not, in most countries, slow migration appreciably. People migrate for a variety of reasons and the relative short or long run lure of jobs, higher incomes, and educational opportunities in urban areas would generally be unchanged by the provision of rural water supply systems.

Of course, through time, if rural water supply systems, which are improvements in the local infrastructure, result in an increase in economic activity in rural areas, migration may be slowed. On the other hand, if improved rural water systems were to result in a more healthy and vigorous rural population,
more migrants might journey to the cities looking for alternative employment and education opportunities.

In summary, the contention that improving village water supplies in rural areas might significantly slow migration to the cities is an interesting theoretical possibility; however, at this time there is very little empirical evidence to support it, and there is some limited evidence which does not support it.

A related contention which deserves a brief review relates to the fact that there is some statistical evidence from both developing and developed countries which suggests that migrants generally do not go directly from the dispersed population rural areas to the big cities (Redford, 1968; Appalachia, 1969; Riddell and Harvey, 1972; Lowry, 1966; Safilios-Rothschild, 1971). Instead, in many cases there is a tendency to move first to the nearest regional population center (intermediate size city or larger village) and, after an indeterminant stay, to move on to the capital city or to one of the country's other large urban areas.

As a result of this the argument is sometimes made that if one of the objectives of a national development policy is to slow the migration into the very large urban centers, then resources should be channeled into the intermediate size regional population centers in an attempt to stimulate their economic viability and to make them attractive enough to hold the population flowing through them. Following this reasoning, and given a scarcity of national resources in the water supply sector, a country attempting to slow migration into the capital city would attempt to improve or install water supply systems in intermediate or secondary size cities and villages and not necessarily use up investment in the improvement or protection of systems in the more rural areas (see the discussion on growth points in Chapter VI). However, since empirical studies have shown that migrants are primarily responsive to employment, income, and education opportunities, the investment in water supply should be followed up, or supplemented, by employment or education generating activity in order to increase the probability of a significant decline in out-migration (Levy and Wadycki, 1972).

Finally, it is worth noting that an alternative argument has been made that policies aimed at encouraging the growth of regional intermediate size cities or villages could actually increase the flow of population to the largest or capital city. This would be the case if the more visible and prosperous regional centers attracted an increased number of migrants from the rural areas who in turn, after an indeterminant stay, passed on to the biggest or capital city (Riddell and Harvey, 1972).

4. (Attempt to Achieve Optimum City Size)

Related to the above population migration argument for rural water supplies is the contention that the very large urban areas are already too large to be compatible with an efficient allocation of national resources and that additional water supply and other social and economic investment in the "big" cities could result in an even greater misallocation of national resources. This argument is essentially that as cities grow they experience economies of scale up to a
certain size. After reaching that "certain" size, average costs of providing public services begin to rise and as the cities grow even larger significant diseconomies of scale are experienced. The so-called optimum size city would of course depend on many factors but several studies based on a minimum public service cost approach suggest that the lowest average public service cost occurs with a population of between 30,000 and 250,000, with larger average costs occurring in cities with populations of over 250,000 or in very small cities with a population of less than approximately 5,000 (Associazione per lo sviluppo dell' industria nel Mezzogiorno, 1967; Alonso, 1971; Khorev, 1969).

Other evidence suggests, however, that the cost of infrastructure for "an increase in industrial activity" declines or at least remains relatively constant with increases in city size (R. Morse, et. al., 1968). Further, a cursory examination of the relation of urban costs and total urban product with city size in West Germany, Japan, the U.S.S.R. and the U.S.A. suggests that the biggest cities are not too big from the viewpoint of economic efficiency i.e., as cities get larger average costs do increase, but not as rapidly as average output (Alonso, 1971). In summary, since the empirical evidence relating to a so-called optimum size for cities is spotty and generally inconclusive, investment in water supply systems in rural areas should probably be based on arguments that can be better supported.

5. (Financial Viability)

The contention is also made that rural areas deserve "special" attention because in many cases public water supply systems in rural areas cannot be immediately self-supporting. Because of the low income and economic productivity of the population (low ability to pay) rural systems may have to be subsidized. Therefore it is argued that special financial and economic arrangements should be implemented in a special program for rural areas.

This urban-rural financial viability dichotomy is probably valid for many low income subsistence agriculture countries in Africa, Asia, and parts of South America. However, using this as a reason for devoting scarce resources to rural areas rather than urban areas is essentially contending, again, that there should be a redistribution of real income in the country from urban to rural areas.

6. (Diminishing Benefits in Cities with Existing Systems)

In a more advanced developing country where all big cities and most intermediate size towns have some form of functioning water supply system, it is sometimes argued that greater health and economic benefits will be generated if water is improved in rural "bad water" areas rather than urban ones. The argument is that while urban areas may need additional investment to reach World Health Organization water supply standards, the actual change in health and economic activity generated by the urban water supply improvement will be small relative to the change that would be generated by a series of new water supply systems being set up in rural areas or smaller villages which are completely without potable water systems. Additional investment in urban areas would run into diminishing returns while initial investment in rural areas would not immediately experience that problem. There is very little empirical evidence available which relates specifically to this contention.
It is worth noting that there is at least one argument for improving the water supply systems of the big cities which cannot be ignored. It is argued that in some cases meeting the demands imposed by the increasing population pressure in larger cities should take precedence since failure to do so may result in water supplies being furnished on an intermittent basis which, because of wastewater seepage, could turn the water distribution system into a vehicle for the transmission of the very diseases which water supply systems are designed to prevent.

7. (Political Considerations)

Any discussion of the reasons given for making investments in rural rather than urban areas in developing countries would be remiss if purely political considerations were not mentioned. There are numerous cases, of course, where investment in rural areas in water supply systems, as well as in other forms of economic and social overhead capital, are made for local or national political reasons which overshadow economic, engineering, and social priorities. One example might be that village agitation for a water supply system is conveyed to a political representative and it is largely the representative's influence, rather than the intrinsic value of the particular project, which causes a reallocation of funds to the village. In practice this might mean that the more articulate, better educated communities obtain priority. As noted in Chapter VI, where strategies for choosing villages are discussed, this might not be a bad solution.
II. DEFINITIONAL PROBLEMS

The focus of this report is on supplying water for human consumption in rural areas of developing countries. Supplying water for the primary purpose of agricultural irrigation or industrial or commercial use, with secondary human consumption goals will not be considered in detail. In irrigation or multiple-purpose industrial water supply projects the measurable economic benefits of the project, in most cases, would overshadow the measurable direct human-related benefits so that investment decisions would depend primarily on projected changes in the short-run agricultural output or economic activity of the area.

For purposes of this report an improved water supply will include everything from a relatively sophisticated pumping, storage, treatment, and distribution system to a simple protected spring or well with no storage, treatment, or extensive distribution system.

No specific distance to, or time necessary to reach, a supply of water will be used as a cutoff to determine when a source of water is not actually an accessible water supply. In some rural areas of developing countries women and children travel for over an hour each way to and from a source of water. Generally, whether or not a particular improved water supply is accessible, and will be used by the local population, is a relative question and depends on available water supply alternatives during that season of the year and on the local population's perception of the value of clean water.

It is further assumed that the amount of water used on a per capita basis for human consumption will depend primarily on the accessibility of the water, with water supplied through house taps under pressure resulting in greater per capita consumption than if water must be carried to the house in containers.

Alternative Definitions of Village or Rural Water Supplies

When examining "rural" or village water supply systems the question which always arises is what constitutes a rural area or what exactly is a "village". For purposes of water supply investment there are many alternative ways to define rural or village target areas and most of the definitions noted here are in use somewhere. Following is a list and brief discussion of several ways in which rural has been defined or categorized for purposes of water supply. These definitions are not necessarily mutually exclusive.

1. (Population Size).

Limits on the size of population of eligible villages to receive improved water is the most common means of defining rural. This size-of-population definition is, of course, somewhat arbitrary and it varies widely from country to country, region to region, and sometimes among different program agencies within the same country. Generally, for "rural" water supply programs the lower limit seems to vary from settlements with more than 300 village inhabitants to "rural" cities with a
population of over 20,000. A few examples of population size definitions include (a) a program administered by the Ministry of Health in Peru which concentrates on villages with a population of less than 2,000, (b) a program administered by the Secretary of Hydraulic Resources in Argentina which concentrates on towns with a population of 3,000 or less inhabitants who can be feasibly connected to a central water system, (c) a program in Mexico administered by the Ministry of Health concentrating on towns with a population of less than 2,500 and a sister program administered by the Secretary of Hydraulic Resources concentrating on towns with a population of 2,500 to 5,000, (d) a program administered by the national water agency (INAPA) in The Dominican Republic which is attempting to serve all localities with a population of 2,000 or less in which there is a concentrated population of at least 500, and (e) a program administered by the Sanitary Engineering Division of the Ministry of Health in Thailand which concentrates on communities with a population between 500 and 5,000.

One advantage of a population size definition is that the country can review its needs, its available resources, the institutions within the government, and its priorities and then assign "workable" village population size limits that fit best. The major problem with the population size definition is that if the limits are strictly adhered to, the largest rural communities could receive water supply investment priority over the smallest so-called urban communities.

2. (Population Density, Clusters, and Agglomerations).

Modifications to the size of population guideline for villages can be made to allow for cases where two or more very small villages are located close to one another or for clusters of relatively dense population not centered around a particular village. In cases such as these some additional cluster or population density parameter might be included in the program definition to allow the engineers and planners greater flexibility of system location and design. The Dominican Republic definition cited above in which the localities with a population of 2,000 or less must have a "concentrated" population of at least 500 is an example of a definition of this sort.

In several countries, notably India, it is common to find many villages being served by the same water source. Even though, in many cases, a single network serves a large population, it is still considered a rural system. Using an approach such as this a complete valley might be served by one system even though several of the villages in the valley are smaller than would be sufficient to be supplied separately.

3. (Financial Viability).

As noted previously, due to the low income of rural populations in developing countries water supply investments in the rural areas of many countries may not be financially viable (able to cover maintenance, operating cost, depreciation, loan repayments, and interest) in the foreseeable future. Consequently, for program purposes "rural"
areas could be defined as areas which are not, with a certain degree of probability, financially viable. This would have to be taken into consideration in the planning, design, construction, and administrative and technical support phases of the program. Projects that will sustain themselves financially are a lesser problem.

There are many reasons for the financial non-viability of projects. Existing projects are non-viable because (a) the cost of the project was relatively large due to geography, geology, climate, or inefficient design and/or administration, (b) there is little economic activity in the area and the recipient population has a very low income, (c) the administrative organization of the scheme is inadequate, is out of control, or is just inefficient, (d) there is an inadequate pricing or taxation scheme by which the project is supposed to generate revenue, or (e) the country has a national or regional policy of subsidization, whether or not the population can pay the full cost.

In some countries a combination of the above factors may be present in communities in such a way as to be roughly coincidental with a more easily measurable economic or demographic characteristic. In Ghana, for example, rural systems are defined as those which supply water to communities with populations of 10,000 and below. This is because, in Ghana, a community with a population less than 10,000 is thought to be generally unable to support urban (economic) rates of service.

There is of course a difference between an individual project being financially nonviable and the overall scheme or program being nonviable. Presumably, if a few projects could not pay for themselves but others in the program were capable of generating slight surpluses the program could be viable and there would be no financial problem. This situation is an equivalent to that experienced in most large cities in the developing world where cross-subsidization between the relatively high income population and the inhabitants of urban slums is possible.

Finally, if an open-ended "not financially viable" definition is used for "rural" one would have to be prepared for an occasional very large project with some unique problems. For example, there is some doubt if Calcutta, India with a population in the millions will have an expanded water supply system which is financially viable in the foreseeable future.

4. (Technical, Administrative, and Regional Requirements of the Water System).

There exists a contention that the major factor in differences among water supply programs is not financial or size-related, but is related to technical and administrative requirements. For example, community wells with hand pumps, protected springs, or earth dams serving low density rural populations usually require a level of technology and administrative organization that is quite different from a system which entails a pumped well or other pumped water source, some storage facilities, and a rudimentary distribution network to several public
standposts and a few house connections. A more sophisticated system yet might entail a larger source and pumping facilities, a larger storage tank, some filtration or chlorination facilities, and multiple outlets to standposts and private dwellings, some of which are metered. This system would require an even higher level of expertise for maintenance and administration.

In view of this, rather than classifying systems by names such as urban or rural it has been suggested that the classification system should relate more to the differences in the technical and administrative requirements of the system.

Related to differences in potential technical and administrative requirements brought about by differences of population density, local technical expertise, income of the population, etc., are differences in the availability of an adequate water source. A program designed to be undertaken in a relatively arid or mountainous region of a country would generally experience an entirely different set of problems from one being undertaken in a rainforest or in a coastal section of that same country. When defining which types of communities should be targeted for inclusion in a country's rural water supply program, regional variations in climate, geology, and geography should be considered.

5. (Relative Prominence of Local Institutions, Local Leaders, or Local Government).

Related to the technical and administrative difference definition is the suggestion that villages or areas should be classified or assigned priorities on the basis of the ability and willingness of local government, or local institutions, to generate the support and active participation of the local population. It is argued that a stable, enthusiastic, and widely accepted local leadership can bring about a project's financial, health-related, and economic success by generating local labor for construction, by making certain the system is maintained and used through time, and by helping collect fees for water use. Villages which cannot generate local leadership support and enthusiasm for an improved water supply system will have a much higher probability of project failure and will require a greater initial financial investment and a greater flow of maintenance expenses through time while the economic, social, and health benefits of the project will be less pronounced.

In support of this contention, it is not uncommon to find statements made by evaluators of existing rural systems such as: "it has been observed that greater numbers of those supposedly served by the wells are not using them during seasons when a nearby pond, canal, or backyard dug well has plenty of water at shorter carrying distance, or are not using the water at all because of taste or high iron content, or prefer a traditional family source" (McJunkin, 1969); "The maintenance of hand pumps has so far proved to be an insurmountable problem" (McJunkin, 1969). Consequently, a characteristic which might define a rural area for water supply purposes is that the probability of project success is acceptable only if promotional, financial, educational, and technical assistance is
available locally or is imported from outside the area. Typically one would expect this necessary expertise to be found in urban areas.

An alternative possibility is that eligible rural villages might be defined as those which have good local leadership and which are able to generate enthusiasm for the water supply project. In this case only those villages which had good leadership and which were very enthusiastic would be considered eligible for participation in the rural water supply program.

6. (Structure of Industry, Employment, or Income in the Area).

Another approach for defining what is a rural community and what is not for purposes of water supply investment relates to the essential economic underpinnings of the area. A community in which the primary source of employment is in agriculture, or possibly subsistence agriculture, could be classified as a rural community for purposes of potable water supply investment. A rural community definition such as this was suggested by UNESCO in 1958 and is in use in the USSR (Donaldson, 1972).

It is sometimes argued, by administrators who are involved in programs which require some community participation, that villages in which the primary employment base is agriculture are generally more willing to organize and contribute labor to the digging of the distribution system and, perhaps, to the hauling of gravel for construction. This might be because there is generally a greater amount of underemployment, and therefore free time in these villages, or perhaps because people in some farming communities are accustomed to cooperating and working together during such times as harvest and planting.

A variant to an employment structure definition is one which takes account of the relative income level of the population of the villages or rural areas. For example, if the per capita or median family income of a village or area is in the bottom one-third of the distribution of incomes in the country, then, those villages may qualify for water supply systems under slightly different financial and self-help conditions from those which are better off economically. Or alternatively, they might be passed over completely as being poor risks for public investment-induced economic development.

Depending on the goals and priorities of the country, the policy variants are endless. The point is, however, that employment structure and income are important parameters for differentiating communities or regions.


Another approach to deciding which is a rural village, for purposes of inclusion in a "rural" water supply program, is to look at the areas or villages from which population are migrating. If one of the goals of the country is to slow the rate of population migration to the capital
or "big" cities, those areas or villages with the largest out-migration rates might be given a high priority in the definition of what kinds of areas or villages would qualify for aid in constructing water supply systems. However, as noted in Chapter I, there is some doubt about the extent to which improved water will effect outmigration.

Other Definitional Considerations

In practice, when choosing the types of villages which should be served under a particular water supply program there will be an overlap in the villages or geographic areas which fit under the above possible considerations for definitions. An "eligible" village with a population between 500 and 4,000 could also be a source of outmigration to urban areas, have a predominately subsistence agriculture economy, and a strong and supportive local government, and be close to several other smaller clusters of population which could also be served efficiently from a central water supply system.

In choosing an exact definition and a program focus, the way in which the country's rural population is located on a spatial basis is probably one of the most important factors to consider. It is generally not feasible, because of high per capita costs, to provide potable water near all dwellings when the target population is relatively dispersed. In the case of a so-called "dispersed" population which is not concentrated in clusters or in villages with more than the equivalent of 80 to 100 single family dwellings the best that can probably be done is to sponsor a program of occasional protected springs, or dug wells with hand pumps, each of which serve a particular geographical area. A more sophisticated system for a dispersed population would generally be very costly on a per-consumer basis. A program for non-clustered population could simply be called a "Dispersed Population Rural Water Supply Program" or some similar name which actually describes the problem which is the focus of the program. Of course, there are many acceptable ways in which to define or classify problem-oriented programs for a particular country. One example of a specific classification system is the one which has been proposed by the Pan American Health Organization (Donaldson, 1973) in which the possibilities were consolidated into three groups: (a) a community well program for the dispersed population, (b) a rudimentary aqueduct program for semi-concentrated populations, and (c) a rural aqueduct program for the concentrated and village populations.

Ignoring differences in the cost of obtaining water from different sources, when considering relatively more sophisticated piped water supply systems for clusters of population in rural areas, the average per-consumer cost of the system tends to be less for larger villages. Larger villages also tend to be better able financially to contribute to the support of a piped system and in some countries are more likely to contain a population which have the skills to be trained to help maintain a piped system. Figure I illustrates this general over-simplified relationship.
The point is that the less the population is dispersed (the more spatially concentrated) the more likely it is that a water supply system can be financially viable, and will be properly maintained, not only because of higher per capita income but also because average system costs will be lower (Lauria, 1972). Experience in several Latin American countries indicates that for a water supply system with storage and distribution facilities and with a mixture of house connections and public fountains, the minimum size village which can be served satisfactorily is one with 100 dwellings, or approximately 500 to 700 people. A so-called satisfactory system would mean one that functions technically as it was designed to do and in which the financial contribution of the water consumer covers at least operating and maintenance costs. Clearly, however, the minimum size of the system will vary from one part of the world to another.

Given these general size-cost guidelines, a rural water supply program which is designed to do more than dig wells and install hand pumps could actually be defined as "non-urban concentrated population" water supply program. In fact, one of the effects of a non-urban concentrated population water supply program could be to further concentrate or cluster rural population. This is one of the objectives of the rural water supply program in Mexico. In Mexico in 1971, approximately 13,600 communities had a population between 500 and 2,500. These communities were targeted as communities which should be served by a rural water supply program. It was hoped that by providing water to these communities they would increasingly attract some of the 9.5 million people living in the 87 thousand communities with a population less than 500. If so, more people would be served with available resources at a lower average cost.

Even a "dispersed population well program" could serve to concentrate population into clusters. In Panama, water supply systems are currently
being introduced into communities which essentially grew up around wells with hand pumps which were installed with UNICEF assistance in the early 1960's. Exact data on the specific reasons for the increased population clustering are not available but the protected wells with hand pumps could have been a contributing factor.

Arriving at an Acceptable Definition of Rural for Water Supply Purposes

As outlined in the preceding sections, the obvious reason for having different sets of conditions for supplying water in urban and rural areas is that there are sometimes different problems to be overcome and different goals to be met. If there were not differences, there would be no reason to create different water supply programs for so-called urban and rural areas.

Essentially, the larger urban water supply systems experience economies of scale in water production and usually are financially viable. Since they are financially viable, it can be assumed that the benefits of the water supply systems are at least equal to the costs of supplying the water.

On the other hand, rural water supply systems, for an equal quality of water supply service, usually have higher average costs and in many cases are not financially viable. If rural systems are not financially viable, benefit measurement becomes a problem and financial subsidy provisions must be arranged. Also, extra attention must be given to assuring the continued proper operation and maintenance of the systems and perhaps to setting up local self-help programs in an attempt to lower both construction and operating costs.

With this in mind, when defining "rural" for purposes of a rural water supply and sanitation program the following factors also should be used as guidelines.

1. Towns and villages which qualify for subsidy provisions under the program should be incapable of paying the total costs of their water supply systems themselves. If they can pay the total costs (including ongoing operation, maintenance, and technical assistance) of a water supply system with a quality of service not too far below the norm for most urban areas in the country, they should be eligible to receive loans under the National Urban Water Supply Program. (The major distinction between urban and rural has been removed.)

2. Towns and villages which qualify under the rural program should be able to demonstrate that a potable water supply system will solve some of the problems which have been termed priority problems by the national government. For example, the towns might have water-related health problems, or the economic development of the towns might be demonstrably held back by a lack of a piped water supply.

3. The requirements by which towns and villages qualify under the so-called rural program should be flexible as far as community size and location. There should be no totally inflexible population cutoff figures (Politically or institutionally this may sometimes be impossible.) Low income urban suburbs as well as rural towns
and villages should be able to qualify for the program. In fact, any community should be able to qualify under the so-called rural program if it meets the above requirements, including inability to pay total costs, and if it can meet program standards for repayment, total cost, per capita cost, village participation, etc.

4. Towns and villages which qualify under the so-called rural program should be able to choose the quality of water supply service which they receive if they are able to pay the incremental costs of any improvements in quality of service above the program minimums. For example, if a small village wants taps at each dwelling (which brings them up to urban area standards) and will pay the difference in cost between that system and the basic lower-quality communal tap system, they should be able to receive the better system under the rural program. (The village of course cannot be able to cover the total costs of the higher quality of service system or it would not qualify for the rural program.) Conversely, if a larger town cannot pay the extra amount for, or would not make efficient use of, a water supply system with taps at most dwellings, it should not be provided with such a high quality of service system.

5. The institution or agency which administers the so-called rural water supply program should have institutional goals similar to the goals of the program, should have some experience working with smaller communities in provincial areas, should have close ties with other agencies which are administering related environmental sanitation programs, and should have the technical expertise not only to administer the construction phase of the program, but also to make sure that the rural water supply systems are properly operated and maintained through time. In addition, institutionally there should be no competition between so-called rural and urban areas or programs for water supply investment. Water supply investment should be allocated on the basis of national priorities.
III. IMPROVED HEALTH

An improvement in water supply and sanitation can generate health, economic, and social benefits for a so-called rural population. While such benefits are used to justify massive investment expenditures, in practice they are difficult to identify and still more difficult to measure. It is, of course, possible to make rational decisions about unquantifiable goals or benefits if the net economic costs of achieving them are known. Unfortunately, however, frequently even this information is unavailable.

There are many possible goals (benefits) of a rural water supply and sanitation program. This Chapter will discuss one of the goals which is frequently cited in existing project literature, improved health. Other goals to be discussed in following chapters are (a) economic growth and output, (b) income redistribution, (c) spatial population changes, (d) establishment of an organizational infrastructure, and (e) changes in the quality of life. An attempt will be made to note some of the major problems associated with achieving each goal as well as some of the problems in assessing the extent of potential benefits associated with each goal.

Water-Associated Diseases and Their Link with Man

Water-associated diseases which affect the health of man are relatively widespread in rural areas of less developed countries. Their incidence depends specifically on local climate, geography, culture, sanitary habits, and facilities, and, of course, the quantity and quality of the local water supply.

Table III-1 shows in summary fashion how some of the more common water-associated diseases are transmitted to man. They are broken down into four general groups which are somewhat useful for helping to predict the likely effects of changes in water supply upon the health of man. An explanation of the classification system is as follows (the groups are not necessarily mutually exclusive):

Diseases Related to Poor Sanitation: lack of water, lack of proper waste disposal facilities, and poor personal hygiene create conditions favorable for the spread of disease.

Waterborne Diseases: water acts as a passive vehicle for the infecting agent.

1/ The four-group classification system and the group definitions which follow are derivatives of those proposed by Gilbert White, et. al., 1972 and by David Bradley, 1971. The primary source of the disease transmission information presented in Table III-1 was Arthur P. Miller, 1962.
<table>
<thead>
<tr>
<th>Classification</th>
<th>Definition Of Class</th>
<th>Diseases in Each Class</th>
<th>Ways in Which Infecting Agents Reach Man</th>
</tr>
</thead>
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<td>Diseases Related to Poor Sanitation</td>
<td>Lack of Water, Lack of Proper Waste Disposal Facilities, and Poor Personal Hygiene Create Conditions Favorable for the Spread</td>
<td>Ascariasis (Roundworm)</td>
<td>eggs in feces-soil-water-man</td>
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<td>Trichuriasis (Roundworm)</td>
<td>eggs in soil-water-man</td>
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<td>Whipworm (Enterobiasis)</td>
<td>eggs-clothing-bedding-food-water-man</td>
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<td>Hookworm (Ancylostomiasis)</td>
<td>soil-skin penetration-man, water-ingestion-man</td>
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<td>Paratyphoid Fever</td>
<td>food-milk-contact-shellfish-soiled hands-water</td>
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<td>Salmonellosis</td>
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<td>Scabies</td>
<td>mites-contact</td>
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<td>Bacillary Dysentery (Shigella)</td>
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<td>Trachoma</td>
<td>contaminated hands-houseflies-water</td>
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<td>Typhus</td>
<td>contaminated hands, hair, lice, fleas</td>
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<td>Waterborne Diseases</td>
<td>Water Acts as a Passive Vehicle for the Infecting Agent</td>
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<td>water</td>
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<td>Infectious Hepatitis</td>
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<td>Leptospirosis</td>
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<td>Typhoid Fever</td>
<td>food-flies-contact-water</td>
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<td>Amebiasis</td>
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<td>Classification</td>
<td>Definition Of Class</td>
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<tr>
<td>Water-Based Diseases</td>
<td>Diseases Where a Necessary Part of the Life Cycle of the Infecting Agent Takes Place in Aquatic Animals</td>
<td>Schistosomiasis (Bilharziasis)</td>
<td>water-snails-water-man</td>
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<td>Dracontiasis (Guinea Worm)</td>
<td>water-crustacean-man</td>
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<td>Echinococcosis (Hydatidosis)</td>
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<td>Water-Related Diseases</td>
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<td>Dengue</td>
<td>man-mosquito-man</td>
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<td>Diphyllobothriasis</td>
<td>crustacean-fish-man</td>
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<td>Encephalitis</td>
<td>animals-mosquito-man</td>
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<td>Fasciolopiasis</td>
<td>snail-aquatic plant-man</td>
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<td>Filariasis</td>
<td>man-mosquito-man</td>
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<td>Loaiasis</td>
<td>man-fly-man</td>
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<td>Malaria</td>
<td>man-mosquito-man</td>
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<td>Onchocerciasis</td>
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<td>Paragonimiasis</td>
<td>man-snail-crayfish-man-animals</td>
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<td>animals-mosquito-man</td>
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<td>Yellow Fever</td>
<td>man-mosquito-man-animals</td>
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<td></td>
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<td>West Nile Fever</td>
<td>man-mosquito</td>
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Water-Based Diseases: diseases where a necessary part of the life-cycle of the infecting agent takes place in an aquatic animal

Water-Related Diseases: infections spread by insects that breed in water or bite near it

It can be assumed from the information supplied in Table III-1 that if all water in a rural area were improved to the point where pathogenic bacteria or disease-carrying vectors did not exist, or were not contaminated, the health of the local population would be better than that of a population living in a similar but unimproved area. Conceptually, this statement is true although, in practice, with limited resources for water supply and sanitation improvement, there are at least three major problems which a potential rural water supply and sanitation investor must consider.

These three problems relate to the fact that (a) there are multiple sources of diseases and there are a large variety of physical and cultural factors which must be taken into consideration in attempting to control these diseases, (b) a water and sanitation improvement scheme which eliminates all water-associated health problems would, in most rural areas of less developed countries, be very costly, if not impossible, in terms of available resources and in terms of the opportunity costs of those resources, and (c) as the project engineer or economist attempts to make tradeoffs between costs and benefits, he finds it difficult (and sometimes arbitrary) to attach a meaningful "value" or "measurable benefit" to different levels of "better" health.

Multiple Disease Sources and Disease Control Factors

In rural South America, Asia, or Africa improving and protecting a spring, or digging a protected well and installing a handpump, or drilling a borehole and setting up a small pumping and storage facility, a distribution system with several standposts and a few house connections will probably eliminate one potential source of a variety of different diseases. However, in most rural areas where disease is a problem any number of the following situations may exist: (a) many members of the local population occasionally visit a nearby area with unimproved water, (b) much of the population still prefers to bath or wash clothes in local waterholes or streams, (c) local cattle and insects are carriers of a variety of diseases, (d) much of the local fruit and vegetables are usually improperly washed, (e) local customs do not dictate the need for localized or sanitary excreta disposal, and (f) the drinking water dispensed at the spring or standposts is stored in containers which are sometimes open to flies and are frequently dipped into thereby exposing the water to a variety of parasites, bacteria, and viruses.

Given situations such as these, it is clear that while improved drinking water is probably a necessary condition for the improvement of people's health, it is not likely to be a sufficient condition. Health is affected by numerous
environmental, social, and cultural factors and as a result, it would be somewhat speculative to attempt to predict what the elimination of potential infections at the "official" water source would mean to the overall "health" of a community. In some cases an improved water supply might not significantly alter the health of the community; however, in other climates or types of terrain, or with house connections and other sanitary and health education measures taken in conjunction with the improvement of the supply of drinking water, it might aid in bringing about a significant improvement in local health. From a general sanitation point of view, however, it can be argued that other desirable sanitary measures, such as improved excreta disposal, food and market sanitation, personal hygiene, and village cleanliness, which are undertaken to prevent and control filth-borne diseases, are so dependent on the availability of a good water supply that permanent improvements in health are unlikely, if not impossible, unless a safe and convenient water supply either precedes or accompanies them.

Given the interrelationships between water supply and other environmental sanitation measures and health, the investor in rural or village water supply and sanitation faces a difficult problem. He must attempt to design a least-cost system of water supply and sanitation-related components which will, with an acceptable probability, bring the "health" of the specific community up to some predetermined "desired" level.

It is apparent that one of the inputs which are necessary in planning a water supply and sanitation program, which is at least partially designed to improve health in rural areas, is a knowledge of the extent of the improvements in health which, in past instances, have been associated with improved water supply and sanitation. The following section represents an attempt to provide an introduction to the empirical work which examines this water supply-health relationship.

The Empirical Evidence

A survey of existing literature has revealed that a variety of studies have been completed which have in some way empirically examined the association between water, sanitation, and health. For purposes of this review the more relevant ones are grouped according to the following five categories: Studies Dealing Primarily With Diarrheal Diseases; Studies Dealing With Several Diseases Including Skin and Diarrheal Diseases; Studies Dealing With Cholera; Studies Dealing With Schistosomiasis or Bilharziasis; Studies on Childhood Mortality.

-Diarrheal Disease-

Causes of Diarrhea can be classified as bacterial, parasitic, and viral (Summary Report on Diarrheal Diseases Studies, WHO, 1966). Shigellae, Salmonellae, and Enteropathogenic E. coli are bacterially caused while various parasites and helminths are related to parasitic causes. Diarrhea can also accompany various viruses. The following studies on the relation between diarrhea and water supply are essentially concerned with bacterial based causes of diarrhea.

1. (Helen Moore, et. al., "Diarrheal Disease Studies in Costa Rica", 1966). This study was undertaken to determine why gastroenteritis is the leading known cause of death in Costa Rica. Researchers examined
general sanitary conditions, rectal swabs, stool specimens, fly populations, and the bacteria content of water supplies, meat, milk and animals for a cross-section of the population. The conclusion stated that piped water was important in reducing infections with enteropathogenic bacteria but was not greatly effective in reducing diarrheal morbidity or parasite infestation. Moore stated that "had a larger proportion of the diarrhea cases been of bacterial etiology, an effect on diarrhea morbidity might also have been visible". However, high rates of ascaris infestation were noted with a lack of toilet facilities.

2. (Arthur C. Hollister, et.al., "Influence of Water Availability on Shigella Prevalence in Children of Farm Labor Families", 1955). This test for Shigella involved between 1/2 and 2/3 of all children ten years and under in California (U.S.A.) farm labor camps. They found Shigella in 1.6% of those living in cabins with inside water faucets, showers (tubs), and/or toilets, 3.0% of those living in cabins with inside water faucets but with all other facilities communal, and 5.8% of those living in cabins with no inside water or other facilities. The researchers then examined a selected group, part of which had no inside facilities and part of which had only an inside faucet. (Both subgroups had approximately the same number of people per shower and per toilet, and approximately the same volume of flies and garbage.) The availability of water for personal hygiene made a great difference; only 1.2% of the group with indoor water had the disease while 5.9% of those without an indoor faucet were infected.

3. (Leland McCabe and T.W. Haines, "Diarrheal Disease Control by Improved Human Excreta Disposal", 1957.) In 1952 a program was undertaken to upgrade the facilities for human excreta disposal in Boston, Georgia. Bore-hole privies were improved and expanded in 178 cases. This study showed a decrease in fly breeding in privies but no change in the number of flies. However, in 18 months following the improvements, there were significantly fewer shigella infections in children under ten years of age.

4. (D.J. Schiessmann, et.al., "Relation of Environmental Factors to the Occurrence of Enteric Diseases in Areas of Eastern Kentucky", 1958.) This study primarily involved a cross-section examination of conditions in seven mining camp areas of eastern Kentucky, U.S.A. between 1955 and 1957. Diarrheal disease rates were measured monthly by taking rectal swabs of preschool children. The presence of parasites was determined by the examination of stool specimens collected semi-annually from all age groups. Fly abundance and local water quality were also measured. The results of the study were that (a) shigella and parasites were found most frequently in children from the area with the poorest sanitation, (b) people with piped water inside their houses but a privy outside had two times as much enteric disease, two times as much shigella, and three times as much ascaris as those
with piped water and inside flush toilets, (c) ascaris infestation was three times as high in people whose water supply was outside the house, (d) shigella was 5 percent lower in children who lived in homes with an indoor water supply, (e) rates of shigella and ascaris were two to three times greater in people from homes without baths than with baths, (f) no association of disease rates with quality of drinking water was observed, (g) housefly abundance was not significantly correlated with morbidity or shigella prevalence, (h) the ratio of "summer" diarrhea to "winter" diarrhea for the years 1955 and 1956 was approximately 2 to 1. The authors concluded that the results of the study strongly support the premise that the incidence of acute infectious diarrheal disease may be reduced significantly through selective modification of specific environmental factors within communities without regard to etiological or sociological differences.

5. (J. Watt, et.al., "Diarrheal Diseases in Fresno County California", 1953.) This was primarily a cross-section study of a sample of migrant farmers living under different types of conditions in Fresno County California, U.S.A. Results showed that shigella rates were lowest in housing projects with plumbing in each house, next lowest in the same type of housing but where the occupants had a lower "socio-economic level", higher yet in housing with no indoor plumbing but with less than 15 people per water outlet, and highest in housing with no indoor plumbing and with more than 15 people per water outlet. A general conclusion was offered that if shigella were eliminated, diarrheal diseases would be reduced by approximately two-thirds.

6. (A. Rubenstein, et.al., "Effect of Improved Sanitary Facilities On Infant Diarrhea in a Hopi Village", 1969.) A Hopi Indian Village in Arizona, U.S.A. was divided into two parts; an upper area in which indoor plumbing was installed and a lower area which was left unchanged. An examination of the health of infants was made "from hospital records" for both areas of the village both before and after the plumbing installations. The results showed that the average number of visits to the hospital per child in their first year of life declined in the upper village from 2.0 before indoor plumbing to .85 visits after indoor plumbing. At the same time the rate in the lower village was declining from 3.1 to 2.6. The decline in the upper village was statistically significant at the .05 level. The decline in the lower village was not. There were several problems with the study which were noted. They included: there seemed to be basic political and social differences between the two parts of the village which might influence the illness of infants; there was no control for breast feeding; many lower village mothers seemed reluctant to seek hospital assistance; and there was no record of who had refrigerators.

7. (Miguel Kourany and Manuel Vasquez, "Housing and Certain Socio-environmental Factors and Prevalence of Enteropathogenic Bacteria Among Infants with Diarrheal Disease in Panama", 1969.) Cross section
data were collected from a sample of parents and from the National Census Bureau on housing, plumbing, sewage systems, number of plumbing outlets, the availability of running water, and diarrheal disease in infants. The general conclusion was that as general sanitation increased, the rate of enteropathogenic E. coli, shigella, and salmonella infections decreased. Other variables which were found to be associated with diarrheal disease were the health habits of the people (negative) and the density of the (urban) population (positive).

8. (William H. Stewart, et.al., "Diarrheal Disease Control Studies: The Relationship of Certain Environmental Factors to the Prevalence of Shigella Infection", 1955.) Researchers examined data on 28,000 rectal swab cultures from children in southwest Georgia, U.S.A. The data were grouped into four categories, poor, fair, good, or very good sanitation depending upon (1) location and type of water, (2) type of excreta disposal, (3) fly densities and potentials for fly population, (4) esthetic quality of the house and surroundings, and (5) structural quality of the house.

Among the conclusions of the study were the findings that (a) shigella infection rates in a neighborhood vary with the proportion of poor housing, (b) infection rates were higher where water was least available for personal hygiene (the availability of water for washing purposes must now be considered along with purity of water in any diarrheal disease control program), (c) infection rates were significantly higher for premises with water sources "far from the house" regardless of whether or not it was well or city water.

9. (WHO Diarrheal Diseases Advisory Team, "Report of a Survey of Diarrheal Diseases in Mauritius", 1960.) On a cross section basis several samples of children and their families were physically examined and rectal swab cultures were taken. The following were among the conclusions of the examinations: (a) greater diarrheal infection rates were found among those who had a less readily available water supply, (b) there was less diarrhea among those using municipal water, (c) occurrences of malnutrition and gastroenteritis were independent (not related) and (d) diarrhea occurs in children both over and under the average height and weight.

10. (WHO Diarrheal Diseases Advisory Team, "Studies on Diarrheal Diseases in Co-operation with the Ministry of Health of Venezuela", 1965.) Two villages were surveyed and briefly monitored. One, the village of Pompanito, was given an improved water system which 100 percent of the population could use. The other, Monay, was essentially tank-truck supported. In Pompanito 70 house connections and 22 standposts were set up. Generally the water was good at the source and the distribution system, but became contaminated in the house during storage. In Monay the water was contaminated at the source. Some regular bathing was possible in Pompanito but not in Monay. Study results showed that
diarrhea was "significantly" lower in Pompanito after the water system was introduced while at the same time there was no significant change in diarrhea rates in Monay. Diarrhea was also found to be more prominent among the children.

11. (WHO Diarrheal Diseases Advisory Team, "Follow-up Report of the Work Started by the Team in Co-operation with the Ministry of Health, Caracas, Venezuela", 1966.) This was a follow-up study of the above two villages and of several other areas. It included the collection of data on diarrhea cases (monthly), fly counts (bi-weekly), meteorological data (monthly), and water supply. Among the conclusions were (a) the area with the worst sanitation had the highest diarrhea rates, (b) the incidence of flies and diarrhea are dependent on climatological conditions (more infections after rain), (c) personal contact, not flies, seems to be the way diarrhea spreads, (d) children with diarrhea checked at health centers had one or more of the following: parasitic infection, trichiuris, balantidium coli, entamoeba histolytica, and lamblia, (e) the areas examined with the worst sanitation had the highest mortality rates, and (f) there were many problems with, and inaccuracies in, the data.

12. (WHO Diarrheal Diseases Advisory Team, "Report of Studies on Diarrheal Diseases by the Team in Co-operation with the Ministry of Health, Sudan", 1961.) This study attempted to compare two population groups which differed especially in their environmental sanitation. Among information collected were cross section data on family size, housing, economic status, and sanitation as well as general information on diarrhea infections and specific information on rectal swabs. Among the conclusions were (a) it took about twice as long to recover from a spell of diarrhea if the person had a lower standard of living, (b) most diarrhea occurred in children 1 to 2 years old, (c) zeers (porous water storage jars used by families) tended to be contaminated, (d) people who had unsanitary privies tended to have more diarrhea, (e) there was no correlation found between diarrhea cases and family ownership of animals, and (f) the amount of water used was inversely correlated with diarrhea infections.

13. (WHO Diarrheal Diseases Advisory Team, "Report on Study of Diarrheal Diseases in Egypt", 1961.) Several villages were examined and a variety of socio-economic and diarrheal infection data were collected on a cross-section basis. No results were drawn from a correlation of diarrhea with literacy, privy conditions, showers, animal availability, or water supply. General conclusions were (a) that sanitation and education were the long run solution to the diarrhea problem, (b) diarrhea was most prevalent in the 0 to 2 years group, (c) diarrheal disease was a very great problem in the areas examined.

14. (Summary Report on Diarrheal Diseases Studies in Seven Developing Countries Over a Five-Year Period, WHO, 1966.) Between 1960 and 1965 surveys on diarrheal diseases were carried out in Mauritius, Sudan, United Arab Republic, Ceylon, Iran, East Pakistan, and Venezuela.
This document summarizes the studies which are noted in 9, 10, 12, and 13 as well as the studies which took place in Ceylon, Iran, and East Pakistan. These studies were essentially cross section in nature. Among the general conclusions of the studies are that "with the availability of water the rate of reported diarrhea was found to decrease. A similar decrease in the isolation rate of shigellae was evident. The trend of the figures was always in the same direction. Differences between the reporting rates of diarrhea in water-supplied and non-water-supplied areas were statistically significant in the UAR and Iran. Differences in the isolation rates of shigellae in the UAR and Venezuela were also statistically significant".

"..... the availability of water definitely influenced the incidence of diarrhea. However, in all areas with basic sanitation, where a piped-water supply was available, diarrhea rates were reduced but still remained at a high level. This indicates that such a facility alone, without complete sanitation, was of little benefit to the population in so far as reducing the incidence of diarrhea was concerned."

"Provision of a piped-water supply to a community with only basic sanitation led to a statistically significant reduction of diarrhea and rates for Shigellae and Balantidium coli. However, in all countries where investigations were made the real reduction was very little and of limited practical importance. Likewise provision of complete sanitation resulted in a statistically significant reduction in the rates of diarrhea, shigellae, etc., especially in the diarrhea rate, which was so low that it strongly indicated the practical importance of complete sanitation."

"For areas with high and low fly counts diarrhea rates were found to be the same. However, after a subdivision of all houses into groups having water and sanitary facilities and those having none, a statistically significant reduction of diarrhea was noted in the better homes. The availability of simple privies, as we noted in several countries, did not add anything to the solution of the problem. Because many of these were unsanitary they proved, in fact, to have a statistically significant adverse effect."

The studies of the seven countries also revealed that children, especially those under three years of age, had by far the highest diarrheal incidence rates.

15. (Gilbert F. White, et.al., Drawers of Water, 1972.) Information on disease patterns at several sites in East Africa was collected by interviewer's questionnaire, by examination of excreta specimens, and by other "specific" investigations. The investigation found a significantly higher rate of diarrhea in families without piped water. Also, diarrheal diseases were both common and severe, especially in children, in all areas lacking a piped water supply.
16. (Goodwin, et al., "Observations on Familial Occurrence of Diarrhea and Enteric Pathogens", 1966.) A sample of families in Arizona, U.S.A. was visited weekly by a nurse who collected information on general illnesses and personal hygiene, and who collected stool specimens. The families in the sample were similar in that each had a newborn infant and at least two other children under five years of age, and all had a piped water supply, water heaters, water-borne sewage systems and refrigerators.

The study concluded that, in general, crowding and general socio-economic conditions were unimportant factors in the occurrence of diarrhea causing pathogens. However, an awareness of and an appreciation for personal hygiene is necessary in order to reap the health benefits from sanitary facilities.

17. ("Health Program Evaluation: Impact Study of the Indian Sanitation Facilities Construction Act", 1968.) Researchers chose six Indian communities in Arizona, U.S.A. and collected information on morbidity and mortality before, during, and after the installation of sanitary facilities in 20 homes in each community. The study lasted six years and was concerned with skin and enteric diseases. The combined disease rates were slightly higher in the before phase of the study for the people who were to receive sanitation facilities than for the people who did not receive sanitation facilities.

After sanitary facilities were installed in the selected groups of homes, the disease rates became significantly lower. It was conjectured that the installation of sanitary facilities has a greater impact through disease containment than through prevention. Houses which received more facilities (more than one indoor faucet, a sanitary privy, a shower or bath) showed the greatest improvement in health. Incidence of skin disease decreased during installation of facilities but increased again later in the period. It was suspected that without proper education on use and operation and maintenance of the facilities, the health benefits deteriorate.

18. ("Rural Water Supply and Sanitation Scheme in Pharenda Block of District Gorakhpur, Uttar Pradesh, India", undated.) Piped water was installed for 34 percent of the population in eleven villages. For three years thereafter the morbidity rates for several diseases were calculated in two of the villages. A general decrease was reported in diarrhea, dysentery, typhoid, scabies, trachoma, and conjunctivitis over the 1966-1968 period for the two villages.

Similar results were reported in a similar study dealing with seven villages in the Banki Block of District Barabanki, Uttar Pradesh between 1965 and 1968.
19. (K.W.H. Fenwick, "The Short Term Effects of a Pilot Environmental Health Project in Rural Africa: Zaina Scheme Re-assessed After Four Years", 1966.) Two communities in Kenya were surveyed in both 1961 and 1965. The communities were similar until an environmental sanitation program was introduced into one of them (Zaina) in 1962. The program included chlorinated water piped to all houses, storage tanks for livestock on farms, drainage pipes for irrigation, concrete latrine slabs for homes, privies and showers in schools, and a public laundry unit, drinking fountain, and aqua privy in the village.

Health was surveyed by a nurse who visited most houses in Zaina and the control area twice a month from March to September. Data were gathered on respiratory diseases, gastrointestinal, and childhood diseases as well as general morbidity and mortality. The "health related" results of the study were somewhat mixed. Morbidity incidence, prevalence, and duration rates showed a general decline in Zaina for infants and children under 12 years of age while there was a slight increase in the control area. Morbidity incidence and prevalence rates were generally lower in both areas in 1965 for people 13 and over. Diarrheal disease rates were higher in the control area in 1965 than in Zaina.

The birth rate stayed constant in Zaina but decreased slightly in the control area from 1961 to 1965. The fertility rate increased in Zaina, but did not significantly increase in the control area. The infantile mortality rate dropped in Zaina and the control area. The crude death rate dropped in both areas. In 1965 worm infestation (Ascaris lumbricoides was the most common) was found to be six times more common in the control area than in Zaina.

There were several problems with the study including drier weather in 1965, difficulties in getting equal responses in both areas, sampling and data problems associated with the nonprofessional field staff, and changes in exogeneous factors which could have affected the study results.

-Studies Dealing with Cholera-

20. (WHO, "Strategy of Cholera Control", 1971.) Between 1968 and 1970 the Philippines Cholera Committee undertook a study of four communities which, at the beginning of the study period, were similar in size, geographic characteristics, and demographic composition. The following sanitary improvements were then made: (a) one community with improved water supply and waste disposal, (b) one community with only improved water supply, (c) one community with only improved waste disposal, and (d) a control community with poor water supply and waste disposal. The population of each community was close to the 750-800 range. The general objective of the study was to test the effect of improved water supply and/or improved waste disposal on cholera infection incidence.
The study results showed that in the three communities where either water, waste disposal, or both were improved there was between a 69.6 percent and 71.3 percent reduction in the incidence of cholera. All three communities had significantly lower incidence rates than the control community. The study concluded that "improvements in water supply or waste disposal facilities, or a combination of both can produce a significant reduction in the cholera incidence in a community. Furthermore, infections that gain access into such communities show less tendency to spread and produce secondary cases. The incidence of infections in the three communities with sanitary improvements, however, show no significant differences. Apparently, a reduction in cholera incidence by sanitary measures is obtainable only as far as a certain level beyond which any further sanitary improvements give only small returns."

21. (Subrahmanyan, K., "A Note on the Importance of Environmental Sanitation in the Campaign Against Cholera", 1951.) In India in the late 1940's borehole wells were dug for several villages, a limited number of latrines were installed, and an attempt was made to educate the local populations on the need to use clean water and latrines. After examining the short-run effects of the improvements in sanitation it was concluded that there was notably less cholera in districts with the sanitation program and that the death rate from cholera was less in towns with piped water than in areas of the districts without piped water.

-Studies Dealing with Schistosomiasis or Bilharziasis-

It has been claimed that Schistosomiasis (Bilharziasis) is the "greatest unconquered parasitic disease now afflicting men and animals" (John Weir, 1969). Schistosomiasis is a disease that affects inhabitants of rural areas and results primarily from a lack of sanitary facilities. The life cycle of the parasitic worm or schistosome includes periods of development in both people and snails. The life cycle can be interrupted by keeping people away from snail infested waters, by providing drinking water which has been filtered, by providing sanitary waste disposal for people so that eggs passed by those who are infected will not reach open water and develop in host snails, and by killing the snail population of the area. Tentative studies to date have shown that the first three alternatives seem to be the most efficient and perhaps the cheapest (R.J. Pitchford, 1966).

22. (Siegel, Francine M., "Schistosomiasis Hematobia in Preschool Children of Ibadan, Nigeria", 1968.) In this cross-section study, 100 single and multi-family houses in one section of Ibadan were chosen at random. A total of 279 preschool children resided in these houses. During the rainy season information was then gathered on (a) the number of preschool children passing ova of schistosomiasis hematobium in urine, (b) which houses were located on the river, (c) which houses were located more than 150 yards from the river or more than three houses away from the river, and (d) which houses had public water sources
and which had private sources. The study results showed that (1) the prevalence of schistosomiasis hematobium ova was significantly greater in the area closest to the river and (2) the rate of infection differed by the source of water; 5% of the children in houses with private water taps were passing ova while 20.9% of the children without private taps were passing ova.

23. (Barbosa, Pinto, and Souza, "Control of Schistosomiasis Mansoni in a Small North East Brazilian Community", 1971.) This study took place between 1960 and 1969 in a small Brazilian village with a population slightly over 1,000. Between 1960 and 1961 an initial sample was taken in which sanitary standards and the prevalence and morbidity of schistosomiasis were recorded. A health education program was introduced in 1963 and in 1964 construction began on household latrines, a central building with sinks, showers, latrines and drinking water taps, and on nine dug wells and hand pumps distributed throughout the village. Between 1963 and 1968 the village was afforded some medical attention, health education, a monthly examination of snails, a check of small mammals, periodic inspections of the sanitary facilities which were installed, and periodic faecal examinations. Faecal examinations were made in three similar small villages in 1963 and in 1969 in order to provide non-project control data for the experiment.

The results showed a significant decline in human infection rates in the project area and in two of the three control areas. It was concluded that there was a general decline in infection due to an improvement in social and economic conditions between 1961 and 1968. It was further concluded that the more dramatic reduction in infections in the project area was a direct result of the sanitation and education program. It was suggested that "the successful degree of control achieved in the project area was mainly due to prevention of contact of the people with the infected waters".

24. (R.J. Pitchford, "Further Observations on Bilharzia Control in the Eastern Transvaal", 1970.) This study took place on a large irrigated farm in South Africa. Between 2,000 and 3,000 Bantu were housed in five villages on the farm. In 1959 construction work started on a system to provide piped water on a communal basis for domestic purposes, on swimming facilities with clean water, and on a system to reduce or prevent access to potentially dangerous (snail infested) water in the vicinity of the villages. Construction was completed in 1963/1964. The objective of the program was to provide the population with reasonably unpolluted water adequate for domestic and recreational purposes at a reasonable cost. The study found that there was a gradual decrease of Schistosoma haematobium and S. mansoni infection rates in schoolchildren during the period 1959 to 1968. For children between five and nine years of age the S. haematobium infection rate dropped from 75% in 1959 to 41% in 1968 while it dropped from 92% to 56% for children 10 to 19 years old over the period.
The S. mansoni infection rate dropped from 68% to 51% and from 85% to 71% for the two age groups over the same period.

-Studies on Childhood Mortality-

25. (PAHO, "Inter-American Investigation of Mortality in Childhood", 1971.) This report represents the beginning of an effort to collect health data on childhood mortality in 15 areas of Central and South America. While water supply was not the specific focus of the report the effect of water was noted in an aggregate sense as follows: "The central cities and other areas with limited water supplies, especially Recife, Resistencia, and San Salvador, are the ones with excessive mortality of children under 5 years of age. In contrast, Kingston and Santiago with water supplies available to high proportions of homes have low death rates. Cali and the other cities in Columbia, however, with water provided to a high proportion of homes have intermediate positions in mortality. Thus the provision of water does not appear to have the same inverse correlation for these areas as presented in the Progress Report, June 1970. Within Brazil the inverse relationship is noted and likewise, when urban and rural areas in projects are studied. In Figure 70 the relationship between availability of piped water and death rates is presented for the rural areas and corresponding cities of four projects. In these an inverse relationship can be observed between mortality and availability of piped water."

The study also stated that, "death rates in childhood are usually higher in rural areas than in cities and water supplies in the rural areas are available for much smaller proportions of the population".

26. (Jarrett, Robert E., "Environmental Factors and Childhood Mortality", 1970.) This study is part of the "Progress Report, June 1970" referred to in the above PAHO report. It is essentially a cross-section examination in which some least squares regression analysis is used and it generally shows somewhat more statistical analysis than did the 1971 Report. Among the conclusions were the following: (a) A strong negative correlation between childhood deaths and the use of piped water; (b) A strong negative correlation between childhood deaths and the use of flush toilets; (c) A quantifiable relationship between access to piped water and flush toilets and childhood mortality. It was also suggested that the "total access" to piped water is a better indicator of mortality than is piped water inside or outside dwellings.

Problems and Results of the Empirical Studies

The twenty-six studies which are summarized above are of two main types: (1) cross-section and (2) time series. Cross-section studies essentially examine existing conditions at one point in time. Although it is not possible to conclude absolute causation from a "better" water supply to lower disease rates, it can be shown that differences in water
quantity and/or quality are associated with differences in disease rates. Unfortunately, however, a cross-section study cannot assign exact causes to the change in the disease rate. Certain unknown or uncontrollable factors of cultural or environmental nature may have been at work or perhaps the difference existed before changes in the water became significant. An observed correlation between better water and health could, in fact, be the result of a more healthy population taking steps to improve their water.

In cross-section studies it must be assumed that the investigators are aware of, and can account for, all differences which exist within or among the target population(s) at the time of the study. Causation from the observed relationships can be imputed only if the investigators are confident of this assumption. However, they are always open to the charge that they have overlooked a relevant factor which could in fact have been associated with observed differences in health or disease rates.

Among the studies which have been summarized, numbers 1, 2, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16, 21, 22, 25, and 26 were essentially cross-section studies.

The second type of study reviewed is time series which examines changes through time. In these studies the emphasis is on changes in and not on differences among as is the case with cross-section studies. The major assumption in time studies is that all changes which are taking place are known and accounted for in the interpretation of the influences on health or disease rates. Generally, these studies are undertaken by improving water or sanitation facilities in an area(s) and monitoring health changes. This can be done with or without monitoring a control area i.e., an unimproved area(s) which is otherwise similar to the one in which sanitation has been improved. Studies with a control area are preferred because investigators are better able to identify and account for hidden factors which change through time and may affect health. Using a control area the "safer" assumption is made that, other than the explicit change in the water supply system in the one area, any hidden or subtle changes which occur in one area will also occur in the other area. Therefore, the relevant study comparisons are the differences in health in the two areas at some point in time after the water supply in the one has been improved, rather than simply the changes in health which occurred sometime after improvements were made in the water supply systems in an area. Studies 3, 18, and 21 are studies which were made on a through-time basis without a control area while 6, 10, 17, 19, 20, and 23 were made on a through-time basis with some type of a control area.

Due to a variety of conceptual and empirical factors the twenty-six studies examining the association between water and health cannot provide an exact statement of what will happen to specific health rates if certain water supply changes are made in known locales. Part of the problem is that empirically, all of the studies experienced one or more of the following problems:
1. It was usually impossible to identify and account for all of the related factors (socioeconomic, environmental, and cultural) which were different or changing either among comparative populations or through time.

2. There were undoubtedly sampling errors brought about by,
   (a) incomplete reporting on disease and sickness
   (b) incomplete and inaccurate records
   (c) lack of cooperation, suspicion, or apathy on the part of the sample population
   (d) reliance on a mother's opinion or memory
   (e) inexperienced or untrained interviewers
   (f) language difficulties
   (g) problems of the sample population attempting to tell the interviewer what he wants to hear.

3. Different seasons of the year have different disease rates.

4. Weather unpredictability influenced unimproved water availability and the frequency of illness.

5. Even though sanitary facilities may be installed there is no guarantee of the extent to which they will be used or maintained.

6. Breast feeding is an important factor in infant disease rates which is difficult to control or measure.

7. In studying the health of older children, the sanitary condition of their school, their job, and their most frequent play areas, should be considered as well as their home.

8. Target populations are not fixed. Populations take trips and migrate.

   The conceptual and empirical problems associated with these studies do not, however, mean that they are of no use. In all likelihood, there is no possibility of designing and carrying out a one-time-only study which, from the point of view of the epidemiologist, economist, and engineer, is completely without drawbacks or problems. Taken as a whole the twenty-six studies which have been examined provide a significant amount of evidence that more and better water is associated with better health.

   Conceptually, diarrheal diseases are included under the "poor sanitation" disease classification, which means that increased quantities of water and better water use should lower infection rates. Empirically, studies have shown that this is generally the case. The primary finding of the diarrheal disease studies is that the
closer a family is to protected water, the lower will be the incidence of diarrhea. Other things being equal, those families with water inside the house have the lowest infection rates, those with water very close outside the house have the next lowest, and those with the water source further away have the highest. The ease with which water can be obtained by users seems to be the key factor.

Factors contributing to the incidence of diarrheal diseases are the availability of some form of sanitary excreta disposal and the extent to which the population is afforded health education. In a given culture, the need for health education seems to increase as the population’s socio-economic state declines.

Skin diseases are also conceptually, and have been found to be empirically, inversely related to the quantity of water available for use. The closer the protected water source is to the family, the greater the probability that they will use larger quantities of it and that they will have a lower incidence of skin disease.

Cholera is a "water-borne" disease which means that the quantity of water available has nothing to do with infection rates. The two cholera studies examined show that protected water supplies in a specific area are associated with significantly lower cholera infection rates in that area. Also, while people can travel out of the protected area, become infected by cholera, and bring it back into the area, if there is a protected water supply in that area the spread of cholera will be better contained. Improved and protected excreta disposal is an additional important factor in the control of cholera.

With regard to the overall prevention of cholera an interesting study on the costs of alternative ways to prevent cholera was carried out on data collected in the Philippines (B. Cvjetanovic, 1971). Given evidence that available anti-cholera vaccines are of low and short-lived effectiveness, the costs and effects of immunization were examined relative to the costs and effects of providing simple privies in rural communities. The conclusion was that "sanitation (excreta disposal) proves to be both more effective and less expensive than vaccination, especially in long term programs for control and elimination of cholera from endemic areas".

Typhoid fever is another so-called "water-borne" disease. While no studies were reviewed which focused on an examination of the specific relationship between improved water and typhoid fever incidence, a study has been completed (Cvjetanovic, Grab, and Uemura, 1971) which compares the costs and effects of typhoid vaccination with the costs and effects of improved sanitation. The conclusion of the study was that the anti-typhoid vaccine which gives high and long-lasting immunity is actually less effective and more costly in the long run than the construction of privies.

Schistosomiasis or Bilharziasis is a "water-based" disease or a disease where a necessary part of the life-cycle of the infecting agent takes place in aquatic animals. It results from infection by several
species of worm which, as larvae, develop inside certain types of snails. Approximately a month after entering the snail the larvae are shed back into the water and at this point can penetrate a person's skin on contact. One of the studies which were reviewed which dealt specifically with schistosomiasis showed that children living closer to a river had higher infection rates and that children living in houses which did not have indoor water taps also had higher schistosomiasis infection rates. The other two studies reviewed showed that sanitary facilities designed to make it unnecessary for people to go near snail-infected waters generally resulted in lower human infection rates.

The Rockefeller Foundation is currently sponsoring a study on St. Lucia of the costs and effects of alternative methods for combating Schistosomiasis (John Weir, Rockefeller Foundation Quarterly, 1969). One of the methods they are examining is to encourage people to stay away from snail-infested creek water by providing alternative water facilities such as piped water to each house, community laundry and shower facilities, and swimming-wading pools for children. The results of their evaluation have not yet been officially reported although tentative unofficial results relating to changes in health reflect favorably on the sanitary improvements. However, a portion of their study which examined the severity of the disease and the daily output of workers on a banana estate, and in a light-industry plant, failed to find any significant association (Weisbrod, et al., 1973).

Finally, the two studies reviewed which focus specifically on childhood mortality concluded, in general, that in Central and South America there is an inverse relationship between the availability of piped water and childhood mortality.

In summary, the above studies provide some evidence to reinforce the intuitive belief that the incidence rates of certain waterborne, water-based, and water-sanitation associated diseases are related to the quantity and/or quality of water and sanitary facilities available to users. Two central questions, however, remain unanswered. First, exactly how much improvement in health can be expected from a specific water supply and sanitation-related improvement in a particular area with its given characteristics? And, second, for purposes of water supply benefit evaluations, how should improvements in health or disease rates be translated into units of measurement comparable to the costs and benefits which might be generated by alternative investment opportunities? These two questions are discussed in the following sections.

**Placing a Value on Better Health**

In deciding upon the allocation of financial resources to a water supply project, or on the choice of which project out of several alternatives is the best project to invest in, the investor would ideally have some means by which to translate the expected improvement in health into units which can be compared with the benefits of alternative expenditures. In practice this requires his having some means of assigning a monetary value to alternative mixes and magnitudes of better health.
Unfortunately, there are many conceptual as well as data-related problems associated with attempting to quantitatively value better health. These problems, however, do not belay the fact that if an investor is to make rational decisions he must have confidence in the theoretical foundation of his method of value or benefit measurement, or at least be aware of the limitations of his method of measurement so that he can exercise the right to make subjective judgments when necessary. The following is a brief summary of some of the conceptual considerations and suggestions for alternative approaches to the economic evaluation of better health.

-Conceptual Problems 1/

One way in which the health of an individual or group of individuals may be evaluated is in terms of how much the individuals concerned are willing to pay for the improvement. If measured this way a direct comparison can be made with the cost of the investment and with operating costs needed to achieve it. It may then be possible to estimate whether the economic benefits to society at large make the investment worthwhile.

Usually, however, a specific investment project will make some people associated with it better off, some worse off, and the remainder indifferent. Suppose the introduction of a water supply project in a village hither to unserved is contemplated. A conceptually sound way of estimating the total effect on everyone associated with the project would be to ask the villages "what is the maximum sum you would pay rather than go without the project". Or, in case there are those who do not want it the question "what is the minimum sum you would accept to put up with the project" should be asked. Then the extent to which total welfare, as measured by willingness to pay, would be increased (decreased) by the project would be determined by whether or not the sum of the payments which would be made by those who would feel better off exceeds (or is less than) the sum demanded by those who would feel worse off. 2/

This approach to project evaluation presents several practical problems. Among them are the following.

1. There is evidence to suggest that the demand for health care (good water) increases as education and income increase even though the need for health care generally declines with increasing income and education (Grossman, 1972; U.N. Research Institute for Social Development, 1965). Consequently, a better-educated or higher-income individual, while he may need a given project less, may be more able and willing to pay for it. Depending on the income distribution of

1/ In the following section the discussion relies heavily on Mishan, 1971; Prest and Turvey, 1965; Rice and Cooper, 1967; and Klarman, 1967.

2/ In a country where there was to be a reallocation of resources for the water supply project, urban dwellers (who would be giving up resources) would have to be quizzed as well as the rural dwellers in the specific project area.
the population, a few high income individuals who have relatively low marginal utilities of income might be able to control the final project result for the entire population.

2. The "summation of individual welfare" approach is based on the premise that individuals are the most qualified to judge what is best for themselves. However, it is sometimes argued that the poor, less educated segments of the population are not really able to determine what is best for themselves in the long run. Given that a local water supply system is both a consumption and investment good, it can be argued that the uneducated poor generally perceive only the immediate consumption-convenience value of the system and would therefore tend to undervalue the total system.

- Educating the poor to the total (consumption and investment) value of the system might be expensive and time-consuming, and as a result would raise the total cost of the system even before a project commitment was made.

3. Questionnaire or personal interview methods of collecting answers to the above questions might be unreliable in many cases. Essentially, you would be asking people to play a game and give an answer to a somewhat hypothetical question. It would be easy for income or education biases to develop such that one or more group would have a greater propensity or ability to exaggerate their answers.

Given these problems, it is not surprising that this summation of individual welfare approach is seldom, if ever, explicitly attempted. While it is an approach which is consistent with the underlying premise of theoretical welfare economics, which holds that individuals should be able to judge what is best for themselves in the public sector of an economy just as they do in the private sector, this approach also illustrates a basic obstacle to the application of the theory. That is that income distribution is implicitly taken as given; yet a basic problem of many rural areas is that the communities are so poor that, almost by definition, the revealed willingness of consumers to pay will not demonstrate the economic justification for water supply projects.

There are, however, a number of other possible approaches to the problem of assigning economic values to improved health. While having only a minor association with the conceptually valid "total welfare" approach described above, these do assist in spotlighting factors which decision makers generally feel need to be taken into account in making economic choices. All but one of the approaches handles the problem of "differences in units of measurement" by converting health, or disease rate changes, which are brought about by an improved water supply system, into monetary units.

Following is a brief description of five of the ways in which an attempt can be made to value changes in an individual's health and/or life span.
1. Calculate the economic worth of a person's more healthful and lengthened life. This entails calculating the loss to the economy from a person's probabilistic sickness or death. The simplest means of doing this would be to discount the future stream of changes in the individual's future gross earnings.

One of the conceptual problems with this method is that it essentially measures a person's income generating power and has nothing to do with the value of his life to him or to his family or friends. Practically, this measure assumes that one of the primary goals of the water supply investor, or national policymaker, is to maximize the country's national output (income).

2. Estimate a person's economic worth by calculating the present value of the additional output which a healthiest person could generate minus the additional amount that the person would consume. This essentially involves discounting the value of the economic losses which accrue only to others as a result of the person's sickness or death. The simplest way of doing this is to discount the difference between the person's future earnings if healthy and his future earnings if diseased, or dead, minus the difference in the amounts he would have consumed.

The assumption underlying this "net-output" method is that what matters to society is the resulting economic gain or loss to it following the death or sickness of one or more of its members. No consideration is given to the gains, losses, or welfare of the individuals actually involved in the sickness or death. At an extreme, a program designed to eliminate elderly unproductive people would generate positive benefits under this net-output valuation method.

3. Calculate a value of human life or health from previous governmental health improvement programs. Occasionally, society makes decisions on investment expenditures which affect the health of the population. Thus, an implicit value of human life and health could be calculated from the expenditures on, and the effect of, existing programs.

The obvious problem associated with this approach is that politicians or government leaders make investment decisions partly through a process of political compromise of conflicting goals, and almost certainly in the absence of knowledge of the true benefits likely to occur. Consequently, the implicit value of life or health calculated from different programs would be somewhat arbitrary, vary greatly, and, in developing countries, would probably depend on programs and where and when they were reviewed.

4. An estimate of the value of human life and health could also be calculated from an aggregate of the death and disability insurance premiums which people are willing to pay, together with the probability of their becoming disabled or dying. The problem with this approach
if that it only reflects concern for the beneficiaries rather than the policyholder. Insurance primarily reflects a need and ability to provide for family and dependents, and does not reflect the value of an individual's life or health to himself or to his family and friends.

5. Finally, there is one suggested approach which does not rely solely on measuring the economic effect of health changes on society, or on the individual. The suggestion has been made that it is not necessary to deal explicitly with the problem of the actual "value" of life and health if a general index can be constructed which could reflect changes in the standard of living or the "social-environmental quality of life" in an area. This is, in concept, a step toward the "total welfare" approach of valuing changes in health brought about by changes in local water supplies. Rough approximations of such an index might be the Level of Living Index suggested by the U.N. Research Institute (1965) or some form of additive weights as proposed by Bartone (1972). Unfortunately, indexes of this nature are generally better suited for macro evaluation problems, and in most cases would have to be specially modified for each country as well as each culture and region within it. This, of course, would bring about problems of comparability. In addition, any attempt to use such an index on a micro-project, or program basis, in developing countries, would encounter numerous data problems.

-Which Way to Proceed-

The preceding section has attempted to summarize several of the more prominent conceptual and practical problems associated with valuing changes in human health and life span. Unfortunately, for the planner and engineer who must go into the field, make decisions, and get things done, there is no one clear-cut method or procedure which avoids these problems.

The fact that problems exist, however, has not stopped empirical attempts at health improvement valuation. Generally, rather than struggle with a complex and perhaps costly total welfare approach to project valuation, investigators have relied on some of the less conceptually sound, but more manageable and still useful, alternative approaches. In attempting to attach some form of comparable value measure to probabilistic changes in disease rates and expected life spans the most common methods used are discounting changes in expected life-time earnings (method 1 discussed above used by: Rice, 1966; Klarman, 1965; Fein, 1958) and discounting changes in expected life-time earnings less changes in expected life-time consumption (method 2 discussed above used by: Pyatt and Rogers, 1962; Weisbrod, 1961; Dublin and Lotka, 1966). Neither of these approaches values life, health, or satisfaction. They are simply attempts to quantify the economic output associated with life or health under the imperfect assumption that the economic output of humans reflects the value of life and health.
The issue of whether or not to subtract changes in consumption from changes in output essentially depends on the decision-maker's decision to place a value on the personal consumption of the individual whose life span or health is altered. Those who do not subtract changes in consumption from changes in the individual's total output (earnings) argue that consumption is an end in itself and should be viewed as a final product. If it can be assumed that an individual's enjoyment increases with his level of consumption, then any increase in satisfaction (through increased consumption) which is a result of a lengthened or more healthy life should not be subtracted out.

With specific reference to (rural) water supply systems, the factors which should be considered in benefit evaluations of better health are also the subject of some discussion. However, a general set of guidelines can be developed. The most workable way to value probabilistic improvements in the health of a population is through discounted changes in potential or expected earnings. Since discussion of this subject is somewhat detailed, the factors to be considered will be outlined later in a section on economic growth and output (Chapter IV).

**Tradeoffs Between Health, Water System Components, and Cost**

When designing a specific water supply system, the engineer is essentially committing resources to the project which cannot then be used on other water supply projects, or for other purposes by the investor. Consequently, the engineer must have guidelines which give him at least some probabilistic statements about what the possible alternative levels and quality of service mean in terms of different magnitudes of improved health. In addition, he must be able to calculate how the "value" of the expected improvements in health stack up against the costs of the alternative "levels of service" which could be designed into the system. The question of the "valuation" of improved health was discussed in the previous section. Now we will attempt to examine the question of exactly how much improvement in health can be expected from an improvement in the water supply of a local area.

The twenty-six studies were reviewed partially in an attempt to determine if any statement could be derived from existing literature, concerning the amount of health improvement that can be expected from different types of water facility improvements. Generally, the study results have shown that no specific statement with any sort of predictive accuracy can be derived for all cultures, types of locations, and types of diseases. However, many relevant variables have been identified and the derivation of an estimate of such a statement is not beyond the realm of possibility if slightly more information were at hand.

A few existing studies have made assumptions about the extent to which disease rates would decline if water supply improvements were undertaken in developing countries. Wagner and Wannoni (1948), in attempting to estimate savings in Venezuela which would result from the construction of safe water supplies in rural areas, chose what they considered to be a conservative figure of 75 percent expected disease reduction.
Pyatt and Rogers (1962) in a cost-benefit calculation of the potential effects of water supply systems in Puerto Rico assumed that only 60 percent of the recorded typhoid, diarrhea, and dysentery rates (excluding infant rates) reflected actual water-borne disease transmission. Therefore, they implicitly assumed that improved water would reduce the reported rates by approximately 60 percent.

If an environment were found which approximated the one investigated by J. Watt et.al. (1953) and if sanitary improvements were introduced which eliminated shigella, a major cause of diarrhea, then an estimate of the reduction in diarrheal disease might be justified. For the situation Watt investigated, he estimated that diarrheal diseases would be reduced by approximately two-thirds if shigella were eliminated.

White, Bradley, and White (1972) have provided perhaps the most extensive set of estimates of the proportions of different diseases which are preventable in rural areas of East Africa by the introduction of improved water supplies. Overall they estimate that approximately 52 percent of water related disease could be abolished if excellent water supplies were available. The following list shows a detailed breakdown of their estimates.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Expected Percent Reduction if Water Supply Is Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoid</td>
<td>80</td>
</tr>
<tr>
<td>Paratyphoid and other Salmonella</td>
<td>40</td>
</tr>
<tr>
<td>Bacillary dysentery</td>
<td>50</td>
</tr>
<tr>
<td>Amebiasis</td>
<td>50</td>
</tr>
<tr>
<td>Dysentery, unspecified</td>
<td>50</td>
</tr>
<tr>
<td>Louseborne typhus</td>
<td>40</td>
</tr>
<tr>
<td>Urinary schistosomiasis</td>
<td>80</td>
</tr>
<tr>
<td>Intestinal schistosomiasis</td>
<td>40</td>
</tr>
<tr>
<td>Schistosomiasis, unspecified</td>
<td>60</td>
</tr>
<tr>
<td>Ascariasis</td>
<td>40</td>
</tr>
<tr>
<td>Guinea worm</td>
<td>100</td>
</tr>
<tr>
<td>Louseborne relapsing fever</td>
<td>40</td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>80</td>
</tr>
<tr>
<td>Yaws</td>
<td>70</td>
</tr>
<tr>
<td>Trachoma</td>
<td>60</td>
</tr>
<tr>
<td>Trypanosomiasis gambiense</td>
<td>80</td>
</tr>
<tr>
<td>Trypanosomiasis, unspecified</td>
<td>10</td>
</tr>
<tr>
<td>Scabies</td>
<td>80</td>
</tr>
<tr>
<td>Inflammatory eye diseases</td>
<td>70</td>
</tr>
<tr>
<td>Otitis externa</td>
<td>40</td>
</tr>
<tr>
<td>Dental caries</td>
<td>10</td>
</tr>
<tr>
<td>Gastroenteritis, 4 wk. to 2 yr.</td>
<td>50</td>
</tr>
<tr>
<td>Gastroenteritis, over 2 yr.</td>
<td>50</td>
</tr>
<tr>
<td>Skin and subcutaneous infections</td>
<td>50</td>
</tr>
<tr>
<td>Chronic skin (leg) ulcer</td>
<td>40</td>
</tr>
<tr>
<td>Diarrhea of the newborn</td>
<td>50</td>
</tr>
<tr>
<td>Tinea</td>
<td>50</td>
</tr>
</tbody>
</table>
The authors qualified the reliability of their estimates with the following:
"These estimates can be little more than guesses, but a basis for them is set out in the discussions of disease given above and, although they are in error, a far greater error probably would be introduced by assuming that these conditions would either disappear or remain unchanged by improving (water) supplies".

The above sets of estimates implicitly concede that there are many ways in which a person can become infected with water-associated disease other than by drinking the water which is available in his home village. Generally, given the current state of the art, in order to have any confidence in an estimate, the health-disease rate benefit occurring from a given water supply improvement should probably be estimated individually for each project taking into consideration the health, geographic, climatic, economic, and cultural mix of the project-population at that point in time.

Those factors which affect benefits also affect the costs of a project. Figure II illustrates two of the many possible relationships between health rates (those which can be influenced directly or indirectly by water supply) and the cost of a water supply project.

In Figure II, health is measured by a hypothetical index from zero which represents the level of health prior to water supply improvements, to 100 the absolute level of health assuming no water supply related diseases. Cost reflects the total cost of the water supply project including engineering, construction, administration, and any additional costs for training, sanitation, continuing technical assistance, etc.
Curve A represents a hypothetical case in which health begins to improve rapidly after an initial relatively small - low cost improvement in the local water supply system such as protecting an existing supply, digging a series of wells and installing hand pumps, or extending water service into homes. Curve B represents a case where a much greater initial investment is required before there is a significant improvement in health.

It is important for the project engineer and the investor to have some feel for the type of situation they are facing. For example, suppose they assume that the case they are facing will be like A which requires only a small investment for substantial results, and therefore decide to invest dollars in order to bring health up to C. However, suppose the situation is actually like B, then the dollars will only bring health up to B and, in effect, a significant expenditure of resources will have resulted in an insignificant change in health.

A possible approach might be to reformulate the problem in the following manner: What amount of improvement in the major disease rates would it take to make a given investment worthwhile? In an attempt to answer that question all related health information and empirical study results, as well as an epidemiologist, could be consulted to judge whether the "target" rate of health improvement (that rate necessary to make the project worthwhile) could be achieved with an acceptable degree of probability.

While answering the above question, additional estimates could be made of the possible health effects of additional or less investment (more people served or a higher quality of service, etc.) and what the effects of somewhat less investment would be. This additional exercise would, in effect, be an attempt to find the placement (on line A, line B, or some intermediate line in Figure II) of the initial projected amount, and the approximate slope of the line at that point.

Some attention should also be given to the program "mix" of physical facilities, water use and health education, system maintenance training, etc., which go into a given investment amount. For example, it is possible that curve B could be shifted to the left (which would result in a greater health improvement for a given investment, or alternatively a smaller investment necessary to achieve a target health improvement). This shift might be brought about by changing the proportions of the investment such that a larger proportion would be spent on water use and health education for the local population than on physical facilities. The end result of this change in emphasis would be a lower quality of service but a greater and more healthful use of the water which is provided. This follows from an observation which is repeatedly found in rural water supply literature that the best water supply system in the world will not have any effects on local health if the population is not willing or able to use it.

-Four Roles in Planning-

When examining the relationship between health and water it is apparent that an adequate quantity of good water is a necessary condition for good health. However, it is not in itself a sufficient condition,
since good drinking water and a population with a significant number of water-associated disease problems can exist in the same village.

From the analysis and review of literature which have been undertaken, it appears that the water supply investor who is interested in "health" benefits must make use of inputs from at least four different analytical focuses: engineering, economics, sociology, and epidemiology.

The engineer can provide technical designs and cost estimates for a given water supply system or for a program with several different cost and quality-quantity of service alternatives. Further, if he is from that country he, with some sociological input, might also be in a good position to exercise judgment concerning the possible social and cultural problems which may affect the efficiency and use of alternative designs of the system.

The epidemiologist can provide a rough estimate of the extent which health or disease rates would improve if each alternative project/program design were implemented.

The economist can assist in project development by estimating shadow values, where appropriate. He could then attempt to place a monetary value on the estimated health improvements and make a comparison between these benefits and the alternative engineering costs and possibilities for water supply investment in that or other programs. In other words, after valuing the probable health improvements in each alternative, the economist could attempt to put together the engineering, social, and epidemiological inputs in such a way as to select a project which comes closest to meeting the overall objectives of the investor, within the constraints of the available resources.
IV. ECONOMIC GROWTH AND OUTPUT

The following is a brief discussion of the principal ways in which potable water supply systems in rural areas of developing countries might be expected to affect local, regional, and national economic output and growth. The potential economic effects of rural water supply systems will be examined in six topic-sections: General Effects on the Overall National Economy, Direct Economic Effects on Development and Output, Economic Effects from Improved Health, Effects of Increased Time for Productive Work, Effects on Income Through Population Change, and Economic Effects Through Averting Costs.

General Effects on the Overall National Economy

The macro economic effects of a rural water-supply program on the national economy of a developing country are probably not worth considering unless the program is large enough in relation to total national output. The effects on the national economy would not be of a significant magnitude for individual village pilot projects or for other small-scale localized projects which are not part of a large national-or regional program. For rural water supply programs which are of a relatively large size, the macro economic effects can be viewed as being associated with (a) economic growth, (b) a redistribution of income, and (c) possible balance of payments problems.

-Economic Growth-

The country will experience an increase in overall economic activity as a result of the water supply program if at a given time, (a) a portion of the funds which are needed for rural water supply investment are obtained from sources outside the country (such as an international agency), (b) if these funds would not have flowed into the country except for the rural water supply program, and (c) if the country is not operating with all of its resources fully employed. At a minimum, the increase in the country's economic activity or output will be equal to that proportion of the increase in direct program expenditures which is financed by outside sources plus the increase in indirect expenditures made by those newly employed in the program and those directly or indirectly supplying services, equipment, and material to the program.

Related to this, if the country finances some portion of the rural water program through increased taxes or user fees and if this additional government revenue is composed partly of money which the population would have otherwise saved, then the fact that the government immediately puts the money back into the economy, thereby increasing aggregate demand, results in a net increase in overall economic activity or output.

Finally, a water supply system is both a consumption and investment good. It is a consumption good in that people begin consuming it immediately upon its completion. It is an investment good in that it is part of the local infrastructure and can indirectly generate additional economic activity in the future by attracting and facilitating local commerce and
village industry through the improved health of local human resources which in turn can increase production. To the extent that village water supply systems are investment goods which are partly financed out of new taxes and user charges which would have been spent on consumption, then the result is a net shift from short-run consumption to investment. This shift could have a net positive effect on long run economic growth in the regional or national economy.

-Redistribution of Income-

If the national government is bearing at least part of the cost of the water supply program (partial national government subsidy) and if it raises its revenues by taxing economic output and/or income, then a rural water supply program will generally result in a redistribution of income within the country (a) from urban to rural and (b) from higher to lower income population. This follows from the fact that per capita economic output and income are almost always higher in urban areas than in rural areas. Therefore, a water supply program which entails a flow of resources into non-urban areas and which is financed at least partially by country-wide taxes on output and/or income would spatially redistribute resources. Income would be redistributed from higher-income urban areas to non-urban areas and generally from higher income population to lower income population.

In addition, as noted above, disposable income would also be redistributed through time since, through taxation and user fees for water supply investment, income is generally shifted from current consumption (assuming low rates of saving in rural areas of developing countries) to consumption in the future at what will hopefully be at a higher per capita level.

-Balance of Payments Problems-

Hard currencies are scarce in most developing countries. Consequently, a national rural water supply program which would require a country to import materials and a significant amount of equipment could be continually postponed in favor of (a) national programs that can be carried out without an outflow of foreign exchange, or (b) national programs which will result in the future generation of exports which, in turn, will generate an inflow of foreign exchange into the country.

This rural water supply-foreign exchange problem is generally more important in smaller countries which do not have a sufficient industrial base to manufacture a significant portion of the needed equipment. Most developing countries are able to manufacture plastic pipe, but many of them still must import plastic pellets for the pipe extruders or at least some of the ingredients for the plastic. On the other hand, all but the more advanced (or larger) developing countries must import pumps, drilling rigs, and service vehicles for a rural water supply program. In some cases while it may be cheaper in monetary terms to import and erect steel reservoir tanks, the country may opt to build tanks out of domestically manufactured cement at a higher money cost (when labor is included) in order to avoid giving up foreign exchange.
In most developing countries labor is an abundant and low priced resource. Capital equipment on the other hand is relatively scarce and in many cases must be imported. Consequently, the balance of payments problems of a rural water supply program can be reduced by designing the program in such a way that the construction, operation and maintenance, and expansion phases of the program are as labor-intensive as is technologically possible, given existing cost constraints. In many countries with viable rural water supply programs, particularly in Latin America, local village populations generally agree to contribute, during construction, as much hand labor as is needed including digging and refilling trenches for the entire water distribution system. This limits the number of tractors or ditch-digging equipment which must be imported by the national program agency. In addition, it provides a way in which villages can reduce the proportion of the cost of the system which they must bear.

Another means which is frequently used to reduce financial costs is for local village populations to collect and furnish the sand and stones which are necessary for the construction of reservoirs and any other concrete-based facilities.

One problem with the use of labor-intensive construction techniques is that they are often less efficient; completion times for projects are generally longer, and somewhat greater amounts of supervision are usually required. While this would not necessarily affect balance of payments problems, it should be considered when assessing both the real and financial costs of the project.

The primary point, however, is that a rural water supply program can have an impact on a developing country's balance of payments. The extent of the impact will vary from country to country depending on its natural and technical resources. In all countries, however, the potential negative impact can be evaluated in advance and can, given that country's needs and resources, be minimized by designing the program and all individual projects in such a way as to take advantage of local labor, materials, supplies, topography, and technology whenever possible. To do this it is necessary to be sure that recognition and use of shadow values for labor and foreign exchange, which is usually appreciated only at the central government level, is somehow conveyed to those responsible for project design, construction, and system operation. This is one of the biggest hurdles to overcome.

Direct Economic Effects on Development and Output

There are several direct effects on a community or region's economic output which can result from the introduction of potable water supply systems which have been designed primarily to provide water for human consumption. These are reviewed as short and long run effects.

-Short Run Effects-

When a system is designed in such a way that there is excess capacity during some portion of the day (at non-peak load times), it can sometimes be beneficial to allow limited irrigation of small garden plots near each
dwelling and/or tap. A policy allowing the watering of small gardens tends to produce the most benefits in areas which have acceptable soil but a dry climate, or in areas with at least one very dry season where the lack of natural water is the inhibiting factor to garden output. In these areas times for watering might be allocated on a spatial basis to different groups of the population and the type of plants allowed to be grown in the irrigated gardens could be restricted to types of produce which consume relatively little water per unit of output. (A similar type of plant-water absorption restriction is enforced in some areas of the Dominican Republic.)

Related to the excess capacity irrigation of small gardens is also the possibility that gardens can be irrigated with wastewater. One example of the successful application of wastewater garden irrigation can be found in Lahore, Pakistan where a significant amount of food is produced by this method.

An additional possibility is that, in some cases, direct economic benefits to local populations might result from encouraging fish farming in the reservoir constructed for the local potable water supply, or in a drainage pool which collects water after it has been used by the village. A reservoir fish farming operation is probably most feasible in areas where a relatively large open-air reservoir must be constructed and where the water must be filtered or otherwise treated before human consumption anyway. Given these conditions, and depending on the costs in that area of feeding the fish, a local community could gain an additional food source, and additional water system revenue, through a fish farming operation which requires little additional capital investment in the water supply system.

Finally, it is possible, in relatively arid areas or in areas with at least one very dry season, that local animal husbandry can experience significant gains through the provision of low cost facilities for livestock watering at non-peak load times. In Kenya it was found that one of the major benefits of the Zaina potable water supply scheme for human consumption was the increase, over a four-year period, in the number of cattle, pigs, sheep and goats, and poultry in the areas where they had access to watering troughs year round. With cattle both the number and the milk output per cow increased. All of the livestock increases were greater than any changes which occurred in a nearby area which was similar to Zaina but which did not receive a potable water supply system (Fenwick, 1966). Similarly, in Jordan it has been reported that the loss of livestock during the dry season was significantly reduced by the installation of a village water supply and by the initiation of a livestock health program (Mendenhall, 1968). On the other hand, several cases have also been reported where water supply systems designed primarily for human and livestock consumption have had little impact on livestock production or on general economic activity in the areas which were provided with water (the Kabare-Inoi and Kibichori studies reported in Carruthers, 1972).

Given excess system capacity at non-peak load times, it generally requires little additional investment to allow the watering of livestock. And in fact, this practice may create an additional small source of water
system revenue. For example, in several of the drier areas of the Dominican Republic, the national rural water supply program (INAPA) allows water taps to be provided for the watering of livestock from a fixed trough at the same monthly charge that would be made for a house connection. This is subject only to the restriction that no more than approximately 600 litres per day be consumed at that tap (this is the estimated amount that is consumed at most house taps).

Finally, in areas where climate and local technology allow the growing and storage of fodder during a wetter growing season, it is possible that water troughs for animals might make a beef cattle, hog, or poultry feeder operation feasible at an initial water-investment cost which is not significantly greater than the cost of the village potable water system for human consumption.

If feasible, any of the above noted small garden irrigation, fish farming, or livestock watering efforts could conceivably generate additional direct economic benefits to a rural community in a relatively short time. These efforts could be directly productive by increasing community income and output and generating measurable benefits for purposes of international agency investment analysis.

One possible negative short run economic effect of a village water supply system could be that in terms of disposable income, or funds which low income people have to spend, a new water supply system in a community might result in the population being financially poorer in the short run. With the above possible exceptions relating to gardens, livestock, and fish it is difficult to argue that potable water for human consumption will directly increase the income of a population in the short run. This is particularly true in rural areas where water is not presently purchased from vendors, where there is general underemployment in the region so that any improvement in health will not increase earnings, and where regional health services are free or at least heavily subsidized by the central government. In cases such as these, in the short run, the necessity of paying from one to five percent of yearly income as a water rate in exchange for potable water which does not immediately increase earnings or output, actually reduces the disposable income of each family and, in monetary terms, makes them poorer.

-Longer Run Direct Economic Benefits-

Over the long run one of the most frequent economic arguments made for rural water supply systems is that a potable water supply system is an integral part of a community's infrastructure, without which it will not be able to take advantage of opportunities to attract industry, or more likely, opportunities to generate an expanding commercial and village-industry sector from within.

There are essentially two things to note about this contention. First it is probably true in the sense that a potable water supply system is necessary for most forms of intensive local economic development. As local commerce grows and village industry develops the lack of a potable water
supply system could retard the rate of local economic growth. However, while a potable water supply system is at some point usually necessary for long run economic development it is certainly not always sufficient to generate development. If there are twenty-five villages in a given region of a country and if they all obtain water supply systems at approximately the same time there is no reason to assume that all, or even most of them, will increase their rate of economic growth as a result. Given existing migration, marketing, and growth patterns, some of the villages may grow and develop. But the odds are that many will not.

It has been noted that two of the most important reasons for migration are a lack of educational opportunities for children and a lack of employment and income generation opportunities for the total family. Since a village water system can at best generate only limited direct employment and income opportunities and since it has no effect on the amount of formal education available, it is generally unrealistic to expect a water supply system, by itself, to generate significant changes in long run economic growth, development, and migration patterns in most rural villages.

Empirical evidence on the relationship through time between economic development and village water supply systems for human consumption in developing countries is difficult to find and even more difficult to evaluate. There are several reasons for this but prominent among them are the twin facts that most developing country rural water supply programs have been in existence for less than ten years and that many villages which received water in the early stages of the older programs have also received a number of other infrastructure and development investments through the years. As a result, it is very difficult to attribute an increase in local economic activity to any one particular government-induced investment in infrastructure, health, or village industry.

The second point to remember is that firms or industries of a significant size are not generally attracted to small villages solely because it has an available domestic water supply system. Large companies, or even small water-using firms, will generally be able to develop their own water source in rural areas and will generally choose a specific location for a variety of economic reasons, most of which are unrelated to whether or not the local village has a potable water supply system; indeed the proportion of business expenditures which go to water supply is normally infinitesimal. For example, in northwestern Argentina, there is a small village near Santiago del Estero where a tomato processing factory located and began production shortly after the village inaugurated its new potable water supply system. The factory immediately hooked into the system and, in fact, required a water meter which in that area is only allocated to "heavy" users (there were six other metered users in the town). On the surface this looks like a perfect example of a water supply system attracting economic activity. However, further investigation revealed that there existed another older tomato processing plant which had been in the area for some time and which had developed its own water source. In addition, the new tomato processing plant located in the area not because of the existence of a new potable water supply system, but because
of increasing economic opportunities for tomato production and processing. In this case the existence of a potable water supply system which could be used at relatively low cost was a small plus for the plant in that it eliminated the need to develop a private water source. However, this was not a primary consideration in determining whether or not the plant would locate in the area. It located there in order to take advantage of the growing opportunity to generate profits and provide employment by processing tomatoes.

A related long run economic consideration which pertains to the financing of village potable water systems is that if the water supply system stimulates economic development, then the resulting new economic activity could generate additional public revenue which can in turn be used to help expand, upgrade, or pay off any loans incurred in building the system. Public revenue derived from income and sales taxes would automatically increase with increasing economic activity.

Property tax revenue, which constitutes a large portion of local revenue in many developing countries, would also increase if property values increased. Increases in property values, and thus the property tax base, could occur in the following ways: (1) new commerce and village industry might develop new property or might expand their existing establishments, (2) as the desirability of potable water becomes more widely recognized, property with on-premises water service, or convenient access to potable water, becomes relatively more attractive and tends to attract population from areas without water, which in turn helps to bid up the price (value) of the property, and (3) women who no longer have to spend a major portion of their day carrying water have more time to spend making improvements in, and attending to, their living facilities. As for empirical evidence, it has been reported that in some areas of the Dominican Republic in which potable water supply systems have been functioning only a short time, some villages have officially revalued homes by as much as twenty-five percent (deGreiff, 1971), the increase being attributed to improved water supply. The difficulties, however, involved in making such judgments are immense (Bahl, et al., 1972).

Nevertheless, if a potable village water supply system does stimulate long run economic activity in an area, the taxable stock of private investment, both commercial and residential, should increase along with the taxable flow of income and sales. This would allow alternative approaches to financing the system to be considered. One method would be to use the additional public sector revenue to help pay off water system debt or to further expand and improve the system without resorting to higher future water rates. On the other hand, higher user charges may become feasible as local ability to pay increases: a gradual increase in rates, possibly on a deferred basis, might be desirable.

Economic Effects of Improved Health

On an intuitive level it is easy to conclude that there is a direct link between economic output and improved health. Empirically, however, especially on a program level, this link is difficult to demonstrate.
One attempt to find the effects of schistosomiasis and four other parasitic
diseases on labor productivity on St. Lucia failed to demonstrate an asso-
ciation between the severity of the disease and the daily output of workers
on a banana estate and at a light-industry plant. This study, however, was
plagued not only by the normal problems of field studies, but also by the
valid question of whether or not schistosomiasis and the other diseases are
sufficiently severe on St. Lucia to affect productivity (Weisbrod, et. al.,
1973).

Empirical work does exist which establishes a link between health
factors and economic output on an aggregative international level. One
study which compared health and economic output across twenty-two African,
Asian, and Latin American countries found that the influence of health
factors on economic output appears to be quantitatively large relative
to the influence of other factors, including agricultural inputs such as
labor and commercial fertilizer. In fact, this study went so far as to
conclude that health inputs are associated with variations in economic
output beyond those which are usually attributed to labor and capital
(Malanbaum, 1970). These findings, of course, could be subject to consider-
able data aggregation and interpretation errors.

The sections which immediately follow focus on the effects of increased
labor inputs (made possible by better rural health) and of a healthier
expanding population on the related longer run effects on per capita income
on economic output.

-Effects on Labor Inputs-

If an improved water supply system has the effect of reducing mortality
and morbidity in a local population, then a greater quantity of labor from
that population will be available to use as an input in increasing local
output, earnings, and income.

A Reduction in Mortality Rates. When mortality rates in a locality
decline, as a result of better drinking water, the final calculated value
of the economic impact depends on whether or not a person's consumption
is viewed as a cost to society or as an objective of society. It is clear
that when a person dies society loses the amount of output which he
would have produced over the remainder of his lifetime. What is gener-
ally debatable (as noted in a previous section on valuing health) is
whether or not this loss to society should be calculated on a net basis
(output which he would have produced minus the amount which he would have
consumed) or in a gross basis (output which he would have produced). If
one is interested only in what the effect is on others then the net basis
would be an acceptable way to calculate society's economic loss. Alter-
atively, however, one could consider consumption to be an objective of
society and therefore argue that the portion of a person's output which
he would have consumed would have increased the total welfare of society
and therefore should not be subtracted from total output. In this case
the gross output calculation would be acceptable. In either case, of
course, the economic value of the loss due to the death would be calculated
in terms of its present value, which means that the flow of income (and
consumption) would have to be discounted back to the value which it could
command at the present point in time.
The age at which a person dies does not affect the method of calculation. If an infant dies, the earnings flow to be discounted would include the following 10-15 years of zero earnings plus the expected earnings of an average individual of that sex over the remaining years of an average lifespan. If it was decided to subtract projected consumption from earnings, it would be discounted from the year of death (birth) throughout an average lifespan. The procedure is exactly the same for individuals in any other age range.

From time to time it has been pointed out that from an economic point of view society loses more if a 12 year old dies than if an infant dies because while neither has started contributing earnings to society more of society's resources (consumption) have been invested in the 12 year old. However, any costs which have been incurred up to that point in time when the water project is initiated are "sunk" costs, or costs which have been incurred but which cannot be recovered. The impact of a water supply project relates to earnings and consumption in the future.

It is true that when discounting earnings into the future, if the same amount of earnings is attributed to both a twelve year-old and a one year old, the twelve year old will have a greater present value. This is because the twelve year old's earnings are realized years earlier. However, if it is assumed that there will be some economic growth which results in increases in the productivity of labor, the one year old during his working years may be more productive, in real terms, than the twelve year old.

Empirically, it has been shown, in numerous instances, that the greatest number of deaths from water related diseases in developing countries occur among children less than 2 or 3 years of age (USAID, 1965; PAHO Provisional Report, 1971). Consequently, a benefit valuation exercise which attempted to attach a "standardized" discounted earnings stream to probable changes in water related deaths without regard to age distribution would probably significantly overvalue the short run economic benefits of a water supply induced reduction in death rates.

A Reduction in Morbidity. The economic value of a reduction in morbidity, as a result of an improved water supply system, is also partly related to the age distribution of the population. A reduction in morbidity among children who are not economically productive would have little short run economic value. However, the long run value could be much greater. A reduction in morbidity might result in an increased learning capacity in children such that they would be able to take more complete advantage of available educational opportunities. In other words, a population of children, which suddenly has lower morbidity rates, might be better able to utilize existing public sector investment in education.

A water supply induced reduction in morbidity rates among those who are currently in the labor force could legitimately affect the local economy through an increase in labor productivity reflected by an increase in local earnings and output. The local economy might experience an increase in output and earnings as a result of (a) reduced worker absentee rates, (less
lost earnings), (b) improved vigor and therefore productivity of workers while they are on the job (higher productivity resulting in increased earnings), and (c) less earnings loss by members of families caring for others who are ill.

In a full-employment economy a reduction in morbidity affecting the labor force in the above three ways would induce increases in economic output. The problem, of course, is that in rural areas of developing countries there is generally substantial underemployment: for example, in some rural areas of Mexico it has been estimated that the population engages in productive economic activity only four months a year while in parts of rural Dominican Republic estimates have been made that the population can find work only 30 - 65 percent of their average workday. Since situations such as these are quite common, studies which attempt to value the economic cost of one or more water related diseases in a developing country by multiplying the country's minimum legal wage by an estimate of disease-caused sick days, without considering what opportunities the afflicted might or might not have to earn that minimum wage, probably considerably overestimates the "economic cost" of the disease (see for example M. Farooq, 1963 and M. Farooq, 1964).

The point is that just because a population is suddenly more healthy and can, on the average, work more frequently and vigorously does not mean that economic output will change. If the limited employment and work opportunities, as the population perceives them, remain unchanged, then economic output and earnings may not change greatly.

On the other hand, some increases in output might take place in those areas where the planting and harvesting seasons are limited to several somewhat short periods and where labor is a scarce resource during those periods. In a situation such as this, lower absentee rates and increased population vigor during these periods could allow more intensive planting, cultivating, and harvesting efforts to pay off in increased output and earnings.

In attempting to place an exact economic value on these benefits there would be some difficulty in trying to estimate (a) the existence and duration of labor-scarce periods during the year, (b) the expected increase in energy resulting from a given reduction in morbidity rates, and (c) the effects of (b) as seen in increases in labor input and economic output. In addition, any attempt to simplify the problems of estimating the economic benefits of water supplies in rural areas by making use of aggregate per capita output and productivity figures for the total country would probably lead to an overestimate of the value of health benefits. In general, per capita output, or per capita contribution to GNP, is higher in the areas where there are greater quantities of capital for labor to use. In most countries this would mean that worker output per capita would be relatively higher in the large urban areas. Consequently, unadjusted country-wide labor productivity figures would generally be too large to use in rural areas, and if used they would cause an overstatement of the estimated economic benefits.
A point worth reemphasizing is that, generally, any dramatic improvements in health which have occurred as a result of improved water supplies have been among children. Consequently, the health-related potential for increased productivity among adults, even if employment were available, may not in many cases, be very great. For example, in the Zaina scheme reviewed earlier (Fenwick, 1965), it was found that adults were sick for less than one-half day per month and that the improved water system apparently caused no change in this rate. Even if the improved water had eliminated all diseases, the increase in the labor force would have been an insignificant half man-day per month.

External Health Effects. In addition to the above potential health-induced effects on the economic output of villages which secure potable water supply systems, there also might be an improvement in the health, and therefore labor inputs, of people who frequently come into contact with the residents of villages which are served by potable water systems. This could come about in the following ways. First, it has been well documented that potable water supply systems help retard the spread of epidemic diseases such as cholera and typhoid (WHO, Strategy of Cholera Control, 1971). As a result, a given subset of a region's population which is served with potable water would have less likelihood of catching such diseases and therefore would not pass them on to others. Conceivably those who did not become afflicted with the disease, because it was not passed on to them by those with potable water, would have lower morbidity and mortality rates and therefore could generate increased economic output.

Second, a population which is not weakened by diarrhea and other water-associated diseases, generally has a lower propensity to (a) contract other more common sicknesses and (b) pass the more common sicknesses on to others. If this is true, the population served by the potable water supply system and those with whom they come in contact should have lower morbidity and mortality rates and should therefore be able to generate a higher level of labor inputs which hopefully could be translated into increased economic output.

More Time for Productive Work

A potable water supply system generally makes it more convenient for the local population to obtain the water they need for drinking, washing, and preparing food. The introduction of a more convenient source of water means that those whose duties include fetching and carrying water for family use will have more time to devote to other things. In the rural areas of most developing countries the provision of water for the family is the primary responsibility of women and children. Depending on season, location, and terrain, water carriers in many parts of the world could be expected to spend approximately one hour each day carrying water. Cases have been cited, however, where up to four hours each day is spent carrying water for family consumption (White, et al., 1972). Furthermore, again depending on location, terrain, and season, although examples have been cited where many of the women walk more than one mile, or even two miles (Warner, 1969; IBRD, May 16, 1972), the distance between dwellings and a usable source of water is generally less than a mile (White, et al., 1972).
After the introduction of a potable water supply system which eliminates the need for women and children to spend a significant proportion of their time carrying water, women would be able to spend that time in more directly productive activities which could increase economic output and earnings. Of course, given the significant underemployment which exists in rural areas of developing countries, the opportunity to increase earnings and output may be relegated to those seasons, if any, in which planting, cultivation, and harvesting make labor, on a temporary basis, a resource in short supply. If during those limited periods of time labor is a scarce resource, the additional woman-hours of labor, and perhaps the additional availability of water-carrying animals, may make it possible for the village to engage in a more intensive and/or extensive cultivation of land and thereby better utilize existing land and agriculture-related capital.

Aside from seasonal factors, whether or not women would spend more time at measurable productive activities would probably depend on the opportunities for such work, and on the personal and cultural factors affecting the inclination of the former water carriers to engage in such work. In a study of nine Tanzanian villages, where agricultural work occupied the largest share of time of a majority of married women, when they were asked what they would do if they had more time available, less than half said they would spend it on agricultural work (Warner, 1969). To the extent that women would spend their newly acquired free time on domestic chores such as washing clothes or tidying up their dwellings there generally would be no directly measurable short-run economic benefit, except perhaps, as mentioned earlier, possible increases in property values.

The freeing-up of children from water-carrying chores might, on the other hand, allow them to attend school more regularly and to take better advantage of existing investment in educational facilities. This again, however, would probably only have a measurable economic impact in the long run, if ever.

Effects on Per Capita Income Through Increases in Population

Given existing birth rates, investment in potable water supply systems, by improving health, can cause an increase in the rate of population growth. Whether or not this is economically desirable depends on what is happening at the same time to income or output in the economy. It is obvious that economic output must grow at a faster rate than population in order to attain a goal of increasing per capita income. However, only limited examples have been found where a potable water supply, which is primarily for human consumption, can be directly productive, and result in a direct increase in economic output and income. Even with regard to better health and the extent to which potable water improves labor inputs, there has been research which contends that only a small proportion of economic growth is accounted for by increases in labor inputs (Kuznets, 1966).

As has been noted, a water supply system is part of the local infrastructure, and as such, may indirectly increase production and output over the long run. However, in general, there is insufficient evidence to
support an assumption that the direct and indirect increases in economic output caused by the potable water supply system would keep up with possible increases in population.

There are two considerations which could obviate the above problem, however. The first is that it might be possible to stimulate the local economy with other directly productive investments which complement the water supply investment and which increase the rate of economic output to a point where it exceeds population growth. This possibility will be discussed in some detail later in the sections on growth points and on multiple investment strategies.

The second possibility, which is more directly relevant to the population side of the problem, is that the decline in infant and child mortality might also cause a decline in the birth rate (Snyder, 1972; Heer and Smith, 1968). This follows from the three primary reasons for people having children (Robinson and Horlacher, 1971). First, children between the ages of eight and eighteen, and particularly those of rural subsistence farmers, contribute work, and therefore income, to the family. Second, children are a form of retirement annuity which rural parents purchase early in life and draw on later in life when they are no longer productive enough to sustain themselves. Finally, there is the non-economic related desire of people in many developing countries to continue their family line and to have sons to preside over their burial and inherit their belongings.

Given these reasons for raising children, a situation in which there is a substantial risk of infant and child mortality, as there is now in many rural areas with non-potable water, would be expected to result in higher birth rates than if there was a much lower risk of infant and child death. If lower infant mortality rates bring about lessened birth rates, long run adverse projections about the relationship between water supply induced population growth and economic output might not be valid.

Unfortunately, very little empirical evidence exists to show what has happened to birth rates in rural areas of developing countries when death rates were drastically lowered. One study examining the consequences of malaria control in Ceylon did find that as mortality rates fell, the population was increasing rapidly. However, on a cross section basis it was also found that those areas with the lowest mortality rates had the lowest birth rates as well as the highest population density, literacy, and the marriage-age of women (Frederiksen, 1968). These results, of course, make it very difficult to support any cause and effect relationship.

Finally, considerable literature does exist on the value of a prevented birth. This literature could be useful in estimating the real costs of a rural water supply system if it were concluded that, in a particular case, the water supply system would, over a foreseeable period, result in the population increasing more rapidly than income (Herrick and Moran, 1972; Simon, 1969; Simon, 1970; Leibenstein, 1969; Enke, 1966). Essentially, the value of a one-person reduction in mortality would be a person's discounted expected lifetime earnings subtracted from his discounted
expected lifetime consumption. Presumably, it would be a cost to society if consumption exceeds earnings and a benefit to society if earnings exceed consumption by a greater amount than that for the average person (so per capita net income does not decline). Of course, this calculation side-steps the argument that consumption, as such, should be a goal of society and therefore does not represent a cost.

**Economic Effects Through Averting Costs**

Conceptually, a rural water supply program could have the effect of reducing some of the costs which the local or national economy of the developing country is currently experiencing. These can be conveniently classified as possible one-time reductions in current expenditures, reductions in periodic revenue losses, and reductions in costs associated with personal consumption.

**-Possible Reductions in Current Expenditures-**

If a rural water supply program brings about lower water-related disease rates which in turn stimulate a more healthy population it might be possible for the country to cut back on some of the expenditures which are currently being made for health and medical services. Specifically, fewer funds might be necessary for (a) vaccination programs (typhoid, cholera, etc.), (b) hospital and health center facilities and equipment, (c) physicians and staff, (d) drugs and medicines, and (e) transportation for health purposes.

Whether or not a particular country would be able to reduce expenditures on health services as a result of a rural water supply program would depend on the extent of the improvement in the health of the population, on the supply of health care and the adequacy of health expenditures before the water supply program was initiated, and on the level of demand for public health care and services in the country. Little empirical information is available about what has happened to health expenditures in such a situation. However, since most developing countries do not currently have an abundance of health care services and medical facilities, it is doubtful if many countries would choose to reduce current levels of expenditures on health.

What is more likely is that, in the short run, the quality of health services will increase because the same staff and facilities will be available to serve a population which is now healthier, thanks to an improved water supply. In the long run, however, there might be some slowing in the rate of growth of public health expenditures which could be counted as reduced expenditures made possible by the rural water supply program.

Whether this happens or not, the important thing is that the countries would now be able to exercise a new option as a result of the rural water program. They would have the option, at a point in time or over a period, of allowing the quality of health care in the country to increase or of maintaining the same quality of care and reducing health related public expenditures.
-Reductions in Periodic Revenue Losses-

A reduction in the frequency and magnitude of water-related epidemics could result in a smoother growth of the national economy. In particular, if a country relies to a significant extent on tourism and trade to generate income, and if epidemics necessitate travel restrictions, hurt tourism through unfavorable publicity, or result in embargoes on trade, then the country loses revenue and income. In situations such as this, a rural water supply program which contributes to a country-wide reduction in water-related epidemics would benefit the country by helping to smooth economic growth and reducing periodic losses in revenue. Estimates of the probable economic impact would have to be derived from estimates of the past frequency and magnitude of epidemic-related losses and by comparing these with probable changes brought about by a rural water supply program.

-Reduction in Costs Associated with Personal Consumption-

One additional set of reduced costs which might be imputed to a rural water supply program relate to the fact that the majority of people served by the new system will now spend less effort procuring water for their personal consumption. It is possible to measure this reduced effort in terms of the cost of calories which are not now needed to carry water. If it is assumed that (a) carrying water requires more calories than the substitute activity and (b) the person would reduce food intake (cost of personal consumption) proportionate to the reduced caloric needs, then estimates of the value of the food not consumed could be made. Presumably, food not consumed would not be purchased, thereby reducing consumption costs (increasing disposable income) of the family. Alternatively, food not consumed would be sold, thereby increasing the disposable income of the family.

Estimates have been made, for several areas in East Africa, of the expenditure of caloric energy for procuring water over a variety of terrains, as well as daily caloric intake and caloric expenditure when one is not procuring water (White, et al., 1972). Another estimate, in Upper Volta, stated that one ton of sorghum was needed to meet the energy expended by 60 women fetching water, each walking 16 km for 150 days of the dry season (IBRD, May 16, 1972). It must be kept in mind, however, that translating estimates of this sort into monetized benefits involves specific assumptions about corresponding changes in food intake and about what a person does with the extra time now available because of a new convenient potable water supply system.

Summary Considerations

The above sections have contained a brief discussion of some of the economic benefits which might be associated with the introduction of a rural water supply program in developing countries. The discussion briefly covered general growth and redistributive effects on the national economy, possible short and long run direct effects (gardening, animal husbandry, property values, commerce and village industry, etc.), effects
on labor inputs and earnings (death, morbidity, external health effects, additional time for productive work), problems of population size and income, and the possibility of averting some costs which the economy is currently experiencing.

From the discussion, it must be clear that it is unlikely that any one particular country would experience all, or even most, of these benefits as a result of a rural water supply program. Depending on the characteristics of the countries, however, each might experience a somewhat different mix of benefits which could be roughly estimated before the program was put into operation.

As was noted above, and in the section on health, a feasible way to estimate the benefits of a rural water supply program, so that they may be compared with costs, is to measure the health or economic impact in terms of changes in output and earnings, or in terms of a redistribution of output or earnings, depending on country and international agency objectives. Given this measurement and estimation constraint, a rural water supply program which is tied to efforts which will be directly productive (animal husbandry, etc.) or to the infusion of other complementary non-water-supply investment, which will result in the direct increase in economic output, will look much more desirable in a cost-benefit analysis than one which depends on improved health to generate increased labor inputs and economic output in a relatively short period of time.

The association between health and economic output, and the valuing of better health, has also been discussed in both the section on health goals and benefits and in this section on economic benefits. From these discussions a central point which emerges is that the improved health-improved earnings and output association is probably weak when examined for rural areas of developing countries.

If the economic output of an area is low because labor is a relatively scarce resource and if labor inputs are scarce partly because of high morbidity and mortality rates, then a rural water supply program which results in lowering the morbidity and mortality rates will bring about greater inputs of the scarce labor resource, and therefore greater economic output and earnings. However, in many rural areas of developing countries unskilled labor is abundant and is greatly underemployed. Therefore, a rural water supply program which is designed solely to improve the health of the labor force may increase the extent to which there is an oversupply of labor while having very little impact on economic output or earnings.

Finally, in the infrequent instance of a locality where most of those who desire income-generating work can find it, estimates of increased income generation from water supply induced health improvement must take into account the age distribution and skill distribution of the population. As was noted in the section on health benefits, most studies have shown that the incidence of water-related diseases is much greater among children
who are not members of the labor force. In addition, skilled members of the labor force will tend to be more productive and tend to increase output to a greater extent than those who are unskilled. Consequently, estimates of the extent of probable improved health among the two groups separately would result in a better estimate of the impact of a potable water supply system on economic output.
V. POPULATION RELOCATION, COMMUNITY ORGANIZATIONAL INFRASTRUCTURE, AND QUALITY OF LIFE

In addition to the improved health and the increased economic output goals of rural water supply systems described in previous chapters a variety of other goals, or expected benefits, are sometimes cited. Prominent among them are relocating population, establishing an organizational infrastructure at the community level, and improving the quality of life for people living in rural areas.

Relocating Population

Possibilities for using potable water supply systems to alter the rate of flow of population from rural to large metropolitan areas have already been discussed in some detail (Chapter I). Likewise, efforts to use potable water supply systems to encourage, over a period of time, the grouping of population into economically viable units in rural areas have also been mentioned (The Choice of Definition Section in Chapter II).

A third possibility which has not been specifically discussed is the planned relocation of population over a relatively short time-span. A variety of reasons might be offered for a country's decision to spatially move population over a short period of time. In some cases groups of population have been relocated from tropical river-basin areas where there existed a variety of diseases which could not be controlled. The population might be moved to an area on higher ground several miles back from the river. An incentive for the move might be a sites and services area which includes a potable water supply system and material for new dwellings. The assumption behind the move would be that, with potable water and the new location, the population would be healthier and possibly more productive.

Other cases of relocating populations en mass have been observed where a new irrigation or hydroelectric dam has resulted in the inundation of a populated valley. In cases such as these, dwellings and a potable water supply system are usually among the facilities provided for the relocated population.

A variation of the relocation problem is provided in those countries that have constantly shifting populations and where population stabilization may be a desired objective. In Zambia, for example, the nomadic tradition is in part the result of wasteful agricultural practices. The burning of crops, which rapidly exhausts the soil, frequently means that the agricultural communities are provided with a certain basic infrastructure which is only used for a few years before the tribe moves on and abandons it. In this particular case complementary investments - say in agricultural education, including the use of fertilizers - might in the long run permit cost savings to be achieved.
Relocation might also be encouraged if it provides an opportunity for the government to provide people with water and other public facilities at a lower unit cost (because of economies of scale) and to create the beginnings of an urban growth area which, as it develops, could become viable. The Ujamaa villages of Tanzania are a good example of this. Moreover, even in developed countries the observation has been made that in certain instances it would be preferable from a strictly economic standpoint to relocate a dispersed farming population than to provide them with public water (Warford, 1969). Although illustrative of the magnitude of economies of scale and concentration in the public water supply field, this study also points out some of the social problems likely to be encountered in attempting to use the relocation solution.

Finally, for reasons of political indoctrination or to generate long run national political and economic power, populations have also been encouraged to move, on short notice, into newly created settlement areas which have potable water supply systems. It is true that an uninformed dispersed or nomadic population does not provide a central government with a very stable or reliable power base. A more concentrated and stable rural population provides a central government with the opportunity to more easily inform people of its merits.

Establishing an Organizational Infrastructure

A cohesive problem-oriented organization of community leaders does not exist in the rural areas of many developing countries. There is no formal group whose goal is to improve the community and to help it to grow and prosper. It is sometimes argued that a community potable water supply project is one way to organize such a group and to demonstrate that such a group can carry on and can continue to function for community betterment long after the water supply project is completed.

It is a well known contention that if a rural water supply program is to succeed there must be involvement by leaders at the community level. Residents of the village must be induced to develop pride in the system, to feel that it belongs to them, or at least to feel that they have some ownership responsibility of it. This is generally accomplished (although there are exceptions) by attempting to have the community contribute some portion of the initial construction cost and to pay, through time, at least the operation and maintenance costs of the system. The community contribution to construction can be in terms of money or by providing free labor, although it is generally difficult to contribute much more than ten percent of system cost if nothing other than labor is involved.

The result of this need for community participation and contribution is that some form of local organization is usually created to help organize and administer the local effort. The organization can take various forms although it is generally a type of committee made up of local leaders. The committee (with the guidance and help of a water program community promoter provided by the national or regional water program office) is very active during the planning and construction phases of the project. After the project is completed the committee also meets occasionally to review system operations, finances, and possible system expansion.
It is contended that a committee of this type, made up of local leaders, is a necessary part of the local infrastructure of a rural area which requires a lot of self-help to make development progress. Evidence to support this contention can be found in northern Argentina. There, local committees were organized and involved in some of the rural areas where electricity was introduced several years ago. Now, similar committees, made up generally of the same people, are attempting to organize their villages and to petition the government for assistance in procuring village water supply systems. These cooperative electricity committees have survived through time and are now (with the help of a trained community water promoter) channeling their efforts in a new direction.

Finally, it is sometimes suggested that the introduction of a community water supply system, which requires the payment of a monthly fee by its users, is a means by which the habit of periodic payments can be introduced into a population. Many rural populations do not understand or participate in periodic tax or revenue payments to the government. In some areas water supply systems, where the population pays for a recognized tangible service, could be one means of developing a so-called habit of payment in the population.

**Improving the Quality of Life**

If health in a given area improves as a result of a new water supply system, the quality of life in the area could also improve. Since fewer people will be sick or involved in caring for the sick, the larger healthy population might have the option of choosing to increase their earnings and consumption. In addition, women would generally be relieved of some portion of their major time-consuming task, drawing and carrying water, and children would have more time for education and leisure.

The extent to which the quality of life in an area changes depends partly on the extent to which the population values and uses the new water supply system. If the majority of the population keeps using the traditional water sources, because the new source has a different taste or is less convenient or because the old source has a religious significance, then there will be very little change in the quality of life in the area. However, if the population does use the improved water and does, in the aggregate, assign a positive value to having the new potable water supply system, then the quality of life in the area should improve.

The primary problem of setting the goal of improving the quality of life in an area, through the introduction of a potable water supply system, is that the quality of life in an area cannot be measured. It is even difficult to arrive at an acceptable array of proxy variables which might relate to the quality of life in an area. Indexes such as the Level of Living Index proposed by the U.N. Research Institute (1965) or the Quality of Housing Index suggested by The American Public Health Association (Cremliza, 1965) might be of some help in ascertaining changes in the quality of life but, in general, given the current state of the art, the concept is too elusive to be of great value in cost-benefit calculations.
VI. STRATEGIES FOR CHOOSING WHICH VILLAGES OR AREAS SHOULD RECEIVE WATER FIRST

In a country which is considering the implementation of a rural water supply program, one of the important questions which must be considered early in the planning stages relates to which areas, or villages, should receive priority. This chapter examines that question under the following four headings: Growth Point Strategies; Income Redistribution and Worst First Strategies; Financial Viability, Community Enthusiasm, and Maximization of the Localities Served; Clustering and Costs.

Growth Point Strategies

Economic growth and development does not take place at the same rate in all localities. At any point in time some areas are growing rapidly, some are stagnant and others are declining.

The rural areas of most developing countries are generally not among those areas which are participating in rapid economic growth. The urban areas are the ones which are attracting people, capital, and firms. People flow to urban areas because of the possibility of better jobs and higher earnings, better educational opportunities for children, and better public facilities and services. Capital flows to urban areas because of the greater demand and higher rates of return. Business firms tend to locate in urban areas because there is a better trained labor force, a large and more accessible market of higher income buyers, better transportation facilities, locally manufactured inputs, and legal, technical, and governmental services.

It is clear why it is difficult for smaller towns and villages to compete with the larger urban areas for skilled labor, innovative entrepreneurs, and financial resources. One suggestion for helping the residents of rural areas to stem the outflow of people and resources is to create points or centers of rapid economic growth in rural areas so that they can more effectively compete with the better established urban areas. These points of economic growth could be a limited number of selected towns or villages which have reasonable transportation access to the surrounding areas and, preferably, which have natural or marketing advantages that have brought about a generally higher level of current economic activity. Once the potential growth points have been selected, government investment in educational facilities, roads, sanitary facilities including water supply, market places, etc. would be necessary. The objective of the investment would be to create centers which would hold population and attract and hold economic activity.

Generally, it is argued that if government investment is spatially concentrated, rather than distributed in small amounts throughout rural areas, it is likely to (a) maximize the flow of income to regional earners in the short run, (b) attract the maximum possible flow of enterprise and capital from outside the area or region, (c) provide the most job opportunities in the shortest time, (d) generate a concentration of people so that adequate public services can be provided at a reasonable per person cost, and (e) provide a situation in which employment and income will spread, or trickle
out, into the non-growth areas of the region.

There is a voluminous literature on growth points, or growth poles, and the problems of selecting and stimulating them. The point here is that it is probable that village potable water supply investment, which is spread randomly among villages in rural areas of developing countries, will not directly or indirectly generate a significant quantity of economic activity. As has been discussed previously, while a potable water supply is necessary for development, it is not sufficient to induce development by itself. If economic development is an objective, then the limited water supply investment must be directed into selected high potential areas or regions, with a relatively concentrated population, and it should be accompanied by complementary investment in other public services.

**Income Redistribution and Worst First Strategies**

The goal of redistributing income from higher to lower income groups could also be a consideration when selecting which villages should have a high priority for receiving a water supply system. As has been discussed in Chapters one and four, any investment emphasis on rural areas will on an overall basis result in a high to low income redistribution since rural populations are generally poorer than urban populations and since the major portion of national revenue (on a per person basis), which is usually generated primarily from output and income based taxes, comes from the higher income urban areas. For most developing countries this is probably true even if a rural growth point strategy is pursued. This is because areas selected for rural growth point development, although they would not be the very poorest rural areas, would nevertheless generally be low income areas relative to the larger urban centers of the country.

Methods which countries currently use for selecting which areas should have a high priority for water service are somewhat diverse and are generally not well defined. An exception to this, in a country in which a worst-first strategy is pursued, is the well-defined system of village selection used in Thailand (Accelerated Rural Development Manual, 1971). There, villages are ranked according to their need for water and those villages with "very extreme need" or "extreme need" are given the highest priority. Ranks are assigned by a team comprised of two individuals who visit four to six villages per day. Both members of the team are equipped with a simple checklist of questions such as how far each villager walks for water in the dry season, and how long must he or members of his family wait to obtain domestic water. Similar questions are asked concerning how far livestock must be driven for water in the dry season. At least nine villagers in scattered parts of each village must be interviewed.

The team members rate the degree of village need for domestic and livestock water during the dry season on a scoring sheet. Those villages which receive a score of between 0 and 10 points fall into the very extreme need category. These villages are usually more than 5 kilometers distant from sources of domestic water during the dry season and the villagers must wait up to and exceeding 24 hours for water at the source of supply. Livestock in these villages must be driven more than 8 kilometers for water in the dry season.

Villages which receive a score between 11 and 14 points fall into the extreme need category. These villages are more than 3 kilometers distant from sources of domestic water in the dry season and villagers must wait for up to
several hours for water at the source of supply. Livestock in these villages must be driven more than 5 kilometers for water in the dry season.

Of the first 24,785 villages surveyed, 450 of them fell into the very extreme need category while 1,872 fell into the extreme need class. This classification system defines need in terms of proximity to water during the dry season and is a form of a worst-first strategy.

In this case, however, those villages which are the farthest from water are also generally smaller and, in many cases, poorer than average. As a result, some of the poorer villages have a good chance of attaining a high priority for water service.

In most countries, however, with viable rural water supply programs there seems to be a built-in bias in the system of selection which works against the very poorest villages and areas. There are several reasons for this. First, in most Latin American, and in several Asian countries, villages must contribute some portion of the cost of the construction of the system. This contribution can be in terms of money, labor, or both. In many cases, however, the required local contribution is more than can be feasibly contributed through labor and local materials, so that at least some monetary contribution is necessary. This means that villages which are too poor or too backward to raise the required local contribution are generally unable to participate in the water supply program.

Second, in many countries (although not all) the villages, or sysstem users, are required to pay water fees which at least cover local operation and maintenance costs. Among the reasons offered by water program officials for water-use charges are that they (a) reduce the subsidy which the national government usually must contribute to the program, (b) help the local populations achieve feelings of pride, ownership, and responsibility toward the system, and (c) help rural populations develop a habit of payment and a feeling of achieving something by cooperating with the government. As in the case of requiring a local contribution to construction costs, the result of charging water user fees is that the poorer villages usually contain a large proportion of people who find it difficult to generate a sufficient flow of extra income to cover their share of system operation and maintenance costs. Consequently, in determining which villages are able to financially support a potable water supply system, the poorer villages are in many cases pushed to the bottom of the priority list.

Third, in many countries in which the criteria for selecting villages for participation in the rural water supply program are loosely defined, those villages which agitate, petition, and frequently demand assistance are those which receive the systems first. And, those villages which first recognize the value of a potable water system and which are the most effective agitators for water supply systems are generally populated by relatively better educated and higher income people. Here, again it is not the poorest rural villages which receive the first systems.

Finally, the Interamerican Development Bank and the Pan American Health Organization have discussed a formula for choosing which villages in a country or region should be supplied with water first. One version of a formula which was developed by the Pan American Health Organization and which has been used experimentally by the Interamerican Development Bank is as follows:
\[ I = \frac{100 \cdot P}{C-A} \cdot r \cdot k \]

where

- \( I \) = an index of project selection priority in which higher values of \( I \) indicate a higher priority for early water supply system installation.
- \( \frac{P}{C-A} \) = the inverse of the cost per capita of the system, excluding the distribution network costs (or the cost of public faucets) and excluding the local counterpart contribution, in which \( P \) is the design population (the expected population of the village in 20 years), \( C \) the total cost (less household connections, if any), and \( A \) is the counterpart contribution supplied by the community.
- \( r \) = an index of the physical availability of water derived as a ratio between the existing water flow at the point of capture and the requirements foreseen in the 20th year of operation of the system.
- \( k \) = an index of the concentration of houses in the community to be served, measured as that proportion of the total number located within 50 meters of the proposed main conduits.

This index (\( I \)) tends to assign a higher priority to villages which require the lowest per capita investment by the national water agency. This result would be consistent with a strategy of maximizing the number of villages served.

Per capita investment which must be contributed by sources outside the village could be low because the village contributes a relatively large proportion of the costs, because the village is relatively large and experiences cost economies of scale, or because the village is fortunate enough to have a water source near by which can be tapped at a low cost. The first two reasons might be consistent with a high financial viability criteria, or with a growth point strategy. The latter reason would be consistent with a strategy of serving a maximum number of villages.

As a result of the inclusion of the availability of water index (\( r \)), villages which tend to have water sources which exceed the projected village water requirements twenty years hence would also tend to be given a higher priority by the priority index (\( I \)). In a technical sense this is probably a good idea up to some physical limit which is considered an adequate water source. It does not seem fruitful, however, to assign a higher priority to a community with a water source which is 750 percent of expected community needs in twenty years than to one with a water source which is only 350 percent of expected needs in twenty years.

In addition to the results achieved by applying the priority index formula, IDB suggests that some attention should also be paid to (a) the distance to the existing water source, (b) the degree of unemployment in the community (it is not stated whether a high or low rate should generate a greater priority), (c) the type of service and the percentage of houses to be connected, (d) land tenure, (e) existence of other infrastructure facilities, and (f) operating and maintenance costs.
In summary, while any water supply emphasis on rural areas tends to foster a redistribution of income, in most developing countries with rural water supply programs, the direct income redistribution in the short run is technically not as large as it could be because the higher income, better educated, larger rural villages tend to be the ones being served.

This result, however, is not necessarily bad. If some variant of a growth point, or a high development potential, strategy is being followed the villages which should be served first would be the higher income, better educated, larger towns and villages. A Worst First strategy, or a strategy of providing water to villages which generally are among the smaller, poorer, and least educated, is a high cost and low probable payoff venture. The poorest villages would have difficulty contributing financial resources to the construction of the system, would have difficulty maintaining adequate user fees to cover operation and maintenance, and would have difficulty generating and maintaining sufficient local expertise to assist in operating the system. In addition, if the villages are relatively small, as the poorest ones usually are, the per person construction and maintenance costs would be high relative to larger - higher income villages. It is difficult to determine, from experience, exactly how much more costly (on a per capita basis) a serve-the-poorest, worst-first, strategy would be since water supply systems in the poorest villages of many countries have become inoperable after a short period of time because of a lack of maintenance or financing.

Furthermore, the poorest villages in a country or region are generally poor for a reason. These villages simply may not have a sufficient current or potential economic base to support the existing population at other than a subsistence level. As a result, a government policy which provides non-viable villages with amenities which encourage the current non-viable subsistence-level existence of the population are not productive and may even serve to the long-run detriment of the population. As described in a preceding section, an alternative policy to help the population relocate closer to a growth center where there are opportunities for increased earnings, employment, and education may be more productive in the long run. Canada is among the countries in which such a policy has been proposed. In 1969 the Quebec provincial government proposed that eleven backwoods villages be wiped off the map. The residents were to be given cash incentives to relocate in larger towns where schools, hospitals, and vocational training centers were available (Hoover, 1971).

Finally if, for purposes of income redistribution, a true worst-first policy were to be adopted by a developing country, the rational water supply sector policy in many cases might be to concentrate on providing improved water for urban slum dwellers. A case can be made that in many instances the residents of slum areas in the big cities of developing countries are worse off than their rural counterparts. Urban slum dwellers usually have very few alternatives for procuring drinking water and, in expanding slums, the quality is questionable and the cost of water is generally high (particularly if purchased from vendors). In addition in densely populated areas, wastewater seepage into water pipes, which can occur where intermittent
water service is the policy, can cause the water supply distribution system to become a vehicle for the transmission of the very disease which the system was designed to prevent. The point is that if for purposes of maximum income redistribution a worst first policy is to be followed, the segment of the population which is worst off, at least in terms of health and sanitation, might in many countries be the urban slum dwellers.

Financial Viability, Community Enthusiasm, and Maximize the Localities Served

As noted in the previous section, a number of Asian and South American countries allow villages to participate in the rural water supply program only if the flow of income which the villages generate through time is sufficient to at least partially support a water supply project. In several countries villages are expected to contribute approximately 20 percent of the construction cost and to pay a water user fee which at the minimum covers operation and maintenance (see Chapter VIII for a more complete discussion of financing). This strategy of providing villages with water supply systems only if the projects are on a financially acceptable footing generally increases the probability that the population will accept, use, and maintain the system.

This financial viability condition is probably not consistent with a worst-first strategy. On the other hand, it could be consistent with a growth point or growth area strategy and if the national government partially subsidizes the program there would still be a redistribution of income in the country.

It is also frequently noted in rural water supply literature that the probability of project failure is much greater if the recipient village is not outwardly enthusiastic about the project. No matter how badly a village needs a better water supply system, if the population does not perceive the need for, or value of, the system the usage rate will be low, system maintenance and local administration will be inadequate, and vandalism could be a problem.

On the other hand, an enthusiastic community will have its contributions completed and its payments submitted on time. It will attempt to see that the system is used and well maintained, and will promptly report any problems which the village is having with the system. As a result, in many countries with viable rural water supply programs, only those villages which are actively enthusiastic about obtaining a water supply system are considered to be eligible. An example of this is found in the criteria for selecting target villages for participation in the rural water supply program in Peru. There, villages which have expressed interest, have requested the system, and have offered assistance in construction and operation are designated as high priority villages (Acurio, 1969).

Villages which for health or economic development reasons need improved water, but which do not perceive that need, might be stimulated or educated to their need by water program community promoters. However, unless community or village enthusiasm is present at the time the system is being
constructed, there is a much greater probability that the system will not be widely used, or that it will fall into disrepair in a short time. An underutilized or non-functioning system reflects an overinvestment in the project area and a misallocation of investment on a national level.

Finally, another strategy for selecting villages would be to choose those villages which can be served most cheaply. This would essentially be an attempt to serve the maximum number of either villages or people with a given amount of financial resources. The PAHO formula, discussed previously, had a selection bias which fit well under this strategy. Generally, while there is nothing wrong with a strategy of minimizing costs and maximizing the number of localities served, many countries, given their objectives, would probably be better off constraining such a strategy to include some consideration of financial viability, growth points, and/or community enthusiasm.

Specific standards for quality of service would also have to be agreed upon, since it could be tempting to trade-off quality of service for number of installations. Also, resources and organization must be available to keep the systems functioning long after the initial construction period. A program which maximizes the number of localities in which construction takes place, but which skims on construction, on the quality of service design, and on follow-up organization and maintenance will not in the long run be successful.

One country in Latin America ran into several difficulties relating to maximizing localities served, quality of service, and community enthusiasm in its rural water supply program. The country set out to provide water supply systems in approximately 400 rural villages. As the program got underway it became apparent that much of the rural population desired a better quality of water service than the project designs called for. In many villages the population complained that they wanted water taps at their houses and that they did not like the public fountain arrangement which was being constructed. In addition they complained that the water reservoirs were too small and that as a result they kept running out of water. Due to these quality of service problems, and to a lack of promotional work and demand analysis which should have been done in the villages before the project began, many villages allowed the systems to fall into disrepair by not assisting with necessary maintenance work and by not supporting user-fee collection.

To alleviate the situation, in some villages, the central program administration authorized additional construction to be undertaken in an attempt to raise standards and quality of service. Increasing the quality of service after the system was already completed, however, increased overall system cost to a level above what it would have cost to construct the better system in the first place. Because of these increased costs and because an unexpectedly high proportion of the villages experienced costly water source problems, water supply systems installed in villages which were served later in the program were underdesigned even further in an attempt to keep total costs down so that the program could serve the total 400 villages which was specified in the loan agreement with the international
agency. This led to further problems of population acceptance and nonpayment and, as a result, the program came to a halt.

This is one example of a few of the more extreme practical problems which have been encountered when a country chose to follow a strategy of maximizing the number of water supply systems to be constructed and when the goals for the number of villages to be served were too inflexible.

Clustering and Costs

Two additional factors which should be considered as possible constraints to any village selection strategy are system costs and the clustering of projects.

Program officials who are assigning priorities to villages should keep in close touch with project costs even if the overall selection strategy is not one of minimizing costs. An example of cost-consciousness is found in one of the criteria which are used to select communities to be included in the rural water supply program in Peru. There, it is simply specified that the proposed village project must not require an unusual or expensive solution (Acurio, 1969).

In a recent Interamerican Development Bank loan agreement there is a statement which says essentially that when the required investment cost per person exceeds a certain amount the executing agency should carry out a detailed analysis of alternatives, considering both the various possible sources of water and different system parameters. Added to this might have been a statement that a close examination of differences in expected benefits between the high-cost village and alternative villages which initially were not given a high priority should be made with a view toward lowering the high-cost village on the village selection priority list.

In general, this procedure has probably been followed in a number of the countries with viable rural water supply programs. The implication of this, however, is that as new loans are made by international agencies to expand or extend current rural water supply programs, the average per capita cost of providing water will increase since many of the low cost water-source villages already have been provided a water supply system.

The second factor which should be considered is that from the point of view of efficiently allocating manpower, supplies, and equipment during the promotion, construction, and operation and maintenance phases of a rural water supply program, it generally reduces financial and real costs if the projects are clustered on a spatial basis. Unless there are specific strategy-based reasons, such as a desire to achieve a demonstration effect, for scattering village water supply projects randomly throughout a region or country, it should be less costly to supply most of the high priority villages in one geographic area before moving on to other areas. If this is done, pipe construction equipment, or drilling rigs will not, on the average, have to be transported great distances between projects and the supervisory
maintenance and administrative body, if there is one, can organize initially by areas in an attempt to minimize transportation and communication problems.

A clustering of project objectives would be generally consistent with a growth point or growth area strategy of village selection. The projects in the limited growth point area could all be completed before the construction equipment was moved elsewhere. This would require, of course, coordinated advance promotion work geared to having all of the villages ready to receive the systems and to contribute their share (if any) of the cost at approximately the same time.
VII. SPECIAL PROBLEMS IN PROGRAM PLANNING

Several factors pertaining to the planning of water supply systems have unique aspects when related to rural areas. Among those which require discussion are pricing, quality of service, population acceptance, estimating the money value of village labor contributions, shadow pricing, level of technology, complementary programs, and the time frame for investment.

Pricing Rural Systems

In establishing the charges for water in rural areas two considerations arise. The first relates to the level of the charge, the second to the price or charging structure.

There are two primary reasons for charging a user-fee for water. One is economic; the other is financial. Price, in an economic sense, rations consumption. If set correctly it can lead to an efficient allocation of resources. An economically efficient price is one which equals the cost of producing an additional unit of water (marginal cost), or to society's valuation of the resources utilized in producing additional units of potable water. If price is set at a level greater than marginal cost the full economic utilization of water may be prevented. If price is less than marginal cost, the marginal benefit incurring to society is less than marginal cost and there may be overinvestment in water supply capacity. The result could be a wastage of water. An extreme example of this would be if water were free. If price is zero, water would be consumed up to the point where its marginal benefit is zero, and if the disposal of waste water is not a problem, there would be little incentive to ever turn the tap off (technical problems of using price to discriminate among users are discussed later in this section).

From a financial point of view the user-charge (price) is one way to recover the cost of investment and to pay for the operation and maintenance of the system. This amounts to setting a price that will cover the average total cost of the system. Since at most levels of output average cost and marginal cost are not equal, the price set on economic grounds will not necessarily equal the price set for financial reasons.

A price which is set for purely financial reasons would generally be one which would cover central administration and construction costs, operation and maintenance, interest on the loan, and depreciation. Although sometimes it is suggested that the price should also provide for a surplus for future expansion, it is frequently the case that low income rural consumers are unable to make any contribution at all toward capital costs.

Many different methods of charging for water are used in developing countries, but in most it is fairly clear that rural consumers normally pay less than average system cost, and frequently even fail to cover
operation and maintenance costs. Rural subsidies are usually defended on grounds of a lack of ability to pay. When determining the so-called ability to pay of a population, however, two things must be investigated. The first is the average real income of the population. This is difficult because money income is usually different from real income in rural areas, primarily due to the prevalence of subsistence agriculture. Also there is generally little or no reliable data available on either money or real income in rural villages and the estimation of the real income of rural populations is a difficult task.

Even if the question of real income level could be answered there is a second question which has no objective method of solution. This is the amount of a family's real income which can be spent on water. A frequently heard word-of-mouth answer to this question is that a rural near-subsistence family should never have to pay more than about 5 percent of their income for water. However, generalizations such as this are dangerous to make. Clearly, the appropriate percentage will be determined in large measure by the degree of monetization of the local economy, the cost of other essential items, and so on. In short, real income, which is always difficult to evaluate, is the relevant basis for judgement.

A few countries, particularly in Latin America, do attempt to make so-called socio-economic surveys of villages. However, these surveys generally consist of little more than forms on which a casual observer documents his impressions of a village after visiting it for an hour or two. In fact, one observer stated that the best way he knew to judge the economic state of a village was to watch what the inhabitants were drinking. He contended that the relative quality (and cost) of the alcoholic beverages which are consumed usually gives a reliable indication of whether or not the village has the ability to pay for water.

A few empirical studies have been made which have attempted to determine how much a given population can pay for water service (see for example Davis, 1968 and Romero, 1970). It is difficult to generalize the results, however, and even if they could be generalized there would still be subjective judgments implicit in them.

Given a general lack of any hard evidence on ability to pay, the assumption which has been made in most developing countries is that the rural population cannot pay the full cost of water. As noted earlier, in a number of Asian and Latin American countries, the beneficiary village is expected to contribute approximately 20 percent to construction cost and to pay for the operation and maintenance of the system. Experience in these countries suggests that this is a necessary prerequisite for program viability. Sometimes, when they opt to, villages are also allowed to accumulate a small surplus for depreciation and future expansion purposes even though they are not covering central administration costs or paying the principal or interest of the loan. A few countries, of course, do not charge for improved water. These countries argue that potable water is a basic human right irrespective of ability to pay, and as a result the national government should completely subsidize the rural water supply program from general revenues. Tanzania and Zambia provide good examples of this attitude,
although their neighbor, Kenya, does not subscribe to this philosophy.

Finally, the fact cannot be ignored that while most rural water supply programs are being partially subsidized by national governments, the same is true for many urban water supply systems (H. Ripman, 1967). This policy stems partly from a notion that water is somehow different from other goods, and should always be "free"; this attitude is indefensible unless there are valid income distributional reasons underlying it. While income redistribution goals may apply to rural consumers or urban slum dwellers, it is questionable to use this as a general argument for subsidizing all water supply.

The various charging schemes which exist in the rural areas of developing countries can best be discussed by separating those which distinguish between consumers in some way such as the basis of use, ability to pay, and those which do not attempt to make distinctions among users. Charging different prices to different consumers, or for different rates of consumption, can be based on one of two conceptual foundations. First, it can be argued that users who receive higher benefits from water consumption should be charged more. Second, it can be argued that low income groups should be charged lower rates than higher income groups because of difference in their ability to pay.

The argument for a simple flat rate (i.e., a common rate for each connection) is simply based on the idea that administratively it is much easier and cheaper to charge a flat monthly fee for each connection than to bother with some form of more complicated or discriminatory pricing system, which requires either metering or a qualitative judgement about the value of consumption by different groups.

Following are several methods of charging for water, and ways in which consumption is regulated in rural areas of developing countries.

(Metering) - House connections in rural areas of developing countries are usually not metered. It is generally accepted that the costs of installing, reading and maintaining meters in rural areas are relatively high, and are likely to exceed the benefits (i.e., production cost savings, to be derived from them. Water consumption in rural areas is usually relatively low, because of a lack of water using appliances and absence of good drainage, and there is not much scope for reduction in consumption, which would save in production costs. The gains in equity are not generally believed to be sufficient to alter this decision, and in any case metering may only have a real effect on the poorest members of society, whose health may suffer as a result.

(House Reservoirs) - The rural water supply program in Argentina makes use of a system of individual house water tanks, or reservoirs, to both regulate the flow of water and to charge according to the volume of water consumed. The system essentially consists of a cement tank which sits on top of each house. Water flows into the tank through a small hole such that it takes a considerable period of time for the tank to fill up. The
inhabitants of the house can use the water at whatever rate they want until the tank is empty. Generally, this means that water users ration their consumption over the period of a day so that the tank is never quite dry except perhaps in the evening. The tank can then refill throughout the night. People pay different water rates according to whether they want a 300, 500, 800, or 1000 litre tank outlet. The tanks, or cement house reservoirs, come in two sizes: 300 and 500 litres. The 300 litre tank serves the 300 and 500 litre outlets (the tank is set so that it refills more rapidly for a 500 litre outlet) and the 500 litre tank serves the 800 and 1000 litre outlets. The price charged for water varies by village but generally the monthly water rate for the 300 litre outlet is approximately one to two percent of the monthly income of the water consumers. This device therefore acts as a means of pricing and regulation of consumption, and is probably cheaper than metering.

There is one potential danger of a system like this, however. That is that since all water consumers have roof-tanks there may be the temptation at some future date to provide users with intermittent service. This could result in a marked deterioration in the health benefits of the system (see the following section on quality of service).

(Flat Rate With Rules About Consumption) - In many countries where a flat monthly rate is charged for each house connection there are rules about how the water can be used. The rules sometimes specify that only the family cow, horse, and chickens can be watered with the potable water or that certain high water-using plants or trees cannot be grown near the water tap. Also in many countries the wasting of water is prohibited (failing to turn the tap off) and the village water committee, or council, has the right to cut off people's water connections for either water wastage or the non-payment of water bills.

In areas where some of the residents, during dry seasons, desire to water their livestock, there may be communal animal watering stations or residents may be allowed to purchase an extra water outlet and have it installed near their residence so that they can water their livestock there. In the case of communal livestock watering stations, water might be provided free or each resident might have to pay a monthly fee for the right to water his livestock. In the cases where the resident acquires an additional outlet to water his livestock he generally has to pay a rate approximately equal to what he would have to pay for another individual house connection.

In countries which have viable water supply programs, and which charge for water, the monthly flat fee water rate for house connections rarely exceeds five percent of estimated monthly income. Generally, several forms of price discrimination are practiced in addition to that based solely on quantity of water consumed. For example, in a number of countries most rural household users are charged a flat rate while any large users in the village (village industry, etc.) are metered.

Also the use of outlets for livestock watering, or for gardens, can be charged at a higher or lower rate than the household rate. In some areas of Kenya, for example, the domestic rate is set in an attempt to cover both fixed and variable costs while the cattle rate only covers variable pumping costs (Carruthers, 1972).
Different rates can, also, be set for different seasons. A low rate could be charged in the wet season (when demand is more elastic) to encourage the use of the protected water, while a higher rate could be charged in the dry season when there is no alternative water source. Water fee collections are also sometimes seasonal so that people can pay their bills after the harvest season and do not have to maintain a monthly flow of payments.

In most countries, different rates are charged to families which use public fountains, or standposts, and to those which have house connections. Those with house connections not only have to pay an initial connection fee, but they also pay a higher monthly rate than those who use public fountains. In many instances, even though the cost of house connections is greater, the proportion of the village with house connections increases rapidly through time. This is partly because real incomes increase and partly because there seems to be a demonstration effect which exists and as people begin to perceive the advantages of having a house connection they somehow manage to save the money necessary to acquire and maintain one. This is sometimes reinforced (as in several Latin American countries) by the closure of public fountains after a certain percentage of the village has house connections, which leaves the remainder little alternative but to connect also.

Finally, in areas where the dual judgements are made that (a) the people should have potable water and (b) the people have an extremely low ability to pay, some consideration should be given to whether or not the small fee which will be charged will generate sufficient revenue to cover fee collection costs. In some cases the revenue collected may not exceed the cost of collection. This probably applies to the rural water supply program of Ghana at the present time. However, it may be preferable to retain the practice with the expectation that collection procedures will become more efficient and/or the principle of payment for water will become more generally accepted.

(Methods to Limit Water Wastage) - When a flat-rate water fee is instituted water wastage can, in some countries and cultures, be a problem. There are essentially two means for dealing with this problem: community moral suasion and the installation of flow limiting devices. Throughout much of Latin America and in some areas in Asia, country officials claim that community moral suasion has been sufficient to keep water wastage within acceptable limits. Generally a village water committee, or village council, attempts to police the water wastage problem and if anyone persists in not turning off the tap they are either barred from using the public fountains, their house connection is disconnected, or a flow limiting device is installed at their residence.

In addition to fears that the reservoir might run dry and that pumping costs will increase, a factor which induces the water committee and the water system users to act against water wasters is the problem of drainage. In most rural areas improved drainage does not exist and, as a result, the wastage of water causes the creation of an area of stagnant water and mud. This is unsanitary and is generally disliked by many water supply users.

In those cases where for reasons of location, culture, education, or habit it is projected that it will be difficult to induce the population to refrain from wasting water, or where the source of supply is small
relative to potential demand, it might be necessary to install flow limiting devices on all non-metered outlets in the system. Beside the Argentine house-reservoir system for limiting flow and setting price, the most common types of flow limiting devices seem to be fordilla-type valves and small diameter outlet pipes.

If the objective of the flow-limiting device is to reduce wastage but not to significantly reduce benefit-producing consumption, fordilla-type valves are probably a good solution. They are a good solution, that is, if they do not require what might be considered to be an unacceptable amount of maintenance. Fordilla valves have been in use on St. Lucia for approximately three years and reportedly have required almost no maintenance. However, imitations of the fordilla valve, manufactured locally, have been used in several other countries and problems of leakage and breakage have been significant. The use of a sophisticated flow-limiting device does raise the per-user construction cost of the system. This increased system cost must be compared with the savings in production and capacity costs which are achieved by use of a flow-limiter.

Finally, another possibility for limiting water consumption is to provide intermittent water service to users. While this would probably cut down on water production and storage costs it would also, undoubtedly, reduce the potential benefits of the system. People would tend to use other water sources when the system was not operating thereby negating much of the health benefits of the system. Furthermore wastewater could seep into the distribution lines when they are not under pressure. This would not only compromise the quality of the water which the system provided, it could also result in the system being the vehicle for the spreading of disease.

(Pricing Through Time) - There are several pricing strategies which involve altering, through time, the price charged for water. The most obvious involves increasing the price charged for water as the ability of the community to pay increases. This is most feasible in areas where the population is currently poor but where it is expected that the water supply system will stimulate an increase in economic output and income. In situations such as these, a low revenue producing pricing policy might be initiated with the expectation that, through future price increases, the system could in a foreseeable period, begin to generate an acceptable level of revenue.

Another rationale for setting a low price during an initial period of water service might be to encourage village residents to make use of the system in the hope that they would begin to recognize the convenience and health benefits of the system and will continue using it when price is raised after, say, the first year. In other words, if it can be assumed that the demand for improved water will become more inelastic over a reasonable time period after a village system has been installed, then it would be feasible to price water at a lower rate while demand is relatively elastic and to raise the price as demand becomes more inelastic.
Finally, it is rational to raise the price of water as the water supply system nears capacity. This practice would be using price to ration water consumption and would generate additional revenue which could be used to cover part of the cost of expanding the capacity of the system. Conceptually, price could be raised until it is equal to long run marginal cost (Warford, 1971).

Of course, while it is easy for the engineer and the economist to discuss possibilities for raising prices through time, in some cases such policies might generate significant political problems, or community cooperation problems. The benefits derived from any price changes must be carefully weighed against the costs (economic and political) of such changes.

Quality of Service Problems

The focus of this section is on the technical design aspects of quality of service problems. Administrative considerations are covered in the following chapter (VIII).

The quality of the water service which is designed into a water system should depend primarily on the goals which the system is supposed to achieve. Most rural water supply projects have both health and economic objectives. As has been discussed previously, every project should be designed in such a way as to maximize the probability that the objectives will be achieved, subject to the constraint that there are other uses, and corresponding benefits, for each additional dollar which is spent on the project.

In the design stage, these things being equal, increasing the probability that the goals will be achieved generally involves an increase in the cost of the project. Whether or not the increase in cost is worth the increment in the probability of success must be assessed by examining the alternative uses to which the additional resources could be put. Overinvestment in a project might be as bad as underinvestment if the overinvestment is viewed in terms of its opportunity cost.

A helpful way to view the question of what level of service should be designed into a project is to consider the two basic water supply factors which most determine the amount of benefits which can be expected: the quality of the water consumed and the quantity of water consumed. In the review of the twenty-six health studies in Chapter III, both of these factors were found to be important in controlling water-associated diseases.

Quality of Water

Whether or not it is desirable to lower standards of water quality in order to achieve cost savings is debatable. (For an interesting discussion on this point see Shipman, 1972.) It is certainly true that a water system which would, from time to time, distribute unsafe water would not be acceptable. However, it also might be difficult to justify spending
a disproportionate amount of funds on a water supply system to eliminate marginal taste, color, or odor problems.

Generally, the argument which states that reasonably safe water is better than no water and that money spent on supplying absolutely safe, tasteless, colorless, and odorless water could be used better by supplying more people with only reasonably safe water is valid. The problem, of course, is in deciding whether or not it is desirable, in some cases, to relax World Health Organization water quality standards in defining what is "reasonably safe" water.

In several of the studies reviewed in Chapter III the quantity of water consumed was found to be more important than the quality of the water in reducing disease incidence rates (particularly water-washed diseases). However, it must also be assumed that the quality of the water in those cases was not particularly bad, i.e., the water was, on the average, of a so-called reasonable quality.

For the engineer, the particularly difficult design decisions arise when several village water supply projects need chlorine or filtration only, during the one or two month dry season, when it is considered possible that small amounts of residue and bacteria could get into the system. The difficult question is whether or not chlorine and filtration facilities should be built into the systems, to be used only one or two months a year, or whether the funds should be used to provide a year round water supply system for an additional village. Adding to this cost-quality tradeoff problem is the fact that the best estimates of probable bacteria levels under different circumstances are generally subject to considerable error.

The quality of water question has no general solution. Probably the best means of handling the problem is to approach it afresh for each project, keeping in mind the dual goals of providing so-called reasonably safe water and keeping project costs as low as possible.

-Quantity of Water-

As noted numerous times, the quantity of water which individuals consume has been found to be associated with incidence rates for a number of the diseases which are common to rural residents in developing countries. Since rural dwellers do not have a significant number of water using appliances, and generally do not have flush toilets, the three major physical factors which influence the amount of water consumed by villagers are (a) the distance the water tap is from an individual's dwelling, (b) the degree of regularity with which water flows from the system, and (c) the rate or ease of water flow from the tap.

The relative convenience (or nearness) of a water tap influences the amount of water users both because they tend to consume more if the tap is near, and because when water is carried to the dwelling and stored in a container until it is used, there is a much greater likelihood of contamination. The array of possibilities for tap location are, of course,
endless; from one public fountain (standpost) in the center of the village, to a series of public fountains along a main trunk line and several smaller lines, to taps at each individual dwelling.

The question of whether or not rural water supply systems should be constructed primarily with public fountains or with an individual tap at each house is one with no fixed answer. Basically, it is a decision which depends on (a) the philosophy or goals of the country or Ministry which is providing the financial subsidy, (b) the demands, or perceived needs, of the rural residents, and (c) the ability of the water-consumers to pay for the more convenient house installation.

The philosophy of countries concerning the question of house taps vs. public fountains can vary greatly even among those in similar regions of the world. For example, in Tanzania the rural water supply program focuses almost entirely on the provision of public standposts. The philosophy of the program is that as many people as is possible should have access to improved water and that this can be facilitated by providing only low cost public standpost installations. Water at the standposts is provided free which means that the program has significant redistribution of income implications.

In Ghana, on the other hand, the program focuses on providing only individual household connections. All dwellings which are served are expected to pay user-fees and if a user falls too far behind on his payments his water service is cut off. Any family which cannot afford to pay the user-fee is not supplied with water.

In the relatively higher income Latin American countries most of the successful programs have encouraged the installation of house connections. Generally, village systems are designed with a capacity of 100 percent house connections even if all dwellings in the village do not hook up initially. For example, when a system is built, only 20 to 50 percent of the houses might pay the additional fee for an individual house connection. The remaining residents of the village use public fountains. As time passes, however, (one or two years) an increasing number of households pay the connection fee and receive taps at their houses.

In several countries, after a certain proportion of the houses have house connections (60 to 80 percent), all or most of the public fountains are disconnected. This, of course, provides a further stimulus for additional house connections. In a few localities, notably in northern Argentina, villages provide one free water tap at which private water vendors can secure safe water which they in turn sell to the more dispersed population in the surrounding areas.

The additional cost of constructing a system with house taps rather than public fountains varies widely. Undoubtedly, more water per capita is consumed when all dwellings have house taps. This, of course, means that a somewhat larger design capacity of the system is required. The additional cost of physically extending water lines from a main line to individual dwellings depends on how extensive the main line distribution
system would be if the house tap option was not planned. In view of the many possible system configurations and variations in population density and service costs, it is almost impossible to make generalizations about the relative cost of household versus standpost supplies.

Moreover, in most developing countries so-called house connections or house taps are not connections inside the house. A house connection is either a patio connection (a connection on the inside wall of an enclosed courtyard-type area) or a connection in the yard beside, or in back of, the house. A connection inside a house implies a drainage system, which does not exist in most rural villages.

The single house connection (in the yard) does permit considerable versatility in the use of the water. In several countries it is not too uncommon to see a plastic garden hose connected to the water tap so that the residents can convey water to an enclosed area where they can take a shower, to a tank in which animals are watered, and to the area where they prepare food for personal consumption.

When attempting to decide whether or not the residents of a certain village should be encouraged to have house connections, or to use public fountains, the income and education level of the residents should be considered. Generally, the demand for improved water, and particularly water located at a dwelling, is a consequence (rather than a cause) of economic development. Therefore, higher income villages (and countries) are more inclined to demand house connections and, of course, are also more able to pay for them. In other villages (and countries) the money value of the house connection might in some cases exceed the value of the dwelling.

Whether or not villagers should be asked to pay the full cost of their house connections at the time of installation depends partially on their ability to pay, on the relative certainty of collecting the payments at a later date, and on the strength of the health-benefit goal which might dictate that a lower (below cost) hook-up fee should be charged in order to encourage house connections. With regard to the health-benefit goal, the question which should be asked is can an acceptable level of health improvement be attained without, or with just a few, house connections.

The other two factors which influence the quantity of water which is consumed, i.e., the degree of regularity with which water flows from the system and the rate or ease of the water flow from the tap, have been discussed previously. Possibilities for, and implications of, flow-limiters were discussed in the section on pricing. The contention that intermittent supplies introduce a considerable danger of contaminating the system through a seepage of wastewater has also been noted, although this problem is not as serious for rural systems as it is for urban.

Population Acceptance

If the majority of the population of a village does not actively support the installation of a water supply system, the probability that the health and development goals of the system will be attained is greatly reduced. As noted in a previous section, if the demand for improved water is generally a derived demand, then the higher income -
better educated villages will be among the first to request a water supply system. Since these villages have an initial enthusiasm for the water supply system, the primary problem in dealing with them is (a) to translate their enthusiasm into concrete action in the form of a local contribution (labor and/or money) to system construction cost and to system operation and maintenance, (b) to ascertain the level of service which the village can afford and will be pleased with and support, and (c) to design and support the operation and maintenance phase of the program so that the village population does not become disenchanted because of inefficiencies and inadequacies.

Villages which are selected as having particularly high priority but which do not themselves perceive the advantages of a piped water supply system must receive considerable attention in the form of water supply promotion and education. The objective would be to stimulate a sufficient enthusiasm for an improved water supply system so that the village would willingly make the local contributions which are required and would enthusiastically support the operation and maintenance function. In the case of very low income and backward villages it is possible that the large amount of promotion necessary to stimulate an acceptable level of enthusiasm, together with the lack of sufficient local ability to assist in, and support, system operation and maintenance, could increase the costs of the system to the extent that better alternatives can be found for the funds elsewhere.

In a more general sense, there are three factors which must be considered in gaining or maintaining a community's enthusiasm about a water supply system: promotion, community involvement, and efficient operation and maintenance. Promotion and operation and maintenance are discussed in the next chapter dealing with administration (VIII). The remaining factor, community involvement, is generally advocated on the psychological grounds that if a community is involved in a project, and if they contribute labor and/or financial resources to it, they will value it and attempt to take care of it to a much greater extent than if it is given to them, or if it is imposed upon them.

Community involvement and participation may be encouraged by an advance water program promoter who helps organize a community water supply committee which in turn decides how the community will raise its portion of the cost of construction. The community contribution can be raised in a variety of ways including asking each family for a cash payment, holding several village-benefit fiestas or bazaars, and organizing a free labor crew which digs trenches for water lines and provide a general purpose supply of unskilled labor.

In at least one Latin American country the job of encouraging villagers to donate their labor to a village water supply project is being made easier by the World Food Program. In that country the World Food Program has an arrangement with the national rural water supply agency whereby for each day that a villager donates four hours work to the water supply project he receives a free food ration which will feed a family of six for one day.
In addition to the psychological and obvious financial reasons for advocating community involvement, there may also be solid economic reasons for supporting such a policy. For example, community involvement, by providing local labor for construction, could lower the real cost of projects. This is because labor in rural areas of developing countries is generally underemployed, and if construction took place at a time other than at harvest or planting the opportunity cost (or shadow price) of the labor involved would probably be close to zero. Of course, a community contribution of labor would require additional promotor or supervisor time which would tend to reduce, somewhat, the real cost advantage of the free labor.

Estimating the Money Value of Village Labor Contributions

In practice there is some uncertainty about how to place a monetary value on the free labor which villages donate to the water supply project as part of their contribution to construction costs. Some of the problems of valuing the local labor contribution are illustrated by the following methods which have been suggested in several Latin American countries.

Water supply authorities frequently estimate the money value of local labor by multiplying the number of man-days of work which are contributed by villagers times the national minimum legal wage. While this is probably the value as perceived by the village itself, it represents a considerable overestimate of the real social value of the labor since few of the workers would have an alternative opportunity to earn income during the time they were working on the water supply project.

Another simple method would be to value the donated labor as being equal to the market value of family food rations which are passed out to workers who contribute labor to the water supply project. As noted previously, in at least one Latin American country the World Food Program has made arrangements with the rural water supply agency to provide free food rations, which will feed a family of six for one day, for each four hour work-day of donated labor. This is one means by which a village contribution of so-called free labor is encouraged. In the country involved, the market value of the food ration is approximately one and one-half times the legal minimum wage which would have to be paid for one-half day of work. Therefore, equating the value of the donated labor with the value of the food allotment would result in an even greater overestimate of the real value of the labor than if the minimum wage was used.

A more legitimate method to calculate the value of donated labor for purposes of determining the financial amount to be credited to the village's contribution to construction costs, would be to compute the cheapest alternative way the job could be done. If a job which took the donated labor three weeks to complete would have taken three days if a tractor with a back-hoe had done it, the value of the donated labor is the amount it would have cost to get the job done with the tractor.
Shadow Pricing

Closely related to the foregoing is the problem of shadow pricing which arises in all investment decisions in developing countries. For any public investment project some estimate of the real resource costs to society should be made so that (a) the real costs can be compared with the expected benefits in order to determine if the investment should be made, (b) the real costs of alternative methods by which the project can be completed can be compared so that project costs can be minimized, and (c) beneficiaries can be asked to pay for the real resource costs which their consumption entails, or alternatively, any subsidy which they receive can be estimated in real terms.

The real costs to society of the resources needed for a water supply project have to be, in principle, scarcity prices which are determined by supply and demand. In developed countries real costs can be estimated, with some degree of accuracy, by using market prices. In developing countries, however, the price of foreign exchange is often underestimated, and the prices of protected goods, and unskilled labor, are overestimated, when market prices are used. In cases such as this when market prices do not reflect real resource costs, other estimates of real costs (shadow prices) are necessary.

Various techniques for computing shadow prices have been proposed. Among the more important is the Little and Mirrlees (LM) method (Little and Mirrlees, 1969), of which the main characteristic is that it uses foreign currency as the numeraire by which costs and benefits of projects are evaluated, while not involving an explicit use of a shadow exchange rate. So-called "shadow exchange rate" methods are exemplified by the other two main techniques, the Bruno-Kruger (Bruno, 1967; Kruger, 1966) and UNIDO (UNIDO, 1972) methods, which use domestic currency as the numeraire.

Important practical advantages are claimed for LM over the others. The first is that because the LM method measures costs and benefits in terms of world market prices for traded and tradable goods, it avoids making the explicit statement that a currency is overvalued, although overvaluation is of course implicit in many cases. A second advantage is that it permits a more sophisticated measurement of costs and benefits by using, not a blanket shadow exchange rate, but by valuing different commodities individually simply by making use of the appropriate world market prices.

In practice, however, this benefit is likely to be more apparent than real. It is very difficult to measure these factors in the precise manner which is implied by such a procedure, and some averaging is always necessary. The LM proposals suggest that where measurement becomes impossible a "standard conversion factor" should be used instead. The standard conversion factor is simply the reciprocal of the shadow exchange rate, so in these circumstances there is even less to choose between LM and the other procedures.

There are several practical problems which may be encountered when
shadow pricing is to be undertaken in a rural water supply program. For example:

1. The use of shadow prices may result in the selection of a project which, although in terms of the economic resources used in its construction and operation, is estimated to be the economically cheapest, but may not be the cheapest in purely financial terms. The additional financial resources then have to be raised somehow by the water supply program Ministry. The water consumers can argue - and on theoretical grounds would be justified in so doing - that the additional financial cost should not be passed on to them. The alternative, of course, is for the water supply Ministry to be allocated a larger subsidy from national general revenues.

2. Presumably consultants would have to employ an economist to enable project design and selection to be made in accordance with shadow pricing guidelines, as well as having to rely upon local economists. As a result, the cost of feasibility and design studies might rise significantly - not simply by the cost of the economist, but because the employment of the latter could mean that very different schemes are evaluated, e.g., labor versus capital intensive projects. This possible high cost of carrying out precision shadow value calculations implies that unless there are very good prima facie reasons for believing that large savings can be achieved by use of shadow values, an acceptable procedure would be to use blanket values, such as the shadow exchange rate as suggested by UNIDO.

3. The complexity of the interaction between the appropriate project selection and design and the appropriate method of construction will be increased by use of shadow pricing. The problems of trying to frame tender documents to reflect the need for the use of shadow values by bidders will also be immense.

The difficulties of handling these problems do not, however, excuse the general absence of shadow pricing in rural water supply investment programs. The fact remains that rural areas of developing countries tend to be characterized by great underemployment and by overvalued local currency. As a result a failure to "shadow price" these factors, together with the availability of government or international agency capital at interest rates below the opportunity cost of the capital, could tend to distort the choice between labor and capital intensive methods of construction and operation and to distort the choices among alternative water supply investment projects.

Level of Technology

One of the primary considerations in designing and building a rural water supply project is to keep the technology involved as simple as is possible so that local operators will be able to operate and maintain the system for long periods of time in the absence of an engineer. The extent to which the concept of "low-level technology" or "intermediate-level technology" is a "buzzword concept" with few policy alternatives is
debatable. The Intermediate Technology Development Group has done some work in the area of lower-level technology (ITDG, 1969) as have engineers at the Asian Institute of Technology in Bangkok. The best document available, which contains both a technical description of many existing rural water supply and sanitation facilities and a review of some problems encountered in designing and maintaining unsophisticated systems, is one distributed by the International Development Research Centre (Burton, et al., 1973).

Generally, however, beside the guideline which states that technical installations and equipment should be kept as simple as possible, there are also the economic considerations that, when possible, local materials and equipment should be used and capital costs and capital imports should be kept to a minimum. This is, of course, in keeping with lowering the financial and real costs of the water supply program, with stimulating economic activity within the country, and with making the program more attractive to the national government by requiring the expenditure of a minimum of foreign exchange.

If plastic pipe represents an intermediate level of technology, then it is clearly one example of a successful adaptation. Polyvinyl chloride or polythene pipe is used in rural water supply programs throughout the world. It has the advantage of being relatively cheap to manufacture, of being simple to manufacture so that most developing countries can purchase an extruder and manufacture it locally, of having a very smooth internal surface, and of being relatively easy to assemble at the construction sight by semi-skilled labor. The relatively minor disadvantages of some plastic pipe is that it is sensitive to light and weather and that its strength decreases with increases in temperature.

Complementary Programs

There may be a number of investments, complementary to a rural water supply program, which either increase the probability that the ultimate objectives of the water supply program will be accomplished, or which in addition, lower the costs of the water supply program. An example of the first type of complementary investment is a sanitary education and latrine program designed to increase the probability that the health objectives of the water supply installation are accomplished. Another would be a directly productive capital investment which is necessary to provide an opportunity for a productive life to those whose health is improved. An example of this would be a program to educate rural water-users about the new opportunities for increasing village livestock production and garden output.

A related possible complementary investment which must always be considered when a water supply project is being designed is drainage. A drainage system, or a means to drain water away from public standpost or cattle watering areas, is not necessary in all instances; the need being related to the slope of the ground, proximity of residential areas, and the absorptive capacity of the soil. Most rural water supply systems do not have drains near water outlets. However, in cases where, because of heavy usage and level terrain, waste water tends to collect, a significant health hazard can result. This health hazard would be particularly noticeable in
areas where there is a potential for malaria, schistosomiasis, or other parasitic diseases. In areas such as these, drainage facilities must be provided if the full potential of health benefits is to be realized.

An example of the second type of complementary program would be a rural electrification program which not only contributes to the development objectives, but also lowers the operating cost of the water supply system itself by allowing the use of an electric powered pump rather than one which requires the continued purchase of gasoline or diesel fuel.

In general, any form of growth point strategy (discussed in Chapter VI) requires complementary investments. Suggestions for complementary development investments in addition to those built into the water supply project (noted in Chapter IV) include sanitation and education programs, feeder roads, rural electrification, village industry, and marketing information programs. If the full, so-called psychological as well as physical impact of these complementary programs is to be realized, they should be undertaken at approximately the same time.

The Time Frame for Investment

If increases in population do not live up to the estimates which were used in designing a water supply system, overinvestment results. On the other hand, if a water supply system reaches capacity quickly, and if deficits in supply capacity are not acceptable, then the secondary expansion of the system raises unit costs above what they would have been if a larger capacity system had been constructed initially.

The amount of water supply excess capacity which should be constructed is essentially a function of economies of scale and of the discount rate (Lauria, 1972). Economies of scale signify that average or unit construction costs decrease as scale increases (marginal cost is less than average cost). Therefore, if economies of scale exist in the construction of water supply systems, the unit cost of a project designed to reach full capacity in 20 years will be less than the unit cost in 20 years of a project which had an initial design capacity of 5 years and which was expanded in size three times over the period.

Empirical evidence to support the existence of economies of scale has been found in studies of community water supply systems in both Guatemala and Honduras (Lauria, 1972). Also, in the rural water supply program in Kenya, it has been estimated that, for a project, the increase in average cost for a five-fold increase in water supply is about 2.5 (Carruthers, 1972). Given this evidence, and the assumption that when a system reaches capacity it will be expanded, it makes good sense to design systems with excess capacity (with larger potential economies of scale corresponding to longer design periods).

The best length for the design period also depends on the discount rate, or the rate at which the cost of probable system expansions is discounted back to the present. Generally, the higher the discount rate the shorter will be the optimum design period because a higher opportunity
cost of resources corresponds to a higher discount rate.

Very simplistic estimates of the optimum design period for rural water supply systems can be computed from calculations done by Lauria (1972) using a model developed by Mann (1967) and using estimates of economies of scale elasticities made by Lauria and implicitly by Carruthers (1972). (Economies of scale elasticity estimates show the percent increase in system construction cost brought about by a one percent increase in system capacity.) In general, if the discount rate is assumed to be ten percent, then the optimum design period for a rural water supply system would be somewhere between a low figure of four or five years, derived by using Lauria's economies of scale elasticity estimates for Guatemala (.77) and Honduras (.85) and twelve or thirteen years using the elasticity estimate implicit in Carruthers' calculations (.50). If the discount rate is only five percent, the optimum design periods would be seven to ten years and slightly over twenty-five years respectively. This contrasts with the common practice in Africa, Asia, and Latin America of designing rural water supply systems with a twenty year capacity.

An additional factor complicating optimum design period calculations is the difficulty of making accurate projections of population changes. Rural-to-urban population migration in most developing countries has been increasing rapidly. Design capacities would have to be larger if it is assumed that rural water supply systems can slow outmigration. On the other hand, if outmigration is not slowed then faulty assumptions could result in significant excess capacities.

Rural to rural migration also causes significant differences in population growth rates among villages. In most countries some villages will not grow and some will even suffer a net loss of population during the next fifteen years. Others will experience a much greater increase in population (because of improved health and migration pattern changes) than they have in the past.

One way to approach the difficulties of estimating population changes among villages in rural areas is to tie population forecasts to forecasts of potential changes in economic activity. The assumption would be that those rural areas which begin to experience an increase in economic activity will be the areas which attract and hold population. Consequently, those areas should be afforded a higher population growth rate figure in water system design capacity calculations than the majority of rural villages. The point is that using a fixed average population growth rate for all villages could result in a much greater amount of over and under investment on a spatial basis than would be the case if different estimates for growth rates were used for different classes of villages.

Finally, when possible, the phasing of investment should be practiced. For example, suppose a water supply system is designed so that it must have two storage or reservoir tanks when it reaches capacity in 15 years. Further suppose that the system will not need the second tank during the
first seven years of its existence (the first tank will reach capacity in seven years). The rational investment policy would be to construct the system without the second tank and then construct the second tank in seven years.

An advantage of this course of action is (a) there is an initial cost savings in terms of real investment and (b) if the population of the village grows at a slower rate than projected, investment in the second reservoir may be postponed for more than seven years. The problem with the phasing of investment is that it assumes resources will be available at the time when they are needed so that the additional tank can then be constructed. This, of course, assumes an efficiently managed and well-planned and financed program which, in practice, is sometimes difficult to achieve.
VIII. THE ADMINISTRATION OF RURAL WATER SUPPLY PROGRAMS

The administration of rural water supply programs can be viewed as being composed of three interrelated stages: planning, construction, and operation and maintenance. Factors which should be considered by the central administrative body during the planning stage have been the topic of much of the previous seven chapters. The important thing in the planning stage is that existing alternatives not only on the supply but also on the demand side should be explored and the implications (costs and benefits) of each alternative should be considered so that the program has, given existing resources and information, a high probability of success.

The administration of the construction phase of the program should not present many new problems to engineers who have worked in developing countries, although a natural resistance to a financially more costly yet economically preferable approach may, in a few instances, have to be overcome (shallow pricing). An example of a practical difficulty which could arise is when communities have agreed to contribute labor, but have not been adequately motivated to be ready at the exact time the labor is needed. There is no doubt that from a purely administrative point of view community participation agreements lead to greater local management difficulties than if the program Ministry, or the contractor, were able to undertake the project in the most technically efficient way. These increased management difficulties are costs which, together with longer construction times associated with labor-intensive methods, must be incorporated into the cost-benefit calculations.

A second factor which is sometimes a problem when administering the construction phase of rural water supply programs is that if private contractors are asked for bids on the construction work, the biggest and most experienced contractors frequently are not interested. The more experienced and financially stable contractors are, in some countries, only interested in relatively large jobs in the urban areas. This leaves smaller, more financially marginal contractors to bid on water supply construction projects in the rural areas. In some countries this has led to problems in getting the contractor to work with the community not to mention getting him to follow through and complete the job.

In one Latin American country the construction contract was written in such a way that the financially marginal contractors received partial payment when they began the project. As a result, they exhibited a propensity to begin construction on as many village projects as they could in order to receive the partial payment. The outcome of this was that the program found that it had a significant number of partially completed projects which were being rapidly overgrown by needs. Furthermore, there were a number of village water committees and populations which became discouraged with the delays and lost much of their enthusiasm for the projects.
The Crucial Issue of Operation and Maintenance

Problems of initial planning and construction are usually slight when compared with problems of operating and maintaining rural water supply systems after they have been constructed. Without doubt, the major administrative problems associated with providing water supplies in rural areas of developing countries relate to the operation and maintenance of the systems. In almost all countries with viable water supply programs it is not difficult to find villages where the water supply system is either not working as planned (either technically or financially) or not functioning at all.

In Thailand in 1971 a survey was taken by students at the Asian Institute of Technology which showed that 69 of the 79 rural water supply systems which were sampled had some difficulties in operating their plants. Among the more frequent complaints which they cataloged were (a) continuing difficulty in collecting money from consumers because of broken taps, the great distance to public fountains and the people's low incomes, (b) operators' salaries were too low to support families, (c) pumps or public fountains were broken or batteries were not charged, (d) there were inadequate tanks or water sources, (e) there was an inadequacy of pipe to extend the distribution system, (f) there was a lack of knowledge about system operation and chemicals, and (g) there was a lack of assistance from the central water supply authority.

Another example of typical operation and administration problems was observed in a Latin American country, when one of the authors and several country engineers were verbally accosted by irate villagers because of a technical problem which they were having with their water system pump. The pump was not delivering enough water to fill the reservoir and, as a result, the village had water only about two hours a day. Because of this many of the villagers were refusing to pay their water-use fees and the system was in danger of being shut down for a lack of operating revenue. In addition, the village had borrowed money in order to finance their initial contribution to the system and, due to inadequate revenues, they were in arrears on the loan.

The village water committee had written the central and regional water program offices about their problem and had received no response. They had also taken the pump to a nearby town of approximately 100,000 population and had paid a mechanic to rebuild it. The mechanic now guaranteed that the pump was functioning properly but they were still getting only a trickle of water. The water committee members had done everything they could think of to solve the problem and they had not succeeded. They were industrious, responsible, and concerned but they were not able to solve their problem because they were unable to get two or three hours of an engineer's time to check out the system and pinpoint the real trouble.

While this case is unique to one country in which the target rural population is relatively well educated, it is typical of many countries in which there is poor technical support and inadequate replacement and
expansion inventories for systems once they have been completed. In fact, in an African country also visited by one of the authors, rural water supply systems were failing at a rate which approached that of new ones being installed.

Part of the general lack of technical support is due to a lack of planning and adequate administrative organization and part is generally due to a tendency, in many countries, for local country or district engineers to prefer to spend their workday in their offices and to avoid going into the field on jobs where they might have to perform some demeaning physical labor. Another influence is that there is greater political impact and glamour attached to construction expenditures than to expenditures for continuing operation and maintenance. Finally, in many cases, national budgetary authorities simply do not recognize the extreme importance of operation and maintenance.

Centralization vs. Decentralization

The question of whether or not a rural water supply program should be administered by a central agency or whether it should have a considerable amount of local, or at least regional autonomy has no unique answer. The organization should be such as to (1) assure the technical and administrative reliability of the program and (2) be as efficient as possible in financial and economic terms. This latter goal implies that there must be at least a reasonable level of local interest and cooperation. Generally, whether or not these goals can be best accomplished through a centralized or decentralized administrative structure in a given country depends upon (1) which stage of the program we are talking about, (2) the size of the country, (3) the level of education and skills which exist among the rural population, and (4) whether or not, in that country, economies of scale exist in administering rural water supply programs.

In most countries during the initial planning phase of the program, efficient administration can probably best be accomplished at the national level, or at that level of government which has authority for regional development planning. This could be at the regional or state level in very large countries although in most smaller developing countries the initial planning of the program generally requires more of an overview than is usually found at the sub-national level.

The construction and the operation and maintenance phases of the program can be carried out efficiently at either the national or the state or local level. Generally, in order to take advantage of a knowledge of local conditions, resources, and problems, these phases of the program should be carried out at the lowest possible level which has the necessary technical expertise.

If a village population is capable of carrying out part of the construction and a significant portion of the local operation and maintenance it is best to design the administrative system so that they can do so. In this way costs might be lowered (at least real costs) and the
probability of community acceptance and appreciation would be increased.

On the other hand, if the rural target population is relatively backward, with few technical skills and with little income and education, then a structure which is more centralized around regional or national level expertise might be the most efficient, and indeed the only way to administer the program. In Latin America, a more localized authority with local promoters, pump operators, revenue collectors, and bookkeepers has worked well in several countries. In parts of Africa, however, where the income and education level of the rural population is much lower, a greater degree of central administration has proven the only solution. In situations such as this, however, it is wise to have local advisory committees so that local populations feel that they are participating in the program and take some pride in the systems.

Also in countries where there are relatively few professional engineers it is sometimes difficult to associate qualified people (who prefer to work and live in large cities) with rural systems. In cases such as this, a professional consciousness in ensuring an adequate operation and maintenance function may require a broad and fairly centralized administrative authority.

Finally, the size of the country also affects the decision concerning what the level of administrative control should be. A national-control program in a small country could be the exact equivalent of a regional-control program in a larger country in everything except name.

Which National Agency Should Be Responsible for the Rural Water Supply Program?

In countries with rural water supply programs it is not unusual to find several national ministries or agencies with separate water supply programs serving rural areas. The Ministry of Health, the Ministry of Hydraulic Resources, the Ministry of Public Works, and a national planning agency might all have water supply programs of a similar nature which focus on slightly different aspects of rural problems, on different sizes of towns, or on different regions. The reasons for this multiplicity of rural water supply agencies are usually historical or political. In some cases this multiple-agency arrangement even seems to work reasonably well.

Conceptually, however, it can be argued that to achieve efficient management control, reduce repetition, and assure better allocation of resources, the national rural water supply program should be under the control of one agency. The specific agency which should be in charge probably depends on the goals of the program. If the primary objective of the program is to stimulate economic development, and/or to attempt to redistribute income, then a national planning ministry, or a national water supply agency with those goals, would be well suited to operate the program.

In order to facilitate national-level cooperation for the ministry in charge of the rural water supply program, the ministers of related ministries (Health, Hydraulic Resources, etc.) might be made members of the program's
board of directors. In this way expertise and cooperation from various sources could be solicited yet one agency alone would have the operating responsibility for the program.

The most commonly cited justification for investment in rural water supplies is health, either as an end in itself or as a means of stimulating productivity. In these cases the Ministry of Health may be best suited to administer the program. This might be particularly true in lower income countries where the chances of rural economic development in the short run are not great.

The World Health Organization has been encouraging developing countries to establish health centers throughout their rural areas. These rural health centers are in some cases the only central government administrative units in the region and could be used by the Ministry of Health as a local administrative base for the rural water supply program. The water supply program could make use of the existing health center facilities in an attempt to hold costs down and to facilitate community acceptance of the water supply program by operating out of a facility which is already locally known and accepted.

One problem, however, with placing the rural water supply program in the Ministry of Health, which has been frequently mentioned by engineers, is that the orientation of health ministries in many countries is toward dispensing pills, buying more hospital beds, and giving vaccinations. The contention is that health ministries, which are staffed primarily by physicians, have insufficient interest in allocating their scarce resources to building and administering water supply systems in rural areas.

In whatever administrative unit the program is ultimately placed, it is generally accepted that for the relatively unsophisticated rural systems, the same Ministry which builds them should also be charged with their ongoing operation. This reduces administrative changeover and coordination problems and allows a less encumbered feedback from the operation and administration groups to the construction group on problems of quality of work and materials, and on problems of design. It could also simplify, somewhat, problems which might be encountered in recruiting qualified engineers and administrators to oversee the operation and maintenance phases of the program.

Financial and Income Distribution Considerations

Like most urban water supply projects, the financing of the construction phase and the financing of the operation and maintenance phase of the program can be handled either together or separately. The difference between the two phases, of course, is that funds for construction are needed in a lump, or in several lumps, near the beginning of the program while funds for operation and maintenance, and possibly expansion, must be generated throughout the life of the facilities.
The magnitude of the international, national, and provincial or state subsidy to the village water systems depends upon the economic conditions in the rural areas of the country (ability to pay), the philosophy of the central government about who should pay for the facilities, and the agreement with the international lending agency. The most common financial arrangement in Latin America, encouraged by IDB, is that the village raises approximately twenty percent of the construction cost of a project with the national and state government picking up approximately thirty percent and the international agency loan covering the other fifty percent. Usually the national government agrees to pay back the international agency loan from general revenues. It is an unusual case when a country is successful in generating a significant amount of funds for payments on interest and loan principal from user-fees paid by low income rural water consumers. In Asia and Africa the situation varies widely. In Thailand and Zambia, for example, villages normally contribute nothing toward the cost of construction of rural water systems. In other countries, including Sri Lanka and several states in India, local contributions of twenty-five to fifty percent of investment cost are required.

Two major problems arise in trying to set water-use charges in such a way as to at least cover operation and maintenance costs. First, in many countries it is difficult to ascertain what operating costs really are, or what they should be. The problem, of course, is that existing systems in most cases are not being properly maintained. As a result the costs of properly operating and maintaining village systems are probably greater than is generally realized or revealed in the accounts of most rural water supply authorities.

The second problem is that in many countries the pricing schemes are badly designed and only randomly enforced. In some countries the same water-use rate is charged to all villages in the country. In other countries the water use rates are subject to few guidelines and there is an implicit acceptance that the village populations will pay as little as they can get by with. In most rural areas of developing countries there is a significant variation among villages in both ability to pay and benefits received, but the haphazard pricing policies generally observed do not recognize either criterion. If either an ability-to-pay or a benefits-received-pricing strategy were followed, it is probable that many of the problems of generating sufficient revenues for operation and maintenance would be reduced significantly (see the pricing section in Chapter VII for further discussion).

Financing a significant expansion of existing systems, and an expansion through time of the number of villages served, generally requires additional funding from outside the water supply program. However, under the guidance of the Interamerican Development Bank and the Pan American Health Organization, several countries in Latin America have attempted to handle program expansion demands by instituting a so-called revolving fund concept. This essentially involves charging a user-fee which covers not only operation and maintenance costs but which also generates additional revenue for a central program fund. As money accumulates in this fund, it can be used for system expansions, or for building new systems.
The revolving fund concept is relatively new in Latin America. Consequently, it is probably premature to judge whether or not it is working. However, in practice it is still difficult to find a country where a significant surplus of revenue, above operation and maintenance costs, is being generated by user-fees.

For project expansion purposes it is also possible to allow individual villages to accumulate their own surplus revenue fund by charging a user-fee greater than operating and maintenance expenses. This is done in Peru where in some of the higher income rural villages the population is very proud of the fact that they are generating a water-supply expansion and contingency fund which is drawing interest for them in a bank.

One of the major problems in most developing countries, where rural water user-fees are not generating sufficient revenue to cover operation and maintenance costs, is that the availability of the revenue subsidy depends on decisions made by a central government far removed from the rural population. Consequently, in a year when competing needs for funds from national general revenue sources are great, the operation and maintenance subsidy for rural water supply systems can be cut back forcing many systems to operate even more inefficiently or sporadically. Generally, there is no intent on the part of the national government to shut down rural systems, but that is sometimes the result of subsidy cutbacks which occur in the absence of a successful effort to increase the amount of revenues generated locally.

One method by which rural water supply systems can be removed from a dependence on general revenues allocated by the national government is to financially link the rural water supply program with the water supply systems of urban areas. A national or regional water authority could be created which includes both higher income urban areas and lower income rural villages. The water authority could adjust water prices so that the authority is on a financially sound footing by charging higher prices in urban areas and using the surplus revenue which is generated to subsidize water supply systems in the lower income rural areas.

A system such as this is currently planned in at least two countries; Ghana and the state of Bahia in N.E. Brazil. In both of these places it is planned that a state water board will determine water supply prices in both the urban and rural areas so that surplus revenues in the urban areas may be generated to subsidize the operation and maintenance of the rural systems.

There are three factors which recommend a regional or national urban-rural pricing authority of this type. First, if a redistribution of income is one of the goals of the country, this system is one way to accomplish it. Essentially higher income urban area residents are taxed through a water-use tax and the proceeds are then distributed to lower-income residents of rural areas by subsidizing the on-going costs of their water supply systems.
Second, if the demand for water is relatively inelastic in urban areas (as has been shown in numerous water-demand studies) then there should be little in the way of a misallocation of resources as a result of the higher price in the urban areas. Even though price will be a higher than marginal cost in the urban areas, if demand is relatively inelastic approximately the same quantity of water will be consumed in the urban areas at the higher price. In the rural areas, where the demand for water is probably somewhat more elastic than it is in the urban areas, people theoretically could end up consuming more water at the lower price. However, the relevant consideration here is that without the lower subsidy price they might not be consuming improved water at all. Further, since it is frequently not feasible to charge consumers in rural areas on the basis of use, rural demand elasticity is not a totally relevant consideration.

Third, a constant source of revenue for subsidizing the operation and maintenance of village water supply systems would be assured. This revenue could be counted on through time and would not be subject each year to the revenue and expenditure problems of the central government. As pointed out earlier, a dependence on the central government for operation and maintenance subsidies frequently leads to periodic system failures.

There are two additional factors which must be considered, however, when deliberating about whether or not to set up a combined urban-rural pricing and revenue authority. The first is that if the goal of income redistribution is to be accomplished, the structure of prices in the urban area must be such that prices are not raised in the slum or ghetto areas. The middle and high income areas should bear the brunt of the higher urban water prices while the slum dweller, who uses a low volume of water, should still be able to purchase the amount that he needs at a low price. In other words, do not raise the price of water to the urban poor in order to subsidize the rural poor, particularly where the latter have better alternative sources.

The second factor to consider is that the rural-urban pricing and revenue authority may not always be able to generate sufficient revenues from urban areas to adequately subsidize operation and maintenance costs in rural areas. This would be the case, for example, in a country where a great majority of the population resided in serviceable rural areas and where the potential amount of surplus revenue which could be generated from the relatively small urban population is not sufficient to cover the water supply subsidy needs of the rural population. This problem, of course, could be handled in a number of ways, including providing water under the regional pricing board scheme only to that number of villages which could be subsidized. The participating villages could be selected according to a growth point or some other priority selection system.

Income redistribution can also take place among rural areas within the framework of a so-called revolving fund. If revolving funds are used not only for their stated purpose of providing funds for expansion, but
also as a fund from which operating and maintenance subsidies can be drawn, then higher income rural villages, which generate a flow of user-payments greater than is needed for their operation and maintenance, can subsidize operations in lower income villages. In fact, this is probably what is happening in several Latin American countries. Of course, a potential problem with this is the possibility that if prices were set by a national authority at a similar level in all villages, a low income village with a cheap water source and low operation and maintenance expenses could end up subsidizing a higher income village which, for geographical or geological reasons, has relatively high operation and maintenance expenses.

One final consideration in the financing of rural water supply programs relates to so-called conditional grants. From time to time developing countries have made economically bad investment decisions because of conditional grants made by more developed countries. For example, it is not necessarily an economically sound decision to accept a $5 million gift from a developed country to begin a rural water supply program if the gift specifies that all, or a large proportion, of the funds must be spent in the developed country for capital equipment and materials.

One reason for this is that, in some cases, the capital equipment can be purchased elsewhere at a cheaper price and lower-cost local materials can be substituted for those which are purchased in the developed country. As a result, the 5 million dollar gift may have a real value of less than 2 or 3 million dollars.

A second reason is that when the rural water supply program becomes tied-in to expensive capital equipment manufactured in the grant-bearing country, it could be tied-in for many years by the purchase of relatively costly replacement parts and compatible equipment. Through time this can result in a considerable drain of resources.

The point is not that conditional grants or gifts for specific program purposes to developing countries are bad. It is simply that before a grant is accepted, it would be wise for the recipient agency in the developing country to have an economist and an engineer examine the short and long run costs and benefits of the grant. These should be compared with the real costs and benefits which would be generated if the country initiated the program with its own funds and/or with an international agency loan.

Training and Incentives for Program Success

In order to assure a reasonable probability of success, a water supply program which is to be implemented in rural areas of developing countries must have a personnel training function. Basically, three kinds of training programs have to be undertaken. First, there must be a program designed to train the bottom-level employees of the system. Depending on how the system is organized, this would usually include bill collectors, bookkeepers, and pump operators.
The training program for the pump operator whose duties include maintaining the technical operation of a local system is particularly important. The extent or depth of the training would depend on the amount of technical support he could call on from the regional program headquarters if something in the system began to malfunction. Even after the construction phase of the water supply program has been completed, there must be a periodically reoccurring training program in order to assure qualified replacements for operators who leave their jobs.

The second kind of training or orientation program which would be necessary would be one for community promoters. The promoters would have to be oriented to the construction and operation procedures of the program and also be acquainted with the advantages which potable water would bring to rural villages. Generally, in most countries which use promoters, they have a better formal education than the villagers with whom they will be dealing, e.g., they are former school teachers, sanitarians, etc.

Third, some form of education or orientation program for the residents of the villages which are being supplied with water would be desirable. If, for example, the full health impact of the water supply investment is to be realized, the villagers should be encouraged to utilize the system to its fullest potential. This includes practicing good water-related sanitation. Many of the empirical health studies which were reviewed in Chapter III emphasized the importance of educating the population in good sanitation and water-use habits.

Finally, in many instances there is the problem of motivating the employees of the rural water supply program to concentrate on reaching the objectives of the program. In most developing countries junior-level public employees are paid a relatively low wage which in many cases forces them to hold more than one job. One method by which water supply employees might be motivated to focus on the objectives of their job would be to create a bonus incentive system which focuses on accomplishing specific program objectives.

Such a system is functioning fairly well in several states in Argentina. There, national water program authorities, when setting up a rural water supply program which is administered through the various-provincial or state governments, found (1) that the central planning and administrative staff at the state level would be composed mostly of existing personnel who would be serving the rural water supply program in addition to their regular duties and (2) that state-level engineers and administrative staff were paid very low wages. As a result the majority of them worked only part of a day in order to hold down other employment in addition to their state jobs.

To overcome these problems, and to stimulate state-level functionaries to devote time and effort to achieving success for the rural water supply program, a system of financial bonuses was instituted whereby state-level engineers and administrators can earn financial rewards by achieving specific objectives during given time periods. Engineers can double their salaries by achieving one hundred percent of their goals. Other state
level program administrators cannot double their salaries but they can substantially increase them.

During the construction phase of the projects the bonuses are primarily based on finishing a certain portion of the project during a given period of time. If one hundred percent of the goal is accomplished the engineer can receive a one hundred percent bonus in salary; if sixty percent is achieved during the allotted time he receives a sixty percent salary bonus, and so on.

During the operation and maintenance phase of the project the bonuses are designed to promote frequent visits by the engineer to villages to advise on maintenance, administration, and expansion, to check chlorine levels, etc. The engineer must send reports by specific dates to the national program office outlining his visits to villages, the problems he encountered, and the solutions which he worked out. The reports must be very detailed and must follow a specific outline. If during a given period the engineer is able to accomplish one hundred percent of his quota visits with one hundred percent satisfaction he then receives a one hundred percent salary bonus.

There are several provinces in Argentina, however, where the bonus system is not working. The reason for the failure of the system in these provinces is that the state-level engineers and staff who are working on the rural water supply system are in a department (or organization) which is closely tied to several other departments which employ engineers and staff of equal qualifications. When the bonus system was proposed for the people who would be working on the rural water supply program, their colleagues who were equally qualified but who would not be working on the rural water supply program complained so vigorously about salary discrimination that the system was not implemented.

One final problem which relates specifically to the rural aspects of a rural water supply program is that it is sometimes difficult to recruit and retain qualified employees, e.g., engineers, if they must spend a significant portion of their time living in relatively backward rural areas. Depending on the specific case, this problem might have various solutions including a salary premium for living in areas without many public services, a personnel rotation system to pull staff back to the city every other year, and so on.
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